ANALYSIS AND EXECUTION OF ROAD WORK ON NH-5

MAIN PROJECT REPORT

Submitted in partial fulfilment of the
Requirements for the award of the degree of

Bachelor of Technology
In
Civil Engineering

By

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STUDENT DECLARATION

We hereby declare that the project entitled " ANALYSIS & EXECUTION OF ROADWORKS ON NH-5" is the work done by us during the academic year 2011-2012 and is submitted in partial fulfillment of the requirements for the award of degree of bachelor of technology in CIVIL ENGINEERING from JNTU, Hyderabad.

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ABSTRACT

Road Transport is vital to India's economy. It enables the country's transportation sector contribute 4.7 percent of India’s gross domestic product, in comparison to railways that contributed 1 percent, in 2009-2010, despite railways handling of passenger and pure cargo. Road transport has gained in importance over the years despite significant barriers and inefficiencies in inter-state freight and passenger movement compared to railways and air. The government of India considers road network as critical to the country's development, social integration and security needs of the country. India's road network carries over 65 percent of its freight and about 85 percent of passenger traffic. Indian road network is administered by various government authorities, given India's federal form of government. National highways connect capitals, important places, ports and places of strategic importance of various states. Though national highways account for only 2% of the total road length, they carry nearly 1/3 of the total traffic.

Flexible pavement is composed of a bituminous material surface course and underlying base and sub base courses. The bituminous material is more often asphalt whose viscous nature allows significant plastic deformation. Most asphalt surfaces are built on a gravel base, although some 'full depth' asphalt surfaces are built directly on the sub grade. Depending on the temperature at which it is applied, asphalt is categorized as hot mix asphalt (HMA), warm mix asphalt, or cold mix asphalt. Flexible Pavement is so named as the pavement surface reflects the total deflection of all subsequent layers due to the traffic load acting upon it. The flexible pavement design is based on the load distributing characteristics of a layered system.

It transmits load to the sub grade through a combination of layers. Flexible pavement distributes load over a relatively smaller area of the sub grade beneath. The initial installation cost of a flexible pavement is quite low which is why this type of pavement is more commonly seen universally. However, the flexible pavement requires maintenance and routine repairs every few years.

Highway surveys involve the location of alignments and computation of volumes materials that must be added, removed, or moved. It initially requires a topographic survey of the site. For large projects, photographic method will be used to develop the base map. The base map is used by

surveyors and other professional to create a base plan for the project. After the alignment has been established, the quantities of earth that must be added or removed are computed. The goal of most projects is to minimize the hauling distances of the earth. This is done using mass diagrams. Eventually surveyors layout the elevation and slope of the various sub-grades, base, and top coat materials. The end result is a smooth alignment with smooth transitions from straight to curved sections allowing for safe public transportation.

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NOTATIONS

ACWC	:	Asphalt concrete wearing course
AIV	:	Aggregate impact value
BC	:	Bituminous concrete
DBM	:	Dense bituminous macadam
GSB	:	Granular sub base
NH	:	National Highway
NHAI	:	National highway authority of India
PUP	:	Passenger under pass
QC	:	Quality control
RCC	:	Reinforced concrete cement
VUP	:	Vehicular Under Pass
WMM	:	Wet mix macadam
BC	:	Black Cotton
MDD	:	Maximum Dry Density
OMC	:	Optimum Moisture Content
CBR	:	California Bearing Ratio
WBM	:	Water Bound Macadam
DLC	:	Dry Lean Concrete
IRC	:	Indian Road Congress

CONTENTS

Introduction

National Highway 5 (NH-5) is a major National Highway in India that runs along India's east coast through the states of Orissa, Andhra Pradesh and Tamil Nadu. The northern terminal is at Jharpokharia in Orissa and the southern terminal is at Chennai in Tamil Nadu. NH 5 is a part of the golden quadrilateral project undertaken by National Highways Development Project. Under the new national highway numbers NH 5 is renamed as NH 16. NH 5 runs for a distance of 1533 km.

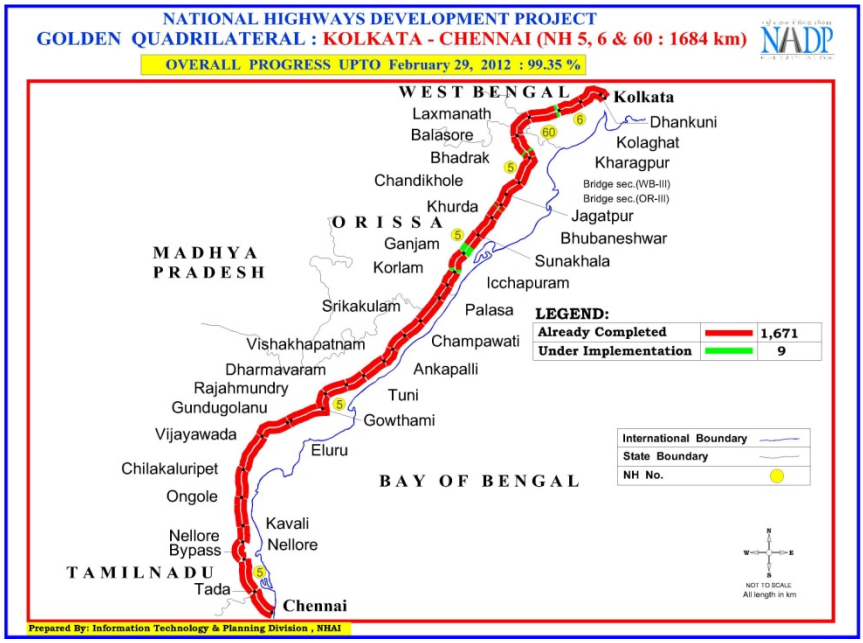
In Tamil Nadu NH 5 starts from Chennai and shortly enters Andhra Pradesh from Gummidipundi.

In Andhra Pradesh, it passes through most of the coastal towns in nine coastal districts including Nellore, Ongole, Chilakaluripet,Guntur, Vijaywada,Eluru,Tanuku,Rajahmundry, Tuni , Visakhapatnam, Srikakulam, Tekkali and Palasakasibugga.

In Orissa, it passés through Baripada, Balasore, Bhadrak, cuttack, Bhubaneswar and Berhampur.

Our project is on Six Laning of Chilakaluripet - Nellore section of NH 5 from km 1182.802 to km 1366.547 (approx length-183.620 km) in the state of Andhra Pradesh under NHDP to be executed as BOT project on DBFOT pattern.

The project was awarded to M/s. KMC-BSCPL JV. BSCPL share is 50 %.



Classification of roads as per IRC (Nagpur Plan)

National Highways: These are main highways running through the length and breadth of the country connecting major ports, foreign highways, state capitals, large industrial and tourist centers etc.

State Highways: These are arterial routes of states linking direct headquarters and important cities within the state and connecting them with National Highways or Highways of the neighboring states.

Major District Roads: These are important roads within a district serving areas of production and markets, and connecting these with each other or with the main highways.

Other District Roads: These are roads serving rural areas of production and providing them with outlet to market centers, taluka/tehsil headquarters, block development headquarters, or other main roads.

Village Roads: These are roads connecting villages or groups of villages with each other and to the nearest road of higher category.

Geometric Design Standards

The layout and other geometric features of a road have direct influence on the initial cost of its construction and the efficiency and economy of its use by traffic. The safety of operation is also

significantly affected by geometric design. The geometric design of a highway is influenced significantly by terrain conditions.

Terrain Classification - The terrain is classified by the general slope of the country across the highway alignment, for which the criterion given in table followed.

Sl. No.	**Terrain classification cross slope of the country**	**Percent**
1.	**Plain**	**0-10**
2.	**Rolling**	**10-25**
3.	**Mountains**	**25-60**
4.	**Steep**	**Greater than 60**

Road lane width:

It is also termed the right-of-way is the land acquired for road purposes. Desirable width for National and state Highways is 45mts in open areas in case of plain and rolling terrain, and 24mts in case of mountainous and steep terrains.

i. **Roadway width:** the width of the roadway for single and two lane roads in plain and rolling terrain is 12mts for National and State highways.

ii. **Carriageway width:** The total width of the carriageway shall be determined in relation to the design traffic and capacity of the roadway. The standard width shall be as indicated below.

Single lane	3.75mts
Two lane without raised kerbs	7.0 mts
Two lanes with raised kerbs	7.5mts
Multi lane pavements width per lane	3.5mts

iii. **Pavement camber or cross fall:** the camber or cross fall on straight sections of roads should be as recommended in table given below for various types of surfaces. For a given surface type, the steeper values may be adopted in areas having high intensity of rainfall.

