QUESTIONS ~ ANSWERS ON ROAD CONSTRUCTION & ROAD STRUCTURE WORKS

(Revised)

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Foreword

For construction supervision of works, Field Engineers and Staff engaged on highway construction projects of various departments, require necessary technical knowhow and acquaintance with the relevant specifications and standards. On the other hand, they normally do not have access to the required literature and specifications in the field.

During site visits to the projects, the senior Departmental officers quite often put technical questions to the field staff to gauge their competence and knowledge.

In order, therefore, to acquaint the field staff with common questions which arise both in theory and practice, a Question ~ Answers booklet has been compiled which covers pertinent specification requirements, materials of construction, quality control, better engineering practices etc.

It is not a text on highway engineering but a simple and brief treatise of technical Questions ~ Answers, which is expected to improve technical knowhow of the field staff and to improve quality control of works.

Feedback to the earlier version by Mr. Shahbaz Safdar, the Material Engineer, is gratefully acknowledged. The effort and help rendered by Mr. Rizwan Munir, the Senior Engineer and Mr. Fazal Rehman Safi, the Junior Engineer, in compilation of this revised booklet is appreciated.

Due rational care has been taken in preparing this booklet. However, project specifications and standards should be consulted if any problem arises. ECSP doesn't accept the responsibility for the consequences of any inaccuracies which it may contain.

Muhammad Iqbal Khokhar

Advisor, Highways, ECSP

EARTH WORKS

1. What is soil and what are its basic types?

Soil in the engineering field refers to all unconsolidated (loose, not compact or dense) material in the earth crust.

Basic Types:

Type	Soil	Grain Size	Soil Group
Coarse	Gravel	Over 4.75mm (3/16in)	Granular
	Sand	From 4.75mm (3/16in) to smallest visible particle	Granular
Fine	Silt	Particles not visible to eye	Silty
	Clay	Particles smaller than silt	Cohesive

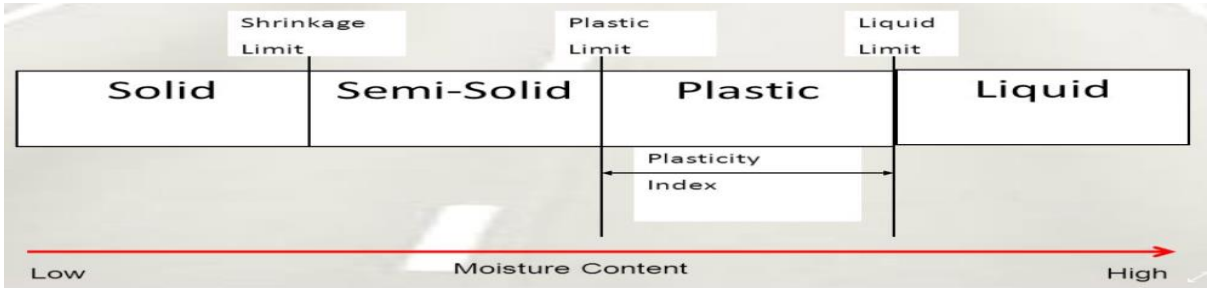
(Source: Highway Material, Soils and Concrete Fourth Edition Harold N. Atkins)

2. What is the difference between gravels and clays?

Gravels	Clays
Gravels and sands are composed of rounded or cubical grains.	Clay grains are extremely small in size or flat in shape
Gravels can carry loads due to friction among them.	Clays are soft and do not carry loads
Do not hold water due to high porosity	Can absorb moisture, hold water and can swell

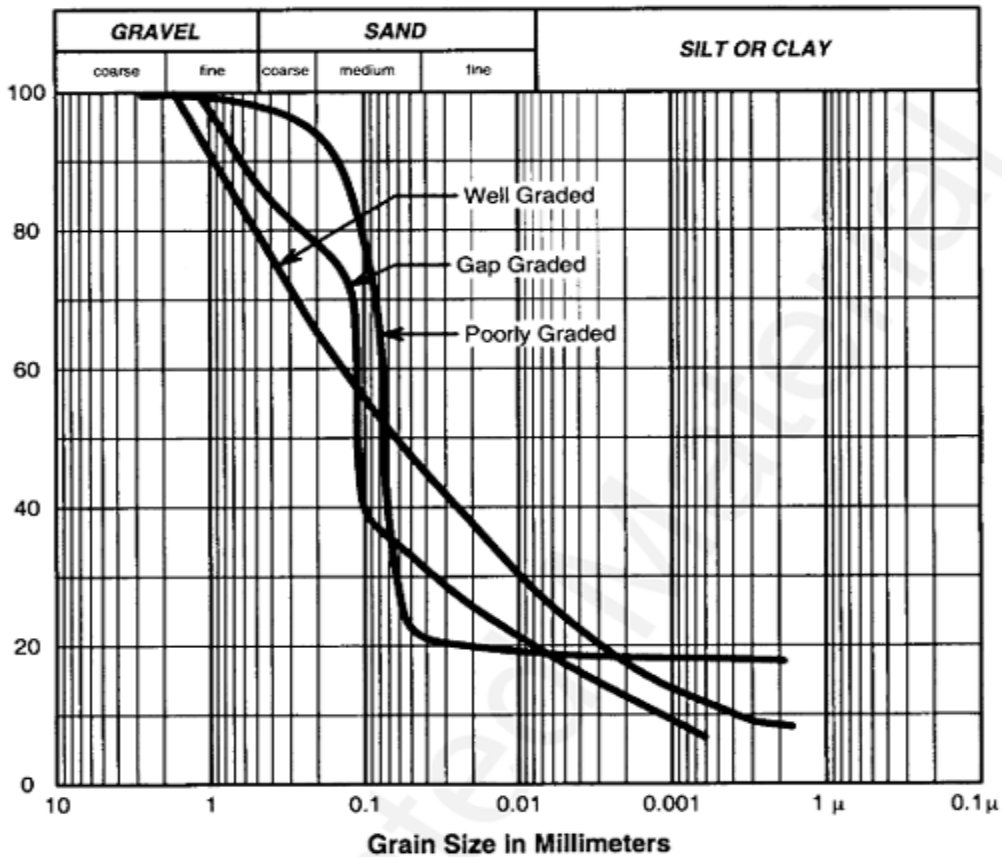
3. What are Atterberg Limits (D4318 ASTM & T89 AASHTO)?

The Atterberg limits are the basic measure of the critical water content of a fine-grained soil: its shrinkage limit, plastic limit, and liquid limit. As dry, clayey soil takes on increasing amounts of water, it undergoes distinct changes in behavior and consistency. These are Liquid Limit (LL), Plastic Limit (PL) and Plastic Index (PI=LL-PL) of soil.



4. What do you know about grain size distribution (D422 ASTM & T88 AASHTO) curve?

A grain size distribution curve is drawn on a chart showing % passing along y-axis and gain size along x-axis to determine the grading of soil e.g. well graded (having different particles size mix), uniform graded (same size particles mix) and gape graded (missing one or more size in mix). The gradation detail is given below:



5. Why do we use Atterberg Limits in Soil Investigation?

To find the behavior of soil when it gets moist such as whether the soil under investigation is plastic (clay), semi plastic (silt) or non- plastic (sand).

6. How Plastic Index (PI) values can be used to classify the plasticity of soil?

PI	Term	Material	Dry Strength
0-3	non Plastic	sand	very low
4-6	slightly plastic	sandy silt	low
7-15	moderately plastic	silt	low to medium
16-35	plastic	clay	medium to high
Over 35	highly plastic	heavy clay	high

(Source: Highway Material, Soils and Concrete Fourth Edition Harold N. Atkins)

7. What is the AASHTO and Unified Soil Classification System (USCS)?

AASHTO Soil Classification:

General Classification	Granular Materials (35% or less passing the 0.075 mm sieve)							Silt-Clay Materials (>35% passing the 0.075 mm sieve)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis, % passing											
2.00 mm (No. 10)	50 max	...	...	...	...	...	...	...	...	...	...
0.425 (No. 40)	30 max	50 max	51 min	...	...	...	...	...	...	...	...
0.075 (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)											
Liquid Limit	...		...	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity Index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min°
Usual types of significant constituent materials	stone fragments, gravel and sand		fine sand	silty or clayey gravel and sand				silty soils		clayey soils	
General rating as a subgrade	excellent to good							fair to poor			

Unified Soil Classification System (USCS) ASTM D 2487

Major Divisions		Letter (3)	Symbols Hatching	Symbols Color	Name	Value for Embankments	Permeability cm per sec
Coarse-Grained Soils	Gravel and Gravelly Soils	GW		Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Very stable, pervious shells of dikes and dams	$k > 10^{-2}$
		GP			Poorly graded gravels or gravel-sand mixtures, little or no fines	Reasonably stable, pervious shells of dikes and dams	$k > 10^{-2}$
		GM		Yellow	Silty gravels, gravel-sand-silt mixtures	Reasonably stable, not particularly suited to shells, but may be used for impervious cores or blankets	$k = 10^{-3}$ to 10^{-6}
		GC			Clayey gravels, gravel-sand-clay mixtures	Fairly stable, may be used for impervious core	$k = 10^{-6}$ to 10^{-8}
	Sand and Sandy Soils	SW		Red	Well-graded sands or gravelly sands, little or no fines	Very stable, pervious sections, slope protection required	$k > 10^{-3}$
		SP			Poorly graded sands or gravelly sands, little or no fines	Reasonably stable, may be used in dike section with flat slopes	$k > 10^{-3}$
		SM		Yellow	Silty sands, sand-silt mixtures	Fairly stable, not particularly suited to shells, but may be used for impervious cores or dikes	$k = 10^{-3}$ to 10^{-6}
		SC			Clayey sands, sand-silt mixtures	Fairly stable, use for impervious core or flood-control structures	$k = 10^{-6}$ to 10^{-8}
Fine-Grained Soils	Silts and Clays LL < 50	ML		Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Poor stability, may be used for embankments with proper control	$k = 10^{-3}$ to 10^{-6}
		CL			Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Stable, impervious cores and blankets	$k = 10^{-6}$ to 10^{-8}
		OL			Organic silts and organic silt-clays of low plasticity	Not suitable for embankments	$k = 10^{-4}$ to 10^{-6}
	Silts and Clays LL ≥ 50	MH		Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor stability, core of hydraulic-fill dam, not desirable in rolled-fill construction	$k = 10^{-4}$ to 10^{-6}
		CH			Inorganic clays of high plasticity, fat clays	Fair stability with flat slopes, thin cores, blankets and dike sections	$k = 10^{-6}$ to 10^{-8}
		OH			Organic clays of medium to high plasticity, organic silts	Not suitable for embankments	$k = 10^{-6}$ to 10^{-8}
Highly Organic Soils		Pt		Orange	Peat and other highly organic soils	Not used for construction	

8. What do you know about soil water?

Water found in soil is of three types given below:

Free Water – Found below the ground water table (GWT) and is free to flow under gravity.

Capillary Water – Water moves up through the soil pores above GWT due to surface tension.

Attached or Held Water – Water in the moisture film around the soil grains.

9. What is ground water table (GWT) and why its level is important to find below existing grade level (EGL)?

Ground water table (GWT) is the surface below which all pores are filled with water that is free to flow. As water, due to its capillary action, can rise to upper layers of road such as subgrade and base course. This water can cause swell of subgrade soil as well as can disturb soil density and moisture content at optimum level. Moreover, it can cause flow of fine particles from base and sub base course making these layers weak. So, water table (W/T) rise potential and monthly fluctuation in level is of great importance for roads to be constructed in an area surrounded by water bodies such as river and canals.

10. What is embankment and why it is constructed?

An embankment refers to a volume of earthen material that is placed and compacted for the purpose of raising the grade of a roadway (or railway) above the level of the existing ground surface. We provide embankment on a road section where there is soil filling and such conditions usually are:

- Before the bridge crossing also called bridge embankment
- To meet the highest flood level (HFL)
- To meet the level of crossing roads in case of urban interchanges
- To avoid the stagnation of surface water

11. What are the types of failures occur in soils?

The main types of failures that occur in soils are:

- Failures due to shear - where grains slide w.r.t other grains
- Settlement failures – (i) where a layer of soil compressed and becomes thinner under loading.
  (ii) where a layer of soil depressed and goes downward.

12. How the shear strength of soil can be measured?

Following tests are used to find shear strength of soil:

- Unconfined Compression Test ,Clays Only (AASHTO T 208, ASTM D 2166)
- Direct Shear Test (AASHTO T 236 & ASTM D 3080)
- Triaxial Compression Test (AASHTO T 296 – 297)

13. What type of tests are usually carried for Soil Investigation?

- Grain Size Distribution by Sieve Analysis
- Relative Density (Specific Gravity) of Soil
- Max. Dry Density at Optimum Moisture Content
- Atterberg's Limits Test
- Unconfined Compression Test

- Direct Shear Test
- California Bearing Ration (CBR) Test

14. What is CBR test (AASHTO T 193) and why it is done?

The California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of natural ground, subgrades and base courses beneath new carriageway construction. It was developed by the California Department of Transportation before World War II.

It is done for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves / equations to determine the thickness of pavement and its constituent layers.

15. What minimum CBR value is normally used for sub grade?

- For top 30 cm CBR shall not be less than 8 % at 95% max. dry density (soil with swell value ≤ 0.5%)
- A minimum CBR of 7%, for embankment material of top 30 cm shall be used with a swell value not more than 0.3%.
- Whereas a minimum soaked CBR of 5% of embankment material below the formation of 30 cm shall be taken unless otherwise stated on the project drawing.

(Source: General Specifications – NHA, December 1998)

16. What alternates are adopted for sub grade if CBR value of a section is less than 8%?

Based on cost and site prevailing conditions one of the alternates is exercised:

- Use the imported material having CBR 8 or more.
- Stabilized the existing soil with lime, cement having min. CBR 5.
- Provide cover / capping layer of suitable material on poor quality existing ground.

17. What is a borehole log?

Small-diameter borings are frequently used to allow a geologist or engineer to examine soil or rock cuttings in case of undisturbed soil sampling. So borehole log is a graphical representation of different layers to find the details of sub surface soil.

18. What is disturbed and undisturbed soil sample?

A **disturbed** sample is one in which the structure of the soil has been changed sufficiently that tests of structural properties of the soil will not be representative of in-situ conditions, and only properties of the soil grains (e.g., grain size distribution, Atterberg's limits, and possibly the water content) can be accurately determined.

An **undisturbed** sample is one where the condition of the soil in the sample is close enough to the conditions of the soil in-situ to allow tests of structural properties of the soil to be used to approximate the properties of the soil in-situ.

19. What do you understand by borrow/imported soil term used in Material Report?

The prime objective of soil investigation of a road section is to determine the quality of existing material as well as material to be used for new construction. The results of different tests such as grain size distribution, CBR value and maximum dry density in terms of compaction are actually indicative

of material quality and help engineer in deciding whether to use available materials or not. If the soil, based on tests results, found to be of poor quality then good quality soil be imported that may be located in surrounding of the road site or in remote area. This soil of good quality is termed as borrow or imported soil/material.

20. What do you know about compaction and dry density of soil?

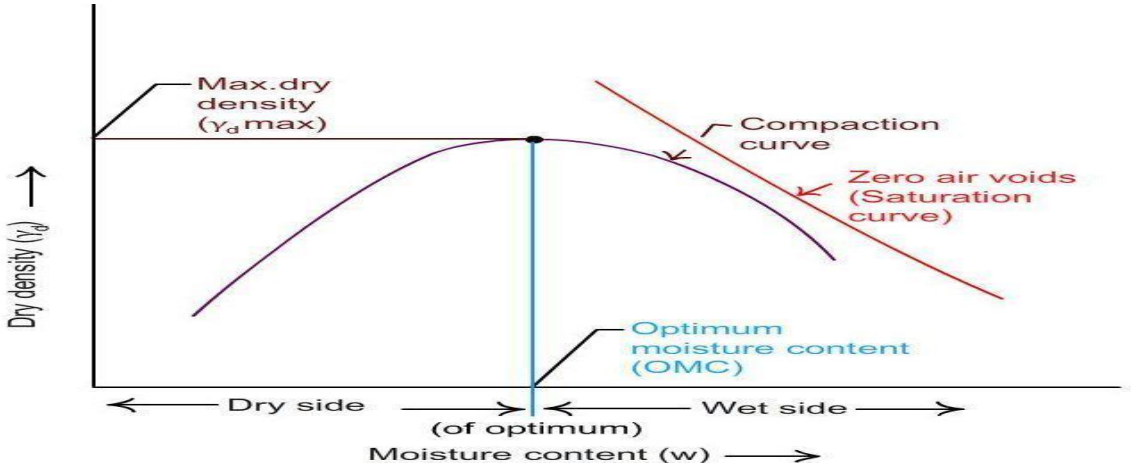
As we know that a dense and solid platform is required to place various layers of a road for its stability, hence, loose soil of existing grade be compacted by applying some mechanical effort that causes expulsion of air voids. Compaction requirements are measured in terms of the dry density of the soil. The expected value for dry density varies with type of soil being compacted. For example, a clayey soil may be rolled/compacted many times and does not reach 2.0 gm/c.c whereas a granular soil may have a dry density above this value without any compactive effort. Therefore, a value of maximum dry density must be established for each soil type. Typical values for maximum dry densities and optimum moisture content (OMC) for soils classified according to AASHTO system are given below:

AASHTO Classification	Max. Dry Density kg/m³ (gm/cc)	Optimum Moisture Content (%)
A-1	1850-2200 (1.85 – 2.20)	7-15
A-2	1750-2150 (1.75 – 2.15)	9-18
A-3	1750-1850 (1.75 – 1.85)	10-18
A-4	1500-2100 (1.50 – 2.10)	10-20
A-5	1400-1650 (1.40 – 1.65)	15-30
A-6	1500-1900 (1.50 – 1.90)	10-25
A-7	1400-1850 (1.40 – 1.85)	15-30

(Source: Highway Materials, Soils and Concretes Fourth Edition Harold N. Atkins)

21. What is Optimum Moisture Content?

During compaction of soil when compacting effort is applied, grains of soil slip, break and rearrange themselves. Some lubrication is required to ease this phenomenon and for that water is used. So, the max value of water or moisture at which maximum dry density achieves, is called optimum moisture content.



22. What criteria is used for % of Max. Dry Density of Embankment?

Formation of Embankment as per NHA

Height of Embankment below sub grade top	% of Max. Dry Density as per AASHTO T-180
0-30cm	95
30-75cm	93
Over 75cm	90
Below the foundation of the structure	95

(Source: General Specifications – NHA, December 1998)

Formation of Embankment as per C&W Punjab:

Since the intensity of stresses induced in the different layers of subgrade and embankment decreases with depth, the requirement of maximum attainable density in the sub grade reduces slightly below 90 cm (3ft) from the top of sub grade such as:

1. At least upper 90 cm (3ft) of the fill should be compacted to obtain a density in excess of 95% of max. Modified AASHTO density and the lower portion to 90% of max. Modified AASHTO density.
2. In the sub grades consisting of A-1 to A-3 groups material, which may eliminates the necessity of sub base, the sub grade compaction should be at least 100% of the max. Modified AASHTO density to a minimum depth of one foot and the lower portion to at least 95% of max. modified density.
3. The soils are compacted in layers of about 15 cm (6 in) at or near the optimum moisture content, which is about 225 mm (9") before compaction.

