Lecture 1-3:

Introduction, Rationale of the Course, Highway Materials, Aggregates, Types, Tests, Blending Specification

Introduction:

What is civil engineering?

What are the works of civil engineers?

Where do the civil engineers work?

Rationale:

What is the rationale of this course? - CE 451 course/Hwy Materials in CE 451

- Why do we need this course for civil engineers?
- What is the necessity of this course material for highway/civil engineers?
- What is the importance of study of materials for civil engineers?
- Materials course is of utmost importance for civil/highway engineers – justify

Materials for Civil Engineering Constructions:

Five groups of all CE Materials are,

- Materials occupying main volume,-- brick, aggregates
  - imparts stability and strength
- Materials for binding, -- cement, bitumen
  - Stability, strength, allowable deformation
- Materials for reinforcement, -- MS bar, Geo-textile
  - Added strength, size reduction
- Materials for protection, -- plaster, coats
  - Prevents deterioration
- Materials for decoration, -- boards, papers, facing materials
  - Improves aesthetic quality

Materials for Construction in Developing Countries:

- Locally available material, surki, gangoo etc
- Low grade materials, local aggregates, bricks
-

Special Materials for Roads, Highways/Airfield, Landing Strips Constructions

Definitions of terms to be used in Tender Document and/or in Contract

what is standard? who use them?

1) Standard:

Defn.:

Standard is a document that has been developed and established within the consensus principles of a 'society' and that meets the approval requirements of the society procedures and regulations.

Sandards are used by –

- Individuals, companies, scientists, engineers, architects, designers, Govt. agencies

2) Specification:

Defn.:

Specification is a precise statement of a set of requirements to be satisfied by a material, product, system or service that indicates the procedures for determining whether each of the requirements is satisfactory.

Specification requirements are –

- Numerical, appropriate units, limits and tolerances

Specification agencies: National—BSTI
International – ASTM, AASHTO, BS, IS (Indian standards), JIS

3) Test Method:

Defn.: Test method is a definite procedure for the identification, measurement and evaluation of one or more qualities, characteristics or properties of a material, product, system or service that produces a test result → এটা requirement

Test methods used in Bangladesh:

- National: BDS – by BSTI
- International: ASTM, BS, ISO etc.

Tender doc:

যেটায় কাজের সব বিবরণ থাকে

(*) specification বানাতে standard & test method লাগে।

The specification of aggregat: ACV ≯ 30 → value (ACV = name of test)

এটার Test standard বলতে হবে

BS 812

এটা ঠিক করেছে British standard Institue

BSTI: Bd standards and testing institution

ASTM: American society for testing & materials

AGGREGATES:

Chapter -19

Chapter -15

1. Text Book: HIGHWAY ENGINEERING [$6^{TH}/7^{TH}$ Edition] –Paul Wright & Karen Dixon

2. Information on aggregates in different sheets

Aggregates: Definition, types, classification, sources, uses, tests and specifications

Definition of Aggregate:

Aggregate is an aggregation of non-metallic minerals obtained in particulate form and can be processed and used for civil and highway engineering constructions

Classification of Aggregates:

- Based on source
  - Natural: crushed stones, crushed boulders, gravels, shingles, sands, etc
  - Artificial: crushed brick, clay +pfa, synthetic etc.
- Based on size
  - Coarse aggregate, CA – passing max size and retained on 4.75 mm sieve
  - Fine aggregate, FA – passing 4.75 mm sieve and retained on 0.15/.075 mm sieve
  - Silt and clay or dust or fines or filler – passing .075 mm sieve
- Based on weight (sp.gr.)
  - Normal weight: bulk unit weight, 1520-1680 kg/m^3 (95-105 pcf), so that normal wt. concrete (NWC) has a unit wt. 150 lb/cft (2400 kg/m^3)
  - Light weight: bulk unit wt. less than 1120 kg/m^3
  - Heavy weight: bulk unit wt. more than 130pcf (2080 kg/m^3)

Properties of Aggregates: Text book- 15-8.1 [Pg. 412] What are the properties of aggregate? → only name

- **Particle size and gradation**
- **H**ardness
- **D**urability
- **Sg** specific gravity
- **Cs** chemical stability
- **Ps**
- **Ds** Deleterious substances

→ এটা বললে এটুকু বর্ণনা দিতে হবে

Question: Briefly state the properties of aggregates for highway construction (from book)

How to evaluate this property

Aggregates work in a mass, so their size distribution, shape and texture are important characteristics along with their strength (individual or in mass).

- Aggregate particle strength
- Aggregates mass strength

The density, voids, compactibility, shear strength etc. largely depends on the characteristics like

- Size distribution
- Shape
- Surface texture

Grading:

The distribution of particle sizes (d) within any batch of aggregate is called gra

- Expressed as a cumulative% of particles that are smaller than each o sieve openings
- The percentages are customarily presented in graphical form known as gra curve or sieve curve
- Theoretically, y = f (d)
- Grading types
    - Continuous
    - Wellgraded $p = (d/D)^{0.5} \times 100$
    - Skip or gap graded
    - Uniform
    - Single graded

Question: Why is grading important for any aggregate construction?

Fineness Modulus (F.M)

F.M. is a numerical characteristics of aggregates, especially for fine aggregates. The original definition by Abrams is

> *The F.M. is obtained by adding the total percentages of an aggregate sample retained on each of a specified Tyler sieve series(?) and dividing the sum by 100, Fineness Modulus,*

- Represents an average particle size
- Proportional to the logarithmic avg. particle size of grading
- Fundamental parameter of the particle size distribution

Question: What is the difference between grading and fineness modulus?

Blending of Aggregates

- What is it?
- Why is needed?
- **How is done? (mix design methods)**

Testing of aggregates:

- Grading, Fineness Modulus
- Strength tests
- Durability tests
- Other tests

Strength tests of aggregates:

- ASTM tests (sheet given for concrete aggs.) - L. A. Abrasion test – Pg. 414 (W&D)
- BS tests for strength and crushing characteristics

¤AIV test ¤ACV test ¤10% Fines Value test ¤ AAV test

①,②,③ দিলে যে কাজ হবে L.A. abrasion দিয়ে একই কাজ হবে

Absorption test: absorption capacity, effective absorption, surface moisture, air dry, oven dry. SSD (saturated surface dry),

concrete const. এ বেশি দরকার hydration এর পানি কতটা থাকবে তাহার জন্য agg. কতটা পানি শোষণ করবে জানতে হবে.

- ASTM C 127
  - Apparent specific gravity
  - Bulk specific gravity (ssd basis)
  - Bulk specific gravity (o-d basis)

Durability tests – % water absorption

- Soundness by sodium sulphate
- Soundness by magnesium sulfate
- Wet and dry test
- Freeze and thaw test

Other tests of aggregates

As per sheets given

Specification of aggregates

As per sheets given

SAND:

Sand is mostly used as fine aggregate in cement concrete and asphaltic concrete

Definition: Sand is a loose, fragmented, naturally occurring material consisting of very small particles of decomposed rocks, corals, or shells. It is basically aggregate and called fine aggregate for building and road construction. Based on size, and is divided into,

- *Very fine sand [1/16 – 1/8 mm]*
- *Fine sand [1/8 – ¼ mm]*
- *Medium sand [¼ - ½ mm]*
- *Coarse sand [½ - 1 mm]*
- *Very coarse sand [1 – 2 mm]*

Sources of sand: based on the source, sand may be divided into,

- River sand: obtained from river bed and banks or by river dredging, round and polished, contains earthy impurities, gravels etc., white in color, globular and smaller in size, some of them are of best quality and least expensive and suitable for plastering work.

- Pit sand: obtained by pit dredging in the flood plain and lake sides, sharp, angular, homogeneous, soft, porous and free from salt, yellowish or light brown in color, most suitable sand for mortar.

- Sea sand: obtained from sea shore and sea beaches, fine, sound and polished, low quality and contains sea salt and causes efflorescence and dampness, should not be used in mortars, plasters, should be washed before use if the salt content is less than 0.5%.