High-type bit surfacing or cement concrete	1.7-2.0 % (1 in 60 to 1 in 50)
Thin bit surfacing	2.0-2.5 % (1 in 50 to 1 in 40)
Water bound macadam, gravel	2.5-3.0 % (1 in 40 to 1 in 33)
Earthen	3.0-4.0 % (1 in 33 to 1 in 25)

iv. **Horizontal alignment:** the horizontal alignment should be fluent and blend well with the surrounding topography. The curves should be sufficiently long and have suitable transitions to provide pleasing appearance. Curve length should be at least 150mts or a deflection angle of 5 degrees, and this should be increased by 30 meters for each one degree decreases in the deflection angle. For deflection angles less than one degree, no curve is required to be designed.

v. **Horizontal curves and super elevation:** horizontal curve is a curve with end transitions to provide change in direction to the centerline of a road. When a vehicle traverses a horizontal curve, the centrifugal force acts horizontally outwards through the center of gravity of the vehicle. The centrifugal force acting on a vehicle negotiating a horizontal curve have a tendency to overturn the vehicle outwards about the outer wheels and tendency to skid the vehicle laterally, outwards. In order to counteract the effect of centrifugal force, the outer edge of the pavement is raised with respect to the inner edge thus providing a transverse slope throughout the length of the horizontal curve. This transverse inclination to the pavement surface is called “super elevation or cant or banking”

Super elevation required on horizontal curves should be calculated from the following formula

$$e=V^2/225R$$

Where,

e= super elevation in meter per meter

V= speed in km/h

R= Radius in meters

vi. **Vertical alignment:** Vertical Alignment should provide for a smooth longitudinal profile consistent with category of the road and lay of the terrain. Grade changes should not be frequent as to cause kinks sand visual discontinuities in the profile. Desirably there should be no change in grade with in a distance of 150mts.

a) For plain and rolling terrain 1 in 30 is the ruling gradient and 1 in 15 is Exceptional gradient.

Vertical curves

Definitions:

i. Vertical Curve: Vertical curves have the shape of a parabola and are used to produce a gradual change between tangent grades.

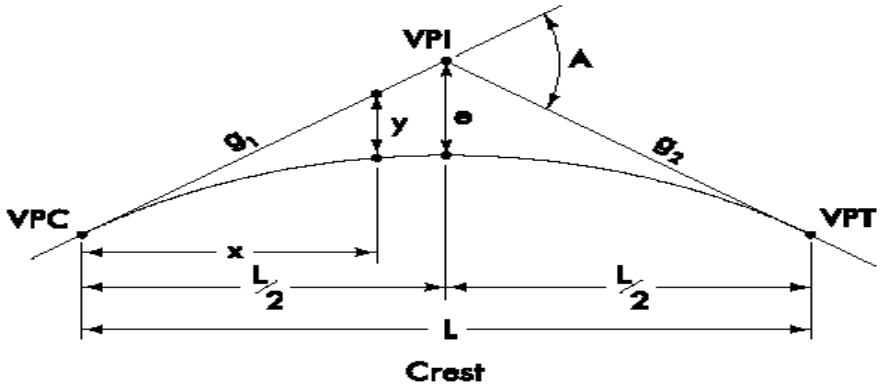
ii. Point of Vertical Intersection (PVI): The PVI is the point where the extension of two tangent grades intersect

iii. Point of Vertical Curvature (PVC). The PVC is the point at which the tangent grade ends and the vertical curve begins.

iv. Point of Vertical Tangency (PVT). The PVT is the point at which the vertical curve ends and the tangent grade begins.

v. Grade Slopes (G1 or G2). The grade slope is the rate of slope between two adjacent PVI's expressed as a percent. The numerical value for percent is the vertical rise or fall in

feet for each 100 feet of horizontal distance. Upgrades in the direction of stationing are identified as plus (+). Downgrades are identified as minus (-).



Different road materials used:

The most important pavement materials are soils, mineral aggregates, bituminous binders, and stabilizers like lime, cement, etc. Mineral aggregates constitute about 90 percent of total volume of road construction materials used. All roads have to be founded on soil and are required to make optimum use of the locally available materials, if it is to be constructed economically. Materials used in the structural layers of the pavement should be selected based on availability, economy and previous experience.

Soil as road construction material:

Sub grade soil is an integral part of the road pavement structure as it provides support to the pavement as its foundation. The main function of the sub grade is to give adequate support to the pavement and for this the sub grade should possess sufficient stability under adverse climatic and loading conditions. The formation of wave, corrugations, rutting and shoving in black top pavements are generally attributed to poor sub grade conditions. When soil is used in embankment construction, in addition to stability, incompressibility is also important as differential settlement may cause failure. Soil is used in its natural form (gravel and sand) or in a processed form (stabilized layer) for pavement construction. Soil is also used as a binder in water-bound macadam layers. Soil is therefore, considered as one of the principal highway materials. The foundation of other cross-drainage structures (culverts, bridges and retaining walls) rests on soils and their stability depends on the soil strength, knowledge of soil properties is necessary to select the embankment material, pavement structure, drainage system and foundation of structures. When a high embankment rests on soft ground, its stability can be predicted by studying the properties of soil. Frost action, common in high altitudes, can be taken care of if the soil properties are well known. Soil consists mainly of minerals matter formed by the disintegration of rocks, by the action of water, frost, temperature, and pressure or by plant or animal life. Based on the individual grain size of the soil particles, soil have been classified as gravel, sand, silt, and clay.

The BIS gives the following limits of particle size.

Gravel	80-4.75 mm
Sand coarse	4.75- 2.00 mm
Medium	2.00-0.475 mm
Fine	0.475-0.075 mm
Silt	0.075- 0.002 mm
Clay	<0.002mm

Types of soil: Soils occur in a fairly wide variety in our country. Some of the major soil types found in the country are:

i. **Alluvial soils:** These are mostly found in the indo-gangatic plane. Generally, these are composed of broadly matching fractions of sand, silt, and clay, and make fair to good sub grade material.
ii. **Fine sand:** It is confined mostly to desert areas in the north western part of the country. This soil lacks binder fraction and is not well graded.
iii. **Coastal soils:** The sands/sandy soils forming the coastal alluvium usually make a good sub-grade.
iv. **B.C soils:** Black cotton soils occur in parts of Madhya Pradesh, Maharashtra, Andhra Pradesh and Karnataka. This soil is characterized by pronounced volume changes (swelling upon wetting and shrinkage after drying) and low strengths at high moisture content.
v. **Red gravelly soils:** The moorums and red gravelly soils are found in various pockets and are less problematic.

The wide range of soil types as highway construction materials have made it obligatory on the part of the highway engineer to indentify and classify the different soils. The classification of soil as per IS nomenclature, the general range of the maximum dry densities of these materials and their approximate CBR values are given below.

Classification of soils as per IS system

Soil group description	**Symbol**	**Unit dry weight**	**CBR %**
Gm/cm^3			

Well graded gravels and gravel sand mixture (fines<5%)	GW	2.00 – 2.24	60 – 90
Poorly graded gravel and gravel sand mixture (fine < 5%)	GP	1.76 – 2.24	25 – 60
Silty gravel and gravel sand mixture (fines>12%)	GM	2.08 – 2.22	20 – 80
Clayey gravels and gravel sand silt mixtures (fines>12%)	GC	1.92 – 2.24	20 – 80
Well graded sand and gravelly sand (fines< 5%)	SW	1.76 - 2.08	20 – 60
Poorly graded sand and gravelly sand (fines<5%)	SP	1.59 - 1.92	10 – 30
Silty sand and sand silt mixtures (fines>12%)	SM	1.92 – 2.16	10 – 40
Clayey sands and sand clay mixtures (Fines >12%)	SC	1.68 – 2.08	15 – 50
Inorganic silt, very fine rock floor	ML	1.60- 2.00	5 – 20
Clayey silt or fine sand, inorganic clay, gravelly, sandy or silty.	CL	1.60 – 2.00	5 – 15
Organic silt and silty clays	OL	1.44 – 1.60	3 – 8
Inorganic silt elastic and micaceous silts	MH	1.28 – 1.60	3 – 8
Inorganic Fat clays	CH	1.44 – 1.76	3 – 5
Organic silt and clays	CH	1.28 – 1.68	2 – 4

Road aggregates:

These have to bear the stresses due to the wheel loads and hence they should possess sufficient strength to resist crushing. They should be **hard** enough to resist wear due to abrasive action of traffic. The aggregates in the pavement are also subjected to impact hence **toughness** is another desirable property of aggregates. The stones used should be durable and resist disintegration due to action of weather, this property is called **soundness.**

The following are the most commonly available rocks in India from which road aggregates can be obtained.

Type of Rock	Properties	Suitability
Basalt	Hard and durable, resistant to abrasion, fine grained.	Good for base courses
Granite	Hard and durable resistant to abrasion, Coarse grained.	Very good for bituminous Courses and WBM
Limestone	Reasonably hard, liable to polish to a Smooth surface under traffic, fine grained and high water absorption.	Good for base course
Quartzite	Hard, durable but is liable to be brittle and adhesion to bitumen is rather poor.	Good for base course
Sand Stone	Moderately hard and durable, fine to medium grained.	Good for road bases

Aggregates may have rounded cubical angular flaky or elongated shape of particles. The flaky or elongated particles will have less strength and durability hence too flaky and elongated particles should be avoided. The following are the physical requirements of coarse aggregates used for WBM as per IS 2386.

Los Angles abrasion value Or Aggregate impact value	40 percent (Maximum) 30 percent (Maximum)
Combined flakiness and elongation indices	30 percent (Maximum)

Grading requirements: The WBM is carried out in layers. The coarse aggregates for each layer should confirm to any of (3) grading below. The use of grading no 1 shall be restricted to sub base courses only.

Size and grading requirements of coarse aggregates for water bound macadam.

Grading No.	Thickness and aggregate per 10 sqm.	Size range	IS sieve designation	Percent by weight passing the sieve
1	10 mm 1.21 to 1.13 cums.	90 mm to 45 mm	125 mm 90 mm 63 mm 45 mm 22.4 mm	100 90-100 25-60 0-15 0-5
2	75 mm 0.91 to 1.01 cums.	63 mm to 45 mm	90 mm 63 mm 53 mm 45 mm 22.4 mm	100 90-100 25-70 0-15 0-5
3	75 mm 0.91 to 1.07 cums.	53 mm to 22.4 mm	63 mm 53 mm 45 mm 22.4 mm 11.2 mm	100 95-100 65-90 0-10 0-5

The compacted thickness for a layer with grading no 1 shall be 100 mm while for layer with other grading i.e. 2&3 shall be 75 mm.

