how to build
a nice home

- *planning*
- *design*
- *execution*
- *quality control*

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(For Builders, Students and Professionals)

- *planning*
- *design*
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5th Enlarged, Revised & Updated Edition

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Contents

Chapter 1.
General

Chapter 2.
Knowing About Building Materials

Chapter 3.
Knowing About Architecture and the Building

Contents

Chapter 4.

Planning Your Home in Urban Areas

Chapter 5.

Planning Your Home in Rural Areas

Chapter 6.

Structural Design of the Building

Chapter 7.

Cost Estimates, Tenders and Contracts

Chapter 8.

Field Execution of the Works

Chapter 9.

Providing Facilities in the Home

Chapter 10.

Beautifying the home

Chapter 11.

Low cost Housing

Chapter 12.

Plot.

Chapter 13.

Plan and design of a house both in bearing wall and framed structure.

Chapter 14.

Design of High Rise Building

Curing of Concrete:

Appendix:

1 General

"Rome was not built in a day"

"God has created man and the tailor has created a Gentleman."And the gentleman is the creator of the Civilisation . How the gentleman marched towards the present day Civilisation is briefly described here.

1.1 Brief History of Civilisation

Searching for a home started with the advent of life on earth. Both man and animal were equally after it. While ants caves, bee's honey comb with uniform hexagonal shape and tailor birds nest weaving skill are amazing to the Architects and Engineers of all Ages. But their house remains in the same shape as it was in pre-historic days.

On the other hand, Man's house has contineously undergone change towards better living. A present day house differs entirely with that of the ancient Age. The cage has now turned into a lovely palace.

But this was not achieved in a day. It has been enriched with the advancement of Science and Technology through different Ages. Worth mentioning are:

Old Stone Age : Archeology proves that human Civilisation was founded at least two million years ago. it has passed through Old Stone Age when Man lived in cages, on trees and in pits dug in the earth. The region of Iraq and West Asia, and the Chinese used to prepare tent like huts with the help of animal skin, bones and tree branches. This Age is also known as Ice Age when most of the animals were dead for prolonged deposite of ice on earth.

New Stone Age : Started about 20,000 years ago. Due to shortage of animals for hunting, man started searching for grass weeds to satisfy his hunger. Such grass was the fore father of paddy and barley. 1st urban Civilisation started to grow up during this Age. Man made his first city in West Asia during this Age.

Bronze Age : As Arabs invented glass while cooking in the desert, the people of West Asia invented bronze from Copper and Tin. Both the metals were available on earth's surface. Many Civilisation like the Sumerian Civilisation, Babilonian Civilisation, Asirian Civilisation were sprung up in Mesòpotemia (present Iraq). Babylon and in Asur in West Asia during this Age.

Dried brick were first invented by the Sumerians. They made it permanent by burning.They invented writing with the help of picture called "Cuniform" writing engraved on earthern plates. They used to cultivate by Irrigation and cultured Astronomy. Latitude and Longitude were invented during this time. Hanging Garden of Babylon of this Age was one of the Seven Wonders of the world. This was created by King Nebuchadnezzar(605-562 B.C)to please his Queen.

Iron Age : With the invention of iron which was cheaper than bronze, Civilisation grew faster in China, Egypt, Greece, Syria, Turkey, Persia (present Iran) and Indus Valley. The Hittaits were first to invent iron in 2300 B.C. The Finisian, Greek, Chinese, American, Caldio, Egyp ion, Hittait, Lidio, Persian, Creet and Indus Civilisation were the footstep of human knowledge to present Atomic and Electronic Age.

The Finisians were the first to invent vocabulary with the help of 22 pictures. Greeks developed it into full fledged alphabate and all other alphabates were made accordingly.

Socretes, Plato, Aristotle are great philosophers and scientists of Greek era when Science and Technology advanced to a reasonable degree.

The Chinese invented paper, sculpture, compass, magnet and printing. Great wall of China was made in 4th century B.C. which is one of the oldest wonder of the world.

In Mexico and South America, Maya, Inka, Ajtake Civilisation made lofty building and suspension bridge for communication.

Caldians were 1st to invent 60 minutes an hour, 24 hours a day and 7 days a week.

Egyptian Civilisation was enriched in Arithmatic, Geometry, Medicine and Astronomy. They made pyramid to preserve dead bodies of the kings. The pyramid is a wonderful creation of this Civilisation.

The Lidians first invented the use of silver and gold coin with kings image engraved on it.

The Persians were also much advanced in constructing lofty palaces and roads and introduced gold and silver coins.

Extraction of oil from olive. was first made by the Creets.

Indus Civilisation was developed by our forefathers at Mohenjadaro and Horoppa in Sind of Pakistan. They have distinctive town planning ability. It has recently been proved that a faction of this Civilisation existed at Lalmai hills of Comilla about 20,000 years ago. Virtually, we had a boastful past for which we can feel proud and try to behave more civilised.

We have learnt from history of Civilisation that about 6000 years ago the Sumerians were the first to invent bricks. They came to know that burnt lime and brick powder mixed in equal proportion can bind brick together. This was the mortar of the old age . How Egyptians used to bind the stone is still not exactly known to us. Invention of cement is a history of three hundred years old. Cement has revolutionised construction technology.

Man is now creating 100 storied buildings in concrete and steel. It was human tendency always to create such lofty buildings. For example Kutub Minar of Delhi of twelve century is 330 ft high. Umpire State Building was built in 1940-41 which was 104 storied high and was the tallest for three decades, untill it is surpassed by World Trade Centre, New York, which is 110 storied high M. Brooth was the Architect of this building. Then came the Searce Tower, Chicago 1450 ft . high . Its planner was Dr. Fazlur Rahman of Faridpur Kenda Tange, a Japaneese Architect designed Hiroshima Peace Tower, Olypic Gymnacium of Tokyo. Prof. Luise. I. Kahn, designed the Capital at Sheer-e- Bangla Nagar, Dhaka. Engineer Tarzaghi, Trotton, William Thonton and so many other Architects, Engineers,Scientist have contributed towards the recent developments of Science and Technology.It's impossible now to move without technology. Neverthless to say, these gentlemen are the creators of modern Civilisation.

1.2 Houses of Different Countries

Bees' and sparow's are the natures architects. Well shaped formulated hexagons of bee's nest and weaving ability of tailor bird in making his house might have inspired man to build his own house. Houses of different tribes and ages are briefly described here.

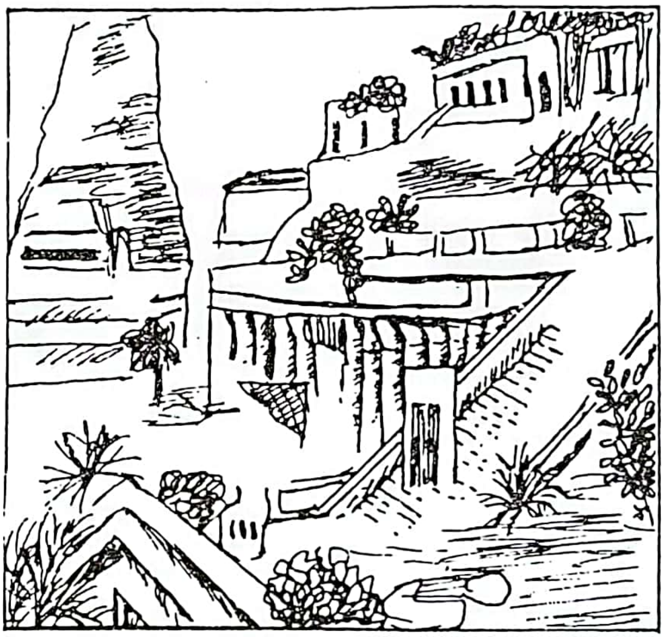


Fig 1 : Hanging garden of Babylon

1. Caves : Is the man's pre-historic house in the primitive age.
2. Lake dwellings of Switzerland: Piled up Boats over lakes were in use in Switzerland.
3. Humpies of Australia: Aboriginals make such house out of wood buckle and leaves called humpies.
4. Honey comb houses of Peru and West Africa : Red Indians prepare such houses out of staw.
5. Igloo of Greenland : Igloo is a house of ice.
6. Houses of Jaluo tribe of Africa: Jaluo's house is made of wood and straw.
7. Wigwam of America: Wigwam is a house of wooden frame.
8. Tepu of America: Is a tent made of grass.
9. Boat house of China: Individual Boats for each family similar to that of Switzerland where rows of Boats were in use as a family dwelling.
10. Straw made house: Are used by South Americans.
11. Earthen house of West Africa : Is conical in shape, lofly in height and is comfortable to live in.

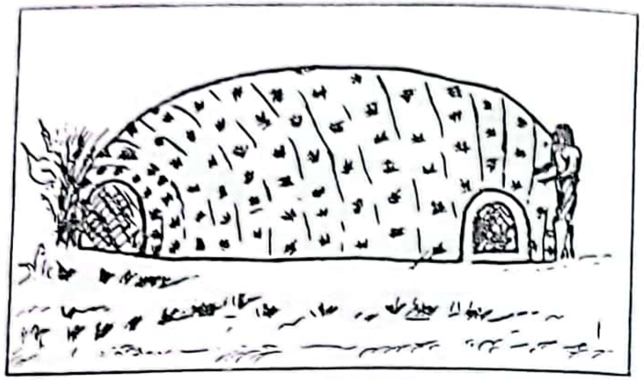


Fig 2 : Jaluo's house of Africa

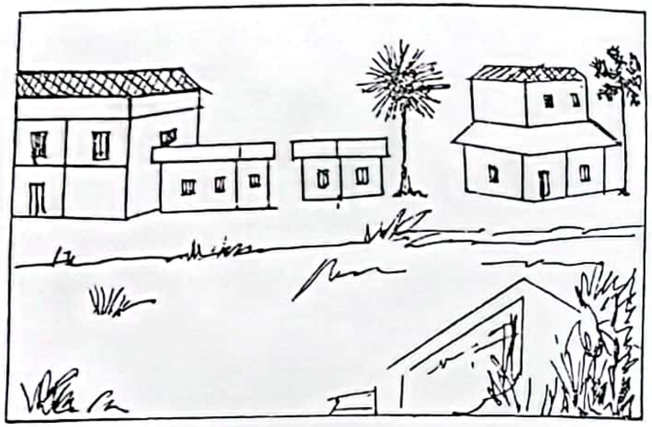


Fig 3 : Earthen house of Nile valley.

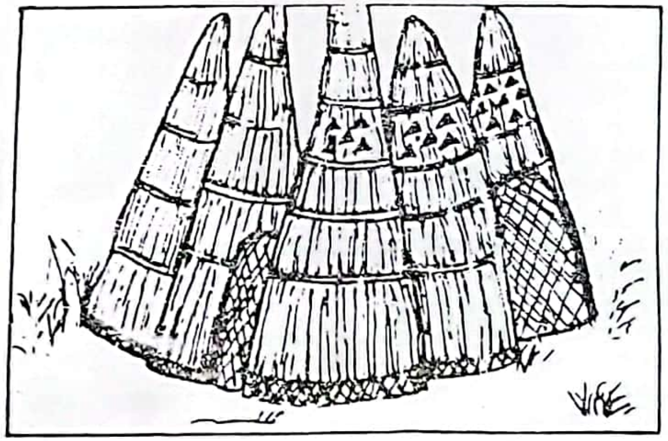


Fig 4 : Conical roofed huts of West Africa

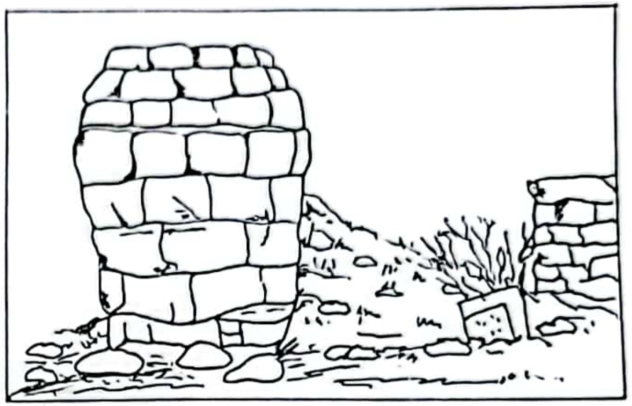


Fig 5 : Stone house of Bolivia

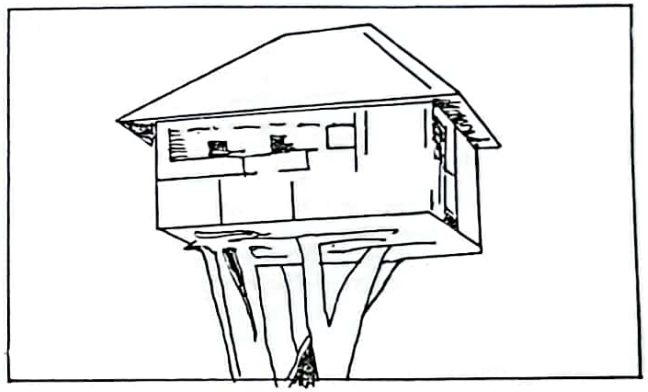


Fig 6 : House on trees, Philippines

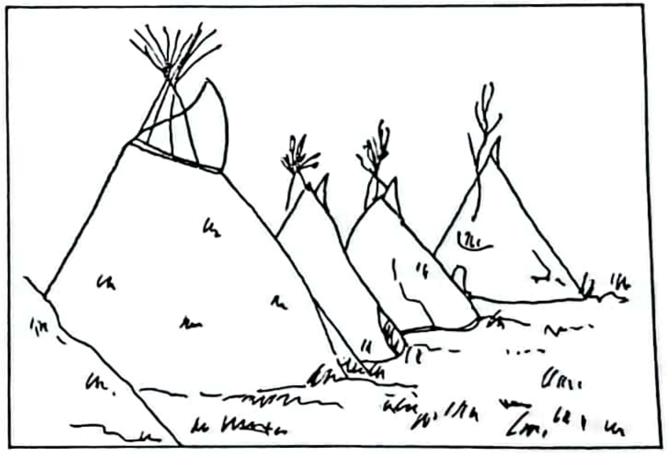


Fig 7 : Red Indian's house made of skin

12. Bolivians stone house: These houses have no windows.
13. Tree top houses of the Phillipines
14. Red Indian's houses made of skin

15. Red Indian's House in Bolivia

16. Conical roofed huts of Somalian : Village give beatiful gesture.
17. Modern Houses : In advanced world such buildings are made mostly of pre-fabricated components.

1.3 The Scope of House Building and its Importance in Bangladesh

The population growth per year in Bangladesh is 2.3% which is one of the highest in the World. According to Population Dev. and Valuation Unit estimated manpower now(1988) is 105.5 million;according to census of 1981, Population growth is almost steady while houses are not built keeping pace with the growth.

The following table shows how many houses we have now and how many houses are to be required to satisfy the demand upto the year 2000.

Statistics on housing:

Type of house	Straw/bamboo	Mud/brick	Cl.sheet/Wood	Cement/brick
Urban	1075182	223856	255139	487744
Rural	8295399	2733383	1461552	250771
Total	9370581	2957239	1716691	738537

National Total-14785048 Nos.

Source : BBS (1981 Census).

Requirement of houses till 1999:

Year	Required no. of houses	Rate of growth per year
1985	201.28.433	3.61
1990	228.87.987	2.57
1995	258.80.026	2.45
2000	292.43.904	2.44

Source : Sachitra Bangladesh ,July, 1985

On analysis, it has been found that we have to construct on an average a number of 7,09,131 houses per year to get rid of the problem.

But this goal is hardly achieved due to many reasons like high cost of land and construction materials which are getting beyond peoples reach day by day.

As such, extensive research work is necessary to find ways and means to construct low cost houses having public acceptibility.

1.4 Earthquake Zones of Bangladesh and Protection of Buildings

EARTHQUAKE is a common natural phenomenon occurring since the inception of the world . Many earthquake belts were active in the past causing so many devastating earthquakes that ruined many cities and hundreds of people lost their lives.Nowadays, there are two most active earthquake belts, namely, the Pacific belt and the Alpine belt.

The Pacific belt starting from West Indies to Philippines and Japan, runs to North and South America, while the 2nd belt originates from the Alpine range in Europe through Eastern Mediterranean to the Himalayas and Assam of India and East Indies where it joins the first belt. About 75% earthquakes occur in the first belt, mostly in Japan and 22% in the second. Remaining 3% occur in the Sub-Marine faults. Bangladesh falls within the range of the second belt and is very much under the influence of earthquake. It may be recalled that Assam suffered a catastropic earthquake in 1950, recorded magnitude was 8.6 on the Richter Scale. Assam is not far away from us. So we should have some knowledge about the phenomenon to take precaution in order to protect our buildings and lives from its effects.

How It Occurs : Earthquake is caused by sudden rupture or by scrapping together of two rough surfaces of the earth by volcanic eruption, movement of rocks along faults, by avalanches, landslide or by the test of nuclear bombs. A loaded lorry also creates feeble earthquake. Most severe earthquake occurs in the sea-bed, a very high wave is formed. In 1933, a 27m(88.5 ft.) high wave occurred in the Japaneese coast causing death to thousands of people. This wave is called Tsunami.

Tectonic earthquake occurs deep into the earth's interior, the centre of occurrance is called the focus. A point vertically above focus on earth surface is called epicentre. It is possible to find out the depth of focus by proportioning to their distances.Tectonic map of Bangladesh is furnished here..The plates shown are most crucial for favour of earthquake. According to the depth of focus, tectonic earthquake is classified as:

I) **Shallow :** depth of focus is less than 60 km.
II) **Intermediate :** depth of focus between 60 to 70 km.
III) **Deep :** depth of focus above 70 km. Earthquakes deeper than 700 km. are seldom felt on the earth surface except by instruments.

Scale : The scale of earthquake intensities was conveniently classified into 12 categories, till 1935, when C.F.Richter devised a scale indicating numerical magnitude of the intensity of earthquake, 10 is the highest on this scale. The greater the number, more is the damaging power. The intensity of earthquake in terms of Richter Scale is expressed as:

1) **Instrumental :** detected by seismograph, magnitude 1-3;
2) **Feeble :** noticed only by sensitive people ;
3) **Slight :** is like vibration of passing lorry, felt on upper floors, magnitude 3.5 to 4.2;
4) **Moderate :** felt while walking, magnitude 4.3 ;

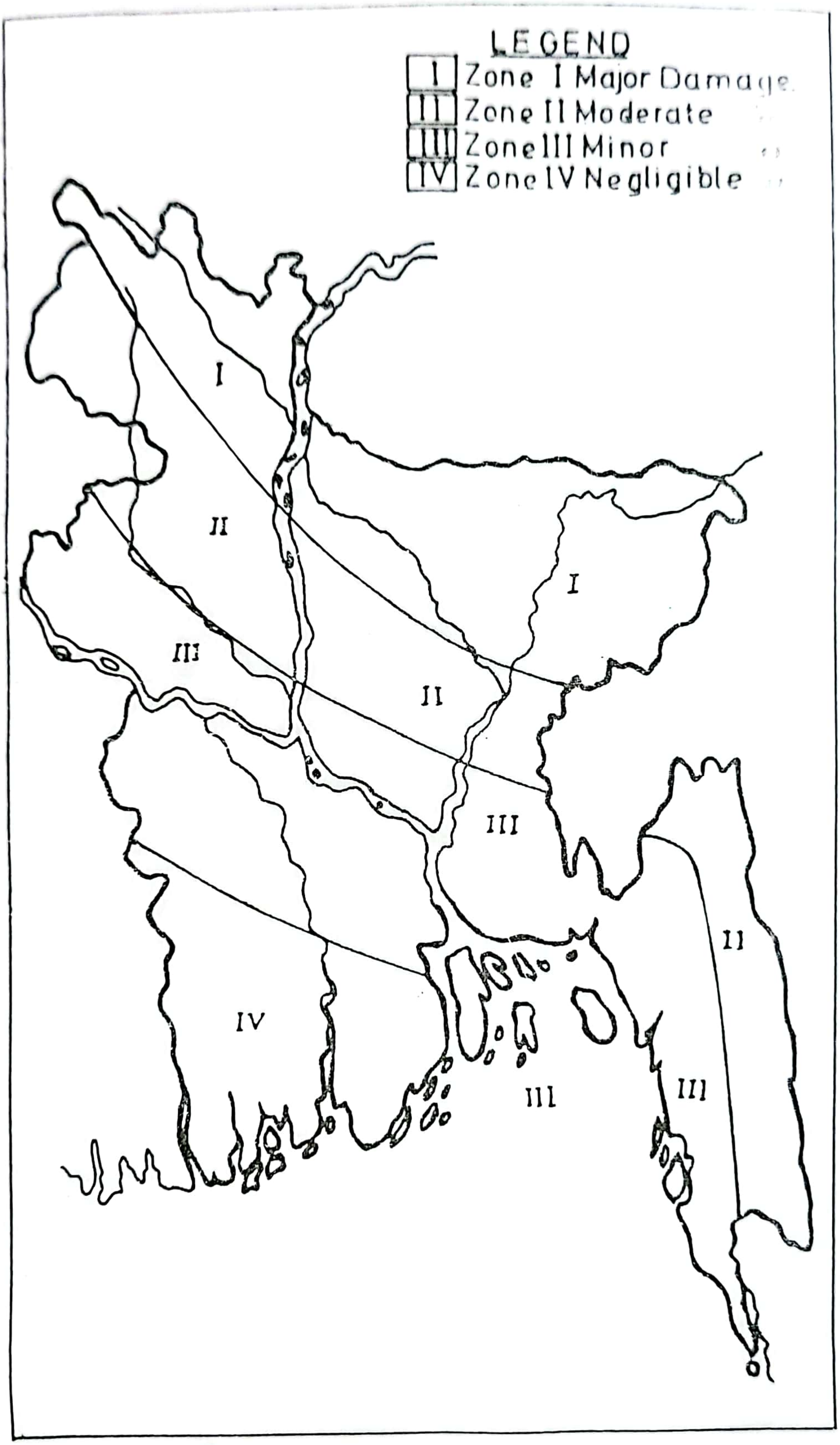


Fig 8 : Map of seismic zones of Bangladesh by Met. Dept.

5) **Rather Strong :** most sleeper awakened, magnitude 4.8;
6) **Strong :** trees sway, suspended objects swing,falling of loose objects, magnitude 4.9-5.4;
7) **Very Strong :** walls crack, plaster falls, magnitude 5.5-6;
8) **Destructive :** chimneys fall, buildings damaged, magnitude 6.8;
9) **Ruinous :** houses collapse. ground cracks, pipes break open, magnitude 6.9;
10) **Disastrous :** ground cracks badly, bldgs. destroyed, rail lines bent. magnitude 7-7.3;
11) **Very Disastrous :** few buildings remain standing, bridges distroyed, great landslide and flood, magnitude 7.4-8.7;
12) **Catastropic :** total destruction,objects thrown into air, ground rises and falls in waves, magnitude 8.2 and above.

Earthquake Records Of Bangladesh and Of The World : Bangladesh has experienced earthquakes many times in the past. A record from the meteorological sources observed at Dhaka from 1962 to 1972 shows that, on 19.6.63 an earthquake with a magnitude of 5.7 was felt in Rajshahi, on 18.2.64 magnitude of 5.6 felt in Kushtia, Jessore and Sathkira, on 13.6.64 magnitude of 5.8 was felt in Chittagong, on 2.2.71 a magnitude of 5.4 was felt in Chittagong. We do not have any idea about the intensity of those earthquakes at Dinajpur, Sylhet and Mymensingh. Since, they are situated closer to Assam belt, the magnitude of earthquakes was always greater in these areas compared to that of Dhaka.

One of the greatest on record of the world earthquakes was the catastropic earthquake that ruined Lisbon in 1755.The magnitude might have greater than 9 on Richter Scale. Great earthquakes with corresponding magnitude on Richter Scale were as follows: 1906, Columbia, Equador 8.6 ; 1906, Chile 8.4; 1911, Sinkiang, China, 8.4; 1920, Kansu, China 8.5; 1933, Japan, 8.5; 1950, North Assam, India 8.6; 1960, Alaska 8.6.

Seismic Zones of Bangladesh : According to probable magnitudes of earthquake, Bangladesh has been divided into four zones, namely, major damage zone, moderate damage zone, minor damage zone and negligible damage zone. The above mentioned zones have been shown in the map. The major damage zone includes Greater Dinajpur.Thakurgaon, Jamalpur, Kishorganj . Tangail and Sylhet. The moderate damage zone includes Greater Rangpur, Pabna, Dhaka, Chittagong Hill Tracts. The minor damage zone includes Greater Rajshahi, Kushtia, Faridpur. Chittagong, Bandarbon, Comilla. The negligible zone includes Greater Jessore Khulna. Barisal, Patuakhali, Noakhali and Bhola.

From the list of earthquakes mentioned earlier it is obvious that the maximum earthquake with the magnitude 5.8 was felt in Chittagong on 13.6.64 which was very strong in nature on the intensity chart. According to meteorological sources, we experienced three medium and 30 minor shocks in 1988. out of which the biggest one happened on 21st Aug. of magnitude 5.6 on Richter Scale; the source of earthquake was 755 km. away in Nepal killing 1200 people there. The magnitude recorded there was 6.4. It was destructive in nature. In 1934, 11,000 people were killed in the same area. Fortunately enough, we are a few hundred miles away from the crucial Zones (in Assam and Nepal).

We have possibilities to face tremor very strong to destructive in intensity. Ruinous earthquake may happen, if prediction of Seismic experts comes true that at the end of this century catastropic earthquake will occur. Since Dinajpur, Mymensingh, Sylhet and part of Chittagong Hill Tracts are close to Assam belt, comparatively greater shocks are supposed to be felt in those areas. We can, however, presume that if 1950 earthquake of Assam is repeated, Dhaka will face tremor equivalent to approximately 7.8 on Richter Scale which may be disastrous.

To protect life and prevent collapse within reasonable means and without excessive cost, certain measures are suggested here which is limited to residential buildings only. The planner of other high rise buildings is supposed to give due attention to seismic load for that particular structure. The theory says that a building should absorb energy rather becoming strong for which ductility should be induced to the building components so that it sways to some extent though seriously damaged, but still maintaining vertical load carrying capacity. Thus, cracks in floor and walls should be allowed so that the building does not yield to collapse. Codes have devised numerical formula for earthquake loads, yet many uncertainities still exist. For convenience in design, an earthquake is translated into an equivalent static load acting horizontally. But it develops both vertical and horizontal ground vibrations, as such vertical stresses can not be ignored. Thus, prediction is difficult yet probable earthquake zones with seimic design load may be specified.

Continental United States has been divided into 4 zones.We have yet to decide such factors for designing our buildings. For rough and ready calculation, corresponding stressess acting in the building may be increased by one-third. That is an extra provision of 33% may be provided in reinforcement to prevent the effect of earthquake.

Residential building which is normally 5 To 6 storied high may be constructed with 'L'type corners columns and two or three 'T' type inner columns tied with beams which in combination will act as the inner core of the building. Such columns are more stable than rectangular or square columns. To make it light, 8" × 12" columns sections with 5" to 8" brick wall thickness may be selected.

Furthermore, the following general principles may be followed : Height should be twice and length should be within thrice the width . Height of each story should not be more than 10 ft. Foundation must be laid on hard soil.The building should be made on framed structure i.e. on beams and columns. Arched roofs and domes should be minimum. Where framed structure is not possible, brick wall should be reinforced with vertical and horizontal rods at regular intervals of 4' to 5' apart. Old houses may be reinforced with 'L' and 'T' type columns. However, due attention should be given for all new construction in major and moderate damage zones.Two storied Buildings may be constructed without columns. But bands should be provided.

Taking Shelter During Tremor : Which is the best place to take shelter ? The author has the experience of tremor of magnitude 7.2 in Japan in 1978. Most of the buildings there were cracked in walls and floors due to frequent earthquakes. The Exit'is always lighted in "red"to facilitate going down to fields. But it is difficult to walk down during tremor, so most of the Japaneese people including the author remained in the corridor. Virtually, short spanned roofs are the best place to take shelter, next to the open fields. Going down under the tables is seldom feasible in such cases.

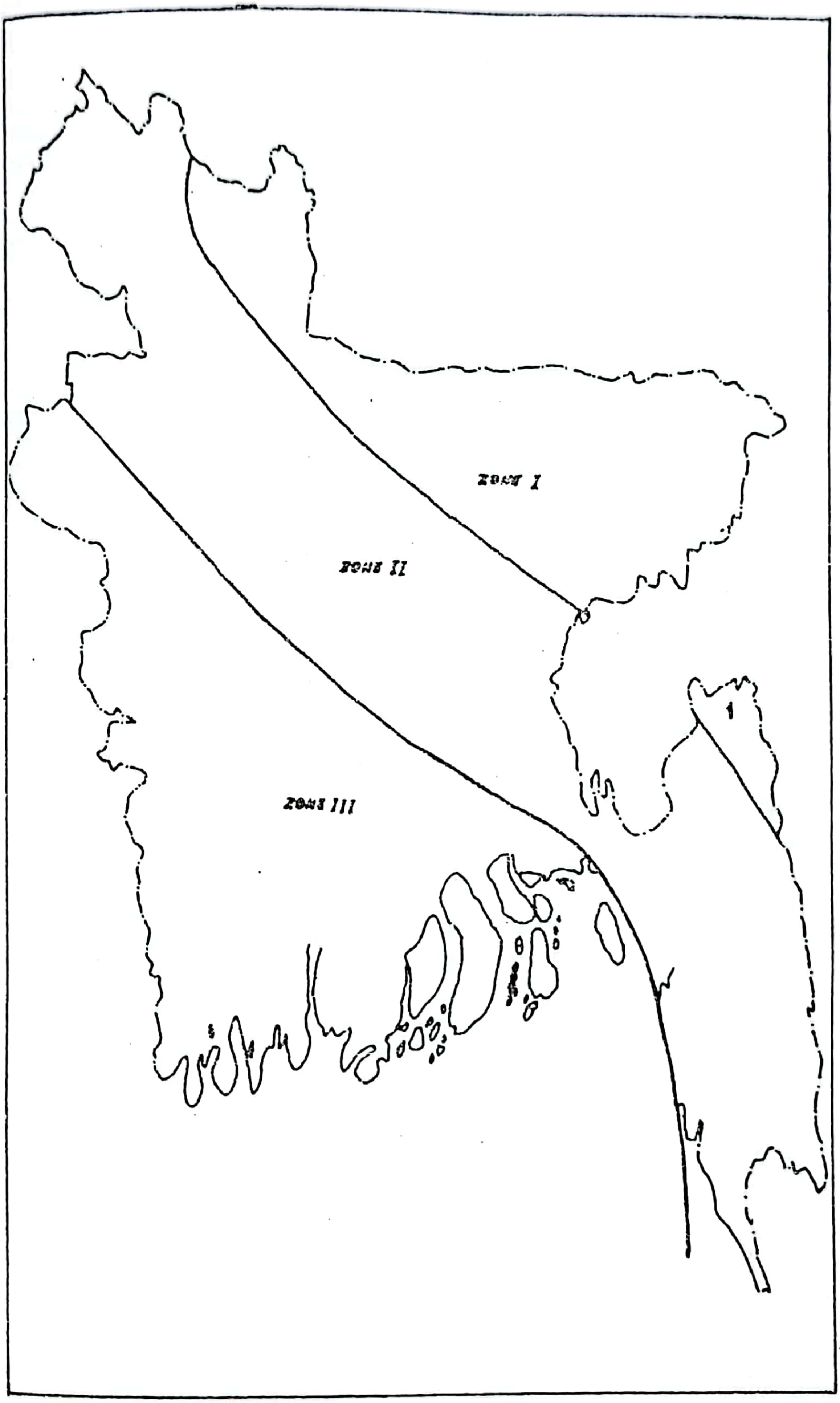


Fig 9 : Map of seismic zones of Bangladesh by committee

1.5 Earthquake Proof Design and Hazard Minimisation

Govt. of Peoples' Republic of Bangladesh formed a Committee of experts in June, 1977 on the subject and the Committee submitted reports in Nov 1979. This report is not yet made public but is followed in all official works. Extracts are taken from the report to satisfy the reader to acquire more knowledge about earthquake. The Committee reviewed the available data and drew the following inferences:

1. North and East of Bangladesh there are areas of high seismic activity and some of the major earhquake originating in these areas have affected adjacent regions of Bangladesh.
2. The only geological structure in Bangladesh or in its immediate vicinity with major earthquake association is the Dauki Fault in the southern edge of the Shillong Plateau.
3. During the last one hundred years severs and wide spread damages/ destruction occurred only once i.e. by the Great Earthquake of 1897 with epicentral tract in the Shillong Plateau. Only two major earthquakes namely the Bengal Earthquake of 1885 and Srimangal Earthquake of 1918 had their epicentres in Bangladesh but caused serious damages only in limited areas surrounding the epicentres.
4. The northern border belt of Mymensingh and Sylhet districts and the eastern part of Rangpur have been affected by frequent tremors and south western Bangladesh has sufferred very little earthquake damage.

Seismic Factors : The Committee has suggested three zones namely zone I, being most active, zone II, less active and zone III, being the minimum possible intensity of earthquake. For the purpose of designing buildings basic Seismic coefficient denoted by Z may be taken as follows:

Zone I $Z = 0.08$
Zone II $Z = 0.05$
Zone III $Z = 0.04$

Seismic probable Magnitude

Zone	(Richter Scale)
I	7.0
II	6.5-7
III	6.0-6.5

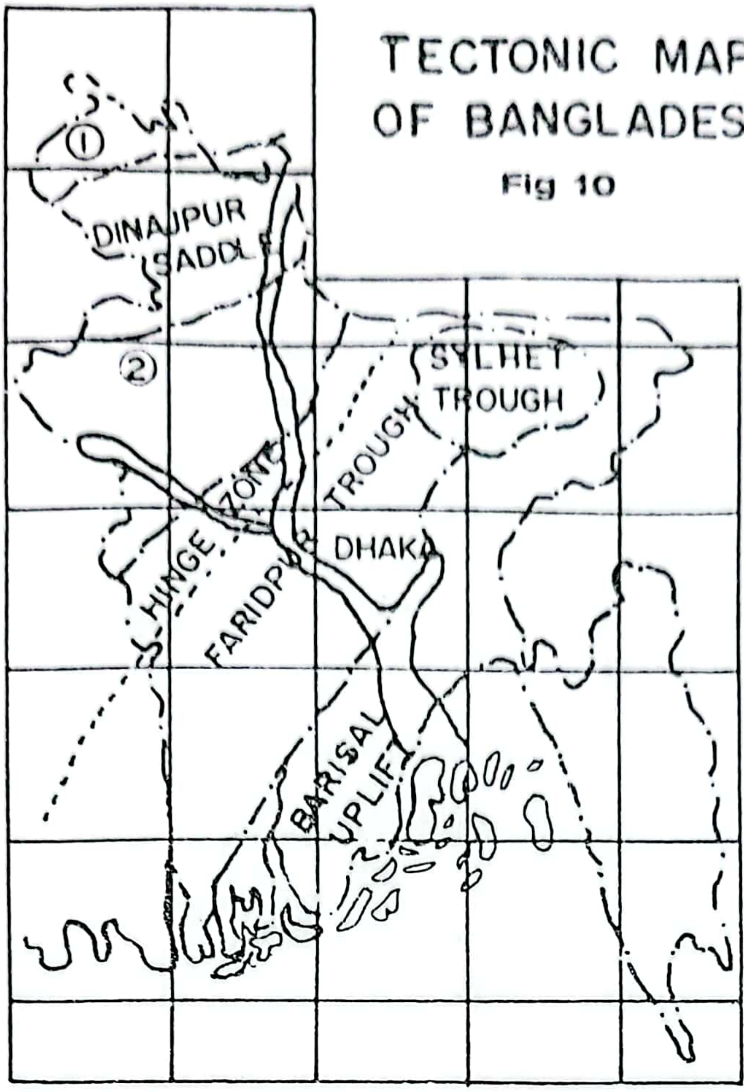
Base Shear :

The shear force at the base of a building is given by the following formula :

$V = ZIKCSW$

where, Z is the basic seismic coefficient for the particular zone
I= Importance factor
K = A factor to take into account structural type.
C = A factor depending on the flexibility of the structure.
S = Soil foundation factor.
W = Dead load plus appropriate reduced value of live load.

The design of buildings against earthquake should obviously be done in Zone I. However, for low height buildings additional provision of 33% reinforcement may be provided. For high rise buildings proper technical design should be done by qualified Civil Engineers.



TECTONIC MAP OF BANGLADESH

Fig 10

Earthquake Hazard Minimisation

Earthquake risk in terms of possible damage to life and property has increased manifold. Earthquake damages occur not only due to collapse of structures due to ground shaking but in some instances on a larger scale by fire flood, tsunami and epidemics following an earthquake. Though there is no way of preventing an earthquake, effective measures can be adopted for hazard minimization.

Prevention or minimization of earthquake losses largely depends on active co-operation from an informed citizenry. Hence, generation of mass awareness of the hazards and possible minimization measures is of prime importance. For protection against earthquake damages, an outline of earthquake resistant design of structures has been suggested. Protection measures involve additional investment and people are generally reluctant to make the extra investment even though it may be very small as earthquakes are n frequent occurrences and public memory is short. However, if it could be brought home to them that the little extra expenditure could mean escape from disaster in case of an earthquake, the code will have wider acceptance. Some repair/reconstruction facilities could be offered against earthquake disasters through earthquake insurance system. Here again public acceptance will need effective campaign.

1.6 Prediction of Earthquake : Extensive studies are currently being carried out in U.S.A. , U.S.S.R., China and Japan to find out reliable precursors of earthquakes and some success has been attained. On the basis of results so, far obtained, it appears that deterministic forecasting, stating date, location, magnitude etc. may not be possible at least for many years to come .

Before the final breaking point is reached the rockmasses undergo some changes or deformation and some of these changes even though very minute can be measured by very sensitive equipment. Abnormal animal behaviours have also reportedly been used in China as earthquake precursors. Any consideration of earthquake prediction research in Bangladesh is premature as the equipment needed are highly sophisticated and expensive and they have been used with some results only in seismic belts along some faults or geological features with established earthquake connection.

1.7 Earthquake Records within and in the vicinity of Bangladesh

Significant earthquake records in and around Bangladesh are furnished below:

Date	Epicentre		Magnitude (Richter scale)
	Latitude Degree.	Longitude Degree.	
08 Jul. 1918	24.3	91.7	7.6
15 Mar. 1927	24.5	95.0	6.5
02 Jul. 1930	25.8	90.2	7.1
24 Mar. 1932	25.8	90.2	5-6
06 Mar. 1933	25.7	90.5	5.8
02 Jan. 1934	25.1	94.7	6.5
31 Aug. 1937	25.9	96.8	6
21 Jan. 1941	27.2	92.0	6.2
22 Jan.1941	27.0	92.8	6.2
23 Oct. 1943	26.8	94.0	7.2
16 Aug. 1950	28.6	95.7	7.0
13 Sep. 1950	27.8	95.3	7.0
02 Mar. 1963	26.1	92.2	4.2 Rajshahi
18 Feb. 1964	27.5	91.1	5.6 Jessore Kushtia Satkhira
13 Jun. 1964	23.0	94.0	5.8 CTG
21 Aug. 1988	—	—	5.8 Felt all over Bangladesh.

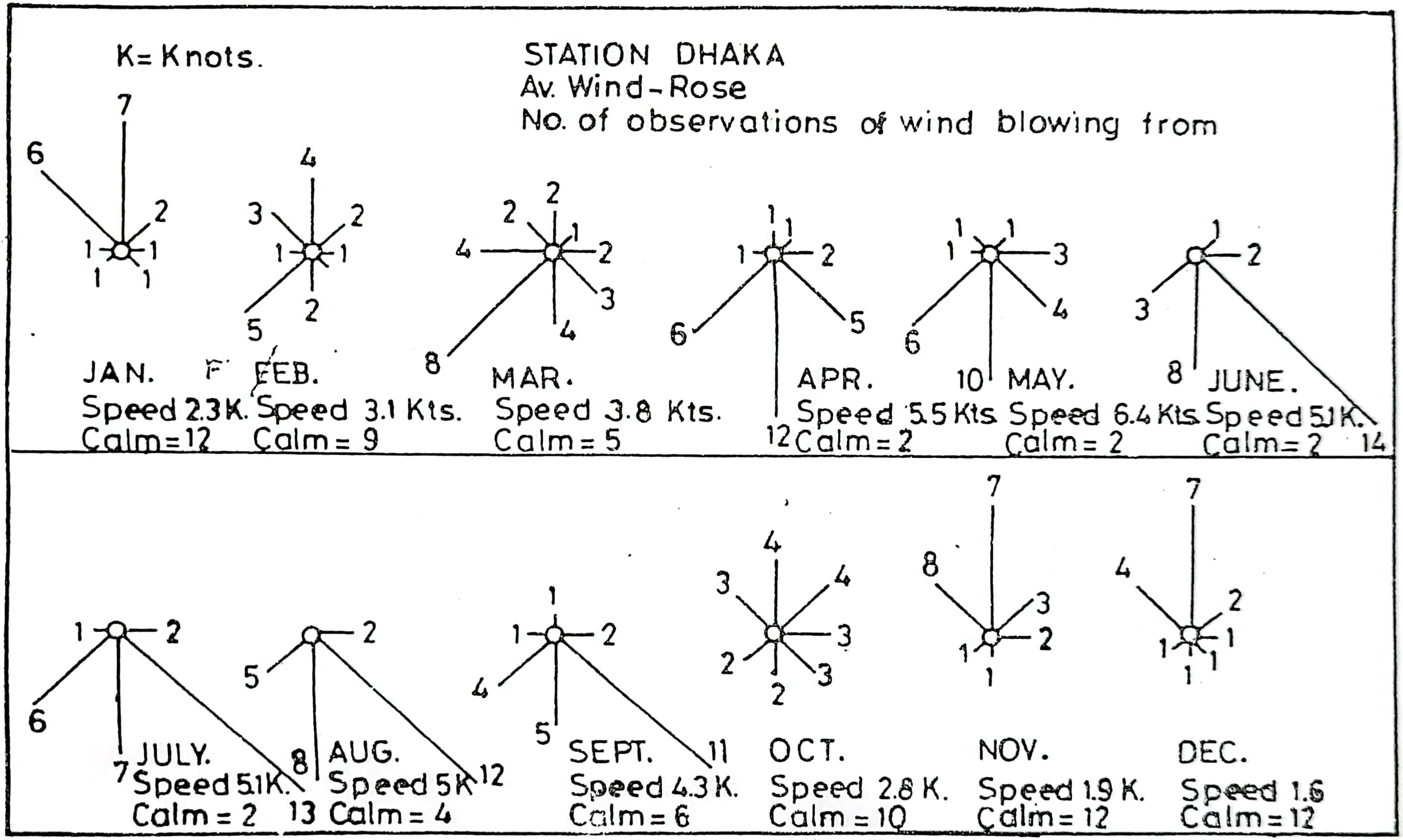


Fig 11 : Wind rose

[illegible] Average Temperature, Relative Humidity and Wind Velocity Observed at Dhaka (Based on Several Years Record)

[illegible]	[illegible]	Temperature in degree Fahrenheit [illegible] Maximum	Mean minimum	Mean daily Minimum	Mean for month Relative humidity %	Maximum wind velocity m.p.h observed at Chittagong
[illegible]	[illegible]	[illegible]	[illegible]	52.5	75.5	100 m.p.h on
[illegible]	[illegible]	[illegible]	60.9	56.2	69.8	11th may/65
[illegible]	[illegible]	[illegible]	70.3	66.7	63.5	103 m.p.h on
[illegible]	[illegible]	[illegible]	85.7	75.4	72.3	23rd October
[illegible]	[illegible]	[illegible]	84.6	77.2	82.0	1970
[illegible]	[illegible]	88.0	83.3	79.0	87.1	58 m.p.h on 2nd
[illegible]	[illegible]	87.0	83.5	79.1	89.0	may 1971
[illegible]	[illegible]	87.8	83.6	79.1	89.3	
[illegible]	[illegible]	88.0	83.2	78.3	87.9	
[illegible]	[illegible]	87.2	80.8	74.4	84.7	
[illegible]	[illegible]	83.2	72.9	62.9	79.8	
[illegible]	[illegible]	78.6	66.4	54.3	82.5	

SOURCE: Meteorological Department, Govt. of Bangladesh

[illegible] Wind Rose : It helps to determine the orientation of a building that will offer the greatest wind coverage for it. Wind rose map consist of radiating lines in several compus direction, each representing to scale the percent of time that the wind blows from the direction in which that line radiates.

In December-January northernly cold wind prevails in the country while southernly soothing breeze prevails from south during summer months. That is why all bed rooms should be located on the southern part of the house for comfort during summer. It is also evident from the wind rose that major wind flows from south to north during summer and from north to south during winter. So for the purpose of cross ventillation windows should be provided on the north and south of a room for maximum wind coverage.

2 Knowing About Building Materials

Earth with her thousand voices,
praises God-Coleridge.

2.1 Water

Water is vitally important in construction as it is to our life. It has two functions :
a) Chemical
b) Physical

Chemical : Cement contains about 6% lime For complete hydration of it, about 14 lbs. of water is needed for 100 lbs of cement. It causes chemical action with cement for setting and hardening.

Physical : It distributes cement and imparts workability to the mixture. Water should be clean and free from acids and salts like sulphates and chlorides and carbon dioxide.

Data on water :	
One cu.ft. of water	= 6.24 imperial gallons.
	= 62.4 lbs. (at 60°F).
One ton of water	= 1 cubic metre
	= 244 imperial gallons.

2.2 Cement

Is a product of mixing calcareous and argillaceous materials. Normal cement is called Portland Cement This is the most widely used cement. It is so named because of the resemblance of its properties with a well known natural stone quarred at Portland, U.K. Joseph Aspdin, a Yorkshire brick layer is discoverer of Portland cement.

There are many types of cement . advantageous for different uses as follows :

Types of cement	**Advantageous for**
a) Rapid hardening cement	For Quick hardening action
b) White cement	Used in Mosaic works.
c) Coloured cement	" " "

d) Aluminous cement	Very rapid harding
e) Clay cement	For Marine use.
f) Masonry cement	Normal cement for masonry work.
g) Air entraining cement	For action against freezing.
h) Pazzolanic silica cement	Against corrosive water and fire resistance

Cement looses strength in storage. But unless, it is hardened by water, its strength never comes to zero. Clotted cement due to storage can be used in construction by grinding it again, but higher proportion should be used. Probable loss in strength will be as under:

3 Months storage	20% less
6 Months storage	30% less
12 Months storage	40% less
24 Months storage	50% less

Data on cement :	
1 bag	50 kg
1 Ton	20 bags.
Av. initial setting time (of ordinary cement)	= 1/2 hr.

2.3 Sand

It plays an important part as Engineering material.

Types: Main types are:

1. River sand
2. Nala sand
3. Viti sand

Sources: 1. From the Padma, the Jamuna and other River beds

2. From nala in hills
3. Viti sand is fined grained and is available on earth surface or underground.
4. From Quarry of Sylhet coarse sand is available.

Identification of good sand

1. It should have sharp, angular and hard grain.
2. Free From silt (For practical purposes 3% to 4% silt may be allowed.)
3. Should not contain rotten leaves etc and other organic materials.
4. Grain Fineness Modulus will be between 1. 5 to 3.

In Dhaka, Kaliakor, Kadda, Mirpur, Mohammadpur and Pagla are the places where sand is available.

2.4 Bricks

Bricks are namely classed as under:

1. Ordinary bricks
2. Ceramic bricks
3. Special purposes bricks like fire bricks used in furnace etc.

Only No. 1 and 2 above are treated here.

Classification : Ordinary bricks are classed as :

1) 1st. Class Bricks/Picked bricks
2) 2nd Class Bricks.
3) 3rd Class Bricks.

Identification of 1st. Class Bricks

a) Faces should be plane
b) Sharp edges
c) Well burnt
d) Gives metallic sound when hit by a hammer.
e) When dropped over another from a hight of 1m. (3.28ft), it should not break
f) Should be free from cracks
g) Water absorption : 15% by weight.

Picked Bricks :
Picked bricks : a) Is overburned than 1st class b) Distorted shape. c) Harder than 1st class and suitable for making khoa chips.

Identification of 2nd Class Bricks
a) Slightly Inferior than Ist. Class.
b) Distorted faces and edges.
c) Burning almost same.
d) Lose sound.
e) Presence of cracks.
f). Water absorption more than 20% by weight.

Identification of 3rd Class Bricks
a) Mostly unburnt, inferior in quality, not used in construction.
b) Breaks easily.
c) High water absorption (over 25%) It becomes soft on immersion in water.

Engineering Data on Bricks	
Weight	=120 lbs/cu ft.
	=2 gr/cu. m.
Crushing strength	
a) 1st class	200 kg/sq.cm
b) Picked	210 kg/sq cm
Water absorption (24 hrs. imersion)=15% by weight Safe percentage of salt (Sulphates of Calcium and Magnesium) =2.5%	
Burning Temperature=1150°C to 1700°C	

Ceramic bricks
Mirpur Ceramics, Brick Linkers of Savar and other Firms are producing ceramic bricks used in facing and in construction works.

Classification : 1) Multicore bricks-3 holes, 10 holes, 17 holes and more holes bricks are available.
2) Solid pressed ceramic bricks : its size is 8" × 4" × 2" normally used in facing works in 2" and 4" thickness. 2" thick facing can be given by interlocking with main wall by means of Z-bars or brick tooths and holes.

Ceramic Jally : Various types of jally are also available. Different designs of jally are shown seperately.

Hollow Blocks : These hollow block are used in making economical roofs and floors.

Partition Blocks : These are hollow bricks used in light weight partition work.

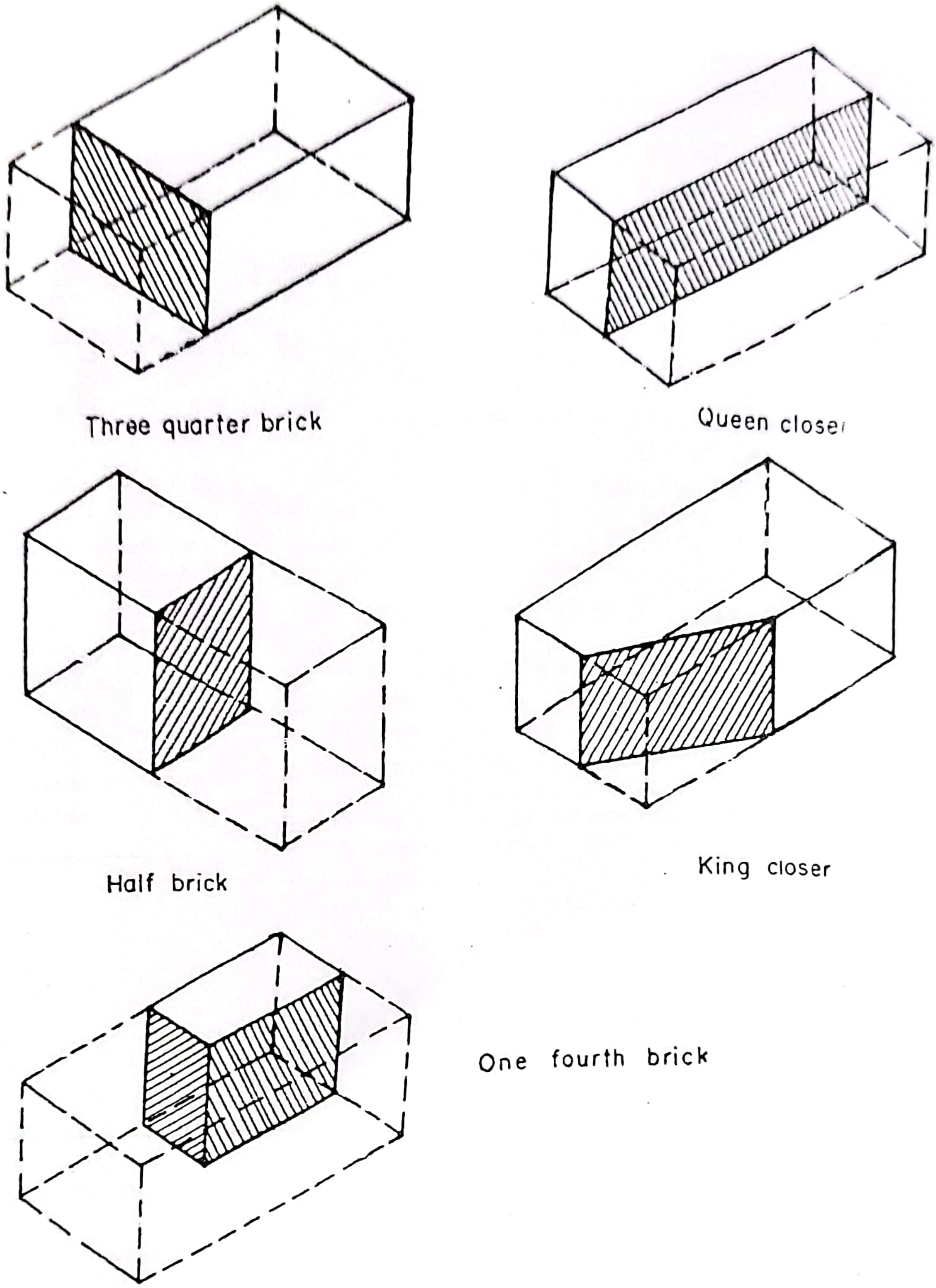


Fig 11, Different shapes of brick

2.5 Building Stone

There are many stones available in nature. Namely, Granite, Limestone, Marble, Basalt. Chalk, Sand stone, Quartzite, Laterite, Slate, Pumice stone etc. Out of which mainly Limestone is available in quarry of Bholagonj of Sylhet, Dinajpur and from mines of Bogra; Slate and Laterite from Chittagong.

Chief requirement of building stone are strength, density and durability Stones of uniform colour are generally found durable. Red or brown shade in it indicate the presence of injurious materials.

In our country, three main types of stones are used in construction as stone chips which forms concrete when mixed with sand cement and water, These are

1. Pea gravels, normal size is 3/4" and below. Does not require crushing
2. Shingles, normal size is bigger than pea gravel but less than 3". It requires breaking into chips.
3. Boulders, bigger than 3 . It needs breaking.

Though we use brick chips in concrete in this region but it is not recommended by ACI Code Only stone chips is recommended for good quality concrete.

2.6 Concrete

Concrete is a heterogeneous mixture of cement, sand, crushed stone (or brick chips) and water. Aggregates like sand and stone are inert while cement and water undergo chemical changes and the mass hardens like artificial stone. Approximately, 7 1/2 gallons of water is needed per bag of cement. When steel is added for strength it is called Reinforced Concrete. There is light and heavy weight concrete used for specific purposes. Building codes do not specify brick chips to be used in concrete instead of stone chips. However, it is used in our country as a substitute of stone, as such for maintaining quality, picked bricks should be used.

Concrete mixtures have different proportion as under:

Cement :	Khoa :	Brick	Usage
1 :	3 :	6	Weak concrete for levelling.
1 :	2 :	4	Slab, beams column
1 :	1 1/2 :	3	Beams, water tanks etc

2.7 Mild Steel Rods and Flat Bars

As compared to concrete, steel is 10 times stronger than concrete in compressive strength and 100 times stronger in tensile strength.

Common steel is billet. Billet has three grades, namely:

1. Structural grade
2. Intermediate grade
3. Hard grade.

Intermediate grade is used in construction. Some other steel rod is also available in our country, called scrap steel extracted from breaking of scrap ship. This is hard grade steel and is not suitable for columns, but can be used in beams and slabs.

Deformed bars are drawn from hard grade steel and is very strong in tensile and bond stress and is economical for roof slabs.

Steel Rods: 1/8" dia rod is called No.1. rod. 2/8" dia is No. 2 rod, 5/8" rod is called No. 5. rod and so on. Masons call them one Suti (one suti mean 1/8" dia) two suti etc. Normally 1/4", 3/4", 1/2", 5/8", 3/8" dia rods are used in house building.

Flat bars:

3/4" x 1/8" flat bars are used in window grills, Z-bars, L-bars I-sections, channels are also used for various fabrication

Why M.S. rods are used in concrete ? : When heated (reversely, when cooled) concrete and steel elongates or contracts in a proportional way. Or Young's Modulas of elasticity is the same for concrete and steel.

That is why concrete and steel are used together.

Hardness of Rods : More the carbon contents, more is the hardness of steel. Strong steel means high carbon contains in it. Lesser percentage of carbon is present in mild steel for which it is possible to shape it in any form.

Mild steel is more ductile and is suitable against earthquake action and is preferable to scrap steel which is hard and less ductile.

High carbon steel is also used in pre-stressed concrete.

Twisted bars, welded fabrics, ribbed mesh. Joist etc. are also used in construction.

2.8. Glass

Main Types are : i) Laminated glass- It is shutter-proof.
ii) Sheet glass- Used in houses as window shutter and glazing.
iii) Foam glass- Used in bulbs.
iv) Structural glass- Bricks or even beams are prepared from such glass.
v) Frosted glass- Transparency is lost.
vi) Glass Crete-Can be sawn or drilled like wood.
vii) Caloren- Heat proof glass.
viii) Vita glass- Specially prepared for ultra violet ray.
Sl. No. (ii) and (v) are mainly used in building construction.

2.9. Paint, Varnish, Distemper

Purpose of Painting : Paints are used for-
a) Protection from weather action.
b) To impart desired appearance.
c) Prevent corrosion.
d) Prevention of fire.
e) Create healthy atmosphere.
Composition : A paint consists of :
a) A Base, b) Pigments
c) A vehicle, d) A drier like litharge and a
e) Thinner like turpentine
a) Base- Zinc white, lead white, red lead etc.
b) Pigments-Colouring matters like black manganese, lamp black, soot, burned umber, brown crome, prussian blue Zinc crome etc. are used.
c) Vehicle- Linseed oil is mostly used. Other are Soyabeen oil, resin oil, etc.

Varieties- i) Enamel paint : Enamel paint has high grade base like zinc white. They are costlier and give long standing results. Best for metallic surfaces.

ii) Emulsion paints : Pigments dissolved in water vehicle and a drier. Oil is also used as vehicle. It is further divided as oil bound or water bound. Best for cement plastered surface finishing.

iii) Cement Paints :
Mixture of : White cement 70% Lime 30%

Add pigment to desired colour and density. This is suitable for rough surfaces.

iv) Cellulose paints :
These are mostly water washable.

v) Metal oxides paints- Zinc or lead oxide is a good protective coating for iron and metals. For drums, water tanks etc.

vi) Bituminous paint-Asphalt or bitumen dissolved in any type of oil or petrolium gives bituminous paints, used for works under water and over roofs.

vii) Anti-corrosion paints-Red oxide paint is commonly used. Powder oxides of metal of iron, zinc, chromium lead is dissolved in oil and is used as prime coats.

viii) Anti-fungus paints are also available.

ix) Ready mixed paints : There are many locally manufactured mix paint in sealed containers which give satisfactory results.

Stages of painting :

1) Selection of Brushes : Good costly brush having paint holding capacity and smooth nails be prefered.
2) Stopping : Repairing to cracks, depressions by white lead and oil be used for making smooth surface.
3) Cleaning : 0 to 1 No. sand paper or emery paper be use for rubbing the surface and then cleaned by soft cloth.
4) Coats : Three coats are normally used for best result including Prime Coat. Priming paints are available. After drying up of prime coat under coat and final coat is given. Each coat should be dried up before applying the next coat. In case of wall a chalk powder wash dissolved in water may be given as prime coat and duly rubbed and cleaned before painting.
5) Spray painting : Painting with spray gun gives better surface than brush painting because uniformity is maintained. Also work can be done quickly.

Varnishing

It is a case which is mainly applied to wood. Sprit varnish is popularly called polishing.

Oil varnish is highly weather resistant which can be used in other metal surfaces and wood.

Composition of Varnish :

a) One base (resineous substance like roson muski, gala etc.)
b) Solvent : Volatile liquid like methylated spirit popularly called as spirit.
c) A drier is sometimes used for quick drying.
d) Pigments for desired colour.

Preparation :

a) Dissolve gala in spirit it takes about 1½ hours.
b) Prepare a solution of roson/ muski in a separate container. Meanwhile, prepare the surface to be varnished.
c) Screen the Solutions through fine cloth.
d) Clean surface till smooth. Close knots and cracks by putty. Apply french powder along with spirit and allow to dry clean again with O no. sand paper.
e) Clean cloth be used for making pad which will act as brush. Apply on (a) soln with this pad. Allow to dry and rub with O sand paper.
f) Finally 3/4 strokes be given with (b) soln. for glaze.

Distempers : These are water bound paints. It is thined by water, can be applied to walls in a manner similar to paints.
Distemper Powder-Oil free powders are available in various colours : can be applied to wall by dissolving into water upto desired consistency. But gum be used in the solution @ 1 chhatak per five gallons of water for adhesion to walls.
Putty : It is made of :
a) Chalk Powder, and
b) Linseed oil
Manganese dioxide may be added for hardness. It is popularly called as 'Puttin'.

2.10. Mosaic Materials

1. White cement. 2. Marble dust. 3. Grey cement. 4. Marble chips. 5. Colouring materials.
Out of these, cementing materials and Filler materials be prepared.
A. Cementing Materials : The former three form the cementing material and is taken in the proportion of :-

White cement : 1 part
Marble dust : 1½ parts.
Grey Cement : 3 parts

B. Filler Materials :
Marble chips are the main filler materials, necessary colouring pigments may be used. For making contrast different marble chips may be taken in different proportion.
Mosaic : Now one part of 'A' and one part of 'B' are mixed with water and is spread over floors in ¼" to ⅜" thickness. This mosaic gives silver grey colour and is called situ masaic. Pigments upto desired density can be used according to choice.
Mosaic Tiles : Standared size is 8" × 8" × ¾". It contains ⅜" thick mosaic materials over a pressed 1 : 2 cement : sand base

2.11. Wood : Is of two types-hard and soft.

Hard wood	**Soft wood**
1) Leaves are broad	1) Leaves are narrow
2) Dense	2) Less dense
3) Well defined annular rings.	3) Not well defined
4) Heavy.	4) Light.
5) Hard	5) Soft

Comparison between Sap wood and Heart wood

Sap Wood	**Heart Wood**
1. Outer layer	1. Inner layer.
2. Rich in plant food and is subject to decay by fungus	2. Stronger cells and is poisoneous to fungus.
3. Undurable	3. Durable.
4. Bigger moisture contents and soaking.	4. Almost nil.
5. Unsuitable for construction work.	5. Most suitable for Construction work

Seasoning of Wood : It is necessary for :
1) Expelling water.
2) Reducing weight for transportation.
3) Create resistance to decay and deformation due to weather action.
4) Suitable for cutting and using in work.
5) Impart suitability for painting and polishing.

Methods of seasoning :
a) Air drying (Natural)
b) Water immersion
c) Applying chemicals like Urea
d) Applying heat (Kiln seasoning)
e) Electrical- For seasoning at rapid rates.
f) Combination of the above.

Few best known wood of the country :
1. Chittagong Teak. 2. Teak Chambal. 3. Telsu. 4. Gammer 5. Chapalish 6. Sal wood 7. Silkorai. 8. Kathal. 9. Garjan. 10. Sundari. 11. Jam. 12. Nim. 13. Mango 14. Simul

2.12 Aluminium Panels

Now-a-day, aluminium panels are extensively used for its long lasting effect, sliding facility and decency. 5 mm plane glass or foreign made tinted glass is used in combination with the panels.

2.13 Water Proofing Agent

Water proofing in underground works is difficult, particularly in water reservoirs. Normal concrete is not water proof, unless admixtures or reagents are used except the wall is made abnormally and uneconomically thick. Few admixtures are stated bellow :
1. Pudloo-It is a ready made water proofing agent used in the concrete mixtures proportions be given as per prescription of the porducer
2. Home made admixtures :
a) 1 percent soap solution may be used in concrete instead of adding ordinary water.
b) For walls and plastered surface alternate application of Alum and Soap solution gives good results $1\frac{3}{4}$ ounce (ozs) of Alum is dissolved in 1 gallon hot water, 1 ounce Soap is also dissolved in 1 gallon hot water. Hot alum solution is first applied to the surface by a brush immediately followed by hot soap solutions. After drying another course may be followed.

2.14 Piles

Piles are of two kind-
1) Pre-cast R.C.C piles
2) Wood Piles.
Details discussion about piles is made in chapter 6.

2.15 Veneer Boards, Gypsum Board, Hard Boards and Other Boards

Veneer means covering of wood sheet or metal sheet over a base of wooden frame of honey comb line or other patterns.

Garjan, Chapalish and Teak veneers are available in the market

There are only one type of hard board mainly used for ceilings, base for formica sheets and in many other furniture making industry.

Formica and Glazed sheets are used for table tops and wall decoration and in furniture making.

Gypsum board, are only used in false ceiling.

2.16 Glues and Adhesives

Different types of glues and adhesives are available in the market which are used for cementing wood, Glazed and formica sheets, glass and rubber works.

2.17 Wall Decors and Floor Covers

Rexin and Poly venyle decorative sheets are also available. Walls and floors can be decorated with such sheets.

2.18 Glazed Tiles and Clay Tiles Glazed tiles are shiny and slippery and are suitable for bathroom walls. Its normal size is 4" × 4", 6" × 6", 4" × 8" etc, while clay tiles look dull and is non-slip surface and is suitable for floors. Varying sizes are available in the market.

2.19 Weight of Construction Materials

Items	Kg per cu.m.	Pounds per cu. ft.
Earth	1600-1760	100-110
Sand	1900	120
Bricks	1900	120
Cement	1440	90
Glass	2560	160
Steel	7840	490
Wood	650-720	40-45
Brick work	2320145	
Water	1000	62.4

3 Knowing About Architecture and the Building

"Art lies in concealing art"
- Ovid.

3.1 Architecture

Architecture is the art and science of designing and constructing functionally graceful structures to serve the user well and satisfy his varying and complex needs.

Architects of the old Greek age developed a style of proportion known as order of Architecture . It was a proportion of base of a column with its diameter. It was based on human body. Doric order was based on a man. Corinthian on a maiden and Ionic on a stout lady.

3.2 Vernacular and Designed Architecture

Architecture is of two kinds :

1) Vernacular Architecture and
2) Designed Architecture.

Vernacular Architecture is old and traditional having minimum originality. Masons and carpenters are experts in constructing such types of building without the help of an Engineer or an Architect.

On the other hand, Designed Architecture is the result of conscious efforts to create something new. It contains element of tradition, but each design is original. Function, form and feeling for utility and aesthetics are the three considerations in designed Architecture. An example is shown in the accompanying diagram.

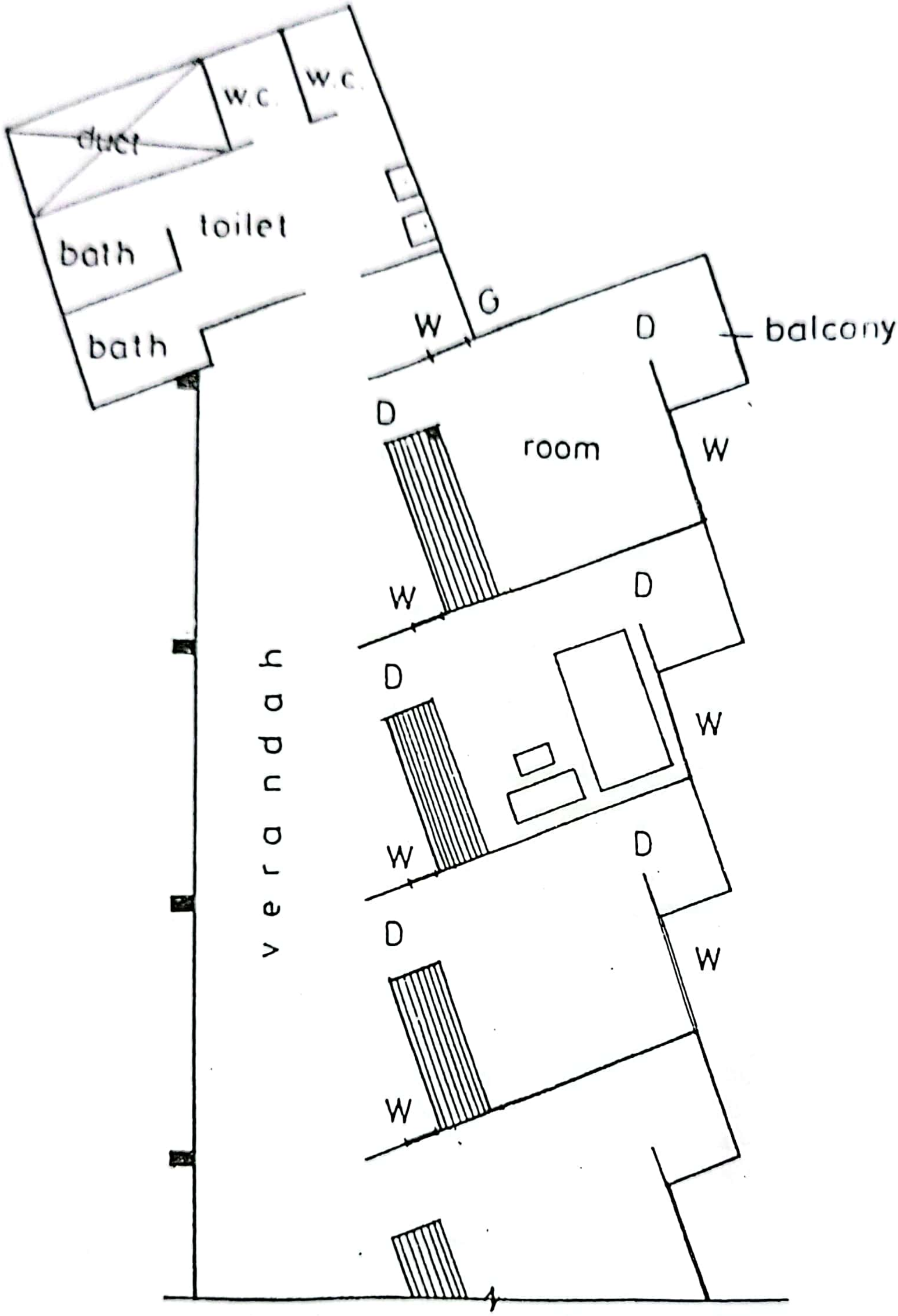


Fig 12 : Plan for hostel based on designed architecture

3.3 Architects on Architecture

Before studying the design considerations in architecture, it is interesting to study different views of architects on architecture. According to the French architect Auguste Perret, an architect is a poet who thinks and speaks in terms of construction. According to the American architect, Louis Sullivan, the true work of the architect is to organise, integrate and glorify utility.

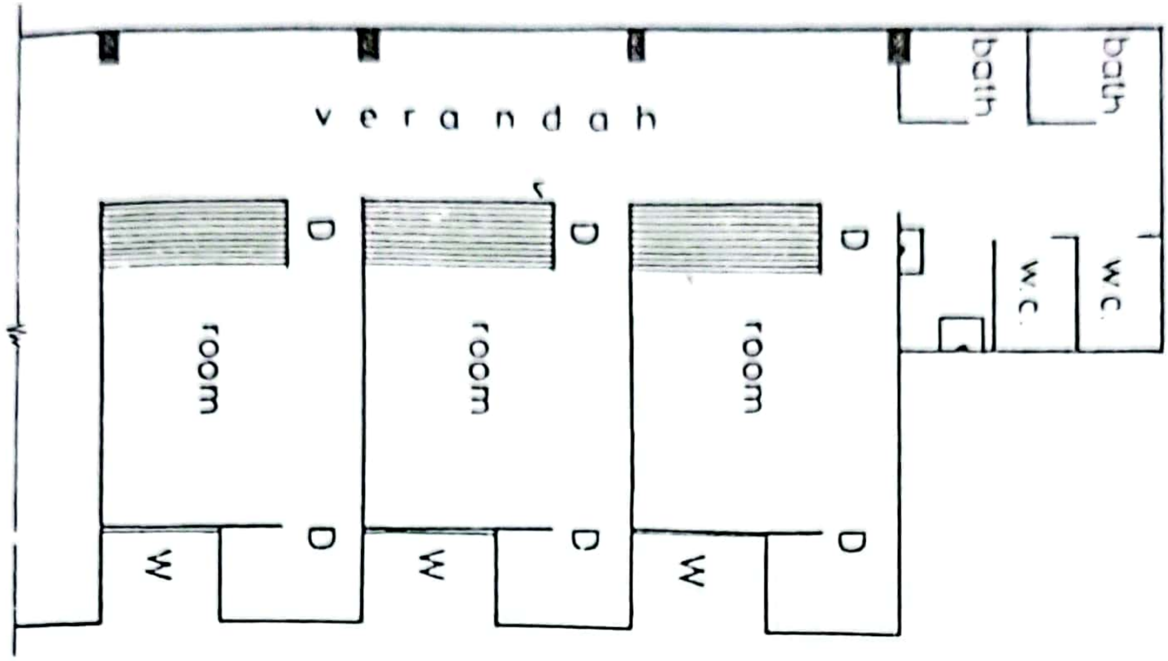


Fig 13 : Plan for hostel based on vernacular architecture

Then and then only is he truely a Master worker. Further, he defines design as 'The Architects graphical solution of a project or programme economicaly, structurally and aesthetically. Vitruvius, the first century Roman writer in his De architecture Libri Decem (Ten Books on Architecture) has stated the first principles and requirements of design : 'Utilitas, Firmitas, Venustas,' i.e. utility (good planning), sound construction and pleasing appearance are the principles of good architecture. As these principles can never be rejected entirely, revolutionary architecture was based on notions added to the above three principles.

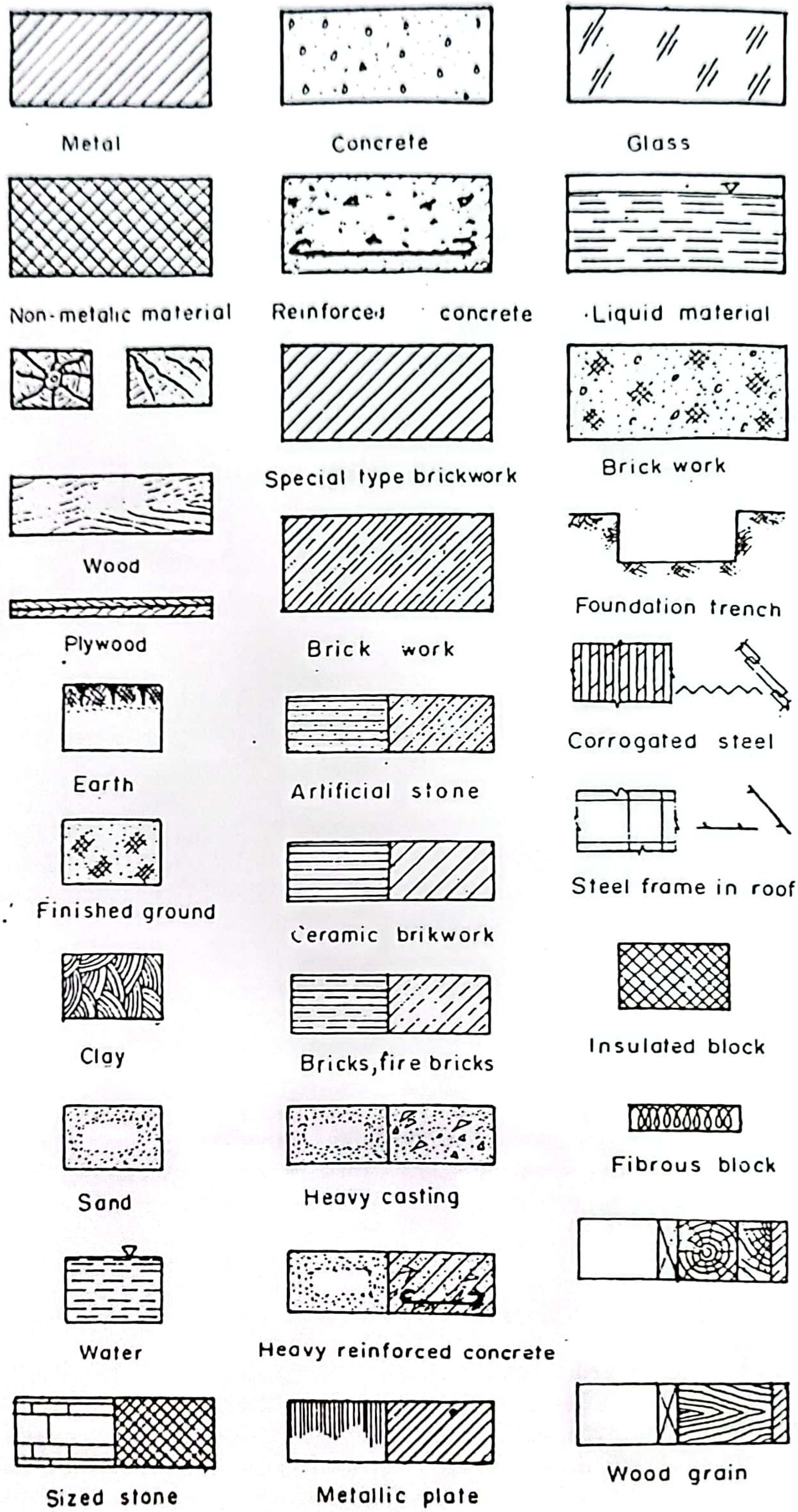
3.4 Prime Job of the Architect

Thus, Architects should concern themselves with planning and with nothing else !

'He goes on to say,' there. are only two problems in architecture, first, the problem of private buildings which was how to provide the optimum accomodation for the smallest sums of the money, and second, the problem of public buildings which was how to provide the maximum accomodation for a given sum.

3.5 Modern Architecture

Wright in the USA were responsible for changing the concepts of architecture and they can be called the founders of modern architecture. F.L. Wright defined modern architecture as power that is to say material resources directly applied to purpose. Le Corbusier defined architecture not in Vitruvian terms, but in terms of the sculptured effects of light and shade. 'Architecture', he wrote, is the masterly, correct and magnificent play of masses brought together in light. Our eyes are made to see forms in light. Thus, cubes, cones, spheres, cylinders or pyramids are the great primary forms which



14 (a), Architectural symbol

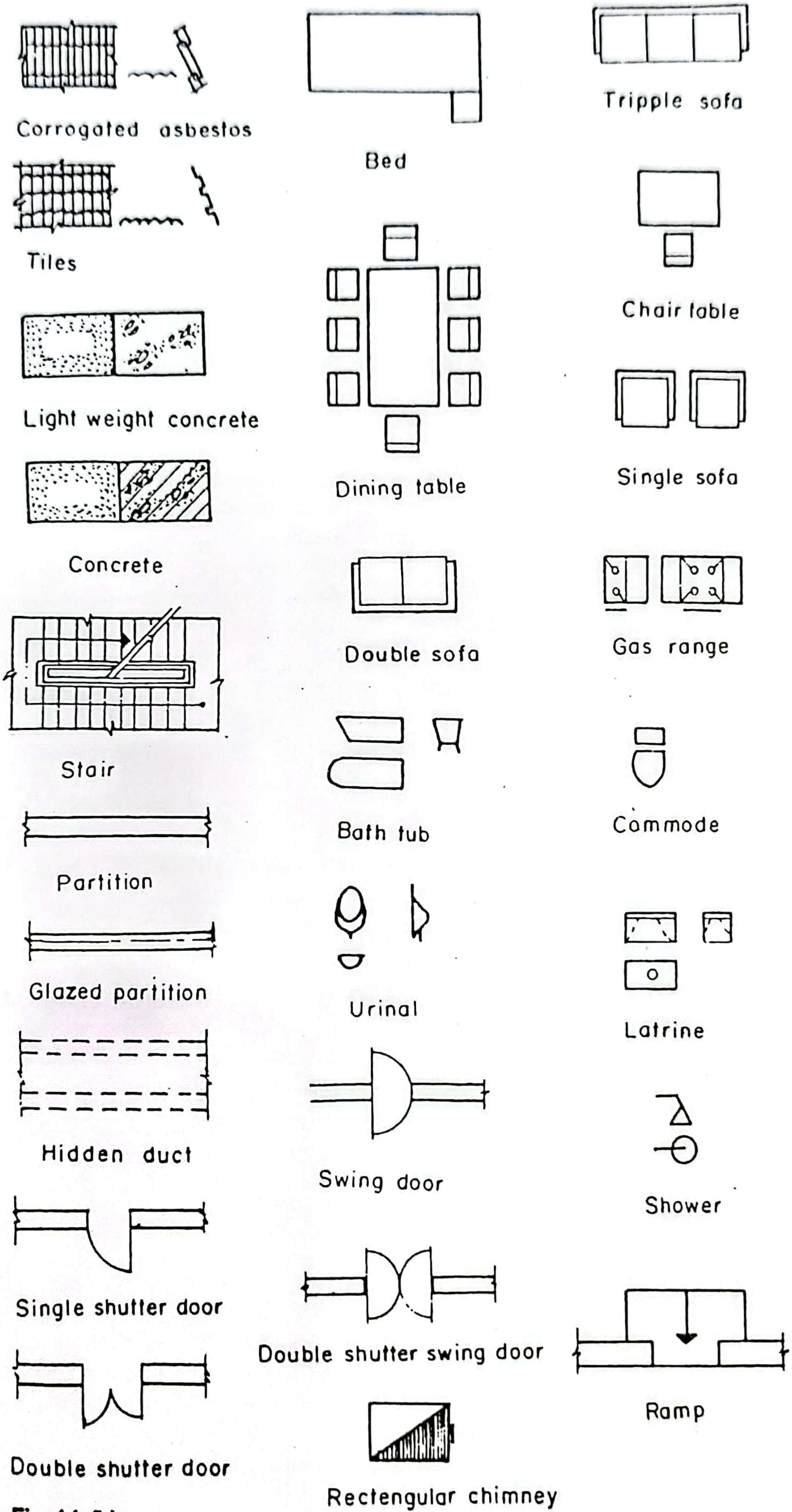

Corrogated asbestos
Tiles
Light weight concrete
Concrete
Stair
Partition
Glazed partition
Hidden duct
Single shutter door
Double shutter door
Bed
Dining table
Double sofa
Bath tub
Urinal
Swing door
Double shutter swing door
Rectengular chimney
Tripple sofa
Chair table
Single sofa
Gas range
Commode
Latrine
Shower
Ramp

Fig 14 (b),

light reveals to advantage. They are not only beautiful forms, but the most beautiful forms. He also stated that the so-called architecture does not exist, only 'functions' exist. Modern architecture consists of functionalism and simplicity using new methods of construction for new materials.
J.N.L. Durand, an architect of the nineteenth century said. "Ornament had nothing to do with architectural beauty. Since a building is only beautiful when it satisfies a need—whether we consult our reason or examine ancient monuments —it is evident that the primary purpose of architecture has never been to please, nor has architectonic decoration been its object.

3.6 The Architect and the Engineer

Le Corbusier has commented on the engineer's and architect's work in the following words :
An Engineer employs geometrical forms- their work is on the direct line of good art.
The Architect by his arrangements of forms, realises and order which is a pure Creation of his spirit. The purpose of construction is to make things hold together, and of architecture, to move us.
Thus, architecture demands a different talent and vision while dealing with its basic necessity. ie. utility, form and aesthetics. A person trained in planning and possessing the urge and natural vision for aesthetics should deal with planning and aesthetics. At the same time, he should have sufficient background for structural design and construction. A person possessing an analytical vision, knowledge of the method of construction, materials and their properties and sufficient background of structural design should deal with sound and ecnomic construction. Planning and execution is thus the job of the architect. Estimation and measurements, structural design, contract and supervision is the job of the architect & civil engineer to have the background of the work of architect and knowledge of principles of architecture, so as to enable him to read the drawings with the vision of an architect.

3.7 Owner, Architect, Civil Engineer and the Contractor

Owner is a Person with an intension to construct some structure on his site. The Architect helps him to plan the structure, the Civil Engineer finds the requirements of structural design and select a Contractor for its execution.

3.8 Modern Houses

The style of house commonly referred to as 'modern' or 'modernistic' developed primarily in Europe during the early 1920's. Architects such as Le Corbusier, Gropius, Hoffmann, and Neutra rejected the traditional way to plan and build a house. Their approach was to plan the interior to suit the needs and way of life of the occupants. Then they covered this plan with a simple shell, devoid of unnecessary decoration. Its function was to shelter the plan from the elements of nature. The exterior, then became simply the result of the developed plan.
The outstanding feature of the modern house was not its exterior

appearance but the interior plan of rooms. The house was designed to be functional and to reflect the modern way of living. Considerable emphasis was placed on working out the best room arrangement and use of space.

Building costs were getting higher, so houses were becoming smaller. The modern house attempted to get a feeling of spaciousness in a small floor area by combining several rooms. It was called an open plan.

The use of large, glass areas in the exterior walls also contributed a great deal to the open feeling. The windows were placed where needed, with little regard to what this did to the exterior. Then emphasis was on a viable, open, floor plan.

3.9 The Building

It is defined as an enclosed space covered by roofs.

Building construction is an engineering science dealing with technics of construction of building.

There are two main types of buildings, public building like Schools, Cinema Halls, Hospitals and Residential building. The technic of construction is the same for both the cases.

Each building has two main parts 1. Sub-Structure or, the foundation including plinth and 2. The Super Structure above plinth level. Plinth level is the height above ground level which is finished as ground floor.

On the basis of materials used in construction, it is further classified as :

1) Kucha- namely, house made of mud, tile, bamboo, tarja, straw etc.

2) Semi pucca-namely house made of brick wall, cemented floor but tin or tile roof in wooden frame.

3) Pucca- Building completely made of bricks, cement, sand, stone and steel.

This text deals with Residential Occupancy only.

Building may be classed as under according to occupancy :

1. Residential occupancy
2. Business occupancy
3. Educational occupancy
4. Institutional occupancy
5. Industrial occupancy
6. Storage occupancy
7. Assembly occupancy
8. High Hazard occupancy

3.10 Some Building Terms

Alcove : A large recess in a room seperated by an arch or so.

Arch : A mechanical arrangement of wedge shaped blocks mutually supporting each other forming an opening and resting on two ends over columns or walls.

Balcony : It a horizontal projection of roofs fitted with railing serving as a sitting out place.

Bay window : A window projecting upward from the wall having rectangular or curved form.

Basement : It is a floor situated below the ground level.
Beam : Is a horizontal member used to support load over opening.
Brace : Used in roof frame as a slanted member for tightening and framing.
Canopy : Is a covering which can be done on roof tops.
Cistern : Is a tank for storing water for flushing pans, urinals water closets and drains.
Condominium : It is a dwelling of individual ownership in a multi- unit building having undivided interest in common areas and facilities.
Conduit : It is a pipe or a channel for conveying wiring and water.
Coping : It is a covering on a wall top usually sloped to through off moisture.
Corbel : A projection from wall to form a support.
Corridor : It is a narrow verandah or a gallery for communication to different parts of the building.
Cornice : Horizontal projection of the roof.
Dormer window : A window set vertically into a slopping roof.
Drop wall : A wall coming downward from roof to protect verandah, balcony or open space.
D.P.C. : Damp proof course.
Eaves : It is paved open space around the building to facilitate movement and through off rain water.
Facade : The principal front of a building.
Grouting : Making repairs with the help of strong cement mortar run into cavities and joints of the masonry works.
Lintel : Horizontal beam like member over the opening of door and window.
L.C. : Lime concrete placed on the last roof.
Louver : Inclined or staight openings with series of slates permitting ventilation but preventing rain and sun.
Lobby : An entrance space or hall is called lobby.
Nosing : Rounded and projected edges of the cornice or stair.
Loggia : A Loggia is a roofed, open gallery along the front or side of a building. It serves as a passage connecting areas of a house. Loggias may be on both ground and second story levels. Modern versions may have doors which can be used to enclose the area in bad weather.
Gallery : A gallery is an interior area which serves as a passage way. It often opens onto a courtyard. Usually, it connects with the foyer. One wall may be glass. Durable materials are commonly used. The gallery might contain potted plants and a few pieces of furniture.
Atrium : An atrium is an area, usually under a roof, in which plantings dominate. The roof admits light needed by the plants. The atrium might have paved paths and private places to sit and relax. Often, rooms open onto it or have glass walls facing it. If totally enclosed, it provides year around greenery to the interior rooms.
Pantry : Is a small room generally provided adjacent to the dinning room for keeping cooked food.
Parging : Thin coat of plastering to smooth off rough walls.
Parapet : A low hight wall provided in the last roof and is used as railing.
Portico : An open space usually with roof provided in front of an entrace for stopover of cars.
R. B. : Reinforced brick work.
Setback : Placing of a building at specified distance from Road.
Soffit : A partial ceiling lower than the main one.
Span : Spacing of supports of beams, arch, truss etc.

W. C. (Water Closet) : This is an arrangement for flushing the pan with water. It does not include the bathroom.

3.11 The Soil

Different soil has different load bearing capacities as described herein. Since foundation rests on soil, its condition at required depth should be carefully observed as to whether the soil is

1) Loose, or
2) Original

In all cases, foundation should rest on original soil even if the depth of foundation is over 7'-0" (2.13m). For filling grounds over this depth, technical advice should be taken.

3.12 Bearing Capacity of Soil

	Tons per sq. ft.	Tons per sq. m.
1) Soft clay	0.185-.348	2-3.75
2) Alluvial soil	0.46-.69	5-7.5
3) Moist clay	1.02-1.67	11-18
4) Made up ground	0.46	5
5) Ordinary clay	2.04	22
6) Mixed with sand	2.00	22
7) Compact dry clay	3.06-4.64	33-50
8) Loose sand	2	22
9) Compact sand	3	32
10) Rock	3.7-7.4	40-80

In case of Dhaka region,.no. 3. is applicable except otherwise soil test may be carried out for different nature of soil.

3.13 Foundation or Sub-Structure

The foundation including plinth is called sub-structure.Foundation rests on soil and spreads the load of the building over it. Types of loads are as follows:-

a) Live loads- Such as man. furniture, stored materials etc.
b) Dead loads- Such as weight of bricks walls, floors, fixed machines etc.
c) Wind and other loads- Such as lateral thrust of storm, earthquakes and water pressure.

3.14 Functions of Foundation

a) In fact it does not carry or bear the load of the structure; rather it distributes the permissible load to the ground.
b) It keeps the structure in position.
c) Provides levelled base for the structure.
d) Prevents tilting or over turning of the structure.
e) Prevents unequal settlement.

3.15 Types of Foundation

1) Spread footing.
2) Stepped footing.
3) Pile footing.
4) Raft footing.
5) Well footing.
6) Caisson foundation.
7) Cantilever foundation.
8) Combined footing.
9) Inverted arch footing.
10) Grillage Foundation.

Pile Foundation :

i) They carry load by skin friction by their sides.
ii) They carry vertical loads on their ends.
This is used in the following situation :
1) When hard soil is at a greater depth.
2) When other foundations are more costly.
3) When the site is marshy.
4) When concentrated loads are there like multi-storied commercial buildings.
5) When foundation is given at river beds for bridges etc.
6) When chances of pond cutting or canalling in the nearby plot is there.
7) When top soil is loose.
Types : According to materials piles are of 5 types.
1) Wooden piles.
2) Concrete piles.
3) R.C.C. piles.
4) Sheet piles.
5) Sand piles.

Raft Foundation : Is used when bearing capacity is very poor. Say, the site is newly filled or marshy and the soil compaction is not satisfactory. It consist of R.C.C. Slab supported by Beams all over the floor area.

Well Foundation : This method is generally applied for bridges which provides a trust worthy foundation in soft sandy soil of the river bed.
Earth is taken away from inside the well. It is sunk slowly by its own wt. or applied weight. It can be tested by putting the desired load on it. The well is filled in with gravel, soil and concrete.

Cassions Foundations : It is almost similar to well foundation, used when water depth is more. It is a bonded drum of steel sunk in upright position by applying load of sand bags. Water is pumped out and concrete is poured to fill up the drum. It remains for ever with the foundation.

Cantilever Foundation : For eccentric loading.
a) Two separate footing are provided for external and internal walls.
b) They are connected by means of beam.

Combined Footing : When two or more columns are supported by a single base.

Inverted Arch : This is uncommon foundation. Where bearing capacity is poor and load is supported by pillars, where deep excavation is not possible. The thickness of arches should not be used less than 30 cm.

Grillage : Suitable for heavy load and poor bearing capacity. This is costly and for domestic buildings it can be avoided.

Spread Footing : This is the normal building foundation generally followed in the country.
Such type of foundation is normally made by providing requisite width of foundation wall or column footing as stated below :
A. Wall foundation :- Normally 3 to 4 ft. deep earth cutting is done width being equal to No. of stories to No. of one bricks lengthwise (10" wise) i.e for 1 storied building 10" wide foundation is necessary for 2 storied 20" for 3 storied 30" and so on may be necessary. A 3" brick soling is provided on the soil 3" thick concrete of 1:3:6 (cement: sand: khoa) is given. 6" steps are given till 15" wall thickness is achieved. It is then taken upto plinth. In any case, steps should not be less than 6". Brick work should be in 1:5(cement:sand) mortar.

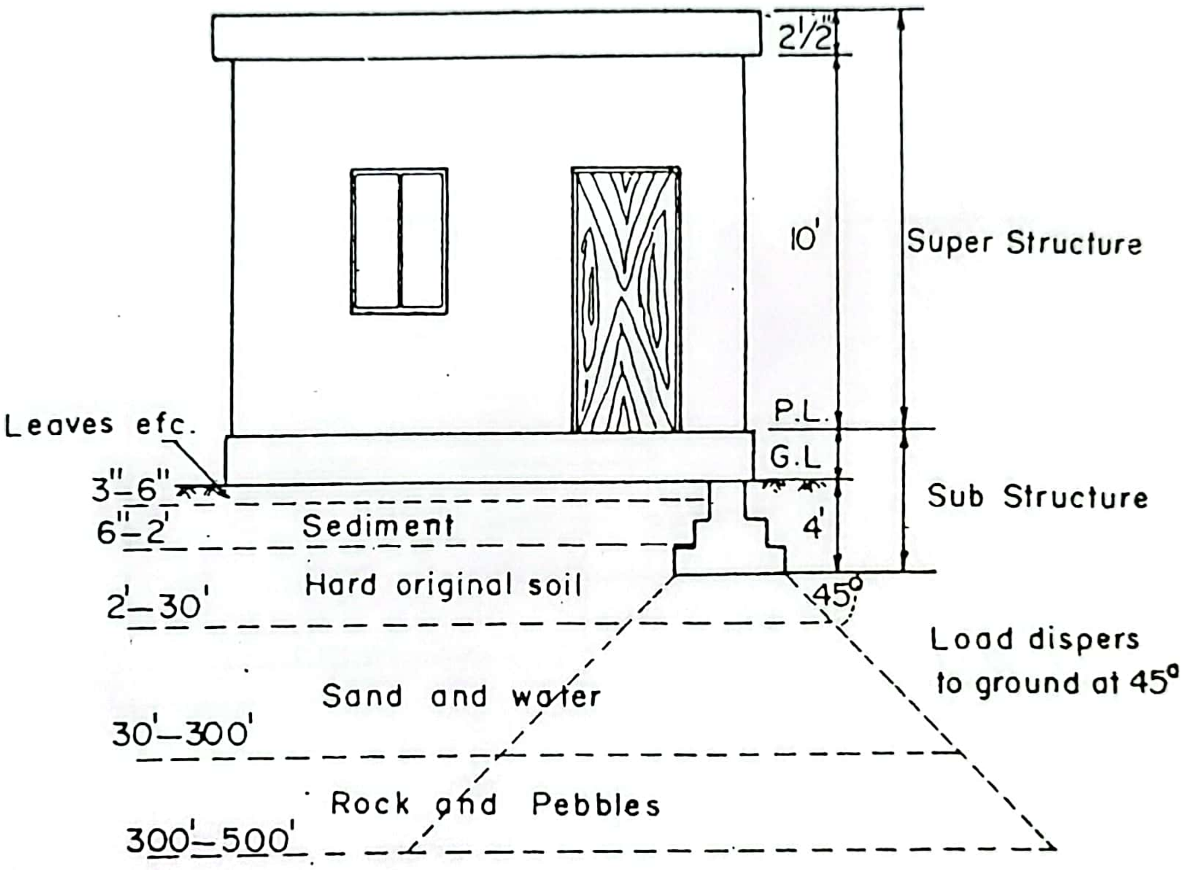


Fig 15 : Sub-structure and superstructure

B. Column Foundation:- Where foundation depth is more due to filling ground or loose soil condition column foundation is preferable. Over a brick soling, 3" lean concrete (1:3:6)is given; ½" dia rod in both directions @ 4" C/C (centre to centre) be provided having 3'×4', 4'×5' base size according to load on the column; then 1:2:4 conerete be poured in foundation which will be not less than 6" thick. It is reduced to 10" × 10" size with four 5/8" vertical column rods ringed by 3/8" dia rings @ 8" C/C (centre to centre). A horizontal beam of 12"×10" or 12"×8" size is provided at plinth level with requisite steel which is normally 4 No, 3/4" dia rod two at top & two at bottom bounded by 3/8" dia rings placed at 8" C/C (centre to centre). For other situation, the following type of foundation may be adopted.
Stepped Foundation : It is suitable only for Hilly regions. Over laps and steps should be equal.

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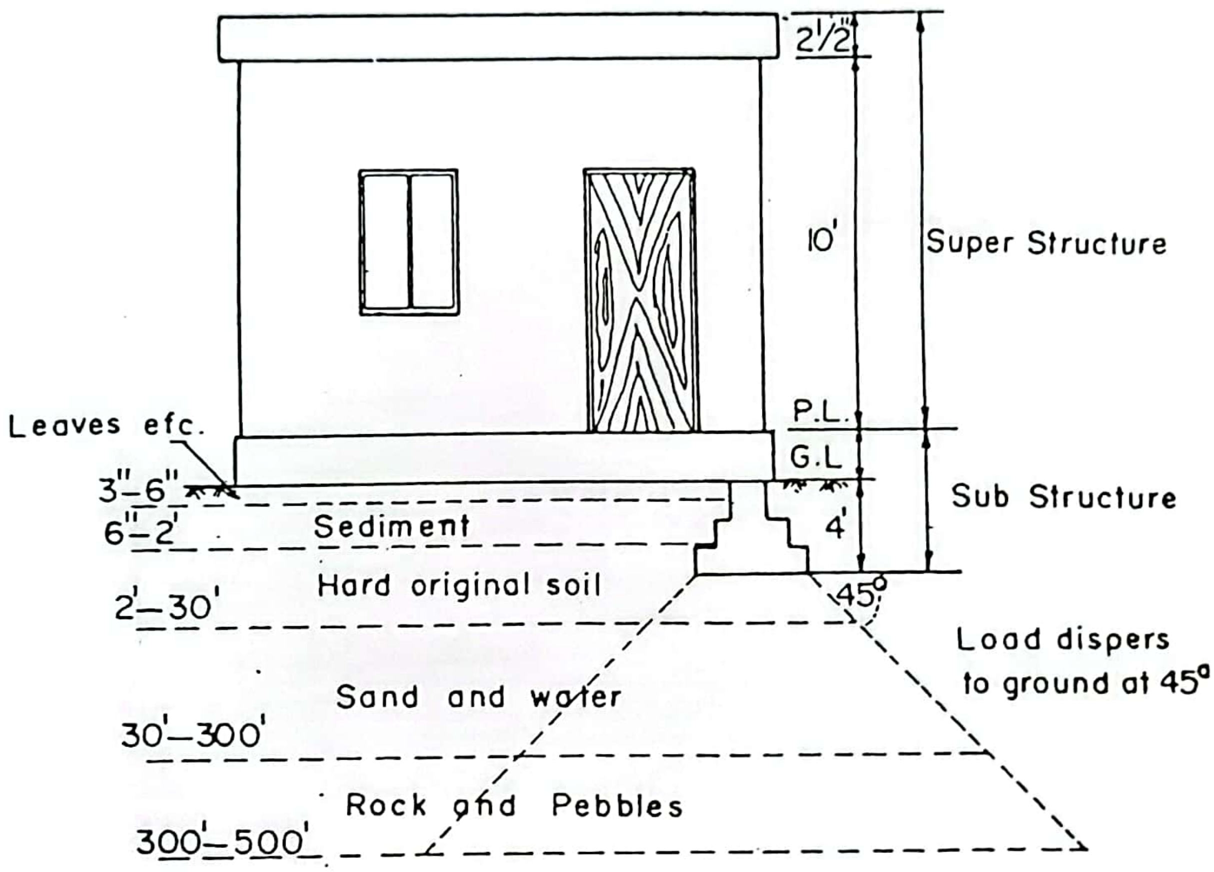

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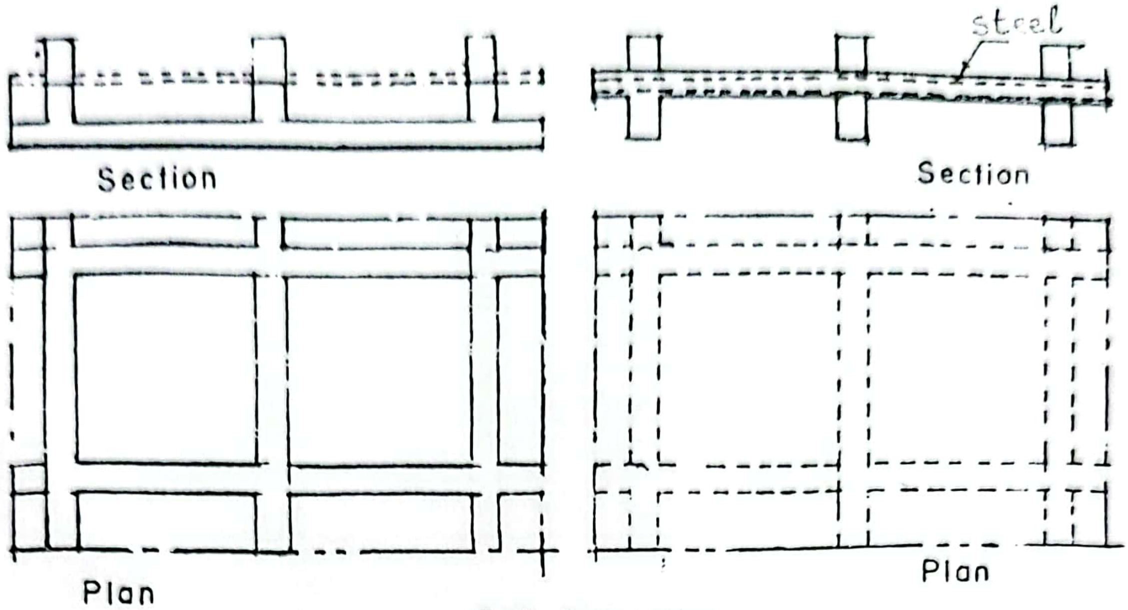
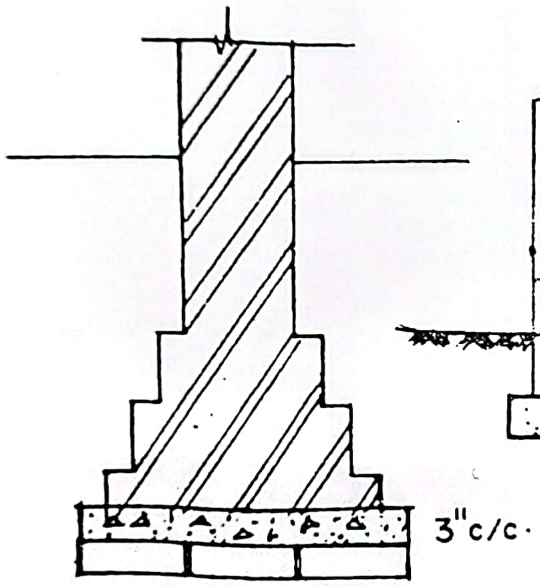
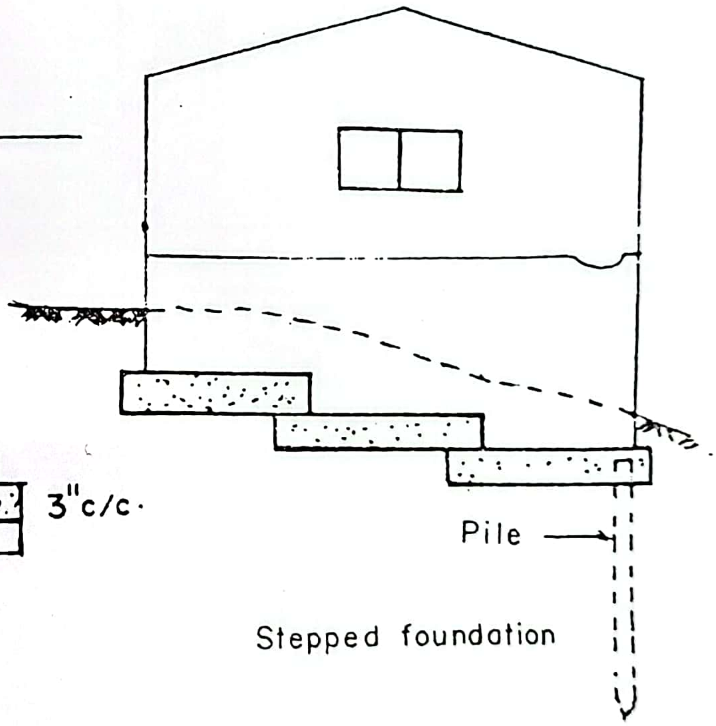


Raft foundation



Wall foundation



Stepped foundation

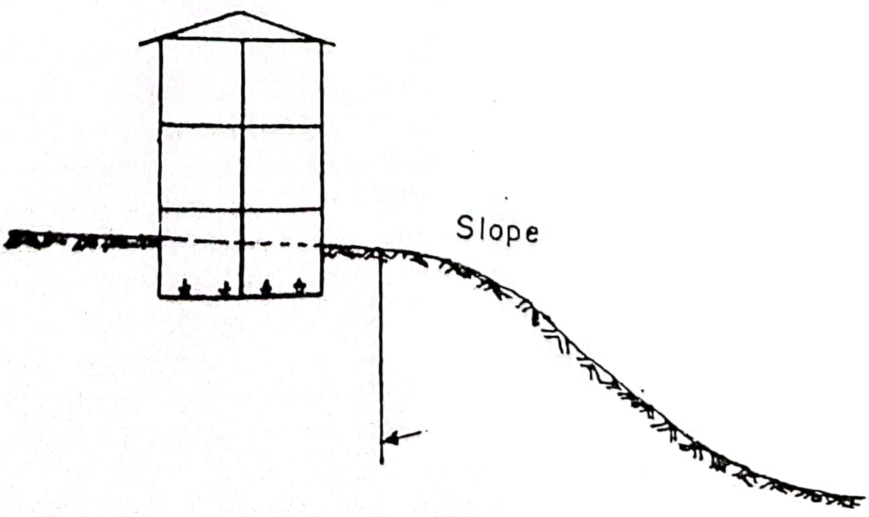
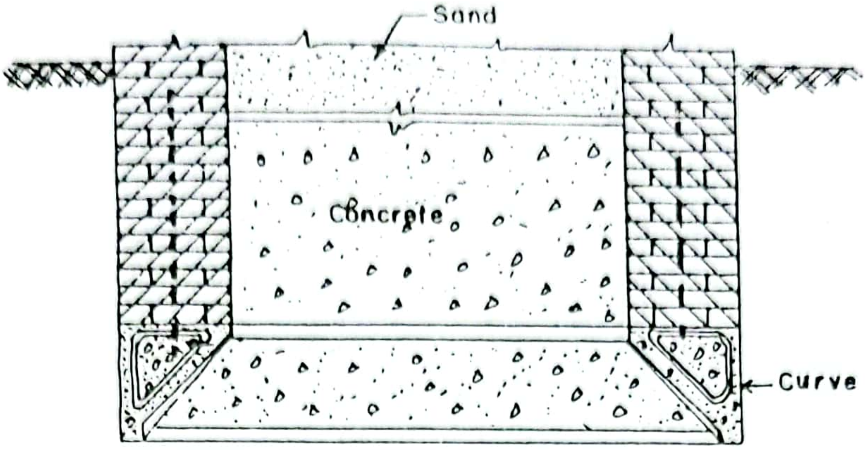
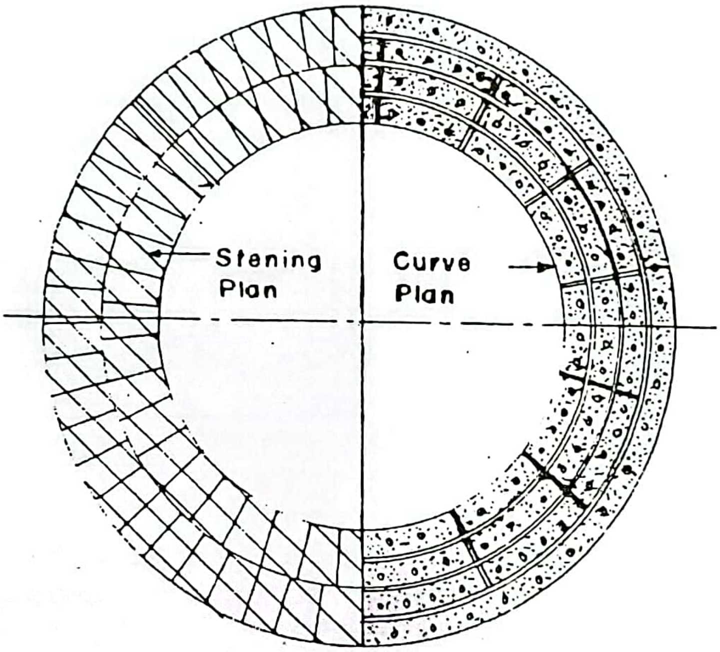


Fig 16 (a), Foundation,

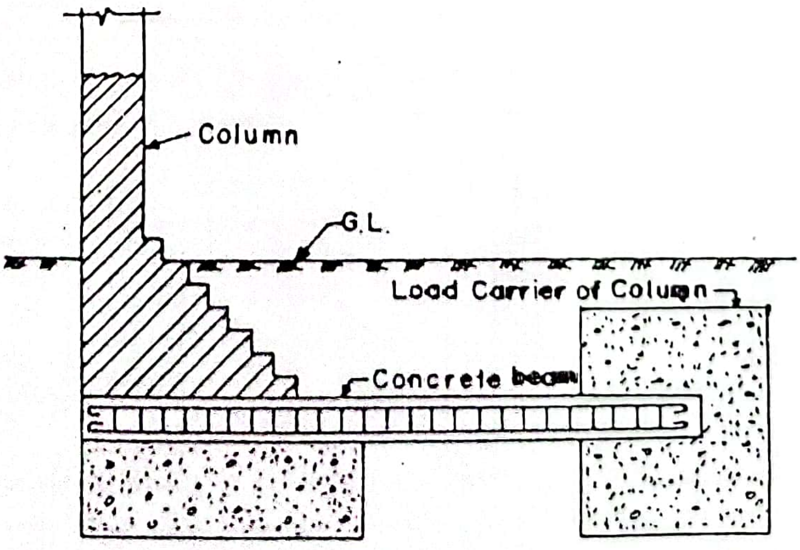
Sheet pile



Vertical Section of Well Foundation

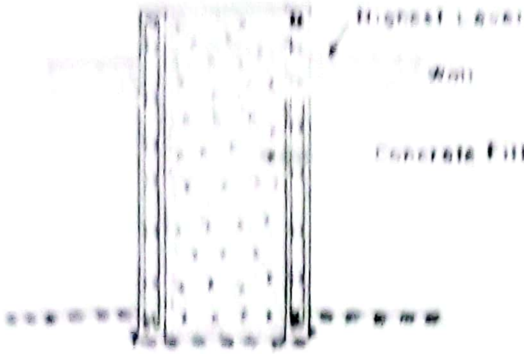


Sectional Plan of Well Foundation



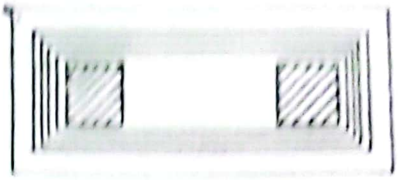
Cantilever Foundation

Fig 16 (b), Foundation

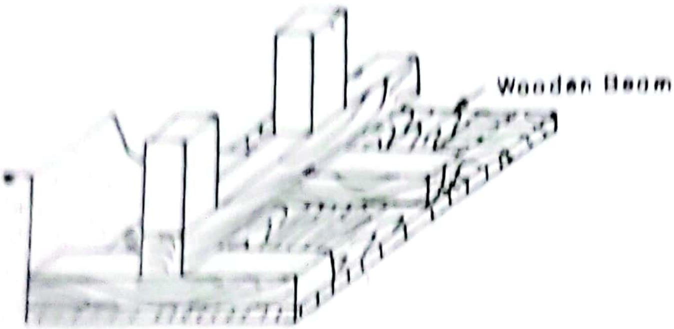


Caissons Foundation

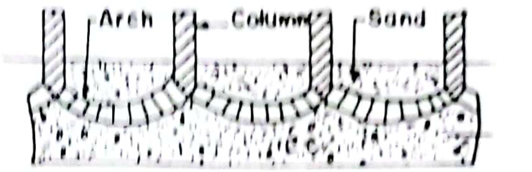
Concrete Base



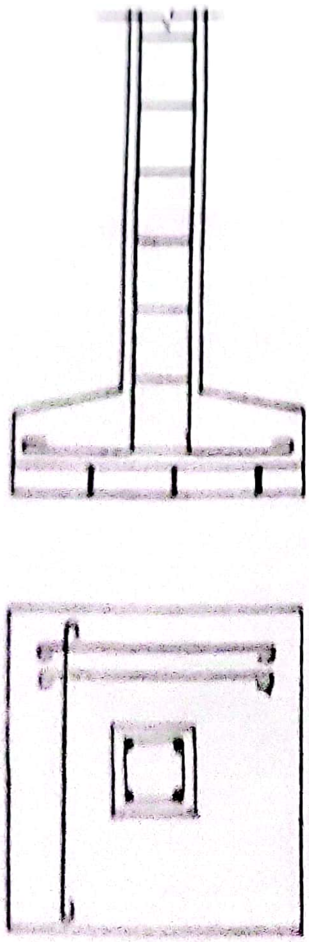
Combind Footing



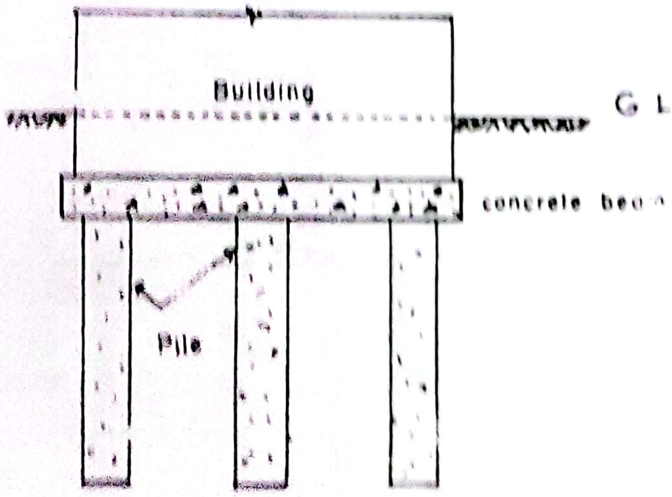
Timber Grillage Foundation



Inverted Arch Foundation



Spread footing



Pile foundation

Fig 16 (e) Foundation,

3.16 Damp Proof Course (D.P.C)

It can be done in three ways :
1) By providing damp proof layers of bitumin and concrete.
2) By providing rich plaster to wall.
3) By providing copings on top of walls.
Generally No. 1 is used as D.P.C at plinth level. D.P.C may be horizontal or vertical but it should be continuous. The course can be applied in the following way :
1) 1:2:4 cencrete with small stone/bricks chip or pea gravel 1" to 1½" thick (2 to 3 cm) is applied. One coat of bitumin over it gives good result.
2) Polythene sheets. Thick sheets spreaded below wall also gives good result. It is cheaper too.
3) Bituminous carpetting can also be made.

