



Construction and Quality Control of Flexible and Rigid Pavements March 03-05, 2022

Quality Control Tests on Various Pavement Layers

National Rural Infrastructure
Development Agency



Ministry of Rural
Development

National Institute of Technology



Warangal, Hyderabad





Lecture-3

Quality Control Tests on Various Pavement Layers





Presentation out line

- **Pavement types and Requirement**
- **Quality of roads and Importance**
- **QC Tests on Subgrade and Embankment**
- **Qc Tests on subbases, base and surfacing**
- **QC of Treated Subbase,Base and Subgrade**
- **Bituminous Construction**
- **Cement Concrete Pavements**





Introduction

With a total road length of

5.4 Mn Km,

India has the

2nd largest

road network in the world comprising National Highways, State Highways and Project and Rural roads

National Highways account for only 1.9% of the total road network but carry

40%

of the total traffic

Roads carry

60%

of the freight and

80%

of the passenger traffic

Thrust on building infrastructure

Under the Pradhan Mantri Gram Sadak Yojana (PMGSY) 1,25,000 Km of road length will be upgraded by 2024

Length of national highway network to reach 2,00,000 Km by 2022

Allocated budget for roads increased to USD 11.7 Bn in 2019-20

Rate of highway construction has more than doubled in the past 5 years



Allocation of Funds:

2014- Rs. 15 34,345 crore

2015-Rs. 16 44,255 crore

2016- Rs. 17 57, 976 crore

2017- Rs. 18 64, 900 crore

60 km /day target





Motivation.....





Excellent Specifications...



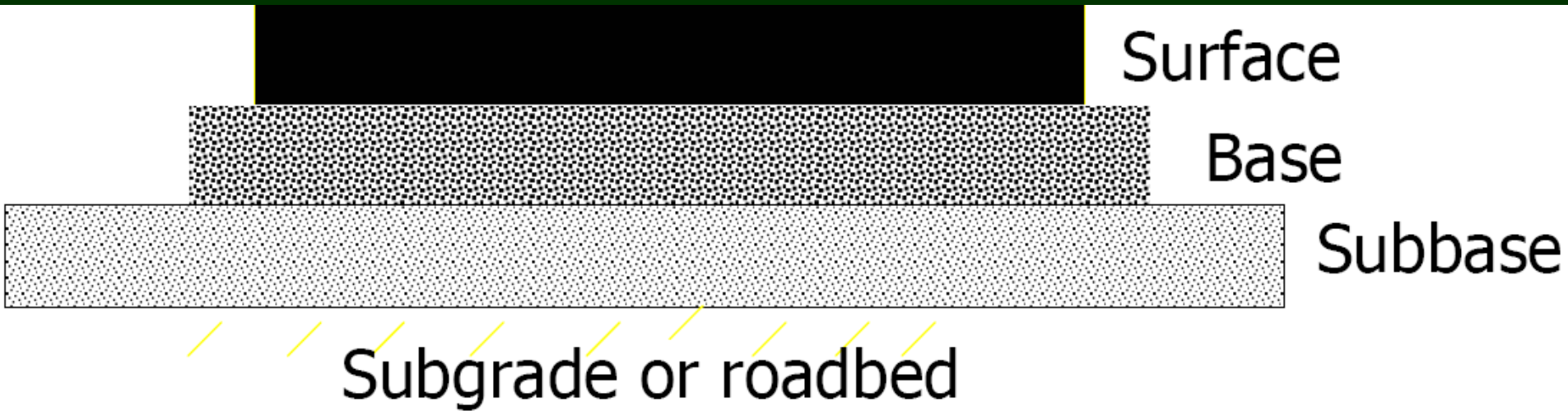


S. No.	Thickness (mm)		Total thickness (Gr-I and Gr-II)
	Grading-II (Layer 1) (100)	Grading-I (Layer 2) (150)	
1	105	101	205
2	90	139	225
3	77	125	207
4	59	106	175
5	77	126	202
6	87	111	195
7	119	0.0	119
8	91	120	216
9	93	105	205
10	92	152	255
11	104	139	231
12	96	141	232
13	90	114	198





Pavement types and Requirements



Functional Requirements

- Riding Comfort
- Economic operation
- Safe operation

Structural Requirements

- Traffic and Load Repetition
- Climatic Variables
- Environmental Factors





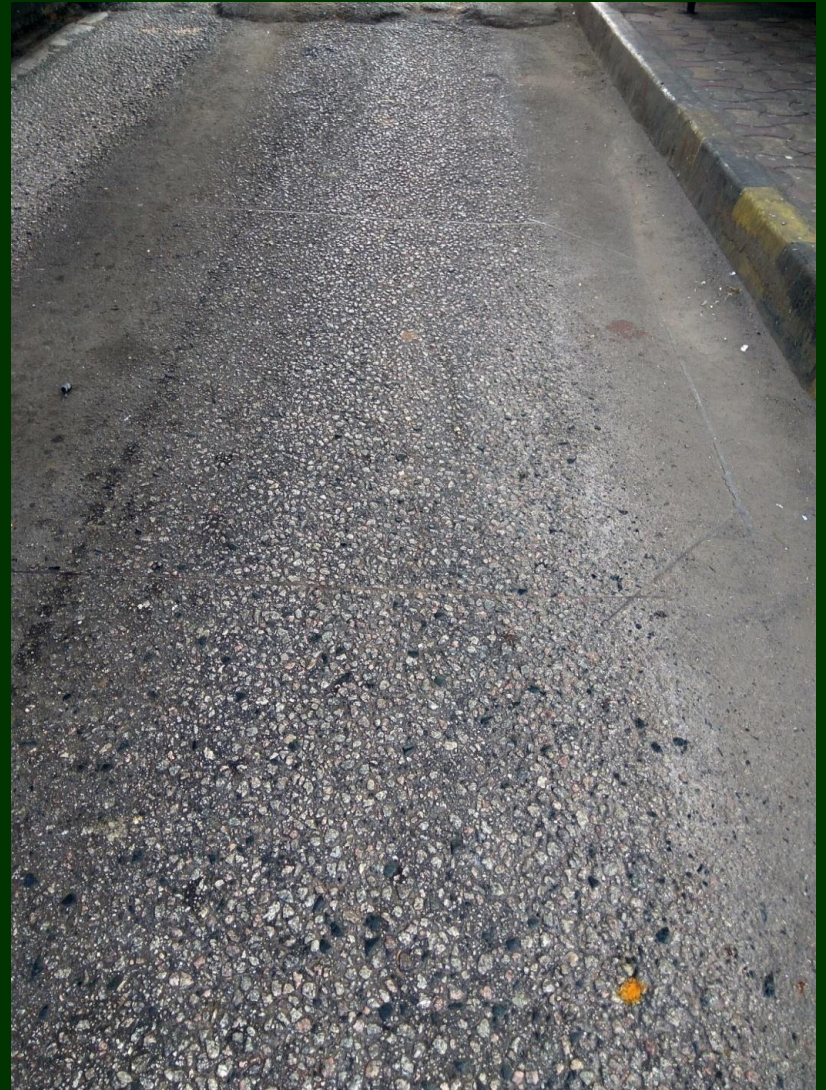
Quality of Roads and Importance

- QC is the responsibility of the construction contractor
- Qualified personnel conducting material sampling and testing
- QAQC activities certified by a nationally recognized organization
- Well equipped in house laboratory is necessary
- PMGSY-PIUs has a quality control wing EE's ,DEEs, AEE's & AE's
- Make use of Quality control lab to ensure good quality works
- PIUs- has to make its own arrangement to for testing
 - **While testing in the laboratory results are good but**
 - **in the filed lot of variations!!!**