Application of screenings:

To fill voids in the coarse aggregates, screenings are generally necessary and shall consist if the same material as the coarse aggregate. As far as possible, the screening material should conform to grading given in the table.

Grading classification	Size of screening	IS sieve designation	Percent by weight passing the sieve
A	13.2 mm	13.2 mm	100
		11.2 mm	95-100
		5.6 mm	15-35
		180 microns	0-10
B	11.2 mm	11.2 mm	100
		5.6 mm	90-100
		180 microns	15-35

Gravel: Non-Plastic material such as moorum or gravel may also be used for filling the voids in the coarse aggregates provided liquid limit and plasticity index of such material are below 20 and 6 respectively and fraction passing 75 microns sieve doesn't exceed 10%.

Bituminous material:

Bitumen is a viscous liquid, semisolid or solid material, colour varying from black to dark brown having adhesive properties consisting essentially hydrocarbons is derived from distillation of petroleum crude or natural asphalt and soluble in carbon disulphide. Bituminous materials used for paving purposes are penetration grade bitumen and liquid bitumen (cutbacks & emulsion).

The bituminous binder should possess the following qualities.

- Adequate viscosity at the time of mixing and compaction.
- Not highly temperature susceptible.
- Should not strip from aggregate in presence of water.

Following suitability tests are followed:

1. Consistency Test

- Penetration test
- Viscosity test
- Softening point test
- Ductility test

2. Composition Test

- Loss on heat test
- Solubility test
- Water content test
- Distillation test
- Spot test

3. Specific Gravity Test

- Varies from 1.00 to 1.28

4. Flash & Fire Point Test

- Safety test to indicate the max temperature to which the bituminous material can be safely heated.

- Measurement of penetration a 100 gm standard steel needle into a bitumen binder kept into a bitumen binder kept at 25 degrees within 5 sec is known as penetration value.
- Viscosity is its important physical property low viscous binder may flow off the aggregate during transit from mixing plant to site and a high viscous material may provide an unworkable mix. Viscometer is used to measure the viscosity of the bitumen.
- The ductility of a bituminous material is measured by the distance in centimeters to which it will elongate before breaking when a briquette specimen of the material of the form is pulled apart at a specified speed (50 mm/min) and specified temperature of 27 degrees- bituminous briquette is subjected to rupture in the testing machine.

Softening point: The temperature at which the bitumen attains the particular degree of softening under specified condition of test- measured with ring and ball apparatus.

Flash point: It is the lowest temperature at which the vapour of bitumen momentarily takes fire in the form of a flash under specified condition of test- pensky-martens tester is the apparatus used to test flash point.

Fire point: It is the lowest temperature at which the material gets ignited and burns under specified condition of test- measured with pensky-martens tester.

Properties of paving bitumen:

Specific gravity at 27 degrees	1.12-1.28
Water content percent by weight, max	0.50
Flash point in degree centigrade	175
Softening point in degree centigrade	45-60
Penetration at 25 degrees	80-100
Ductility at 24 degrees	75
Loss on heating percent by weight	1

The aggregates used in bituminous works shall satisfy the following physical requirements:

Property	**Test**	**Specification**
Cleanliness (Dust)	Grain size analysis	Max 5% passing 0.075 mm sieve
Particle shape	Flakiness and elongation index	Max 30%
Strength	Los Angeles Abrasion Value	Max 35%
	Aggregate impact value	Max 27%
Durability	Soundness Sodium sulphate Magnesium sulphate	 Max 12% Max 18%
Water absorption	Water absorption	Max 2%
Stripping	Coarse and stripping of	Min retained coating 95%

	bitumen aggregate mixtures	

Bituminous courses:

Bituminous courses of different specifications are laid on WBM/WMM base or existing BT surface. A PRIME COAT over macadam base at the rate of 6 to 9 kgs/10 sqms and TACK COAT of 2 to 3 kgs/sqms over existing BT surface shall precede the bituminous courses. The specification for different classes of BT work varies with respect to size of aggregates and quantity of bitumen used. The voids in bituminous surface will be sealed by application of seal coat.

Requirements before laying bituminous courses:

i. Surface should be clean and dry.
ii. There should be no presence of organic or inorganic substances.
iii. The level of DBM layer should be checked before laying bituminous course and if any error is found, it should be corrected.
iv. Aggregates used should also be clean and dry.
v. Loose soil if present should be scratched out.

The following table shows the bituminous generally used:

Sl.no	**Item of work**	**Grade**	**Thickness of layer in mm**	**Nominal aggregate size**	**Bitumen content % by weight**	**Ref to MOST specification**
1	Premix carpet		20 mm	12 mm	2.8	511
2	Bituminous macadam	Grade 1 Grade 2	80-100 50-75	40 mm 19mm	3.1 to 3.4 3.3 to 3.5	504 504
3	Dense bituminous macadam	Grade 1 Grade 2	80-100 50-75	40mm 25mm	4.0 4.5	507 507

4	Semi dense bituminous concrete	Grade 1 Grade 2	35-40 25-30	13 mm 10mm	4.5 5.0	508 508

Apart from conformity with grading and quality requirements individual ingredients the mix shall meet the requirements of Marshall test.

Minimum stability(kg at 60 degree centigrade)	820 kgs
Flow (mm)	2-4
Compaction level (no of blows)	75 blows on each of two faces of the specimen
Percent air voids	3-5
Percent voids in mineral aggregate (VMA)	8-22

Image: Bituminous course

Execution of site work:

Site investigation:

A site investigation report is the basis for all the subsequent decisions regarding cleanup of a contaminated site. This report describes the findings of the desk study and the field work and discuss their implications with respect to the proposed development of the site. An assessment is made in terms of likelihood of the presence of contamination that may affect the feasibility of the site for the intended use.

The sequence of a site investigation is as follows:

- Desk Study
- Site Reconnaissance
- Preliminary report or feasibility study
- Preliminary Ground Investigation - Planning of main GI
- Preliminary report
- Main Ground Investigation
- Laboratory testing
- Final report

Objectives of site investigation

The principal objectives for a highway design Site Investigation are as follows:

- Suitability: Are the site and surroundings suitable for the highway?
- Design: Obtain all the design parameters necessary for the works.

- Construction: Are there any potential ground or ground water conditions that would affect the construction?
- Materials: Are there any materials available on site, what quantity and quality?
- Effect of changes: How will the design affect adjacent properties and the ground water?
- Identify Alternatives: Is this the best location?

In addition to these, it is necessary to investigate existing features such as slopes. If there is a failure of such a feature then it is necessary to investigate the failure and suggest remedial works.

Desk study:

The desk study is work taken up prior to commencing the work on site and the Ground Investigation. It should always be the first stage of the Site Investigation and is used to plan the Ground Investigation. The work involves researching the site to gain as much information as possible, both geological and historical.

Site reconnaissance:

The Site Reconnaissance phase of a site investigation is normally in the form of a walk over survey of the site. Important evidence to look for is:

- **Hydrogeology**: Wet marshy ground, springs or seepage, ponds or streams and Wells.
- **Slope Instability**: Signs of slope instability include bent trees, hummocks on the ground and displaced fences or drains.
- **Mining**: The presence of mining is often signs of subsidence and possibly disused mine shafts. Open cast mining is indicated by diverted streams replaced or removed fence/hedge lines.
- **Access**: It is essential that access to the site can be easily obtained. Possible problems include low overhead cables and watercourses.

Planning a site investigation:

The main investigation is the full investigation of the site using boreholes and trial pits and includes the preparation of the site-investigation report with revised plans and sections, interpretation and recommendations for design.

They consider that there are two aspects to the site investigation .The geological structure and character of the site and the testing of the soil both in the laboratory and in-situ.

Ground investigation:

Ground investigation is taken to be that other than the information available from the walk over survey as discussed previously.

There are two principal methods of investigating the ground conditions, trial pits and boreholes. In addition, the reader should be aware of geophysical techniques such as seismic surveys, which are not discussed here.

Sampling:

Sampling can be either undisturbed, of which in-situ testing is a form, or disturbed. On our site, we used both disturbed and undisturbed/representative.

Reporting:

The Site Investigation report for a highway design scheme should answer all the questions set out in the planning phase of the Investigation. This should include an assessment of the viability of the proposed route and indication of any alternatives.

Included in the report should be a location of all the boreholes, trial pits, other excavations and their logs. These logs should give as much information as possible on the soil and rock structure as it is possible to obtain.

The soil and rock descriptions should be defined and should contain the information described below:

Soil Description - Often remebered using the acronym MCCSSOW obviously!

- Moisture Content - Dry, slightly moist, moist, very moist or wet. Not the measured value just the way it appears in the hand.
- Colour - This is an indicator of chemical and mineralogical content. Charts are available but not often used.
- Consistency - Loose or dense and other descriptions dependant on soil type. An approximate relationship can be made between stifness and undrained shear strentgh (Cu) and between density and the SPT 'N' Values.

	Cu		SPT 'N' Value
Very Soft	<20	Very Loose	<4
Soft	20-40	Loose	4-10
Firm	40-75	Medium dense	10-30
Stiff	75-150	Dense	30-50
Very stiff	>150	Very dense	>50

- Structure - Bedding, laminatesfissure, joints, fractures, shear zones etc.
- Soil Type - Given by particle sizes as described in BS5930 Table 6

- Origin - Try and identify geological area and stratographic unit. This is difficult and often impossible
- GroundWater Conditions - Depth to groundwater and any other observations.

