

\* Pavement is a structure constructed on earth surface for movement of vehicles

Lec-7

26/09/17

\* Aggregate has the max. volume. It occupies most of the volume of road structure.

It is about 80-90%.

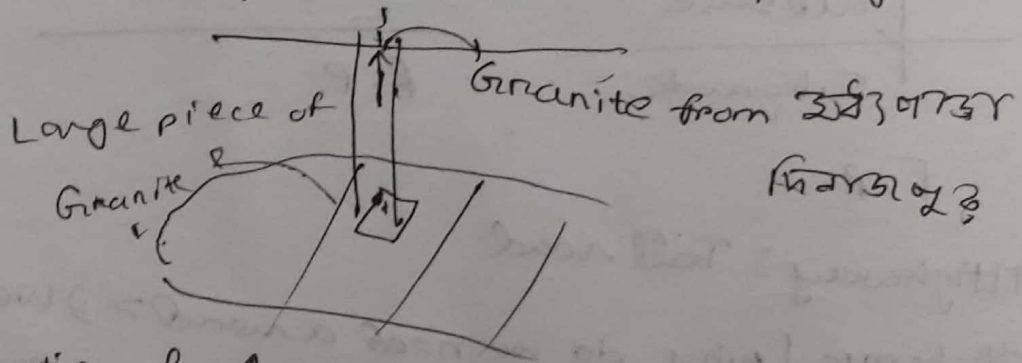
# What is aggregate?

↓  
Aggregation of non-metallic particles minerals

\* Classification of aggregate based on source

\*  $\text{கிணிகல்?}$   $\text{கடிமணிகல்}$  Hard Rock

size  
weight



\* Properties of Aggregates

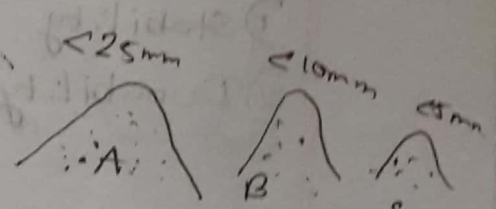
{ Highway Engineering; Wright & Dickson 7th Edition  
Pg 412

1) Chemical stability: Aggregates should be chemically stable. For bituminous construction, it should be hydrophobic.

Water is necessary for construction but it is harmful for structure.

2) Particle size & gradation

Particle size 92, 80 proportion  $\Rightarrow$  Aggregate gradation



Aggregate

Lec. 2: Aggregates

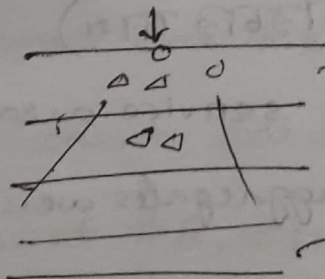
3/10/2017

- $\rightarrow$  Properties
- $\rightarrow$  Tests
- $\rightarrow$  Specifications

Sheet #4, Pg 412 (Chap 15)

P.S.  $\Rightarrow$  Particle size, Service Texture

\* There are some properties needed for a particular work.



$\rightarrow$  This aggregate is resisting load & abrasion action of wheels (surface course)

$\rightarrow$  This aggregate takes only load distribution

## \* Fundamental characteristics

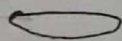
1) Stability

2) Durability → characteristics which enable materials to resist the load under the weathering action

\* severe service condition

3) Water absorption

4) Chemical stability



elongated



flaky

Round aggregate with surface roughness is better

\* Aggregates must be free from deleterious substance (e.g. organic compounds)

→ deleterious  
\* Iron pyrites mixed with aggregate could not be determined by test. When constructed the shoulder became full of rusty spots (खड़बड़ा धाँस)

# Padma Bridge service area

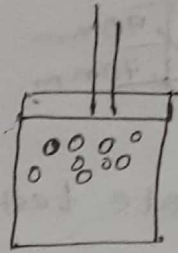
Fes mixed aggregates were used.

## \* Test of Aggregate

→ Los Angeles Abrasion Test

Sheet #9 ⇒ BS Test not IS Test

AIV }  
Acv } 30%



Aggregate weak and voids are filled by crushed aggregates. This occurs when AIV, Acv > 30%

⇒ For this 10% fines test is used

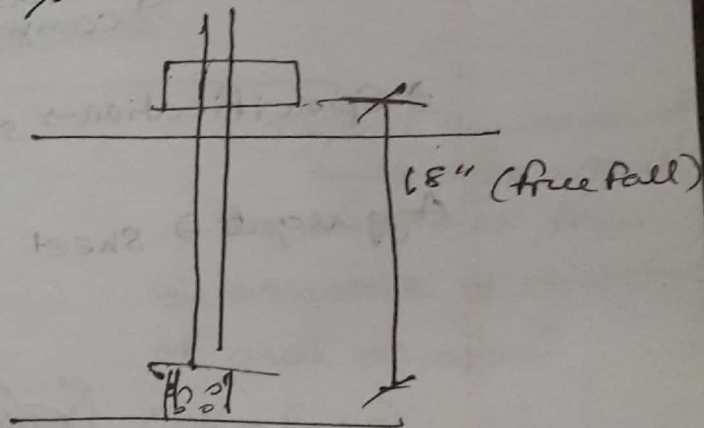
\* AIV, Acv must be within 25%

\* If free fall < 18", value

obtained is less

\* If free fall > 18", larger value is obtained.

\* Specifications: (Sheet #5)



CTQ) What are the aggregate tests performed in different labs of civil engineering?

\* Sheet #6, #11

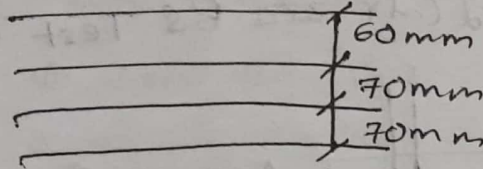
\* Q) What is specification?

Name of the Test - Test standard

\* Asphalt Concrete Table # 8-3

Runway

Asphalting  
concrete in 3  
ways



Q) What are the aggregate test for asphalt  
overlane in Hazrat Shahjalal Int. Airport?

Q) What are the Bitumin tests?  
what are the test of

Q) Asphalt cement for

→ commercial name

\* Specification → set of requirements

Aggregate ⇒ sheet #4, #9, #6, #11

# Lec-4: Bituminous Material

10/10/17

Sources  
—Types

Sheet No. 12, 10, 14, 5

Production

Uses

Properties

Tests

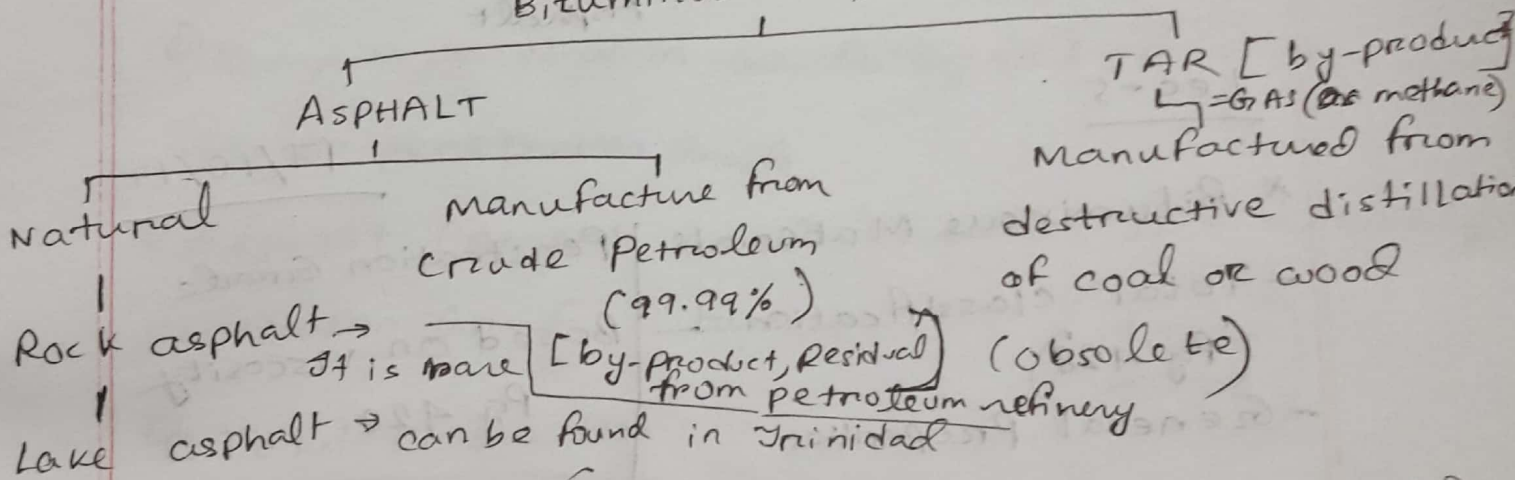
Specifications

## Sheet #12

\*Asphalt → obtained from nature and also manufactured

Bitumen → manufacture having asphalt & tar

### Bituminous Material



Pg-417, 418 (Simplified flow chart of asphalt.)