(Source: Highway Materials, Construction and Quality Control Road Research and Material Testing Institute June, 1985)

23. How the compaction quality be controlled in the field?

Quality control of compaction on the construction project involves measuring field density after compaction and comparing the results with laboratory maximum density values for the soil, to ascertain if the specifications have been met. Field density tests are usually made with:

- Core cutter (Direct in-situ)
- Sand Cone (Direct in - situ)
- Water Balloon (Direct in-situ)
- Nuclear Densometer (Indirect in-situ)
- Standard Penetrometer, Vane Shear, Nilcon Vane (Indirect Lab tests)

24. Please describe the compaction equipments used in the field?

Compaction equipment consists of various types of roller and tamping equipment. Most modern compaction rollers are self-propelled with compacting wheels or wheels equipped to vibrate for improved results. The major types of roller are:

- Vibratory Smooth Drum Rollers – these are very effective for gravel, sand and silty soils as well as asphalt concrete.
- Padded wheel or sheep's foot rollers -these are the most effective type for clay and silty clay soils

- Pneumatic tires rollers – asphalt course is initially kneaded and compacted with these rollers
- Smooth drum non vibrating rollers – may be used for finishing and sealing passes on soil and granular layers and finally leveling passes on asphalt layer.

25. What understanding do you have about EGL and PGL?

Existing grade line (EGL) is a line passing through the elevations or other controlling points of natural surface or top of existing road.

The profile grade line (PGL) is a longitudinal section taken along the centerline and shows the elevations to which road is built.

26. How do you control back filling in the field?

- Granular backfill wherever directed shall be placed in position and to the required depth, shown on the drawings or where and as required in writing by the Engineer and it shall be well compacted in layers not exceeding 20 cm in thickness/fill to 100% of max. dry density as per AASHTO T-180(D). In water logged areas the thickness of layer shall not exceed 50 cm or as directed by Engineer.
- Common backfill shall be compacted in layer not exceed 20 cm in depth to the 95% of max. dry density as per AASHTO T-180(D).

27. How do you declare whether a material for sub grade is suitable or unsuitable?

If a material fulfils the specifications requirement such as CBR value, dry density and soil classification group than it is accepted as suitable material otherwise unsuitable.

<u>The criteria of NHA for suitable material for sub grade are given below:</u>

a) Use A-1, A-2, A-3, A-4 or A-5 soil as specified in AASHTO M-145.
b) CBR of the material shall not be less than five (5) percent, determined in accordance with AASHTO T-193. CBR value shall be obtained at a density corresponding to the degree of compaction
c) Swell value of the material for embankment formation shall not exceed 0.5 percent.
d) In areas subjected to flood and prolonged inundation of the embankment, such as at bridge sites, material used in embankment, unless rock, shall be of AASHTO class A-1 & A-2-4 soils. Others soils can be used only with written consent of Engineer or as provided in the specifications.

<u>C&W Punjab recommendations for suitable material for sub grade:</u>

a) Soil belonging to A-1 group are highly desirable for embankment and sub grade as they can be compacted to high degree of density and stability.
b) A-2 group soils are quite suitable for this purpose, although they require little more careful control of the compaction process during the construction.
c) A-3 soils can be conveniently used but they cannot be satisfactorily compacted by sheep foot roller and for adequate compaction they required pneumatic tire rollers, crawlers tractors and vibratory compactors.
d) Soils of A-4 group require careful control of the compaction process and would give satisfactory performance under pavements where moisture content of soil during the life of the road is expected to remain the same or less than that used in the compaction process i.e. their optimum moisture content. Soils of A-4 group are comparatively more difficult to compact than the soils of the

proceeding group because these soils must be controlled within narrow limit of optimum moisture content during construction in order to secure adequate density and stability.

e) The soil group A-5 is less desirable for embankment and sub grade as its strength undergoes serious changes with varying moisture content.
f) Soils of A-6 and A-7 are not suitable material due to high volume change characteristics. These can, however, be used after stabilization/treatment.

28. What is S.P.T? Describe the procedure of this test in detail.

S.P.T. or Standard Penetration Test: (AASHTO 206 & ASTM D 1586)

The standard slit tube sampler, 18 inches in length and 2 inches diameter is driven into the soil, with a drive weight of 140 lbs. (63.5 kg) at 30 inch of free falling. The blow count for the first 6 inch is not used as this is to seat the sampler below the disturbed soil in the bottom of the borehole. The number of blows to drive the final 12 inches is the penetration resistance. If it is not practical to drive the sampler up to the full 12 inches because of very dense, cemented hardpan, rock, etc., the borelog will indicate the blow count and penetration as ratio i.e. 70:4 for 70 blows 4 inches penetration.

29. Can we use sand as embankment material?

Yes, by plating, which is a method of covering or confining of unstable material fills with stable material or some structure such as wall on both sides.

30. What are the tests you carry out to determine the suitability of sub grade material?

a) Sieve analysis (AASHTO T 27, ASTM D451)
b) Atterberg's test (AASHTO T 89, T90, ASTM D498)
c) Proctor test (AASHTO T 99 T 180, ASTM D451)
d) C.B.R test (AASHTO T 193, ASTM D1883 - 99)
e) Dry density test (AASHTO T 99)

31. How do you determine the shear strength of a soil?

By Tri-axial Test: the basic principle is that a cylindrical soil specimen is first encased in a thin rubber membrane and subjected to fluid pressure around the cylinder surface. The lateral pressure is held constant while an axial load is applied and increased until failure occurs.

32. Why and when C.B.R value needs adjustment?

To determine CBR of given specimens, stress-strain (resistance to penetration-depth of penetration) curve for each specimen is plotted. In some instances, the initial penetration takes place without a proportional increase in the resistance to penetration and the curve may be concave upward. To obtain the true stress-strain relationships, correct the curve having concave upward shape near the origin by adjusting the location of the origin by extending the straight line portion of the stress-strain curve downward until it intersects the abscissa. California Bearing Ratio values are obtained in percent by dividing the corrected load values at 2.54 and 5.08 mm (0.10" and 0.20") by the standard loads of 6.9 and 10.3 MPa (1000 and 1500 psi), respectively, and multiplying these ratios by 100 such as:

CBR (%) = (Corrected Load Value / Standard Load Value) X 100

The CBR is generally selected at 2.54 mm (0.10") penetration. If the ratio at 5.08 mm (0.20") penetration is greater, the test shall be rerun. If the check test gives a similar result, the ratio at 5.08 mm (0.20") penetration shall be used.

33. How you take a sand sample from a sand stockpile?

Take sample from inner middle of stockpile at random.

34. How would you carry out in-situ density test on prepared subgrade?

By sand cone method (in accordance with AASHTO T – 191)

By Core Cutter Method (AASHTO T-204)

35. How will you distinguish between A-1 and A-7 soil visually?

A-1 soil is well graded gravel or sand or a mixture of sand and gravel with or without non-plastic soil binder. A-7 material is clayey soil.

36. What is the pressure in tires of pneumatic rollers?

80 psi

37. What is the construction procedure for preparing natural ground to receive the embankment layers?

Removal of undesirable material (organics) such as logs, tress, stumps, weeds and heavy grass, etc.

38. How much thickness is allowed for rock fill?

Mass per meter width of vibrating roller (kg/m)	Maximum thickness of layer (cm)	Number of passes of the roller on each layer
2300 - 2900	40	5
2900 - 3600	50	5
3600 - 4300	60	5
4300 – 5000	70	5
>5000	80	5

(Source: General Specifications – NHA, December 1998)

39. What types of soil are well suitable for subgrade?

A-1-a, A-1-b, A-2-4, according to AASHTO soil classification

40. What do you mean by relative density?

It is a state of compactness of a soil with respect to the loosest and densest state at which it can be placed.

% R.D. = (ϒ field - ϒ min.) x ϒ max. / (ϒ max. - ϒ min.) X ϒ field X 100

Where ϒ is a unit weight of soil.

41. What is effective grain size and uniformity coefficient?

Effective grain size is the diameter of particles corresponds to 10% passing of particles from a given sieve set. Whereas uniformity coefficient "Cu" is defined as the ratio of D60 by D10 (D60/D10) where D60 corresponds to dia of particles having 60% passing from a given sieves set. So when "Cu" is greater than 4, it is taken as a well graded soil and when the Cu is less than 4, it is considered to be poorly graded or uniformly graded soil.

42. What are the factors effecting density of soil?

a) Relative volume of solid and void spaces: the greater the volume of solids or less the volume of voids, the greater is the density.
b) Specific gravity of solids particles: the greater the specific gravity of solid particles, the greater is the density.
c) Amount of water in void spaces: It is obvious that greater the amount of water greater will be the density up to optimum moisture content. This factor only effects the wet density.

43. What is the permeability and its significance?

Permeability is the hydraulic property of a soil which indicates the ease with which water flows through the mass. It is significant on numerous engineering problems such as seepage through dams and irrigation canal.

44. What is the difference between consolidation and compaction of soil?

Consolidation: is the escape of water and decrease in air voids among the soil particles. Consolidation is time dependent process where a gradual transfer of stress from the water to solid in a soil mass occurs by the load of overburden.

Compaction: is the artificial compression of soil by re-arrangement of its particles to decrease volume by some mechanical effort aided by lubricating effect of water.

45. What is the proctor test?

The Procter Compaction Test is a laboratory method of (experimentally) determining the optimum moisture content at which a given soil becomes most dense.

46. What are the types of tests to determine the strength of subgrade?

In-situ:

a) Loading test
b) Plate bearing test
c) Cone Penetrometer
d) Field CBR

In Laboratory:

a) California bearing ratio (CBR)
b) Tri-axial Compression test
c) Hveem stabilometer test

47. What is group index and how it is determined?

It is empirical value used to evaluate the quality of soil type to use for subgrade material. Group index (GI) is a number assigned to soil based on its physical properties like particle size, liquid limit and plastic index. It varies form a value of 0 to 20, lower is the value, higher is the quality of subgrade and greater the value poorer is the sub grade.

G.I. = (F-35) (0.2+0.005(LL-40) + 0.001(F-15) (PI-10)

Where: G.I. – Group index

F - % passing 0.075 mm (No.200) sieve

LL - Liquid Limit

PI - Plastic Index

Sub Grade	Group Index Value
Very Good	0 (Soil Class A-1)
Good	0 – 1
Medium	2 – 4
Bad	5 – 9
Very Bad	10 – 20

48. What are the engineering properties of soil?

1. Granular soils:

a) Good load bearing qualities
b) Permeable
c) Comparatively incompressible when subjected to static loads.
d) Not subjected to strength and volume change due to vibration and water content

2. Fine grained soils:

a) Poor load sustaining quality
b) Highly impermeable
c) Compressible under sustained loads
d) Subjected to change in strength and volume due to variation in water content.

3. Organic soils:

e) Inferior than fine grained soils with respect to properties stated under the latter group.

49. What is soil stabilization?

Soil Stabilization is the alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. It can be mechanical by using heavy loads/vibration and chemical like lime, cement, bitumen and fly ash etc. are added to improve soil strength. Polymer/synthetic materials like polyethylene, polyester etc. are added to reinforce the soil.

50. What you know about compaction of sand?

Compaction is performed on sand in cases of:

1. Water contents are between dry and saturated state.
2. Completely watered (Saturated).
3. Completely dry (Unsaturated).

Compaction in completely dry sate gives the highest dry density and layer thickness can be increased by using dry compaction. Compaction could be made by vibratory roller with low amplitude with high frequency.

51. What is the relation between standard and modified proctor?

The standard and modified proctor gives the result very close together for granular soil, but for plastic clay soil modified gives higher results/values than of standard.

52. Can we use A-6, A-7 in embankment?

Not desirable at all, however, if it is hard to avoid then we can use A-6 and A-7 in embankment after stabilization by lime or cement.

53. What are the minimum required no. of passes for roller in rock fill?

Min. 5 passes.

(Source: General Specifications – NHA, December 1998)

54. What is the purpose of compaction?

- Increase the shear strength of soil
- Decrease permeability and water absorption
- Decrease swelling and shrinkage of soil when exposed to water.
- Decrease settlement of embankment under repeated loads.

55. What are the factors effecting degree of compaction?

- Optimum moisture content (OMC)
- Type of soil
- Compacting effort

56. State factors effecting density of soil?

a) Water content
b) Temperature
c) Rate of compaction as well as intensity of compactive effort
d) Granular size

57. What is the advantage of plating?

1. Confining A-3 material (to protect against lateral displacement)
2. Protecting A-3 against erosion and scouring

58. How we can say soil is non plastic?

1. When liquid limit cannot be determined
2. When plastic limit is equal to liquid limit
3. When a soil cannot be rolled in to threads of specific dia.

59. What is the time elapse between two embankment layers to get proper compaction?

Not more than 3 days

60. Define these terms: compression consolidation, shrinkage, compaction, rebound, expansion, swelling, loosening or scarifying?

a) Compression:
The loss in external volume under sustained load

b) Shrinkage:
The loss in volume resulting from capillary stress during drying of soil.

c) Consolidation:
Consolidation is the process of reduction in volume due to expulsion of water under an increased load. It is a time related process occurring in saturated soil by draining water from void.

d) Compaction:
The loss in volume due to artificial temporary applied loads such as rolling, tamping, vibration.

e) Rebound:
The increase in volume due to removal of sustained load.

f) Expansion:
The increase in volume with time due to accumulated stresses.

g) Swelling:
The increase in volume resulting from increasing of water content.

h) Loosening or scarifying:
The increase in volume due to artificial operations.

SUB BASE AND BASE COURSE

1. What are various road components and their functions?

The functions of the various components of the pavement are:

a) Sub-base

- Distribution of the traffic loads over the soil formation/sub grade sufficient to prevent the soil from being over stressed.
- Protection of the soil formation from adverse effects of weather by providing proper drainage.
- Prevention of damaging frost heave and salt heave.
- Prevention of volume changes of the sub grade due to excess moisture.

b) Base Course

- Distribution of the traffic loads and hence increasing the structural stability.
- Protection against frost or frost susceptible soil.
- Providing a suitable surface for surface course.

c) Surfacing

- To provide dust free running surface.
- Provide a smooth riding surface and resistance to traffic abrasion.
- Water proofing the pavement structure against surface water.
- Protection of the base against raveling and disintegrating effects of traffic.

2. What are aggregates and their sources?

Aggregates are granular mineral particles used either in combination with various types of cementing material to form concrete or alone as road base and sub-base. Sources of aggregates for construction include:

- Natural sand and gravel deposits
- Crushed rock
- Steel slag and mine refuse
- Artificial and processed material
- Pulverized/ crushed concrete and reclaimed asphalt pavement (RAP)
- Other recycled and waste material

3. Some aggregate terms and types?

Aggregate are very common materials and the terms used to describe them are many and varied. These descriptive terms are based on the source, size, shape, type, use and other properties.

1. **Fine Aggregate** (sand sizes) - Aggregate particles mainly b/w 4.75 mm (No.4 sieve) and 75 um (No.200) in size.

2. **Coarse Aggregate** (gravel sizes) - Aggregate particles mainly larger than 4.75 mm (No. 4 sieve)
3. **Pit run** – Aggregate from a sand or gravel pit without processing
4. **Crushed gravel** – Pit gravel that are put in a crusher either to break or to produce rough surfaces.
5. **Crushed Rock** – Aggregate form the crushing of bed rock. All particles are angular not rounded as in gravel.
6. **Screenings** – the chips and dust or powder that are produced in the crushing of bedrock for aggregates.
7. **Concrete sand** – is a course sand that is washed and screened to a larger grit than Masonry Sand
8. **Fines** – Silt , clay, or dust particles smaller than 75 um (No.200 sieve)

4. What is nominal maximum size of aggregate?

Nominal size term is often use to specify the size of aggregate. It is based on the mass retained and passing each sieve. It is not necessary 100% of the aggregate particles are within specified size range for construction purpose. A small amount, usually 5% to 10%, is allowed to larger or smaller than the specified size, as it would be economically impossible to ensure all the particles size within any specified size range. Therefore, if specifications indicate that 19 mm (3/4 in) is nominal maximum size desired for a concrete mix then, in this case, 90% of the sample (minimum) must be smaller than 19 mm and 100% smaller than the next higher standard size, 25 mm (1 in). In other words, nominal maximum aggregate size (NMAS) is defined as one size larger than the 1st sieve that retains more than 10% aggregate.

5. Describe the important properties of aggregates and tests used for their quality assurance?

- **Gradation** (or grain size analysis) - Grain size distribution curves are used for dense, strong mixture.
- **Relative density** (specific gravity) - RD (SG) = M / V*ρw (Where M=Mass, V= Volume of Agg. and ρw is density of water)
- **Hardness** (resistance to wear) - Los Angeles abrasion apparatus is used to measure the hardness of aggregate
- **Durability** (resistance to weathering) - The soundness test is used to measure susceptibility to weathering.
- **Shape and surface texture** - Flat particles, thin particle and flaky particles break more easily than cubical particles. Particles with rough, fractured faces allow a better bond with cementing material than do round, smooth gravel particles. Test is to find the mount of thin or elongated particles.
- **Deleterious Substances** - These substances include organic coating, dust, clay lumps, shale, coal particles, friable particles (easy to crumble), badly weathered particles, soft and light weight particles etc.
- **Crushing Strength** – is the compressive load that aggregate particles can carry before breaking. This trait is relatively unimportant for most aggregate uses since aggregate strength is much greater than the strength of asphalt and concrete mixture.

6. How do you do sampling in the field for aggregates?

To ensure that samples are as representative as possible, authorities require that specified procedure be followed. The following general rules should be adhered to:

1. Samples should be obtained from the final product.

2. At least three samples should be taken at various times from a production.
3. Conveyor belts should be stopped for sampling.
4. Special precautions must be taken when sampling from stockpiles. Coarse material tends to roll down the sides of the pile during placing. A minimum three samples should be taken, one from the top, one from the midpoint of stockpile, and one from bottom. These should be combined for a sample.

Type	Nominal Max. Size	Approximate Min. Mass (Field Sample in lb or kg)
Fine agg.	No.8 (2.36mm)	25 (10)
	No.4 (4.75mm)	25(10)
Coarse Agg.	3/8 in (9.5mm)	25(10)
	½ in (12.5mm)	35(15)
	3/4 in (19 mm)	55(25)
	1 in (25 mm)	110(50)
	1 ½ in (37.5 mm)	165(50)
	2 in (50 mm)	220(100)
	3 in (75 mm)	330(150)

(Source: ASTM International)

7. Why do we blend aggregates?

To meet the gradation requirements for asphalt mix or concrete, it is often necessary to blend two or more aggregates together. Charts and diagrams are available for this blending, but the trial and error method is simple and just as fast as any more complex methods.

8. Describe the aggregate base course material?

Material: (Crushed stone or crushed gravels)

- Hard
- Durable
- Free from dirt
- Not more than 8% flat, elongated, soft, disintegrated pieces

9. What do you know about Fuller Maximum Density Gradation?

Gradation has a profound effect on material performance. But what is the best gradation? This is a complicated question, the answer to which will vary depending upon the material (HMA or PCC), its desired characteristics, loading, environmental, material, structural and mix property input.