Rock Descriptions - The acronym makers came up with CGTSWROS in a moment of inspiration

- Color - Same terminology as for soils with principal and secondary
- Grain Size - Range of sizes present and the dominant sizes.
- Texture & Fabric – Porphyritic, crystalline, granular, glassy, amourphous, homogeneous and many more as described in BS5930 Table 9.
- Structure - Dependant on the type of rock, reference should be made to BS5930 Table 9. Discontinuities in the rock can be caused by the drilling action, weathered surfaces indicate natural and clean surface indicate recent fractures.

Term	Field recognition	Cu(MPa)	Point Load Strength(MPa)
Extremely Strong	Rocks Ring on hammer blows. Sparks fly	>200	>12
Very Strong	Lumps only chip by heavy hammer blows. Dull ringing sound	100-200	6-12
Strong	Lumps or core broken by heavy hammer blow	50-100	3-6
Moderately Strong	Lump or core broken by light hammer blow	12.5-50	0.75-3

Moderately weak	Thin slabs broken by heavy hand pressure	5-12.5	0.3-0.75
Weak	Thin slabs break easily in hand	1.25-5	0.075-0.3
Very Weak	Crumbles in hand	<1.25	<0.075
Very Stiff	Can be indented by thumb nail	>0.3	

Site clearance:

General:

Site clearing generally consists of the cutting and/or taking down, removal and disposal of everything above ground level, including objects overhanging the area to be cleared such as tree branches, except such trees, vegetation, structures or parts of structures and other things which are designated in the contract to remain or be removed by others to which the engineer directed to be left undisturbed.

The material to be cleared usually but not necessarily is limited to trees, stumps, logs, brush, undergrowth, long grasses, crops, loose vegetable matter and structure.

The entire road area shall be cleared as described above, unless otherwise shown on the drawing and/or directed by the engineer.

Setting out:

The right of way (R.O.W) shall be surveyed and set out before any site clearance is cleared out. Wooden pegs usually indicate the surveyed rights of ways.

Procedure for setting out:

1. Fixing of centre line of alignment by using total station, theodelite.
2. Calculating curvature and refractures(for curves and embankment) by using auto levels or dumpy level.
3. To establish traverse bench mark (TBM) at required intervals adjacent to alignments.
4. Location of levels at major conflict junctions.
5. To mark the longitudinal and cross sectional pavement structure.
6. To make efficient, minimum and desired sight distance at major conflicts and terrain and also setting out of horizontal curves throughout the alignment was done by using theodolite and total survey station.

Steps involved in surveying:

- Benchmark
- Temporary benchmark at regular intervals.
- Centre line marking
- Road markings
- Profile marking (for longitudinal and cross sectional structures)
- Establishment of different levels providing gradients as per to design considering different factors like-
    - SSD(STOPPING SIGHT DISTANCE)

- OSD(OVERTAKING SIGHT DISTANCE)
- ISD(INTERMEDIATE SIGHT DISTANCE)

Surveying using dumpy level

Plants and equipments:

Site clearing of trees, vegetation, undergrowth, bushes and minor structures are carried out by dozers and or hydraulic excavators. Trees that cannot be felled by the aforesaid equipment shall be felled by using saws.

Major structures that cannot practically be cleared by hydraulic excavators and/or dozers, these demolitions can be carried out using pneumatic tools, explosives and/or other

specialized equipment depending on the size and type of structures. Before commencing explosive demolition all necessary permits and licenses will be obtained and a blasting plan detailing the size of charges, locations of holes, system of detonation and safety precaution will be forwarded to the engineer together with the request sheets.

Image: Double barrel Asphalt Premix plant.

Image: Single barrel Asphalt Premix Plant.

Image: Sensor Paver

Image: Aggregate Crusher

Sequence of works:

Prior to the commencement of the site clearance, the following shall be carried out either independently or jointly with the Engineer's Representative.

I. The right of ways (R.O.W) shall be surveyed and set out according to the data stated in the drawings.

II. Photographs shall be taken of structures, landscaping trees and shrubs, fences, telephone and electrical poles and other if they are payable under individual measured item apart from the general site clearance in the bill of quantities.

III. The above site clearance items shall be measured according to the method of measurement jointly with the Engineer's Representatives. The location of these items shall be identified according to the survey data or offsets from the centerline of the proposed alignment in road construction.

IV. Prior to demolition of existing buildings, liaison with the respective authorities terminates the utilities supply to the building.

V. Removal of landscaping trees and shrubs shall be carried out with the prior approval of the concerned authority.

VI. Fencing or others that are to be relocated or salvaged shall be carried out according to the drawings or as per the instructions given by Engineer.

VII. Obtain confirmation that the employer or relevant authority have acquired the right of way lands.

VIII. Access roads to the site shall be constructed if required to enable vehicles, equipment and plants to be brought into the site.

IX. Solid waste dumps sites shall be predetermined within or outside the site for the dumping of the site clearing materials.

X. The site clearance then shall be proceeded to clear the trees, vegetation, undergrowth, bushes and minor structures by hydraulic excavators or dozers.

Excavation for cutting:

Construction method:

The excavation of cutting shall be carried out in accordance with the drawings and to the slopes, levels, depths, widths and heights shown on the drawings. Prior to commencement of works, surveyor will use the survey data of road alignment and TBM provided by the engineer for setting out the extent of cutting in accordance with the cross sections and put in such pegs, bars, sight rails and reference markers necessary to control the works.

A survey team shall monitor and control each stage of work. All the major setting out works will be carried out jointly with the engineer's surveyor. At the same time, the cut material below the top soil level shall be sampled and tested for laboratory compaction, laboratory CBR, grading and index properties, so that it may be classified as suitable or not for the various categories to fill. Requests for approvals for use of that material as fill will then be submitted.

Before commencement of cut/fill, it will be ensured that the haul roads have sufficient width for to and fro traffic and for smooth movement of the plant. The diversion of traffic, warning signs, flagmen etc to the agreed traffic management plan shall be deployed for the safety of the works, and all necessary ramps be provided to maintain existing accesses to and off the road.

Before starting the mass excavation the top soil shall be stripped from the area, either to a thickness agreed from the soil sampling holes, or as directed on site by the engineer or his designated staff, and afterwards measured by leveling. Requests for approval for commencement of cutting shall then be submitted.

When approvals are received, the mass excavation shall be started from the top of the high ground down to the formation levels. At the specified frequency and at any change of

material the engineer will be notified and the material will be sampled and tested for continued suitability of use. If the changed material is considered to be Hard Rock a request for approval for re classification will be submitted.

Slopes in cutting shall be trimmed mechanically to neat and even surfaces in accordance with the designed gradients. The tolerance for widths of excavations shall not exceed the dimensions shown on the drawings by more than 150mm or specified limits. Erosion protection measures if desired by the engineer shall be carried out after the completion of trimming.

The construction of side drain shall follow closely to the slope trimming and surface water shall be regulated to discharge to the side drain.

If directed by the engineer the slope of cutting shall be cleared of all rock boulders or rock fragments, which move when, pressed by the crowbar.

The formation of sub grade on the cut area shall be sampled and tested for lab compaction, lab CBR, and grading and index properties. If found to be suitable for sub grade this will be compacted and tested as to CI.301 and CI.305. Request for approval for placing of sub base will then be submitted. If there is likely to be a delay in immediately placing the sub base then a protective layer 300mm thick shall be left in place above the sub grade level for removal at a later date.

Machinery used:

i. Excavator – J.C.B. or Hitachi EX 100 for bulk excavation, loading on trucks and slope trimming.
ii. Dump truck – For transporting cut materials from the cut area.
iii. Bulldozer – ripping & loosening of earth and rock mixed soil etc.
iv. Grader for trimming to final level and maintaining the surface parallel to the finished grade line.

Image: JCB

Image: BMEL BH100 Dump truck

Image: Backhoes

Filling for embankment:

Construction method:

The embankment shall be constructed to the level, heights, widths and slopes shown on the drawing with following procedures.

General:

The area to receive fill shall be sampled and tested below topsoil in accordance with the specification. If the test results indicate that the material is for suitable to receive fill then a request of Approval starting compaction of existing ground will be submitted. Before starting the compaction of the existing ground the topsoil will be stripped from the area, either to a thickness agreed from the soil sampling holes or as directed on site by the Engineer or his designated staff and afterwards measured by leveling. After compacting the existing ground to specified standard density tests will be carried out and a Request for Approval to start filling will be submitted. Where it is the intention to commence filling will be commence by cutting to firm material, for cross fill.

Fill materials for use in forming embankments shall be suitable material obtained from excavation cuttings or borrow pits.

Prior to commencement of the works, the selected sample from the source of cutting or borrow pits shall be sent for laboratory test.

Trial compaction shall be carried out at the designated area of the site to determine the pattern of compaction for type of material to be used. This shall include the use of compaction plant and the number of passes in relation to the loose depth of material to achieve desired compaction. The approximate quantity of water required per unit area to bring the fill close enough to the Optimum Moisture Content to achieve the specified compaction standard economically shall be computed and thereafter uniformly mixed throughout the material depth and width to be compacted.

After the required passes for compaction has been accepted, the filling shall be carried out in layer not exceeding 200 mm compacted depth and shall be compacted by the compaction plant as used and achieved in the trial areas.

The density test shall be carried out in every compacted layer of approx. 200 mm depth and the Nos. of test shall be done in accordance with the MORT&H specification.