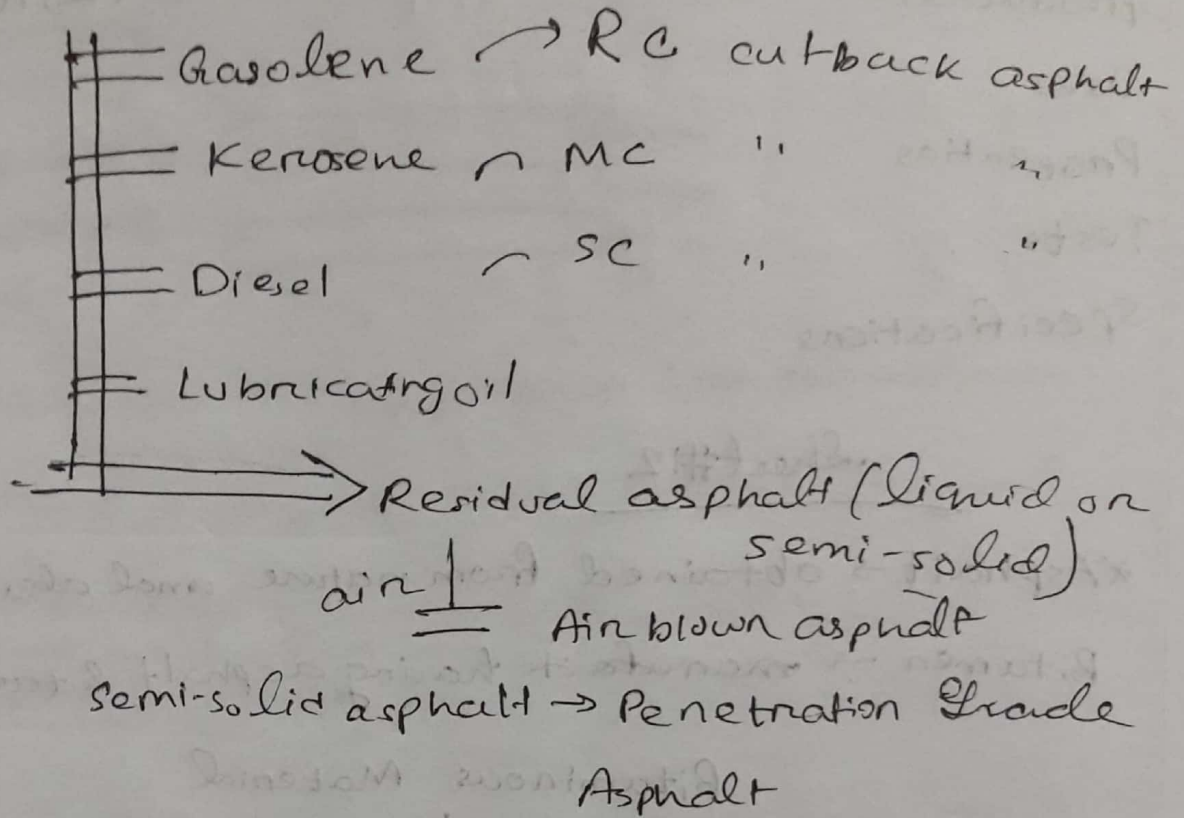
Sheet #10 → @115 Refining Crude Petroleum

→ vacuum distillation of petroleum

\*Asphalt can be liquid or semi-solid

Sheet #12

## Common properties of Asphalt



Lec-5

17/10/17

- \* Bituminous Materials | Penetration Grade
- Total classification (Pg 428) | Based on viscosity Pg 428
- General Properties
- Desirable Qualities
- Tests | Groups Table 15.4
- Specification | For overlay sheet #11 → Table 8.4

- Modified Binders } types }  
 } advantages } Sheet No. 10  
 Pg 467

- Bitumen Quality for BD - Sheet No. 11

\* Straight Run Asphalt → 1) Airblown Asphalt  
 → Penetration Grade: Fig 15.8  
 (Pg 428)

Sheet No. 14

Table 1: US

Table 2: UK

40-50	} American Penetration Grade Classification
60-70	
85-100	
120-150	
200-300	

② Compare penetration Grade by US & UK.

80-100 penetration Grade

\* Asphalt Cement used in roads. It is actually Penetration Grade Bitumen

☐ Total Classification

(40pen  
40-50)

→ 2 test ⇒ Based on standard

⇒ Based on residue from

Pg-428 92 24 table Exam 9 @ 100



Table 15.6 → 272

\* General group 9, test specific gravity (6th Edition 9 @ 1.5 7th edition 9.2.15)

Pg 427 \* Bitumen Tests

Sheet #5 20 tests

Sheet #11 → Table 8.3 → Test of aggregates

Q) What are the requirements of asphalt cement for overlay mixture

Table 8.4 → requirements of asphalt cement

Q) Flash Point

COC → Cleveland Open Cup

\* Modified Binder

Q) What are the advantages of modified binder?

Types of modified binder

Table 20.6 → Elastomers

\* SMA → Stone Mastic Asphalt on B&B concrete deck

→ SBS Modified Asphalt Cement

↳ Polymer melted & mixed with Bitumen  
→ to reduce stripping of Bitumen from the surface. (used in Cox's Bazar)

Q) What are the desirable qualities of Bitumen for road construction in BD? → sheet 14

\* Improvement of Bitumen Quality

In the context of Bangladesh

\* 80/100 is for low to medium traffic.

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: 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/Highway Engineering Constructions:

Five groups of all CE Materials are,

- Materials occupying main volume, -- brick, aggregates *has max volume, occupies most of the volume of road structure. (80-90%)*
  - 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

Q. what is aggregate?  
Aggregation of non metallic minerals.

Materials for Construction in Developing Countries:

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

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

Tender Document: - General

- Technical Specification

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's procedures and regulations.

Standards are used by –

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

Specification:

*what is 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, JIS

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

Test methods used in Bangladesh:

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

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

- Rationale:
- 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 Construction:

Bldg. Materials for Developing Countries:

Standard:

Specification:

Test Method:

Aggregates:

- properties
- test
- specification

sheet #14, Pg-412 (Chp-15)

P.S → particle size, service texture

✓ AGGREGATES: Q: what is aggregate?

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

✓ Defn. 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:

→ properties of aggregate:

H. Engineering wright, Pg-412

→ chemical stability: aggregates should be chemically stable.

For bituminous construction it should be hydrophobic.

coater is necessary for construction but it is harmful for structure.

▪ Based on source

تصانيف الصخور hard rock.

- 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 0.15/0.075 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<sup>3</sup> (95-105 pcf), so that normal wt. concrete (NWC) has a unit wt. 150 lb/cft (2400 kg/m<sup>3</sup>)
- Light weight: bulk unit wt. less than 1120 kg/m<sup>3</sup>
- Heavy weight: bulk unit wt. more than 130pcf (2080 kg/m<sup>3</sup>)

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

→ particle size & gradation

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

✓ Question: Why is grading important for any aggregate construction?

Grading; Fineness Modulus : Sheet # 7

The distribution of particle sizes (d) within any batch of aggregate is called grading or gradation.

- Expressed as a cumulative% of particles that are smaller than each of a series of sieve openings
- The percentages are customarily presented in graphical form known as grading 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

Test of aggregates:

→ Los Angeles abrasion test sheet #9 (BS test not IS)  
 ⇒ (AIV & ACV > 30%)  
 2<sup>nd</sup> aggregate weak so pressure  $\sqrt{\text{val}}$  aggregate  $\sqrt{\text{val}}$  or 2<sup>nd</sup> void fill 2<sup>nd</sup> mpa.

AIV & ACV must be within 25%.

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

→ IS free fall < 18" obtained is less

→ free fall > 18"

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

Large value is obtained

Blending of Aggregates

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

⇒ specification: sheet #5

✓ Testing of aggregates: - Sheet # 65

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

Q: what are the aggregate test performed in different lab of CE, built?

Q: what is specification?

Name of test - test standard (sheet #16, #11)

## Strength tests of aggregates:

- ASTM tests (sheet given for concrete aggs.) - L. A. Abrasion test
- BS tests for strength and crushing characteristics

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

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

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

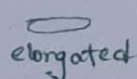
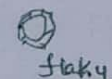
## Durability tests

- 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 - # 6, 8,

 elongated  flaky (round aggregate with surface roughness is better)

Aggregates must be free from deleterious material (e.g. organic compounds)

**SAND:** [ mostly used as fine aggregate in cement concrete and asphaltic concrete ]

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 - 1/4 mm ]
- Medium sand [ 1/4 - 1/2 mm ]
- Coarse sand [ 1/2 - 1 mm ]
- Very coarse sand [ 1 - 2 mm ]

Iron pyrites (FeS) (deleterious material) :  
when mixed with aggregates, could not be determined by test, when constructed the shoulder become full of rusty spots.