Functions of sand:

- well graded sand increases density in an aggregate mass
- subdivides the paste of binding material into thin film
- offers requisite surface area
- acts as medium between stones and cementing material
- prevents shrinkage of cementing material

Properties of good sand: good sand for most civil engineering works should be,

- sharp,
- strong
- angular
- durable
- hard grains
- pure silica (SiO_2)

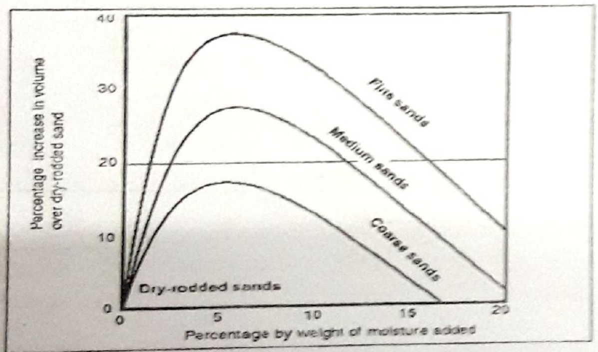
- Sand should be free from - coatings of foreign matter
  - clay, silt, and
  - organic matter

Uses of sand: sand as an engineering material has versatile use in,

- sand is often one of the principal component of concrete
- sand is used in foundry for sand casting
- graded sand is used as an abrasive in sandblasting
- sand is used as filter media
- sand in one of the principal constituent of clay bricks, glass manufacturing etc.
- sand is used in landscaping, construction of golf courses, sea beaches etc.
- sandbags are used for protection against flood, gun fire
- sand is used in railroads to improve the traction of wheels on the rails
- sand is used in the plastering work and in mortar
- sand is used in improved subgrade, subbase and base courses of pavements
- sand is used as a bedding course and cheap filler material for brick and block pavement
- sand is sometimes used for lining of aquariums

imp **Moisture content and bulking of sand**:

Water film around sand particles create a barrier thus increasing the inter-particle distance and the volume increases over the real volume at zero moisture content. This is bulking of sand. At certain moisture level the barrier breaks and volume decreases. So when sand is completely under water the volume is same as dry volume. Coarse graded sand has around 18% bulking at 5% m/c while fine grained sand has 34% bulking at 7% m/c



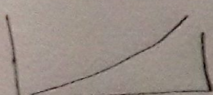
বালি ফুলে যায়। অল্প পানি দিলে এটা particle সরে যায় & ফুলে যায়। বালি ফুলে থাকে, so vol^m basis এ দিলে বেশি বালি দেয়া হচ্ছে, so Always wt এর ratio তে মিশাতে হবে। যেটা যত fine সেটা তত ফুলবে।

Tests of sand:

- Sieve analysis and gradation/Fineness Modulus (FM) of sand
- Shear strength of sand
- Percentage of silt and clay
- Presence of salt → imp → Aflocence test on brick
- Presence of organic impurities

Specification of sand:

Depends on the type of use and project.



এই portion sand

Question: Why is sand necessary for any aggregate construction?

gradation এর finer portion will be sand. we cannot fill the voids of agg without sand. so any gradation is not possible without sand.

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Bangladesh University of Engineering and Technology, Dhaka-1000

Department of Civil Engineering

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not for exam

Name of Tests	Test Rate (Tk.)
Aggregates (Sample Preparation Charge Tk.2000 per Sample)	
Sieve analysis (CA) / Gradation /FM (CA)	6,800
Sieve analysis (CA) / Gradation (Base/subbase)	10,600
Sieve analysis / Gradation / FM (CA) (Ballast)	8,700
Sieve analysis / Gradation / FM (CA) (Ballast)/Specified Sieve size	11,500
Sieve analysis (FA) / FM	3,800
Material finer than # 200 sieve / Fine content/Silt content	3,800
Aggregate crushing value(ACV) / Compressive Strength	7,700
Aggregate Impact value (AIV)	5,700
Ten percent fine value (TFV)	11,500
Angularity number (Including sp. gr.)	9,600
Elongation Index (EI) / Shape Test	8,700
Flakiness Index (FI)	8,000
L.A. Abrasion of CA	7,700
L.A. Abrasion of Ballast	8,000
Unit weight of aggregate (CA)	5,000
Unit weight of aggregate (FA)	4,500
Soundness with Na2SO4 (4000/- for chem.)	19,200
Soundness with Mg2SO4 (6000/- for chem.)	19,200
Absorption and Specific Gravity / Density (for Ballast)	6,800
Clay lump & friable particles	5,700
Moisture Content	2,900
Percentage of Uncrushed Particle (Fractured face)	8,700
Mica Content of Fine Sand using Microscope	26,200
Mica Content of Fine Sand / CA by visual observation	16,600
Effect of organic Impurities (1300/- for chem)	19,200
Organic Impurities/Salt content / Sulphate content / Salinity	4,000
Bulking of sand	5500/15000
Void Ratio / Porosity / Moh. Hardness	7,700
CBR of Base or Sub-base material	59,800
Standard Proctor test of aggregate (MDD)	24,100
Modified Proctor or Vibrating Hammer	39,500

Sl. No.	Name of Tests	Test Rate (Tk.)
	Bitumen (Sample Preparation Charge Tk.3000 per Sample)	
1	Specific gravity / Sp. Gr. / Density	5,200
2	Penetration / Grading	5,200
3	Naphta Xylene Equivalent	22,200
4	Flash & Fire points	5,200
5	Solubility (300/- for Chem.)	5,900
6	Ductility (300/- for Chem.)	5,900
7	Softening point (R&B) (300/- for Chem.)	5,900
8	Thin Film Oven / Loss-on-heating	6,400
9	Float test	5,200
10	Foaming Test	5,200
11	Spot Test	5,200
12	Viscosity, Saybolt Furol (S.F.)	9,600
13	Viscosity (Kinematic)	12,800
14	Viscosity (Absolute / Dynamic)	19,200
15	Ash Content / Inorganic Matter	9,600
16	Any test on residue from Loss on heating test/TFOT (if TFOT/LOH included separately)	9,600
	Any test on residue from Loss on heating test/TFOT (if TFOT/LOH not included separately)	16,100
17	Any test on residue fromThin Film Oven test	15,400
18	Coating & Stripping test with/without Anti-Stripping Agent/Dose	7,300
19	Asphalt Concrete Mix Design (Marshall)	81,500
20	Particle Charge Test of Bitumen Emulsion	6,100
	Asphalt or Bituminous Material / Pavement Core (Sample Preparation Charge Tk.3000 per Sample)	
21	Bitumen content (4000/- for Chemical)	15,400
22	Water Content	11,500
23	Theoretical Max. Sp. Gr.	7,700
24	Density	3,800
25	Marshall Stability and Flow Test	6,800
26	In-Situ per core cutting	11500+Field Visit
27	Job Mix Formula & Marshall Test	131,000
28	TSR (Tensile strength ratio) Test	81,500

Bricks (Bricks needed for ASTM = 5 Nos., BS = 10 Nos.)	
Absorption (ASTM / BS Standard)	2,400 /4,600
Crushing strength(ASTM / BS Stand; 300/400/- capping mat.)	4,800 / 7,900
Size & shape (ASTM / BS Standard)	3,100 / 3,100
Unit Weight (ASTM / BS Standard); 200/300 for L.C.	4,300 /5,700
Unit Wt. & Absorption (ASTM / BS Stand); 200/300 for L.C.	6,100 /9,100

Sl. No.	R.C.C Pipes	
1	Pipes (dia up to 600mm)	7,200
2	Pipes (dia above 600mm and up to 900mm)	7,900
3	Pipes (dia above 900mm and up to 1200mm)	10,200
4	Pipes (dia above 1200mm and up to 1524mm)	13,000
5	In-situ pipe testing	[illegible]

Sheet # 6/July '14

Jamuna bridge এর জন্য যেগুলো করতে হবে।

Table 3.12.1: Tests for Concrete Aggregates

		Test	Limits
1.	Description and Classification of materials	BS 812: Part 1:1975 Section 6	as specified (cement concrete)
2.	Particle size distribution by sieve analysis	BS 812: Part 1:1975 Test method 7.1	as specified
3.	Clay, fine silt and fine dust 5% in fine or coarse 7.2.4	BS 812: Part 1:1975 Test method sands, 1% mix. for natural or crushed gravel coarse aggregates. 3% max. for crushed rock coarse aggregates.	3% max. for natural or crushed gravel sands, max. for crushed stone
4.	Clay lumps	ASTM C-142: 1978	3% max. for fine aggregate, 2% max. for coarse aggregate
5.	Flakiness Index	BS 812: Part 1:1975 Test 7.3	25% max. for all coarse aggregate test fractions
6.	Elongation Index	BS 812: Part 1:1975 Test 7.4	25% max. for all coarse aggregate test fractions
7.	Angularity Number	BS 812: Part 1:1975 Test 7.5	9 or 10. To be confirmed by the Engineer
8.	Determination of Relative Densities and Water Absorption	BS 812: Part 2:1975 Tests 5	Water absorption - 2.5% , max. for all aggregates
9.	Determination of Bulk Density and Voids and Bulk-Aggregates	BS 812: Part 2:1975 Test 6.3	To be determined by the Engineer from test ·ing of results
10.	Field Settling Test	BS 812: Part 1:1975 Test 7.2.5	To be determined by the Engineer from test results
11.	10% Fines Value	BS 812: Part 3:1975	For concrete Class 40 and above not less than 100kN. For other con-crete not less than 50kN

Aggregate Crushing Value (ACV) and Ten Per cent Fines Value, after subjecting them to different cycles of wetting and drying. Each cycle of wetting and drying was consisted of 24 hours of wetting followed by a 24 hours of drying in the oven at a temperature of 110°C. Fig. 2 shows the variation of strength, in terms of ACV and 10 per cent fines value, for different number of cycles of wetting and drying.