3.17 The Super Structure

It is comprised of wall, column, beam and slab.

Wall :
1) Load bearing brick walls 10" wide and is build in 1:6 (cement: sand) mortar.
2) False brick wall 5" or 3" wide in bath rooms and other partition works in (1:4) mortar.

Columns
Columns are mainly of three types :
1) Wooden, steel
2) Masonry brick column, and
3) R.C.C. column.
Size of brick columns is preferably selected of the following sizes :
10" × 10", 10" × 15", 10" × 25", 15" × 20", 15" × 25"
On the other hand, R.C.C. columns are normally of 10"× 10" size. For smaller spans 5" × 10" or 5" × 12" size may also be used at corners and at partitions L or T size columns can be used. Minimum reinforcement for column according code requirement is 4-5/8" dia rods. However, flexiblity is there for residencial buildings; ½" dia rod can also be used. Details about reinforcement in columns are shown in reinforcement section of chapter 6.

Beams
This horizontal member of the building supports the roof. It may be wooden, steel or R.C.C. Requirement of R.C.C. beam is discussed in chapter 6.

Slab
All R.C.C. slab should have minimum thickness of 3". Slab details is discussed in Chapter 6.

3.18 The Stair.

1) Definition of Stair- It is a Stepped path for going up.
2) Stair case- A room where the stair is enclosed.
3) Riser- Hight of steps is called riser.
4) Tread- Width of a step.

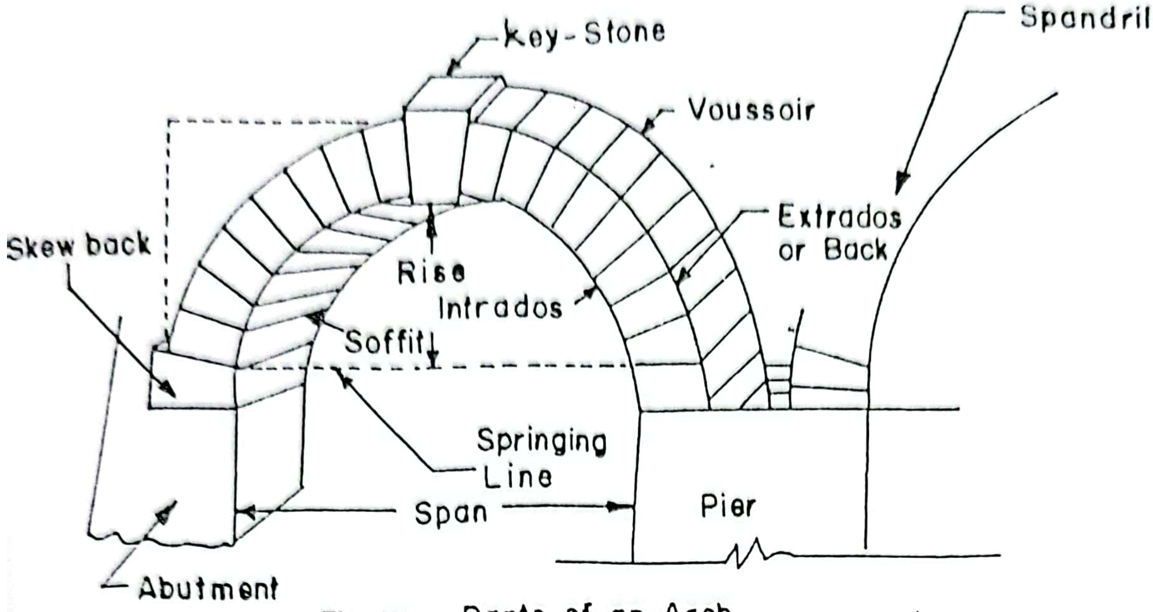


Fig 17, Parts of an Arch

5) Flight- Length of Step in one direction.
6) Landing- A Platform in between two flights.
7) Railing- Provides protection while walking.
8) Balusters- These are vertical members supporting the railing.
9) Newal post- Is the principal baluster provided at end of flights for strengthening the railing.
10) Soffit : It is the under surface of a stair.

Types of stairs:
1) Straight flight.
2) Dog legged.
3) Quarter turn.
4) Bifarcated.
5) Geometrical.
6) Spiral.

Design of stair is given in chapter 6.

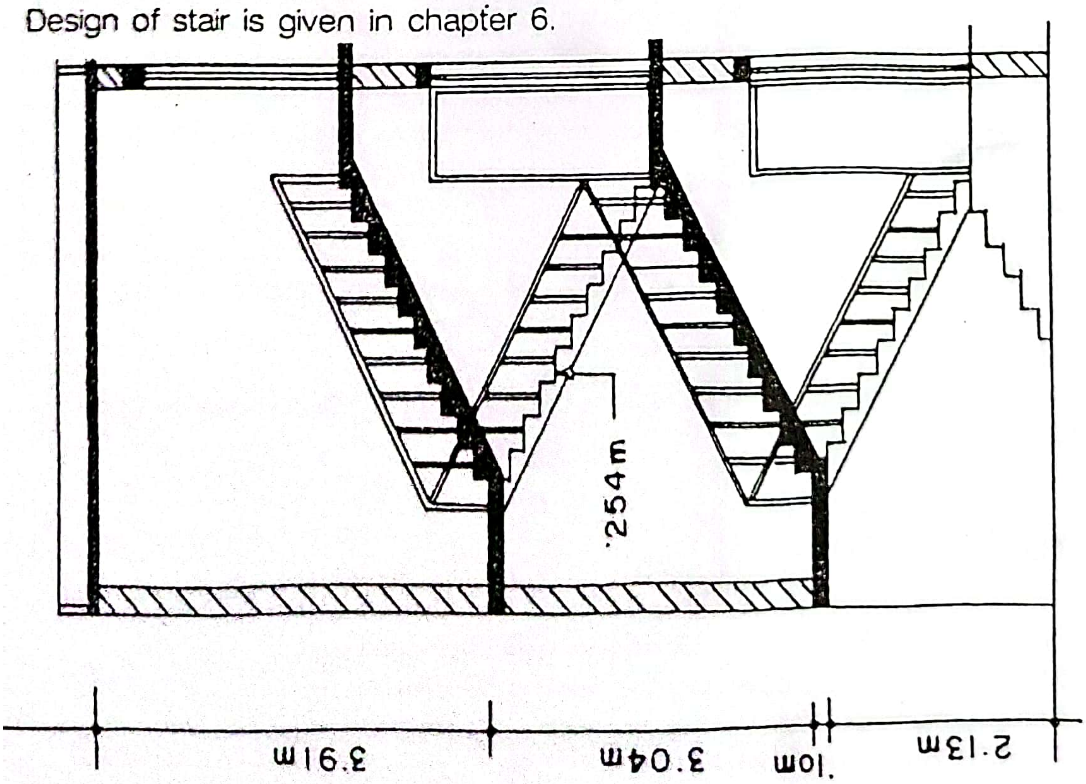
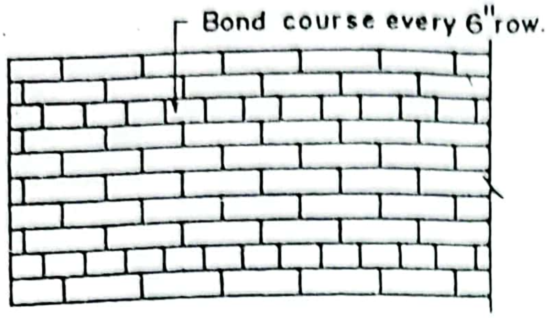
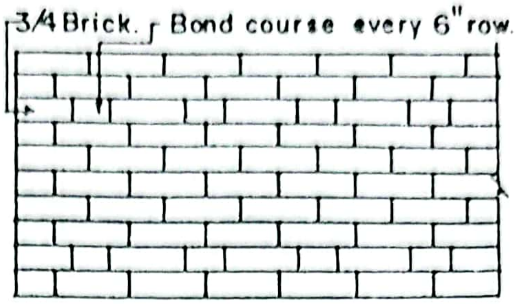


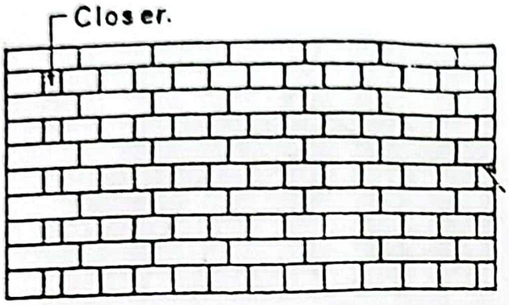
Fig 18 Stair Section



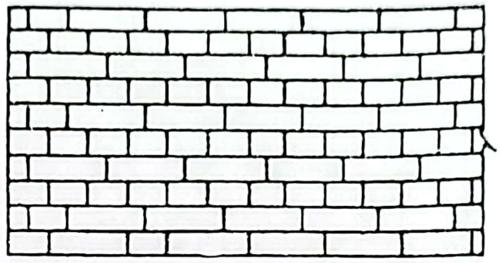
COMMON (Header Bond)



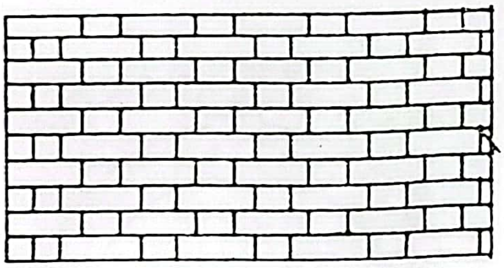
COMMON (Flemish Bond)



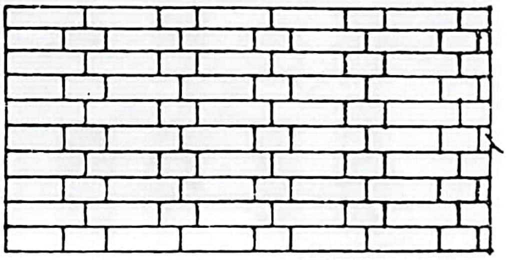
ENGLISH



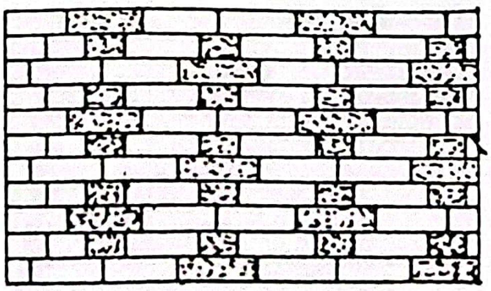
ENGLISH (Cross)



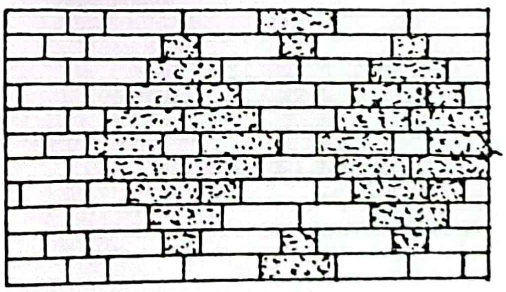
FLEMISH



FLEMISH (Double Stretcher)



FLEMISH (Cross)



FLEMISH (Diagonal)

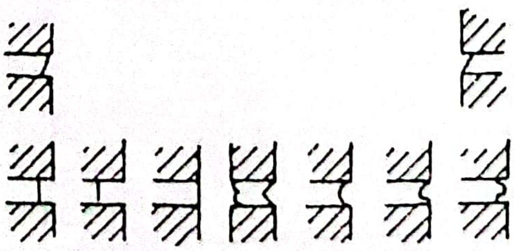


Fig 19, BRICK JOINTS

3.19 The Arch

According to shape, Arches can be divided into 12 categories.

1) Flat	7) Lancet
2) Segmented	8) Venetian
3) Semicircular	9) Drop
4) Horse shoe.	10) Elliptical
5) Stilled	11) Multicentered
6) Equilateral	12) Ogee . Arch

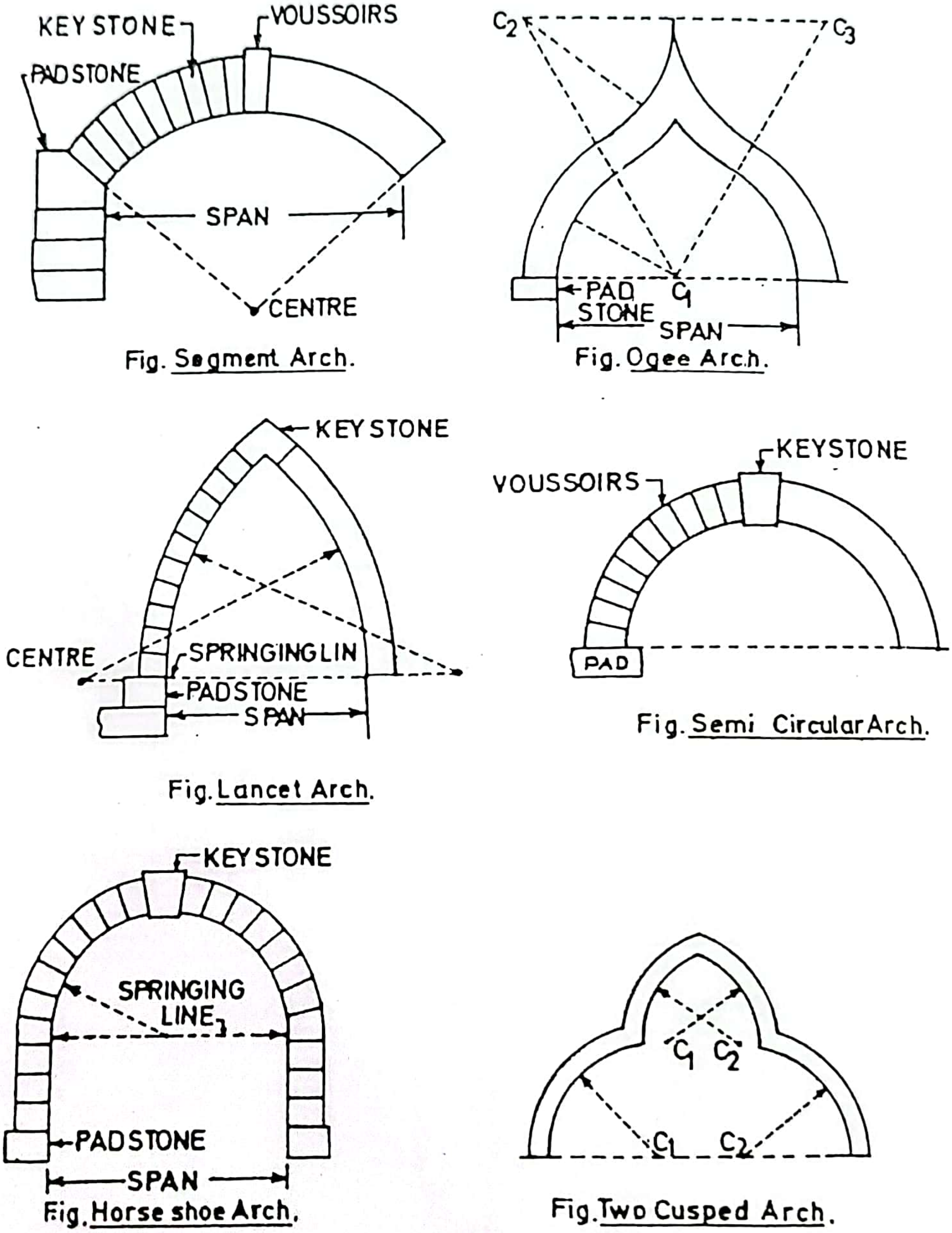


Fig 20, ARCHES

3.20 L
1. Wooder
2. R.B. (R
3. R.C.C.
can be pro
for a spa

3.20 Lintels : Lintels may be made of the following

1. Wooden
2. R.B. (Reinforced bricks) Lintel.
3. R.C.C. lintel, 4 Nos. 1/2" rods are provided at 4 corners. Rings (stirrup) can be provided 3/8" dia @ 6" C/C. 6" high and 9" wide lintels can be safely used for a span upto 6ft.

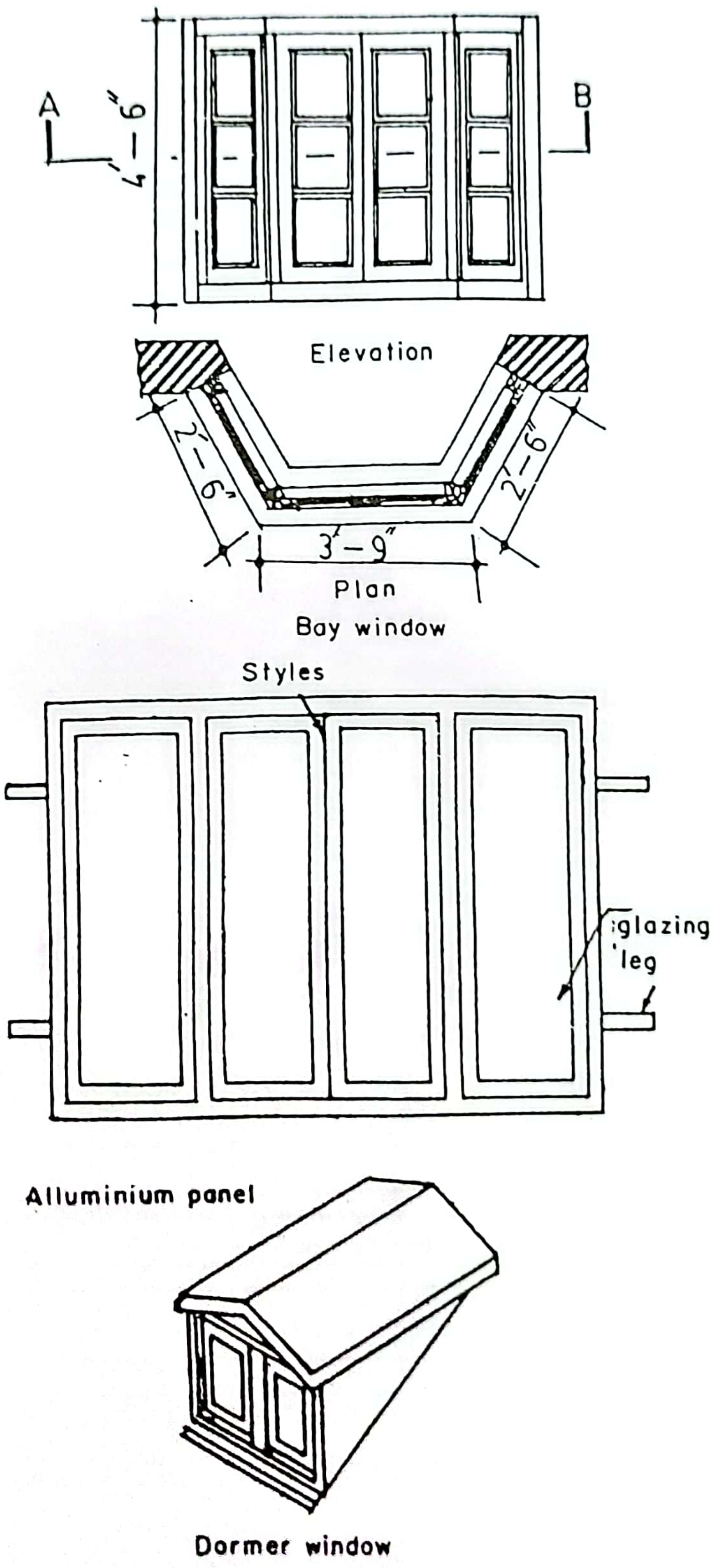


Fig 21 Windows,

3.21 The Door and the Window

Definitions : Doors and windows are openings for communicating light and air. They are consist of frames, grills and shutters.

Types of Doors

1) Legged doors.
2) Panelled doors.
3) Glazed doors.
4) Flush doors.
5) Louvered doors.
6) Collapsible doors.
7) Revolving doors.
8) Rolling Shutters.
9) Sliding doors.
10) Electrically operated doors.

Types of Windows

1) Casement windows.
2) Pivoted windows.
3) Bay windows
4) Dormer windows.

Fittings

Hinges :

1) T-hinge.
2) Strap hinge.
3) Parliamentary hinge.
4) Butt hinge.
5) Rising hinge.

Bolts and Locks :

1) Tower Bolts.
2) Aldrop Bolts.
3) Hasp and stable.
4) Yale lock.
5) Mortice lock.
6) Rim lock.
7) Cup Board lock.

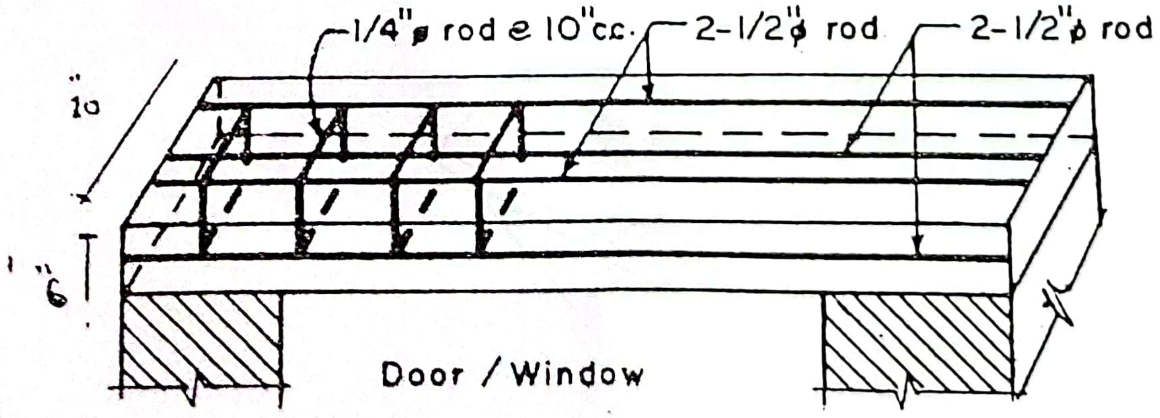


Fig 22, Concrete Lintel

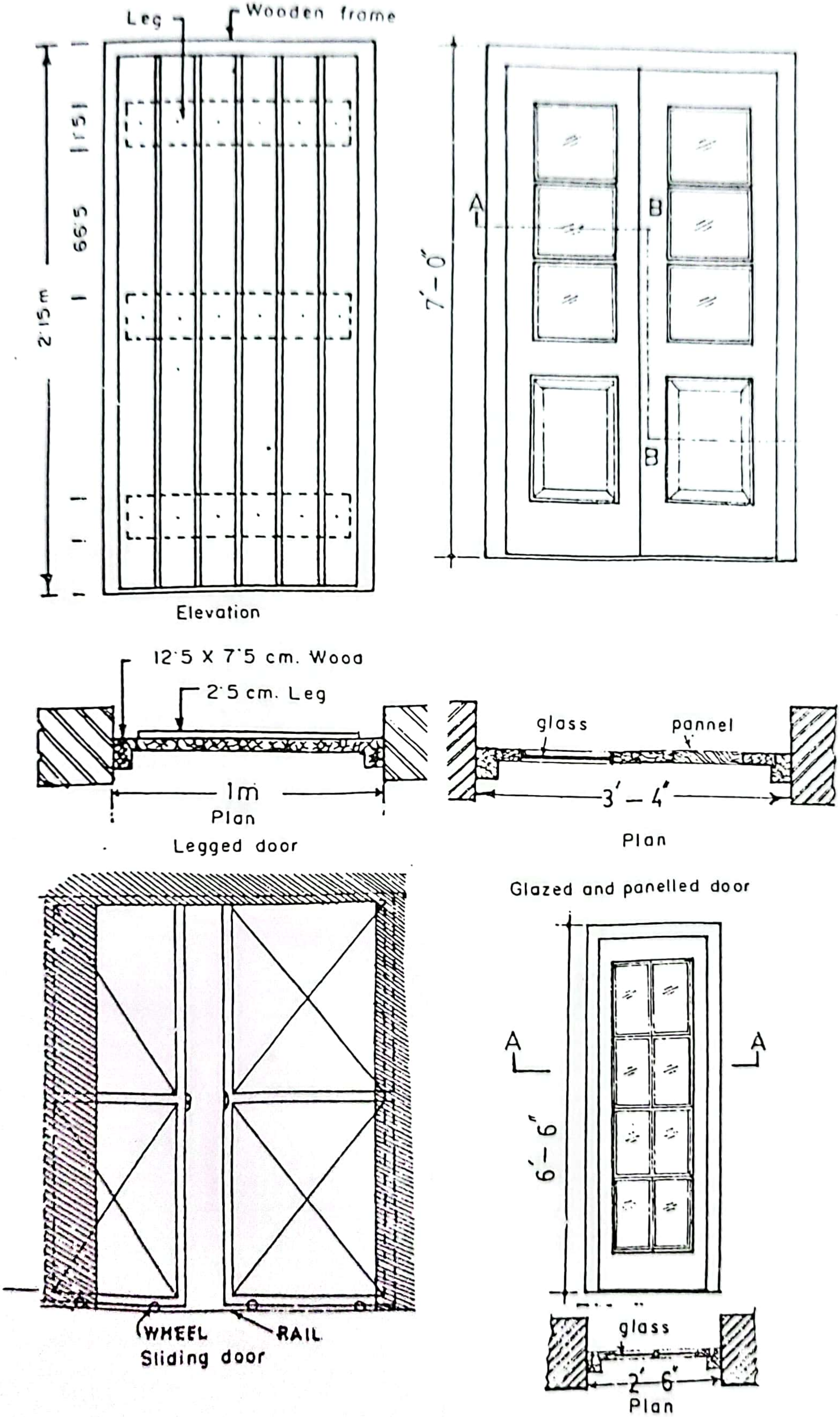
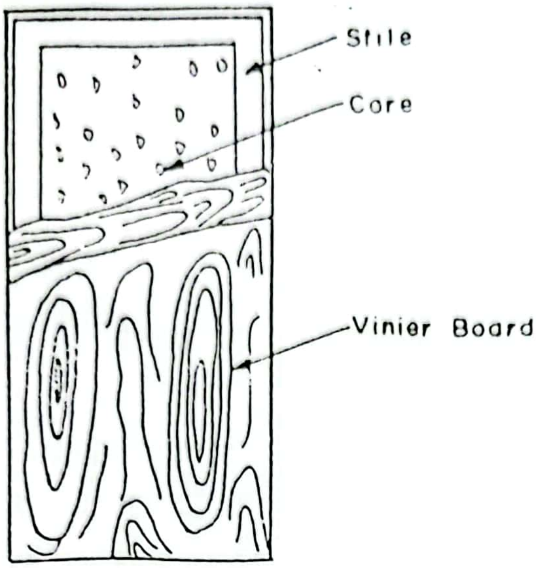
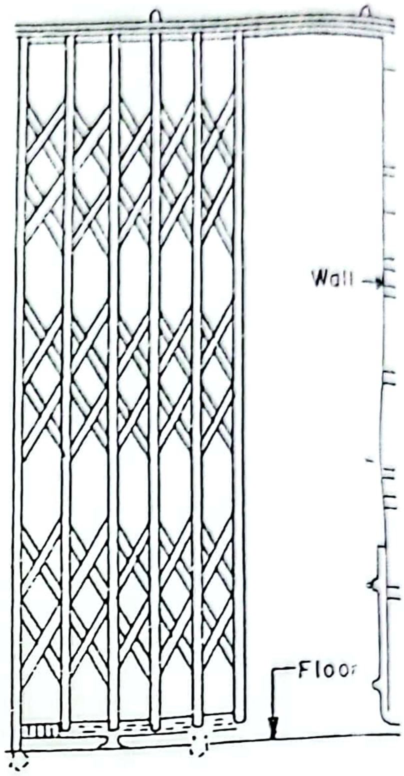


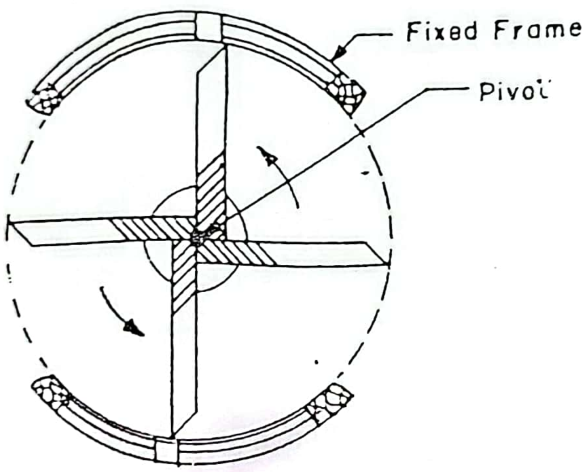
Fig 23 (a) Doors, Glazed door



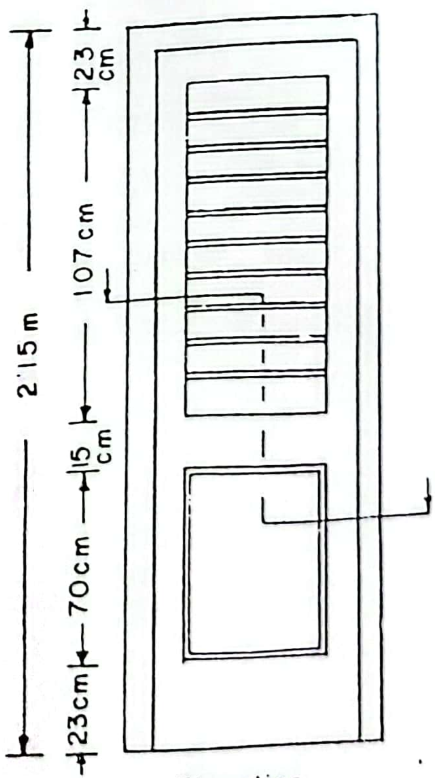
Flush Door



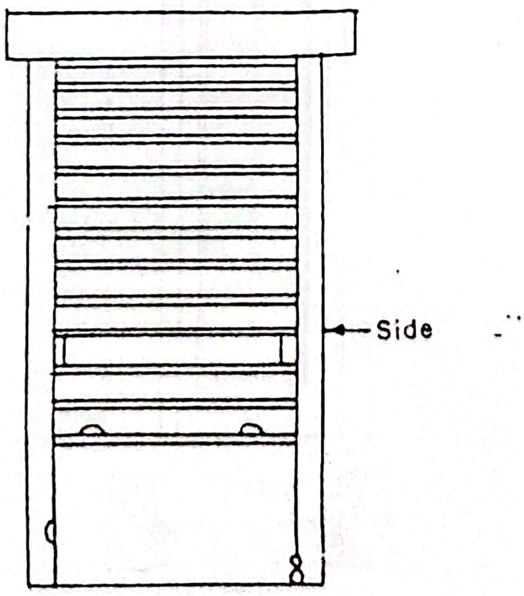
Collapsible Door



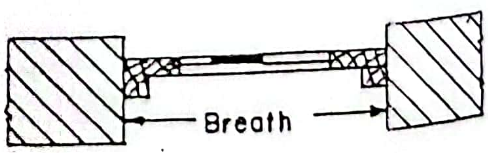
Revolving Door



Elevation

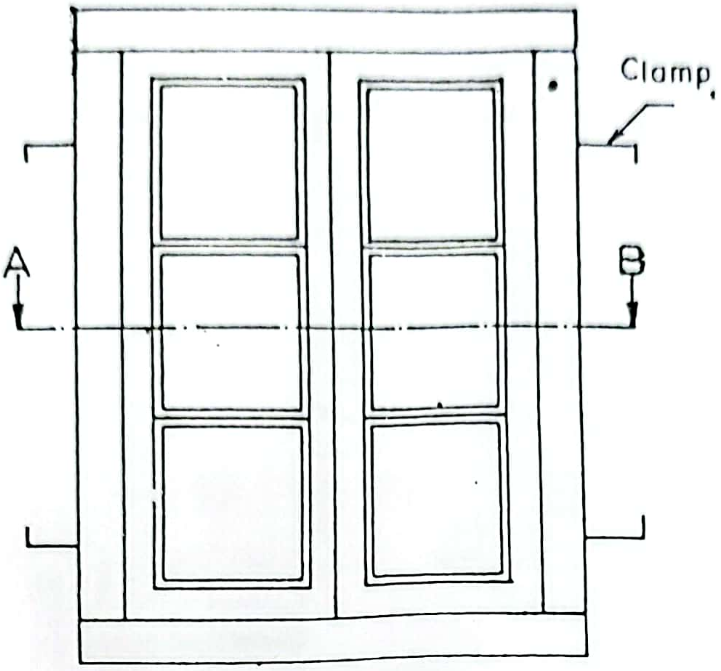


Rolling Shutter

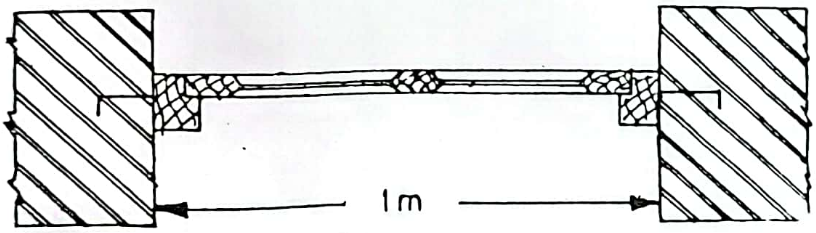


Louvered Door

Fig 23 (b) Doors,



Elevation



Plan .

Casement window

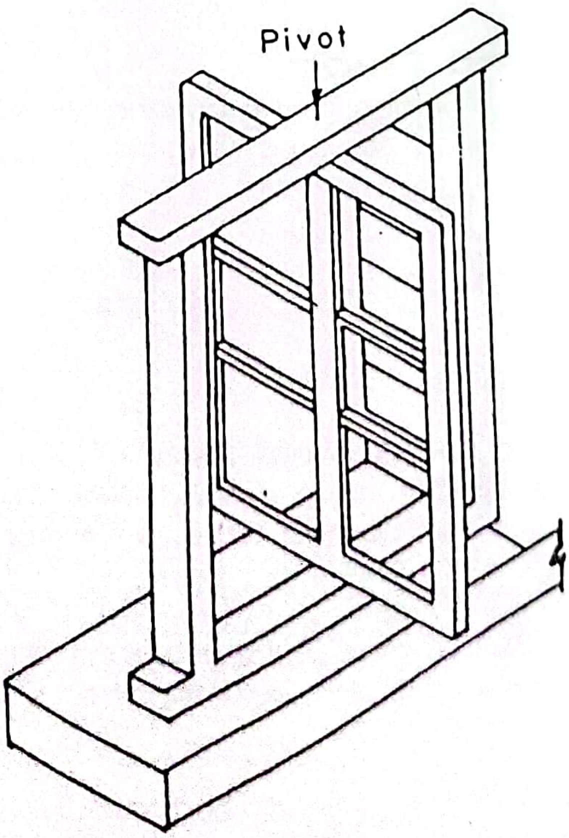


Fig 23 (c) Catchment and pivoted window.

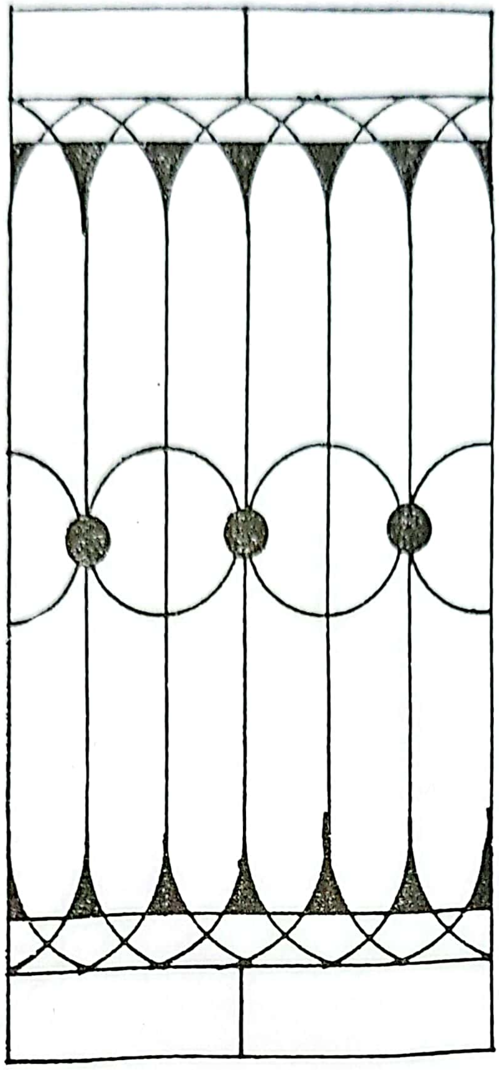


Fig 24, Window grill

3.22 The Ground Floor

Definition : It is horizontal portion of the building. Floors below ground level is called basement. Ground floor is just situated above ground level.

Types of Flooring :

1) Brick flooring
2) Concrete flooring
3) Mosaic in situ floors
4) Mosaic Tiled flooring
5) Plastic floor coverings.

Preparation of Bed for Ground Floor

Viti sand be filled in the room up to desired level in 6″ layer duly rammed. Watering be made for a minimum of 10 days for proper consolidation.

1. Brick floor :

Bricks can be fixed over L.C. (Lime Concrete) bed in 1 : 4 (lime : surki) mortar. They give rough surface. It is only suitable when some flooring work be quickly done.

2. Concrete floor : This is most common type of floor easily and conveniently constructed which lasts longer. Care should be taken in

constructing neat cement finishing which should not be less than 1/8" in thickness and should be done on the day of casting other wise no satisfactory result is achieved. It is not fully coherent with the casting. Scraps comes up causing constant headache to you. No satisfactory repair can be made to it.
Cement finish 1" to 1½" patent stone flooring be done or neat finishing (1:2:4) needs be applied on the same day of casting.

Procedure :

a) Ram, sand fills, water it keep for some days for compaction.
b) Provide one flat soling on the top of fill.
c) Lay 1:3:6 concrete over it as bed and allow to set for 3/4 days.
d) Cast 1:2:4 concrete 1" to 1½" thick and get the neat finished by sprinkling dry pure cement on the same day of casting.
e) Panelling can be made by 3mm glass sheets 3/4" wide panel.
f) Apply flooded water after 24 hours and keep it for at least 7 days.

3. Mosaic floor : This type of flooring is actually called Terrazo flooring. It is a combination of stone chips, white stone powder, white cement and pigments. Thickness should not be less than 1/4" or more than 3/4"

Procedure : Follow (a), (b) and (c) as above.

d) For grey mosaic, 1 part ordinary cement, one part white cement, 2 part sand and four part white chips (3mm size is preferable) mixed with 1/8 th part by vol. of black or other coloured chips be used. Details can be had from chapter 2.
e) Glass panelling of 2'×2', or 2'×2'-6" size or else can be fixed on floors and the mixture is laid over it and allowed to dry then kept moist for 3 days.
f) Use mosaic cutting machine for finishing. Carboramdum stone is also available of number varying from "0" to "3" according to grain size. With such stone cutting be made by hand.
g) Wax finishing is also given but this can be avoided. Acid treatment may be given.
h). Pigments can be used in the proportion 1 ch. of pigment per bag for coloured mosaic.
i) Sufficient water be used during cutting.

Mosaic Tiles :

Are 3/4" to 1" thick, preferably 8"×8" size is used. Hexagonal, octagonal sizes are also used. These are fixed over lime concrete(1:4) 1½" thick (10 to 15 mm.) kept for curing for 2/3 days and cut by machine or by hand with carboramdum stone as already stated.
For decoration in mosaic work crushed pottery of different size and colour may be pushed into the tile while making.

4 Planning Your Home In Urban Areas

–"Good deeds ring clear through heaven

like a bell" –Richter.

4.1 House Plan

There should be a plan passed by competent Authorities DIT(Rajuk),Municipalities etc. showing plan of rooms, elevation, section, layout of the building and site plan.

This plan should necessarily be prepared by Architects. In India, Civil Engineers are allowed to prepare plans. Since, profession of Architects is developed in the country, they should prepare the plan.

4.2 Why a Plan is Necessary

It is necessary because of : 1) It provides proper arrangements for present and furture needs with proper land utilisation.

2) Proper ventilation of dwelling space provision all around the building for maintaining proper environmental atmosphere to a community.

3) Arrangement of rooms and facilities can be fixed up in an economical way.

4) Providing proper approach of road, light and air including sanitation.

5) Building safety is assured.

6) Financial involvement can be worked out.

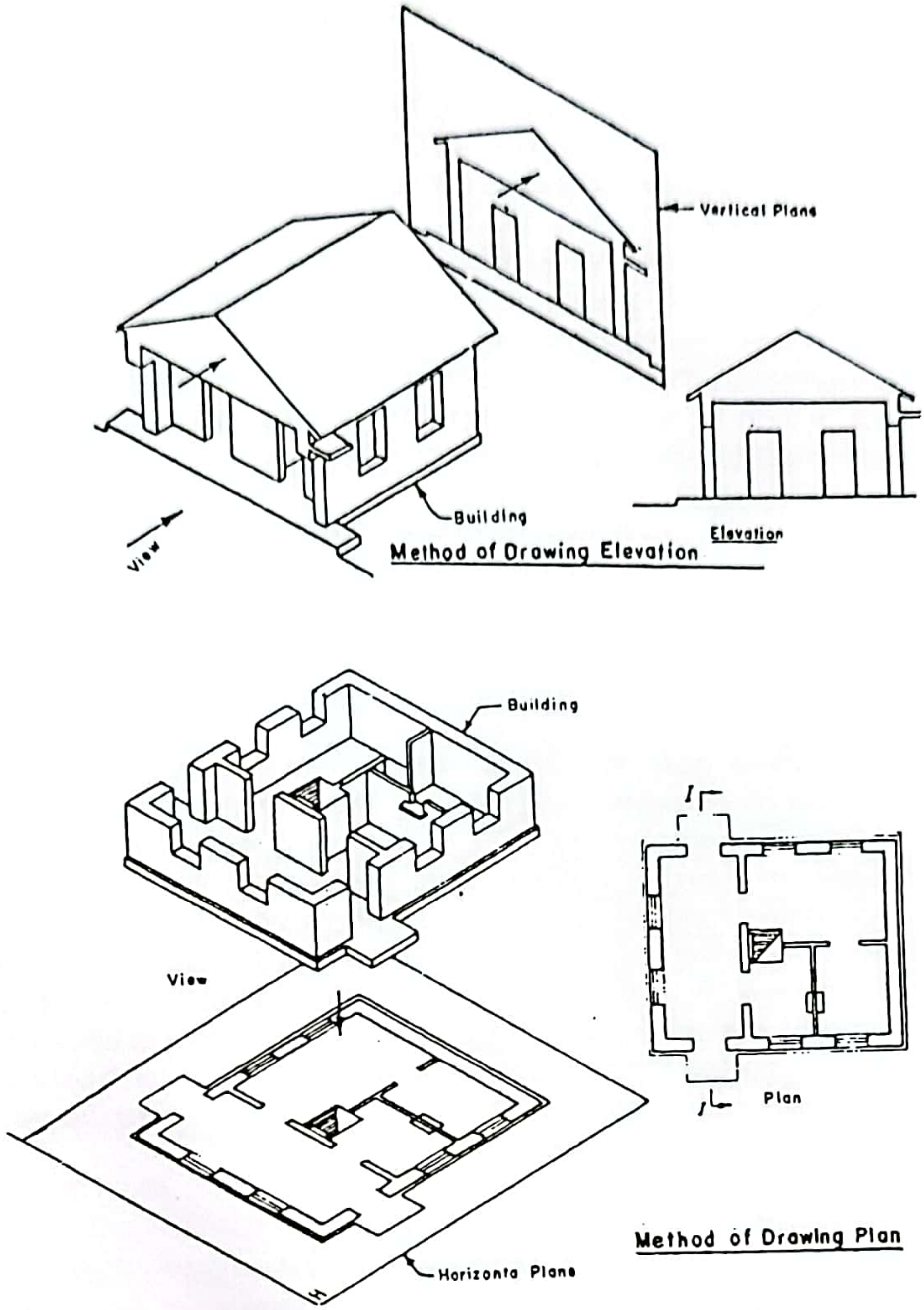


Fig 25, Method of drawing plan and elevation,

4.3. Types of Buildings from Planning Point of View

For the purpose of planning, building may be classed as under

1. Residential occupancy.
2. Business occupancy.
3. Educational occupancy.
4. Institutional occupancy.
5. Industrial occupancy.
6. Storage occupancy.
7. Assembly occupancy.
8. High Hazard occupancy.

This text deals with Residential Occupancy only.

4.4. An Architects Approach to Planning

While planning, one has to consider each requirement of the OWNER seperately in respect of function, utility and feeling for aesthetics. The design should not be separated from its surroundings. It should integrate both. A house is not mere a "Shelter". It should be suitable for health, living, sleeping, study and entertainment.
As one approaches a building, the location of it with reference to surroundings, proportion, shades, colour combinations of construction materials etc. all create a visual impact on the observer.
The design depends on major details but also on minor details like planning of switch, door, windows etc. to achieve the desired goal.
Careful consideration should also be given in respect of :

Privacy.	Economy.
Elegance.	Aesthetic

4.5. Privacy

Privacy is of two types :
1) Privacy of the whole building with reference to the surrounding buildings and roads. This can be achieved by screening the entrances(front and back), planting of trees and creepers, etc.
2) Privacy in different rooms i.e. bedrooms, bathrooms, kitchen, etc. This is achieved by the correct positioning of doors and openings of shutters. The shutters should open in such a way that a person entering the room will get the minimum view. A large portion of the details of the room(such as beds in a bedroom) should not be visible at a glance. For maximum privacy single shutters are better than double shutters. Provision of frosted glass for windows provide more privacy than plain glass. Louvers for shutters provide ventilation as well as privacy.

4.6. Elegance

Elegance is related to the effect produced by elevation, which depends upon the proportion of width, height, doors and windows, as also the choice of materials. The visualisation of elevation should always be kept in mind while preparing a plan. Utility is the main consideration, keeping in mind the cost. Architectural design and composition should be studied in detail as a whole for achieving success in creating an elegant structure.

4.7 Economy

Economy inhibits the freedom of an Architect in planning. At the very outset, he should discuss with the client the aspect of current cost. A false idea of economy should not be given. Scope should be kept for future expansion. Economy can be achieved by providing rooms of minimum necessary dimentions,minimum door and window areas. Simple design for windows, plain tiles as well as fixtures and fastening of simple type for internal doors and use of locally available materials. Rectangular or square sized plan offers more economy.

4.8. Feeling for Aesthetics and Utility

In architecture, certain relationships are basically important for well planned buildings. "The three conditions for well planned buildings are briefly stated as commodity; firmness and delight." The first relates to fitness for the purpose, the second to the constructional aspect and the third to the aesthetic quality which distinguishes architecture from mere civil engineering construction.

4.9 Finance

The financial implications consist of :
1) Cost of civil construction including compound wall, water supply and drainage.
2) Cost of electrical work.
3) Cost of interior design(decoration)
4) Cost of furniture.
5) Cost of acoustics.
6) Cost of air-conditioning.
7) Cost of landscaping, development of premises, filling and levelling etc.
8) Fee of the architect.
9) Fee of the structural designer(engineer).
10) Consulting engineer's fee for the foundation or any special work. (Some times this is covered under item 9).
11) Supervisor's and watchman's wages.
12) Fees of other specialists, for instance, the interior designer, furniture designer, acoustic consultant, air-conditioning consultant, landscape consultant etc. Lawyer's fee for legal advise, if any, for purchase of the plot etc.

The planner should provide the owner an idea of finance involved in the construction being taken during conversation with him so that the owner does not run bankrupcy at the end of the project.

4.10 Principles of Planning

On the principles discussed above, one should approach to make plan considering the following points :
1. Visit site and study surroundings.
2. Maintain roominess : Rectangular rooms are more convenient to square rooms.
3. Flexibility : To provide independent access to sanitation to other rooms.
4. Sanitation.
5. Lighting.
6. Cross ventilation.
7. Privacy.
8. Orientation.
9. Elegance.
10. Economy. etc.

4.11 Standardization

We have no standardisation system as yet. We may try to produce factory made materials to fit a modular plan. All types of materials, such as floor tile, paneling, and sheathing panels are sized to fit the modular plan.

The standard module for the U.S. Customary system of measurement is a 4 inch cube. This unit is used to build larger modules. A 4'-0" cube is a major module. It is made of 4 inch modules. Minor modules are 16 inch and

24 inch cubes.

The standard module for a metric modular system will probably be 100 mm. The major module will probably be 1200 mm. and the minor modules 400mm. and 600 mm.

The modular system includes length, width and height. All three must be considered for maximum effectiveness.

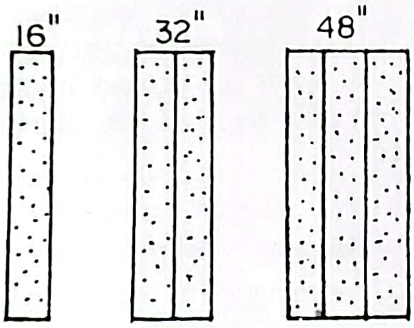
The exterior wall components may be built on a 16 inch module. This provides normal structural support.

4.12. Landscape Plans

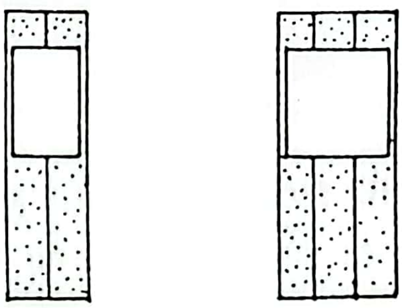
A landscape plan indicates the location of the house, garage and drives and walks. It also shows the location and frequently, the species of the plantings that are to be made on the Plot

Such a plan is made by a landscape architect. These services are most often used by owners of expensive houses, because a fee is charged. Many nurseries offer free landscaping services and advice to their customers. This enables most persons to have some assistance in planning the planting that will surround their house.

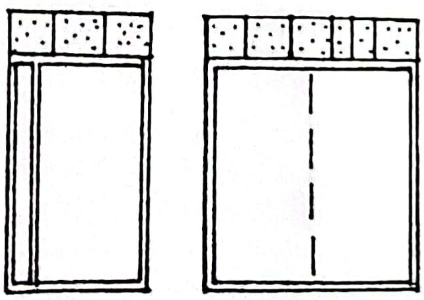
Since the plan as drawn by the landscape architect indicates the species of the plantings, it can be used to obtain competitive bids on the plantings and their installation.



Typical Modular Exterior Wall Components



Typical Modular Window Components



Single Door With Side Glass

Double Door

Fig 26, : Standardization

4.13 Prevailing Winds

A little time spent in a study to determine the direction from which the prevailing winds blow will pay big dividends.

In the Summer, the air should blow through the living area and sleeping area. If something blocks these breezes, one must resort to fans or air conditioning. Examination be made if a hill or growth of trees will block the summer breeze. A house in a hollow may miss all breeze and be stifling.

Undesirable Winter winds present an entirely different problem. Every attempt should be made to block them.

Winds can bring smoke and odors from nearby factories and make living objectionable in what would other wise be an acceptable area. In areas where high winds are common, construction must be strengthened to resist damage.

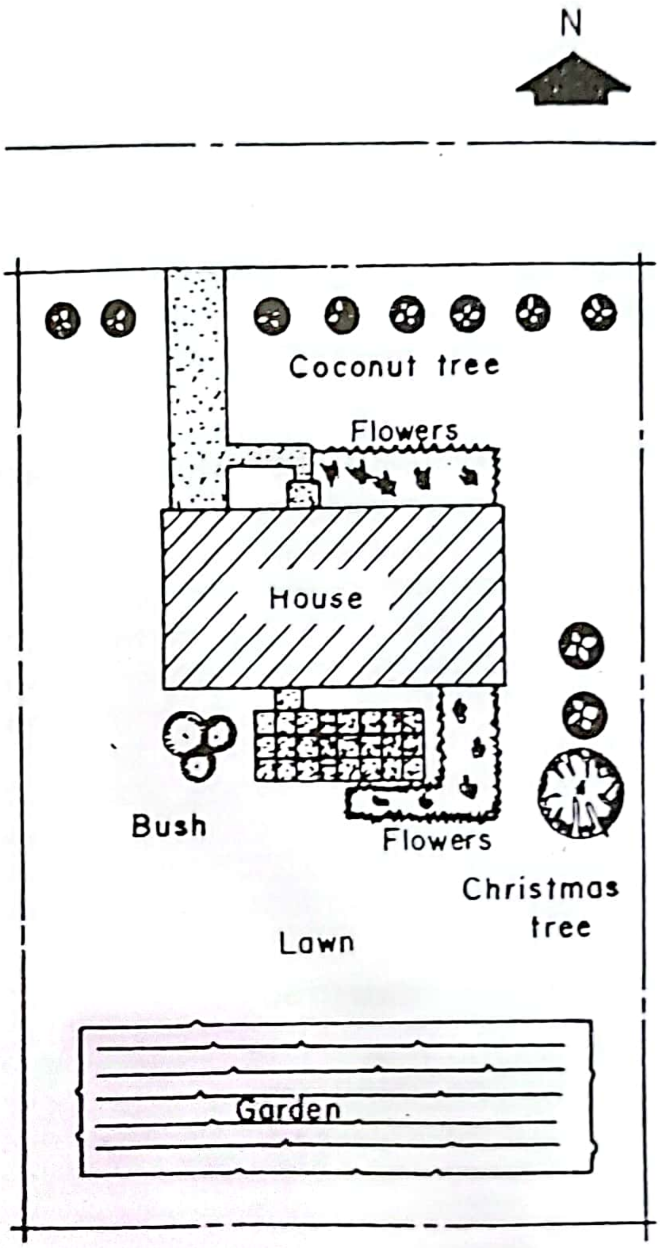


Fig 27, Landscape Plan

4.14 Proposal

A house should provide all comforts. Yet it should be constructed economically. It may be a one or two-room tenement in a chawl or a three to four room

flat in an apartment house or it may be a separate bungalow constructed on a small or big plot. The owner may wish to invest in a 'theatre'or 'shopping centre'.
These factors should be collected from the owner.

4.15 Site

A visit to the site will give a clear idea about the surroundings and the nature of the plot. If necessary, the architect may do a contour survey of the area. The size, dimensions, shape and nature of the ground surface- level or sloping- the rate and direction of slope with reference to the front road etc. are important considerations while preparing the layout plan. Trial-pit results help to know about the nature of the soil, foundation conditions of the site and its geology.i.e. the depth of the surface soil,the various strata which may be met with etc. Hard murum, i.e. non-cohesive soil having a safe-bearing capacity of 1 Ton/sq.ft. within a depth of one of one to two metres may be considered as the best geological condition. The type of construction depends upon the depth at which hard strata are available. Availability of water, electricity and drainage facilities are favourable points. The position of the ground water table should be predetermined as it effects the cost of excavation and foundation. Exposed rocks near the site of construction are not favourable as they get heated up during the day and radiate the same heat during the night creating uncomfortable conditions in Summer.

4.16. A Modular System for Apartment

The System to be described was developed by the Magnolia Homes Division of Guerdon Industries. Inc. as experimental housing under the Federal Housing Administration's Experimental Housing Program, U.S.A.
The basic technique used was to design the apartments in units that could be factory built and stacked on top of each other on the building site. The final design had two modules- an upper module and a lower module- which made up one apartment.
The lower floor module was 12'-0" (3658 mm) wide and 32'-0" (9754mm) long. It contained a living room, a kitchen-dining room, a stairwell, and a pantry. The upper floor was a module 12'-0" (3658mm) and 34'-0" (10363mm) long. Such modular system may be introduced in our country.

4.17 Orientation of Rooms

Good orientation means proper placement of plan units of the building in relation to the sun, wind, rain, topography and outlook and at the same time providing convenient access both to the street and backyard. The position of a building in relation to the prevailing wind or to the sun is an important consideration. Different rooms have different functions. Activities in the different rooms take place at different times of the day.
However, special consideration should be attributed to bed rooms.

1. Bed Rooms

a) At least one wall should be exposed for free atmospheric ventilation.
b) Should receive direct sun light in the morning.
c) It should get free breeze at night.

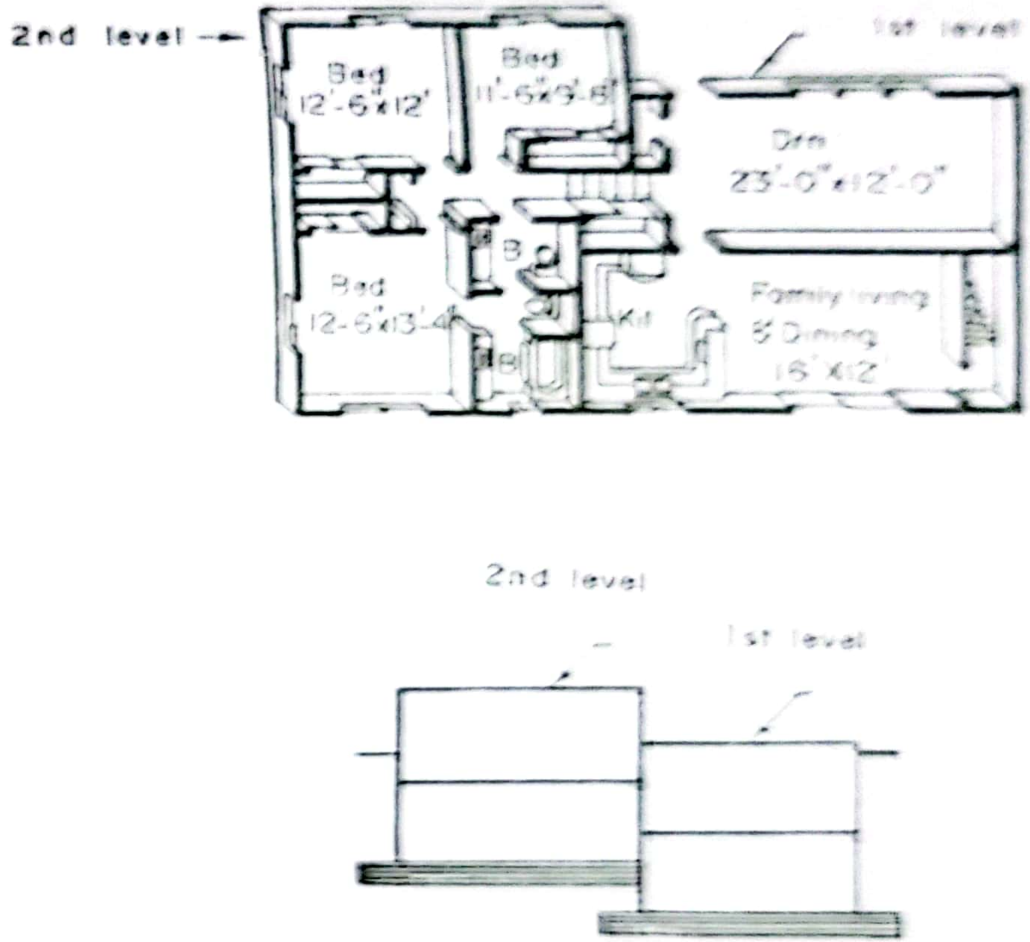


Fig 28, Split level house

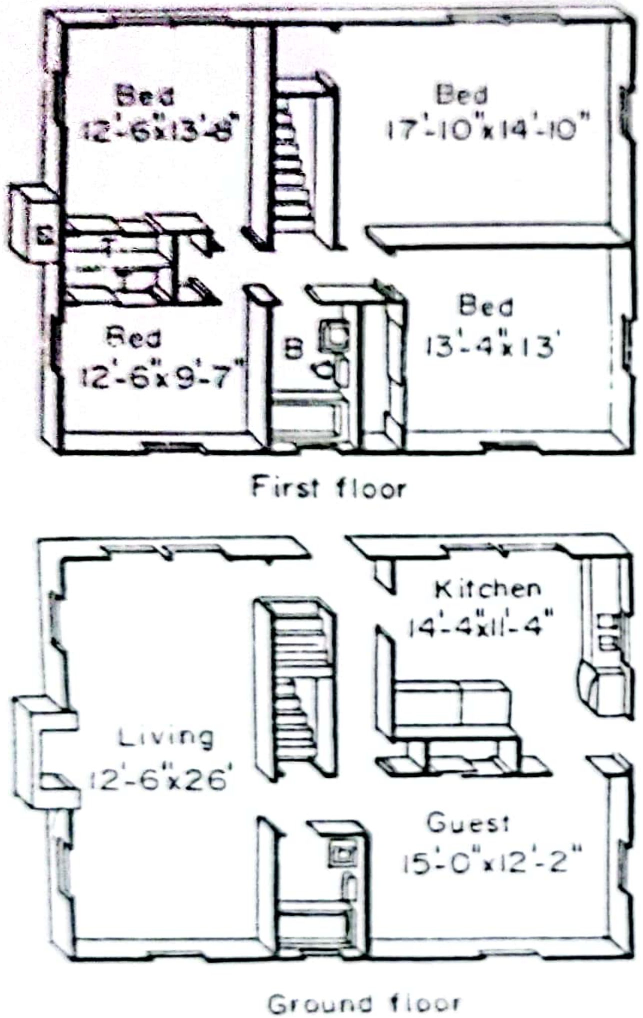
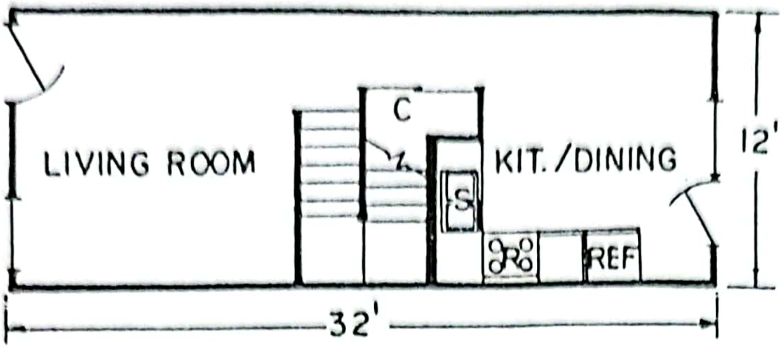
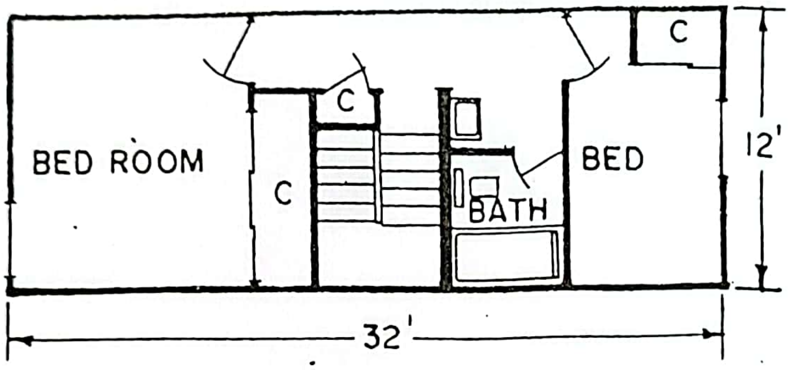


Fig 29, One unit house



GROUND FLOOR



1 ST FLOOR

Fig 30, Modular system

d) Attached bath and dressing room be there.
e) It should be beautifully decorated.

2. Drawing/Living Rooms
a) Free access be there from all rooms and should be in the front.
b) Should be well ventilated and lighted.
c) It can be accompanied with a lobby in the front and dinning space in the back.

3. Dinning Room
a) Should be close to Drawing and Kitchen.
b) Provision for Cup-board, freeze and storing space be there.
c) From economic point of view, Drawing cum Dinning or Kitchen cum Dinning room may be used.

4. Office Cum Study Room
It should be detached from all other rooms.

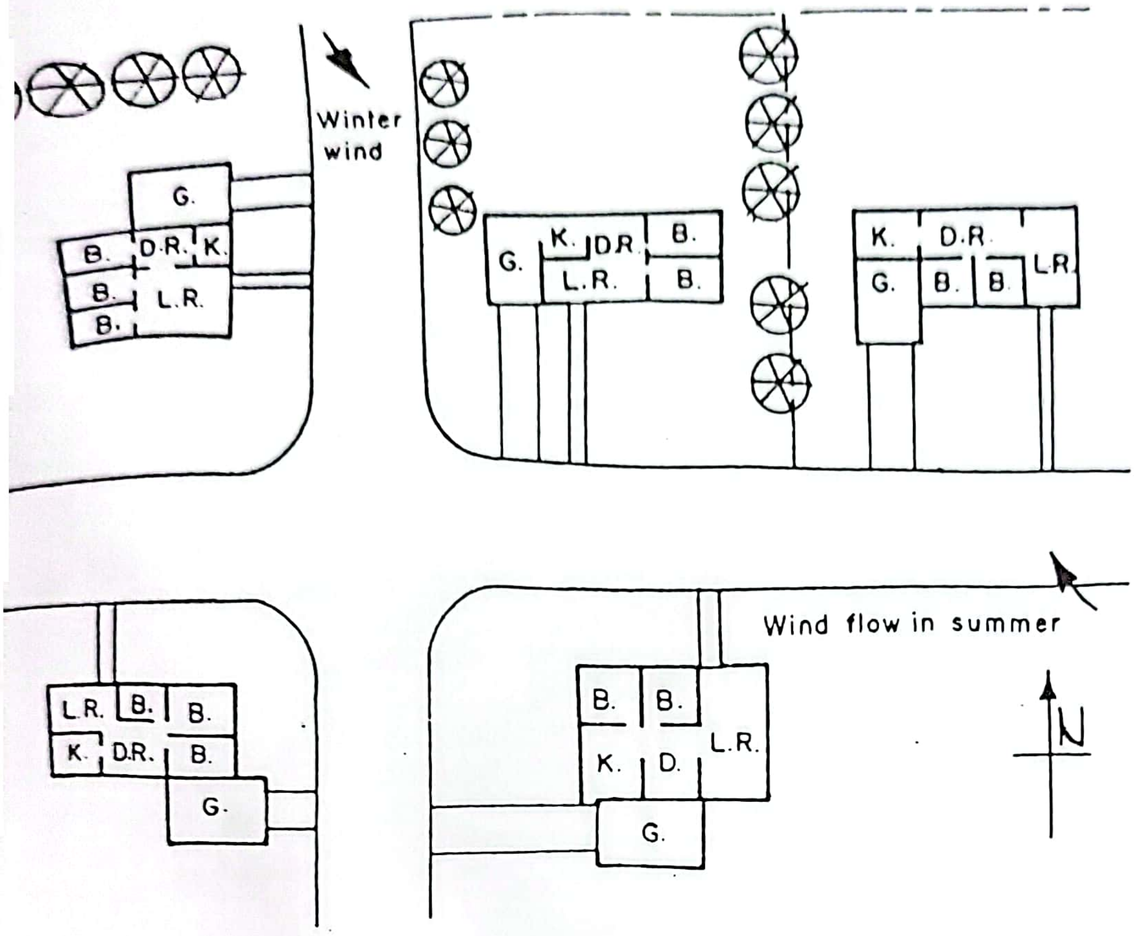


Fig 31, Orientation

5. Guest Room

a) Should be detached from bed area and furnised with seperate bath.

b) It should have direct entrance and exit.

6. Kitchen

a) Be provided at rear of the house and situated at a corner opposite to the direction of wind flow.

b) It may be detachable by means of a lobby or kitchen verandah.

c) Fly proof doors and windows may be provided.

7. Store and Pantry : Should be situated nearer to the kitchen.

8. Dressing Room : Should be adjacent to bath.

9. Verandah, Balcony : Verandah should be in the front and Balcony in the Back.

10. Servants Quarter and Garage : May be provided together.

4.18. Building By-Laws

House Building Act. 1952 holds good in almost all Municipal Areas of the Country. It proclaims that prior approval is necessary from proper Authority before constructing house, digging pond or cutting canals.

Violator's may be penalised upto Tk. 10,000/- or may be imprisoned for six months.

Such by Laws Clearly indicates the procedure regarding planning and construction of building as briefly described herein.

Approval of plans : The following details need be provided in the plan :

1. Six copies plan showing PLAN ELEVATION, SECTION, SITE PLAN, LAY-OUT PLAN be submitted to the Authorised Officer or the Executive Officers with requisite fees.
2. Scale of PLAN, ELEVATION AND SECTION will be 1" =8′ ft.
3. SITE PLAN Scale will be 1"=330′ ft. plot concerned be shown in red.
4. LAY-OUT Plan should show road, distance of the building from road side front and rear clearance.
5. Rooms should be named in the plan.
6. Foundation of the proposed building be shown in the SECTION.
7. Scale, Mouza, plot no. and owners name be clearly stated.
8. Owner will sign on the plan.
9. Scheduled form for passing plan be duly filled up by the owner.

Site plan should show the following :

a) Plot boundary along with adjacent plots.
b) Road with name.
c) Location of main road.
d) Distance of building from Centre of road.
e) North Direction.

4.19 Set Back Rules

a) Where the road is less than 40′ wide, distance of building from road centre will be 20′
b) In residential areas, 10′ clearance from road margin should be provided.
c) No building be erected within 15 ft. by the Highway.

Covered area will be 2/3rd of the plot area.

Garages or similar structure can be made on clear spaces up to 8 ft.

Without causing inconvenience to the neighbour, servant room over garage may be made.

For Commercial and Industrial plots the following provisions should be made.

a) Car park area,
b) Provision of lift.
c) Multistoried foundation.
d) Sufficiently wide stair.

4.20 Covered Area in Residential Plots

P/A= Plot Area	Clearance		
	Front	Rear	Side.
a) Above 1½ bigha 33% of P/A area maximum No. of bed room= 12. Building height= 26 ft.	15′	10′	10′

b) 15 katha to 1½ biga 50% of P/A maximum No. of bed room= 11 Building ht.= 26 ft.	15'	10'	10'
c) 10 katha to 15 katha 66% of P/A maximum No. of bed room= 9 Building ht. = 26 ft.	10'	10'	7'
d) 7½ katha to 10 katha 66% of P/A maximum No. of bed room= 7 Building ht. = 26 ft.	10'	10'	5'
e) 5 katha to 7½ katha 66% of P/A maximum No. of bed room= 7 Building ht. = 26 ft.	10'	10'	4'
f) Less than 5 katha 66% of P/A maximum No. of bed room= 6 Building ht. = 26 ft.	8'	10'	4'
g) Less than 3 katha 66% of P/A maximum No. of bed room = 5 Building ht.	=For multistoried, 45' ft ht. may be possible in certain Areas.		

4.21 Stairs

	Riser	Tread (width)
Domestic building :	6" (19 cm)	=10" (25 cm)
Public building	= 5" (15cm)	= 12" (30cm.)
Ideal R+T	= 17½" with R = 6".	

4.22 Distance from Electric Lines

Supply Voltage:	Vertically :	Horizontally
220 v. to 440 v.	2.4 m(8 ft)	1.22 m (4 ft)
11000 v.	3.66 m (12ft.)	1.83 m (6 ft)
33000 v.	3.66 m (12ft.)	1.83 m (6ft)

4.23 Car Parking Spaces

Required area for a Car	= 24 Sq. m	(260 sq.ft)
Scooter/M. cycle	= 28 Sq. m	(30 sq. ft)
Bicycle	= 1.4 Sq. m	(15 sq. ft)

4.24. Standard and Ordinary Room sizes

Drawing/Living Rooms		Ft x Ft		M x M
	Std.	13'-6"x13'		4.2x4.0
	Ord.	-		-
Din.	Std.	17'x15'-6'	5.2x4.8	(Combined Drn/Din.)
	Ord.	13'-6"x13'	5.2x40	
Bed.	Std.	13'-6"x15'-6"	4.2x4.8	
	Ord.	10'x13-6"	3.8x4.2	
Office	Std.	10'x11'-9"	3.0x3.6	
	Ord.	-	-	

Guest	Std.	10'×11'-9"	3.0×3.6
	Ord.	–	–
Kitchen	St.	9'-10"×9'-10"	3×3
	Or.	8'×9'-10"	2.5×3
Store	St.	9'-10"×9'-10'	3×3
	Or.	8'×8'	2.5×2.5
Pantry	St.	8'×9'-10"	2.5×3
	Or.	–	–
Dressing	St.	8'×9'-10"	2.5×3
	Or.	–	–
Baths	St.	5'-10"×8'	1.8×2.5
	Or.	5'-10"×5'-10"	1.8×1.8
Verandah	St.	8ft wide	2.5m wide
	Or.	5-10" wide	1.8m
Garage	St.	9'10"×19'-8"	3×6
	Or.	–	–
Servants Room.	St.	9'-10"×9'-10"	3×3
	Or.	–	–

4.25 Plot sizes in sq. feet and sq. yds and sq. metre

Area of Plot	Sq. ft	Sq. Yds	Sq. m.
1 Katha plot	= 720 sq. ft.	=80 sq. yds	= 66.89m
1½ " "	= 1080 " "	=120 " "	= 100.33 "
1¾ " "	= 1260 " "	=140 " "	=117.06 "
2 " "	= 1440 " "	=160 " "	=133.78 "
2½ " "	= 1800 " "	= 200 " "	=167.23 "
3 " "	= 2160 " "	=240 " "	=200.67 "
3½ " "	= 2520 " "	= 280 " "	=234.115 "
4 " "	= 2880 " "	= 320 " "	= 267.56 "
4¼ " "	= 3240 " "	= 360 " "	= 301.01 "
5 " "	= 3600 " "	= 400 " "	= 334.45 "
7½ " "	= 5400 " "	= 600 " "	= 501.68 "
10 " "	= 7200 " "	= 800 " "	= 668.90 "

4.26 Building Standards Fixed by Planning Commission

1. Residential Buildings

There will be three types of residential buildings-(a) Permanent. (b) Semi-pucca and (c) Temporary.

a. Permanent Residential Buildings

In the future only six different sizes/types of permanent buildings will be constructed for different grades of employees of Government, Semi-government and Autonomous bodies and Institutions as per Table below :

Table Ia

Building type	Entitlement of Grade of employees.	Plinth area.
P-I		1120 sft.
P-II	II,III,IV	900 sft.
P-III	V-IX	750 sft.
P-IV	X-XIV	550 sft.
P-V	All others	400 sft.
P-VI (dormitory)		100 sft.

* This does not include the area for stair case.

b. Semi-pucca building

Semi-pucca building will have masonry walls and C.I. sheet roofing. These are meant for less developed areas of cities and project sites. The types are shown in Table Ib.

Table Ib.

Building type.	Entitlement of Grade of employes.	Plinth area.
SP-I	I to IV	800sft.
SP-II	V to IX	500sft.
SP-III	all others	400sft.
SP-IV (barracks)..		75sft./person

c. Temporary Houses

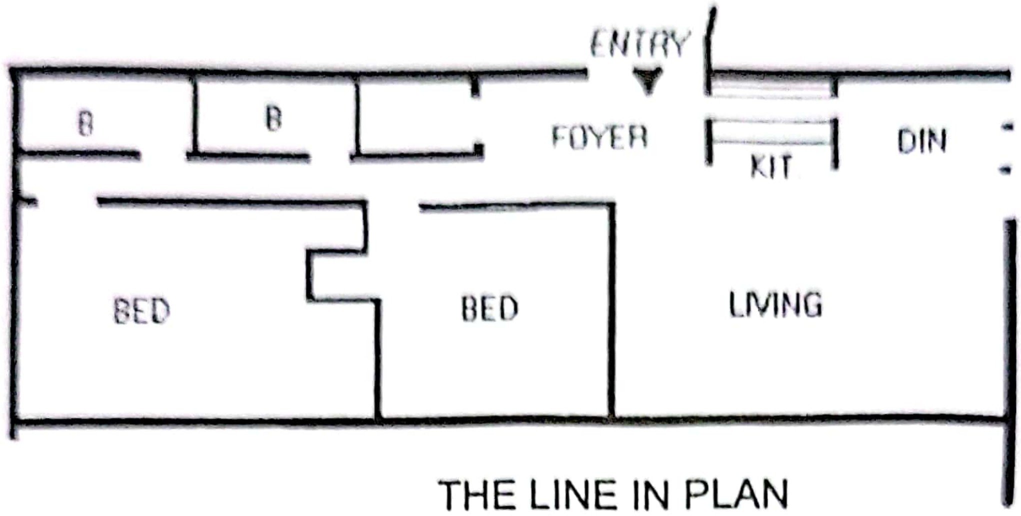
Temporary houses will be built for small and medium projects under execution in the outskirts of big cities and when accommodation is needed only for a few years(not exceeding 5 years). These houses may have precast/wooden/bamboo posts, C.I. sheet/bamboo roofing Temporary house will be of following types(Table Ic.)

Table Ic.

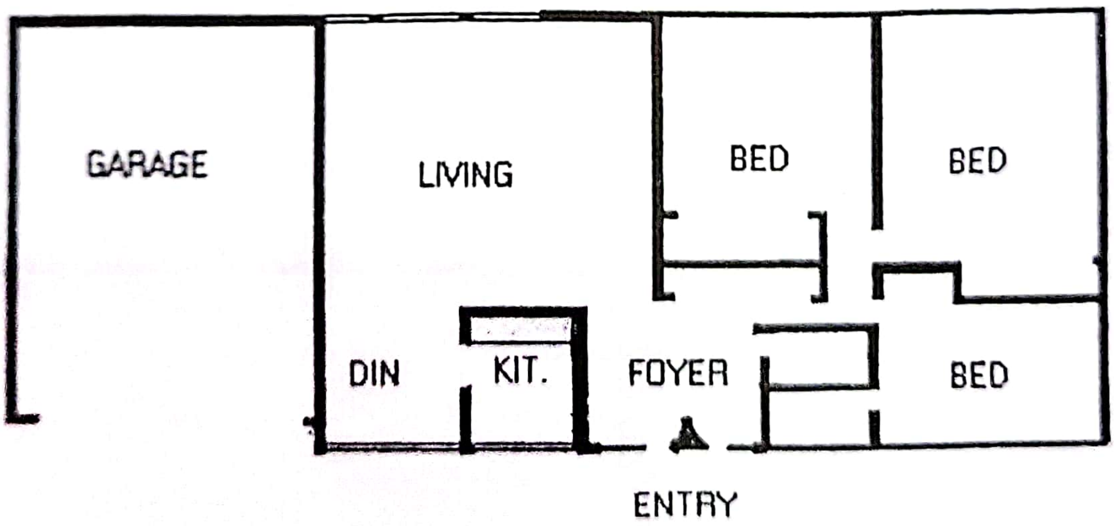
Temporary House Type	Plinth area.	Floor
T-I (family)	400sft.	Cement plastering over brick flat
T-II (family)	300sft.	Ditto
T-III (barracks)	@ 60 sft/person	Ditto

In mofassil areas including Subdivisional H.Qs. only semipucca and temporary houses will be built. In case pucca buildings are considered essential it should be cleared by the Planning Commission.

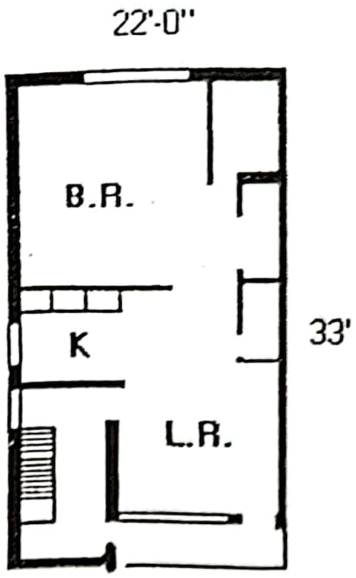
Example Of basic House Plans :



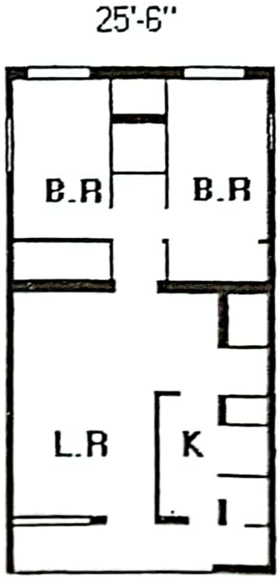
THE LINE IN PLAN



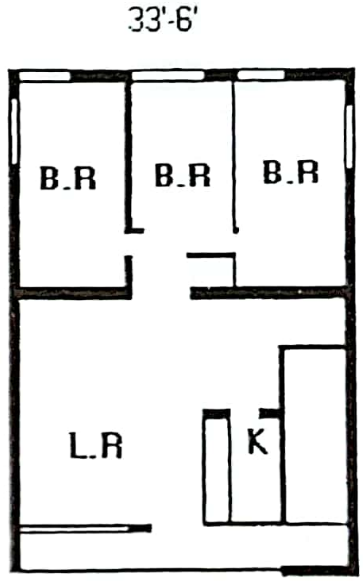
THE SIMPLE BASIC RECTANGULAR PLAN



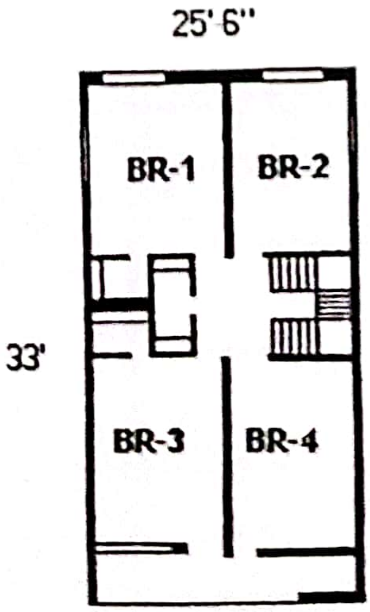
ONE B.R. APT.



TWO B.R. APT.

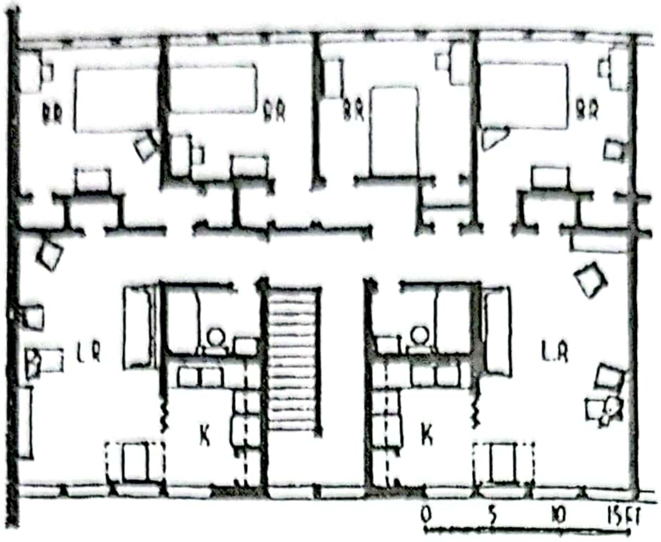


THREE B.R. APT.

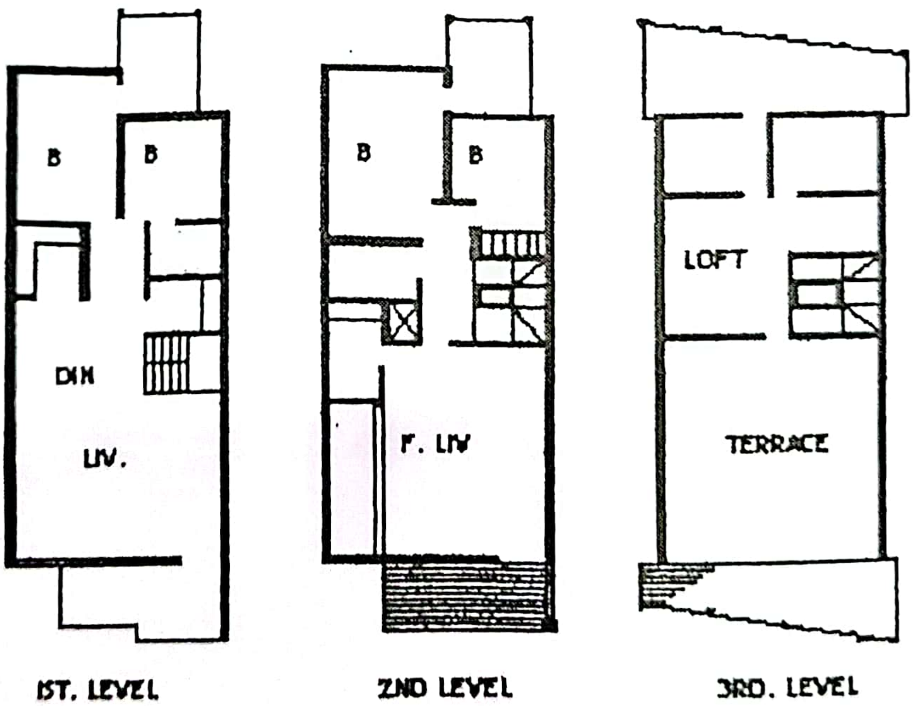


BASIC ARRANGEMENT OF ONE, TWO THREE & FOUR BEDROOM HOUSE

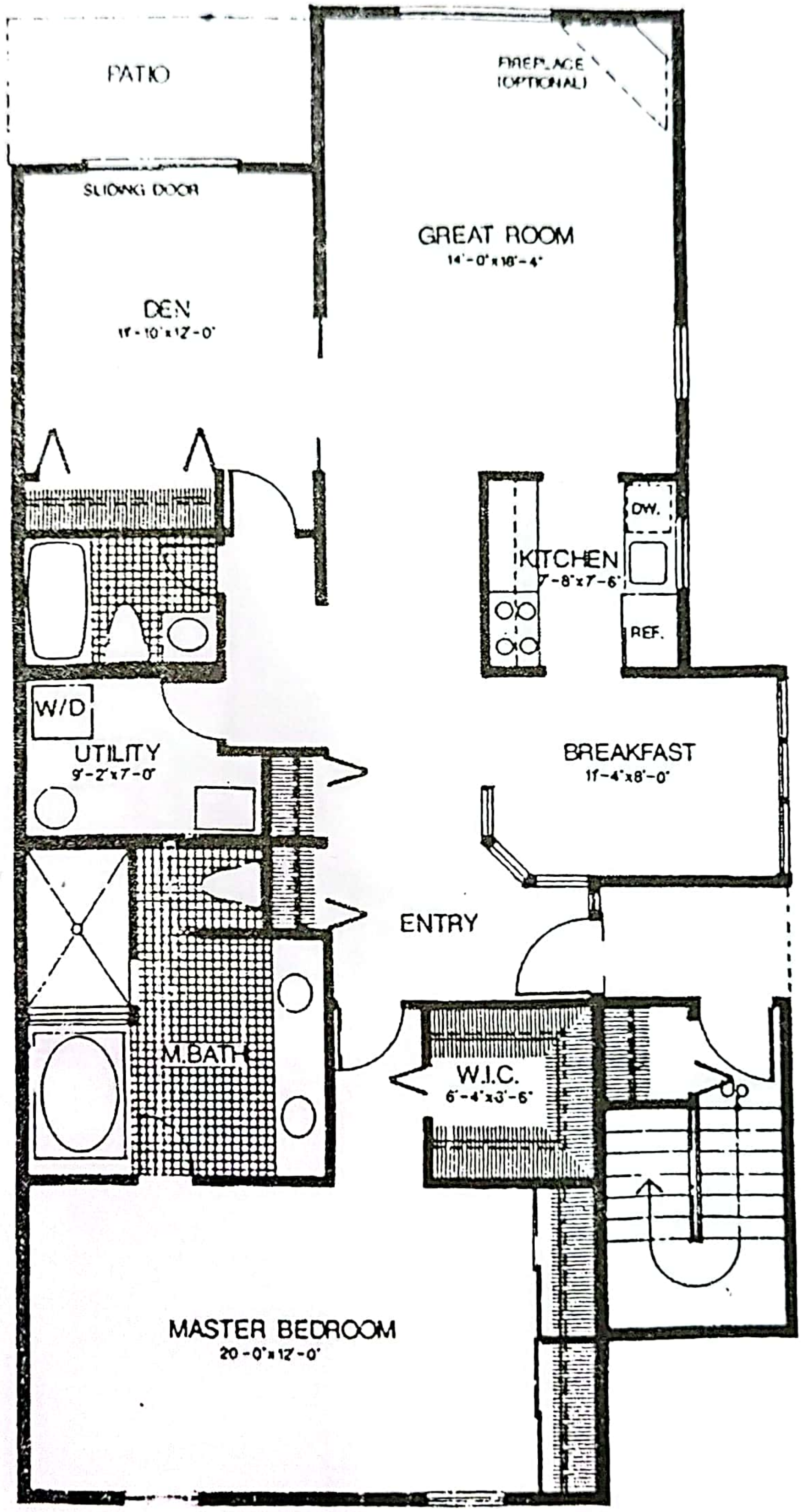
FOUR B.R. APT



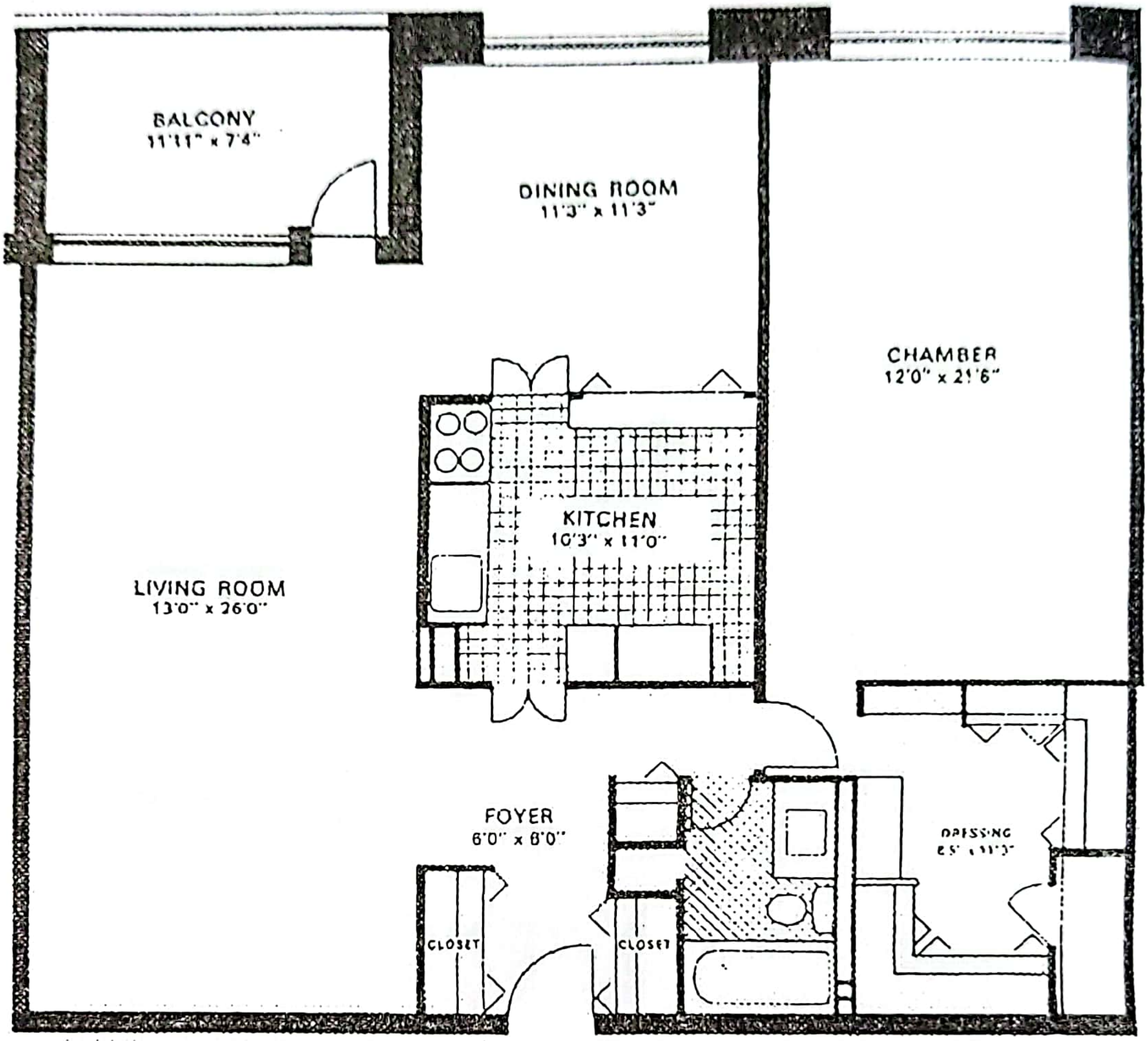
COMBINED ONE OR TWO BEDROOMS APARTMENT



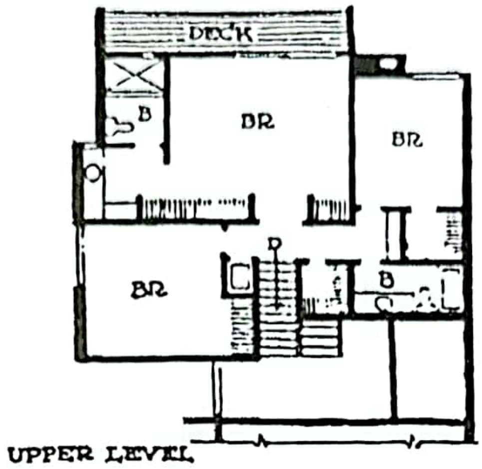
EXAMPLE OF VACATION HOUSES

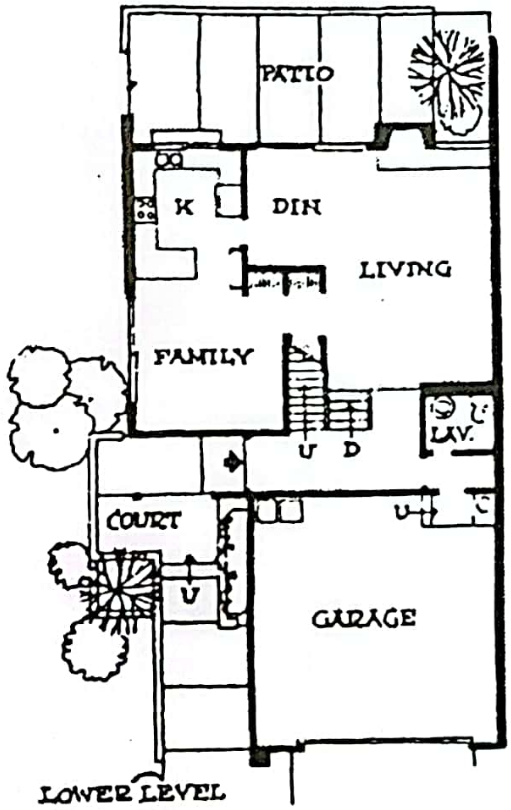


EXAMPLE OF SIMPLEX TYPE GARDEN APARTMENT

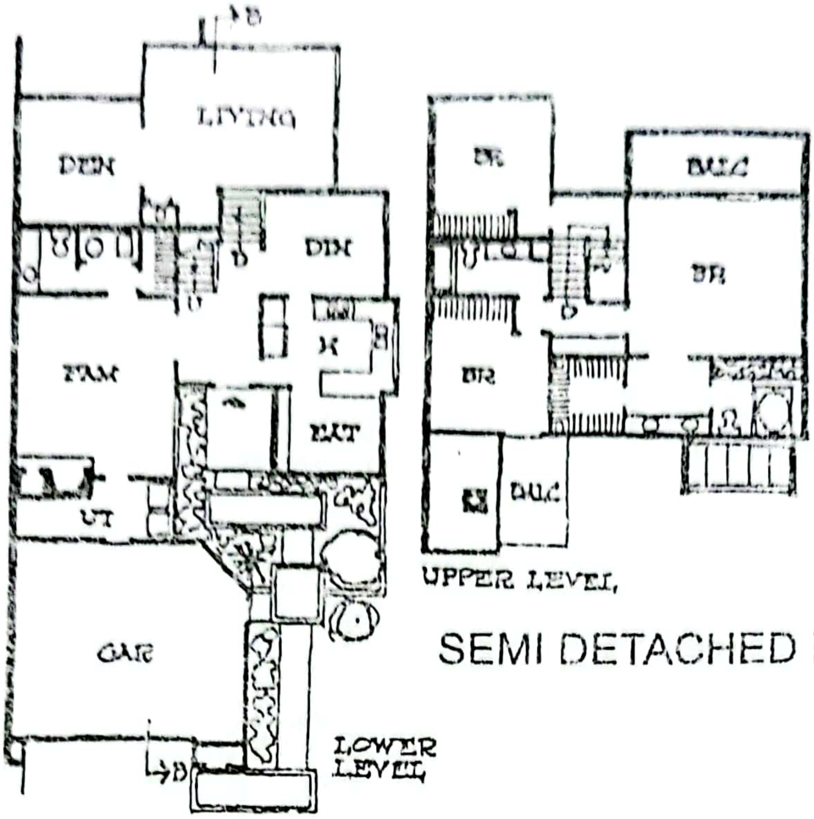


SIMPLEX APARTMENT / FLAT

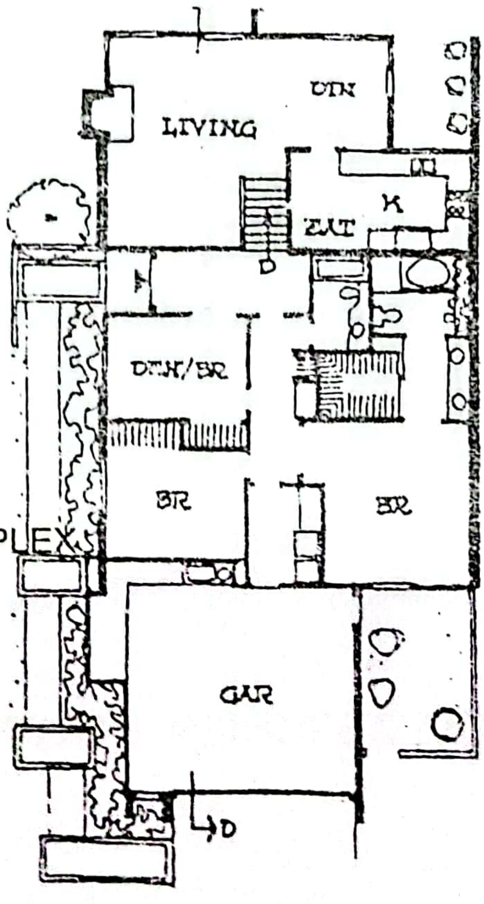




EXAMPLE OF DUPLEX SYSTEM, 2 STORIED, 3 BEDROOMS



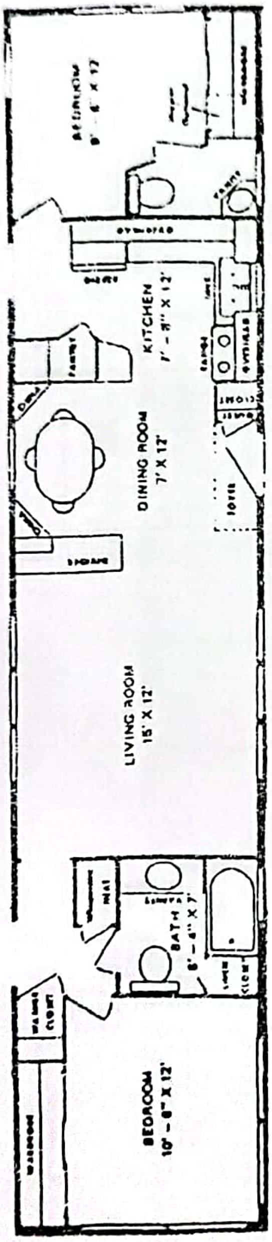
SEMI DETACHED DUPLEX



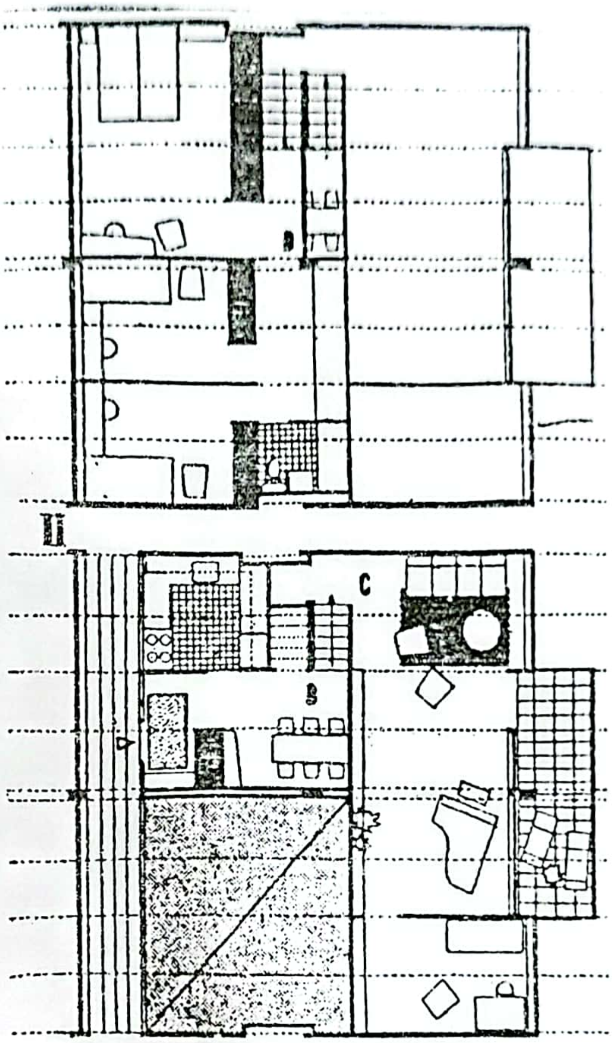
SIMPLEX

EXAMPLE OF INDEPENDENT UNITS

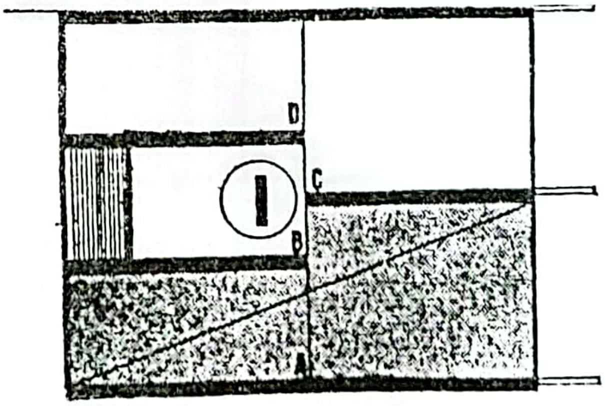
MOBILE HOMES



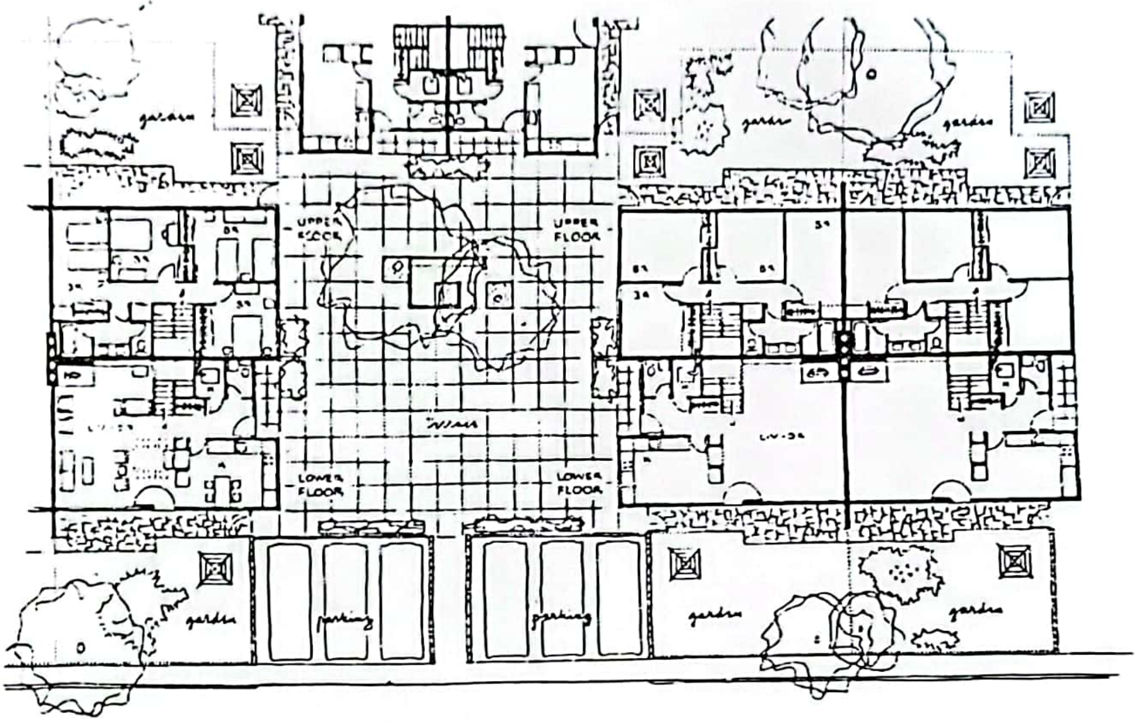
12-wide—56 by 12 ft, 672 ft², two bedrooms, two baths.