**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.



**BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA**  
**DEPARTMENT OF CIVIL ENGINEERING**

*Committed to Quality Assurance for Better Bangladesh*



**APPROVED RATES FOR TESTING OF MATERIALS AND SERVICES**

These rates include VAT (15%), University Overhead (30%) & Laboratory Development and Maintenance (3.5%) **Effective from 1st July 2016**  
 Department of Civil Engineering reserves the right to change the rates at any time without any prior notice

**Contact person: Prof. Dr. Abu Siddique ; Room No 408; Mobile: 01819 557964**

PABX Nos.: 55167100, 55167228-57, 861 4640-44, 861 8344-49, Ext. 7226; Fax - 9665639; Web: www.buet.ac.bd/ce

**BRTC Office Time : Sat to Wed => 9:00 am - 5:00 pm & Thu => 9:00 am - 2:00 pm**

Name of Tests	Test Rate (Tk.)
<b>Aggregates (Sample Preparation Charge Tk.2000 per Sample)</b>	
Chemical analysis (CA) / Gradation / FM (CA)	6,800
Chemical analysis (CA) / Gradation (Base/subbase)	10,600
Chemical analysis / Gradation / FM (CA) (Ballast)	8,700
Chemical analysis / Gradation / FM (CA) (Ballast)/Specified Sieve size	11,500
Chemical 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
100 percent fine value (TFV)	11,500
Uniformity number (Including sp. gr.)	9,600
Angular Index (EI) / Shape Test	8,700
Flakiness Index (FI)	8,000
Abrasion of CA	7,700
Abrasion of Ballast	8,000
Unit weight of aggregate (CA)	5,000
Unit weight of aggregate (FA)	4,500
Soundness with Na <sub>2</sub> SO <sub>4</sub> (4000/- for chem.)	19,200
Soundness with Mg <sub>2</sub> SO <sub>4</sub> (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
Percentage Content of Fine Sand using Microscope	26,200
Percentage Content of Fine Sand / CA by visual observation	16,600
Percentage of organic Impurities (1300/- for chem)	19,200
Percentage of organic Impurities/Salt content / Sulphate content / Salinity	4,000
Classification of sand	5500/15000
Shrinkage Ratio / Porosity / Moh. Hardness	7,700
Strength 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.)
<b>Bitumen (Sample Preparation Charge Tk.3000 per Sample)</b>		
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.)	5,000
6	Ductility (300/- for Chem.)	5,000
7	Softening point (R&B) (300/- for Chem.)	5,000
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)	12,600
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 TFOTALOH included separately)	9,600
16	Any test on residue from Loss-on-heating test/TFOT (if TFOTALOH not included separately)	16,100
17	Any test on residue from Thin 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
<b>Asphalt or Bituminous Material / Pavement Core (Sample Preparation Charge Tk.3000 per Sample)</b>		
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

<b>Bricks (Bricks needed for ASTM = 5 Nos., BS = 10 Nos.)</b>	
Compressive strength (ASTM / BS Standard)	2,400 / 4,600
Compressive strength (ASTM / BS Stand; 300/400/- capping mat.)	4,800 / 7,900
Shape & size (ASTM / BS Standard)	3,100 / 3,100
Unit Weight (ASTM / BS Standard); 200/300 for L.C.	4,300 / 5,700
Water Absorption (ASTM / BS Stand); 200/300 for L.C.	6,100 / 9,100

<b>R.C.C Pipes</b>		
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	8,700

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
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

Table 3.12.2: Frequency of Aggregate Testing  
(The test numbers correspond to Table 3.12.1)

Test	Frequency	Remarks
2. Particle size distribution	Daily	More frequently at start of production
3. Clay, fine silt, etc	Daily	
4. Clay lumps	Daily	Reducing stable to weekly when
5. Flakiness index	Daily	Reducing stable to weekly when
6. Elongation index	Daily	Reducing stable to weekly when
7. Angularity No.	Daily	Reducing stable to weekly when
8. Water absorption	Daily	
10. Field settling	Daily	
11. 10% Fines	Weekly	
12. Sulphate soundness	Weekly	Reducing stable to monthly when
14. Sulphate content	Weekly	For natural sand - each lorry load until control ensures stability.
15. Chloride content	Daily	For natural sand - each lorry load until control ensures stability
19. Mica	Weekly	Initially - each delivery until control ensures stability.
Others		As required by the Engineer

0085R-04

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Table 3.12.1 ctd.

	Test	Limits
12. Soundness of Aggregate by use of 5 cycles of magnesium sulphate tests	ASTM C88-76	Coarse Fine Magnesium Sulphate 15% 10%
13. Aggregate Shrinkage	British Building Research Station Digest No. 35 (2nd Series)	0.05%
14. Total acid	Wet chemical aggregate soluble sulphate (as SO <sub>3</sub> )	0.4% max. of each proposed analysis
15. Total acid soluble chloride content (as NaCl)	BS812: Part 4:1976	0.1% max. of fine aggregate; 0.05% max. of coarse gate
16. Potential Reactivity of Aggregate (Chemical Method)	ASTM C289-71	To be innocuous
17. If required by the Engineer as a result of the above, Potential Alkali Reactivity of Cement combinations (Mortar Bar Method)	ASTM C227-71	Expansion less than 0.10% at six months
18. Gel-Pat Test	National Building Studies Research Paper No. 25	As given in NBS Research Paper No. 25
19. Concrete Prism Test (alkali-silica reaction)	BS812: Part 123 (Draft for comment No 88/11922DC, June 1988)	
20. Mica Content	By physical separation	1% max (muscovite) 1.5% max (biotite) 1.5% max (combined)

0085R-04

9

2. (a) Describe the use of gravel as a pavement course.  
(b) What are the desirable properties of gravel?  
(c) Give the gradation requirements of gravel for use as a pavement course.
3. (a) Describe briefly the construction of a gravel road.  
(b) Describe how a gravel road is maintained.
4. (a) How does a water-bound-macadam layer derive its strength?  
(b) What are the materials generally used for water-bound-macadam?  
(c) Give the gradation requirements for water-bound-macadam.
5. Give a detailed specification for water-bound-macadam layer.
6. Describe the constructional practice in laying a water-bound-macadam layer.
7. What are the defects commonly noticed in water-bound-macadam and what are the likely causes?
8. What are the advantages and disadvantages of water-bound-macadam?
9. Write short notes on:
  1. Dry Bound Macadam
  2. Wet-mix Macadam.

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Aggregate sheet #14, #19, #6, #11  
 test sheet #15  
 Specification sheet #16  
 ↳ set of requirements

Sheet# 9/July '14

Dr. Kadyala  
 Highway Eng.

**19**

**Stone Aggregates**

**19.1. Aggregates**

19.1.1. Aggregate is the major component of materials used in road making. It is used in granular bases and sub-bases, bituminous courses and in cement concrete pavements. A study of the types of aggregates, their properties and tests is of great-importance to a highway engineer.

**19.1.2. Types of aggregates**

Natural aggregates for road-making are obtained from rock. In India, the road-making aggregates fall into the following geological groups :

1. Igneous rocks, which are formed by the cooling of molten material.
2. Sedimentary rocks, which are formed by deposition of granular material.
3. Metamorphic rocks, which are igneous or sedimentary rocks that have undergone transformations due to heat and pressure.

The most popular rocks under the above groups frequently met with in India, along with a brief description and suitability for use in road-making is given in Table 19.1.

**Table 19.1. Road-making aggregates in India**

S. No.	Name of rock	Geological Group	Properties	Suitability for road-making
1.	Granite	Igneous Rock	1. Hard, durable 2. Bulk Density below 2.80 3. Blue, pink in colour 4. Fine-grained to coarse grained texture 5. Resistant to abrasion 6. Low absorption of water	1. Very good for bituminous courses and cement concrete pavements 2. Suitable for masonry work 3. Suitable for R.C.C. work
2.	Basalt (Also called Trap)	Igneous Rock	1. Hard, durable 2. Bulk Density about 2.8—3.0 3. Blue or dark blue in colour 4. Fine grained 5. Resistant to abrasion 6. Low absorption of water	1. Very good for bituminous courses and cement concrete pavements 2. Suitable for masonry work 3. Suitable for R.C.C. work

S. No.	Name of rock	Geological Group	Properties	Suitability for road-making
3.	Quartzite	Metamorphic Rock	<ol style="list-style-type: none"> <li>Reasonably hard and durable</li> <li>Fine to medium grain size</li> <li>Light brown or pink in colour</li> <li>Resistant to abrasion</li> <li>Low absorption of water</li> <li>Reasonably high bulk density of 2.5-2.8</li> </ol>	<ol style="list-style-type: none"> <li>Good for base courses, bituminous courses and cement concrete pavements</li> <li>Used for R.C.C. work</li> <li>Suitable for masonry work</li> </ol>
4.	Limestone	Sedimentary Rock	<ol style="list-style-type: none"> <li>Reasonably hard and durable</li> <li>Liable to polish to a smooth surface under traffic</li> <li>Fine grained</li> <li>High water absorption</li> <li>Bulk Density low in the range 1.9-2.2</li> </ol>	<ol style="list-style-type: none"> <li>Good for base courses</li> <li>Unsuitable for wearing surfaces because of polishing characteristics</li> </ol>
5.	Sandstone	Sedimentary Rock	<ol style="list-style-type: none"> <li>Moderately hard and durable</li> <li>Fine to medium grained</li> <li>Bulk Density in the range 2.3-2.7</li> </ol>	<ol style="list-style-type: none"> <li>Good for road bases</li> <li>Generally, unsuitable for wearing courses</li> </ol>
6.	Laterites	Decomposition of basalt and other rocks	<ol style="list-style-type: none"> <li>Yellowish to reddish brown in colour</li> <li>Spongy porous open texture</li> <li>Bulk Density varies from 2.2-2.6</li> <li>Water absorption very high, 5-25 per cent.</li> <li>Soft to medium hard, losing strength when it absorbs moisture.</li> </ol>	<ol style="list-style-type: none"> <li>Good for sub-base and base courses</li> <li>Used as surface course in un-important roads</li> </ol>
7.	Kankar	Sedimentary rock, impure form of lime stone	<ol style="list-style-type: none"> <li>White to brown in colour</li> <li>Soft to medium hard</li> <li>Bulk Density in the range of 2.2-2.6</li> <li>Water absorption high</li> </ol>	<ol style="list-style-type: none"> <li>Good for sub-base and base courses</li> <li>Used as surface course in un-important roads.</li> </ol>
8.	Dhandla	Gypsum	<ol style="list-style-type: none"> <li>White in colour</li> <li>Soft and highly abraded</li> <li>Absorbs water to a high degree</li> <li>Bulk Density varies from 2.2-2.5.</li> </ol>	<ol style="list-style-type: none"> <li>Used for sub-bases and bases</li> <li>Used as a surfacing material in Rajasthan on unimportant roads</li> </ol>

### 19.1.3. Artificial aggregates

The artificial aggregate common in India is broken brick ballast. Slag is also used as an aggregate in countries abroad. Broken brick ballast is soft, water-absorbant and gets powdered under traffic. Overburning of bricks increases the hardness. The material is very commonly used in WBM base courses in the Gangetic plains of Northern India, where stone materials are scarce, it also is used in Mehra's method of soil stabilisation.