TABLE 2. INTRINSIC PROPERTIES OF BRICK AGGREGATES

Name of test	Test designation	Average value
Shape & Texture of Coarse Particles	BS 812 : 1975	Angular & rough
Aggregate Impact Value	"	32
Ten Per cent Fines Value	"	70
Aggregate Crushing Value	"	36
Angularity Number] average	"	9
Flakiness Index] result of	"	19
Elongation Index] all sizes	"	34
Los Angeles Abrasion Value	ASTM C 131-81	37
Soundness Value	TRRL LR 293	20
Oven Dried Relative Density	BS 812 : 1975	1.85
Absorption Value	"	15

Density—moisture content : Compaction tests were performed for aggregate mixtures in all five gradings to find the optimum moisture contents (OMC) and dry densities. Compaction was carried out by BS vibratory hammer technique (BSI : 1977). Results of compaction test for grading type 'Dense' are shown in Figs. 3 (a) and 3(b).

Bearing ratio tests : Load bearing capacities of the compacted aggregate mixtures were determined by a recently devised Modified Bearing Ratio (MBR) test. MBR test method is suitable for larger sized base/subbase aggregate and was developed by Lees and Bindra (1982) to avoid the worst of the problems associated with the inherent confining effect of CBR mould. In this test the aggregate mixture is compacted in a 400 mm diameter by 250 mm high cylindrical mould applying an equivalent compactive effort to that of the CBR mould. MBR value is determined from the load penetration plot obtained during penetration of a 100 mm diameter plunger in the centre of the mould with an equivalent CBR surcharge weight. The maximum size of aggregate using this plunger could be 40 mm.

Compaction of MBR specimens were performed by a heavy duty, electrically driven, vibrating Kango hammer having a power consumption of 0.75 kw with a 100 mm diameter tamping foot. The compactive effort applied was equivalent to.

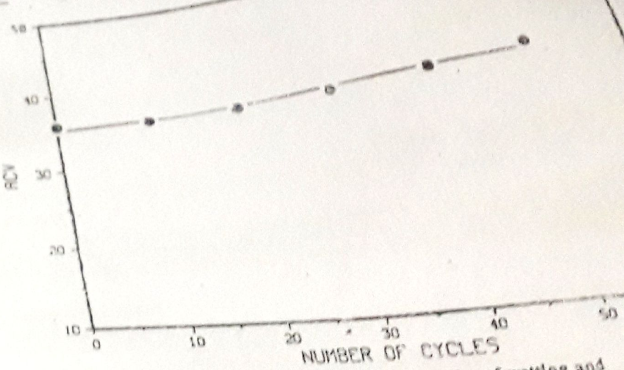

Fig. 2(a). Variation of ACV with different cycles of wetting and drying for brick aggregate

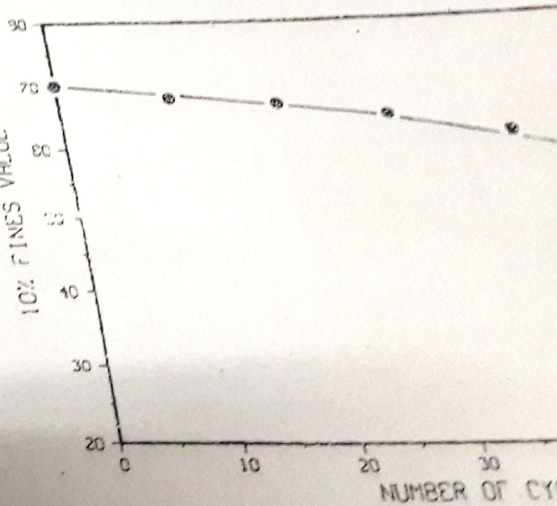

Fig. 2(b). Variation of 10 per cent fines value

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Sheet # 10/July '14

20 Bituminous Materials

20.1. BITUMEN

20.1.1. Historical

As early as 5000 years ago, bitumen was used by man as a waterproofing and bonding agent. The ancient civilisation in Mesopotamia was familiar with bitumen, which was used for mummification, cementing building blocks and waterproofing irrigation channels. In Mohanjodrao in the Indus Valley, a ritual pool waterproofed with a layer of bitumen on the walls has been found. The use of bitumen on roads in recent times picked up in the nineteenth century. Natural rock asphalt was initially used, but as petroleum distillation began to grow as an industry to fuel the road vehicles, the residue found equally increasing use in constructing better roads.

20.1.2. Definition of terms

There is some intermixing of terms such as bitumen and asphalt. Different countries attach different meanings to these terms. American teminology uses the name "Asphalt" for substances known by the name "Bitumen" in British terminology. Some of the terms are described below.

Bitumen, in British terminology, is defined as a viscous liquid, or a solid, consisting essentially of hydrocarbons and their derivatives, which is soluble in carbon disulphide. It is substantially non-volatile and softens gradually when heated. It is black or brown in colour and possesses waterproofing and adhesive properties. It is obtained by refinery processes from petroleum, in which case it is known as "petroleum bitumen". It is also found as a natural deposit, in which case it is known as "native bitumen" or "natural bitumen".

Asphalt, in British terminology, is a natural or mechanical mixture in which bitumen is associated with a substantial proportion of inert matter. If found in lakes, as in Trinidad, it is known as "Lake Asphalt". If found as a naturally occurring calcareous rock (*e.g.* in Italy and Switzerland), it is known as "Rock Asphalt".

In American terminology, the materials coming under the two British terms "Bitumen" and "Asphalt" are commonly known as "Asphalt".

Asphaltic Cement or Asphalt Cement is a binder, consisting of bitumen, or a mixture of lake asphalt and bitumen or lake asphalt and flux oils or pitch/bitumen.

In India, the definition of bitumen is generally on the lines of British practice. "Asphalt" refers to the mixture of bitumen and intert mineral matter, again in conformity with British practice.

A "straight-run bitumen" is a petroleum bitumen of which the viscosity composition has not been adjusted by blending or by softening with fluxing or cutting-back oil or by any other treatment.

"Penetration grade bitumen" is a bitumen whose degree of hardness can be measured by the standard penetration test.

A "blown bitumen" is a bitumen obtained by further treatment of straight run bitumen by running it, while hot, into a vertical column and blowing air through it. In this process, bitumen undergoes a chemical change as a result of which it attains a rubbery consistency, has a higher softening point than a straight-run bitumen of the same hardness and a greater resistance of flow (Ref. 4).

20.1.3. Manufacture of bitumen

Crude oils, the main source for bitumen, differ among themselves in their physical and chemical properties. Paraffinic crudes yield an undesirable wax or wax-like residue on distillation. Some varieties of Indian crude are overly paraffinic with low asphaltene content and, therefore, not considered the best for bitumen manufacture. Naphthenic crudes yield substantially wax-free bitumens and mixed base crudes yield bitumens containing wax in some proportions. The petroleum crude imported from the Middle East yields good bitumen.

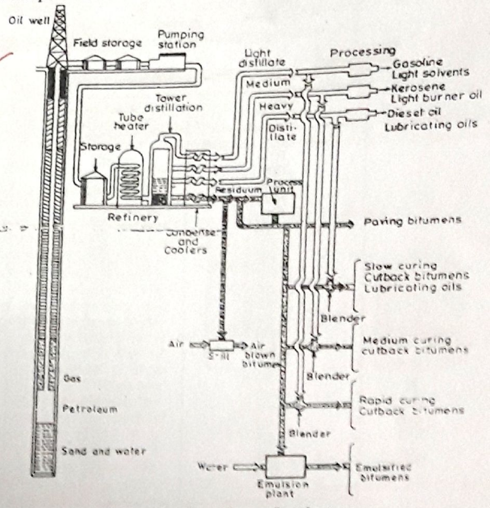


Fig. 20.1. Petroleum bitumen flow chart.

of the petroleum crude in refineries is carried out on the principle of ion". The crude oil is heated in a tube-still. The volatiles are separated in mn (Fig. 20.1). Gasoline, kerosene, gas oil and heavy oil get separated thus to the fractionating column to assist in the process. The residue is collected

n refining process, the distillation is achieved in two or three stages. In the de oil is first passed through a tube still operating at a relatively low han 350°C), to take off, in a fractioning column operating at atmospheric nds of the crude oil, *i.e.*, naphtha/gasoline and kerosene. The "topped crude" gh another still for subsequent transfer to another column operating under ssistance of steam injection. A more modern system dispenses with steam s on dry vacuum only, thus enabling a wider range of bitumens to be

of bitumen in India

ves the quantity of bitumen produced in Indian refineries for the past few

Table 20.1. Production of bitumen in India

Year	*Production (Thousand tonnes)*
1970	765
1971	982
1972	1090
1973	1167
1974	873
1975	708
1976	884
1977	959
1978	1025
1979	1027
1980	1103
1981	1082
1982	1298
1983	1397
1984	1069
1985	944
1986	1107
1987	1124
1988	1374
1991	1603
1992	1710
1993	1862
1994	1874
1995	1845

at over one million tonnes of bitumen are produced yearly, and nearly the sumed. Very little is imported and very little is exported.

