external loads on the earthen subgrade, so that the subgrade itself can bear it.

⊛ Why do we need a road?

Ans:

- We need a road to move from one place to another to fulfill human needs.
- for the movement of people
- for the distribution of natural resources.
- for sharing goods
- Road ensures us door to door service.

07-08, 06-07

Q-5 What are the characteristics of a pavement?

Ans: Pavement should be

- structurally sound enough
- sufficiently thick
- Hard wearing surface
- dust-proof
- Good riding quality
- low friction
- should have a texture and adequate roughness
- Impervious surface

- Produces low levels of sounds
- Long life and low cost of maintenance.

07-08, 06-07

Q-6 What are the types of pavements?

Ans:

(i) Flexible:

- A flexible pavement is essentially a layered system which has low flexural strength.
- The external load is largely transmitted to the subgrade by the lateral distribution with increasing depth.
- The pavement deflects momentarily under load but rebounds to its original level on removal of load.

(ii) Rigid:

- A rigid pavement derives its capacity to withstand loads from the flexural strength or beam strength, permitting the slab to bridge over minor irregularities in the subgrade, sub base or base upon which it rests.
- The inherent strength of the slab itself is called

upon to play a major role in resisting the wheel load.

Semi- Rigid:

- it represents an intermediate state between the flexible and the rigid pavement..
- much lower flexural strengh
- derives support by the lateral distribution of loads through the pavement depth.

Composite:

- comprises of multiple, structurally significant layers of different, - sometimes heterogeneous
- composition.

Q-7 What are the layers in different pavements?

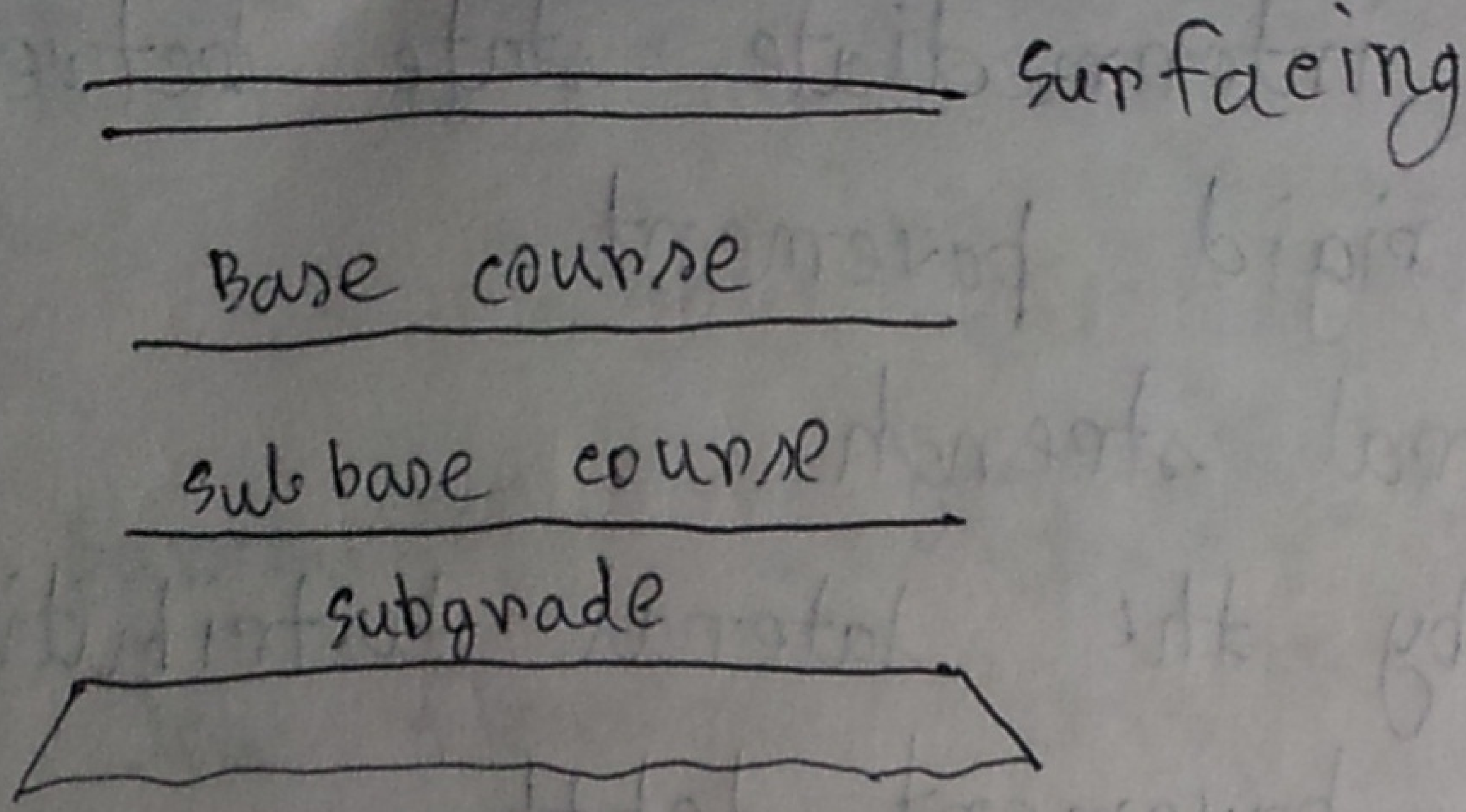
Ans: - A pavement consists of one or more layers.

- Top most layer is the surfacing. It's purpose is to provide a smooth abrasion resistance.

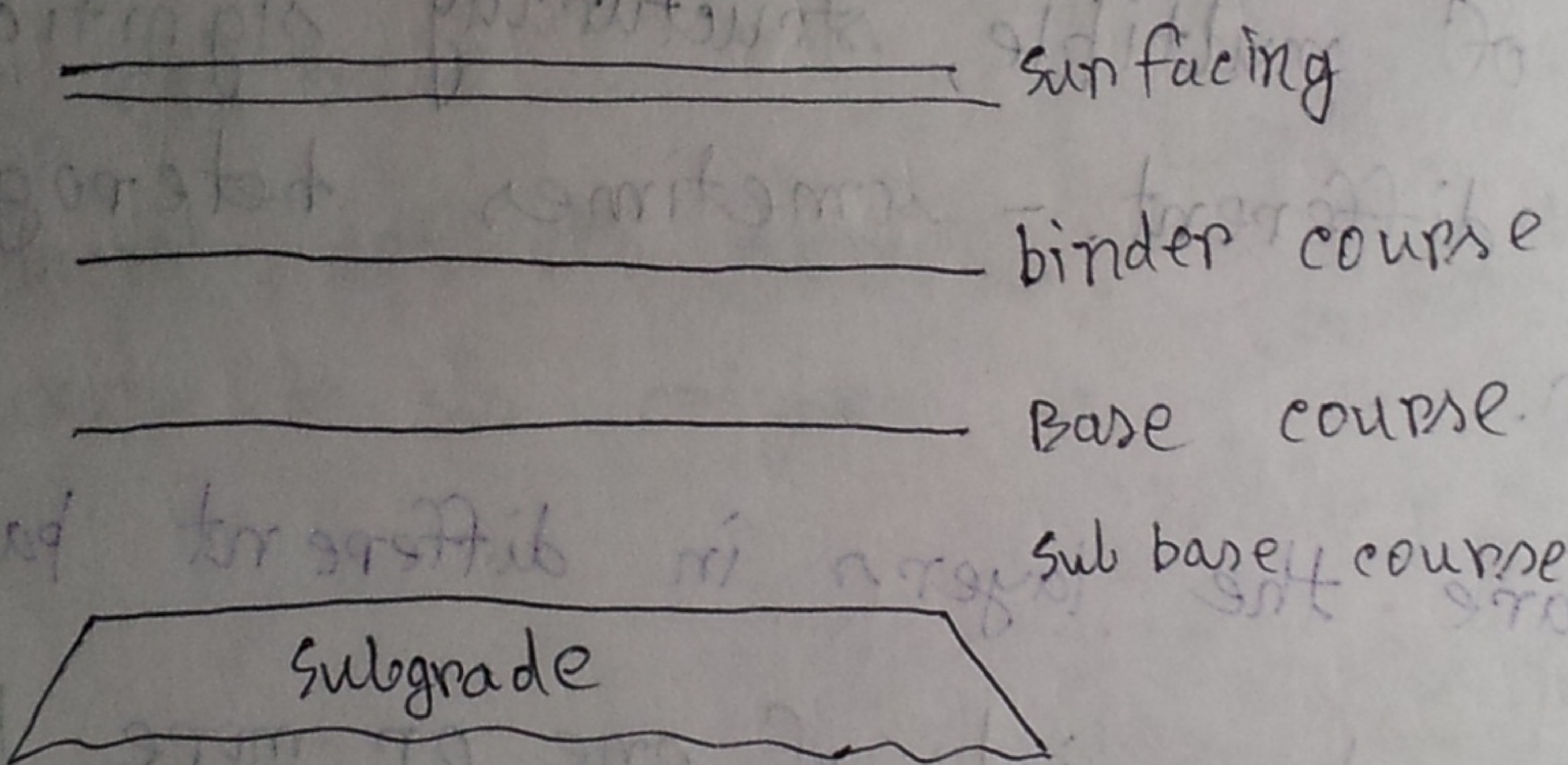
- Bases: immediately below the surface. distribute stresses imposed on it.

- Sub base layers: additional help to distribute the loads.

Subgrade: compacted natural earth immediately below the pavement.



Indian Practice



American Practice

Q-8 What is the comparison between American and British pavements:

Ans: In American practice, the top course in a flexible pavement is itself composed of the surface course and a binder course beneath it.

In UK practice, the surfacing is similarly composed of the wearing course at top and a base course beneath it.

07-08

Q-9 What are the comparisons between flexible and rigid pavements?

Ans:

i) **Design Precision:** A cement concrete pavement is amneable to a much more precise structural analysis than a flexible pavement.

ii) **Life:** Well designed concrete slab can give trouble free performance for 3 to 4 decades or even more. Compared to this, the life of a flexible pavement generally varies from 10 to 20 years.

iii) **Maintenance:** Well-designed rigid pavement needs very little maintenance, only to the joints. But flexible pavement needs great input in maintenance.

iv) **Initial cost:** Initial cost for rigid pavement is very high, compared to flexible pavement.

v) Stage Construction: A new road is constructed with minimum specification, which may involve just a thin bituminous surfacing. As traffic grows, additional layers are given. This is a great advantage of flexible pavement.

Rigid pavements do not fit into such a scheme of stage construction.

vi) Surface Characteristics:

→ A good cement concrete surface is smooth and free from rutting, potholes and corrugations. Thus the riding quality of a cement concrete surface is always assured.