### 19.1.4. Testing of Aggregates

The tests required to be conducted on representative samples of aggregates depend on the specific use in a road pavement, so as to ensure that they meet the specified requirements laid down for that specific use (Ref. 1). First and foremost, it needs to be emphasized that the repeatability and reproducibility of test results depend primarily on the sampling. A laboratory sample is obtained from a bulk sample collected, either in a number of increments or in one go, from a batch or a stockpile. Samples are normally collected using a sampler which is in the form of metallic tube or a scoop whose opening is 3 times the maximum aggregate size. Sampling of aggregates is sometimes done at various production sources in order to avoid the segregation which occurs in stockpiles. Some of the sampling procedures followed are :

1. Sampling from stationary conveyor belt
2. Sampling at belt and chute discharge points
3. Sampling from stockpiles
4. Sampling from railway wagons, transporting dumpers/trucks etc.

A sample collected for testing purposes has to be reduced in size to prepare laboratory samples. The aggregates are quartered either manually or by using rifle boxes.

The common laboratory tests and the corresponding test methods are given below :

Presence of deleterious materials	IS : 2386-Part-2 IS : 2720-Part-37
Water absorption and Bulk specific gravity	IS : 2386-Part-3
Particle size distribution	IS : 2386-Part-1
Plasticity Index	IS : 2720-Part-5
Flakiness and Elongation	IS : 2386-Part-1
Mechanical properties including aggregate crushing value, impact value, abrasion value and polished stone value.	IS : 2386-Part-4 BS : 812-Part-114
Soundness Test using either sodium sulphate or magnesium sulphate	IS : 2386-Part-5
Bitumen Coating and Stripping Test	IS : 6241
Water Sensitivity Test	AASHTO T 283

**19.1.4.1. Deleterious Materials.** Aggregates containing foreign or deleterious materials are undesirable for road works. Objectionable materials are vegetable matter, shale, soft particles, clay lumps, and clay-clad coarse aggregates. The sand-equivalent test is a suitable method for determining the proportion of silt and/or clay size material in fine aggregate. IS 2720 (Part 37) (Ref. 11) gives the details of the determination of sand equivalent value of fine aggregates.

The flakiness index is defined as the percentage by weight of aggregate particles whose least dimension is less than 0.6 of their mean size. It is determined according to the procedure laid down in IS : 2386 (Part I) (Ref. 3).

The elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than one and four-fifths times their mean dimension. This test is not applicable to aggregates smaller than 6.3 mm. The test is covered by IS:2386 (Part-I).

The standard flakiness and elongation gauges are shown in Fig. 19.2.

The combined value of flakiness and elongation indices, recommended by the MOST specification (Ref. 1) for aggregates for many of the bituminous materials for roadworks, is 30.

**19.1.4.5. Aggregate Impact Test.**

This is a test designed to evaluate the resistance of an aggregate to sudden impact. Since vehicle loads cause impact, this test gives an indication of the performance of aggregates to resist crushing under impact. The test has been adopted as an Indian Standard (IS : 2386 Part IV) (Ref. 6). The IRC Specifications also indicate the minimum acceptable values as per this test.

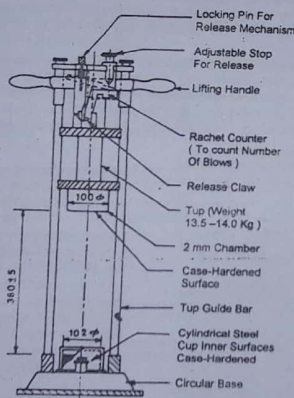
The test consists of subjecting a specimen of aggregates (passing 12.5 mm sieve and retained on 10 mm sieve) filled into a cylindrical mould 10.2 cm internal dia and 5 cm height. The impact is provided by dropping a hammer of weight 13.5—14.0 kg through a height of 380 mm (Fig. 19.3). Aggregates passing fully through 12.5 mm sieve and retained on 10 mm sieve are filled in the cylindrical measure in three layers, each layer being given 25 strokes with a rod. The sample is then transferred to the cup of the aggregate impact testing machine and tapped 25 times with the rod.

After subjecting the specimen to 15 blows through the hammer, the crushed aggregate is sieved on 2.36 mm sieve. The weight of materials passing through this sieve expressed as a percentage of the total weight of the sample gives the Aggregate Impact Value.

The test is conducted in dry state as well as in wet state.

For low-grade aggregates, a maximum of 50 per cent wet aggregate impact value is allowed when used in sub-base. When used as base course, the limit is 40 per cent. For surfacing courses, the limit is 30 per cent.

**19.1.4.6. Los Angeles Abrasion Test.** This is a very popular test for measuring the abrasion resistance of aggregates. The top layers of a pavement get abraded due to the



(All dimensions are in millimetres)  
Fig. 19.3. An Aggregate Impact Test equipment.

movement of tyres. A material which is highly abrasion resistant has a long life. The test has been standardised in India (I.S. : 2386—Part IV) (Ref. 6).

The machine consists of a circular drum of internal diameter 700 mm and length 500 mm mounted on a horizontal axis enabling it to be rotated (Fig. 19.4). An abrasive charge consisting of cast iron spherical balls of 48 mm dia and weight 390—445 gm is placed in the cylinder along with the aggregates. The weight and number of the abrasive spheres varies according to the grading of the sample. The quantity of aggregates to be used depends upon the gradation and is 5—10 kg. The cylinder is rotated at a speed of 30—33 revolutions per minute, for 500—1000 revolutions (depending upon the material). After the specified revolutions, the material passing through 1.7 mm size sieve is separated. The weight of this material (fines) expressed as a percentage of the total weight of the sample is known as the Los Angeles Abrasion Value. For WBM base course in India, a maximum value of 40 per cent is allowed. For bituminous courses, a maximum of 30 to 35 per cent is specified (Ref. 1).



Fig. 19.4. Los Angeles Abrasion Test Apparatus.

**19.1.4.7. Aggregate Crushing Test.** One of the modes in which a pavement material can fail is by crushing under severe stresses. A test devised to express the crushing strength is the aggregate crushing test. The test has been standardised by the Indian Standards Institution (I.S. : 2386-Part IV) (Ref. 6).

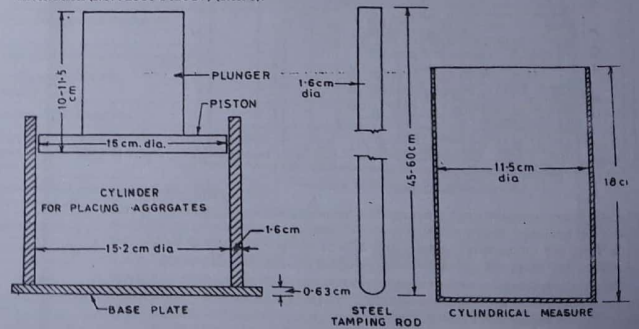
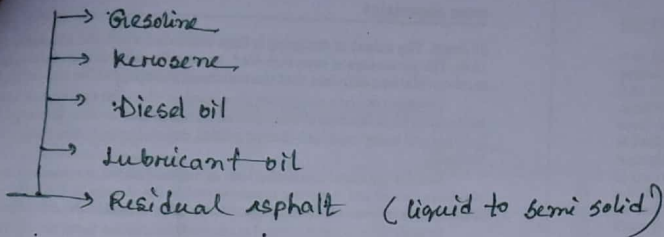


Fig. 19.5. Aggregate Crushing Strength apparatus.

pg: 417, 418 (simplified flow chart of asphalt)



bituminous asphalt → { air → 1. air blown asphalt  
semi solid asphalt → 2. penetration grade asphalt

Lec-B

17.10.17

→ Bituminous material - total classification - based on viscosity (Pg 428)

- General properties
- Desirable qualities
- tests → table 15.4
- specification → for overlay  
sheet #1 table B.4

total classification - based on standard  
- based on residue form

(Pg 428 by 2br table exam is same)  
table - 15.6 - 2/25

Bitumen tests → sheet #15

aggregate tests → sheet #11 (table 8.3)

Bituminous material

Bituminous Materials

source: petroleum

- 1. source - type
- 2. Production
- 3. Uses
- 4. Properties
- 5. tests
- 6. specification

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 Mohenjodrao 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 terminology 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 inert 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.

BITUMINOUS MATERIALS

"Penetration grade bitumen" is a bitumen whose degree of hardness can be determined 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: Refining of crude petroleum

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. Napthenic 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.

vacuum distillation of petroleum

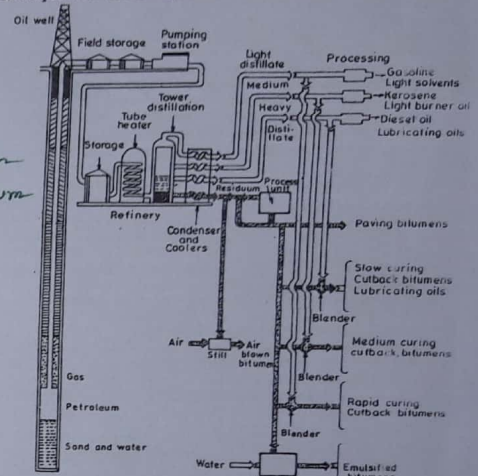


Fig. 20.1. Petroleum bitumen flow chart.