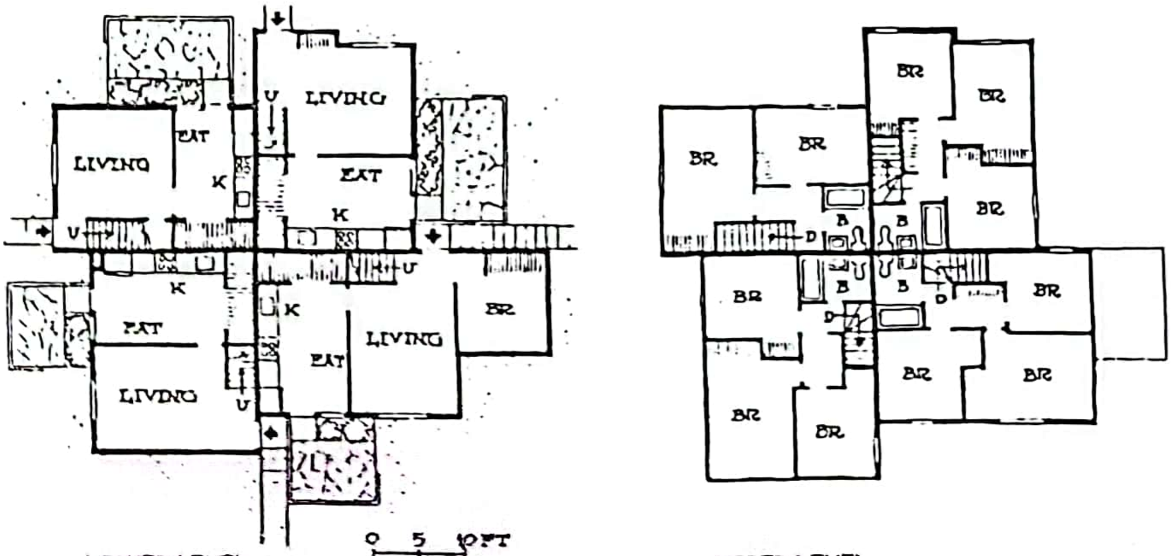


2 BAYS, ON THREE LEVELS



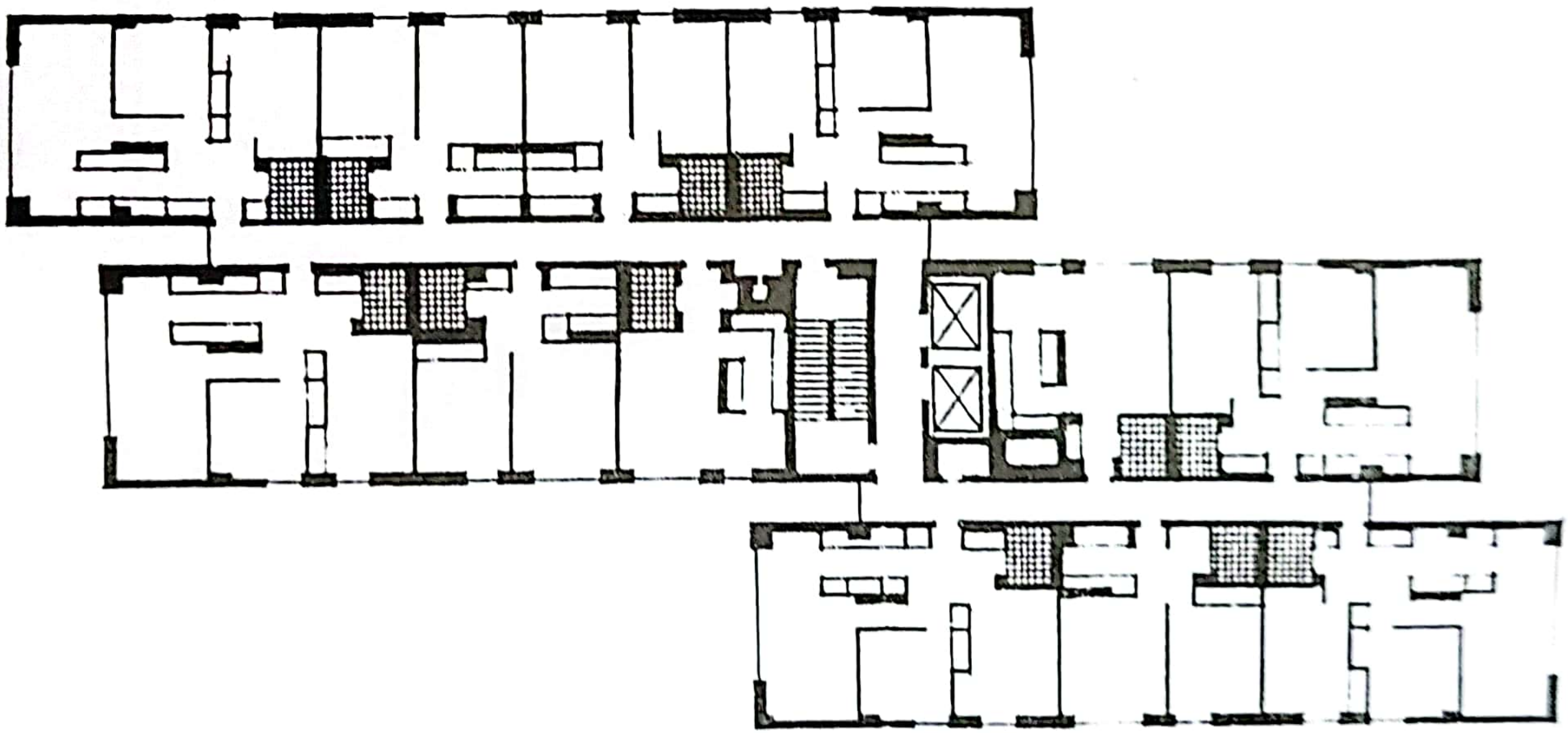
TRIPLEX APARTMENT



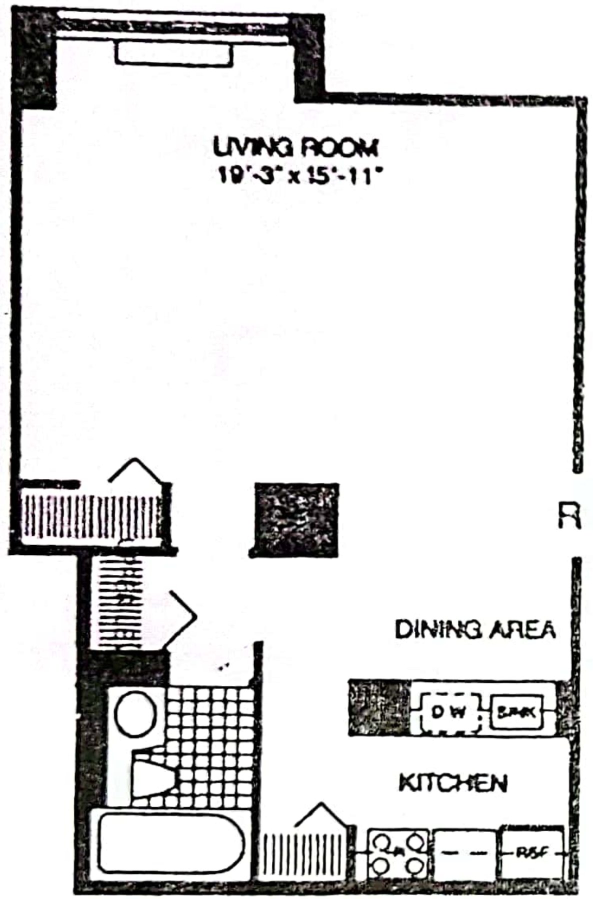


Randles Estate, Cleveland, Ohio, Whitley-Whitley-Architects. FOURPLEX

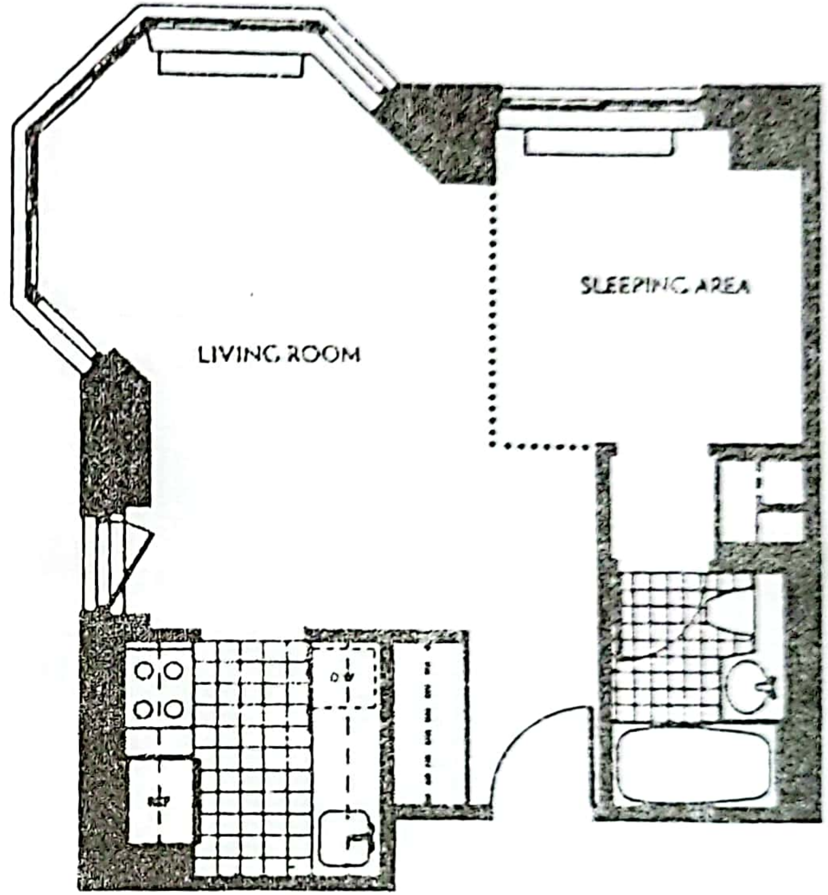
CENTER-CORRIDOR PLAN, OFFSET



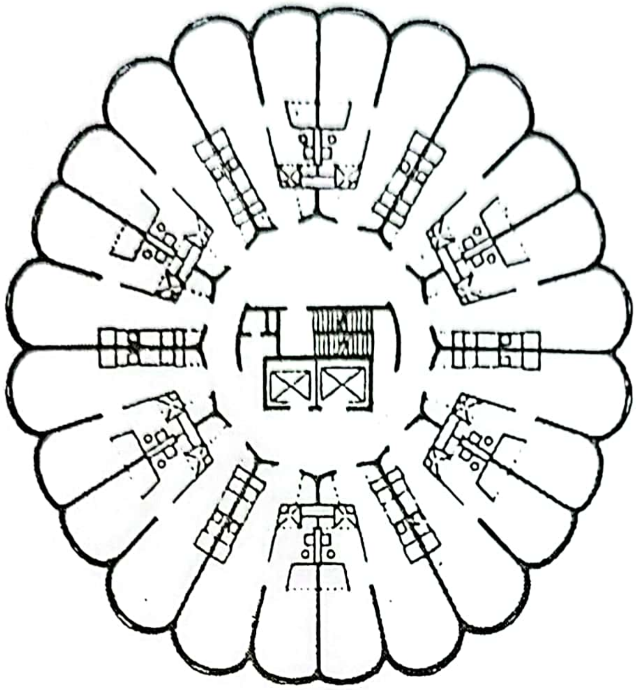
EXAMPLE OF CENTRAL CORRIDOR PLAN



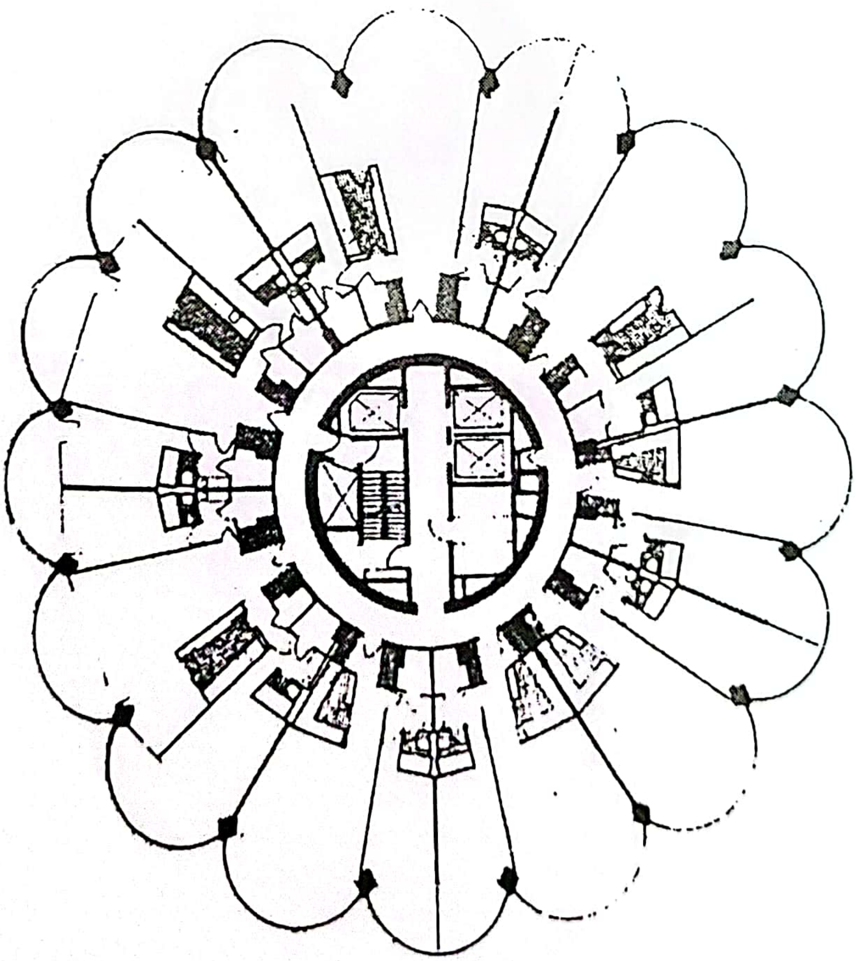
One-bathroom studio apartment. Liberty Court, Battery Park City, New York, N.Y.



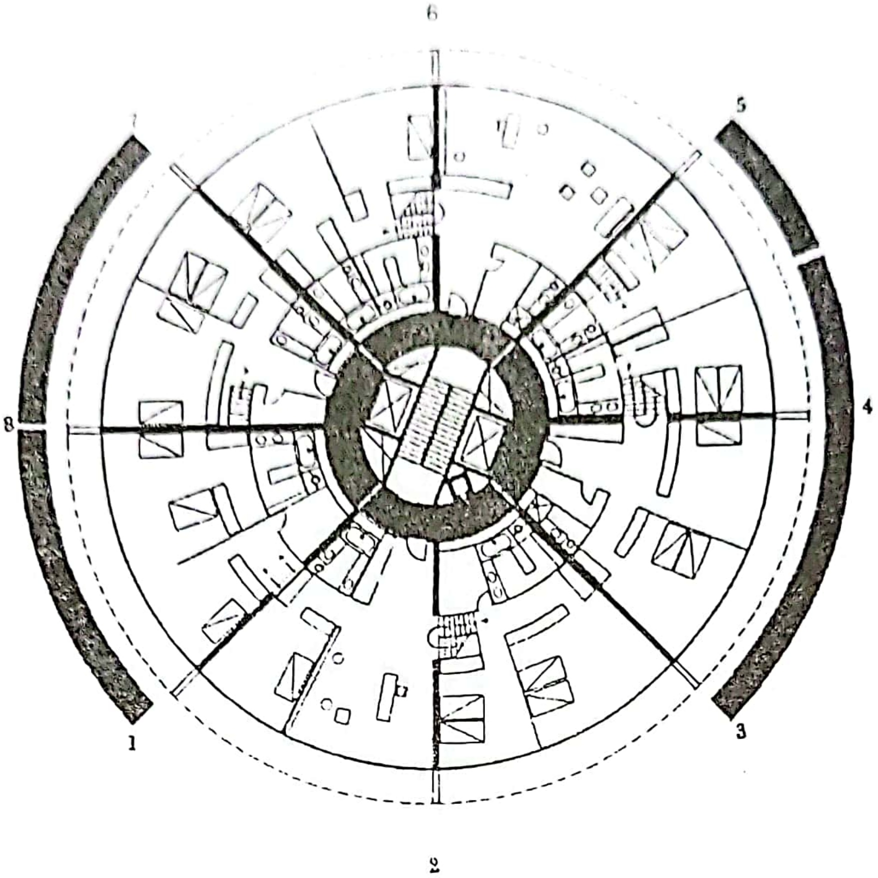
Tribeca Tower, New York, N.Y.

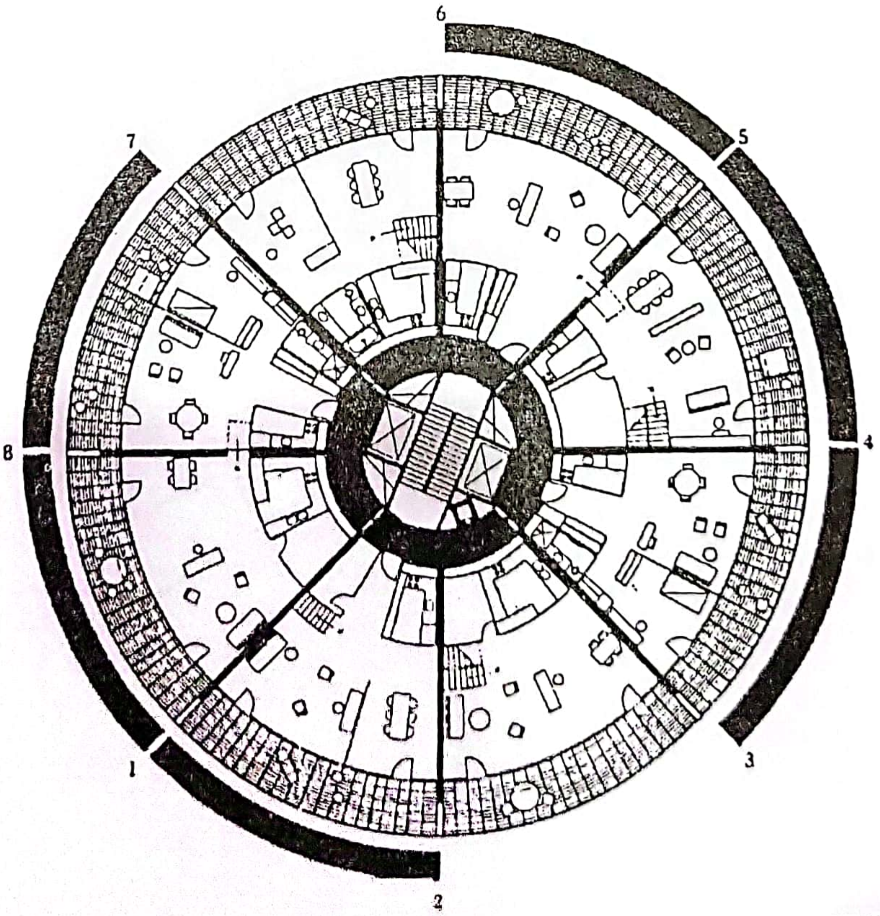


Hilliard Center, Chicago, Ill. Bertrand Goldberg-Architect.



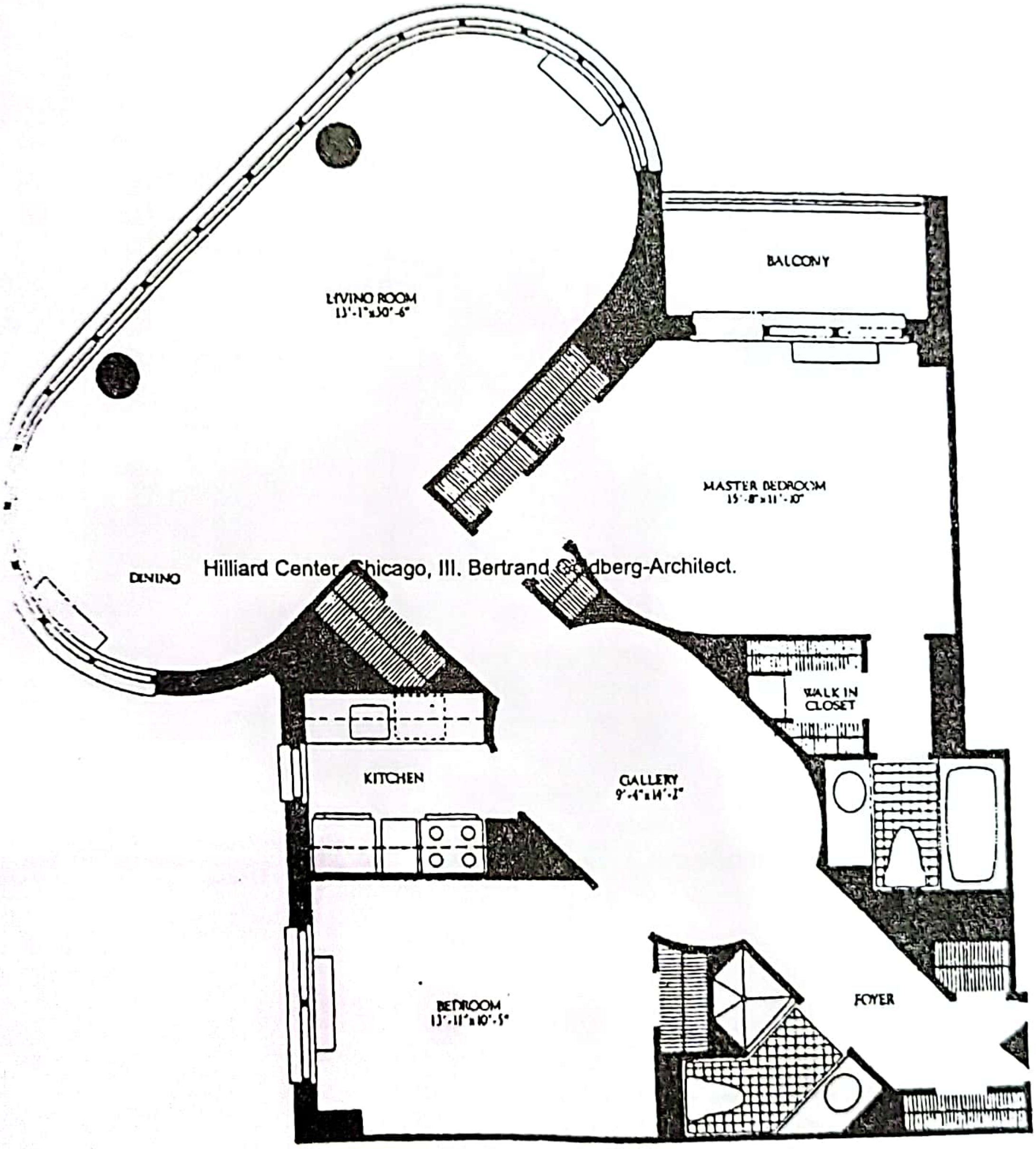
Marina City, Chicago, Bertrand Goldberg-Architect.



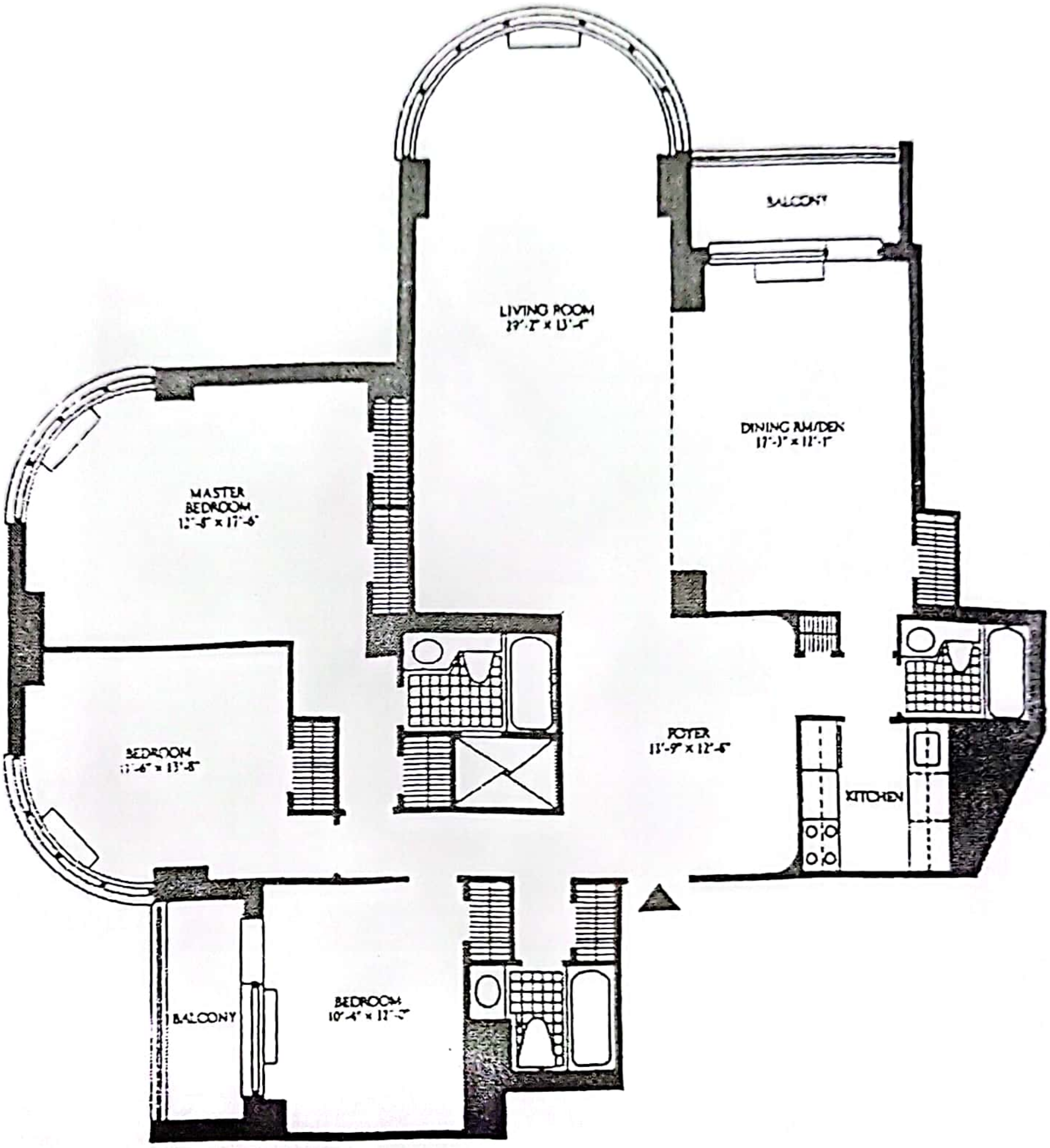


Apartment helix, New York City. I. M. Pei-Architect

SPIRAL PLAN



EXAMPLE OF TWO ROOM LUXURY APARTMENT
COURTESY : TRIBECA TOWER, NEW YORK



The Corinthian Condominiums, New York, N.Y.

EXAMPLE OF THREE BEDROOM LUXURY APT.

THREE-BEDROOM APARTMENT

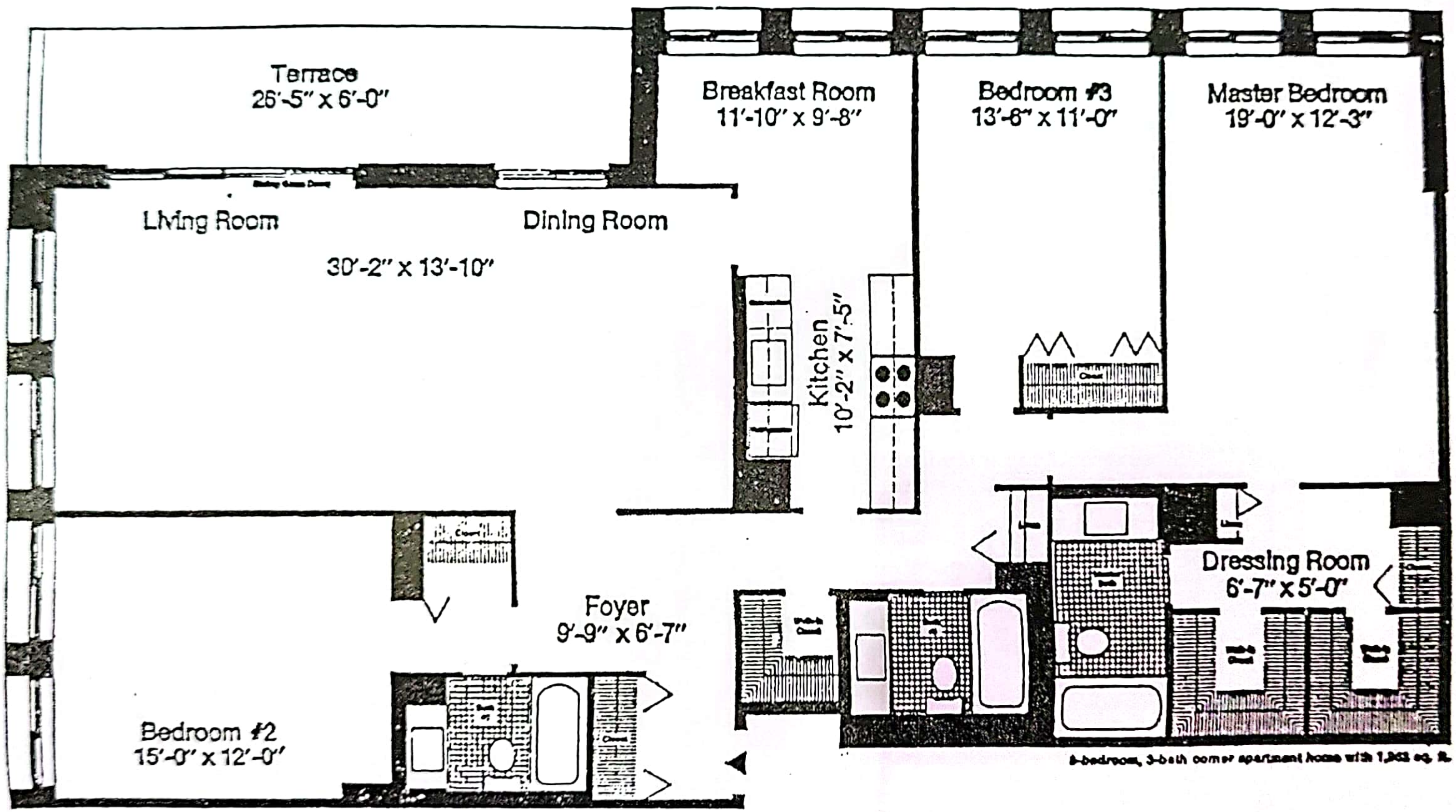
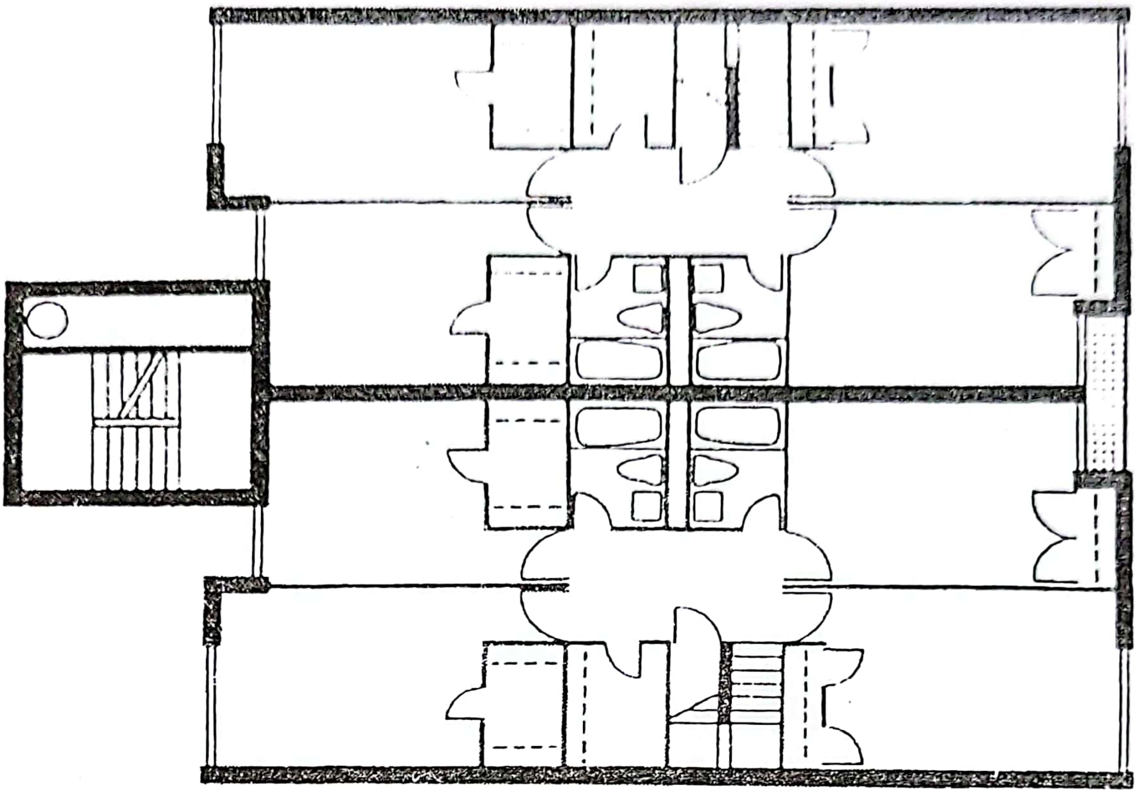
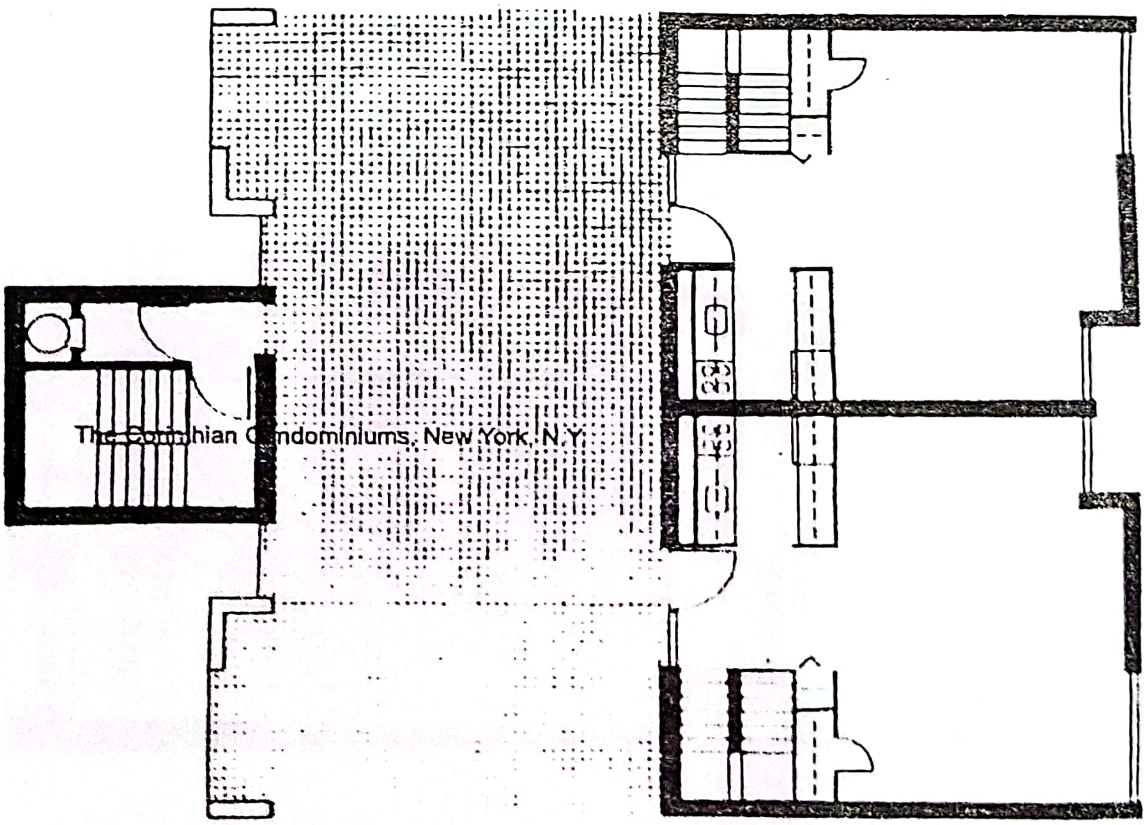


Fig. 15 Winston Towers, Fort Lee, N.J.

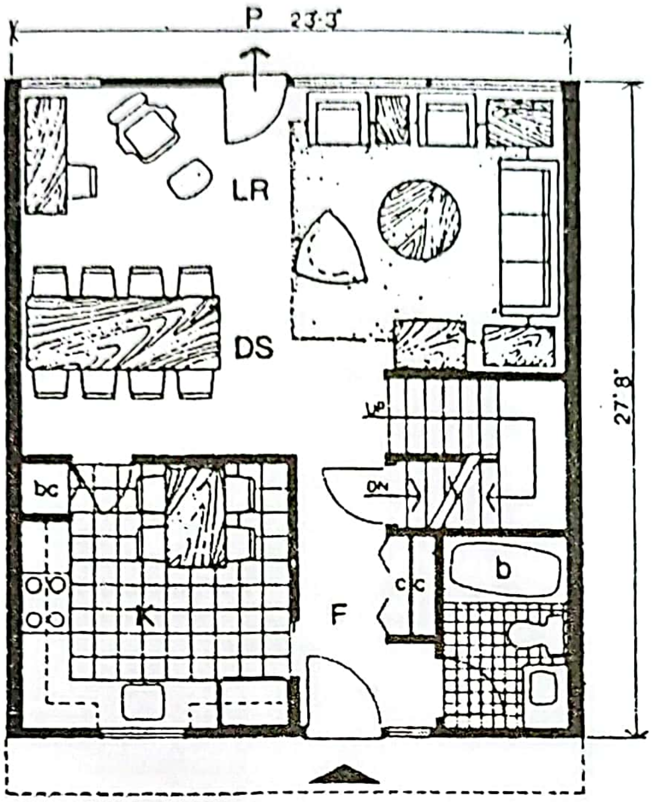




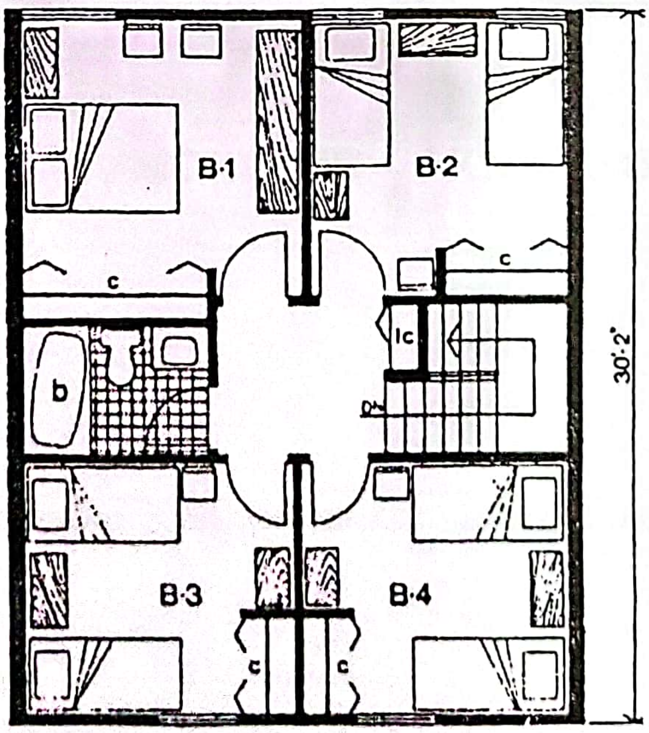
The Corinthian Condominiums, New York, N.Y.

Lavanburg Community, New York, N.Y. Conklin & Rossant-Architects.

FOUR BEDROOM APARTMENT

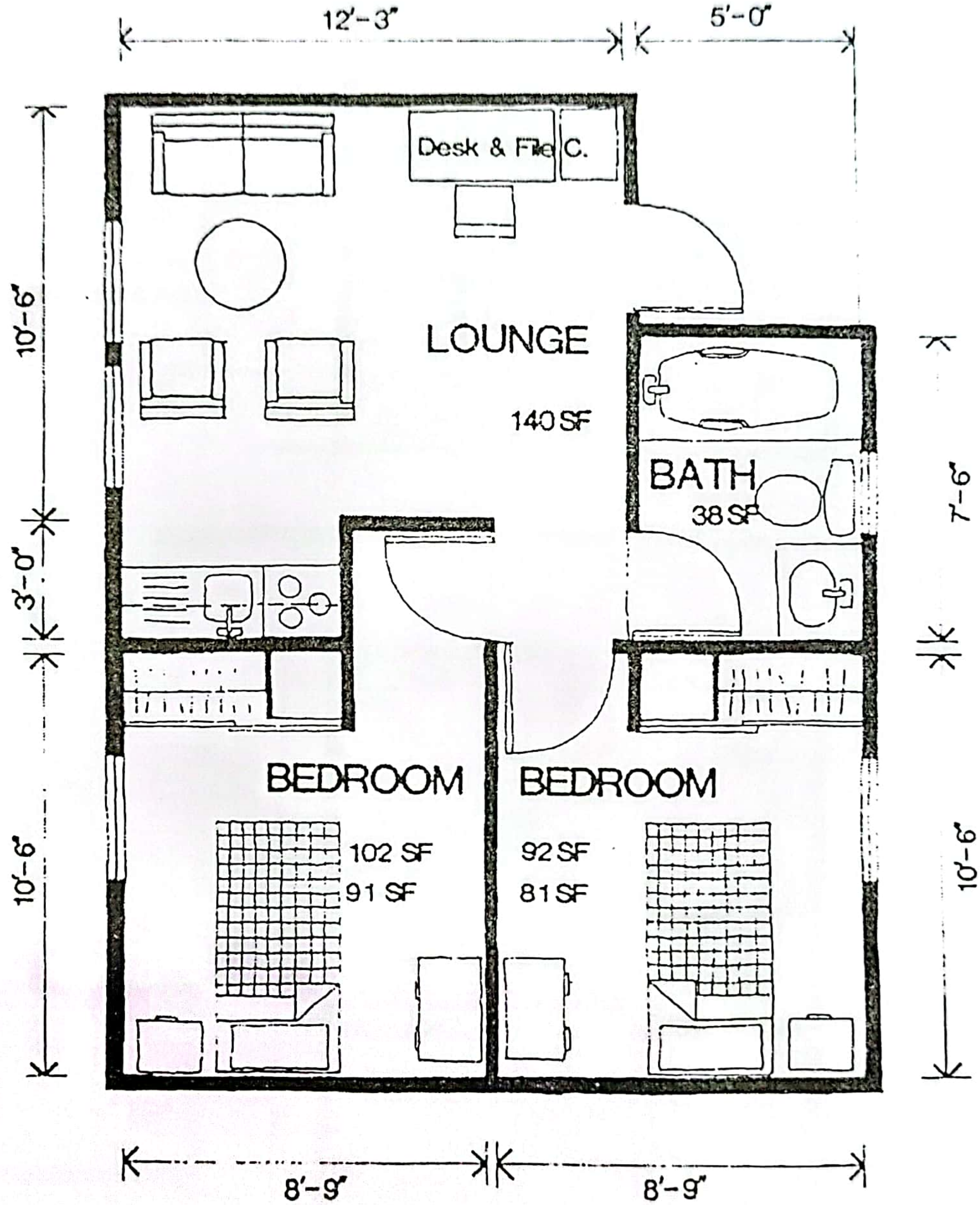


GROUND FLOOR.



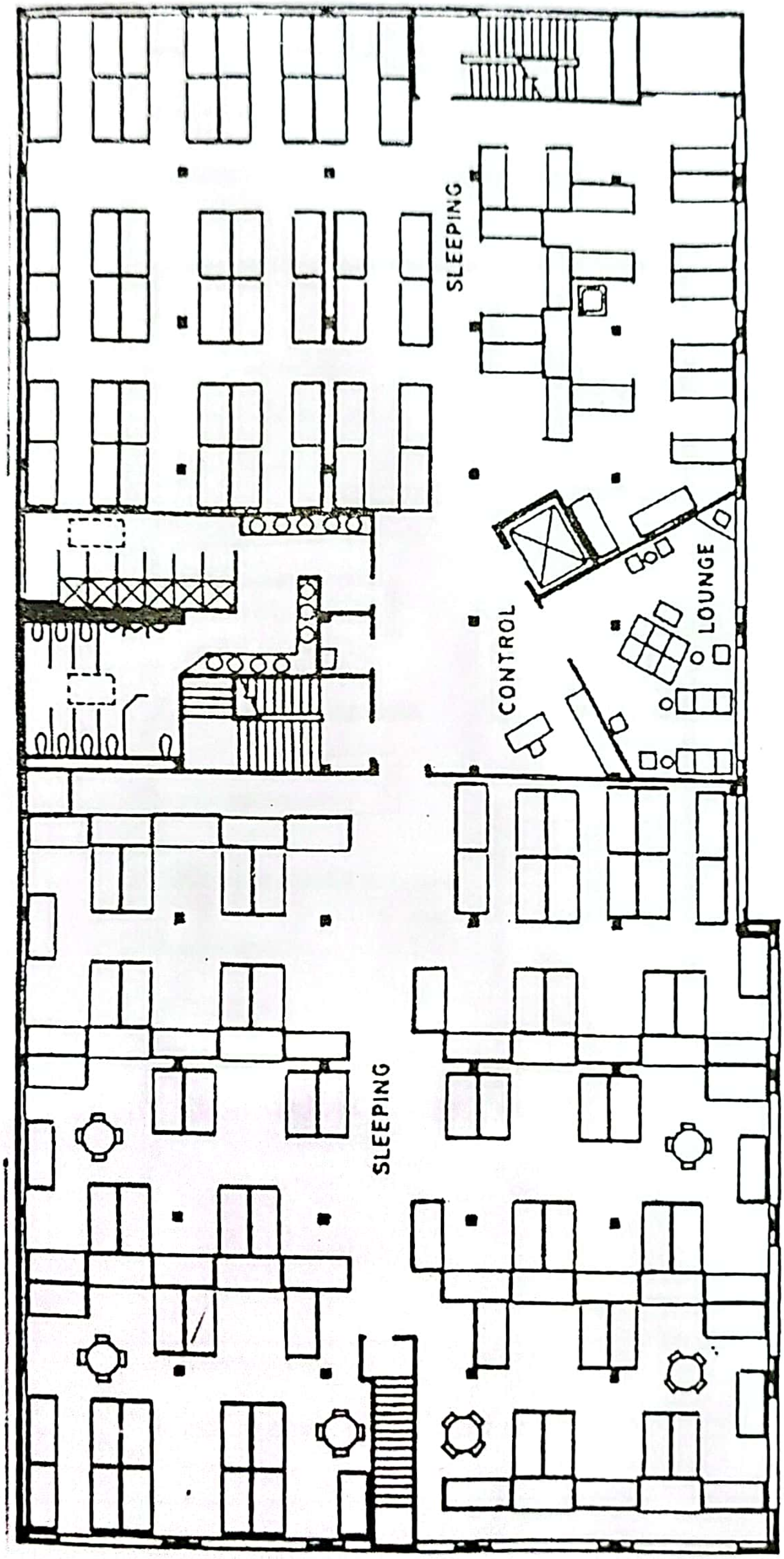
1ST FLOOR

FOUR BEDROOM APARTMENT



EXAMPLE OF SPECIAL TYPE HOUSING

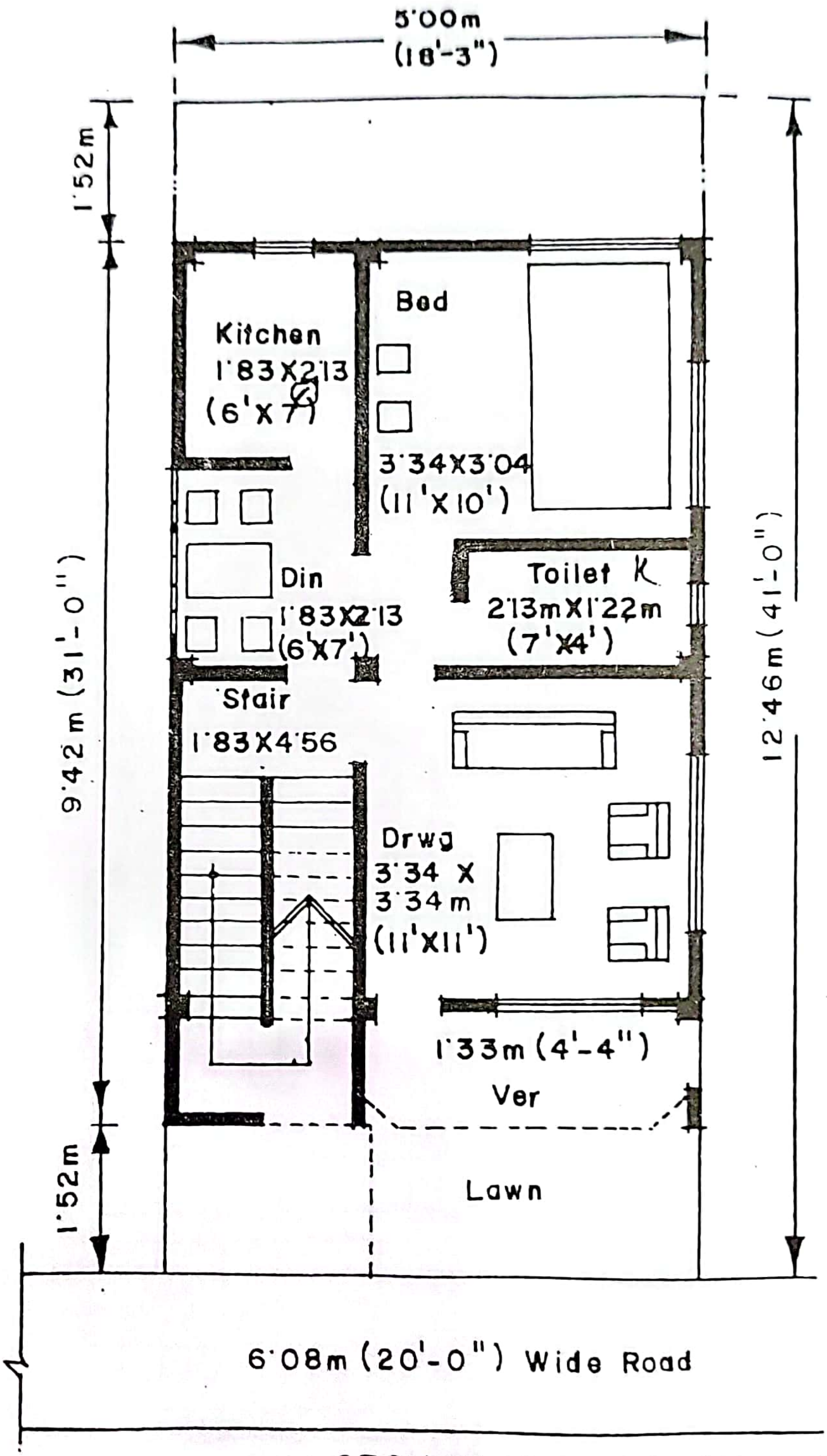
TYPICA FLOOR PLAN FOR THE MENTALLY RETARDED

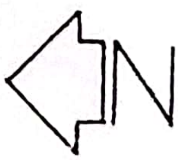


EXAMPLE OF SPECIAL TYPE HOUSING:

CENTER FOR THE HOMELESSS

4.27. Some Typical House Plans





GROUND FLOOR PLAN

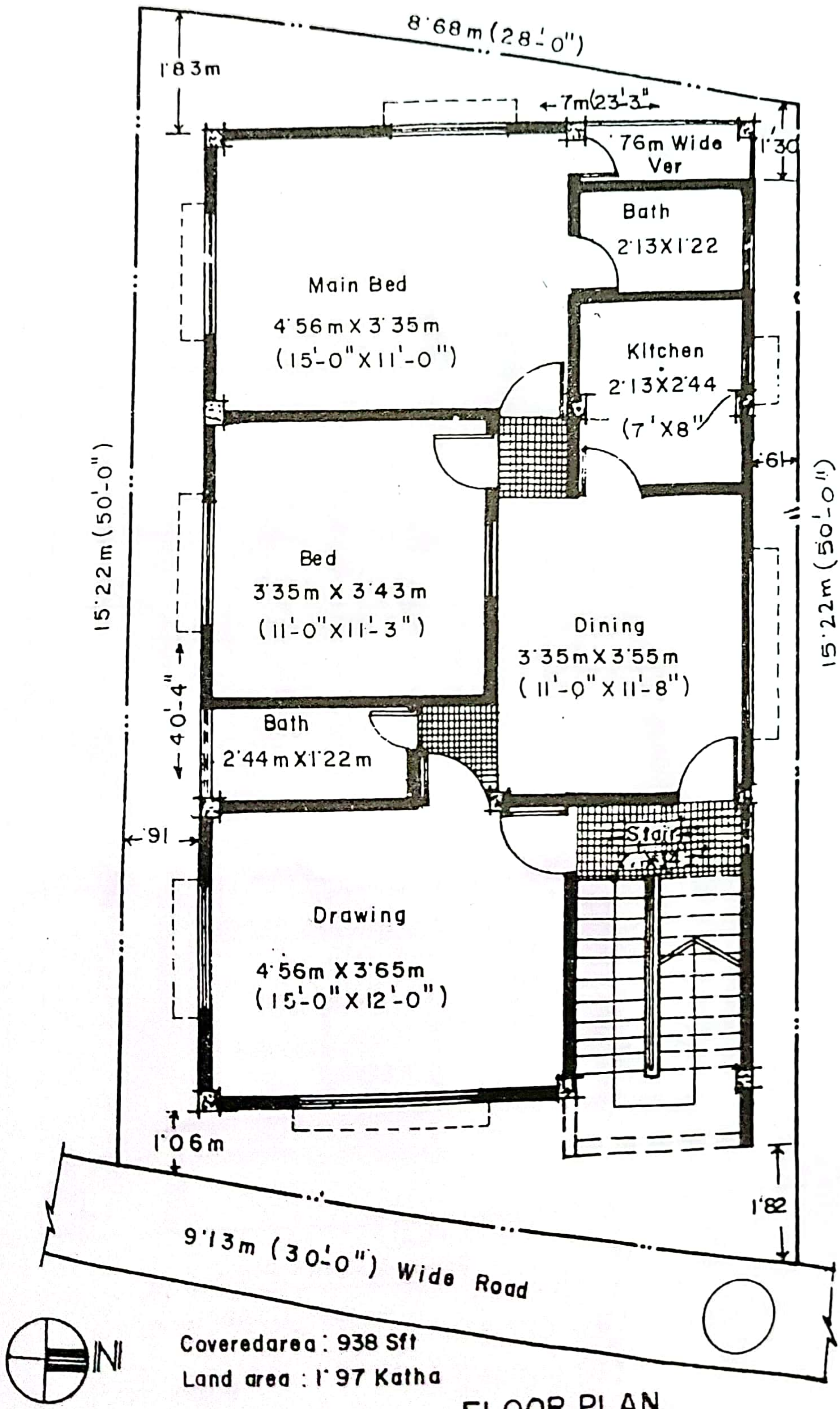
Upper Floors Similar

Scale, 1 : 100

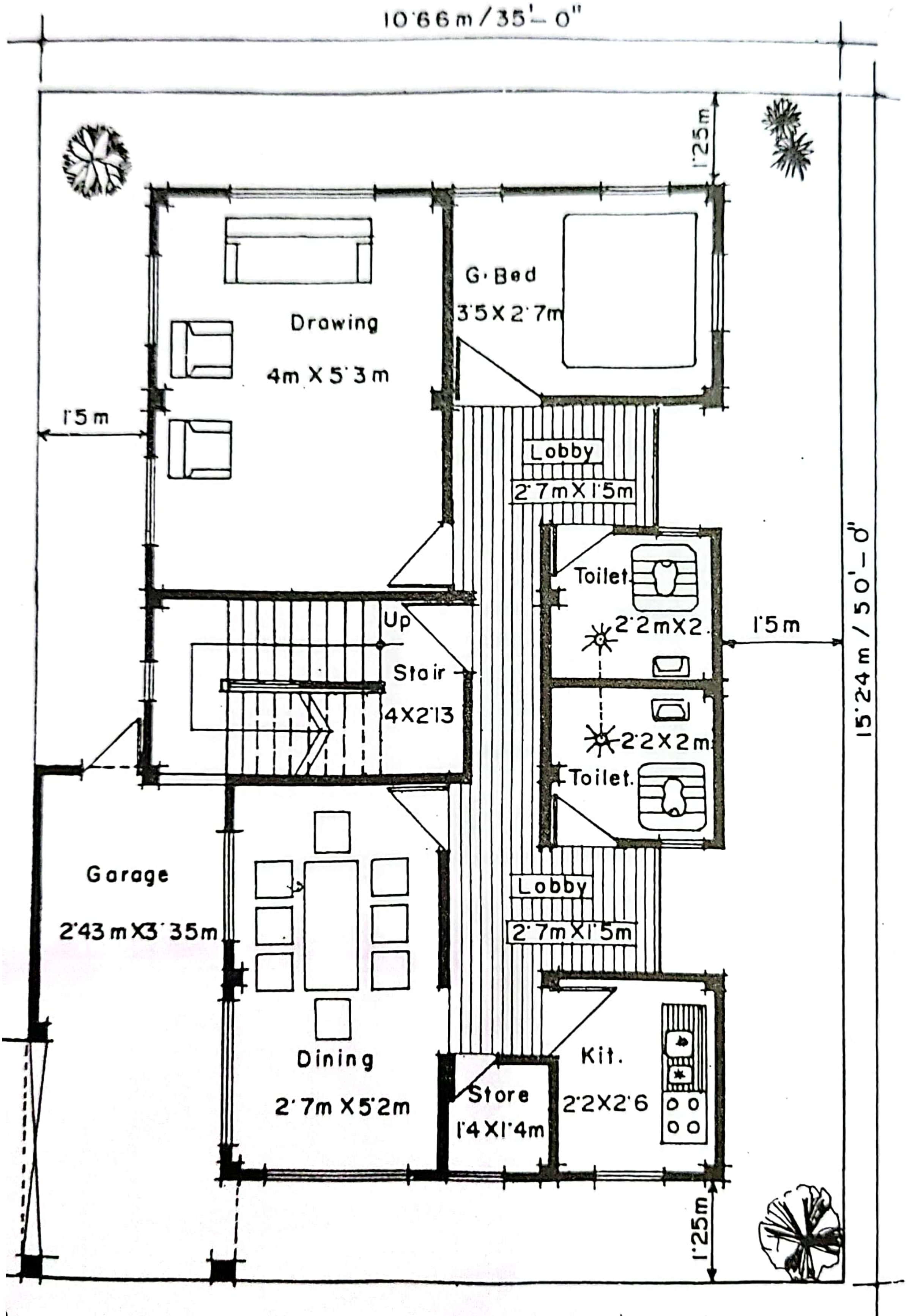
Covered area : 47'10m² (566 Sft)

Land area --- 1'04 Katha

(1)


8·68 m (28'-0")
1·83m
·7m(23'-3")
·76m Wide Ver
1·30
Bath
2·13X1·22
Main Bed
4·56 m X 3·35 m
(15'-0" X 11'-0")
Kitchen
2·13X2·44
(7'X8")
·61
15·22m (50'-0")
15·22m (50'-0")
Bed
3·35m X 3·43m
(11'-0" X 11'-3")
Dining
3·35m X 3·55m
(11'-0" X 11'-8")
40'-4"
Bath
2·44m X 1·22m
·91
Stair
Drawing
4·56m X 3·65m
(15'-0" X 12'-0")
1·06m
1·82
9·13m (30'-0") Wide Road
N
Coveredarea : 938 Sft
Land area : 1·97 Katha

FLOOR PLAN



Ground Floor Plan

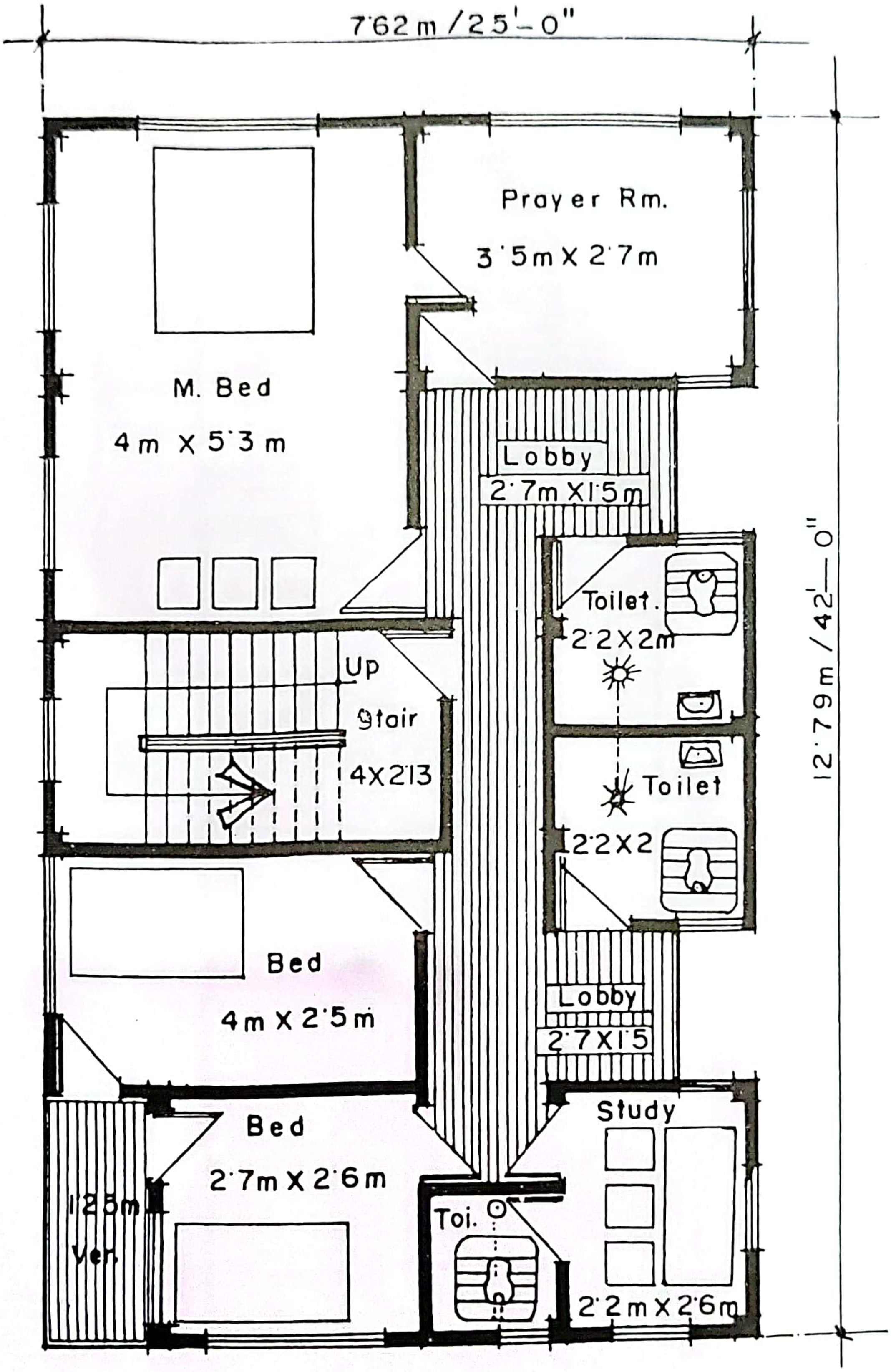
Land Area : 2·48 Katha.

Scale : 1:100

Covered Area : 90·62 Sq.m.

(975·12 Sft.)

Plan no. ◯



First Floor Plan

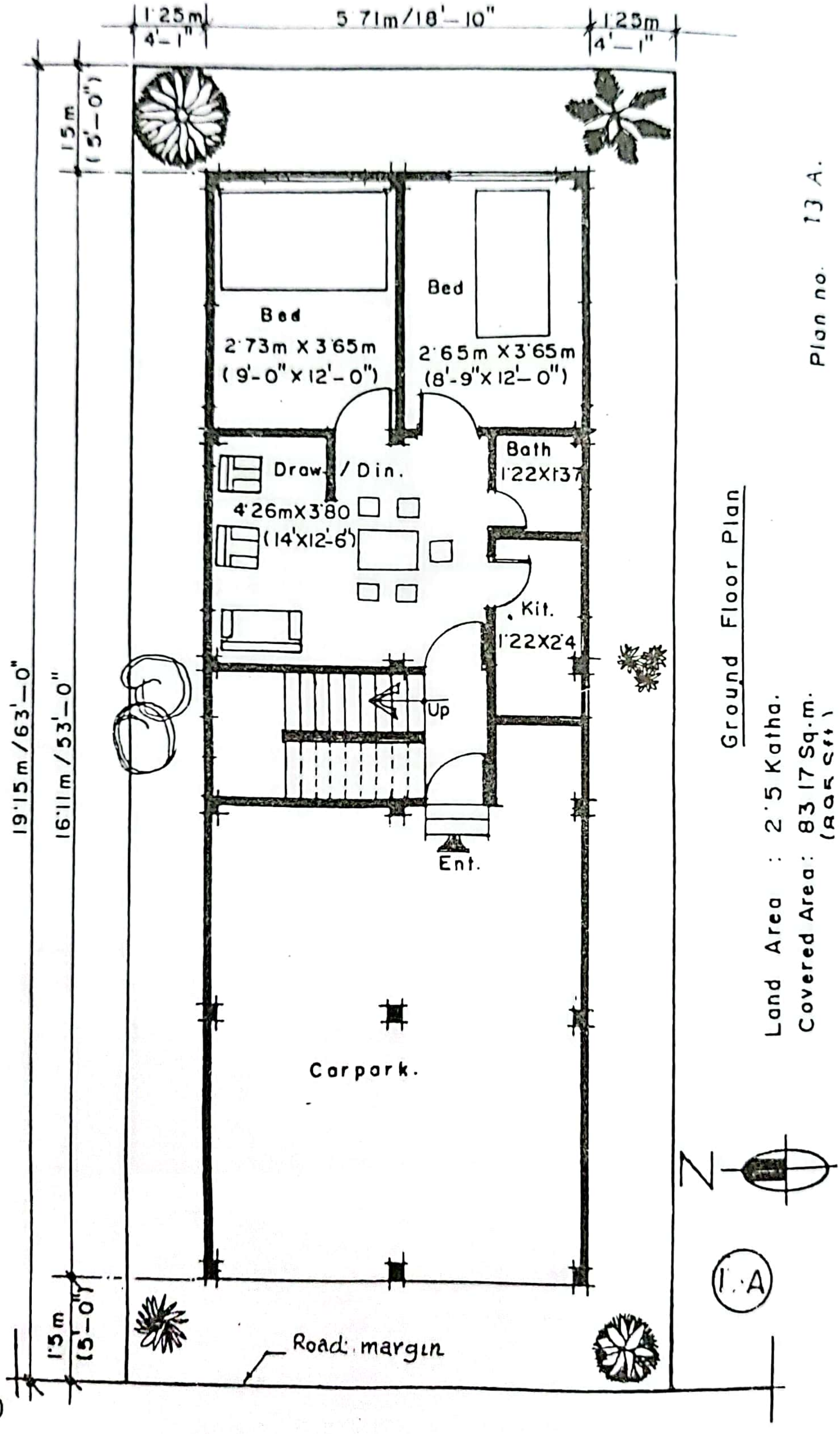
Scale: 1:100

Land Area : 2'48 Katha.

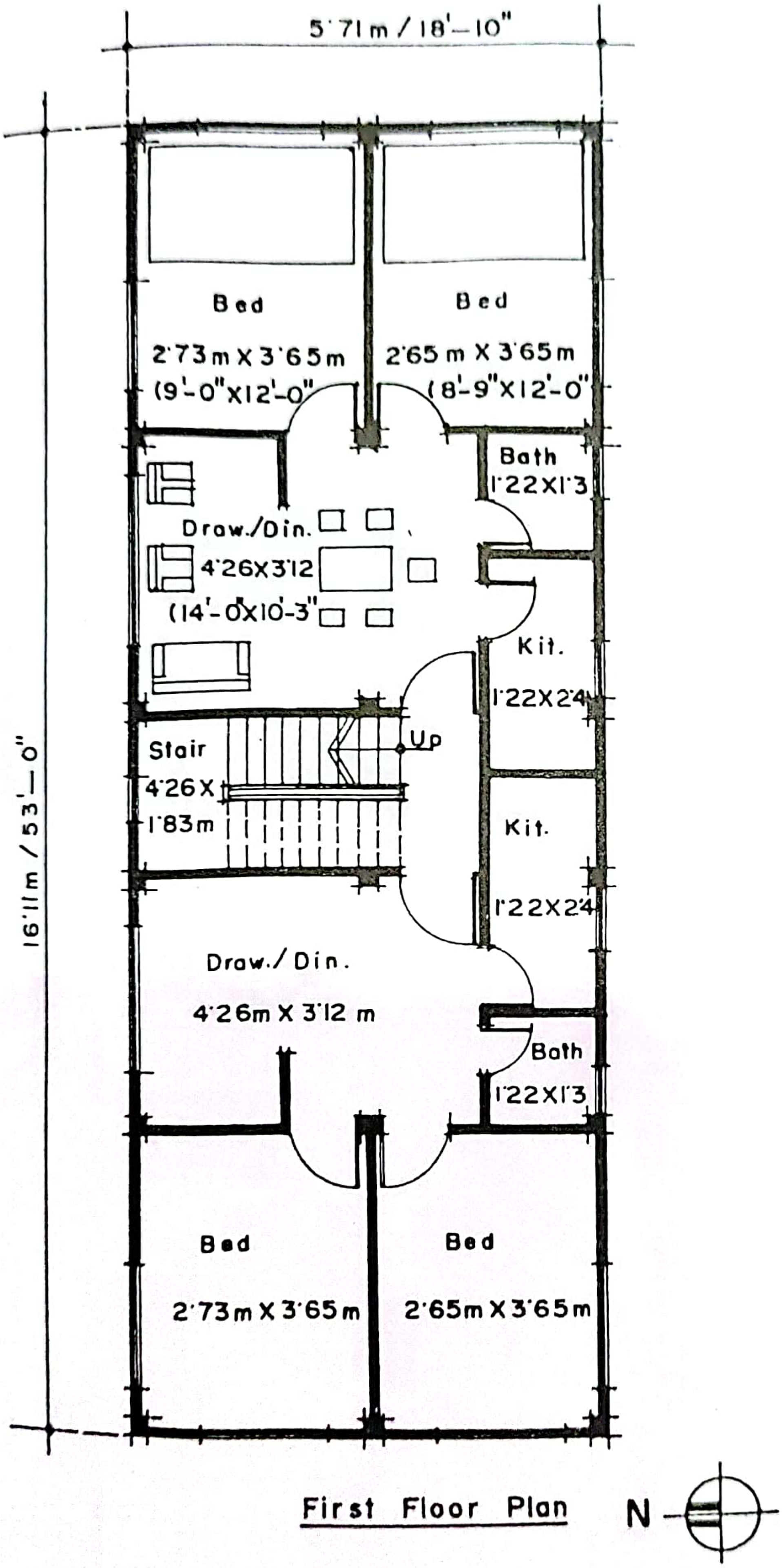
Covered Area: 96'37 Sq.m.

(1037 Sft.)

Plan no



1·25m
4'–1"
5·71m/18'–10"
1·25m
4'–1"
1·5m
(5'–0")
19·15m/63'–0"
16·11m/53'–0"
Bed
2·73m X 3·65m
(9'–0" x 12'–0")
Bed
2·65m X 3·65m
(8'–9" x 12'–0")
Bath
1·22X1·37
Draw. / Din.
4·26m X 3·80
(14' X 12'-6")
Kit.
1·22X2·4
Up
Ent.
Carpark.
1·5m
(5'–0")
Road margin
N
1-A
Plan no. 13 A.
Ground Floor Plan
Land Area : 2·5 Katha.
Covered Area: 83·17 Sq.m.

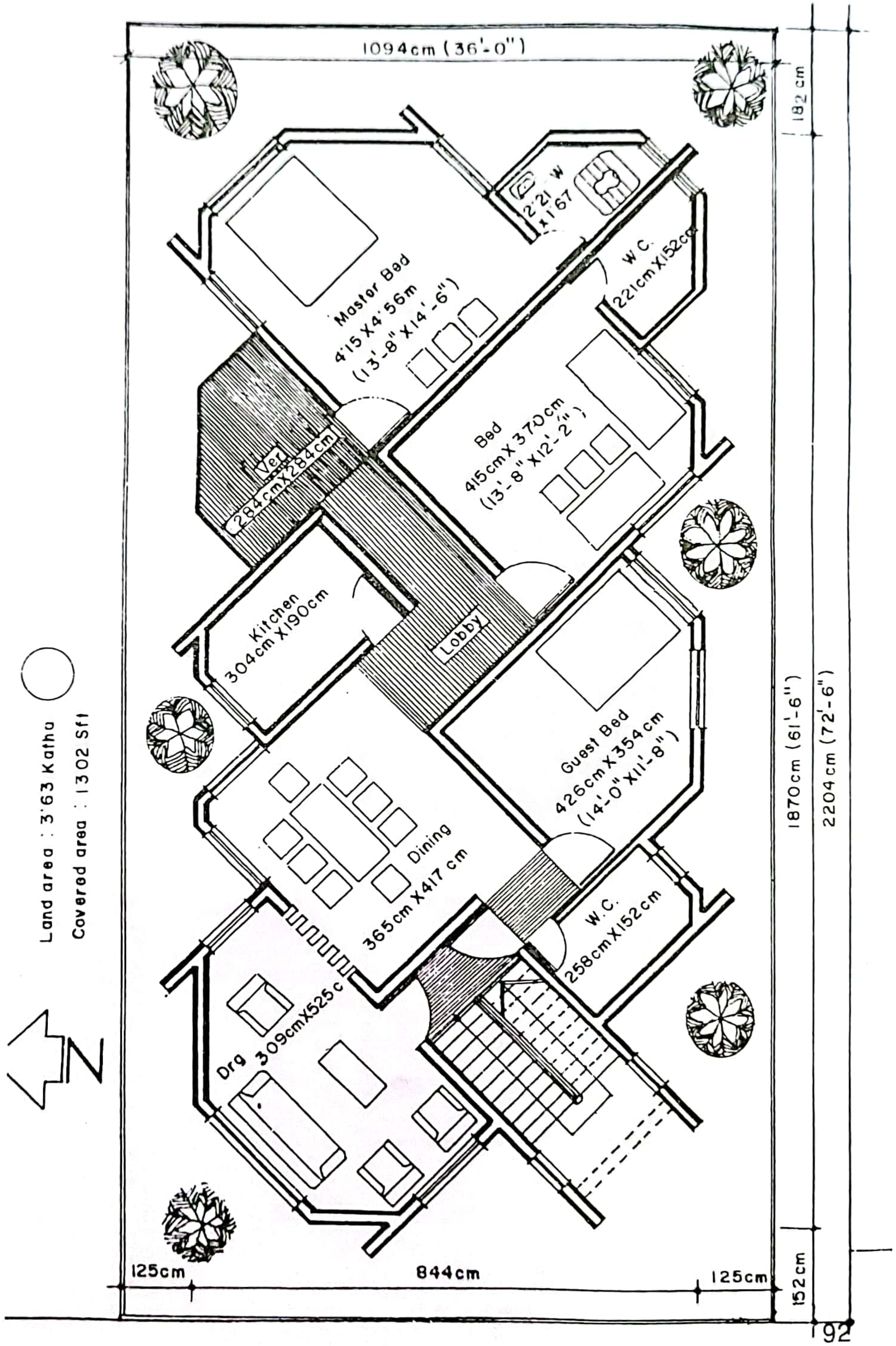


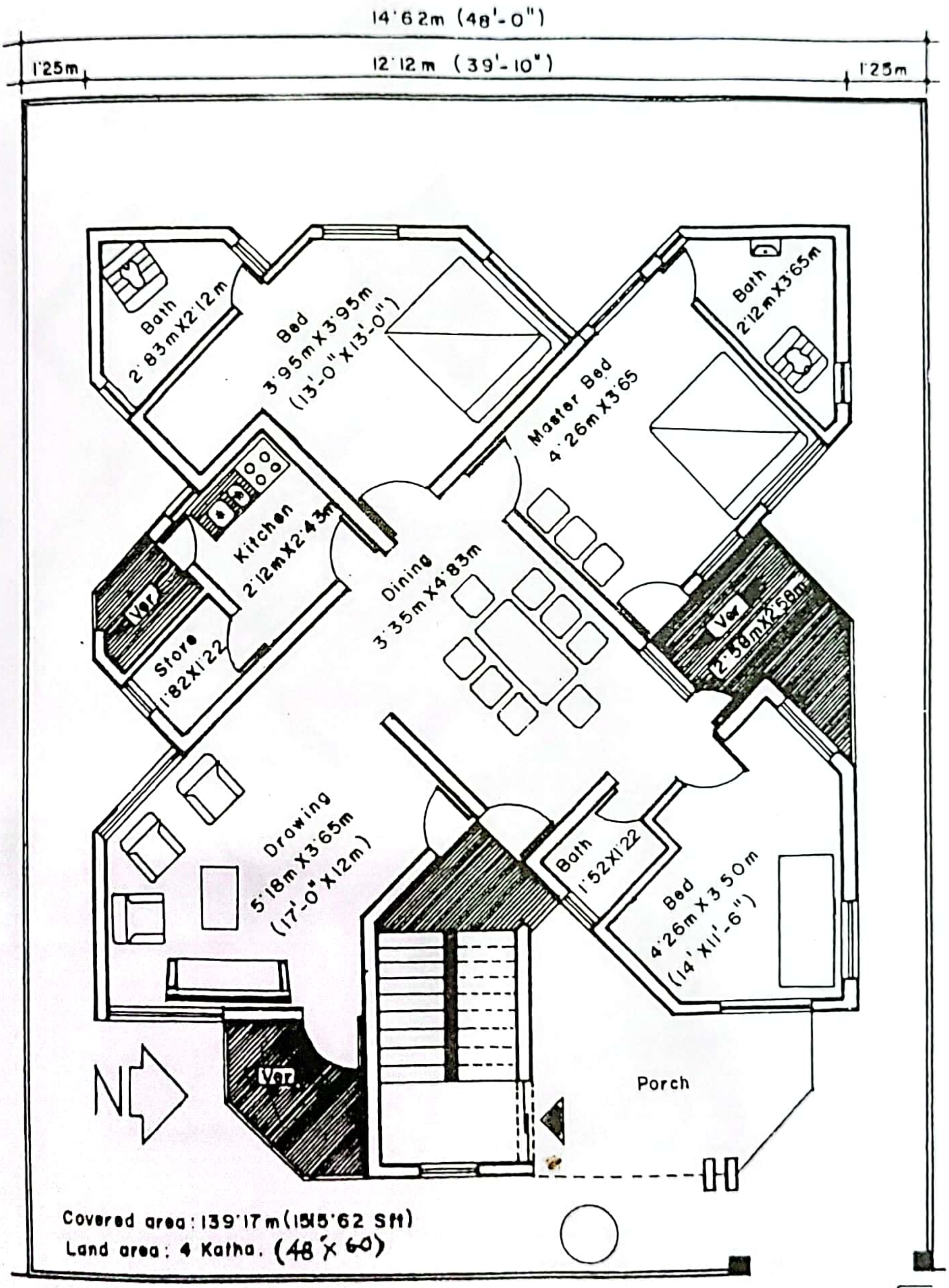
First Floor Plan

Covered Area: 83·17 Sq.m

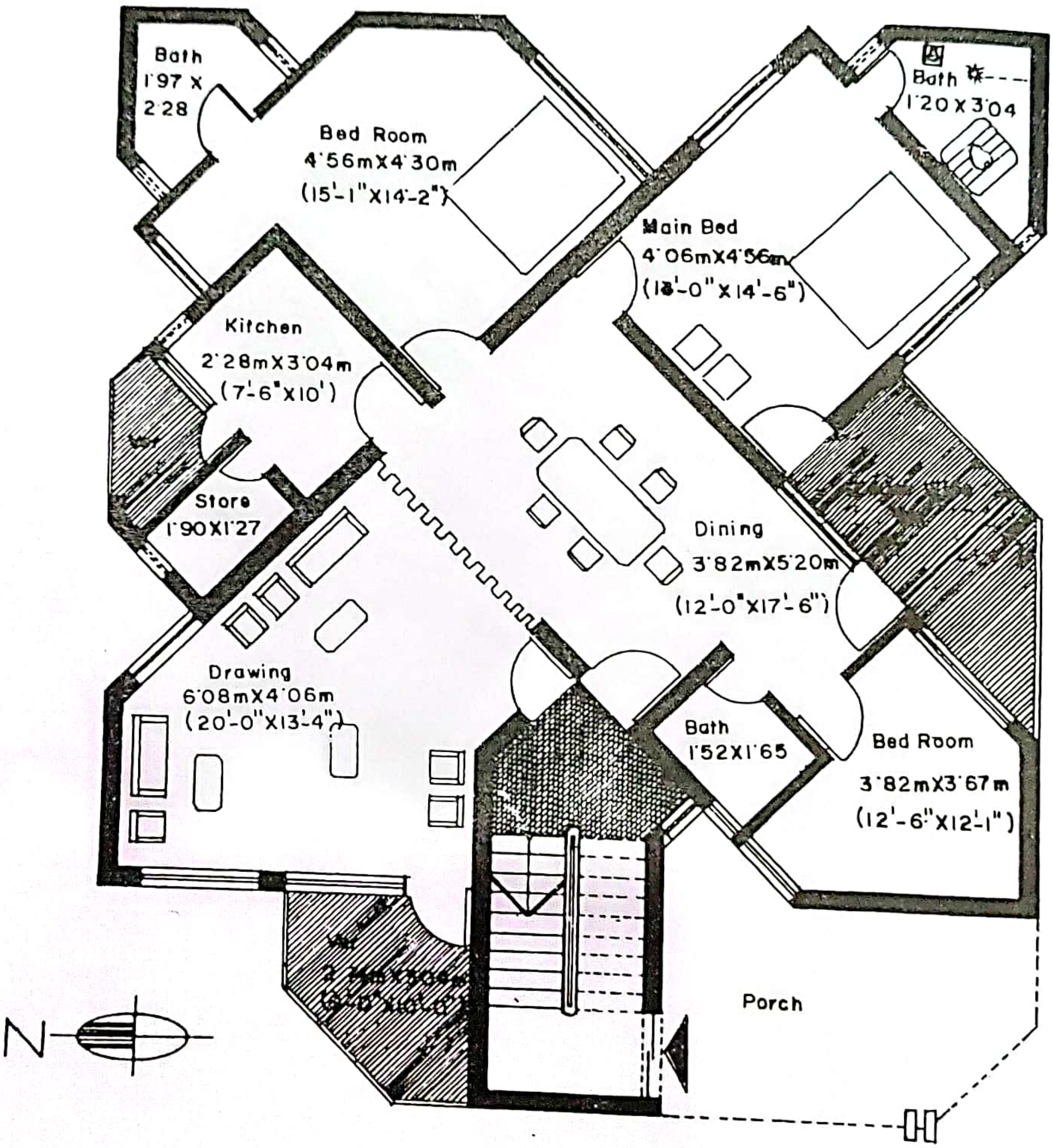
(895 Sft.)

Plan no. 1 B


1094cm (36'-0")
182 cm
Master Bed
4'15 X 4'56m
(13'-8" X 14'-6")
2'21 W
X 1'67
W.C.
221cm X 152cm
Ver.
284cm X 284cm
Bed
415cm X 370cm
(13'-8" X 12'-2")
Kitchen
304cm X 190cm
Lobby
Guest Bed
426cm X 354cm
(14'-0" X 11'-8")
Dining
365cm X 417 cm
W.C.
258cm X 152cm
Drg 309cm X 525c
125cm
844cm
125cm
152cm
1870cm (61'-6")
2204cm (72'-6")
Land area : 3'63 Katha
Covered area : 1302 Sft
N

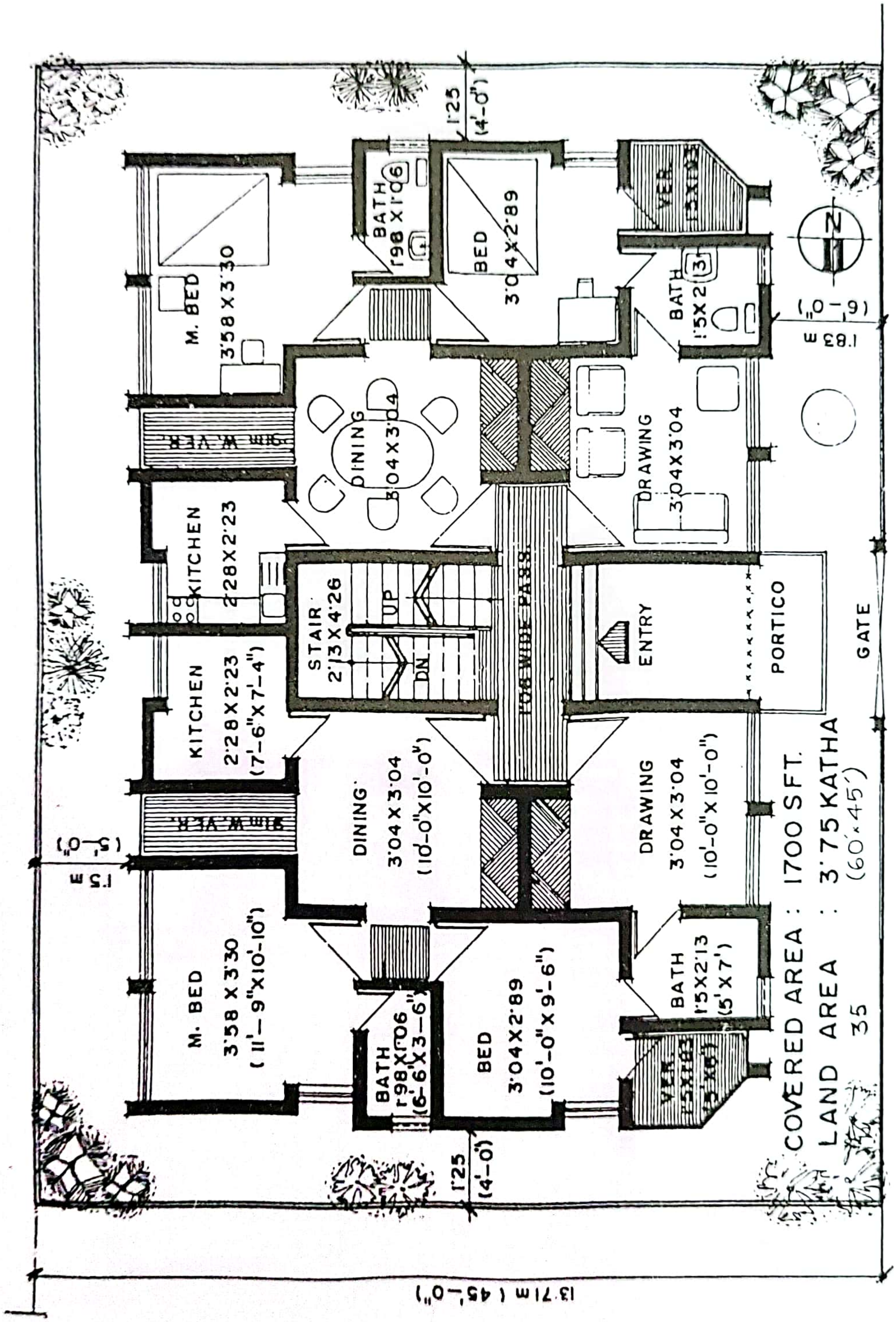


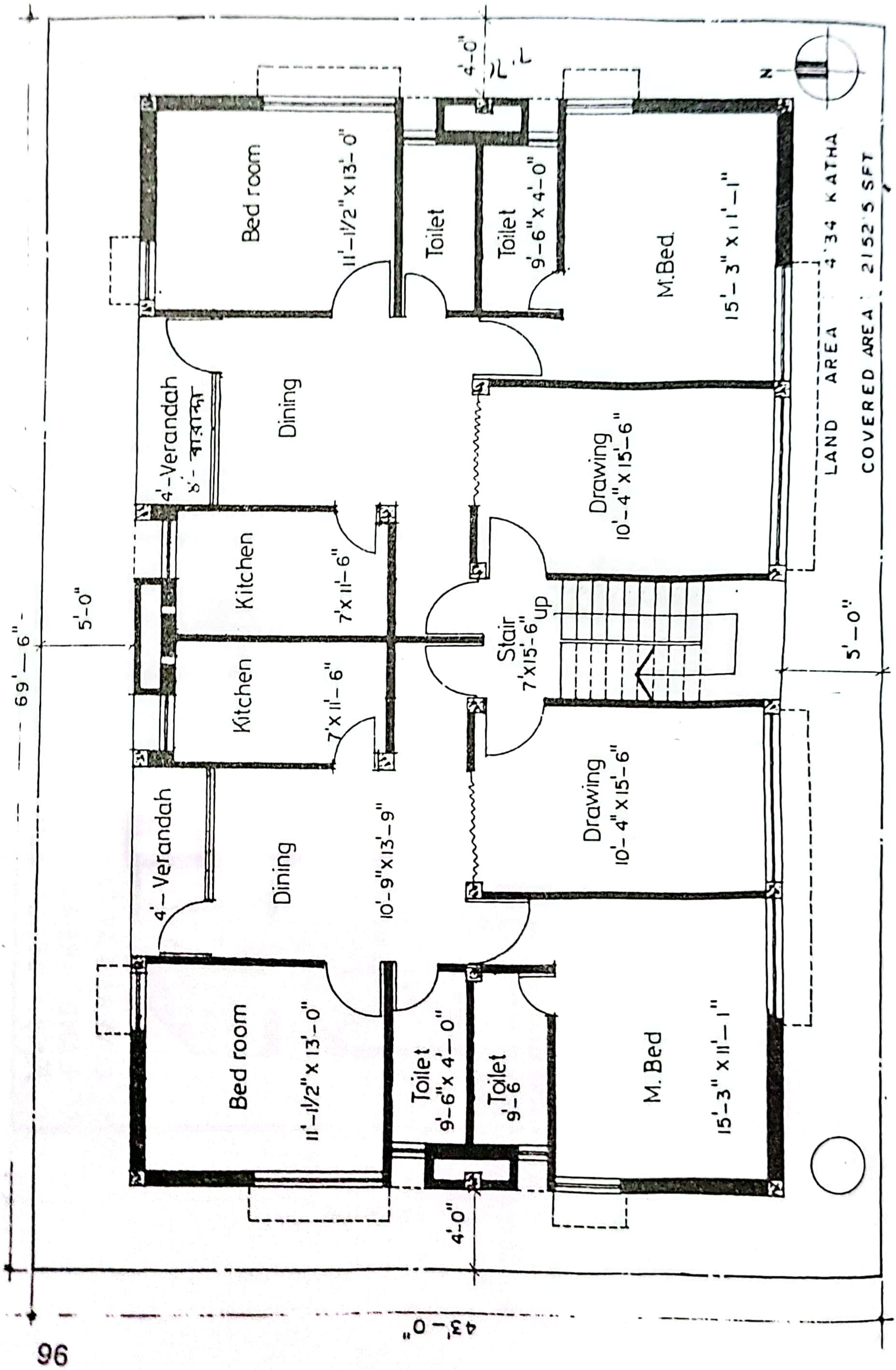
Covered area: 139'17m (1515'62 Sft)
Land area: 4 Katha. (48' X 60)

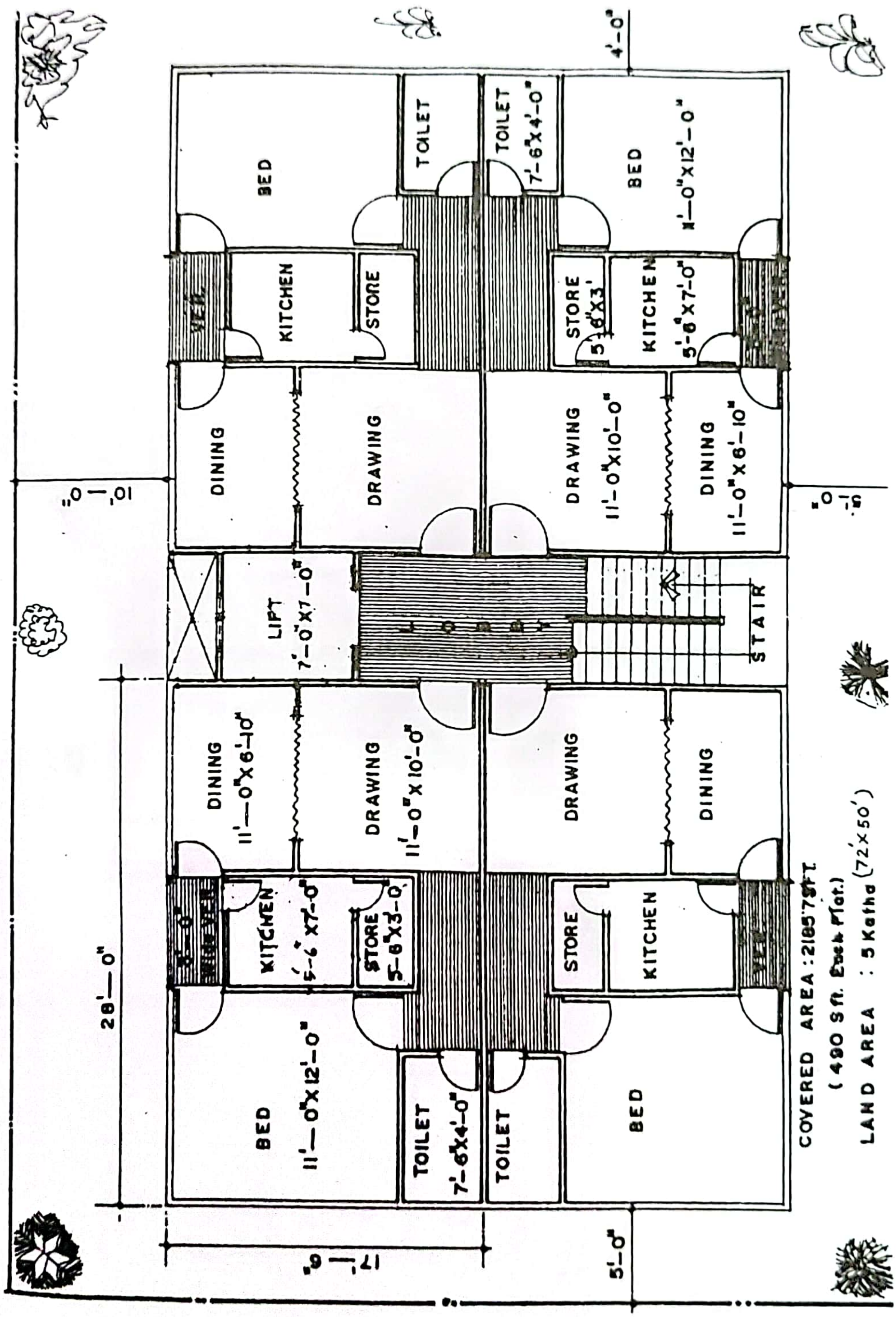


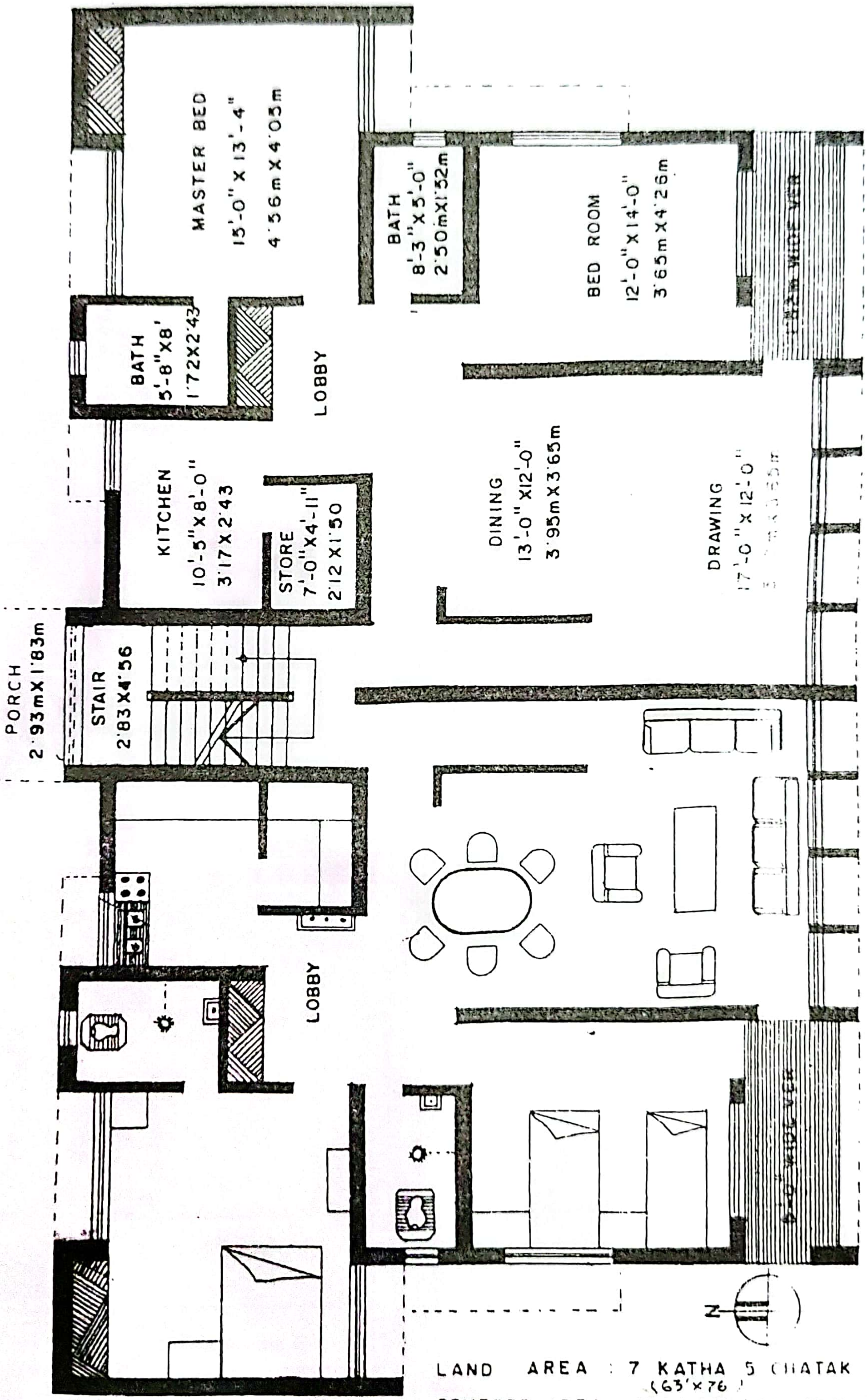
TYPICAL FLOOR PLAN

Land area : 5.75 Katha. 58'x71'
Covered area : 2000 Sft.

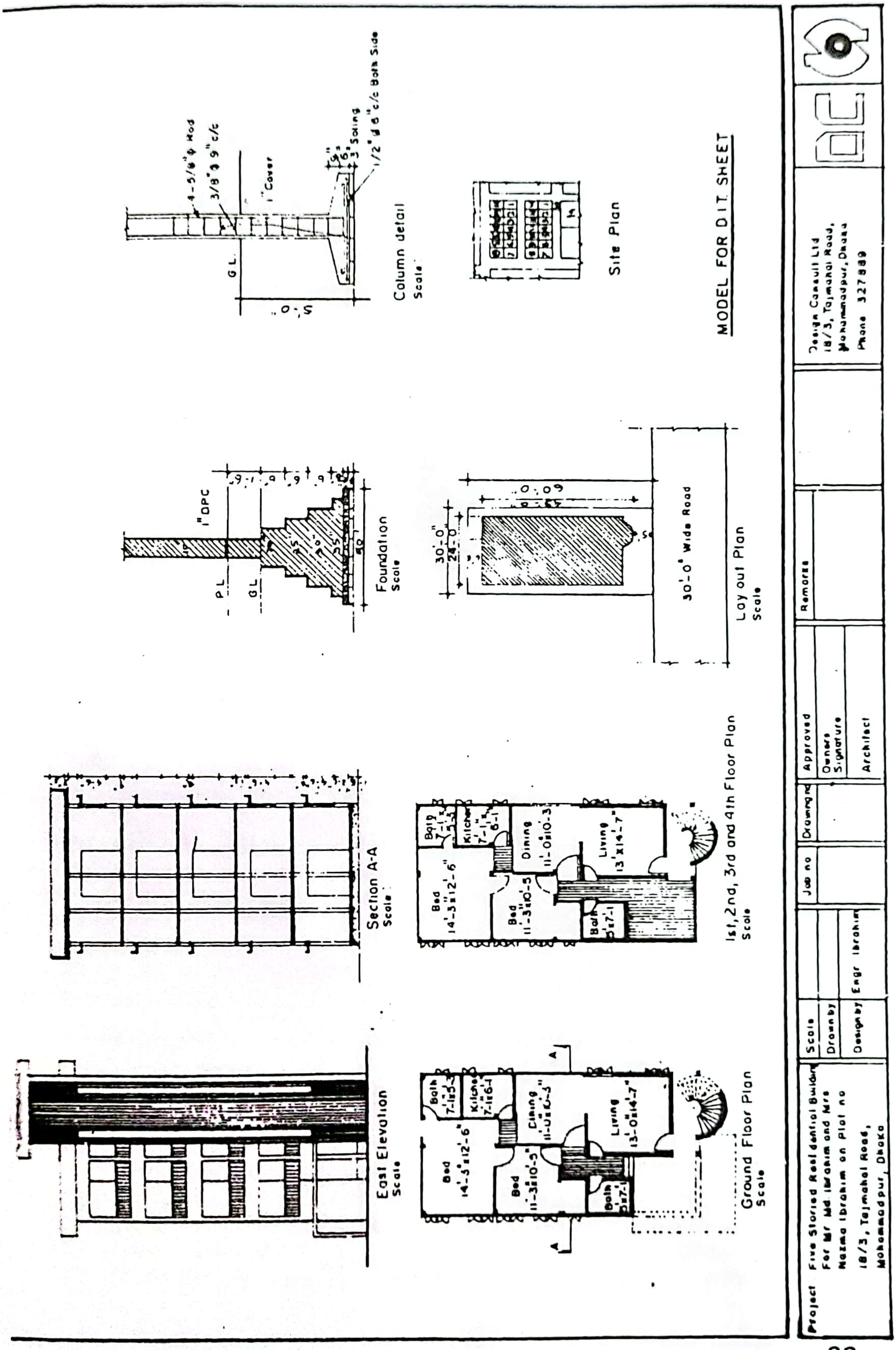

M. BED
3'58 X 3'30
(11'– 9"X10'-10")
BATH
1'98 X 1'06
BED
3'04 X 2'89
(10'-0"X 9'-6")
VER.
BATH
1'5X2'13
(5'X7')
DINING
3'04 X 3'04
(10'-0"X10'-0")
DRAWING
3'04 X 3'04
(10'-0"X 10'-0")
KITCHEN
2'28 X 2'23
(7'-6"X 7'-4")
STAIR
2'13 X 4'26
UP
DN
1'06 WIDE PASS
ENTRY
PORTICO
GATE
1'25
(4'-0")
1'83 m
(6'-0")
1'5 m
(5'-0")
13.71 m (45'-0")
N
COVERED AREA : 1700 SFT.
LAND AREA : 3'75 KATHA
(60'x45')
35


Bed room
11'-1/2" x 13'-0"
Toilet
Toilet
9'-6" x 4'-0"
M.Bed
15'-3" x 11'-1"
Dining
4'-Verandah
Drawing
10'-4" x 15'-6"
Kitchen
7' x 11'-6"
Kitchen
7' x 11'-6"
Stair
7' x 15'-6"
up
Drawing
10'-4" x 15'-6"
Dining
10'-9" x 13'-9"
4'- Verandah
Bed room
11'-1/2" x 13'-0"
Toilet
9'-6" x 4-0"
Toilet
9'-6
M. Bed
15'-3" x 11'-1"
LAND AREA 4'34 KATHA
COVERED AREA 2152'5 SFT
4'-0"
5'-0"
69'-6"
5'-0"
4'-0"
43'-0"
N


BED
TOILET
TOILET 7'-6"X4'-0"
BED 11'-0"X12'-0"
VER.
KITCHEN
STORE
STORE 5'-6"X3'
KITCHEN 5'-6"X7'-0"
DINING
DRAWING
DRAWING 11'-0"X10'-0"
DINING 11'-0"X6'-10"
LIFT 7'-0"X7'-0"
LOBBY
STAIR
DINING 11'-0"X6'-10"
DRAWING 11'-0"X10'-0"
DRAWING
DINING
KITCHEN 5'-6"X7'-0"
STORE 5'-6"X3'-0"
STORE
KITCHEN
BED 11'-0"X12'-0"
TOILET 7'-6"X4'-0"
TOILET
BED
4'-0"
10'-0"
5'-0"
28'-0"
17'-6"
5'-0"
COVERED AREA : 2185 SFT
(490 Sft. Each Flat.)
LAND AREA : 5 Katha (72'x50')



LAND AREA : 7 KATHA 5 CHATAK
(63'×76')
COVERED AREA 2768 SFT (257'25 Sq m)


MODEL FOR D.I.T. SHEET
Column detail
Scale
Site Plan
Foundation
Scale
Lay out Plan
Scale
30'-0" Wide Road
1st, 2nd, 3rd and 4th Floor Plan
Scale
Section A-A
Scale
East Elevation
Scale
Ground Floor Plan
Scale
Bed
Kitchen
Dining
Living
Bath
1" Cover
1" DPC
G.L.
P.L.
Project
Five Storied Residential Building For Mr Md. Ibrahim and Mrs Nazma Ibrahim on Plot no 18/3, Tajmahal Road, Mohammadpur, Dhaka
Scale
Drawn by
Design by
Engr Ibrahim
Job no
Drawing no
Approved
Owners Signature
Architect
Remarks
Design Consult Ltd
18/3, Tajmahal Road,
Mohammadpur, Dhaka
Phone 327889

5 Planning Your Home in Rural Areas.

"To be doing good is man's most glorious task "
—Sophecles

5.1. Definition of Village

This chapter have been adapted from Johannes Jahne's construction practice in Rural Areas.
"Village" is defined as an assemblage of dwellings, farm buildings and communal buildings whose inhabitants and users run a farm or are primarily employed in Agriculture. Bangladesh consist of 68 thousand villages and more than 80% people are engaged in farming. Govt. has given much emphasis for development of villages and upgraded thanas are already functioning as Upa-zilla. Creation of ideal villages are much talked about now-a-days. Development of these villages means development of the country.

5.2. Determining Ideal Villages and Affiliated Villages

Naturally, a member of various individual, cooperative authorities and organisations must concern themselves with the development of the village, namely.

a) There should be a village Magistrate.
b) Machine and tractor lending Station.
c) Agricultural trading Cooperatives.
d) Agricultural Producers Cooperative.
e) Handy craft Cooperatives.
f) Cooperative Societies.
g) Health authorities.
h) Educational Institutions.
i) Vocational Schools.
j) Postal Administration and Telecommunication
k) Fire- brigades.
l) National park and Sport Association.

Various new buildings must be concentrated in certain villages. Consequently, the buildings must be combined into a new social centre of the village and arranged in such a way that they promote the economic life of the village. Another extremely important factor is the architectural style, the village should be beautiful and attractive, the architectural style characteristic of the landscape and national individuality, and the village should off course be a modern one.
It is only natural that the great number of dwelling places, buildings for farming purposes, communal institutions and Social facilities, village roads, and farm tracks can only be designed and constructed in stages. However, with the first dominating new building, be it a dwelling-house or a small farmstead comprising dwelling place and Livestock housings, be it a School, a Club house or a motor fire engine garage, a decision on architectural style, design features, and landmark of the village has to be taken. Decisions on the arrangements of the various spheres of village life within a larger area to be settled have to be taken with care and with a bold outlook.

Selection of Rural Development Centres :

A rural development centre should be called principal Village or "Ideal Village". It may be necessary for a principal village having the bigger with a smaller population, so called affiliated villages, for certain purposes.
Generally, agriculture is the economic basis of the village. If agriculture determines the character of a village, Ideal villages should be developed and promoted by all means. If ideal villages are industrial villages or workman's residential. villages, they have to be developed by the industrial plants in question. Agricultural principal villages which have been developed according to the requirements can be considered economic, political, communal and social centres. In particulars this applies to villages centrally situated in an area of about 3,000 hectares of arable land and surrounded by affiliated smaller villages. However, it is indispensable that the principal village provides for the need of about 1,500 inhabitants, to stick to the ideal case, by economic, political, social, communal, and health institutions and the facilities as required by a village community.
the number and capacity of social Institutions and facilities in principal villages must be the greater, the larger their range and the further they are away from towns or other central places. There is no need for developing principal villages in the suburbs of a town. Villages in the vicinity of towns are affiliated to a town.

Affiliated Villages :

Affiliated villages are villages without central importance which normally are affiliated to an ideal village.
The efforts made to overcome the differences between the living conditions of towns and countryside not only aim at the development of Ideal villages but also call for rearrangements and constructional improvements of affiliated villages. The differences between principal and their affiliated villages consists in the restriction to buildings and facilities in affiliated villages of local significance and in the time schedule of the Construction Projects. The most important development centres will be, in most cases, in the principal village and this must be carried out first.

Above all, dwelling places and small farmsteads including dwelling place and livestock housings suitable for individual cattle breeding as well as buildings for agricultural production should be erected in affiliated villages. An urgent problem both for principal and their affiliated villages is the improvement and modernisation of the housing conditions. This does not exclude, however, the development of buildings for Social purposes and facilities similar to those of the principal village. The urgency and priority of construction projects depend on the number of inhabitants, the actual need, and the utilisation of the available capacitv of the construction industry.

5.3. Required Buildings and Facilities in Ideal Village

The following buildings and facilities must be erected in an agricultural principal ideal village.
(a) Dwelling-Places for the Agricultural and Agricultural village Population :
Single-Storey and two-storey dwelling-houses near or on scattered towards the village centre.
(b) Buildings for Social purposes and facilities :
Club house (with club room for film shows) as social centre including library and various club rooms.
Primary or Secondary School.
Building for the village administration.
Agricultural training School, if required.
Kinder Gardens, nurseries, and after-school clubs.
Homes for aged persons and disabled workers.
Sports grounds and halls.
Small playing-fields.
Open-air swimming pool.
Park for recreation.
Rural outpatient department or hospital or nursing service.
Posts, according to the required.
Practice of Physician, if required.
Village-inn with small recreation-room.
Ware-house run by a cooperative society.
Shops for consumer goods.
Shops for industrial consumer goods durables.
(c) Buildings and Installation for Agricultural Production :
Machine and tractor lending station.
Farm buildings of every description, Livestock housings. milk collection houses.
Store houses for agricultural produce.
vaterinary service post, if required.
Dairy, if required.
Industry processing agricultural products, if required.
(d) Sundry village and Service Installations :
Domestic service building including laundry, ironing department and other services.
Buildings for craftsmen including dwelling-place, livestock housing and workshop for blacksmiths, wheel wrights, basket makers, butchers, hairdressers, shoemakers, tailors, handicraftsmen.
Garage for motor fire engine or fire-extinguishing appliances with fire-house tower and sheltes for the fire-brigade if required :

Post Office with telephone equipment, Police out posts.

(e) Communication Problem :

The principal village should be situated close to a highway or a highway crossing. It must be possible to reach the principal village from the affiliated villages on local or service streets. The village roads of the affiliated villages should join the local or service roads, whenever possible.

(f) Pre-requisites and Condition of the Full Development of Principal village :

The following condition must be given for a principal village to develop and fulfil it properly :

(a) The affiliated villages which avail themselves of the central facilities and services of the principal village must be situated within convenient reach of the Principal village. The distance between affiliated villages and the main village should normally not exceed one and half mile.

(b) The village must lie within convenient reach of highways. A convenient approach to trunk roads of railways is recommendable.

(c) The type of village must be suitable for a principal village.

(d) The village in question must be large enough to ensure a population 1,500 within its premises. In case of very small selected villages the suggested population of 1,500 will frequently not be reached. In such cases it is necessary to develop one of these hamlets or small villages with a particularly convenient situation into a rural supply and service centre. The buildings and facilities which have to be erected in this village must than be planned.

(e) If villages lie on the banks of rivers, lakes, in forests and in mountainous area, the topographical particularities and the traffic problem of the area controlled by the affiliated villages must be studied with great care to avoid mistakes.

(f) The highway distance between several principal villages may be anything between 6 and 8 km. The scope of principal village should be precisely limited.

(g) When selecting villages for principal villages, care should be taken to see that the local conditions are suitable for building purposes to ensure the planned development.

(h) Principal villages should not be erected on the soil above exploitable mineral deposit.

The above mentioned conditions are not exclusive but should be applied with flexibility and adopted to the given conditions.

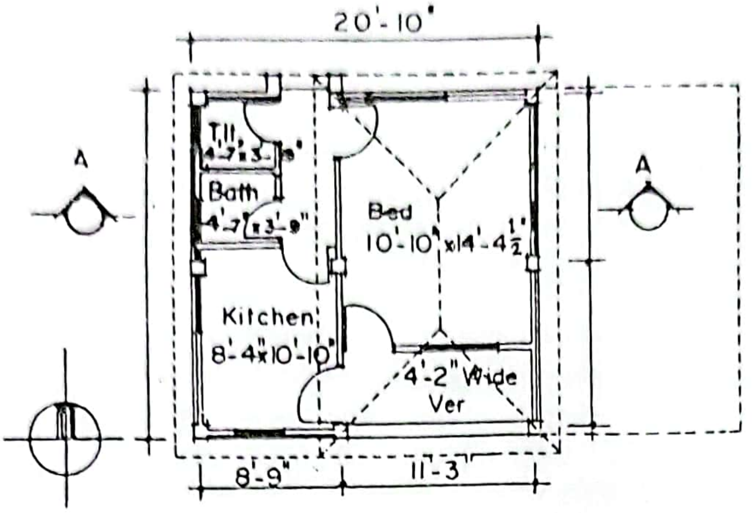
5.4 Low Cost Village Homes : House Building Research Centre has developed low cost plans suitable for rural people.

The plan may be excuted in mud and straw or, as semi-pucca structure on brick wall and tin roof. The brick wall may have 10" × 10" brick columns spaced 6' to 8' apart having 3/8" dia rod at centre of the column and 3" brick wall can be erected in between the columns. Such wall can also bear the load of roof slab.

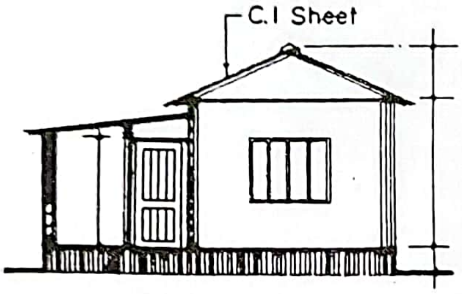
5.5 Mobile Homes

A mobile home is a factory-built unit. We can built such homes in areas subject to erosion by rivers. The design of a floor plan for a mobile home follows basically the same principles as for house planning. However, space is at a premium and its use requires more careful consideration.

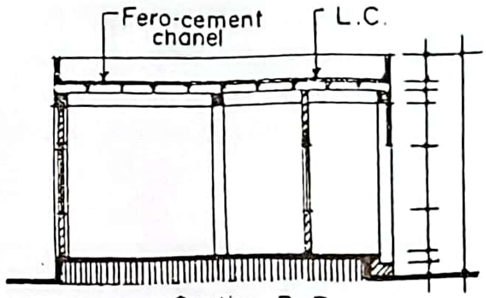
A typical floor plans for 12'-0" wide is furnished here. A 24'-0" wide unit is



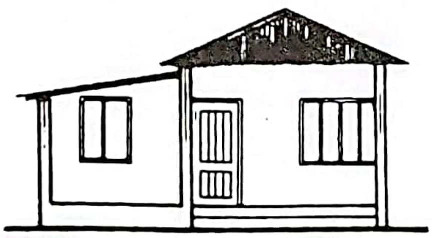
Plan-I Covered area : 425 Sft



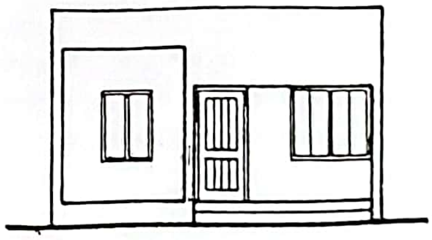
Section A-A



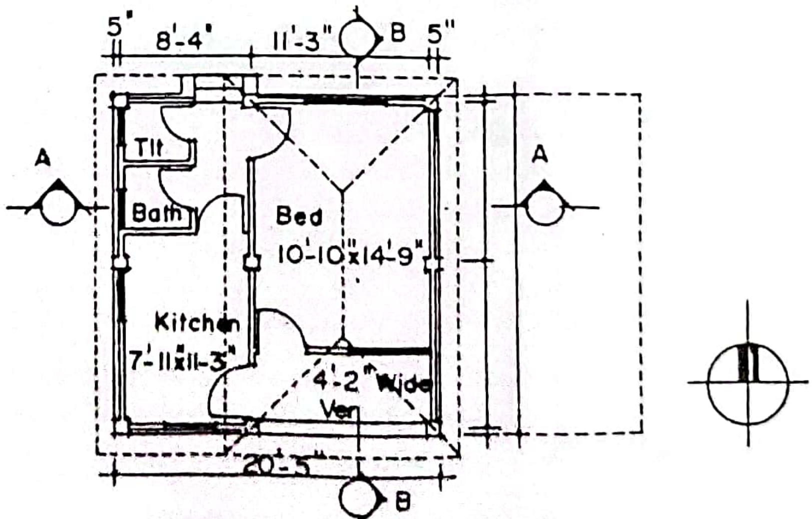
Section B-B



South elevation



South elevation



Plan-2 Covered area : 425 Sft.