→ In a bituminous surface, it is only the asphaltic concrete surface that can give comparable rideability.

vii) Penetration of Water:

A concrete slab is practically impervious except at joints. If joints are sealed, water will not penetrate. Bituminous surface is not impervious. Water can find its way into the lower layers through cracks.

viii) **Glare and night visibility:**

Concrete pavements have a grey colour which can cause glare under sunlight. Black bituminous pavements are free from this defect.

Bituminous roads need more street lighting.

ix) **Overall economy on a life cycle basis:**

A good rigid road is costly to construct, but once constructed, such a road requires less maintenance.

A rigid pavement is far more economical than a flexible one, in the long run.

Q-10 What are the functions of different layers of pavement?

Ans: The functions of sub-base layer are:

i) To provide additional help to the base and surface courses in distributing the loads.

ii) To prevent intrusion of fine-grained road-bed soils into the base courses.

iii) To minimize the damaging effect of frost action.

iv) To facilitate drainage of free water that might get accumulated below the pavement.

The functions of the base course are:

i) To act as the structural portion of the pavements and thus distribute the loads.

ii) If constructed directly over the sub-grade, to prevent intrusion of subgrade soils into the pavements.

The functions of the surface course are:

i) To perform as a structural portion of the pavement.

ii) To resist the abrasive force of traffic.

iii) To reduce the amount of surface water penetrating the pavement.

iv) To provide a skid-resistant surface.

v) To provide a smooth and uniform riding surface.

Q-17 What are the classifications of pavements in Bangladesh?

Ans:

Type	Defination	Ownership and Responsibility
National Highways	Highways connecting national capitals with Divisional HQ/s or sea ports or land ports or Asian Highways	RHD
Regional Highways	Highways connecting districts HQ/s or main river or land ports or with each other not connected by National Highways	RHD
Zila Road	Roads connecting district HQ/s with ~~additional~~ upazila HQ/s or connecting one Upazila HQ to another Upazila HQ by a single main connection with national/regional Highway, through shortest distance/route.	RHD
Upazila Road	Roads connecting Upazila HQs with Growth Centers or one Growth center with another Growth center by a single main connection or connecting Growth center to Higher Road System, through shortest distance	LGED/LGI
Union Road	Roads connecting Union HQs with Upazila HQs, growth centers or local markets or with each other.	LGED/LGI

Village Road	a) Roads connecting Villages with Union HQs, local markets, farms and ghats or with each other. b) Roads within a Village.	LGED/LGI

Q-12 What are the principles of pavement design?

Ans: Before designing a pavement, it is essential to understand the processes which influence the behavior of any pavement under the action of time and traffic.

Flexible Pavements:

- As soon as traffic begins to flow, permanent deformation will start to develop in the area of the wheel tracks followed by the commercial vehicles.
- This permanent deformation in a well-designed pavement is fairly evenly distributed between the asphaltic materials, base, subbase and subgrade.
- Wheel loads produce vertical compressive stress. Any bituminous base material will also be subjected to tensile stress as the wheel load passes.

- Unbound granular materials cannot accept significant tensile stress.
- The transient deflection of the pavement under the passage of a wheel load is shared by the pavement layers and the subgrade.
- The viscosity increases markedly with time.
- The stiffness of the wearing course increase with time, causing a marked decrease in the transient deflection under traffic.
- Structural failure will generally be initiated by fatigue cracking in the wearing course, followed by similar cracking in the binder course and any other bituminous layers.

Concrete Pavements:

- Are not susceptible to surface deformation under traffic.
- Structural deterioration is initiated by cracking.
- Wheel loads give rise to tensile stress in the underside of the slab, which give rise to fatigue cracking.

- Both the compressive and flexural strength of concrete increase considerably with age, continues up to a life of 10 years.

- The increase in flexural strength will increase the tensile stress at the underside of the slab, generated by a wheel load.

- The fatigue life increases much more rapidly with time than is the case with the tensile stress.

06-07,

Q-13 What are the pavement design approaches?

Ans: The Empirical Approach:

- This approach involves the ~~layer~~ laying of a large number of experimental pavement sections on heavily trafficked normal highways. representing the full range of road materials currently in use.

- Used in UK since 1940s.

- The experiments are generally continued for period up to 30 years.

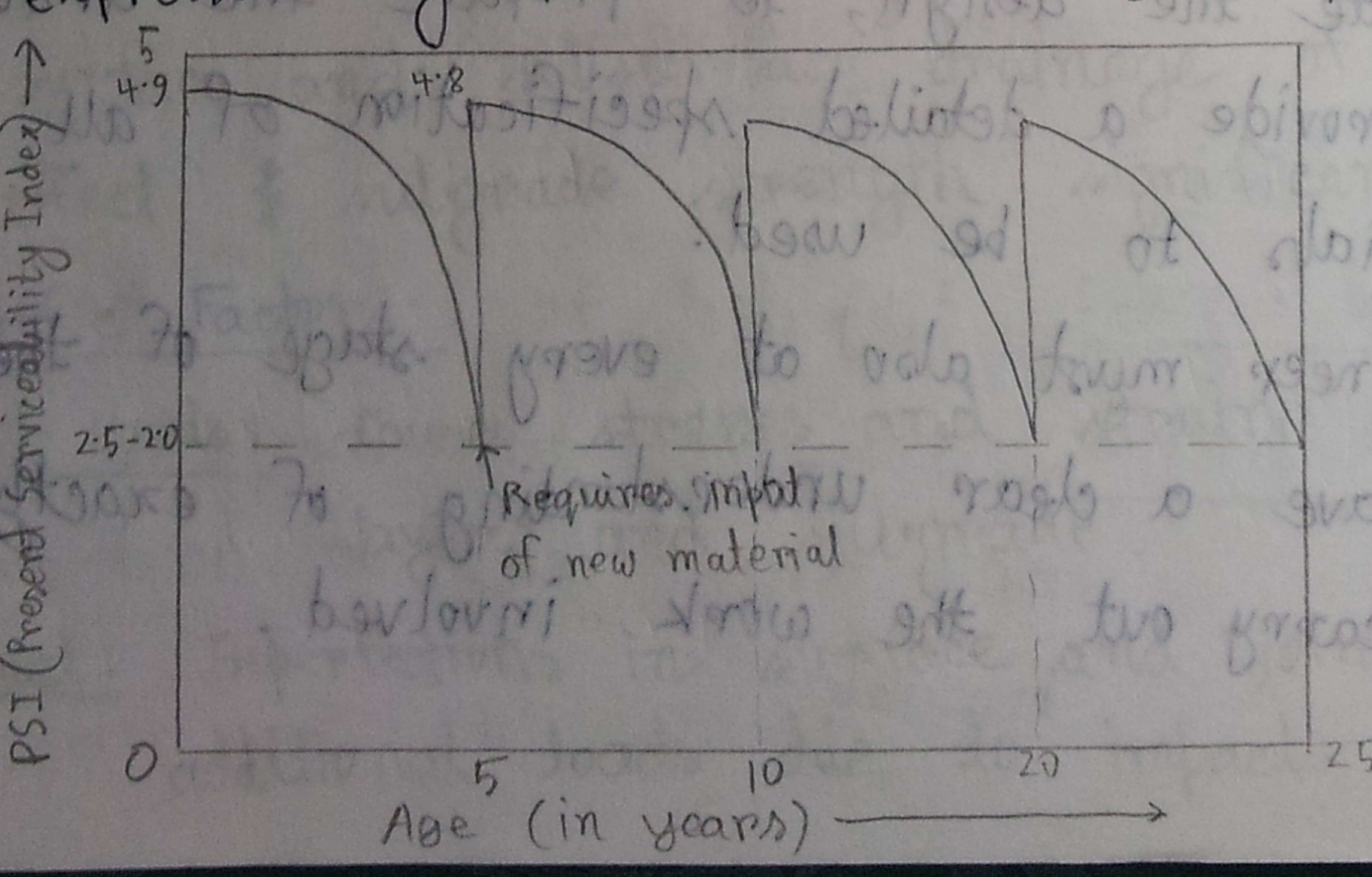
Theoritical Approach:

- The theoritical approach to pavement design has been around for a long time - at least 50 years.
- Theory will explain why asphalt and concrete pavements behave as they do.
- Most of the contributions have been from universities throughout the world and not from the people who design, build, maintain real roads.

Q-13 What is the relationship between serviceability and age/traffic?

Ans: Serviceability:

- Ability of the pavement to give service of its intended purpose.
- expressed by index number (0 to 5).



PSI = 0, for lands

PSI = 5, → No friction with pavement.

(dream pavement, not possible)

PSI = 2.0–2.5 → Potholes are created.

→ need resurfacing / reconstruction.

06-07

$\boxed{\text{Q-14}}$ What are the responsibilities of a design engineer?

Ans:

- Various difficult situations demand firmness, tact and above all knowledge and expertise on the part of the engineer.
- On the engineer falls the responsibility to formulate the design, to prepare the drawings and to provide a detailed specification of all the materials to be used.
- The engineer must also at every stage of the design have a clear understanding of exactly how to carry out the work involved.

Q-15 Briefly state the elements/factors of pavement Design.

Ans: 1 **Design Life:**

→ period of time for which the initially designed pavement structure will last before any reconstruction is needed.

2 **Reliability:**

→ probability that a particular type of distress will remain below or within the permissible level during the design life.

3 **Subgrade Strength and Drainage:**

→ soil type and density significantly affect pavement design.

→ surface and subsurface drainage of pavement affect & subgrade strength significantly.

4 **Traffic Factors:**

Wheel Loads: causes stresses and strains in pavement layers and subgrade.

Impact: Imperfections in surface and joints cause additional loads due to impact.

Position
~~Repititions~~ of
wheel loads: The concentration of wheel loads cause extra distress.

Repititions of
wheel loads: Cumulative load applications during the design life cause plastic and elastic deformations.

From tyred wheels: Cause severe stresses in pavements.

5 Climate Factors:

i> Rainfall: affects pavement drainage

ii> Frost: can disrupt pavement structure.

iii> Temperature: variation of temperature can cause stresses in pavements.

6 Road Geometry:

i> Horizontal curves: Subjected to extra stresses

ii> Vertical profile: Pavements are subjected to extra forces due to acceleration, braking.

7 Material Properties:

Stresses Underneath Pavements

Q What are the elements for rational pavement design procedure?

A For a rational pavement design procedure, the elements to be considered are:

→ The theory used to predict the failure or distress parameters

→ The evaluation of the pertinent material properties necessary for the theory.

→ The determination of the relationship between the magnitude of the parameter in question for the failure or performance level desired.