The Engineer’s Site representative will witness the test and the result sent to the Engineer for approval to proceed further with next layer.

On the fill slope, the filling shall be in layer and with extended extra width for cut back to form the compacted slope.

Prior to the commencement of massive cut/fill, the haul roads shall be constructed with sufficient width for to and fro traffic and to ensure smooth movement of the plant.

Excavators shall be deployed for excavation and loading the cut material on the dump trucks for filling. At the filling area, the dump trucks transport the material to the spread spot and tip from one end. One bulldozer or grader shall be used for spreading the material into loose layers to the thickness indicated by the compacted thickness or less. Water shall be spread and mixed in as required until the whole layer is of one uniform moisture content and the vibrating roller shall be used for compacting the layer. Field Density tests shall carry out, and if the results indicate compliance with the specification then a Request for Approval to place the next layer will be submitted.

The slope trimming shall be completed after the pavement and shoulders are completed.

The trimmed slope is to be turned, if specified.

Subsoil drain:

General:

This work shall include the supply and installation of subsoil drains constructed in accordance with the contract specification at the locations and in accordance with the lines, levels and grades as shown on the drawings and or as directed by the Engineer.

Materials:

CONCRETE PIPES OR Polyvinyl chloride (PVC) pipes for the subsoil drains shall comply with the relevant contract specification.

Filter material used in the construction of subsoil drains shall consist of hard, clean, crushed rock or gravel having a grading limits given in the specification. The aggregate crushing value of the material shall not exceed 30%.

The filler cloth shall be geotextile fabric as specified in the contract.

Construction method:

Excavation of longitudinal and cross trenches shall be carried out all in accordance with the approximate provisions of specification and drawings. At the completion of excavation, Request for Approval forms for placing filter materials will be submitted to the Engineer.

Filter cloth shall then be placed to cover the perimeter of the longitudinal trench excavated, with the top open to facilitate the placement of filter material. Subsoil cross pipe is then laid in the cross trench at minimum 1% slope, with the inlet face covered with filter cloth and the outlet being free outfall. The inlet of cross pipe is to be imbedded in the filter material fill placed in the longitudinal trench. Care shall be taken against damage of filter cloth during the construction stage.

Filter material shall be placed in longitudinal trench and uniformly compacted. The filter cloth shall be closed at top and backfilled with soil. At the completion of placing filter materials a Request for Approval for placing compacted backfill will be submitted. During backfilling random field density check tests will be carried out.

Granular sub-base:

General:

Sub base is the lowest of all the pavement layers consisting of natural sand, mooram, gravel, crushed stone or combination thereof necessary to comply with the grading requirements of Table 400-1 Grading I.

Materials:

Prior to the laying of sub base, a Request for Approval of Material shall be submitted which will indicate compliance with the specified properties of sub base material.

a) Fraction of material passing the 22.4 mm sieve shall have a soaked CBR of 30% or greater.

b) The fraction passing the 0.425 mm sieve shall have Liquid Limit not greater than 25 and a Plasticity Index not greater than 6.
c) The soaked 10% fines value (KN) shall be greater than 50.
d) If the water absorption is greater than 2% the Soundness Test IS 383 shall be carried out.

The grading shall be as follows:

SEIVE SIZE (MM)	PERCENTAGE PASSING
75	100
53	80-100
26.5	55-90
9.5	35-65
4.75	25-55
2.36	20-40
0.425	10-25
0.075	3-10

Laying equipment:

The following plants are required for the laying of sub-base:-

i. Motor Grader
ii. Tipper Trucks
iii. Vibratory Roller
iv. Water Tanker

Wet mix macadam:

General:

Wet mix macadam (WMM) is a base material in road pavement structure, which is batched from a mixing plant, and laid in position with a paver.

Materials:

WMM consists of crushed graded aggregate and granular material pre mixed with water.

Equipments:

Constructional plants required are as follows:-

		NO. OF UNIT/TEAM
A)	WMM MIXING PLANT	1
B)	PAVER	1
C)	MOTOR GRADER	1
D)	VIBRATORY ROLLER	1
E)	TIPPER	3

Procedures:

Work shall commence on site upon Approval and Acceptance of the sub-base layer.

The wet mix macadam shall be plant mixed with moisture content within reasonable limits of the Optimum Moisture Value, as determined in accordance with IS 2720 (Part 8).

The approved wet mix macadam shall be delivered to site by tipper trucks. To prevent the loss of moisture, the materials shall be covered, if necessary.

i. The wet mix macadam shall be laid by using a paving machine.
ii. Segregation at localized areas shall be made good by back casting with fines or by immediate removal and replacement of the freshly laid wet mix macadam.
iii. Transverse joint shall be lapped and longitudinal joints due to stoppage of work will have the loose removed before paving resumes.
iv. Compaction shall be carried out using vibratory roller and as per specifications.

v. The surface of the wet mix macadam shall be finished to the grade and line as required by the drawings, and within specified tolerance limits.
vi. On completion of laying and compaction, approval of the Engineer will be obtained for compliance with the specified requirement, before proceeding with the next layer.
vii. Sampling of mixture shall be carried out at the plant or site.

Dense bituminous macadam:

General:

DBM is a bituminous road base mix consisting of graded aggregates, bitumen and filler. It is used in main pavement course.

Materials:

DBM consists of the following materials:

i. Road base material complying with IS:2386 (Part- 1,3,4,5) and IS:2720 (Part 37) and table 500-8 of the MOST specification and the grading shall be within the range shown below and the design mix shall be approved from the Engineer.
ii. The plasticity index of the fraction passing the 425-micron sieve should not exceed 4.
iii. Bitumen – (6-/70) penetration grade. The quantity will be as specified in the contract and bitumen 4.0 percent.
iv. Cement lime/stone dust- as specified in the contract.
v. Temperature of materials.
vi. The aggregates shall be surface dry and shall be mixed at 155^{o} C to 163^{o}C temperature with binder temperature at 150^{o} C to 163^{o} C. the mixed material as delivered to the laying site shall be between 120^{o}C to 160^{o} C.

Mixing:

The materials including any added filler, shall be weighed or measured into a mechanical mixer and thoroughly mixed in such a manner that all particulars of the aggregate are completely and uniformly coated.

Equipments:

Plant required to produce DBM:

i. Premix Plant
ii. Wheel Loader

Machineries required for laying:

i. Tipper Trucks
ii. Asphalt Paver
iii. Tandem Roller – 80-100 Km
iv. Bitumen Sprayer

Procedure:

Work shall commence on site upon approval and acceptance of the wet mix macadam and prime coating. Tack coat shall be sprayed on the surface, to receive the DBM.

The dense bituminous macadam shall be plant mixed as specified in design mix.

The approved DBM mix shall be delivered to site by tipper trucks. To prevent the loss of heat, the mixture shall be covered.

The dense bituminous macadam shall be laid by paver in 50 to 100mm layer as specified in the contract.

If the laid surface is open-textured, back casting shall be carried out and the bigger size aggregates removed before rolling.

At the end of the paving operation, the transverse joint shall be feathered down. Lap joint shall be provided for the next operation of paving.

Compaction shall be carried out using the specified/ equivalent type of compactors and for rolling pattern shall be as per specifications.

Rolling shall always commence from the lower to the higher side of the carriageway. The minimum rolling temperature shall be 100^{o}C.

The surface of the dense bituminous macadam shall be finished to the grade and line as required by the drawings, within the specified tolerance limits of +6 mm.

On completion of laying and compaction, checks shall be carried out to verify compliance with the specified requirements.

Bituminous concrete wearing course

General:

The B.C. wearing course is the final layer of the pavement.

The material quality shall meet the requirements of MORTH Technical specifications.

The aggregate shall be surface dry and shall be mixed at 155 degree Celsius to 163 degree Celsius temperature. The mix material as delivered to the laying site shall be 120 to160 degrees Celsius.

Equipments:

Plant required to produce WC shall be:

i. Asphalt Premix Plant
ii. Wheel loader

Machineries required for laying WC:

i. Tipper Trucks
ii. Asphalt Paver
iii. Tandem Roller
iv. Bitumen Sprayer

Procedures:

Trial mix and trial lay shall be carried out to assess the suitability of the mixing, laying and compacting plant and to establish the sequence of the laying operation.

Works shall commence on site upon approval and acceptance of the asphalt concrete wearing course.

The surface to receive the Asphalt concrete wearing course shall be freed of all dirt, loose materials and standing water.

Tack coat of approved bitumen emulsion or cut back shall be applied as per the specifications on the prepared surface prior to laying of the asphaltic concrete wearing course.
The ACWC shall be plant mixed with bitumen content as established in the Job Standard Mixture.
The approved asphaltic concrete mixture shall be delivered to site by tipper trucks. To prevent the loss of heat, the mixture shall be covered if necessary.

The ACWC shall be laid in single layer.

If the said surface is open textured, back casting shall be carried out and the bigger size aggregates removed before rolling.

At the end of paving operation, the transverse joint shall be feathered down. Vertical joint shall be provided for the next operation of paving.

Compaction shall be carried out using the specified/equivalent type of compactors and the rolling pattern shall be as agreed with the Engineer. In our project, every layer was compacted six times, with first and last compaction, plain and middle four compactions, with vibrations.

Rolling shall always commence from the lower end to the higher side of the carriageway. The minimum rolling temperature shall be 100 degree Celsius.
The surface of the ACWC shall be finished to the grade and line as required to the drawings within the tolerance limits.
On completion of laying and compaction, checks shall be carried out to verify compliance with the specified requirements.