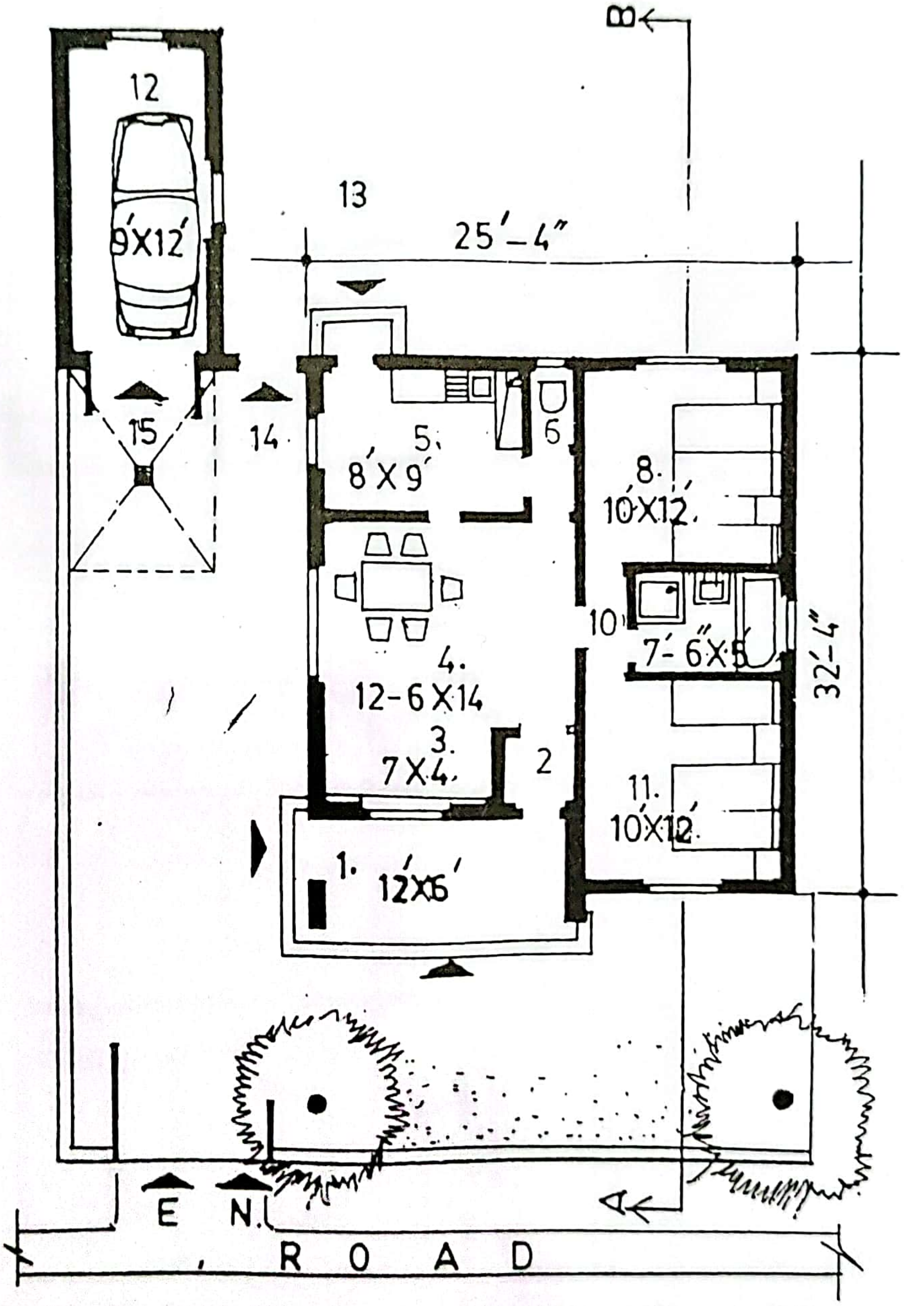
Rural housing

called a double wide since it is made from two 12'-0" wide units placed together.

Storage is an important aspect of planning. It is necessary to locate storage, closets and cobinets carefully. They must be near the area in which the items to be stored are to be used. Mobile homes must be designed to use space economically.

5.6 Some Typical Village House Plan

Some typical house plan suitable for rural housing are furnished here along with constructional details in the accompanying plates.

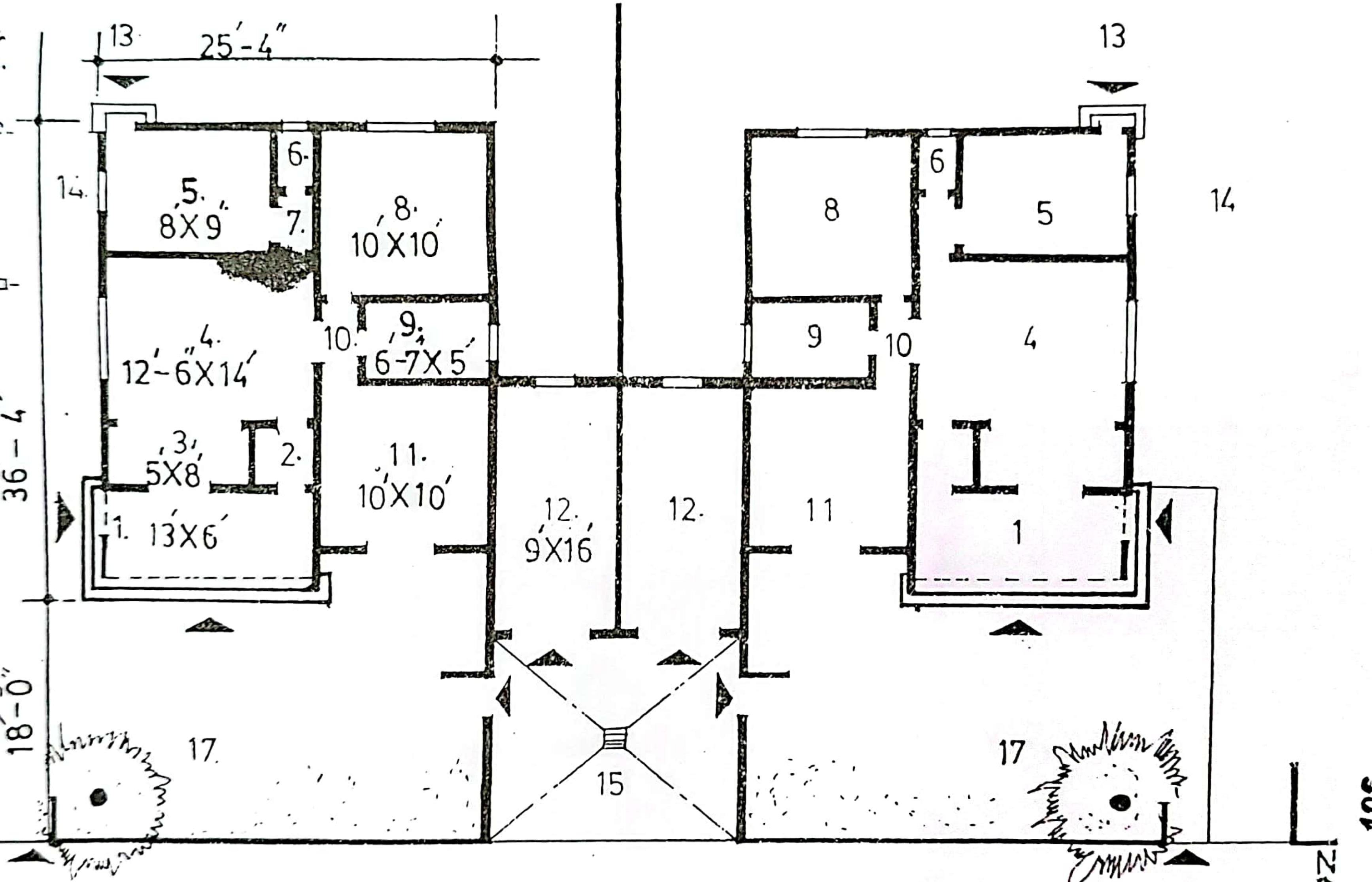


1. Roofed, shady, open veranda. 2. Vestibule with wardrobe
3. Sitting corner. 4. Living room. 5. Kitchen room. 6. Water closet
7. Small antechamber. 8. Bed room. 9. Bath room with shower bath, basin.
10 Small antechamber. 11. Bed room. 12. Garage. 13. Farm yard.
14. Entrance to farm yard. 15. Carwashing place.
16. Main entrance. 17. Front garden.

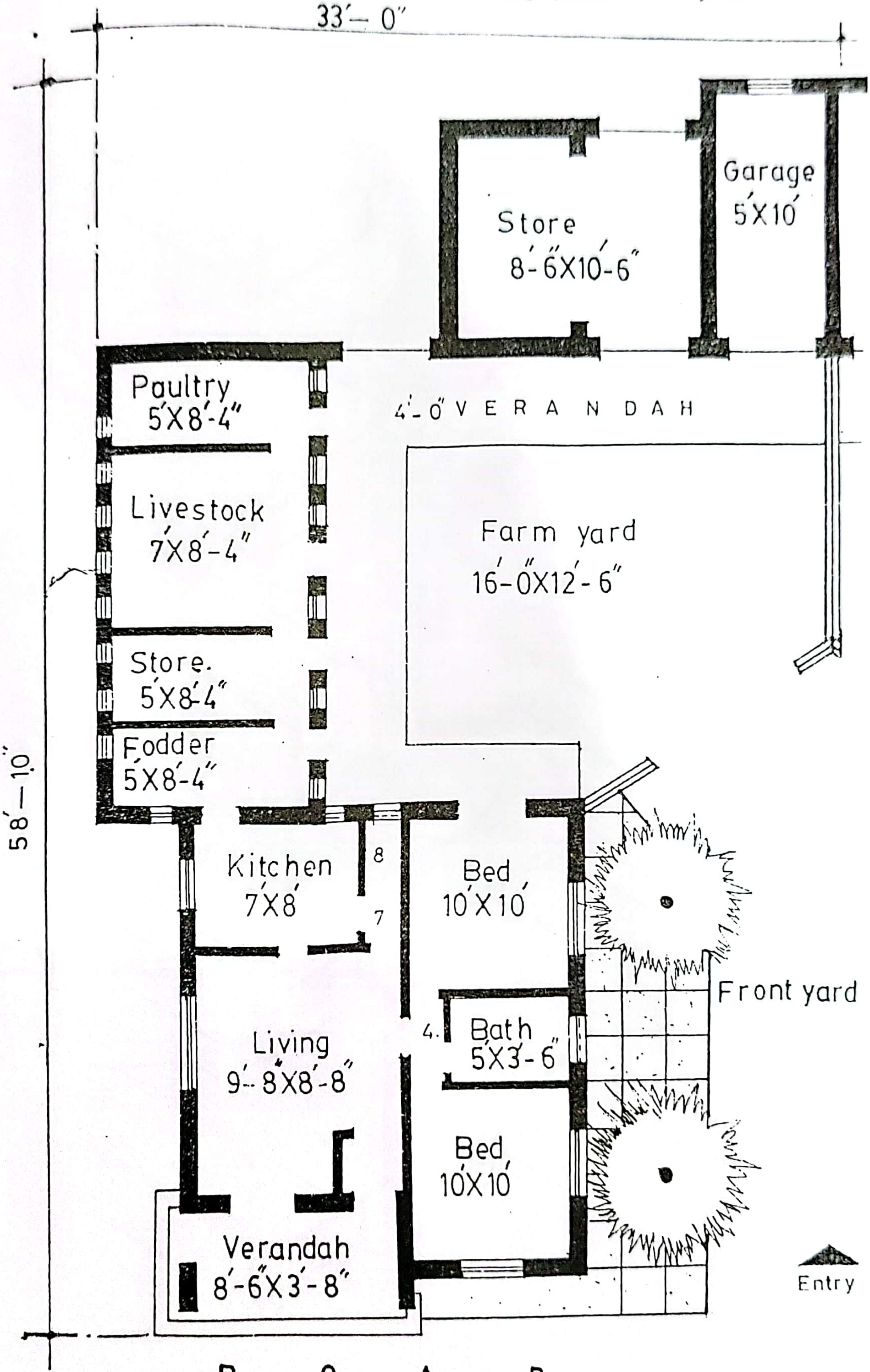
COVERED AREA: 930 SFT. PLAN NO: 1

N

1. Roofed, shady, open veranda.
2. Vestibule with wardrobe.
3. Sitting corner
4. Living room.
5. Kitthen room.
6. Water closet.
7. Small antechamber.
8. Bed room.
9. Bath room.
10. Small antechamber.
11. Bed room
12. Garage
13. Farm yard.
14. Entrance.
15. Car washing place
16. Main entranc
17. Front garden

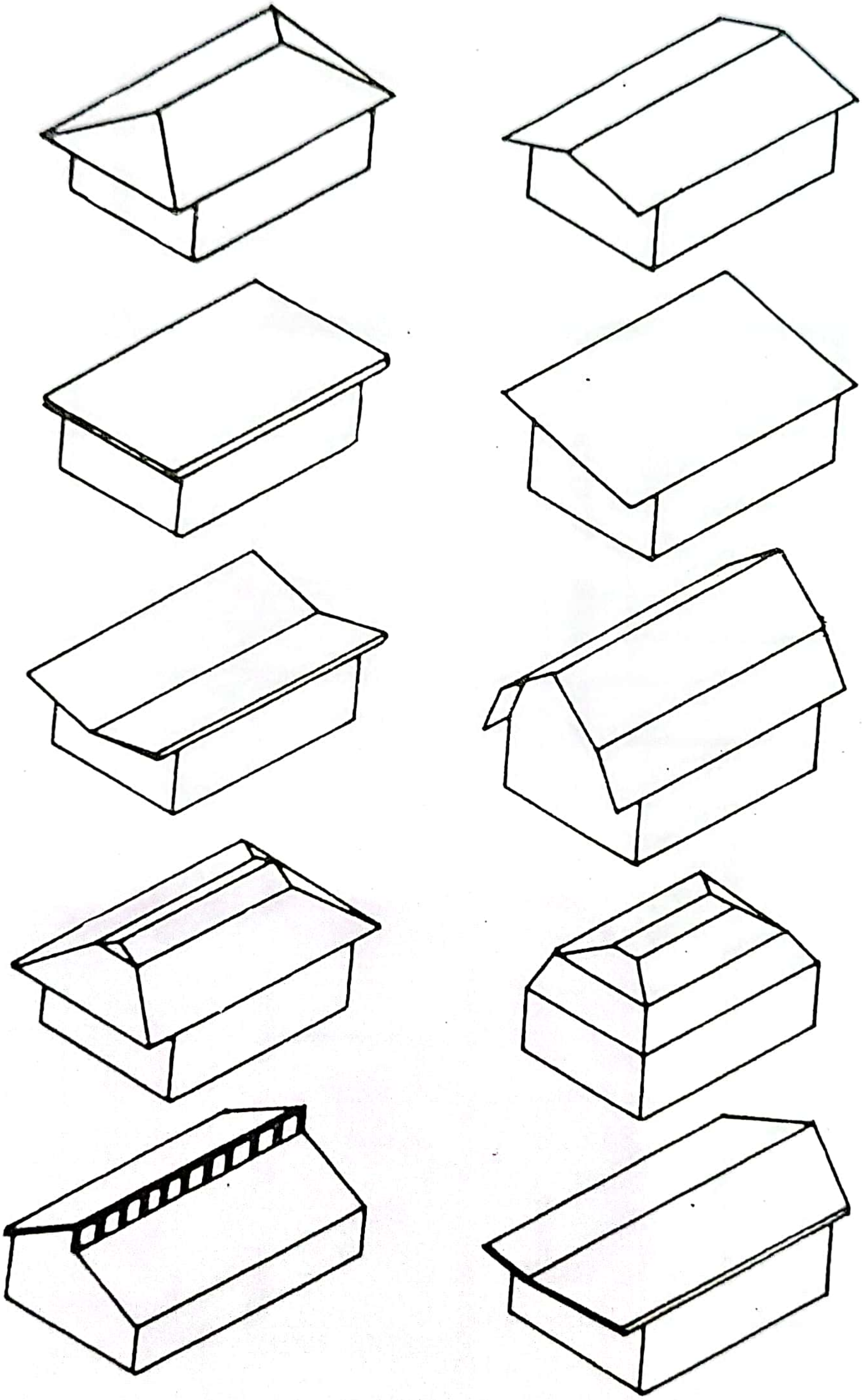


PLAN NO : -2. COVERED AREA : 935 SFT.

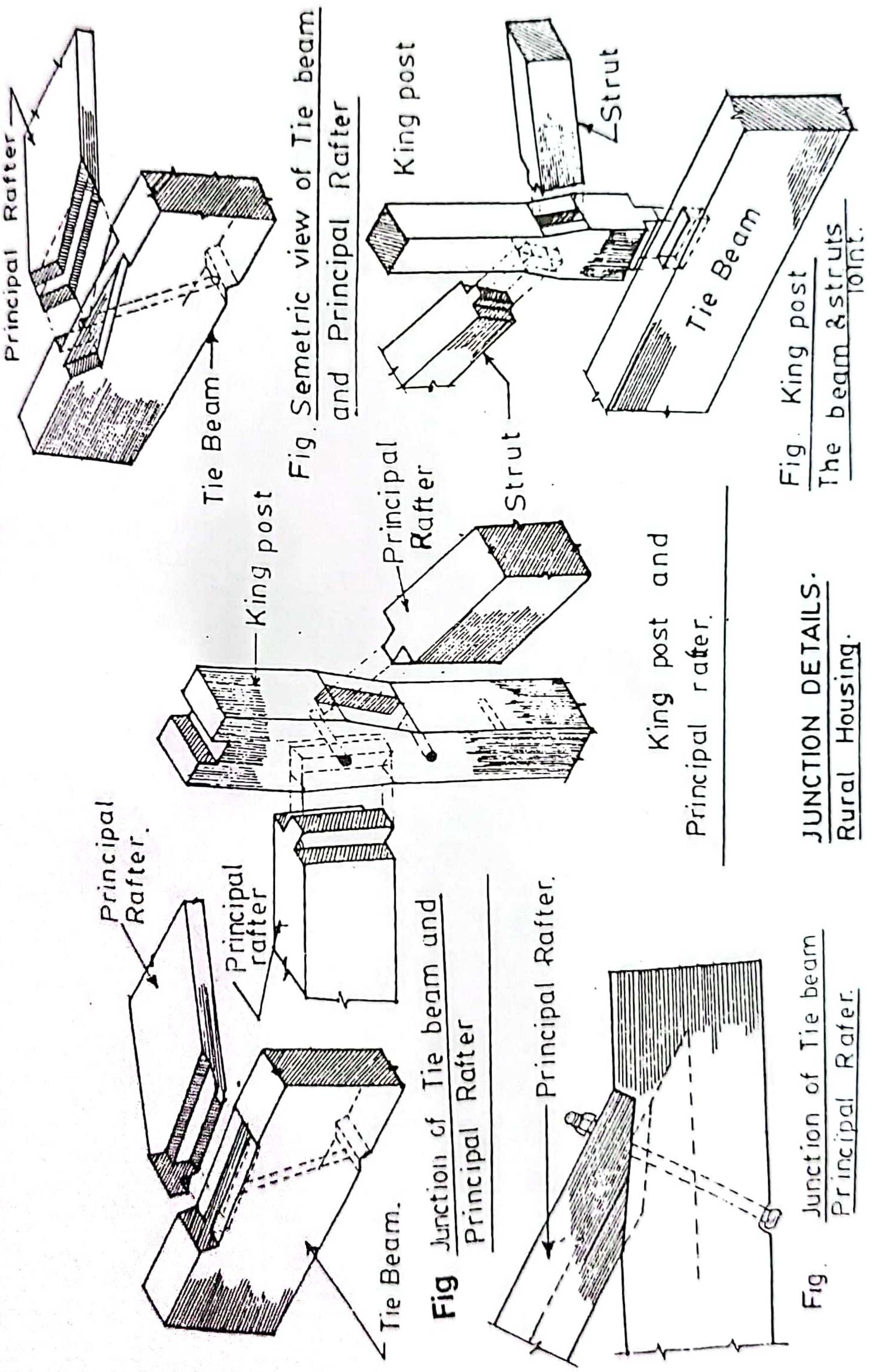


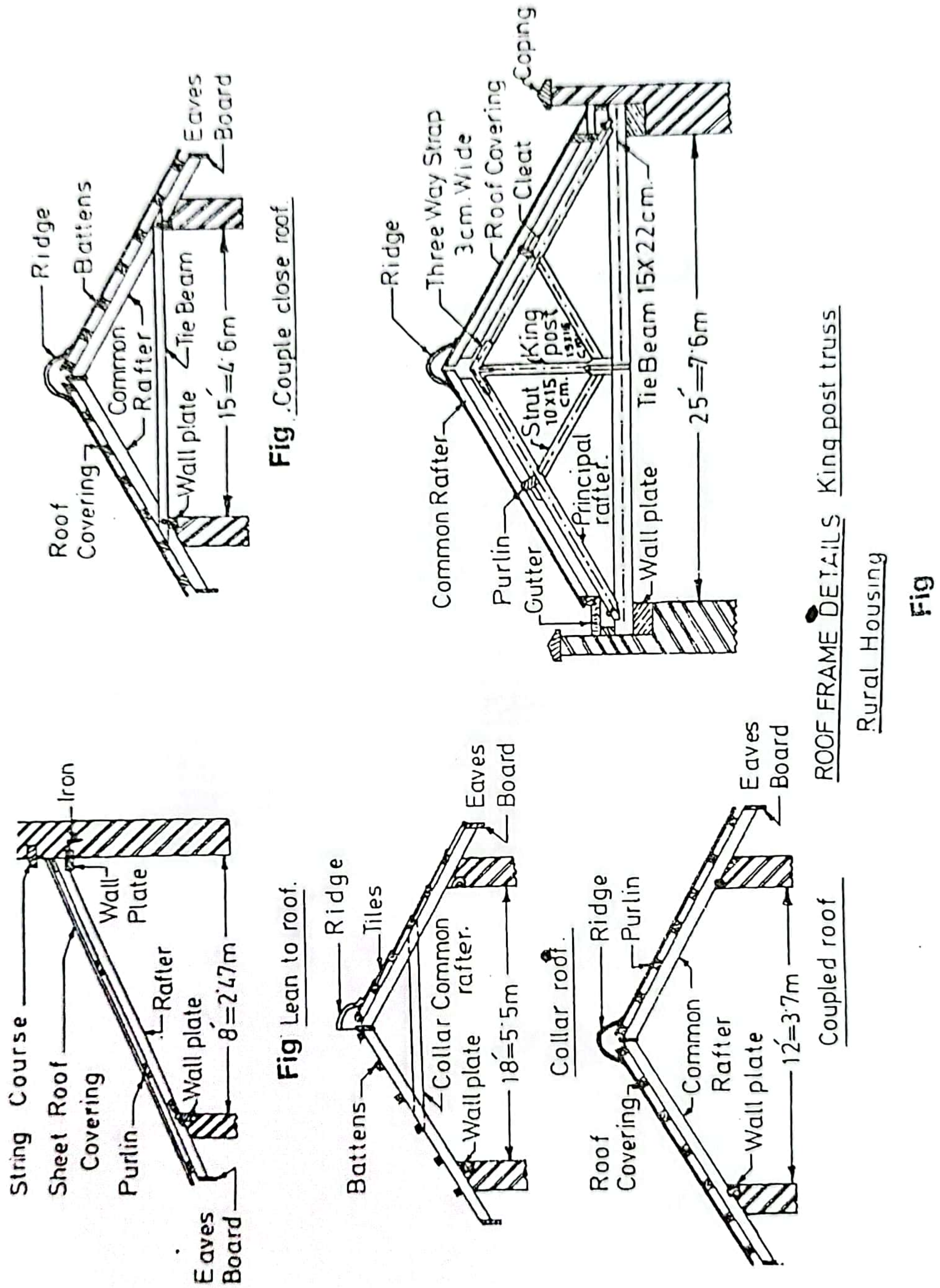
R O A D

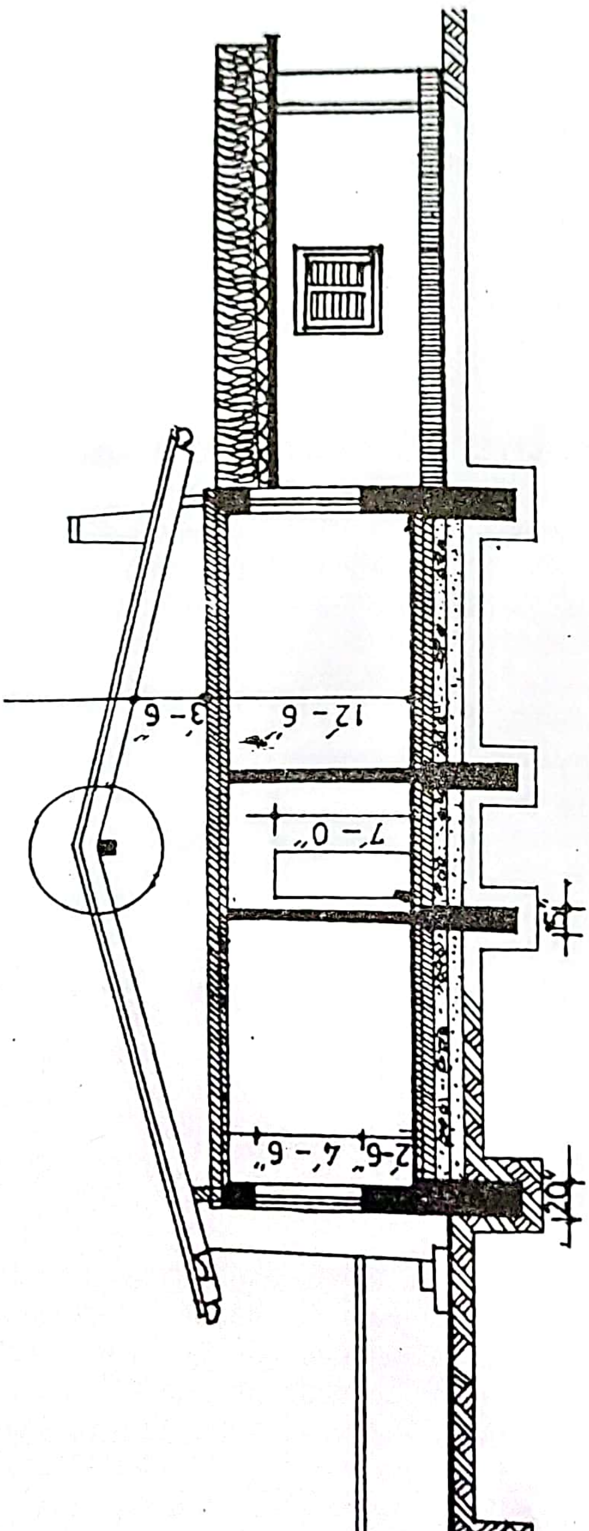
COVERED AREA: 1740 SFT. PLAN NO.3



Different types of roof


Principal Rafter
Tie Beam
Fig. Semetric view of Tie beam and Principal Rafter
King post
Strut
Tie Beam
Fig. King post
The beam & struts joint.
King post
Principal Rafter
Strut
King post and Principal rafter.
JUNCTION DETAILS.
Rural Housing.
Principal Rafter.
Principal rafter
Tie Beam.
Fig Junction of Tie beam and Principal Rafter
Principal Rafter.
Fig. Junction of Tie beam Principal Rafer.


String Course
Sheet Roof Covering
Purlin
Eaves Board
Iron
Wall Plate
Rafter
Wall plate
8'=2.47m
Fig Lean to roof.
Battens
Ridge
Tiles
Collar Common rafter.
Wall plate
18'=5.5m
Eaves Board
Collar roof.
Roof Covering
Ridge
Purlin
Common Rafter
Wall plate
12'=3.7m
Eaves Board
Coupled roof
Roof Covering
Ridge
Battens
Common Rafter
Wall plate
Tie Beam
15'=4.6m
Eaves Board
Fig. Couple close roof.
Common Rafter
Ridge
Three Way Strap 3cm. Wide
Roof Covering
Cleat
Coping
Purlin
Gutter
Principal rafter.
Strut 10x15 cm.
King post
Wall plate
Tie Beam 15X22cm.
25'=7.6m
ROOF FRAME DETAILS King post truss
Rural Housing
Fig



SECTION = A - B. OF PLAN NO : 1

CROSS SECTION A - B OF A SINGLE FAMILY DWELLING HOUSE.

In relation to tension, compression and neutral axis, the followitng notations and design formulas have been derived.

f'_c = Compressive value of concrete which is often called value of concrete
d = the effective depth of the beam, the distance from the uppermost surface down to the center of the longitudinal reinforcement, in inches
b = the width of a rectangular beam, in inches.
k = the ratio of the depth of the neutral axis to the effective depth, d
j = the ratio between the distance from center of compression to the center of tension and the depth,d.
f_c = the allowable compressive unit stress in the extreme fiber of concrete in pounds per square inch.
f_s = the allowable tensile unit stress in the steel, in pounds per square inch.
A_s = the area of the cross section of tensile reinforcement, in square inches.
P = the percentage of reinforcement, or P=As/bd
A = the modulus of elasticity of steel divided by the modulus of elasticity of concrete or Es/Ec, Es/Ec normally taken as 15
E_s = young's modulus of elasticity of steel.
E_c = young's modulus of elasticity of concrete.
M = the bending moment, in pounds inch.

6.4 Allowable Stresses of Concrete and Steel

A Table for allowable stresses in concrete :

Flexure :		ACI,	**ACI, maximum value, PSI**
	Extreme Fiber stress	.45 f_c'	1125 psi when f_c' =2500psi
Shear			
Beams		.03 f_c'	90
Flat Slabs	25% (-) ve steel/30% (-) ve steel passes over col.caps	.025 f_c'/.03 f_c'	80/100
Bond			
Plain		.03 f_c'	105
Deformed		.07 f_c'	245

Shear, $v = 1.1\sqrt{f_c'}$

Bond, $u = 2.4\sqrt{f_c'}$

B Table for allowable stresses in steel :

40 grade	Tension = 18000 psi Compression = 18000 psi
60 grade	Tension = 24000 psi Compression = 24000 psi

6.5 What is Ultimate Strength

If a load of sufficient magnitude is applied to a test speciment, rupture occurs. The unit stress within the bar just prior to its breaking is called the ultimate strength.
For the steel, failure occurs at a unit stress of about 60,000 psi (pounds per sq. inch.). A structural member stressed beyond this limit is usually unsafe even though the ultimate strength of the material is not reached.

6.6 What is Working Stress

The working unit stress or allowable stress is taken ⅓rd of the ultimate strength and is used in design as the maximum permissible one.
Ultimate strength of steel is 60,000 psi and is denoted by fy. Strength of steel taken in design is 20,000 psi and denoted by f_s. It is one third of fy.

6.7 Factor of Safety

It is a number denoting the ratio of ultimate strength to working strength. The factor of safety of steel discussed above is 3. It indicates how much extra load it can actually carry beyond the allowable strength. Here, this steel is 3 times safer compared to the load it is actually carrying. Safety factor for concrete is approximately 2.5. Now a days, for the question of economy, safety factor is not extensively employed.

6.8 Design of Brick Wall, Column, Beam and Slab

The design involves the determination of shape and size of specific dimensions of a particular structure.
There are two methods of designing reinforced concrete members. Namely,

1. WSD, or Working Stress Design.
2. USD, or Ultimate Stress Design.

Out of the two methods, WSD is widely followed in our country. It involves certain safety factors in strength of concrete and steel and is safe against deficiencies in execution. While, USD is based on ultimate strength of the components and needs carefull selection of material and proper quality control. This method is seldom followed in our country. As such, WSD method is discussed here to acquaint the curious reader with the basic knowledge of the subject.
It may be kept in mind that the procedure of design is complicated and can hardly be understood by a non-technical person. Hence, it is simplified in the form of Tables and Charts so that the requirements are easily found out.

6.9 Design of Brick Wall

Thickness of brick wall :
As per code specification load bearing wall thickness should be 8", 10" or 12".
Load bearing wall upto 5 stories is arbitrarily selected to be 10" with smaller room height(8'-6"), maximum 6 stories may be constructed by providing lintel althrough the wall.

3" and 5" walls are only used as partition on building frames separated by beams from floor to floor. Span for 3" wall should be limited to 8 ft. and height should not exceed 7ft. It may continue to furthur height by providing a lintel like concrete band.

6.10 Design of Brick Columns

A design criteria may be developed by considering crushing strength of 1st class bricks to be 2800 psi (210 kg/cm²) with a safe allowable compressive stress of 250 psi. and calculating load on the column. However, the following arbitrary selection is quite satisfactory.

upto 2 stories	10" x 10"
upto 3 "	10" x 15"
upto 4 "	15" x 20"
upto 5 "	15" x 25"

6.11 Design of Column Base

Size of base of the column must be based on load calculation.
Let,
P = Load on column, Ton.
B = Bearing capacity of soil, Ton/sq.ft
A = Area of footing required under the column.
Now, if load
P = 15 Ton, Bearing capacity
B = 1 Ton/sq.ft. Then area required

$$A = \frac{15}{1}$$

=15 sq.ft.

A size of 3′ x 5′ base may be selected.
Depth may be found out from formula of Depth of Foundation.

6.12 Determination of Depth of Foundation

Out of all the types of foundation, spread footing for walls and columns is commonly used in our country. Two main factors are involved :
1. Width of foundation.
2. Depth of foundation.

Depth of foundation (footing).

Minimum depth of footing can be found out by Rankin's Formula :

$$D= \frac{B}{W}\left(\frac{1-\sin \emptyset}{1+\sin \emptyset}\right)^2$$

where, D= Depth into the ground (ft. or metre)
B= Bearing capacity of soil (lb/sq. ft. or kg./m²)
W= Unit wt of soil (lb/cu.ft.or kg/cu.m.)
$\emptyset$ = Angle of repose of soil.

Value of $\emptyset$ for moist soil is 40° and for dry sand 30°: sin 30°=0.50 and sin 40°=0.64, W for soil is 100 lbs/cu. ft (1600 kg/cu. m) and for sand 110 lbs/cu. ft (1760 kg/cu. m)

Almost all original soil shows a bearing capacity of 1 ton/sq. ft at a depth of 3 to 4 ft. Soil test should be carried out in newly filled ditches.

Example : If a foundation is laid on sand having bearing capcity 1 ton/sq. ft find out minimum depth required for foundation.

Solution : given that,

Bearing capacity,

Unit out of sand,

$B = 1\ t/ft^2$ or 2000 lb/sq. ft.

$W = 110$ lbs/cu. ft. (ft² = sq. ft.)

Ø of sand = 30°

= 0.5 depth.

$$D = \frac{B}{W}\left(\frac{1-\sin\varnothing}{1+\sin\varnothing}\right)^2 \text{ as above}$$

$$= \frac{2000}{110} \cdot \frac{(1-0.5)}{1+0.5}\ 2$$

= 2.02 ft

or

2'-1"

Minimum depth required= 2'-1"

6.13 Determination of Width of Foundation

In determining width of foundation of load bearing wall, load per feet of the wall is calculated, so that the width is readily found out by the formula, W= L/B

Where,

W= Width of foundation (ft or metre)

L= Load on the foundation (ton)

B= Bearing Capacity of soil (T/sq. ft or T/sq. m.)

Example : If load bearing wall of a building carries load of 3 tons per ft. including self weight per ft. and bearing capacity of soil is 1 Ton/sq. ft. then required width will be

W= L/B, B= 1 Ton/sq. ft,

L=3 Tons/ft. W= 3/1 = 3 ft.

6.14 Angle of Repose of Common Fill Soil

Material	Ø Angle of repose, degree	Value of sin Ø
Clay, wet	20	sin 20° = 0.3420
Clay, dry	30	sin 30° = 0.5
Sand, wet	30	
Sand, dry	35	sin 35° = 0.5735
Earth, loose	45	sing 45° = 0.7071
Earth, dry	40	sin 40° = 0.6427
Shingle	40	
Silt, wet	20	sin 20° = 0.3420
Vegetable Soil, wet	17	sin 17° = 02923
Vegetable Soil, dry	30	sin 30° = 0.5

6.15 Design of Concrete Column

According to tie used to hold vertical rods, axially loaded R.C.C. columns are class as :

1. Tied columns.
2. Spiral columns.

The tie of spiral column is like a spring and is seldom used in house building. As such, only tied column is discussed here. When load falls on edges of the column other than at the centre it is callled eccentric column.
According to length it is again divided as :
1. Long column, when L/d = more than 10. and, 2. Short column, when L/d = less than 10. Here, L = Lenght of column
d = Least dimension (width) of column
In residential buildings, almost all columns are short, tied and axially loaded.

6.16 Design Formula for Tied Column

As prescribed by ACI Code, axially loaded tied columns can carry load P, according to the following formula :

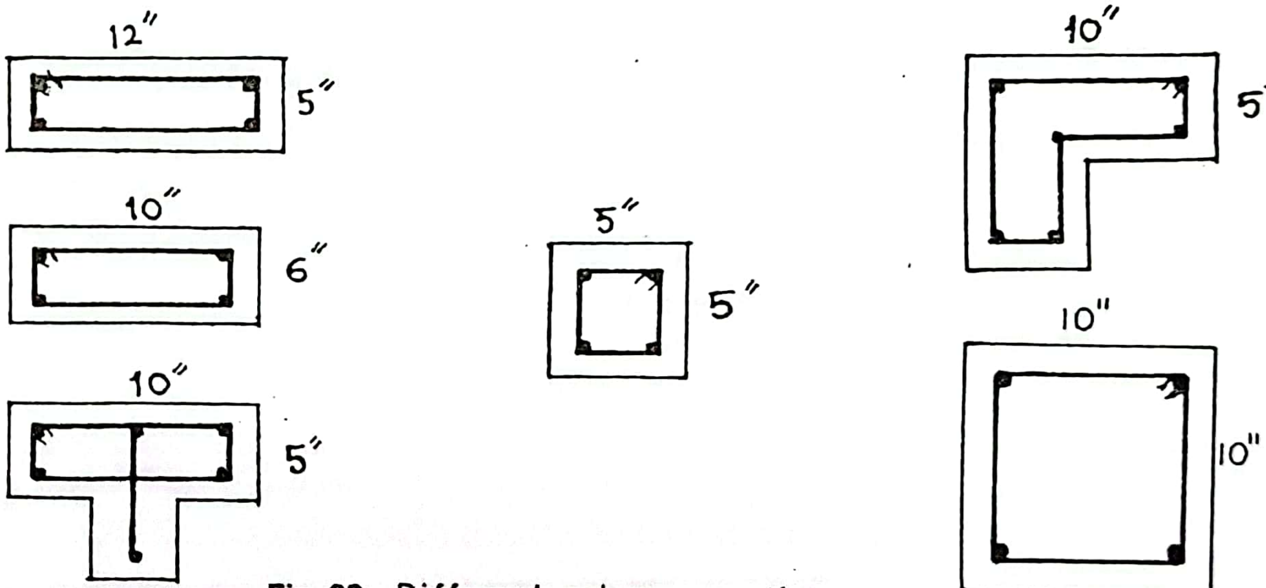
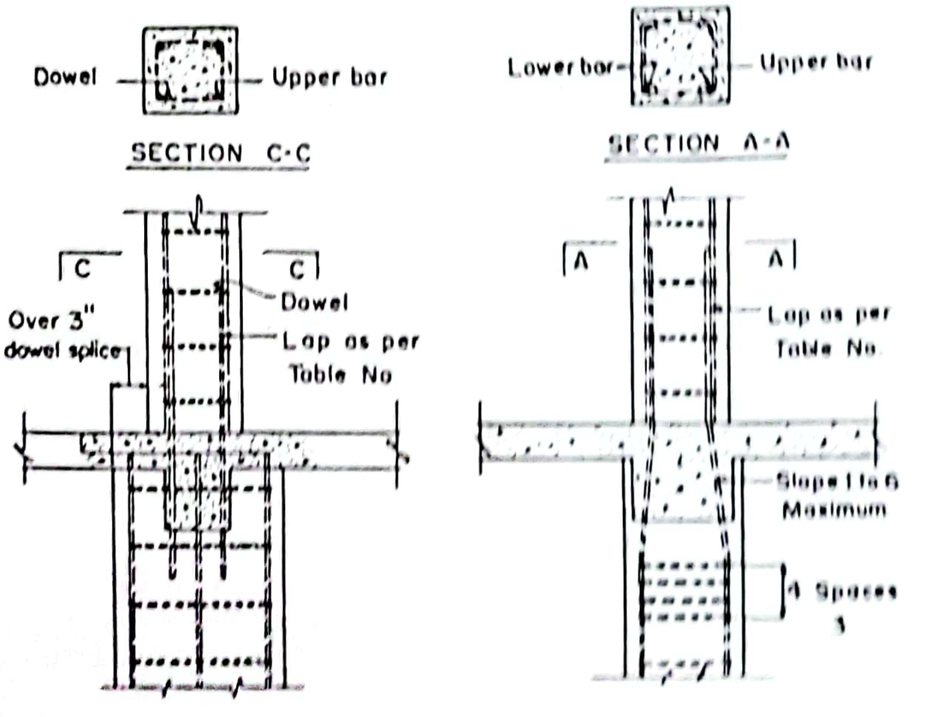


Fig 33, Different column section

$P = .85\ Ag\ (.25\ f_c' + f_s\ P_g)$.
where,
A_g = gross area of column, in²
f_c' = Compresive stress of concrete at 28 days. 2000 psi.
f_s = Allowable compressive stress in steel 20,000 psi.
P_g = Ratio of effective cross sectional area of steel to gross area or A_s/A_g limited to 0.01 to 0.04
Safe load bearing capacity of a column is found out by means of trial.
Example :
A tied column, 10" x 10" have a 4-5/8" dia vertical rods. Find out safe load bearing capacity of the column.
Solution :
Assume,

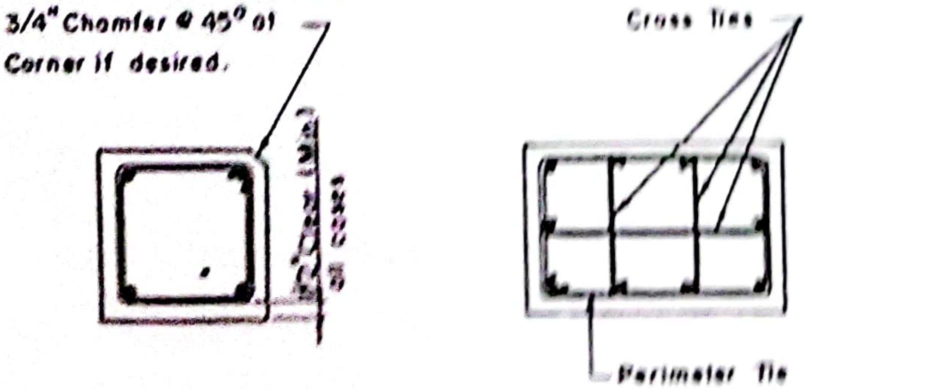
f_s = 20,000 psi
f_c' = 2000 psi. Formula for tied column is.
$P = .85\ A_g\ (.25 f_c' + fs\ P_g)$
Here, A_g = 10" × 10"
= 100 in^2
f_c' = 2000 psi
f_s = 20,000 psi.
Applying the values in the formula
$P = .85 \times 100\ (.25 \times 2000 + 20{,}000 \times 0.012)$
=62900 lb
= 31.45 Tons

Fig 34, TYPICAL TIED COLUMN DETAILS



DETAIL SHOWING RECTANGULAR TIED COL. DETAIL SHOWING TYPICAL TIED COL

Fig 35, LATERAL TIE DETAILS



4 – BARS
1 TIE PER SET

6 OR MORE BARS
1 PERIMETER TIE PLUS 1 CROSS TIE FOR EVERY 2 ADDITIONAL VERTICAL BARS OVER 4

6.17 Design Formula for Spiral Column

Formula for a spiral column :
$P = A_g (0.225 f'_c + f_s P_g)$.

Tie
Spacing of ties should be minimum of the following limitations :

1) 16 bar dia in inch
2) 48 tie dia in inch
3) Least dimension of the column,

Tie should be preferabley of 1/4" dia or 3/8" dia rod.

6.18 Table for Safe Load of Column

Size of column	Reinforcement Provided	Spacing of Tie	Safe allowable load
5" x 12"	4-1/2" Ø	1/4" Ø @ 5" c/c	20 Tons
5" x 12"	4-5/8" Ø	1/4" Ø @ 5" c/c	23 Tons
6" x 10"	4-1/2" Ø	1/4" Ø @ 6" c/c	20 Tons
6" x 10"	4-5/8" Ø	1/4" Ø @ 6" c/c	23 Tons
5" x 10" by 5" x 10" "L" or Tee	6-1/2" Ø	1/4" Ø @ 5" c/c	21 Tons
5" x 10" by 5" x 10" "L" or Tee	6-5/8" Ø	1/4" Ø @ 5" c/c	25 Tons
8" x 8"	4-1/2" Ø	Ø 1/4" @ 7" c/c	20 Tons
8" x 8"	4-5/8" Ø	Ø 1/4" @ 7" c/c	24 Tons
10" x 10"	4-1/2" Ø	Ø 3/8" @ 9" c/c	28 Tons
10" x 10"	4-5/8" Ø	Ø 3/8" @ 9" c/c	32 Tons
10" x 10"	4-3/4" Ø	Ø 3/8" @ 9" c/c	34 Tons
10" x 10"	6-5/8" Ø	Ø 3/8" @ 9" c/c	37 Tons
10" x 10"	6-3/4" Ø	Ø 3/8" @ 9" c/c	43 Tons

Recommended Column Sections :
I Sections, L-Section, T-section and square Section.

6.19 Different Types of Beam

A beam is a structural member that bears load in horizontal direction.
Types:
According to supported end position, beam may be classed as follows :
1) A simple beam is a beam which rests upon a support at each end, there being no restraint at the supports. This is the most common type.
2) A Cantilever beam is a beam that is supported at only one end. A beam projecting from a wall is an example.
3) An over hanging beam rests upon two or more supports, one or both ends projecting beyond the supports.
4) A continuous beam is a beam that rests upon more than two supports.
5) A fixed beam is a beam that is restrained against rotation at its ends. This position occurs when the end is monolithically casted with column and slab or it bears the wall load of next story.

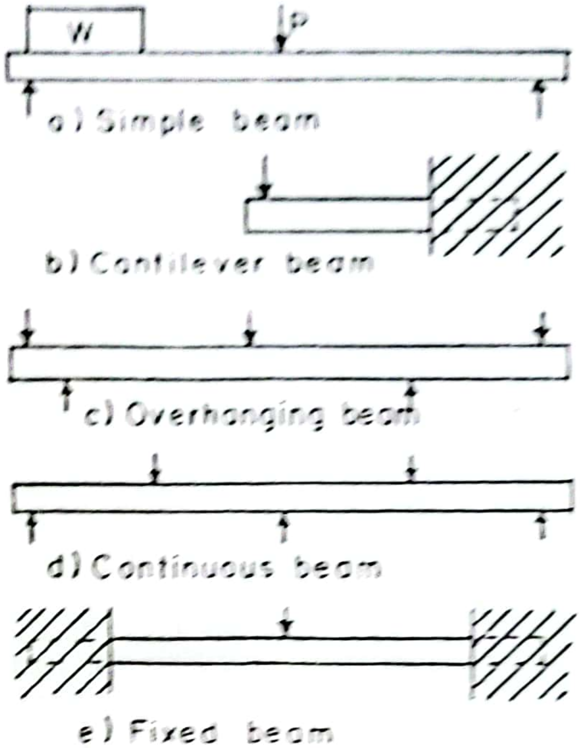


Fig 36, Different types of beam

6.20 Design of Beam

From design point of view, beams are either rectangular or T-beam.

6.21 Span Length of a Beam

It is the distance between centres of supports but should not exceed the clear span plus the depth of beam or slab. The span length for continuous or restrained beams is taken as the clear distance between faces of supports.

6.22 Kinds of Load

Two types of load commonly occur in beam :
1. Concentrated load.
2. Distributed load.
When a column rests on a beam, the load is concentrated, while the slab is exerting distributed load on the beam. Distributed load is mostly applied in design and computed as under.
Live load = 40 lbs/sq.ft (for residence only)
Dead load of slab = 50 lb/sq.ft (for a 4" slab)
Floor finish = 12 lb/sq.ft
Add, self weight of beam.

6.23 Load per Feet

For computing bending moment, load per feet is required to be found out. Load exerted by slab along the beam is to be calculated. If a beam is provided at the middle of a room, then 50% slab load is carried by the

beam, the two walls take 25% each. Thus, if the beam share a length of X ft of slab, distributed load per feet will be X × 40 p.ft. for live load, (50 + 12) × X for dead load plus self wt. of the beam.
After load per ft. is calculated it is necessary to find out bending moments with the help of moment co-efficients prescribed by ACI code.

6.24 Bending Moments

The forces which tend to cause bending in a beam are the reactions and the loads. Consider the section X-X at 6' from R,(Fig). The force R, or 2,000 # tends to cause a clockwise rotation about this point. Since the force is 2,000 # and the lever arm is 6', the moment of the force is 2000 × 6 = 12 000' # . This same value may be found by considering the forces to the right of the section X-X.
There are two forces to the right of section X-X, R_2 which is 6000 # and the load 8,000 # having lever arms of 10' and 6' respectively. The moment of the force 8,000 # is 8000 × 6 = 48,000' # and its direction is clockwise. Subtracting. 60000–48000 = 12000' # the resultant moment tending to cause counterclockwise rotation about the section X-X. This is the same magnitude as the moment of the forces on the left which tends to cause a colckwise rotation.
Thus, it makes no difference whether we consider the forces to the right of the section or the left, the magnitude of the moment is the same. It is called the bending moment and it is the algebraic sum of the moments of the forces on either side of the section. For simplicity, let us take them on the left, then we may say the bending moment at any section of a beam is equal to the moments of the reactions minus the moments of the loads to the left of the section. Since, the bending moment is the result of multiplying forces by distances, the denominations are pounds foot or pounds inch. For computation of steel required, bending moment always converted into pound inch (lb. in.).

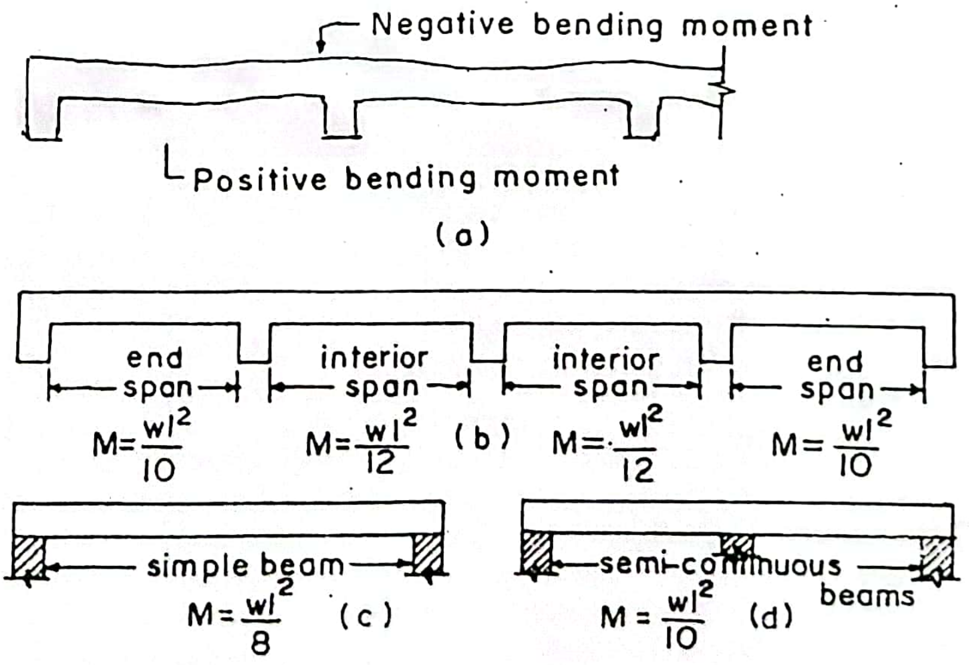
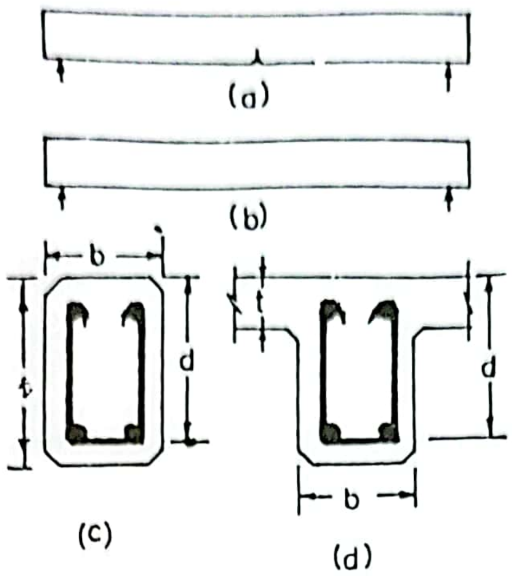


Fig 37 : Bending moment



Rectangular T-beam.

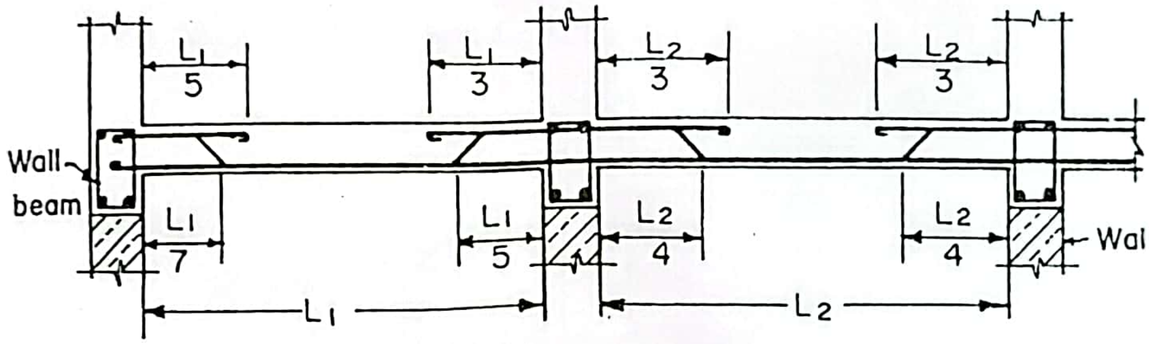


Fig 38 : Bend location in beam/slab

6.25 Moment and Shear Values Using ACI Coefficients

Positive moment :

Simply supported (Midspan)	(+) $wl^2/8$
End spans :	
If discontinuous end is unrestrained	(+) $wl^2/11$
If discontinuous end is integral with the support	(+) $wl^2/14$
Interior spans	(+) $wl^2/16$

Negative moment :

At exterior simply supported face of first interior support	(−) $wl^2/10$
Two spans	(−) $wl^2/9$
More than two spans	(−) $wl^2/10$
Negative moment at other faces of interior supports	(−) $wl^2/11$

Negative moment at face of all supports for, (1) slabs with spans not exceeding 10ft, and (2) beams and girders where ratio of sum of column stiffnesses to beam stiffness exceeds eight at each end of the span (−) $wl^2/12$

Nagative moment at interior faces of exterior supports for members built integrally with their supports :

Where the support is a spandrel beam or girder	(−) $wl^2/24$
Where the support is a column	(−) $wl^2/16$
Shear in end members at first interior support	1.25 $wl^2/2$
Shear at all other supports	$wl^2/2$

w = total load per unit length of beam or per unit area of slab.

l = clear span.

wl = W

6.26 Design Formula for Rectangular Beams

1) $A_s = \frac{M}{f_s jd}$ Where, A_s = Area of steel required (in²)

f_s = Allowable stress of steel,(20.000 psi).

j = 7/8 or .875

d = effective depth(in).

M = Bending Moment, (lb-in).

2) $d = \sqrt{\frac{M}{Rb}}$

$R = 1/2\ f_c jk$,

when, f_c = 750 psi

j = .875

k = .375

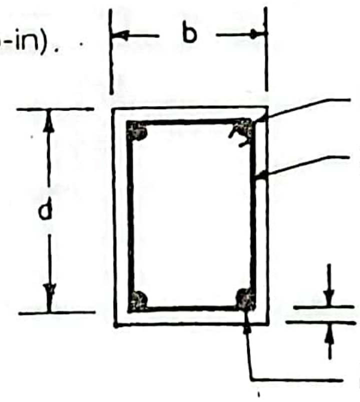


Fig 39, A typical beam Section

Steps in Design

1) Assume size and apporximate weight

2) Find d by $d = \sqrt{\frac{M}{Rb}}$

3) Compute steel required by $A_s = \frac{M}{f_s jd}$

4) Compute Shear stress by $v = \frac{V}{jbd}$

5) Find spacing of sti. up by $S = \frac{A_v f_v}{v.b}$

6) Determine bond stress by $u = \frac{V}{\Sigma ojd}$

6.27 Check for Bond and Shear

Formula for bond : u=V/Σ ojd, where u = Bond stress V = external shear = sum of perimeter of all bars j= .875 d= effective depth, in

6.28 Diagonal Tension

A concrete beam without tensile reinforcement will fail because of tensile stresses in the concrete as indicated in Fig33( )The area of the required tensile reinforcement is computed by means of formula, where such reinforcement is introduced, the beam has a further tendency to fail by tensile stresses indicated in Fig32(b). These cracks are due to a combination of tension and vertical shear, and the stress is known as diagonal tension. To prevent failure due to diagonal tension vertical steel rods called stirrups are used. For rectangular and T-beams they are illustrated in Fig (c). and (d). They are generally round in section 3/8" or 1/2" in diameter.

The unit shearing stress; which is a measure of diagonal tension, is found by the formula:

v = V/jbd

where, v = the unit shearing stress in pounds per square inch.

V = the total maximum vertical shear in pounds (for uniformly loaded beams).

V = W/2

j = 0.875 or 7/8 the value employed in computing shear.

b = the width of rectangular beam in inch.

d = the effective depth of the beam, in inch.

Since j = 7/8,

v = V/jbd

It is necessary to use web reinforcement throughout the entire length of a beam since the shearing stresses are maximum at the supports and decrease toward the centre. To find the distance from the support in which web reinforcement is required we use the formula:

a = L/2 × v'/v

in which, a = the distance from the support in which stirrups are required in feet

L = the span of the beam, in feet

Vc = the allowable shearing unit stress permitted in plain concrete, 40 lb/in² for 2,000 lb concrete.

v = the maximum shearing unit stress in pounds per square inch, found from formula.

V' = V-Vc = the excess shear to be resisted by the stirrups.

The distance in which web reinforcement is required having been found, it is next necessary to determine the spacing of the stirrups, This is found by the formula

$S = A_v f_v / V'b$

where, S = the spacing of the stirrups, in inches

A_v = the total cross-sectional area of the legs of one stirrup, in square inch.

f_v = the allowable tensile unit stress in stirrups, in pounds per square inch, usually 18,000 or 20.000 lb/in²

V' and b are as noted above.

A 3/8" round rod has an area of 0.11 in² and since a U-shaped stirrup has two legs, A_v for 3/8" stirrups = 2 × 0.11 in². Similarly A_v for 1/2" stirrups = 2 × 0 2 = 0.4 in².

Allowable bond stress according to code is :
Top bars $1.7\sqrt{f'c}/D$ or less than or equal to 160 psi.
Bottom bar 2.4 f'c/D or, less than or equal to 250 psi.
If anchor or hook is provided at the end of the bars, sufficient bond is developed. Shear stress is given by the formula, v = V/bjd
where, v = sheár stress, psi.
V = Maximum shear in the beam lb.
b = width of beam, in
j = .875
d = effective depth of beam, in.
ACI Code value of allowable shear is given by V= 1.1 $\sqrt{f'_c}$ · or 50 to 60 psi
Example: A reinforced concrete beam, 22′ in length between faces of supports has a uniformly distributed load of 22,000 lb exclusive of the weight of the beam. The ends of the beam are fully continuous. With the following
Let the beám size 'be 10"×30"
Concrete weighs approximately 150lb/ft³. Then the estimated weight of the beam = (10 × 30 × 22 × 150)/144 = 6,875 lb.
W, the total uniformly distributed load =22,000 + 6875 = 28,875 lb.
Bending Moment.
The maximum (-) ve, nding moment = $wl^2/12$
= (28,875 × 22 × 22)/12
= 635,250/lb.in .

6.29 Effective Depth

Formula (1), d = $\sqrt{M/Rb}$, R = 123, Therefore,
d =$\sqrt{635{,}250/(123 \times 10)}$ = 22.75", the effective depth.
Allowing 1/2" for the diametre of the tensile reinforcement, and 1½" for cover, the total depth of the beam equals 22.75 + 0.5 + 1.5 = 24.75"

6.30 Stirrups

The total load W equals 28.875 lb, hence
Maximum shear V =28,875/2 = 14,438 lb.
V = V/jbd = 8V/7bd
V = (8 × 14,438)/(7 × 10 × 21.5) = 77lb./in², the shearing unit stress.
Since this stress exceeds 40 lb/in², it will be necessary to use stirrups to aid in resisting the diagonal tension.
To find the distance from the supports in which stirrups are required use formula :
a = L/2 × v′/v = 22/2 × (77 - 40)/77 = = 5′3"
The spacing of stirrups is determined by the use of formula : s = $A_v f_v / v' b$.
The sectional area of the two legs of a stirrup made up of a 3/8" round rod is 2 × 0.11 = 0.22 in², there fore, S = (0.22 × 18,000)/{(77- 40)} × 10 = 11"

6.31 Bond

The unit bond stress is found by formula,

$$u = \frac{V}{\Sigma o j d}$$

The perimetre of one 7/8" round rod equals 2.75" then
u = 14,438 {(4 × 2.75) × 0.875 × 21.5} = 69.76 lb/in².
This bonding unit stress being less than 80 lb/in² plain bars are acceptable.

6.32 Design of T-beam

Design of T-beam is some what similar to rectangular beam. In design, slab thickness is determined first. The slab acts as compression flange in designing the beam.

The flange acts as compressive zone, which is balance by steel embeded in the bottom web of the beam.

Flange width b, in.

Slab thickness t, in

d = Effective depth, in

b' = Width of web

Width of flange should be least of the three alternatives,

1) Span/4
2) b' + 16t.
3) Centre to centre spacing of beams.

Formula :

Moment can be found out by

$$M = f_s A_s (d - t/2)$$

$$\text{or, } M = f_s A_s jd.$$

$$A_s = \frac{M}{f_s (d - t/2)}$$

$$A_s = \frac{M}{f_s jd}$$

Example: Determination of moment capacity.

A floor slab 4" in. thick is supported by beams centered 9 ft apart to be casted monolithically so that T-beam action is introduced. Beams are simply supported having 19ft span. Section of beam is 10" × 20" below slab and reinforced with 8 3/4" dia rods. Assume cover 2½" in, f_s = 20000 psi and f_c = 2000 psi What is the maximum allowable moment it can resist ?

Solution :

Find out width of flange, b :

b = span/ 4 = (19 × 12)/ 4 = 57 in

b = 16t + b'= (16 × 4) + 10 = 74 in

b = Centre to centre spacing = 9 × 12 = 108 in.

6.33 Design of RCC Slab

Slabs provide flat covering over the wall.

Design of slab is carried out with the help of same formulas as those of the beam design due to the reason that a 12" strip of slab acts as a rectangular beam of unit width (1ft) with depth equal to the thickness of the slab

From design point of view, slabs are of four kinds :

1. One way slab,
2. Two way slab, and
3. Ribbed slab
4. Flat slab

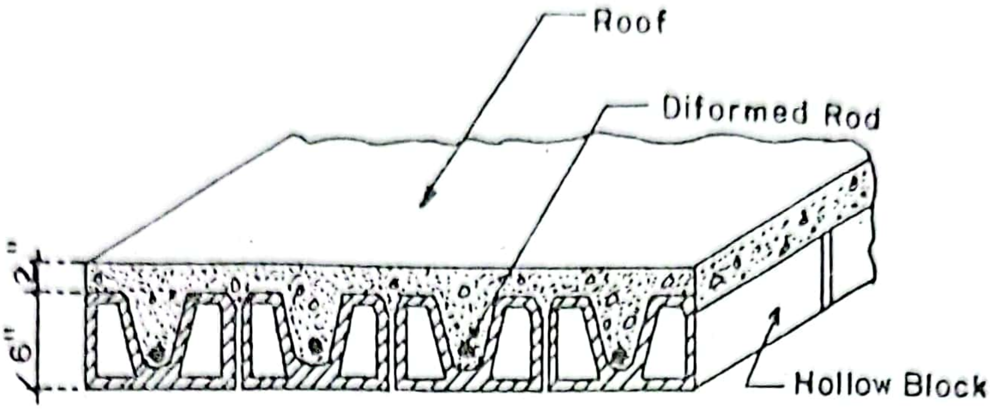


Fig 40, Hollow Roof

6.34 One Way Slab

Main reinforcement of one way slab is provided in shorter direction (width wise) of the room, binders are provided in long direction. Imagine a rail line two rails are like two walls along long direction and the sleeper is like main rod placed in shorter direction. Thus, a one way slab may be continued miles after miles. Thus, load is shared mainly by two walls.
One way slab is provided when length is more then one and half times the width of the room.

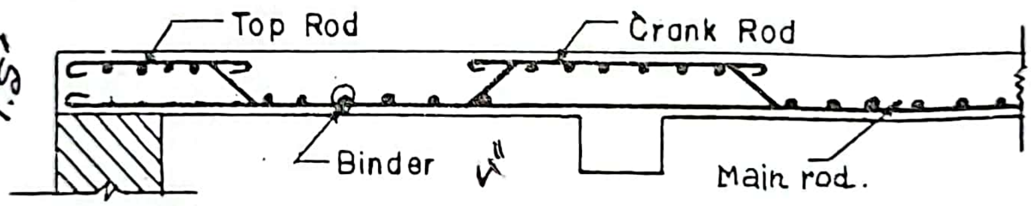


Fig 41, R.C.C. Roof

6.35 Two Way Slab

In two way slab, rods are placed in both directions and load is shared by four walls. This happens when ratio of longer to shorter one is less than 1.5.

6.36 Ribbed Slabs

Ribbed slab is thin and is constructed with most of concrete thin beams. It is good looking and economical too.

6.37 Ribbed Slab With Metal Pans

One of the most economical systems of floor construction for long spans with light loading consists of the use of metal pan fillers between concrete joists. The steel forms, often known as "tin pans,"are generally 20" wide. The ribs are usually 5" wide at the bottom and are slightly wider at the top. The slab over the pans varies from 2" to 3" thickness ;it is cast integrally with the ribs, and since together they form a T-section, The computations for the design are similar to those for a T-beam, Ribbed floors with tile fillers are designed in a similar manner.

6.38 Flat Slab

Flat slab is supported directly by columns without the help of beams and girders.Sometimes a column drop and capital is provided below the slab. Such type of slab is seldom constructed in residential buildings and is beyond the scope of this book.

6.39 Design Criteria of One Way Slab

a) ACI code prescribes that perpendicular to main reinforcement temperature or shrinkage rod be placed within 5 times the slab thickness but not more than 18".
b) Concrete cover below the rods should be 3/4".
c) Distance between parallel bars shall be min. 1½" times the size of khoa. In this case, 3/4" size should be used.
d) Temperature and shrinkage rod which is provided as binder should be as follows :
A_t = .0025 × A_g
Where, A_t = Area of temperature and shrinkage reinforcement.
A_g = Gross area of concrete.
e) Slab thickness for simply supported slab should be L/25 or perimeter of room divided by 180. 3/4" cover be added.

Bending Moments in slab

With the help of moment coefficient , bending moments can be calculated. At middle positive moments occurs. Negative moment occurs at the end and over support

Example :
Design a simply supported slab with clear span of 10ft. of a bed room of size 10′ × 15′. Live load for residential building is 40 psf, f_s = 18000 psi, f_c = 750, j = 7/8, R = ½ $f_c$jk, k = .375

Solution :

First calculate average thickness of the slab :
Span, L = 10ft.
t = L/25 = (10 × 12)/25 = I in.
Perimeter/180, perimeter = 2 × 10 + 2 × 15 = 50ft or 600 in.
t = 600/180 = 3.33 in.
Add cover, 3/4" + 0.75
4.08 in.
Average 4" slab will be necessary.
Effective depth, d = 4" -3/4" = 3.25 in.
Now calculate load, w per ft. of slab in 1ft. strip.
Live load = 40 psf

Dead load of slab
4" × 1' × 1' × 150 = 50 psf
Floor finish 12 psf
Total 102 psf
Calculation of moment :
Moment coefficient at free end
$M = wl^2/11$
$= (102 \times 10 \times 10)/11$
= 927.27 lb ft say 950 lb ft.
Check thickness of slab by formula
$d = \sqrt{M/Rb}$, $R = ½ f_c jk$, $f_c = 750$ psi, ∴ R = 123, b=1' or 12"
$= \sqrt{(950 \times 12)/(123 \times 12)}$
= 2.77" say 3"
plus cover 3/4"
Approximately 3.75" is required it may be rounded to 4".
Steel required :
$A_s = M/f_s jd = 950 \times 12/18.000 \times .875 \times 3.25 = 0.22$ in²
This steel is required in a strip of 12". Select 3/8" dia rod. Area of 3/8" Ø rod = .11 in²
spacing of rod: 0.22 in² required in 12 in.
0.11 in² " " = 12 × .11/0.22 = 6 in.
provide 3/8" Ø rod @ 6" c/c alternately cranked up. Extra top bars should be provided in between two cranked bars to meet up negative moment.
Provide nominal binder 3/8" @ 9" c/c
Check for bond and shear may be done as per procedure already discussed in beam design.

Table for minium thickness of slab.	
Simply supported	L/25
One and continuous	L/30
Both ends continuous	L/35
Cantilever	L/12
Formula previously used peremeter of room in inch/180	

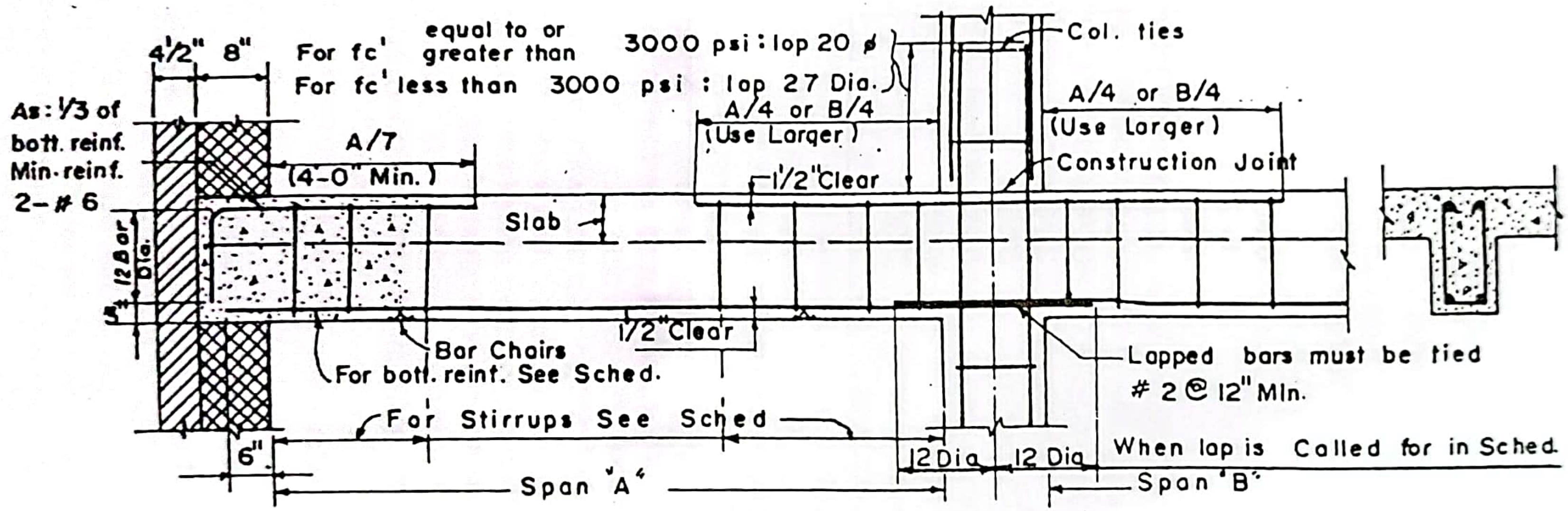
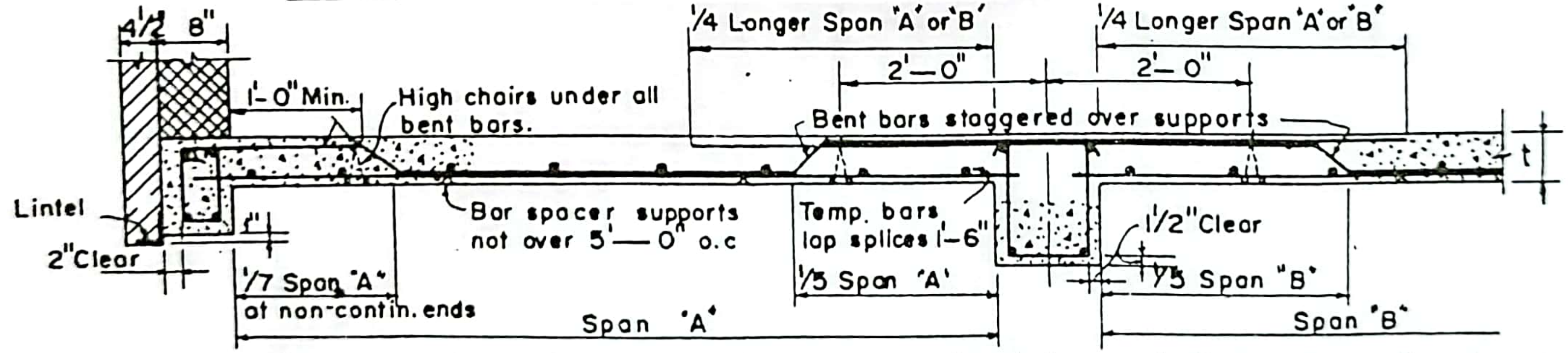


Fig 42, TYPICAL BEAM AND COLUMN DETAIL



NOTE: Main reinforcement : alternate bars to be bent up over support and staggered with bars from adjacent span.
At non-continuous ends of slabs, bent bars shall extend 3'— 0" beyond ℄ of support.
Temperature bars shall project 4" into walls and beams at end conditions.

Provide #3 @ 12" X 6'- 0" in top of slabs over all supports where main reinforcement runs parallel to supports on both sides; and #3 @ 12" X 3'— 0" in top of slabs over supports which are adjacent to openings where slabs frame parallel to support

Fig 43, DETAIL OF TYPICAL SLAB USING BENT BARS.

6.40 Design of Two-Way Slab

When floor panels are square or nearly so,two-way reinforcement may be used. If the slab length equals or exceeds 1½ times the width,the load is carried by reinforcement in the short direction only.

Table : Load Distribution in slabs with two-way reinforcement

Ratio of Length to Width of Panel	Ratio of Load carried by Shorter Span	Ratio of Load carried by Longer Span
1.00	0.50	0.50
1.05	0.55	0.45
1.10	0.60	0.40
1.15	0.65	0.35
1.20	0.70	0.30
1.25	0.75	0.25
1.30	0.80	0.20
1.35	0.85	0.15
1.40	0.90	0.10
1.45	0.95	0.05
1.50	1.00	0.00

For uniformly distributed loads, Table gives the proportion of load carried by the shorter and longer spans. This system of reinforcement consists of two bands of rods running at right angles to each other. The bending moment is less in the portions of the band which are adjacent and parallel to the supporting beams, and the ¼width of band on each side may have the moments reduced 50 percent. The method of designing a slab with two-way reinforcement is similar to that in which the reinforcement runs in one direction only. However, since the rods in one direction are placed above those in the other, the effective depth is different for each system of rods.

Example : Design with two-way reinforcement a floor panel 16' x 20' having a live load of 70 lb/ft² and a finished floor load of 25 lb/ft². The end conditions are fully continuous.

Specification data :

f_s = 20,000 lb/in² j = .875

f_c = 800 lb/in² k = .375

Solution : If the depth of slab is assumed to be 6", the weight of slab equals 75 lb/ft² (one cubic foot concrete weighs 150 lb)

Live load = 70 PSF.

Finished floor = 25 PSF.

Slab = 75 PSF.

Total weight = 170 PSF.

Ratio of length to width of panel = 20/16 = 1.25. Referring to Table we find that 75 percent of total load will be carried by the short span and 25 percent

long span. The loads carried on strips of slab 12" in width are
170 × 16 = 2,040 lb total load carried by short span.
170 × 20 = 850 lb, total load carried by long span
ıum bending moment for short span (Art 6.25)
$wl^2/12$ = (2040 × 16 × 12)/12 = 32,640" lb. (wl = W)
ıum bending moment for long span,
$l^2/12$ =(850 × 20 × 12)/12 = 17,000" lb
/M/(R xb)
/2 $f_c jk$ = 131
t span, d = √32,640/(131 × 12) = 4.5"
ȷ span, d = √17,000/(131 × 12) = 3.3"
effective depth of the short span determines the slab thickness in this
ınce, therefore accept 5.25 for the total depth of slab. by adding
er 0.75".
= $M/f_s jd$
= 0.875

ort direction A_s = 32,640/(20,000 × 0.875 × 4.50) = 0.41 in^2
e 1/2" round rods 6" on centres
ng direction, A_s= 17,000/(20,000 × 0.875 × 4.50) = 0.2 in^2
se 1/2" round rods 6" and 11" on centres for short and long spans
is reinforcement will be used in the central two quarters of the long and
ort spans and since a reduction of 50 percent of the bending moment
permitted in the quarter bands paralel and adjacent to the beams, use
2" round rods 11" on centers, for the outer bands of the short span and
2" round rods 22" on centres for the outer bands of the long span.
ıese are the spacings. The actual spacing depend on the dimensions of
ıe panel and are shown in Fig.
lternate rods are bent up over the supporting beams to provide for the
egative bending moments.
ond stress

$$u = \frac{V}{\Sigma ojd}$$

' = 2040/2 = 1020 lb the maximum shear for the short span
2/6 = 2 the number of roads at 6" spacing in each 12" strip
.57" = the perimetre of a 1/2" round rod (table)
= 0.875 u = 1020/{(2 × 1.57) × 0.875 × 4.75} = 78 lb.in^2 is
ıe bond stress for short span. Simlarly
ı = 425/{(1.09 × 1.57) × 0.875 × 4.25} = 66 lb/in^2 is
he bond stress for the long span, Plain rods are acceptable.

5.41 Design of Footing Under Brick Wall

Reinforced concrete wall footings are designed by considering the projection beyond the face of the wall as a cantilever beam tending to bend upward. It is customary to compute the load on I linear foot of wall and to design the width, depth and required reinforcement for this portion of the footing. In this type of footing it is not desirable to use stirrups to resist diagonal tension, and the footing must therefore, be designed accordingly. The critical section for diagonal tension is at a distance d out from the face of the wall, d being the effective depth of the bond stress frequently determines the effective depth.

Example : An 20" thick wall exerts a load on a footing of 15,500 pounds per linear foot of wall. If the allowable soil load is 2 tons/sq. ft. design a reinforced concrete footing in accordance with the following data :

f_s= 20,000 psi (allowable stress in steel)

f_c= 800 psi (allowable stress in concrete)

V_c= Limited to 60 psi (special anchorage)

u= Limited to 150 psi (deformed bars anchored)

n= 15

Solution : Assume the weight of the footing 1 linear foot of wall to be 500 lb. Then 15,500+500= 16,000 lb, the total load on the foundation bed per = 8 tons/linear foot of wall.

Area of footing = 8/2 = 4ft² Since the strip of footing is 12" wide its total length will be 4'.

Thickness of wall = 1.5' Then (4-1/5)/2 = 1.25'=l, the projection of the footing from the face of the wall. M = $wl^2/2$ the bending moment in the footing at the face of the wall in which w=the upward pressure of the soil in pounds per square foot and l=the length of the projection of the footing in feet. Then M= 4,000 × $1.25^2/2$ = 37,500" lb. d = $\sqrt{M/Rb}$ R = 131 and b = 12", the width of the strip of footing. Then d= $\sqrt{37,500/(131 \times 12)}$ = 5" Provide 7" as the effective depth including covers to avoid excessive bond stress and rusting of rods against the moist soil.

The vertical shear used to determine the diagonal tension unit stress is taken at distance d from the face of wall. As the length of the projection is 1.25', 1.25-1 = 0.25' the length of footing from the outer edge to the section to be tested for diagonal tension. Then V= 4,000 × 0.25=1000 lb.

1000/(0.875 × 12 × 12) = 7.9 psi Since $v = V/jbd$, .

$$u = \frac{V}{\Sigma ojd}$$

This stress is well within the 60 psi is allowable. In investigating the bond stress, V is taken at the face of the wall. Then V= 1.25 × 4000 = 5,000 lb.

Let us assume that the tensile reinforcement will consist of round rods for which the perimeter is 1.57". We shall let u, the bond stress, be 150 psi, its maximum value, and let x be the number of rods required for the strip of footing. The number of ½" rods required for each 12" length of footing. We shall accept, therefore ½" round rods 6" on centres.

Now let us investigate the tensile stress in the ½" rods with 6" spacing. The area of a ½" rod is .2 in² and there are 2 rods.

Note that this stress is well within the 20,000 psi allowable and that the effective depth has been determined by the bond stress, which will be its maximum allowable value.

For a protection to the reinforcement of concrete will be placed below the rods, Three round shrinkage and temperature rods will be placed in the footings parallel to the wall.

6.42 Design of Lintel

Theory of design is this, when a lintel fails, the amount of brick work which would collapse, would be a semi cricle or a

equilateral triangle. h= L/2 × tan 60°

Here, h gives the height of 10" brick wall it carries and L is the opening.

Reinforcement required can be worked out with design formula.

Lintel upto 6′ opening will have the following dimensions :

Thickness = 6″
Width = 10″ (According to wall width)
Rods = 2–½″ dia rods at top and bottom, clearance 1″ from both faces. For bigger openings, beams should be provided.

6.43 Design of Piles

Piles are used below foundation when the soil is filled, thereby lacking compaction and bearing capacity is low. To improve its bearing capacity, pre-cast R.C.C or wood piles are driven into the ground.
Piles bear load in two ways :
1. Point (end) bearing
2. Friction bearing.

The bearing value of piles or pile value is determined with the following factors :
1. Weight of pile
2. Weight of pile driving hammer
3. Height of fall of hammer
4. Length driven in last five blows

In house building, Gajari or Sal bollah piles are widely used due to easy avaibility and less cost compared to R.C.C pre-cast piles.

Timber piles

It should have girth of 7″ to 9″ at top and minimum of 4″ at bottom for an average of 25′ to 30′ long piles. Girth may be more for a bigger sized wood pile. Average 2 to 3 ton load is taken by such a pile.
Safe value of a pile is determined by the following formula :
$B = 2\ W\ H/(S \times 11.00)$
where, B = Safe bearing value in pounds.
W = Wt. of hammar in pounds
H = Ht. of fall in feet.
S = Average penetration in inches per blow during last five strokes.

6.44 Design of Concrete Stairs

A concrete stair way may be considered as an inclined slab or beam. Since the stairs are usually built after the frame and floor slabs are in place, the stair way is figured as a simple beam having a maximum bending moment of $M = Wl^2/8$, Note particularly that the length of the span, l is the horizontal distance between supports plus the approximate thickness of the slab. As in designing a floor slab with one-way reinforcement, a strip of stair way 12″ in width is considered and the depth and required steel area are computed in a similar manner. In addition to the tensile steel reinforcement, 3/8″ round rods are generally placed 18″ or 24″ on centres as cross reinforcement to prevent shrinkage and temperature cracks.
Many building codes require a live load for stair ways of 100 lb/ft² Table shows the total slab thickness and required reinforcement for various horizontal span lengths. This table was computed for 100 lb/ft² live load, and by its use proper depths and reinforcement may be selected without further computation.

6.45 Concrete Stair Slabs

Table for 100 lb/Sq. ft. L.L.

f_s = 20,000 lb/in² 1" clear protective covering
f_c = 800 lb/in²
n = 15

Horizontal Span of Stairs in Feet	Total Thickness of Slab in Inches	Reinforcing Steel				
4	3	3/8"	Ø	@	7 1/2"	c/c
5	3	3/8"	Ø	@	6 1/2"	c/c
6	4	3/8"	Ø	@	5 1/2"	c/c
7	4	3/8"	Ø	@	4 1/2"	c/c
8	5	1/2"	Ø	@	7 1/2"	c/c
9	5	1/2"	Ø	@	6 1/2"	c/c
10	6	1/2"	Ø	@	5 1/2"	c/c
11	6	1/2"	Ø	@	5"	c/c
12	7	5/8"	Ø	@	7"	c/c
13	7	5/8"	Ø	@	6 1/2"	c/c
14	8	5/8"	Ø	@	6"	c/c
15	9	5/8"	Ø	@	5 1/2"	c/c
16	9	3/4"	Ø	@	7"	c/c
17	10	3/4"	Ø	@	6 1/2"	c/c
18	10	3/4"	Ø	@	6"	c/c

Courtesy of the Portland Cement Association.

u = 1,135/{(12/5.5 × 1.57) × 0.875 × 5}= 76 lb/in²
Use plain bars with hooks at ends or continuous over slab supports.

6.46 Design of Water Tank

Underground water tanks can be made with brick masonry or R.C.C.
When tank is empty, its wall behaves as a retaining wall. When filled, it balances the earth pressure and tend to bend out side. So it is necessary to introduce sufficient strength to the wall to prevent both inside and outside pressure. So both of the wall are reinforced.
It has been observed that 15" wall imparts retaining action and is leake proof. But the wall itself cover an area of 2'-6" of the available space. So, R.C.C. tanks are preferable.
The design procedure for cantilever slab may be applied for designing underground water tank. Base slab will have to resist a load of per sq.ft. where unit weight of water : 62.4 lb/cu.ft and h is depth of tank. Thickness of slab is usually 1/12th of the depth. For 4' depth, wall thickness will be 4"

for 6' depth, wall thickness will be 6" Both faces of the wall should be reinforced with vertical rods. Base slab may have the same reinforcement to prevent bulging at the middle. Atleast 1/3 rod of the wall height should be casted on the same day the base slab is casted. A design table is furnished for ready reference.

6.47 Table for Capacity of Water Tank

Size of tank Lenght bredth ht	Capacity	Wait thickness	Vartical rod both faces	Binder
6' x 4' x 4'	600 gallons	4"	3/8" @ 4" c/c	3/8" @ 9" c/c
8' x 4' x 5'	1000 gallons	5"	1/2" c/c 6" c/c	3/8" c/c 9" c/c
8' x 6' x 5'	1500 gallons	5"	1/8" @ 5" c/c	3/8" @ 7" c/c
10' x 6' x 5'	1900 gallons	6"	1/8" @ 4" c/c	3/8" @ 7" c/c
10' x 6' x 6'	2250 gallons	6"	1/8" @ 4" c/c	3/8" @ 6" c/c

* Provide same reinforcement in double layer in bottom as that of vertical ones.

6.48 High Rise Condomonium or Multistoried Housing Complex

It is difficult to define a multistoried building. A building having only ground floor may be called single storied building. A building having minimum 2 to 4 stories upto 10 stories may be called multistoried building. Buildings beyond 10 stories are called high-rise building. A current trend is observed that some firms are constructing 12 storied or more high housing complex buildings in and around Dhaka.

Basic design principle are same for one storied, multistoried and high rise building. Except that when a building rises high two factors become prominent :

No. 1. Higher vertical load requires larger columns, walls and cores.

No.2. Overturning by lateral forces like strong wind and earthquake requires careful study and proper provision against overturning must be provided.

Material requirement becomes more for high rise building compared to that for low rise buildings to resist both vertical and horizontal loads.

In the case of either concrete or steel design there are certain basic principles for providing additional resistance to lateral forces and deflections in high-rise buildings without too much sacrifice in economy such as :

1. Increase the effective width of the moment-resisting subsystems. This is very useful because increasing the width will cut down the overturning force

directly and will reduce deflection by the third power of the width increase, other things remaining constant. However, this does require that the vertical components of the widened subsystem be suitably connected to actually gain this benefit.

2. Design systems such that the components are made to interact in the most efficient manner. For example, use truss systems with chords and diagonals efficiently stressed, place reinforcing for walls at critical locations and optimize stiffness ratios for rigid frames.

3. Increase the material in the most effective resisting components. For example, materials added in the lower floors to the flanges of columns and connecting girders will directly decrease the overall deflection and increase the moment resistance without contributing mass in the upper floors where the earthquake problem is aggravated.

4. Arrange to have the greater part of vertical loads be carried directly on the primary moment-resisting components. This will help stabilize the building against tensile overturning forces by precompressing the major overturn-resisting components.

5. The local shear in each story can be best resisted by strategic placement of solid walls or the use of diagonal members in a vertical subsystem. Resisting these shears solely by vertical members in bending is usually less economical, since achieving sufficient bending resistance in the columns and connecting girders will require more material and construction energy than using walls or diagonal members.

6. Sufficient horizontal diaphragm action should be provided at each floor. This will help to bring the various resisting elements to work together instead of separately.

7. Create mega-frames by joining large vertical and horizontal components such as two or more elevator shafts at multistory intervals with a heavy floor subsystem, or by use of very deep girder trusses. The design of a 65 story building using eight massive columns and three horizontal transfer floors to form a giant earthquake-resistant cage, which is further stiffened by individual posttensioned concrete waffle floors.

Remember that all high-rise buildings are essentially vertical cantilevers which are supported at the ground. When the above principles are judiciously applied structurally desirable schemes can be obtained by walls, cores,rigid frames, tubular construction and other vertical subsystems to achieve horizontal strength and rigidity.

6.49 Systems followed in Designing High Rise Building

1. Shear wall system 2. Rigid frame system 3. Tabular system is a new concept and is applied to Sears Tower 110 storied, 1450 ft. high. So far tallest in the world. It was designed by Dr. Fazlur Rahman of Faridpur(Skidmore Owings and Merrill, Engineers and Architectures.) and 4. Special systems. Systems need elaborate discussions which is

6.50 Seismic Load

Why a high-rise building cannot be easily designed to resist both wind and seismic forces in an optimum manner. Buildings can be designed to be rigid

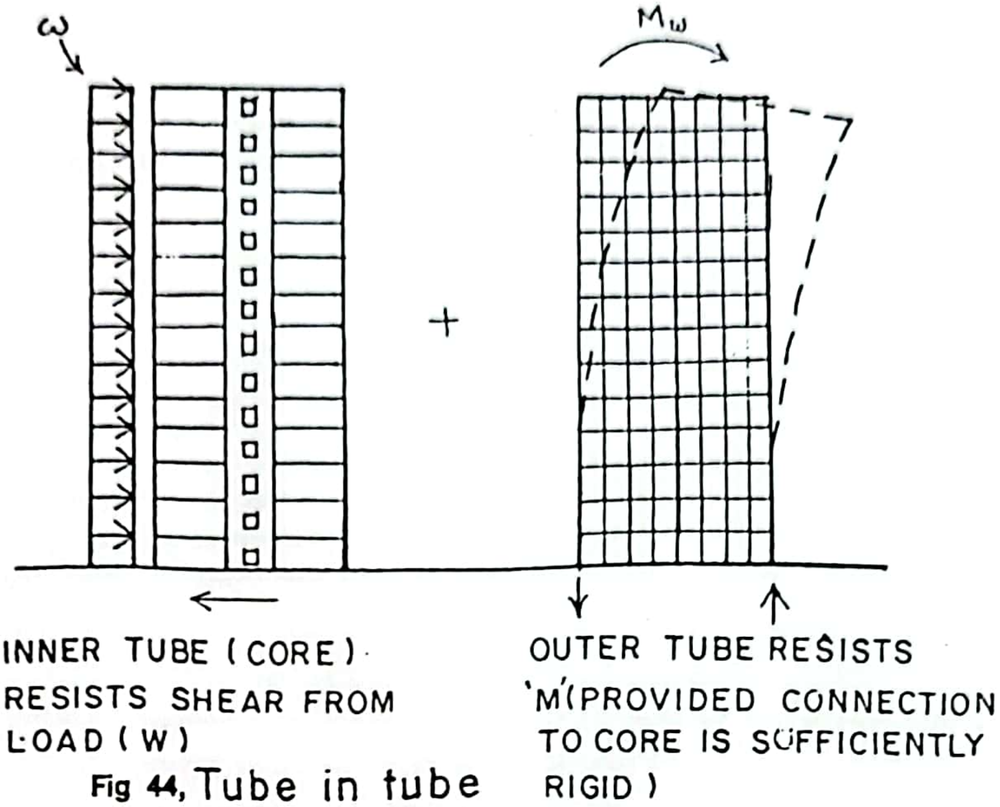


Fig 44, Tube in tube

under wind action and to escape damage under code specified earthquake forces. In order to resist catastrophic earthquakes, certain parts of the structure may be allowed to yield or crack in local areas, then the buildings' period of vibration would be lengthened and its damping increased. Thus the building will be able to resist strong seismic action without a structural failure. Initially, it was thought that soil of Dhaka is not capable of holding high raise building. 24 Storied Shilpa Bank building is a break through. By developing soil bearing capacity and giving proper allowance for wind and seismic loads, 60 storied building can be constructed in Dhaka Metropolish.

6.51 Standard Hooks

The dimensions and bond radii for hooks have been standardized by the ACI Code as follows :

1. A Semi Cirular turn plus an extension of
atleast four diameters, but not less than 2½ in at free end of the bar, or
2. A 90° turn plus an extension of at least 12 bar diameters at the free end of the bar, or
3. For stirrup and tie anchorage only, either a 90° or 135° turns plus an extension of at least six bar diameters, but not less than 2½ in. at the free end of the bar

Table for hook radius

Bar No.	Minimum radius
3, 4 or 5	2½ bar dia meters
6, 7 or 8	3 bar diameters
9, 10 or 11	4 bar diameters

6.52 Lapping of Rods

Lapping is neccessary due to reason that cut pieces of rods can be used in construction by overlapping one rod over the other. American Society of Testing and Materials (ASTM) has suggested the following requirements for lapping (splices)

Splices	Minimum lap Requirement	But not lessthan
Tension (beams, slab)	36 bar dia	12 in
Compression (Column)	24 bar dia	12 in.

Example : Determination of steel Area

A floor system has 4" thick concrete slab supported by Contineous T-beams of 16 ft span spaced. 10 ft centre, web is 10" wide and effective depth is 16" in. Compute steel required at mid span of the beam if given moment is 1200 kips-in.

Given, t = 4" f_s= 20,000 psi

d= 16" M= 1200 × 1000 lb-in. A_s?

A_s = M f_s (d−t/2) = 1200 × 1000 20000 (16−4/2) = 4.28 in²

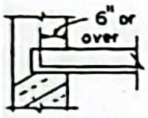
This can also be calculated by formula of rectengular beam,

A_s = M $f_s$jd =1200 × 1000 2000 × .875 × 16 = 4.28 in.

TABLE : ANCHORAGE

CASE I

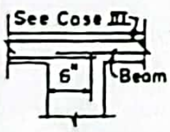
NON. CONTIN. ENDS OF BEAMS



At least 1/3 of positive reinforcement shall extend 6 in. into support.

CASE II

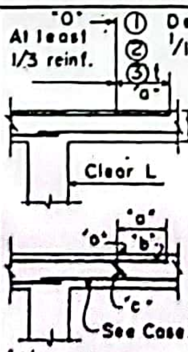
POSITIVE REINFORCE-MENT IN CONTINUOUS CONSTRUCTION



Not less than 1/4 of positive reinf. shall extend 6 in. into support. Every reinf. bar shall extend 12 dia. min. beyond point at which it is no longer needed to resist stress.

CASE III

NEGATIVE REINFORCE-MENT IN CONTINUOUS CONSTRUCTION



① Develop by bond 10,000 p.s.i.
② 1/16 of clear L
③ t

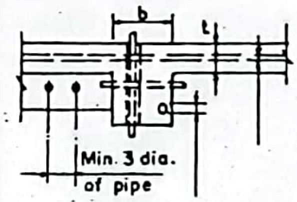
("a") At least 1/3 of negative reinf. shall extend largest of ①, ② or ③

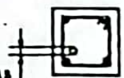
("b") Every reinf. bar shall extend 12 dia. min. beyond point at which it is no longer needed to resist stress.

("c") Bend the not needed bars across the web at an angle not less than 15° into region of compression and make continuous with positive reinf.

"O" = Extreme position of point of inflection.

PIPES EMBEDDED IN CONCRETE





Max. area of cross Sect. 4% of col. area.

NOTE :

Pipes Containing Liquid, Gas or Vapor may be embedded in Structural Concrete if tested prior to Concreting design pressure or minimum pressure of 150 p.s.i.; for 4 hours. Miximum pressure to be 200 p.s.i.; Max. temperature 150°F.

No liquid, Gas or Vapor to be placed in the pipes until the Concrete has thoroughly Set.

Piping shall be placed between top bottom steel.

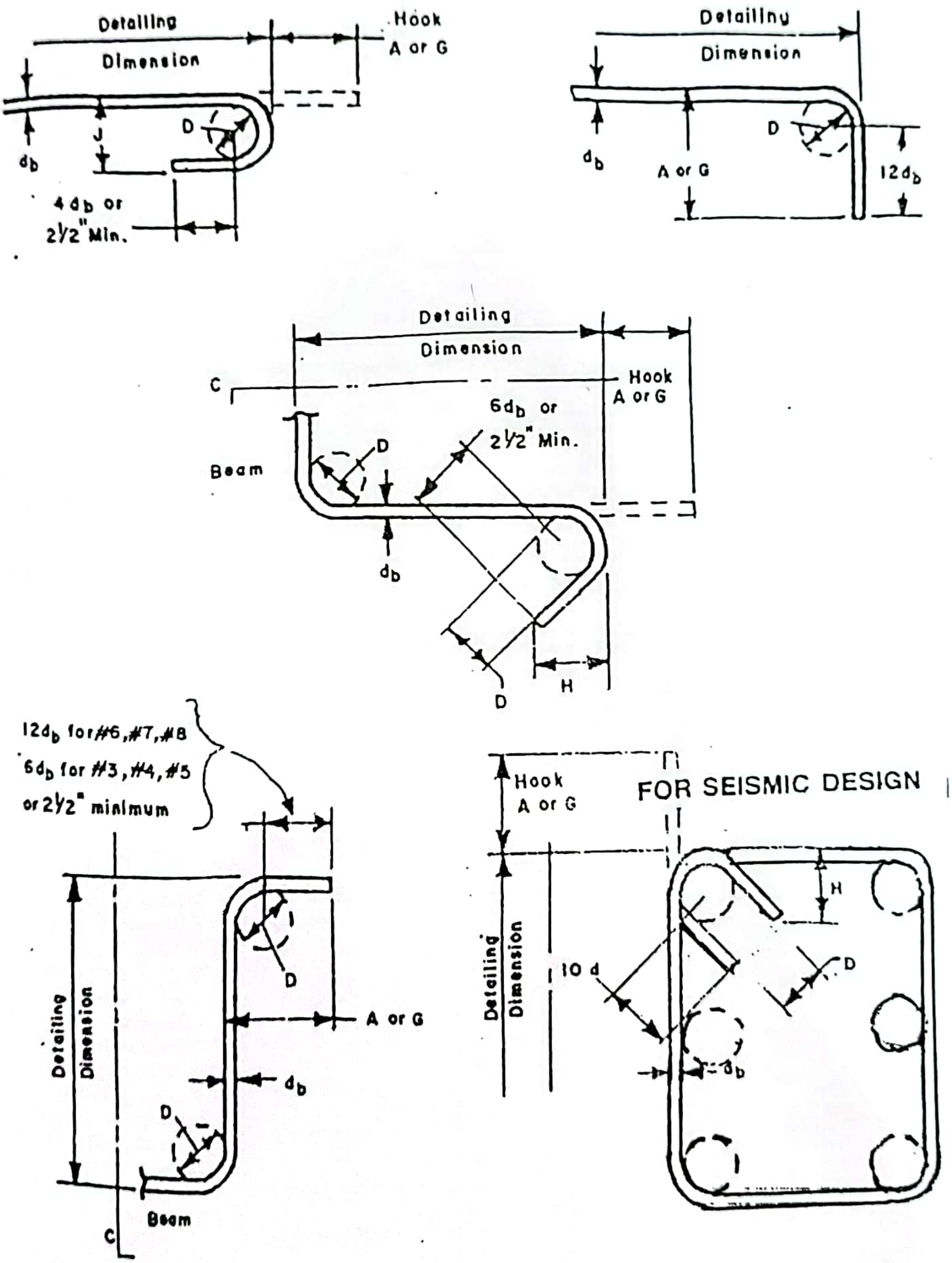
Concrete covering of pipes to be min. 1".

Reinforcement with a min. area of 0.2 Percent of Concrete Section Area to be provided normal to piping.

No Liquid, Gas or Vapor which may be injurious or detrimental to pipes shall be placed in them.

Uncoated pipes or sleeves of 2 in or less in diameter and not less in thickness than standard steel or wrought iron pipe may be considered to replace the displaced concrete.

Fig 45, Standard Hooks



6.53 Comparison between Convensional Brick and Framed Structure :

Convensional brick structure	Framed structure.
1. Time saving, can be quickly erected.	1. Time consuming. Because unless curing time is over forms can't be taking out.
2. Less strong against earthquake.	2. Very strong against earth quake.
3. Limited to 5 stories.	3. Multi strioried even upto 40 stories.
4. Due to 10" wall, room space is less.	4. Due to 5" wall, room space is more.
5. No cobla in wall or roof.	5. Cobla of columns is visible.
6. Changing or extension is not possible easily.	6. Change or extension in wall is possible.
7. Outer wall being 10", room remains cool, outer wall normally not damp.	7. Wall being 5", normally hot and may be damp.
8. Cost : 5% less.	8. Cost : 5% more.

6.54 Ready Made Charts and Tables

Designers seldom follow the cumbersome way of design by formulas. Ready made charts and table are widely followed. A building is constructed from bottom to the top. But a designer comes from top to bottom. He designs the slab first, then beams and column with footing, Because wt. of slab helps him to design beam and wt. of slab and beam helps him to design column or wall and its footing.

Table for Design of One Way Slab

Simply Suppored, Mid + M = $wl^2/8$

End–M= Interior (–) wl^2 10 f_s = 18000 psi.

f_c= 750 psi R = 123

Span	End Condition	Thickness	Main Reniforcement	Distribution	Remarks
8'-0'	Simple	4"	3/8 Ø@ 6½" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod.
	End	4"	3/8 Ø@ 6½" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod
	Interior	4"	3/8 Ø@ 7½" c/c alternated crankedup	3/8 Ø@ 15" c/c	Provide extra top between cranked rod
9'-0'	Simple	4"	3/8 Ø@ 6½" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod.
	End	4"	3/8 Ø@ 6½" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod
	Interior	4"	3/8 Ø@ 7½" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod
10'-0'	Simple	4"	3/8 Ø@ 6½" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod.
	End	4"	3/8 Ø@ 6½" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod
	Interior	4"	3/8 Ø@ 6½" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod

Span	End Condition	Thickness	Main Reinforcement	Distribution	Remarks
11'-0'	Simple	4 1/2"	3/8 Ø@ 5 1/4" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod.
	End	4 1/2"	3/8 Ø@ 5 1/2" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod
	Interior	4 1/2"	3/8 Ø@ 6" c/c alternated crankedup	3/8 Ø@ 15" c/c	Provide extra top between cranked rod
12'-0'	Simple	4 1/2"	3/8 Ø@ 4 1/2" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod.
	End	4 1/2"	3/8 Ø@ 4 1/2" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod
	Interior	4 1/2"	3/8 Ø@ 4 1/2" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod
13'	Simple	4 1/2"	3/8 Ø@ 4" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod.
	End	4 1/2"	3/8 Ø@ 4 1/2" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod
	Interior	4 1/2"	3/8 Ø@ 4 1/2" c/c alternated crankedup	3/8 Ø@ 12" c/c	Provide extra top between cranked rod
14'-0"	Simple	5 1/2"	3/8 Ø@ 4" c/c alternated crankedup	3/8 Ø @ 10" c/c	Provide extra top between cranked rod.
	End	5"	3/8 Ø@ 4 1/2" c/c alternated crankedup	3/8 Ø @ 10" c/c	Provide extra top between cranked rod
	Interior	5"	3/8 Ø@ 4 1/2" c/c alternated crankedup	3/8 Ø @ 10" c/c	Provide extra top between cranked rod
15'-0"	Simple	5 1/2"	1/2" Ø@ 4" c/c alternated crankedup	3/8 Ø @ 9" c/c	Provide extra top between cranked rod.
	End	5"	1/2" Ø@ 4" c/c alternated crankedup	3/8 Ø @ 9" c/c	Provide extra top between cranked rod
	Interior	5"	1/2" Ø@ 4" c/c alternated crankedup	3/8 Ø @ 12" c/c	Provide extra top between cranked rod
16'-0"	Simple	5 1/2"	1/2" Ø@ 4" c/c alternated crankedup	3/8 Ø @ 9" c/c	Provide extra top between cranked rod.
	End	5 1/2"	1/2" Ø@ 4" c/c	3/8 Ø @ 9" c/c	Provide extra top
	Interior	5 1/2"	1/2" Ø@ 4" c/c alternated crankedup	3/8 Ø @ 9" c/c	Provide extra top between cranked rod
17'-0"	Simple	6"	1/2" Ø@ 3 1/2" c/c alternated crankedup	3/8 Ø @ 8" c/c	Provide extra top between cranked rod.
	End	5 1/2"	1/2" Ø@ 3 1/2" c/c alternated crankedup	3/8 Ø @ 8" c/c	Provide extra top between cranked rod
	Interior	5 1/2"	1/2" Ø@ 3 1/2" c/c alternated crankedup	3/8 Ø @ 9" c/c	Provide extra top between cranked rod

Table for design of two-way slab by ACI coefficient

f_s = 18000 psi f_c = 750 psi R = 123

Short Span in ft.	Long Span in ft.	Thicness of slab in Inch.	Positive Reinforcement: Shorter direction	Positive Reinforcement: Longer director	Negative Reinforcment: Shorter direction	Negative Reinforcment: Longer direction
8	8	4"	3/8Ø @12" c/c	3/8Ø @12" c/c	3/8Ø @ 12" cc	3/8 @ 12" c/c
8	10	4"	3/8Ø @12" c/c	3/8Ø @12" c/c	3/8Ø @ 12" cc	3/8 @ 12" c/c
10	10	4"	3/8Ø @12" c/c	3/8Ø @12" c/c	3/8Ø @ 12" cc	3/8 @ 12" c/c
10	12	4"	3/8Ø @12" c/c	3/8Ø @12" c/c	3/8Ø @ 8" cc	3/8 @ 12" c/c
12	12	4"	3/8Ø @12" c/c	3/8Ø @12" c/c	3/8Ø @ 9" cc	3/8 @ 9" c/c
12	16	4"	3/8 Ø @7" c/c	3/8 Ø @10" c/c	3/8 Ø @ 5 1/2" cc	3/8 @ 7 1/2" c/c
14	14	4"	3/8 Ø @8 1/2" c/c	3/8 Ø @8 1/2" c/c	3/8 Ø @ 6 1/2" cc	3/8 @ 6 1/2" c/c

14	16	4"	3/8Ω @7½" c/c	3/8Ω @7" c/c	3/8Ω @ 5½" cc,	3/8 @ 51/2" c/c
18	22	5½"	3/8Ω @5½" c/c	3/8Ω @7" c/o	3/8Ω @ 4" cc	3/8 @ 5½" c/c
18	24	5½"	3/8Ω @5" c/c	3/8Ω @7" c/c	3/8Ω @ 312" cc	3/8 @ 5½" c/c
20	20	5½"	3/8Ω @6" c/c	3/8Ω @6" c/c	3/8Ω @ 4" cc	3/8 @ 4" c/c
20	22	5½"	3/8Ω @5" c/c	3/8Ω @6" c/c	3/8Ω @ 4" cc	3/8 @ 4" c/c
20	24	5½"	3/8Ω @4" c/c	3/8Ω @6" c/c	3/8Ω @ 3" cc	3/8 @ 4" c/c
20	22	6"	3/8Ω @6" c/c	3/8Ω @5½" c/o	3/8Ω @ 4½" cc	3/8 @ 4½" c/c
20	22	6"	3/8Ω @5½" c/c	3/8Ω @7" c/c	3/8Ω @ 4" cc	3/8 @ 5½" c/c
22	26	6"	3/8Ω @4" c/c	3/8Ω @5" c/c.	3/8Ω @ 3" cc	3/8 @ 4" c/c

Design of beam as per PWD STANDARD

Notation :
D = diameter
Bott = bottom rods
Stirr = Stirrups

Span	12'-0"	14'-0"	16'-0"	18'-0"	20'-0"	22'-0"	24'-0"
Spacing	Size 11" x 7"	Size 12" x 7"	Size 14" x 8"	Size 18" x 9"	Size 18" x 10"	Size 18" x 10"	Size 21" x 10"
8'-0"	Bott 5-5/8"D	Bott 6-5/8"D	Bott 3-3/4"D	Bott 5-3/4"D	Bott 1-7/8"D	Bott 5-7/8"D	Bott 4-7/8"D
			2-5/8"D		5-3/4"D		2-3/4"D
	Top 2-3/8"D	Top 2-3/8"D	Top 2-1/2"D	Top 2-1/2"D	Top 2-5/8"D	Top 2-5/8"D	Top 2-3/4"D
	Stirr 1/4"D	Stirr 1/4"D	Stirr 1/4"D	Stirr 1/4"D	Stirr 3/8"D	Stirr 3/8"D	Stirr 3/8"D
	Size 11" x 17"	Size 12" x 8"	Size 14" x 8"	Size 16" x 9"	Size 18" x 10"	Size 21" x 10"	Size 21" x 10"
	Bott 3-3/4"D	Bott 3-3/4"D	Bott 5-3/4"D	Bott 1-7/8"D	Bott 5-7/8"D	Bott 5-7/8"D	Bott 4-7/8"D
	Bott 1-5/8"D						
Spacing		3-5/8"D	3-5/8"D		5-3/4"D	2-	3/4"D
9'-0"	Top 2-3/8"D	Top 2-1/2"D	Top 2-1/2"D	Top 2-1/2"D	Top 2-5/8"D	Top 2-5/8"D	Top 2-3/8"D
	Stirr 1/4"D	Stirr 1/4"D	Stirr 1/4"D	Stirr 1/4"D	Stirr 3/8"D	Stirr 3/8"D	Stirr 3/8"D
	Size 12" x 8"	Size 13" x 9"	Size 15" x 9"	Size 17" x 9"	Size 18" x 10"	Size 21" x 10"	Size 21" x 10"
Spacing	Bott 5-5/8"D	Bott 3-3/4"D	Bott 4-5/8"D	Bott 4-3/4"D	Bott 5-7/8"D	Bott 4-7/8"D	Bott 3-1"D
10'-0"		3-5/8"D	2-3/4"D	2-7/8"D		2-3/8"D	3-
	Top 2-3/8"D	Top 2-3/8"D	Top 2-1/2"D	Top 2-1/2"D	Top 2-5/8"D	Top 2-5/8"D	Top 2-3/4"D
	Stirr 1/4"D	Stirr 1/4"D	Stirr 1/4"D	Stirr 1/4"D	Stirr 3/8"D	Stirr 3/8"D	Stirr 3/8"D
Span	12'-0"	14'-0"	16'-0"	18'-0"	20'-0"	22'-0"	24'-0"
	Size 12" x 9"	Size 13" x 9"	Size 15" x 9"	Size 17" x 9"	Size 18" x 9"	Size 21" x 11"	Size 22" x 11"
Spacing	Bott 6-5/8"D	Bott 5-3/4"D	Bott 6-5/8"D	Bott 1-7/8"D	Bott 4-7/8"D	Bott 6-7/8"D	Bott 4-1"D
11'-0"				5-3/8"D	2-3/4"D		2-7/8"D
	Top 2-3/8"D	Top 2-3/8"D	Top 2-1/2"D	Top 2-1/2"D	Top 2-5/8"D	Top 2-5/8"D	Top 2-3/4"D
	Stirr 3/8"D	Stirr 3/8"D	Stirr 3/8"D	Stirr 3/8"D	Stirr 3/4"D	Stirr 3/8"D	Stirr 3/8"D
	Size 12" x 10"	Size 14" x 10"	Size 16" x 10"	Size 17" x 10"	Size 18" x 10"	Size 21" x 10"	Size 22" x 11"
Spacing	Bott 6-5/8"D	Bott 5-3/4"D	Bott 6-5/8"D	Bott 1-7/8"D	Bott 4-7/8"D	Bott 6-7/8"D	Bott 4-1"D
12'-0"	2-3/8"D	2-7/8"D				3-7/8"D	
	Top 2-3/8"D	Top 2-3/8"D	Top 2-1/2"D	Top 2-1/2"D	Top 2-5/8"D	Top 2-5/8"D	Top 2-3/4"D
	Stirr 3/8"D	Stirr 3/8"D	Stirr 3/8"D	Stirr 3/8"D	Stirr 3/4"D	Stirr 3/8"D	Stirr 3/8"D

Design by Engr. T. Hossain, PWD

6·55 CRACKING IN BEAMS AND SLABS

All reinforced concrete beams and slabs develops hair crack, generally due to shrinkage and at loads well below service level. Flexural cracking due to loads is not only inevitable, but is actually necessary for the reinforcement to be used effectively.