It might be reasonable to believe that the best gradation is one that produces the maximum density. This would involve a particle arrangement where smaller particles are packed between the larger particles, which reduces the void space between particles. This creates more particle-to-particle contact, which in HMA would increase stability and reduce water infiltration. In PCC, this reduced void space, and hence, reduces the amount of cement paste required. However, some minimum amount of void space is necessary to promote rapid drainage and resistance to frost action for base and subbase courses. Therefore, although it may not be the "best" aggregate gradation, a maximum density gradation does provide a common reference. A widely used equation to describe a maximum density gradation was developed by Fuller and Thompson in 1907. Their basic equation is:

$$P = \left(\frac{d}{D}\right)^n$$

where: P = % finer than the sieve

d = aggregate size being considered

D = maximum aggregate size to be used

n = parameter which adjusts curve for fineness or coarseness (for maximum particle density $n \approx 0.5$ according to Fuller and Thompson)

Calculations for a 0.45 Power Gradation Curve Using 19.0-mm (0.75-inch) Maximum Aggregate Size

Particle Size (mm)	% Passing
19	$P = (19/19)^{0.45}$ = 1.00 X 100 (100%)
12.5	$P = (12.5/19)^{0.45}$ = 0.828 X 100 (82.8%)
9.5	$P = (9.5/19)^{0.45}$ = 0.732 X 100 (73.2%)
2.00	$P = (2.00/19)^{0.45}$ = 0.363 X 100 (36.3%)
0.300	$P = (0.300/19)^{0.45}$ = 0.155 X 100 (15.5%)
0.075	$P = (0.075/19)^{0.45}$ = 1.00 X 0.083 (8.3%)

10. Why is washed sieve analysis performed?

- This is the best method of separating silts and clays from sand and gravels
- To obtain the grain-size distribution curve for fine aggregate
- It is difficult to break up soil particles into individual soil grains so they can pass through the small openings of the #200 sieve. Washing the soil through the #200 sieve with water produces more accurate results as the water helps to break the soil down into its elemental particle size and wash the silts and clays off of individual sand and gravel particles

11. What are the specifications and gradation of sub – base?

Grading requirements for Sub Base material (Dense graded mechanically stabilized) – C&W Punjab

Sieve	Percentage by weight passing square mesh sieve			
Designation	Grading A	Grading B	Grading C	Grading D
50 mm (2 in)	100	100	-	-
25 mm (1 in)	60-80	75-95	100	100
9.5 mm (3/8 in)	30-65	40-75	50-85	60-100
4.75 mm (No.4)	25-55	30-60	35-65	50-85
2 mm (No.10)	15-40	20-45	25-50	40-70
0.425 mm (No.40)	8-20	15-30	15-30	25-45
0.075 mm (No.200)	2-8	5-20	5-15	5-20

(Source: Highway Materials, Construction and Quality Control Road Research and Material Testing Institute June, 1985)

Grading Requirements for Subbase Material as NHA

Sieve Designation		Percent Passing by Weight	
(mm)	**(in)**	**A**	**B**
60.6	2.5	100	--
50.0	2	90~100	100
25.0	1	50~80	55~85
9.5	3/8	--	40~70
4.75	No. 4	35~70	30~60
2.0	No. 10	--	20~50
0.425	No. 40	--	10~30
0.075	No. 200	2~8	5~15

(Source: General Specification NHA, 1998)

12. What are the specifications and gradation of Base?

50 mm to 25 mm (2 in 1 in) size	Percent
Passing 63 mm (2 ½ in) sieve	100
Passing 50 mm (2 in) sieve	95 - 100
Passing 37.5 mm (1 ½ in) sieve	37 - 50
Passing 25 mm (1 in) sieve	0 - 15
Passing 12.5 mm (½ in) sieve	0 -5
63 mm to 37.5 mm (2 ½ in to 1½ in) siz	
Passing 75 mm (3 in) sieve	100
Passing 63 mm (2½ in) sieve	90 - 100
Passing 50 mm (2 in) sieve	35 - 70
Passing 37.5 mm (1½ in) sieve	0 -15
Passing 19 mm (3/4 in) sieve	0 – 5

(Source: Highway Materials, Construction and Quality Control Road Research and Material Testing Institute June, 1985)

Grading Requirements for Base Material

Sieve Designation		Percent Passing by Weight	
(mm)	(in)	A	B
50.0	2	100	100
25.0	1	70~95	75~95
9.5	3/8	30~65	40~75
4.75	No. 4	25~55	30~60
2.0	No. 10	15~40	20~50
0.425	No. 40	8~20	12~25
0.075	No. 200	2~8	5~10

(Source: General Specification NHA, 1998)

13. What are the main quality specifications for granular base & sub base course?

1. **Grain size distribution** – the shape of the curve is a good indication of strength. Strength is not so important for sub base; therefore, grading requirements are usually more open.
2. **Maximum value for plasticity** – to control the amount of clay fines, since these are considered more dangerous as for as frost damaged is concerned.
3. **Maximum loss in abrasion test** – to ensure that hard aggregates are used that will not degrade to smaller sizes.
4. **Maximum loss in soundness test** – to prevent degradation due to cycles of freezing and thawing.
5. **Petrographic requirements** - to govern over all base and sub base quality.
6. **Compaction** - Field density results are compared with the max. dry density achieved in lab.

Test Property for Base Course	Specified Limit
Los Angeles Abrasion Value % (Max)	40
Sand Equivalent (Min) Liquid Limit and Plastic Index (Max)	45 25 and 6
Soundness % (Max): Loss with sodium sulphate-5 cycles Loss with magnesium sulphate-5 cycles	 12 18
Water Absorption % (Max)	2
Laminated Material % of Total Volume (Max)	15
CBR % (Min)	80
Coefficient Of Uniformity(D60/D10)	> 4

(Source: General Specification NHA, 1998)

Test Property for Sub Base Course	Specified Limit
Los Angeles Abrasion Value % (Max)	≤ 50
Fraction Passing 0.075 mm (No.200)	≤ 2/3 of Fraction Passing 0.425 mm
Sand Equivalent (Min)	25
Liquid Limit and Plastic Index (Max)	25 and 6
Soundness % (Max): Loss with sodium sulphate-5 cycles Loss with magnesium sulphate-5 cycles	 12 18
Water Absorption % (Max)	2
CBR % (min)	50
D15(subbase)/D85(subgrade)	< 5

(Source General Specification NHA, 1998)

14. Why screening is added to base and sub base material?

Screening or stone dust is added in base and sub base to increase its density and strength. Screening has also cementing property and hence, it provides bonding among interlocked aggregate particles.

15. How screening is added to base and sub base?

The stone screenings may be spread by means of mechanical spreader or by manual labor. Spreading, brooming and rolling operations are carried out at the same time. Enough screenings are applied, preferably, in installments till the surface voids of the course are filled up.

16. How water is added while rolling of base and sub base?

The surface of layer is sprinkled with water and rolling is continued until all the voids are filled and wave of grout flushes in front of the roller. Water should preferably be applied through the pressure distribution mounted on pneumatic tires of a water lorry.

17. In which meaning "Hydrophilic" term is used for Aggregates?

Some siliceous aggregates such as quartz are hydrophilic (water liking), meaning they have greater affinity for water than asphalt due to their surface charges. This may lead to stripping, as asphalt coating comes away from the particles in the presence of water.

18. Why water bound macadam (WBM) is preferred over granular base course?

Irrespective of dry granular base course, in WBM water is sprinkled on the placing layer of base course to flush the slurry in to the voids among the relatively larger aggregate particles. The complete water bound macadam (WBM) is allowed to cure under traffic for a period of at least 7 days. It derives strength through interlocking of particles. All these actions make water bound macadam a dense matrix.

In the light of experience and field results, Water bound macadam (WBM) have high strength as compare to granular base course, and also have better resistance against shear stresses, that is why it is preferable over granular base course.

Coarse Aggregate Grading for Water Bound Macadam (WBM) as per NHA

Sieve Designation		Percent Passing by Weight		
(mm)	(in)	A	B	C
102	4	100	--	--
89	3 ½	90~100	--	--
76	3	--	100	--
63.5	2 ½	25~60	90~100	100
50	2	--	25~60	90~100
37.5	1 ½	0~15	0~15	35~60
25	1	--	--	0~15
19	3/4	0~5	0~5	0~5
12.5	1/2	---	--	--

Fine Aggregate Grading for WBM as per NHA

Sieve Designation		Percent Passing by Weight
mm	in	
9.50	3/8	100
4.35	No. 4	85~100
0.15	No. 100	10-30

Similarly, the additional physical requirements of coarse aggregates for water bound macadam will satisfy the following limits:

a) Loss Angeles Abrasion Value max. 45%
b) Flakiness Index max. 15%
c) Loss when subjected to five cycles of Sodium Sulphate (AASHTO T104) < 12

19. When we did not provide sub base?

Sub bases are usually not provided on sub grade belonging to A-1 to A-2 groups (granular sub grade).

20. What are criteria's of NHA & C&W Punjab for sub base and base course of CBR and compaction (%)?

Agency	Material	Min. CBR %	Min. Compaction %
NHA	Sub Base Course	50	98
	Base Course	80	100
C&W Punjab	Sub Base Course	30	100
	Base Course	80	100

21. What do you understand about artificial aggregate?

Blast furnace slag is the most commonly used artificial aggregate, having unusual resistance to wear and it is used in bridge deck and roof deck.

SURFACE TREATMENT & HOT MIX ASPHALT

1. **What is the function of surface treatment?**

   A surface treatment is placed on a crushed stone base to provide a roadway with the least expensive permanent type of bituminous surface. It seals and protects the base and gives waterproof cover over the existing pavement surface and provide resistance to abrasion by traffic.

2. **What is Bituminous Surface and how many treatments are applied?**

   It is a top layer made from mineral aggregates together with the bitumen or tar:

a. Surface application in which the bitumen binder and the aggregates are applied separately to the road.
b. Premixed materials in which the bituminous binder and aggregate are apportioned and mixed together in mixing plant before being spread on the road.

1. **Single Surface Treatment:** A single surface treatment is a wearing course of bituminous material and aggregate in which aggregate is placed uniformly over the applied bituminous material in a single layer, the thickness of which approximate the nominal maximum size of aggregate used. Single surface treatment is applied only for very low traffic and favorable field conditions.
2. **Multiple Surface Treatment:** A multiple Surface Treatment, Double (DST) or preferably Triple (TST), is a wearing surface composed of bituminous material and aggregate in which coarse aggregate is placed uniformly over initial application of bituminous and followed by subsequent applications of bituminous material and finer aggregate. Generally, the maximum size of the smaller aggregate is one – half of the aggregate used in the proceeding application. Each application of aggregate is placed uniformly in a single layer. Out of these, triple surface treatment is considered most appropriate.

3. **What are the quantities of materials used in Surface Treatment?**

Treatment	**Application**	**Nominal Size** mm (inch)	**Rate of Application**			
			Aggregate		**Bitumen**	
			$m^3/100m^2$	$ft^3/100\ ft^2$	$kg/100m^2$	$lbs/100\ ft^2$
Surface Dressing	Initial	12.5 (1/2”)	0.76	2.5	107	22
	-do-	9.5 (3/8”)	0.61	2.0	98	20
DST (Heavy)	Initial	25 (1”)	1.68	5.5	195	40
	2nd	12.5 (1/2”)	0.48	2.75	122	25
DST (Light)	Initial	19 (3/4”)	1.22	4.0	171	35
	2nd	9.5(3/8”)	0.61	2.0	88	18

Treatment	Application	Nominal Size	Rate of Application			
		mm (inch)	Aggregate		Bitumen	
			$m^3/100m^2$	$ft^3/100\ ft^2$	$kg/100m^2$	lbs. /100 ft^2
TST (Heavy)	Initial	25 (1")	1.68	5.5	195	40
	2nd	9.5 (3/8")	0.84	2.75	122	25
	3rd	6.3 (1/4")	0.46	1.5	68	14
			2.98	**9.75**	**385**	**79**
TST (Light)	Initial	19 (3/4")	1.22	4	171	35
	2nd	9.5 (3/8")	0.61	2	88	18
	3rd	6.3 (1/4")	0.46	1.5	68	14
			2.29	**7.5**	**327**	**67**

(Source: Highway Materials, Construction and Quality Control, Road Research and Material Testing Institute 1985)

4. What type of Aggregate and Bituminous material are used in Bituminous or Asphalt Concrete?

Aggregate Material:

Aggregate used are crushed stone, natural screened gravel and crushed gravel. The aggregate should be clean, tough, durable and free from excessive amount of flat or elongated pieces, dust, clay film and other objectionable materials.

Bituminous Material:

The selection of grade of bituminous material used and its rate of application govern the final performance of surface treatment and should be given careful consideration. The type of wearing surface whether it be a single or multiple surface treatment, texture of the base surface, character of aggregate and season of the year or prevailing weather condition for the execution of work and expected traffic are the principle factors to be considered.

The use of the bitumen (asphalt cement), heavy grades of liquid asphalt high viscosity road tars (RT-10 and thicker grades) is practicable in warm weather. Asphaltic grades of bitumen most suitable during warm months are 40+ penetration grades of bitumen say 40-50.

5. In how many layers Bituminous/Asphalt Surface can be applied?

Depending upon the total thickness of Bituminous Surface, it is generally applied in following layers:

- Asphaltic Wearing or Surface Course
- Asphaltic Binder Base Course (also called Intermediate Base Course)
- Asphaltic Base Course

6. Asphalt Concrete Base and Surface Course?

Hot mix, hot laid and dense graded asphalt concrete is used for high type pavements which comprises of suitable grade of bitumen and graded aggregate so that the voids in the coarse material are filled with the finer materials and those finer materials that are filled with bitumen thus creating very dense mixture. The asphalt concrete mix is produced in a central mixing plant and then hauled by trucks (dumpers) to the mechanical paver on the project site where it is placed in smooth layer and compacted by rollers.

7. What are Asphalt Gradings?

Asphalt is normally used in following grades depending on weather and traffic condition:

1. Penetration Grade (e.g. 60/70, 80/100 and 120/150)
2. Viscosity Grades (e.g. AC-5, AC-10 and AC-30)
3. Superpave Performance Grading (e.g. PG 64-22 where PG is performance grade, 64°C is average 7 days max. temperature of pavement and -22 °C is minimum pavement temperature).

8. Which grade is commonly used in Pakistan?

Penetration grade is widely used in Pakistan.

9. Which grade is normally used in hot and cold climate?

The penetration depth (albeit only roughly) correlated with asphalt binder performance. Therefore, asphalt binder with high penetration grade (called soft) are used for cold climates while asphalt binders with low penetration grades (called hard) are used for warm climates. Asphalt of 40-50 is used in very hot climate, 60-70 penetration grade is used in hot climate condition, 85-100 & 120-150 penetration grade used in mild climate condition. Whereas, 200-300 grade used for very cold climate (northern areas).

10. What tests are used for quality of Asphalt?

Following properties of asphalt are measured for its quality:

1. Viscosity Test
2. Penetration Test
3. Flash Point Test
4. Solubility in trichloroethylene
5. Ductility Test
6. Spot Test
7. Rolling Thin Film Oven Test
8. Specific Gravity
9. Softening Point

11. What is Job Mix Formula (JMF)?

JMF is an economical blend of aggregate and asphalt/bitumen that meet design requirements such as:

- Sufficient asphalt to ensure a durable pavement.
- Sufficient stability under traffic loads.
- Sufficient air voids to accommodate volumetric changes due to climate and loading.
- Upper limit to prevent excessive environmental damage.
- Lower limit to allow room for initial densification due to traffic.

12. What methods are used for Job Mix Formula (JMF) and which one is common in Pakistan?

- Marshall
- Hveem
- Superpave gyratory

Marshal Mix Design is most common in Pakistan

13. What are the basic steps of Job Mix Formula (JMF)?

Mix design involves the following steps:

1. Selection of aggregate proportions to meet the specifications requirements
2. Conducting trial mixes at a range of asphalt contents and measuring the resulting physical properties of the samples
3. Analyzing the results to obtain the optimum asphalt content and to determine if the specifications can be met
4. Repeating with additional trial mixes using different aggregates blends, until a suitable design is found

14. Explain Marshal Method of Job Mix Formula (JMF) Design?

1. The aggregates blended in proportions that meet the specification
2. The mixing and compacting temperatures are obtained from the temperature viscosity graph.
3. A number of specimens, 4 in diameter and 2 ½ in high, are mixed using 1200g of aggregates and asphalt cement content at various percentage both above and below the optimum. Therefore theses specimens would be made at 3.5%, 4.0%, 4.5%, 5.0% and 5.5% asphalt content are recommended in MS-2 Asphalt Mix Design Method.
4. The Marshall specimens are immersed in water bath at 60±1 ◦C for 30-40 minutes. Stability and flow values are obtained in a compression test in the Marshall apparatus to measure strength and flexibility.

15. Define the stability and flow w.r.t. Marshall Test?

Stability – is the maximum load taken in kg that a specimen in briquette can carry.

Flow – is the deformation, elastic plus plastic, (measured in units of hundredths of an inch or in millimeters) that the sample undergoes between no load and maximum load in compression test.

16. What are the factors that affect stability?

a) Gradation of aggregate
b) Hardness of aggregate
c) Shape and surface texture of aggregate
d) Quantity of asphalt
e) Degree of compaction: at least 95% compaction
d) Temperature

17. If stability is low say 400 kg which is less than the specification, what is the problem?

i) Asphalt content is less than optimum
ii) Poor gradation of aggregate used
iii) Round aggregate, little or no crushed surfaces.

iv) Excessive medium size sand in mixture
v) Degree of compaction is less than specified i.e. 97%

18. What are the specifications of Marshall Method for Job Mix Formula (JMF)?

As per C&W Punjab (1985):

Layer	Base Course	Surface Course
No. of Blows	50	75
Marshal Stability Min.	300 kg.	500 kg.
Flow	2.4 – 5.0 mm	2.4– 4.0 mm
Voids in Mineral Aggregate (VMA)	12 – 20 %	12 – 20 %
Voids in Total Mix (VIM)	3 – 8 %	3 – 5 %

As per NHA (1998):

Layer	Base Course	Surface Course
Compaction, No. of Blows	75	75
Marshal Stability Min.	1000 kg.	1000 kg.
Flow 0.25 mm (0.01 in)	8 – 14	8 – 14
Voids in Mineral Aggregate (VMA)	as per AI, MS-2 1993	as per AI, MS-2 1993
Loss in Stability	25 % (Max.)	20 % (Max.)
Voids in Total Mix (VIM)	4 – 8 %	4 – 7 %

19. What is the difference between Prime Coat and Tack Coat?

Prime Coat:

When a bituminous / asphaltic wearing course is to be placed over an untreated and compacted base course layer (say water bound macadam), the base is generally given a single light application of a liquid bituminous material called a prime coat. It serves to promote adhesion or bond between base and wearing course.

The bituminous materials used for prime coats should have high penetrating qualities. After curing, it should leave a high viscosity residue in the voids of the upper portion of the base course. The suitable materials for this purpose is liquid asphalt (cut-back) or road tar (RT) of low viscosity. Rapid curing grades are not generally used because of their rapid increase in viscosity after application. Medium curing grades are most widely used which best serve the purpose. The grade and rate of application will be govern by the condition of the existing surface.

The ideal rate of application of primer is maximum that will, under favorable weather conditions, be completely absorbed by the base material within 24 hours from the time of application. When a prime

coat is not entirely absorbed within 24 hours or so, it is customary to apply a very light sand blindage to blot up the excessive primer.

Primer	Rate of Application	Surface
MC-30	0.8 – 1.5 Kg/m² (18 - 32 lbs. per 100 sq.ft)	Dense Flexible Base
MC-70	1.2-2.4 Kg/m² (27 - 54 lbs. per 100sq.ft)	Open and Loose Surface

(Source: Highway Materials, Construction and Quality Control, Road Research and Material Testing Institute 1985)

Tack Coat:

Tack coat is a single and initial application of bituminous material on surface which have been previously treated or prepared, such as existing bituminous surface, cement concrete or even brick surface.

The purpose of tack coat is to ensure adhesion between the existing bituminous or concrete surface and new bituminous surface. A tack coat would not be required if a wearing surface is to be single or multiple coat surface treatment but would be required for asphaltic concrete wearing surface.

Materials commonly used for tack coats include the rapid curing liquid asphalt, RC-250, RC-800, emulsified asphalt of quick breaking type, bitumen (asphalt cement) of 80-100, 120-150 or 150-200 penetration and higher grades. Regarding the rate of application, the quantity of bituminous materials which is normally required for a tack coat is usually 0.25-0.5 kg/m² (5 - 10 lbs. /100 sq.ft maximum).

Tack coats do more harm than good when they are applied in too large a quantity as it would unnecessarily enrich the superimposed course and decrease its stability. Care should be taken not to cover a large area at one time, so that a tack coat may cool and harden before the mat is placed over it.

20. What is seal coat?

Seal coat is a very thin surface treatment which is either applied as final step in the construction of certain bituminous surfaces or to existing road surfaces which have cracked or oxidized over a number of years and have commenced to ravel.