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Bituminous material

Asphalt

Natural  
Rock asphalt  
lake asphalt  
can be found in Trinidad

Manufactured from crude petroleum (99.98%)  
(by product residual)  
from petroleum refinery

tar [by product of gas methane]  
↑  
manufactured from destructive distillation of coal or wood  
(obsolete)

### 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:

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

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

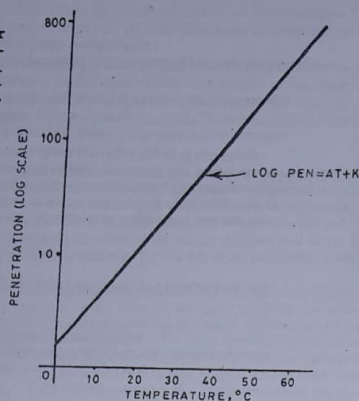


Fig. 20.6. Penetration temperature test.

### 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.

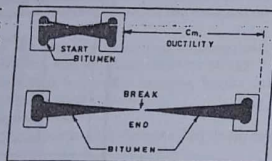


Fig. 20.7. Ductility test.

### 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.

## BITUMINOUS MATERIALS

### 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.

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.

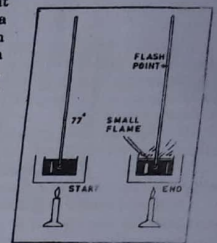


Fig. 20.8. Flash point test.

The effect of heat on a bituminous binder is the loss of volatile constituents. This loss causes the binder to harden. Thus, one 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<sub>2</sub>. 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 value is needed in mix design. The property is determined at 27°C, by a pycnometer or by preparing a cube of a sample. The specific gravity of road-making bitumens varies from 1.02 to 1.04. Tars 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.

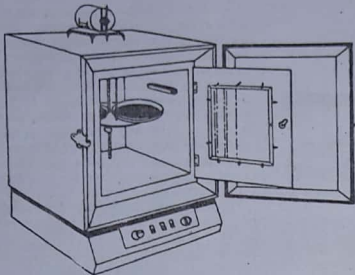


Fig. 20.9. Thin film oven test.

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.

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Table 20.2. Requirements for Paving Bitumens (Ref. 5)

S. No.	Characteristics	Requirements for Grades										Methods of Test, Ref. to
		S 35	S 46	S 55	S 65	S 90	S 200	(9)				
(1)	Specific gravity at 27°C, Min.	0.99	0.99	0.99	0.99	0.99	0.99	IS 1202 : 1978				
(ii)	Water, percent by mass, Max.	0.3	0.2	0.2	0.2	0.2	0.2	IS 1211 : 1978				
(iii)	Flash point, Cleveland open cup, °C, Min.	175	175	175	175	175	175	IS 1209 : 1978				
(iv)	Softening point °C	50 to 65	45 to 60	40 to 55	35 to 50	30 to 45	IS 1206 : 1978					
(v)	Penetration at 25°C, 100 g, 5 Sec., 1/10 mm	30 to 40	40 to 50	50 to 60	60 to 70	80 to 100	175 to 225	IS 1203 : 1978				
(vi)	Penetration ratio <sup>a</sup> , Min.	35	35	35	35	35	35	—				
(vii)	Ductility at 27°C, cm, Min.	50	75	75	75	75	75	IS 1208 : 1978				
(viii)	Paraffin wax content, percent by mass, Max.	4.5	4.5	4.5	4.5	4.5	4.5	IS 10612 : 1983				
(ix)	Loss on heating, thin film oven test, percent by mass, Max.	-4	-4	-6	-6	-8	-8	IS 8381 : 1979				
(x)	Loss on heating, thin film oven test, percent by mass, Max.	1	1	1	1	1	2	IS 1212 : 1978				
(xi)	Retained penetration after thin film oven test, 25°C, 100 g, 5 sec., 1/10 mm, percent of original, Min.	55	55	52	52	47	42	IS 8382 : 1979				
(xii)	Matter soluble in trichloroethylene, percent by mass, Min.	99	99	99	99	99	99	IS 1216 : 1978				
(xiii)	Viscosity at : (a) 60°C, Poise (b) 135°C, cent, Min.	2500 ± 500 230	2000 ± 400 210	1500 ± 300 180	1000 ± 200 150	500 ± 100 110	250 ± 50 20	IS 1206 (Part 2) : 1978 IS 1206 (Part 3) : 1978				

<sup>a</sup>Penetration ratio =  $\frac{\text{Penetration at } 4^\circ\text{C, } 100 \text{ g, } 5 \text{ sec.}}{\text{Penetration at } 25^\circ\text{C, } 100 \text{ g, } 5 \text{ sec.}}$

The cut-back bitumen enables use of the binder at relatively low temperatures. Upon application and use, the volatiles slowly evaporate, leaving behind the original bituminous binder.

Cut-backs are further classified according to their fluidity by suffixing a number ranging from 0 to 5. A suffix of 0 indicates the most liquid cut-back, whereas a suffix of 5 indicates the most viscous in the series. The modern trend is to use a suffix that denotes the viscosity. For example MC-70 grade implies a medium-curing cutback, the suffix 70 standing for its viscosity.

#### 20.1.16. Emulsions

Some of the cut-backs may be handled when the binder is cold and the aggregates are cold, but still some need to be heated. By emulsification, all binders can be converted to a fluid form at atmospheric temperature above 0°C. An emulsion is a relatively stable dispersion of a liquid, minutely sub-divided (disperse phase) in another liquid in which it is not soluble (continuous phase). In a bituminous emulsion, bitumen is the disperse phase and water the continuous phase. Stability of the emulsions is achieved by the use of an emulsifying agent contained in the aqueous phase.

Based on the type of emulsifier used, the bitumen particles can be negatively charged or positively charged. Emulsions having negatively charged bitumen particles are called anionic emulsions and those having positively charged particles are called cationic emulsions. The emulsifier used for the anionic emulsions are normally fatty acids derived from mineral, vegetable or wood sources saponified with sodium or potassium hydroxide. The emulsifiers in cationic emulsions are generally amine salts made by reacting hydrochloric acid or acetic acid with an organic amine or diamine. IS : 3117—1965 contains the requirements of anionic emulsions. Cationic emulsions are covered by IS : 8837—1978.

Emulsions have become popular in the recent past. They enjoy a number of advantages, as under :

- They are more tolerant than penetration grade bitumens, of the presence of dampness, although they should not be used in the presence of free water, on the road surface or on aggregates.
- Because emulsions are of relatively low viscosity at normal temperatures, they eliminate the need to heat the aggregates and binder, and thus they conserve energy.
- Their use reduces environmental pollution (especially because, unlike cutback bitumen, they do not release harmful diluents into the environment).
- They can be used when the weather is relatively cold.
- They are ideal for patching and repair work, particularly because they do not require heating before use.
- They are useful for sealing cracks, since they can penetrate fine cracks.

Emulsions are, however, costly and since they contain a substantial quantity of water, the transportation costs are higher.

The three types of bituminous emulsions as per IS:8837 Bitumen Emulsions for Roads (Cationic Type)-Specification are merely Rapid Setting (RS), Medium Setting (MS) and Slow Setting (SS). However, the classification of bituminous emulsions as per AASHTO/ASTM is more elaborate (also adopted in MOST revised specification), outlined below :

#### BITUMINOUS MATERIALS

Anionic	Cationic
RS-1	CRS-1
RS-2	CRS-2
MS-1	—
MS-2	CMS-2
MS-2h	CMS-2h
HFMS-1	—
HFMS-2	—
HFMS-2h	—
HFMS-2s	—
SS-1	CSS-1
SS-1h	CSS-1h

Besides the Rapid Setting (RS), Medium Setting (MS) and Slow Setting (SS), the emulsions are further classified by numbers and letters related to viscosity of the emulsions and hardness of the base straight-run bitumen. The letter "C" in front of the emulsion type denotes Cationic while the absence of "C" denotes Anionic. The numbers in the classification relate to the viscosity e.g., MS-2 is more viscous than MS-1; the "h" means harder base bitumen and "s" stands for the softer base bitumen. In the anionic grades, the "HF" before the grade indicates high float as measured by the float test. High float types have a gel quality that permits a thicker film of bitumen on the aggregate particles.

With the ever increasing use of polymer modified bitumens, a new set of emulsion grades have come up ending in p (s or l) e.g. HFMS-2 p implies a modified bitumen emulsion.

The emulsion breaks down on application to the road. In this process, the particles of the binder in the emulsion separate from the aqueous component and coalesce into a coherent film of binder. The breaking down process changes the brown colour of the emulsions to black. The water content evaporates, leaving behind the bitumen particles which get more closely packed together.

Practically all grades of straight-run bitumens can be emulsified. Tar or tar-bitumen blend can also be emulsified.

Emulsions have a number of advantages :

- They can be used when the aggregates are wet.
- They eliminate the need to heat the aggregates and binder and thus conserve energy.
- Their use eliminates environmental pollution.
- They can be used when the weather is cold.
- They are ideal for patching and repair work.
- They are useful for sealing cracks since they can penetrate fine cracks.

Emulsions are particularly useful for cold-weather work, and under wet conditions of aggregates. They become very handy for maintenance work and work in remote areas. They are also used in soil stabilisation. Emulsions are costly, since the bitumen has to be treated further to obtain emulsions. The bitumen content is in the range of 50—65 per cent, the rest being water.

#### 20.1.19. Guide to selection of bituminous binders

The selection of an appropriate grade and type of binder is the key to the success of a specification. The selection itself depends upon a number of factors such as :

- Type of specification—whether it is spraying or mixing.