A Stresses in a Homogeneous Mass: Boussinesq's Theory

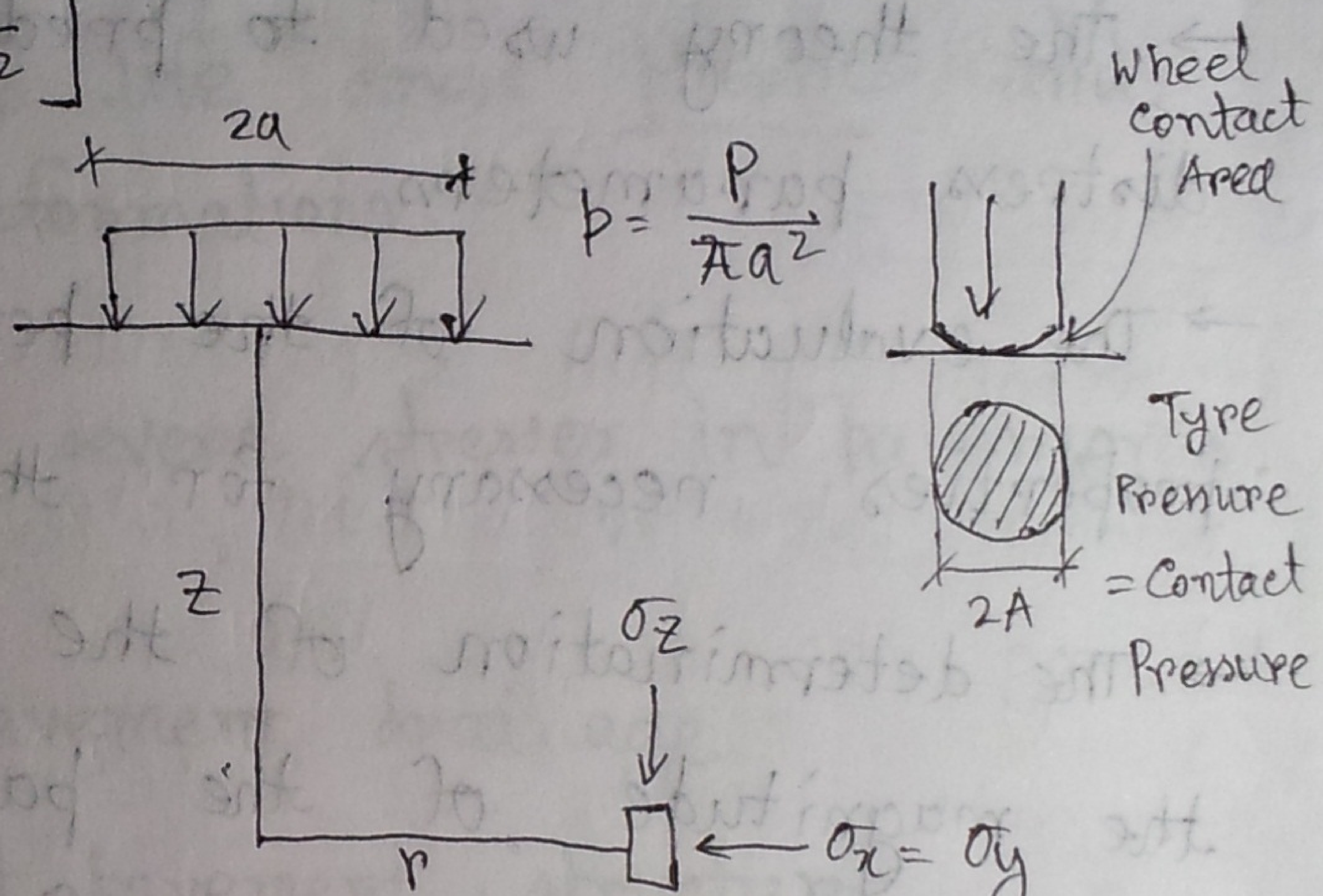
In 1885, Boussinesq analysed the distribution of stresses in an ideal elastic, homogeneous and isotropic solid obeying Hooke's Law and presented equations for horizontal and vertical stresses in such a material under a load.

For a point load on the surface, $\sigma_z = \frac{P}{z^2} k$,

where, $k = \frac{3}{2\pi} \cdot \frac{1}{[1 + (r/z)^2]^{3/2}}$

Pavement with a wheel load P and radius of contact area "a",

$$\sigma_z = p \left[1 - \frac{z^3}{(a^2+z^2)^{3/2}}\right]$$



The radial (horizontal) stress is given by:

$$\sigma_x = \sigma_y = \frac{p}{2}\left[(1+2\mu) - \frac{2(1+\mu)z}{(a^2+z^2)^{1/2}} + \frac{z^3}{(a^2+z^2)^{3/2}}\right]$$

where,

σ_z = vertical stress on a point on the z-axis

$\sigma_x = \sigma_y$ = radial or horizontal stress

p = applied pressure per unit area

a = radius of circular loaded plate

z = depth

μ = Poisson's ratio. $\mu = \dfrac{\text{strain normal to the applied stress}}{\text{strain parallel to the applied stress}}$

($\simeq 0.5$)

The vertical displacement at the surface ($z=0$) under the centre of the applied load is

$$\boxed{\Delta = \frac{2pa}{E}(1-\mu^2)}$$

Put $\mu = 0.5$

$$\therefore \boxed{\Delta = 1.5\frac{pa}{E}} \longrightarrow \text{applicable for a flexible plate}$$

For a rigid plate

$$\boxed{\Delta = 1.18\frac{pa}{E}}$$

Problem 16.1 Calculate the deflection at the surface of a pavement due to a wheel load of 40 kN and tyre pressure of 0.5 MN/m^2. The value of the E of the pavement and subgrade may be assumed to be uniformly equal to 20 MN/m^2.

Solution:

$$\text{Tyre pressure} = \frac{\text{Wheel load}}{\pi a^2}$$

$$\therefore a = \sqrt{\frac{40 \times 10^3}{\pi \times 0.5 \times 10^6}} = 0.1596\,m$$

$$= 15.96\,cm$$

$\therefore p$ = applied pressure per unit area

$$= \frac{40 \times 10^3}{\pi \times 0.1596^2} = 499855.35\ N/m^2$$

$$\therefore \text{Deflection} = 1.5\,\frac{p.a}{E}$$

$$= 1.5 \times \frac{499855.35 \times 0.1596}{20 \times 10^6}$$

$$= 0.5983\ cm$$

$$= 0.6\ cm$$

Ques: What are the criticisms/drawbacks in the simple Boussinesq's theory?

Ans:

i) The assumption that soil is perfectly elastic and homogeneous is not true. Soil may be elastic upto a certain limit.

ii) Pavement consists of a number of layers, each with its own modulus of elasticity. Hence the assumption of one constant property for the entire mass is not justified.

iii) The assumption that the load is uniformly distributed may not be correct.

Stresses in layered systems: Burmister's Theory

2 layers
- Top layer: Finite thickness (represents surfacing base and subbase)
- Bottom layer: Semi-infinite mass (represents the subgrade soil).

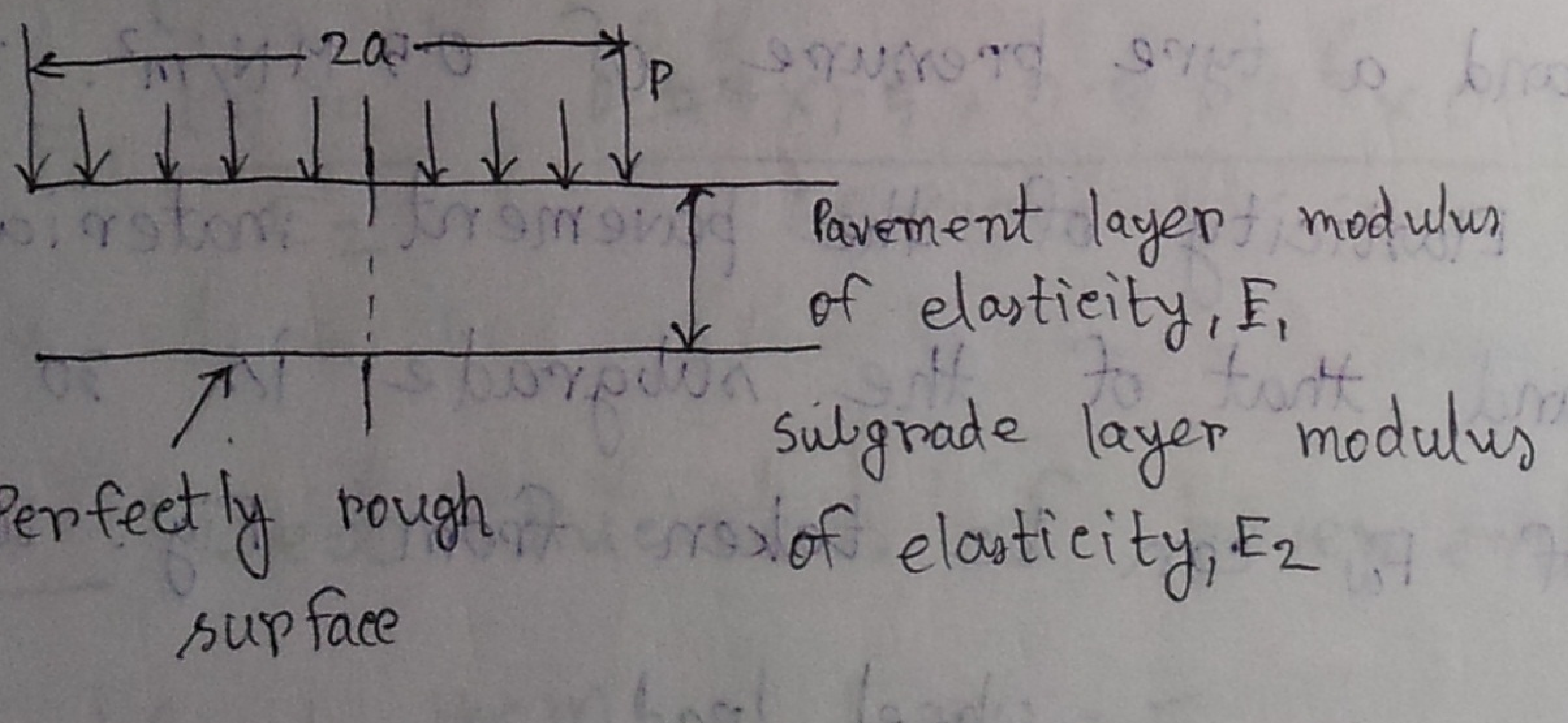


Fig: Burmister's two-layer system.

→ Deflection at the surface,

$$\Delta = F_\omega \frac{1.5\, pa}{E_2} \quad \text{(For a Flexible plate)}$$

$$\Delta = F_\omega \frac{1.18\, pa}{E_2} \quad \text{(For a rigid plate)}$$

Here,

p = load intensity on the circular plate

a = radius of plate

E_2 = Modulus of elasticity of the lower layer

F_ω = Displacement factor (can be obtained from figure 16.4).