Poor choices for pavement preservation





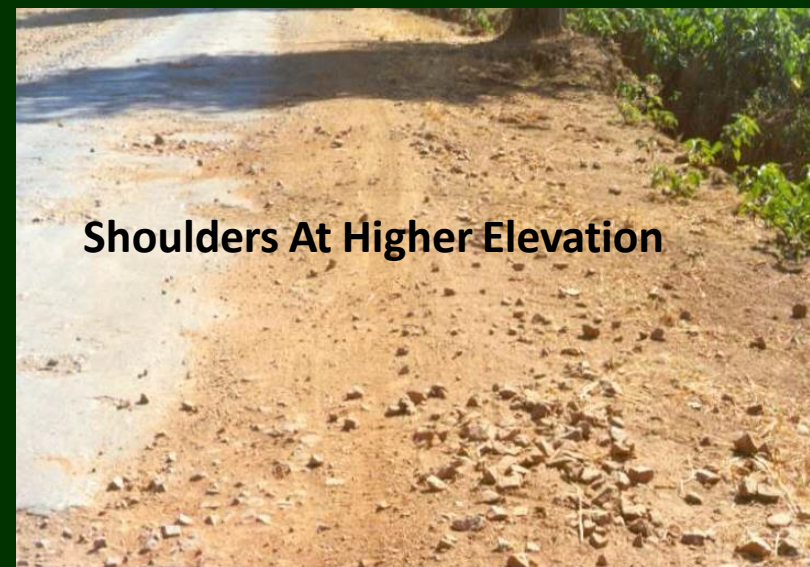
Contd....



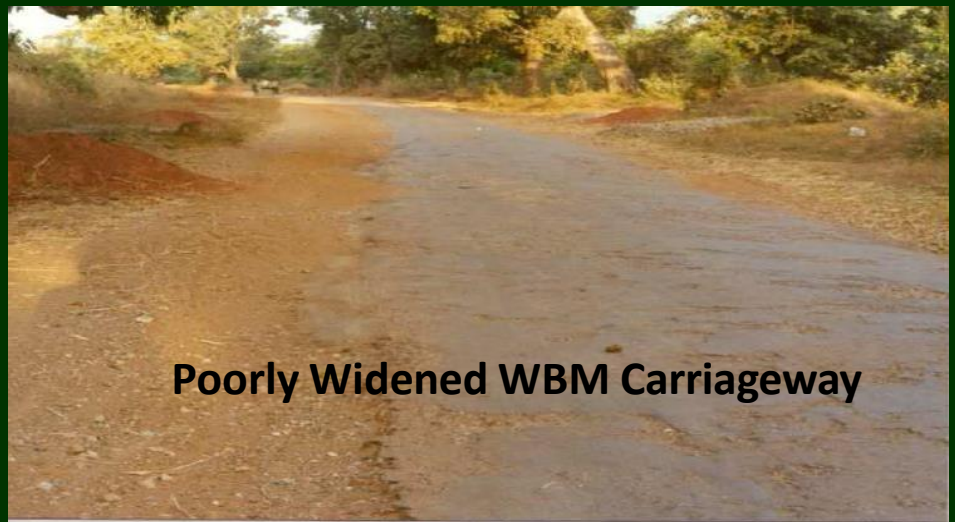
Inadequate Compaction And Excess Binding Material