Table 20.4. Grades of Road Tars for different purposes  
(as per IS : 215—1961)

Grade	Uses
RT-1	Surface dressing for very cold weather conditions and at high elevation on hill roads.
RT-2	Surface dressing under normal climatic conditions.
RT-3	(A) Surface dressing and renewal coats. (B) Precoating chippings; light chipping carpet.
RT-4	Premix tar macadam.
RT-5	Grouting.

Table 20.5. Standard Specification for Road Tars  
(as per IS : 215—1961)

Characteristic	RT-1	RT-2	RT-3	RT-4	RT-5
1. Viscosity (a) Temperature °C (b) Seconds	35 30—35	40 30—55	46 35—60	55 40—60	65 —
2. E.V.T. °C	32—36	37—41	43—46	53—57	63—68
3. Softening point of the residue	48	50	52	54	56
4. Water content %	0.5	0.5	0.5	0.5	0.5
5. Distillation % (a) Below 200 (b) 200—270 (c) 270—300 (d + c) max	0.5 4—12 4—10 16	0.5 2—9 4—8 14	0.5 1—6 3—6 12	0.5 0—5.4 2—7 10	0.5 0—4 1—5 7
6. Phenol % by vol.	2.0	2.0	2.0	2.0	1.0
7. Naphthalene % wt.	4.0	3.5	3.0	2.5	2.0
8. Matter insoluble in toluene %	22	22	24	24	24
9. Sp. gravity	1.16—1.26	1.16—1.26	1.18—1.28	1.18—1.28	1.18—1.28

#### 20.2.6. Low temperature tar

The coal-tar produced in the manufacture of coking coal results from carbonisation at high temperatures (above 1000°C). In recent years, the need to increase the availability of binders has given rise to a new technology of tar manufacture. This is known as "low temperature carbonisation" since the carbonisation of coal is carried out in the temperature range of 600—750°C in a smokeless fuel process. The crude tar so produced is now being successfully used for manufacturing road tars.

#### BITUMINOUS MATERIALS

*Q. what are the type of modified binders?*

#### 20.3. MODIFIED BINDERS

##### 20.3.1. Tar-bitumen mixtures

Tar and bitumen possess certain individual characteristics which, when combined in proper blending of the two materials, provide a road binder of excellent quality. The practice of blending tar and bitumen has thus become very popular in some countries. Bitumen has greater durability and lower temperature susceptibility than tar. But bitumen has poor adhesion with certain stone aggregates, especially in the presence of water, resulting in stripping. Tar has better adhesion with aggregates because of the presence of phenols. Tar, when exposed, weathers and hardens. Tar mixtures show better skid resistance properties than bitumen mixtures. The tar-bitumen blend exhibits the following improvements:

(i) As more and more bitumen is blended with tar, the benzene insoluble, which is normally not a binding material is decreased. The mixture thus has a better binding property.  
(ii) The softening point is increased and the penetration is lowered. Thus the temperature susceptibility of bitumen is lowered. The viscosity-temperature relationship is considerably improved.

(iii) Rheological nature of the binder is altered.

It is now common in countries abroad to mix bitumen and tar in proportions approaching 50—50. There are problems such as incompatibility, since bitumen and tar are chemically different. But with careful control, the materials can be blended.

##### 20.3.2. Rubberised tar and bitumen

The addition of a small quantity of natural rubber vastly changes the properties of tar and bitumen to great advantage. The important change is that the change in viscosity with temperature of the bitumen is significantly reduced. The softening point of the binder is increased and its brittle point is reduced. The elasticity of the binder increases with the addition of rubber (Ref. 2). In locations such as bus stops, rotary intersections and steep grades where frequent acceleration and deceleration are caused, it is advantageous to add rubber so that the flow of the mix is checked and the mixture is toughened. Rubber increases the resistance to brittle fracture at low temperature. Rubber improves the adhesion between the binder and the stone aggregates.

Natural rubber is introduced either as latex or rubber powder. The frothing which takes place is a disadvantage.

The use of crumb rubber powder, further improved by additives such as Gilsonite, is known to improve the properties of bitumen and the bituminous mixes. The suggested dosage is 12 per cent by weight of bitumen. TBM Super is one such material available in India.

##### 20.3.3. Polymer Modified Bitumen (PMB)

The following types of plastics and elastomers are also being used as bitumen modifiers (Ref. 31):

SMA : Stone mastic asphalt on concrete deck  
 SBS : Modified asphalt cement is polymer modified & mixed with bitumen to reduce the stripping of bitumen from the surface

Table 20.6. Types of Bitumen Modification

Sl. No.	Type of modifiers	Example	Indicative dose level, % by wt. of bitumen
1.	Plastics • Thermoplastics • Thermosets	Polyethylene (PE) Ethylacrylate (EVA) Epoxy resins	3-6 3-5
2.	Elastomers • Natural Rubber • Synthetic elastomers	Dry rubber content Styrene Butadiene copolymer (SBR) Styrene Butadiene Styrene block copolymer (SBS)	2-4 3-5
3.	Reclaimed rubbers	The Crumb Rubber Powder further improved by additives	10-12

20.3.4. Advantages of modified bitumens a. Advantage of modified binders.

The following advantages of modified bitumens may be noted :

- (i) Lower susceptibility to daily and seasonal temperature variations
- (ii) Higher resistance to deformation at elevated pavement temperature
- (iii) Better ageing resistance properties
- (iv) Higher fatigue life of mixes
- (v) Better adhesion between aggregates and binder, especially under exposure to water
- (vi) Preventing cracking and reflective cracking
- (vii) Overall improved performance in extreme climatic conditions and under heavy traffic conditions.

20.3.5. General requirements of modifiers

Whatever be the choice of a binder, the modifiers have to meet certain general requirements as under :

- (i) be compatible with bitumen
- (ii) be able to resist degradation of bitumen at mixing temperature
- (iii) be capable of being processed by conventional mixing and laying machinery
- (iv) produce coating viscosity at application temperature
- (v) maintain premium properties during storage, application and in service
- (vi) be cost-effective.

20.4. TYPES OF BITUMINOUS COURSES

Bitumen and tar are used as a binder in a variety of specifications. The specifications can broadly be classified as follows :

1. Prime coats and tack coats.
2. Surface dressing and seal coats.
3. Thin premixed surfacings.
4. Base courses.
5. Dense surfacings.

6. Stabilised courses containing bitumen.
7. Maintenance treatments.

Prime coats and tack coats have been dealt with in Section 20.5. Surface dressing and seal coats have been dealt with in Section 20.6. Thin premixed surfacings are of three types, viz, thin premixed open-textured carpets (dealt with in Section 20.8), coarse graded mix-seals (dealt with in Section 20.14), Semi-dense carpet (dealt with in Section 20.13). Bituminous base courses comprise of following specifications :

1. Built-up-spray, treated in section 20.9.
  2. Penetration macadam, including full-grout and semigrout, treated in section 20.11.
  3. Premixed macadam, treated in section 20.10
- Dense surfacings include the following specifications :
1. Asphaltic concrete, treated in section 20.12
  2. Mastic Asphalt, treated in section 20.17.
  3. Rolled Asphalt, treated in section 20.16
  4. Sheet Asphalt, treated in section 20.15.
  5. Stone Mastic Asphalt, treated in Section 20.18.

The use of bitumen in soil stabilisation has already been discussed in Chapter 17.

20.5. PRIME COATS AND TACK COATS

20.5.1. Definition of prime coat and tack coat

A prime coat is an initial application of a low viscosity liquid bituminous material to an absorbent surface preparatory to any super-imposed bituminous treatment or construction (Ref. 9).

A tack coat is an application of a bituminous binder to an existing surface (blacktopped or otherwise) to ensure a bond between the new construction and the old surface.

20.5.2. Objective of priming

Bituminous specifications are often to be provided directly over untreated layers such as gravel, water-bound macadam and stabilised soil. These courses contain considerable voids and present a porous texture, with the result that moisture can penetrate into the layers either from the superimposed layers, or from the sides or from underneath due to capillary action. One way of improving the situation is to apply a low viscosity liquid bitumen to such surface to penetrate the surface, plug capillary voids and to coat and bond dust and loose mineral particles. The process hardens or toughens the surface and promotes adhesion between it and the superimposed layer.

20.5.3. Objective of tack coat

The difference between a tack coat and a prime coat is that unlike the latter, the binder does not penetrate into the layer receiving the new application. It remains at the interface between the old surface and the new application and promotes necessary bond between the two. Such a bond becomes very crucial if the old surface is already dry and hungry and if the new treatment is very thin. Thin carpets have a tendency to peel off under excessive tangential stresses, unless they are adequately bonded to the old surface.

Sheet #11  
# Feb 2016

Where transverse and longitudinal joints meet, the mat may be butted or overlapped. Additional tack coat is required to bond the two mat areas together where overlapping is used.

Cornering can be accomplished without sectioning material walking gathered material to one spot and slicing the bubble out with the razor knife and tacking the overlap.

Removal and replacement of material that is damaged after placement, is the responsibility of the Contractor.

### ✓ c. Material Overlay

Hot mix overlay can immediately follow placement of the material or be delayed and opened to traffic as required. Prior to hot mix overlay, material shall be tacked over along with the existing surface at a rate prescribed by the Engineer. Any tack coat other than a bituminous emulsion must be approved by the Engineer prior to its application.

## 8.3 Materials for Asphalt Concrete Overlay and Construction Methods

### 8.3.1 Introduction

The section gives the specifications of materials for asphalt concrete overlay, describes the methods of construction and includes the quality control requirements of construction.