20.1.5. General properties of bitumen

The general properties of bitumen are enumerated below :

(*i*) They contain predominantly hydrocarbons, with small quantities of sulphur, oxygen, nitrogen and metals.

(*ii*) They are predominantly soluble in carbon disulphide (CS_2) the portion insoluble in CS_2 being generally less than 0.1%.

(*iii*) Most bitumens are colloidal in nature.

(*iv*) Bitumens are thermoplastic, *i.e.* they soften on heating and harden on cooling.

(*v*) They have no specific melting point, boiling point or freezing point, though a form of softening point (Ring and Ball) is used in their characterisation.

(*vi*) Bitumens are insoluble in water.

(*vii*) They are highly impermeable to the passage of water.

(*viii*) They are generally hydrophobic (water-repellent), but may be made hydrophillic (water liking) by the addition of small quantity of surface active agents.

(*ix*) They are chemically inert.

(*x*) They oxidise slowly.

For satisfactory performance as a road material, bitumen should have the following desirable properties :

1. It should be fluid enough at the time of mixing to coat the aggregates evenly by a thin film. Fluidity is achieved either by heating or by cutting-back with a thin flux or by emulsifying the bitumen.

2. It should have low temperature susceptibility, or in other words, it should exhibit little change in viscosity with change in temperature. At least within the range of temperatures prevailing on the road, it should show uniform viscosity characteristics. This property becomes very difficult of fulfilment in the case of regions having wide temperature range as in Northern India. If the binder has low temperature susceptibility, it will not become soft during the summer months nor hard and brittle in the cold months.

3. The bitumen should have a good amount of volatiles in it, and it should not lose them excessively when subjected to higher temperature. This will ensure its durability.

4. The bitumen should be ductile and not brittle.

5. The bitumen should be capable of being heated to the temperatures at which it can be easily mixed without any fire harzards.

6. The bitumen should have good affinity to the aggregates and should not be stripped off in the continued presence of water.

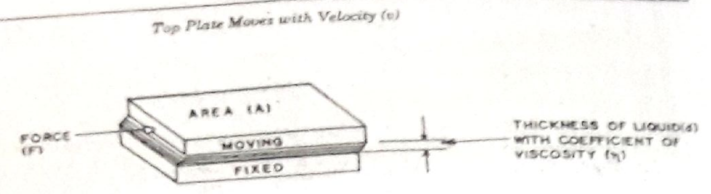
20.1.6. Viscosity of bitumen

Viscosity is the property of a fluid that determines the resistance offered by the fluid to a shearing force under laminar flow conditions. It is thus the opposite of fluidity.

Dynamic or absolute viscosity (symbol η) is the internal friction resulting from unit tangential force acting on planes of unit area separated by unit distance of the fluid, producing unit tangential velocity (Fig. 20.2).

The unit of measurement of the dynamic viscosity in S.I. Units is Ns/m^2 (Newton second per sq. metre) and in C.G.S. unit is Poise (dyne sec per sq. cm.) 1 Ns/m^2 = 10 Poise.

30



For simple liquids $F = \eta \frac{A.v}{d}$ i.e. $\eta = \frac{F.d}{A.v}$

Fig. 20.2. Concept of viscosity.

Kinematic viscosity (symbol η) is the quotient of the dynamic viscosity and the density of fluid (ρ). Thus

$$\gamma = \frac{\eta}{\rho} \quad ...(20.1)$$

The unit of kinematic viscosity is sq. m per second (m^2/sec) in S.I. Units and Stoke (cm^2/sec) in C.G.S. Units.

One centistoke = 0.01 Stoke

One centipoise = 0.01 Poise.

The determination of viscosity is generally done by efflux viscometers. They work on common principles, though they differ in detail. The liquid under test is poured to a specified level into a container (Fig. 20.3) surrounded by water or oil bath, providing temperature control. At the base of the container is a small orifice with a simple valve control. On opening the valve, the time in seconds is recorded for a stated quantity of liquid to discharge into a measuring liquid below.

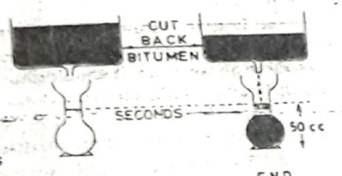


Fig. 20.3. Viscosity test.

The viscometers commonly used are :

(*i*) STV (Standard Tar Viscometer) for cut-backs (10 mm dia orifice and 50 ml of fluid to discharge)

(*ii*) Saybolt Furol Viscometer (for bitumen) (3 mm dia orifice and 60 ml of fluid to discharge)

(*iii*) Redwood Viscometer (4 mm dia orifice and 50 ml of fluid)

(*iv*) Engler Viscometer (for emulsions) (3 mm dia orifice and 200 ml of fluid to discharge).

These efflux viscometers determine viscosity in an indirect manner by measuring the time taken for flow through the orifice. The time measured does not bear any relation to the absolute velocity.

Another disadvantage of the efflux type viscometers is that when penetration grade bitumen is tested, it has to be heated to temperatures generally in excess of those expected under service conditions. In order to overcome this drawback, a sliding plate viscometer is used. The principle is illustrated in Fig. 20.2. A thin film of bitumen, of thickness approximately 20—50 microns, is formed between two glass plates 3 × 2 × 0.7 cm thick. One plate is fixed and the other attached to a loading device, the whole assembly being immersed in a thermostatically controlled water bath. The degree and rate of movement of the plate to which load is applied is measured electronically.

20.1.7. Penetration tests

An indirect measure of viscosity is the amount of penetration of a standard needle under standard conditions of load, time and temperature. The test measures the hardness or softness of biumen in terms of penetration, expressed in units of mm/10 of the standard needle. The apparatus is indicated in Fig. 20.4. The standard conditions selected are :

Temperature	:	25°C (test to be performed after sample is kept for one hour in water-bath at this temperature).
Load on needle	:	100 gms.
Time in which penetration is recorded	:	5 secs.

The penetration is measured by a graduated dial. Owing to limitations in the dimensions of the needle and other conditions, penetrations less than 2 and greater than 500 cannot be determined satisfactorily. If log (penetration) is plotted against temperature, practically a straight line is obtained. This enables extrapolation of values.

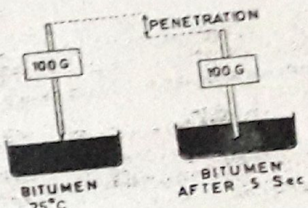


Fig. 20.4. Penetration test.

Penetration values and absolute viscosity cannot be correlated precisely.

A bitumen of penetration 80/100 signifies that the range of penetration of the bitumen is 80—100, expressed in tenths of a millimetre. The lower the penetration value, the harder is the grade of bitumen.

20.1.8. Softening point

A viscous material like bitumen or tar does not have a well defined softening point. However, a standard test determines the temperature at which a standard ball will pass through a disc of bitumen contained in a ring. The test is known as the "Ring and Ball test" (Fig. 20.5). A brass ring containing the bitumen sample is suspended in water or glycerine at a given temperature. A steel ball is placed on the disc of bitumen. The liquid medium is then heated at the rate of 5°C increase per minute. The temperature at which the softened bituminous material touches the bottom metal plate placed at a specified distance below the ring is recorded as the softening point. The hardest grade of bitumen in India is 30/40, which has a softening point of 50—65° C. The soft paving bitumen is 180/200 grade, having a softening point of 30—45°C.