$\boxed{\text{Problem 16.2}}$ Design the thickness of a flexible pavement by Burmister's two layer analysis, for a wheel load of 40 KN and a tyre pressure of 0.5 MN/m². The Modulus of Elasticity of the pavement material is 150 MN/m² and that of the subgrade is 30 MN/m². The value of F_ω can be taken from Fig. 16.4.

Soln:

$$\text{Tyre pressure} = \frac{\text{wheel load}}{\pi a^2}$$

$$\Rightarrow 0.5 \times \cancel{10^6}\,10^3 = \frac{40 \times \cancel{10^3}}{\pi a^2}$$

$$\Rightarrow a = \sqrt{\frac{40}{\pi \times 0.5 \times 10^3}} = 0.1596 \text{ m} = 15.96 \text{ cm say } 16 \text{ cm}$$

Select a thickness of pavement of 2a, i.e., 32 cm

$$\frac{E_1}{E_2} = \frac{150}{30} = 5$$

From Fig. 16.4, for $\frac{E_1}{E_2} = 5$ and pavement thickness of 2a

$F_w = 0.43$

$$\Delta = F_w \frac{1.5pa}{E_2} = \frac{0.43 \times 1.5 \times 0.5 \times 10^6 \times 0.16}{30 \times 10^6} = 0.00172 m$$

$$= 0.172 cm$$

Allowable settlement is 0.5 cm

Trial-2: select thickness of pavement of 1a, i.e., 16 cm

$$\frac{E_1}{E_2} = 5$$

From Fig. 16.4, $F_w = 0.6$

$$\therefore \Delta = F_w \frac{1.5pa}{E_2} = \frac{\cancel{0.43}\ 0.6 \times 1.5 \times 0.5 \times 10^6 \times 0.16}{30 \times 10^6} = 0.0024 m$$

$$= 0.24 cm$$

Trial-3 select thickness of pavement of 0.25a,

i.e., 4 cm ; $E_1/E_2 = 5$

From Fig 16.4, $F_w = 1.0$

$$\therefore \Delta = F_w \frac{1.5pa}{E_2} = \frac{1.0 \times 1.5 \times 0.5 \times 10^6 \times \cancel{0.04}\ 0.16}{30 \times 10^6} = 0.004 m$$

$$= 0.4 cm$$

Which is less than allowable settlement and

max^m value for Δ (as max^m value of $F_\omega = 1.0$).

Stresses in a Concrete Pavement (Rigid):

1. Stress due to load:

Westergaard defined a property, which he termed as the relative stiffness of the slab and subgrade. The radius of relative stiffness is defined as:

$$l = \sqrt[4]{\frac{Eh^3}{12(1-\mu)^3 K}}$$

where, l = radius of relative stiffness (in.)

E = modulus of elasticity of pavement (psi)

h = pavement thickness (in.)

μ = poisson's ratio of the pavement = 0.15

K = modulus of subgrade reaction (lb/in^3)

Eq^n 22.2, 22.3, 22.4 $\longrightarrow$ From sheet.

2. Stress due to temperature:

The warping stress at the edge has been calculated by Bradbury:

$$f_{te} = \frac{E \alpha \Delta t}{2} \cdot C$$

where, f_{te} = temperature stress in the edge region, psi

α = co-efficient of thermal expansion of concrete

Pavement Design: Lecture 6

Pavement Materials characterization

⇒ Material characterization is used to define failure criteria for various distress modes such as fatigue cracking, permanent deformation and thermal cracking effects. Material characterization can be divided into three general categories:

A: Conventional strength and Deformation tests (Routine tests)

These tests are:

* Plate Bearing - * Triaxial - * CBR - * Stabilometer for bituminous mix - * Modulus of rupture

-* Indirect Tensile strength

B: Tests used to define input parameter for layered theory solutions.

These are :

* Resilient Modulus -* Complex Modulus
-* Dynamic Stiffness -* Diametrical Resilient Modulus
-* Asphalt Mix Stiffness -* Creep -* Wave Propagation

C: Test procedures to determine fundamental distress properties.

-* Fatigue -* Permanent Deformation.

Most Common Tests For Pavement Design:

1. CBR – California Bearing Ratio → Flexible Pavement
2. Plate Bearing — Rigid Pavement
3. Shear Strength
4. Stabilometer
5. Modulus of rupture → Rigid pavements.

⑥ Indirect Tensile

⑦ Resilient modulus → TAI method of flexible pavement

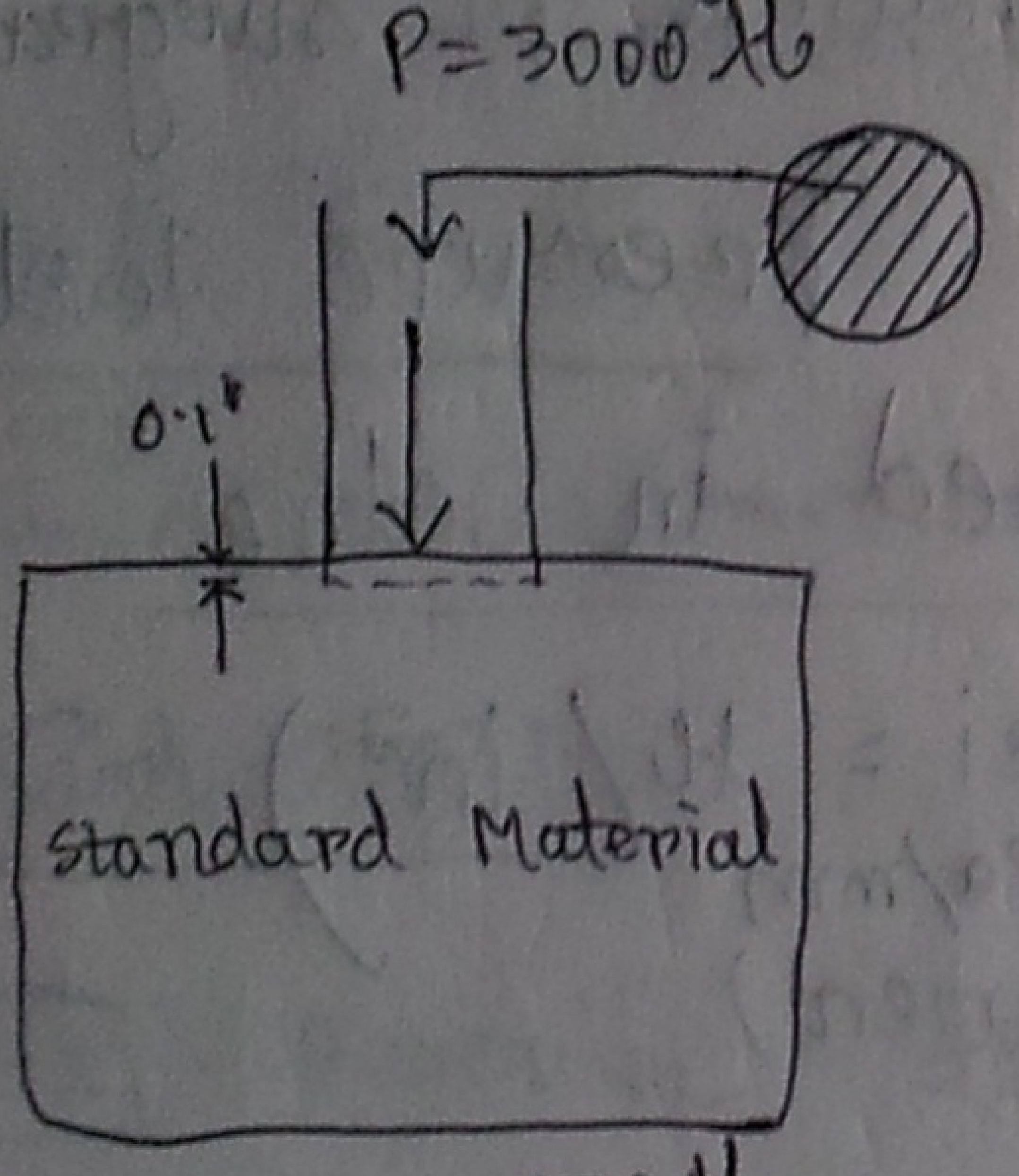
⑧ Poisson's ratio

⑨ Fatigue test.

CBR Test:

Developed by O. J. Porter of CDH (California Department of Highway) in 1939.

Modified by core of Engineers of US Army.



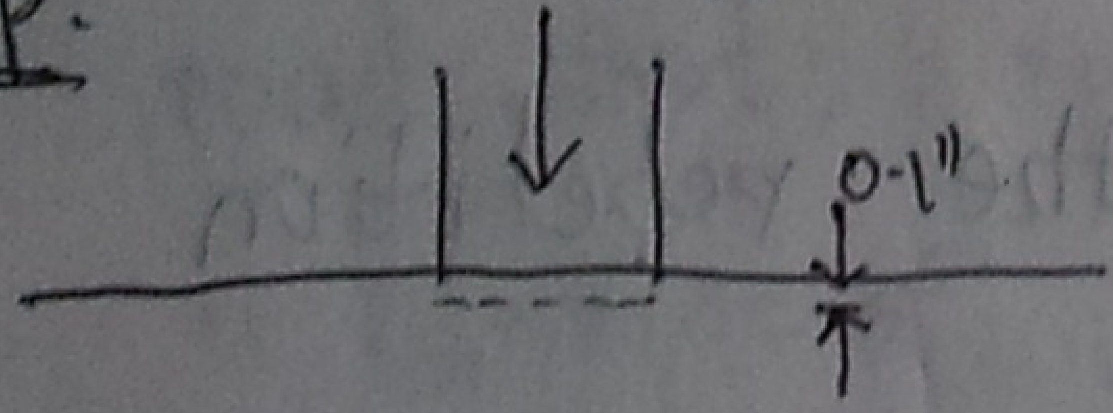
Area = 3 in²

Dia = 1.95"

stress = 1000 psi

Soil, sand, granular materia → requires CBR test.