In a well-designed beam, flexural cracks are fine, almost invisible to the observer, the number and width of cracks increases, and at service load level a maximum width of crack of about 0.01 in (0.25 mm) is typical. If loads are further increased, crack widths increase further.

Cracking of concrete is a random process, highly variable and influenced by many factors. Because of the complexity of the problem, present methods for predicting crack widths are based primarily on test observations.

Slabs mostly develop cracks at corner due to faulty placement of corner reinforcement.

The Gergely-Lutz Equation for Crack Width

Based on their research at Cornell University which involved the statistical analysis of a large amount of experimental data, Gergely and Lutz proposed the following equation for predicting the maximum width of crack at the tension face of a beam :

$$w = 0.076\, B f_s \sqrt[3]{d_c A}$$

in which w is the maximum width of crack, in thousandth inches, and f_s is the steel stress at the load for which the crack width is to be determined, measured in ksi.

d_c = thickness of concrete cover measured from tension face to center of bar closest to that face, in

B = ratio of distances from tension face and from steel centroid to neutral axis

A = concrete area surrounding one bar, equal to total effective tension area of concrete surrounding reinforcement and having same centroid, divided by number of bars, in²

Permissible Crack Widths

The acceptable width of flexural cracks in service depends mostly on the conditions of exposure and should be established in view of the possibility of corrosion of the reinforcement. The recommendation of the ACI Committee 224 are summarized in Table below.

Table : Tolerable crack widths for reinforced concrete

Exposure condition	Tolerable crack width in	mm
Dry air or protective membrane	0.016	0.41
Humidity, moist air, soil	0.012	0.30
Deicing chemicals	0.007	0.18
Seawater and seawater spray ; wetting and drying	0.006	0.15
Water-retaining structures, excluding nonpressure pipes	0.004	0.10

Source : From Winter.

Loading tests indicate that a doubling of crack width can be expected with time. Under most conditions the spacing of cracks does not change with time at constant levels of sustained stress or cyclic stress range.

6.55 ACI CODE PROVISIONS FOR CRACK CONTROL

In view of the random nature of cracking and the wide scatter of crack width measurements, even under laboratory conditions, excessive precision in calculating the crack width is not justified. Accordingly, the Eq. can be simplified for typical beams by adopting a representative value of $B = 1.2$ Then a parameter z may be ... as follows :

$$z = f_s \sqrt[3]{d_c A}$$

in which

$$z = W/0.076 \times 1.2 = w/0.091$$

Control of the maximum crack width can be thus obtained by setting an upper limit on the parameter z. The ACI Code specifies that z shall not exceed 175 for interior exposure and 145 for exterior exposure. These limits correspond to maximum crack widths of 0.016 and 0.013 in respectively.

7 Cost Estimates Tenders and Contracts

"Order is Heaven's first law" - Pope.

Before execution, pre-knowledge about the expected expenditure is necessary which is worked out with the help of estimating.

7.1 Estimates

Estimate of your house can be broadly classed into two:

I) Lump Sum Estimate : It is done on the basis of plinth Area rate.

II) Detailed Estimate : It constitutes in finding out the Bill of Quantities including labour and material cost of the work.

7.2 Lump Sum (L.S.) Estimate

Now a days, plinth area cost per sq. ft. for low rise building may be assumed as follows :

1.	Upto 1st Floor	Tk. 1050/-	per sq. ft.
2.	2nd Floor	Tk. 750/-	" " "
3.	3rd Floor	Tk. 825/-	" " "
4.	4th Floor	Tk. 850/-	" " "

Example : A house plan having 1050 sq. ft. in ground floor will cost you 1050 x 1050 = Tk. 11.03 lac. For 1st floor having 1000 sq. ft. area an amount of Tk. 1000 x 750/- = Tk. 7.50 lac only will be required.

7.3 Detailed Estimate

It involves in working out bill of quantities of works and there from material requirement and labour cost can be found out.

In percent of total cost, material cost will be approximately 85% and labour will be 15%.

7.4 Over all break up of cost of your House

Approximately, civil works in making building frame will be 60% while fitting fixing & finishing will be about 40% being 15% on account of foundation. Sanitary work 15% Electrification 9%, and gas supply 1%. Civil Works are the major constituents which may be further classified as under :

1.	Earth work	1/2%
2.	Foundation work	4%
3.	DPC	1/2%
4.	Brick work	33%
5.	Roof	20%
6.	Floor	6%
7.	Door/Window	16%
8.	Plaster/Painting	10%
9.	Finishing	5%
10.	Miscellaneous	5%
		100%

7.5 Material and Labour Cost

Both are variable and also differ from place to place. As such prevailing market rates should be verified. This subject is discussed in details.

7.6 Assessment of Material Requirement

Item wise standard material requirement are furnished in Article 7.7 A rough and ready procedure can be followed on the basis of per sq. ft. as per table bellow :

Per sq. ft. materials requirement		Per sq. metre material requirement
1. Brick	48 Nos.	500 Nos.
2. Cement	0.14 bags	1.5 bags
3. Sand	0.35 cft.	3.76 cu.m
4. M.S. Rod	0.14 cwt.	15 cwt.
5. Wood :		
a) 3" x 4" (75 x 100mm) size chowkat 17rft per door		5.18 per door
b) 1.5" (37 mm) size shutter 18 sq. ft. per door		1.68 m. per door

Plinth Area Rates

The cost of the building is roughly calculated on the basis of plinth area rate. The valuation of your building for the purpose of income tax calculation is done by the income Tax Department on this rate published by PWD (Public Workes Department) in their schedule of rates corrected from time to time. Rates per sq. ft. or per sq. m. averaged upto March, 2007 is furnished here for making estimates, schemes, projects for building having the following characteristics :

1. First class buildings in bricks with four storied foundation with brick flat soling, cement concrete (1:3:6) and brick work (1:4/1:6) (in/c. 75 mm thick D.P.C) in foundation and plinth, 250 mm thick brick work, superstructure doors and windows made of best local timber with standard window grills. R.C.C. works (1:2:4) in roof slab, beams, lintels, stair cases, minimum 12mm thick cement plaster (1:6) to both sides of superstructure walls, minimum 12mm thick cement plaster (1:4) in plinth, steps and dado 6 mm thick cement plaster (1:4) to ceiling, beams etc. White washing

colour washing and necessary earth work in foundation, earth and sand filling in plinth and other petty sanitary and electrical items as required.

1.	Foundation cost upto plinth level	
	a) 2 (two) storied building Tk. 240/- P.Sft.	(Tk. 2560.00 per sq.m)
	b) 3 (three) storied building Tk. 275/- P.Sft.	(Tk. 2960.00 per sq.m)
	c) 4 (four) storied building Tk. 310/- P.Sft.	(Tk. 3317.00 per sq.m)
	d) 5 (five) storied building Tk. 380/- P.Sft.	(Tk. 4066.00 per sq.m)
2	Cost of Superstructure without foundation	
	a) Upto 1st floor Tk. 750/- P.Sft.	(Tk. 8025.00 per sq.)
	b) 2nd Floor Tk. 775/- P.Sft.	(Tk. 8292.00 per sq.m)
	c) 3rd floor Tk. 825/- P.Sft.	(Tk. 8827.00 per sq.m)
	d) 4th floor Tk. 850/- P.Sft.	(Tk. 9095.00 per sq.m)

If the building is of more than five storied additional amount for foundation to be added as per requirement and design on the basis of actual calculation. Construction of flats will now cost from. Tk. 950 to Tk. 1200/- Per sft. depending on fittings and fixtures.

From the above data we may work out how much extra cost is increased over the next floor on account of foundation and different stories of the building.

Percent increase over next floor : 5% to 10%

This increase is mainly for labour cost for lifting of material to the next floor. Normally 5% is allowed for 1st floor and an average of 10% over the next floors.

A house of 1000 sft. will involve cost as follows :

Ground floor 750 x 1000 = Tk. 7.5 lac

1st floor 750 x 1000 = Tk. 7.5 lac

2nd floor 775 x 1000 = Tk. 7.75 lac

3rd floor 825 x 1000 = Tk. 8.25 lac

If supervision of the house is made by the owner, 15% saving is possible and this is also admitted by the Taxation Department.

7.7 Standard Reqirement of Materials

Item	Quantity	Cement	Brick Nos.	Sand	Lime	Surki
i) Cement concrete (1:2:4)	100Cft	18 Bags	850	44 Cft	-	-
Cement concrete (1:3:6)	100 "	$12^1/_2$ "	850	45 "	-	-
Lime concrete (2:2:7)	100 "	"	850	45 "	9 Mds.	33 Cft.
ii) Brick work in cement (1:4)	100 Cft.	6 Bags	1150	29 Cft.	-	-
Brick work in cement (1:3)	100 "	8 "	1150	28 "	-	-
Brick work in lime moter (1:4)	100 "		1150	-	12 Cft	24 Cft
iii) $^1/_2$" Cement Plaster (1:4)	100 Sft.	1 Bag	-	5 Cft.	-	-
$^1/_2$" Cement Plaster, (1:6)	100 "	0.72 "	-	5 "	-	-
$^1/_4$" Cement Plaster (1:4)	100 "	0.50 "	-	21/2 "	-	-
iv) 3" Brick flat soling.	100 "	-	300	5Cft.	-	-
5" Herring bone bond	100 "	-	500	-	-	-
v) 5" Brick wall 1:4	100 "	21/2 bags	480	11 Cft.	-	-
3" Brick wall 1:4	100 "	1.8"	250	7.5 "	-	-
vi) White wash 2 coats	1000	-	-		34 Seer	+Gum 1ch
White wash 3 coats	1000 "	-	-	48 Seers 1ch. -		

Ready mixed distemper, 2 coats %c Sft - 1/4 gallon

7.8 Tender

Tender may be made in three different ways :
a) L.S. basis or Turn-key basis.
b) Item rate basis.
c) % (percent) above or below than estimate basis.

a) L.S. (Lump sum) basis or Turn key basis

It is the way of executing the whole building as per approved plan and design on the basis of whole cost and after its completion the key is handed over to the owner.

b) Item rate tender

Bill of quantities or the B.Q. of each item of the building is previously scheduled on a paper and tender is taken on each item on the basis of per unit rate.

c) Percent above/below tender

In this case, schedule of work is prepared on the basis of estimate by using approved rates which shows the total estimated cost of the Building and bid is quoted percent above or below it.

7.9 Model Tender Notice

As per normal practice three competitive tenders are necessary to finalise the rate. As such, to attract more people to compete in the tender, it is necessary to make a press notification. A model of the notice is furnished below which is normally followed in Govt. offices. However, for your purpose, rates may be picked-up on personal contact.

TENDER NOTICE

Sealed Tenders in the prescribed schedule are hereby invited from bonafide Contractors for the work of construction of housing quarters at Dhaka and will be received by the undersigned till 12-00 hrs on 30th instant and shall be opened on the same day at 12-05 hours in presence of tenderers who like to be present.
Earnest money @ 2% of the quoted rate in the form of Bank draft/Call deposit/ Treasury challan/ Defence bond in favour of the undersigned should accompany each tender failing which the tender will be summerily rejected.
Tender papers and schedule of work will be available at a non-refundable price of Tk. 10/- from the office of the undersigned on working days except on the date for opening of tender.
The Authority reserves the right to accept or reject any or all the tenders without assigning any reason thereof.

Signature

For official use, there are two prescribed Govt. forms which states all terms and conditions of the contract-
1) Form No 2908 for supply of materials in which case, Earnest money is taken @ 5% of the value of supply.
2) Form No. 2911 for construction works earnest money being 2%
Each tender should clearly specify time allowed for completion of the work.
However Public works are carried out on the basis of schedule of Rates

which includes Material cost, labour cost and Contractors profit. Analysis of such rates are furnished in

For private works, labour rates should be taken from skilled Masons or Contractors and materials be procured on your own so that quality and a good saving are insured.

7.10 Contract

Contracts can be made on the basis of schedule of rates by signing on behalf of owner and the Contractor. It can preferably be done on fifty · Taka stamp paper on terms and condition mutually agreed upon. Standard terms and conditions are statedbelow · next article.

Terms and conditions of Contract

For private and official use the following terms and conditions may be laid in the Contract :

1. Time of Completion should be clearly stated.
2. Works should be specified in a memorandum.
3. A suitable security deposite (for Public works) may be there. Normally 10% SD is deducted from running bills.
4. Mode of payment may be clearly writen.
5. Compensation for delay clause be there.
6. Bonus for completion ahead of schedule may also be mentioned.
7. Conditions when time extention may be given.
8. Timely supply of stores by the owner be insured. Supplies from contractor's side be also stated.
9. Works are to be executed according to specification.
10. Inspection be made regularly.
11. Notice be given to owner before work is covered.
12. Works not to be sublet.
13. Drinking water, medical facilities to be given to labours.
14. Conditions when contracts may be rescinded.

8 Field Execution of the Works

"You can not beat experience"
— Pan American Airways

8.1. Starting the Work

Now, real game begins. During the work of execution you will come to know manythings which were never written in books or ever known to you. Unless you have enough money to engage a firm to execute your plan on turn key basis, you are to involve yourself in procurement of materials right from nails to anything like G.I.wire, M.S. rods. cement. bricks wood. sanitary materials. electrical goods and gas appliances. Your supervision and direct involvement in the work will give you satisfaction with a good saving in the expenditure.It is of utmost importance to find out items of works involved and select a Mason. Plumber, Electrician, Carpenter, Welder and so on and finalise rates of units of the items involved. Details have been furnished in the following article.

It is advisable to start the work in dry weather. Particularly the foundation work should be done in winter. Material collection may continue side by side.

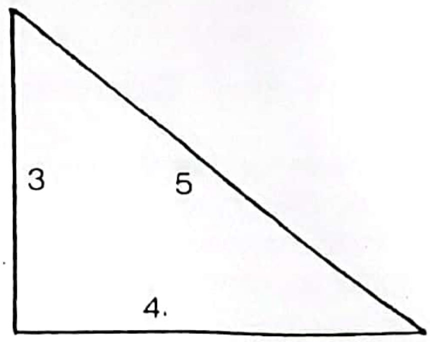


Fig 46. 3:4:5 method

8.2 Fixing Lay-outs

Lay-out means fixing your building from paper to the ground keeping proper margin from roads and sides. The perpendicularity of walls can be checked by 3:4:5 method.

At one corner take 3ft (or 3m) on one side and 4′ (or 4 metre) on the other. If rightly set, the diagonal will be 5ft. (or 5m). It is necessary to keep centre line marks of walls which is normally made by means of brick pillars with nail marked centre constructed at a safe distance from the foundation trench. The following procedure be followed :

1. Take the road side plot margin as reference line.
2. Measure distance of wall foundation from the margin and mark the cutting width of wall with lime powder or dry sand or red surki.
3. Fix centre line of the wall and fix two pegs at two ends at a safe distance from trench. After checking such pegs be converted into 10"×10" brick pillars upto plinth level height, nail be fixed on the centre.
4. In a similar way, fix other 3-sides perpendicular to the reference line and check it by 3:4:5 method.

8.3 Determining Plinth Level

It sould be fixed at 1'-3" to 2'-0" higher than the existing road level. Road level raising is done from time to time, proper allowance be kept for such raising, otherwise, in course of time, the plinth level may go below the road level.

8.4 Cutting Foundation and Observing Soil Condition

Depth of cutting will be as per design but it is also dependable upon the soil condition at site.

"Thumb Rule" :

a) Depth of foundation in ft. equals No. of stories. i,e, for a four storied house, cutting depth will be around 4' but soil be firm at this depth otherwise you are to go more deep into the ground.

b) Width of cutting will be as per design. It normally equals one brick wide for each story. i.e. for 2 storied building, foundation width will be atleast two bricks wide or 20". For 3 storied-30", for four storied 40" and so on.

8.5. Foundation for Partition Wall

5" walls which does not lay on the ground, no foundation is necessary for it. It can be constructed on floors. For 1st and top floors, a concealed beam in the roof slab be provided under the wall.
A concealed beam is nothing but providing 2 nos. 1/2" dia rod inside slab along the wall position. Clearance will be 3/4" above from the bottom.

8.6 Improvement of Soil Condition

If loose soils are found at designed depth, excavate more deep upto the firm soil and fill it back to the design level with sand filling by layers. Sand, when compacted, is further incompressible and has almost no secondary settlement. It is a safe media for filling works.

8.7 Sand Pile

If the soil seems to be loose, its condition can be further improved by a simple means - the sand pile. Take a bollah or firm wood 3" to 4" dia and 3' to 4' long and drive it into the base of foundation then take it away. The hole thus left be filled with coarse grained sand duly compacted by few blows over it. Such piling may be spaced 1' to 3' apart in both directions.
By driving brick bats and bamboos, compaction can be considerately increased. Bailing out water during digging may be necessary, pumps may be used. For severe cases, 3 or more 1½" dia 10' strainers be driven into the soil and by interlocking them, water may be bailed out.

8.8 Wood Pile

If soil condition is too poor, then wooden piles may be necessary. It demands technical advice. Please see art 6.43

8.9 Item of Works Involved

CMl Works : Civil works form the bulk of the task. Unless there is provision for concealed electric lines and water piping, it is advisable that the main structure be constructed first. Main item for such work are furnished along with probable labour rates; all materials are supplied by you. It is always better to select a main as executing agent and rates for the items are finalised before hand. Other facilities to be provided in your house is written in a separate chapter.

Items		Units.	Av. labour rate as on December'88
1.	Earth work : a) in cutting	a) 1000 cft.	Tk. 1200.00
	b) in filling	b) 1000 cft.	Tk. 1000.00
2.	Brick Soling	100 sft.	Tk. 100.00
3.	C.C. Casting in foundation (including screening khoa and sand)	100 cft.	Tk. 300.00
4.	Brick work in foundation	100 cft.	Tk. 450.00
5.	D.P.C. Casting	1 rft	Tk. 2.50
6.	10" brick work above plinth	100 cft.	Tk. 450.00
7.	Facing work above plinth	Per sft.	Tk. 6.50
8.	5" or 3" brick work (for partition)	Per sft.	Tk. 3.50
9.	3" C.C. casting on floor with 1" to 11/2" patent stone flooring with neat cement or red oxide finishing.	Per sft.	Tk. 3.00
10.	Mosaic work / Glazed Tiles :	Per sft.	
	a) Situ Mosaic	Per sft.	Tk. 11.00
11.	R.C.C work	Per cft.	Tk. 6.50
12.	Plaster work :		
	a) In ceilings	100 sft.	Tk. 375.00
	b) In walls	100 sft.	Tk. 360.00
13.	a) White wash/colour wash	100 sft.	Tk. 80.00
	b) Distemper/Snowcem/Painting	100 sft.	Tk. 300.00
14.	4" Lime concerete	100 sft.	Tk. 415.00
15.	Wood work : (including fittings)		
	a) Door window frame	Per rft.	Tk. 8.00
	b) Shutter	Per sft.	Tk 30.00
16.	Window Grills including shutter	Per sft.	Tk. 200.00
17.	Making Door, windows fitting	Per piece	Tk. 120.00
18.	Glass fitting	Per sft	Tk. 3.00

19	Roof shuttering (excluding wood and bamboo)	100 sft	Tk. 330.00
20	Rod bending, binding. For any other item not included in the list be accounted on the basis of market rate. For getting competitive rates some times tenders may be taken from different sources. Roof area based rate is also in force which varies from Tk. 70/-, Tk. 75/- Per sft.	per Cwt	Tk. 70.00 and so on

8.10 Few Bogus Rates

Most of the Masons and some of the Contractors are apt to tax you heavily by charging high bills on the basis of bogus and exaggerated rates. Some examples are sighted below :

(i) Earth work

a) In filling and consolidating in 6" layers.

b) Durmuj the work layer by layer.

The former is genuine rate inclusive of the later.

(ii) Rate for screening of khoa or sand

All casting works are inclusive of screening, hence separate rate does not involve.

(iii) Casting works : There may be as many as six rates quoted for casting like lintel casting, Beam casting, Column casting, 4" roof casting, Railing casting, Stair casting; drop wall casting etc. Except in case of stair, rate for casting work should be one.

(iv) Plaster work : Similarly for plaster he may quote like this :

a) Ceiling plaster
b) Wall plaster
c) Floor plaster
d) Stair plaster
e) Floor mom (wax) polish
f) Floor colour finish.
g) Skirting margin
h) Sunshade plaster etc.

Out of this, first two are genuine, polishing or finishing are all inclusive with the rate. Floor finish is inclusive with c.c. casting.

Please note that no floor can be plastered. It is treated either with mosaic or patent stone flooring which include rough casting (1" thick) with neat finish at the top. All stages are inclusive within the rate. Only one rates can be made for all such works.

8.11 Material Collection and Storing

To avoid price hike and steady supply for the works, it is advisable to collect and store materials.

Bricks : One truck can carry 2 thousand bricks. Stacking at site can be made accordingly. 1st class brick for wall and picked bricks for underground masonry is suggested. Picked bricks be broken for making khoa

Cement : The site should have a tinshed for storing such materials and the platform should be elevated so that water and dampness cannot touch it.

Sand and Khoa : Should be stored over a brick flat soling so that grass and other organic material are not mixed with them. They should be screened before use.

M.S. Rod : M.S. rod is liable to rusting. Hence, it should not be kept in open sky rather it is to be stored indoor on elevated platform.

Paints, Snowcem Distempers :

It is better not to open the lid much before use. However, if it is opened for use and some materials is retained, it is necessary to insure the lid is refitted air tight otherwise the materials may be spoiled.

8.12 Economy in Execution

Economy can be derived out of the following :

a) Out of planning.

b) Out of material cost.

c) Out of Labour cost.

a) Economy out of planning :

This can be achieved in the following way-

As far as practicable common walls for different rooms be provided. Square rooms are economic.

b) Economy out of material cost : Chambal wood may be a substitute of Teak. Difference of cost is considerable where possible ordinary bricks may be used in place of ceramic etc. Deformed bars save 20% in steel.

c) Labour cost : Selected labours and competative cost may save a lot.

8.13 Nature of Foundation

Selection of brick wall foundation or column foundation is very important, as it is one of the costliest portion of your house.

Brick foundation; when original soil is there in your plot, it is advisable to go for this type of foundation.

Framed structure : Cost is 5% more or sometimes equal but stable against earthquake.

8.14 Column Foundation

When it is a filled ground and depth or filling is more than 4 ft. such type of foundation is economical. 10" × 10" R.C.C. columns need be provided from firm ground having wide footing and beam be provided at plinth level in a manner as described herein.

For 3 storied house inner columns may have 3' × 4' footing over a brick soling and 6 R.C.C ½" dia rod at the rate of 6" centre to centre (C/C) be provided at bottom position of the footing. Use 4 Nos. 5/8" (minimum) vertical rods and 3/8" dia ring spaced at 8" C/C. For outer columns 3' × 3' footing may be enough. Others will remain unaltered.

Column footings should rest on original ground even if it is 10 ft. deep. For extra ordinary conditions other foundation aspects may be considered.

Verandah walls in ground floor

For verandah portion and portion below the beam, brick wall can be made with 50% 10" wall and 50% 5" wall bounded in 1:4 mortar having foot at 6' depth of ground level. This saves a lot.

8.15 Unnecessary Hooking of Steel

For one suti(1/8" dia) rod hook should be 1" at either end, for 2 (1/4" dia) Suti rod 2", 3 Suti (3/8" dia) 3", 4 Suti (1/2" dia) 4", 5 Suti (5/8" dia) 5" and so on. Hooks if not embeded in concrete is of no value to the structure. For spans of less than 9 ft. no hooking of bars is necessary. It saves about 15% on the use of steel. No hook is necessary for deformed bars

8.16 Procurement of Materials at a Reasonable Rate

For this, prior contract with suppliers is necessary. Procurement should be made in season, otherwise rate heavily varies.

8.17 Reasonable Labour Rate

Since it forms 15% (approx,) of the total work, prevailing rates need be throughly studied.
A Mason or a Contractor or a Sub-Contractor is always apt to give bogus rates and claims bill for it. It is always advisable to have bill from him and get it verified by technical man or evaluation can be made by self.

8.18 Supervision of the Work

It is always better to take help from a Technical person constantly, if this is not possible, then a periodical inspection by him is necessary. A reliable man should be deputed to the site to keep day to day account of the work and can also keep an eye to the proper mixing of concrete, screening of sand and chips consolidation of sand filling in floor, watering the works and other main item so that it is done according to specification and normal practice. He can also maintain the store.

8.19 Do's and Don'ts of the Works

A. Earth work : involves in

a) Cutting foundation
b) Back filling foundation trenches.
c) Filling ground floor with earth or fine grained sand.

Do's : 1) In case of trenches, allow 3" more width of cutting than what is actually required

2) Keep earth at a safe distance from the trenches.
3) For floors fine grained sand like viti sand be filled in 9" layer duly rammed and consolidated by water. Sand soil in 6" layers may also be used.

Don'ts :

1) Don't give any foundation over loose soil.
2) When filling height in floor is above 2'-0, don't flood the plinth with excess water, otherwise cracks may develop in the wall due to bulking of fills and porewater pressure.

3) Don't caste floors over filled ground so hastly. Sufficient time (about 1½ months) be elapsed so that due compaction is achieved and the fill is dried up

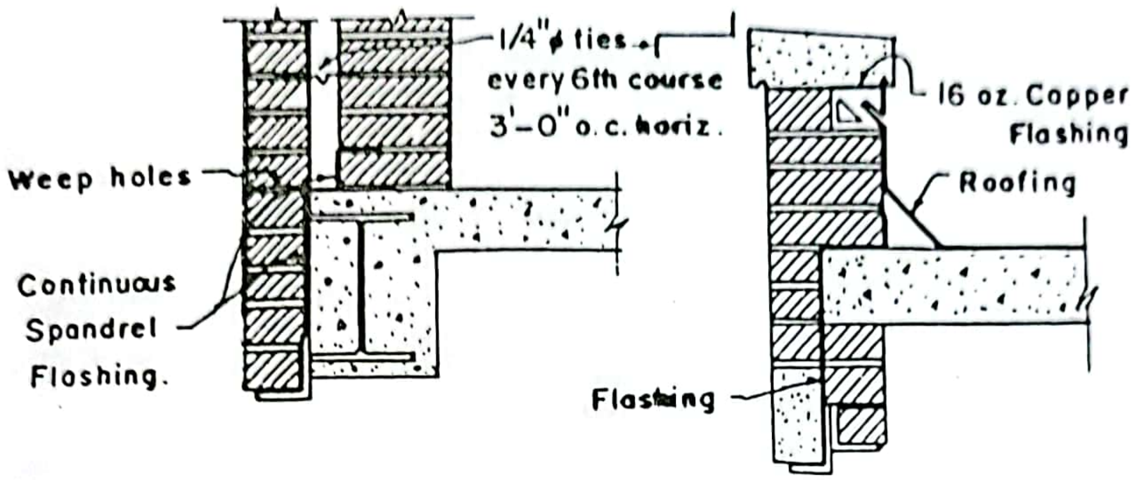


Fig 47. CAVITY WALL   LOW PARAPET FLASHING

B. Brick soling in foundation and floors.

Use 1st class or picked bricks in soling. Fine sand @ 5 cft per 100 sft to be used as bed and fill in gaps in between two bricks.

Don'ts : Don't use under burnt brick in soling, otherwise it will arrest moisture and make your floor damp.

C. 4" to 6" C.C. (Cement Concrete 1:3:6) Casting

This is called lean concrete and is used in the proportion of 1:3:6, (cement: sand: khoa) in following way:

a) Proper seiving and soaking of khoa be done. Sand may be cleaned for.

b) Mix measured sand and cement seperately.

c) Now mix it with khoa and water, uniformly to achieve a workable consistency so that it is neither too loose nor too dry.

Don'ts :

1. Don't add water to the mixture much ahead of time to caste it. Because, as soon as water is added, chemical reaction for setting of cement starts. In most cases, initial setting time of cement is 30 to 45 minutes counted from additing water. So the mixture need be casted as early as possible
2. Don't pour over stored water lying in the foundation. Bail out water before casting.
3. Don't add water before 24 hours for the purpose of curing.

D. Brick work in foundation.

a) Use 1:5 (cement:sand) mortar.

Immersion of bricks into water be made for a minimum of 6 hours for quality works. Your septic tank be constructed first to use it for the purpose

b) For 100 cft. brick work, you need 1100 Nos. bricks, 36 cft sand and 4 bags of cement.

Don'ts : 1) Don't make steps of footing less than 6". That means, offsets be atleast 6" thick and 2½" wide

2) Don't use unclean water.
3) Don't make haphazzard bonds.
4) Joints should not be racked, rather, it should be levelled vertically.

E. D.P.C. (Damp proof course)

Can be done in the following ways :
a) By 1:2:4 concrete with pea gravels or khoa 1" to 1½" thick.
b) Laying polythene paper on wall and concreting above, it in 1" to 1½" thickness. Coat of bitument may also be applied.
c) Bitumenous layer @ 1.5 kg/m² is also applied.
Don'ts
1. While applying bitumen over concrete, see that it is dried up for atleast 24 hours. Don't apply bitumen over wet surface.

F. 10" Brick work above plinth
1:6 (cement:sand) mortar be used. Others are same as item 4. In this case racking can be made for the purpose of pointing or plastering.

Facing brick works (of ordinary brick size).
10 hole and 17 hole machine made bricks can share load of the building as well as it can act as facing one by interlocking inner 5" wall and facing 5" wall by means of z bars made of 12 gauze G.I. wire or ¼" M.S. rod. For 100 sft of (5") brick work materials needed are bricks: 480 nos. Cement: 2.6 bags, sand 17 cft. Joints for facing works should be racked and brick faces be cleaned with brush (preferably of hair) immediately after placement.
Don'ts : 1. Don't use such porous brick in walls of rooms than face wall, because it absorbs moisture .and make walls damp. A core wall of 5" solid bricks in inner side and 5" facing bricks be interlocked as stated.

2. Don't allow haphazzard gaps between bricks. Such gaps should not be less than ¼" and a maximum of ½"
3. Washing by bruss is important, other wise permanent-cement scratch will remain on the face.
4. Don't allow dry bricks for use. It should be properly soaked in water like usual bricks.
5. Don't use red oxide and linseed oil wash over such bricks which is subject to disfiguration. Use bricks colour paint liquified in pure linseed oil in 1:1 (paint:oil) proportion.
6. Don't apply thick painting coats which may come out as scraps.

G. Facing Bricks : Pressed solid bricks of 8" × 4" × 2" size.
This is the best of the facing bricks at the same time costly. But if sawn into halves, it becomes very economical. So, 4" and 2" facing work is possible with these brick by bonding with Z bars or brick bonding with main wall in usual manner. Now, 2"×2"×8" bricks are available.

8.20 Material Requirements: for 100 sft face work

a) 4" thick wall :
Bricks - 700 Nos.
Cement - 2 bags.
Sand - 10 cft.

b) 2" thick wall :
Brick - 355 Nos.
Cement - 1 bag
Sand - 5 cft.

8.21 5" and 3" Thick Ordinary Brick Walls

Such wall should be constructed in cement:sand mortar in 1:4 proportion. They can be directly constructed over floors or concealed beams.
Don't : Don't allow length of 5" wall beyond 10 ft. (3.05 m.) 10" × 10" brick pillar supports may be used. In case of 3" wall the limit should be 6' (1.83 m).

8.22 3" Concrete Flooring

After the sand fill is made in the plinth satisfactorily compacted, a soling may be given or brick bats may be rammed into it for preparing firm bed. Then 2½" to 3" (62 mm to 75 mm) thick C.C. (Cement concrete) in 1:3:6 (cement:sand:khoa) be applied using all procedures for lean concrete as in foundation.
2" thick 1:2:4 concrete may be used for cheaper neat cement finished floors. Pure cement sprinkling ½" (3mm) thick over it be made the same day of casting concrete.
This floor may be used for rough floors. For neat finishing works, a treatment of patent stone flooring or mosaic need be done over it and for such work due clearance at the top be kept. Don't cast such floors over highly filled ground unless the fills are properly compact.

8.23 1" or 1½" (25 or 37 mm) Thick Patent Stone Flooring with Neat Cement Finishing

Pea chips of stone or bricks in 1:2:4 be used in the above mentioned thickness properly rammed and levelled. Pure cement sprinkling be made upto ⅛" (3mm) thickness on the same day of patent stone casting so that proper bond is maintained.
If, somehow or other, it is not possible to make neat finishing on the same day of casting, scraching be made with hard brush on the surface to facilitate bonding.
Flooding water after 24 hours be kept for at least 7 days.
Don'ts : 1) Don't apply neat finishing course after the base floor is dried up. It is of utmost importance that finishing be done on the same day of casting other wise broken pieces will come out in scrap form.
2) Don't forget to count the days of curing period which is normally one week; two weeks is better.

8.24 ⅛" (3 mm) Thick Red Oxide Colour Flooring

Now a days, pure colours are hardly available and such type of floor finishing is discouraged. However, for dry regions this is agreeable. But never do it where water table is closer to the ground surface. Presence of water causes disfiguration of the colour.

8.25 $^3/_8$" (9 mm) Thick Silver Grey Situ Mosaic

Mixture : White cement:Marble dust:Grey cement, be taken in 1:1$^1/_2$:3 proportion.
Paste : 1 part of marble chips : 1 part of mixture. Base be prepared of $^3/_4$" to 1" patent stone flooring.

8.26 Contrast

For better look the following proportion of different marble chips be taken.

3 mm white marble chips (out of 10 part)		7
"	Black	1
"	Red	1
"	Yellow	1

1st cut may be given after 24 hours, consecutive cuts may follow for 3 days. After every cut (except the final) white and grey cement mixture be sprinkled over the floor. Oxalic Acid wash and wax may be used for better finish. But wax finishing may be avoided, because it arrests dust and forms a coating on the floor.
For small works, hand cutting by a pumice stone may be done. For big areas electric cutting machine be used.
Panneling by 3 mm glass $^3/_4$" wide gives good out look.
Don'ts : Don't delay in cutting after casting of mosaic material. More it is delayed more it becomes difficult to achieve desired finishing.
Coloured Mosaic : Add sufficient pigment to desired colour in item no 8.25 Only change is that, grey cement be omitted and the proportion of mosaic chips to white cement will be 1:1.
Mosaic Tiles : Size 8" x 8" x $^3/_8$"
Thickness of Top mosaic =$^3/_8$" (as in item 8.25)
Pressed mortar base 1:2 (cement:sand) $^3/_8$" i.e. 50% base 50% mosaic topping for coloured and design tiles necessary pigment and set of designs can be provided.
Fixing Mosaic Tile : Lime mortar is preferred. In the proportion of 1:3(lime: surki) be used. Mortar thickness is preferably 1$^1/_2$" (37 mm).

8.27 R.C.C. Works in Column, Lintel , Beam , Roof and Slab

Proportion 1:2:4 (cement:sand:khoa)
Use picked jhama chips and best quality coarse local sand. If the sand is not coarse, then use a mixture of 2/3rd local and 1/3rd sylhet sand for good results.

8.28 Cement Plaster (C.P)

a) For wall $^1/_2$" thick 1:6 (cement:sand) plaster is normally given.
b) $^1/_4$" thick C.P.1:4 is given to ceiling columns, beams, stairs, sunshades, cornices, railing, drop walls, louvers, fins, including finishing corner, cleaning surfaces corners and edges..
c) Ruled pointing is done in (1:2) by racking out joints.

Don't : a) Don't apply c.p to surfaces not properly cleaned.
b) Don't forget to keep it soaked with water for atleast 7 days continuously.

8.29 White Wash

Slacked lime, gum and blue pigment be applied in three coats. For maintenance works, two coats are enough.
Don't : Don't allow coats unless previous one is completely dry.

8.30 Colour Wash

Prime coat with slaked lime is first given after necessary cleaning, then two coats of colour wash yellow/red or any colouring pigment mixed with gum and lime be applied.
Don't allow next coat untill previous one is dried up.

8.31 Distemper : Oil bound or water bound distemper two coats over a priming of chalk wash with glue is applied. Before applying cleaning surface with sand paper is necesary. Don't apply coats unless previous one is dry.

8.32 Snowcem Wash : Of approved colour required two coats over a coat of priming. It needs curing with water.
Don't : a) Don't allow next coat before the previous coat is dried up and cured. b) Don't forget to water the surface. After the final coat is given (which is normally the 2nd or 3rd coat) spray water over snowcem surface for curing for a minimum of 5 to 7 days. Examine that it does not come out with finger tips when pressed over it.
Don't select these colours : (i) Brick-red (ii) Mid-Cream, (iii) Primrose, (iv) Apple Green, (v) Turquose, (vi) Medium Blue, (vii) Slate, (viii) Dove Grey. ∴ are subject to fade away in our atmosphere.
Selective colours will be : (i) Pink, (ii) Cream, (iii) Light green, (iv) Silver grey, (v) Pale grey and (vi) White (VII) offwhite

8.33 Painting : For wood surface, ready mixed enamel paint is used. 2 coats are enough. For plastered wall, brick face etc. plastic paint is used. Enamel paint is diluted with tarpentine and plastic one with water. Don't try to give one thick coat at a time rather 2 thin coats are prefered.

8.34 Lime Concrete over Top Roof

Usually 2:2:7 Lime:surki:khoa is used. After mixing the ingradients it is better to keep intact for 3/4 days and then laying to proper slope is made and beating follows: Finally 1;1 (lime:surki) wash 3/4" thick be given.
Don't : Allow white wash or ceiling plaster on the last roof before L.C. is completely dried. Otherwise, permanent scraches on walls and ceiling will appear on faces and hiding it with white or colour wash may become difficult.

8.35 Wood Work : It includes door, window, shutters and frames. Few best quality woods are named as under :

a) Burma Teak
(b) Chittagong Teak.
c) Teak chamble
(d) Gammer,
e) Telsu
(f) Chapalish.
g) Sal wood
(h) Sil Karai
i) Kathal
(j) Garjan etc.

Height of standard Door is 6'- 10". Wooden shutter thickness 1½". Height of standard window is 4'-0"

8.36 Mild Steel Work

A. Window grills : are made of ¼" x ½" section, shutter be made of Z' section of size ¼" x ¾" x ⅛"
B. M.S. Rods in columns : should be billet.
C. In beams and slabs : scrap steel may be used. Billet and deformed bars are preferable.
D. Corner reinforcement : be provided at free corners in a manner of 3 rods diagonally at top, length being L/4, another three rods at bottom cross to the diagonal rod. Dia of rod same as that of main reinforcement.

8.37 Water Proofing : 1:1 cement plaster mixed with ¼th, part of water proofing cement like padlo concentrated cement may be used. For heavy water proofing 1:3(padlo cement: sand) proportion be used. Practically all 15" brick wall in 1:4 are water proof.

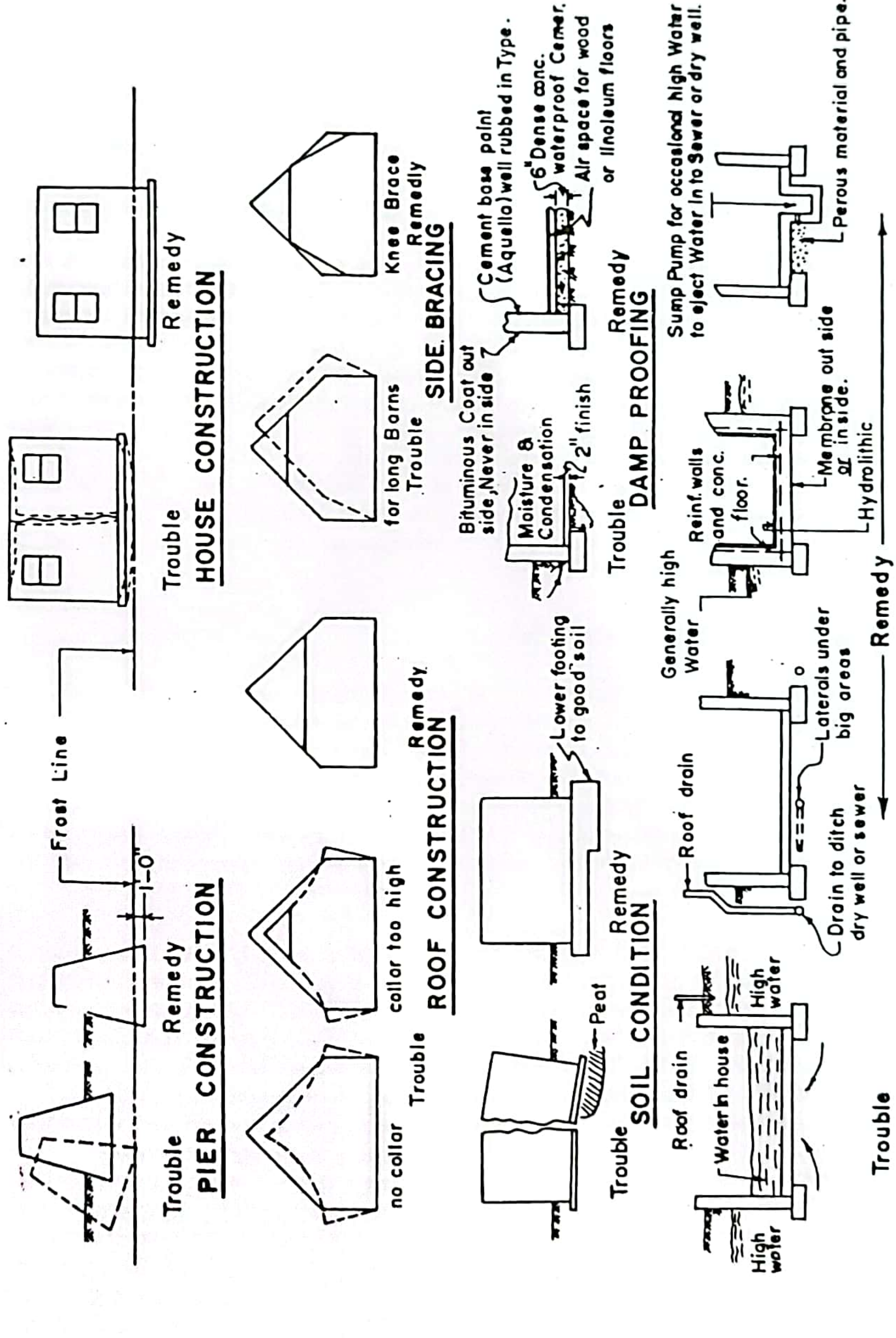
8.38 Cantilever Works

Any projection supported by the main wall or beam fall under this category. Stair, Verandah or portico may be a cantilever one. It should be kept in mind that all cantilever members are very critical in its construction and special care should be given to it.
R.C.C. cantilevers develop tension at the top near the support. As such, reinforcing rods be placed at the top with nominal reinforcement at the bottom. For example, you want to make cantilever stairs i.e. each step is a seperate one except connected by means of railing. Each step will be 10" wide and 3' long. The supprting wall should be 10" wide or a beam of similar width be proivded. Four nos, ½" dia rod, two full length and two half length be placed at the top having ¾" cover. Two ⅜" dia rod be placed at bottom. Rings may be provided with ⅜" dia rod placed 9" c/c casting forms must be leakproof. 1:1½: 3 or 1:2:4 concrete be used.
When taking away wood, plane sheets of the form, notice that support of the free end is taken away first. In any case don't push the free end upward.

8.39 Common Defects and Remedies

Few defects have been graphically shown in accompanying sketch. Other common defects are.

Fig 48 ERRORS & REMEDIES



1. Hair cracks
2. Cracks in walls.
3. Cracks in roofs.
4. Dampness etc.

Hair cracks

These minute cracks are harmless. Poor curing also creates such cracks.

Wall cracks may be due to soil pressure which increases in rainy season, due to bulking of moist soil and decreases during winter due to shrinkage. This may also occur due tr uneven settlement of foundation. This may be harmful.

Repair with grouting is necessary. Severe settlement cracks may need under pining.

Cracks in roofs are two fold. One occurs in corner due to faulty corner reinforcement and the other occurs at middle of the slab due to excessive tension and more concrete covers. Concrete covers should be correctly 3/4" in slabs.

Another type occurs below pvc concealed conduit. Such conduits should be placed over rods. Even extra pieces of rods may be provided perpendicular to the conduit in the bottom position.

Dampness causes serious damage to walls and floors, Walls should be furnished with DPC and ground floor should be casted over 2" stone chips and 3/4" pipes may be inserted in the floor bottom to arrest moisture. Concealed water pipes also causes dampness. It should be repaired by breaking the wall and replastered.

8.40 Quality Control

QC should be maintained for all construction works. The quality of mill-produced materials, such as structural or reinforcing steel, is guaranteed by the producer,who must exercise systematic quality controls, usually specified by pertinent ASTM (American Society for Testing and Materials) standards. Concrete, in contrast is produced at or close to the site, and its final qualities are affected by a number of factors which have been briefly discussed. Thus, systematic quality control must be instituted at the construction site.

The main measure of the structural quality of concrete is its compressive strength. Tests for this property are made on cylindrical specimens of height equal to twice the diametre, usually 6×12 inch or 6"× 6" ×6" cube. Impervious molds of this shape are filled with concrete during the operation of placement as specified by ASTM. The cylinders are moist-cured at 70 ± 5°F, generally for 28 days, and then tested in the laboratory at a specified rate of loading. The compression strength obtained from such tests is known as the cylinder strength f'_c and is the main property specified for design purposes.

To provide structural safety, continuous control is necessary to ensure that the strength of the concrete as furnished is in satisfactory agreement with the value called for by the designer. The "Building Code Requirements for Reinforced Concrete of the American concrete Institute, ACI 318-63 (referred to as the ACI code). Specify that a pair of cylinders shall be tested for each 150 yd3 of concrete. It provides two degrees of control (1) the avarage of any five consecutive pairs shall be at least equal to the specified design strength, and not more than 20 percent of the pairs of tests may have values smaller than specified, and (2) the avarage of any three consecutive design strength and not more than 10 percent of the pairs of tests may have values smaller than the specified strength. These requirements provide for adequate average strength as well as for satisfactory uniformity. At the same time they recognize that it is not economically possible to manufacture concrete, or any other material, for that matter, without occasionally producing small quantities of some what substandard quality. The more advanced design methods known as ultimate-strength design may be used only when control conforms to the more rigorous requirements of 2,above.

Inspection during construction should be carried out by a: qualified, engineer, preferably the one who produced the design or one who is responsible to the design engineer. The inspector's main functions in regard to materials quality control are sampling, examination, and field testing of materials, control of concrete proportioning, inspection of batching, mixing, conveying,placing, compacting, and curing, and supervision of preparation of specimens for laboratory tests. In addition, he must inspect foundations, formwork, placing of reinforcing steel, and other pertinent features of the general progress of work, keep records of all the inspected items and prepare periodic reports.

9 Providing Facilities in the Home

"Earnestness is enthasiasm tempered by reasons"
— Pascal.

After the main structure is complete, it becomes necessary to provide different facilities within it. Sanitary, water supply. electrification and gas supply works are the necessities in life while air conditioning, hot water, cold water system, installing lifts, escallators are luxary items which can be seldom provided by the General people. Since, they are modern amenities of life, discussion regarding the subjects is however made herein.

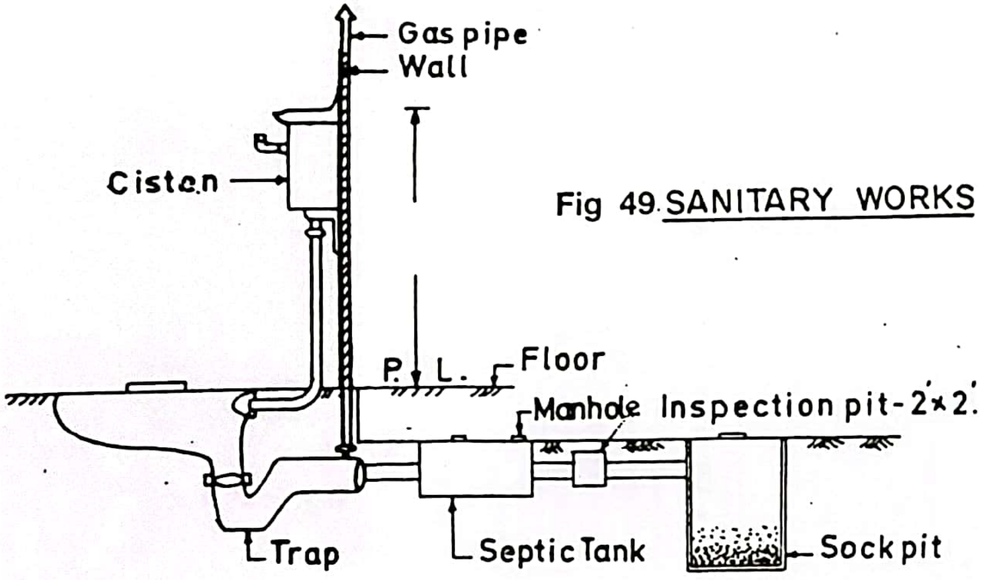
9.1 Sanitary and Water Supply Works

The Works Include :

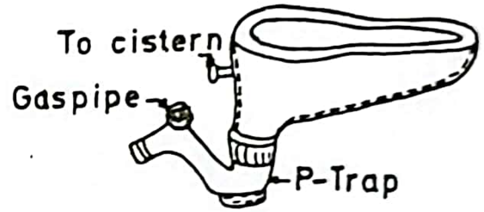
1. Constructing Service line i.e. connection with main supply line through a metre preferably with 1" dia G.I. pipe.
2. Constructing underground reservoir.
3. Procurement of a water pump (for more than two storied homes).
4. Construction of over head R.C.C. or G.I. Tank. Convensional Tank size is 4'×4'×4' made of 16 gauge, galvanised iron sheets.
5. Constructing pipe lines to baths, kitchens gardens etc.
6. Waste water outlet.
7. Sanitary piping
8. Septic tank
9. Soak pit.
10. Inspection pit with man holes
11. Bath room fitting.

   Plans of household septic tank is furnished at page 195 Normally, 10 or 30 users septic tank is necessary. For community use 100. and 200 users septic tank is used. Its plan is furnished at Page 196 Plan of standard soak pit is furnished at Page 197

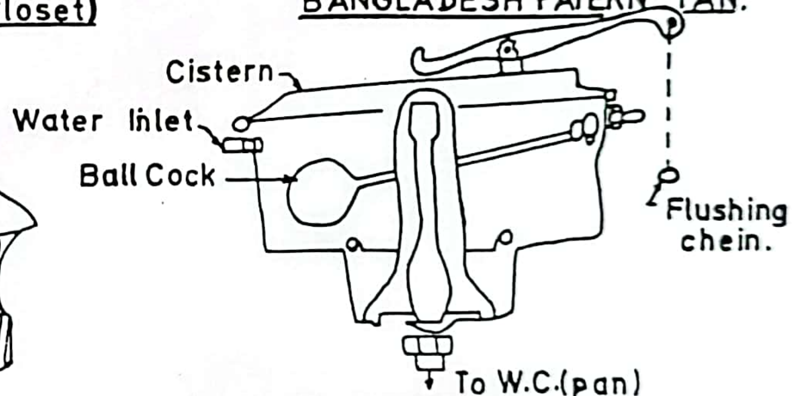
Fig 49. SANITARY WORKS



INDIAN OR BANGLADESH TYPE W.C(Water Closet)

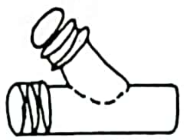


BANGLADESH PATERN PAN.



FLUSHING SYSTEM.

PLAIN BEND



JUNCTION

COWL(Over gaspipe)

9.2 Service Connection

For one or two storied house, connection may be given to over head tank directly. But where such water pressure is not available, 3/4" to 1" dia line be connected to the under ground reservoir. Such reservoir is helpful to store water during construction also.

At the inlet, a ball cock be furnished to check over flow and water wastage.

N.B. Never make septic tanks nearer to this reservoir. They should be approximately 20' apart.

Minimum Sizes of Water Supply Pipes

Fixture Device	Pipe Size
Bathtubs	1/2 Inches.
Drinking fountain	3/8 Inches.
Kitchen sink, residential	1/2 Inches.
Kitchen sink, commercial	1/2 Inches.
Lavatory	3/4 Inches.
Laundry	3/8 Inches.
Shower (single head)	1/2 Inches.
Urinal (direct fluch valve)	3/4 Inches.
Water Closet (tank type)	3/8 Inches.
Water Closet (flush valve type)	1 Inches.
House bibbs	1/2 Inches.
Wall hydrant	1/2 Inches.

Capacities of Building Drains and Sewers :

Diametre of Pipe (inches)	Maximum number of fixture units that may be connected to any portion of the building drain or the building sewer (Fall per foot)			
	1/16 Inch.	1/8 Inch.	1/4 Inch.	1/2 Inch.
2			21	26
21/2			24	31
3		20**	27**	36**
4		180	216	250
5		390	480	575
6		700	840	1000
8	1400	1600	1920	2300
10	2500	2900	3500	4200
12	3900	4600	5600	6700
15	7000	8300	10,000	12,000

Courtesy :
American Society of Mechanical Engineers.

* Includes branches of the building drain.

** Not over two water closets.

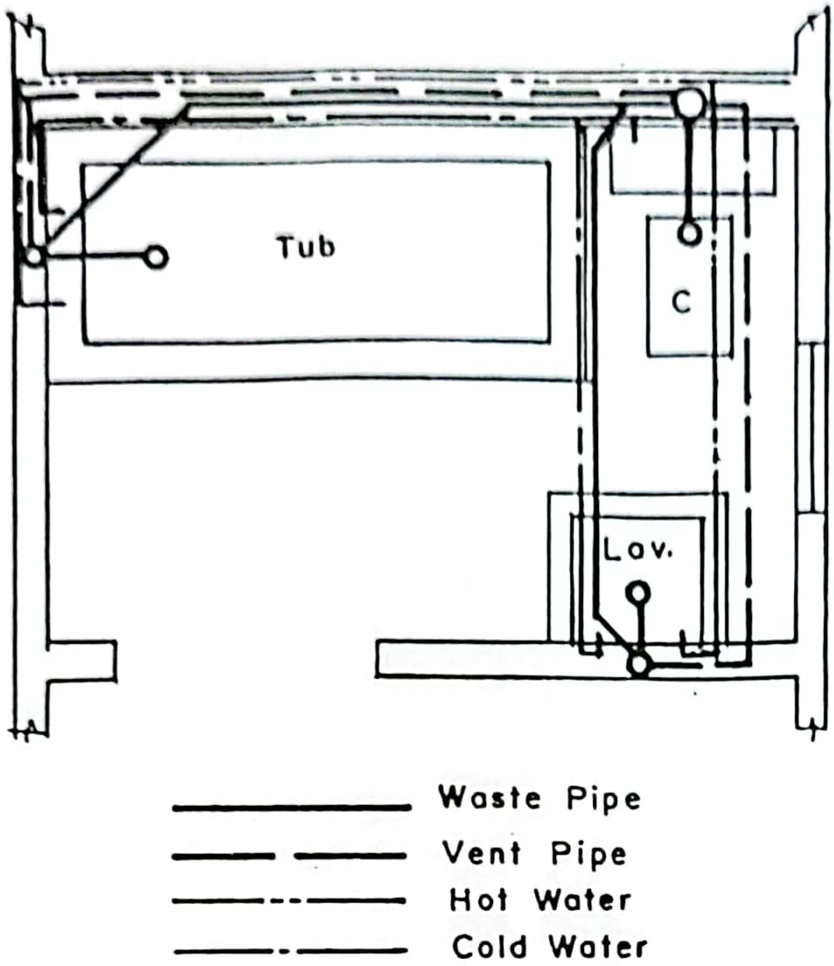


Fig 50 : Typical piping layout for a bathroom

9.3 Under Ground Reservoir

Size :- Depends upon No. of users. The following specification can be used.

	Length		Breadth		Depth
For one storied house	6′	×	4′	×	4′
" two " "	6′	×	5′	×	5′
" three " "	7′	×	5′	×	5′
" four " "	9′	×	6′	×	5′

Side walls : Practically, all 15″ wall are water proof except a negligible seepage due to water height in tank. For economy, 10″wall in (1:4) mortar over 6″-9″ high 15″ wall from the bottom be made. The bottom slab should not be less than 5″ in thickness.

Plaster work be in 1:3 (cement:sand) mixed with av. 5% water proofing agent like the pudlo cement. Polythene sheets at the bottom upto 1/3rd wall height may be used for better results. For heavy water proofing pure pudlo and sand in the proportion 1:3 be used.

9.4 Pumping Water to Over Head Tank

A pump preferably of 1 H.P. (horse power) fitted with condenser gives troube free service.

A cutout and a 5 amps main switch be provided in the line or otherwise

specified by the manufacturer.
For safety of the pump it can be installed in a suitable place in Ist floor. All pumps can lift water theoritically upto 26'. But the bends and skin friction of pipe and other head loss, practical height will vary from 15' to 20'. Provide good check valve and avoid more bends and elbows.
The over head tank be fitted with a over flow pipe to ease the pump operation.

Summary of materials you need :

1. One pump complete with motor preferably having 1" suction and 3/4" or 1" delivery sides.
2. 1"-3/4" pipes, bends, tees
3. Platform for fixing pump.
4. Electric wire preferably of 7/.044 size.
5. One cut out 5 amps and a 5-amps main switch and switch board.

9.5 Over Head Tank

Convensional 4'×4'×4' (64 cft) size G.I. tank may be used. 1 cft. of water equals 6.25 gallons. The capacity of the above tank is 64×6.25= 400 gallons. In developed countries one person (per capita) uses av. 25 gallons of water per day. In our country av.10 gallons/person may be assumed. One such Tank can serve two families per day. For four, 2 tanks are required.
At least 1½" dia pipe be used for interlocking two tanks, if needed.

9.6 R.C.C. Tanks

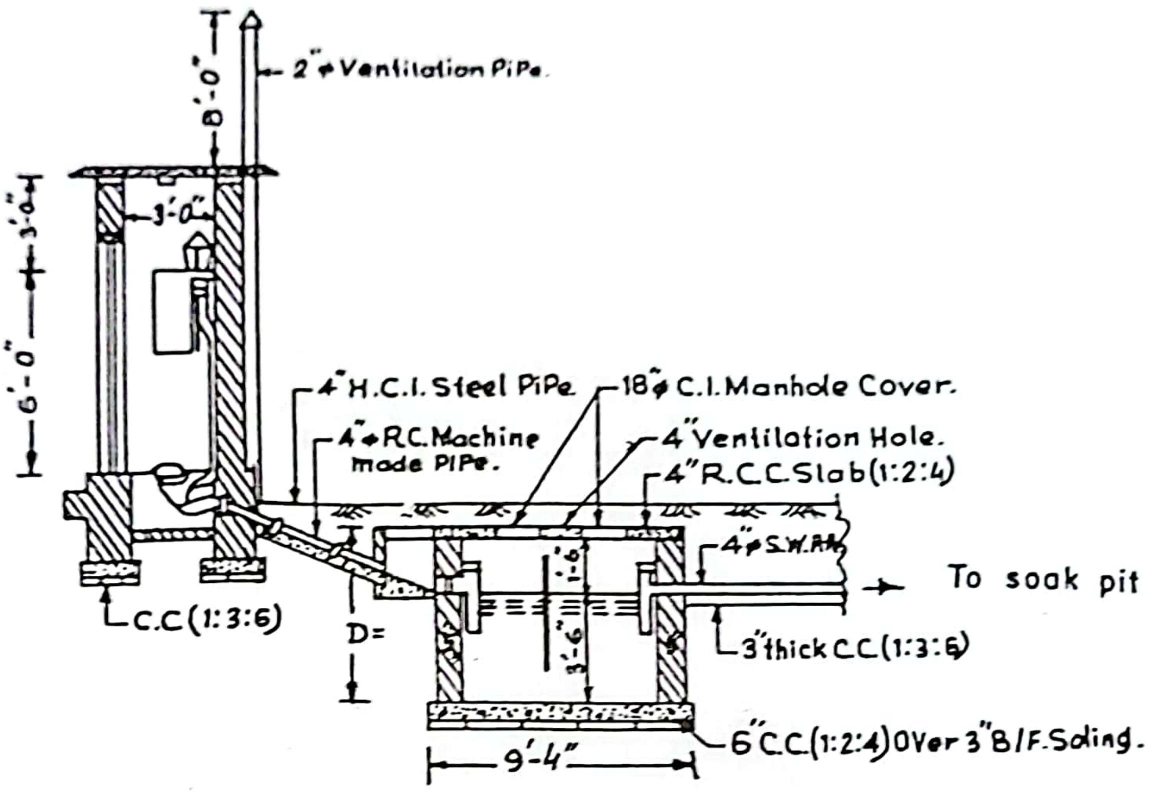
Floors of such tank should be minimum 5 thick. Height of the tank should not be over 5'-0' having same wall thickness, doubly reinforced with 3/8" dia rods @ 4" C/C. Plaster with water proofing agent like pudlo to be used to prevent leakage.
Point to note : Never construct it just over the roof. Otherwise, it will make the building damp. It should have elevated beams all around the bottom situated at least 1'-6" above the roof level.

9.7 Septic Tank

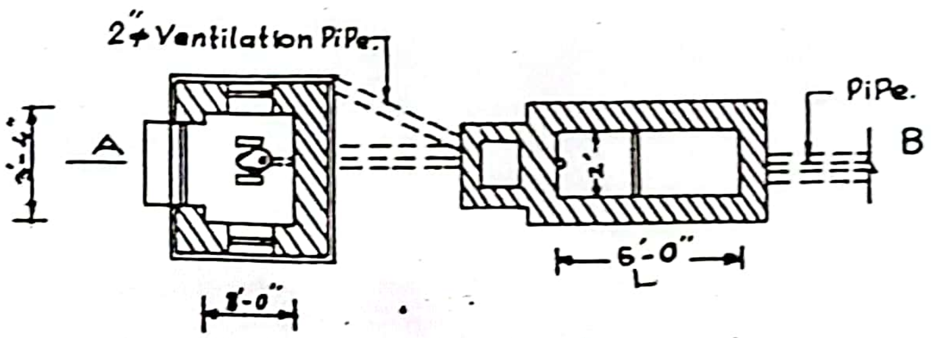
Construction of septic tank for 10 users may have two manhole covers 10" brick work(1:6) over 6" cement concrete floor (1:2:4) with 5" brick work in partition 3/4" cement plaster (1:4) to inside walls including supply fitting fixing of two R.C.C. Tees and providing 18" dia, water sealed heavy type C.I manhole cover with locking arrangement 4" thick R.C.C. cover over with 1% reinforcement, necessary earth work, shoring, bailing out water etc. complete as per design.

9.8 Soak Pits

Connecting soil plpes should not be less than 6" dia.
For 10 users 10" solid brick and 10" honey comb brick work in cement mortar(1:6) ovet R.C.C.(1:2:4) well curb,cover slab with 1% reinforcement, supplying and fitting fixing 10" dia water sealed heavy type manhole cover with locking arrangement, fitting well with graded khoa and sand necessary earth work side filling, bailing water etc. complete as per design.



SECTION ON-A.B.



PLAN

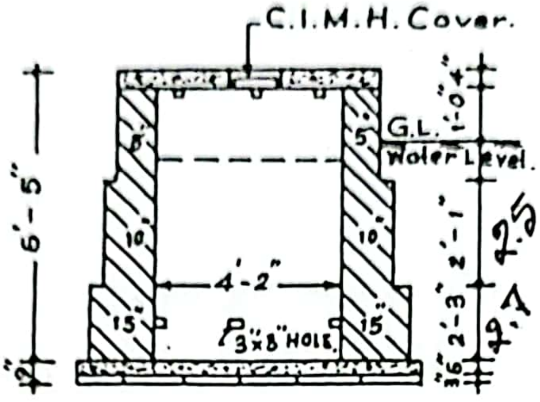
Fig 51 HOUSE HOLD SEPTIC TANK
(FOR 10 AND 30 USERS SEE TABLE BELOW)

TABLE FOR DIFFERENT SIZES OF SEPTIC TANK.

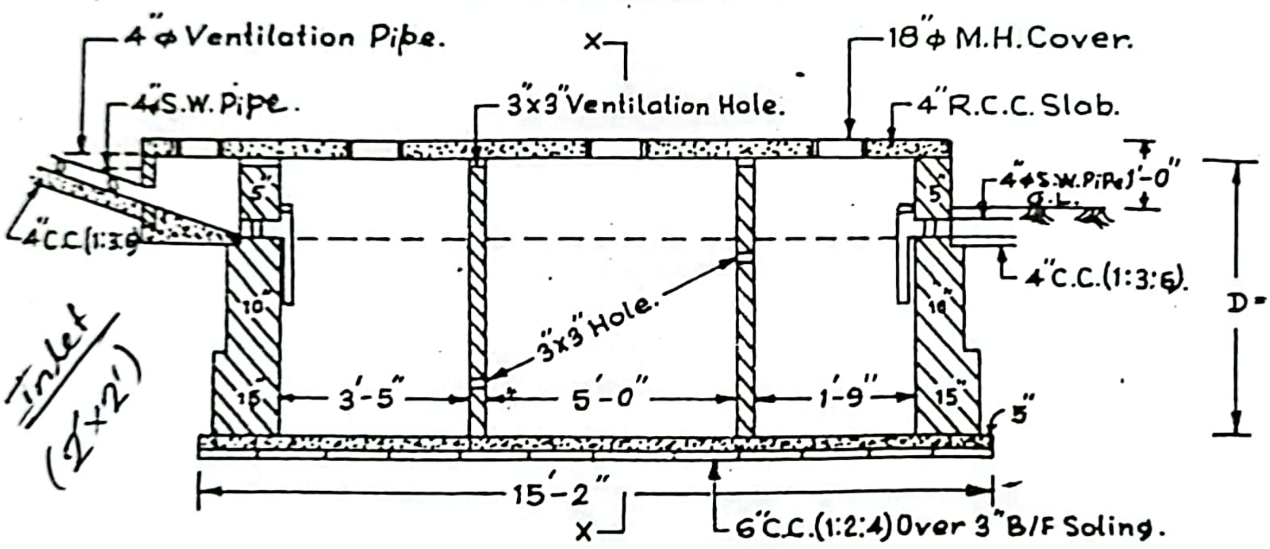
No. Of USERS	L.	B.	D.
10	6'-0"	2'-0"	3'-6"
30	9'-0"	2'-0"	4'-6"

Fig 52 **100 USERS SEPTIC TANK**

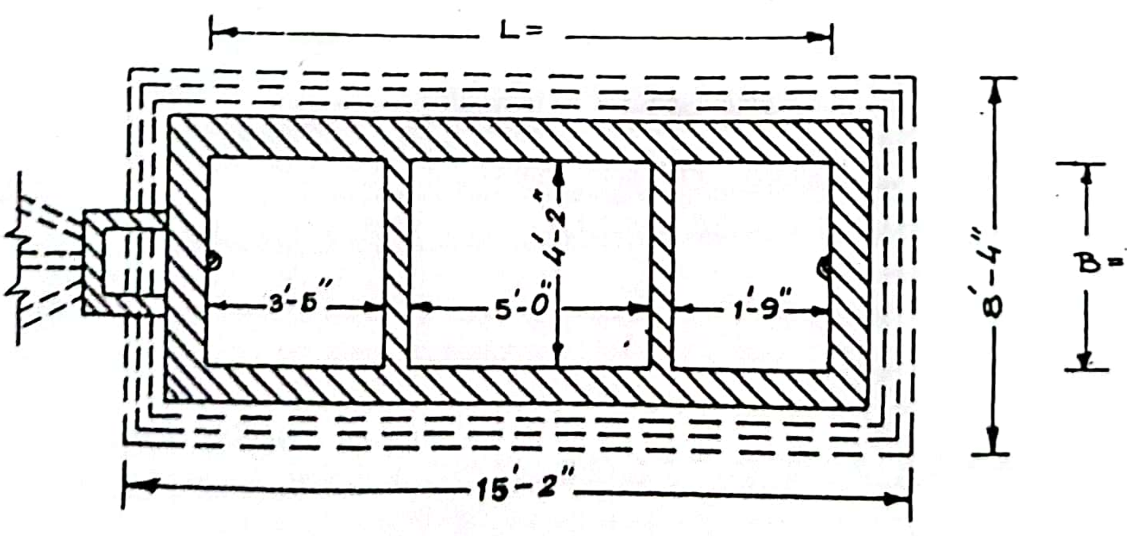
(FOR 100 & 200 USERS SEE TABLE BELOW:)



CROSS SECTION. X-X.



LONG SECTION



PLAN

TABLE FOR DIFFERENT SIZES OF SEPTIC TANK.

NO OF USERS.	L.	B.	D.
100	11'-0"	4'-2"	5'-10"
200	22'-0"	6'-0"	7'-2"

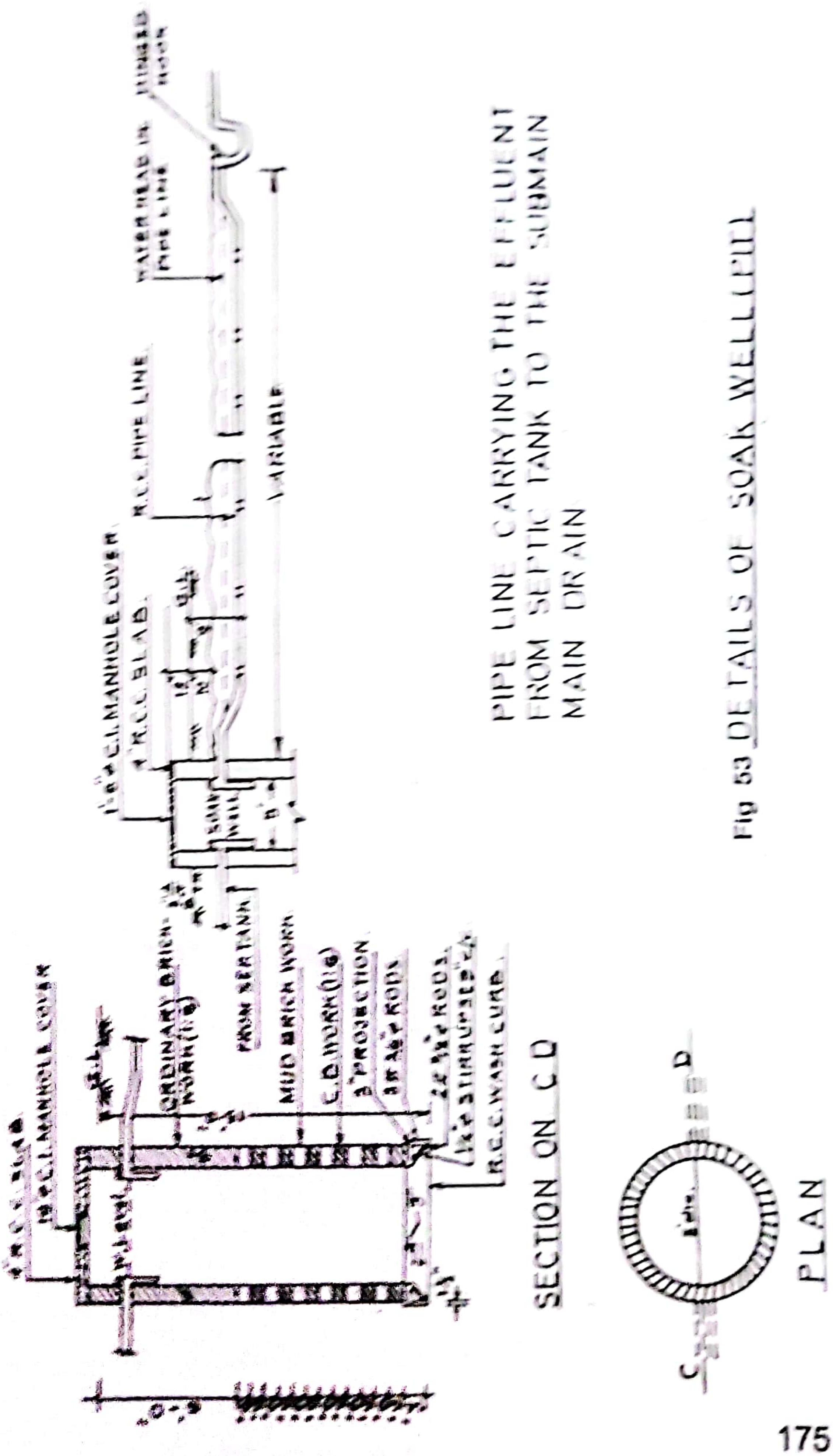


Fig 53 DETAILS OF SOAK WELL (PIT)

9.9 Fitting and Fixture List

1.18" W.C. pan shanks or Twyford or Bangladesh made. China, Thailand etc.

2. European type commode (Shanks or Twyford, IFO. Switzerland. with low down vitrous cistern , plastic seat cover and accessories.
3.2 Gallons capacity C.A cistern with 1¼" dia P.V C. flush pipe, brass coupling, brackets lead or plastic, pipes, stop cocks ball valve, pulling chain etc. complete.
4. Wash hand Basin of 16"×22" size ½" dia brass stop cocks, chromium plated pillar cock 1½" dia, waste water pipe etc. complete.
5. 24"×5"×¼" thick plate glass shelf.
6. Towel rails 24"×¾" or rings.
7. Inspection pit with 18" dia manhole. Size 2'×2'×2'
8. 4" dia soil pipes with bend, reducing sockets, junction door bend, coweis anti syphon etc.
9. 6" dia R.C.C.pipe laid over 3" thick 1:3:6 concrete.
10. 4" dia grating at the mouth of openings.
11. Porcelain sink for kitchen.
12. G.I. pipes 1½" dia.
1" dia.
¾" dia.
½" dia.
13. ½" bib cocks.

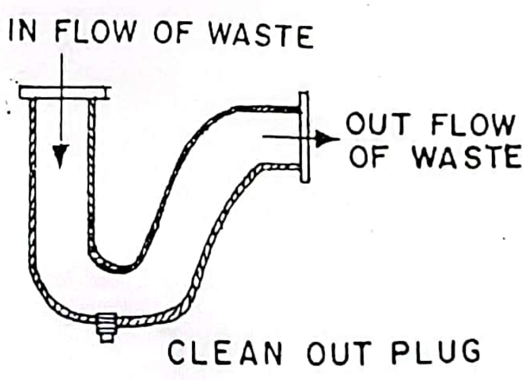


Fig 54 : P-trap

14. ½" stop cocks.
15. ½" peet valve, elbow, Tee plough, short piece, long/short trap, Doc Tee, Niple etc.
16. 3" to 5" dia shower rose.
17. 16 or 18 gauge G.I. Tanks 400 gals. size 4'×4'×4'
18. 18" dia manhole covers.
19. Soap holders.
20. Mirrors.
21. Heating Unit : 10 gals. to 20 gals. capacity gas fired and electrical heating units are locally available.
22. Cooling Unit : Conventional cooling units electrically operated are available in the market

9.10 Labour Rates

Rates received from a sub-contractor will be normally inflated ones as well as it may contain many items intermixing between them. Probable items are furnished herewith :

Probable rates for

Sanitary and water supply work

1.	a) 6" R.C.C. piping (including fixing stockiest, unions, bends etc complete line constructions)		Tk. 20.00 per rft
	b) 4" soil pipe		Tk. 17.00 per rft.
2.	Pit (2' x2' size)		Tk. 300.00 each
3.	Pan, cistern etc fitting		Tk. 150.00 per piece
4.	Basin fitting		Tk. 100.00 per piece
5.	G.I. Piping line construct including fittings -	$1\frac{1}{2}$" dia	Tk. 20.00 per. rft
		$\frac{3}{4}$" dia	Tk. 12.00 per. rft
		$\frac{1}{2}$" dia	Tk. 10.00 per. rft
6.	G.I. Tank fitting		Tk. 700.00 each
7.	Selves, soap case		Tk. 25.00 each

9.11 Electrification Works

The work includes :

1. Service connection i.e. connection of your house with main line.
2. Internal wiring which may be surface or concealed.
3. Furnishing panel Board Main switch, busbar, circuit, bridges and fuses.
4. Earthing
5. Light points
6. Fan points
7. Sockets for fridge, calendar etc.
8. Power line socket for air-conditioners.
9. Lightening arrester for high raise buildings over 60'.

9.12 Service Connection

a) Wire required : 7/.044 or 7/.064 sheathed wire is mainly required upto four storied houses, consumption limits being 60 amps to 90 amps.

b) PVC conduit pipe : 1" size.

c) Suspender : 12 gauge G.I. wire to support line may be necessary.

9.13 Wiring

a) Wire 14/.0076 flexible wire are used for ordinary lights. Wiring in the building is done with 3/.029 for light and fan, 7/.036 for 3 pin plug points.

b) Battens : CTG Teak or Garjan.

c) PVC conduct pipe : $\frac{1}{2}$" dia

9.14 Panel Board

a) 250 volt 15 amps circuit breaker.

b) CWT, iron clad busber of 100/500 A V (triple pole)

c) 15 amp. t.p. switch with re-wireable fire carrier.

9.15 Earthing : It is done by means of a Copper plate of 2' × 2' × $^{1}/_{8}$" size buried in the ground at a depth of 21 ft. or else depending upon avaibility of water table, the pit being partly filed with Charcoal powder and Common salt (sodium chloride) and drawing a 8 gauge copper wire from plate to the mains in $^{1}/_{2}$" dia G.I pipe.

9.16 Lightening Arrester : Normally 1" dia 3' long Copper rod with 5 spikes and balls are placed at roof top and a copper plate 2' × 2' × $^{1}/_{2}$" be embedded in a ground pit filled with carbon charcoal powder and common salt (Sodium Chloride) Both are connected by means of copper tape of 1$^{1}/_{2}$" × $^{1}/_{2}$" size in 2" G.I. Pipe.

9.17 Probable Labour Rates for Electric Works :

1. Main wiring per point (including fitting, battens, pipes bends, junctions etc complete).
   a) Concealed — Tk. 140/-
   b) Surface — Tk. 100/-
2. Earthing — Tk. 500/-
3. Bracket — Tk. 25/-
4. Main Switch fitting — Tk. 180/-
5. Main line — Tk. 5/- per rft.

A fan point is a point, a light point is a point. AV, Tk. 70/- is charged per point for all involvements incurred in making the point.

9.18 List of Materials for Electrical Works :

1. Wire : 7/.064 or 7/.044, 9/22
   3/.029 or 3/.022
   18 gauge Copper wire
2. Pannel and Switch boards of different sizes.
3. 5 amps. 10 amps cutout.
4. 15 Amps main switch
5. Combined switches, piano switches, ceiling and sockets, braket holder, batten holder etc.
6. P.V.C. pipes (1/2", 1" size as per requirement)
7. Bends, boxes, circular junction boxes.
8. Plastic tape
9. Bulbs
10. Tube lights.
11. Fans.

9.19 Gas Works :

For domestic use $^{1}/_{2}$", $^{3}/_{4}$", dia M.S. Pipe for 50 psi supply line is required to be connected with the burner through a one way stop cock made of heavy type brass.

Coaltering and wiring by black tape should be done around pipes before laying under ground.

Testing and purging the house line against leakage be made before the burner is actually commissioned, it is always advisable to contact an approved Titas Gas contractor for the purpose.

Involvements

1. Cutting road and its mending.
2. Laying pipe lines.
3. Fitting one way stop cocks as per specification of Titas Gas Co. Ltd
4. Fixingg single or double burner.
5. Testing and purging.

9.20 Air Conditioning

It can be done in two ways:

1. By making central air conditioning system.
2. By fixing air conditioners (package) units.

9.21 Central Air Conditioning This consists in big capacity cooling plants which supply regulated conditioned air through out the building through ducts and vents.

Ideal condition for comfort cooling is 80° F (Appx 26°C) temperature and 50% relative humidity.

The capacity is expressed in Ton. A TON OF REFRIGERATION is the amount of cooling that can be done by a ton of ice melting in 24 hours.

The load is expressed in Btu. (British thermal unit) Relationship to TON is as follows :

Capacity in ton = Capacity in Btu/12000

For installation of each central cooling system, experts must be called in.

9.22 Air-Conditioners These package units are easy to handle and can be fixed in different rooms having different sizes, Voltage required for such units vary from 220 to 250 volts, 50 cycles.

The following chart may help you in selecting the air conditioners according to room size.

A. Room size (Approx. 80 sq.ft.)	8'×10' 9'×9'	Air conditioner of 1/2 H.P. motor 5000 Btu/Hr (0.42 ton) is required. Approx. power consumption=770 watts Voltage 230-250v Volts, 50 cycles(Hz)
B. Room Size : (Approx. 150 sq.ft.)	10'×15' 11'×13' 12'×12'	1 H.P. Capacity 9000 Btu/Hr (0.75 ton. Voltage range 220-250 V 50 cycles (Hz) Power consumption=1360 watts.
C. Room size : (Approx. 200 sq.ft.)	10×20' 12'×16' 13'×15'	1 1/2 H.P. Capacity 12000 Btu/Hr (1 ton) Voltage range 220-250 V 50 cycles (Hz) Consumption 2060 watts.
D. Room size : (Approx. 240 sq.ft.)	12'×20' 13'×18' 15'×16'	2 H.P. Capacity 14,500 Btu/Hr. (1.20 Ton) Voltage range220-250V, 50 cycles (Hz) Power consumption= 2300 watts.

E. Room Size : (Approx. 300 sq.ft.)	12'×25' 13'×23' 15'×20'	2H.P. Capacity 18000 Btu/Hr. (1.5 ton) Power consumption 2600 watts Others are same.
F. Room Size (Approx. 350 sq.ft)	12'×30' 15'×23' 18'×20'	2½ H.P. Capacity=21,000 Btu/ Hr. (1.75 ton) Power consumption =2800 watts.

9.23 Lifts (Elevators), Escalators

These are two types :

1. Hydraulic lift normally used upto 50' height.
2. Electrical lift is used upto any height.

A lift has necessarily the following component :

1. Car or cab.
2. Hoist wire rope
3. Driving machines.
4. Control equipments.
5. Counter weight.
6. Shaft
7. Rails
8. Penth house and
9. Lift well

Capacity : Varies from 4 to 16 persons. One person weighs av. 65 kg.
Speed : Varies from 20 to 85 ft. per second. For upper stories, more speed can be designed.
Internationally famous lift makers :
1. National and Hitachi of Japan.
2. Hanslutz, Germany.
3. Schindler, Germany.

9.24 Escalators

These are inclined bridges carrying large number of people in market places. They have low power consumption. It looks like a stair moving always upwards.
Components :

1. Steel truss frame work.
2. Handle rails.
3. Belt with steps.
4. Roller chain.
5. Motor dirven sproket wheels.
6. Driving macines.

Speed : Normally moves at 90 or 120 foot per minute.
Slope : 30° standardised.
In Bangladesh, Chittagong Bipani Bitan is furnished with Escallators.

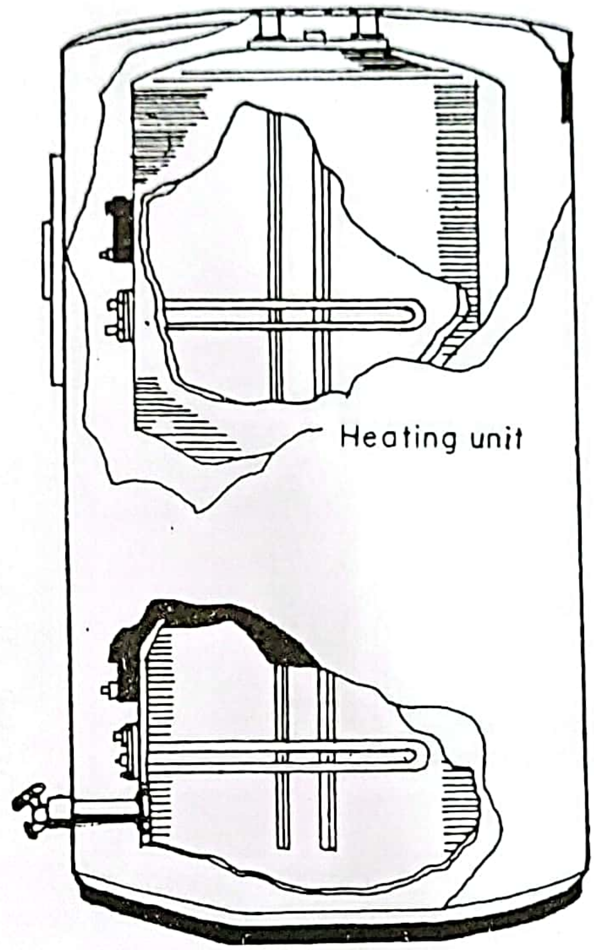
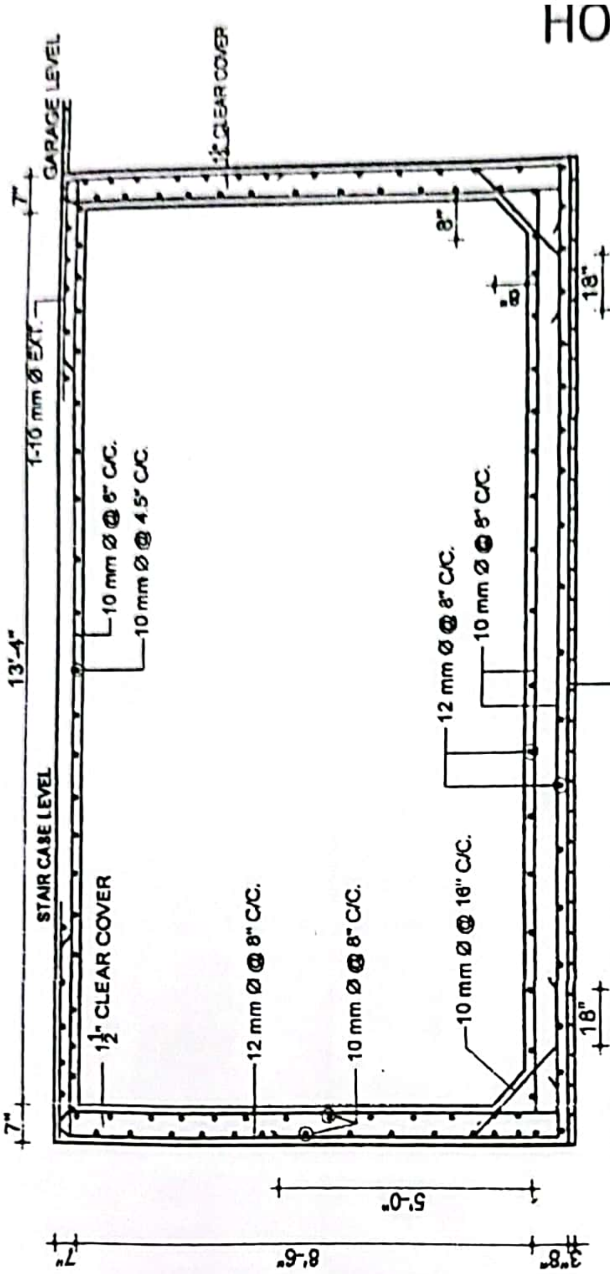


Fig 55 : Electric water heater

9.25 Hot and Cold Water System

In residential building, water is usually heated by gas or electricity. The hot water system carries the water, from the water heater to various fixtures. Units heat the water to a predetermined temperature and automatically shut off. When hot water is drained off and cold replaces it, they automatically turn on and again heat water to the desired temperature. All water heaters must have a pressure relif valve to prevent explosions. The accompanying diagram shows how water heaters works.



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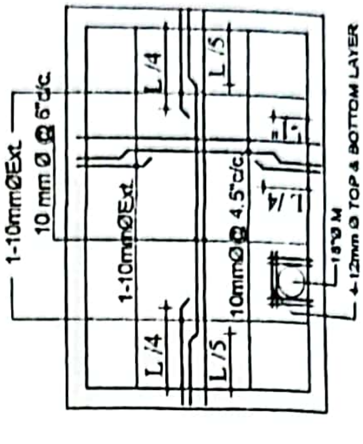
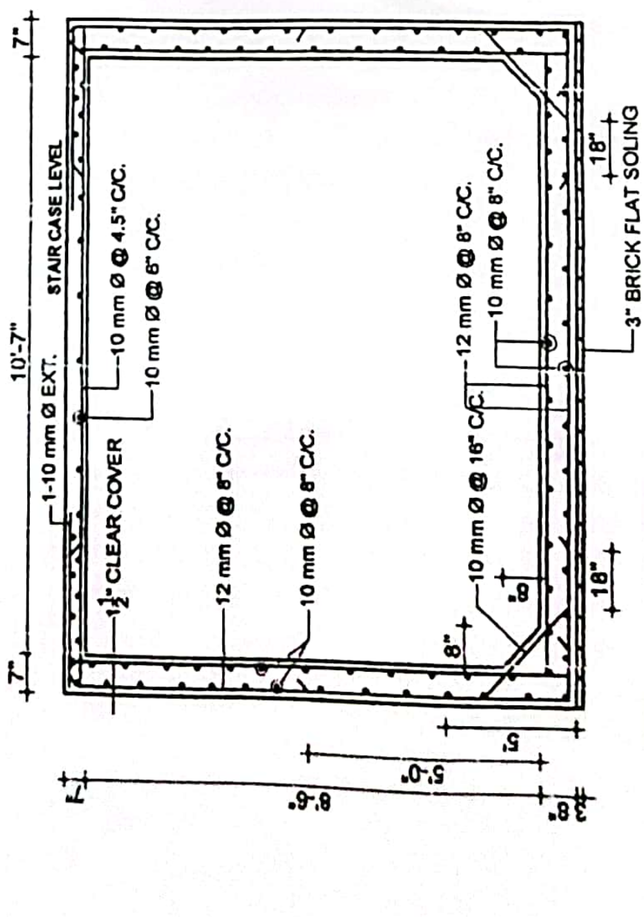


TOP SLAB OF U.G.W.RESERVOIR

A MODEL PLAN OF UNDER GROUND WATER RESERVOIR



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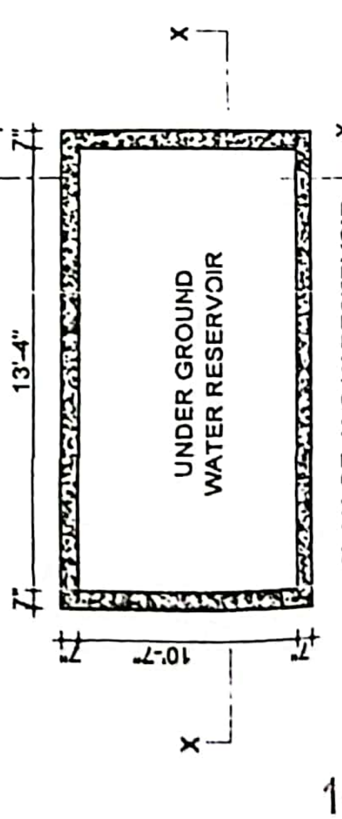


PLAN OF U.G.W.RESERVOIR

10 Beautifying The Home

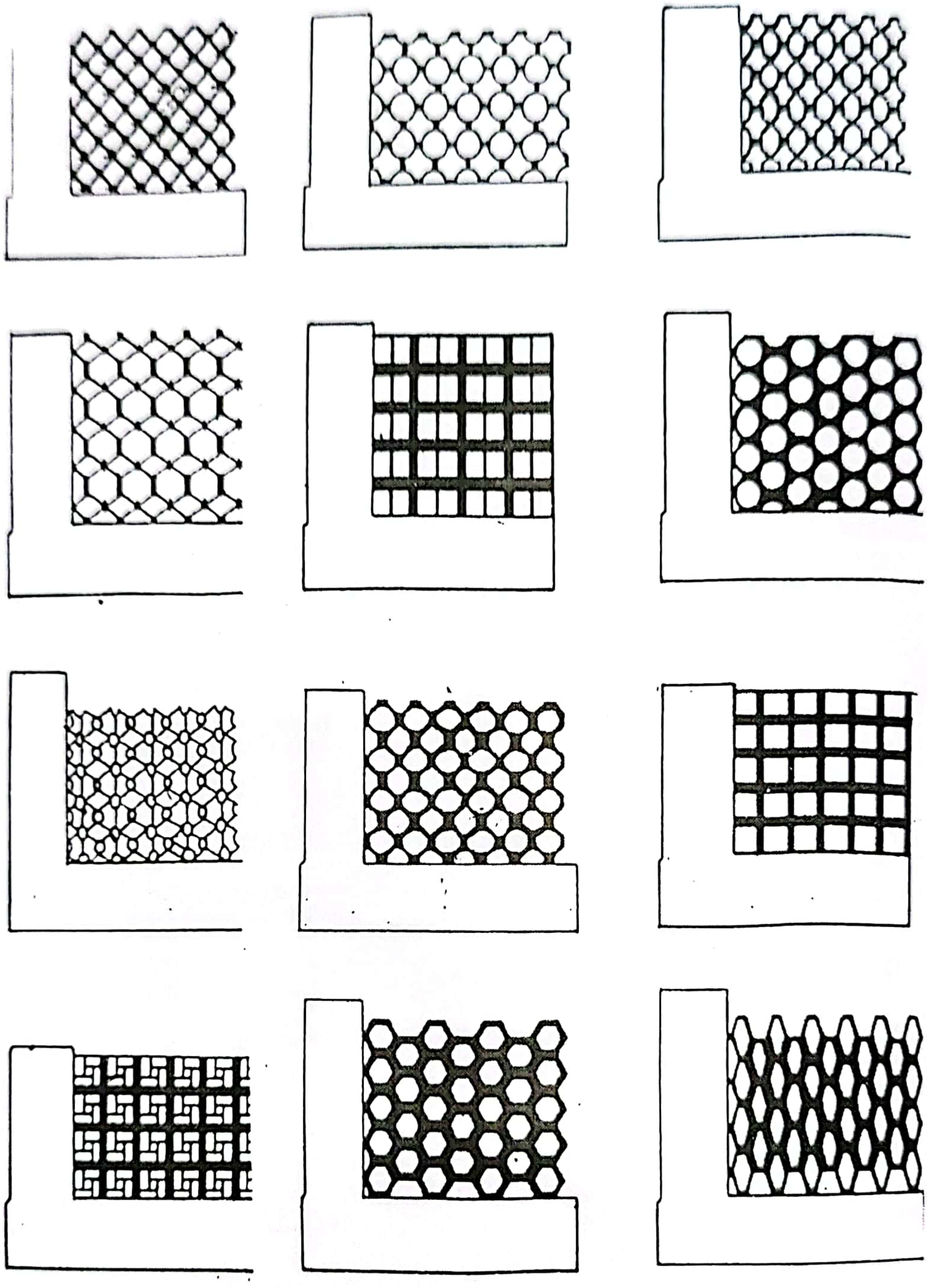
"Everything on earth is created for the Mankind"
— Al-Quran.

Beautification of the Home may be classed into two folds :
1. External beautification, and
2. Internal decoration.

10.1 External Beautification.

The former mainly consists in beatifying the building itself including its facade and the later in furnishing furniture, fabrics and other decors within the Home. Such job is best performed by an Architect and the Decorator. But they are beyond the reach of common people. As such, some ideas are reflected here with the help of colour photographs so that one can find out ways for making his home a nice one.
External beautification can be done in the following ways :
A. Providing architectural furnishings in the building.
B. Colour finishings.
C: Providing Greeneries in the front.

10.2 Architectural Furnishing :- Such things are permanently furnished while constructing the structure. Projection of decorative bricks, pattern of brick bonds, arches etc can be provided. Different types of arches and brick bonds are furnished. Decorative patterns of jally can be selected from catalog.



DEFFERENT TYPES OF JALLY

10.3 Colour Finishings :- As far as possible, the facade should be simple, wider and clean without too many engravings and decoration. Use of colour shades should be limited within three.

Ceramic brick colour and grey or pink shades give good contrast. Selection of colours may be made as per suggestion given in this book. One deep and one light colour be prefered. Colours shades are along with few snaps of goods buildings of Dhaka are furnished in the book.

10.4 Complementary Colour Schemes

While architectural renderings are sometimes done in analogous colour schemes, the most used are the complementary schemes. They greatly aid in developing contrast and are more natural.Nature uses complements such as the red rose on the green bush. The proper use of complementary colour produces a harmonious picture. If contrast is uncontrolled harmony is destroyed.

When a color scheme for a rendering is selected, one colour should dominate. Never should a colour scheme be based on complementary colours used in equal areas and full strengths. If an area is to be one colour, such as red, then its complement, green should be used in a smallar area or should be neutralized so it is not the same strength as the red.

A simple, yet effective, use of complementary colours is to use two-one warm and one cool. Usually, these are not used in full intensity. For example, portions could be done in orange with combinations of yellow and brown, while other areas could be in blue with green and violet indications. The cool colours complement the warm and are less assertive.

A person trained in the use of colour can successfully use complementary colour schemes in which the colour used are not exact opposites on the colour wheel, but are near opposites. For example, green is the true opposite of red, but yellow-green and blue-green are near opposites and can be used effectively in complementary schemes.

10.5 The Colour Wheel

The colour wheel will be of assistance in selecting a colour of your choice.

10.6 Greeneries :- Gardens are the beauty spots of the home. However the small plot it may be, a small greenery should always be provided. If space is available pools with artificial spring can be there.

The garden can be furnished with pernament types of trees like the palms, Aricaria or the like and seasonal flower can be sowed in seasons, Side by side, some vegetable can also be grown.

Cow-dung manure is the best. Compost can be prepared from waste leaves of the garden stored in a pit. Care should be taken for use of chemical manures. Plants may die, if such manures are applied close to the plant body.

10.7 Season Flowers : Some flowers are named here which are sown in Sept. to December.

10.8 Winter Season Flowers

1. Acter	9. Chrysanthemum
2. Cosmos	10. Dahlia

3. Clarkia
4. Gypsophilic
5. Lupines
6. Gailardia
7. Rose
8. Sunflower
11. Hollyhoch
12. Balsam
13. Calendula
14. Dianthus
15. Marygold
16. Poppy
17. Zinia

10.9 Summer Season Flowers

1. Balsam
2. Celosia
3. Coreopsis
4. Petunia
5. Marygold
6. Rose
7. Salvia
8. Portuluca
9. Time flower

10.10 Internal Decoration

Key to successfull internal decoration lies in three factors.
a. Colour
b. Furniture, and
c. Fabrics
Colour can transform plain things into instant beauty. Different furniture styles in teak or formcia or vineers makes the rooms handsome. Fabrics from cotton to velvets with colourful patterns induce pleasant soothing and dignified look in the Home.

10.11 Bed Room

Bed room is oasis for quiteness and peace. It should be absolutely personal for sleep, writing letters, reading books, seeing TV, music and a place to ponder thoughts.
A unique ceiling, distempered or wood panelled wall. furniture with clean lines and fabrics on bed, door and window, some fern in the tub, few sceneries on the frame can turn the bed into fancy one. Colour photograph of bed and child bed with internal decoration in American and Japanese style is furnished in this book.

10.12. Living Room (Drawing Room)

Living or Drawing rooms are the most looked at areas of the home. It says everything about you, your personality, taste and interest.
Use colour,furniture and fabrics to give it a smashing look. An American pattern furnishing is provided.

10.13 Bath Room

Bath rooms must be fancy and friendly. Glazed tiles, floor covering, w.c and accessories, tubs, hot water cold water systems enriches the dignity of the home. Modern designs can be seen in the accompanying colour photograph. Sanitary wares now produced in the country can be seen in the accompanying photographs.

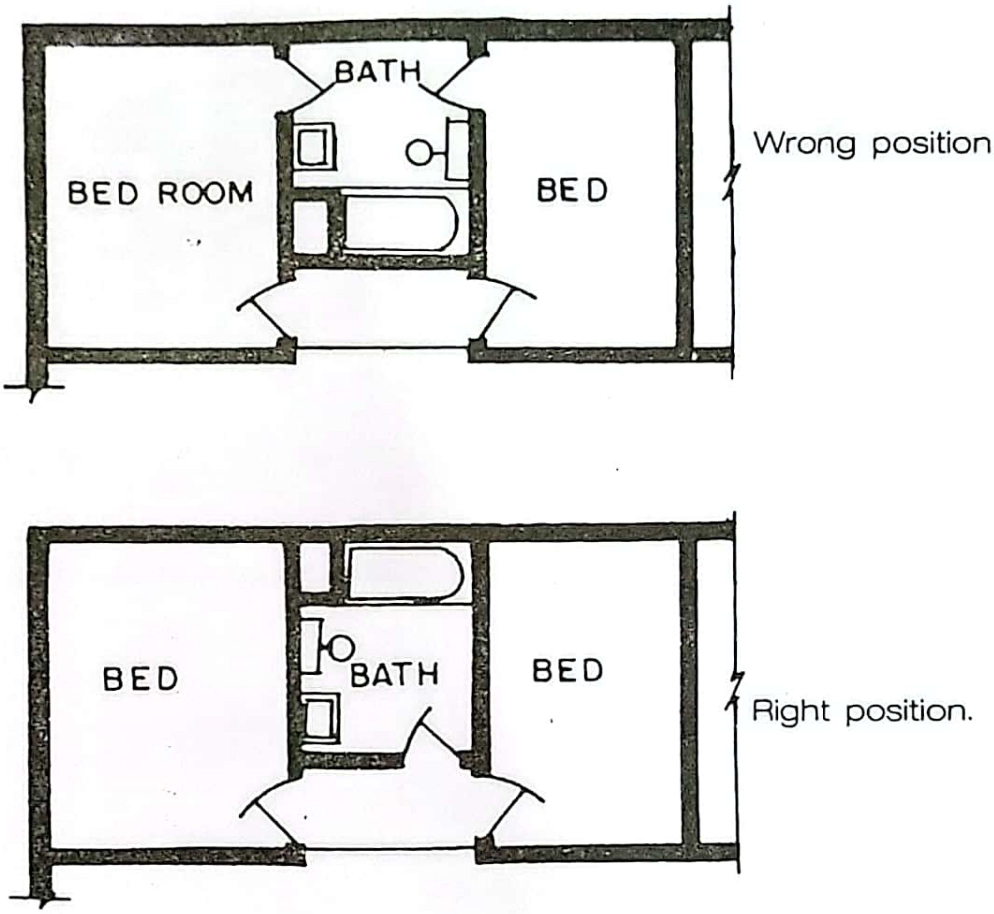


Fig 48 : Bathroom

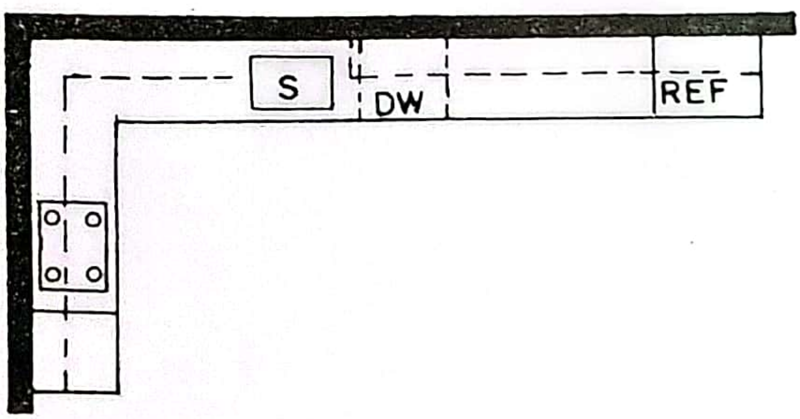


Fig 49 : Kitchen

10.14 Kitchen

Kithen cum dinning concept is getting popular in modern world becaus of he fact that the adventure in preparing food and its aroma of cooking can be shared by all.
Two seperate kitchen designs can be seen in the photographs.

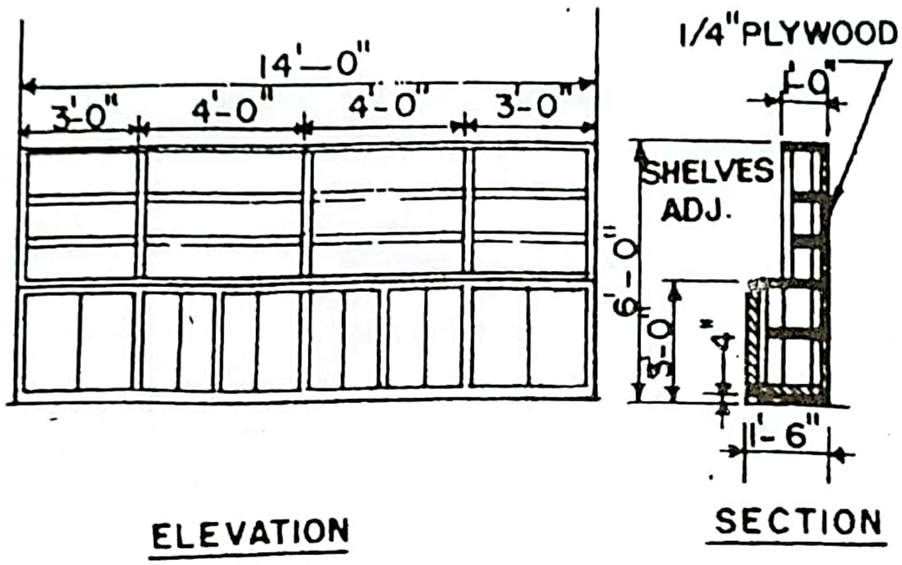


Fig 54 : Typical cabinet elevation with a section

11

LOW COST HOUSING

"Faith is my seed, torment is my rain, knowledge is my yoke, shame is my pode, mindrulness is my goad: -Buddha

WHAT DOES IT REALY MEAN

The term "LOW COST HOUSING" means housing for all walks of people at a lower cost compared to current cost levels. Some feel that the house should be cost effective with the intersion to reduce cost in its construction. But the case is considered nationally for the general mass. It impiles housing for low income familes who can afford to buy or construct a house within a minimum means. Thus, the house should be cost effective no doubt, but should be within affordable means of common people.

It should not, however, mean low quality house. It should have definite life to serve the owner and should be most cost effective, though cost and quality go together.

Achievement of housing at low cost is virtually a process of synthesizing various requirements for its cost effectiveness and acceptability to those for whom it is planned. It demands attention to the following aspects-

1. Use of indigenous building materials.
2. Sutiable physical planning.
3. Architectural and Engineering requirements.
4. Location and land use development.
5. Energy utilsation.
6. Environement and ecological balance.
7. Safety from natural disaster.

A close combination of the above mentioned aspects particularly with the use of indigenous building materials in a property planned manner may make a house at lower cost affrodable by common people. The rich can afford to buy a costly house and can enjoy many luxuries within it, thus low cost house is meant for the low income people who live in rural and slum area.

According to World Bank report rural housing deficit is about 3 times the urban housing deficit. That means this deficit is affecting the rural people who are mostly poor.

RESOURCE LIMITATIONS

In view of low saving capacity of our people due to low cost of agricultural prodct and high cost of construction commodities, it is necessary to provide financial assiatance to the house builders. Subsidy based though may be necessary or loans on easy terms be evoled by the Govt. to ease the problem. Grameen Bank may play an important role in this respect.

ENVIRONMENTAL PROBLEM

Rural housing selttment and slums in cities lack amenities like

1. Potable water.
2. Sanitation.
3. Electricity.
4. Disposal problem of garbage and waste.
5. Diminishing greens and covering open fields.
6. Congestion and overcrowding.

These lackings causes serious health hazards. So, such amenities be made easily available to the people.

HABITAL CONCEPT

Basic necessities of social living implies clustering and arrangement of houses in space for economy of design and construction cost, natural ventilation, paved roads with lighting, drinking water, sanitary facilities, community centres. All these should be provided in the complete plan for the beneficiaries to promote their economic, social and cultural life.

RESEARCH

Research for evolving low cost techniques and materials is necessary. Some techniques envolved in developing countries are described here which may be adopted to our needs :

1. Water proofing of mud wall.
2. Fire retardant for bamboo, Goalpata, straw houses.
3. Water proofing treatment,
4. Pre-cast agro waste components.
5. Frameless door/windows.
6. Anti termite treatment to wood and other organic materials.
7. Clay block stabilisation.
8. Thin brick walls.
9. Micro tiles of mud/concrete etc.

DEVELOPMENT OF NEW BUILDING MATERIALS

If we consider three M (i.e. man, money and material) in construction of the house, it will reveal that materials constitute more than three fourth of the total cost. Cost of labour is approximately 1/4th of the total cost. So, money required for materials is 75% and for man 25%. Reasonable saving in the cost of material may be possible with the invent of new building materials as building materials form the bulk of construction cost, reduction in cost of the house must be co-related with the materials used in it. Housing research Institute may play a vital role in finding innovative techniques for evolving new cheap and durable material. But such research work is found very inadequate and is limited to ferro cement sheets and some corrogated oval roofing materials which could not draw public accepability Our neighbouring country has as many as six such research centres and they have developed a number of materials using indigenous ones. Some are described below :

1. Sandlime Bricks

Autoclaved sand lime bricks has good structural qualities and does not require burning.

2. Fly Ash Bricks

Thermal power plants generate fly ash which mixed with clay, sand and some lime produce bricks which is less costly and durable.

3. Laterite Blocks

Laterite soil using lime stabilisation produce such bricks which give strength of about 90 kg/cm².

4. Cellular Concrete

Cellular concrete blocks could be a good substitute of clay bricks. It is light weight and has good structural qualities and is suited for multi-storied housing

5. Dry Hydrated Lime

Lime and pozzolana binder is a good substitute of cement. A modern process for production of dry hydrated lime of standard quality has been developed in India. This dry hydrated lime can be used in place of cement for making mortars and plasters mixed with pozzolana. It is cheaper than cement and can be produced in small scale industrial units.

6. Rice Husk Pozzolana

Plenty of rice husk is available in the region. When rice husk is calcined under controlled condition, a highly reactive material is formed, grinded and mixed with lime forms plastering material which is cheaper than cement.

7. Hollow Concrete Blocks

It can replace bricks for multi-storied construction. It can be used in walls in R.C.C. frame.

8. Asphaltic Roofing Sheets

It primarily consists of a board impregnated with asphaltic media and protected with conserving materials. Thus, scrap paper, bagasse, jute waste and other waste materials can be used. These roofing sheets can be well used in area below 44°C. It is much cheaper than asbestos cement sheets and can be used for low cost housing.

9. Stones

Lime stone, sand stone, granite, basalt and other stones which are locally available are used in place of bricks in walls by means of pre-cast blocks.

10. Gypsum Boards

Gypsum fibre board manufactured from low grade gypsum or phosphogypsum is a useful substitute for timber products. It can be used in ceiling, partitions and doors.

11. Ferrocement Products

Wire mesh reinforcement and cement mortar form ferrocement possessing having good strength and serviceability. Rafter, trussers, water tanks, storage bins door shutters can be made from ferrocement.

Apart from the above mentioned product, innovation of light weight concrete is highly prospective. By means of kadma and khaja technology, hollow aggregates can be evolved which will reduce weight of the building by 30% thus, considarable savings can be achieved.

CHOICE OF MATERIAL

State policy would be laid down in such a manner that the following three factors are duly preserved.

1. Ecological balance.
2. Energy conservation.
3. Environmental pollution.

ECOLOGICAL BALANCE

Cutting excessive trees for burning bricks and timber and quarrying of lime stone disturb ecological balance. Suitable alternative should be used.

ENERGY CONSERVATION

Production of good durable building materials requires use of energy of considerable quantity. Much gas is used in burning of bricks. Solar energy source be explored so that conserved energy is not exhausted.

ENVIRONMENTAL POLLUTION

Smoke coming out during burning of bricks damages plant life. Digging soil for making building materials creates swampy atmosphere and thereby causing unhygenic condition and agricultural soil is lost. Switch over to new building materials may solve environmental pollution.