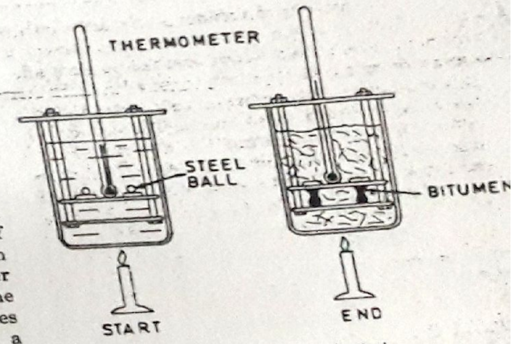


Fig. 20.5. Softening point test.

20.1.9. Temperature susceptibility

The rate of change of viscosity or consistency of a given bitumen determines its temperature susceptibility. This property is of great use in designing satisfactory bituminous mixes for use under any given range of temperature change. The criterion is that the bitumen should exhibit as little change as possible in its viscosity in the given range of temperature change. The most common method to characterise temperature susceptibility is to find the Penetration Index (PI). Plotting log penetration against temperature, one gets :

$$\log(\text{pen}) = AT + K \quad \text{...(20.2)}$$

The slope of the line A is an indication of temperature susceptibility (Fig. 20.6).

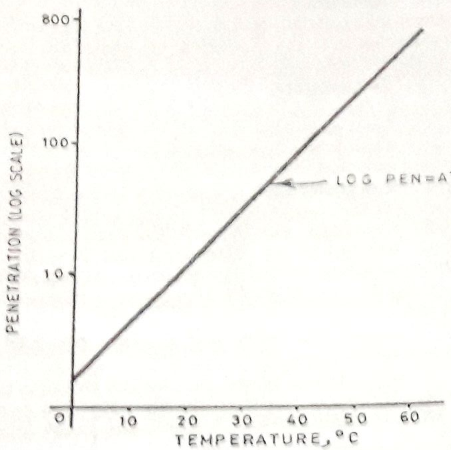


Fig. 20.6. Penetration temperature test.

20.1.10. Ductility

The ductility of a binder is an indication of its elasticity and ability to deform under load and return to original condition upon removal of the load. A material which does not possess adequate ductility would crack under a load. This is unsatisfactory since water can penetrate into the surfacing through these cracks. The property is determined by measuring the distance that a standard briquette of bitumen, necked to a cross-section of 1 sq cm will stretch without breaking when elongated at a rate of 5 cm/min at 27°C. (Fig. 20.7). The ductility value should be a minimum of 50 as per I.S. (Ref. 5). Since the conditions of this test are entirely arbitrary, and unrelated to the conditions of actual use in the field, there is some doubt as to the value of this test.

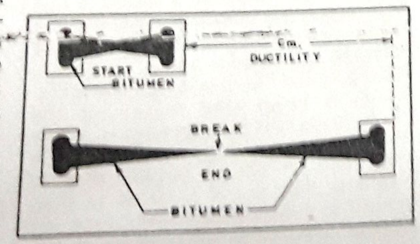


Fig. 20.7. Ductility test.

20.1.11. Brittleness

Brittleness is the state when fracture occurs without appreciable deformation at low stress. This property is very important in determining the desirable properties of a bituminous mixture. The Fraass Break Point test is the most generally adopted procedure for determining brittleness. The test involves a thin film of bitumen (0.5 mm thick) formed on a flexible metal plaque. The film is bent under standardised conditions. The Break Point is that temperature at which cracking occurs.

20.1.12. Heat stability

All bituminous binders undergo changes in their properties with heat. The binders become fluid at temperatures around 90°C above their softening point, and upto these temperatures, such changes in their properties are reversible. At higher temperatures, however, more important changes take place. These effects are studied by three tests :

(*i*) Flash point

(*ii*) Fire point and spontaneous ignition temperature

(*iii*) Loss on heating.

The Flash Point of a bitumen is that temperature at which it gives off vapours, which ignite in the presence of a flame, but do not continue to burn. The Flash Point is an indication of the critical temperature at and above which suitable precautions should be taken to eliminate fire hazards. The ISI test describes the Pensky-Martin Method (Ref. 6). The method involves a cup into which the bitumen is filled. (Fig. 20.8). The bitumen sample is then heated at a rate of 5—6°C per minute, stirring the material constantly. The test flame is applied at intervals. The flash point is taken as the temperature read on the thermometer when the flame causes a bright flash in the interior of the cup in a closed system and at the surface of the material in an open system.

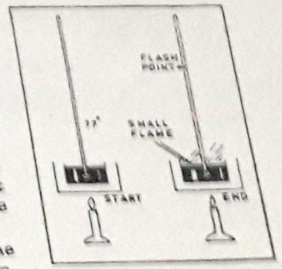


Fig. 20.8. Flash point test.

If heating is continued beyond the flash point, the vapours ignite in the presence of a flame and continue to burn, indicating the 'Fire Point' temperature. There is no standard method to determine the Spontaneous Ignition Temperature, which can only be broadly indicated.

The effect of heat on a bituminous binder is the loss of volatile constituents. This loss causes the binder to harden. Thus, the method of testing the desirable property of a binder is to find out the loss on heating. This is achieved by an accelerated heating test. A 50 gm sample is taken and maintained at a temperature of 163°C for 5 hours. The loss in weight expressed as a percentage of the original weight is determined. Indian specifications (Ref. 5) stipulate a maximum 1 per cent loss for all bitumens except 180/200 pen, for which the maximum is 2 per cent. The penetration of the bitumen after the test is also determined and expressed as a percentage of the original penetration. It should be a minimum of 60 per cent.

20.1.13. Solubility

It has already been indicated that all bitumens are substantially soluble in CS_2. This is one of the points that define a bitumen. Insolubles indicate the presence of mineral matter. The Indian specifications require 99 per cent solubility.

20.1.14. Specific gravity

Specific gravity of a binder does not influence its behaviour. But all the same, its valu is needed in mix design. The property is determined at 27°C, by a pycnometer or by preparin a cube of a sample. The specific gravity of road-making bitumens varies from 1.02 to 1.04. Ta have a higher specific gravity (1.16—1.28).

20.1.15. Thin Film Oven Test

In this test, a sample of bitumen is subjected to hardening conditions as would be expected during hot mixing operations. A 50 ml sample of bitumen is placed in a flat bottomed sample pan 140 mm inside diameter and 10 mm deep. The weighed sample and container are placed in a shelf which rotates at 5 to 6 r.p.m for 5 hours in a ventilated oven (Fig. 20.9) maintained at 163°C. The loss in weight of the sample is expressed as a percentage of the original weight. The hardened bitumen sample is then poured into a container for use in the viscosity or penetration test.

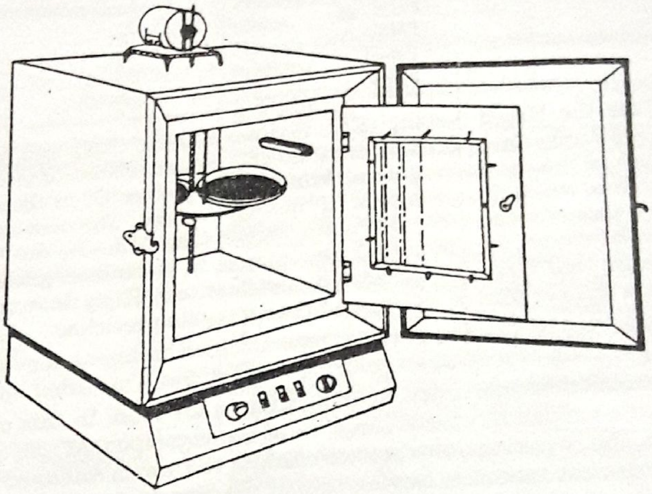


Fig. 20.9. Thin film oven test.

A Rolling Thin Film Oven Test (RTFOT) is a similar test which is considered to simulate the short term ageing or hardening that occurs during the mixing process.

20.1.16. I.S. requirements for paving bitumens

The Indian Standard requirements for paving bitumens are given in Table 20.2 on next page.

20.1.17. Cutbacks

All hard penetration grade bitumens require to be heated to a specified temperature during use so as to bring down the viscosity to a value at which the coating of the aggregates with the binder film becomes possible; the aggregates also have to be heated. To overcome this difficulty, cut-backs are used. A cut-back is a bitumen, the viscosity of which has been reduced by a volatile diluent. Depending upon the diluent used, there are three types of cut-backs :

Rapid-Curing (RC)	:	Bitumen which has been fluxed or blended with a naphtha type of distillate.
Medium Curing (MC)	:	Bitumen which has been fluxed or blended with a kerosene type of distillate.
Slow Curing (SC)	:	A liquid residue produced in the refining process, containing little or no volatile constituents.

contain no clay balls. The … aggregate, shall have a plasticity index of not more than 4 and a liquid … 25 when tested in accordance with ASTM D4318. The fine aggregate shall have sand equivalent values of 45 or greater when tested in accordance with ASTM D2419.