WBM Surface Without Key Aggregates And Excess Binding Material

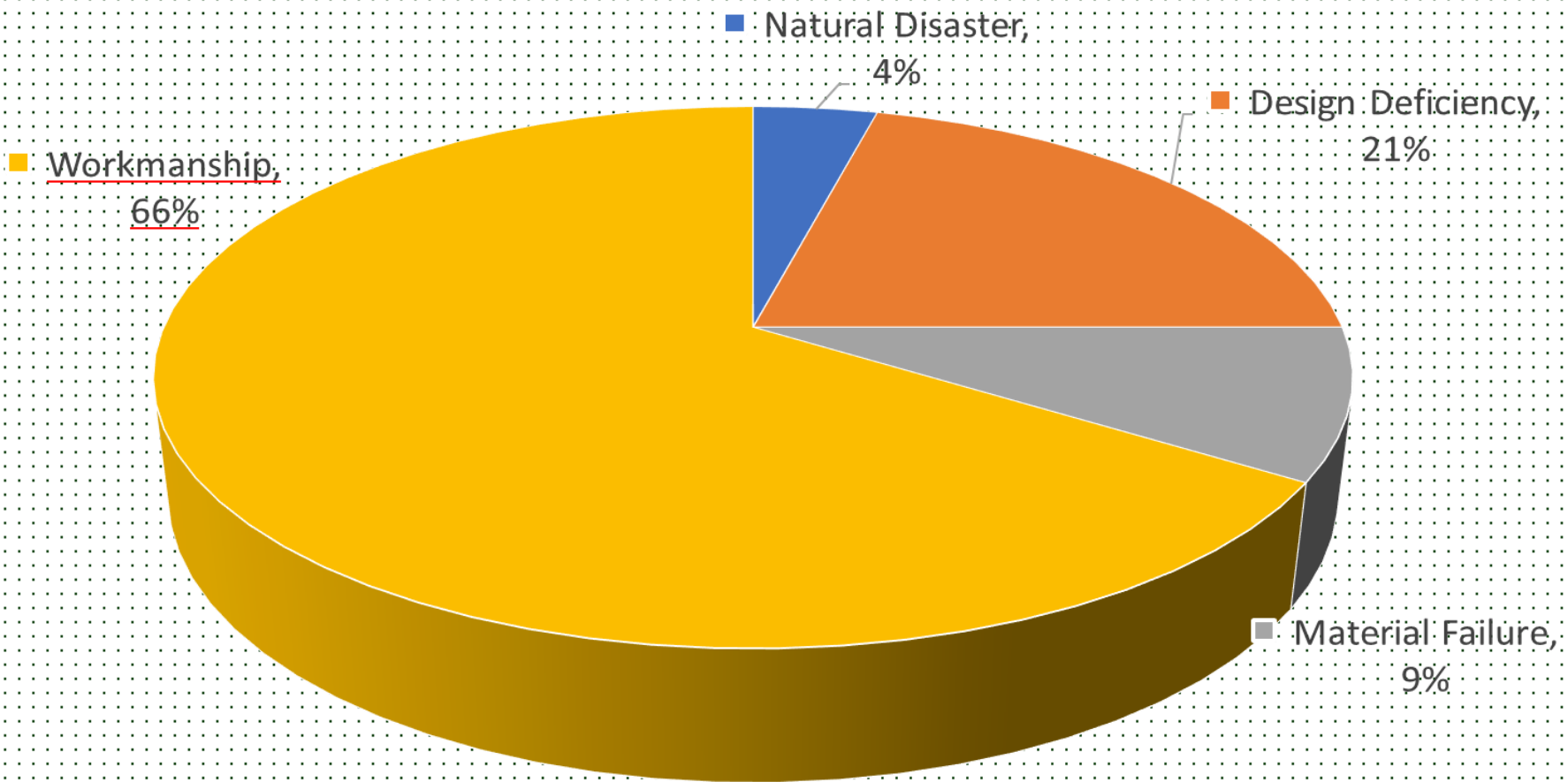


Shoulders At Higher Elevation



Poorly Widened WBM Carriageway





Causes of Poor Pavement Performance





Quality Assurance Vs Quality Control

Quality Assurance

Overall management plan to guarantee the integrity of data

Quality Control

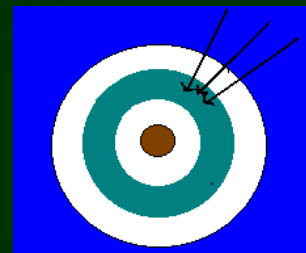
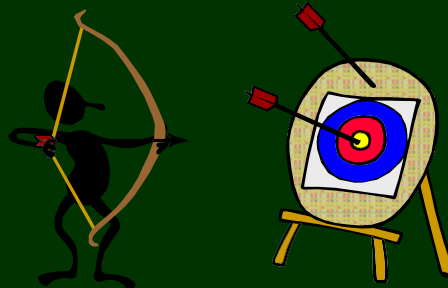
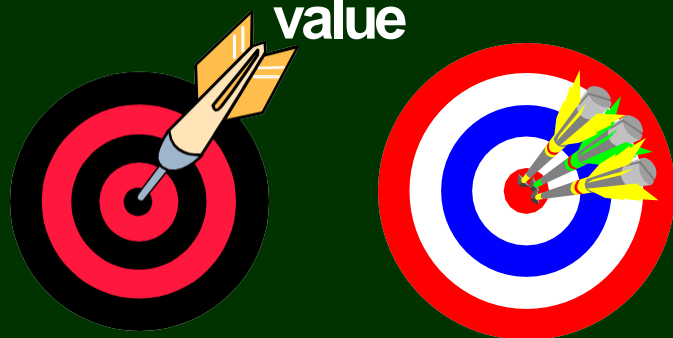
Analytical measurements used to assess the quality of the analytical data

Accuracy

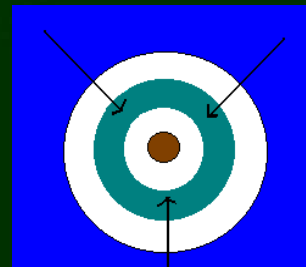
How well a measurement agrees with an accepted value

Precision

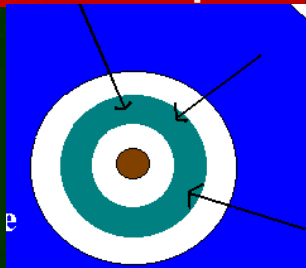
How well a series of measurements agree with each other



Precise not accurate



Accurate not precise



Neither precise nor accurate





Why Tests : Prior to Construction

- To ensure the conformance to specifications
- To finalize the source identified by the contractor
- Representative materials for testing
- Test results shall form the basis of source approval
- Test certificates from Accredited laboratory

Quality Control Records.....

- Inventory of equipment and QA plans
- Method statements and source approvals
- Mix designs and calibration records
- Control tests and frequency monitoring
- Consolidated Test Records and Borrow pits





Tests on embankment



Grain Size



Atterberg limits



SPDT

- Free Swell Index
- Deleterious Content





Tests on Subgrade (Cutting and Filling)

- Thickness of Subgrade layers ? Any Non destructive method?



- 150 mm-small cylinder- fine and med grained and not > 250-large mould
- Density, moisture and degree of compaction
- Measuring Range : 1100 kg/ m³ to 2750 kg/m³
- Temperature: 0-50 °C; Humidity: 5-90%.





Contd...



03 samples are often prepared, using different number of blows per layer for each sample. Typically, 15, 35, and 65 blows per layer are used

The material used in the remoulded specimen should all pass through a 19 mm IS sieve. Allowance for larger material may be made by replacing it by an equal amount of material which passes a 19 mm sieve but is retained on a 4.75 mm IS sieve.





Granular Sub Base : Prior and during Construction

- **Test Prior to Construction**
 - Gradation and wet sieve analysis
 - Atterberg's limit
 - Standard proctor compaction test
 - Wet aggregate impact value
 - California bearing ratio
- **Test During the Construction**
 - Gradation and wet sieve analysis
 - Atterberg's limit
 - Placement moisture content
 - In-situ density measurements
 - Thickness of compacted layer





Lime / Cement Treated Soil Sub-Grade / Sub Base

- **Test Prior to Construction**
 - Purity of lime / quality of cement
 - Optimum quantity of lime / cement
 - Plasticity index of lime treated soil
 - California bearing ratio
 - Unconfined compressive strength
- **Test During the Construction**
 - Placement moisture content
 - In-situ density





WBM/WMM(Base Course)

- **Test Prior to Construction**
 - Aggregate Impact value
 - Water absorption tests
 - Soundness and Gradation Test
 - LL and PI (Binding material)
 - Proctor Compaction
- **Test During the Construction**
 - Gradation and Shape test
 - Aggregate Impact value
 - In-situ Moisture content
 - PI (Binding material)
 - Thickness & Density of Compacted layer





Definitions of Aggregates: Tests

- **Coarse Aggregate**
 - Retained on 4.75 mm (No. 4) ASTM D692
 - Retained on 2.38 mm (No. 8) Asphalt Institute
 - Retained on 2.00 mm (No. 10) HMA Book
- **Fine Aggregate.**
 - Passing 4.75 mm (No. 4) ASTM D1073
 - Passing 2.38 mm (No. 8) Asphalt Institute
- **Mineral Filler**
 - At least 70% Pass. 0.075 mm ASTM D242
- **Test on Aggregates**
 - Sieve analysis
 - Bulk density
 - Specific gravity and water absorption
 - Impact and crushing value
 - Shape test and sand equivalent test





Aggregate Impact test

✓ To assess its resistance to disintegration against loading

- Passing 12.5 mm retained on 10 mm
- 4hrs at 105 -110°C and cool them
- 3 layers by 25 blows.
- Height of fall 38cms
- ✓ Surface course : 30%
- ✓ Base course : 40%
- ✓ Subbase : 50%





Aggregate Shape Test

- ✓ To know the loss of strength of granular base and surface
- ✓ 63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 and 6.3 mm.
- ✓ 200 pieces of each fraction are tested to be taken.
 - Surface course : ≤ 20
 - Base course : ≤ 25
 - Subbase : ≤ 30
- ✓ Not applicable to sizes < 6.3 mm.
- ✓ Combined FI +EI for BT and Non BT mixes $\leq 30\%$



Thickness gauge





Water Absorption Test

- To know the porosity of aggregates and indirectly indicate the its strength against external loading.
- Sample of about 1kg and immersed in water for 24hrs.
- Sample will be dried in an oven at 100- 110°C
- The ratio of the mass of water absorbed by the aggregate to the mass of the aggregates expressed as a percentage
- Water absorption should not exceed 2%