The production and supply of indigenous materials like mud, bamboo, timber, stone, bricks and the like is handled by private sector. To promote use of appropriate building materials for mass housing construction, suitable state policy should be laid by the Govt.

Matrix to guide choice of building materials for low cost housing is shown in the accompanying diagrame.

APPROPRIATE TECHNOLOGY FOR LOW COST HOUSING

Technology developed so for in western countries and through research in developing countries may be classed as under:

1. Technology of design and physical planning.
2. Technology of construction.
3. Technology to improve traditional technology.
4. New technology to evolve new building material for low cost house.

1. TECHNOLOGY OF DESIGN & PHYSICAL PLANNING

Emphasis is often given for a type design of house due to the reason that the same plan is repeated for construction and its components can be produced in factories and can be streamlined for quick erection. However, the design itself should be compact. Square or nearly square sized rooms save cost in its roof slab due to two way slab system of design. Arrangement of rooms and facilities in a compact form saves in wall length and allied works.

For example a low cost house to be designed for a covered area not exeeding 475 sq. ft. having one multipurpose room, one bed room, one bath, one kitchen room. If it is planned in a traditional way it will get a form as shown in Fig.

A comparison between the traditional and planned compact way of arranging facilities reveals the following facts :

Way of arrangement	Covered area	Wall length	Verandah
1. Traditional way of arrangement	475.75 sft.	114'-2" rft.	128.30 sft
2. Planned compact arrangement	357.63 "	109.00 "	48.00 "
Difference =	118.12 sft.	5'-2" rft	80.32 sft.

In a compact design same size of rooms, the purpose may be served within smaller covered area, less wall length with requesite facilities can be arranged.

From the above, an inference can be drawn that design itself can save a lot.

PLANNING FOR LAND USE

Growing population has tremendous pressure on the physical resources of the country. New dwellings are covering agricultural land and open space hampering production and creating hazard to health and atmosphere. For this reason multi-storied housing is being increasingly adopted to effect saving in land. It helps check in undue rise in land cost and contribute to many other factors.

RESIDENTIAL DENSITIES ON LAND

The following densities are considered as optimum for a healthy situation :

1. 50 to 65 single storied houses per hectare.
2. 65 to 100 two-storied houses per hectare.
3. 100 to 125 three-storied houses per hectare.
4. 125 to 150 four-storied houses per hectare.
5. 150 five-Storied houses per hectare.

This will include open spaces, roads, parks and requisite community facilities.

2. TECHNOLOGY OF CONSTRUCTION

Prefabricated components may replace old method of consturction. It saves construction cost by 30% to 40%. It increases productivity, speed and economy. Technological advances in respect of the following should be given due importance

i. Type Design :

Typification of building design helps in repeatation of the components and streamlines its assembly and operation in construction.

ii. Standardisation :

Example of standardisation has been discussed in chapter 6. To facilitate economical erection on a large scale, standardisation should be adopted for mordinisation of building methords.

iii. Modular co-ordination :

For massive housing programme with economy and speed, all builders, housing authorities should adopt dimensional co-ordination which is governed by modular co-ordination. It is based on 10 cm module, and is universally accepted. It reduce wastage, labour cost and appreciable time in construction.

iv. Building codes :

Building should be framed in such a way that it does not inpede the pace of development. It need be modified to encourage the use of new housing concepts and design, material and time.

MODIFICATION OF TRADITIONAL TECHNOLOGIES

People has developed faith and confidence in old traditional methods of construction as a successful and proven technology, though new technology preserves a balance between cost and resource. Mass awareness is necessary for the choice of housing technology in the aspect of economical, social and environmental planning for housing development.

EVOLVE NEW BUILDING MATERIALS FOR LOW COST HOUSE

Research in developing countries is limited and the challege to solve housing problem through development of new building materials out of indigenous material is meagre.

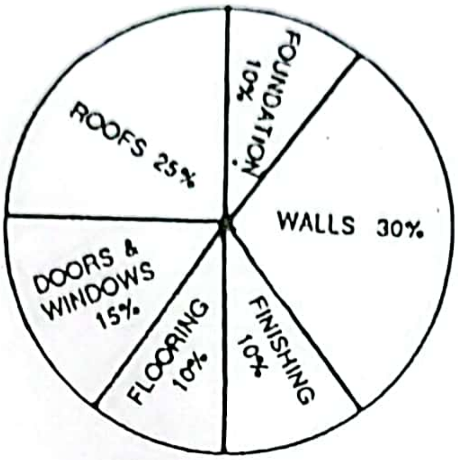
However, low cost building materials can be evolved by application of science and technology through :

i) Production of clay bricks, pozzolana, light weight concrete by mininuning wastage and reduced cost.
ii) Industrial agricultural waste, garbage etc. may be turned into building material through industrial enterprises.
iii) Cheaper materials can be augmented as alternate materials.
iv) Using indigenous raw material resources, new products can be organized at economical cost. Attempts should be made to use non-convensional energy resource like sun dried bricks, solar energy for kilns are noteworthy developments.
v) Housing development enterpreneurship programme (HDEP) is a potential means to transfer technology. Indian Government has established Building materials and technology promotion council (BMTPC) for the purpose. UNESCO, ESCAP (Economic & Social Commission for Asia and the Pasific) and many other agencies are working on inovative technologies and its transfer to developing countries.

COMPUTERISATION

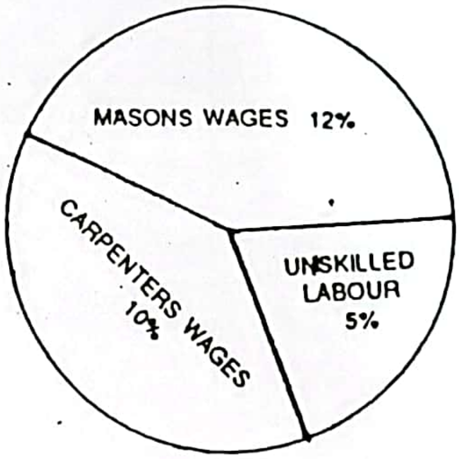
Planning, designing and construction of housing is becoming common and is revolutionising the housing process. So, computers can be used to facilitates its development.

ELEMENTS



100%

LABOUR



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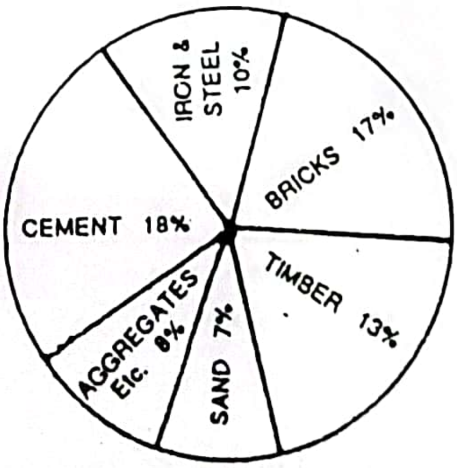
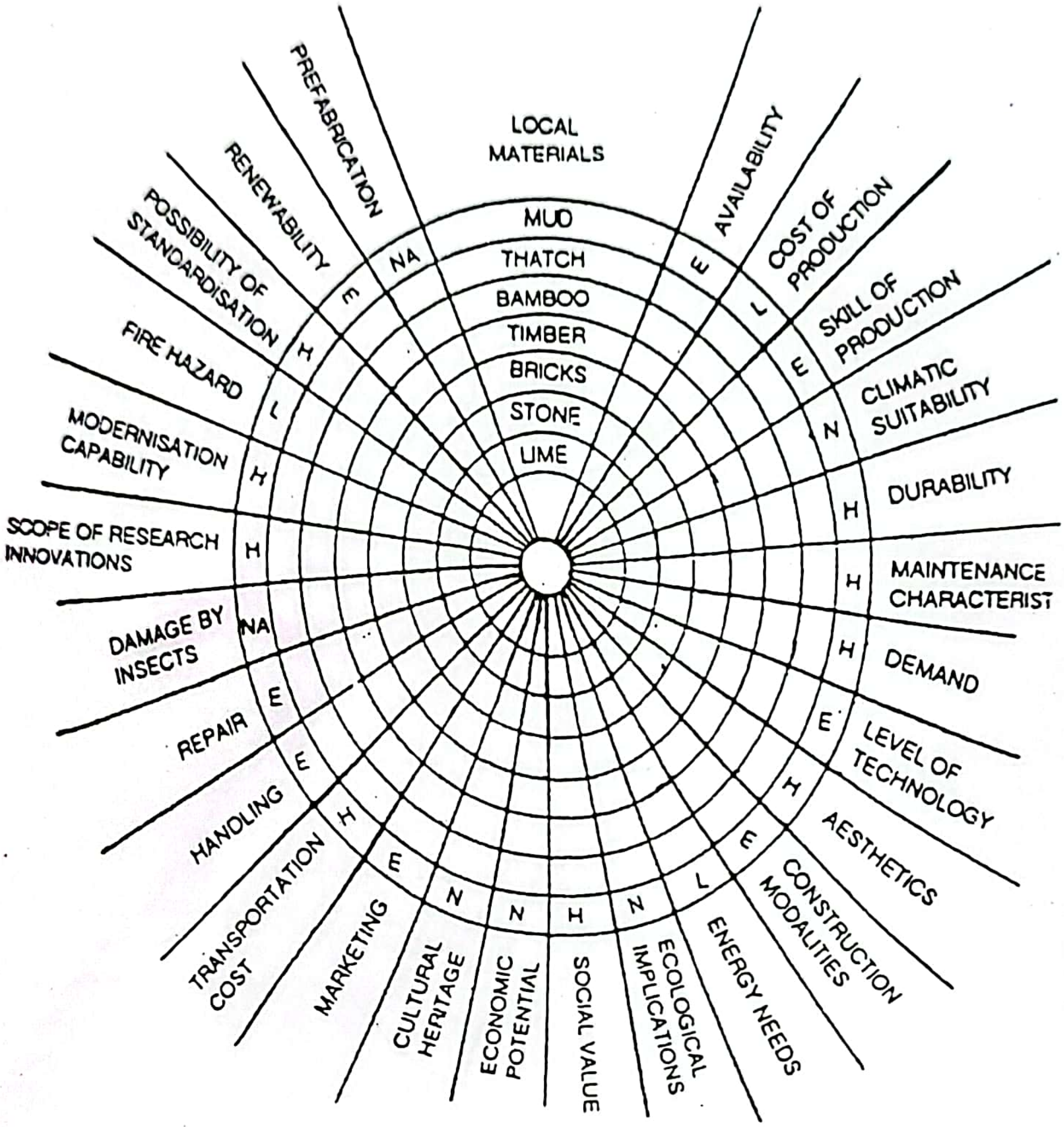
MATERIALS



73%

COST BREAKUP



NOTATIONS
EASY.......................................E
LOW..L
NORMAL...................................N
HIGH..H
NOT APPLICABLE.......................NA

Diagram : Matrix for choice of building materials.

12 PLOT

"What you do not want done to yourself
do not to others" -Confucius.

A plot is a piece of land having different amenities like approach road, water, gas, electricity etc. and over which a house or any other construction work is carried out.

- It is sometimes called the 'site.'

Most of the plots are filled, made up ground. If filling depth is more than 7 ft., foundation cost becomes high.

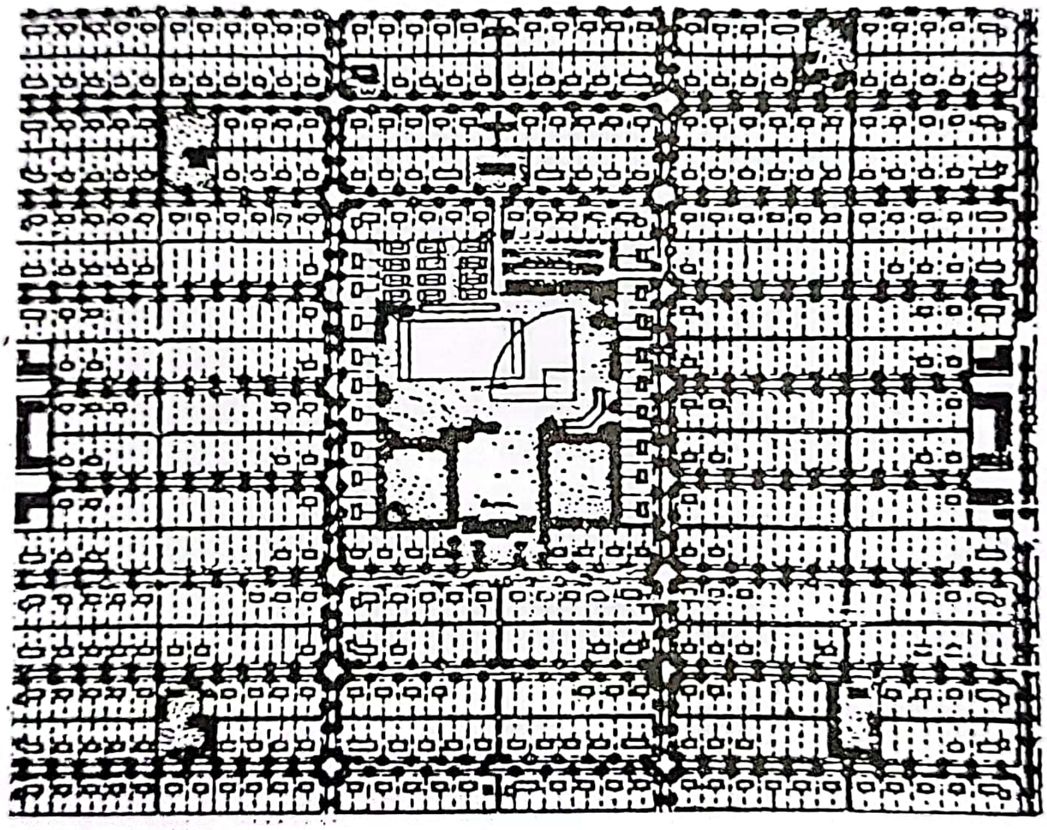
Plot Planning :

While planning plots in a housing area, a planner keeps his eye on the following aspects :

1) Based on different human activities each city should have three distinct areas, namely :
   a) Industrial area,
   b) Commercial area, and
   c) Residential area.
2) Housing area should be away from industrial area so that smoke, noise, business etc. does create hazzard to human health and peace. However, each of the above three areas should be interconnected with each other by means of a suitable road.
3) Ideally 8 acre land is necessary for a housing complex. The complex should be divided in sectors. Earch sector should be given a name.
4) Lower income group should be provided with comparatively smaller plots in one sector while higher income group may be given plots in a separate sector. Small plots means plots upto 2 Katha, 2 to 3 Katha is medium sized and biggers plot is above 3 Katha according to the present trend of choice and propulation growth.

Preferable plot size should be as under :

Size of plot, Katha	Probable size, ft × ft	Area, sq. ft.
1¾	25 × 50	1250
2	30 × 48	1440
2½	30 ×60 or 36 × 50	1800
3	36 × 60	2160
3½	40 × 63	2520
4	45 × 64	2880
5	50 × 72	3600
7½	60 × 90	5400

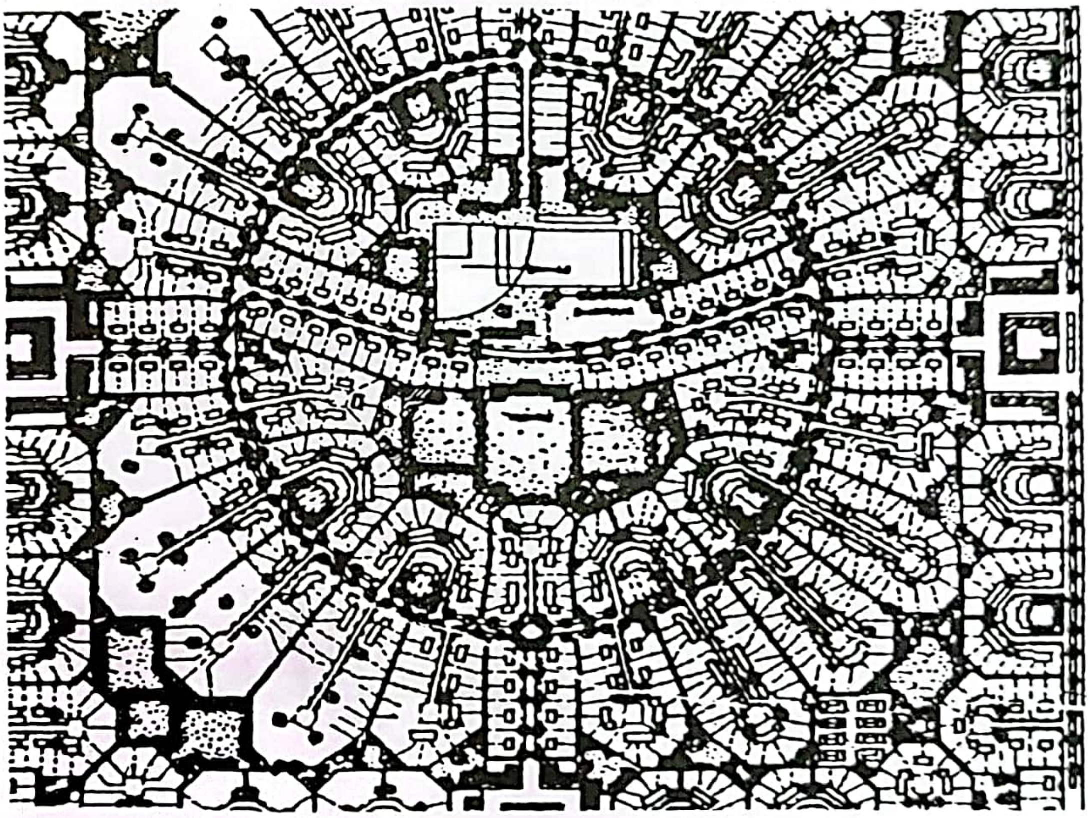


Grid Pattern

5) Some open space be kept for :
   a) Parks.
   b) Swimming pool, gymnasium etc.
   c) Lawn, tennis courts etc.
   d) Football, playgrounds.
   e) Office, Club, Community Centres etc.
   f) Police camp, Water, Gas, Electricity Offices etc.

g) Preservation of old monuments of historical importance.
h) Planting tree, Gardens, water, sewer lines etc.
i) Height restrictions for locations near airports.
j) Shopping centres.
k) Future extension.

6) Firstly big roads and avenues be fixed that are connected with highways through smaller roads, Bigger roads should have footpaths. Width of bigger road should be 60', medium road 30' and smaller ones 18 .
7) Big, medium and smaller plot be arranged in sequence and should be rectangular in size.



Loop pattern.

PLOTTING PATTERN :

There are two ways of arranging plots.

1) Grid Pattern
2) Loop pattern.

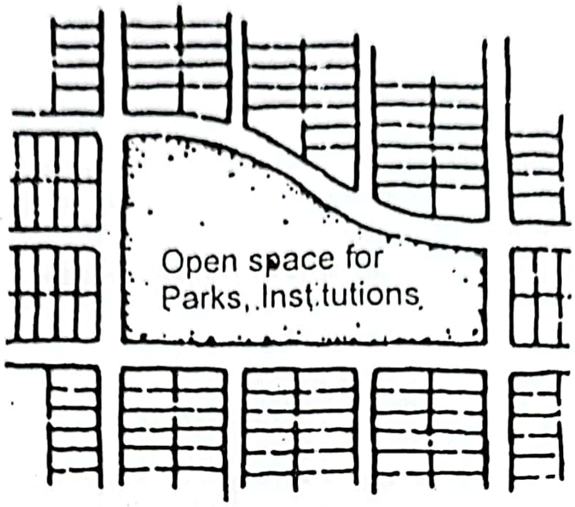
Grid pattern : It is the oldest way of making plots. It insures maximum land utilisation by dint of its rectangular size. Roads intersect each other at right angle. The plotting is shown in the accompanying diagram.

In grid pattern an area of 800' × 1200' is ideal. Plots will be back to back, roads will strech in the front. Sewer and water line should run along the side of the road and not at the near of the plot.

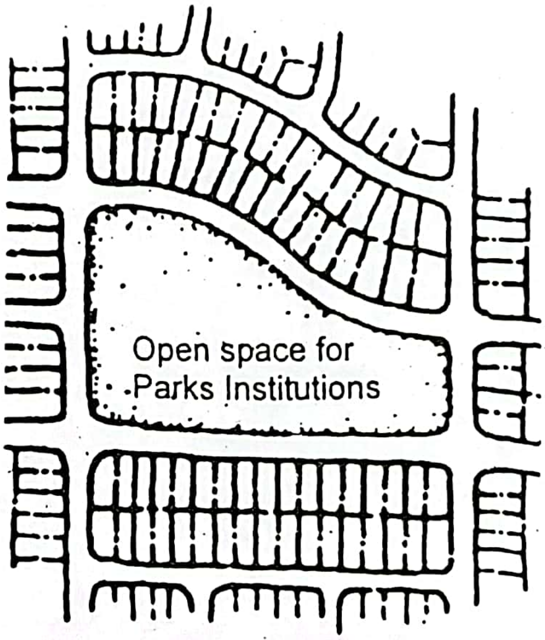
Loop pattern : A block of 800' × 1200' is necessary for a loop pattern of arranging plots. Roads get shape of 'U' which is connected to a circular main road. A wide road is necessary at the peripheri of the block. Please see accompanying diagram.

This pattern leaves much more open space than required and land can not be properly utilized. It is only suitable for an aristrocratic area.

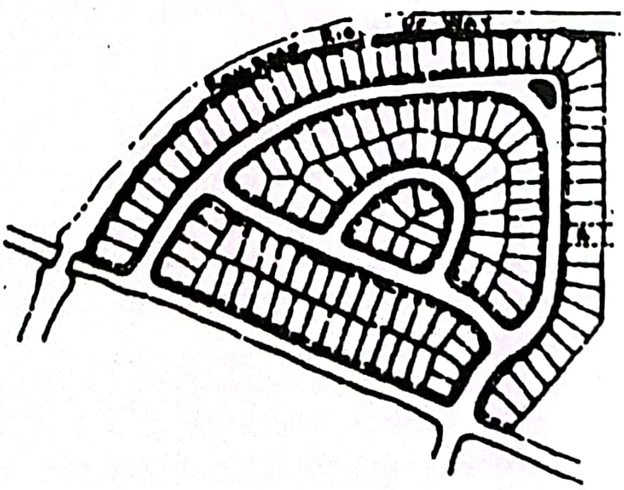
Few such blocks together with form a housing complex



Example of conventional plot plan.

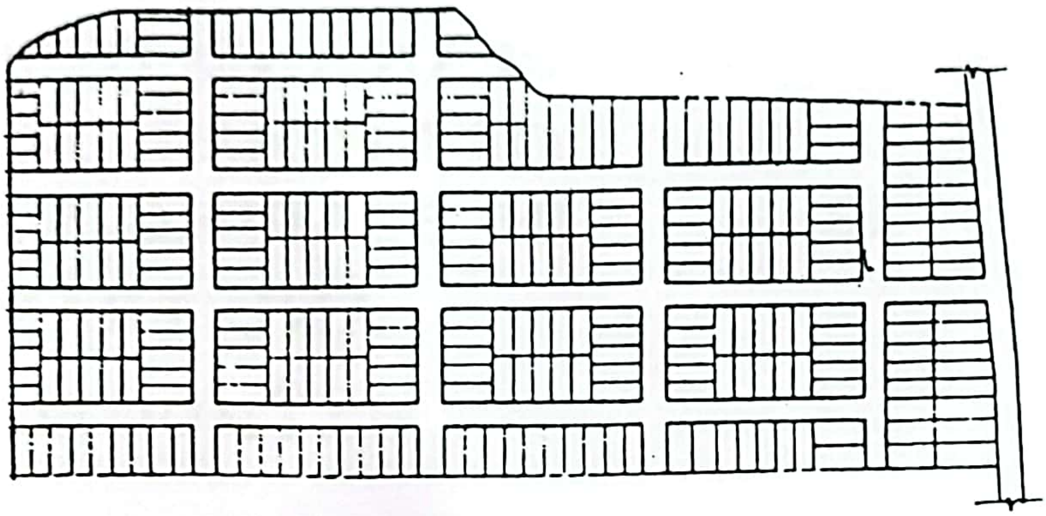


Same Plot improved Version

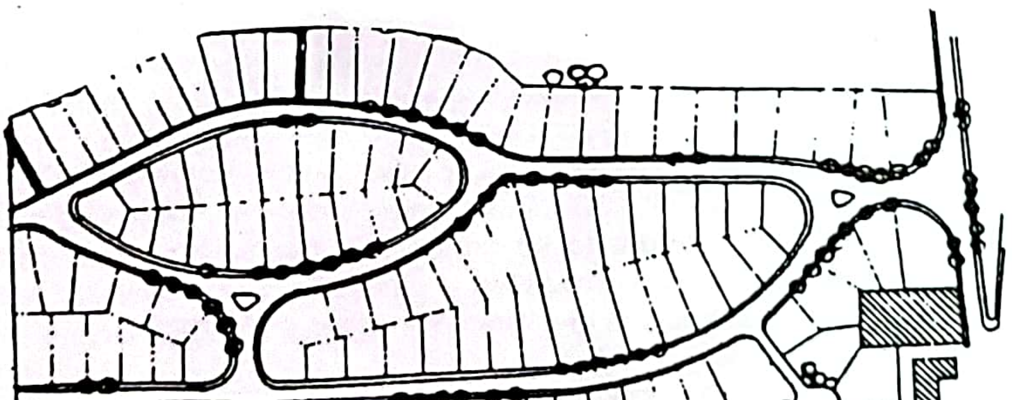


Modern Plot Planning

Courtesy : Time savers



Example of plot planning for low-income group.



The same plot planning for high-income group.

13 PLAN AND DESIGN OF A HOUSE BOTH IN BEARING WALL AND FRAMED STRUCTURE.

"If you can not help the helpless atleast try to behave softly with him" -Hazrat Ali (Ru)

PLANNING PHASE :

This plan is meant for a five-storied house over a 2½ Katha plot in a housing society. The plot measures 36′ × 50′. Road passes on the north of the plot. The following facilities in each floor are to be provided in the house :

1. Beds- 3 nos. (1 Master Bed, 1 Child Bed, 1 Guest Bed)
2. Bath- 2 nos. (One attached with M. Bed, the other is common)
3. Verandah/Balcony- 2 Nos.
4. Drawing-cum-Dining room, one combination.
5. Store- 1 no.
6. Garage- 1 no.

Now, 1st step is to visit the plot and check its measurements on the field (art 4.10) and draw it on a piece of paper preferably to ⅛" to a feet or 1 : 100 scale showing north line. Planning will be made with the aid of this paper.

The planner will now consider each requirement of the owner in respective functions of privacy, economy, utility, aesthetic, surrounding etc. and represent it on a paper with major and minor details to achieve the desired plan of a nice home.

While placing the rooms, consideration of summer and winter winds be done and bed rooms be placed on the south or on the east. Kitchen and toilets be placed on the north or on the west or on north-west corner.

In this particular case, two beds are placed on the south with a hanging verandah that can receive sunlight from the east. The western wall of child bed may be provided with sun breaker or inclined louvers. Out of two toilets, one should remain attached with master bed the other be placed in central place having easy access and quick circulation. A verandah is placed in the front. Stair case is placed on north-west of the house.

It is customary to prepare a rough sketch first for discussion with the client and accord his approval over it before a final plan is chalked out on tracing paper of 20" x 30" size showing the following details :-

1. Ground floor plan, scale 1/8" to a feet or 1 : 100.
2. 1st, 2nd, 3rd and 4th floor plan in same scale.
3. Front elevation.
4. Sectional elevation.
5. Layout plan showing set backs and septic tank, soak pit positions with connecting pits.
6. Site plan, and
7. Typical column or a wall foundation.

This plan is called architectural plan six copies of which are normally required for approval of the concerned authorities. Architectural plans may also furnish many other details in separate sheets.

While development of the plan is in progress, a suitable firm may be engaged to carryout soil test report. Design of foundation should be based on soil test reports.

On getting approval of the architectural plan, one structural Engineer is engaged for working out structural requirements of the building and represent the design on sheets known as structural design. Normally four to six sheets are required to furnish full details of the structural requirements. Namely :

1. Floor plan and trench showing dimensions.
2. Beam plan with long and cross-section, bent locations of rods and its position requisite cover etc.
3. Slab plan with sections, bent location of rods, covers etc.
4. Design of stair, underground water reservoir and overhead tank, septic tank soak pit with sanitary details and piping layouts.
5. Electrical plan with circuit diagram.
6. Any other details like wood work, brick joints, gas work etc.

Floor plan of the building on the said plot is represented in accompanying diagramme in two different modes. One with load bearing wall, the other in framed structure.

SIMPLIFIED DESIGN CONSIDERATIONS :

To select the type of foundation for this particular building, the following considerations comes up :

1. The building is situated in Dhaka and falls in moderate earthquake damage zone.
2. Building is five-storied, room ht. is 10' including slab. So building height is 50' plinth ht. is 2'-0" and paraphet is 2'-6"
3. The plot was low lying beel area and is filled up with silty clay soil. Soil test report says that firm original soil strata exist at 6' below FGL (Finished ground level).
4. Angle of internal friction of soil is 30°
5. Bearing capacity of soil is 1 TSF (Tons per sq. ft) at a depth of 6'-6"

Two major points controls the selection. The situation of the building is in moderate earthquake zone and depth of foundation is more than required by Rankings formula (Art 6.12). So, column foundation is desirable.

However, brick wall foundation can be adopted by improving the soil condition. Soil condition can be imporved by excavating to required width and depth of 6'-6" into the original strata and backfilling to shallow depth with medium grained sand in layers and consolidating by watering and ramming. Brick foundation can be laid over this consolidated base.

There are few methods like moment distribution metheod, slope deflection method etc. for analysis of stresses and bending moments occuring in the frame. But they are cumbersome compaired to ACI co-efficient and shear value method. This method is easy to work out and provides sufficient safety provision and is suitable for all practical purposes. Hence, for finding out moments and shear values, ACI co-efficients are used. WSD (Working stress design) method is applied. Concrete quality should be maintained, if possible cylinder test be carried out on 28 days for designed f'c, f'c being crushing strenght of cement at 28 days.

Workability and consistency should be such that it works readily into the forms and around rods without segregation and excessive bleeding. Concrete shall be placed in forms within 1/2 hrs. after adding water to the mixture.

SAFETY PROVISIONS :

As discussed in art 6.7, safety primarily means adequacy against collapse. Strength of the structure should be sufficient to counteract against all loads foreseably acting on it.

A building is safe if constructed according to design and material specification. WSD method provides sufficient safety against material failure. But loads shall be precisely calculated and calculated area for steel and concrete be provided in proper position. Materials shall be tested for quality and field condition should be maintained in such a way that it conforms closely to standards specified in the design.

Contineous beams and frames are statically indeterminate. End moments keep them in fixed position. B.M. in members are functions of geometry of the structure, moment of inertia, modulas of elasticity loads and spans.

In framed structure, columns are horizontally braced by lintel at 7' ht. This makes almost all columns to behave as short column where l/b ratio is around 10. ACI Committee for columns has recommended that 90% columns of a building can be designed as short column if braced and thereby ignoring bending in it. Here, a 8" x 10" column upto lintel has unsupported length 7' and length to least dimension ratio 7×12/ 8=10.5 which is around 10 and is considered as sort column. Thus column is designed for axial load only.

However, live loads on columns and bearing walls can be reduced @ 10% per floor upto a maximum of 60% due to the fact that all floors are not simultenuously loaded with live load. Moreover, ACI Code specifies 96 sq. inch X-sectional area of columns with minimum 4 Nos. 5/8" Ø rod. But as per BSS code of practice, this can be of any size for houses having smaller loads with a minimum of 4 Nos. 1/2" Ø rods.

Slabs, beams and columns should be casted monolythically to induce rigidity in the frame. When beams and slabs are casted monolithically, T beam action is induced. Beams supported by such columns are considered fixed at ends and so are the slabs. Mement co-efficients shall be calculated accordingly. For all practical purposes, sections of slabs, beams resulting from maximum bending moment is provided althrough for easy workmanship and stiffness of the structure.

Some codes specifics that, bearing walls in brick or concrete should not be constructed beyond 75' high having wall thickness 12" to 16". Dr. Rashid, V.C. BUET cherished that 55' high brick masonry walls could be safely constructed with 10" thickness but thickness upto plinth should be 15".

Concrete made of stone chips in 1 : 2 : 4 mix may give crushing strength f'_c = 2500 psi. For economy, chips made of picked jhama bricks can be used but f_c should not be considered over 2000 psi or as per test results from field mix.

Since, brick chip absorbs moisture in humid weather, covers for slab shall be minm. 3/4", beams 1" and columns 1½". Underground works should have a cover of minimum 2".

If brick chips are used safety factor for concrete and M.S. rod is as follows :-

Concrete :	Crushing value (brick chips) f'_c	= 2000 psi.
	Value used in design	= .45 f'_c
		= .45 × 2000
		= 900 psi.
	Safety factor	$= \frac{2000}{900}$
		= 2.22

2. M.S. rod, billet grade yields at 40,000 psi.

Value used in design	= 18,000 psi or 20,000 psi.
Safety factor	$= \frac{40,000}{20,000}$
	= 2
When 18,000 psi is used S.F.	$= \frac{40000}{18,000}$
	= 2.2

A. STRUCTURAL DESIGN CONSIDERING BEARING WALL.

The building is erected from bottom, but design takes place from the top due to the fact that unless slab thickness, beam dimension and the other load factors are known, actual load on foundation can not be worked out.

Design Criteria for Slab.

Denote different room slabs as S_1, S_2, S_3 etc. Given,

Live load, LL = 40 psf.

Floor Finish = 12 psf.

f_s = 20000 psi.

f'_c = 2000 psi.

$f_c = .45 f'_c = 900$ psi.

$j = \frac{7}{8}$ or .875

$j = 1 - \frac{K}{3} = .375$

Allowable stresses :

Shear, $v = 1.1 \sqrt{f'_c}$

= 49 psi

Bond $u = 2.4 \sqrt{f_c}$

= 107 psi.

$R = \frac{1}{2} f_c jk = \frac{1}{2} \times 900 \times .875 \times .375 = 148$ (rounded).

Slab over largest room will control the thickness of the slab. It is resting on wall, so is not restrained over support.

Moment co-efficients will be seclected accordingly. Moment co-efficient for semi restrained end is $\frac{wl^2}{10}$ for -M and for + M is $\frac{wl^2}{11}$ (Art 6.25).

Design of S_1

Clear dimension of S_1 = 14'×18'-6"

Thickness, $t = \frac{L}{35} = \frac{14 \times 12}{35} = 4.8"$ (Art 6.39)

Say, 5"

$$\text{Also, } t = \frac{\text{Perimeter, inch}}{180} = \frac{(2\times14+2\times18'\text{-}6'')\times12}{180} = 4.33''$$

Let t = 5", Actual t will be governed by moment.

Slab S_2 and S_3 may have smaller thickness, but for practical purposes, controlling thickness will prevail throught the roof. But economy in steel may be derived because d will be more and steel area will be less for such smaller slabs. On the other hand smaller slab thickness may be casted by raising scaffolding between walls/beams keeping top of slab at same level.

Load calculations : (w per ft.) :

Assumed t = 5"

LL (Live load) = 40 psf

Floor finish = 12 psf.

Self wt : $\frac{5}{12} \times 1 \times 1 \times 150$ = 62.5 psf.

Total w = 114.5 psf.

This is considered as load per ft because 1 ft strip of slab is considered.

Ratio of spans : $\frac{L}{B} = \frac{18.5}{14} = 1.32$

Load Sharing Factor : Short span .5 + .32 = .82 (because when ratio is 1, short span
Long span .5 − .32 = .18 share .5 and also long span shares .5

Bending Moment :

Short span

$-M = \frac{w1^2}{10} = \frac{.82 \times 114.5 \times 14^2}{10} = 1840.24\#/$

$+M = \frac{w1^2}{11} = \frac{.82 \times 114.5 \times 14^2}{11} = 1672.90\#/$

Max. M is 1840.24 #

Now, $d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{1840.24\times12}{148\times12}} = \sqrt{12.43} = 3.52''$

t = 3.52+.75+.19

= 4.46"

Say, 4.5"

Long span

$-M = \frac{w1^2}{10} = \frac{.18 \times 114.5 \times 18.5^2}{10}$

705.38 #′

$+M = \frac{w1^2}{11} = \frac{.18 \times 114.5 \times 18.5^2}{11}$

= 641.25#′

1 ft. strip, b = 12"

Add cover .75" and centre of rod

Use 4.5" slab. Correct load factor again with smaller t.

d = 4.5-(.75+.19)

= 3.56"

LL = 40 psf

FF = 12 psf

Self wt $\frac{4.5}{12}\times1\times1\times150$ = 56.25 psf

Total = 108.25 #

Find maximum moment, $-M = \frac{w1^2}{10}$

$$-M = \frac{.82 \times 108.25 \times 14^2}{10} = 1739.79\#'$$

Corrected $d = \sqrt{\frac{M}{Rb}}$

$= \sqrt{\frac{1739.79 \times 12}{148 \times 12}}$

$= \sqrt{11.76}$

$= 3.42$

t = d+cover

= 3.42+.75+.19 (for centre of 3/8" Ø rod)

= 4.36" Use 4.5 slab.

d = 4.5 -(.75+.19)

= 3.56". Rounding brings about same result.

Bending Moments :

Short span

$-M = \frac{w1^2}{10} = \frac{.82 \times 108.25 \times 14^2}{10}$

$= 1739.79\#/$

$+M = \frac{w1^2}{11} = \frac{.82 \times 108.25 \times 14^2}{11}$

$= 1581.63\#/$

Long span

$-M = \frac{.18 \times 108.25 \times 18.5^2}{10}$

$= 667.05\#/$

$+M = \frac{.18 \times 108.25 \times 18.5^2}{11}$

$= 606.40\#/$

$As = \frac{M}{fsjd}$, $f_s = 20000$ psi

$j = .875$, $d = 3.56"$

REINFORCING BAR (REBAR)

fsjd = 20000×.875×3.56

= 62300

Short span

$-As = \frac{1739.79 \times 12}{62300} = .34 \text{ in}^2$

spacing 3/8" Ø @ 3.88" c/c

$+As = \frac{1581.63 \times 12}{62300} = .33 \text{ in}^2$

3/8" Ø 4" @ c/c.

Long span

$-As = \frac{667.05 \times 12}{62300} = 13 \text{ in}^2$ spacing

3/8" Ø @ 10.15" in c/c

$+As = \frac{606.40 \times 12}{62300} = .12 \text{ in}^2$spacing

3/8"Ø @ 11" in c/c.

Final spacing of rods will be done considering all the slabs so that minimum rod is cut avoiding overlaps. Now, design S_2 and S_3. Before that, shear and bond check is necessary.

Check for Bond and Shear :

Given allowable stresses for :

Shear, v $= 1.1\sqrt{f'_c} = 1.1\sqrt{2000}$

$= 1.1 \times 44.72$

= 49 psi, fraction neglected.

Bond, u $= 2.4\sqrt{f'_c}$

$= 2.4 \times 44.72$

= 107 psi, fraction ignored.

Shear :

Shear developed in 1' strip of short span = 108.25×14#

Shear at one end, $V = \frac{108.25\times14}{2} = 431.92\#$

Now, given V = 431.92#
j = .875
b = 12"
d = 3.56"

Developed, $v = \frac{V}{jbd} = \frac{431.92}{.875\times12\times3.56}$ = 11.55 psi. Less than 49 psi.

Bond :

Perimeter of 3/8" Ø rod = 1.18"

Spacing is 3.88". How many rods are there in 12"?

In 3.88" there is 1 rod

In 1" " " $\frac{1}{3.88}$

In 12" " " $\frac{1\times12}{3.88}$ = 3.09 Nos.

Perimeter = 3.09×1.18
= 3.65"

Developed bond, $u = \frac{V}{\Sigma ojd}$

$= \frac{431.92}{3.65\times.875\times3.56}$

= 37.99, psi Less than 107 psi.

Design of S_2 :

Clear dimension : 12'-6"×8'-0"

$\frac{L}{B} = \frac{12.6}{8}$ = 1.56 More than 1.5, one way slab.

Bending Moment :

w = 108.25# /ft. Contineous over two supports.

$-M = \frac{wl^2}{10} = \frac{108.25\times8^2}{10} = 692.8\ \#$

$+M = \frac{108.25\times8^2}{11} = 629.8\#$ /

Rebar :

As = M/fsjd

$-As = \frac{692.8\times12}{62300}$ = .13 in² Spacing 3/8" Ø @ 10.15" c/c

$+As = \frac{629.8\times12}{62300}$ = .12 in² Spacing 3/8" Ø @ 11" c/c

Binder or temperature rod

As = .0025 bt
= .0025×12×4.5
= .14 in² Provide 3/8" Ø @ 9.43" c/c

Design of S_3 :

Clear dimension : 13'×11'

$\frac{L}{B} = \frac{13}{11} = 1.18$. Two way slab

Load sharing : short span $.5+.18 = .68$

Long spn $.5-.18 = .32$

Bending Moment :

Short spn.

$-M = \frac{.68 \times 108.25 \times 11^2}{10}$

$= 890.68\#/$

$+M = \frac{.68 \times 108.25 \times 11^2}{11}$

$= 809.71\#/$

Long spn.

$-M = \frac{.32 \times 108.25 \times 13^2}{10}$

$= 585.42\#/$

$+M = \frac{.32 \times 108.25 \times 13^2}{11}$

$= 532.20\#/$

Rebar :

Short spn.

$-As = \frac{M}{fsjd} = \frac{890.68 \times 12}{62300}$

$= .17\ in^2$

Provide 3/8" @ 7.76" c/c

$+As = \frac{809.71 \times 12}{62300} = .16\ in^2$

Provide 3/8" @ 8.25" c/c.

Long spn.

$-As = \frac{585.42 \times 12}{62300} = .11\ in^2$

Provide 3/8 Ø @ 12" c/c.

$+As = \frac{532.2 \times 12}{62300} = 10\ in^2$

Provide 3/8" @ 13.20" c/c.

SUMMERY OF SLABS

As per design :	Provide
S_1, Two way	
Short 3/8" @ 3.88" c/c.	3/8" @ 3.75" c/c.
Long 3/8" @ 10.15" c/c.	3/8" @ 10" c/c.

S_2, Oneway, Main road 3/8" @ 10.15" c/c.
Binder· 3/8" @ 10" c/c.

S_3, Two way :	
Short 3/8" Ø @ 8.25" c/c.	3/8" Ø @ 7.7" c/c.
Long 3/8" Ø @ 13.20" c/c.	3/8" Ø @ 12" c/c.

ACTUAL PROVISION

1/3rd rod should go straight, so that rods should be alternately cranked up and extra top rod be provided in between two cranked up rods.

Rods actually provided is shown in the accompanying sketch.

DESIGN OF BEAM

No beam is involved in this case. For partition walls in kitchen, toilets two 1/2" Ø rods may be placed just below wall alignment to act as a concealled beam. However, 3" or 5" partition wall may be erected directly over the slab upto 10' ht with a lintel at 7' and spans not exceeding 12 ft. Opening between DRN and DINING may have a drop wall, 5" thick and 2'-6" high with 1/2" rod, 2 at top, 2 at bottom and 3/8" Ø rings spaced 6" c/c.

DESIGN OF WALL

Inn er walls carry load on both sides but outer walls carry load on one side only. It is customary to design the inner wall and outer wall with critical load imposed over it.

Inner Wall

Wall between drawing and dinning is critial, find out load over 1 ft. of wall.

Load calculation.

1. D. L. of slab $5\times\left(\frac{14}{2}+\frac{12'\text{-}11"}{2}\right)\times1'\times4.5"\times150$ = 3785.65#
2. Self wt. (5×10'+4'-6") ×10"×1'×120 (Paraphet 2'-6", plinth 2') = 5450.00 #
3. D.L. of foundation 10% of (2) = 545.00 #
4. Floor finish $12\times\left(\frac{14}{2}+\frac{12'\text{-}11"}{2}\right)\times11'$ = 161.52 #
5. L.L. 50% $.5\times5\left(\frac{14}{2}+\frac{12'\text{-}11"}{2}\right)\times1\times40$ = 1346.00 #

Total = 11288.17÷2240
= 5.04 tons.

Bearing capacity of soil, q_a =1 TSF
Given P = 5.04 Tons
q_a = 1 TSF

Width, $W = \frac{P}{q_a}$

$= \frac{5.04}{1}$

= 5.04 ft.
or 60" appx.

Outer wall load calculation.

Max load occures in drawing room.

Length of 1 ft. strip $= \frac{14}{2} = 7'$

1. DL of slab = 5'×7'-0"×1'×4.5"×150÷12 = 1968.75 #
2) DL of wall (as above) = 5450 #
3) DL of foundation 10% of item-2 = 545 #
4) Floor finish @ 12 psf = 5×1'×9×12 = 540 #
5) 50% L.L. = .5×5×40×7×1 = 700#

Total = 9203.75# = 4.11 Tons.

Width $= \frac{P}{q_a} = \frac{4.11}{1} =$ 4.11 ft.
= 49.32"
Say 50".

Depth of Foundation :

$\varnothing = 20°$

$\sin 20° = .34$

$$D = \frac{B}{W}\left(\frac{1-\sin\varnothing}{1+\sin\varnothing}\right)^2$$

$$D = \frac{1\times2240}{110}\left(\frac{.34}{1+.34}\right)^2 \text{ (Art 6.12)}$$

$= 20.36\ (.33)^2/(.492)^2$

$= 4.92'$

Say 5'-0"

D = depth in ft.
B = Bearing capacity of soil in lb
W = Unit wt. of soil lb/cu ft.
Q = Angle of repose of soil.

Since foundation should be laid on firm soil i.e. at a depth of 6'-6" from FGL which's high depth is costly. For economy, excavate upto 6'-6" and fill back 1'-6" with sand so that foundation depth remains at 5' but some economy is achieved by sand filling. Compacted sand is a firm base for foundation.

B. STRUCTURAL DESIGN CONSIDERING FRAMED STRUCTURE

This time room dimension has increased by 10" for using 5" wall. Column support makes beams and slabs fixed at ends, so moment co-efficient has changed. Now - ve $M = wl^2/12$ and + ve $M = wl^2/16$ (Art 6.25).

Design of Slab S_1

Clear dimension = 19'-9"×14'

$\frac{L}{B} = \frac{19'\text{-}9"}{14} = 1.41$ Less than 1.5 Two way slab.

$t = \frac{L}{35} = \frac{14\times12}{35} = 4.8"$, Say 5"

Load Sharing Factor :

Short spn. .5+.41 = .91

Long spn. .5- .41 = .08

Load :

LL = 40 psf

F.F. = 12 "

5" slab = 62.5 "

Total = 114.5 psf

BENDING MOMENTS :

Short span :

$$M = \frac{wl^2}{12} = \frac{.91\times114.5\times14^2}{12} = 1701.85\#$$

$$+M = \frac{wl^2}{16} = \frac{.91\times114.5\times14^2}{16} = 1276.39\#$$

Find d : M max = 1701.85#

$$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{1701.85\times12}{148\times12}} = \sqrt{11.5} = 3.39"$$

Long span :

$$-M = \frac{wl^2}{12} = \frac{.08\times114.5\times19.75^2}{12} = 297.75\#$$

$$+M = \frac{wl^2}{16} = \frac{.08\times114.5\times19.75^2}{16} = 223.31\#$$

t = 3.39 + Cover (.75+.19) for 3/8" Ø rod
= 4.33" Say 4.5"
d = 4.5 - (.75+.19)
= 3.56"

Correct load :

LL = 40 psf
FF = 12 "
4.5" slab = 56.25 "
Total = 108.25 psf.

$$\text{Max. B.M.} = \frac{wl^2}{12} \quad \text{(short span)}$$

$$= \frac{.91 \times 108.25 \times 14^2}{12}$$

$$= 1608.96 \ \#'$$

$$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{1608.96 \times 12}{148 \times 12}} = \sqrt{10.87} = 3.29''$$

t = 3.29" + Cover (.75+.19) for 3/8" Ø rod
= 4.23", Say 4.25"

Use 4.25" slab. Bearing wall slab thickness was 4.5"
So, .25" economy is possible in frame.
Now, d = 4.25 - (.75+.19)
= 3.31".
Correct loading accordingly
LL = 40 psf
FF = 12 "

$$\frac{4.25}{12} \times 1 \times 1 \times 150 = 53.12 \text{ "}$$

Total = 105.12 # Say 106#

Bending Moments :

Short span :

$$-M = \frac{wl^2}{12} = \frac{.91 \times 106 \times 14^2}{12} = 1575.51\#'$$

$$+M = \frac{wl^2}{16} = \frac{.91 \times 106 \times 14^2}{16} = 1181.64\#'$$

Long span :

$$-M = \frac{wl^2}{12} = \frac{.08 \times 106 \times 19.75^2}{12}$$

$$= 2.75.64\#'$$

$$+M = \frac{wl^2}{16} = \frac{.08 \times 106 \times 19.75^2}{16}$$

$$= 206.73\ \#$$

Rebar : $As \ \frac{M}{f_s j d'}$ f_s = 20000 psi, j = .875, d = 3.31"

fsjd = 57925

Short $- As = \frac{1575.51 \times 12}{57925}$ = .33 in², 3/8" Ø @ 4" c/c

$+ As = \frac{1181.64 \times 12}{57925}$ = .24 in², 3/8" Ø @ 5.50" c/c

Long $- As = \frac{275.64 \times 12}{57925}$ = .06 in², 3/8" Ø @ 22" c/c

$+ As = \frac{206.73 \times 12}{57925}$ = .04 in², 3/8" Ø @ 33" c/c

Shear and bond can be checked in the same manner already worked out.

Design of S_2
Clear dimensions :

G. Room 10'×8'-11" $L/B = \frac{10}{8'\text{-}11"} = 1.12$, Two way.

Din 13'-4"×8'-11" $L/B = \frac{13'\text{-}4"}{8'\text{-}11"} = 1.49$, Two way.

T, 7'-5"×5'-6" $L/B = \frac{7'\text{-}5"}{5'\text{-}6"} = 1.35$, Two way.

All are two way slabs, dining is critical, $\frac{L}{B} = 1.49$

Load Sharing Factor :
Short : .5+.49 = .99
Long : .5-.49 = .01

Bending Moments :

$$\text{Short} - M = \frac{Wl^2}{12} = \frac{.99 \times 106 \times 13.33^2}{12} = 1553.89\#\,'$$

$$+ M = \frac{wl^2}{16} = \frac{.99 \times 106 \times 13.33^2}{16} = 1165.42\#\,'$$

$$\text{Long} - M = \frac{wl^2}{12} = \frac{.01 \times 106 \times 8.92^2}{12} = 7.03\#\,'$$

$$+ M = \frac{wl^2}{16} = \frac{.01 \times 106 \times 8.92^2}{16} = 5.27\#\,'$$

Rebar : fsjd = 57925

Short - $As = \frac{1553.89 \times 12}{57925} = .32$ in² provide 3/8" Ø @ 4.13" c/c

+ $As = \frac{1165 \times 12}{57925} = .24$ in² provide 3/8" Ø @ 5½" c/c

Long span : Small moments, so temp. rod be provided

As = .0025 bt, b = 12", t = 4.25"
= .13 in² use 3/8" Ø 10.15" c/c.

Shear and bond check will be as usual.

Design of S_3 :
Clear dimensions :

M. BED 13'-10"×11' $\frac{L}{B} = \frac{13'\text{-}10"}{11'} = 1.26$, Two way.

BED 12'-11"×11' $\frac{L}{B} = \frac{12'\text{-}11"}{11'} = 1.17$, Two way.

M. Bed slab is critical. Design this slab.

Load Sharing : $\frac{L}{B} = 1.26$

Short span; .5+.26 = .76
Long span, .5-.26 = .24

Bending Moments :

Short span - $M = \frac{wl^2}{12} = \frac{.76 \times 106 \times 11^2}{12} = 812.31\#$

$+M = \frac{wl^2}{16} = \frac{.76 \times 106 \times 11^2}{16} = 609.24\#'$

Long span - $M = \frac{wl^2}{12} = \frac{.24 \times 106 \times 13.83^2}{12} = 405.49\#'$

$+M = \frac{wl^2}{16} = \frac{.24 \times 106 \times 13.83^2}{16} = 304.12\#'$

Rebar : fsjd = 57925.

Short span - As = $\frac{812.31 \times 12}{57925}$ = .17 in², provide 3/8" Ø @ 7.76" c/c.

Short span + As = $\frac{609.24 \times 12}{57925}$ = .13 in², provide 3/8" Ø @ 10.15" c/c.

DESIGN OF BEAMS

Beam B_1 : Span = 19'-9"

It is an 'L' beam having flange on one side.
Investigate to see whether n. axix falls within flange or in web. If n.a. is within web, T beam design will follow, if in flange, rectangular beam design will follow :

1) Slab $\frac{14}{2}$ ×1×4.25"×150	= 371.87#
2) Beam, self wt, 20"×10×1"×150 (Assuming 20"×10")	= 208.33
3) 5" wall, 5"×1'× {(10'-(1'-8")}×120	= 417.0 "
4) F. F 1×7×12	= 84.0 "
5) L.L 1×7×40	= 280.0 "
Total	= 1361.2#
	Say, 1362#

Bending Moments :

$-M = \frac{wl^2}{10} = \frac{1362 \times 19.75^2}{10} = 59029.45\#'$ (Single span, Art 6.25)

$+M = \frac{wl^2}{14} = \frac{1362 \times 19.75^2}{14} = 37947.50\#'$

∴ Max. -Ve moment controls.

here b = 10", R = 148

Check d. $d = \sqrt{\frac{M}{Rb}}$

$= \sqrt{\frac{59029.45 \times 12}{148 \times 10}}$

$= \sqrt{478.61}$

= 21.87" + Cover 1.5" (incl. rod dia).

Total thickness 23.37", Say 23½". Closer to assumption.

Now investigate for T - beam action.

$$P = \frac{As}{bd}$$

$$K = \frac{pn + .5\left(\frac{t}{d}\right)^2}{pn + t/d}$$

Where, n = Modular ration = $\frac{Es}{Ec}$ = 9.

M = Bending moment, 1b in,

f_s = Allowable steel strees, 20,000 psi.

d = Effective depth, in.

t = Slab thickness in.

p = Steel ratio.

b' = Web width, in.

b = Flange width, in.

n.a = Neutral axis.

Effective flange width equals :

i) b'+16t = 10+16×4.25 = 78 in

ii) Span/4 = $\frac{19.75 \times 12}{4}$ = 59.25 in.

iii) Centre to Centre spacing-not appliable.

2nd criteria i.e. b = 59.25" governs.

Now, As = $\frac{59019.45 \times 12}{20000\ (21.87 - \frac{4.25}{2})}$ = 1.79 in² P = $\frac{As}{bd} = \frac{1.79}{59.25 \times 21.87}$ = .00138

$$K = \frac{.00138 \times 9 + .5\left(\frac{4.25}{21.87}\right)^2}{.00138 \times 9 + \frac{4.25}{21.87}}$$

$$= \frac{.0124 + .0188}{.0312} = .151$$

Kd = .151×21.87 = 3.30" less than 4.25". i.e. neutral axis falls within flange. Follow rectangular beam design.

- As = $\frac{M}{fsjd} = \frac{59029.45 \times 12}{20000 \times .875 \times 21.87}$ = 1.85 in²

+ As = $\frac{37947.5 \times 12}{20000 \times .875 \times 21.87}$ = 1.19 in² use 3 # 6 bar.

Total depth of beam = 21.87+1.5 (cover) = 23.37" say 23½" incl. slab.

Check for Shear :

V = $\frac{w1}{2} = \frac{1362 \times 19.75}{2}$ = 13449.75 #

Shear strees developed v = $\frac{V}{bd} = \frac{13449.75}{10 \times 21.87}$ = 61.49 psi.

v allowable = 1.1 $\sqrt{f'_c}$ = 49 psi exceed allowable limit So, stirrup is necessary.

Design of Stirrup :

Excess V = Vdev - Vall = 61.49-49

= 12.49 psi.

Use 3/8" rod. Vertical area on both sides = 2x.11 = .22 in²

Spacing, $S = \frac{Avfv}{V'b} = \frac{.22 \times 20000}{12.49 \times 10} = 35.23''$ c/c.

Also min spacing = $\frac{Depth}{2} = \frac{21.87}{2} = 10.94''$ c/c.

Use 3/8" Ø @ 10" c/c.

Check for Bond :

Due to vibratory compaction, some cement particles drops down to bottom. Hence bottom part is stronger than top. Allowable limits for plain bars are :

Top: $\frac{1.7 f'_c}{d}$ or 160 psi. Botm. $\frac{2.4 f'_c}{D}$ or 250 psi.

$U = \frac{V}{\Sigma o j d}$, Top: 5 # 6 bar $\Sigma o = 5 \times \pi \times 3/4$ (Perimeter)

Top: 5 # 6 bar = 11.77 in

Using in formula, $u = \frac{13449.75}{11.77 \times .875 \times 21.87}$

$= 59.71$ psi. Less than 160 psi O.K.

Bottom. $\Sigma o = 3 \times \pi \times 3/_4 = 7.065$ in

$U = \frac{13449.75}{7.065 \times .875 \times 21.87}$

= 99.48 psi. Less than 250 psi O.K.

Results are represented in drawings. Other beams are quickly designed for d and As considering critical section and that section is run all over for design simplicity and easy workmanship.

Beam B_2 :

Maximum span = 14′ (DRN RM).

Load calculations :

1)	Slab: $\frac{14}{2} \times 1' \times 4.25'' \times 150$	= 371.87#
2)	Self wt of beam : 10"x14"x1'x150 (assuming 10"x14")	= 145.83#
3)	5" wall 5"x1'x(10'-(1'-2")x120	= 441.99#
4)	F. F. 1x12x7	= 84.0#
5)	L.L. 1x40x7	= 280.0#
	Total	= 1323.69#
		Say 1324#

$- M_{max} = \frac{w l^2}{12} = \frac{1324 \times 14^2}{12} = 21625.33$ #

$= \frac{21625.33 \times 12}{148 \times 10} = 175.34$

$= 13.24$

Cover = 1.50

14.75

Say, 15". close to assumed size. O.K.

- As = 1.12 in² Use 4 # 5 bars.

+ As = 0.84 in² Use 3 # 5. bars. Stirrup min d/2 use 3/8" Ø 6½" c/c.

Beam B₃ span (max) = 10'-0" Moment coefficient are
Investigation shows it is not a T beam. Hence, rect. beam design is followed

$$-M = \frac{wl^2}{12} \quad +M = \frac{Wl^2}{16}$$

It has defined flange. Investigate with T beam formula.

1) Slab : $\left(\frac{14+13'-4"}{2}\right)\times 1'\times 4.25"\times 150$ = 725.95#

2) Self wt of beam: 1'×10"×10"×150 = 104.16#

3) 5" wall = 5"×1'×(10'-10")×120 = 453.50#

4) FF+LL : $1\times\frac{14+13'-4"}{2}\times(12+40)$ = 710.58#

Total = 1994.19#

Say, 1995#

$$M\ max = \frac{wl^2}{12} = \frac{1995\times 12^2}{12} = 23940\#'$$

$$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{23940\times 12}{148\times 10}} = \sqrt{194.10}$$

= 13.93". Say 14"

$$A_s = \frac{M}{f_s\left(d-\frac{t}{2}\right)} = \frac{23940\times 12}{20000\left(13.93-\frac{4.25}{2}\right)}$$

More than assumed; load correction necessary.
t = 14+1.5 = 15.5"

Find b :

1) b = b'+16t = 78 in

2) span/4 = $\frac{14}{4} = \frac{14\times 12}{4}$ 42"

3) C/C spacing; not applicable

Least is 42"

$$\text{Now, } P = \frac{A_s}{bd} = \frac{1.22}{42\times 13.93} = .00208$$

$$k = \frac{.00208\times 9+.5\left(\frac{4.25}{13.93}\right)^2}{.00208\times 9+\frac{4.25}{13.95}}$$

$$= \frac{.0652}{.3237} = .201$$

kd = .201×13.93

= 2.79" less than 4.25". Not behaving as T beam. Follow rectangular beam design.

Correct load for self wt : 1×(13.93+1.5)×10"×150 = 160.72/ instead of 104.16 =

M = 33499.67# '

$$-As = \frac{M}{fsjd} = \frac{33499.67\times 12}{20000\times .875\times 16.48} = 1.39 \text{ in}^2 \text{ use 5 \# 5 bar}$$

$$+As = \frac{wl_2/16}{fsjd} = \frac{2051\times 14/16\times 12}{20000\times .875\times 16.48} = 1.05 \text{ in}^2\text{, use 4 \# 5 bar.}$$

Stirrup . Depth/2 = 7", use 3/8" Ø # 7" c/c.

BEAM B_4: Span = 11'-9".

1) Slab, $\frac{12'\text{-}11"+13'\text{-}10"}{2} \times 14.25 \times 150 = 710.81$#

2) Beam 1'×10"×12"×150 = 125.00#

3) 5" wall, 5"×1×(10'-1') 450.00#

4) F.F.+L.L, $1\times\frac{12'\text{-}11"+13'\text{-}10"}{} \times 52$

= 645.76#

Total = 1981.57#,
Say 1982#/

Investigate for T-beam action.

1) b = b'+16t = 78 in

2) Span/4 = $\frac{11\times12}{4}$ = 33 in

3) C/C spacing, N.A. least in 33"

$$M\ Max = \frac{wl^2}{10} = \frac{1982\times11^2}{10} = 23982.20\#'$$

$$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{23982.20\times12}{148\times10}} = \sqrt{194.45} = 13.94"$$

$$A = \frac{M}{f_s\left(d-\frac{t}{2}\right)} = \frac{23982.20\times12}{20000\left(13.94-\frac{4.25}{2}\right)} = 1.22\ in^2$$

$$P = \frac{A_s}{bd} = \frac{1.22}{33\times13.94} = .0026$$

$$k = \frac{pn+.5\left(\frac{t}{d}\right)^2}{pn+t/d} = \frac{.0026\times9+.5\left(\frac{4.25}{13.94}\right)^2}{.0026\times9+\frac{4.25}{13.94}} = .211$$

kd = .211×13.94 = 2.94" less than 4.25". Follow rect. beam design.

Bending Moments :

Correct w. d = 13.94"
+ 1.50"
14.94", Say, 15"

Self wt = 10"×15"×1×150 = 156.24, 156.24 - 125 = 31.24+1981.57
= 2012.81

Say, 2013# instead of assumed 1982.#

$$-M = \frac{wl^2}{10} = \frac{2013\times11^2}{10} = 24357.3\#' \quad As = \frac{243.3\times12}{20000\times.875\times13.94} = .16\ ins^2$$

Use 4 # 5 bar.

$$+M = \frac{wl^2}{14} = \frac{2013\times11^2}{14} = 17398.07\# \quad As = \frac{17398.07\times12}{2000\times.875\times13.94} = 0.85\ in^2$$

Use 3 # 5 bar.

Use stirrup 3/8" Ø @ 15/2 or 7.5" c/c

DESIGN OF GRADE BEAM :

It is a rect. beam carrying load of 5" wall in ground floor only. Designate GB_1 for span of 19'-9" and GB_2 for the rest area. It is constructed at P.L.

GB. Span 19'-9"

Load 1) 5" wall. 5"×1×(10'-1.66)×120 = 417#

2) Self wt. 1×20"×10"×150 = 208.33#

625.33#

Say 626#

$-M = \frac{wl^2}{10} = \frac{626 \times 19.75^2}{10} = 27131\#$

$d = \sqrt{\frac{M}{Rb}} = 14.83"$

$+ 1.50"$

16.33"

Say 17"

$+M = \frac{wl^2}{14} \quad \frac{626 \times 19.75^2}{14} = 17441\#$

$-As = \frac{2713 \times 12}{20000 \times .875 \times 14.83}$ 1.25 in$_2$. Use 5 # 5 bar

$+As = \frac{1744 \times 12}{20000 \times .875 \times 14.83}$ .80 in$_2$. Use 3 # 5 bar

Use nominal stirrup.

GB_2 : Span = 14', contineous

Same loading $-M = \frac{wl^2}{12}$ $+M = \frac{wl^2}{12}$

$-M = 626 \times 14^2$

$-M = \frac{10224.66 \times 12}{12} = 10224.66\#$

$+M = \frac{626 \times 14^2}{16} = 7668.50\#'$ $\quad d = 9.10" + 1.5" = 10.6"$ Say, 11"

$-As = \frac{10224.66 \times 12}{20000 \times .875 \times 9.1} = .77$ in^2, Use 3 # 5 bar.

$+As = \frac{7668.50 \times 12}{20000 \times .875 \times 9.1} = .58$ in^2, Use 2 # 5 bar.

Use nominal stirrup

COLUMN DESIGN :

Denote almost similarly loaded columns as C_1, C_2, C_3 etc. Assume 50% live load acting over each column, because all the floors are not simultaneously loaded with LL. This is permitted by Code.

Col C_1 : Col. betn. G. Bed and DRN is critical.

LOAD : DL : 1) Slab, $5x \frac{14+8'-11"}{2} x \frac{10'}{2} x\ 4.25" x 150$ = 15220.31 #

2) Beam, $5x \frac{14'+10'+8'-11"}{2} x\ 10" x \frac{11"+14"}{2} x\ 150$ = 10716.15 #

3) 5" wall, $5x \frac{14+10+8'-11"}{2} x5" x$(Av 10'-1'-3") x 120 = 36006.25 #

4) Self wt. (54'-6"+6") x 10"x10"x150 = 6302.08 #

Assuming 10"x10" col.

5) F.F. $5x \frac{14+8'-11"}{2} x \frac{10'}{2} x\ 12$ = 3438.00 #

6) L.L 50% liveload, $5 x \frac{14+8'-11"}{2} x \frac{10'}{2} x\ 40x.5$ = 5730.00 #

Total = 77412.79 #

= 34.56 tons

Provide 4 # 6 bar : As = 4×.44 = 1.76

$Pg = \frac{As}{Ag} = \frac{1.76}{100} = 0.176$

P = .85 Ag (.25f + $f_s p_g$

P = .85×100 (.25×2000+20000×.0176)

= 85 (500+352) = 72420# ÷ 2240 = 32.33 Tons.

Imposed load is 34.56T which is slighly more than designed load. Additional 2 # 5 bars be added, so that A_s = 2.38 in² and P = 35.90T O.K.

Tie Spacing :

1) 16 bar dia or 16×³/₄ = 12" c/c

2) 48 tie dia or 48×³/₈ = 18" c/c (using ³/₈" Ø rod)

3) Least dimension of col. or 10"×10" = 10" c/c.

Least of the three is 10". Use ³/₈" Ø tie @ 10" c/c.

Design of Footing :

Imposed load, P = 34.56 Tons,

Say, 35 Tons.

Given bearing capacity, q_a = 1 TSF (Tons per sq. ft.)

= 35 sq. ft.

Size of footing is 6'×6'

Net apward pressure = $\frac{P}{A}$

$= \frac{35 \times 2240}{6' \times 6'}$

=2177.78 psf.

Checks : Following checks are necessary.

A. By moment consideration.

B. By Shear consideration, and

C. Against punching shear.

A. Moment consideration : Compute moment at face of column. Total force = 2'-7"×6'×2177.78

= 33712.03#

M = 33712.03×2'-7"

= 43488.52#'

$d = \sqrt{\frac{M}{Rb}}$

$= \sqrt{\frac{43488.52 \times 12}{146 \times 12}}$

$= \sqrt{293.84} = 17.14"$

$A_s = \frac{M}{fsjd} \quad \frac{43488.52 \times 12}{20000 \times .875 \times 17.14}$ = 1.74 in².

Since, moment is max at face and zero at peripheri, footing slab may be sloped towards peripheri for economy.

Rebar : Consider 3" cover on sides and bottom, so that 1.74 in² be provided 5'-6" in both direction. Using # 4 bar, no of bar required in one direction $\frac{1.74}{2}$ = .87 in²

Bond.

Bond check may be done with critical section same as for bending. Bond stress

$u = \frac{V}{\Sigma o jd}$

V = 6×2'-7"×2177.78 = 33712.08#

Σo = 9×π×½ = 14.13"

$u = \frac{33712.08}{14.13 \times .875 \times 17.14}$ = 159.08 psi, less than 250 psi O.K.

B. By shear: Max. shear occurs at a distance d from face of column.

Total shear V = Area x net upward pressure

= 6'×13.84'×2177.78

= 180842.85 #

Shear length b = 72"

Shear developed, $v = \frac{V}{bd}$, d = 17.14"

$\frac{180842.85}{72 \times 17.14}$

= 12.21 psi

less than 49 psi. O.K.

C. Punching shear: Critical section occurs at a distance d/2 from face of column along its four sides as shown in sheared area. Under pressure column tends to punch through this area, shear length being the peripheri of the area. This area is deducted in computing shear.

Length of one side = $\frac{d}{2}+\frac{d}{2}$+10"

= 27.14"

b = 4×27.14 = 108.56"

Total shear area, A = 6'×6'-$\left(\frac{27.14}{12}\times\frac{27.14}{12}\right)$

A = (36-5.12)×2177.78

= 64249.85#

Shear stress, $v = \frac{V}{bd}$

Here, V = 64249.85

b = 108.56"

d = 17.14"

$v = \frac{64249.85}{108.56 \times 17.14}$

= 34.53 psi, less than 49 psi O.K.

Col C_2:

Between G.Bed, DRN & DIN is critical.

Load calculation:

D.L:

1) Slab, 5×$\frac{10'+8'-11"}{2}$×$\frac{14'+13'-4"}{2}$× 4.25"×150 = 34350.15#

2) Beam, 5×$\frac{13'-4'+10+8'-11"}{2}$×$\frac{11"+14"}{2}$(Av. less slab)× 10"×150 = 10459.30#

3) 5" wall, 5×$\frac{10'+13'-4"}{2}$×Av.'9'×5"×120 (3"partition ignored) = 26257.50#

4) Self wt., 10"×10" section, same as C i.e. 9.46×13.67"= 6302.08#

5) F.F. Slab area in item (1) above ×12×5 = 7759.09#

6) L.L. 50% of slab area in (1) 9.46'×13.67'×40×5×.5 = 12931.82#

Total = 98059.94#

÷ 2240

= 43.78^T

Vertical rod :
Assume size = 10"×10"   Ag = 100 sq. in

Use 8 # 6 bar., A_s = 8×.44 = 3.52 in², Pg = .0352

Then P = .85 Ag (.25f_c+$f_s p_g$)
= 45.69 Tons. Imposed is 43.78T O.K.

Tie : 1) 16 bar dia or 16×3/4 = 12" c/c.
2) 48 tie dia or 48×3/8 = 18" c/c.
3) Least dimension of col. 10"×10" = 10" c/c.
Use 3/8" Ø tie @ 10" c/c.

Footing : Use square footing : A = $\frac{43.78}{1}$ = 43.78 sq. ft.
One side = √ 43.78 = 6.61'
Use 6'-9"×6'-9" = 45.56 sft.

Rebar : Net upward pressure = $\frac{44.73 \times 2240}{6'\text{-}9'' \times 6'\text{-}9'' \times 12}$ 2199.07 psf

Total force = 6'-9"×12 ×2199.07
= 43912.68#

M = 43912.68×$\frac{35.5''}{12 \times 12}$
= 64954.17#'

d = $\sqrt{\frac{M}{Rb}} = \sqrt{\frac{64954.17 \times 12}{148 \times 12}} = \sqrt{438.88}$ = 20.94"
Cover = 3.0"
23.94"

$A_s = \frac{M}{fsjd} = \frac{64945.17 \times 12}{20000 \times .875 \times 20.94}$ in²

Use # 4 bar. No. of bar = $\frac{2.13}{0.2}$ = 10.65, Say, 11 Nos.

Bottom and side cover = 3". Provide 11 bars in 6'−3"

Bar spacing = $\frac{6.25 \times 12}{11}$ = 6.82" c/c.
Say 6½ c/c. bothways

Check other criteria as usual.

Column C_3 : Between child bed and toilet.

D.L :

1) Slab, 5×$\frac{10+2'\text{-}11''}{2}$×$\frac{12'\text{-}11''+13'\text{-}4''}{2}$ appx.×4.25"×150 = 22530.26#

2) Beam, 5×$\frac{10'+2'\text{-}11''}{2}$×$\frac{14''\text{-}11''}{2}$ Av.×10"×150 = 8513.98#

3) 5" wall, 5×$\frac{10+2''\text{-}11''\text{-}4''}{2}$

4) Self wt. Same as Col_2 = 6302.08 #

5) F.F. 5×$\frac{10+2'\text{-}11''}{2}$×$\frac{12'\text{-}11''+13'\text{-}4''}{2}$×12 = 5087.25#

6) LL : .5×5× $\frac{10+2'\text{-}11''}{2}$ × $\frac{12'\text{-}11''+13'\text{-}4''}{2}$ × 40 = 8470.27#

Total = 80446.34#
÷ 2240 = 35.91 T
Say 36 Tons.

Try 6 # 6 bar and 10"×10" size

Ag = 10"×10" = 100 sq in

As = 6×.44

= 2.64 in² $Pg = \frac{As}{Ag}$

$= \frac{2.64}{100}$

= .0264

Now, P = .85 Ag (.25f'$_c$ + f'$_s$p$_g$)

= .85×100 (.25×2000+20000×.0264)

= 85 (500+528)

= 87380÷-2240

= 39 Ton. Slightly over than required O.K.

TIE : As in previous case i.e. 3/8" @ 10" c/c.

Footing

imposed load, P = 36 Tons.

Area, A = $\frac{36}{1}$ = 36 sq. ft

Size of footing = 6'×6'

Net upward pressure $= \frac{36 \times 2240}{6 \times 6}$

= 2240 psf.

Without going for further investigation, it may be concluded that C_3 is subjected to same criteria as those of C_1.

Reinforcement of footing, vertical rod and tie shall be provided accordingly.

Since, footing of C_2 and C_3 overlaps, it may be rectangular in shape or combined together.

In former case, there is clear gap of 3'-6" plus 10" centres of both columns, total gap is 3'-6"+10" = 4'-4". So from centre of each column width of footing can be 2'-2"×2 = 4'-4" or 4.33 Length of footing for C_2 is $\frac{45.56}{4.33}$ = 10.52' or 10'-6" and for C_3 is $\frac{36}{4.33}$ = 8.31 or 8'-4".

Here, moment and shear be checked along longer side.

When combined footing is provided total area will equal to 45.56+36 = 81.56 sq ft or 9.03'×9.03' size. Thickness 23.94" will prevail. When two columns are seperated apart a beam will connect the columns. The design of the beam will be based on net upward pressure.

DESIGN SUMMERY

A. Bearing Wall Foundation :

Outer wall foundation	= 50"
Inner wall foundation	= 60"
Foundation depth	= 5'-0"
Slab thickness	= 4½"
Bearing wall width	= 10"

B. Framed Structure :

Column and size		Base of column	Vertical rod	Tie
C_1	10"×10"	6'×6'	4 # 6 2 # 5	3/8" @ 10"c/c " " "
C_1	10"×10"	6'-9"×6'-9" and 4'-4"×10'-6"	8 # 6	" " "
C_3	10"×10"	6'×6" and 4'-4"×8'-4"	6 # 6	" " "

Depth of foundation = 6'-6"

Beams	Span (maximum)	Size
1. GB_1	19'-9"	10"×17"
2. GB_2	14'-0"	10"×11"
3. B_1	19'-9"	10"×23½" including slab.
4. B_2	14'-0"	10"×15' " "
5. B_3	10'-0"	10"×15½' " "
6. B_4	11'-0"	10"×15½' " "

Slab thickness = 4.25".

Design Against Wind Load

It may be necessary to analyse a building against wind force. But unnecessary cost should not be increased by considering extra provision for wind load because walls are sufficiently stiffened against wind by cross walls, beams and floor slabs. It should, however, be checked against overturning.

Wind pressure P, psf on a vertical surface is given by the formula, $P = KV^2$, where K is a coefficient whose value in normally taken as .01.
V = Wind velocity, miles per hr. (mph).

Overturning moment.
Wind velocity for Dhaka Zone is 60 mph.

$P = KV^2$
$= .01 \times 60^2$
$= 36$ psf.

Horizontal wind force on a vertical area of the building = 54'-6"×60' (On longer side)

Total wind force = P×area
= 36×54.5×40
= 78480#
÷ 2240
= 35.04 Tons.

Now, $M = \text{Force} \times \frac{ht}{2}$

$= 35.04 \times \frac{54.5}{2}$

 = 954.84 Ton ft

Resisting Moment.

For bearing wall building

Find total wt. of building, W

Length of outer wall×load per ft. and

length of inner wall×load per ft. will give W.

Outer walls	2×40	= 80 rft
	2×28'-(1'-8")	= 52.34 rft
	Total :	132.34 rft
Inner wall :	2×(28'-(2×10"))	52.68 rft.
	1×11	= 11 "
	1×14	= 14 "
	2×12'-6"	= 25 "
		102.68 rft.

W = Outer wall×load/ft.+Inner wall×load/ft.

= 132.34×4.11+102.68×5.04

= 543.31+517.51

= 1062.82 Tons.

This acts at the centre of gravity of the building, (eccentricity ignored), lever arm is width/2.

Resisting moment = $W \times \frac{L}{2}$

$= 1062.82 \times \frac{28}{2}$

= 14876.68 Ton ft. More than overturning moment O.K.

Factor of safely = $\frac{\text{Resisting moment}}{\text{Overturning moment}}$

$= \frac{14876.68}{954.84}$

= 15.58 Much more safe against wind.

B) For framed structure :

C_1 = 10 Nos., load 39 Tons.

C_3 = 3 Nos., load 49 Tons.

C_2 = 2 Nos., load 41 Tons.

W = 10×39+3×49+2×41

= 619 Tons.

Overturning moment = 954.84 Ton ft as in previous case.

Resisting moment = $619 \times \frac{28}{2}$

= 8666 Ton ft.

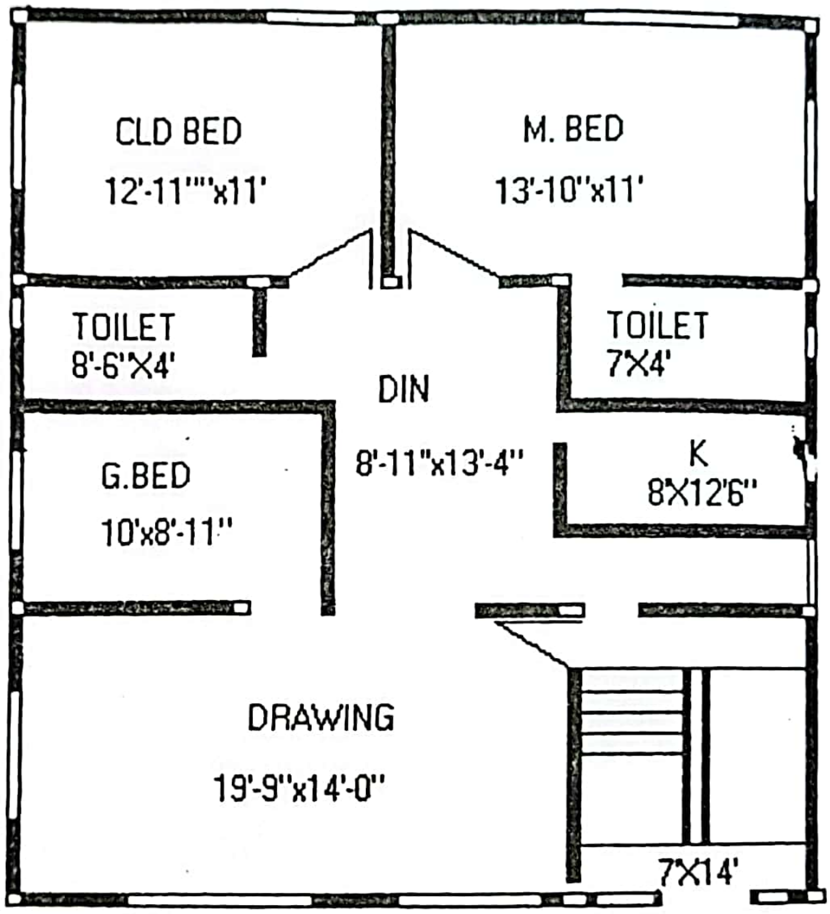
Factor of safely = $\frac{\text{Resisting moment}}{\text{Overturning moment}}$

$= \frac{8666}{954.84}$

= 9 O.K.

Design Against Earthquake Load :

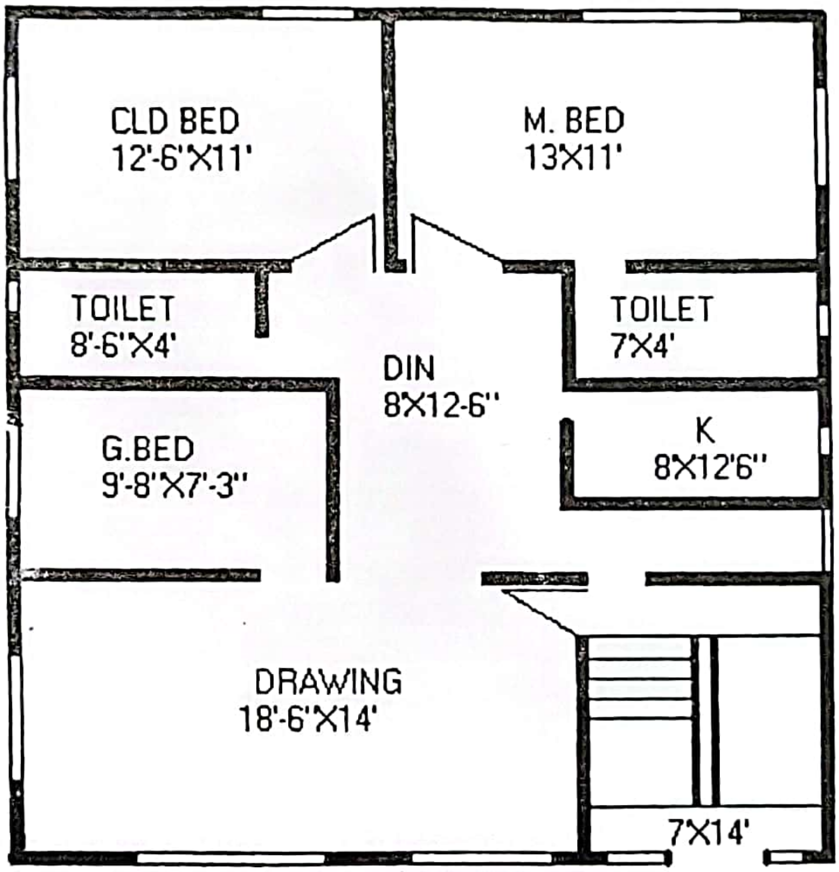
Earthquake load EQ or siesmic load causes to and fro vibration in the building that acts in any direction. During tremor it produces stresses or deofrmation in structural elements.



PLAN WITH RCC FRAME

COL. SIZE 10"X10"

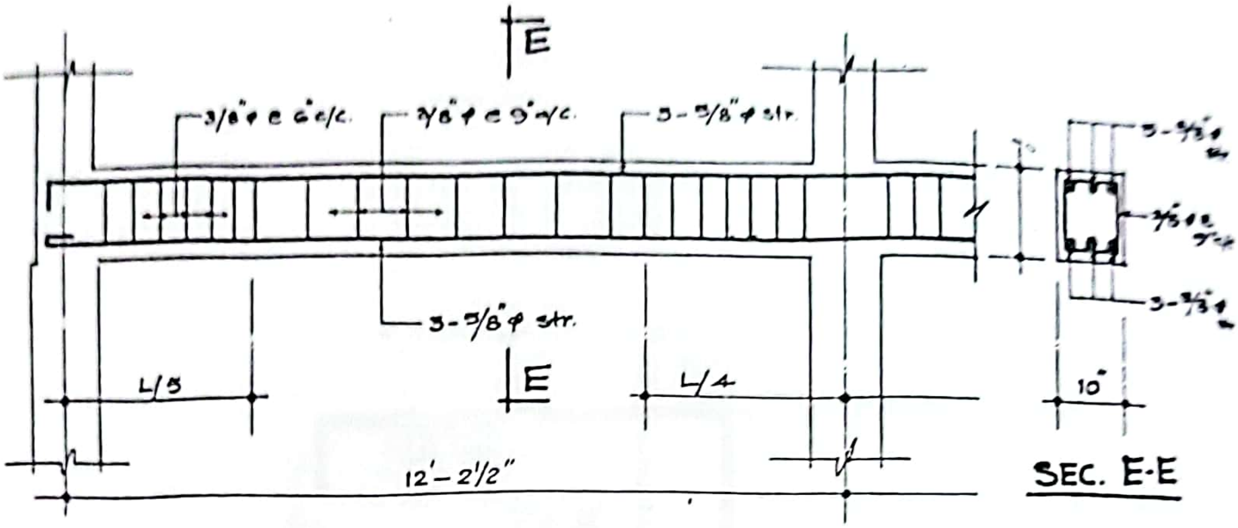
Not to scale



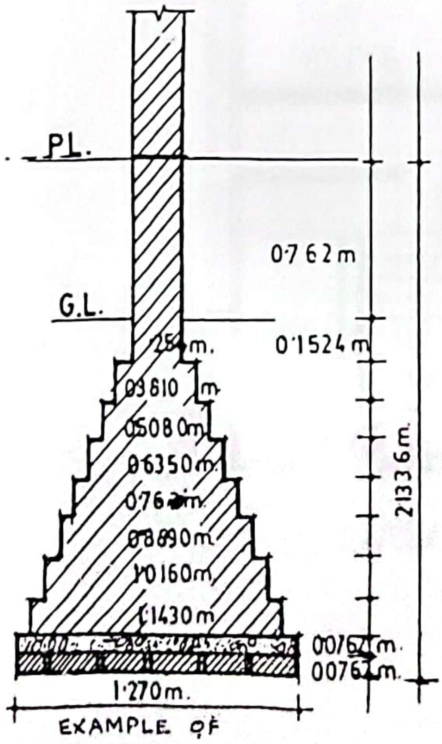
PLAN WITH LOAD BEARING WALL

WALLS 10" WIDE

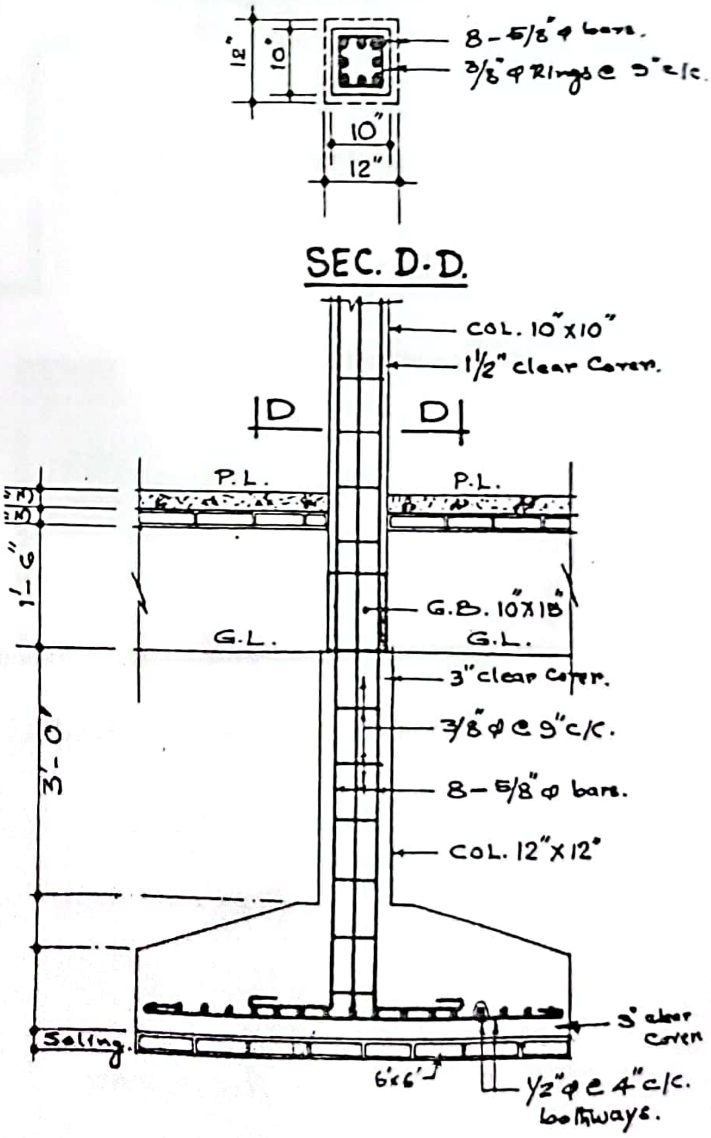
Not to scale



EXAMPLE OF
REINF. DET. OF GRADE BEAM-GB



EXAMPLE OF
FOUNDATION WALL
Scale 0127m = 0·3048m



WALL FOUNDATION

COLUMN FOUNDATION

Example of beam, column one wall foundation

There are two main factors affecting a building (1) one is total base shear and (2) Moment of horizontal mass that causes overturning
1) Base shear total horizontal base shear is given by,

V = ZKCW (Art 1.5)

The formula is simplified

by combining the factors as below.
V = ZKCW, where Z is seismic coefficient in particular Zone, K is a factor of 1.33 for box type building C = .1, W is the DL of the building with reduced value of live load

Here, Z = 05, K = 1.33, C = .1,
W = 619 Tons. (Framed).
V = .05×1.33×.1×619
4.12 Tons×2240
9228.8#, Say 9229#.
Considering point of inflection at mid ht. of column, i.e. $\frac{10}{2}$, base moment

$$M = 9229\times\frac{10}{2} = 46135\#'$$

Lateral dimension of col = 10" = .83'
Axial force per col.

$$= \frac{46145}{.83\times15} = 3706.43\#/\text{column. (There are 15 col.)}$$

Keeping, size of the column unaltered increase rod for this load in each col. This load is within tolerable limits in respect of design already performed.
For bearing wall, axial forces will be more for greater W. To resist, reinforcement may be provided in brick work for such extra load.

Overtering moment :

Horizontal movement at base is zero but is maximum at top. As if a bamboo tree is disturbed at the base and its tip moves to and fro windely. Thus, earthquake is felt more at the top floors of the building.

Here, M = Horizontal mass×$\frac{2}{3}$ ht.

Horizontal mass = wt of slabs and beams

wt. of slabs = $5\times40'\times28'\times\frac{4.25"\times150}{12\times2240}$ = 132.81 Tons

Add, wt. of beams, 15% 19.92
Total wt : 152.73 Tons
Say 153 Tons.

$$M = 153\times\frac{2}{3}\times54.5$$
$$= 5559 \text{ Ton ft.}$$

Less than resisting moment of 8666 Ton ft. This indicates that gravity load controls the design. O.K.

Mind that making buildings strong against EQ is not the criteria. Some technic energy absorbsion is necessary against this natural calamity.

14

Design of High rise Building

If one pays a visit to Hong Kong, Singapore, Beijing or New York, he will feel the necessity of constructing 50 to 118 story high building here in Dhaka because of the fact that Bangladesh has got highest population density in the world. Land is limited but space is unlimited which the other nations have selected for its right utilization. Amazingly, concerned authorities here do not allow even 15 story building on the plea of environmental pollution, though it is an established fact that a building of min. 15 story becomes economical with the provision of lift facility. Instead of creating the facilities for utility services for environment friendly atmosphere, height restrictions are imposed contradictory to more space utilization and limited land use.

In early sixties, our front line professors of BUET were of opinion that max. 6 story building in load bearing wall shall be constructed at Dhaka. At that time this idea was fully justified, as most of the Dhaka's soil are alluvial deposits with poor bearing value. But, now with technological development in four major fields namely, development of high strength materials like 5000 to 7000 psi concrete, 60 to75 grade steel, USD and limit design close to actual behavior of material, development of new structural design concept like tube in tube, shear wall etc. and improved construction methods like lift slabs, pre cast members and laboratory made concrete in drum trucks with concrete pumping facilities are now available in the country. All these factors are favorable now to plan and execute tall buildings here in Bangladesh up to any height.

Dhaka's horizon was once adored with 15 storied WAPDA building, then came the 24 storied Shilpa Bank building which is surpassed by 34 storied Bangladesh Bank building. Now time has come to plan 50 story or more high rise buildings along with creation of proper utilities and environmental facilities as well as with earth quake proof design.

14.1 The pioneer of high rise building design:

Bangladeshi civil engineer, Engr. Dr. F.R. Khan is the pioneer in this field; he is proudly & respectfully remembered for his innovative tube-in-tube system that became a phrase in the history of construction of high rise building both in steel and concrete. Further development of bunded tube system enabled the civil engineers to go up to any height they desire. Based on his design, 110 story Sears Tower in Chicago is now soaring to world's record of 1450 ft high. Recently, Petronus Tower of Malaysia has surpassed this record with a ht. of 1482 ft.

One of his papers submitted to ACI entitled "Tubular Structure for tall buildings" is a historical guideline for design and construction of high rise building. So far no more remarkable development in this field could be achieved after him. He was honored as the "man of the year" for consecutive four years and a monument in his name is erected in Chicago to memorize his outstanding contribution to Civilization. But he is least remembered in his own country.

14.2 What Is High Rise Building

Which building should be called high rise? The reply needs some explanation. In early sixties, our Professors in BUET cherished the idea of making maximum 6 (six) storied building with load bearing brick wall. At that time, six story high building was rare, the ugly DIT Building with central watch monument which was later renovated was the highest in Dhaka. 15 storied WAPDA (Water & Power Development Authority) building was a break through.

Department of Environment has put some embargo on the construction of taller buildings if it exceeds six story. According to them, if the building just crosses six i.e. if it is just 7 storied then clearance from Civil Aviation, PBD, Titas Gas, WASA, Municipal Corporation, Traffic Department is necessary and an IEE. Initial Environmental Examination report is to be prepared for their clearance.

Thus, a 7 storied building is a tall building. But a building is not high rise in New York that has at lest 110 storied higher ones. So, a 6-story building may be termed as low rise, 7 to 25 story as medium rise and more than 25 story as a high rise one.

14.3 Brief history of high rise building

Modern 10 story building was first constructed in steel in 1883 in Chicago. It was Home Insurance building. So that the history of high rise construction goes back to 1883.

In 1913, 60 story 792 ft high Woolworth building in lower Manhattan was completed.

During 1920-1930, 67 story Wall Tower building was made in New York, followed by 77 story Crysler Building in the same place. Tall building shows America's prestige in the eyes of the world. In 1929, Empire State building came as 104 story high. In 1960, tube-in-tube system was developed by F. Rahman who is termed as imaginative creator of most of the modern framing system particularly the bundled tube system. The tallest RCC building is 74 story Water Tower Place building in Chicago completed in 1976. Steel framed Twin Tower, 110 story World Trade Center in New York city, and 110 story Sears Tower came in bundled tube structural system as the crowning glory of high rise steel structure.

Though the two world wars of 1918 and 1938 hindered the development of high rise construction, yet remarkable development was achieved by civil engineers.

Sky scrapers like the Wall Tower building in New York, 71 story Bank of Manhattan Building in New York and 77 story Crysler Building in New York was constructed onwards.

Tallest building with flat plate shear wall combination was 70 story Lake Point Tower apartment building in Chicago.

In the field of steel structures, in the late sixties brought the diagonally braced 100 story John Hancock Building in Chicago and 110 story World Trade Center in New York known as the Twin Tower demolished by terrorist attack on 11th September, 2002. Using bundled tube system 110 story Sears Tower in Chicago is now soaring high to the world record of 1450 ft high. Malaysia's Patronus Tower is a breakthrough having ht. of 1482 ft.

14.4 Agricultural land grabbed by normal building construction every year.

Low rise buildings are grabbing agricultural land evry year. Art 1.3 of this book states that average growth rate of housing is minimum 2.44% over the previous year. An average of 709,131 nos. houses are built every year. From this data one can guess easily how much land is grabbed by residential occupancy alone. In order to have a national total including other occupancies, an estimation can be arrived at as under:

Estimate of land occupied by building per year

Sl No.	Type of Company	Av. total no of building per year	Av. Coverage area of building sq.ft.	Total Area Acre	Remarks
01.	Residential	709,131Nos.	2000 sft	32,555	Growth rate 2.44%
02	Business / Commercial	3545 Nos.	3000 sft	244	.5 of sl. no. 1
03.	Educational/Institutional	1772 Nos.	5000 sft	203	0.25 "
04.	Industrial	709 Nos.	7500 sft	122	0.1% "
05.	Storage/ Assembly	355 Nos.	3000 sft	24	0.05% "
06.	High hazard occupancy	70 Nos.	10,000 sft	16	0.01% "

Appx. National Total : 33168 acre

Thus, we see that a considerable amount of cultivable land is being exhausted every year. We have a population of about 140 million people now having highest population density of 834/km^2 according to census of 2001. The projected density is 904/km^2. So, there is no justification to limit a building height for utilization of space than to occupy precious cultivable land. Few more reasons justifying high rise construction is furnished below:

14.5 Reasons justifying high rise construction

1. Available land is limited but space is always unlimited.
2. Bangladesh has highest population density. Rehabilitation of such big number of people, space must be utilized.
3. In case of high rise construction land cost is abruptly reduced, though construction cost is slightly increased due to height
4. Space utilization helps availability of more land for play grounds and greeneries and contribute to environmental uplift
5. Because of more people living together, community development becomes easier.
6. Fresh air and light is readily available.
7. Hong Kong is termed as Pearl of the Orient. Singapore, New York has adopted space with high rise building that has enhanced their prestige in the eyes of the world.

14.6 Creation of utilities for high rise building:

The following agencies / departments are involved.

Sl. No.	Name of Agencies Involved	Nature of Involvement
1.	Ward commissioner	NOC for construction
*2.	Municipality	Clearing solid waste
3.	Civil Aviation	Ht. that can be allowed
4.	Fire & civil defense	Meet fire accidents.
*5.	Wasa	Water & Sewerage
6.	Desa	Electricity supply
7.	Titas Gas	Gas connection
8.	D.C. Traffic	Traffic congestion
9.	Environment	Environmental Clearance

If we analyze the above involvements only the star marked two agencies have environmental concern while the remaining are environment friendly. It is necessary to create respective service facilities by concerned agencies /

departments or a high rise building commission may be formed by the Govt. to identify zones for high rise construction and make liaison with all such concerned departments.

Ward Commissioner may be bewildered to hear that a 100 story building is going to be constructed in his ward. But, Municipal Corporation may take planned steps for tall building & plan wider roads to avoid traffic jam.

Main problem lies with water supply and sewerage. How the size of these lines are calculated? The biggest ever is only 6 ft. dia. line and is obviously insufficient for a metropolitan city like Dhaka. In cow boy series, we have seen few people is walking side by side in the sewerage line passing under some American cities. American Society of mechanical engineers have fixed up data for the size of water & sewerage line which provides sufficient average for efficient sewerage disposal. The data is furnished here for ready reference:

- A lavatory discharge about 7.5 gals of liquid / min. which is equivalent to 1 ft of water and is considered as one unit. Thus 7.5 gals / m = 1 unit.

- <u>Pipe capacities (without slope, but fitted with pump)</u>
  12" Pipe will serve 3900 nos. such units
  15" Pipe will serve 7000 nos. such units
  From above it is found that on the av. 37 units can be served per sq. in

- Pipe capacities with $\frac{1}{8}$" slope or 1 in 100 for hilly high areas.

  12" pipe serves 4600 units
  15" pipe serves 8300 units
  From above it is found that on the av. 43 units can be served per sq in of pipe.

Water supply : Riverine Bangladesh should have no. water supply problem for example, all big fertilizer factories provide chlorinated drinking water from river sources. Almost all big fertilizer projects have 10,000 nos. family accommodation.

Planning for other utility will not point a big problem,

14.7 Philosophy of EQ proof design:

For most practical purposes, code provisions are right tools to be followed in designing high rise building. The philosophy behind the code is its reliability as design guide. Code provision are good prescription to be relied upon for its simplicity and applicability.

The basic form and features of latest code provisions on EQ resistant design have been evolved from simplified concept of dynamic behavior of the structure as observed under actual EQ load.

Super computers have made it possible to determine analytical findings of inducted forces in the realistic modules of the structure under the influence of EQ.

Codes also describe that column should be strong and beam should be weak with the intension of limited yielding of the beams while columns should remain elastic throught their seismic response.

The shape of the building also contribute well against overturning and to the sub-system design. A post card can not remain standing on its edge but a fold will make it 'L' shaped that enables it to remain standing. A (plus) '+' shaped frame is very firm against O.T (over turning) caused by wind and EQ. Overturning and collapse are the two major phenomenon to be encountered against these two forces.

14.8 Big EQ records:

Country	Date	Richter Scale
A. America:		
▪ Sanfrancisco	April 18, 1906	8.3
▪ Olympia, Washington	April 13, 1949	7.1
▪ California	July 21, 1952	7.1
B. Other Countries:		
▪ Chile	1906	8.4
▪ Siankiang, China	1911	8.4
▪ Japan	1933	8.5
▪ Alaska	1960	8.6
C. Bangladesh & its vicinity:		
▪ Assam, India	1918	8.0
▪ North Assam, India	1950	8.6
▪ Bangladesh: Longi. 24.3, Lat 91.7	1918	7.6
▪ Bangladesh: Longi. 28.6, Lat 95.7	1950	7.0

Maximum horizontal ground acceleration caused by EQ over 8 on Richter Scale is 0.33g and in other cases it varied from 0.18g to 0.31g

On the average, in Bangladesh for zone 1, EQ, up to Richter scale 7.0 is to be encountered.

Seismic zones and corresponding seismic co-efficient are stated in art 1.5 of this book. Applying seismic co-efficient, base shear value at the base of the structure can be easily worked out.

Since the building is pinned to the ground firmly by virtue of its foundation (deep pile supported mat) wind and EQ produces pure cantilever action at the base of the building forming a couple of tension on the side of applied force and compression on opposite side of the applied force.

Thus, determination of the base shear is very important which forms the basis of structural stability. Base shear will be encountered by shear wall which will continue up to entire length of the building. These two external forces have separate distinctive activities on the structure, wind normally acts from one direction except gust, while EQ acts in to and fro direction causing bending and deflection to its members.

EQ's dominant period of vibration is a fraction of second whereas a flexible high rise building will have a period of vibration several seconds keeping it out of phase of resonance and seismic response is kept limited.

Period of vibration in structure is dependant on damping which resists motion due to EQ load. It lengthens the period of vibration. Where flexible friction or damping is more, vibration is less.

For study of dynamic response of a building under EQ, models are prepared for linear single degree of freedom (SDF) and multi-degree of freedom (MDF). Code provisions are based on such studies.

Studies have formulated current practice in EQ design prescribing that the structure should be able to act as follows:

1. Frequent but minor shocks should be resisted by the structure without change within its elastic limits.

2. The structure should be able to resist moderate EQ with minor structural and non structural damage within design limits and can be repaired.

3. Resist major catastrophic EQ without collapse.

The above criteria are only applicable to typical ground shaking. Sliding, taulting effect close to the building and many other uncertainties may cause the building very badly damaged. Still it is desired that though badly damaged it should remain standing and later repaired. For this, adequate strength and ductility be incorporated in design to prevent collapse and save life. Damage control by mechanical means like providing springs, rubber pads, sand cushion under the columns increases period of vibration and is also desirable as a second safety measure. Providing shafts at corners and core walls at the center of the structure is a good means to keep the building remain standing and prevent collapse.

14.9 Design procedure

Design criteria for low, medium or high rise building is the same for all the three cases except that when the building rises higher two factors become prominent:

1. Higher vertical load with greater vertical mass, and

2. Greater O.T (over turning) moment produced by two prominent external forces, the wind and the EQ.

Again, higher vertical load and greater vertical mass in a R.CC building over 40 story posses three problems:

1. More mass of steel and concrete for vertical sub system members like columns & walls becomes necessary.

2. Bigger dimensions need be provided for the members occupying usable space.

3. Frame cost becomes high and economic stability and stiffness are lost.

As a result only 74 storied Water Tower Building in Chicago was built in R.CC while all other higher buildings like 110 storied Sears Tower is made in steel. I beams and channels which is about 20 times stiffer then concrete are easy to cover more ht having comparably smaller weights and thereby reduces cost.

14.10 Tube In Tube system :

To overcome the problems stated above, Engr. Dr. F.R. Khan's innovative design concept of tube in a tube revolutionized the system of high rise construction to reach up to any height.

The system consists of closely spaced exterior columns tied at each floor level with relatively deep spandrel beams thereby creating a hollow concrete tube having door and window openings. An inner tube is similarly developed. The outer tube takes the load of external forces like the wind & EC   the inner tube takes internal load of the building.

Till mid sixties the conventional WSD and USD methods of designing were followed with the concept that outer columns carry $\frac{1}{2}$ the load than that carried by the inner columns along with DL, LL and its self wt. and also the external forces. Tube in tube system is a major break through over the conventional type of design.

The system was first applied to on the design of 43-story Dewitt Chestnut apartment building in Chicago in 1963. Since then, the system has received wide acceptance. It was a major break through over conversional type design and provide a distinct economic advantage for taller buildings with two parallel walls indicates reasonably uniform shear force in formed tube type structure.

Tube in tube system became a phase in the history of taller buildings. He further developed this system to bundled tube system that enabled the constructions of 110 story Shears Tower at Chicago. The simple proposition that the outer tube either rectangular or tubular will take external load while the inner tube will carry the internal loads of the building.

The system is based on some computer modeling having simple mathematical deductions. Dr. Rahman became man of the year for consecutive four years in America and a monument is erected in Chicago in his name.

His prematured death (1989) is a great loss to the Engineers Society.

14.11 Design steps:

It is customary to 1st make a preliminary design on rough sketches and then make major details by proportioning vertical and horizontal members to satisfy flexural requirements of gravity and external loads. One may proceed with the following:

A. Load consideration:

(i) No reduction for DL of column, beam, slabs be allowed.

(ii) Only LL may be reduced up to 40% to 60%

B. Guide to selection of stories

According to different structural system no. of story or height can be selected from the following guide:

Structural System	No. of story	
	Office	Apartment
1. Frame	up to 15	up to 20
2. Staggered beam	15	40
3. Shear wall acting with frame	40	70
4. Single framed tube	50	60
5. Tube in tube including bundled tube	80	100

C. Design limitations of framed tube structure.

Components		Min.	Max.
1.	Center to center spacing of external columns	4 ft.	10 ft.
2.	Spandrel beam depth	2 ft	4 ft.
3.	Spandrel beam width	10ft	36 ft
4.	Lateral deflection or sway due to wind force	5ft	7 ft. Depends on ht. of building

D. Structural properties to prevent overturning

The overturning moment resisted by the two equivalent channels will produce axial force in closely spaced columns and shear force in the connecting spandrel. Based on the classical beam theory, the phenomenon can be expressed as under:

1. $$P_W = \frac{MxCxAc}{Ie}$$

2. $$V_S = \frac{V_W xQxh}{Ie}$$

Where, Pw = axial force due to wind

M = Overturning moment

Ie = effective moment of inertia. of the tube

Vs = Spandrel shear

Vw = Total wind shear

Q = Summation of 1st moment column areas about n.a.

C = distance of any col. from n.a.

h = Story ht.

Ac = X-sectional area of column.

E. Influence Curves:

Influence curves were developed by the author (F. Rahman) for more accuracy. Significant structural properties affecting the tube action are :

1. Bending stiffness, $k = \frac{Ic}{H}$ or. $\frac{I_b}{l}$

2. Shear in beams $S_b = \frac{12\,E\,I_b}{L^3}$

3. Axial Column stiffness, S c =Ac E/H

Where,

Ic = moment of inertia of column.

I_b = moment of inertia of Sp. beam

Ac = X-area of the columns

H = ht. of col.

L = effective span of Sp. beam

E = Modulus of elasticity.

These findings may be converted to ratios, ratio limitations being worked out as stated below.

F. Ratio limitations

Ratio	Given by	Limiting range
1. Stiffness ratios, S_r	$S_r = \frac{Kc}{Kb}$	0.75 at roof 0.50 at ground level
2. Stiffness factor, S_f	$S_f = \frac{S_b}{S_c}$	1.0 to 10.0
3. Aspect ratio, R	$\frac{\text{Flange frame}}{\text{Web frame}}$	0.5 to 1.50

G. Column shortening

Office buildings demands column free spaces while in apartment buildings, there are so many interior columns spaced closely, thereby forming a inner tube that greatly enhances the structural qualities of the structure and considerably reduces the shear deflections of the columns. Gravity load may also be shared by the inner tube. Column shortening of the external. tube can be adjusted by the actual moment of inertia of inner shear wall to an equivalent moment of inertia slightly larger than the actual value. The following formula will hold good for such cases:

1. Col. axial force at level I = $\frac{M \times C}{I}$ x Ac kips

2. Spand beam shear at center = $\frac{Vq}{I}$ x H kips

3. Ie = I x (1+K)

H. Deflection

Deflection: is defined as the amount of total movement induced at a point of a member from the position before application of the load to the position after application of the load.

Two types of deflection occurs:

1. Axial deflection due to dead load

2. Bending deflection due to Horizontal load.

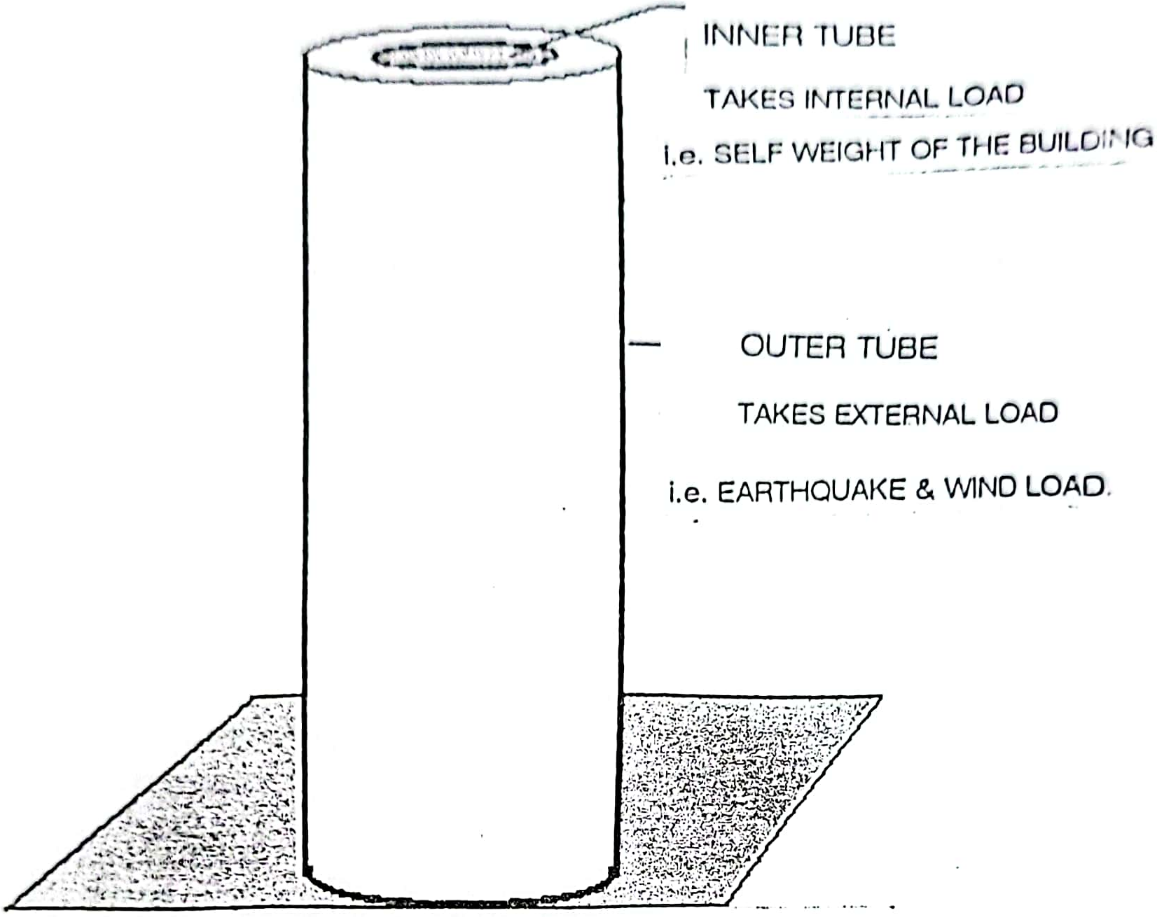
Axial stiffness is directly influenced by stress strain properties of structural material i.e. the modulus of elasticity E. So, sectional area & E will control axial deflection. Lower modulus means higher deflection under a given load

Deflection. is not a problem for beams, because they are extremely rigid elements.

Shape and depth act together with material properties to determine the resistance to bending deflection.