8.3.2.3 Mineral Filler

The mineral filler shall consist of finely divided mineral matter such as rock dust or other suitable mineral matter. At the time of use it shall be sufficiently dry to flow freely and essentially free from agglomerations. The mineral filler shall conform to the specification ASTM D242.

8.3.2.4 Portland Cement

Portland cement Type-I must comply with the requirements of ASTM C-150. Quantity of cement shall be at least 1.5% by weight of total aggregates and filler.

8.3.2.5 Bituminous Material

The bitumen to be used in overlay mixes shall be asphalt cement Penetration Grade 60-70 and shall conform to the requirements of ASTM D946. Table 8.4 shows the requirements of the bitumen to be used in overlay mixes. Emulsified asphalt CSS-1/CSS-1h meeting the requirements of ASTM D2397 shall be used for tack coat as specified (Table 8.5).

Each consignment of bitumen shall be accompanied by a certificate from the manufacturer stating the grade and other requisite properties. The Engineer may specify tests for checking compliance with specification as required in Clause 8.3.4 of this specification before according approval for use.

Table 8.4: Requirement for Asphalt Cement for Overlay Mixes
[Penetration Grade: 60-70, ASTM D946]

Test	ASTM Designation	Limiting Value	
		Minimum	Maximum
Penetration, 25°C, 100g, 5 sec.	D5	60	70
Flash Point, COC, °C (F)	D92	232 (450)	–
Solubility in trichloroethylene, %	D2042	99.0	–
Retained Penetration after thin film oven test	D1754	52+	–
Ductility 25°C, 5 cm/min, cm, after thin film oven test test	D113	50	–

Note: Practice for sampling bituminous materials: ASTM D140

Sheet # 17

Lecture 4-5:

BITUMINOUS MATERIALS: PRODUCTION, TYPES, TESTS AND SPECIFICATION

ASPHALT, BITUMEN & TAR:

British: Asphalt – naural
Bitumen – manufactured

American: Bitumen – general name for asphalt and tar
Asphalt – natural or manufactured

(see sheet 14 for intro of bitumin)

Defn:

Asphalt, bitumen and tar are referred to as 'bituminous material' are essentially mixture of hydrocarbons frequently accompanied by their non-metallic derivatives. They may be gaseous, liquid, semi-solid or solid in nature and are completely soluble in carbon-di-sulphide(CS_2). They possess some common properties as follows:

- It is characteristically solid, semi-solid or liquid
- Thermo-viscosity and thermo-plastic i.e. variance of viscosity with temperature
- Colloidal in nature
- No specific melting, boiling or freezing point
- Insoluble in water
- Oxidizes slowly
- Chemically inert
- Adhesion to solid surfaces
- Durability
- Water-proofing characteristics under normal circumstances

The above desirable properties of 'bituminous materials' render them very useful as a binding material, protective agent, and a sealant.

Manufacture and Types of Asphalt/Bitumen: major types are,

- Natural asphalt:
  - Lake asphalt: obtained in Trinidad, Bermudez, at 3-6m depth, composite material containing 40 to 70% pure bitumen, refined by boiling in a tank, water evaporates and impurities collected at the top are removed, widely used for road and pavement construction
  - Rock asphalt: limestone rocks impregnated with asphalt are found in Switzerland, France, Germany etc., contains 4-20% pure bitumen by volume, crushed, heated to construct road pavements.
- Residual or petroleum asphalt/bitumen: also known as artificial asphalt, obtained by fractional distillation of crude petroleum.

Production of Petroleum Asphalts:

Crude Petroleum: produced from organic component of marine animal and plant deposits mingled with and covered by sedimentary mineral matter. The action over million years of bacterial attack, moderate heat, pressure and catalytic action of finely divided mineral particles has converted the fatty residues into crude petroleum. Mainly three types,

- Paraffinic base
- Asphaltic base
- Mixed base

Q. steps of

Refining of Crude Petroleum: it is a very complex process producing a tremendous range of products from very simple hydrocarbon gas methane to the hardest bitumen with molecular weight of the order of several thousand. Full range of asphaltic materials are obtained by,

1) Dehydration: heating in the storage to remove water
2) Fractional Steam Distillation: this is the main refining process after which the crude produces all oil varieties like gasoline, kerosene, diesel, lubricating oil and residual asphalt or bitumen in liquid or semisolid state.
3) Air rectification: air is passed through residual asphalt
4) Cutbacks: residual asphalt is mixed with light oil fractions
5) Emulsification: discuss (Bangla report)

So, the total classification of asphaltic materials from straight run asphalt from refinery is as,

- Air blown asphalt:
- Penetration grade asphalt:
  - Different grades depending on penetration/viscosity values
- Cutback bitumen:
  - Slow curing
  - Medium curing
  - Rapid curing
- Air blown asphalt:
- Asphalt emulsion:
  - Anionic
  - cationic

Fig. 15-8 (Pg. 436) of Highway Engineering, Paul H. Wright (6th Edition) shows simplified flow chart of recovery and refining of petroleum asphalts.

Desirable Properties of Asphalt/Bitumen:

- It should be fluid enough at the time of mixing to coat the aggregates evenly
- It should have low temperature susceptibility or little change in viscosity with temp.
- It should have some volatiles to ensure durability
- It should be ductile and not brittle
- Its flash and fire point should be well above the mixing and laying temp.
- It should have good affinity to adhere to the aggregates and should not be stripped off

BITUMEN QUALITY FOR ROAD CONSTRUCTION IN BANGLADESH

— Dr. M. Zakaria*

ABSTRACT

This paper reviews the desirable qualities of petroleum bitumen for the construction of bituminous mixes for flexible pavements. It considers the climatic condition of Bangladesh and the relevant properties, particularly for penetration grade bitumen to be used, are discussed. Methods for the improvement of binder quality regarding cementing capacity, resistance to stripping, temperature susceptibility and durability are reviewed. It is felt necessary, from experiences of past researches, to incorporate a lower grade bitumen than 80/100 for the existing climatic and traffic condition in the country. It also seems necessary that the bitumens to be used possess high adhesive power, high resistance to stripping, low temperature susceptibility so that the resultant mix is durable. Finally a recommendation is made to develop an intensive research programme for laboratory and field studies in order to establish specifications for the construction of flexible roads in Bangladesh.

INTRODUCTION

The name 'bitumen' originated in the sanskrit where, as Jitu-krit, it referred to the pitch producing certain resinous trees. Later the Latin terms of Gwit-men and Pixtu-men became shortened into bitumen. Bitumen as an engineering material has been used since 3800 to 3000 B. C. In the Euphrates and Indus valleys it was used as mortar for masonry and waterproofing. Bitumen is one of man's oldest engineering materials, and it is the responsibility of engineers to ensure its effective use and avoid waste of the valuable resource.

Bituminous road binders are of two main kinds : bitumen from petroleum and tar from coal. Petroleum bitumen has certain advantages over tar and is being extensively used throughout the world for road construction. The majority of bitumen products used for road purposes are derived from asphaltic base petroleums, although it is possible to derive bitumen from other types of petroleum. The manufacture of bitumen from crude petroleum involves distillation, blowing and blending. Depending on the origin of the crude and manufacturing process the ultimate product has a wide variety of qualities.

Although the proportion of bitumen in bituminous mixes is much less than that of aggregate the quality of bitumen has a marked influence on the behaviour of the mixes. Like other varieties of binders penetration grade bitumens differ in a wide range of quality and selection of appropriate grade of desired qualities is important for the success of its use.

ESSENTIAL CHARACTERISTICS OF PENETRATION GRADE BITUMEN

For road construction, the thermoplastic behaviour of the bitumen is utilized to ensure that the bitumen is sufficiently fluid during application and sufficiently stiff when in use. It also should be so flexible at low road temperatures that the finished surfacing will resist fracture and disintegration.

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For penetration grade bitumens, the thermoplastic properties are characterized by consistency and temperature susceptibility. Results from simple tests like penetration and ring and ball softening point can be used to establish the important engineering property of 'stiffness'. Pfeiffer as reported by TRRL (1) developed the best known expression by which the results of the above tests give a measure of the temperature susceptibility or viscosity. The expression is logP = A T + K where the slope 'A' represents the temperature susceptibility of the logarithm of the penetration of the bitumen. Vander Poel (2) has shown that the penetration corresponding to ring and ball softening point is 800. Pfeiffer and van Doormal, as reported by TRRL (1), do not use the slope A as such but indicate this temperature susceptibility by the 'penetration index' (PI) defined according to the relation

$$A = \frac{d \log pen.}{dT} = \frac{20-PI}{10+PI} \cdot \frac{1}{50}$$

Where T is °C.