LoS Angeles Abrasion Test

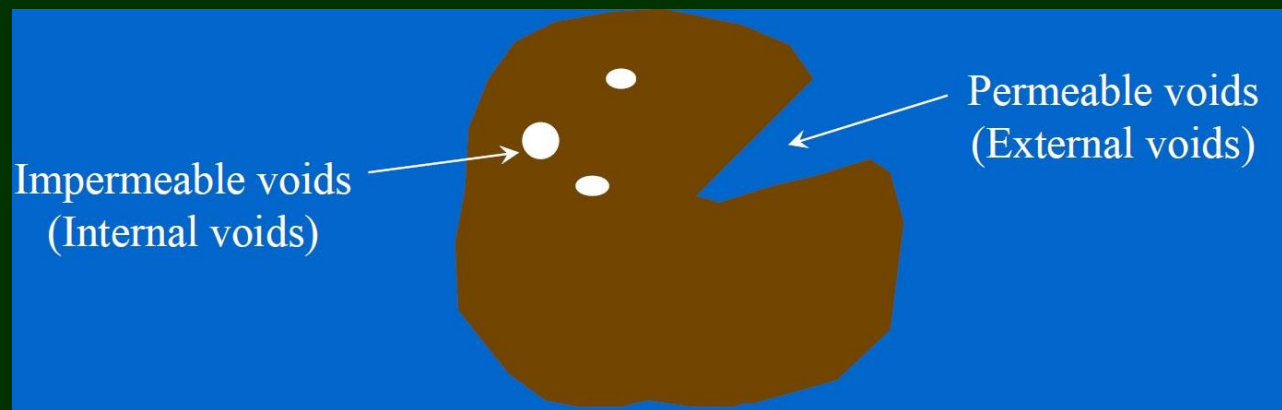
- **Suitability of aggregates for use in road construction.**
 - ✓ **Sieve: 1.70,2.36,4.75,6.3,10,12.5,20,25,40,50,63,80 mm**
 - ✓ **Balance of capacity 5kg or 10kg.**
 - ✓ **Clean aggregates dried in oven at 105° – 110°C.**
 - ✓ **Speed of 30 – 33 revolutions per minute.**
 - ✓ **For 500 revolutions grading A, B, C and D.**
 - ✓ **For 1000 revolutions for grading E, F and G**
-
- **WBM surface course : 40%**
 - **WBM base course : 50%**
 - **WBM sub base : 60%**





Aggregate Specific Gravities

- Which specific gravities do we need to know and how do we determine them?
 - Bulk Specific Gravity (G_{sb})
 - Apparent Specific Gravity (G_{sa})
 - Effective Specific Gravity (G_{se})
- Absorption (%)




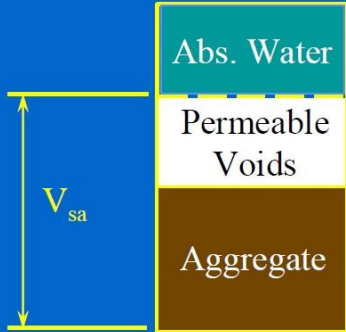


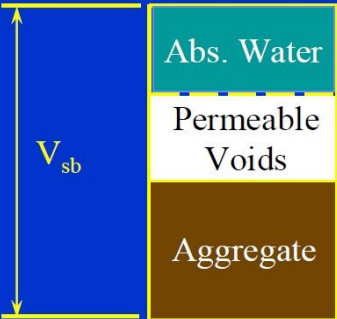


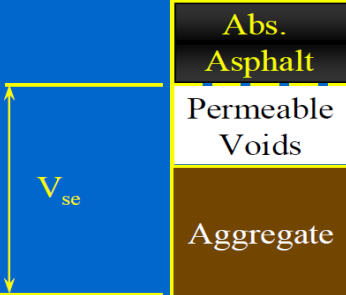
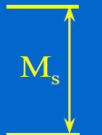
Permeable voids - voids that will hold water in a SSD condition

Impermeable voids - voids that water can not permeate





Specific Gravity

	Volume	Mass
$G_{sa} = \frac{M_s}{V_{sa} * \gamma_w}$ 		
$G_{sb} = \frac{M_s}{V_{sb} * \gamma_w}$ 		
$G_{se} = \frac{M_s}{V_{se} * \gamma_w}$ 		

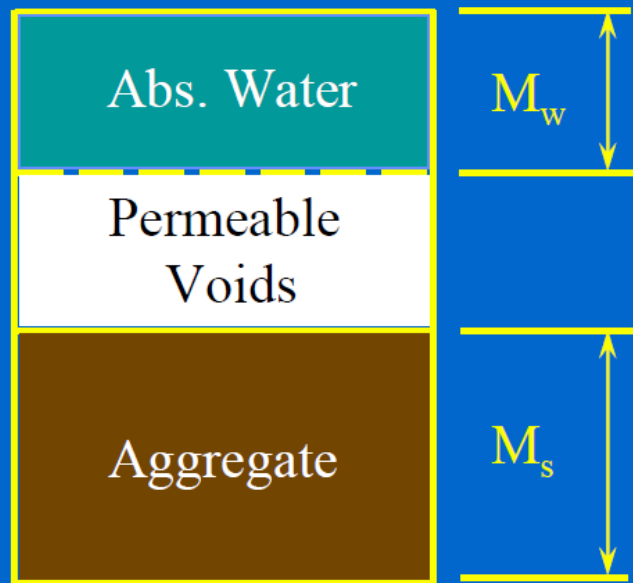




Absorption (%)

The ratio of the mass of water absorbed by the aggregate to the mass of the aggregates expressed as a percentage