I. Deflection for beam

Common limits in the form of max. permissible deflections are often specified in building codes for beams, it varies from L/240 to L/360. A general expression for Δ is given by, $\Delta = \frac{5WL^3}{384E1}$ Deflection of the total system can also be determined by computer modelling as Δ = sum of frame deflection + model deflection x magnification factor.



TUBE IN TUBE

J. Deflection: For wall and tube

Deflection at top of shaft which has taken entire lateral load W, is given by.

$\Delta = Wh^4/8EI$, Since the shaft is slender shear deflecting is neglected.

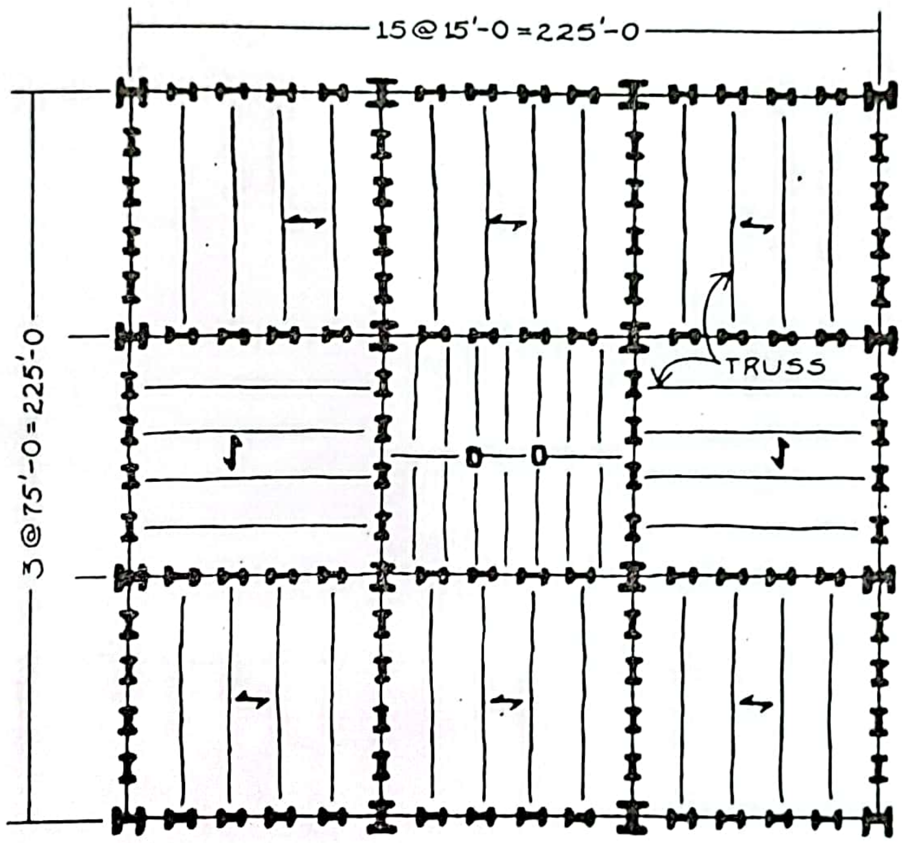
K. Lateral deflection

1. Wall cantilever $\Delta = \dfrac{wh^4}{8E1}$, where $w = \dfrac{bd^3}{12}$ (about 2-2) $= \dfrac{db^3}{12}$

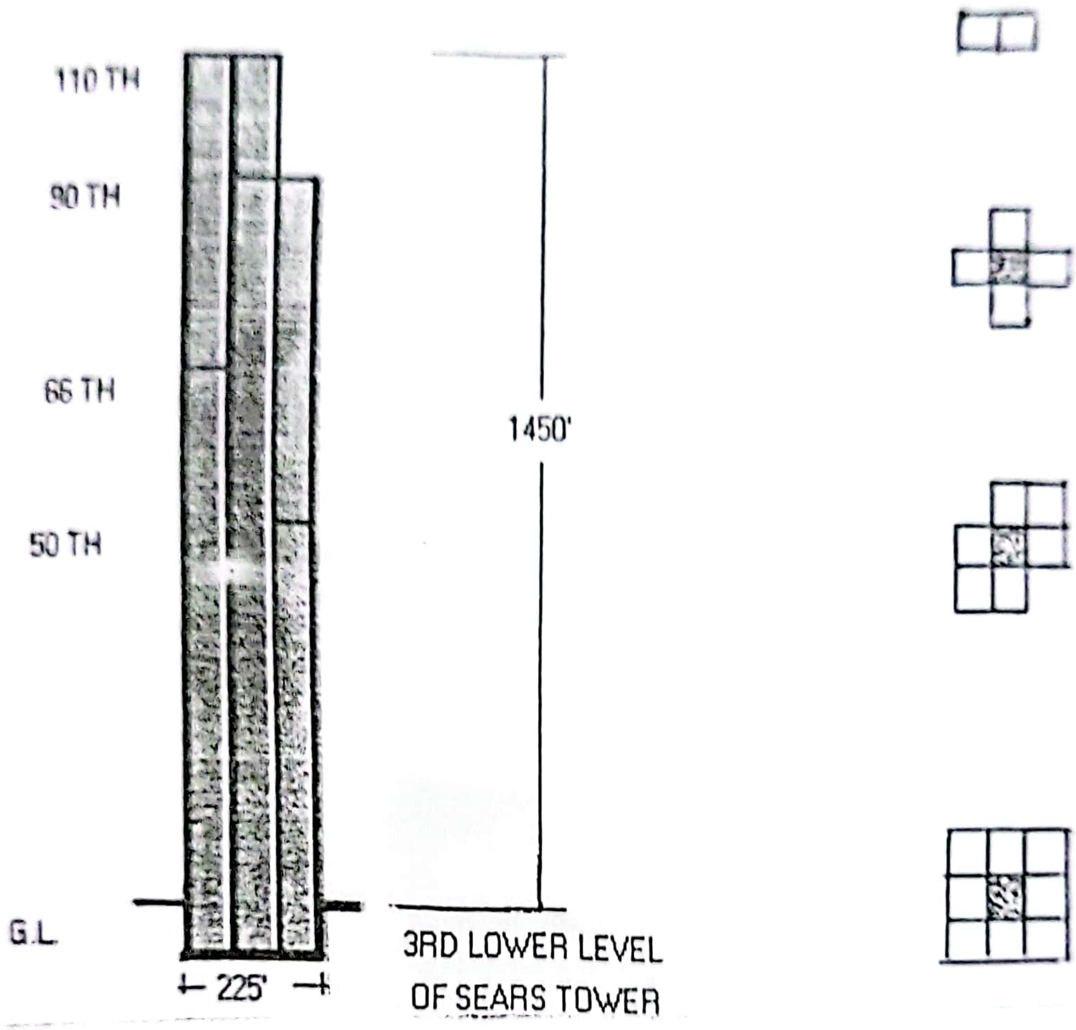
2. For tube, $I_b = \dfrac{b_1 d_1^3 - b_2 d_2^3}{12,}$ about 1-1

Other than shear wall, rigid frame and tubes and some other special systems like staggered truss arrangement, truss frame, outer thin shaft to achieve mega frame action may be of interest to the designer. Text book like Hand book of concrete engineering edited by Mark Fintel may be consulted.

Finally, design of base shear, checking O.T moment, (Art 1.5 and chapter 15, seismic provisions 318-88 of this book) proportioning of horizontal and vertical members to satisfy induced shear & moments, insure ductility in the structure, seismic requirements of hooks and hoops, top tie beam and frame will result in an EQ resistant high rise building.



SEARS TOWER FLOORING PLAN IN BUNDLED TUBE FRAME

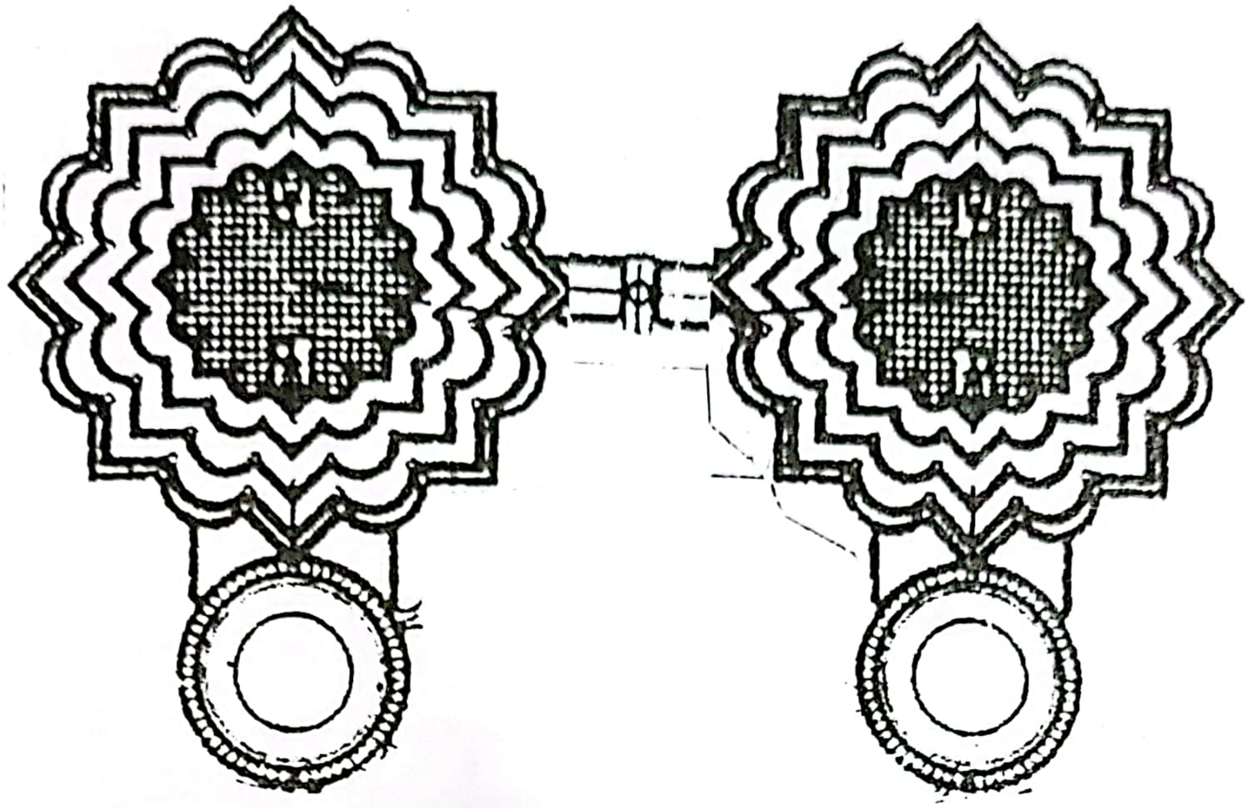


LEVEL WISE PLAN AND ELEVATION OF SEARS TOWER

14.12 Design example

Example 1. Design of a 50 story round tube building

A 50 story R.CC round building with diameter of 100ft having inner tube of 30ft dia. carries 5/8 floor loads. The outer wall is 10" thick with window openings for about 50% surface area carries 3/8 floor loads and resist wind forces. Investigate the strength of the walls for a wind load of 50 psf. use shape factor 0.8 for this round building.

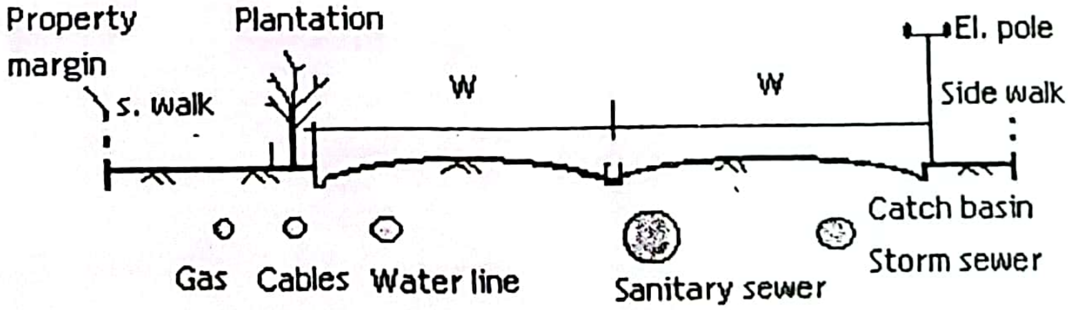


PLAN OF PETRONAS TOWER, KUALALAMPUR

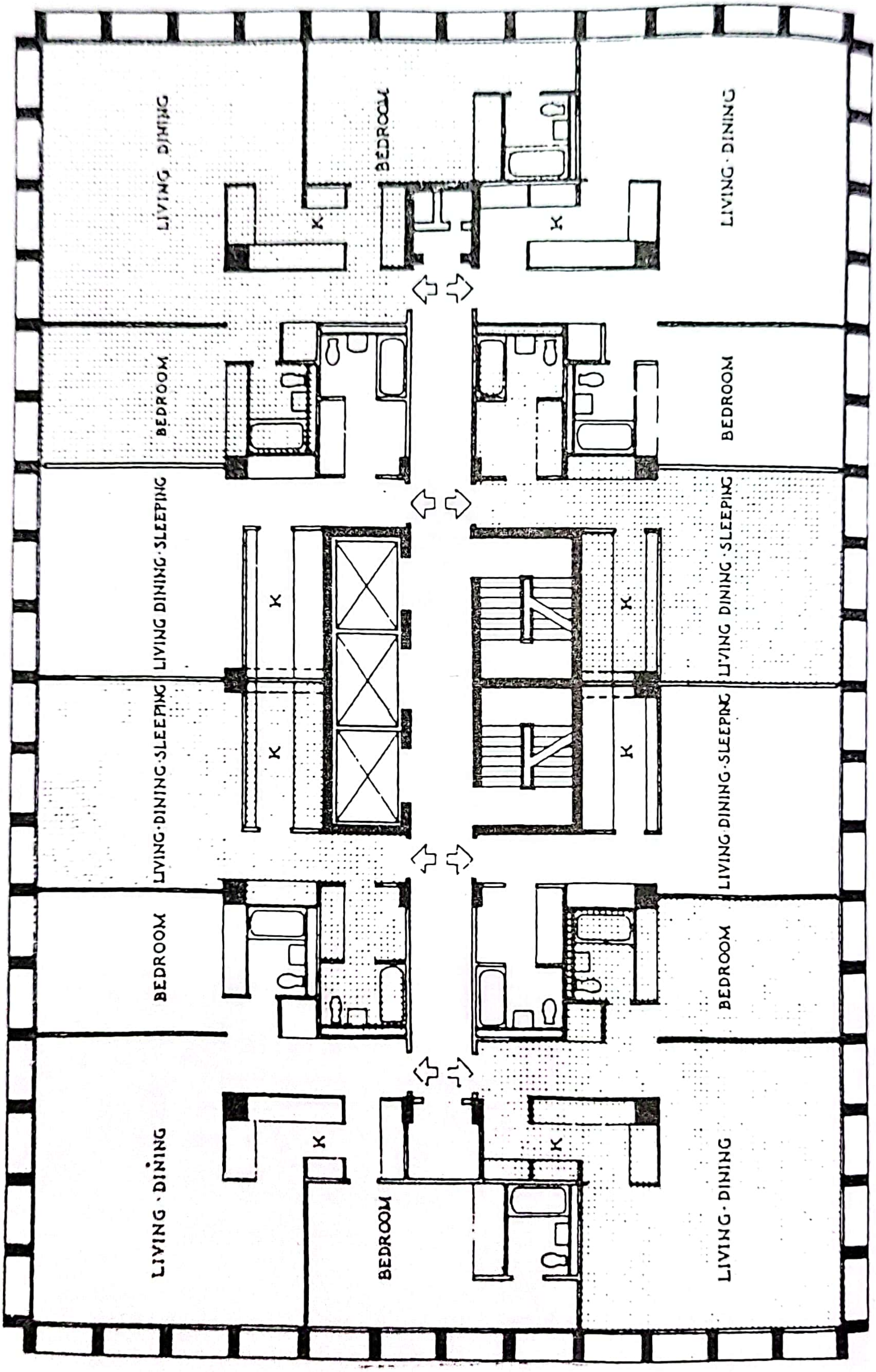
Solution : Wind force per ft of building ht = 50 x 0.6 x 100 = 3 kip / ft O.T

moment at the base of the building = $\frac{wL^2}{2} = \frac{3 \times 500^2}{2}$ = 3,75,000 kip ft.

Moment of inertia, I of outer wall 0.83 ft thick and dia 100 ft, 1 = $\Pi r^3 t = \Pi\ 50^3 \times 0.83 = 325775\ ft^4$



A ROAD CROSS SECTION SHOWING LOCATION OF UTILITIES



COURTESY : SOCIETY HILL, PHILADELPHIA, PA. I.M PEI & PARTNERS ARCHITECTS

TOWER PLAN

The tensile or compressive stress at extreme fibre is

$$f = \frac{Mc}{I} = \frac{375\,000 \times 50}{325775} = 50 \text{ ksi}$$

Now, vertical self load of walls is about 100 psf of wall surface. Hence, it exerts weight at base equals to 100 x 500 = 50k Calculate av. dead load of other member which is assumed to be 120 psf. For a 15 sft per foot of wall perimeter, load is

15 x 120 x 50 floors = 90k

Adding with self wt. total wt. on wall base is,

50 + 90 = 140 k/ft

Thus, max and min. stresses per foot of wall are

140 + 50 = 190 k. comp. compression controls

140 - 50 = 90 k. comp. compression controls.

Considering 50% wall area is effective due to window openings, effective area across 10" wall is $\frac{10}{2} \times 12 = 60$ in^2.

Av. unit compressive stress is $\frac{190 \times 1000}{60} = 3166psi$. Which is higher than allowable .45f 'c or 1350 psi for 3000 lb concrete.

Comment : Thickness of wall is to be increased.

Design example 2

Design of Petronus Towers, Kualalampur, Malaysia

Structure height : 452m (1482 ft)

No. of story : 88

Designed by : Cesar Pelli & Associates, USA in Association with KLCC architects.

Design concept : Floor plan is based on simple Islamic geometric forms of two interlocking squars creating the shape of eight pointed stars.

Structure : 88 story, 452m high (1482 ft). The hollow space between the two towers is linked by the sky bridge at levels 41 and 42. An annex acting as shaft reaches 44th floor and is supporting each tower. Circular multi tube action.

Lift facility :	29 double decker lifts
	6 heavy duty lifts
	4 executive lifts at each tower
	Time to reach top floor : 90 Sec.
	Speed 3.5 m/s to 6m/s
	Passenger deck has capacity of 52 people.
Escalator:	10 at each tower
Quick facts:	Length of sky bridge : 58.4 m
	Ht. of each pinnacles : 73.5 m
Basement	Car park at five level basement for 5400 cars.
Foundation:	4.5 m raft foundation support by 104 barette piles ranging from 60-115m in length.
Concrete:	In foundation 13,200 cum, weighing 32550 tonnes.
	Total concrete 1,60,000 cum.
Steel used:	36,910 tons.

Construction period : March 1993 to August 1999.

Comment: This type of foundation is significantly suitable for high rise building in Dhaka.

Design example 3.

Design of Sears Tower

No of Story:	110
Ht. of building:	1450 ft
Structure Design:	Bundled 9 tubes of 75' x 75' square having 3 basements structure
Frame	Link their faces to make up two exterior and two interior diaphragms in each direction.

Steel usage : Only 33 lb per sft. compared to traditional rigid frame system where wt. might be 60 to 70 lb per sq.ft.

Calculation of column size at base:

Plan module by story :

2 x 20	=	40
5 x 24	=	120
7 x 16	=	112
9 x 50	=	450
		722

722 ÷ 9 mod. = an average of 80 mod. for each tube.

$$\text{Av. ht} = \frac{80}{110} \times 1450 = 1060 \text{ say } 1100 \text{ ft}$$

Wind force @50 psf. $W_h = 50 \times 225 = 11.5$ k / ft

$$M = 11.5 \times 1100 \times \frac{1400}{2} = 9{,}000{,}00 \text{ kft.}$$

Assuming that flange takes $\frac{2}{3}M = 6000{,}000$ kft

Flange load M ÷ 225 = 2400 k, there are 16 columns in 225 ft

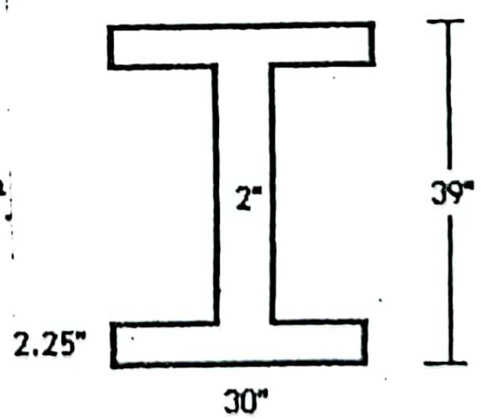
Each column carry 2400 + 16 = 1500 k / column

Vertical load : 80 stories [(225^2 x 100 psf) = 5000 k / floor] = 400,000 k

W total = 400, 000 + 112 = 3800 k / col.

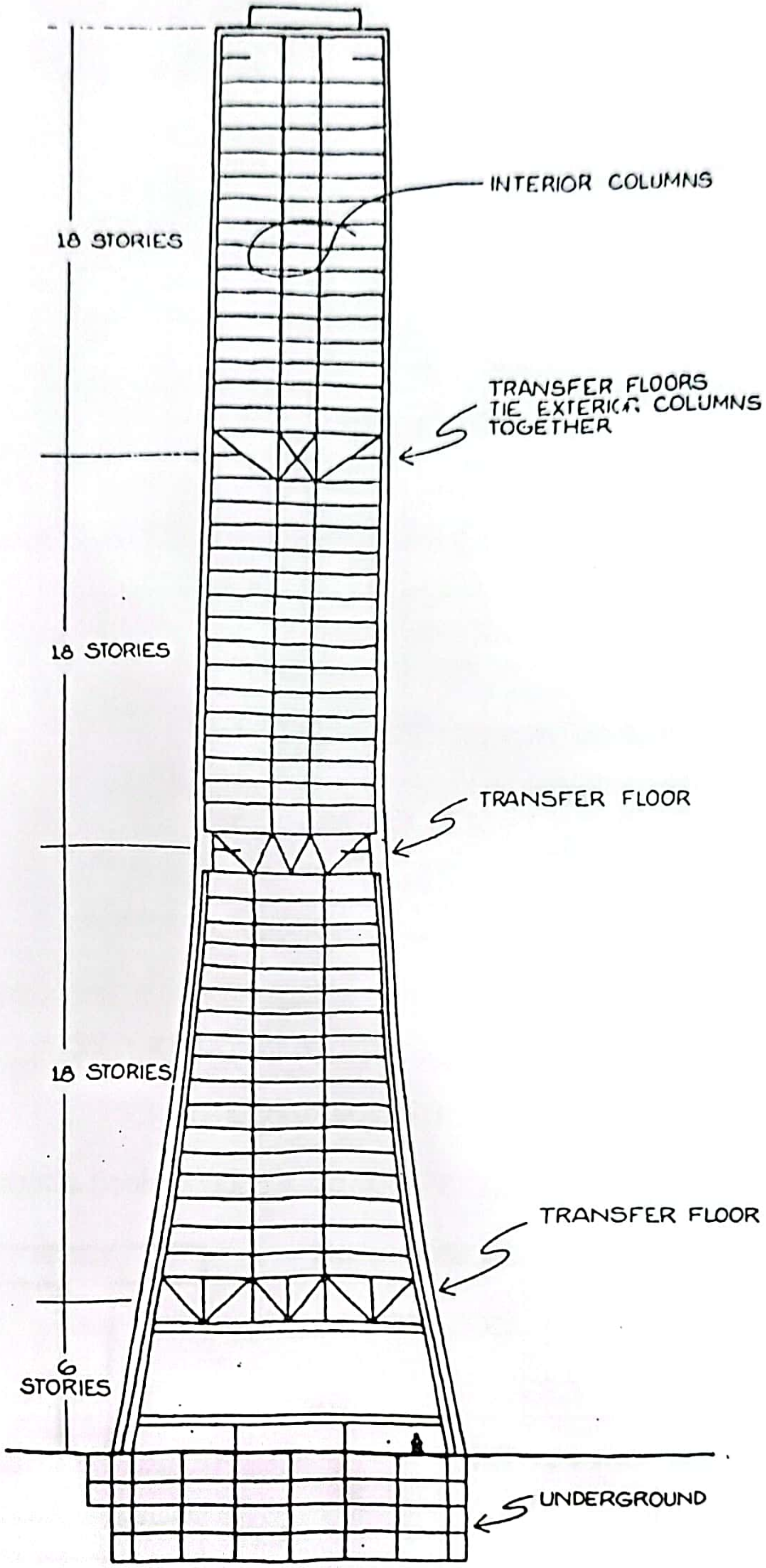
W flange col. = 3800 + 1500 = 5300 k

$$\text{As flange col} = \frac{5300}{20\text{ks}\left(\frac{4}{3}\right)} = 200 \text{ in}^2$$

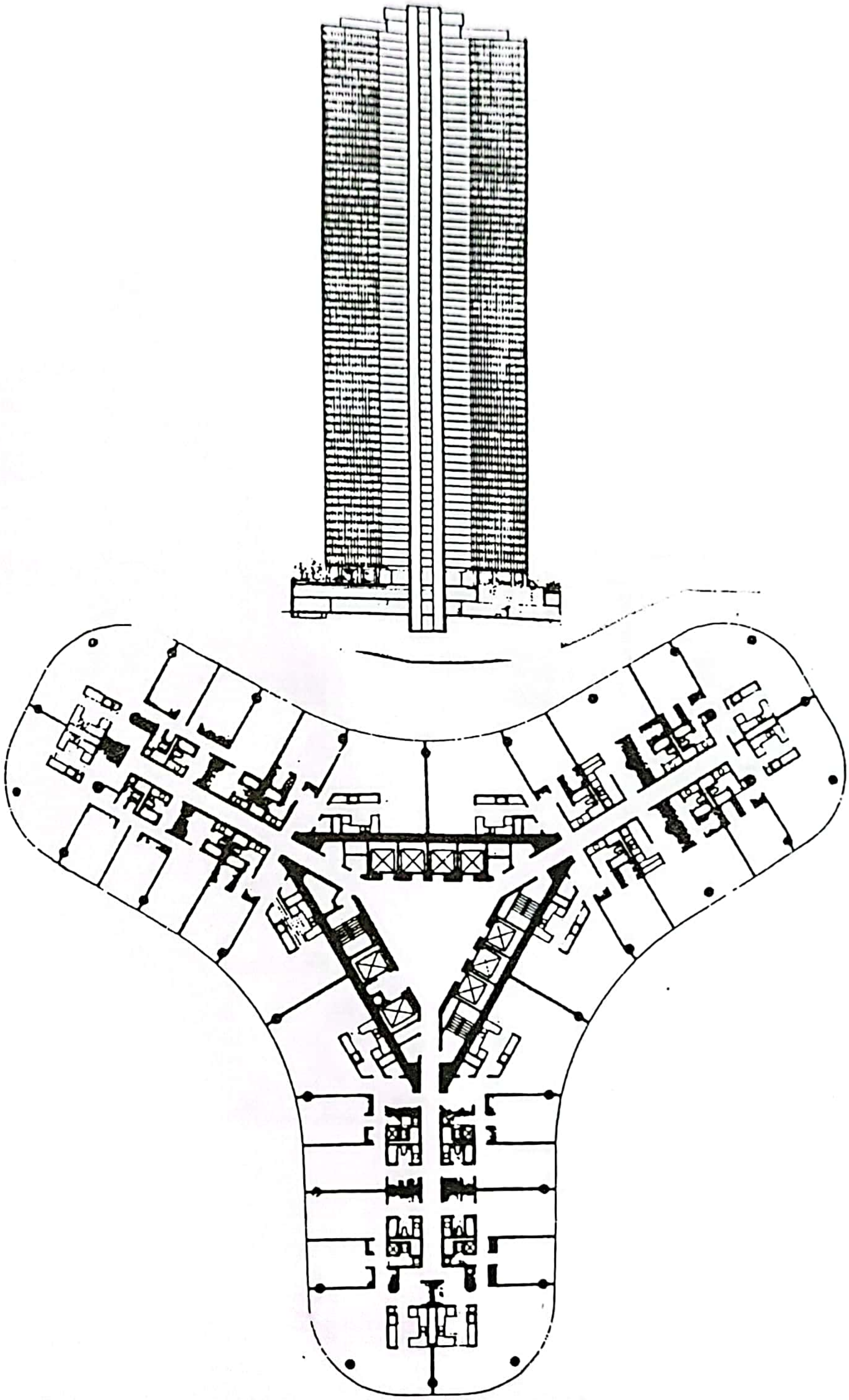


SECTION OF THE FLANGE.

Area provided=204 sq.in

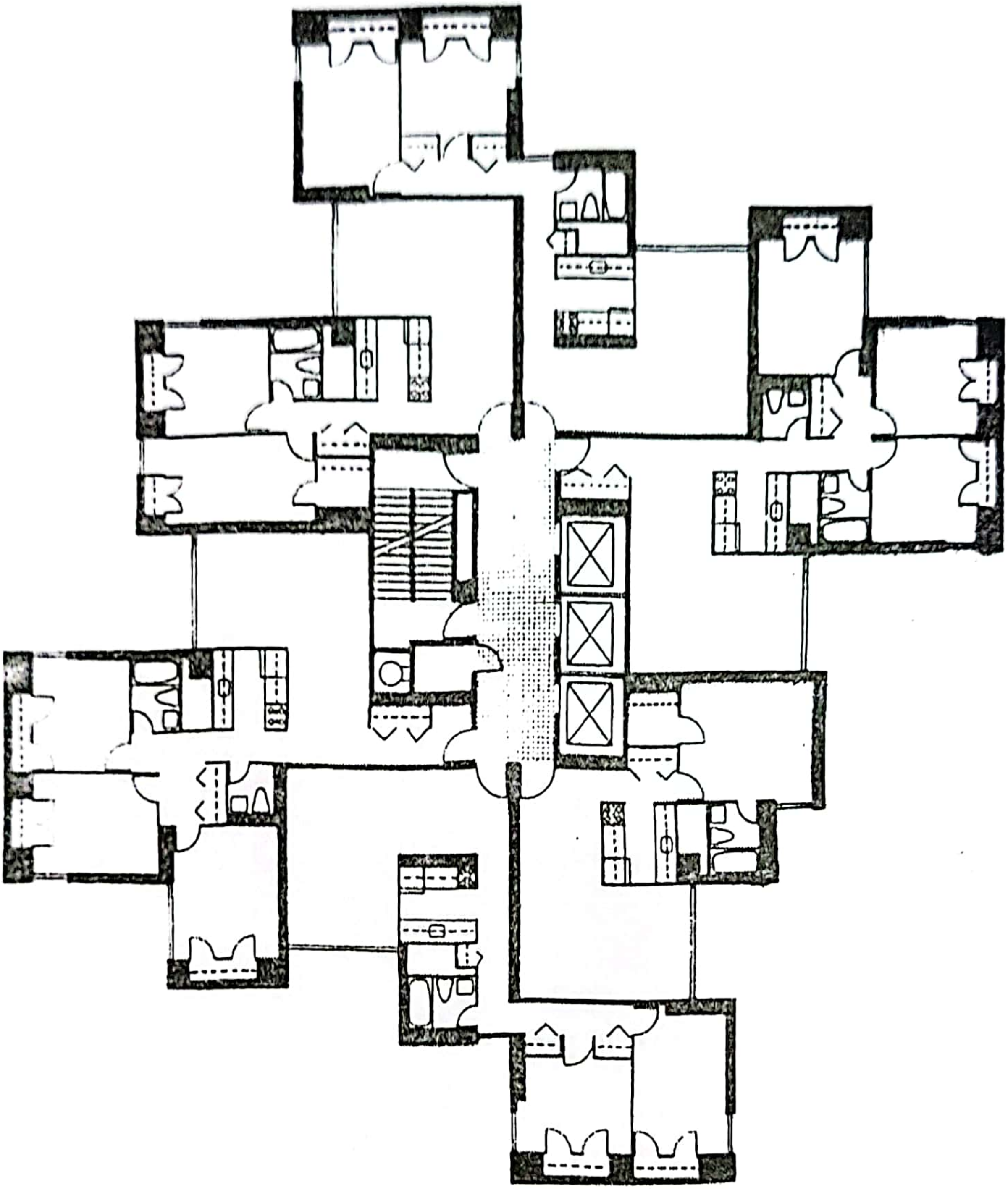


Tower Framing



THE Y TOWER PLAN

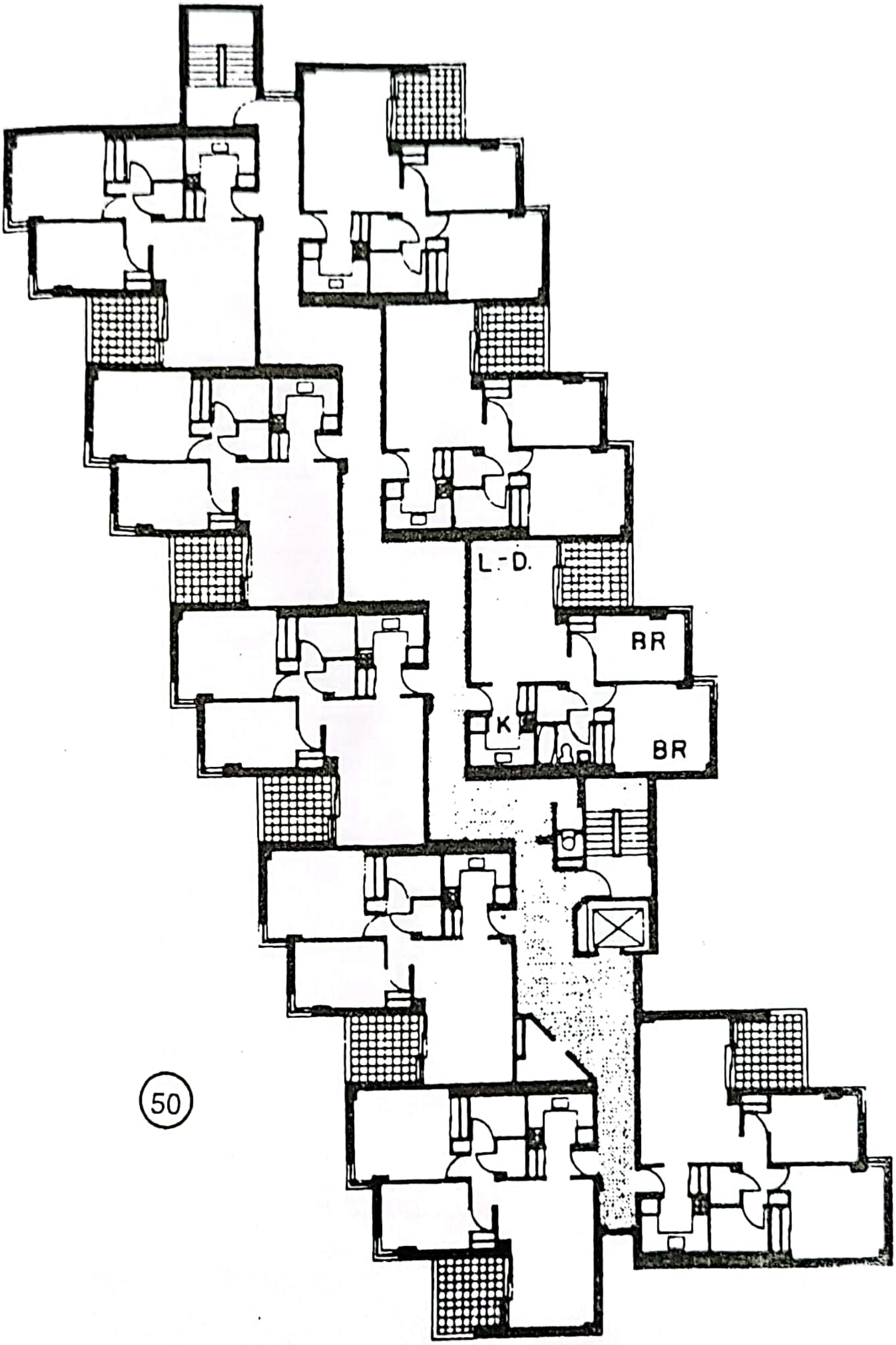
COURTESY : PROMONTING APARTMENT, CHICAGO



Lavanburg Community, New York City, Conklin & Rossant - Architects.

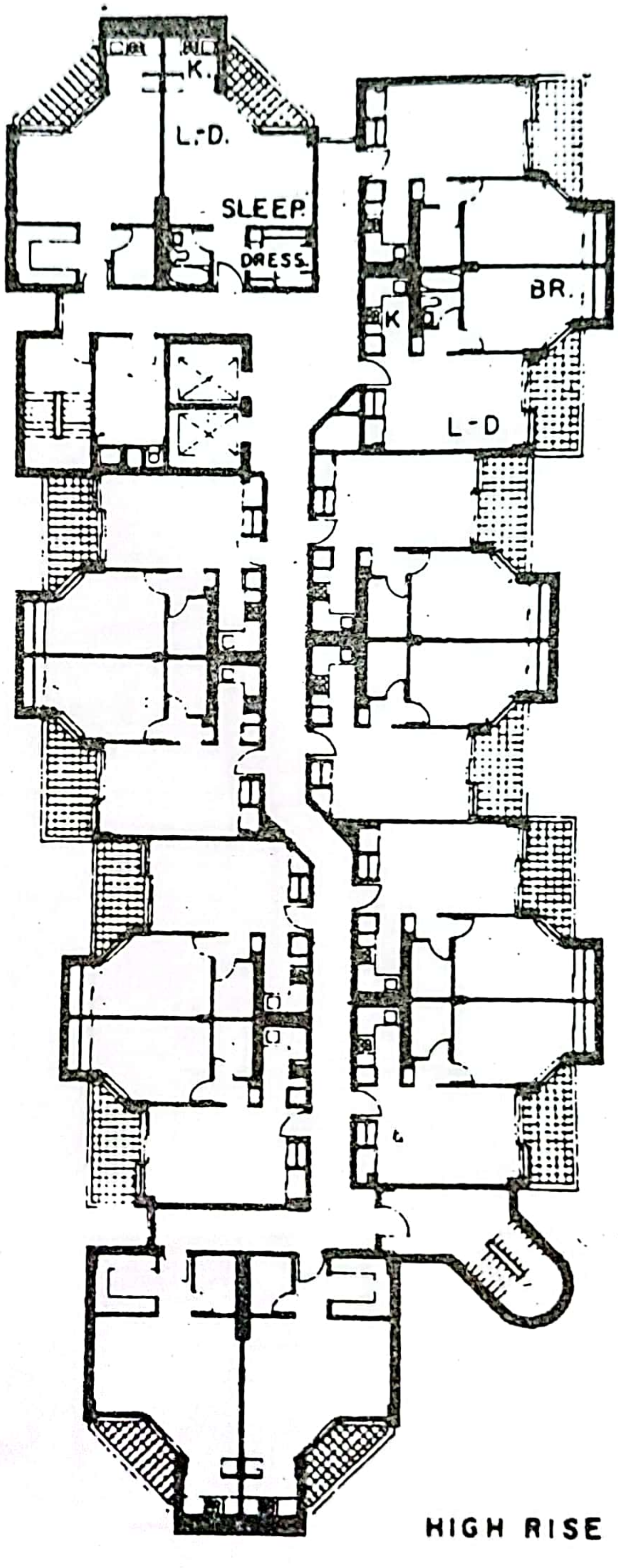
EXPANDED TOWER PLAN

TOWER PLAN

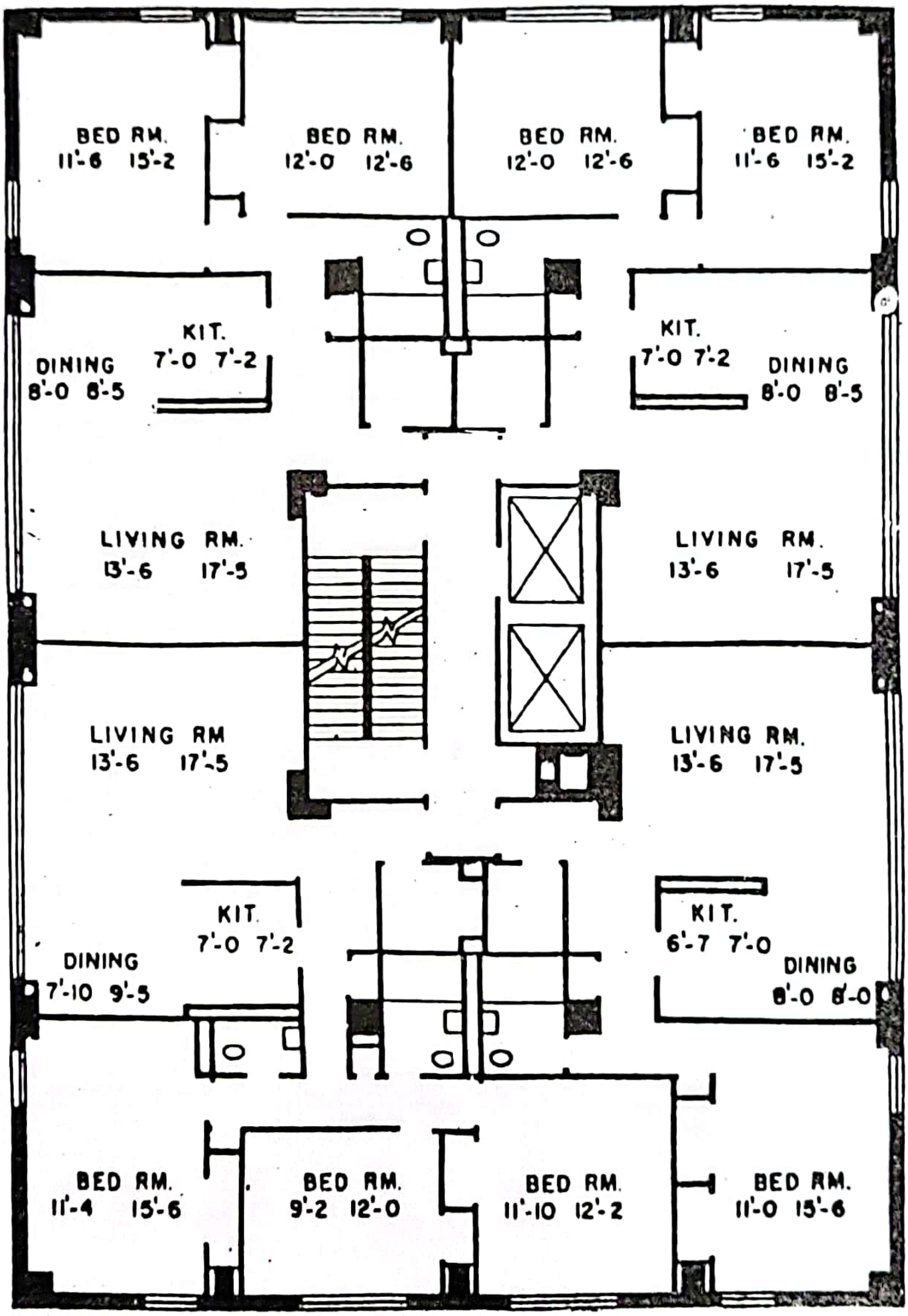


50

51

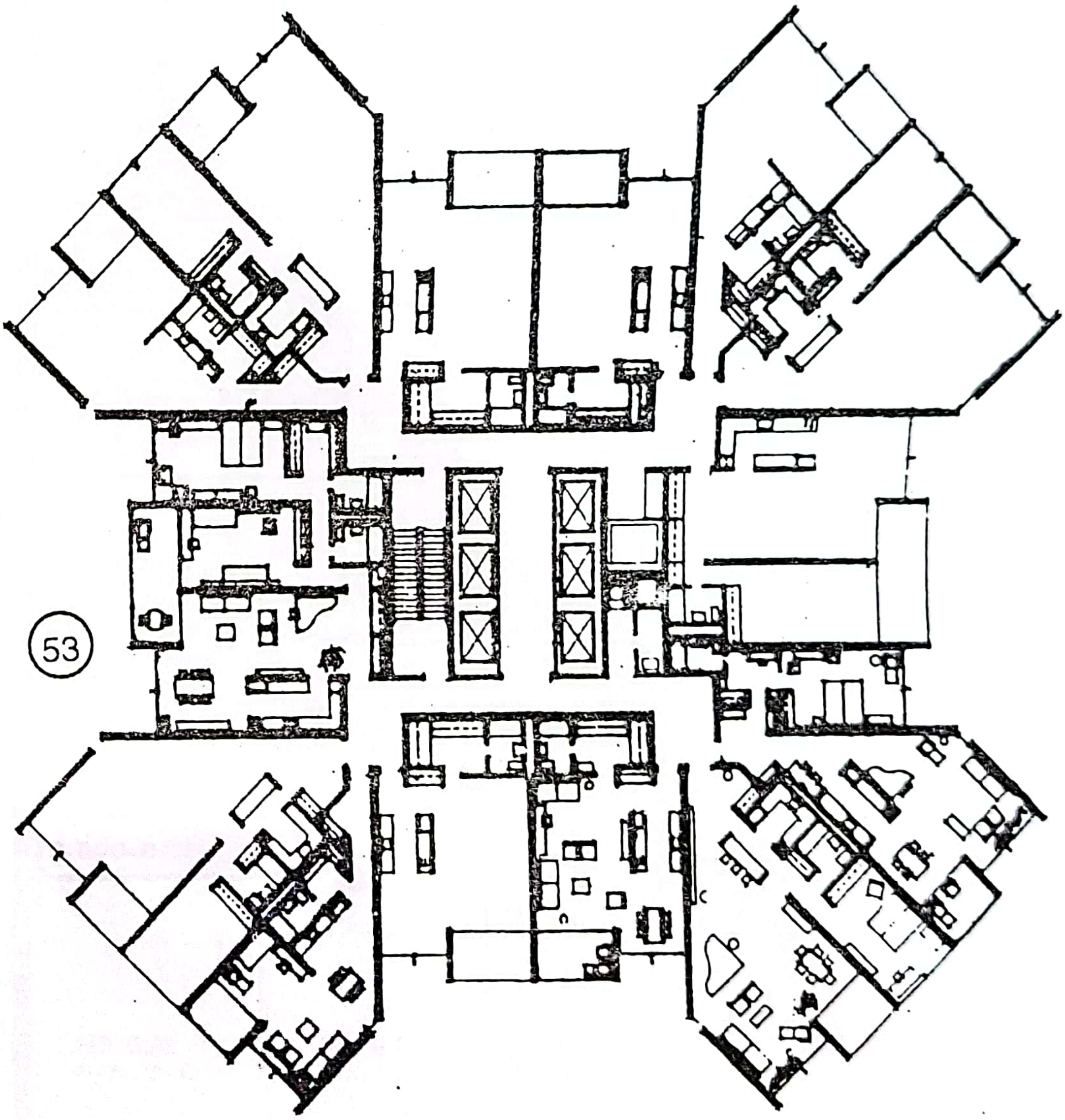


Typical Floor Plan

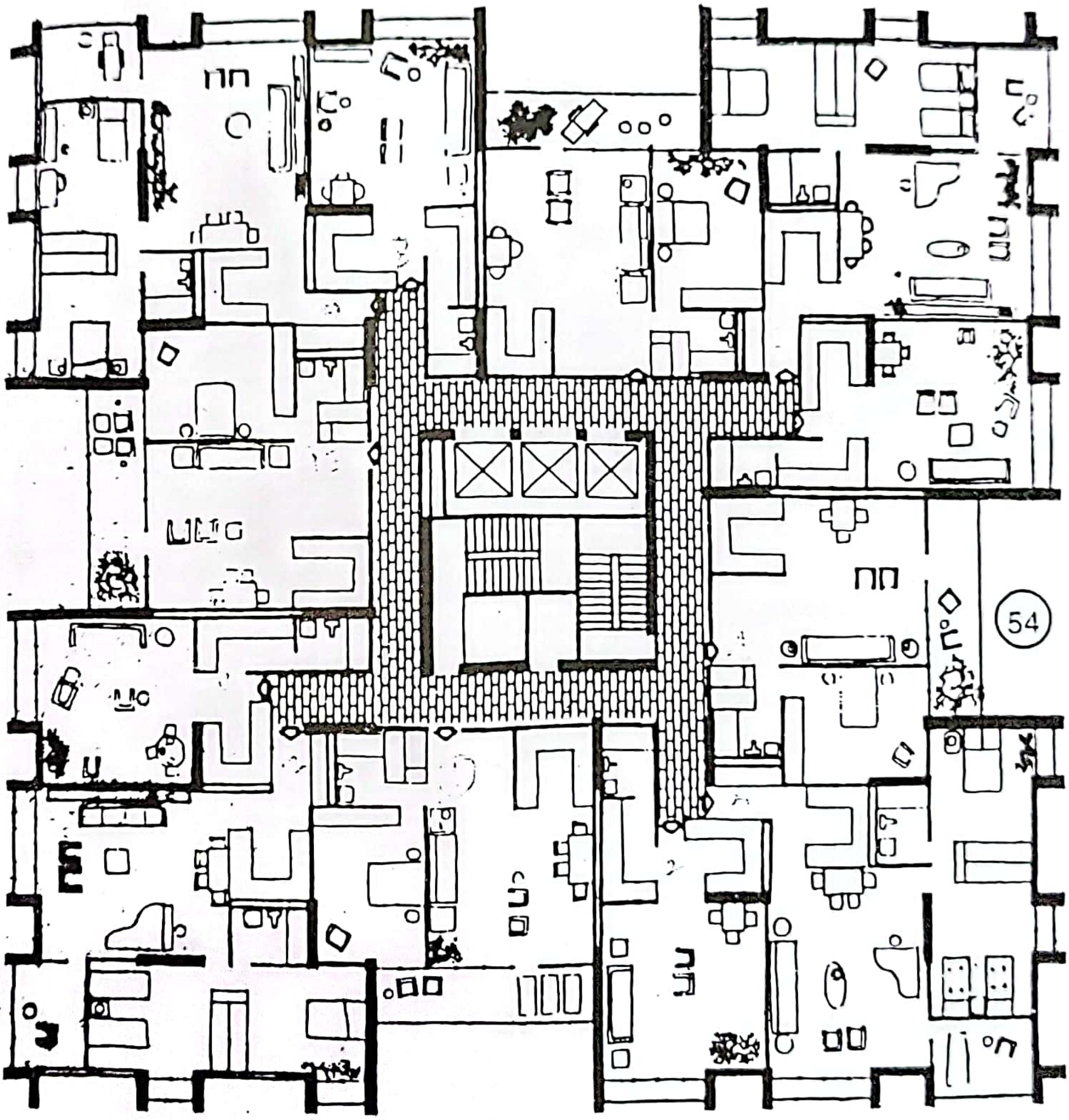


52

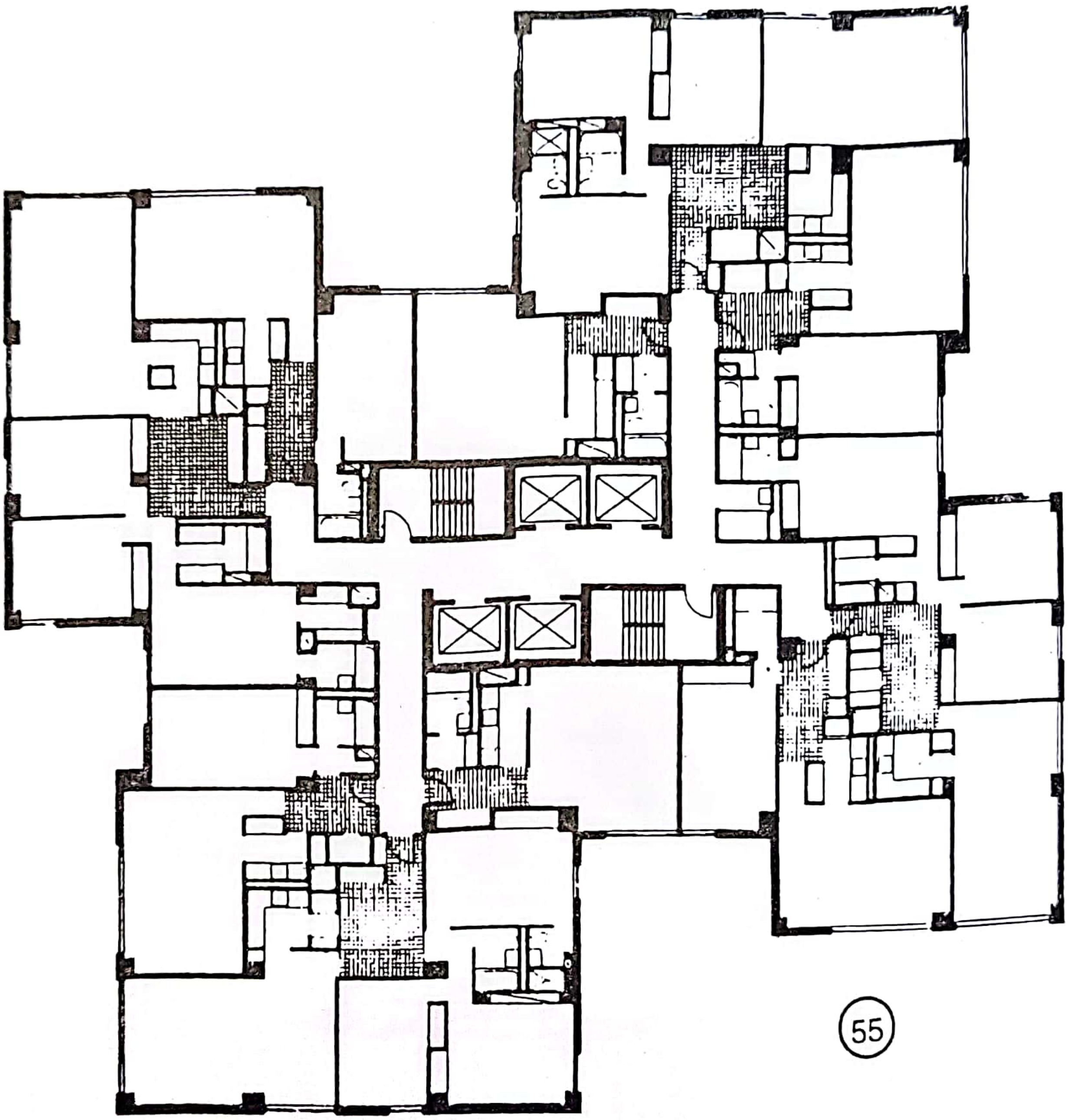
Typical floor plan of tower apartment building.



Typical Floor Plan Courtesy : Kelley and Gruzen

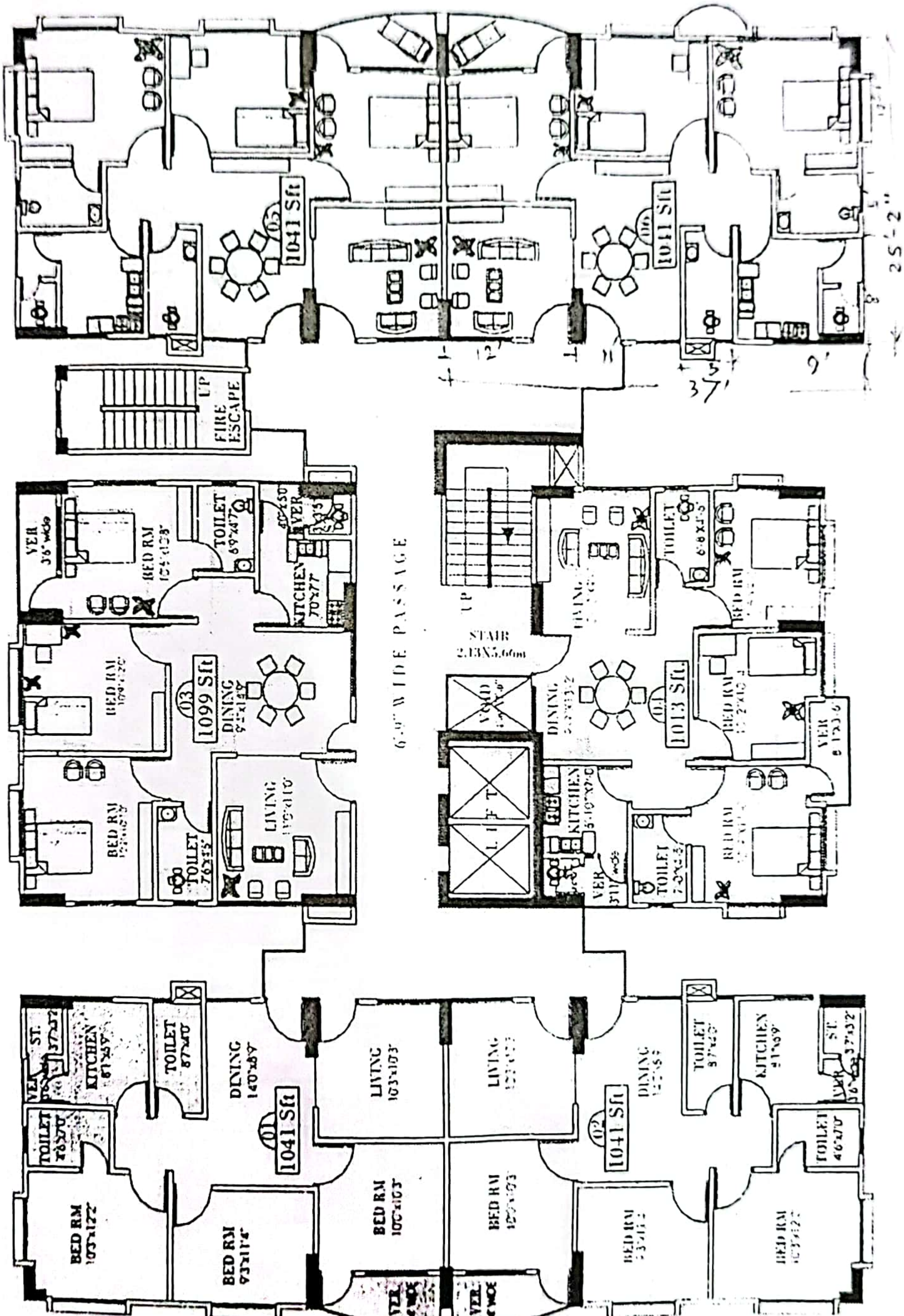


Courtesy : Obata & Kassabaum - Architects.

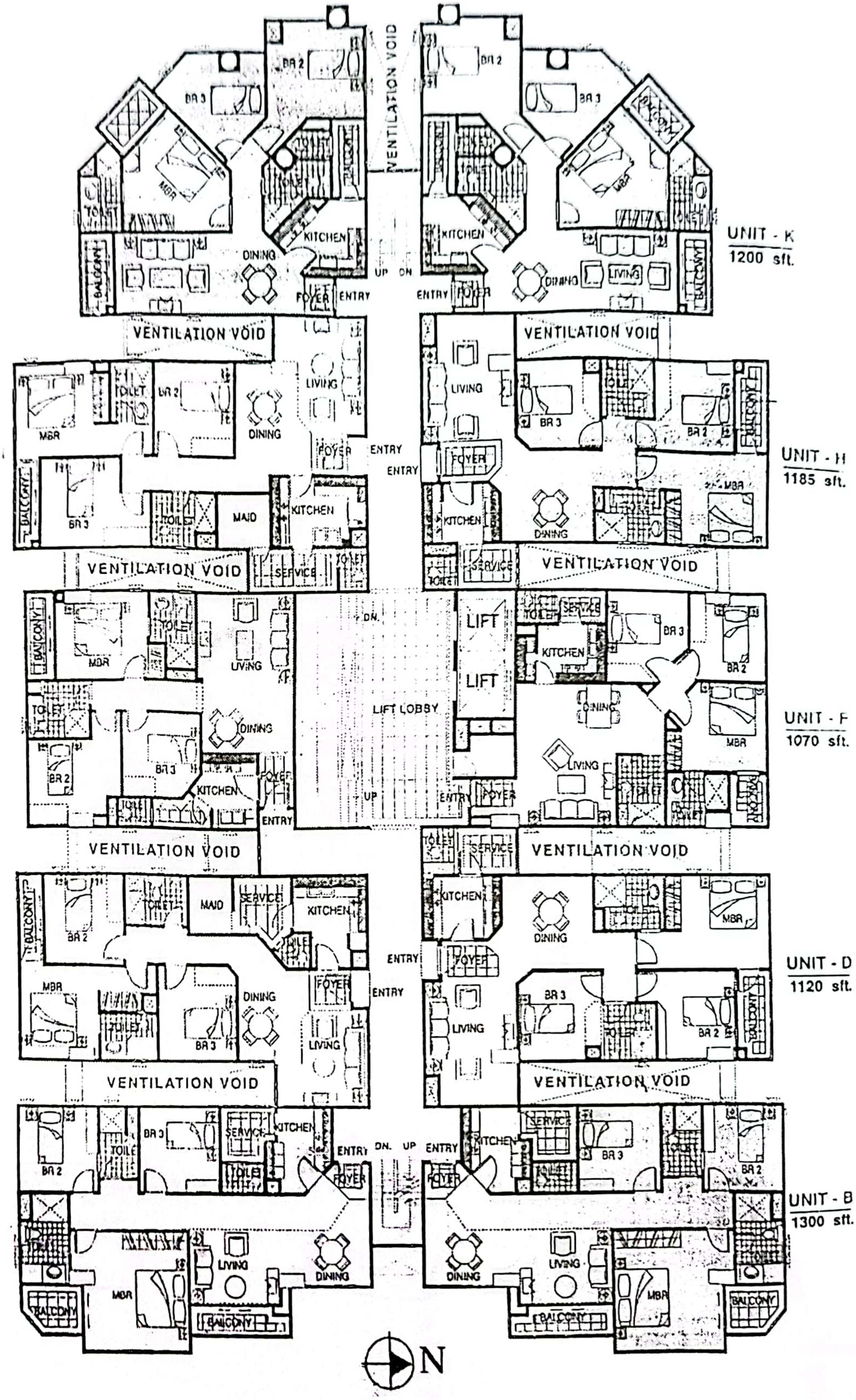


Courtesy : Brody and Associates

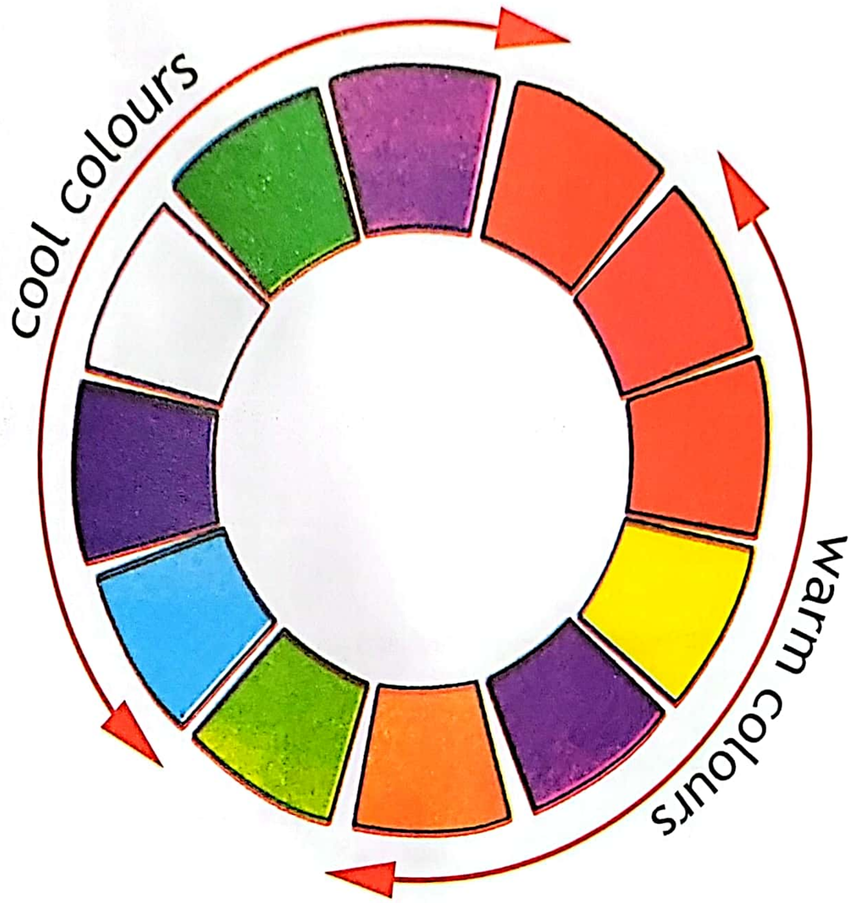
Floor Plan


1041 Sft
1041 Sft
UP
FIRE
ESCAPE
6'-0" WIDE PASSAGE
STAIR
2.13X5.66m
UP
LIFT
VOID
1099 Sft
1013 Sft
BED RM
TOILET
KITCHEN
VER
DINING
LIVING
1041 Sft
1041 Sft
25'-2"
37'
9'

Floor Plan



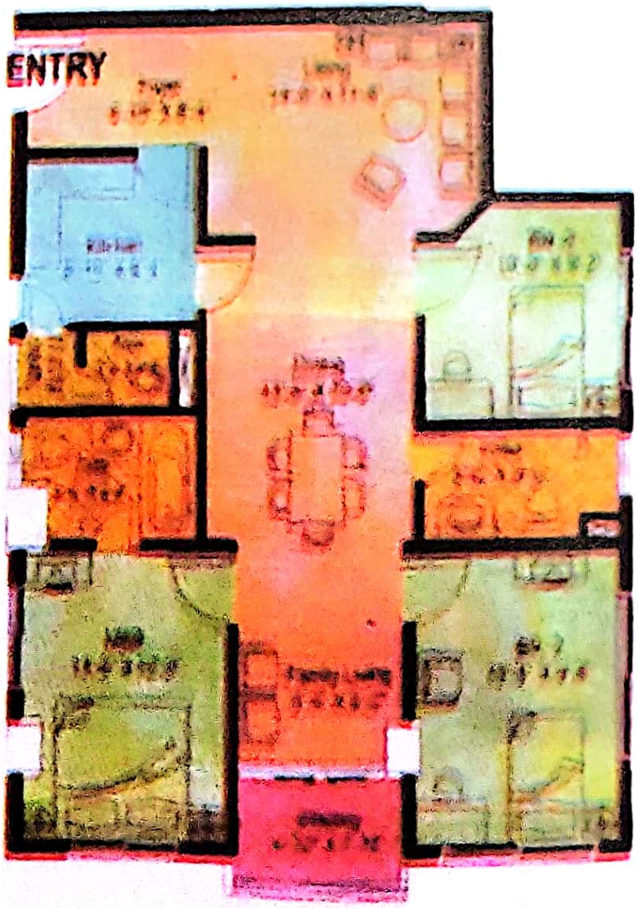
VENTILATION VOID
LIFT
LIFT
LIFT LOBBY
UNIT - K
1200 sft.
UNIT - H
1185 sft.
UNIT - F
1070 sft.
UNIT - D
1120 sft.
UNIT - B
1300 sft.
N

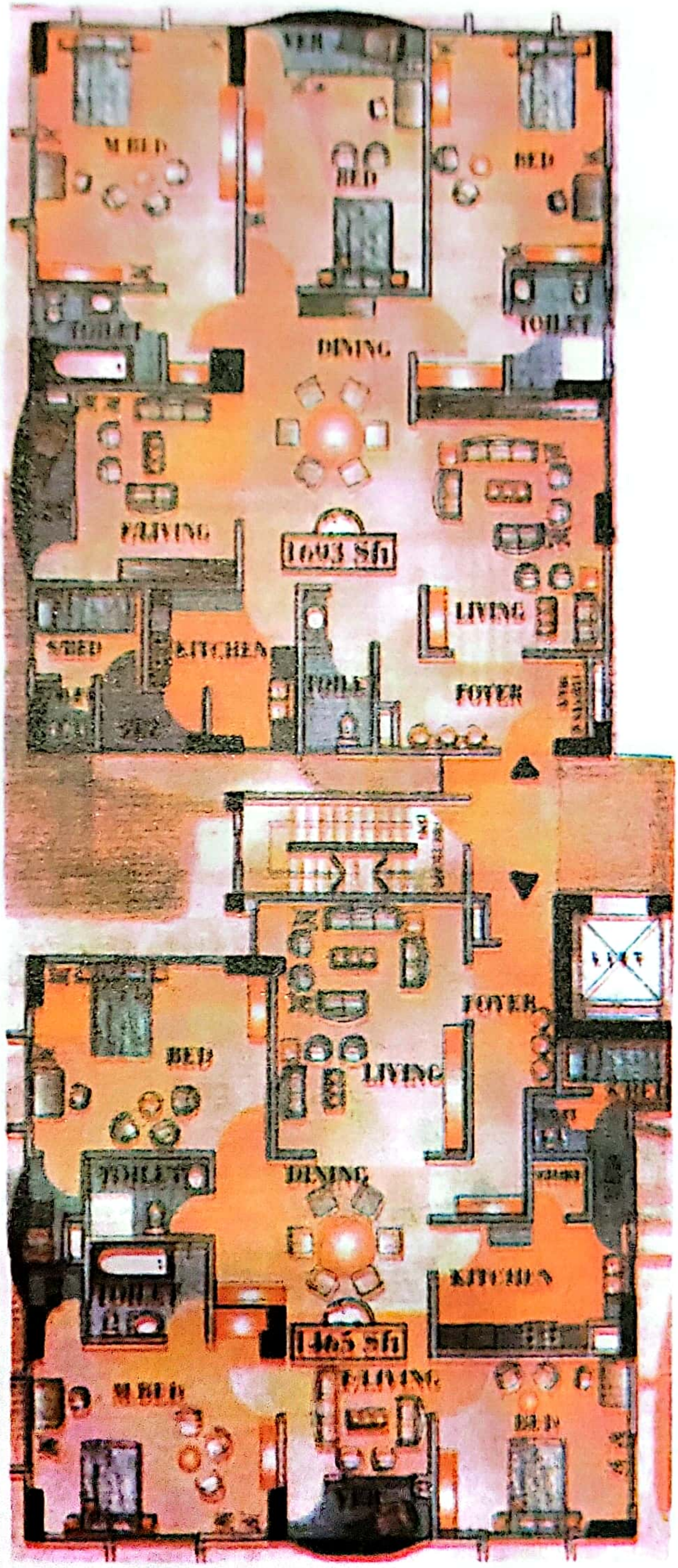


The Colour wheel:

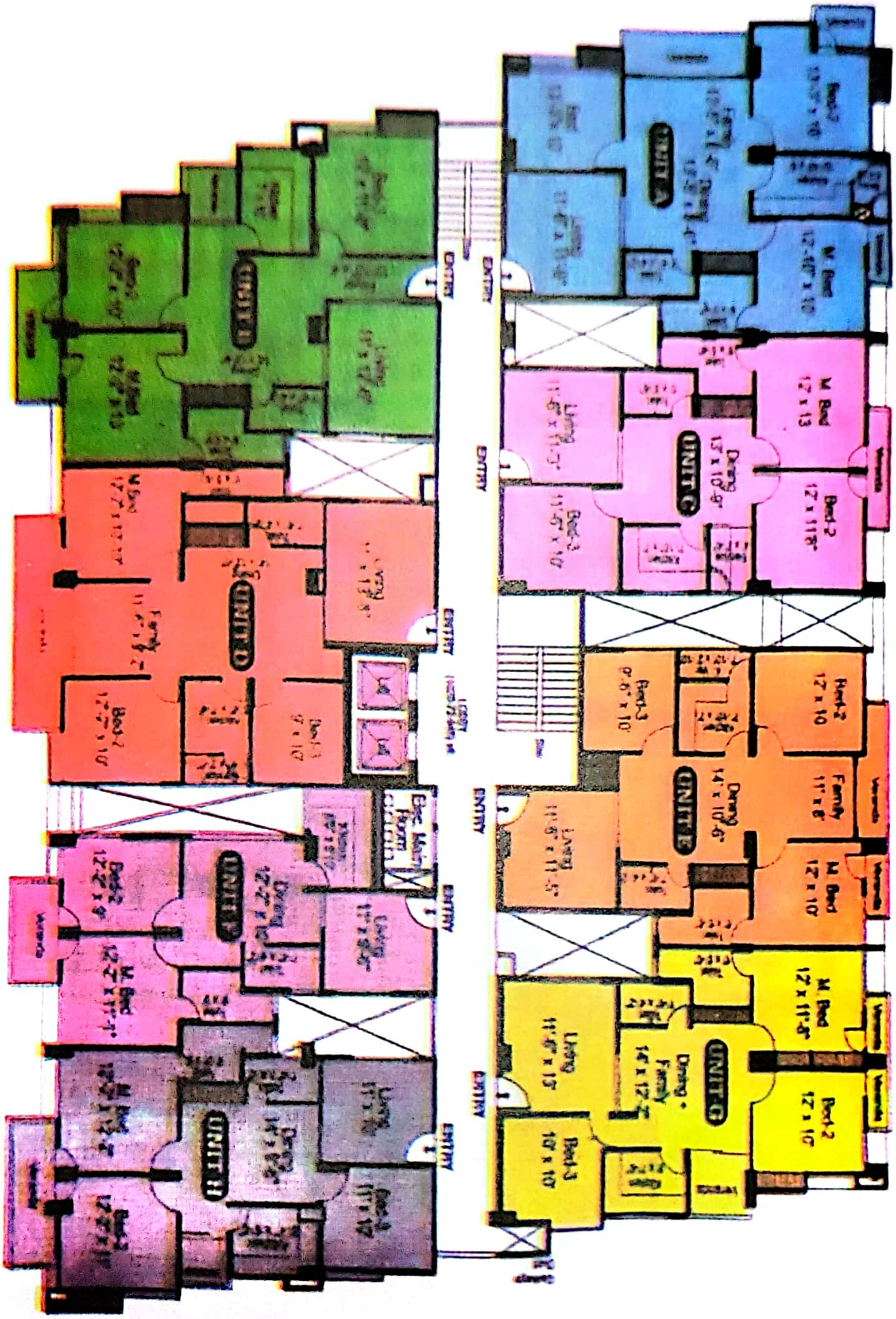
Red, Yellow and blue are the primary colours, mixtur of two primary colors is a secondary colour, Mixture of primary and secondary is a tertiary colour

TYPICAL FLOOR PLAN

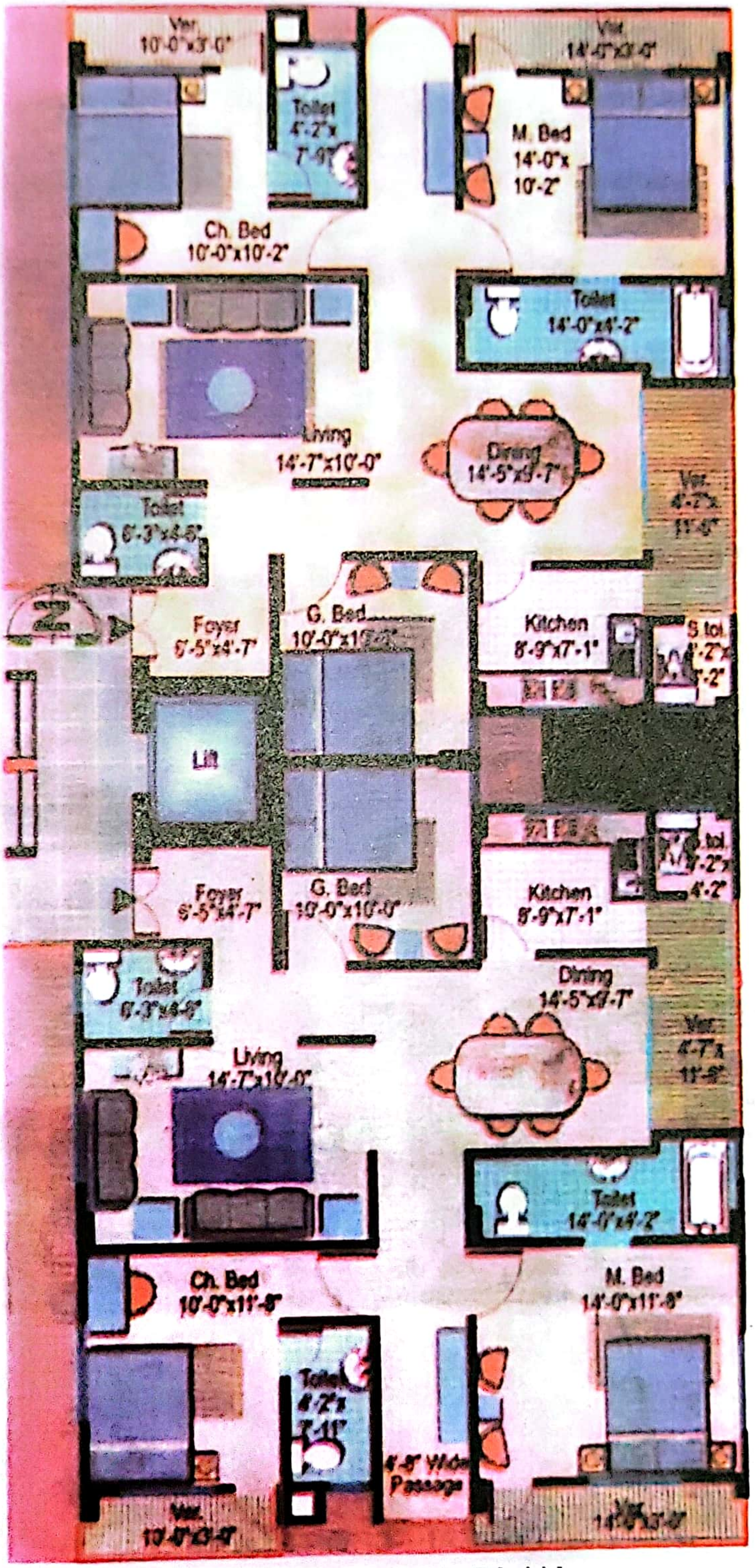




LUXURY APARTMENT

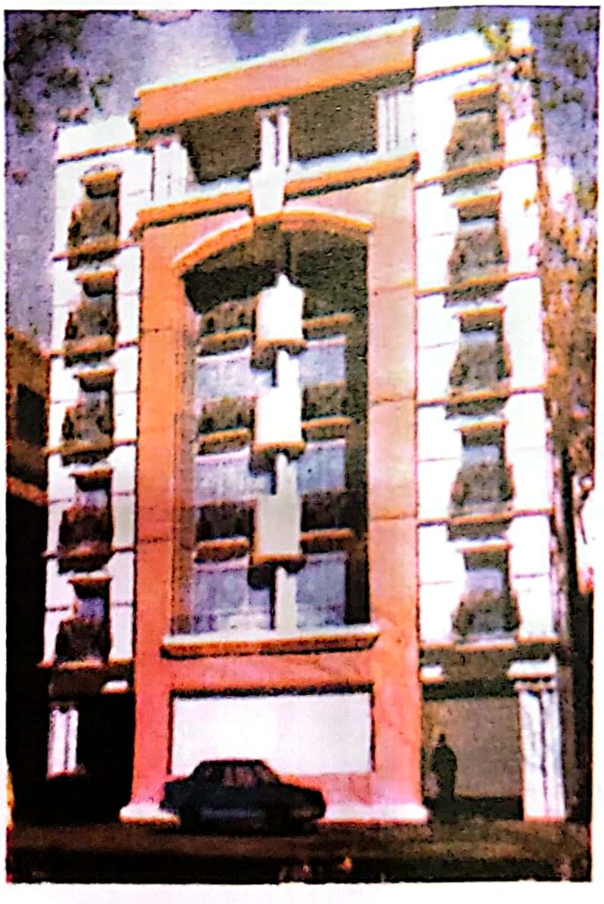


TYPICAL FLOOR PLAN



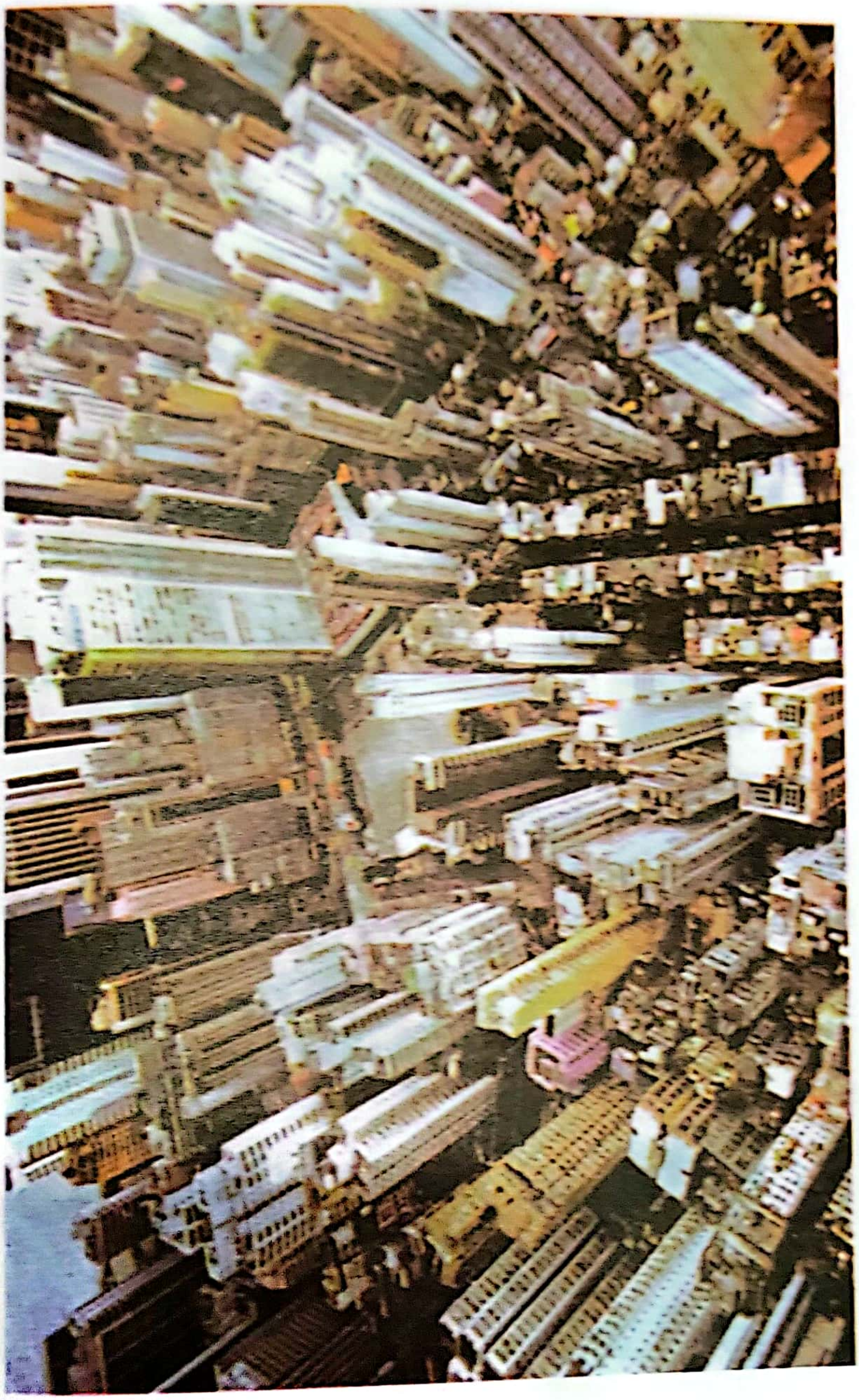
TYPICAL FLOOR PLAN

A TEN STORIED APARTMENT PROJECT
EXECUTED UNDER AUTHORS SUPERVISION



EXAMPLE OF MODERN HOUSES OF DHAKA

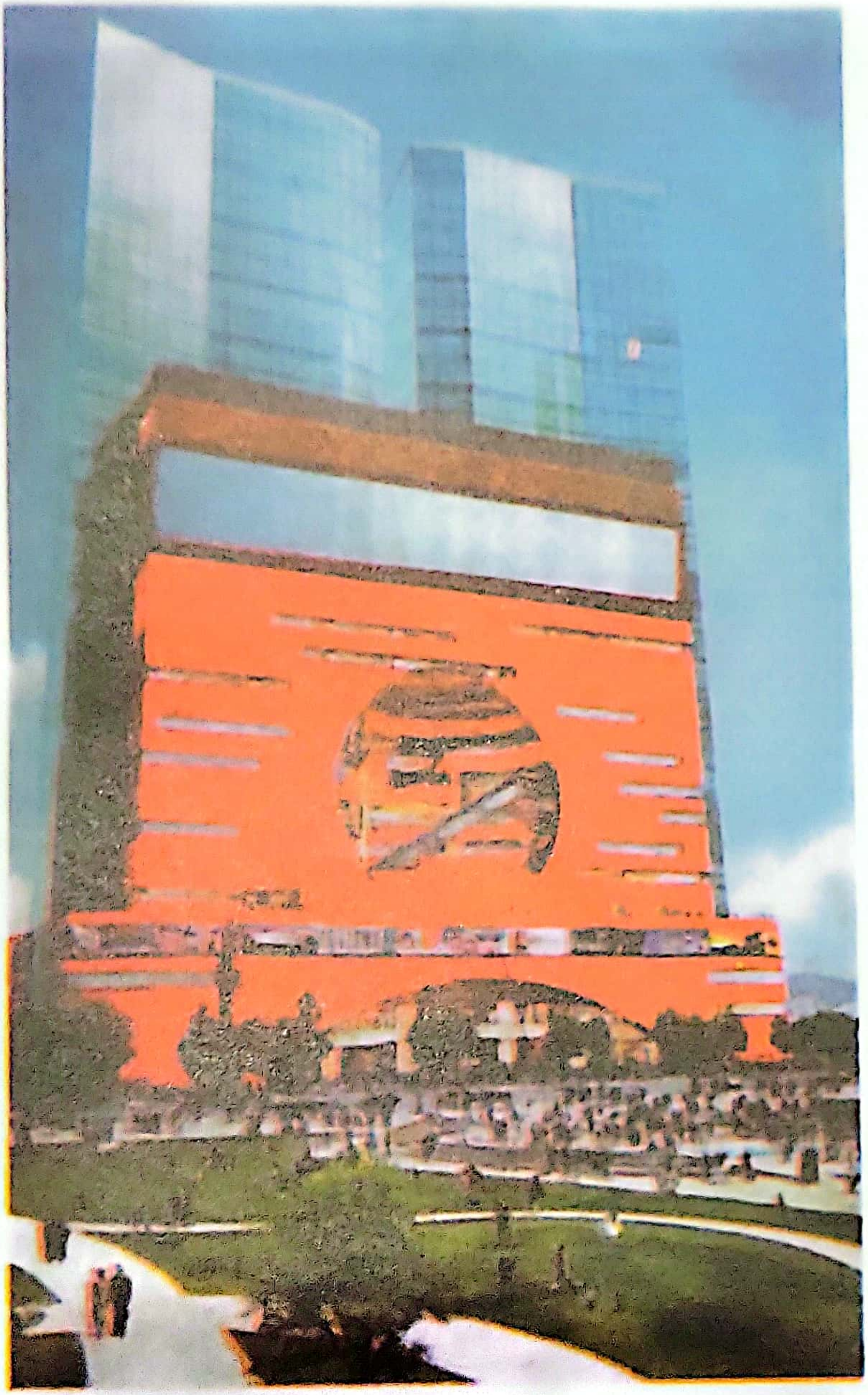
AN APARTMENT PROJECT



HONG KONG, THE PEARL OF THE ORIENT

SHOULDER TO SOULDER SKY SCRAPERS SHOOT UP TOWARDS THE SKY

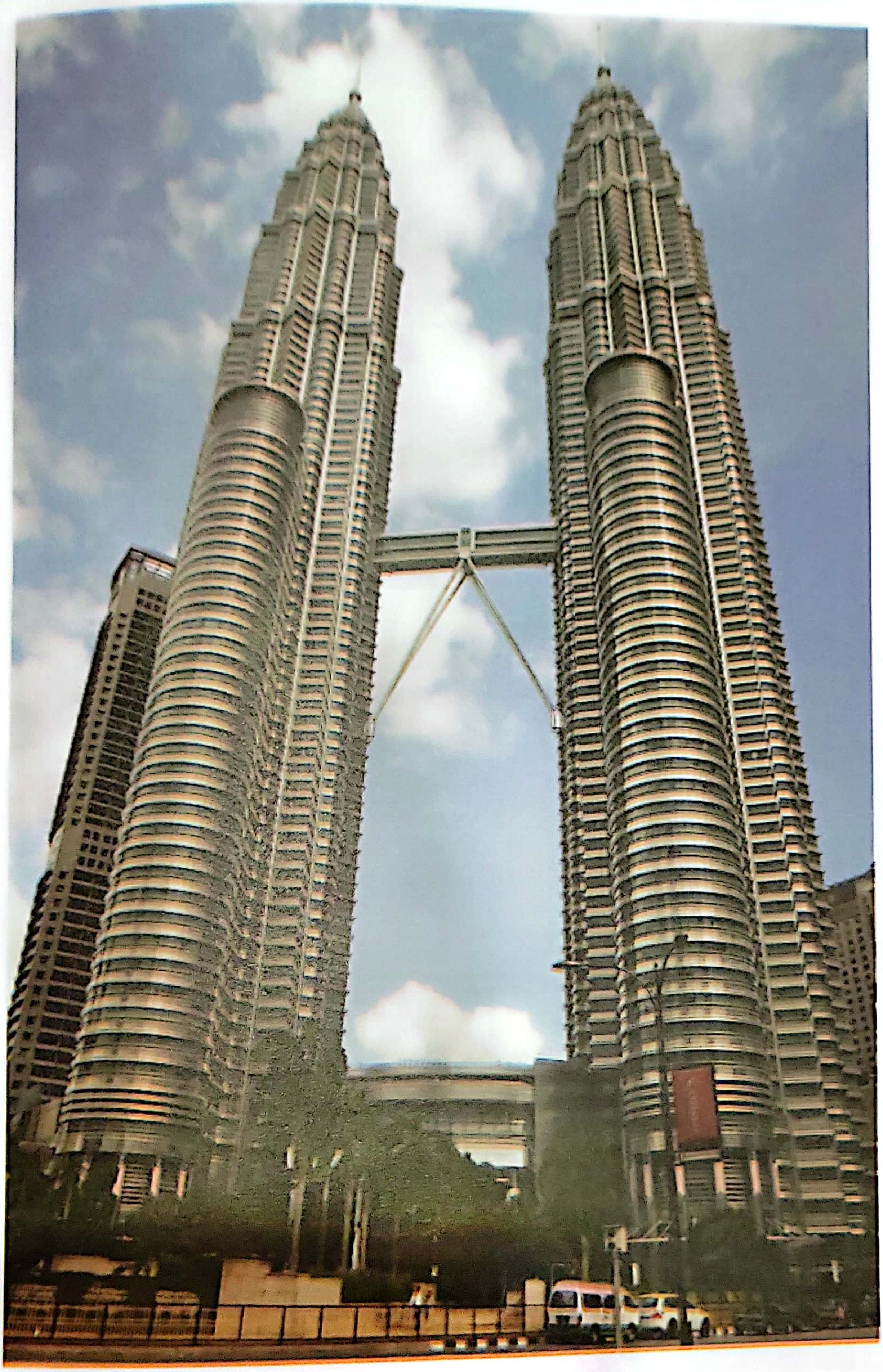
COURTESY:
RESIDENTIAL DEVELOPMENT, HANG LUNG PROPERTIES



COURTESY:
LUXURY RESIDENTIAL DEVELOPMENT, KERRY PROPERTIES
HONG KONG

THE SEAR'S TOWER

CHICAGO, USA, FLOOR: 108+3 BASEMENT, HEIGHT : 1729 FT



PETRONAS TWIN TOWER
KUALALAMPUR, MALAYSIA, FLOOR : 88+5 BASEMENT, HEIGHT: 1483 FT

WORLD'S TALLEST BUILDING: BURJ KHALIFA
RASHID BOULEVARD, DUBAI, TOTAL FLOOR 211 (2 BASEMENT), HT; 2717 FT

Curing

Routine for curing works

SL No	Nature of work	After how many hours water should be applied.	For how many days water should be kept.	Method of curing
01.	Lean concrete at base or elsewhere 1: 3 : 6	18 hours	7 days	Lay / wrap jute bag / mat over the casting and keep it soaked with water.
02.	All sorts of masonry works in 1: 4, 1:5 or 1:6 mortar	18 hours	7 days	"Keep it moist by applying pumped water with pipe or manually form top of the works twice or thrice a day.
03.	C.C 1: 2: 4 in D. P C	12 hours	3 days	Lay / wrap jute bag / mat over the work and keep it moist with water.
04.	Patent stone/ C.C./R.C.C 1: 2: : 4 at ground floor,	12 hours	7 days	Same as above for patent stone casting, keep 2" standing water.
05.	C.C / R.C.C 1: 2 : 4 in. lintel sun shade, beams	12 hours	15 days	Wrap with jute mat and keep it moist, where possible keep standing water.
06.	Roof casting with or without floor beam	12 hours	21 days	Keep 2" deep standing water by making brick bundh all around the roof. The roof may be sub-divided, if required
07.	All types of plaster 1:3, 1:4, 1:5, 1:6	18 hours	7 days	Keep it moist with sprinkling water manually or with pump.
08.	Lime concrete over roof	24 hours	15 days	Keep it moist with the help of soaked straw and water hyacinth.

Appendix

15

If you have two paisa,
expend on for food and the other for flower
-Porphet Muhammad (sm).

15.2 Standards of M.S.Rod

Diameter in inches.	Cross Sectional area	Weight per foot.	Lineal feet in 1 cwt.
1/4"	0.049 in sq	.167 pound	667 ft.
3/8"	0.11 " "	.376 "	297 "
1/2"	0.196 " "	.669 "	167 "
5/8"	o.307 " "	1.043 "	107 "
3/4"	0.442 " "	1.502 "	74 "
7/8"	0.601 " "	2.044 "	54 "
1"	0.785 " "	2.670 "	42 "

15.2 Assessment of Rods for Various Spacings Rod/Bar dia in inches. Wt in pound per sp. yd.

Centre to Centre Spacing	1/4"	3/8"	1/2"	5/8"	3/4"
2 1/2"	7.23	16.24	28.86	45.06	64.88
3"	6.02	13.53	24.04	37.60	54.07
3 1/2"	5.15	11.60	20.61	32.20	46.40
4"	4.51	10.15	18.03	26.16	40.55
4 1/2"	4.01	9.02	16.03	25.03	36.10
5"	3.61	8.12	14.42	22.50	32.50
5 1/2"	3.28	7.33	13.12	20.50	29.51

6"	3.01	6.76	12.02	18.77	27.02
7"	2.58	5.80	10.31	16.9	23.17
$7^1/_2$"	2.41	5.41	9.62	15.02	21.63
8"	2.26	5.07	9.02	14.09	20.31
$8^1/_2$"	2.12	4.78	8.49	13.25	19.06
9"	2.00	4.51	8.02	12.51	18.02
$9^1/_2$"	1.90	4.27	7.59	11.86	17.05
10"	1.80	4.06	7.22	11.26	16.22
11"	1.64	3.69	6.55	10.24	14.74

Note. 1sq. yd. = 9 sq ft. So to weight per sq. ft. divide by 9.

11.3 Analysis of Rates

A few standard model analysis of rates are furnished here for determining constituent elements of the rate normally followed by private and Govt. offices. A sound knowledge on the subject help you to promote quality of work and assess cost thereof. If you want to maintain quality, the contractor should be properly paid for this and involvements should be known to you for which analysis is only answer.

The rate of labour and material are subject to change and corrections be made accordingly. It is customery to keep contractors profit @10% to 17% on labour cost supplied by the owner, hence no profit on material is considered.

The analysis is kept united for civil and sanitary work. For Gas, Electricity and other items such models can be used provided material cost and labour cost are known to you.

11.4 Rates Considered in the Accompanying

A. Labour Rate

(1) Ordinary labour	Tk. 120/-
(2) Skilled labour	Tk. 140/-
(3) Mason, Rod Mistry, Carpenter	Tk. 250/-
(4) Plumber, Painter	Tk. 250/-

1. Item :
Earth work in foundation trenches :
for 1000 sft

(a) $^2/_3$ rd Mason @ Tk. 250/- each	Tk. 166.66
(b) Skilled labour 2 Nos. @ Tk. 140/- each	Tk. 280.00
(c) Ordinary labour 8 Nos. @ Tk. 120/- each	Tk. 960.00
(d) Laying centre lines, construction pillars	Tk. 280.00
	Tk. 1686.66
(e) EOP (Establishment over head & profit) 17%	Tk. 286.73
	Total = Tk. 1973.49

2. Item :

One layer of brick flat soling

For 100 sft. :	Unit 100 sft.
(a) Bricks 300 Nos., @ 4000 per 1000.	Tk. 1200.00
(b) Fine sand 5 cft. @ Tk. 7/- per cft.	Tk. 35.00
(c) Mason No. 1/4 @ Tk. 250 each	Tk. 62.50
(d) Skilled labour 1 No. @ 140.00 each	Tk. 140.00
(e) Local carriage of bricks	Tk. 10.00
Sundries	Tk. 2087.50
EOP 17%	Tk. 354.87
	Total = Tk. 2442.37

3. Item :

10" 1st class brick work in superstructure (1:6)

For 100 cft. :	Unit 100 sft.
(a) Bricks 1100 Nos.. @ 4000 per % Nos.	Tk. 4400.00
(b) Sand 30 cft. @ Tk. 7/- per cft.	Tk. 210.00
(c) Cement 4 bags @ 310/- per bag	Tk. 1240.00
(d) Labour cost including Mason labour for staging, carriage, curing tools and plants etc.	Tk. 175.00
	Tk. 6025.00
Add contractor's EOP 17%	Tk. 1024/50
	Total = Tk. 7049.25

4. Item :

1/4 Thick (finished) silver grey situ mosaic

For 100 sft

(1:1½:3) on 1" thick artificial patent stone flooring (1:2:4) including supply of all materials for 100 sft.

(a) Marble chips @ 325.00 per bag, 2 bags	Tk. 650.00
(b) White cement 1/2 bag @ Tk. 500.00	Tk. 250.00
(c) Marble dust 3/4 bag @ Tk. 150.00 per bag	Tk. 375.00
(d) Grey cement 3/4 bag @ Tk. 310.00 per bag	Tk. 232.00
(e) Labour charge including polishing, finishing, curing, including cost of pumice, acid wax and sun-dries etc. @ Tk. 12/- p. sft for 100 sft	Tk. 1200.00
Machine charge etc.	Tk. 1200.00
EOP 17%	Tk. 3907.50
	Tk. 664.27
Rate per sft. = Tk. 45.71 only	Total = Tk. 4571.77

5. Item :

White washing 3 coats. For 1000 sft. of work :

(a)	Slaked stone lime 15 seers @ Tk. 8/- per seers	Tk. 120.00
(b)	Shell lime 5 seers @ Tk. 7/- per seer	Tk. 35.00
(c)	Gum 1 chatak @ Tk. 8/- per chhata	Tk. 8.00
(d)	Blue 1 chattak @ Tk. 6/-	Tk. 6.00
(e)	Labour :	
	(i) Masion $1\frac{1}{2}$ Nos. @ 250.00 each	Tk. 375.00
	(ii) Labour 1 No. @ Tk. 120.00 each	Tk. 120.00
(f)	Scaffolding and sundries.	Tk. 20.00
		Tk. 684.00
	EOP 17%	Tk. 116.28
	Total =	Tk. 800.28

Lime terracing 4" thick (7:2:2) in roof slab. For 100 cft of work.

(a)	Chips 100 cft (900) Nos. bricks @ Tk. 4000 per % Nos.	Tk. 3600.00
(b)	Lime 29.25 cft = 10 maund @ Tk. 80.00 per maund	Tk. 1170.00
(c)	Breaking cost of chips	Tk. 300.00
(d)	Sukri 34 cft. @ Tk. 25/- per cft.	Tk. 850.00
(e)	Molasses, T & P, sundries (L.S.)	Tk. 70.00
(f)	Labour : Mason 1 No. @ Tk. 250 each	Tk. 250.00
	Skilled labour 3 Nos. @ Tk. 140 each	Tk. 420.00
	Ordinary labour 4 Nos. @ Tk. 120 each	Tk. 480.00
		Tk. 7720.00
	EOP 17% Except on (a)	Tk. 131.24
	Total =	Tk. 7851.24

11.5 Units of Measures and Weights Power, Speed and Temperature

A. Units of Measures

The units deal with here come under the heading of

1. Linear Measures.

2. Square Measures.
3. Weights.
4. Power. ·
5. Speeds.
6. Temperatures.

1. Linear measures

Foot to Metre: 1 ft = .3048 m.

1 mile = 1.609357 Km
1 yard = 09144 m = 91.44 cm= 914.4 mm
1 foot = 0.3048 m = 30.48 cm= 304.8 mm
1 inch = 0.0254 m = 2.54 cm= 25.4 mm

Metre to Foot: 1 m = 3.281 ft

1 k m = 0.621370 mile.
1 m = 3.28 ft = 39.4 inch.
1 c m = 0.033 ft = 0.394 inch.
1 m m = 0.0394 inch.

2. Square Measures : British

1 square mile (sq. mile) = 640 acres.
1 acre = 10 square chains
1 square chain = 16 square rods.
1 square rod(sq. rod) = 30.25 square yards.
1 square yard = 9 square feet.
1 square feet = 144 square inches.

Metric

1 square kilometre (km^2) = 1,000,000 square metres (m^2)
1 square metre = 1000 square centimetres (cm^2)
1 square centimetre = 100 square millimetres (mm^2)

3. Weight (Avoirdupois)

Metric British equivalent of
weight. Metric weight.
1 cwt. (long) = 50.8023 kg @ 1 kg = 2.2046 1b
1 lb.= 0.4536 kg
1 oz = 28.35 gr
1 grain = 0.0648 gr

4. Power and Work Metric

1 metric horse power (H.P) = 75 Kilogram-metres/Sec.
= 75 kgs/ Sec.
1 Kilo watt (KW) = 1000 watts (W) = 102 Rgm/s.
= 1.39 H.P.

Metric Measures of Linear Distances :

1 kilometre (km)	= 1000 metres (m)
1 hectometre (hm)	= 100 metres (m)
1 decametre (dkm)	= 10 metres (m)
1 metre (m)	= 1 metre (m)
1 decimetre (dm)	= 0.1 metre (m)
1 centimetre (cm)	= 0.01 metre (m)
1 milimetre (mm)	= 0.001 metre (m)

To Convert :	Multiply :
inches to milimetres	inches by 25.4

milimetres to inches	milimetres by 0.0394
inches to centimetres	inches by 2.54
centimetres to inches	centimetres by 0.394
inches to metres	inches by 0.0254
feet to metres	feet by 0.3048

Metric Measures of Mass :

1 kilogram (kg)	= 1000 grams (g)
1 hectogram (hg)	= 100 grams (g)
1 decagram (dkg)	= 10 grams (g)
1 decigram (dg)	= 0.1 gram (g)
1 centigram (cg)	= 0.01 gram (g)
1 miligram (mg)	= 0.001 gram (g)

To Convert	Multiply
pounds to kilogram	pounds by 0.454
kilograms to pounds	kilograms by 2.205

Metric Measures of Volume :

1 cubic metre (m^3)	= 1000 cubic decimetres (dm^3)
1 cubic metre (m^3)	= 1000000 cubic centimetres (cm^3)
1 cubic metre (m^3)	= 1000000000 cubic milimetres (mm^3)

To Convert	Multiply
cubic yards to cubic metres (m^3)	cubic yards by 0.765
cubic feet to cubic metres (m^3)	cubic feet by 0.028
gallons to cubic metres (m^3)	gallons by 0.0038
quarts to cubic metres (m^3)	quarts by 0.00095
ounces to cubic metres (m^3)	ounces by 0.000029

Metric Measures of Area :

1 square metre (m^2)	= 100 square decimetres (dm^2)
1 square metre (m^2)	= 10000 square centimetres (cm^2)
1 square metre (m^2)	= 1000000 square milimetres (mm^2)
Designation of Large Areas :	
1 square kilometre (km^2)	= 1000000 square metres (m^2)
1 square hectometre (hm^2)	= 10000 square metres(m^2)

To Convert	Multiply
Square inches (in^2) to square milimeters (mm^2)	in^2 by 645.200
Square inches (in^2) to square centimeters (cm^2)	in^2 by 6.452
Square centimetres (cm^2) to square inches (in^2)	cm^2. by 0.155
Square feet (ft^2) to square metres (m^2)	ft^2. by 0.093
Square yards (yd^2) to square metres (m^2)	m^2 by 10.836
Square metres (m^2) to square yards (yd^2)	m^2 by 1.196
acres to square metres (m^2)	acres by 4046.870
square miles (mi^2) to square meters (m^2)	mi^2 by 2589988
square miles (mi.^{2}) to square kilometres (km^2)	mi^2 by 2.590

11 6 Applying Procedures for House Building Loan

You are to apply for loan in prescribed form of House Building Finance

Corporation. A sample is furnished here.

Presently two types of loan are given, one is general the other is Multi-storied one. Max of 10 (Ten) laks Taka is given for the former and no limit is there for the later.

Present rate is Tk. 535/- for gr. floor and Tk. 432/- for other floors. Interest rate is 12% You are to bear roughly about 15% of the total cost.

Loan Application Form

1. Name :
2. Age : Nationality
3. Father's/Husband's Name
4. Address : Permanent

Mailing Address

5. (A) How many dependents you have. Furnish their names

(B) Is there any earning member in your family other than you.

6. (A) What is your monthly income.

(1) Amount

(2) Source

(B) What is the income of your Guarantor.

(1) Amount Source

7. Statement of the Plot and Boundary on the house is proposed to be built.

8. (A) Statement of the proposed house.

(B) How far it has been completed.

(C) How much is spent so far.

9. How much you require.
10. What is source of extra amount required.
11. Is the land (at 7) is free from any incumbrance.
12. Whether any loan is taken from any other source.
13. Have you been guarantor for any body else.
14. Have you applied previously for such loan.
15. Any member of your family has taken loan from this Corporation.
16. Refer two persons who can give your antecedents.
17. Any other information you like to give.

Witness **Signature**

Document to be Furnished With the Application

1. Bank Receipt for application fee Tk. 1/- per thousand on the amount of loan applied for to be deposited to the Sonali Bank.
2. D.I.T. approved Building plan
3. Letter approving the Building Plan
4. One spare copy of plan
5. Documentary proof of income of the applicant or his Guarantor
6. Original title deed/Lease deed/Sales deed/Possession letter, allotment letter,, etc.
7. Permission to Mortgage the land in form No. L-19 (for Cantonment area)
8. Site Plan.
9. Baya Deed (Previous title deed) covering 29 years.
10. Non-encumbrance Certificate for the last 12 years from the Registration Department.
11. C.S. Khatian (Certified copy).

12. S.A. Khatian/R.S. Khatian(Certified copy)
13. Rent Receipt and Municipal Tax Receipt, if Municipal holding.
14. Name Plot at construction site.
15. Certificate regarding up to date payment of the land (in case of Govt. and D.I.T. Plots)
16. Hand Drawn Route Map to make inspection easy.
17. Phone No. of Office or Residence if any
18. No objection certificate from Ministry of works and Urban Development.
19. Mutation certificates, Rent Receipt,D.C.R. and certified copy of Khatian in the name of the application.
20. In case of Multi-Storied Building details structural designs of foundation with earth cutting lay out along with a loan bearing certificate from any Executive Engineer or B.Sc. (Civil) Engineer with 5 years experience.

A Non encumbrance certificate to be furnished also. You are to address the District Registrar,through the Bangladesh House Building Finance Corporation in the following manner :

To
The District Registrar,
Dhaka.
Through the Bangladesh House Building Finance Corporation Dhaka.
Dear Sir,
I require a Non-encumbrance Certificate in connection with my loan application to the Bangladesh House Building Finance Corporation,Dhaka in respect of the land described below :-
Searching fee, if any will be paid by me.
Schedule of the property.

1. Name of the District:
2. Name of the P.S.
3. Name of the House and B.L.No.
4. C.S.Khatian No.
5. S.A/R.S. Khatian No.
6. C.S. Plot No.
7. S.A/P.S. Plot No.
8. Area of the land unencumbered :

Yours faithfully,

Signature
Address

Forwarded.
Non-encumbrance certificate may please be issued to the applicant after searching index No. I and II and records of other officers having concurrence jurisdiction over the property for the last twelve years.

sd/- Illegible
Law officer
Bangladesh House Building
Finance Corporation, Dhaka.

This code is revised periodically by supplement. The official ACI standard includes this document plus the most recently adopted supplement.

This document has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

3rd PRINTING, DECEMBER 1985

Editorial corrections made as of November 1985

BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE (ACI 318-83)*

REPORTED BY ACI COMMITTEE 318

This code covers the proper design and construction of buildings of reinforced concrete. It is written in such form that it may be adopted by reference in a general building code, and earlier editions have been widely used in this manner.

Among the subjects covered are: permits and drawings; inspection; specifications; materials; concrete quality; mixing and placing; formwork, embedded pipes, and construction joints; reinforcement details; analysis and design; strength and serviceability; flexural and axial loads; shear and torsion; development of reinforcement; slab systems; walls; footings; precast concrete; prestressed concrete; shells and folded plate members; strength evaluation of existing structures; special provisions for seismic design in Appendix A, and an alternate design method in Appendix B.

The quality and testing of materials used in the construction are covered by reference to the appropriate ASTM standard specifications. Welding of reinforcement is covered by reference to the appropriate AWS standard.

Keywords: admixtures; aggregates; anchorage (structural); beam-column frame; beams (supports); building codes; cements; cold weather construction; columns (supports); combined stress; composite construction (concrete and steel); composite construction (concrete to concrete); compressive strength; concrete construction; concretes; concrete slabs; construction joints; continuity (structural); cover; curing; deep beams; deflections; drawings; earthquake resistant structures; embedded service ducts; flexural strength; floors; folded plates; footings; formwork (construction); frames; hot weather construction; inspection; joints (junctions); joists; lightweight concretes; loads (forces); load tests (structural); materials; mixing; mix proportioning; modulus of elasticity; moments; pipe columns; pipes (tubes); placing; precast concrete; prestressed concrete; prestressing steels; quality control; reinforced concrete; reinforcing steels; roofs; serviceability; shear strength; shearwalls; shells (structural forms); spans; specifications; splicing; strength; strength analysis; structural analysis; structural design; T-beams; torsion; walls; water; welded wire fabric.

Adopted as a standard of the American Concrete Institute in September 1983 to supersede ACI 318-77 in accordance with the Institute's standardization procedure.

*This document has been written separately in the U.S. inch-pound system of measurements and the SI (Système International) metric system. One version or the other must be used in its entirety.

CONTENTS

PART 5—STRUCTURAL SYSTEMS OR ELEMENTS

PART 2 – STANDARDS FOR TESTS AND MATERIALS

CHAPTER 3 – MATERIALS

3.0 – Notation

d_b = nominal diameter of bar, in.
f_y = specified yield strength of nonprestressed reinforcement, psi

3.1 – Tests of materials

3.1.1 – Building Official shall have the right to order testing of any materials used in concrete construction to determine if materials are of quality specified.

3.1.2 – Tests of materials and of concrete shall be made in accordance with standards of the American Society for Testing and Materials, listed in Section 3.8.1.

3.1.3 – A complete record of tests of materials and of concrete shall be available for inspection during progress of work and for 2 years after completion of the project, and shall be preserved by inspecting engineer or architect for that purpose.

3.2 – Cements

3.2.1 – Cement shall conform to one of the following specifications for portland cement:

(a) "Specification for Portland Cement" (ASTM C 150).

(b) "Specification for Blended Hydraulic Cements" (ASTM C 595), excluding Types S and SA which are not intended as principal cementing constituents of structural concrete.

3.2.2 – Cement used in the work shall correspond to that on which selection of concrete proportions was based. See Section 4.2.

3.3 – Aggregates

3.3.1 – Concrete aggregates shall conform to one of the following specifications:

(a) "Specification for Concrete Aggregates" (ASTM C 33).

(b) "Specification for Lightweight Aggregates for Structural Concrete" (ASTM C 330).

3.3.2–Aggregates failing to meet the specifications listed in Section 3.3.1, but which have been shown by special test or actual service to produce concrete of adequate strength and durability may be used where authorized by the Building Official.

3.3.3 – Nominal maximum size of coarse aggregate shall be not larger than:

(a) 1/5 the narrowest dimension between sides of forms, nor

(b) 1/3 the depth of slabs, nor

(c) 3/4 the minimum clear spacing between individual reinforcing bars or wires, bundles of bars, or prestressing tendons or ducts.

These limitations may be waived if, in the judgment of the Engineer, workability and methods of consolidation are such that concrete can be placed without honeycomb or voids.