Dry lean concrete:

General:

The work shall consist of construction of dry lean concrete sub base for Cement Concrete Pavement in accordance with the requirements of MORT&H Specifications. IRC 43-1972 and IRC 15-1981. The construction shall also be in conformity with lines, grades and cross sections shown on drawings and/or as directed by the Engineer.

Materials:

All the materials required in the construction will be from the source approved by the Engineer and according to the relevant clauses of MORT&H specifications mentioned in the contract.

Cement - 601.2.2

Coarse aggregates - 602.2.4.2

Fine Aggregates - 602.2.4.2

Water - 601.2.4

Aggregate gradation given in table 600-1 of MORT&H specifications shall be adopted after blending the coarse and fine aggregates.

Sieve Designation	**% passing Proposed by Weight**	**% passing Limits by Weight**
26.50 mm	100	100
19.00 mm	87.4	80-100
9.50 mm	67.6	55-76
4.75 mm	46.1	35-60
600.00 Micron	18.2	10-35
75.00 Micron	5.4	0-8

Aggregates are fed into the cold bins from online storage bins of a 4-stage crusher or from the approved stacks. Cement is obtained either in bags or bulk and necessary support system will be employed for feeding the 120-140 MT storage silos of the concrete batching plant.

Mix for dry lean concrete will be appropriately proportioned to achieve the strength requirements mentioned in the specifications and prior approval shall be taken from the engineer before adopting for the site trials.

The calibration trial of the batching plant will be undertaken with the approved proportions after the calibration of the plant. The approved mix will then be used on the trail length already identified jointly by the representatives of the contractor and the engineer.

Equipment:

The following plants and equipment will be deployed for the construction of DLC:

i. Concrete batching plant (200 Cum/hr) with all the required accessories and storage facilities.
ii. Tippers
iii. Sensor Paver
iv. Excavator/JCB
v. Vibratory Roller
vi. Water Tankers
vii. Equipment for laboratory and survey

Preparation:

i. The GSB surface already approved will be given a fine sprayed with water and rolled with the earth compactor giving a couple of passes after a lapse of 2-3 hours of watering. This will stabilize the loose surface. Prior to watering, loose or dislocated spots, if any, will be identified and they will be rectified by removing loose material and back filling with appropriate material and compacting to the required degree of compaction as the adjoining areas. The GSB surface will be kept ready at least one day in advance of DLC laying.
ii. Before start of laying, it will be ensured that the guide/sensor wires are in position on both sides or on one side of the Paver depending upon the paver pressed used for the work. For SP1600, guide wires will be provided on both sides of the paver. For normal sensor pavers, guide wires will be provided on one side with slope control provision. There will be designated entry points for the trucks carrying concrete on to the new carriageway or prepared GSB layer.

Paving:

i. Paving is kept in position and the concrete is dumped in hopper in case of normal sensor paver and paving is done by spreading a loose thickness of about 200 mm for achieving the compacted thickness of 150 mm. the loose thickness is ascertained by

conducting trial laying of DLC. The paving will be done on the same day matching with the first lane.

ii. In case of use of SP 1600, the DLC is laid to full width with guide wires fixed on both sides relative to the line and grade and cross- slope as per the drawings. The concrete is dumped in front of the paver and it is spread across the width by the spreader.

iii. It will be ensured that traverse and longitudinal construction joints are staggered by 500-1000 mm and 200-400 mm respectively from the corresponding joints in the overlaying pavement quality concrete.

Transporting:

The concrete is transported in tippers from the batching plant and to the place of laying. The tippers are covered with tarpaulins in order to prevent water loss due to evaporation during transit. It will be ensured that there will be sufficient number of tippers for uninterrupted supply of material to the paving equipment.

Compaction:

The compaction is carried out immediately after the material is laid and leveled. Rolling shall be continued on full width till there is no further visible movement under the roller and surface is compact. The required compaction effort in terms of number of passes is ascertained by employing one single drum smooth wheeled vibratory roller and one double drum smooth wheeled vibratory roller on the trail stretch of DLC. After arriving at the efficiency of the proposed set up in the trial length, depending upon the programmed quantity and period of laying, additional rollers will be deployed. Initial two passes will be plain passes on order to roll down the loose DLC. Then vibratory pass will be given followed by plain passes for providing a finished and closed surface.

Curing:

Curing of the DLC will be done by covering the surface by gunny bags or hessian cloth, which will be kept continuously moist for seven days by sprinkling water using water tankers.

Testing:

After the construction of the trial length, the in-situ density of freshly laid material will be determined by sand replacement method with 20 cm diameter density cone. The density will be taken at three location along the diagonal that bisects the trail length. The locations for testing will be at least 50 cm from the edges. The average density of three holes will be considered as 100% and the field density of regular work will be compared with this reference density in accordance with clauses 601.5.5.1 and 903.5.1.2 of MORT&H specifications. Course will be cut to check segregation or any other deficiency. The routine quality control tests for levels alignment and material will be exercised as per the frequency norms given in table 900-6. Other tests will be done at the frequency mentioned therein. If there could be any reduction in total number tests depending upon the consistency of the results, ration will be taken up with the Engineer.

Description	**Frequency**
Testing of cubes	Each 100 sqm or part there of laid each day from the un-compacted material
In-situ density	Holes at location equally spaced along the diagonal that bisects each 2000 sqm or part there of laid each day.
Thickness	Cores at random

Repairs:

Rectification, if any will be taken up before overlaying PQC. The low spots, loose material, pot holes etc will be made good by using fresh lean concrete material duly compacting the same as per specifications. For repairing honey combed surface, and any other spots which cannot be repaired with DLC material, concrete with aggregates of size 10mm and below will be used after roughening the surface for proper keying in.

Typical construction of cross section in highway:

Compaction of soils:

The road crust is founded on sub grade and any deficiencies in the stability of earthwork results in settlements and other distress develop in pavement during service under traffic. Therefore good stability is necessary for the sub grade. Proper compaction at appropriate moisture is the most effective and economical way to improve the stability of soils.The density test is the principal means by which the engineer determines whether or not the specified compaction requirements have been met.

Moisture density relationship (M.D.D & O.M.C):

For a given compaction effect as the moisture content is changed density of soil varies and maximum density is achieved at “optimum moisture”. Soil is compacted in proctor’s apparatus and dry weight is assessed for different moisture contents. The results are plotted and the maximum dry weight is the highest point of the curve and is called “proctor’s density of soil”.

Embankment and sub grade formation:

The materials used in embankment shall be soil, moorum, gravel, and a mixture of these. The materials satisfying the density requirements shall be employed for construction of embankment and sub grade.

Type of work	Max.lab dry unit weight when tested as per IS 2720
Embankment upto3 meters height not subjected to extensive flooding	Not less than 1.52 gm/cc
Embankment exceeding 3 meters height or Embankment of any height subjected to long periods of inundation	Not less than 1.60 gm/cc
Sub grade and earthen shoulders/verges	Not less than 1.75gm/cc

The size of the coarse material in the mixture of earth shall ordinary not exceed 75mm when being placed in the embankment and 50mm when placed in the sub grade.

The soil for embankment and sub grade must be tested for compaction requirements.

Type of work/material	Relative compaction as % of maximum lab dry density as per is 2720
Sub grade and earthen shoulders	Not less than 97
Embankment	Not less than 95
Expansive soils a> Sub grade and 500mm portion just below the sub grade.	Not allowed

b> Remaining portion	Not less than 90

Clayey soils if any should be removed and replaced by good granular soil.

The embankment and sub grade material shall be spread in layers of uniform thickness not exceeding 200 mm compacted thicknesses over the entire width of embankment. Successive layers shall not be placed until the layer under construction has been thoroughly compacted to the specified requirements. Moisture content of each layer of soil is checked in accordance with IS-2720.

Determination of field density:

The in situ dry density of soil in the embankment/sub grade must be tested to check the degree of compaction in the field. The field density of soil can be determined popularly by

1> Core cutter and
2> Sand replacement methods.

Weight of the soil obtained in the core cutter of known volume is determined; moisture content is assessed and dry density is calculated. In sand replacement method pre-calibrated density of sand is used to measure the volume of pit dug out from the sub grade and the moisture content is assessed. Knowing the weight and volume of excavated soil and moisture content the field density can be calculated which should not be less than 95% and 97% of proctor's density for embankment and sub grade respectively.

Nuclear gauges are being used to measure the field density of soils, the principle being gamma rays emitted into the soil and number of rays returned and counted on a scalar. A low gamma ray count indicates high density and vise versa.

California bearing ratio (CBR) of soils:

Load carrying capacity of soil is measured from penetration resistance i.e. test conducted on compacted specimen and expressed as per percentage of a standard crushed rocks specimen and called as CBR of Soil.

CBR 100 Percent (viz) Load of 1360 kg to drive cylindrical plunger of 19.30 sqcms to a distance of 0.250 mm at the rate of 0.125 mm per minute.

Type of Soils	CBR
Gravel and sand mixtures	20-90
Sand and Silt mixtures	10-40
Sand and clay mixtures	15-40
Inorganic silt & clay	5-15
Organic silt & clay	3-8

Granular sub base:

This is being practiced to act as transition zone between hard base courses and sub-grade as well a drainage layer to drain pout the seepage water from base courses and avoid capillary water from sub-grade.

The CBR requirement for sub base layer is not less than (15) percent. The Material to be used for the work shall be natural sand, moorum, gravel, Crushed Stone or combination of these. The material shall be non-plastic i.e. plasticity index of material passing 425 micron sieve shall be less than (6) and liquid limit less than 20 percent.