$$\text{Abs. \%} = \frac{M_w}{M_s} * 100$$





Tests on Bitumen and Emulsions

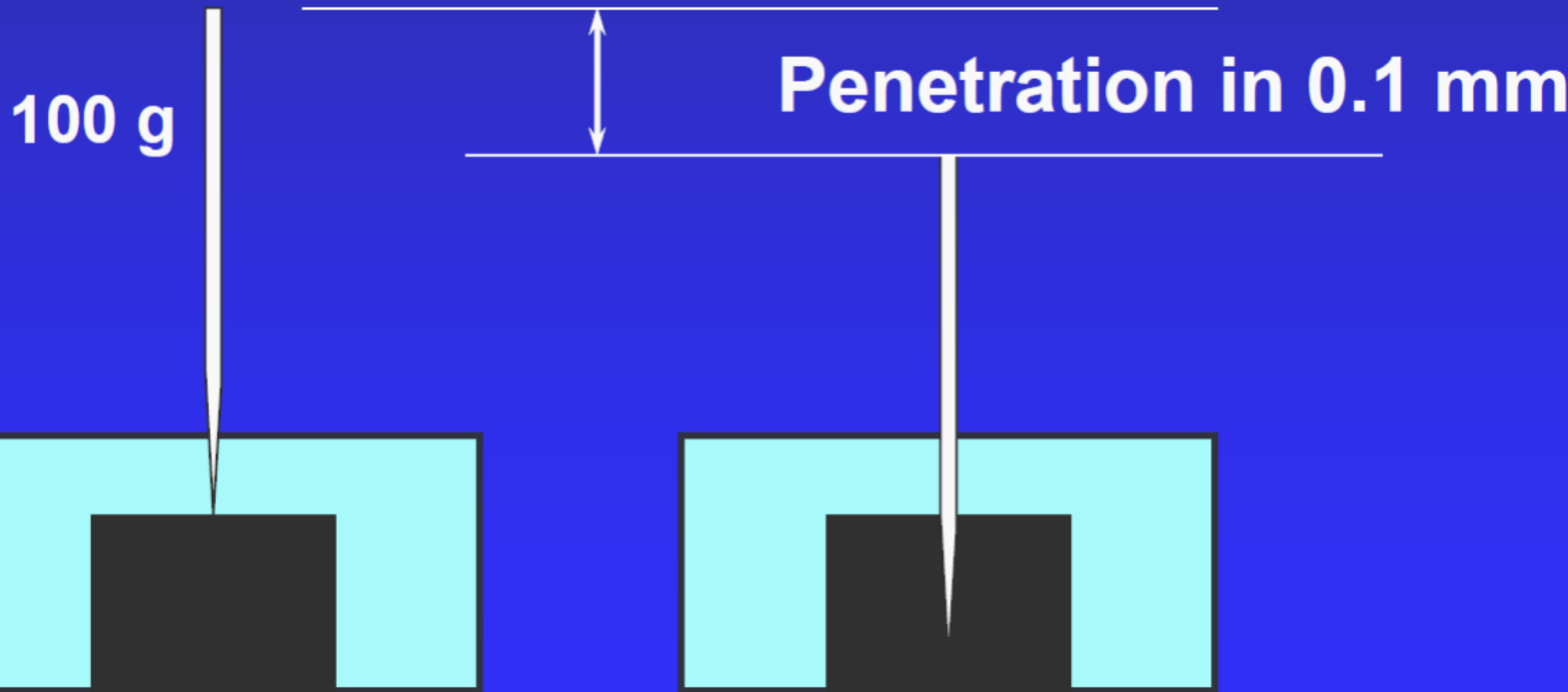
- Softening Point
- Penetration Test
- Ductility Test
- Viscosity(Absolute & Kinematic)
- Separation tests
- **Water Content**
- **Miscibility with Water**
- **Residue by Evaporation**