The overlay construction on the runway and shoulder shall be completed in three layers. Asphalt concrete overlay on the overrun strips on either end of the runway may be of 1-3 layers of variable thickness. Hot mix asphalt concrete prepared in central mixing plants as specified shall be used. The placement of the mix shall conform to the lines, grades, thickness and typical cross sections shown on the plans. Each lift (course) shall be constructed to the depth, or elevation required by the plans and shall be rolled, finished and approved before the placement of the next course.

### 8.3.2 Materials

Materials in bituminous overlay are coarse aggregate, fine aggregate, mineral filler, Portland cement and bitumen. Aggregates shall consist of crushed stone with or without sand or other finely divided mineral aggregate. The portion of materials retained on the No. 4 (4.75 mm) sieve shall be known as coarse aggregate. The portion passing No. 4 (4.75 mm) sieve and retained on No. 200 (0.075 mm) sieve shall be known as fine aggregate and the portion passing No. 200 (0.075 mm) sieve as mineral filler. The requirements of materials for asphalt concrete overlay construction are given below.

#### 8.3.2.1 Coarse Aggregate

Coarse aggregate shall consist of sound, tough, durable particles, free from adherent films of matter that would prevent thorough coating with the bituminous material. Course aggregates, to be used in overlay construction shall conform to be requirements in Table 8.3.

Q. what are the aggregate test for asphalt overlay in Hagnat shahjalal. Intl. Airport? → table 8.4

Q. what are the bitumen test → sheet #15

Q. what are the test for asphalt concrete? → table 8.3

Table 8.3: Tests for Aggregates and Filler for Asphalt Concrete

Test	Test Designation	Limits
1. Gradation (Combined Aggregates)	ASTM C136	See Table 8.7
2. Materials Finer than 75 µm Sieve	ASTM C117	3% maximum for natural or crushed gravel sands; less than 5% for crushed stone sands 1% maximum for natural or crushed gravel coarse aggregate 3% maximum for crushed rock coarse aggregate.
3. Clay Lumps	ASTM C-142	3% maximum for fine aggregate 2% maximum for coarse aggregate
4. Flakiness Index	BS 812: Part 105 Section 105.1, 1989	25% maximum for all coarse aggregate test fractions
5. Water Absorption for Coarse and Fine Aggregates	ASTM C127, ASTM C128	2% maximum for all aggregates
6. Bulk Specific Gravity of Coarse Aggregate	ASTM C127	Minimum 2.55
7. Specific Gravity of Fine Aggregate	ASTM C 128	-
8. Soundness of Aggregate by use of 5 Cycles of Sodium Sulphate Tests	ASTM C 88	9% maximum
9. Aggregate Crushing Value (ACV)	BS812, Part 110, 1990	30% maximum
10. Aggregate Impact Value	BS 812:part 3:1975 para.6	30% maximum
11. Los Angeles Abrasion Value	ASTM C131 (Grading 3)	30% maximum
12. Specific Gravity of Mineral Filler	ASTM C 188	-
13. Sand Equivalent Value of Fine Aggregate	ASTM D2419	45 minimum

Aggregates shall contain at least 75 percent by weight of crushed pieces having two or more fractured faces and 85 percent at least one fractured face.

The aggregate shall not contain more than 8 percent, by weight, of flat particles, elongated particles and flat elongated particles, when tested in accordance with ASTM D4791 with a value of 5:1.

Coarse aggregates shall be clean and dust free and if necessary they shall be washed before storage as well as use.

### 8.3.2.2 Fine Aggregate

Fine aggregate shall consist of clean, sound, durable, angular particles produced by crushing stone or gravel that meets the requirements given in Table 8.3. Any combination of crushed fine aggregate and natural sand will be permitted provided that the percentage of natural sand does not exceed 15 per cent of the total blend of aggregates. Fine aggregate

particles shall be free from coatings of clay, silt or other objectionable matter and shall contain no clay balls. The fine aggregate including any blended material for the fine aggregate, shall have a plasticity index of not more than 4 and a liquid limit of not more than 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.

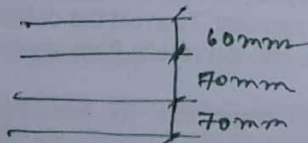
Table 8.4: Requirement for Asphalt Cement for Overlay Mixes  
[Penetration Grade: 60-70, ASTM D946]

Test	ASTM Designation	Limiting Value	
		Minimum	Maximum
Penetration, 25°C, 100g, 5 sec.	D5	60	70
Flush point COC, °C (F)	D32	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

Q: what are the requirements for overlay mixes?

Runway:



Asphaltic concrete overlay in 3 layers

Asphalt: obtained from nature & manufactured  
Bitumen: having asphalt & tar

### BITUMINOUS MATERIALS: PRODUCTION, TYPES, TESTS AND SPECIFICATION

#### ASPHALT, BITUMEN & TAR:

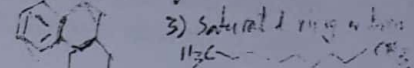
British: Asphalt - natural  
          Bitumen - manufactured  
American: Bitumen - general name for asphalt and tar  
            Asphalt - natural or manufactured

Asphalt Molecule  $H_{12} & C_{10}$  chain

1) Aliphatic - straight or branched



2) Unsaturated ring or aromatic structure



3) Saturated ring or heterocyclic

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

#### Refined Asphalt

Carbon	85%
Hydrogen	10%
Nitrogen	0.5%
Sulphur	3.5%
Oxygen	0.6%
Others	0.9%

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:

- o 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
- o 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.

based on residue

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

(total classification of bituminous material)

over million years of bacterial attack, moderate heat, pressure and catalytic action of finely divided mineral particles has converted the residues into crude petroleum. Mainly three types,

- Paraffinic base
- Asphaltic base
- Mixed base

**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,

- Dehydration: heating in the storage to remove water
- 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.
- Air rectification: air is passed through residual asphalt
- Cutbacks: residual asphalt is mixed with light oil fractions
- Emulsification: discuss (Bangla report)

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

Q. what is the total classification of straight run asphalt?

- based on residue*
- 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 (6<sup>th</sup> Edition) shows simplified flow chart of recovery and refining of petroleum asphalts.

Desirable Properties of Asphalt/Bitumen: *Common properties of asphalt.*

- 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

Q. what are the desirable qualities of bitumen?

## Testing of Asphalt/Bitumen:

Before using bituminous materials, in any construction, the material must be tested to satisfy intended requirements. A large number of tests have been developed by different agencies, most of which are accepted or approved by AASHTO and ASTM. Table 15.1 (Wright and Dixon) contains tests which are for asphalt, for tar or for both tar and asphalt. The groups of tests are as follows:

- general tests
- solubility tests\
- consistency tests
- ductility tests
- volatility tests

Details of the above tests should be included in CE354 course.

Besides the tests of semisolid asphaltic materials, there are special tests for emulsified asphalt which are listed in page no. of the sheet supplied. (Chapter 15, Wright and Dixon)

### Specification of Bituminous Materials:

As per the sheets supplied.

Asphalt/bitumen is used in wide variety of civil engineering constructions.

**Tar:** is a black solid or semi-solid mass obtained during the destructive distillation of coal, peat, wood, or other organic material. Its properties depend upon the raw material used, method of distillation and the proportion of residual matter incorporated. Tar hardens much quicker than asphalt, it is more adhesive and possesses more toxicity. It is used for road making and roofing and as a protective material for timber and wood products.

viscosity (ताप और flow को ध्यान में रखकर)

1. capillary viscometer test
2. capillary viscometer or thin film oven test

Emulsified Asphalt, Appropriate Bitumen for Bangladesh: Mix Design, Types, Ingredients, Requirements

### Emulsified Asphalt

What is it?

Why is required?

How is done?

Section 20.1.18 Pg. 462, Sheet # 10

Testing of Emulsified Asphalt, Section 15-16, pg. 427 Wright & Dixon (7<sup>th</sup> Edition)

## ✓ BITUMEN Quality for Road Construction in Bangladesh

Introduction

Essential Characteristics of Penetration Grade Bitumen

Climate of Bangladesh and Appropriate Bitumen Type

Improvement of Bitumen Qualities

Conclusions

Discuss above topics as per sheet supplied. (Sheet # )

Questions: What is the appropriate bitumen type for road construction in Bangladesh?  
What are the qualities required for bitumen to be used in road construction of BD? How are these qualities be achieved?

### Bituminous Mixes:

When an aggregate mass, in any grading, is mixed with liquid bitumen it is a bituminous mix. It may be low, intermediate or high type depending on,

- Specification of the work
- Aggregate type and grading
- Binder type and viscosity
- Construction method, and
- Cost involved

### Types of bituminous mixes:

- Surface treatments
  - Surface coats
    - Prime coat
    - Tack coat
    - Seal coat

## 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 Jiu-krit, it referred to the pitch producing certain resinous trees. Later the Latin terms Gwit-men and Pxiu-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 petroleum, 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, ring and ball softening point can be used to establish the important engineering properties 'stiffness'. Pfeiffer as reported by TRRL (1) developed the best known expression for 'stiffness'. Pfeiffer's expression is  $\log P = A \cdot T + K$  where the slope 'A' represents the temperature susceptibility of the logarithm of the penetration of the bitumen. Vander Ploeg (2) has shown that the penetration corresponding to ring and ball softening point is related to the penetration corresponding to 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:

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

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 Association (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 aggregate 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 slipping after a known period is then measured by visual inspection.