The purpose of seal coat is to water proof or seal the surfaces and thereby prevent its deterioration from moisture and air oxidation. If the surface has oxidized and become open texture, a portion of the binder will penetrate the existing surface and will practically act as a primer. This condition requires a heavier application than for the non-absorptive surface having a smooth texture.

Rates of application of bituminous material materials may range as high as 2.0 kg/m² (40 lbs. per 100 sq.ft) for seal coat of open textured and absorptive surface or when covered with aggregate of 25 mm (1") maximum size to as low as 0.9 kg/m² (18 lbs. per 100 sq.ft) when covered with aggregates of 9.5 mm (3/8") maximum size.

Prevailing climatic conditions and the season of the year in which the seal coat is applied has considerable bearing on the selection of the type and grade of asphaltic material. For best result, the work should be performed during the early part of the warm season so that the newly sealed surface may be subjected to a considerable amount of traffic during the warmer months.

21. What should be mixing and compacting temperature of asphalt concrete?

As per C&W Specifications:

- In case hard grade bituminous material are used, mixing temperature should be 148°C (300° F) and the difference of temperature between aggregate and asphalt should not exceed ±11°C (20° F). However, the temperatures would vary according to the grade of the bituminous used in the mix. In case of soft grade materials these temperatures would vary depending upon the grade selected.
- The rolling of mixture is recommended as soon as the spread mixture will sustain the rolling without excessive displacement. Some highly stable mixes can be rolled at 121°C (250° F) or more, whereas a very fine mix with low stability may not be able to rolled until the temperature has reached 93° C (200° F) or less.
- Roughly initial rolling should be done at a temperature so that the sum of air temperature and mix temperature equal to 150°C - 190°C (300° F - 350° F).

(Source: Highway Materials, Construction and Quality Control Road Research and Material Testing Institute June, 1985)

As per NHA Specifications:

- Asphalt Cement shall be mixed at a temperature as required to achieve a kinematic viscosity of (150-300) centistokes. Typical plant mixing temperature is 155° C - 163° C (310 °F - 325 °F) and at no time shall the mixing temperature exceed 163° C (325 °F).
- In no case shall the temperature be less than 120° C for initial breakdown rolling and all other compaction operations shall be completed before the temperature drops down to 110° C.
- All mixtures shall be spread at a temperature of not less than hundred and thirty degree (130° C) and all initial rolling and tamping shall be performed when the temperature of the mixture is such that the sum of the air temperature plus the temperature of the mixture is between 165° C - 190° C. The mixture shall not be placed on any wet surface or when weather conditions prevent its proper handling or finishing.
- Hot asphaltic mixture shall be placed only when the air temperature is four (4) degree centigrade or above and no asphalt shall be laid under foggy or rainy weather.

(Source: General Specifications NHA, Dec – 1998)

22. What precautions should be exercised while compacting asphaltic mixture?

After each course has been laid, it is rolled while still hot until it is thoroughly compacted. When a mix is rolled at too high a temperature, it will creep out rather than being compressed downward or alongside this, it will oxidize at faster rate which might cause premature cracks. Also blisters will sometimes form behind the roller as it passes. When this occurs, the irregularities thus created should be quickly repaired by raking. Rolling performed after the pavement has partially chilled may be responsible for some cracking.

23. What are the stages of rolling an asphaltic mixture?

Breakdown Rolling:

The initial rolling is done by 8 tone 2-axle or 12- ton 3 axle tandem rollers, as soon as the roller can safely get on the mixture. Breakdown rolling compacts the material to obtain practically all the density it will receive. This requires usually 2 -3 passes of the roller. Maximum speed of breakdown roller is 3 miles per hour.

Intermediate Rolling:

This is done by employing pneumatic roller with 45 psi tire pressure immediately behind the breakdown roller. It imparts a very high density particularly in top 25 mm (1 in) or so by kneading the mixture into a compact position without particular crushing. A pneumatic roller usually operates at 15 mph during intermediate rolling.

Final Rolling:

This is accomplished by 12 ton, 3 axle tandem roller which adds little more density to the material and removes all the irregularities left by breakdown roller.

24. How to determine layer thickness of asphalt concrete for high degree of compaction?

As per C&W Punjab Specifications:

- To achieve high degree of compaction, asphalt concrete base course, should not be laid in a placement thickness, exceeding **10 cm (4 in).**
- Similarly placement thickness for asphalt concrete surfacing should not exceed **8 cm (3 in)** in the binder course.
- **5 cm (2in)** in wearing course when compacted.

(Source: Highway Materials, Construction and Quality Control Road Research and Material Testing Institute June, 1985)

As per NHA Specifications:

Mix Designation	**Class A**	**Class B**
Course	Leveling /Base	Leveling /Base
Compacted Thickness	70 -90 mm	50m – 80 mm

Mix Designation	**Class A**	**Class B**
Course	Asphaltic Wearing Course	Asphaltic Wearing
Compacted Thickness	50 -80 mm	35m – 60 mm

(Source: General Specifications – NHA, December 1998)

25. Determine optimum asphalt content by immersion-compression stability test?

A. a) Prepare trial mix specimen at different emulsified asphalt content at 1% increments using the specified compaction method.

b) Calculate theoretical maximum density (D) of each specimen from equation,

$$D, g/cc = \frac{100}{\frac{\% \text{ aggregate}}{SG. (Aggregate)} + \frac{\% \text{ asphalt}}{S.G. (asphalt)}}$$

Whereas, S.G= is the specific gravity.

b) Determine actual density (d) of each compacted specimen and determine "dry stability" by unconfined comparison test.

d) Calculate percent air voids in total mix from equation,

$$\% v = \frac{D-d}{D} \times 100$$

d) Determine wet stability to evaluate resistance to water action on duplicate specimen after immersion in water for 4 days. Loss in strength is considered measure of water action.

26. How would you adjust the mix if stability is low?

Either by reducing the asphalt content or by increasing the amount of aggregate particles.

*Air void is kept above 4% to allow film thickness of asphalt to the aggregate particle which give durable and stable asphalt mix.

27. What is Slow Curing (SC) Medium Curing (MC) and Rapid Curing Cutbacks (RC)?

Asphalt cutbacks use petroleum solvents for dissolving asphalt cement. If the solvent used in making the cutback asphalt is highly volatile, it will quickly escape by evaporation. Solvents of lower volatility evaporate more slowly. On the basis of the relative speed of evaporation, cutback asphalts are divided into three types: rapid curing (RC), medium curing (MC) and slow curing (SC).

The degree of liquidity developed in each case depends principally on the proportion of solvent to asphalt cement. To a minor degree, the liquidity of the cutback may be affected by the hardness of the base asphalt from which the cutback is made. The degree of fluidity results in several grades of cutback asphalt—some quite fluid at ordinary temperatures and others somewhat more viscous. The more viscous grades may require a small amount of heating to make them fluid enough for construction operations.

Slow Curing (SC) asphalt cement and oils of low volatility generally in the heavy distillate range **(SC-70, 250, 800, 3000)**. The degree of liquidity developed in each case depends principally on the proportion of solvent to asphalt cement. Slow Curing (SC) cutback asphalts are often called road oils and are used primarily in road-mixing and dust-laying applications. This term originated in earlier days when asphalt residual oil was used to give roads a low-cost, all-weather surface.

Medium Curing Cutback (MC-30, 70, 250, 800, 3000) is a liquid asphaltic material having kerosene as a solvent. Its purpose is to stabilized and waterproof the absorbent surface and to promote adhesion to the bituminous courses. The medium setting grades are designed for mixing with aggregates. Because these grades do not break immediately upon contact with aggregate, mixes using them can remain workable for extended periods of time.

Rapid Curing Cutback (RC-70, 250, 800, 3000) is a liquid asphaltic material having gasoline or naphtha as a solvent. Its purpose is to provide bond with a super imposed course. The rapid-setting grades are designed to react quickly primarily for spray applications, such as bond/tack coats, aggregate chips seals, sand seals, and similar surface treatments.

28. What are the tests you should run on a compacted asphalt pavement?

a) Density and Thickness test
b) Smoothness test

29. How would you classify cutback asphalt respective spraying temperatures?

Cutback, also called liquid asphalt, is simply a combination of asphalt cement and petroleum solvents. Cutbacks are used because they reduced asphalt viscosity for lower temperature uses e.g. Tack coats, fog seal, slurry seal and stabilization.

Cutback Asphalts (RC, MC, SC)	Spraying Temperature (°C)Surface Treatments
30	30 min
70	50 min
250	75 min
800	95 min
3000	110 min

(Source: General Specifications – NHA, December 1998)

30. What is rutting and its causes?

It is the channel like grooves those occur in the wheel track of a pavement. The main causes are:

a) Poor compaction
b) Fine graded mix
c) Excessive asphalt content, low air voids
d) High temperature
e) Excessive wheel and traffic loads
f) Natural aggregates
g) Dune sand more than 7.5% of fine aggregates
h) Low softening point

31. On the mixing plant, how can you say that hot mix is okay or not okay?

For hot mix is ok, following are the requirements:

a) Require temperature should be uniform
b) Mix should be free from excessive fines
c) Mix should be free from free asphalt
d) Large aggregates should not be uncoated
e) Appearance should be uniform
f) Should not be burnt
g) Should not be too brown or gray
h) Should not be too fat
i) Should not steam in trunk

32. When do you put the flow meter to determine the flow of an asphalt mix?

Before Marshall testing starts.

33. What is the Marshal mixing and compacting temperature of hot mix asphalt?

Mixing temp. 160° C ± 5° C
Compacting temp. 145° C ± 10° C

These temperatures are those required to produce viscosities of 1.7±0.2 cm^2/s (170±20 centistokes) for mixing and 2.8±0.3 cm^2/s (280 ± 30 centistokes) for compaction.

(Source: MS-2: Asphalt Mix Design Methods, 7th Edition, Asphalt Institute)

34. From where will you get asphalt sample during production and paving operation?

During production, samples should be taken from the truck, one sample consisting of four mix samples taken in a small quantity to form a composite sample. During paving, samples should be taken behind the paver, sample units taken from different locations constituting of minimum of four sub-samples to make one composite asphalt sample for grading, Marshal Tests and Extraction.

35. What is raveling and its causes?

It is a progressive loosening or separation of aggregate particles in a pavement surface course.

The causes are;

a) Lack of compaction
b) Construction in thin lift during cold weather
c) Dirty or disintegrated aggregates
d) Too little asphalt in the mix
e) Overheating of asphalt mix
f) Mix is very close to coarse (over % of coarse material)
g) Action of water
h) Sensitive aggregate refuse asphalt coating due to special charge (anti stripping materials must be used)

36. What is softening point of asphalt?

It is an indicative measurement of temperature at which the harden asphalt reach an arbitrary degree of softening. This is useful in the classification of certain asphalts (bitumen) and tars. Softening point can be determined using AASHTO T53.

37. What is stripping test and its purpose?

Bitumen and tar adhere well to all normal types of aggregates provided they are dry and are not exceptionally dusty. The film stripping test is used to measure the resistance of bituminous material to stripping from the rock particles and is generally used to evaluate adhesive capacity of mineral aggregate and bituminous material. Its purpose is also to determine the retention of a bituminous film on an aggregate surface in the presence of water.

38. What is the reason for some spots appear after every 20 meter behind the paver?

a) Dirty lumps of old asphalt from the paver
b) Temperature of the mix is low
c) Auger is not distributing the mix properly
d) Paver operator is folding the hopper sides after each load
e) Screed is tilted or uneven
f) Screed is not vibrating properly
g) Screed is not heated properly
h) Stopping of Continuity

39. What is the temperature for bituminous mixture delivered to the paver at site?

The mixture delivered at site will not be less 130° C.

(Source: General Specifications – NHA, December 1998)

40. What is the rate of application of the bituminous/ asphaltic material?

Type of surface	Liters per square meter	
	minimum	maximum
Subgrade, subbase, water bound base course and crushed stone base course	0.65	1.75
Bridge, wearing surface, concrete pavements	0.15	0.4

(Source: General Specifications – NHA, December 1998)

41. What is the maximum loss of marshal stability allowed for asphalt mix?

25%. (Asphaltic Base Course) and 20% (Asphaltic Surface Course).

(Source: General Specifications – NHA, December 1998)

42. What is the min. temp, required for applying prime coat?

15° C. (the application is prohibited when the weather is fogy, rainy or atmosphere temperature is below 15° C unless otherwise directed by Engineer).

(Source: General Specifications – NHA, December 1998)

43. How do mineral filler improve properties of mix?

When voids are high but stability is satisfactory in the mix, it leads to higher permeability resulting in premature hardening of the asphalt. To reduces voids, filler is increased which improves the properties of the mix.

44. What will happen if we over use the filler?

Over use of filler may bring the voids low in the mix, consequently, instability or flushing may occur after the pavement is exposed to traffic.

45. What factors affect the compaction of asphalt mix?

a) Mix Properties:

1) <u>Aggregate</u>

If maximum aggregate size or percentage of coarse aggregate in the mix increases, the workability decreases and greater compactive effort is required to achieve the target density.

Natural sand turns the mixes tender which are easily over-stressed by heavy rollers and by too much rolling.

Combination of filler and asphalt produces necessary cohesion when the mix cools. But too many fines will make the mix "gummy" and very difficult to compact.

2) <u>Asphalt</u>

Proper compaction can be achieved only when asphalt is still fluid enough. Consequently, compaction of the mix is extremely difficult once the mix has cooled to 85°C. Grade of asphalt is also important. Higher viscosity asphalt in the mix requires higher compaction, temperature and/or greater compactive effort. If quantity of asphalt in mix increases, film thickness of asphalt on aggregate also increases, which make the mix workable and easy in compaction and vice versa.

3 a) Mix Temperature

Up to a certain point, the hotter the mix, the more fluid is the asphalt and hence, less resistant to compaction and vice versa if it cools.

3 b) Environmental conditions

Ambient temperature, humidity, wind and the temperature of the surface under the mix also affects the compaction.

3 c) Layer (lift) thickness

Generally, it is easier to achieved target density in thicker layers, up to a specified limit, of asphalt concrete than thinner ones, because of the difference in rate of cooling.

46. What do you check, when you go to the mixing plant?

a) inspection of truck beds
b) Mixing of aggregate - mixing time
c) Weighing of ingredients i.e., aggregate, filler & bitumen
d) Temperature of the mixture i.e. is it uniform?
e) Appearance of the mix
f) Rate of mixing should coordinate with paving requirements.

47. During the production of asphalt mix what do you look for the stockpiled material?

a) Do aggregate meet quality specifications

b) Are proper sizes being produced?

c) Satisfactory storage

d) Separation of stockpiles

e) No segregation allowed

f) Mineral filler kept dry

g) No deleterious materials to acceptable limits

48. As asphalt inspector, what important properties you are looking for and what is your target on site?

a) Asphalt content should be checked with job mix formula

b) Aggregate gradation should be checked with job mix formula

c) Required temperature should be uniform

d) Mix should be free from excessive fines

e) Mix should be free from free asphalt

f) Mix should not be too brown or gray

g) Mix should not be too fat

h) Mix should not steam in truck

i) Mix should not produce smoke on discharge from hopper.

j) Large aggregate particles should not be uncoated, etc.

49. What do you watch during paving?

a) Temperature of the paving mixtures

b) Appearance of the paving mixtures

c) Alignment and thickness of the pavement

d) Rolling at correct time and temperature

e) Sufficient rolling

f) Surface irregularities and its repairs

g) Quantity paved during the day

h) Stations/Locations paved in each shift

i) Coordination with the mixing plant to maintain the rate of mixing and rate of paving

j) Weather conditions of the day, etc.

50. What is the rate of loading of test machine in the marshal stability test?

2 inches (50.8 mm) per minute

51. If asphalt sample in laboratory is cooled then reheated for 2 or 3 times (for a breakdown in equipment), what will heating do to the sample?

Re-heating of asphalt sample in laboratory is not permissible because by this process the asphalt loses its viscous properties which will not yield the actual stability, voids in the mix, and flow etc., and aside of it, re-heated samples will no longer be a representative of the in-situ pavement.

52. Why not to use high penetration asphalt say 100 - 120, Are air voids affected?

Harder asphalt cements are recommended for heavy duty pavements and for weather condition. Generally, asphalt of penetration grade 60 - 70 is used in medium to heavy types of pavements. Higher penetration grade like 100 - 120 will not produce a thick film of coating around the particles. This will turn the mix unstable, and low air voids. This will fill the air voids comparatively more, making the mix more brittle and easily disintegrated when opened to traffic.

53. What are the types of Asphalt Mixes?

The most common type of flexible pavement surfacing is hot mix asphalt (HMA). Hot mix asphalt is known by many different names such as hot mix, asphalt concrete (AC or ACP), asphalt, blacktop or bitumen. Following are the important types of asphalt mix:

a) **Dense graded Type:** A dense-graded mix is a well-graded HMA intended for general use. When properly designed and constructed, a dense-graded mix is relatively impermeable. Dense-graded mixes are generally referred by their nominal maximum aggregate size and can further be classified as either fine-graded or coarse-graded. Fine-graded mixes have more fine and sand sized particles than coarse-graded mixes.

b) **Open Graded Type:** Unlike dense-graded mix, an open-graded HMA mixture is designed to be water permeable. Open-graded mixes use only crushed stone (or gravel) and a small percentage of sand. The two most typical open-graded mixes are:

- Open-graded friction course (OGFC). Typically 15 percent air voids and no maximum air voids specified.

Purpose:

- OGFC – Used for surface courses only. They reduce tire splash/spray in wet weather and typically result in smoother surfaces than dense-graded HMA. Their high air voids reduce tire-road noise by up to 50-percent (10 dBA) (NAPA, 1995)
- ATPB (Asphalt Treated Permeable Base) – Used as a drainage layer below dense-graded HMA, SMA or PCC.

c) Stone Matrix Asphalt (SMA):

Stone matrix asphalt (SMA), sometimes called stone mastic asphalt, is a gap-graded HMA originally developed in Europe to maximize rutting resistance and durability. The mix design goal is to create stone-on-stone contact within the mixture. Since aggregates do not deform as much as asphalt binder under load, this stone-on-stone contact greatly reduces rutting. SMA is generally more expensive than a typical dense-graded HMA because it requires more durable aggregates, higher asphalt content, modified asphalt binder and fibers. In the right situations it is cost-effective because of its increased rut resistance and improved durability.

Purpose:

Improved rut resistance and durability.

Other reported SMA benefits include wet weather friction (due to a coarser surface texture), lower tire noise (due to a coarser surface texture) and less severe reflective cracking.

(Source: National Asphalt Pavement Association (NAPA), 1995)

54. How to improve filler?

By adding certain amount of:

a) Portland Cement
b) Crusher Powder
c) Earth Fillers
d) Asbestos Powder
e) Limestone Powder

55. How to determine the mixing time of asphalt?

$$\text{Mixing Time in Seconds} = \frac{\text{Pug mill dead capacity in kilograms}}{\text{Pug mill output in kilograms / second}}$$

56. What parameters are defined in the job mix formula (JMF)?

a) Definite grading of aggregate
b) Definite Percentage of Asphalt
c) Delivery temperature

57. What do you mean by effective asphalt content?

Asphalt concrete consists of asphalt cement, aggregates and air voids. However, some of the asphalt cement seeps into air voids in the aggregate particles and therefore not available to coat and bind aggregate together. Hence, effective asphalt content is the volume of asphalt not absorbed by aggregates or the amount of asphalt that effectively forms a boning film on the aggregate surfaces and serve as binder.

58. What do you mean by voids of Mineral Aggregate (VMA)?

It is cumulative granular spaces among the mineral aggregate particles.

59. Did asphalt effect by acids, alkalis, and salts?

No.

60. Why asphalt is called thermo-plastic material?

Because of its softness as it is heated and hardens as it is cooled

61. What is the percentage of Aggregate in Asphalt mix?

Normally from 90% to 95%

62. What is the desired properties of asphalt cement?

1. Consistency: Is the term used to describe the degree of plasticity of asphalt at any particular temperature specified and measure by penetration test or a viscosity test.