Exp:



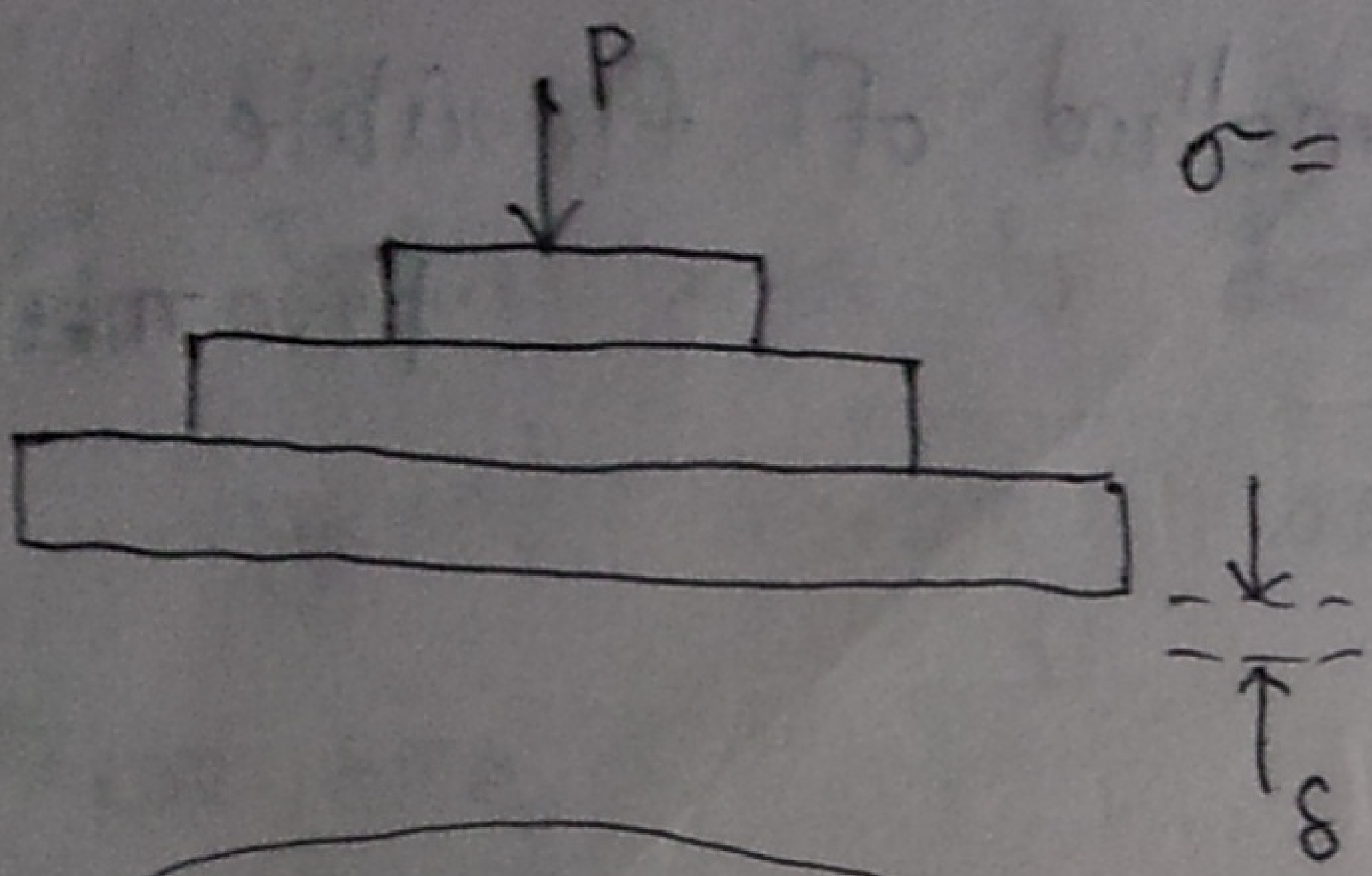
stress = 50 psi

Buet soi

$$\therefore \text{CBR value of the soil} = \frac{\overset{5}{\cancel{150}}}{\cancel{3000}} \times 1\cancel{00}$$

$$= \boxed{5}$$

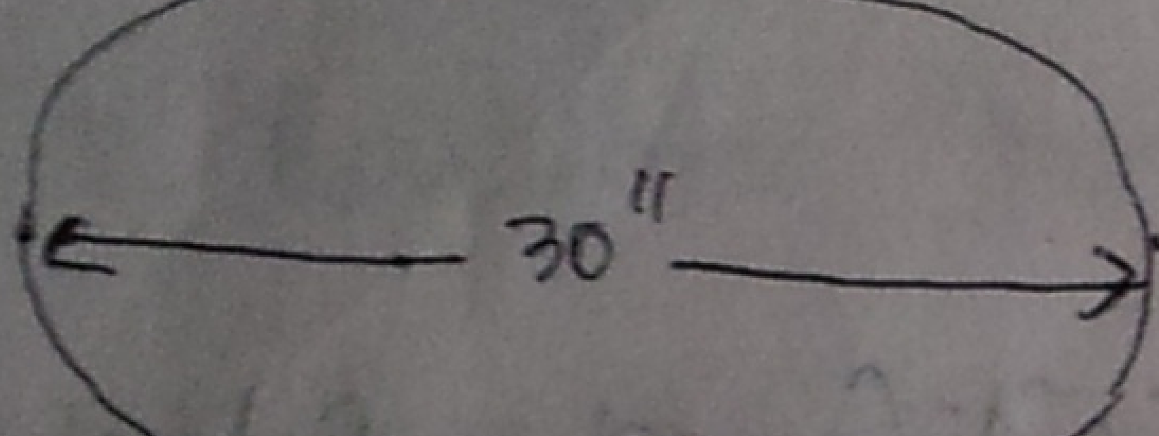
Plate Load Test



$\sigma = \frac{P}{A}$

→ it provides the value of the modulus of subgrade reaction of the subgrade soil & the bearing capacity of the soil.

→ also used for estimation of elastic modulus of subgrade.



k = modulus of subgrade reaction = defined as the pressure sustained per unit deformation of subgrade at the specified deformation or pressure level, with the specified plate size used in the plate load test. $= \frac{\sigma}{\delta}$ (pci = lb/in³ or, MPa/mm)

(1.25 mm = displacement)

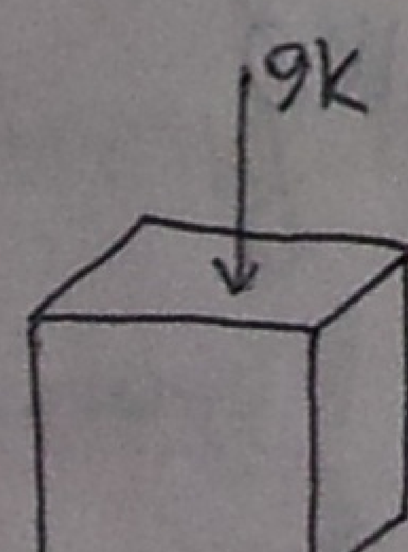
Fatigue:

Failure of road by the repetition of load less than the capacity.

9K —— repeated 100 time

↓

Fails



Fails normally at 10K.

Pavement Design: ROAD TESTS

In order to develop a rational pavement design procedure engineers and scientists of Europe and USA constructed test roads and predicted performances under different conditions of design elements such as:

- Materials
- Traffic
- Environment, and
- Maintenance

ROAD TESTS:

7-08
1. AASHO (American Association of State Highway Officials)

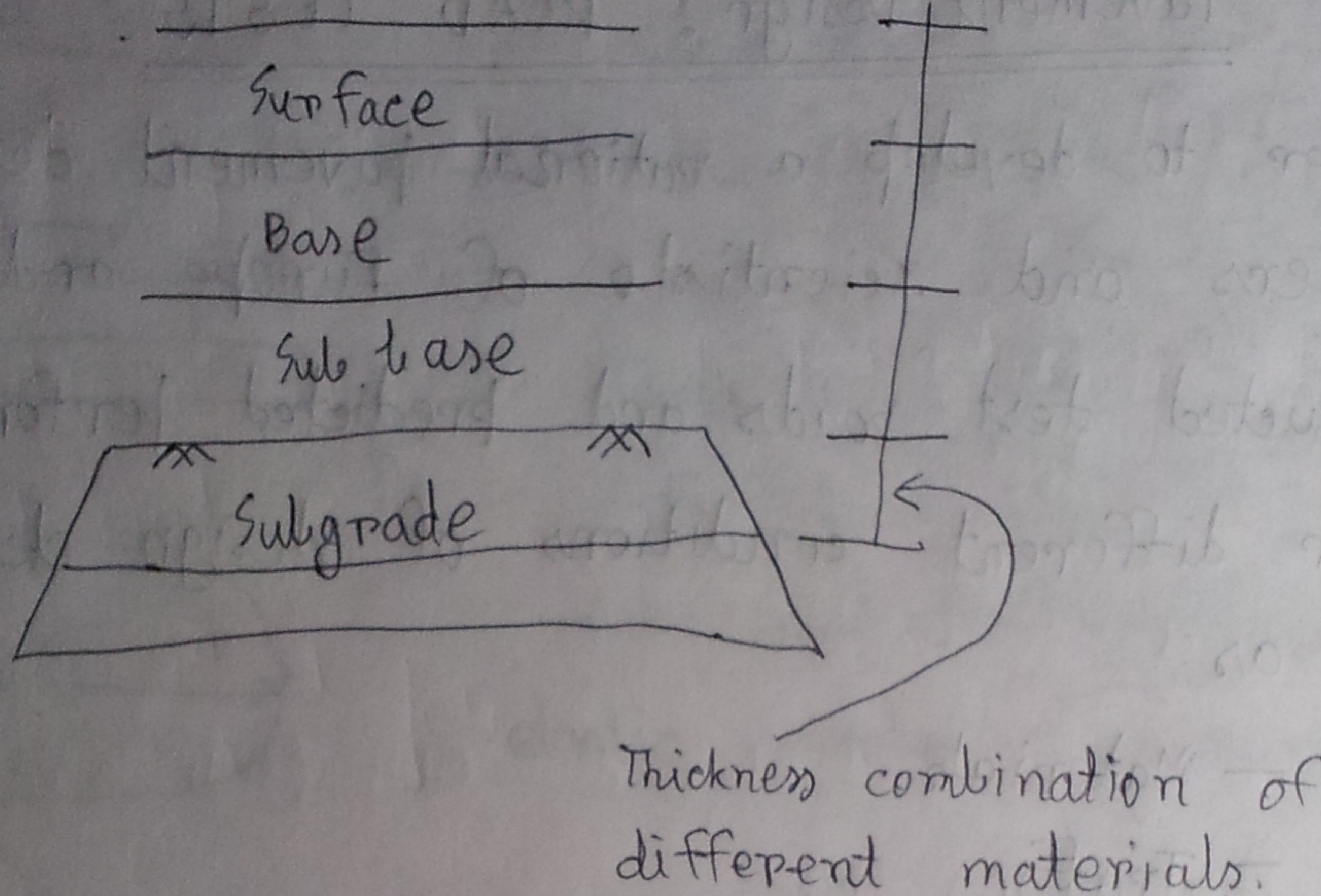
~~Road Tests~~

Q-1 Describe the following things for AASHO road test:

- Purpose of
- Site and soil
- Construct and Pavement sections
- Test Traffic

P.T.O.

Ans:



→ The AASHTO (previously known as AASHO) was a $ 27 M project undertaken co-operatively by 49 of the states, the district of Columbia.