If thickness of layer does not exceed 100 mm a smooth wheeled roller of 8 to 10 tons weight may be used. For compacted single layer of 225mm the compaction shall be done with the help of a vibratory roller of 8 to 10 tons weight with plain drum or pad foot drum. Rolling shall commence at the lower edge and proceed towards upper edge longitudinally for portions having unidirectional cross fall and super elevation. Rolling shall commence at edges and progress towards the center for portions having cross fall on both sides. The Speed of the roller shall not

exceed 5 kms per hour. Rolling shall be continued till the density achieved is at least 98% of the maximum dry density for the material as per IS 2720 (Part 8).

Water bound macadam base:

The basic need of WBM base is to distribute the load over a soft sub-grade in such a way that there will be no sinking of the road crust into the sub-grade. WBM is constructed with hard and soft metals called aggregates obtained from breaking/crushing of rocks. The aggregates spread in layers are interlocked by rolling and bonding together with screenings, blinding material and water.

Road aggregates: These have to bear the stresses due to the wheel loads and hence they should possess sufficient strength to resist crushing. They should be **hard** enough to resist wear due to abrasive action of traffic. The aggregates in the pavement are also subjected to impact hence **toughness** is another desirable property of aggregates. The stones used should be durable and resist disintegration due to action of weather, this property is called **soundness.** The following are the most commonly available rocks in India from which road aggregates can be obtained.

Type of Rock	Properties	Suitability
Basalt	Hard and durable, resistant to abrasion, fine grained.	Good for base courses
Granite	Hard and durable resistant to abrasion, Coarse grained.	Very good for bituminous Courses and WBM
Limestone	Reasonably hard, liable to polish to a Smooth surface under traffic, fine grained and high water absorption.	Good for base course
Quartzite	Hard, durable but is liable to be brittle and adhesion to bitumen is rather poor.	Good for base course

Sand Stone	Moderately hard and durable, fine to medium grained.	Good for road bases

Aggregates may have rounded cubical angular flaky or elongated shape of particles. The following are the physical requirements of coarse aggregates used for WBM as per IS 2386.

Los Angles abrasion value Or Aggregate impact value	40 percent (Maximum) 30 percent (Maximum)
Combined flakiness and elongation indices	30 percent (Maximum)

Grading requirements: The WBM is carried out in layers. The coarse aggregates for each layer should confirm to any of (3) grading below. The use of grading no 1 shall be restricted to sub base courses only.

Size and grading requirements of coarse aggregates for water bound macadam.

Grading No.	**Thickness and aggregate per 10 sqm.**	**Size range**	**IS sieve designation**	**Percent by weight passing the sieve**

1	10 mm 1.21 to 1.13 cums.	90 mm to 45 mm	125 mm 90 mm 63 mm 45 mm 22.4 mm	100 90-100 25-60 0-15 0-5
2	75 mm 0.91 to 1.01 cums.	63 mm to 45 mm	90 mm 63 mm 53 mm 45 mm 22.4 mm	100 90-100 25-70 0-15 0-5
3	75 mm 0.91 to 1.07 cums.	53 mm to 22.4 mm	63 mm 53 mm 45 mm 22.4 mm 11.2 mm	100 95-100 65-90 0-10 0-5

The compacted thickness for a layer with grading no 1 shall be 100 mm while for layer with other grading i.e. 2&3 shall be 75 mm.

Application of screenings:

To fill voids in the coarse aggregates, screenings are generally necessary and shall consist if the same material as the coarse aggregate.

As far as possible, the screening material should conform to grading given in the table.

Grading classification	Size of screening	IS sieve designation	Percent by weight passing the sieve
A	13.2 mm	13.2 mm 11.2 mm 5.6 mm 180 microns	100 95-100 15-35 0-10
B	11.2 mm	11.2 mm 5.6 mm 180 microns	100 90-100 15-35

Gravel:

Non-Plastic material such as moorum or gravel may also be used for filling the voids in the coarse aggregates provided liquid limit and plasticity index of such material are below 20 and 6 respectively and fraction passing 75 microns sieve doesn't exceed 10%.

Construction operations:

The coarse aggregates shall be spread uniformly and evenly upon the prepared sub grade/sub base/base to proper profile by using templates placed at 6 mts apart and all high or low spots remedied by removing or adding aggregates. Immediately after spreading of coarse aggregates rolling shall be started with power roller of 8 to 10 tons of capacity or vibration roller of 8 to 10 tons weight. First the edge shall be compacted and move inward parallel to the centre line of the road duly lapping preceding tracks by at least one half width. Rolling is continued until the aggregates are well compacted and no waveform is seen when the roller is advancing. Screening shall be applied gradually brooming and dry rolling is continued until no more screenings be forced into voids of the coarse aggregates. All this operations shall be carried out in only such lengths of road, which could be completed within one day. Now the surface be copiously sprinkled with water, wet screenings swept and rolled until the coarse aggregates has been thoroughly keyed well bonded and firmly set in its full depth. The binding material shall be applied successively in 2 or more thin layers and the surface shall be copiously sprinkled with water, the resulting slurry swept in with brooms to fill the voids. The rolling shall be continued until the resulting slurry after filling voids forms a wave ahead of wheels of the moving roller.

After final compaction the pavement shall be allowed to dry over night and no traffic is allowed for 2 or 3 days until the macadam has set. The roads shall be kept watered so that it remains in damp condition under traffic for about a fortnight.

Wet mix macadam: (WMM)

Graded aggregate and granular material and water are premixed in pug mill and shall be laid in one or more layers. The thickness of a single compacted layer shall not be less than 75mm and can be increased to 200mm when compaction is with vibratory roller. The aggregates shall satisfy the physical requirement of aggregates i.e. impact value of 30 percent (max) and flakiness index 30 percentage (max).

The aggregates shall confirm to the following grading.

IS sieve	% by weight passing
53mm	100
45mm	95-100
22.4mm	60-80
11.2mm	40-60
4.75mm	25-40
2.36mm	15-30
600 micron	8-22
75 micron	0-8

The mix shall be spread uniformly using a paver finishers or motor grader and no segregation of larger and finer particles be allowed. While constructing WMM confinement of mix against lateral movement shall be ensured by simultaneous shoulder development. Traffic shall not be allowed until the mix has dried at least for 24 hours.

Bituminous pavement:

Pavement made of aggregates and bitumen as binding material are smooth, dust free and have higher load carrying capacity and longer life period of 10 to 15 years; hence most of the roads are being constructed/converted to black top.

Bituminous material:

Bitumen is a viscous liquid, semisolid or solid material, colour varying from black to dark brown having adhesive properties consisting essentially hydrocarbons is derived from distillation of petroleum crude or natural asphalt and soluble in carbon disulphide. Bituminous materials used for paving purposes are penetration grade bitumen and liquid bitumen (cutbacks & emulsion).

The bituminous binder should possess the following qualities.
Adequate viscosity at the time of mixing and compaction.
Not highly temperature susceptible.
Should not strip from aggregate in presence of water.
The following suitability tests are followed.

Consistency test:

Penetration test

Viscosity test

Softening point test

Ductility test

Compaction test:

Loss on heat test

Solubility test

Water content test

Distillation test

Spot test

Specific gravity test:

Varies from 1.00 to 1.28

Flash and fire point test:

Safety test to indicate the max temperature to which the bituminous material can be safely heated.

Measurement of penetration a 100 gm standard steel needle into a bitumen binder kept into a bitumen binder kept at 25 degrees within 5 sec is known as penetration value.

Viscosity is its important physical property low viscous binder may flow off the aggregate during transit from mixing plant to site and a high viscous material may provide an unworkable mix. Viscometer is used to measure the viscosity of the bitumen.

The ductility of a bituminous material is measured by the distance in centimeters to which it will elongate before breaking when a briquette specimen of the material of the form is pulled apart at a specified speed (50 mm/min) and specified temperature of 27 degrees- bituminous briquette is subjected to rupture in the testing machine.

Softening point: The temperature at which the bitumen attains the particular degree of softening under specified condition of test- measured with ring and ball apparatus.

Flash point: It is the lowest temperature at which the vapour of bitumen momentarily takes fire in the form of a flash under specified condition of test- pensky-martens tester is the apparatus used to test flash point.

Fire point: It is the lowest temperature at which the material gets ignited and burns under specified condition of test- measured with pensky-martens tester.

Properties of paving bitumen:

Specific gravity at 27 degrees	1.12-1.28
Water content percent by weight, max	0.50
Flash point in degree centigrade	175
Softening point in degree centigrade	45-60
Penetration at 25 degrees	80-100
Ductility at 24 degrees	75
Loss on heating percent by weight	1

The aggregates used in bituminous works shall satisfy the following physical requirements.

Property	Test	Specification
Cleanliness (Dust)	Grain size analysis	Max 5% passing 0.075 mm sieve
Particle shape	Flakiness and elongation index	Max 30%
Strength	Los Angeles Abrasion Value	Max 35%
	Aggregate impact value	Max 27%
Durability	Soundness Sodium sulphate Magnesium sulphate	 Max 12% Max 18%
Water absorption	Water absorption	Max 2%
Stripping	Coarse and stripping of bitumen aggregate mixtures	Min retained coating 95%

Bituminous courses:

Bituminous courses of different specifications are laid on WBM/WMM base or existing BT surface. A PRIME COAT over macadam base at the rate of 6 to 9 kgs/10 sqms and TACK COAT of 2 to 3 kgs/sqms over existing BT surface shall precede the bituminous courses. The specification for different classes of BT work varies with respect to size of aggregates and quantity of bitumen used. The voids in bituminous surface will be sealed by application of seal coat.