2. Purity: Refined asphalt are almost pure bitumen and are usually more than 99.5% soluble in carbon disulfide (Solubility test).

3. Safety: Asphalt not foam at temperature up to 175°C and flash point of asphalt should be known.

63. Why you add filler to mix?

a) To improve resistance to weathering.
b) To improve strength.
c) To increase stability.
d) To close the space between coarse and fine aggregate, etc

64. What are the penetration grades of asphalt?

a. 40 – 50 penetration grade
b. 60 – 70 penetration grade
c. 80 – 100 penetration grade
d. 120– 150 penetration grade
e. 200 – 300 penetration grade

65. How to determine the grade of Asphalt?

a) By Penetration Test: Old Method
b) By Viscosity Test : Modern Method at temperature of 60 °C to 135 °C

66. Q. What is the suitability of aggregate for use in asphalt construction?

1) Size and grading

a. Dense graded
b. Open graded
c. One size (uniform graded)
d. Coarse graded

e. Fine graded
f. Gap graded

2) Cleanliness:

3) Toughness

4) Soundness

5) Particle shape affect workability and strength

6) Surface texture

7) Absorption – A certain degree of porosity is desirable as it permits aggregate to absorb asphalt which then forms a mechanical linkage between the asphalt film and the stone particle.

8) Affinity for asphalt: Stripping, separation of the asphalt film from the aggregate through the action of water such material is referred to as hydrophilic (Water Loving) such as siliceous aggregate (quartzite and some granites).

Aggregates that exhibit a high degree of resistance to film stripping in the presence of water are usually most suitable in asphalt paving mixes, such material is referred to as hydrophobic (water hating) such as limestone and dolomite usually have high resistance to asphalt film stripping.

67. What are desired properties of asphalt mix?

a) Stability – Resistance to displacement and shearing stress caused by stationery and moving loads
b) Durability – Resistance to disintegration due to the effects of traffic, water, and temperature change.
c) Flexibility – Ability of pavement to adjust the settlement of the pavement without cracking.
d) Skid Resistance – The frictional resistance between the surface of the pavement and the vehicle tire to resist skidding.
e) Workability – Is the ease by which the material can be placed to its desired form and compacted to required density.
f) Fatigue Resistance – Resistance to wear and aging.
g) Impermeability – Resistance to penetration of water.

68. What are the factors affecting durability?

a) Density of the compacted pavement
b) Properties of the aggregate
c) Quality of the asphalt

69. What are the factors affecting the flexibility?

a) Quality of the asphalt
b) Quality of the mineral filler
* The more viscous the asphalt the more flexible it is.

70. What are the factors affecting skid resistance?

a) Quantity of asphalt
b) Surface texture of the aggregate
c) Non polishing of aggregate particles

71. What is the effect of hydrated lime on asphalt concrete?

Hydrated lime, alkaline in nature, starts a chemical reaction to change the character of the aggregate surface and neutralized any acidic properties present in mix. It improves the coating ability and bonding process of mix without reveling and bleeding with durable surface. It is usually added to aggregate at the pug mill.

72. What are the tests recommended on fillers?

1) Particles size analysis by hydrometer (Mineral Filler)
2) Plasticity index (Mineral Filler)
3) Immersion compression test (Joint Filler)

73. What will be your recommendation to minimize rutting?

Asphalt mixes can be designed to resist rutting with the proper selection of materials, good construction approaches and use of appropriate design method. The following recommendations are, however, important:

1) Gravel should be scalped on at least 1.5 in screen to prevent small aggregate size entering the batch.
2) Natural sand limited to 15% from fine aggregate and should not contain more than 50% dune sand.
3) Trial section should be made to determine the maximum density in the field and air voids in the mix at that density.
4) Filler to asphalt cement ratio should be between 1.3 -1.5 to get the maximum softening point of 85°C to 95°C.
5) Use asphalt 40/50 instead of 60/70 penetration in very hot climate areas.
6) The total thickness of asphalt layers shall not exceed 20 cm.
7) Use of polymer modified asphalt for areas having extreme temperature.
8) Rutting is also directly correlate to compressive strain on the top of subgrade. So, compaction up to specified limit is also important to avoid rutting.

74. What are the types of asphalt cracks?

Fatigue/Alligator Cracks: These are interconnected cracks forming a series of small blocks resembling an alligator skin.

Causes: Excessive deflection of the surface over unstable subgrade or lower course of the pavement or heavy loadings.

Repair: Deep patch, skin patch, Aggregate Seal coat patch, slurry seal patch

Edge Crack: Longitudinal cracks, 1/3 meter from the edge of pavement with or without transvers cracks branching towards shoulder.

Causes: 1) Due to lack of lateral (shoulder) support.

2) Settlement or yielding of the material under the cracked area due to result of poor drainage.

Repair: 1) Fill as for reflection cracks.

2) Fill with asphalt emulsion slurry.

Edge Joint Cracks: It is the separation of joint between the pavement and shoulder.

Causes: Alternate wetting and drying beneath the shoulder surface.

Shoulder settlement, mix shrinkage and truck straddling the joint.

Repair: Improve the drainage by getting rid of the condition that trapes water.

Lane Joint Cracks: Longitudinal separation between the adjoining lanes.

Causes: A weak seam between the adjoining lanes in the course of pavement.

Repair: Same as reflected cracks.

Reflection Cracks: These types of cracks occur when bituminous surface course is laid over the existing cement concrete pavement with some cracks. These cracks reflect in the same pattern on bituminous surface as beneath cement concrete pavement surface.

Repair: Fill with asphalt emulsion slurry or light grade of emulsified asphalt mixed with fine sand.

Shrinkage Cracks: Cracks forming a series of large blocks usually with sharp corner or angles.

Causes: Volume change in the asphalt mix or in the base of subgrade

Repair: Fill cracks with asphalt emulsion slurry followed by a surface treatment or a slurry seal over the entire surface.

Slippage Cracks: Crescent-shape cracks that point in the direction of thrust of wheels on the pavement surface.

Causes: 1) Lack of good bond between the surface layer beneath, may be due to dust, oil, rubber, dirt, water or other non-adhesive material between the two courses.

2) Mixture having a high sand content.

3) Improper compaction during construction caused the bond layers to be broken.

Repair: Remove the surface layer around the crack to the point where good bond between the layers is found, then fill the area with plan mixed asphalt material.

75. What are the major causes of distortion in asphalt pavement?

1. Too little compaction of the pavement course.
2. Too many fines of surface mixture.
3. Too much asphalt
4. Swelling of underlying courses or settlement.

76. What are the different forms of distortion?

1. Grooves or ruts
2. Shoving
3. Corrugation
4. Depression
5. Upheaval

77. What is the disintegration in asphalt pavement?

Disintegration is the breaking up of a pavement in to small loose fragments. Two common types are:

1. Potholes (these are bowl shaped holes of various sizes in the pavement resulting from localized disintegration).

2. Raveling (these are the progressive separation of aggregate particles in the pavement from the surface downward or from the edge inward).

78. What are the causes of skid hazard or slipping?

1. A thin film of water on the smooth surface.
2. May also develop from surface contamination such as from oil spillage or certain types of clay.

79. What is the bleeding in asphalt?

Bleeding or flushing is the upward movement of asphalt in an asphalt pavement resulting in the formation of a film of asphalt on the surface.

Causes:

1. Too much asphalt in one or more of the pavement courses.
2. Too heavy a prime or tack coat.
3. Overweight traffic.

Repair:

1. Repeated applications of hot sand
2. slag screening
3. Hot rock screening to blot the excess asphalt.

80. What is the polished aggregate?

Due to the passage of traffic over time, the angular aggregates become round due to the wear and tear of sharp edges. These smooth and round aggregates particles called polished aggregates.

81. What is longitudinal streaking in asphalt?

Alternating lean and heavy lines of asphalt running parallel to the centerline of asphalt.
Causes:

1. Spray bar on the asphalt distributor not set at the correct height.
2. Wrong asphalt pump speed.
3. Too cold asphalt.
4. Too low a pump pressure.

82. What are the basic parts of asphalt plant?

1. Cold bines
2. Cold feeder
3. Cold elevator
4. Dryer
5. Dust collector
6. Hot elevator
7. Gradation control unit
8. Asphalt / aggregate weight buckets
9. Pug mill or mixer

83. What are different rejuvenating surface treatments for a road pavement?

1. Slurry seal
2. Fog seal
3. Seal coat
4. Chip seal
5. Sand seal

84. What are the classifications of asphalt treatment?

1) Sprayed asphalt treatment:

a. Dust laying
b. Road oiling
c. Prime coating
d. Tack coating
e. Fog sealing

2) Sprayed asphalt and cover aggregate treatment:

a. Single surface treatment
b. Multiple surface treatment
c. Sand seal

3) Asphalt aggregate mixture:

a. Emulsion slurry seal
b. Road mix
c. Plant mix

85. What are the advantages of pneumatic rollers?

1. Pneumatic rollers not increase density irrespective of steel wheels rollers but increases stability which assures minimum distortion under heavy traffic.
2. They provide a more uniform degree of compaction.
3. They orient the aggregate particles for greatest stability.

86. How will you determine the deficiencies of asphalt mixture?

1. Too Hot: blue smoke rising from the mix indicating an overheated batch.
2. Too Cold: stiff appearance and improper coating of larger aggregate particles.
3. Too Much Asphalt: mix in truck appears lying flat.
4. Too Little Asphalt: granular appearance and poor coating
5. Non – Uniform Mixing: brown dull appearance
6. Excessive Coarse Aggregate: poor workability and coarser appearance.
7. Excessive fine aggregate: different texture from a properly graded mix after it has been rolled.
8. Excessive moisture: steam rising from the mix during dumped in to paver.
9. Segregation: Improper handling and load have become contaminated.

87. What are the reasons to provide drainage in pavement?

1. To collect and drain surface and sub-surface water.
2. To prevent and retard embankment erosion.
3. To lower the ground water table.

88. Which requires more prime coat, A-1-a or A-2-4 material?

A-2-4 material because it absorbs more prime coat due to more surface area.

89. What is the use of hydrated lime in hot mix?

Hydrated lime added to some low grade aggregates to render them suitable for use in asphalt mixture in highway construction. Sometimes, it is difficult to coat certain aggregates with asphalt because of their siliceous or acidic surface. Hydrated lime which is highly alkaline, starts a chemical reaction that changes the character of aggregate surfaces and adding hydrated lime often improved the coat ability and bonding properties of asphalt to these aggregates.

90. How do you add anti stripping material?

At Pug Mill.

91. How do you get softening point of asphalt?

By Ring and Ball Apparatus (AASHTO T 53 & ASTM D 36)

92. What is the initial compaction rendered by paver?

80% of the required compaction.

93. What is the asphalt macadam?

Asphalt macadam is compacted crushed rock.

94. How do you express penetration and ductility?

Penetration by mm/10.

Ductility by cm.

95. Which has more sand equivalent, natural sand or crushed sand?

Natural sand gives more sand equivalent and fineness modulus because less filler and clay.

96. What is the function of loss of stability?

Stability is the resistance against deformation under applied load. Loss in stability is actually tolerance of asphalt mix stability i.e. a safety margin that how stable will be the mix in field when actual traffic arrive on it.

97. What is the relation between voids filled with asphalt (V.F.A) and asphalt content?

VFA increases as asphalt content increases.

98. What is the relation between air voids and asphalt content?

Voids are more at low asphalt content.

99. What is the relation between asphalt content and stability?

As per the curve between these two, the stability increases with increasing asphalt binder content, reaches a peak, then decreases.

100. Can bitumen absorption be higher than the absorption of water in the asphalt mix design?

Bitumen absorption cannot be higher or even equal to water absorption in any case. As bitumen is more viscous and has high molecular volume as compared to water.

101. In case bitumen absorption is higher than the water absorption in your asphalt mix design? What does it mean?

It means either G_{se} is abnormally higher or G_{sb} is lower. In case, G_{se} is higher than theoretical maximum specific gravity (G_{mm}) will also higher. So both G_{se} and G_{sb} need to be rechecked. This is all due to the experimental error.

$(G_{sa} > G_{se} > G_{sb})$

Where G_{sa} is "apparent specific gravity" which only includes the volume of impermeable pores i.e.

Apparent Specific Gravity = Mass of aggregate oven dry / vol. of aggregate not including surface pores

Effective Specific Gravity (G_{se}) = Mass of aggregate oven dry / vol. of aggregate including pores not filled with asphalt

Bulk Specific Gravity is a real specific gravity i.e. Mass of aggregate oven dry / vol. of aggregate including pores (including both vol. of permeable and impermeable pores).

102. What is rigidity or stiffness? How it is caused in asphalt mix and what does it harm?

Rigidity or stiffness caused in mixes where low penetration asphalt is used, making the pavement rigid and gives higher values of marshal stability and low flow values.

Pavement of such hot mix is cracked under heavy volume of traffic.

103. What are causes of high loss of stability?

1) Stripping more than 5%.
2) Natural sand is more.
3) Plasticity index is more (more clay).
4) More asphalt contents.
5) Less value of sand equivalent (more clay).
6) Temperature of marshal mold and water temperature.
7) % of filler asphalt ratio.

104. How to determine Optimum Binder Content as per Marshall Mix Method?

The optimum asphalt binder content is finally selected based on the combined results of Marshall stability and flow, density analysis and void analysis. Optimum asphalt binder content can be arrived at in the following procedure:

1. Plot the following graphs:

Asphalt binder content vs. density: Density will generally increase with increasing asphalt content, reach a maximum, and then decrease. Peak density usually occurs at a higher asphalt binder content than peak stability.

Asphalt binder content vs. Marshall Stability: Stability increases with increasing asphalt binder content, reaches a peak, then decreases.

Asphalt binder content vs. flow: Asphalt binder content vs. air voids. Percent air voids should decrease with increasing asphalt binder content.

Asphalt binder content vs. VMA: Percent VMA should decrease with increasing asphalt binder content, reach a minimum, and then increase.

Asphalt binder content vs. VFA: Percent VFA increases with increasing asphalt binder content.

2. Determine the asphalt binder content that corresponds to the specifications median air void content (typically this is 4 percent). This is the optimum asphalt binder content.
3. Determine properties at this optimum asphalt binder content by referring to the plots. Compare each of these values against specification values and if all are within specification, then the preceding optimum asphalt binder content is satisfactory. Otherwise, if any of these properties is outside the specification range the mixture should be redesigned.

105. What are the aggregate specifications for Asphaltic Base Course & Asphaltic Wearing Course?

Test Property for Asphaltic Base Course Aggregate	**Specified Limit**
Los Angeles Abrasion Value % (Max)	40
Sand Equivalent (Min) Liquid Limit and Plastic Index (Max)	45 25 and 6
Soundness % (Max): Loss with sodium sulphate-5 cycles	 12
Flaky and elongated particles % (Max)	15
Stripping test as per AASHTO T 182	Qualify Test

(Source: General Specifications – NHA, December 1998)

Test Property for Asphaltic Wearing Course Aggregate	**Specified Limit**
Los Angeles Abrasion Value % (Max)	30
Sand Equivalent (Min) Liquid Limit and Plastic Index (Max)	45 25 and 6
Soundness % (Max): Loss with sodium sulphate-5 cycles	 12
Flaky and elongated particles % (Max)	10
Stripping test as per AASHTO T 182	Qualify Test

(Source: General Specifications – NHA, December 1998)

CONCRETE WORKS

1. Describe different types of concrete?

The concrete is classified as follows:

1. **Plain Cement Concrete (PCC)** – consist of cement, sand and coarse aggregate mixed in suitable proportion in addition to water. Relatively weaker to tensile stresses.
2. **Lime concrete** – lime is used for replacing cement. This is cheaper and has less strength than plain concrete.
3. **Reinforced Cement Concrete (RCC)** – Reinforced concrete is a cement concrete in which reinforcement such as steel bars are embedded. This is equally good both for compressive as well as tensile stresses.
4. **Pre Stressed Cement Concrete** – Type of RCC in which high compressive stresses are artificially developed before its actual use. This type of concrete can take up high tensile and compressive stresses without development of cracks.
5. **Light Weight Concrete** – The light weight concrete is prepared by using coke – breeze, cinder or slag as aggregate in cement concrete. It is used for partition and wall lining purposes.

2. What is Bulking of Sand?

The increase in the volume of sand due to the presence of moisture up to certain extent is called bulking of sand. The ratio of the volume of moist sand to the volume of dry sand is known as bulking factor of sand. It is noted that fine sand bulks more compare to coarser sand.

3. What is Fineness Modulus?

Fineness modulus of sand (fine aggregate) is an index number which represents the mean size of the particles in sand. It is calculated by performing sieve analysis with standard sieves. The cumulative percentage retained on each sieve is added and then divided by 100 gives the value of fineness modulus. This test should be conducted as per AASHTO M-6. It is calculated by

FM = ∑ Cummulative % retained on specified sieve / 100

Fineness modulus gives the idea about how coarse or fine the sand is. Lower FM indicates fine sand and higher FM indicates coarser sand. Fine sand requires more cement paste due to high surface area and tendency to develop cracks. On the other hand, coarse sand produces a concrete mixture that is harsh and difficult to finish and will cause segregation. Therefore recommended FM range is:

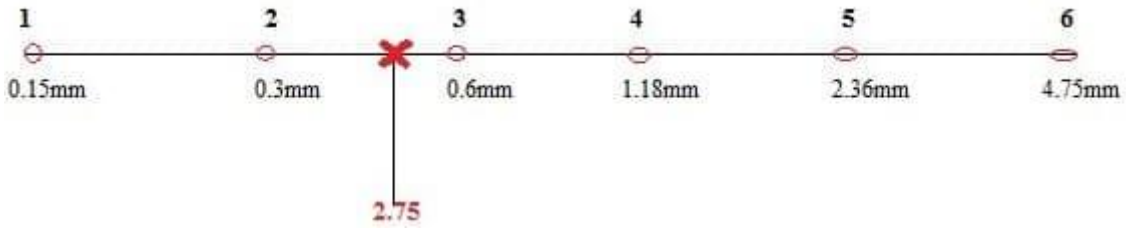
Type of Sand	FM Range
Fine Sand	2.2-2.6
Medium Sand	2.6-2.9
Coarse Sand	2.9-3.2

To understand the FM index value, following example given:

Sieve Size	Weight Retained (g)	Cumulative Weight Retained (g)	Cumulative % Weight Retained
4.75 mm	0	0	0
2.36 mm	100	100	10
1.18 mm	250	350	35
0.6 mm	350	700	70
0.3 mm	200	900	90
0.15 mm	100	1000	100
TOTAL			275

Therefore, fineness modulus of aggregate = (cumulative % retained) / 100 = (275/100) = 2.75

Fineness modulus of fine aggregate is 2.75. It means the average value of aggregate is in between the 2nd sieve and 3rd sieve. It means the average aggregate size is in between 0.3mm to 0.6mm as shown in below figure.



4. What is water cement ratio and why it is important?

It is ratio of water and cement (by weight or by volume) in a concrete mix. It is usually expressed in liters of water per bag of cement (50kg). The strength of concrete depends upon the amount of water used in the preparation of concrete mix i.e. strength of concrete is inversely proportional to water cement ratio. In other words, the strength of concrete decreases as water cement ratio increases. It may be noted that when water cement ratio is less than 0.4 (maximum value of W/C ratio as per NHA is 0.45, whereas as per C&W 1971 its maximum value is 0.43), the concrete is not workable and causes honey combed structure containing a large number of voids. If the water cement ratio is more, then the capillary voids will be more in the physical structure of hydrated cement.