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

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d. What are the desirable qualities of bitumen for road construction in Bd? \* improvement of bitumen quality

2. Bitumen quality for road \*  
 2. compare penetration grade by US & UK (80-100 penetration grade)  
 ⇒ Asphalt cement used in roads - penetration grade (40-50)

ductility and is applicable to semisolid binder material. A briquette of standard dimension is elongated without breaking at standard temperature and the distance of elongation measures ductility. Ductility test result is interpreted to be a measure of cementing power of bitumen (4). Since high cementing qualities are desirable in most applications, it is held that a bitumen that is to be used as a binder should be ductile.

Most highway departments of developed countries have specifications for binder materials. The AASHTO(5) and the British Standard Institution specifications for penetration grade bitumen are shown in Tables 1 and 2 respectively.

\* Table 1 : Standard specification for Penetration Graded Asphalt Cement with AASHTO Designation M 20-70(5)

	Penetration Grade									
	40-50		60-70		85-100		120-150		200-300	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Pen. at 25°C	40	50	60	70	85	100	120	150	200	300
Flash point	450	—	450	—	450	—	425	—	350	—
Ductility at 25°C	100	—	100	—	100	—	100	—	—	—
Solubility (CCL <sub>4</sub> )	99	—	99	—	99	—	99	—	99	—
Loss on heating, %	—	0.8	—	0.8	—	1.0	—	1.3	—	1.5
Pen. of residue, % of original	58	—	54	—	50	—	46	—	40	—
Ductility of residue at 25°C	—	—	50	—	75	—	100	—	100	—

Table 2 : BS 3690 : 1982 Requirements for Penetration Bitumens (6)

Property	Penetration Grades							
	35Pen	40Pen	50Pen	70Pen	100Pen	200Pen	300Pen	450Pen
Pen. (25°C)	35+7	40+10	50+10	70+10	100+20	200+30	300+45	450+65
SPT°C min	52	58	47	44	41	33	30	25
max	64	68	58	54	51	42	39	34
LOH (Shr) %	0.2	0.2	0.2	0.2	0.5	0.5	1.0	1.0
pen. loss %	20	20	20	20	20	20	25	25
Sol. (CCL <sub>4</sub> )	99.5	99.5	99.5	99.5	99.5	99.5	99.5	99.5
Ash con.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Por. (min)	2.63	2.65	2.65	2.65	Not Required			
Sn. Gr 25°C	1.03	1.03	1.03	1.029	1.029	1.029	1.028	1.027

A thorough study of the Tables (1 & 2) reveal that specification requirements for some qualities are similar. AASHTO specifies ductility and flash point requirements for the binder which are not present in BS specification. On the other hand BS included extra requirements regarding softening point, ash content, permittivity, and mobile specific gravity. BS also specified for 3 more penetration grades of bitumen as compared to AASHTO specification. From a comparison of these specifications one has the feeling that BS specification is more specific and rigid than AASHTO specification.

### CLIMATE OF BANGLADESH AND APPROPRIATE BITUMEN TYPE

The climate of Bangladesh is characterized by moderate to high temperature, heavy rainfall, often excessive humidity and fairly marked seasonal variations. Though more than half of the country is on the north of the tropics, yet the effect of the Himalayan mountain chain is such as to make the climate tropical more or less throughout the year. The maximum temperatures in the year are reached between March and April(7). The mean maximum temperature ranges from 88°F, the mean minimum goes down to 72°F. In the western part there are even sharper falls. During severe winter i.e in the last week of December the northern areas of the western region record mean minimum of 48°F. From these temperature information it is seen that the overall variation throughout the year is 48°F to 97°F.

The average rainfall is 143 inches at Cox's Bazar but only 102 inches at Chittagong. There is an increase in rainfall as one goes north from Chittagong. At Sylhet rainfall average is 159 inches and near the foot of Meghalaya Plateau, at Sunamgonj it is 210 inches and at Lalakhal it is 256 inches the highest of any station in Bangladesh. In the rest of Bangladesh, with the exception of southern part of the country the annual average varies from 70 inches to 90 inches. In the southern part of the northern region the average is around 55 inches.

A third factor important for roads in Bangladesh is occasional flood. There are few areas which are not liable to serious flooding once every two or three years. Days of heavy, late season monsoon rains overflow the rivers transforming the low lying countryside into a virtual lake. Although the formation level of most of the roads in Bangladesh are above HFL, during severe flood, a portion of country's road network lay under knee to waist high sheet of muddy water (e.g. during flood in 1988). The whole pavement structure remains submerged and due to the passage of vehicles and pedestrians the damage reaches to maximum.

Under the prevailing climatic condition in Bangladesh bitumen, to be used for road construction, should possess all its desirable qualities. It should be easily workable at low temperature and at the same time have sufficient stiffness throughout the range of temperature. The first thing which has to be sorted out is the appropriate penetration grade. The traditional use of 80 - 100 penetration grade may not be suitable under the existing temperature and traffic condition. Swaminathan et al(8) reported a field study on the choice of appropriate bitumen grade in order to achieve the twin objectives of optimum use of binder and overall economy of bituminous surfacing. The test site was near Delhi, India where the temperature variation is nearly similar to that exists in some parts of Bangladesh. Three grades of bitumen, 40/50, 60/70 and 80/100 and four types of aggregate grading were used. For statistical evaluation of the comparative performance of the sections, a detailed quantitative approach in addition to the visual observations was used. The influence of bitumen grade on the overall performance of the test section is shown in Fig. 2.

It is seen from Fig. 2 that the general pattern of curves appear to have a negative slope indicating that 30/40 perform the best, followed by 60/70 and 80/100 respectively. The discrepancy at some sections were reexamined and observed that the sections had prematurely failed. On their rejection, the ranking order of decreasing performance become 30/40, 60/70 and 80/100 respectively. For the interaction of bitumen type and aggregate grading it was reported that for mixes with coarse grading, penetration grade 30/40 performs better than 80/100.

The selection of bitumen grade is also dependent on traffic intensity. For general application a grade of 40/60 is recommended by TRRL(1). For situation where high rainfall and colder conditions prevail a higher grade of 60/80 is specified. For heavy traffic in equable climate 30/40 penetration is recommended (1). In the context of Bangladesh, from the light of above discussions, it can be inferred that a lower grade than 80/100 may be suitable, at least, for the major highways and city arterials where traffic intensity is maximum.

Other desirable qualities of bitumen to be used in roads of Bangladesh are high adhesive or cementing capacity, low rate of stripping, low temperature susceptibility and low tendency of age hardening. These qualities depend mainly on the origin and manufacturing process of bitumen. However, a bitumen can be improved or modified in order to achieve desirable qualities.

#### \* IMPROVEMENT OF BITUMEN QUALITIES

Having established the grade or viscosity of the semisolid bitumen and its desirable qualities it is necessary to improve the qualities as far as possible. Early attempts to modify bitumen were directed towards decreasing temperature susceptibility by use of natural rubber in crumb or latex form. As problem of high temperature degradation is associated with rubber/bitumen blends, they are replaced by polymer/bitumen blends(9). Choyce and Wooley(10) reported that a great deal of improvement in softening point (R&B) are possible by using Ethylene and Vinyl Acetate (EVA) Copolymers. It is also claimed that the improvement of binder properties resulting from the incorporation of copolymers, is reflected in large improvements in resistance to deformation(10). Loveday (11) reported that EVA modified bitumen gives an additional workability which is useful during construction at relatively low temperature. This type of modification will be of great use in controlling bitumen bleeding and high deformation on the surface during the hot summer days in Bangladesh.

In order to improve adhesive bond between stone and bitumen and to reduce the tendency for replacement by water, certain anti-stripping agents can be used. A number of material can be used such as heavy metal soaps, quarternary ammonium salts and certain organic amines(12). Cetyl pyridinium bromide and other similar cationic detergents when dissolved in water are absorbed strongly on to the stone surface thereby resisting stripping. Best results are reported to be obtained when these agents are used with cold and wet aggregates before the binder is added(12). As bituminous surfaces, in Bangladesh, frequently remain submerged under rain or flood water, it is of utmost necessary to improve adhesion and resistance to stripping of the binders to be used in bituminous mixes.

Bitumens are often modified in order to reduce susceptibility to oxidation or to loss of volatile oils. This is essentially required that bitumen is resistant to changes due to the influences of water and air. Addition of Sulphur or air blowing are claimed to bring beneficial effect on the durability of bitumen<sup>1</sup>. The best method of laying bituminous mix intended to have long life under difficult conditions is to use impervious dense mix with appropriate compaction.

<sup>1</sup> bituminous mix.

The mechanical properties of a bituminous road mixture depend, not only on the quality of the binder but also on the compacted structure of aggregate particles. The internal frictional property, on which the stability of the mix largely depends, is a function of many factors including aggregate types, maximum size of aggregate, grading, and amount of filler material. High stability values are claimed to be achieved with certain penetration grade bitumen using suitable aggregates in appropriate grading(13). Research has to be intensified for a comprehensive evaluation of bitumen aggregate reaction, and different combinations of aggregate types, penetration grade, aggregate grading and compaction, in order to find out exact material characteristics.

#### CONCLUSIONS

From the discussions set forth above, a series of broad conclusions could be drawn, which may not be completely justifiable to draw definite conclusions without result from intensive laboratory and field studies on the selection of appropriate binder for road construction in Bangladesh. The general conclusions are as follows:

- i) selection of appropriate bitumen grade and its desirable qualities is of utmost importance towards the development of a rational mix design procedure using local aggregates.
- ii) For better performance, a lower penetration bitumen than 80/100 is felt necessary for the climatic and traffic conditions in Bangladesh.
- iii) Qualities of penetration grade bitumen regarding adhesion, temperature susceptibility and durability can be improved by using proper reagents in required amount.
- iv) A comprehensive research programme is necessary for exact evaluation and development of specification for road binders to be used in roads of Bangladesh.

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