The concept of penetration index which has been used for many years is used in the prediction of the engineering property of bitumen stiffness. Suitable nomographs such as one shown in Fig. 1, published by the Refined Bitumen Associated (3), can be used to determine the PI of a bitumen when its softening point (R & B) and its penetration at 25°C are known. Using this nomograph the PI of bitumens varies between - 5 to 10. Bitumens of lower and negative PI soften readily than those with higher PI. With a PI below - 2 bitumens are usually characterized by brittleness at low temperatures. Bitumens with an index above + 2 are usually less brittle and show marked time dependant elastic properties.

One of the main functions of bitumen is to act as an adhesive either between aggregate particles or between the aggregate and the underlying road surface. In general, good adhesion is obtained in the absence of water or excessive dust. The presence of water, in particular, can lead to difficulties either in the initial coating of the aggregates or in maintaining an adequate bond.

Bitumen after use should be such that it is not easily stripped away from the surface of the stone. The problem of stripping is experienced with bituminous mixtures which are subjected to rainfall of long duration, permeable to water or kept under water. It is universally accepted that the affinity between stone and water is better than that between the binder and stone. So in the prolonged presence of water there is a tendency for the binder to be stripped from the aggregate and this tendency is more pronounced if the binder is fresh and has not developed the full viscosity to secure a strong bond.

Hughes et al, as reported by TRRL (1) have shown experimentally that water may penetrate through a film of binder to reach the stone surface. Once such a process starts it is possible for water to spread between the stone and the binder to produce a detached film of binder. The speed with which the process will work depends on the type and viscosity of the binder, the nature of the stone surface, and the thickness of the film of binder. In general, the higher the viscosity of the binder, the slower the process.

Most of the methods for the determination of adhesive quality use coated aggregate immersed in water. The degree of stripping after a known period is then measured by visual inspection.

Bituminous binder during service condition, in some cases, needs to undergo gr[...] deformation (elongation) without breaking. In USA this quality, in particular, is term[...]

§ Tests on the Hveem Specimens

The compacted Hveem specimens are subjected to the following tests:

- Stabilometer Test
- Bulk Density Determination
- Swell Test – performed only on swell specimens
- Cohesiometer Test (not recommended in new versions)
  ⇓ If the bitu passes ductility test, there is no need to perform cohesiometer test

§ Stabilometer Test

- The specimen compacted and contained in the mould is heated to 60±3°C for 3 to 4 hrs.
- Using a plunger, the specimen is forced into stabilometer device
- The specimen is then subjected to vertical loads and the horizontal pressure developed is recorded. The vertical displacement is also recorded.

Stabilometer Value is calculated as,

$$S = \frac{22.2}{\frac{P_h D}{P_v - P_h} + 0.22}, \text{ where,}$$

বইয়ে ছবি আছে

D = vertical displacement, mm
P_v = vertical pressure (typ. 2.76 MPa / 400 psi)
P_h = horizontal pressure at P_v = 2.76 M.

§ Bulk Density Determination :

After the stabilometer test, the specimens are cooled to room temp. and bulk density test is performed, as per ASTM D1188 or D 2726. The maximum specific gravity is determined by ASTM D2041. % Air voids is calculated. for different asphalt contents.

• Swell Test :

After 1 hr. curing the swell specimens are immersed under water with dial gauge-tripod arrangement and dial readings are recorded after 24 hrs. The change is the 'swell value'. The water height change inside the mould gives the permeability or percolation through the specimen.

§ Hveem Design Criteria :

New version excludes cohesiometer value requirement. Requirements depend on the traffic condition. but marshall এ compaction এর no of blows ও একটা criteria.

§ Design Asphalt Content : the (highest) percentage of asphalt, the mix will accomodate without reducing stability or voids below min.
The DAC is determined from

- Stabilometer value, Percent air voids & observation for flushing, as
  - Step1 : Exclude the % asphalt which shows flushing or bleeding.
  - Step2 : Select two highest %s that provide min spec. stabilometer value
  - Step3 : Select the highest % that has at least 4% air voids
  - Step4 : The asphalt content selected in step3 is the design asphalt content (DAC)

If the max. asphalt content in step1 is the asphalt content entered in step 4, additional specimens must be prepared with increased asphalt content in 0.5 percent increments and a new design asphalt content determination should be made.

EXAMPLE

5.0, 5.5, 6.0, 6.5 (m.s.f.) [max surface flushing] → 5.0, 5.5, 6.0 (lowest stab. value)
→ 5.0, 5.5 (5.0% has min 4% air voids) → 5.0

The Design Asphalt Content is 5.0 percent

Mixing of the Ingredients

- The aggregates and the asphalt are heated to a temperature depending on the asphalt type.
  e.g. for Grade AC-10 (85-100 pen.) min. temp. is 121°C and max is 149°C
- When the temp. is reached, asphalt is poured in a crater formed within the hot aggregates. These are vigorously mixed until all particles are coated.
- The mix is then cured for 2 to 3 hrs at 146±3°C (in another procedure for 15 to 18 hrs at 60°±2.8°C) মিশানোর পরপরই marshall এ compaction করি, no curing করি না Hveem এর মত (this is another diff)

§ Compaction of the Mixture

- After curing, the mixture is reheated to 110°C before compaction.
- Half of the mix is poured in the preheated 101.6mm (4") dia mould and rodded 20 times. The rest is placed and rodded again.
- The mould assembly is then placed into position on the mechanical kneading compactor and 20 tamping blows at 1.7 MPa (250psi) pressure are applied to achieve a semicompacted condition.
- Final compaction is then ~~placed~~ applied at 3.45 MPa (500psi) pressure by 150 tamping blows.
- The mould with specimen is placed in an oven at 60°C for 1 hr and then a levelling of load of 56 kN is applied by the double plunger method.

Marshall এই machine চালাই, Automatic compactor এ সাথে

দুইদিক থেকে চাপ দিচ্ছে

§ Preparation of Test Specimens

- By the C.K.E. procedure, approximate or estimated design asphalt content is determined.
- For the determination of 'Design Asphalt Content' test specimens are prepared for a range of asphalt contents both above and below the approximate design asphalt content. (Imp)

Test Schedule:

For hot-mix design, using an average aggregate tests are scheduled as,

- one specimen with approx. design asphalt content by C.K.E.
- two specimens above the CKE amount in 0.5% increments
- one specimen with 0.5 percent below the CKE amount.

i.e. A total of 4 specimens with different asphalt contents shall be prepared for normal mixes.

- For critical mixes (sensitive to asphalt content) an increment of 0.3 percent and three above CKE percentage is used. 5.3, 5.6, 5.9
- For non-absorptive and non-critical mixes, 1.0 percent increments are used. 4, 5, 6, 7

- The above specimens are scheduled for stabilometer tests. The stabilometer specimen series should have at least one specimen containing an excess of asphalt indicating moderate or heavy flushing after compaction.
- In addition two swell specimens are later prepared at design asphalt content determined from Stabilometer test series. For normal mixes, a total of six test specimens will be required.

7: Determine the approximate oil ratio (%) for the mix based on cutback asphalts of RC-250, MC-250 and SC-250 grades from Fig. 19.8.

Fig. 19.8 employs Case-1, and Case-2.

As per old version: employ Case-1 when K_f and K_c are approx. equal, case-2 when K_f and K_c values are markedly different. Employ case-2 in all cases when % passing #4 sieve is less than 35%.

New version describes the input parameters in both cases.

Case-1: Given C.K.E., sp.gr. of aggregates, % passing #4-sieve

Case-2: Given surface area, sp.gr., and K_m of aggregate.

Step 8: Determine the asphalt content / bitumen ratio / approximate or estimated asphalt content for the mix, corrected for bitumen type to be used, from Fig. 19.9.

Approximate Bitumen Ratio (ABR) for dense graded bituminous mixtures, from Fig. 19.8, is for SC, MC, RC-250 liquid asphalt. This amount is corrected for heavier varieties in Fig. 19.9.

AASHTO-M 226-80 (1993) ~~not~~ specifies in

Table 1: Asphalt cement graded by viscosity at 60°C (AC2.5-AC-40, pen. 200-20)

Table 2: Asphalt cement graded by viscosity at 60°C (AC2.5 — AC40 & AC30, pen 220 — 40)

In the event of the absence of specifying limits, Table 1 shall apply. Table 2 has one more type and more tests & limits.