→ Construction began in April 1986, test traffic began in October 1958. The test road was located near Ottawa, Illinois, about 80 miles South-West of chicago.

→ One one subgrade soil, an A-6 was used in the pavement test.

→ The major portions of the test dealt with flexible pavements, rigid pavements and short-span bridges.

→ Main design factors in the principal experiments were surface, base and subbase thicknesses.

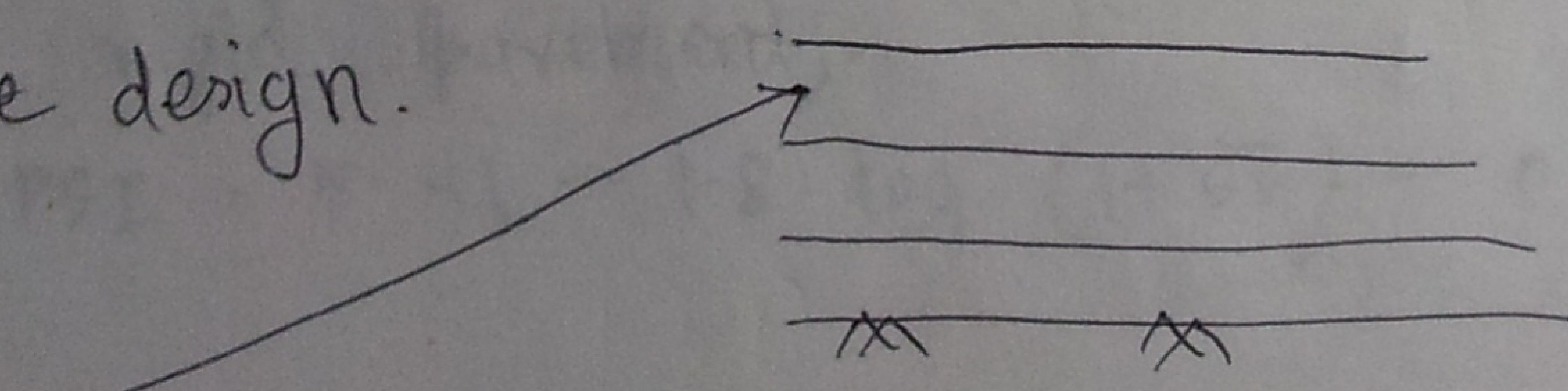
→ Surface thickness ranged from 1" to 6",
base thickness from 0 to 9".
Subbase thickness from 0 to 16".

→ Test traffic included both single and tandem axle vehicles with 10 different axle.

→ Single axle loads 2 – 30 kip.
Tendem axle loads 24 ~ 48 kip.

Q-2 Why do you need road test?

Ans: For the development of rational pavement base design.



Observe the change in roads, take a

The thickness Index (SN):

SN = Structural Number

$= a_1 D_1 + a_2 D_2 + a_3 D_3$

where, a_i = Layer co-efficient

D_i = Layer thickness.

$SN = a_i D_i + a_2 D_2 M_2 + a_3 D_3 M_3$

where, M = drainage co-efficient

Ques: What are the assumptions made for the Asphalt institute method?

Ans:

① The wheel load, W, is transmitted to the pavement surface through the tire at a uniform vertical pressure P_0. The stresses are then spread through the pavement structure ((to produce a reduced max^m vertical stress, P_1, at the subgrade surface.))

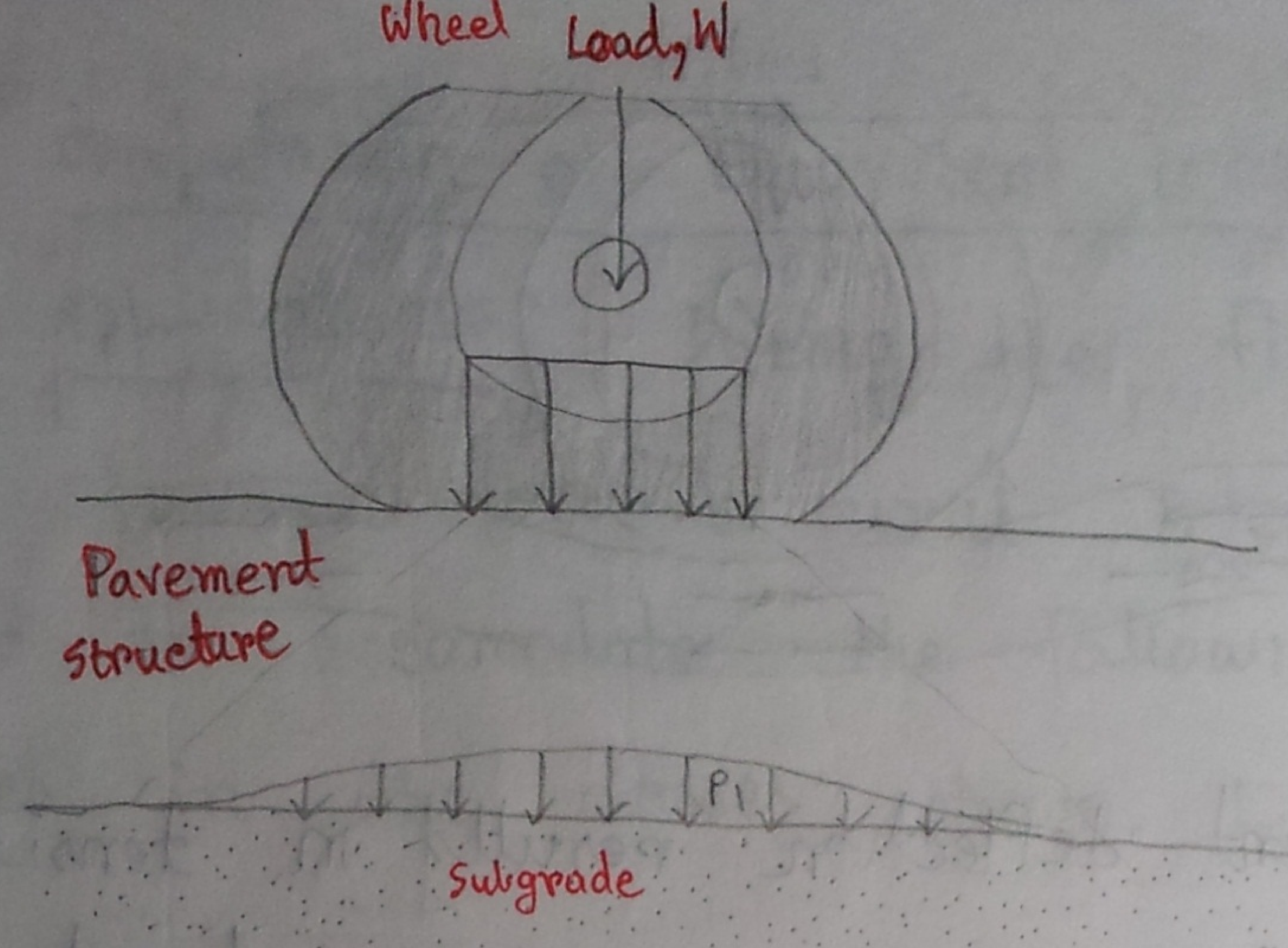


Fig: Spread of wheel load pressure through pavement structure

[2] The wheel load, W, causes the pavement structure to deflect, creating both compressive and tensile stresses in the pavement structure. In developing the design procedure, Asphalt Institute Engineers to calculated induced horizontal tensile strain, ϵ_t, at the bottom of the asphalt layer and vertical compressive strains, ϵ_c, at the top of the subgrade."

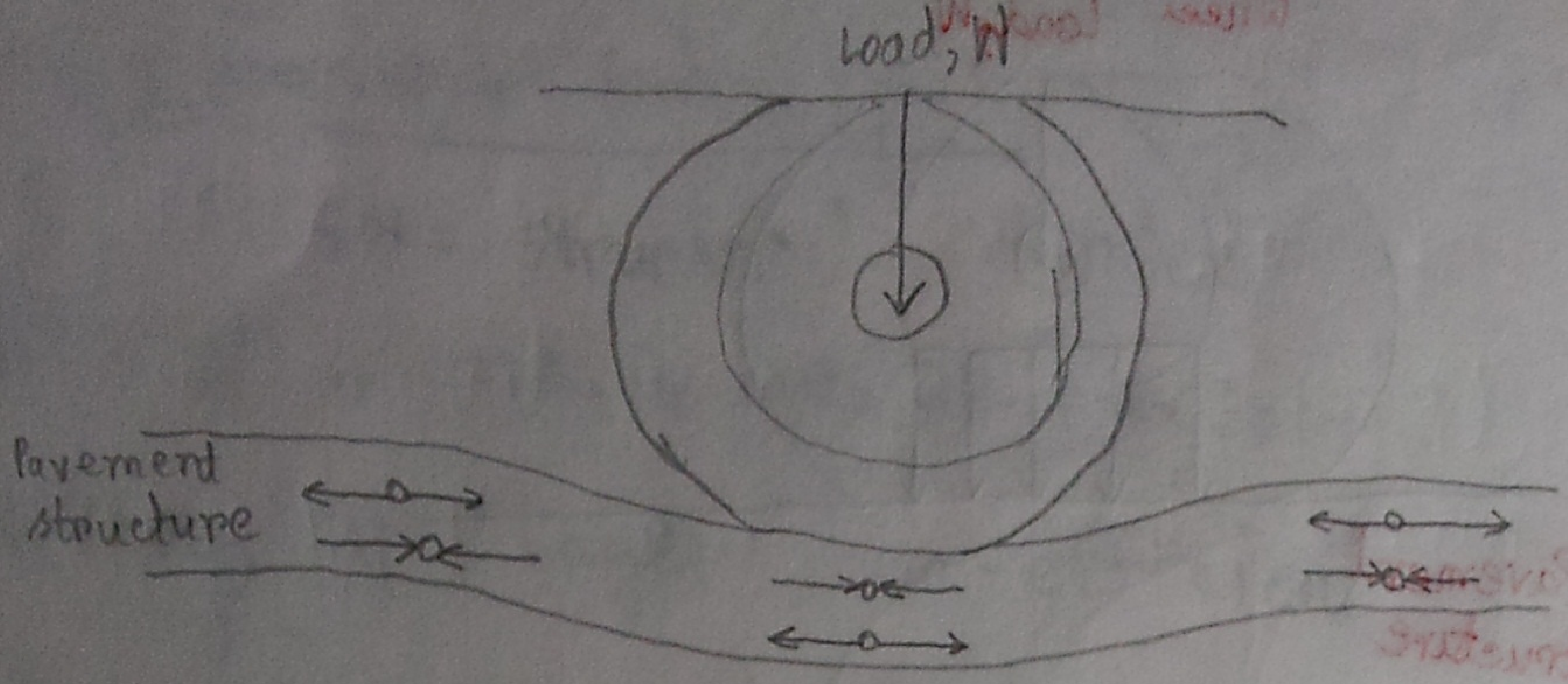


Fig: Pavement deflection results in tensile and compressive stresses in pavement structure.