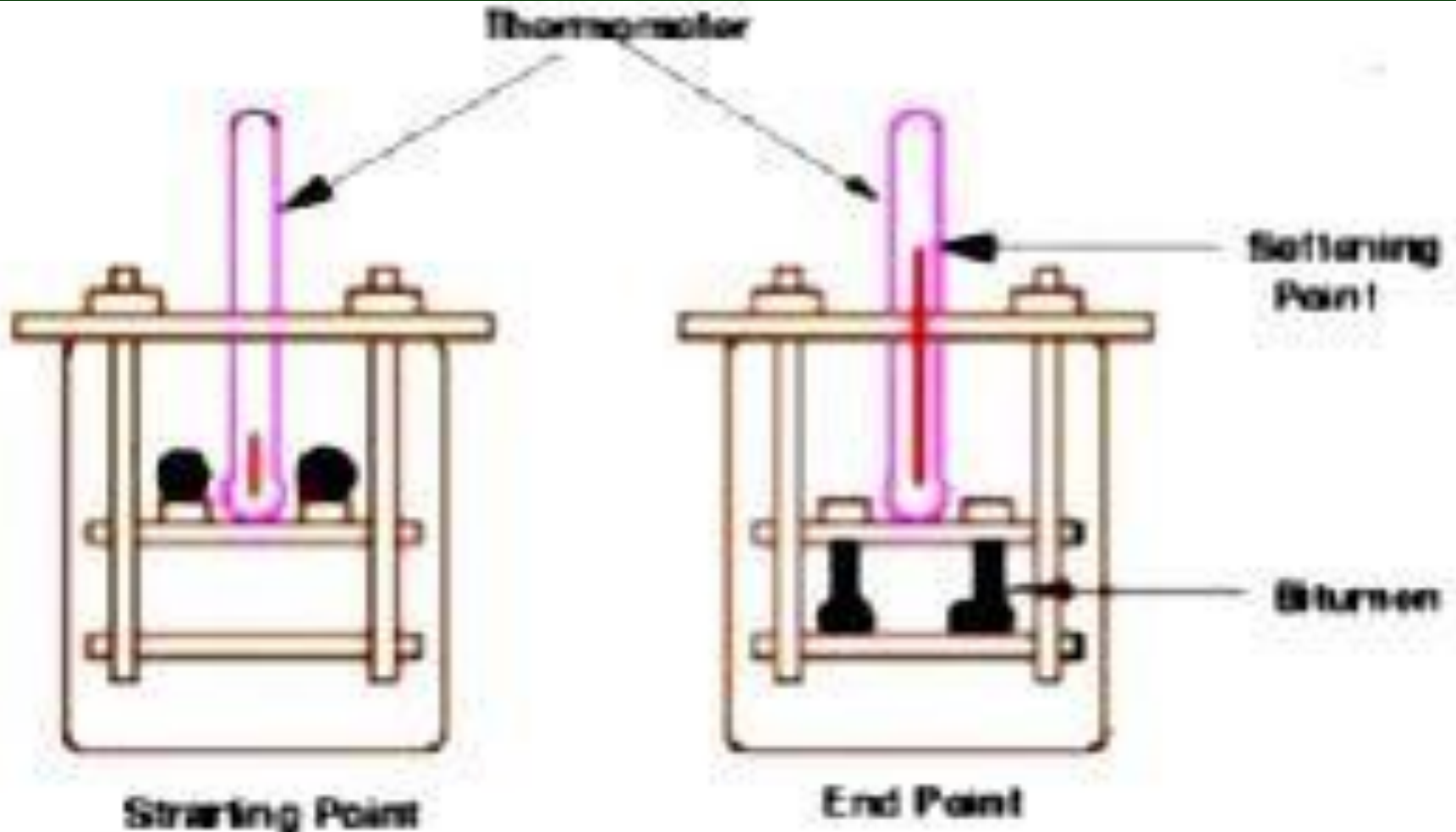
Test on Bitumen: Penetration

- Sewing machine needle
- Specified load, time and temperature



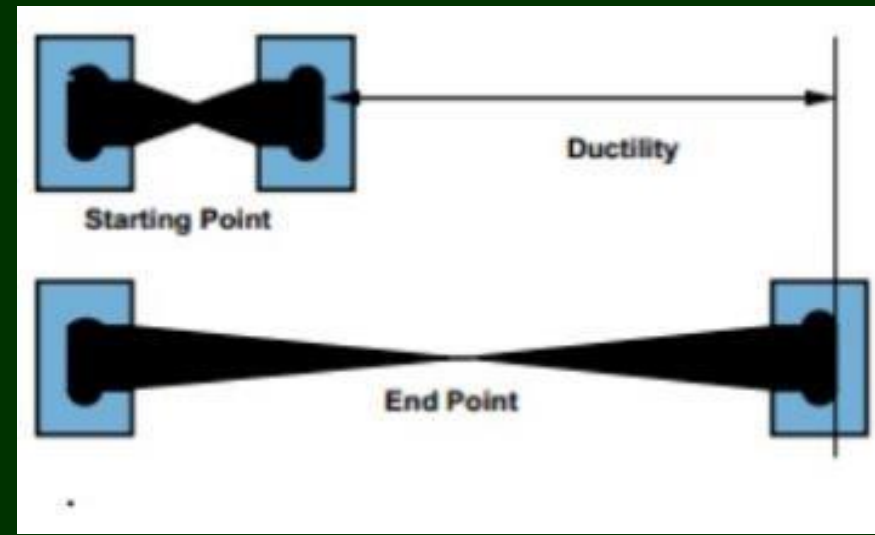


Tests on Bitumen: Softening Point





Ductility Test





Test Frequencies on Earth Work: Prior and during

Type of test	Frequency
Earth work for Eambankment	
Soil classification as per IS:1498 <ul style="list-style-type: none"> Sieve Analysis and Atterberg limits 	01 per km
SPDT (Part 7)	01 per km
FSI (2720 Part 40)(a)	01 per km
Deleterious Content	01 per km
Earth work for subgrade(cutting/filling)	
In case if subgrade meets the requirements then no need to perform the above 4 tests	01 per km
CBR Test	01 per km
During Construction	
In-situ moisture(IS:2720 Part-2) <ul style="list-style-type: none"> Sand bath and rapid moisture meter 	Atleast 3 tests daily
In-situ density(IS:2720 Part-28)	Atleast 3 tests daily
Thickness of subgrade layer	At random





Tests on Granular Subbase

Type of tests

Frequency

Soil classification as per IS: 1498

3 tests from each source

- **Wet sieve Analysis and Atterberg limits**
- **Liquid and plastic tests**

Combined grading and plasticity tests

1 test per 0.5 km length

Proctor compaction test (IS:2720 Part7)

1 test from each source

Wet aggregate Impact value Test(IS:5640)

1 test from each source

CBR on representative sample compacted at 100% proctor dry density.

1 test per km length

Type of tests

Frequency

Wet sieve Analysis

1test daily

Liquid and Plastic limit (IS 2720 Part 5)

1 test daily

Placement moisture content (IS:2720 Part2)

3 tests daily

Insitu density(IS:2720 Part 28)

3 tests daily

Thickness of compacted layer

At random





Lime Treated Soil Subgrade/Subbase

Type of tests

Purity of lime (IS 1514)

Determination of optimum quantity of lime to attain the specified reduction in PI and/or to achieve the specified CBR

PI lime treated soil I (IS 2720 Part 5)

CBR / (IS 2720 Part 16) / UCS (IS 4332 Part 5)

Frequency

01 for each lot of lime

Mean of two tests

Mean of 02 tests / km length

01 test on a set of 3/km

Type of tests

Pulverization of soil clods

Placement moisture content (IS:2720 Part 2)

In situ density measurements (IS:2720 Part 28)

Thickness of compacted layer

Frequency

At least 3 tests daily

At least 3 tests daily

At least 3 tests daily

At random





Tests on Cement treated Soil Subbase/base

Type of tests

Quality of cement and purity of lime (IS 1514)

UCS (IS:4332 Part 5)

Frequency

One test for each lot

One test on a set of 3 specimens /km

Type of tests

Pulverization of soil clods

In-situ moisture content

In-situ density (IS:2720 Part 28)

Thickness of compacted layer

Frequency

At least 3 tests daily

At least 3 tests daily

At least 3 tests daily

At random





Tests on WBM subbase/base/surface

Type of tests	Frequency
Aggregate impact value test	01 for source
Water absorption test	01 for source
Soundness water >2%	01 for source
Gr ,LL,PI of crushable screenings	01 for source
LL & PI of binding material	01 for source

Type of tests	Frequency
Grading of stone and screenings	2tests per day
FI Index of stone aggregates	2 tests per day
Gr ,LL,PI of crushable screenings	2 tests per day
Aggregate impact value	One test per km
Thickness of compacted layer	At random





Tests on W M M and crusher run macadam

Type of tests

Aggregate impact value

Flakiness Index

Water absorption test(IS:2386 part 3)

Soundness water absorption 2%

Grading Test(IS:2386 part 1)

Atterberg limits

Proctor compaction test

Frequency

1 to 2 representative

1 to 2 representative

1 to 2 representative

1 to 2 representative

1 to 2 representative

1 to 2 representative

1 to 2 representative

Type of tests

Grading Test

Aggregate Impact value

Placement moisture content

Density of compacted layer

Thickness of compacted layer

Frequency

At least 01 /day

At random 01/ km

At least 03 /day

At least 03 /day

At random





Wearing Course

- ✓ **High resistance to deformation and resistance to fatigue;**
- ✓ **Sufficient stiffness to reduce stresses in the underlying layers**
- ✓ **High resistance to environmental degradation; durable**
- ✓ **Low permeability – water Layer against ingress of water**
- ✓ **Good workability – allow adequate compaction**
- ✓ **Sufficient surface texture – good skid resistance in wet weather**
- ✓ **Bituminous materials used in wearing course tested by Marshall**





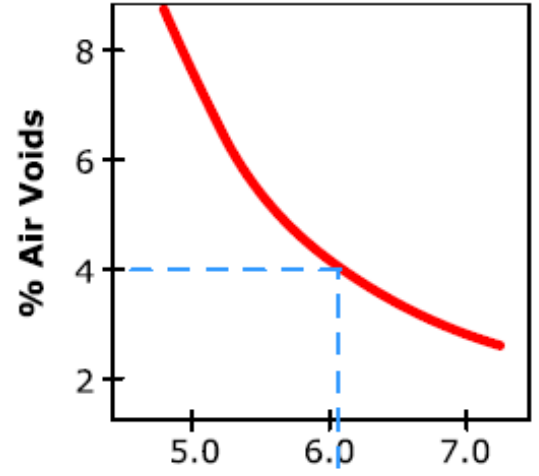
Job Mix Formula Information

- Source and location of all materials
- Proportions of all materials expressed
 - Binder type, and % by weight of total mix
 - CA and FA including mineral filler
- A single definite % passing each sieve for the mixed aggregate
- The individual grading of the aggregate fraction, and the proportion of each in the combined grading
- The results of mix design such as maximum specific gravity of loose mix (G_{mm}), compacted specimen densities, Marshall stability, flow, air voids, VMA, VFB and related graphs and the moisture susceptibility test results.