5. What is workability and on which factors does it depend upon?

It is defined the property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, compacted and finished. The concrete mix is said to be workable if it has mixability, stability, movability, compactibility and finishability. Following are the factors on which its value depends upon:

- Water content
- Size of aggregates
- Shape of aggregates

- Surface texture of aggregates
- Grading of aggregates
- Temperature

6. How the workability is measured in the field?

Following are the empirical tests widely used:

Slump Test. In this test a cone of dimensions 100x200x300mm is used to measure the slump. This method is only suitable only for the concrete of medium to high workability. The slum value for high degree of workability should vary between 80 to 100mm, its value normally varies with activity and densification of reinforcement such as high workable concrete is recommend for columns and beams compare to raft slab. This test is conducted in accordance with AASHTO T-119.

Compaction factor test. This test is more accurate than slump test especially for concrete of medium to low workability.

Vee - Bee Test. The vee-bee test is only suitable for concrete mixes having low and very low workability.

Recommended Workability Values (Civil Engineering by R.S. KHURMI)

Degree of Workability	Slump in mm	Compacting Factor	Vee - Bee time in Seconds
Very low	0 -25	0.75 – 0.8	20 – 10
Low	25 - 50	0.8 – 0.85	10 – 5
Medium	50 - 75	0.85 – 0.92	5 – 2
High	75 - 150	> 0.92	2 - 0

7. What Concrete Grades are commonly used in Pakistan?

C&W Department, Standard Specifications for Road & Bridges 1971 Govt. of Punjab Concrete Classes:

Concrete Class	Mix Ratio	Cube Crushing Strength (psi)		Rough Proportion of Material			Remarks
		7 days	28 days	Cement	Fine Aggregate	Coarse Aggregate	
A	1:1:2	4500	6000	1.25 cft	1.25 cft	2.5 cft	Used for road pavement and Pre stressed Conc.
B	1:1½ :3	2500	3750	1.25 cft	1.88 cft	3.75 cft	For R.C.C Work
C	1:2:4	2000	3000	1.25 cft	2.5 cft	5.0 cft	For R.C.C Work
D	1:3:6	1500	2000	1.25 cft	3.7 cft	7.5 cft	For mass concrete in foundation
E	1:4:8	1200	1800	1.25 cft	5.0 cft	10 cft	For mass concrete in foundation

NHA General Specifications 1998 Concrete Grades:

Class of Concrete	Min. Cement Kg/ Cubic Meter	Max. Size of Coarse Aggregate	28 days Compressive Strength (Cylinder) kg/sq.cm (psi)	Consistency (Range in Slump) mm	Max. Permissible Water Cement Ratio
A1	300	20	210 (3000)	25 – 75	0.58
A2	350	25	245 (3500)	100 – 150	0.58
A3	400	38	280 (4000)	100 – 150	0.58
B	250	51	170 (2500)	25 – 75	0.65
C	275	38	210 (3000)	25 – 75	0.58
D1	450	25	350 (5000)	50 – 100	0.4
D2	500	25	425 (6000)	50 – 100	0.4
D3	550	25	500 (7100)	50- 100	0.4
Y	400	13	210 (3000)	25 – 75	0.58
Lean Concrete	175	51	100 (1400)	-------	

8. Why 28 days cube strength is taken?

If we draw a graph between compressive strength and aging in days, graph will show a trend of increase in strength. After 28 days, the curve showing increase in strength roughly becomes straight exhibits a little increase in strength with aging.

9. How do you consider the importance of curing of concrete as an Engineer?

Curing of concrete is defined as the process of maintaining the moisture and temperature conditions of concrete for hydration reaction, so that concrete develops hardened properties over time. The main components which needs care to be taken are moisture, heat and time of curing.

- Curing of concrete is done to maintain the Optimum Moisture Content (OMC) i.e. to prevent the loss of water which is required for the hydration of cement to avoid shrinkage cracks, premature stressing or disturbance in concrete.
- After concrete is placed, the concrete increases in strength very quickly for a period of 3-7 days. Concrete which is moist cured for 7 days is about 50% stronger than uncured concrete. Curing can be done by water as well as by the application of chemicals called concrete curing compounds.
- A 28 days curing is generally specified. It is desirable to keep the surface of the concrete wet or damp after it initially sets up and prevent dry out which ends the curing process and limits final strength.

- Properly cured concrete has an adequate amount of moisture for combined hydration and development of strength, volume stability, resistance to freezing and thawing, abrasion and scaling resistance.

10. What are the curing procedures?

a) Water Method: By maintaining a moist environment by application of water through ponding or sprays.

b) Curing Compound Method: By preservation of loss of mixed water from the concrete by means of sealing material such as impervious materials such as sheets of paper or plastic by application of a membrane forming curing compound to the freshly placed concrete.

c) Reinforce Waterproof Paper Method: The exposed finished surfaces of concrete shall be sprayed with water, using a nozzle that so atomizes the flow that a mist and not a spray is formed, until the concrete has set, after which the waterproof paper shall be placed. The paper shall remain in place for a period of not less than seventy two (72) hours.

d) Forms-in-place Method: Formed surfaces of concrete may be cured by retaining the forms-in-place. The forms shall remain in place for a minimum period of seven (7) days after the concrete has been placed, except that for members over five (5) cm in least dimension, the forms shall be in place for a minimum period of five (5) days. Wooden forms shall be kept wet by watering during the curing period.

e) Steam Method: After placing and vibrating, the concrete shall be allowed to attain its initial set before steam is applied. During the placing of concrete and application of steam, provision shall be made to prevent surface drying by means of a coating of approved material. The optimum curing temperature shall not exceed sixty-five (65) °C.

f) Polyethylene Sheeting Method: The wet surface of fresh concrete shall be covered with white polyethylene sheeting as soon as possible without marring the surface and should cover all exposed surfaces of the concrete.

11. Factors on which curing of concrete depends?

The length of adequate curing time is dependent on the following factors:

- Mixture proportions
- Specified strength
- Size and shape of concrete member
- Ambient weather conditions
- Future exposure conditions

12. What are the methods used to accelerate curing of concrete cylinder samples?

- To boil the cylinder for a certain period of time
- To cure the cylinder in an autogenous curing box

13. Minimum period for curing?

Slabs on ground (e.g. Pavements, sidewalks, parking lots, driveways, floors, canal linings) and structural concrete (e.g. bridge decks, piers, columns, beams, slabs, small footings, cast-in-place walls, retaining walls) require a minimum curing period of 7 days for ambient temp. above 40 ˚F (4.4˚C).

American Concrete Institute (ACI) Committee 301 recommends a minimum curing period corresponding to concrete attaining 70 percent of the specified compressive strength. The often specified seven-day curing commonly corresponds to approximately 70 percent of the specified compressive strengths. The 70 percent strength level can be reached sooner when concrete cures at higher temperatures or when certain cement/admixture combinations are used. Similarly, longer time may be needed for different material combinations and/or lower curing temperatures.

14. What are the methods used to accelerate curing of concrete cylinder samples?

- To boil the cylinder for a certain period of time
- To cure the cylinder in an autogenous curing box

15. What is difference between creep and shrinkage of concrete?

Creep:

Creep can be defined as the elastic and long-term deformation of concrete under a continuous load. Generally, a long term pressure changes the shape of concrete structure and the deformation occurs along the direction of the applied load.

Shrinkage:

The volumetric changes of concrete structures due to the loss of moisture by evaporation is known as concrete shrinkage or shrinkage of concrete. It is a time-dependent deformation which reduces the volume of concrete without the impact of external forces.

16. What is honeycombing and what its causes are?

When concrete is poured into the foundation forms it flows like water and fills up the forms to the top. If it is not vibrated properly it may leave voids called “honeycombs.” The exposed aggregate leaves a honeycomb look.

Concrete honeycombing is usually caused by a few common factors, including:

- Improper cement to water ratio that causes poor workability.
- Poor consolidation practices or inefficient means of vibration.
- Insufficient fine material in the mix.
- Incorrect aggregate grading.
- Leakage of grout or mortar fraction from the concrete at formwork joints.

17. What are the remedial measures for Honeycombing

This can be corrected by increasing the sand and cement content of the mix and by proper mixing, placing and compaction. The obvious solution is to ensure that joints are well sealed and leak-free.

Small, shallow areas of honeycombing are probably mainly cosmetic. However, deeper areas will lead to a local reduction in the protection to the reinforcement from the concrete cover and hence can cause durability problems in the future.

The honeycombing developed in the concrete be corrected as under:-

- Remove the laitance (an accumulation of fine particles on the surface of fresh concrete due to an upward movement of water) and clean.

- Wash the surface with clean water.
- Prepare approved bonding agent (Sika dur 32) as recommended by the manufacture / approved by the Engineer.
- Prepare the concrete mix confirming the approved design.
- Fill the honeycombing area.
- Trowel with force.
- Finish smoothly with float.
- Next Morning cure with water and clean.
- Continue curing as desired.
- The site Engineer, Foreman and workers have been strictly instructed to follow the specification and fully understand the scope of work.
- Foreman must remain at site while the work goes on.

18. What is segregation and bleeding of concrete?

Segregation in concrete is a case of particle isolation in concrete applications, in which particular solids tend to isolate by virtue of differences in the size, density, shape and other properties of particles of which they are composed.

Bleeding is a form of segregation where some of the water in the concrete tends to rise the surface of the freshly placed material. Conversely, if evaporation of the surface water is faster than the rate of bleed, plastic shrinkage cracking may occur.

Bleeding in fresh concrete refers to the process where free water in the mix is pushed upward to the surface due to the settlement of heavier solid particles such as cement and water. Some bleeding is normal but excessive bleeding can be problematic. A higher W/C ratio can also lead to excessive bleeding

19. How shrinkage cracks and honeycombing are repaired?

By Guniting - It is pneumatically applied mortar.

By Shotcreting – it is pneumatically applied concrete.

20. How you will choose or specify the nominal maximum size of aggregate?

Nominal maximum size of coarse aggregate shall be not larger than:

a) 1/5 of the narrowest dimension between the sides of forms, nor
b) 1/3 of the depth of unreinforced slab, nor
c) 3/4 of the minimum clear spacing between the individual reinforcing bars.

(Source: ACI 318 – 05)

21. What is the minimum length of splicing of rebars?

a) 40x dia of rebars: in case of tension.
b) 20x dia of rebars: in case of compression.

(Source: General Specifications – NHA, December 1998)

22. What is the criteria of accepting the concrete cores?

According to American Concrete Institute (ACI) 318:

No individual sample should be less than 75% of the required compressive strength and their avg. strength should not be less than 85% of the required compressive strength.

As per NHA General Specifications 1998:

Average test result of cores shall not be less than the minimum required 28 days strength. No individual core shall show a strength less than 95% of the required 28 days strength in accordance with the specifications of AASHTO T 24.

23. Why are trial batches prepared for concrete mix production?

The placing of concrete shall not begin until trial batches of the mix design to be used have been produced by the Contractor and tested and approved by the Engineer. The trial mix proportions shall be such that the average strength of five (5) consecutive test cylinders shall be twenty (20) % higher than the specified twenty-eight (28) days' strength and no individual test cylinder shall be below the specified strength.

When concrete compressive strength is specified as a prerequisite to applying loads or stresses to a concrete structure or member, test cylinders will be cured under conditions similar to those at the casting site. The compressive strength of concrete determined for such purposes will be evaluated on the basis of individual tests. Equipment used for trial batches will be the one that would be used on that specific job.

(Source: General Specifications – NHA, December 1998)

24. What are the usual tests for Portland cement?

1. Chemical Test:

a) Chemical composition
b) Loss on ignition
c) Insoluble residue

2. Physical Test:

a) Initial and final setting time
b) Compressive strength of the mortar
c) Air content of mortar
d) Fineness
e) Autoclave expansion

25. If you have ready mix design, how to inspect batch plant?

1. Calibration of plant
2. Accurate weighing as per mix design
3. Drying mixing of aggregate prior to adding the water
4. Wet mixing of mix should be sufficient
5. Doses of admixture should be controlled
6. Temperature of concrete should be 15 ◦C – 33 ◦C
7. Should meet slump requirements
8. Rate of batching should meet rate of pouring at site
9. Avoid segregation of stockpiles, etc.

26. When adjustment of water cement (W/C) ratio in the mix design is required?

1. If the slump is incorrect
2. If the required strength is not achieved

27. What happens it rains on a wet concrete?

If the rain occurs when the concrete is fresh (about 2-4 hours after mixing), the surface should be protected from the rain. If the finishing process was recently completed, rainwater may not cause damage as long as it is not worked into the surface and the slab is left untouched.

28. Can we use snow water in concrete?

No, because this kind of water carries carbon dioxide, which can react with lime in cement causing concrete cracking.

29. What is the effect of efflorescence in concrete?

Efflorescence is described as the deposition of salts (e.g. white powdery sulphates) on the surface and within the pores of concrete, masonry mortar and plaster, which occurs when a salt solution evaporates. Due to evaporation from concrete dissolved salts are left behind the surface as it will appear to be dry, and the deposition take place within pores under the surface, which will result in the disruption and corrosion of reinforcement of concrete.

30. If a choice is given where from you will start pouring concrete of an ordinary beam?

From the center of beam, according to recent ACI findings.

31. What is the maximum and minimum slope of chutes during concrete pouring?

Minimum slope is 1:3

Maximum slope is 1:2

Maximum height of chute: 1.5 m

Typical height not less than 1.0 m

(Source: Q ? A Road Construction Nagy Zidan, KSA)

32. What should be the mixing speed of mixer?

6 to 18 revolutions per minute (Central Plant Mixing)

6 to 10 revolutions per minute (Transit Mixing)

(Source: General Specifications – NHA, December 1998)

33. How many cylinders or cube samples are you going to get in every pouring?

One set of six samples for every 50 m^3 of concrete.

(Source: General Specifications – NHA, December 1998)

34. Why do we cure concrete samples while structure has different curing procedures?

In sample, volume is less compared to surface area. So, the water for hydration is easy to lose. Whereas, in structure, volume is bigger compared to area, so loss of water for hydration is minimal.

35. Why do we provide capping on concrete cylinder sample?

To provide flat, smooth ends that are perpendicular to axis of sample.

36. Where is the weakest point in concrete structure?

In the joints.

37. What is fatigue and creep in concrete?

Fatigue is the failure of concrete after a number of repeated loads (may call it as plastic deformation i.e. deformation does not recover when load is removed), whereas creep is the elastic deformation (deformation that recover when load is removed) occur immediately when concrete is loaded.

38. What should be the mixing time for a batching plant?

Mixing time shall be measured from the time all material except water is in the drum.

Mixing time should neither be less than 50 seconds nor more than 90 seconds.

(Source: General Specifications – NHA, December 1998)

39. Why volume of concrete changes and what are the effects of volume change on concrete?

The major cause of volume change in concrete is variation in moisture and temperature. Change in volume has two important effects on concrete:

1) It induces tensile stresses and causes the concrete to crack.
2) It causes the joint to open and decreases load transfer efficiency.

40. Why do we provide dowels and tie bars in rigid pavement?

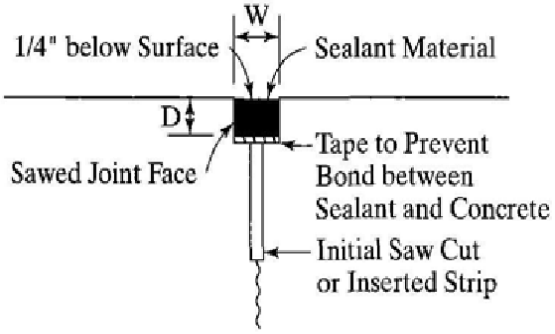
Dowels bars are provided on transverse joints for the efficient load transfer, whereas, ties bars are provided on longitudinal joints to hold up the concrete interlocking.

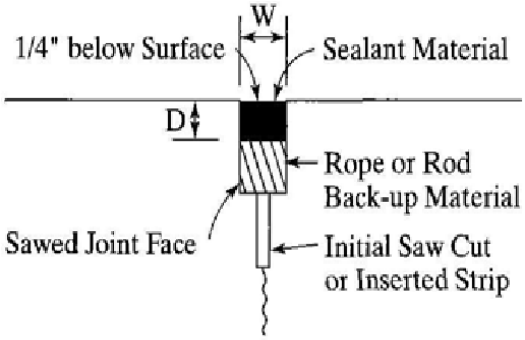
41. At what depth these bars are provided?

At the mid of concrete slab.

42. What do you know about sealants?

Joint openings are sealed with sealants. The sealant used in the joints must be capable of withstanding repeated extensions and compression as the temperature and moisture in the slabs change. Sealants can be classified as field molded and performed sealants. Field molded sealants are applied in liquid or semi liquid form and performed sealant are shaped during manufacturing.





43. Why the sand equivalent is determined?

Clay-like materials have a direct effect on the performance of Hot Mix Asphalt (HMA) and the amount should be controlled. A large amount of clay-like particles can coat the aggregate surfaces and prevent liquid asphalt cement from completely coating and adhering to the aggregate.

The sand equivalent test (ASTM D-2419, AASHTO T-176) quantifies the relative % of sand versus clay in soil. The test is used to qualify aggregates for applications where sand is desirable but fines and dust are not. A higher sand equivalent value indicates that there is less clay-like material in a sample. NHA recommends a minimum value of sand equivalent of 30 for filler used in base course.

44. What is the difference b/w sand equivalent and material passing no.200 sieve?

Sand equivalent gives the relative proportion of clay and dust materials in fine aggregate by volume while material passing no. 200 sieve is the same thing determined through gradation/sieve analysis by weight.

45. Which one gives more strength, standard cube or standard cylinder? Why?

Standard cube, because of the ratio L/D is equal to 1 and also the test load is applied parallel to layers.

46. What is the initial and final setting time for concrete?

Ambient temperature, relative humidity and wind velocity are determinant factors that set the initial and final setting time of a newly placed concrete mixture. Admixtures are also be used to increase or reduce the setting time of concrete. So, truly speaking, mix design determines the initial and final setting time of concrete. Most commonly, 30 - 45 minutes for initial setting and 8 - 10 hours for final setting.

47. What are types of admixtures?

a) Plasticizer
b) Retarder
c) Accelerator
d) Plasticizer with retarding agent
e) Plasticizer with accelerating agent
f) Super plasticizer

48. What is the effect of retarder in concrete mix?

To delay the initial setting time of about 1 – 4 hours.

49. At what time concrete should be placed after mixing water?

As soon as possible, not more than 30 minutes.

50. What are the factors affecting the strength of concrete?

1) Age of concrete
2) Coarse aggregate
3) Richness of mix
4) Curing of concrete
5) Temperature of concrete

6) W/C ratio
7) Surface texture
8) Percentage of cement
9) Fineness of cement
10) Type of cement
11) Type of water

51. What is petrographic examination of aggregate?

To know the following:

1. Physical and chemical properties of aggregate.
2. To describe and classify the constituents of aggregate.
3. To identify the constituents of aggregate e.g. lime stone, basalt, diorite etc.

52. What is DPC and why it is provided? Is there any difference between DPC and water proofing?

Damp proofing in construction is a type of moisture control applied to building walls and floors to prevent moisture from passing into the interior spaces. Damp problems are among the most frequent problems encountered in homes.

Rising damp is caused by capillary action drawing moisture up through the porous elements of a building's fabric. Rising damp, and some penetrating damp, can be caused by faults to, or the absence of a damp-proof course (DPC) or damp-proof membrane (DPM)

American Concrete Institute defines waterproofing as a treatment of a surface or structure to resist the passage of water under hydrostatic pressure, whereas damp proofing is defined as a treatment of a surface or structure to resist the passage of water in the absence of hydrostatic.

53. What is the purpose of Vertical DPC to provide?

The purpose of a Vertical Damp Proof Course is to prevent the ingress of damp and water into subterranean structures such as basements, cellars, tunnels and earth shielded buildings.

54. What are the advantages RCC have over PCC?

The tensile strength of reinforced concrete is about one-tenth of its compressive strength. PCC is not good enough for tensile stresses whereas reinforcement used in PCC is good for these stresses. So, RCC is good in withstanding the tensile stresses compared to PCC.