ESAL = Equivalent (18000 lb) Single Axle Load

= is based on the no. of commercial vehicle using the design lane in one direction. Because serious damage on the pavement is caused by the inner wheel truck close to the edge of pavement.

over loaded >1

under loaded <1

Truck = 1 ESAL / vehicle

Bus = 0.4 ESAL / vehicle.

Example 16-1

Computation of Equivalent 18,000-lb Load Applications: During the first year of service, a pavement on a rural Interstate highway is expected to accomodate the following numbers of vehicles in the classes shown. Estimate the ESALs.

Soln:

Vehicle Type	No. of Vehicles	Truck Factors	Product
Single-unit trucks			
Two-axle, four-tires	87,600	0.003	262.8
Two-axle, six-tires	23,600	0.21	4956
Three-axle or more	4,400	0.61	2684
Tractor-semitrailers			
Four-axle or less	2,100	0.62	1302
Five-axle	7,300	1.09	7957
Six-axle or more	50,200	1.23	61746

ESAL = Sum = 78907.8

Example 16-2

Design ESAL for 20-Year Design Period.

If the traffic using the pavement grows at an annual rate of 4 percent, determine the design ESAL for a 20-year design period.

Solution:

We know, $T = \left[\frac{(1+r)^n - 1}{r}\right] T_1$

here, $T_1 = 78907$ (from previous math)

r = rate of growth = 0.04

n = design period = 20

$\therefore$ Design ESAL $= \left[\frac{(1+0.04)^{20} - 1}{0.04}\right] 78907$

$= 2349699$

(*) If the traffic is expected to grow nonuniformly among weight classes, Eq. 16-6 should be applied to each weight class using appropriate rates of growth.

[Q] What are the design inputs in AASHTO flexible pavement design?

Ans:
i) Traffic
ii) Reliability level (R)
iii) Environmental effects
iv) Roadbed soil resilient modulus (M_R)
v) Serviceability (ΔPSI)

for 5 marks.

Details → P-449

Design of Flexible Pavement

The Asphalt Institute (TAI) method

Salient Features:

- characterizes asphalt pavement as multilayered elastic system.
- used theory, experience, test data to develop structural thickness design.

(*) On which two stress-strain condition TAI method is based on

- the method is based on two assumed stress-strain conditions

i) Fracture or cracking of the asphalt treated layer (tensile strain ϵ_t)

ii) Distortion or rutting of subgrade and other layers (compressive strain ϵ_c)

- Subgrade resilient modulus and total ESAL are used to find thickness (T_s) from design charts prepared for six material types at 3 temperatures.

Design steps for TAI method:

Step-1: Estimate the number of total traffic in the 1st year.

Step-2: Estimate the percentage of truck traffic

Step-3: For each weight class, determine the truck factor (Page - 444)

Step-4: Determine the 1st year ESAL (Example 16-1, Pg - 445).

Step-5: Determine the design ESAL for growth rate (r) and design period (n) [Example 16-2, Pg - 445]

Step-6: Find the subgrade resilient modulus, M_R [section 16-8, Page-438]. TAI recommends,

$$M_R (psi) = 1500$$

Step-7: Using appropriate M_R and total ESAL, find the Asphalt concrete (Ac) thickness, T_a from design chart. [Fig - 16.7]

Step-8: Determine the minimum surface thickness (usually 3"-4").

Step-9: Determine the thickness of other layers using substitution ratios (S_R).

$\boxed{\text{Problem}}$ Find at least two design sections as per TAI method with the following information:

i) The total AC thickness from TAI design chart = 10.5"

Min^m surface thickness = 3"

S_R for asphalt treated base = 1.5

S_R for granular base = 2.0

S_R for granular subbase = 2.7

Section-1

	3" Asphalt Concrete
$4\times1.5"$ $=6"$	6" Asphalt treated base
$3.5 * 2.7$	$=10"$ Granular subbase

Section - 2

	3" AC
$4"*2"$ $=8"$	8" granular base
$3.5*2.7$ $=10"$	10" granular subbase

(not adequate)

07-08

AASHTO method of Flexible Pavement Design

Steps:

1. Find the total no. of 18k ESAL for the design period (W_{18})

   $W_{18} = D_D \times D_L \times W_{18}'$ where . . . (book: P-449)

2. Find the reliability level (R), standard deviation (S_0)
3. Find environmental effects.
4. Find initial serviceability (P_0), terminal serviceability (P_t), and $\Delta PSI = P_0 - P_t$

5. Estimate the effective roadbed soil resilient modulus, M_R.

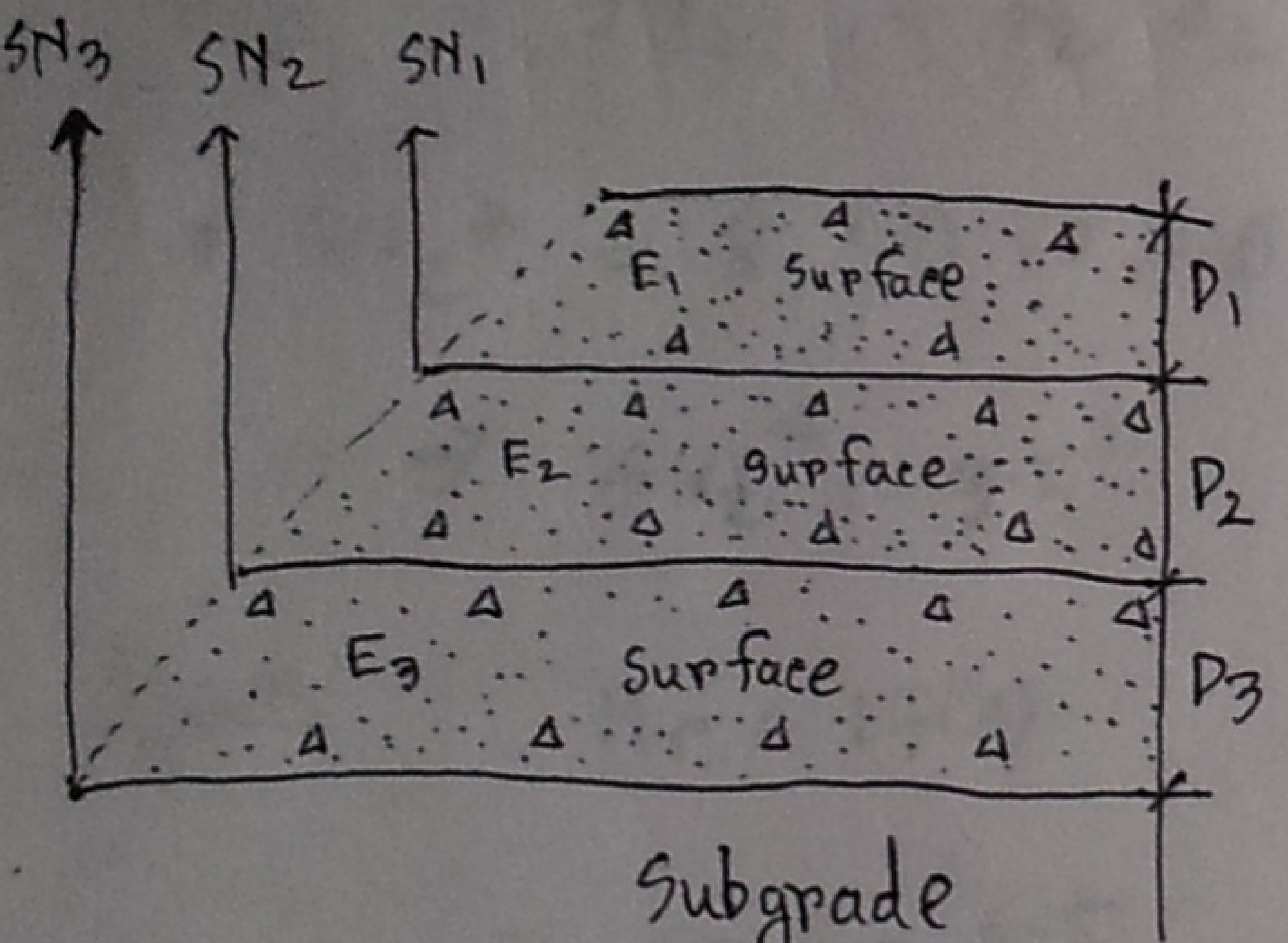
6. Using AASHTO design chart (Fig. 16-11), determine the required structural number, S_N.

7. Determine the thickness of various layers corresponding to design SN.

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3 \quad \cdots \text{ where } \cdots \quad (P-453)$$

07-08

General Procedure for Selection of layer thickness:



1 Using E_2 as M_R and Fig 16-11, determine SN_1

$$SN_1 = a_1 D_1 \; ; \; D_1 = \frac{SN_1}{a_1} \simeq D_1^*$$

$$a_1 D_1^* = SN_1^*$$

2 Using E_3 as M_R and Fig 16-11, determine SN_2.

$$SN_2 = a_1 D_1^* + a_2 D_2 m_2 \quad \therefore D_2 = (SN_2 - a_1 D_1^*)/a_2 m_2$$
$$= D_2^*$$

$$\therefore SN_2^* = a_2 D_2^* m_2 \; ; \; SN_2^* + SN_1^* \geq SN_2$$

3 Using the subgrade M_R and Fig 16-11, determine SN_3.

$$SN_3 = SN_1^* + SN_2^* + a_3 D_3 m_3$$

$$\therefore D_3 = [SN_3 - SN_1^* - SN_2^*] / a_3 m_3 \simeq D_3^*$$

$$SN_3^* = D_3^* a_3 m_3$$

$$SN_1^* + SN_2^* + SN_3^* \geq SN_3 \text{ (or design SN)}$$

$\boxed{\text{Example 16-3}}$

Design ESAL = 3×10^6

Step-1: Total No. of 18^k ESAL, $W_{18} = 3.0 \times 10^6$

Step-2: $R = 85\%$. $S_o = 0.45$

Step-3:

Step-4: $\Delta PSI = 2\%$.