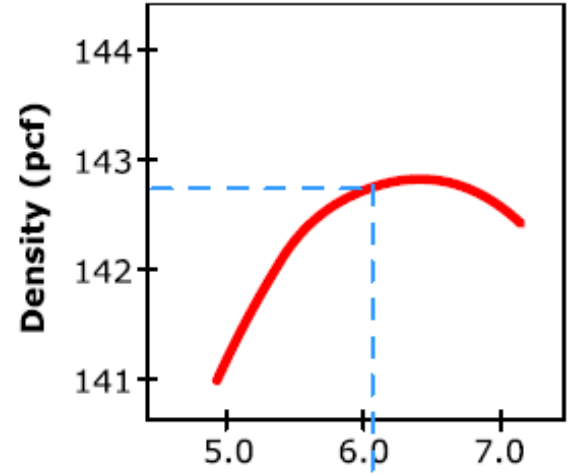




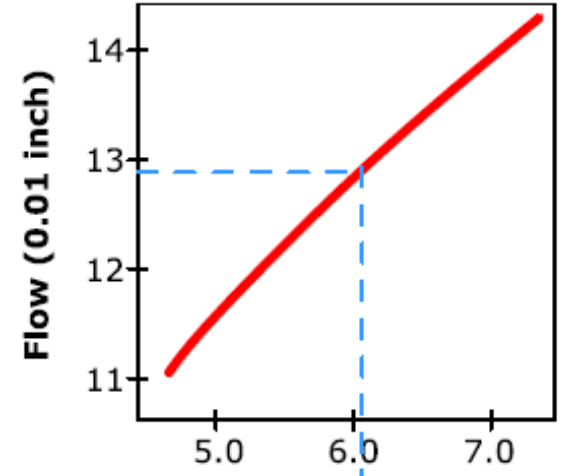
Marshall Method of Mix Design



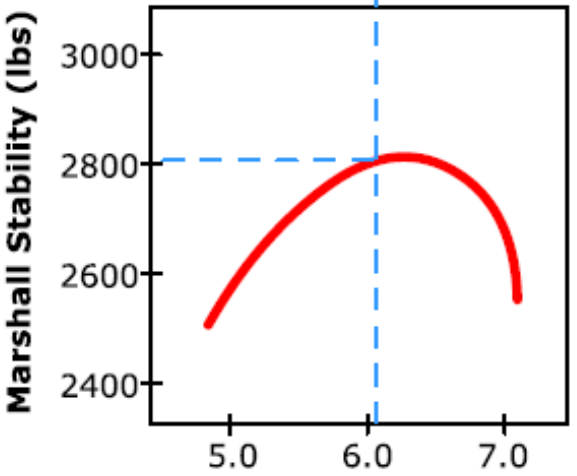
% Asphalt Binder by Weight



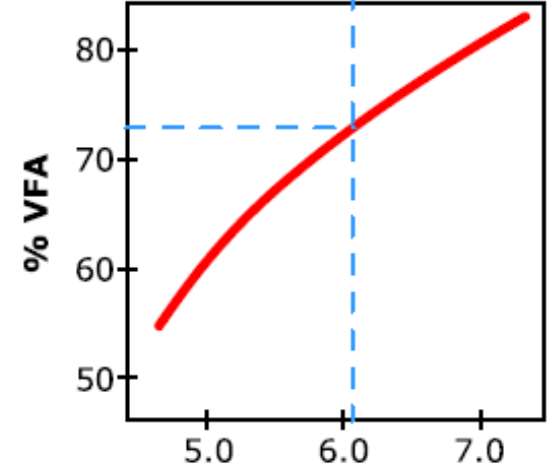
% Asphalt Binder by Weight



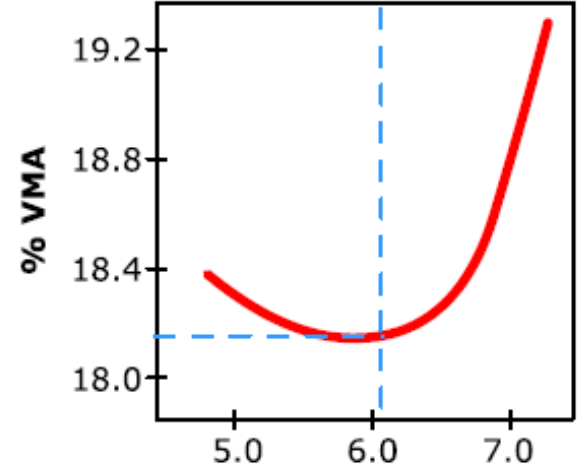
% Asphalt Binder by Weight



% Asphalt Binder by Weight



% Asphalt Binder by Weight



% Asphalt Binder by Weight





Tests on Cements and Cement Concrete

❖ Tests on Cement

- Standard Consistency
- Setting Time (Initial and Final)
- Soundness (Le- Chatelier Method)
- Soundness (Autoclave)
- Compressive Strength
- Fineness (By Blain Air)

❖ Tests on Cement Concrete

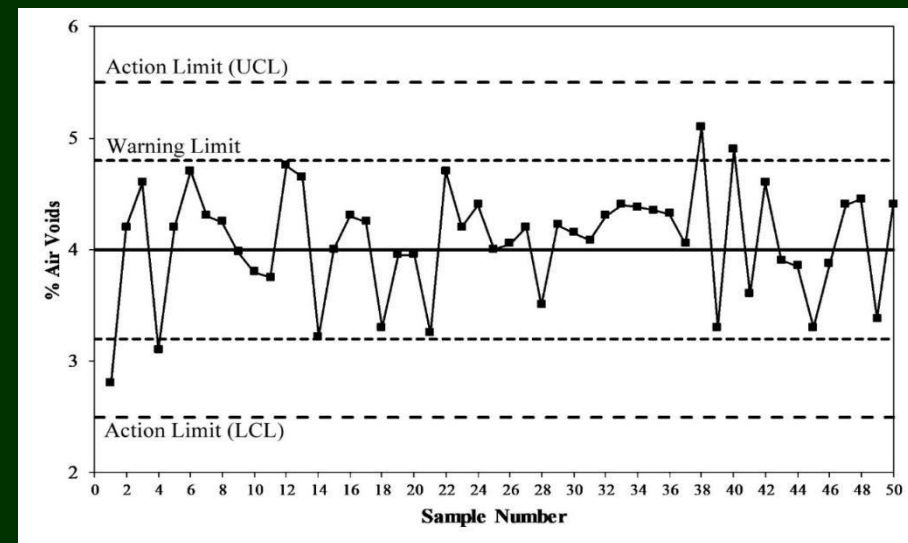
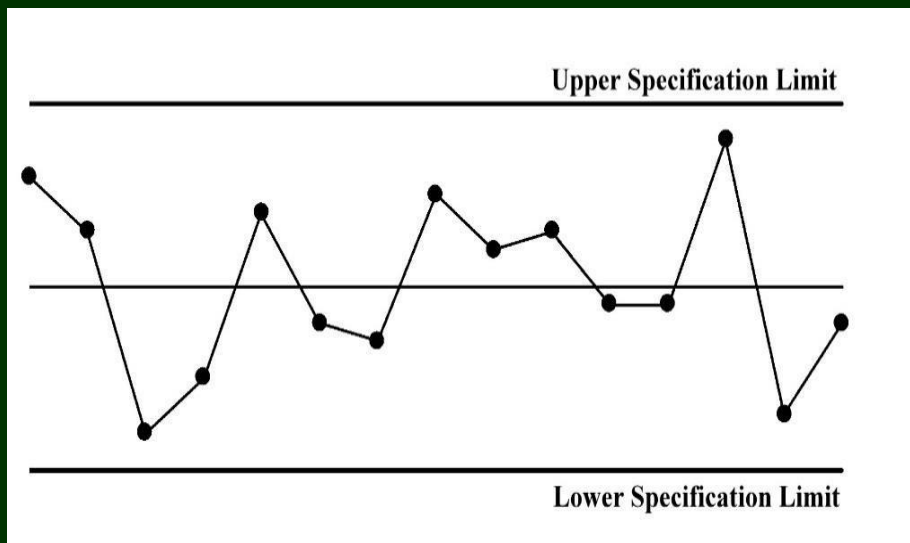
- Workability by Slump Test
- Compressive Strength of Cubes
- Concrete Mix Design