PCC exhibits brittle failure whereas RCC behaves as ductile in case of failure. So, use of RCC is safer compared to PCC.

55. When the concrete pavement be opened to traffic?

Pavement shall remain closed to traffic until tests show the concrete to have a minimum modulus of rupture, when tested in accordance with AASHO T-177 of not less than 500 pounds per square inch, but in no case shall the pavement be opened to traffic in less than 14 days after concrete is placed, unless otherwise directed by the Engineer, concrete bridge floors and culverts shall be closed to traffic for a period of at least 14 days after placing for normal strength concrete and 7 days for high early-strength concrete, and for such additional time as may be deemed advisable. In the operation of placing, concrete may be wheeled across previously poured slabs after they have set for 24 hours, provided plank runways are used to keep the loads over the beams.

No stockpiles of aggregates, no heavy equipment or other material other than light forms or tools, shall be stored on concrete bridge floors until 14 days after they have been poured. All stockpiles, tools and equipment stored on bridge floors at any time shall be subject to approval by the Engineer, and the Contractor will be required to disperse any such stored materials or equipment to avoid overloading any of structural part. In the case of piers or bents with concrete caps the weight of the superstructure or of beams shall not be placed on the caps until they have reached the ages required in the following table:

Structural Part	Normal Strength Concrete	Early Strength Concrete
Superstructure	7 days	3 days
Beams	3 days	24 hours

C&W Department, Standard Specifications for Road & Bridges 1971 Govt. of Punjab

56. Removal of Form Work?

The time and method of removal of forms shall be as directed by the Engineer. Removal shall be done with care to avoid injury to the concrete. No loading on green concrete shall be permitted. As soon as the forms are removed, the surface of the concrete shall be carefully examined, and any irregularities immediately repaired to the satisfaction of the Engineer. Unless otherwise specified, during a moderate weather about 60°F (16°C) the form work of various types of work shall be removed after the period shown in the following table:

Type of Formwork	Ordinary Portland Cement	Rapid Harding Portland Cement
Formwork to vertical surfaces such as beam, side wall and column	12 hours	- -
Slab (Props left under)	3 days	2 days
Beam soffits (props left under)	7 days	4 days
Props to slabs	7 days	4 days
Props to beams	16 days	8 days

Source: C&W Department, Standard Specifications for Road & Bridges 1971 Govt. of Punjab

If the temperature falls down to 45° F (7°C), the above timing shall be multiplied by 1-1/2 and if it falls down still further i.e. up to 40° F (4.4°C), the time shall be doubled.

As per NHA General Specifications:

If field operations are not controlled by beam or cylinder tests, the following periods, exclusive of days when the temperature is below five (5) °C, for removal of forms and supports shall be used as a minimum subject to the approval of the Engineer.

Type of Formwork	Removal Period
Arch Center	14 days
Centering Under Beams	14 days
Supports under Flat Slabs	14 days
Floor Slabs	14 days

Vertical Wall Surfaces	24 Hours
Columns	24 Hours
Side of Beams	12 Hours
Top Slabs R.C. Box Culverts	14 days

- If high early strength cement is used or by the use of additional cement, these periods may be reduced as directed.
- When field operations are controlled by cylinder tests, the removal of forms and supports may begin when the concrete is found to have the required compressive strength, provided in no case shall supports be removed in less than seven (7) days after placing the concrete.
- All forms shall be removed, except when no permanent access is available to the cells, the forms supporting the deck of box girders and the forms in hollow abutments or piers may remain in place.
- Methods of form removal likely to cause overstressing of the concrete shall not be used. In general, the forms shall be removed from the bottom upwards.
- In general, arch centering or falsework shall be struck and the arch made self-supporting before the railing or coping is placed. This precaution is essential in order to avoid jamming of the expansion joints and variations in alignment.

57. What are the types of concrete mix design?

- Water Cement Ratio Method
- Weight Method
- Absolute Volume Method

58. How much cover is provided in concrete structures?

The minimum covering, Measured from the surface of the concrete to the face of any reinforcement bar shall, unless otherwise shown on the Drawings or directed by the Engineer, be not less than five (5) cm except as follows:

Top of slab	4.0 cm
Bottom of slab	3.0 cm
Stirrups and ties in T-beams	3.5 cm

in the footings of abutments and retaining walls the minimum covering shall be 7.5 cm. In work exposed to the action of sea water the minimum covering shall be 10 cm.

59. What are the types of joints in concrete? Explain?

1) <u>Construction Joints:</u>
   These joints are merely stopping places of construction. They separate the areas of concrete placed at different times, and should bond new concrete to existing concrete.
2) <u>Cold Joints</u>
   When the placement of concrete delayed for any reason and concrete takes its initial set, a cold joint said to be occurred.
3) <u>Expansion Joints:</u>
   A narrow space is left between two parts of a concrete structure to allow for expansion of concrete with changes in temperature and loading. These joints are provided to permit both horizontal and vertical movement at adjoining parts of structure.
4) <u>Contraction Joints:</u>
   These joints are needed to permit horizontal differential movement in the plan of a slab or wall. These joints are most effective method of preventing unsightly cracking.

CULVERTS AND BRIDGES

1. What is the difference between a Culvert and a Bridge?

Bridge is a structure that spans a physical natural hurdle or obstruction like river or a valley. A bridge carries a passage that can be a roadway or railway across an obstruction such as a river, a railroad or even another road etc.

Culvert is a structure that allows the easy passage of water through a physical obstruction that can be a channel, a roadway, a passage or a walkway".

Technically the only difference is the span length. Culverts are up to 6.5 m length whereas Bridges are longer than 6.5 m.

Bridges are classified as Minor Bridges if the span ranges from over 6.5 m up to 60 m and as Major Bridges if longer than 60 m.

Culverts Terminologies and Definitions.

Back fill - To refill (something, such as an excavation) usually with granular or better fill material.

Trench - A trench is a cut or an excavation made in the ground for the placement of culvert.

Bedding - The bedding is the material placed at the bottom of the trench on which the pipe is laid. Bedding is placed in the bottom of the trench to cushion the bottom of the culvert from crushing forces.

Cover - The cover is the depth of backfill over the top of the culvert pipe.

Critical Flow - Flow where the velocity head is equal to one-half the hydraulic depth (the area of the flow section divided by the top water surface width).

Crown - The crown is the inside top of the culvert.

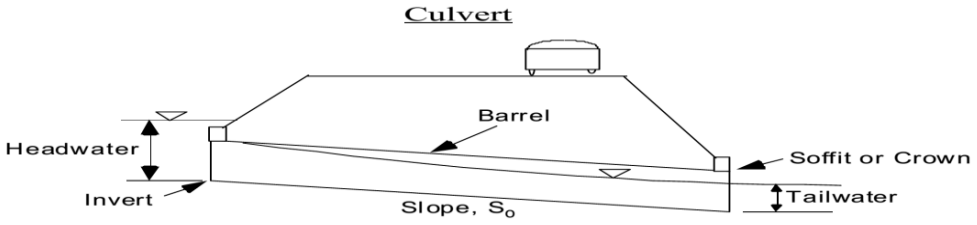
Hydraulic Grade Line (**HGL)** - The hydraulic grade line represents the depth to which water would rise in vertical tubes connected to the sides of the culvert barrel.

Head Water - The headwater is the depth of the upstream water surface measured from the flowline at the culvert entrance.

Tail Water - The tailwater at a culvert is the depth of water at the downstream end of the culvert

Invert - The invert is the inside bottom of the culvert. It can be considered floor level

Soffit – The soffit is the highest point of the internal surface of a pipe or culvert at any cross section



2. What types of culverts are normally used?

Following types are common:

- Masonry (Brick and stone masonry) Culvert
- Pipe culvert (single or multiple)
- Box culvert (single or multiple)
- Arch culvert.

3. What is bed plate?

To attain the crown in the slab of culvert, a bed of suitable material is provided under the slab of culvert.

4. What is the hydrological data?

1. Drainage area
2. Slope factor
3. Silt factor / roughness coefficient
4. Design discharge
5. Slope of channel
6. Highest flood level
7. Hydraulic radius

5. What are the types of protections in road construction?

1) Slope protection.
2) Irsh crossing
3) Grouted and loose rip rap.
4) Retaining Walls
5) Guard Rails
6) Gabions
7) Dykes
8) New Jersy Barrier
9) Benching
10) Kerb stones etc.

6. What are the materials used for culvert construction?

The most common culvert materials are:

- Concrete (reinforced and un-reinforced)
- Brick / stone masonry
- Corrugated aluminum
- Corrugated steel
- Plastic (corrugated or non-corrugated)
- High density polyethylene

7. What is Highest Flood Level (HFL) and why it is important to know this level for a culvert?

Highest Flood is the level at which a body of water's surface has risen to a level to cause sufficient inundation of areas that are not normally covered by water, causing an inconvenience or a threat to life and/or property.

The soffit level of a culvert slab is always keep above the Highest Flood Level (HFL). Moreover, it is very important to know the top level of a culvert slab, when placing the profile grade line (PGL) of a road.

8. Describe the common types of Bridges?

- Deck / Box Girder Bridge
- Arch Bridge
- Truss Bridge
- Cable Stayed Bridge
- Suspension Bridge

9. Where we do provide Piles foundation?

- In a soil whose bearing capacity cannot sustain the weight of a structure?
- In high level of water where excavation is not possible.

10. What types of Piles are normally used?

<u>Based on Function:</u>

- Load Bearing Piles
- Sheet Piles
- Friction Piles
- Anchor Piles

Driven Piles

Cast in Place or Bored Piles

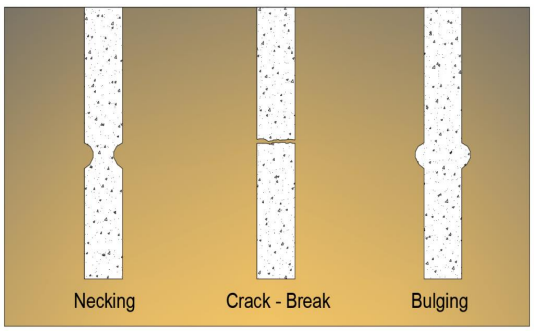
<u>Based on Material:</u>

- Timber Piles
- Concrete Piles
- Composite Piles
- Steel Piles

11. What are the integrity problems in concrete piles?

Following are the integrity problems in concrete piles:

- Necking.
- Crack-Break.
- Bulging



12. What are the construction requirements of Piles?

a) Driven Piles

- Location and Site Preparation:

  Piles shall be used where indicated on drawing. All excavations for the foundation in which the piles are to be driven shall be completed before the driving is begun

- Determination of Pile Length:
  The criteria for pile length and bearing capacity will be determined by Engineer according to results from test piles and load tests. The piles are driven to such depths, that the bearing load mentioned on drawing are obtained.

  The criteria for pile length may be one of the following:

1. Piles in sand or gravels are driven to a bearing value determined by pile driving formula.
2. Piles in clay are also driven as per pile driving formula.
3. Piles are driven to refusal on rock or hard layer.

- Pile Driving:

1. All piles shall be driven accurately to the vertical. Piles shall be supported in line and position with leads while being driven. Piles driving leads shall be constructed in such a manner as to afford freedom of movement of hammer.
2. Piles shall be used only in places where a minimum penetration of three (3) meters in firm material and five (5) meters in soft material can be obtained. Where soft stratum overlies a hard stratum, the piles shall penetrate to hard material up to a sufficient distance to fix the ends rigidly.
3. Full length piles shall be used where practicable. Splicing of piles when permitted shall be in accordance with the provision of standard and specifications.

b) Cast in Place / Bored Piles

- Boring Procedure:

1) The method and equipment of boring generally either the dry method, wet method, temporary casing method or permanent casing method shall be one that maintains stability and verticality.
2) All holes are drilled up to the tip elevation shown on drawing. Rejected boreholes shall be filled with lean concrete.
3) The boring method shall be such that allows soil samples to be taken and in site soil test (if required) to be carried out during or ahead of boring operations. The procedure used in execution of borehole shall not be such as to cause vibrations resulting in damage of piles and adjacent structure or causing harmful loosening or softening of soil outside the pile. The equipment used for execution of borehole shall be adequate to ensure that each pile penetrates to required founding level.

- Drilling Methods: To stabilize the bore hole, three methods can be used:
  Dry Pile Construction – is used where the soil is stable
  Wet Pile Construction - drilling mud (bentonite and polymer mud) is used to fill the borehole while drilling to prevent the borehole walls from collapsing.
  Cased Pile Construction - To drill the borehole, casings are used to maintain open the borehole. It has two methods such as Temporary Casing Method and Permanent Casing Method.

Drilling Stages without casing: The construction process consists of drilling the pile, removing loose material from the borehole, placing the reinforcement cage, and concreting the shaft.

Stage 1 - When drilling through loose soil or very soft clay below the water table, special bentonite or polymer slurries are used to stabilize the borehole walls. Due to greater specific weight of bentonite slurry compared to water and its capacity to create a waterproof layer over the borehole walls, these slurries, when applied at least meter above the water table, help make the shaft watertight.

If drilling fluids cannot be used, boreholes can be supported by temporary casings. As for the foreshaft, the temporary casing can be driven into the ground using the rotary head of the drilling rig (up to 15-20 m) or a hydraulic vibratory hammer connected to a service crane. As a general rule, the techniques described above are not effective at depths greater than 20 m and the temporary casing can only be driven using a special piece of hydraulic equipment called "casing oscillator".

Stage 2 - Descending

Stage 3 - Insert reinforcement

Stage 4 - Casting concrete

Stage 5 – Finished Pile

Drilling Stage with Casing: Segmental casing is used as a temporary or permanent support for a bored piling system with deeper unstable soil conditions. It is utilized during the drilling stage and can be installed and extracted by using a drilling rig or an oscillator attached to a rig or service crane. A large casing driving plate is fitted under the rotary to couple the first 1.5 m-casing section. The soil therein is removed by means of boring tools such as an auger or drilling buckets. The sections are joined using mechanical joints until the desired length is achieved.

Temporary Casing: The temporary casing remains in place until the concrete has been poured to a level sufficient to withstand ground and groundwater pressures. The casing is removed after the concrete is placed.

Permanent Casing: Permanent casing remains and becomes a permanent part of the foundation.

Stage 1 - Casing + Drilling

Stage 2 - Insert reinforcement

Stage 3 - Casting concrete

Stage 4 - Casing extraction

c) Limitations of Boring Sequence

Piles shall be constructed in such a manner and sequence as to ensure that no damage is sustained by piles already constructed in adjacent positions. The Contractor shall submit to the Engineer for his approval a program showing sequence of construction of various piles.

d) Tolerances

Following construction tolerances shall be maintained:

1. The drilled shaft shall be within 3 inches of the plan position in the horizontal plane at the plan elevation for the top of the shaft.
2. The vertical alignment of the shaft excavation shall not very from the plan alignment by more than 1/4 inch per foot of depth.

3. After all the shaft concrete is placed, the top of the reinforcing steel cage shall be no more than 6 inches above and no more than 3 inches below plan position.
4. When casing is used, its outside diameter shall not be less than the shaft diameter shown on the plans. When casing is not used, the minimum diameter of the drilled shaft shall be the diameter shown on the plans for diameters 24 inches or less and not more than 1 inch less than the diameter shown on the plans for diameters greater than 24 inches.
5. The bearing area of bells shall be excavated to the plan bearing area as a minimum. All other plan dimensions shown for the bells may be varied when approved, to accommodate the equipment used.
6. The top elevation of the shaft shall be within 1 inch of the plan top of shaft elevation.
7. The bottom of the shaft excavation shall be normal to the axis of the shaft within 3/4 inch per foot of shaft diameter.

13. What do you know about Defective Piles and Test Piles?

Defective Piles:

Any pile delivered with defects such as damaged during driving or cast in situ, placed out of its proper location, incapable or partially capable of permanently carrying the load which it is intended to carry, driven below the elevation provided in drawing, due to immature setting of concrete in the pile or due to collapse of borehole fully or partially. In a case, when casting pile is found to be defective, following actions then to be taken:

- The pile shall be withdrawn and replaced by a new and when necessary by longer pile.
- A second pile shall be driven or cast adjacent to defective pile.
- The pile shall be spliced or built up properly.

Test Piles:

Any pile that is used to conform to the requirements for piling with the given or set specifications. If the pile, which after serving its purpose as a test pile, is found unsatisfactory for utilization in the structure shall be removed or cut off below the ground line as directed by the Engineer. Test piles are generally driven with the same equipment that is to be used for driving foundation pile.

14. What is Load Test and why it is used?

Load testing is a method to assess a pile's bearing capacity by applying a load to the pile head (a falling mass) while recording acceleration and strain on the pile head. Load testing is a high strain dynamic test which is applied after pile installation.

A load test shall consist of the application of a load equal to a minimum of 2 times the specified bearing capacity. Suitable approved apparatus for determining accurately the load on the pile and settlement of pile under each increment of load should be used.

All pile load settlement shall be measured with adequate devices such as gauges. Increment of deflection shall be read just after each load increment is applied and at 15 - minutes interval thereafter. The safe allowable load should be considered as 50% of the load, after 48 hours of continuous application, has caused not more than 6 mm of permanent settlement, measured at the top of pile.

The first load applied to the test pile shall be 50% of the pile design load and the first increment shall up to the pile design load by applying additional loads in three equal increments. A minimum 2 hours

shall intervene between the applications of each increment, except that no increment shall be added until a settlement of less than on tenth (0.1) mm is observed for period of 15 – minutes under the previously applied increment. If there is a question whether the test pile will support the test load, the test load shall be reduced 50%. The full test load shall remain on the test pile not less than 48 hours. The full test load shall then be removed and the permanent settlement read.

The pile may be considered to have failed when the total permanent settlement exceeds (6) mm.

(General Specifications NHA, Dec – 1998)

15. How to calculate the pile load?

Pile Driving Formula:

Pile driving formulas may be used to determine the number of blows of hammer per unit of pile penetration needed to obtain the specified bearing capacity for piles driven in the sub-soils at the Site. Piles shall be driven to a final resistance as indicated on the plans determined by the following formula:

For drop hammer:

$$Q_{all} = \frac{WH}{[6(S+2.5)]}$$

For single-acting steam or air hammers and for diesel hammer having unrestricted rebound of rams:

$$Q_{all} = \frac{WH}{[6(S+0.25)]}$$ (Use when driven weights are smaller than striking weights)

$$Q_{all} = \frac{WH}{[6\{S+0.25\left(\frac{WD}{WS}\right)\}]}$$ (Use when driven weights are larger than striking weights)

For double-acting steam or air hammers and diesel hammers having enclosed rams:

$$Q_{all} = \frac{WH}{[6(S+0.25)]}$$ (Use when driven weights are smaller than striking weights)

$$Q_{all} = \frac{WH}{[6\{S+0.25\left(\frac{WD}{WS}\right)\}]}$$ (Use when driven weights are larger than striking weights)

(General Specifications NHA, Dec – 1998

In the above formulae:

Q all = Allowable pile load in kilograms

W = Weight of striking parts of hammer in kilograms

H = Height of fall in centimeters for steam and air hammers and the observed average height of fall in centimeters, of blows used to determine penetration for diesel hammers with unrestricted rebound of hammer

S = Average net penetration per blow in centimeters for the last 10 to 20 blows of steam, air, or diesel hammer; or for the last 15 cm of driving for a drop hammer

E = Actual energy delivered by hammer per blow in kg-cm

WD = Driven weights in kilograms

(Note: Ratio of driven weights to striking weights should not exceed three)

WS = Weight of striking parts in kilograms

For piles driven to and seated in rock as high capacity end-bearing piles:
Drive to refusal (approximately four (4) to five (5) blows for the last 0.625 cm of driving). Re-drive open end pipe piles repeatedly until resistance for refusal is reached within two and a half (21/2) cm of additional penetration.
ii) For piles driven through stiff compressible materials unsuitable for pile bearing to an underlying bearing stratum:
Add blows attained before reaching bearing stratum to required blows attained in bearing stratum.
iii) For piles into limited thin bearing stratum:
Drive to predetermined tip elevation and determine allowable load by load test.
The bearing power as determined by the appropriate formula in the foregoing list will, be considered effective only when it is less than the crushing strength of the pile. Other recognized formula for determining pile bearing power may
be used when given in special specification. However, it shall be understood that the relative merits and reliability of any of the pile formula can be judged only on the basis of comparisons with the results of load tests.