Table 3: Asphalt cement graded by viscosity of residue of RTFO test. AR-10, 20, 40, 80, 160 (pen. on residue, 65, 40, 25, 20, 20) [Conversion Fig. 19.9] ③

Stage D: Determination of Approximate Asphalt Content

In the Hveem method of mix design, the properties of the ingredients are used to estimate the 'approximate asphalt content' in the following steps. [Ch. 19, Pg. 566-573] Table 19.8

CKE [illegible]

Step 1: Determine the surface area of aggs. (combined) from aggregate gradation and surface area factors (Table 19.8

Step 2: Determine C.K.E. for fine aggregate as per the suggested procedure. Correct the C.K.E. value obtained if the sp. gr. of the supplied aggregate is > 2.70 or < 2.60, as

$$CKE_{corrected} = \frac{\text{sp.gr. of fine aggregate}}{2.65}$$

Step 3: Determine the surface capacity for coarse aggregate by the recommended method and correct for sp.gr. as in step #2

Step 4: Find the surface constant K_f for fine material from Fig. 19.5 using corrected CKE value (determined in Step #2).

Step 5: Find the surface constant K_c for coarse material from Fig 19.6 using the % oil retained (i.e corrected surface capacity in Step 3)

Step 6: Using the value K_f and K_c determine the surface constant K_m for combined aggregate from Fig. 19.7, as

$$K_m = K_f + \text{correction to } K_f$$

if $K_c - K_f$ is +ve, correction is +ve

if $K_c - K_f$ is -ve, correction is -ve.

From Fig. 19.7 correction to K_f is determined for surface area of agg., % C.A. & $K_c - K_f$.

আলকাতরা % is on the basis of dry wt.

①

HVEEM METHOD OF MIX DESIGN .. #16 #17 '14

§. Development of Hveem Method :

- Advanced and developed under the direction of Francis N. Hveem, Materials and Res. Engr., CDT, USA.
- Developed over a period of years, certain features were improved and others were added.
- Test procedures and their application have been developed through extensive research and correlation studies on asphalt pavements.

** Imp. Compare Marshall and Hveem method of mix design

§ Application of Hveem Method : Regarding ....

The method is applicable to,

1. paving mixes using asphalt cement or cutback asphalt → Marshall এ কোন cutback নাই, Hot mix and Hot-...
2. mixes containing aggs. up to 25mm(1") max. size
3. design of hot-mix hot laid and cold-mix cold laid mixes.

§ Outline of Method : 7 টা stage এ করা হয়

Stage A : Procurement of materials as per the physical requirements of the project specifications.

Stage B : Blending of aggregates to meet the grading requirements of the project specifications.

Stage C : Storing and preparation of an ample supply of aggregates (washing, drying) and asphalt for testing and mixing.

Stage D : Determination of 'approximate asphalt content' by Centrifuge Kerosine Equivalent (CKE) method.

②

Stage E : Preparation of 102mm (4") dia x 64mm (2.5") high specimens from asphalt-aggs. mixes for diff. asphalt contents.

Stage F : Testing of the prepared specimens in the specified procedure.

Stage G : Selection of 'design asphalt content' comparing the test results using Hveem Design Criteria.

Discussion : Comparison of Marshall and Hveem Method

- for approximate asphalt content,
- for preparation of the specimens,
- for testing of the specimens,
- for design criteria, and
- for design asphalt content.

Marshal : assumed optimum asphalt

Hveem : two asphalt content below 5%, " " " above 5%.

...ations comprise uninterrupted flow, with no ... and should be capable of
...er vehicles, 12-ft wide traffic lane

voids এর adjustment কোনভাবেই হবে না।
4% air void এর test টা ready করেছিলাম।

Marshall Design Criteria
Table 5-2, MS-2, 6th Edition

Find the 4.8% Asphalt content

Marshall Method Mix Criteria 1	Light Traffic Surface & Base		Medium Traffic Surface & Base		Heavy Traffic Surface & Base	
	Min	Max	Min	Max	Min	Max
Compaction, number of blows each end of specimen	35		50		75	
Stability, N (lb.)	3336 (750)	—	5338 (1200)	—	8006 (1800)	—
Flow, 0.25 mm (0.01 in.)	8	18	8	16	8	14
Percent Air Voids ✓	3	5	3	5	3	5
Percent Voids in Mineral Aggregate (VMA)	See Table 5.3					
Percent Voids Filled With Asphalt (VFA)	70	80	65	78	65	75

NOTES
1. All criteria, not just stability value alone, must be considered in designing an asphalt paving mix. Hot mix asphalt bases that do not meet these criteria when tested at 60°C (140°F) are satisfactory if they meet the criteria when tested at 38°C (100°F) and are placed 100 mm (4 inches) or more below the surface. This recommendation applies only to regions having a range of climatic conditions similar to those prevailing throughout most of the United States. A different lower test temperature may be considered in regions having more extreme climatic conditions.
2. Traffic classifications
   - Light: Traffic conditions resulting in a Design EAL < 10^4 (EAL: Equivalent standard axle)
   - Medium: Traffic conditions resulting in a Design EAL between 10^4 and 10^6
   - Heavy: Traffic conditions resulting in a Design EAL > 10^6
3. Laboratory compaction efforts should closely approach the maximum density obtained in the pavement under traffic.
4. The flow value refers to the point where the load begins to decrease.
5. The portion of asphalt cement lost by absorption into the aggregate particles must be allowed for when calculating percent air voids.
6. Percent voids in the mineral aggregate is to be calculated on the basis of the ASTM bulk specific gravity for the aggregate.

Q: 1200 gm agg
5% bitumin

PREPARATION OF MARSHALL SPECIMENS

95 gm agg

i) No. of Specimens : At least 3 at each asphalt content.

ii) Preparation of Aggregates : Aggregates are dried to 105°c-110°c for each specimen (1200 gm) separately.
5%

iii) Mixing and Compaction Temperature :
Temp. at which asphalt produces 170 ± 20 cs (Kinamatic) is the mixing temperature (around 250°F).
Temp. at which asphalt produces 280 ± 30 cs (Kinamatic) is the compaction temperature.

iv) Preparation of Mold and Hammer :
Mold assembly and the face of the compaction hammer should be heated to 93°C to 149°C. A waxed paper is to be placed in the bottom of the mold before the mix is placed

v). Preparation of the Mixture :
- Approx. 1.2 Kg mix is reqd. for 63.5 mm ± 1.3 (2.5 ± 0.05 in) high and 100 mm dia (4") specimen.
- Weight is to be adjusted after the compaction of trial spec.
- Specimens are prepared with asphalt contents at intervals of 0.5 percent.
- Hot aggs. are mixed, hot asphalt is placed in the crater, aggs. and asphalt are mixed thoroughly as quickly as possible to yeild a mix having a uniform distribution of asphalt throughout.

vi) Compaction of Specimen :
- Mixture is placed in the mold at the compaction temp.
- A compactive effort of 35, 50, or 75 blows is applied to each side of the specimen.
- Remove the specimen from the mold and cool overnight.

Typical Aggregate Gradings:
Pg. 582 (WP 5th Ed) Table 19.1 – Alabama Hwy Dept. (USA)
Pg. 583 (WP 5th Ed) Table 19.2 – Kentucky Dept. of Hwys.

STEP 2 & STEP 3 : DETERMINATION OF JOB-MIX FORMULA (WP)
- Selection & combination of aggs. (STEP 2)
- Determination of Optimum Asphalt Content (STEP 3)

Selection & Combination of Aggs. (WP)

Selection as per specification requirement.

Combination by 'Trial & Error', 'Graphical' or 'Equation' method

Example of combination : W.P. 4th/5th Edition. Pg.

STEP 3 Optimum Asphalt Content

1. Methods for OAC/DAC or OBC/DBC
   - Marshall Method
   - Hveem Method
   - Hubberd-Field Method
   - Smith Triaxial Method

   (Marshall, Hveem, Hubberd-Field, Smith Triaxial: USA)
   - BS 594 (UK) – involves Marshall for Rolled Asphalt
   - Lees Asphaltic Concrete
   - LDM (Leeds Design Method)

2. General Steps
   - Preparation of trial specimens
   - Determination of density, stability, flow etc. of specimens
   - Density-void Analysis to find
     - Voids in Mineral Aggregate (VMA)
     - Voids in Compacted Mix (Pa)
     - Voids Filled with Asphalt (VFA)
   - Plotting of parameters for different asphalt content
   - Determination of ~~avg./4% (Pa)~~ the parameters at asphalt content. airvoids
   - Checking with 'Design Criteria'.

4in dia
2.5in height

Lab sheet এ ৬রকার word ফাইলে MS2
দেওয়া দিব