QC in Roads Statistical Analysis

- Representative' samples- **accept or reject the material/process**
- Typical control chart and **chart for air voids**

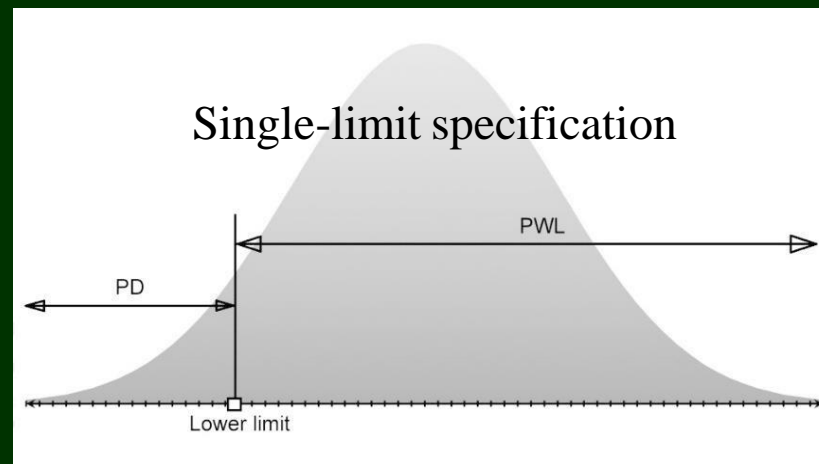
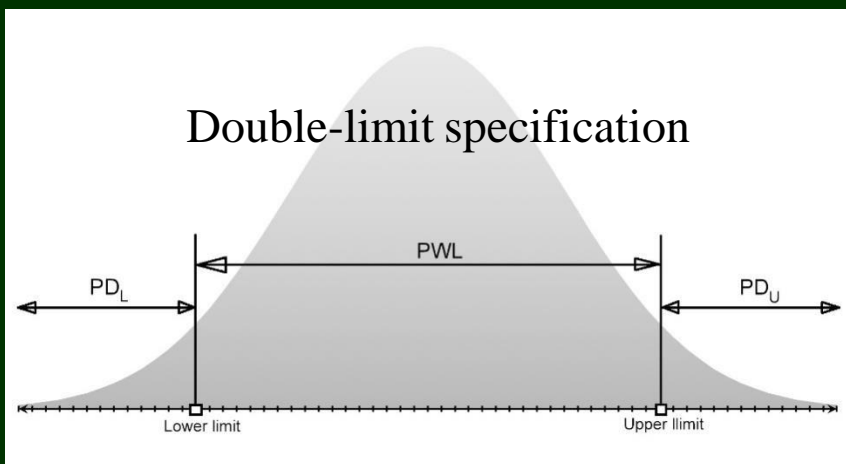
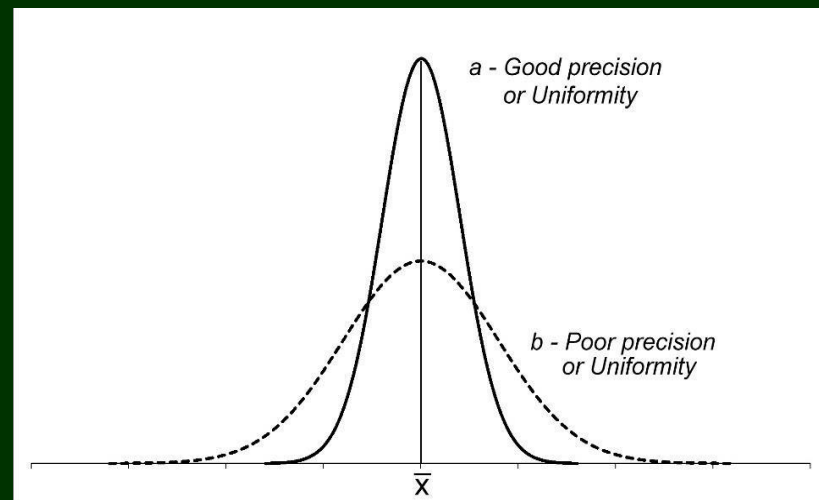
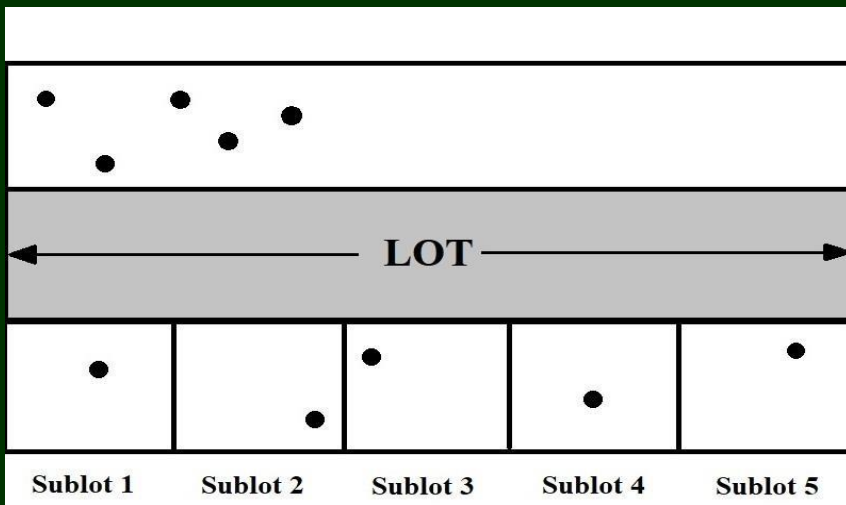


- Early detection of an impending problem,
- Identify the cause(s) of problem from other control charts,
- Decrease variability, Decrease inspection frequency, and
- Reduce potential rejection/price adjustments by the owner





Sampling and Concept of PD and PWL





Pay Factors Based on PWL





Quality Control Mechanism in Rural Roads

Three Tier Setup for QA in RRs

- **First Tier**
 - JE/AE/EE/PIU/CE
 - QC-Records of tests
 - Non-Conformance reports
- **Second Tier**
 - SQC-NIT Coordinated by a person of the rank SE
 - State Quality Units/Monitors should be set up by the States
- **Third Tier**
 - NRRDA engaging independent National Quality Monitors (NQM)
 - Consists of Retired Senior Engineers with State/Central Organization
 - NQM cover three districts every month
 - NQM shall submit a copy to State Government and NRRDA





Summary

- **Good Understanding and updated knowledge**
- **Effective Observations and Visual Inspection**
- **Capability of Proper Interpretation**
- **Exposure and Experience**