16. What are the kinds of bearings?

1. Single roller bearing
2. Multiple roller bearing
3. Linear rocker bearing
4. Point rocker bearing
5. Knuckle pin bearing
6. Knuckle cylindrical bearing
7. Knuckle spherical bearing
8. Knuckle leaf bearing
9. Plate sliding bearing
10. Elastomeric laminated bearing

17. What are the construction and cold joints?

Construction Joints:

It is merely a stopping places of construction. They separate the areas of concrete placed at different times, and should bond new concrete to existing concrete.

Cold Joints:

When the placement of concrete delayed for any reason and concrete takes its initial set, a cold joint said to be occurred.

18. Where to provide metal beam guardrail?

a) Where height of embankment is more than 3m or 10ft
b) In the sharp curve
c) In the hilly areas
d) In the steeper slopes
e) To high rise structural locations

19. What are various steel grades in use?

Grade	Yield Strength	Tensile Strength
Grade 40	40000 psi	60000 psi
Grade 60	60000 psi	90000 psi
Grade 75	75000 psi	100000 psi

(Source: ASTM International A615)

20. Are grade 40 & grade 60 steel could be welded?

Grade 40 steel: Could be welded.

Grade 60 steel: welding involve special electrodes (otherwise its properties will change and its yield strength reduce, nearly becoming 40 grade)

21. What is the difference between formwork and falsework?

Formwork:

Temporary structure built to contain fresh concrete so as to form it to required shape and dimensions.

Falsework:

The extensive supporting on framework such as in bridges and large structures.

22. When we use caissons (wells) in foundation?

1. Required to extend the well below the river bed in order to attract necessary net soil resistance against overturning.
2. The sub-strata contains large boulders which obstruct penetration of piles.
3. The foundation is subjected to large lateral forces.

23. What are precautions for concreting underwater?

1. Concrete must be completed in one operation.
2. Rich cement(370kg/cum), slump not less than 15 mm
3. Temporary Casing (stand by)
4. Use the tremie pipe

24. What are the precautions for concreting in hot weather areas?

1. Moisten subgrade, steel reinforcement, and form work prior to concrete placement.
2. Erect temporary wind breaks to limit wind velocities and sunshades to reduce concrete surface temperatures.
3. Cool aggregates and mixing water added to the concrete mixture to reduce its initial temperature. The effect of hot cement on concrete temperature is only minimal.
4. Use a concrete consistency that allows rapid placement and consolidation.

5. Protect the concrete surface during placement with plastic sheeting or evaporation retarders to maintain the initial moisture in the concrete mixture.
6. Provide sufficient labor to minimize the time required to place and finish the concrete, as hot weather conditions substantially shorted the times to initial and final set.
7. Consider fogging the area above the concrete placement to raise the relative humidity and satisfy moisture demand of the ambient air.
8. Provide appropriate curing methods as soon as possible after the concrete finishing processes have been completed.
9. In extreme conditions consider adjusting the time of concrete placement to take advantage of cooler temperatures, such as early morning or night time placement.

25. What are the types of reinforced and pre stressed concrete in super structure?

Reinforced Concrete:

a) Solid slab
b) Slab and girder (T-Beam)
c) Hollow box girder

Pre Stressed Concrete:

a) Void slab
b) Slab and girder (T-Beam)
c) Hollow box girder

26. What are the causes of horizontal deck movement?

1. Shrinkage of concrete
2. Creep of compressed concrete
3. Elastic shorting of concrete
4. Change in body mean temperature
5. Movement due to externally applied loads (Earthquakes, wind and vehicle braking)

27. What are the causes of foundation movement?

1. Differential Settlement
2. Slide failure
3. Bearing failure
4. Consolidation
5. Seepage effect
6. Water table variations
7. Scouring

28. What is P.T.F.E?

It is poly-tera-flouro-ethylene, used in sliding bearing.

29. What are the components of Bridge Super Structure?

1. Deck
2. Beams / Girders
3. Diaphragms of cross frames
4. Truss components
5. Bearing devices
6. Arch components
7. Connectors

30. What are the components of Bridge Substructure?

1. Abutments
2. Piers
3. Transom

31. What is the difference between substructure and superstructure of a Bridge?

Substructure is portion of bridge that supports the superstructure such as piers, abutments. Whereas structure that is part of bridge which takes the live load is called as super structure of a bridge. Some examples of super structure are girders, deck slabs and walkways.

32. What is the difference between Abutment and Pier?

Abutment: In engineering, abutment refers to the substructure at the ends of a bridge span whereon the structure's superstructure rests or contacts.

Pier: A pier is a raised structure typically supported by well-spaced foundation system. The foundation system can be a Pile, Caisson or simple brick pillar based on the sub-soil condition.

33. What are the causes of structural cracks?

1. Over loads
2. Over stresses
3. Dynamic loads
4. Impact load
5. Fire
6. Foundation Movement
7. Superstructure Movement
8. Bearing Failure

34. If the contractor submits Bearing, how would you accept it?

The contractor shall submit calculations, shop drawing and manufacturing specifications to the Engineer which include all details about the bearing.

35. What are the types of vibrators?

1) Internal vibrator
2) External vibrator
3) Surface vibrator

36. What are the factors effecting anchorage slippage?

1. Wedge slippage due to rust
2. Elastic deformation of wedge
3. Yielding of concrete under anchorage plate

37. What are the causes of yielding at anchorage?

1. Concrete does not reach to required strength
2. Honey combing or air voids
3. Over vibration

38. What is the function of approach slab?

1. To absorb impact effect
2. To protect entrance of bridge from sudden effect

39. What is the value of friction for free sliding bearing?

0.03

40. Where do you prefer to put fixed bearing on abutment or pier?

On Pier

41. What is end block?

Enlarged end section of a member designed to reduce anchorage stresses.

42. What type of loads are considered while designing Bridge Structure?

1. Live Load
2. Dead load
3. Impact or dynamic impact of live load
4. Wind load
5. Horizontal forces due to water currents
6. Longitudinal forces due to the tractive effort or by braking of vehicles
7. Centrifugal forces

8. Buoyancy
9. Earth pressure
10. Thermal forces
11. Shrinkage forces
12. Rib shortening
13. Erection stresses
14. Earthquake stresses

43. What are the types of foundations?

a) Shallow foundation:

- Spread footing
- Combined footing
- Strip footing
- Mat or raft foundation

b) Deep foundation:

- Basement.
- Buoyancy raft (hollow box foundations)
- Caisson.
- Cylinders.
- Shaft foundation.
- Pile foundation.

44. What is the function of foundation?

Foundation is the lower portion of the building usually located below ground level, which transmits the loads of the super structure to the supporting soil. Following are the major functions of a foundation:

- Uniformly distribute stresses due to applied loads on a wider area.
- Protect structure from differential settlement.

45. What is the difference between foundation footing and foundation mat?

Foundation footing:

Footings are an important part of foundation construction. They are typically made of concrete with rebar reinforcement that has been poured into an excavated trench. The purpose of footings is to support the foundation and prevent settling.

Foundation mat:

Mat-slab foundations are used to distribute heavy column and wall loads across the entire building area, to lower the contact pressure compared to conventional spread footings. Mat-slab foundations can be constructed near the ground surface, or at the bottom of basements.

46. Why we use raft foundation?

Raft foundation is a type of foundation used for heavy loading, or construction on soft ground, composed of a continuous slab of reinforced concrete below the entire surface. We prefer raft foundation when soil below ground is of poor quality or bearing capacity is very low.

47. What is a strip foundation used for?

Strip foundations are used where the soil is of good bearing capacity. The key sizes of a strip foundation for concrete cavity wall construction and timber frame cavity wall construction are similar. The size and position of the strip is directly related to the overall width of the wall.

ANNEXURE – I

ANNEXURE - 1

QUALITY CONTROL OF BRICK MASONRY

Materials

1. The standard size of bricks shall be $9x4^{1/2}x3$ inch (ASTMC 62). Three samples of each type of bricks shall be submitted.
2. The bricks shall be of first class well burnt, uniform in shape, size, texture, color and should produce a ringing sound when struck.
3. Compressive strength of bricks shall be 2000psi or as specified.
4. Certificate of compliance for cement shall be obtained.
5. Sand for mortar shall be free from organic matter and other deleterious materials. It shall have a fineness modulus of 2.4 (plus minus 0.1)
6. Water used in bricks and in mortar shall be free from objectionable quality of silt, organic matter, alkali, salts and other impurities. Water shall be tested as per BS-3148, where directed.
7. Mortar shall have a minimum compressive strength of 12.4 Mpa. (ASTMC 270).
8. Mortar shall be mixed only in sufficient quantities for immediate use and shall be used within 30minutes after mixing. Mortars not used within $2^{1/2}$ hours after initial mixing shall be discarded.

Laying

9. All bricks to be used shall be soaked in water for 3 to 4 hours before laying / placing to ensure that each brick is thoroughly and uniformly wetted.
10. Bricks shall be laid "frog" upward (except for lining in drain) with mortar joints and in English Bond or as approved.
11. At all corners, alternate courses of bricks shall be laid header wise and stretcher wise so as to bond the two walls well together.
12. Both bed and vertical joints shall be not less than 1/4 inch and shall not be more than 3/8 inch (10mm) in thickness completely filled with mortar and each brick shall be bedded by firmly tapping with the handle of trowel.

13. The height of four courses and three joints as laid shall not exceed by more than one inch the height of four bricks as piled dry upon the other.
14. Facing bricks of irregular size, shape, damaged and defective edges and faces shall be rejected outright.

Joints

15. Bricks shall be laid true to line, level and plumbs. All joints shall be perfectly straight, parallel and sharp.
16. Excess mortar at the outer edges shall be removed and joints drawn straight.
17. All horizontal joints shall be parallel and all vertical joints in alternate courses shall be directly over one another.
18. Exterior faces of walls shall be finished by striking the joints as the work proceeds. Tooling shall be done when the mortar is partially set.
19. Joints shall be struck by raking the green mortar after the brick work and finish the joints with a pointing tool. Horizontal joints shall be struck to form a weathered joint and vertical joints shall be struck with a V-notch (the object of striking is to compress the mortar into the joints).

Curing and Repair

20. All brick masonry shall be water cured and shall be kept wet for at least 10 days.
21. Repair or patching of the defective area will not be acceptable.
22. Damage to masonry from scaffolding or from any other cause shall be repaired by the contractor at his own cost.
23. If chiseling of masonry is required, the contractor shall do so at his own cost. Where the height of wall is short of ceiling height, it shall be made good with class 'C' concrete.

QUALITY CONTROL OF CONCRETE

CHECK LIST

1) Tests of Aggregates for Concrete.

a) Sieve analysis.
b) Specific gravity & absorption.
c) Unit weight.
d) Abrasion test.
e) Soundness test.
f) Sand equivalent.
g) Organic impurities.
h) Thin & Elongated pieces.
i) Fineness modulus.
j) Friable particles, etc.

2) Choosing / Specifying maximum size of the Aggregate.

a) 1/5 of the narrowest dimension between the sides of forms.
b) 3/4 of the minimum clear spacing between the reinforcing bars and forms and between adjacent bars.
c) 1/3 of the depth of unreinforced slabs.

3) Tests for Water for Concrete (AASHTO).

a) Chemical analysis: Acidity and Alkalinity. If the hydrogen ion concentration is determined and PH value is less than 4.5 or more than 8.5 the water is refused. PH value shall be determined either by electrometric or colorimetric method.
b) Total solids and inorganic matter (water containing less than 2000 PPM of dissolved solids can be used for concrete)
c) Action on setting time by using a cement paste tested by vicat needle apparatus: Any marked change in setting time is sufficient to reject the water under test.
d) Strength of the same cement past: A reduction more than 10 percent in strength from paste mixed with distilled water is sufficient to reject the water under test.

4) Tests for Cement.

4.1-Chemical tests

a) Chemical composition.
b) Loss on ignition.
c) Insoluble residue.

4.2-Physical tests

a) Initial and Final setting time.
b) Compressive strength of the mortar.
c) Air content of the mortar.
d) Fineness.
e) Autoclave expansion.

5) At the Batching Plant.

a) Calibration of plant.
b) Accurate weighing as per mix design.
c) Dry mixing of aggregate prior to adding of water.
d) Wet mixing of mix should be sufficient.
e) Dozes of admixture should be controlled.
f) Mixing time of concrete for a stationary or central batching plant should not be less than 50 seconds nor more than 90 seconds.
g) Temperature of concrete should be (15^0C – 33^0C).
h) Should meet slump requirement.
i) Rate of batching should meet rate of pouring at site.
j) Avoid segregation of stockpiles, etc.
k) Appropriate adjustments should be made in the mixing water if the slump is incorrect, or in water / cement ratio if the required strength is not achieved. Then new batch weights must be calculated.
l) Concrete should be placed as soon as possible after mixing water,
- not more than one 30 minutes if truck mixer is used.
- not more than one hour if truck agitator is used.

m) After 24 hours, samples should be brought to laboratory for proper curing until the time of test.
n) Temperature of cement allowed to be used for concrete 77^0C maximum.

6) Hot Weather Concreting.

6.1-During mix production

a) Lower the fresh concrete temperature by using cool aggregates and cool mixing water.
b) Dampen the aggregate if they are dry and absorptive.

6.2-During Construction

a) Dampen the subgrade and forms.
b) Erect windbreaks to reduce wind velocity over the concrete surface.

c) Erect sunshades to reduce concrete surface temperature.
d) Protect the concrete with coverings during any appreciable delay between placing and finishing.
e) Reduce time between placing and start of curing by improved construction procedures.
f) Protect the concrete during the first few hours after placing and finishing to minimize evaporation, by application of moisture to the surface, using a light fog of spray.

7) Cold Weather Concreting.

a) Avoid overheating of fresh concrete.
b) Appropriate equipment should be available for heating the concrete materials.
c) Maintaining favorable temperature after concrete is placed, etc.

8) Concreting underwater.

a) Concreting must be completed in one operation.
b) Rich cement (370kg/m^3), slump not less than 150mm.
c) Temporary casing (stand by).
d) Use the tremie pipe.

9) Construction Procedure for Post-Tensioning

a) All tendons are free to move between jacking points.
b) No application of tensions before the concrete reach to the required compressive strength.
c) Arrange datum point to measure extension and jack pressure.
d) Add jack losses and friction due to duct alignment and curvature.
e) The stresses in tendons shall not exceed 70% of their ultimate tensile strength, not more than 80%.
f) If the measured extension differs by more than 5% from the estimated extension, corrective action shall be taken.
g) Stressing shall be from both ends.
h) After applying the force, the tendons shall be anchored and jack pressure shall be released to avoid shock to the anchorage of tendons.
i) The tendons shall not be cropped less than 3 days after grouting.

10) Important steps for grouting ducts

a) Water cement ratio should be low as possible, not higher than 0.45.
b) Admixture containing chlorides or nitrates shall not be used.
c) Efflux time immediately after mixing – 11 seconds.
d) The grout consist of only Ordinary Portland Cement (Type-I) and water.
e) Bleeding not exceed more than 2% after 3 hours and 4% maximum.
f) The water caused by bleeding should be re-absorbed after 24 hours.
g) Grout shall be mixed for 2 minutes (minimum)

Hot Mix Asphalt Paving Inspection Check List

A. Before Construction

1. Traffic Control Plan (TCP) by project engineer is approved.
2. The Production Plant has been certified by authorized laboratory.
3. Quality Control Plan is approved.
4. Newly constructed base courses are properly prepared, compacted, and graded.
5. The prepared base course is true to specified line, grade, and cross section.
6. The surface is clean, dry, and free of dust before application of priming / Tracking
7. Fat or rich asphalt patches or material on existing pavement is removed before tacking.
8. Tack coat is applied to existing surfaces of non-absorbent material.
9. On resurfacing projects, grades of existing pavement are checked with proposed grades so that limits for wedge/leveling course is established.
10. Elevations of intersecting roads are checked so that proposed surfacing will blend in with existing pavement conditions.
11. Drainage conditions are checked before resurfacing existing pavements.
12. Specified temperature limitations are observed.
13. The Contractor's equipment is of proper size and capacity to perform the work properly, is in good condition and proper adjustment, and meet with Specification requirements.

B. During Constructions

1. HMA mixture is placed with approved paving machine.
2. The screed is kept hot, clean, and properly adjusted during paving operation; cold or dirty screeds will pull or tear the surface of the mat. Also see that the screed has been set and checked for proper crown.
3. The thickness mechanism is not over-manipulated; changes in thickness should be made gradually and only when necessary.
4. The texture of =unrolled surface is checked to determine its uniformity. Adjustment of screed, tamping bars or vibrators, feed screws, hopper feed, and other adjustment points should be checked to ensure uniform spreading of the mix.
5. The thickness of each layer is frequently checked by measuring the depth before rolling starts. See also that compacted material is placed to the planned thickness.
6. The temperature of the mix is frequently checked in trucks and payer by an immersion-type thermometer / infrared temperature gauge to see that the mix is above the specified temperature.
7. Delivery tickets are collected and signed upon satisfactory placement of mix on the roadway.
8. Yield of first round of truck loads is checked by comparing material used in the paved area with material required. Yield checks are continued at regular intervals.
9. The density of the particular mix being placed is obtained from the Contractor's QC Field Technician. This figure is used as the basis for computing the yield for the daily log.
10. The mixture is spread by hand only at locations inaccessible to machine spreading. Material spread by hand must be distributed uniformly to avoid segregation of fine and coarse aggregates.
11. If segregation of materials occurs, operations are suspended and the cause determined and corrected.
12. The payer operates at a speed or rate of production compatible with the plant production and delivery rate.

13. Continuous notice is taken of both transverse and longitudinal joint construction. See also that material at the joint is kept high enough to allow for compaction.
14. Each course is rolled soon after material is placed and at a time when the roller will be supported without undue displacement of hair-cracking.
15. Specified rolling procedure is adapted to suit existing field conditions for most satisfactory results. Factors affecting results are weight, type, and speed of roller; temperature of mix; and depth of course.
16. Proper sequence of initial, intermediate, and finish rolling is adhered to.
17. Immediately following rolling, the surface is straight edged, as specified, to determine if required smoothness is being obtained.
18. Specification for pavement drop-off is enforced.
19. Temporary pavement markings are installed in conformance with the Contract Documents.
20. Cores are taken on a daily basis to determine the in-place density.
21. The longitudinal and transverse joints are painted with a thin coating of hot asphalt cement or tack coat material if adjacent lanes are placed on different days.
22. Deliveries from the plant are controlled by notifying the Plant to hold shipments because of bad weather or any other unsatisfactory condition.
23. Contact is kept with the Plant when necessary. Also see that any pertinent information is forwarded as soon as possible.
24. The Contractor knows his responsibility concerning traffic control, public convenience, and safety.
25. An Inspector Delivery Report (IDR) is prepared which includes such data as quantity of material used, location of paving, area paved, and computed yield. The report and signed delivery tickets are submitted to the field office daily.

C. After Construction

1. The finished surface is profiled by the Contractor in the presence of the Project Engineer. The Profile data shall be provided to the Project Engineer within 24 hours after placement of the pavement.
2. Shoulders are completed as soon as possible after completion of surface course on any lane used by traffic.
3. Delivery tickets are completed to show total material used, location, description, etc.

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