3.4 – Water

3.4.1 – Water used in mixing concrete shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials, or other substances that may be deleterious to concrete or reinforcement.

3.4.2 – Mixing water for prestressed concrete or for concrete that will contain aluminum embedments, including that portion of mixing water contributed in the form of free moisture on aggregates, shall not contain deleterious amounts of chloride ion. See Section 4.5.4.

3.4.3 – Nonpotable water shall not be used in concrete unless the following are satisfied:

3.4.3.1 – Selection of concrete proportions shall be based on concrete mixes using water from the same source.

3.4.3.2 – Mortar test cubes made with nonpotable mixing water shall have 7-day and 28-day strengths equal to at least 90 percent of strengths of similar specimens made with potable water. Strength test comparison shall be made on mortars, identical except for the mixing water, prepared and tested in accordance with "Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-inch or 50-mm Cube Specimens)" (ASTM C 109).

3.5 – Metal reinforcement

3.5.1 – Reinforcement shall be deformed reinforcement, except that plain reinforcement may be used for spirals or tendons; and reinforcement consisting of structural steel, steel pipe, or steel tubing may be used as specified in this code.

3.5.2 – Reinforcing bars to be welded shall be indicated on the drawings and welding procedure to be used shall be specified. ASTM reinforcing bar specifications, except for ASTM A 706, shall be supplemented to require a report of material properties necessary to conform to welding procedures specified in "Structural Welding Code – Reinforcing Steel" (AWS D1.4) of the American Welding Society.

3.5.3 – **Deformed reinforcement**

3.5.3.1 – Deformed reinforcing bars shall conform to one of the following specifications:

(a) "Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement" including Supplementary Requirements S1 (ASTM A 615 including S1).

(b) "Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement" (ASTM A 616); except that all bars shall be bend tested and shall meet the bend test requirements for axle steel reinforcing bars, ASTM A 617, Grade 60; and the bar markings rolled into the surface of the bars shall include the letter "R" to designate rail steel meeting these requirements.

(c) "Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement" (ASTM A 617).

(d) "Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement" (ASTM A 706).

3.5.3.2 – Deformed reinforcing bars with a specified yield strength f_y exceeding 60,000 psi may be used, provided f_y shall be the stress corresponding to a strain of 0.35 percent and the bars otherwise conform to one of the ASTM specifications listed in Section 3.5.3.1. See Section 9.4.

3.5.3.3 – Bar mats for concrete reinforcement shall conform to "Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement" (ASTM A 184). Reinforcing bars used in bar mats shall conform to one of the specifications listed in Section 3.5.3.1.

3.5.3.4 – Deformed wire for concrete reinforcement shall conform to "Specification for Deformed Steel Wire for Concrete Reinforcement" (ASTM A 496), except that wire shall not be smaller than size D4 and for wire with a specified yield strength f_y exceeding 60,000 psi, f_y shall be the stress corresponding to a strain of 0.35 percent.

3.5.3.5 – Welded smooth wire fabric for concrete reinforcement shall conform to "Specification for Welded Steel Wire Fabric for Concrete Reinforcement" (ASTM A 185), except that for wire with a specified yield strength f_y exceeding 60,000 psi, f_y shall be the stress corresponding to a strain of 0.35 percent. Welded intersections shall not be spaced farther apart than 12 in. in direction of calculated stress, except for wire fabric used as stirrups in accordance with Section 12.13.2.

3.5.3.6 – Welded deformed wire fabric for concrete reinforcement shall conform to "Specification for Welded Deformed Steel Wire Fabric for Concrete Reinforcement" (ASTM A 497), except that for wire with a specified yield strength f_y exceeding 60,000 psi, f_y shall be the stress corresponding to a strain of 0.35 percent. Welded intersections shall not be spaced farther apart than 16 in. in direction of calculated stress, except for wire fabric used as stirrups in accordance with Section 12.13.2.

3.5.3.7 – Reinforcing bars may be galvanized or epoxy coated in accordance with "Specifiction for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement" (ASTM A 767) or "Specification for Epoxy-Coated Reinforcing Steel Bars" (ASTM A 775). Zinc or epoxy-coated reinforcing bars shall conform to one of the specifications listed in Section 3.5.3.1.

3.5.4 – **Plain reinforcement**

3.5.4.1 – Plain bars for spiral reinforcement shall conform to the specification listed in Section 3.5.3.1(a), (b), or (c).

3.5.4.2 – Smooth wire for spiral reinforcement shall conform to "Specification for Cold-Drawn Steel Wire for Concrete Reinforcement" (ASTM A 82), except that for wire with a specified yield strength f_y exceeding 60,000 psi, f_y shall be the stress corresponding to a strain of 0.35 percent.

3.5.5 – **Prestressing tendons**

3.5.5.1 – Tendons for prestressed reinforcement shall conform to one of the following specifications:

(a) Wire conforming to "Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete" (ASTM A 421).

(b) Low-relaxation wire conforming to "Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete" including Supplement "Low-Relaxation Wire" (ASTM A 421).

(c) Strand conforming to "Specification for Uncoated Seven-Wire Stress-Relieved Steel Strand for Prestressed Concrete (ASTM A 416).

(d) Low-relaxation strand conforming to "Specification for Uncoated Seven-Wire Stress-Relieved Steel Strand for Prestressed Concrete" including Supplement "Low-Relaxation Strands" (ASTM A 416).

(e) Bar conforming to "Specification for Uncoated High-Strength Steel Bar for Prestressed Concrete" (ASTM A 722).

3.5.5.2 – Wire, strands, and bars not specifically listed in ASTM A 421, A 416, or A 722 may be used provided they conform to minimum requirements of these specifications and do not have properties that make them less satisfactory than those listed in ASTM A 421, A 416, or A 722.

3.5.6 – Structural steel, steel pipe, or tubing

3.5.6.1 – Structural steel used with reinforcing bars in composite compression members meeting requirements of Section 10.14.7 or 10.14.8 shall conform to one of the following specifications:

(a) "Specification for Structural Steel" (ASTM A 36).

(b) "Specification for High-Strength Low-Alloy Structural Steel" (ASTM A 242).

(c) "Specification for High-Strength Low-Alloy Structural Manganese Vanadium Steel" (ASTM A 441).

(d) "Specification for High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality" (ASTM A 572).

(e) "Specification for High-Strength Low-Alloy Structural Steel with 50,000 psi Minimum Yield Point to 4 in. Thick" (ASTM A 588).

3.5.6.2 – Steel pipe or tubing for composite compression members composed of a steel encased concrete core meeting requirements of Section 10.14.6 shall conform to one of the following specifications:

(a) Grade B of "Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless" (ASTM A 53).

(b) "Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes" (ASTM A 500).

(c) "Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing" (ASTM A 501).

3.6 – Admixtures

3.6.1 – Admixtures to be used in concrete shall be subject to prior approval by the Engineer.

3.6.2 – An admixture shall be shown capable of maintaining essentially the same composition and performance throughout the work as the product used in establishing concrete proportions in accordance with Section 4.2.

3.6.3 – Calcium chloride or admixtures containing chloride from other than impurities from admixture ingredients shall not be used in prestressed concrete, in concrete containing embedded aluminum, or in concrete cast against stay-in-place galvanized metal forms. See Sections 4.5.3.1 and 4.5.4.

3.6.4 —Air-entraining admixtures shall conform to "Specification for Air-Entraining Admixtures for Concrete" (ASTM C 260).

3.6.5 – Water-reducing admixtures, retarding admixtures, accelerating admixtures, water-reducing and retarding admixtures, and water-reducing and accelerating admixtures shall conform to "Specification for Chemical Admixtures for Concrete" (ASTM C 494).

3.6.6 – Fly ash or other pozzolans used as admixtures shall conform to "Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete" (ASTM C 618).

3.7 – Storage of materials

3.7.1 – Cement and aggregates shall be stored in such manner as to prevent deterioration or intrusion of foreign matter.

3.7.2 – Any material that has deteriorated or has been contaminated shall not be used for concrete.

3.8 – Standards cited in this code

3.8.1 – Standards of the American Society for Testing and Materials referred to in this code are listed below with their serial designations, including year of adoption or revision, and are declared to be part of this code as if fully set forth herein:

A36-81a	Standard Specification for Structural Steel
A53-82	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
A82-79	Standard Specification for Cold-Drawn Steel Wire for Concrete Reinforcement
A184-79	Standard Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement
A185-79	Standard Specification for Welded Steel Wire Fabric for Concrete Reinforcement
A242-81	Standard Specification for High-Strength Low-Alloy Structural Steel

A416-80	Standard Specification for Uncoated Seven-Wire Stress-Relieved Steel Strand for Prestressed Concrete
A421-80	Standard Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete
A441-81	Standard Specification for High-Strength Low-Alloy Structural Manganese Vanadium Steel.
A496-78	Standard Specification for Deformed Steel Wire for Concrete Reinforcement
A497-79	Standard Specification for Welded Deformed Steel Wire Fabric for Concrete Reinforcement
A500-82a	Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
A501-81	Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
A572-82	Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality
A588-82	Standard Specification for High-Strength Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point to 4 in. (100 mm) Thick
A615-82(S1)	Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement including Supplementary Requirements (S1)
A616-82a	Standard Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement
A617-82a	Standard Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement
A706-82a	Standard Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement
A722-75 (1981)	Standard Specification for Uncoated High-Strength Steel Bar for Prestressing Concrete
A767-79	Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement
A775-81	Standard Specification for Epoxy-Coated Reinforcing Steel Bars
C31-69 (1980)	Standard Method of Making and Curing Concrete Test Specimens in the Field
C33-82	Standard Specification for Concrete Aggregates
C39-81	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
C42-77	Standard Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C94-81	Standard Specification for Ready-Mixed Concrete
C109-80	Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-inch or 50-mm Cube Specimens)
C144-81	Standard Specification for Aggregate for Masonry Mortar
C150-81	Standard Specification for Portland Cement
C172-82	Standard Method of Sampling Freshly Mixed Concrete
C192-81	Standard Method of Making and Curing Concrete Test Specimens in the Laboratory
C260-77	Standard Specification for Air-Entraining Admixtures for Concrete
C330-80	Standard Specification for Lightweight Aggregates for Structural Concrete
C494-81	Standard Specification for Chemical Admixtures for Concrete
C496-71 (1979)	Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
C567-80	Standard Test Method for Unit Weight of Structural Lightweight Concrete
C595-82	Standard Specification for Blended Hydraulic Cements

PART 3 – CONSTRUCTION REQUIREMENTS

CHAPTER 4 – CONCRETE QUALITY

4.0 – Notation

f'_c = specified compressive strength of concrete, psi

f_{ct} = average splitting tensile strength of lightweight aggregate concrete, psi

f'_{cr} = required average compressive strength of concrete used as the basis for selection of concrete proportions, psi

s = standard deviation, psi

4.1 – General

4.1.1 – Concrete shall be proportioned to provide an average compressive strength as prescribed in Section 4.3.2. Concrete shall be produced to minimize frequency of strengths below f'_c as precribed in Section 4.7.2.3.

4.1.2 – Requirements for f'_c shall be based on tests of cylinders made and tested as prescribed in Section 4.7.2.

4.1.3 – Unless otherwise specified, f'_c shall be based on 28-day tests. If other than 28 days, test age for f'_c shall be as indicated in design drawings or specifications.

4.1.4 – Where design criteria in Sections 9.5.2.3, 11.2 and 12.2.3.3 provide for use of a splitting tensile strength value of concrete, laboratory tests shall be made in accordance with "Specification for Lightweight Aggregates for Structural Concrete" (ASTM C 330) to establish value of f_{ct} corresponding to specified value of f'_c.

4.1.5 – Splitting tensile strength tests shall not be used as a basis for field acceptance of concrete.

4.2 – Selection of concrete proportions

4.2.1 – Proportions of materials for concrete shall be established to provide:

(a) Workability and consistency to permit concrete to be worked readily into forms and around reinforcement under conditions of placement to be employed, without segregation or excessive bleeding.

(b) Resistance to special exposures as required by Section 4.5.

(c) Conformance with strength test requirements of Section 4.7.

4.2.2 – Where different materials are to be used for different portions of proposed work, each combination shall be evaluated.

4.2.3 – Concrete proportions, including water-cement ratio, shall be established on the basis of field experience and/or trial mixtures with materials to be employed (Section 4.3), except as permitted in Section 4.4 or required by Section 4.5.

4.3 – Proportioning on the basis of field experience and/or trial mixtures

4.3.1 – Standard deviation

4.3.1.1 – Where a concrete production facility has test records, a standard deviation shall be established. Test records from which a standard deviation is calculated:

(a) Shall represent materials, quality control procedures, and conditions similar to those expected and changes in materials and proportions within the test records shall not have been more restricted than those for proposed work.

(b) Shall represent concrete produced to meet a specified strength or strengths f'_c within 1000 psi of that specified for proposed work.

(c) Shall consist of at least 30 consecutive tests or two groups of consecutive tests totaling at least 30 tests as defined in Section 4.7.1.4, except as provided in Section 4.3.1.2.

4.3.1.2 – Where a concrete production facility does not have test records meeting requirements of Section 4.3.1.1, but does have a record based on 15 to 29 consecutive tests, a standard deviation may be established as the product of the calculated standard deviation and modification factor of Table 4.3.1.2. To

TABLE 4.3.1.2 – MODIFICATION FACTOR FOR STANDARD DEVIATION WHEN LESS THAN 30 TESTS ARE AVAILABLE

No. of tests*	Modification factor for standard deviation†
less than 15	Use Table 4.3.2.2
15	1.16
20	1.08
25	1.03
30 or more	1.00

*Interpolate for intermediate numbers of tests.

†Modified standard deviation to be used to determine required average strength f'_{cr} of Section 4.3.2.1

be acceptable, test record must meet requirements (a) and (b) of Section 4.3.1.1, and represent only a single record of consecutive tests that span a period of not less than 45 calendar days.

4.3.2 – Required average strength

4.3.2.1 – Required average compressive strength f'_{cr} used as the basis for selection of concrete proportions shall be the larger of Eq. (4-1) or (4-2) using a standard deviation calculated in accordance with Section 4.3.1.1 or Section 4.3.1.2.

$$f'_{cr} = f'_c + 1.34s \tag{4-1}$$

or

$$f'_{cr} = f'_c + 2.33s - 500 \tag{4-2}$$

4.3.2.2 – When a concrete production facility does not have field strength test records for calculation of standard deviation meeting requirements of Section 4.3.1.1 or Section 4.3.1.2, required average strength f'_{cr} shall be determined from Table 4.3.2.2 and documentation of average strength shall be in accordance with requirements of Section 4.3.3.

TABLE 4.3.2.2 – REQUIRED AVERAGE COMPRESSIVE STRENGTH WHEN DATA ARE NOT AVAILABLE TO ESTABLISH A STANDARD DEVIATION

Specified compressive strength, f'_c, psi	Required average compressive strength, f'_{cr}, psi
Less than 3000 psi	f'_c + 1000
3000 to 5000	f'_c + 1200
Over 5000	f'_c + 1400

4.3.3 – Documentation of average strength

Documentation that proposed concrete proportions will produce an average compressive strength equal to or greater than required average compressive strength (Section 4.3.2) may consist of a field strength test record, several strength test records, or trial mixtures.

4.3.3.1 – When test records are used to demonstrate that proposed concrete proportions will produce the required average strength f'_{cr} (Section 4.3.2), such records shall represent materials and conditions similar to those expected. Changes in materials, conditions, and proportions within the test records shall not have been more restricted than those for proposed work. For the purpose of documenting average strength potential, test records consisting of less than 30 but not less than 10 consecutive tests may be used provided test records encompass a period of time not less than 45 days. Required concrete proportions may be established by interpolation between the strengths and proportions of two or more test records each of which meets other requirements of this section.

4.3.3.2 – When an acceptable record of field test results is not available, concrete proportions may be established based on trial mixtures meeting the following restrictions.

(a) Combination of materials shall be those for proposed work.

(b) Trial mixtures having proportions and consistencies required for proposed work shall be made using at least three different water-cement ratios or cement contents that will produce a range of strengths encompassing the required average strength f'_{cr}.

(c) Trial mixtures shall be designed to produce a slump within ±0.75 in. of maximum permitted, and for air-entrained concrete, within ±0.5 percent of maximum allowable air content.

(d) For each water-cement ratio or cement content, at least three test cylinders for each test age shall be made and cured in accordance with "Method of Making and Curing Concrete Test Specimens in the Laboratory" (ASTM C 192). Cylinders shall be tested at 28 days or at test age designated for determination of f'_c.

(e) From results of cylinder tests a curve shall be plotted showing relationship between water-cement ratio or cement content and compressive strength at designated test age.

(f) Maximum water-cement ratio or minimum cement content for concrete to be used in proposed work shall be that shown by the curve to produce the average strength required by Section 4.3.2, unless a lower water-cement ratio or higher strength is required by Section 4.5.

4.4 – Proportioning by water-cement ratio

4.4.1 – If data required by Section 4.3 are not available, permission may be granted to base concrete proportions on water-cement ratio limits in Table 4.4.

TABLE 4.4 – MAXIMUM PERMISSIBLE WATER-CEMENT RATIOS FOR CONCRETE WHEN STRENGTH DATA FROM FIELD EXPERIENCE OR TRIAL MIXTURES ARE NOT AVAILABLE

Specified compressive strength, f'_c, psi*	Absolute water-cement ratio by weight	
	Non-air-entrained concrete	Air-entrained concrete
2500	0.67	0.54
3000	0.58	0.46
3500	0.51	0.40
4000	0.44	0.35
4500	0.38	†
5000	†	†

*28-day strength. With most materials, water-cement ratios shown will provide average strengths greater than indicated in Section 4.3.2 as being required.

†For strengths above 4500 psi (non-air-entrained concrete) and 4000 psi (air-entrained concrete), concrete proportions shall be established by methods of Section 4.3.

4.4.2 – Table 4.4 shall be used only for concrete to be made with cements meeting strength requirements for Types I, IA, II, IIA, III, IIIA, or V of "Specification for Portland Cement" (ASTM C 150), or Types IS, IS-A, IS(MS), IS-A(MS), I(SM), I(SM)-A, IP, IP-A, I(PM), I(PM)-A, IP(MS), IP-A(MS), or P of "Specification for Blended Hydraulic Cements" (ASTM C 595), and shall not be applied to concrete containing lightweight aggregates or admixtures other than those for entraining air.

4.4.3 – Concrete proportioned by water-cement ratio limits prescribed in Table 4.4 shall also conform to special exposure requirements of Section 4.5 and to compressive strength test criteria of Section 4.7.

4.5 – Special exposure requirements

4.5.1 – Normal weight and lightweight concrete exposed to freezing and thawing or deicer chemicals shall be air entrained with air content indicated in Table 4.5.1. Tolerance on air content as delivered shall be ±1.5 percent. For specified compressive strength f'_c greater than 5000 psi, air content indicated in Table 4.5.1 may be reduced 1 percent.

TABLE 4.5.1 – TOTAL AIR CONTENT FOR FROST-RESISTANT CONCRETE

Nominal maximum aggregate size, in.*	Air content, percent	
	Severe exposure	Moderate exposure
3/8	7-1/2	6
1/2	7	5-1/2
3/4	6	5
1	6	4-1/2
1-1/2	5-1/2	4-1/2
2†	5	4
3†	4-1/2	3-1/2

*See ASTM C 33 for tolerances on oversize for various nominal maximum size designations.

†These air contents apply to total mix, as for the preceding aggregate sizes. When testing these concretes, however, aggregate larger than 1-1/2 in. is removed by handpicking or sieving and air content is determined on the minus 1-1/2 in. fraction of mix. (Tolerance on air content as delivered applies to this value.) Air content of total mix is computed from value determined on the minus 1-1/2 in. fraction.

TABLE 4.5.2 – REQUIREMENTS FOR SPECIAL EXPOSURE CONDITIONS

Exposure condition	Maximum water-cement ratio, normal weight aggregate concrete	Minimum f'_c, lightweight aggregate concrete
Concrete intended to be watertight:		
(a) Concrete exposed to fresh water	0.50	3750
(b) Concrete exposed to brackish water or seawater	0.45	4250
Concrete exposed to freezing and thawing in a moist condition:		
(a) Curbs, gutters, guardrails or thin sections	0.45	4250
(b) Other elements	0.50	3750
(c) In presence of deicing chemicals	0.45	4250
For corrosion protection for reinforced concrete exposed to deicing salts, brackish water, seawater or spray from these sources	0.40*	4750*

*If minimum concrete cover required by Section 7.7 is increased by 0.5 in., water-cement ratio may be increased to 0.45 for normal weight concrete, or f'_c reduced to 4250 psi for lightweight concrete.

4.5.2 – Concrete that is intended to be watertight or concrete that will be subject to freezing and thawing in a moist condition shall conform to requirements of Table 4.5.2.

4.5.3 – Concrete to be exposed to sulfate-containing solutions shall conform to requirements of Table 4.5.3 or be made with a cement that provides sulfate resistance and used in concrete with maximum water-cement ratio or minimum compressive strength from Table 4.5.3.

4.5.3.1 – Calcium chloride as an admixture shall not be used in concrete to be exposed to severe or very severe sulfate-containing solutions, as defined in Table 4.5.3.

TABLE 4.5.3 – REQUIREMENTS FOR CONCRETE EXPOSED TO SULFATE-CONTAINING SOLUTIONS

Sulfate exposure	Water soluble sulfate (SO_4) in soil, percent by weight	Sulfate (SO_4) in water, ppm	Cement type	Normal weight aggregate concrete	Lightweight aggregate concrete
				Maximum water-cement ratio, by weight*	Minimum compressive strength, f'_c psi*
Negligible	0.00–0.10	0–150	—	—	—
Moderate†	0.10–0.20	150–1500	II, IP(MS), IS(MS)	0.50	3750
Severe	0.20–2.00	1500–10,000	V	0.45	4250
Very severe	Over 2.00	Over 10,000	V plus pozzolan‡	0.45	4250

*A lower water-cement ratio or higher strength may be required for watertightness or for protection against corrosion of embedded items or freezing and thawing (Table 4.5.2).

†Seawater.

‡Pozzolan that has been determined by test or service record to improve sulfate resistance when used in concrete containing Type V cement.

4.5.4 – For corrosion protection, maximum water soluble chloride ion concentrations in hardened concrete at an age of 28 days contributed from the ingredients including water, aggregates, cementitious materials and admixtures shall not exceed limits of Table 4.5.4.

TABLE 4.5.4 – MAXIMUM CHLORIDE ION CONTENT FOR CORROSION PROTECTION

Type of member	Maximum water soluble chloride ion (Cl^-) in concrete, percent by weight of cement
Prestressed concrete	0.06
Reinforced concrete exposed to chloride in service	0.15
Reinforced concrete that will be dry or protected from moisture in service	1.00
Other reinforced concrete construction	0.30

4.5.5 – When reinforced concrete will be exposed to deicing salts, brackish water, seawater, or spray from these sources, requirements of Table 4.5.2 for water-cement ratio or concrete strength and minimum concrete cover requirements of Section 7.7 shall be satisfied.

4.6 – Average strength reduction

As data become available during construction, amount by which value of f'_{cr} must exceed specified value of f'_c may be reduced, provided:

(a) 30 or more test results are available and average of test results exceeds that required by Section 4.3.2.1, using a standard deviation calculated in accordance with Section 4.3.1.1, or

(b) 15 to 29 test results are available and average of test results exceeds that required by Section 4.3.2.1 using a standard deviation calculated in accordance with Section 4.3.1.2, and

(c) special exposure requirements of Section 4.5 are met.

4.7 – Evaluation and acceptance of concrete

4.7.1 – Frequency of testing

4.7.1.1 – Samples for strength tests of each class of concrete placed each day shall be taken not less than once a day, nor less than once for each 150 cu yd of concrete, nor less than once for each 5000 sq ft of surface area for slabs or walls.

4.7.1.2 – On a given project, if total volume of concrete is such that frequency of testing required by Section 4.7.1.1 would provide less than five strength tests for a given class of concrete, tests shall be made from at least five randomly selected batches or from each batch if fewer than five batches are used.

4.7.1.3 – When total quantity of a given class of concrete is less than 50 cu yd, strength tests may be waived by the Building Official, if in his judgment evidence of satisfactory strength is provided.

4.7.1.4 – A strength test shall be the average of the strengths of two cylinders made from the same sample of concrete and tested at 28 days or at test age designated for determination of f'_c.

4.7.2 – Laboratory-cured specimens

4.7.2.1 – Samples for strength tests shall be taken in accordance with "Method of Sampling Freshly Mixed Concrete" (ASTM C 172).

4.7.2.2 – Cylinders for strength tests shall be molded and laboratory-cured in accordance with "Method of Making and Curing Concrete Test Specimens in the Field" (ASTM C 31) and tested in accordance with "Test Method for Compressive Strength of Cylindrical Concrete Specimens" (ASTM C 39).

4.7.2.3 – Strength level of an individual class of concrete shall be considered satisfactory if both of the following requirements are met:

(a) Average of all sets of three consecutive strength tests equal or exceed f'_c.

(b) No individual strength test (average of two cylinders) falls below f'_c by more than 500 psi.

4.7.2.4 – If either of the requirements of Section 4.7.2.3 are not met, steps shall be taken to increase the average of subsequent strength test results. Requirements of Section 4.7.4 shall be observed if requirement of Section 4.7.2.3(b) is not met.

4.7.3 – Field-cured specimens

4.7.3.1 – The Building Official may require strength tests of cylinders cured under field conditions to check adequacy of curing and protection of concrete in the structure.

4.7.3.2 – Field-cured cylinders shall be cured under field conditions in accordance with Section 7.4 of "Method of Making and Curing Concrete Test Specimens in the Field" (ASTM C 31).

4.7.3.3 – Field-cured test cylinders shall be molded at the same time and from the same samples as laboratory-cured test cylinders.

4.7.3.4 – Procedures for protecting and curing concrete shall be improved when strength of field-cured cylinders at test age designated for determination of f'_c is less than 85 percent of that of companion laboratory-cured cylinders. The 85 percent may be waived if field-cured strength exceeds f'_c by more than 500 psi.

4.7.4 – Investigation of low-strength test results

4.7.4.1 – If any strength test (Section 4.7.1.4) of laboratory-cured cylinders falls below specified value of f'_c by more than 500 psi [Section 4.7.2.3(b)] or if tests of field-cured cylinders indicate deficiencies in protection and curing (Section 4.7.3.4), steps shall be taken to assure that load-carrying capacity of the structure is not jeopardized.

4.7.4.2 – If the likelihood of low-strength concrete is confirmed and computations indicate that load-carrying capacity may have been significantly reduced, tests of cores drilled from the area in question may be required in accordance with "Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete" (ASTM C 42). In such case, three cores shall be taken for each strength test more than 500 psi below specified value of f'_c.

4.7.4.3 – If concrete in the structure will be dry under service conditions, cores shall be air dried (temperature 60 to 80 F, relative humidity less than 60 percent) for 7 days before test and shall be tested dry. If concrete in the structure will be more than superficially wet under service conditions, cores shall be immersed in water for at least 40 hr and be tested wet.

4.7.4.4 – Concrete in an area represented by core tests shall be considered structurally adequate if the average of three cores is equal to at least 85 percent of f'_c and if no single core is less than 75 percent of f'_c. To check testing accuracy, locations represented by erratic core strengths may be retested.

4.7.4.5 – If criteria of Section 4.7.4.4 are not met, and if structural adequacy remains in doubt, the responsible authority may order load tests as outlined in Chapter 20 for the questionable portion of the structure, or take other appropriate action.

CHAPTER 5 – MIXING AND PLACING CONCRETE

5.1 – Preparation of equipment and place of deposit

5.1.1 – Preparation before concrete placement shall include the following.

(a) All equipment for mixing and transporting concrete shall be clean.

(b) All debris and ice shall be removed from spaces to be occupied by concrete.

(c) Forms shall be properly coated.

(d) Masonry filler units that will be in contact with concrete shall be well drenched.

(e) Reinforcement shall be thoroughly clean of ice or other deleterious coatings.

(f) Water shall be removed from place of deposit before concrete is placed unless a tremie is to be used or unless otherwise permitted by the Building Official.

(g) All laitance and other unsound material shall be removed before additional concrete is placed against hardened concrete.

5.2 – Mixing

5.2.1 – All concrete shall be mixed until there is a uniform distribution of materials and shall be discharged completely before mixer is recharged.

5.2.2 – Ready-mixed concrete shall be mixed and delivered in accordance with requirements of "Specification for Ready-Mixed Concrete" (ASTM C 94) or "Specification for Concrete Made by Volumetric Batching and Continuous Mixing" (ASTM C 685).

5.2.3 – Job-mixed concrete shall be mixed in accordance with the following.

(a) Mixing shall be done in a batch mixer of approved type.

(b) Mixer shall be rotated at a speed recommended by the manufacturer.

(c) Mixing shall be continued for at least 1-1/2 min after all materials are in the drum, unless a shorter time is shown to be satisfactory by the mixing uniformity tests of "Specification for Ready-Mixed Concrete" (ASTM C 94).

(d) Materials handling, batching, and mixing shall conform to applicable provisions of "Specification for Ready-Mixed Concrete" (ASTM C 94).

(e) A detailed record shall be kept to identify:

(1) number of batches produced;

(2) proportions of materials used;

(3) approximate location of final deposit in structure;

(4) time and date of mixing and placing.

5.3 – Conveying

5.3.1 – Concrete shall be conveyed from mixer to place of final deposit by methods that will prevent separation or loss of materials.

5.3.2 – Conveying equipment shall be capable of providing a supply of concrete at site of placement without separation of ingredients and without interruptions sufficient to permit loss of plasticity between successive increments.

5.4 – Depositing

5.4.1 – Concrete shall be deposited as nearly as practicable in its final position to avoid segregation due to rehandling or flowing.

5.4.2 – Concreting shall be carried on at such a rate that concrete is at all times plastic and flows readily into spaces between reinforcement.

5.4.3 – Concrete that has partially hardened or been contaminated by foreign materials shall not be deposited in the structure.

5.4.4 – Retempered concrete or concrete that has been remixed after initial set shall not be used unless approved by the Engineer.

5.4.5 – After concreting is started, it shall be carried on as a continuous operation until placing of a panel or section, as defined by its boundaries or predetermined joints, is completed except as permitted or prohibited by Section 6.4.

5.4.6 – Top surfaces of vertically formed lifts shall be generally level.

5.4.7 – When construction joints are required, joints shall be made in accordance with Section 6.4.

5.4.8 – All concrete shall be thoroughly consolidated by suitable means during placement and shall be thoroughly worked around reinforcement and embedded fixtures and into corners of forms.

5.5 – Curing

5.5.1 – Concrete (other than high-early-strength) shall be maintained above 50 F and in a moist condition for at least the first 7 days after placement, except when cured in accordance with Section 5.5.3.

5.5.2 – High-early-strength concrete shall be maintained above 50 F and in a moist condition for at least the first 3 days, except when cured in accordance with Section 5.5.3.

5.5.3 – Accelerated curing

5.5.3.1 – Curing by high pressure steam, steam at atmospheric pressure, heat and moisture, or other accepted processes, may be employed to accelerate strength gain and reduce time of curing.

5.5.3.2 – Accelerated curing shall provide a compressive strength of the concrete at the load stage considered at least equal to required design strength at that load stage.

5.5.3.3 – Curing process shall be such as to produce concrete with a durability at least equivalent to the curing method of Section 5.5.1 or 5.5.2.

5.5.4 – Supplementary strength tests in accordance with Section 4.7.3 may be required to assure that curing is satisfactory.

5.6 – Cold weather requirements

5.6.1 – Adequate equipment shall be provided for heating concrete materials and protecting concrete during freezing or near-freezing weather.

5.6.2 – All concrete materials and all reinforcement, forms, fillers, and ground with which concrete is to come in contact shall be free from frost.

5.6.3 – Frozen materials or materials containing ice shall not be used.

5.7 – Hot weather requirements

During hot weather, proper attention shall be given to ingredients, production methods, handling, placing, protection, and curing to prevent excessive concrete temperatures or water evaporation that may impair required strength or serviceability of the member or structure.

CHAPTER 6 – FORMWORK, EMBEDDED PIPES, AND CONSTRUCTION JOINTS

6.1 – Design of formwork

6.1.1 – Forms shall result in a final structure that conforms to shapes, lines, and dimensions of the members as required by the design drawings and specifications.

6.1.2 – Forms shall be substantial and sufficiently tight to prevent leakage of mortar.

6.1.3 – Forms shall be properly braced or tied together to maintain position and shape.

6.1.4 – Forms and their supports shall be designed so as not to damage previously placed structure.

6.1.5 – Design of formwork shall include consideration of the following factors:

(a) Rate and method of placing concrete

(b) Construction loads, including vertical, horizontal, and impact loads

(c) Special form requirements for construction of shells, folded plates, domes, architectural concrete, or similar types of elements.

6.1.6 – Forms for prestressed concrete members shall be designed and constructed to permit movement of the member without damage during application of prestressing force.

6.2 – Removal of forms and shores

6.2.1 – No construction loads shall be supported on, nor any shoring removed from, any part of the structure under construction except when that portion of the structure in combination with remaining forming and shoring system has sufficient strength to support safely its weight and loads placed thereon.

6.2.1.1 – Sufficient strength shall be demonstrated by structural analysis considering proposed loads, strength of forming and shoring system, and concrete strength data. Concrete strength data may be based on tests of field-cured cylinders or, when approved by the Building Official, on other procedures to evaluate concrete strength. Structural analysis and concrete strength test data shall be furnished to the Building Official when so required.

6.2.2 – No construction loads exceeding the combination of superimposed dead load plus specified live load shall be supported on any unshored portion of the structure under construction, unless analysis indicates adequate strength to support such additional loads.

6.2.3 – Forms shall be removed in such manner as not to impair safety and serviceability of the structure. All concrete to be exposed by form removal shall have sufficient strength not to be damaged thereby.

6.2.4 – Form supports for prestressed concrete members may be removed when sufficient prestressing has been applied to enable prestressed members to carry their dead load and anticipated construction loads.

6.3 – Conduits and pipes embedded in concrete

6.3.1 – Conduits, pipes and sleeves of any material not harmful to concrete and within limitations of Section 6.3 may be embedded in concrete with approval of the Engineer, provided they are not considered to replace structurally the displaced concrete.

6.3.2 – Conduits and pipes of aluminum shall not be embedded in structural concrete unless effectively coated or covered to prevent aluminum-concrete reaction or electrolytic action between aluminum and steel.

6.3.3 – Conduits, pipes, and sleeves passing through a slab, wall, or beam shall not impair significantly the strength of the construction.

6.3.4 – Conduits and pipes, with their fittings, embedded within a column shall not displace more than 4 percent of the area of cross section on which strength is calculated or which is required for fire protection.

6.3.5 – Except when plans for conduits and pipes are approved by the Structural Engineer, conduits and pipes embedded within a slab, wall, or beam (other than those merely passing through) shall satisfy the following.

6.3.5.1 – They shall not be larger in outside dimension than 1/3 the overall thickness of slab, wall, or beam in which they are embedded.

6.3.5.2 – They shall not be spaced closer than 3 diameters or widths on center.

6.3.5.3 – They shall not impair significantly the strength of the construction.

6.3.6 – Conduits, pipes, and sleeves may be considered as replacing structurally in compression the displaced concrete provided:

6.3.6.1 – They are not exposed to rusting or other deterioration.

6.3.6.2 – They are of uncoated or galvanized iron or steel not thinner than standard Schedule 40 steel pipe.

6.3.6.3 – They have a nominal inside diameter not over 2 in. and are spaced not less than 3 diameters on centers.

6.3.7 – In addition to other requirements of Section 6.3, pipes that will contain liquid, gas, or vapor may be embedded in structural concrete under the following conditions:

6.3.7.1 – Pipes and fittings shall be designed to resist effects of the material, pressure, and temperature to which they will be subjected.

6.3.7.2 – Temperature of liquid, gas, or vapor shall not exceed 150 F.

6.3.7.3 – Maximum pressure to which any piping or fittings shall be subjected shall not exceed 200 psi above atmospheric pressure.

6.3.7.4 – All piping and fittings except as provided in Section 6.3.7.5 shall be tested as a unit for leaks before concrete placement. Testing pressure above atmospheric pressure shall be 50 percent in excess of pressure to which piping and fittings may be subjected, but minimum testing pressure shall not be less than 150 psi above atmospheric pressure. Pressure test shall be held for 4 hr with no drop in pressure except that which may be caused by air temperature.

6.3.7.5 – Drain pipes and other piping designed for pressures of not more than 1 psi above atmospheric pressure need not be tested as required in Section 6.3.7.4.

6.3.7.6 – Pipes carrying liquid, gas, or vapor that is explosive or injurious to health shall again be tested as specified in Section 6.3.7.4 after concrete has hardened.

6.3.7.7 – No liquid, gas, or vapor, except water not exceeding 90 F nor 50 psi pressure, shall be placed in the pipes until the concrete has attained it's design strength.

6.3.7.8 – In solid slabs, piping, unless it is for radiant heating or snow melting, shall be placed between top and bottom reinforcement.

6.3.7.9 – Concrete cover for pipes and fittings shall not be less than 1-1/2 in. for concrete exposed to earth or weather or 3/4 in. for concrete not exposed to weather or in contact with ground.

6.3.7.10 – Reinforcement with an area not less than 0.002 times area of concrete section shall be provided normal to piping.

6.3.7.11 – Piping and fittings shall be assembled by welding, brazing, solder-sweating, or other equally satisfactory method. Screw connections shall not be permitted. Piping shall be so fabricated and installed that cutting, bending, or displacement of reinforcement from its proper location will not be required.

6.4 – Construction joints

6.4.1 – Surface of concrete construction joints shall be cleaned and laitance removed.

6.4.2 – Immediately before new concrete is placed, all construction joints shall be wetted and standing water removed.

6.4.3 – Construction joints shall be so made and located as not to impair the strength of the structure. Provision shall be made for transfer of shear and other forces through construction joints. See Section 11.7.9.

6.4.4 – Construction joints in floors shall be located within the middle third of spans of slabs, beams, and girders. Joints in girders shall be offset a minimum distance of two times the width of intersecting beams.

6.4.5 – Beams, girders, or slabs supported by columns or walls shall not be cast or erected until concrete in the vertical support members is no longer plastic.

6.4.6 – Beams, girders, haunches, drop panels and capitals shall be placed monolithically as part of a slab system, unless otherwise shown in design drawings or specifications.

CHAPTER 7 – DETAILS OF REINFORCEMENT

7.0 – Notation

d = distance from extreme compression fiber to centroid of tension reinforcement, in.

d_b = nominal diameter of bar, wire, or prestressing strand, in.

f_y = specified yield strength of nonprestressed reinforcement, psi

ℓ_d = development length, in. See Chapter 12

7.1 – Standard hooks

The term "standard hook" as used in this code shall mean one of the following:

7.1.1 – 180-deg bend plus $4d_b$ extension, but not less than 2-1/2 in. at free end of bar.

7.1.2 – 90-deg bend plus $12d_b$ extension at free end of bar.

7.1.3. – For stirrup and tie hooks*

(a) #5 bar and smaller, 90-deg bend plus $6d_b$ extension at free end of bar, or

(b) #6, #7, and #8 bar, 90-deg bend plus $12d_b$ extension at free end of bar, or

(c) #8 bar and smaller, 135-deg bend plus $6d_b$ extension at free end of bar.

7.2 – Minimum bend diameters

7.2.1 – Diameter of bend measured on the inside of the bar, other than for stirrups and ties in sizes #3 through #5, shall not be less than the values in Table 7.2.

7.2.2 – Inside diameter of bend for stirrups and ties shall not be less than $4d_b$ for #5 bar and smaller. For bars larger than #5, diameter of bend shall be in accordance with Table 7.2.

7.2.3 – Inside diameter of bend in welded wire fabric (smooth or deformed) for stirrups and ties shall not be less than $4d_b$ for deformed wire larger than D5 and $2d_b$ for all other wires. Bends with inside diameter of less than $8d_b$ shall not be less than $4d_b$ from nearest welded intersection.

Table 7.2 – MINIMUM DIAMETERS OF BEND

Bar size	Minimum diameter
#3 through #8	$6d_b$
#9, #10, and #11	$8d_b$
#14 and #18	$10d_b$

7.3 – Bending

7.3.1 – All reinforcement shall be bent cold, unless otherwise permitted by the Engineer.

7.3.2 – Reinforcement partially embedded in concrete shall not be field bent, except as shown on the design drawings or permitted by the Engineer.

7.4 – Surface conditions of reinforcement

7.4.1 – At time concrete is placed, metal reinforcement shall be free from mud, oil, or other nonmetallic coatings that adversely affect bonding capacity.

7.4.2 – Metal reinforcement, except prestressing tendons, with rust, mill scale, or a combination of both shall be considered satisfactory, provided the minimum dimensions (including height of deformations) and weight of a hand-wire-brushed test specimen are not less than applicable ASTM specification requirements.

7.4.3 – Prestressing tendons shall be clean and free of oil, dirt, scale, pitting and excessive rust. A light oxide is permissible.

7.5 – Placing reinforcement

7.5.1 – Reinforcement, prestressing tendons, and ducts shall be accurately placed and adequately supported before concrete is placed, and shall be secured against displacement within tolerances permitted in Section 7.5.2.

7.5.2 – Unless otherwise specified by the Engineer, reinforcement, prestressing tendons, and prestressing ducts shall be placed within the following tolerances:

7.5.2.1 – Tolerance for depth d, and minimum concrete cover in flexural members, walls and compression members shall be as follows:

	Tolerance on d	Tolerance on minimum concrete cover
$d \leq 8$ in.	±3/8 in.	−3/8 in.
$d > 8$ in.	±1/2 in.	−1/2 in.

Except that tolerance for the clear distance to formed soffits shall be minus 1/4 in. and tolerance for cover shall not exceed minus 1/3 the minimum concrete cover required in the design drawings or specifications.

*For closed ties defined as hoops in Appendix A, a 135-deg bend plus an extension of at least $10d_b$ (see Section A.1).

7.5.2.2 – Tolerance for longitudinal location of bends and ends of reinforcement shall be ±2 in. except at discontinuous ends of members where tolerance shall be ±1/2 in.

7.5.3 – Welded wire fabric (with wire size not greater than W5 or D5) used in slabs not exceeding 10 ft in span may be curved from a point near the top of slab over the support to a point near the bottom of slab at midspan, provided such reinforcement is either continuous over, or securely anchored at support.

7.5.4 – Welding of crossing bars shall not be permitted for assembly of reinforcement unless authorized by the Engineer.

7.6 – Spacing limits for reinforcement

7.6.1 – Clear distance between parallel bars in a layer shall be not less than d_b nor 1 in. See also Section 3.3.3.

7.6.2 – Where parallel reinforcement is placed in two or more layers, bars in the upper layers shall be placed directly above bars in the bottom layer with clear distance between layers not less than 1 in.

7.6.3 – In spirally reinforced or tied reinforced compression members, clear distance between longitudinal bars shall be not less than $1.5d_b$ nor 1-1/2 in. See also Section 3.3.3.

7.6.4 – Clear distance limitation between bars shall apply also to the clear distance between a contact lap splice and adjacent splices or bars.

7.6.5 – In walls and slabs other than concrete joist construction, primary flexural reinforcement shall be spaced not farther apart than three times the wall or slab thickness, nor 18 in.

7.6.6 – Bundled bars

7.6.6.1 – Groups of parallel reinforcing bars bundled in contact to act as a unit shall be limited to four in any one bundle.

7.6.6.2 – Bundled bars shall be enclosed within stirrups or ties.

7.6.6.3 – Bars larger than #11 shall not be bundled in beams.

7.6.6.4 – Individual bars within a bundle terminated within the span of flexural members shall terminate at different points with at least $40d_b$ stagger.

7.6.6.5 – Where spacing limitations and minimum concrete cover are based on bar diameter d_b, a unit of bundled bars shall be treated as a single bar of a diameter derived from the equivalent total area.

7.6.7 – Prestressing tendons and ducts

7.6.7.1 – Clear distance between pretensioning tendons at each end of a member shall be not less than $4d_b$ for wire, nor $3d_b$ for strands. See also Section 3.3.3. Closer vertical spacing and bundling of tendons may be permitted in the middle portion of a span.

7.6.7.2 – Post-tensioning ducts may be bundled if shown that concrete can be satisfactorily placed and if provision is made to prevent the tendons, when tensioned, from breaking through the duct.

7.7 – Concrete protection for reinforcement

7.7.1 – Cast-in-place concrete (nonprestressed)

The following minimum concrete cover shall be provided for reinforcement:

	Minimum cover, in.
(a) Concrete cast against and permanently exposed to earth ...	3
(b) Concrete exposed to earth or weather:	
#6 through #18 bars	2
#5 bar, W31 or D31 wire, and smaller	1-1/2
(c) Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists:	
#14 and #18 bars	1-1/2
#11 bar and smaller	3/4
Beams, columns:	
Primary reinforcement, ties, stirrups, spirals	1-1/2
Shells, folded plate members:	
#6 bar and larger	3/4
#5 bar, W31 or D31 wire, and smaller	1/2

7.7.2 – Precast concrete (manufactured under plant control conditions)

The following minimum concrete cover shall be provided for reinforcement:

(a) Concrete exposed to earth or weather:	
Wall panels:	
#14 and #18 bars	1-1/2
#11 bar and smaller	3/4

Other members:	
#14 and #18 bars	2
#6 through #11 bars	1-1/2
#5 bar, W31 or D31 wire, and smaller	1-1/4
(b) Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists:	
#14 and #18 bars	1-1/4
#11 bar and smaller	5/8
Beams, columns:	
Primary reinforcement ... d_b	but not less than 5/8 and need not exceed 1-1/2
Ties, stirrups, spirals	3/8
Shells, folded plate members:	
#6 bar and larger	5/8
#5 bar, W31 or D31 wire, and smaller	3/8

7.7.3 – Prestressed concrete

7.7.3.1 – The following minimum concrete cover shall be provided for prestressed and nonprestressed reinforcement, ducts, and end fittings, except as provided in Sections 7.7.3.2 and 7.7.3.3:

	Minimum cover, in.
(a) Concrete cast against and permanently exposed to earth ...	3
(b) Concrete exposed to earth or weather:	
Wall panels, slabs, joists	1
Other members	1-1/2
(c) Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists	3/4
Beams, columns:	
Primary reinforcement	1-1/2
Ties, stirrups, spirals	1
Shells, folded plate members:	
#5 bar, W31 or D31 wire, and smaller	3/8
Other reinforcement ..... d_b	but not less than 3/4

7.7.3.2 – For prestressed concrete members exposed to earth, weather, or corrosive environments, and in which permissible tensile stress of Section 18.4.2(b) is exceeded, minimum cover shall be increased 50 percent.

7.7.3.3 – For prestressed concrete members manufactured under plant control conditions, minimum concrete cover for nonprestressed reinforcement shall be as required in Section 7.7.2.

7.7.4 – Bundled bars

For bundled bars, minimum concrete cover shall be equal to the equivalent diameter of the bundle, but need not be greater than 2 in.; except for concrete cast against and permanently exposed to earth, minimum cover shall be 3 in.

7.7.5 – Corrosive environments

In corrosive environments or other severe exposure conditions, amount of concrete protection shall be suitably increased, and denseness and nonporosity of protecting concrete shall be considered, or other protection shall be provided.

7.7.6 – Future extensions

Exposed reinforcement, inserts, and plates intended for bonding with future extensions shall be protected from corrosion.

7.7.7 – Fire protection

When the general building code (of which this code forms a part) requires a thickness of cover for fire protection greater than the minimum concrete cover specified in Section 7.7, such greater thicknesses shall be used.

7.8 – Special reinforcing details for columns

7.8.1 – Offset bars

Offset bent longitudinal bars shall conform to the following:

7.8.1.1 – Slope of inclined portion of an offset bar with axis of column shall not exceed 1 in 6.

7.8.1.2 – Portions of bar above and below an offset shall be parallel to axis of column.

7.8.1.3 – Horizontal support at offset bends shall be provided by lateral ties, spirals, or parts of the floor construction. Horizontal support provided shall be designed to resist 1-1/2 times the horizontal component of the computed force in the inclined portion of an offset bar. Lateral ties or spirals, if used, shall be placed not more than 6 in. from points of bend.

7.8.1.4 – Offset bars shall be bent before placement in the forms. See Section 7.3.

7.8.1.5 – Where a column face is offset 3 in. or greater, longitudinal bars shall not be offset bent. Separate dowels, lap spliced with the longitudinal bars adjacent to the offset column faces, shall be provided. Lap splices shall conform to Section 12.17.

7.8.2 – Steel cores

Load transfer in structural steel cores of composite compression members shall be provided by the following:

7.8.2.1 – Ends of structural steel cores shall be accurately finished to bear at end bearing splices, with positive provision for alignment of one core above the other in concentric contact.

7.8.2.2 – At end bearing splices, bearing shall be considered effective to transfer not more than 50 percent of the total compressive stress in the steel core.

7.8.2.3 – Transfer of stress between column base and footing shall be designed in accordance with Section 15.8.

7.8.2.4 – Base of structural steel section shall be designed to transfer the total load from the entire composite member to the footing; or, the base may be designed to transfer the load from the steel core only, provided ample concrete section is available for transfer of the portion of the total load carried by the reinforced concrete section to the footing by compression in the concrete and by reinforcement.

7.9 – Connections

7.9.1 – At connections of principal framing elements (such as beams and columns), enclosure shall be provided for splices of continuing reinforcement and for anchorage of reinforcement terminating in such connections.

7.9.2 – Enclosure at connections may consist of external concrete or internal closed ties, spirals, or stirrups.

7.10 – Lateral reinforcement for compression members

7.10.1 – Lateral reinforcement for compression members shall conform to the provisions of Sections 7.10.4 and 7.10.5 and, where shear or torsion reinforcement is required, shall also conform to provisions of Chapter 11.

7.10.2 – Lateral reinforcement requirements for composite compression members shall conform to Section 10.14. Lateral reinforcement requirements for prestressing tendons shall conform to Section 18.11.

7.10.3 – Lateral reinforcement requirements of Sections 7.10, 10.14, and 18.11 may be waived where tests and structural analysis show adequate strength and feasibility of construction.

7.10.4 – Spirals

Spiral reinforcement for compression members shall conform to Section 10.9.3 and to the following:

7.10.4.1 – Spirals shall consist of evenly spaced continuous bar or wire of such size and so assembled to permit handling and placing without distortion from designed dimensions.

7.10.4.2 – For cast-in-place construction, size of spirals shall not be less than 3/8 in. diameter.

7.10.4.3 – Clear spacing between spirals shall not exceed 3 in., nor be less than 1 in. See also Section 3.3.3.

7.10.4.4 – Anchorage of spiral reinforcement shall be provided by 1-1/2 extra turns of spiral bar or wire at each end of a spiral unit.

7.10.4.5 – Splices in spiral reinforcement shall be lap splices of $48d_b$ but not less than 12 in., or welded.

7.10.4.6 – Spirals shall extend from top of footing or slab in any story to level of lowest horizontal reinforcement in members supported above.

7.10.4.7 – Where beams or brackets do not frame into all sides of a column, ties shall extend above termination of spiral to bottom of slab or drop panel.

7.10.4.8 – In columns with capitals, spirals shall extend to a level at which the diameter or width of capital is two times that of the column.

7.10.4.9 – Spirals shall be held firmly in place and true to line by vertical spacers.

7.10.4.10 – For spiral bar or wire smaller than 5/8 in. diameter, a minimum of two spacers shall be used for spirals less than 20 in. in diameter, three spacers for spirals 20 to 30 in. in diameter, and four spacers for spirals greater than 30 in. in diameter.

7.10.4.11 – For spiral bar or wire 5/8 in. diameter or larger, a minimum of three spacers shall be used for spirals 24 in. or less in diameter, and four spacers for spirals greater than 24 in. in diameter.

7.10.5 – Ties

Tie reinforcement for compression members shall conform to the following:

7.10.5.1 – All nonprestressed bars shall be enclosed by lateral ties, at least #3 in size for longitudinal bars #10 or smaller, and at least #4 in size for #11, #14, #18, and bundled longitudinal bars. Deformed wire or welded wire fabric of equivalent area may be used.

7.10.5.2 – Vertical spacing of ties shall not exceed 16 longitudinal bar diameters, 48 tie bar or wire diameters, or least dimension of the compression member.

7.10.5.3 – Ties shall be arranged such that every corner and alternate longitudinal bar shall have lateral support provided by the corner of a tie with an included angle of not more than 135 deg and no bar shall be farther than 6 in. clear on each side along the tie from such a laterally supported bar. Where longitudinal bars are located around the perimeter of a circle, a complete circular tie may be used.

7.10.5.4 – Ties shall be located vertically not more than 1/2 a tie spacing above the top of footing or slab in any story, and shall be spaced as provided herein to not more than 1/2 a tie spacing below the lowest horizontal reinforcement in slab or drop panel above.

7.10.5.5 – Where beams or brackets frame from four directions into a column, ties may be terminated not more than 3 in. below lowest reinforcement in shallowest of such beams or brackets.

7.11 – Lateral reinforcement for flexural members

7.11.1 – Compression reinforcement in beams shall be enclosed by ties or stirrups satisfying the size and spacing limitations in Section 7.10.5 or by welded wire fabric of equivalent area. Such ties or stirrups shall be provided throughout the distance where compression reinforcement is required.

7.11.2 – Lateral reinforcement for flexural framing members subject to stress reversals or to torsion at supports shall consist of closed ties, closed stirrups, or spirals extending around the flexural reinforcement.

7.11.3 – Closed ties or stirrups may be formed in one piece by overlapping standard stirrup or tie end hooks around a longitudinal bar, or formed in one or two pieces lap spliced with a Class C splice (lap of $1.7\ell_d$), or anchored in accordance with Section 12.13.

7.12 – Shrinkage and temperature reinforcement

7.12.1 – Reinforcement for shrinkage and temperature stresses normal to flexural reinforcement shall be provided in structural slabs where the flexural reinforcement extends in one direction only.

7.12.1.1 – Shrinkage and temperature reinforcement shall be provided in accordance with either Section 7.12.2 or 7.12.3.

7.12.2 – Deformed reinforcement conforming to Section 3.5.3 used for shrinkage and temperature reinforcement shall be provided in accordance with the following:

7.12.2.1 – Area of shrinkage and temperature reinforcement shall provide at least the following ratios of reinforcement area to gross concrete area, but not less than 0.0014:

(a) Slabs where Grade 40 or 50 deformed bars are used 0.0020

(b) Slabs where Grade 60 deformed bars or welded wire fabric (smooth or deformed) are used 0.0018

(c) Slabs where reinforcement with yield stress exceeding 60,000 psi measured at a yield strain of 0.35 percent is used . . . . . . $\dfrac{0.0018 \times 60{,}000}{f_y}$

7.12.2.2 – Shrinkage and temperature reinforcement shall be spaced not farther apart than five times the slab thickness, nor 18 in.

7.12.2.3 – At all sections where required, reinforcement for shrinkage and temperature stresses shall develop the specified yield strength f_y in tension in accordance with Chapter 12.

7.12.3 – Prestressing tendons conforming to Section 3.5.5 used for shrinkage and temperature reinforcement shall be provided in accordance with the following:

7.12.3.1 – Tendons shall be proportioned to provide a minimum average compressive stress of 100 psi on gross concrete area using effective prestress, after losses, in accordance with Section 18.6.

7.12.3.2 – Spacing of tendons shall not exceed 6 ft.

7.12.3.3 – When spacing of tendons exceeds 54 in., additional bonded shrinkage and temperature reinforcement conforming to Section 7.12.2 shall be provided between the tendons at slab edges extending from the slab edge for a distance equal to the tendon spacing.

APPENDIX A – SPECIAL PROVISIONS FOR SEISMIC DESIGN

A.0 – Notation

A_{ch} = cross-sectional area of a structural member measured out-to-out of transverse reinforcement, sq in.
A_{cp} = area of concrete section, resisting shear, of an individual pier or horizontal wall segment, sq in.
A_{cv} = net area of concrete section bounded by web thickness and length of section in the direction of shear force considered, sq in.
A_g = gross area of section, sq in.
A_j = minimum cross-sectional area within a joint in a plane parallel to the axis of the reinforcement generating the shear in the joint. Where a girder frames into a support of larger width, effective width of the joint shall be assumed not to exceed the width plus the overall depth of the joint, sq in.
A_{sh} = total cross-sectional area of transverse reinforcement (including crossties) within spacing s and perpendicular to dimension h_c
A_v = total cross-sectional area of shear reinforcement within spacing s and perpendicular to longitudinal axis of structural member, sq in.
b = effective compressive flange width of a structural member, in.
b_w = web width, or diameter of circular section, in.
d = effective depth of section
d_b = bar diameter
E = load effects of earthquake, or related internal moments and forces
f'_c = specified compressive strength of concrete, psi
f_y = specified yield strength of reinforcement, psi
f_{yh} = specified yield strength of transverse reinforcement, psi
h = overall thickness of structural member
h_c = cross-sectional dimension of column core measured center-to-center of confining reinforcement
h_w = height of entire wall (diaphragm) or of the segment of wall (diaphragm) considered
ℓ_d = development length for a straight bar
ℓ_{dh} = development length for a bar with a standard hook as defined in Eq. (A-5)
ℓ_o = minimum length, measured from joint face along axis of structural member, over which transverse reinforcement must be provided, in.
ℓ_w = length of entire wall (diaphragm) or of segment of wall (diaphragm) considered in direction of shear force
M_s = portion of slab moment balanced by support moment
s = spacing of transverse reinforcement measured along the longitudinal axis of the structural member, in.
s_o = maximum spacing of transverse reinforcement, in.
V_c = nominal shear strength provided by concrete
V_e = design shear force determined from Section A.7.1.1 or A.7.1.2
V_n = nominal shear strength
V_u = factored shear force at section
α_c = coefficient defining the relative contribution of concrete strength to wall strength. See Eq. (A-7)
ρ = ratio of nonprestressed tension reinforcement = A_s/bd.
ρ_g = ratio of total reinforcement area to cross-sectional area of column
ρ_n = ratio of distributed shear reinforcement on a plane perpendicular to plane of A_{cv}
ρ_s = ratio of volume of spiral reinforcement to the core volume confined by the spiral reinforcement (measured out-to-out)
ρ_v = A_{sv}/A_{cv}; where A_{sv} is the projection on A_{cv} of area of distributed shear reinforcement crossing the plane of A_{cv}
ϕ = strength reduction factor

A.1 – Definitions

Base of structure – Level at which earthquake motions are assumed to be imparted to a building. This level does not necessarily coincide with the ground level.

Boundary members – Portions along wall and diaphragm edges strengthened by longitudinal and transverse reinforcement. Boundary members do not necessarily require an increase in the thickness of the wall or diaphragm. Edges of openings within walls and diaphragms may also have to be provided with boundary members.

Collector elements – Elements that serve to transmit the inertial forces within the diaphragms to members of the lateral-force resisting systems.

Crosstie – A continuous bar having a 135-deg hook with at least a ten-diameter extension at one end and a 90-deg hook with at least a six-diameter extension at the other end. The hooks shall engage peripheral longitudinal bars.

Design load combinations – Combinations of factored loads and forces specified in Section 9.2.

Development length for a bar with a standard hook – The shortest distance between the critical section (where the strength of the bar is to be developed) and a tangent to the outer edge of the 90-deg hook.

Factored loads and forces – Specified loads and forces modified by the factors in Section 9.2.

Hoop – A closed tie or continuously wound tie the ends of which have 135-deg hooks with ten-diameter extensions, that encloses the longitudinal reinforcement.

Lateral-force resisting system – That portion of the structure composed of members proportioned to resist forces related to earthquake effects.

Lightweight-aggregate concrete – "All lightweight" or "sanded-lightweight" aggregate concrete made with lightweight aggregates conforming to Section 3.3.

Shell concrete – Concrete outside the transverse reinforcement confining the concrete.

Specified lateral forces – Lateral forces corresponding to the appropriate distribution of the design base shear force prescribed by the governing code for earthquake-resistant design.

Structural diaphragms – Structural members, such as floor and roof slabs, which transmit inertial forces to lateral-force resisting members.

Structural trusses – Assemblages of reinforced concrete members subjected primarily to axial forces.

Structural walls – Walls proportioned to resist combinations of shears, moments, and axial forces induced by earthquake motions.

Strut – An element of a structural diaphragm used to provide continuity around an opening in the diaphragm.

Tie elements – Elements which serve to transmit inertia forces and prevent separation of such building components as footings and walls.

A.2 – General requirements

A.2.1 – Scope

A.2.1.1 – Appendix A contains special requirements for design and construction of reinforced concrete members of a structure for which the design forces, related to earthquake motions, have been determined on the basis of energy dissipation in the nonlinear range of response.

A.2.1.2 – The provisions of Chapters 1 through 18 shall apply except as modified by the provisions of this Appendix.

A.2.1.3 – In regions of moderate seismic risk, reinforced concrete frames resisting forces induced by earthquake motions shall be proportioned to satisfy only Section A.9 of Appendix A in addition to the requirements of Chapters 1 through 18.

A.2.1.4 – In regions of high seismic risk, all structural reinforced concrete members shall satisfy Sections A.2 through A.8 of Appendix A in addition to the requirements of Chapters 1 through 17.

A.2.1.5 – A reinforced concrete structural system not satisfying the requirements of this appendix may be used if it is demonstrated by experimental evidence and analysis that the proposed system will have strength and toughness equal to or exceeding those provided by a comparable monolithic reinforced concrete structure satisfying this appendix.

A.2.2 – Analysis and proportioning of structural members

A.2.2.1 – The interaction of all structural and nonstructural members which materially affect the linear and nonlinear response of the structure to earthquake motions shall be considered in the analysis.

A.2.2.2 – Rigid members assumed not to be a part of the lateral force resisting system may be used provided their effect on the response of the system is considered and accommodated in the structural design. Consequences of failure of structural and nonstructural members which are not a part of the lateral force resisting system shall also be considered.

A.2.2.3 – Structural members below base of structure required to transmit to the foundation forces resulting from earthquake effects shall also comply with the requirements of Appendix A.

A.2.2.4 – All structural members assumed not to be part of the lateral force resisting system shall conform to Section A.8.

A.2.3 – Strength reduction factors

Strength reduction factors shall be as given in Section 9.3 except for the following:

A.2.3.1 – Except for determining the strength of joints the shear strength reduction factor shall be 0.6 for any structural member if its nominal shear strength is less than the shear corresponding to development of its nominal flexural strength for the factored-load combinations including earthquake effect. Shear strength reduction factor for joints shall be 0.85.

A.2.3.2 – The strength reduction factor for axial compression and flexure shall be 0.5 for all frame members with factored axial compressive forces exceeding ($A_g f'_c/10$) if the transverse reinforcement does not conform to Section A.4.4.

A.2.4 – Concrete in members resisting earthquake-induced forces

A.2.4.1 – Compressive strength, f'_c of the concrete shall be not less than 3000 psi.

A.2.4.2 – Compressive strength of lightweight-aggregate concrete used in design shall not exceed 4000 psi. Lightweight-aggregate concrete with higher design compressive strength may be used if demonstrated by experimental evidence that structural members made with that lightweight-aggregate concrete provide strength and toughness equal to or exceeding those of comparable members made with normal weight-aggregate concrete of the same strength.

A.2.5 – Reinforcement in members resisting earthquake-induced forces

A.2.5.1 – Reinforcement resisting earthquake-induced flexural and axial forces in frame members and in wall boundary members shall comply with ASTM A 706. ASTM A 615 Grades 40 and 60 reinforcement may be used in these members if (a) the actual yield strength based on mill tests does not exceed the specified yield strength by more than 18,000 psi (retests shall not exceed this value by more than an additional 3000 psi) and (b) the ratio of the actual ultimate tensile stress to the actual tensile yield strength is not less than 1.25. Reinforcement required by design load combinations which include earthquake effect shall not be welded except as specified in Sections A.3.2.4 and A.4.3.2.

A.3 – Flexural members of frames

A.3.1 – Scope

Requirements of Section A.3 apply to frame members (a) resisting earthquake-induced forces (b) proportioned primarily to resist flexure, and (c) satisfying the following conditions:

A.3.1.1 – Factored axial compressive force on the member shall not exceed $(A_g f'_c/10)$.

A.3.1.2 – Clear span for the member shall not be less than four times its effective depth

A.3.1.3 – The width-to-depth ratio shall not be less than 0.3.

A.3.1.4 – The width shall not be less than (a) 10 in. and (b) more than the width of the supporting member (measured on a plane perpendicular to the longitudinal axis of the flexural member) plus distances on each side of the supporting member not exceeding three-fourths of the depth of the flexural member.

A.3.2 – Longitudinal reinforcement

A.3.2.1 – At any section of a flexural member and for the top as well as for the bottom reinforcement the amount of reinforcement shall not be less than $(200b_w d/f_y)$ and the reinforcement ratio, ρ, shall not exceed 0.025. At least two bars shall be provided continuously both top and bottom.

A.3.2.2 – Positive-moment strength at joint face shall be not less than one-half of the negative-moment strength provided at that face of the joint. Neither the negative- nor the positive-moment strength at any section along member length shall be less than one-fourth the maximum moment strength provided at face of either joint.

A.3.2.3 – Lap splices of flexural reinforcement shall be permitted only if hoop or spiral reinforcement is provided over the lap length. Maximum spacing of the transverse reinforcement enclosing the lapped bars shall not exceed $d/4$ or 4 in. Lap splices shall not be used (a) within the joints, (b) within a distance of twice the member depth from the face of the joint, and (c) at locations where analysis indicates flexural yielding caused by inelastic lateral displacements of the frame.

A.3.2.4 – Welded splices and mechanical connections conforming to Sections 12.14.3.1 through 12.14.3.4 may be used for splicing provided not more than alternate bars in each layer of longitudinal reinforcement are spliced at a section and the center-to-center distance between splices of adjacent bars is 24 in. or more measured along the longitudinal axis of the frame member.

A.3.3 – Transverse reinforcement

A.3.3.1 – Hoops shall be provided in the following regions of frame members:

(1) Over a length equal to twice the member depth measured from the face of the supporting member toward midspan, at both ends of the flexural member.

(2) Over lengths equal to twice the member depth on both sides of a section where flexural yielding may occur in connection with inelastic lateral displacements of the frame.

A.3.3.2 – The first hoop shall be located not more than 2 in. from the face of a supporting member. Maximum spacing of the hoops shall not exceed (a) $d/4$, (b) eight times the diameter of the smallest longitudinal bars, (c) 24 times the diameter of the hoop bars, and (d) 12 in.

A.3.3.3 – Where hoops are required, longitudinal bars on the perimeter shall have lateral support conforming to Section 7.10.5.3.

A.3.3.4 – Where hoops are not required, stirrups shall be spaced at no more than $d/2$ throughout the length of the member.

A.3.3.5 – Hoops in flexural members may be made up of two pieces of reinforcement: a stirrup having 135-deg hooks with ten-diameter extensions anchored in the confined core and a crosstie to make a closed hoop. Consecutive crossties shall have their 90-deg hooks at opposite sides of the flexural member. If the longitudinal reinforcing bars secured by the crossties are confined by a slab only on one side of the flexural frame member, the 90-deg hooks of the crossties shall all be placed on that side.

A.4 – Frame members subjected to bending and axial load

A.4.1 – Scope

The requirements of this section apply to frame members (a) resisting earthquake-induced forces, (b) having a factored axial compressive force exceeding ($A_g f'_c/10$) and (c) satisfying the following conditions:

A.4.1.1 – The shortest cross-sectional dimension, measured on a straight line passing through the geometric centroid, shall not be less than 12 in.

A.4.1.2 – The ratio of the shortest cross-sectional dimension to the perpendicular dimension shall not be less than 0.4.

A.4.2 – Minimum flexural strength of columns

A.4.2.1 – Flexural strength of any column proportioned to resist a factored axial compressive force exceeding ($A_g f'_c/10$) shall satisfy Section A.4.2.2 or A.4.2.3.

Lateral strength and stiffness of columns not satisfying Section A.4.2.2 shall be ignored in determining the calculated strength and stiffness of the structure but shall conform to Section A.8.

A.4.2.2 – The flexural strengths of the columns shall satisfy Eq. (A-1)

$$\Sigma M_e \geq (6/5)\, \Sigma M_g \qquad \text{(A-1)}$$

ΣM_e = sum of moments, at the center of the joint, corresponding to the design flexural strength of the columns framing into that joint. Column flexural strength shall be calculated for the factored axial force, consistent with the direction of the lateral forces considered, resulting in the lowest flexural strength.

ΣM_g = sum of moments, at the center of the joint, corresponding to the design flexural strengths of the girders framing into that joint.

Flexural strengths shall be summed such that the column moments oppose the beam moments. Eq. (A-1) shall be satisfied for beam moments acting in both directions in the vertical plane of the frame considered.

A.4.2.3 – If Section A.4.2.2 is not satisfied at a joint, columns supporting reactions from that joint shall be provided with transverse reinforcement as specified in Section A.4.4 over their full height.

A.4.3 – Longitudinal reinforcement

A.4.3.1 – The reinforcement ratio, ρ, shall not be less than 0.01 and shall not exceed 0.06.

A.4.3.2 – Lap splices are permitted only within the center half of the member length and shall be proportioned as tension splices. Welded splices and mechanical connections conforming to Sections 12.14.3.1 through 12.14.3.4 may be used for splicing the reinforcement at any section provided not more than alternate longitudinal bars are spliced at a section and the distance between splices is 24 in. or more along the longitudinal axis of the reinforcement.

A.4.4 – Transverse reinforcement

A.4.4.1 – Transverse reinforcement as specified below shall be provided unless a larger amount is required by Section A.7.

(1) The volumetric ratio of spiral or circular hoop reinforcement, ρ_s, shall not be less than that indicated by Eq. (A-2).

$$\rho_s = 0.12\, f'_c/f_{yh} \qquad \text{(A-2)}$$

and shall not be less than that required by Eq. (10-5).

(2) The total cross-sectional area of rectangular hoop reinforcement shall not be less than that given by Eq. (A-3) and (A-4).

$$A_{sh} = 0.3\,(s h_c f'_c/f_{yh})[(A_g/A_{ch}) - 1] \qquad \text{(A-3)}$$

$$A_{sh} = 0.12 s h_c f'_c/f_{yh} \qquad \text{(A-4)}$$

(3) Transverse reinforcement may be provided by single or overlapping hoops. Crossties of the same bar size and spacing as the hoops may be used. Each end of the crosstie shall engage a peripheral longitudinal reinforcing bar. Consecutive crossties shall be alternated end for end along the longitudinal reinforcement.

(4) If the design strength of member core satisfies the requirement of the specified loading combinations including earthquake effect, Eq. (A-3) and (10-5) need not be satisfied.

A.4.4.2 – Transverse reinforcement shall be spaced at distances not exceeding (a) one-quarter of the minimum member dimension and (b) 4 in.

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A.4.4.3 – Crossties or legs of overlapping hoops shall not be spaced more than 14 in. on center in the direction perpendicular to the longitudinal axis of the structural member.

A.4.4.4 – Transverse reinforcement in amount specified in Sections A.4.4.1 through A.4.4.3 shall be provided over a length ℓ_o from each joint face and on both sides of any section where flexural yielding may occur in connection with inelastic lateral displacements of the frame. The length ℓ_o shall not be less than (a) the depth of the member at the joint face or at the section where flexural yielding may occur, (b) one-sixth of the clear span of the member, and (c) 18 in.

A.4.4.5 – Columns supporting reactions from discontinued stiff members, such as walls, shall be provided with transverse reinforcement as specified in Sections A.4.4.1 through A.4.4.3 over their full height beneath the level at which the discontinuity occurs if the factored axial compressive force in these members, related to earthquake effect, exceeds $(A_g f'_c/10)$.

A.5 – Structural walls, diaphragms, and trusses

A.5.1 – Scope

The requirements of this section apply to structural walls and trusses serving as parts of the earthquake-force resisting systems as well as to diaphragms, struts, ties, chords and collector members which transmit forces induced by earthquake.

A.5.2 – Reinforcement

A.5.2.1 – The reinforcement ratio, ρ_n, for structural walls shall not be less than 0.0025 along the longitudinal and transverse axes. Reinforcement spacing each way shall not exceed 18 in. Reinforcement provided for shear strength shall be continuous and shall be distributed across the shear plane.

A.5.2.2 – At least two curtains of reinforcement shall be used in a wall if the in-plane factored shear force assigned to the wall exceeds $2A_{cv}\sqrt{f'_c}$.

A.5.2.3 – Structural-truss members, struts, ties, and collector members with compressive stresses exceeding $0.2 f'_c$ shall have special transverse reinforcement, as specified in Section A.4.4, over the total length of the member. The special transverse reinforcement may be discontinued at a section where the calculated compressive stress is less than $0.15 f'_c$. Stresses shall be calculated for the factored forces using a linearly elastic model and gross-section properties of the members considered.

A.5.2.4 – All continuous reinforcement in structural walls, diaphragms, trusses, struts, ties, chords, and collector members shall be anchored or spliced in accordance with the provisions for reinforcement in tension as specified in Section A.6.4.

A.5.3 – Boundary members for structural walls and diaphragms

A.5.3.1 – Boundary members shall be provided at boundaries and edges around openings of structural walls and diaphragms for which the maximum extreme-fiber stress, corresponding to factored forces including earthquake effect, exceeds $0.2 f'_c$ unless the entire wall or diaphragm member is reinforced to satisfy Sections A.4.4.1 through A.4.4.3. The boundary member may be discontinued where the calculated compressive stress is less than $0.15 f'_c$. Stresses shall be calculated for the factored forces using a linearly elastic model and gross-section properties.

A.5.3.2 – Boundary members, where required, shall have transverse reinforcement as specified in Sections A.4.4.1 through A.4.4.3.

A.5.3.3 – Boundary members of structural walls shall be proportioned to carry all factored gravity loads on the wall, including tributary loads and self-weight, as well as the vertical force required to resist overturning moment calculated from factored forces related to earthquake effect.

A.5.3.4 – Boundary members of structural diaphragms shall be proportioned to resist the sum of the compressive force acting in the plane of the diaphragm and the force obtained from dividing the factored moment at the section by the distance between the edges of the diaphragm at that section.

A.5.3.5 – Transverse reinforcement in walls with boundary members shall be anchored within the confined core of the boundary member to develop the yield stress in tension of the transverse reinforcement.

A.5.4 – Construction joints

A.5.4.1 – All construction joints in walls and diaphragms shall conform to Section 6.4 and contact surfaces shall be roughened as specified in Section 11.7.9.

A.6 – Joints of frames

A.6.1 – General requirements

A.6.1.1 – Forces in longitudinal beam reinforcement at the joint face shall be determined by assuming that the stress in the flexural tensile reinforcement is $1.25 f_y$.

A.6.1.2 – Strength of joint shall be governed by the appropriate strength reduction factors specified in Section 9.3.

A.6.1.3 – Beam longitudinal reinforcement terminated in a column shall be extended to the far face of the confined column core and anchored in tension according to Section A.6.4 and in compression according to Chapter 12.

A.6.2 – Transverse reinforcement

A.6.2.1 – Transverse hoop reinforcement, as specified in Section A.4.4 shall be provided within the joint, unless the joint is confined by structural members as specified in Section A.6.2.2.

A.6.2.2 – Within the depth of the shallowest framing member, transverse reinforcement equal to at least one-half the amount required by Section A.4.4.1 shall be provided where members frame into all four sides of the joint and where each member width is at least three-fourths the column width.

A.6.2.3 – Transverse reinforcement as required by Section A.4.4 shall be provided through the joint to provide confinement for longitudinal beam reinforcement outside the column core if such confinement is not provided by a beam framing into the joint.

A.6.3 – Shear strength

A.6.3.1 – The nominal shear strength of the joint shall be assumed not to exceed the forces specified below for normal weight-aggregate concrete.

For confined joint .... $20\sqrt{f'_c}A_j$

For others .... $15\sqrt{f'_c}A_j$

where A_j is the minimum cross-sectional area of the joint in a plane parallel to the axis of the reinforcement generating the shear force.

A joint is considered to be confined if members frame into all vertical faces of the joint and if at least three-quarters of each face of the joint is covered by the framing member.

A.6.3.2 – For lightweight-aggregate concrete, the nominal shear strength of the joint shall not exceed three-quarters of the limits given in Section A.6.3.1.

A.6.4 – Development length of bars in tension

A.6.4.1 – The development length, ℓ_{dh}, for a bar with a standard 90-deg hook in normal weight-aggregate concrete shall not be less than $8d_b$, 6 in., and the length required by Eq. (A-5).

$$\ell_{dh} = f_y d_b / 65\sqrt{f'_c} \qquad \text{(A-5)}$$

for bar sizes #3 through #11.

For lightweight-aggregate concrete, the development length for a bar with a standard 90-deg hook shall not be less than $10d_b$, 7.5 in., and 1.25 times that required by Eq. (A-5).

The 90-deg hook shall be located within the confined core of a column or of a boundary member.

A.6.4.2 – For bar sizes #3 through #11, the development length, ℓ_d, for a straight bar shall not be less than (a) two-and-a-half (2.5) times the length required by Section A.6.4.1 if the depth of the concrete cast in one lift beneath the bar does not exceed 12 in. and (b) three-and-a-half (3.5) times the length required by Section A.6.4.1 if the depth of the concrete cast in one lift beneath the bar exceeds 12 in.

A.6.4.3 – Straight bars terminated at a joint shall pass through the confined core of a column or of a boundary member. Any portion of the straight embedment length not within the confined core shall be increased by a factor of 1.6.

A.7 – Shear-strength requirements

A.7.1 – Design forces

A.7.1.1 – Frame members subjected primarily to bending

The design shear force, V_e, shall be determined from consideration of the statical forces on the portion of the member between faces of the joints. It shall be assumed that moments of opposite sign corresponding to probable strength act at the joint faces and that the member is loaded with the factored tributary gravity load along its span. The moments corresponding to probable strength shall be calculated using the properties of the member at the joint faces without strength reduction factors and assuming that the stress in the tensile reinforcement is equal to at least 1.25 f_y.

A.7.1.2 – Frame members subjected to combined bending and axial load

The design shear force, V_e, shall be determined from consideration of the forces on the member, with the nominal moment strengths calculated for the factored axial compressive force resulting in the largest moment, acting at the faces of the joints.

A.7.1.3 – Structural walls, diaphragms and trusses

The design shear force, V_u, shall be obtained from the lateral load analysis in accordance with the factored loads and combinations specified in Section 9.2.

A.7.2 – Transverse reinforcement in frame members

A.7.2.1 – For determining the required transverse reinforcement in frame members in which the earthquake-induced shear force calculated in accordance vith Section A.7.1.1 represents one-half or more of otal design shear, the quantity V_c shall be assumed to be zero if the factored axial compressive force including earthquake effects is less than $(A_g f'_c/20)$.

.7.2.2 – Stirrups or ties required to resist shear shall e hoops over lengths of members as specified in ections A.3.3, A.4.4, and A.6.2.

.7.3 – Shear strength of structural walls and diaphragms

.7.3.1 – Nominal shear strength of structural walls nd diaphragms shall be determined using either ection A.7.3.2 or A.7.3.3.

7.3.2 – Nominal shear strength, V_n, of structural walls d diaphragms shall be assumed not to exceed the ear force calculated from

$$V_n = A_{cv}(2\sqrt{f'_c} + \rho_n f_y) \quad \text{(A-6)}$$

'.3.3 – For walls (diaphragms) and wall (diaagm) segments having a ratio of (h_w/ℓ_w) less than . nominal shear strength of wall (diaphragm) may determined from Eq. (A-7).

$$V_n = A_{cv}(\alpha_c\sqrt{f'_c} + \rho_n f_y) \quad \text{(A-7)}$$

ere the coefficient α_c varies linearly from 3.0 for $/\ell_w) = 1.5$ to 2.0 for $(h_w/\ell_w) = 2.0$.

3.4 – In Section A.7.3.3, value of ratio (h_w/ℓ_w) used determining V_n for segments of a wall or diagm shall be the larger of the ratios for the entire (diaphragm) and the segment of wall (diagm) considered.

3.5 – Walls (diaphragms) shall have distributed r reinforcement providing resistance in two oronal directions in the plane of the wall (diagm). If the ratio (h_w/ℓ_w) does not exceed 2.0, recement ratio, ρ_v shall not be less than orcement ratio ρ_n.

:.6 – Nominal shear strength of all wall piers ng a common lateral force shall not be assumed ceed $8A_{cv}\sqrt{f'_c}$ where A_{cv} is the total cross-secarea and the nominal shear strength of any one individual wall piers shall not be assumed to d $10A_{cp}\sqrt{f'_c}$ where A_{cp} represents the crossnal area of the pier considered.

7 – Nominal shear strength of horizontal wall ents shall not be assumed to exceed $\sqrt{f'_c}$ where A_{cp} represents the cross-sectional of a horizontal wall segment.

A.8 – Frame members not proportioned to resist forces induced by earthquake motions

A.8.1 – All frame members assumed not to be part of the lateral force resisting system shall be investigated and shown to be adequate for vertical load carrying capacity with the structure assumed to have deformed laterally twice that calculated for the factored lateral forces. Such members shall satisfy the minimum-reinforcement requirements specified in Sections A.3.2.1 and A.5.2.1 as well as those specified in Chapter 7, 10, and 11.

A.8.2 – All frame members with factored axial compressive forces exceeding $(A_g f'_c/10)$ shall satisfy the following special requirements unless they comply with Section A.4.4.

A.8.2.1 – Ties shall have 135-deg hooks with extensions not less than six tie-bar diameters or 2.5 in. Crossties, as defined in this appendix, may be used.

A.8.2.2 – The maximum tie spacing shall be s_o over a length ℓ_o measured from the joint face. The spacing s_o shall be not more than (a) eight diameters of the smallest longitudinal bar enclosed, (b) 24 tie-bar diameters, and (c) one-half the least cross-sectional dimension of the column. The length ℓ_o shall not be less than (a) one-sixth of the clear height of the column, (b) the maximum cross-sectional dimension of the column, and (c) 18 in.

A.8.2.3 – The first tie shall be within a distance equal to $0.5s_o$ from the face of the joint.

A.8.2.4 – The tie spacing shall not exceed $2s_o$ in any part of the column.

A.9 – Requirements for frames in regions of moderate seismic risk

A.9.1 – In regions of moderate seismic risk, structural frames proportioned to resist forces induced by earthquake motions shall satisfy the requirements of Section A.9 in addition to those of Chapter 1 through 18.

A.9.2 – Reinforcement details in a frame member shall satisfy Section A.9.4 if the factored compressive axial load for the member does not exceed $(A_g f'_c/10)$. If the factored compressive axial load is larger, frame reinforcement details shall satisfy Section A.9.5 unless the member has spiral reinforcement according to Eq. (10-5). If a two-way slab system without beams is treated as part of a frame resisting earthquake effect, reinforcement details in any span resisting moments caused by lateral force shall satisfy Section A.9.6.

with Section A.7.1.1 represents one-half or more of total design shear, the quantity V_c shall be assumed to be zero if the factored axial compressive force including earthquake effects is less than $(A_g f'_c/20)$.

A.7.2.2 – Stirrups or ties required to resist shear shall be hoops over lengths of members as specified in Sections A.3.3, A.4.4, and A.6.2.

A.7.3 – Shear strength of structural walls and diaphragms

A.7.3.1 – Nominal shear strength of structural walls and diaphragms shall be determined using either Section A.7.3.2 or A.7.3.3.

A.7.3.2 – Nominal shear strength, V_n, of structural walls and diaphragms shall be assumed not to exceed the shear force calculated from

$$V_n = A_{cv}(2\sqrt{f'_c} + \rho_n f_y) \qquad \text{(A-6)}$$

A.7.3.3 – For walls (diaphragms) and wall (diaphragm) segments having a ratio of (h_w/ℓ_w) less than 2.0, nominal shear strength of wall (diaphragm) may be determined from Eq. (A-7).

$$V_n = A_{cv}(\alpha_c\sqrt{f'_c} + \rho_n f_y) \qquad \text{(A-7)}$$

where the coefficient α_c varies linearly from 3.0 for $(h_w/\ell_w) = 1.5$ to 2.0 for $(h_w/\ell_w) = 2.0$.

A.7.3.4 – In Section A.7.3.3, value of ratio (h_w/ℓ_w) used for determining V_n for segments of a wall or diaphragm shall be the larger of the ratios for the entire wall (diaphragm) and the segment of wall (diaphragm) considered.

A.7.3.5 – Walls (diaphragms) shall have distributed shear reinforcement providing resistance in two orthogonal directions in the plane of the wall (diaphragm). If the ratio (h_w/ℓ_w) does not exceed 2.0, reinforcement ratio, ρ_v shall not be less than reinforcement ratio ρ_n.

A.7.3.6 – Nominal shear strength of all wall piers sharing a common lateral force shall not be assumed to exceed $8A_{cv}\sqrt{f'_c}$ where A_{cv} is the total cross-sectional area and the nominal shear strength of any one of the individual wall piers shall not be assumed to exceed $10A_{cp}\sqrt{f'_c}$ where A_{cp} represents the cross-sectional area of the pier considered.

A.7.3.7 – Nominal shear strength of horizontal wall segments shall not be assumed to exceed $10A_{cp}\sqrt{f'_c}$ where A_{cp} represents the cross-sectional area of a horizontal wall segment.

A.8 – Frame members not proportioned to resist forces induced by earthquake motions

A.8.1 – All frame members assumed not to be part of the lateral force resisting system shall be investigated and shown to be adequate for vertical load carrying capacity with the structure assumed to have deformed laterally twice that calculated for the factored lateral forces. Such members shall satisfy the minimum-reinforcement requirements specified in Sections A.3.2.1 and A.5.2.1 as well as those specified in Chapter 7, 10, and 11.

A.8.2 – All frame members with factored axial compressive forces exceeding $(A_g f'_c/10)$ shall satisfy the following special requirements unless they comply with Section A.4.4.

A.8.2.1 – Ties shall have 135-deg hooks with extensions not less than six tie-bar diameters or 2.5 in. Crossties, as defined in this appendix, may be used.

A.8.2.2 – The maximum tie spacing shall be s_o over a length ℓ_o measured from the joint face. The spacing s_o shall be not more than (a) eight diameters of the smallest longitudinal bar enclosed, (b) 24 tie-bar diameters, and (c) one-half the least cross-sectional dimension of the column. The length ℓ_o shall not be less than (a) one-sixth of the clear height of the column, (b) the maximum cross-sectional dimension of the column, and (c) 18 in.

A.8.2.3 – The first tie shall be within a distance equal to $0.5s_o$ from the face of the joint.

A.8.2.4 – The tie spacing shall not exceed $2s_o$ in any part of the column.

A.9 – Requirements for frames in regions of moderate seismic risk

A.9.1 – In regions of moderate seismic risk, structural frames proportioned to resist forces induced by earthquake motions shall satisfy the requirements of Section A.9 in addition to those of Chapter 1 through 18.

A.9.2 – Reinforcement details in a frame member shall satisfy Section A.9.4 if the factored compressive axial load for the member does not exceed $(A_g f'_c/10)$. If the factored compressive axial load is larger, frame reinforcement details shall satisfy Section A.9.5 unless the member has spiral reinforcement according to Eq. (10-5). If a two-way slab system without beams is treated as part of a frame resisting earthquake effect, reinforcement details in any span resisting moments caused by lateral force shall satisfy Section A.9.6.

A.9.3 – Design shear strength of beams, columns, and two-way slabs resisting earthquake effect shall not be less than either (a) the sum of the shear associated with development of nominal moment strengths of the member at each restrained end of the clear span and the shear calculated for factored gravity loads or (b) the maximum shear obtained from design load combinations which include earthquake effect E, with E assumed to be twice that prescribed by the governing code for earthquake-resistant design.

A.9.4 – Beams

A.9.4.1 – The positive-moment strength at the face of the joint shall be not less than one-third the negative-moment strength provided at that face of the joint. Neither the negative- nor the positive-moment strength at any section along the length of the member shall be less than one-fifth the maximum moment strength provided at the face of either joint.

A.9.4.2 – At both ends of the member, stirrups shall be provided over lengths equal to twice the member depth measured from the face of the supporting member toward midspan. The first stirrup shall be located at not more than 2 in. from the face of the supporting member. Maximum stirrup spacing shall not exceed (a) $d/4$, (b) eight times the diameter of the smallest longitudinal bar enclosed, (c) 24 times the diameter of the stirrup bar, and (d) 12 in.

A.9.4.3 – Stirrups shall be placed at not more than $d/2$ throughout the length of the member.

A.9.5 – Columns

A.9.5.1 – Maximum tie spacing shall not exceed s_o over a length l_o measured from the joint face. Spacing s_o shall not exceed (a) eight times the diameter of the smallest longitudinal bar enclosed, (b) 24 times the diameter of the tie bar, (c) one-half of the smallest cross-sectional dimension of the frame member, and (d) 12 in. Length l_o shall not be less than (a) one-sixth of the clear span of the member, (b) maximum cross-sectional dimension of the member, and (c) 18 in.

A.9.5.2 – The first tie shall be located at not more than $s_o/2$ from the joint face.

A.9.5.3 – Joint reinforcement shall conform to Section 11.12.1.2.

A.9.5.3 – Tie spacing shall not exceed twice the spacing s_o.

A.9.6 – Two-way slabs without beams

A.9.6.1 – Factored slab moment at support related to earthquake effect shall be determined for load combinations defined by Eq. (9-2) and (9-3). All reinforcement provided to resist M_s, the portion of slab moment balanced by support moment, shall be placed within the column strip defined in Section 13.2.1.

A.9.6.2 – The fraction, defined by Eq. (13-1), of moment M_s shall be resisted by reinforcement placed within the effective width specified in Section 13.3.3.2.

A.9.6.3 – Not less than one-half of the reinforcement in the column strip at support shall be placed within the effective slab width specified in Section 13.3.3.2.

A.9.6.4 – Not less than one-quarter of the top reinforcement at the support in the column strip shall be continuous throughout the span.

A.9.6.5 – Continuous bottom reinforcement in the column strip shall be not less than one-third of the top reinforcement at the support in the column strip.

A.9.6.6 – Not less than one-half of all bottom reinforcement at midspan shall be continuous and shall develop its yield strength at face of support as defined in Section 13.6.2.5.

A.9.6.7 – At discontinuous edges of the slab all top and bottom reinforcement at support shall be developed at the face of support as defined in Section 13.6.2.5.

Table 6.2.8

Basic Wind Speeds for Selected Locations in Bangladesh

Location	Basic Wind Speed (km/h)	Location	Basic Wind Speed (km/h)
Angarpota	150	Lalmonirhat	204
Bagerhat	252	Madaripur	220
Bandarban	200	Magura	208
Barguna	260	Manikganj	185
Barisal	256	Meherpur	185
Bhola	225	Moheshkhali	260
Bogra	198	Moulvibazar	168
Brahmanbaria	180	Munshiganj	184
Chandpur	160	Mymensingh	217
Chapai Nawabganj	130	Naogaon	175
Chittagong	260	Narail	222
Chuadanga	198	Narayanganj	195
Comilla	196	Narsinghdi	190
Cox`s Bazar	260	Natore	198
Dahagram	150	Netrokona	210
Dhaka	210	Nilphamari	140
Dinajpur	130	Noakhali	184
Faridpur	202	Pabna	202
Feni	205	Panchagarh	130
Gaibandha	210	Patuakhali	260
Gazipur	215	Pirojpur	260
Gopalganj	242	Rajbauri	188
Habiganj	172	Rajshahi	155
Hatiya	260	Rangamati	180
Ishurdi	225	Rangpur	209
Joypurhat	180	Satkhira	183
Jamalpur	180	Shariatpur	198
Jessore	205	Sherpur	200
Jhalakati	260	Sirajganj	160
Jhenaidah	208	Srimangal	160
Khagrachhari	180	St. Martin`s Island	260
Khulna	238	Sunamganj	195
Kutubdia	260	Sylhet	195
Kishoreganj	207	Sandwip	260
Kurigram	210	Tangail	160
Kushtia	215	Teknaf	260
Lakshmipur	162	Thakurgaon	130

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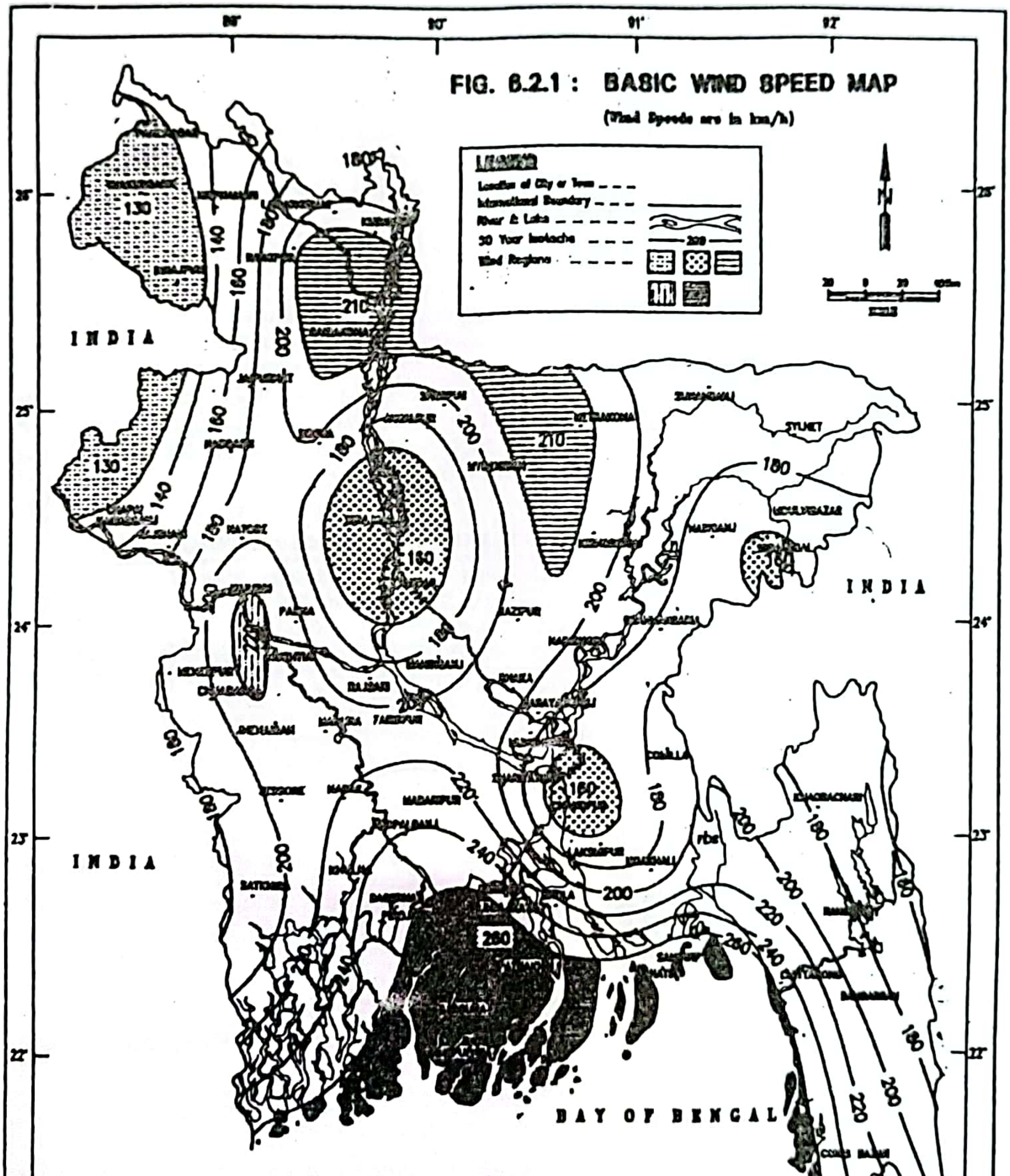


FIG. 6.2.1 : BASIC WIND SPEED MAP

(Wind Speeds are in km/h)

NOTE : a) Isotach at a region boundary has the same value as that of the region

b) Basic wind speed for a particular location shall be obtained as follows :

i) When a location is listed in Table 6.2.8, value of the basic wind speed shall be taken from that table.

ii) When the location lies within any region (shown coloured in the map), the value marked for that region shall be taken.

iii) For a location lying on any isotach in this map, the value of that isotach shall be taken.

iv) For a location lying outside the positions (i) through (iii) above, linear interpolation shall be made between the adjacent isotachs to obtain the basic wind speed.

2.5.6 Equivalent Static Force Method

This method may be used for calculation of seismic lateral forces for all structures specified in Sec 2.5.5.1(a)

2.5.6.1 Design Base Shear : The total design base shear in a given direction shall be determined from the following relation :

$$V = \frac{ZIC}{R} W \qquad (2.5.1)$$

where, Z = Seismic zone coefficient given in table 6.2.22
I = Structure importance coefficient given in Table 6.2.23
R = Response modification coefficient for structural systems given in table 6.2.24
W = The total seismic dead load difired in Sec 2.5.5.2
C = Numerical coefficient given by the relation :

$$C = \frac{1.25S}{T^{2/3}} \qquad (2.5.2)$$

S = Site coefficient for soil characteristics as provided in Table 6.2.25
T = Fundamental period of vibration in seconds, of the structure for the direction under consideration as determined by the provisions of Sec 2.5.6.2.

The value of C need not exceed 2.75 and this value may be used for any structure without regard to soil type or structure period. Except for those requirements where Code prescribed forces are scaled up by $0.375R$, the minimum value of the ratio C/R shall be 0.075.

Table 6.2.22
Seismic Zone Coefficients, Z

Seismic Zone (see Fig 6.2.10)	Zone Coefficient
1	0.075
2	0.15
3	0.25

Table 6.2.23
Structure Importance Coefficients I, I'

Structure Importance Category (see Table 6.1.1 for occupancy)	Structure Importance Coefficient	
	I	I'
I Essential facilities	1.25	1.50
II Hazardous facilities	1.25	1.50
III Special occupancy structures	1.00	1.00
IV Standard occupancy structures	1.00	1.00
V Low-risk Structures	1.00	1.00

2.5.6.2 Structure Period : The value of the fundamental period, T of the structure shall be determined from one of the following methods :

a) Method A : For all buildings the value of T may be approximated by the following formula :

$$T = C_t (h_n)^{3/4} \qquad (2.5.3)$$

where, C_t = 0.083 for steel moment resisting frames
= 0.073 for reinforced concrete moment resisting frames, and eccentric braced steel frames
= 0.049 for all other structural systems
h_n = Height in metres above the base to level n.

Alternatively, the value of C_t for buildings with concrete or masonry shear walls may be taken as $0.031/\sqrt{A_c}$. The value of A_c shall be obtained from the relation :

$$A_c = \Sigma A_e \left[0.2 + (D_e / h_n)^2\right] \qquad (2.5.4)$$

where, A_c = The combined effective area, in square metres, of the shear walls in the first storey of the structure.
A_e = The effective horizontal cross-sectional area, in square metres of a shear wall in the first storey of the structure.
D_e = The length, in metre of a shear wall element in the first storey in the direction parallel to the applied forces.

The value of D_e/h_n for use in Eq (2.5.4) shall not exceed 0.9.

Table 6.2.24
Response Modification Coefficient for Structural Systems, *R*

Basic Structural System[1]	description of Lateral Force Resisting System	*R* [2]
a. Bearing Wall System	1. Light framed walls with shear panels	
	i) Plywood walls for structures, 3 storeys or less	8
	ii) All other light framed walls	6
	2. Shear walls	
	i) Concrete	6
	ii) Masonry	6
	3. Light steel framed bearing walls with tension only bracing	4
	4. Braced frames where bracing carries gravity loads	
	i) Steel	6
	ii) Concrete [3]	4
	iii) Heavy timber	4
b. Building Frame System	1. Steel eccentric braced frame (EBF)	10
	2. Light framed walls with shear panels	
	i) Plywood walls for structures 3-storeys or less	9
	ii) All other light framed walls	7
	3. Shear walls	
	i) Concrete	
	ii) Masonry	8
	4. Concentric braced frames (CBF)	8
	i) Steel	8
	ii) Concrete [3]	8
	iii) Heavy timber	8
c. Moment Resisting Frame System	1. Special moment resisting frames (SMRF)	
	i) Steel	12
	ii) Concrete	12
	2. Intermediate moment resisting frames (IMRF), concrete [4]	8
	3. Ordinary moment resisting frames (OMRF)	
	i) Steel	6
	ii) Concrete [5]	5
d. Dual System	1. Shear walls	
	i) Concrete with steel or concrete SMRF	12
	ii) Concrete with steel OMRF	6
	iii) Concrete with concrete IMRF [4]	9
	iv) Masonry with steel or concrete SMRF	8
	v) Masonry with steel OMRF	6
	vi) Masonry with concrete IMRF [3]	7
	2. Steel EBF	
	i) With steel SMRF	12
	ii) With steel OMRF	6
	3. Concentric braced frame (CBF)	
	i) Steel with steel SMRF	10
	ii) Steel with steel OMRF	6
	iii) Concrete with concrete SMRF [3]	9
	iv) Concrete with concrete IMRF [3]	6
e. Special Structural Systems	See Sec 1.3. 2, 1. 3. 3, 1.3.5	

Notes : (1) Basic Structural Systems are defined in Sec 1.3 2, Chapter 1.
(2) See Sec 2.5.6.6 for combination of structural systems, and See 1.3.5 for system limitations.
(3) Prohibited in Seismic Zone 3.
(4) Prohibited in Seismic Zone 3 except as permitted in Sec. 2.5.9.3.
(5) Prohibited in seismic Zones 2 and 3. See 1.7.2.6.

2.8.3.4 Earth Lead

(a) Earth lead is the link which provides connection between the earth conductor(s) and the earth electrode(s). The earth conductors shall be brought to one or more connecting points, according to size of installation; the copper wire earthing leads shall run from there to the electrodes.

(b) Earthing lead can either be of copper wire or of copper strip. Other metals can also be used as in case of earth conductors.

(c) Earthing leads shall be run in duplicate down to the earth electrode so as to increase the safety factor of the installation. Copper wire used as earthing lead must not be smaller than 8 SWG ($12mm^2$).

Table 8.2.11

Minimum Cross-sectional Area of Copper Earth Conductors in Relation to the Area of Associate Phase Conductors

Cross-sectional Area of Phase Conductor(s) (mm^2)	Minimum Cross-sectional Area of the Corresponding Earth Conductor (mm^2)
Less than 16	Same as cross-sectional area of phase conductor but not less than 14 SWG
16 or greater but less then 35	16
35 or greater	Half the cross-sectional area of phase conductor

2.8.3.5 Earth Electrodes

(a) The earth electrode shall, as far as practicable, penetrate into permanently moist soil preferably below ground water table. The resistance of earth electrodes shall not be more than one ohm.

(b) The following types earth electrodes are recognized for the purpose of this Code:

- Copper rods,
- Copper plates,
- Galvanized iron pipes.

(c) Details of typical pipe and plate earth electrodes are given in Fig 8.2.1 and 8.2.2. The following is a guideline for electrode size:

- Copper rods shall have a minimum diameter of 12.7 mm,
- GI pipes shall have a minimum diameter of 50 mm,
- Copper plates shall not be less than 600 mmx600mm in size, with 6 mm thickness.

2.9 LIGHTNING PROTECTION OF BUILDINGS

2.9.1 General

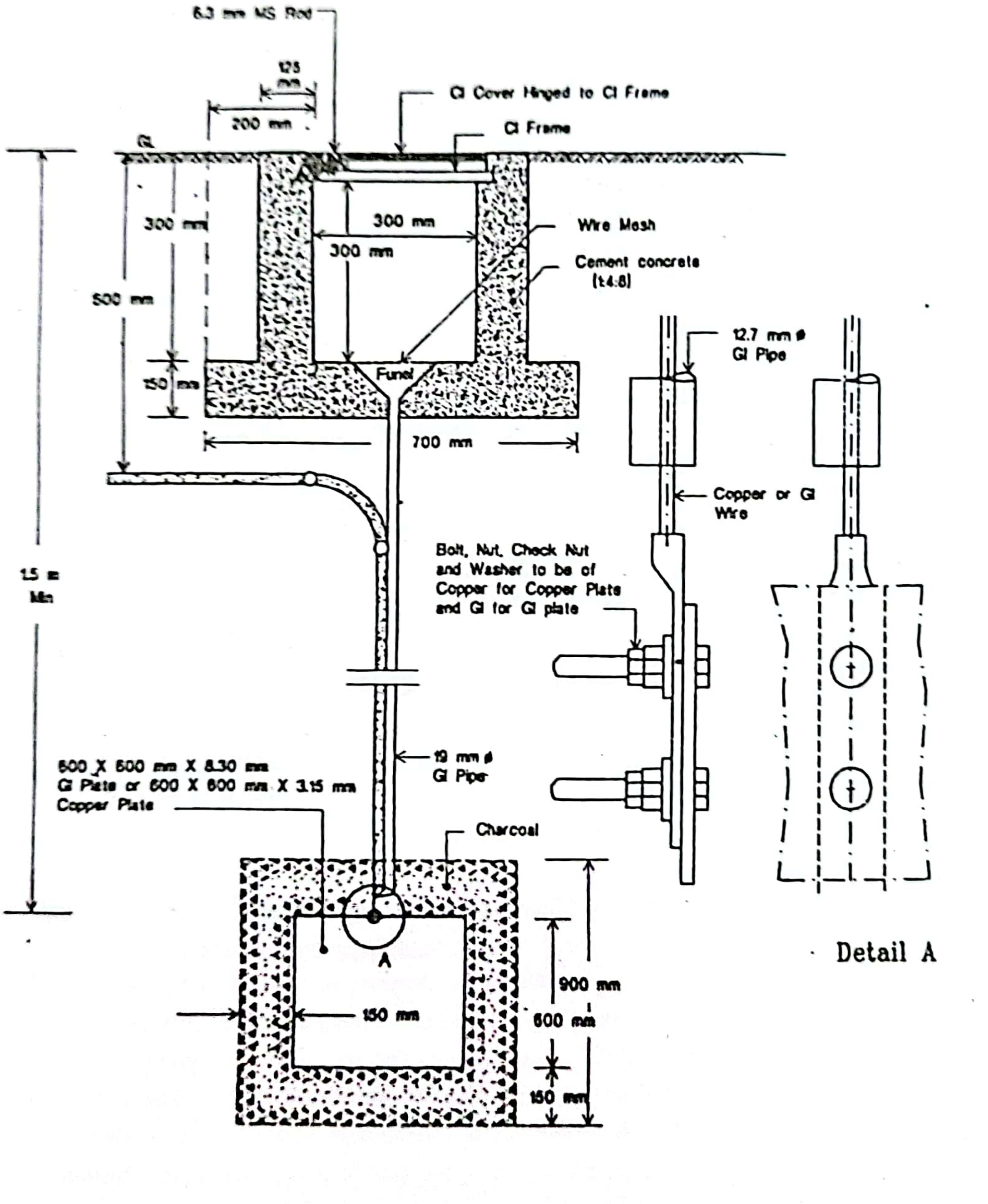
Whether a building needs protection against lightning is a matter of judgement on the part of the designer; obviously it depends on the probability of a stroke and acceptable risk levels. For example, a higher risk is presumably acceptable for an isolated small bungalow than, say, for a children's hospital. Whilst no exact rules can be laid down which would eliminate the designer's judgement entirely, certain steps can be taken for an objective assessment of the risk and of the magnitude of the consequences. As an aid to making a judgement, a set of indices is given in Table 8.2.12 and elaborated in Sec 2.9.1.1 to 2.9.1.7 below for the various factors involved.

2.9.1.1 Usage of Structure: The lightning hazard to human beings within a structure or a building is a very important factor in deciding how far to go in providing lightning protection. Schools, hospitals, auditoriums, railway stations, etc., are places where a large number of people congregate and, therefore, would in general be structures of greater importance than small buildings and houses.

2.9.1.2 Type of Construction: The type of construction of the structure has a large influence upon the extent of protection to be provided. A steel framed building to some extent is self-protecting and may not generally require additional protection, while brick buildings or buildings with thatched roof require greater degree of protection.

2.9.1.3 Contents or Consequential Effects: In addition to direct loss due to destruction of building by lightning, fire resulting from lightning, killing of livestock, etc. there may be indirect losses which sometimes accompany the destruction of buildings and their contents. An interruption to business or to farming operations, specially at certain times of the year, may involve losses quite distinct from, and in addition to, the losses arising from the direct destruction of property. There are also cases where whole community depends for safety and comfort in some respect on the integrity of a single structure, as for instance on the brick chimney of a water pumping plant. A lightning strike to it may have a serious consequence due to disruption of sanitary facilities, drinking water, water for irrigation, fire protection, etc., The contents of buildings should also be considered as to whether they are replaceable, explosive, combustible, flammable vapour or explosive dust. These may present a hazard in a building that is otherwise immune to lightning. Contents like hay or cotton may make protection measures specially desirable.

2.9.1.4 Degree of Isolation: The relative exposure of a particular building will be an element in determining whether the expense of lightning protectian is warranted. In closely built-up towns and cities, the hazard is not as great as it is in open country.



Note : Three or four buckets of water to be poured into sump every few days to keep the soil surrounding the earth plate or pipe permanently moist

Fig. 8.2.1 Plate Earthing

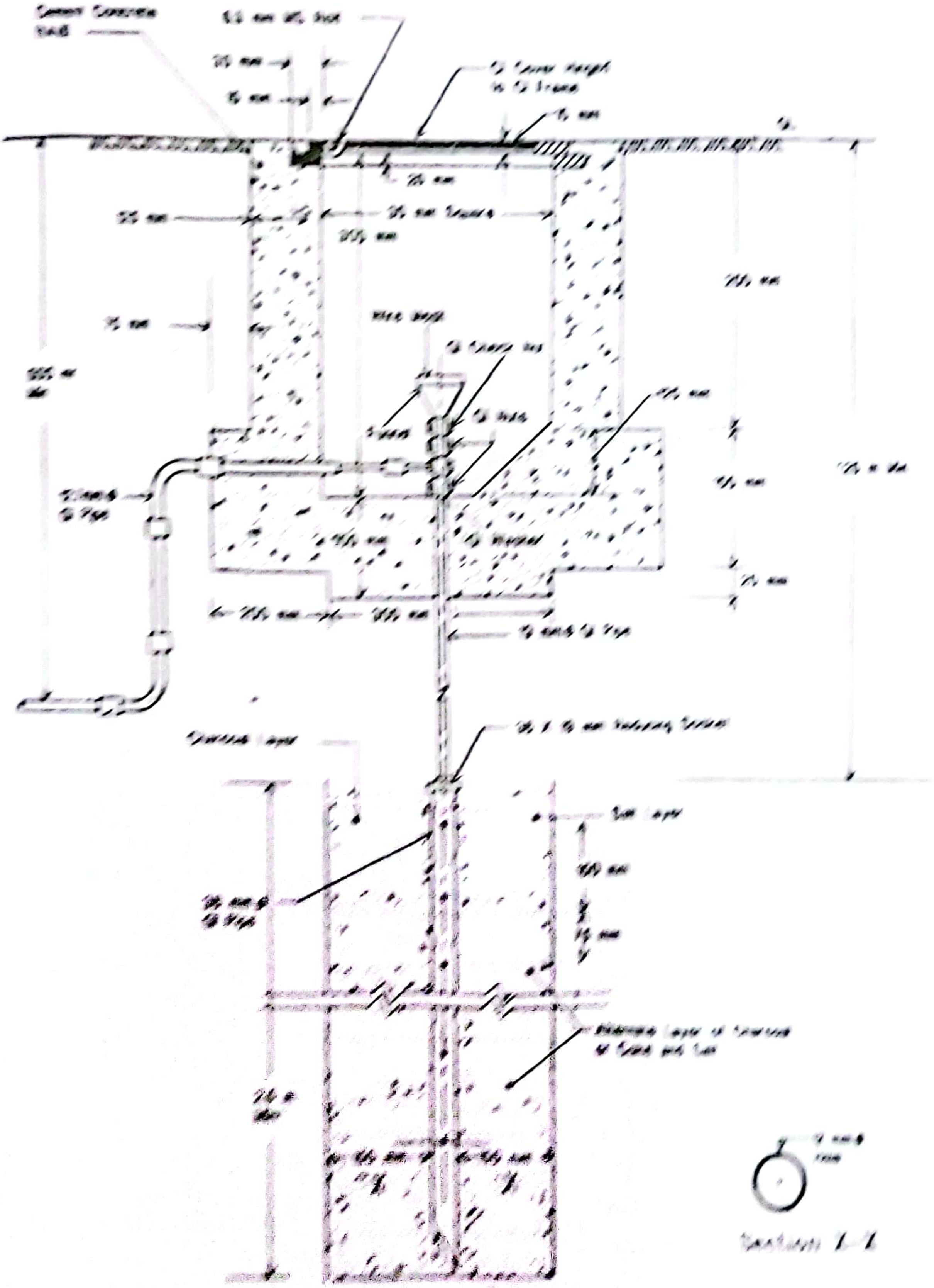


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Fig. 3.2.2 Pipe Earthing