Step-5: $M_R = 24{,}000$ p

Step-6: Using chart 16-11, $SN_1 = 2.5$

$a_1 = 0.42$ (for ~~resilient~~ M_R of AC = 420000 psi from fig. 16-13)

$$D_1 = \frac{SN_1}{a_1} = \frac{2.5}{0.42} = 5.95''$$

$$D_1^* \approx 6''$$

$SN_1^* = a_1 D_1^*$

$= 0.42 \times 6 = 2.52$

Again using $M_R = 10000$, $SN_2 = 3.5$

$$D_2 \geq \frac{SN_2 - SN_1^*}{a_2 m_2}$$

$m_2 = 0.95$ (from table 16-7)

$$D_2 \geq \frac{3.5 - 2.52}{0.13 \times 0.95}$$

$D_2 \geq 7.9''$

Let, $D_2^* \approx 8''$

$SN_2^* = SN_1^* + D_2^* a_2 m_2$

$\Rightarrow SN_2^* = 8 \times 0.13 \times 0.95 + 2.52$

$\Rightarrow SN_2^* = 3.5''$

Again $M_r = 1500$

$\therefore SN_3 = 6.5$

$$D_3 \geq \frac{SN_3 - SN_2^* - SN_1^*}{a_3 m_3}$$

$$\geq \frac{6.5 - 3.5 - 2.52}{0.075 \times 0.9}$$

$\geq 7.0''$

$D_3^* = 7.5''$

According to AASHTO method

6" surface

8" base

7.5" subbase

Sheet-6 : পড়ে নিব

Chapter - 20

Concrete Pavement

07-08, 06-07

Q What are the characteristics of concrete pavement?

Ans:

i) Capable of carrying almost unlimited amount of any high type of traffic with ease.

ii) Surfaces are smooth, dust free, skin resistant.

iii) Having high degree of visibility, both day and night.

iv) Low maintenance cost.

v) Economical in many locations because of low maintenance cost.

vi) Construction expansive.

07-08, 06-07

Q Types of concrete pavement.

Ans:

① Jointed plain concrete pavements (JPCP)
(Joint spacing 15' - 20')

② Jointed reinforced concrete pavements (JRCP)
(30 - 100')

③ Continuously reinforced concrete pavements (have no joints)

Q Why joints ?

Ans:

→ Joints are installed in concrete pavements to control the stresses induced by vol^{m} changes in the concrete.

→ stresses may be produced in a concrete slab because of (i) its contraction due to a uniform temperature drop (ii) its ~~expantion~~ expansion due to a uniform temperature rise.

→ The effects of the warping of pavements due to a vertical temperature differential in the slab.

07-08.

Q Types of joints ?

(i) Transverse contraction joints

(ii) Transverse ~~exp~~ construction joints

(iii) Transverse expansion joints

(iv) Longitudinal contraction and construction joints.

8] Transverse expansion joints.

ns: complete separation of two slabs.

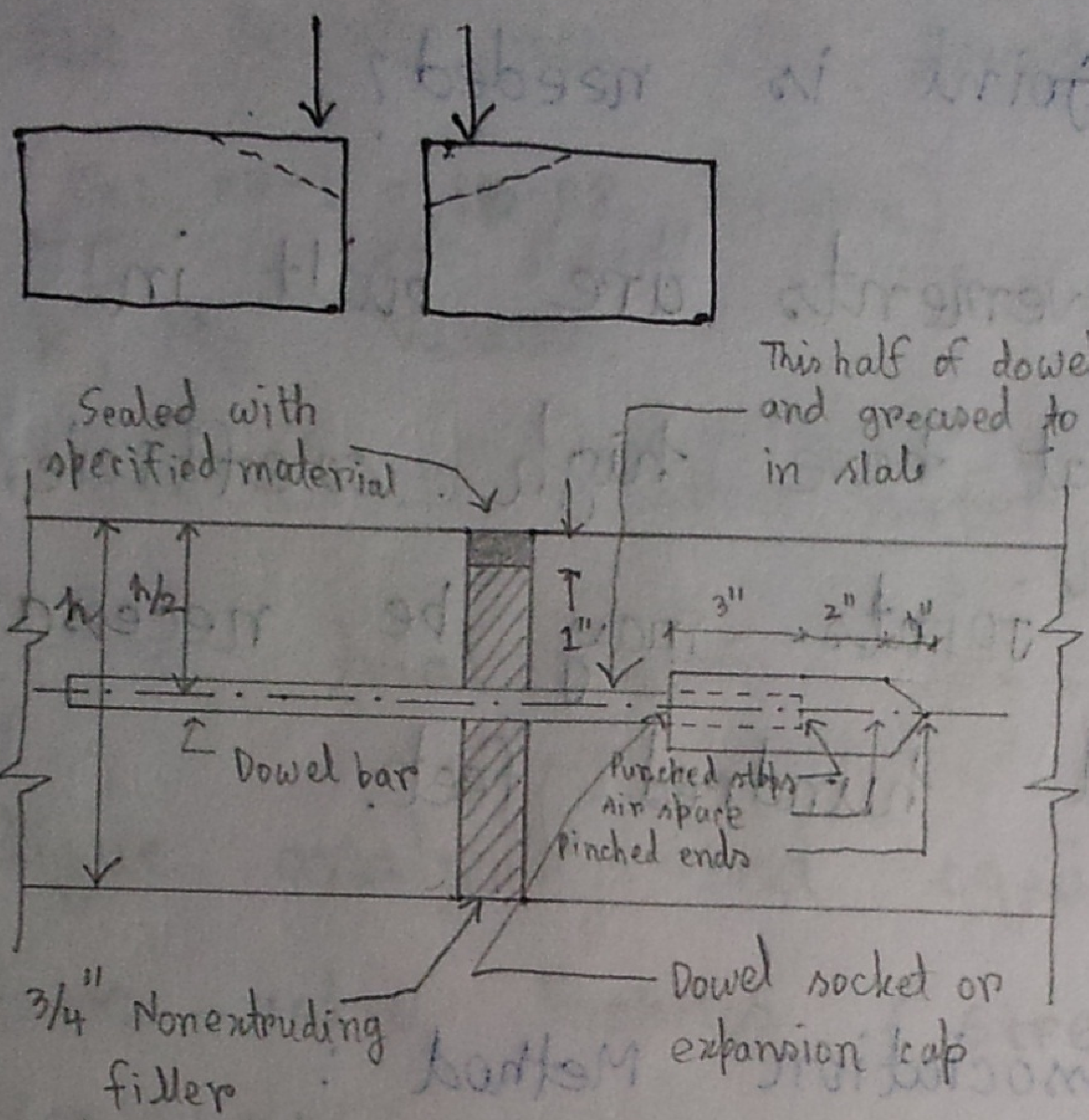


Fig: Typical doweled expansion joint.

→ expansion joints are 3/4 to 1" wide and extend the full depth of the slab.

→ Dowel bars: Length 12" to 20"

Dia 5/8" to 1.5"

Spacing 12" c/c to 15" c/c

→ The dowels must be adequate to perform their load-transfer function.

Q Briefly state the construction of expansion joint.

Q When expansion joint is needed?

Ans: If concrete pavements are built in cold weather, or of materials that have high coefficients of expansion, expansion joints may be necessary at intervals of several hundred feet.

Q Thickness design

Portland Cement Association Method :

7-08, 06-07

Design Criteria.

① Fatigue: Stress developed on inside due to repitition of wheels.

② Erosion: The effect of excessive deflection at the corner on pavement distresses, such as pumping, erosion of foundation, and joint faulting.

7-08, 06-07

Design Factors:

① Concrete Modulus of Rupture (MR)
② Subgrade and Subbase support
③ Design period (T)
④ Traffic

Q PCA method

Design steps:

1. Find the total no. of truck in the design lane. (Ex: 20-1 = 18.88 million)
2. Find k, M_R values.
3. Decide on L.S.F. (Load safety factor) → (1.2 in Ex: 20-1)
4. Assume a trial depth (= 9.5" in the ex: 20-1)
5. For fatigue analysis, find equivalent stress (Table 20-6) and stress-ratio factors (stress / M_R)
6. Find allowable repetitions from fig. 20-7
7. Find expected repetitions for each class.
8. Calculate % of fatigue use (col. 3/col. 4 * 100)
9. Find total % fatigue used (= 62.8 for the example)
10. For erosion analysis, determine erosion factors from table 20-7.
11. Find allowable repetitions from Fig. 20-8.
12. Find damage due to erosion (col. 3 / col. 6 * 100) for all classes.
13. Find the total erosion damage (= 38.9 for the example)

(14) Sum up fatigue use & erosion damage

($= 62.8 + 38.9 = 101.7$ for the example)

if the sum is

→ between 90–110%, assumed thickness is ok

→ <90, reduce thickness by 0.5" and repeat step 4–14.

→ >110, increase thickness by 0.5" and repeat step 4–14.

Example 20-1

Step-1:

design ADT = 12,900 × 1.5 = 19,350 vehicles/day

ADTT = 19,350 × 0.19 = 3680

Truck traffic each way $= \frac{3680}{2} = 1840$

Total no. of traffic in the design lane

= 0.81 × 1840 × 20 × 365

= 10.88 million trucks

Step-2:

Take,

k for subgrade = 100 lb/in^3, with a 4" untreated granulars subbase.

∴ combined k = 130 lb/in^3

M_r = 650 lb/in^2

Step-3: LSF = 1.2

Step-4: assume depth = 9.5" (slab thickness)

Step-5: equivalent stress = 206 (table 20-6)

$$\text{stress ratio} = \frac{E_s}{M_r} = \frac{206}{650} = 0.31$$

Step-6: ~~allowable load repetition~~ =

single axle load = 30 k

multiplied by LSF = 30 × 1.2 = 36 k

∴ allowable load repetition = 27000

Step-7: expected " " = 6310 (given)

$$\text{Step-8: } \% \text{ of Fatigue} = \frac{6310}{27{,}000} \times 100\%$$

$$= 23.3\%$$

step-9: Total % of fatigue = 23.3 + 19.1 + 13.1 + 5.4 + 1.9

= ~~61%~~ 62.8%

step-10: erosion Factor = 2.59 (table 20-7)

step-11: allowable repetition = 1700000 (table 20-8)

step-12: % damage = $\frac{6310}{1700000}$ = 0.4%

step-13: Total % of damage = 38.9%

step-14: sum = 62.8 + 38.9

= 101.7% $(90 < 101.7 < 110)$

OK

assumed slab thickness = 9.5" is OK.

Q Cumulative number of standard axles:

$$N_S = \frac{365 \times A \times VDF \left[(1+r)^n - 1 \right]}{r}$$

where,

A = initial traffic, in terms of number of commercial vehicles per day

VDF = vehicle damage factor

r = annual growth rate of commercial traffic

n = design life (in years)

Problem 15.2

$VDF = 3 \quad r = 10\% = 0.1 \quad n = \text{design life} = 15$

$$N_S = \frac{365 \times A \times VDF \times \left[(1+r)^n - 1 \right]}{r}$$

construction period

factor for two

$$= \frac{365 \times 1000 \, (1+0.1)^5 \times 0.75 \times 3 \left[(1+0.1)^{15} - 1 \right]}{0.1 \times 10^6}$$

million এ নেয়ার জন্য

$= 42.03$ million standard axles

$= 42.03$ msA