The following table shows the bituminous generally used.

Sl. No	Item of work	Grade	Thickness of layer in mm	Nominal aggregate size	Bitumen content % by weight	Ref to MOST specification
1	Premix carpet		20 mm	12 mm	2.8	511
2	Bituminous macadam	Grade 1 Grade 2	80-100 50-75	40 mm 19mm	3.1 to 3.4 3.3 to 3.5	504 504
3	Dense bituminous macadam	Grade 1 Grade 2	80-100 50-75	40mm 25mm	4.0 4.5	507 507
4	Semi dense bituminous concrete	Grade 1 Grade 2	35-40 25-30	13 mm 10mm	4.5 5.0	508 508
5	Bituminous concrete	Grade 1 Grade 2	50-65 30-45	19 mm 13 mm	5 to 6 5 to 7	509 509

Apart from conformity with grading and quality requirements individual ingredients the mix shall meet the requirements of Marshall test.

Minimum stability(kg at 60 degree centigrade)	820 kgs
Flow (mm)	2-4
Compaction level (no of blows)	75 blows on each of two faces of the specimen
Percent air voids	3-5
Percent voids in mineral aggregate (VMA)	8-22

Mixing and spreading operation:

The mix for bitumen courses shall be prepared in hot mix plant (HMP). The plant will have cold aggregate feed system with minimum (4) bins having belt conveyor arrangement and variable speed drive motors, dryer unit with burner capable of heating the aggregate and bitumen supply unit capable of heating and spraying of bitumen at specified temperature. The plant should have centralized control panel cabin to ensure for quality of mix.

The mix from the HMP shall be transported to the site and spread on the road surface using paver and compacted with suitable rollers. The following temperature shall be maintained during the process.

Temperature of binder at the time of mixing – 150 to 163 degree centigrade.
Traffic will be diverted until the rolling is finished and the course is well set.

Aggregate blending:

The aggregates from the crusher are stored in BINS. For getting the desired mix three or four aggregates have to be mixed and proper proportioning of different aggregates is called aggregate blending.

The following table illustrates aggregates blending of DBM.

Sieves	37.5	26.5	12.5	4.75	2.36	0.3	0.075	
Min Pass	100	90	56	29	19	5	1	MOST

Max Pass	100	100	80	59	45	17	7	MOST
Avg Pass	100	95	68	44	32	11	4	
Designed	100	93.2	66.2	48	31.3	8.9	2.1	Blending
Bin- A	100	65.9	.6	.5	.4	.3	.2	20
Bin-B	100	100	33.5	1	.9	.7	.4	21
Bin-C	100	100	100	61.2	9.7	2.9	1.3	29
Bin-D	100	100	100	100	94.1	26.1	5.5	30
								100

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Dry lean concrete (DLC):

Dry lean concrete is used for construction of base course under the concrete pavement. The DLC general consists M- 10 concrete of thickness not less than 112 mm laid over thin layer of WBM/WMM. Graded aggregate of size varying from 25 mm to 4.75 mm are used. The mix shall be proportioned with a maximum aggregate cement ratio of 15: 1 and water cement ratio around 0.70. The minimum cement content shall not be less than 150kgs/cum of concrete and the average compressive strength shall not be less than 100 kg/cm2 at (7) days.

The mix is produced in the central batching and mixing plant and transported to the paving site in trucks. Concrete pavers equipped with tampers and vibrators are used for spreading without segregation. The compacting and finishing shall be within (90) minutes of concrete mixing. Longitudinal and traverse construction joints shall be provided as per drawing. Curing shall be done by covering the surface with gunny bags/hessian, which shall be kept continuously for (7) days by sprinkling water. Initial curing can also be done by spraying liquid curing compound and wet hessian for 3 days. Light vehicles may be allowed after (7) days of construction. Trial mixes with varied moisture contents of 5 to 7% shall determine the optimum moisture and trial length

of minimum 60 meters length shall be constructed and dry density of the mix shall be determined to be used as reference density.

Cement concrete pavement:

This work consists construction of unreinforced, dowel jointed, plain cement concrete pavement. The thickness of pavement slab, grade of concrete and joint details shall be stipulated in the drawings. Ordinary Portland cement of 43 Grade or higher is generally used. The coarse aggregate shall be of crushed stone maximum size not exceeding 25 mm and shall be devoid of soft flaks, elongated, splintery pieces and water absorption shall not be more than 2%. The fine aggregate shall be natural sand or crushed stone or combination of the two. The cement concrete shall not be less than 350 kgs/cum of concrete and water content ratio shall be 0.50. The mix is produced in mechanized batch mix plant and transported with dumpers or transit mixers. The mix from the plant shall be transported in trucks/tippers and spreading and finishing shall be completed within (90) minutes of concrete mixing, curing shall be for (14) days using liquid curing compound and covering with moist hessian. A separation membrane shall be used between concrete slab and the sub base. The location and type of joints shall be as shown in the drawings.

Different laboratory tests on field:

Laboratory test for CBR:(California Bearing Ratio)

Objective: To determine the CBR of soils from the re- moulded specimens by dynamic compaction method in soaked state at laboratory.

CBR: The ratio of the force per unit area required to penetrate a soil mass with a plunger of 50mm diameter at the rate of 1.25mm/minute to the required corresponding penetration of standard material.

Generally the ratio is determined for 2.5mm and 5.0mm penetrations, and where the ratio at 5.00mm is consistently higher than that at 2.5mm, the ratio at 5.00mm is considered.

Apparatus: Cylindrical mould , metal rammer, spacer disc, metal weights, perforated base plate, metal tripod stand, penetration plunger, loading machine with moving head, sieves, balances, oven , air tight container, tray, trowel, measuring jar.

Procedure:

i. Take a representative sample to be tested, pour it in the form of a heap and divide into 4 equal parts by quartering method and mix the material in one of the two diagonals and sieve it through 19mm sieve, the material retained shall be replaced by the equal amount of passing through 19mm sieve, but retained on 4.75mm sieve, obtained from the material of the other two diagonals, so that the passing material shall weigh a minimum of 5500gm.

ii. Place it in a tray and mix with the equal amount of that water required obtaining OMC.

iii. Note the empty weight of the cylindrical mould to the nearest 1 gm.

iv. Place the mould on a solid base, such as concrete floor or plinth.

v. Make the water mixed soil into 5 equal parts, place the spacer disc in the mould and a filter paper and place one part into the mould fitted with collar.

vi. Compact the soil with the metal hammer by distributing the 55 blows equally on the surface of the soil.

vii. Continue this process till the fourth layer, make an impression on the fourth layer of the compacted soil to a depth of 25mm, so that the next layer will plug into this and avoid separation of the top layer from the previous while removing the collar.

viii. Add fifth layer and compact it with metal hammer by giving 55 blows.

ix. Remove the collar and also remove the excess soil up to the level exactly equal to the cylindrical mould by using trowel or spatula. Note the weight of the sample with the mould to the nearest 1 gm.

x. Reverse the compacted mould, tighten the mould on the base plate, place the perforated disc with surcharge weights of 5kg on the compacted soil specimen with the mould and soak it in water for 96hours. Maintain constant water level in the tank throughout the soaking period.

xi. After the soaking period, take out the mould with the soil specimen from the water tank and allow it to drain free water collected in the mould, downward for 15 minutes.

Image: CBR apparatus

Grain size analysis of soil:

Objective: To determine the quantitative distribution of grain size distribution of soils.

Apparatus: Wash the sample under water by allowing the washed water through the lowest size of sieve, balance of 0.1 gm sensitivity, IS sieves of 100mm, 75mm, 19mm, 4.75mm, 425 microns and 75 microns and rubber pestle, water tight trays or a bucket.

Procedure:

i. The soil sample received from the field shall be dried in the oven at 105 to 110 degree centigrade.
ii. The oven dried sample shall be taken by quartering method to have a minimum weight.
iii. The mass of the sample taken for testing shall be weighed to nearest 0.1gm.
iv. Pour water in the sample with water tight tray and leave it for 2hrs.
v. Wash the sample under water by allowing the washed water to go through the lowest size of sieve.
vi. Wash bigger size aggregate first by rubbing in between two hands, ensure that the 75 microns sieve never gets overloaded, since it may get damaged.

vii. Wash the sample till the water passing the sieve is substantially clean, collect all the material retained on 75 microns, drain out the excess water and keep it in oven for 24hrs at 105 to 110 degree centigrade.

viii. Allow the sample to cool, and perform dry sieving with the largest size of sieve first and the next sizes consecutively.

ix. Ensure that the sieving is complete, and the amount of material retained on each sieve shall be weighed and noted.

x. The cumulative mass of the soil fraction shall be then calculated, and percentage of passing on each sieve shall then be reported.

xi. The material passing 100mm sieve and retains on 75mm sieve is called ‘Cobble’.

xii. The material passing 75mm sieve and retains on 4.75mm sieve is called ‘Gravel’.

xiii. The material passing 4.75mm sieve and retains on 75 microns is called ‘Sand’.

xiv. The material passing 75 microns sieve is called ‘Silt’.

Determination of free swell index of soil:

To determine the free swell index of soil as per IS: 2720 (Part XL) – 1977. Free swell or differential free swell, also termed as free swell index, is the increase in volume of soil without any external constraint when subjected to submergence in water. The apparatus used:

i) IS Sieve of size 425µm

ii) Oven

iii) Balance, with an accuracy of 0.01g

iv) Graduated glass cylinder- 2 nos., each of 100ml capacity

Procedure to determine free swell index of soil:

i. Take two specimens of 10g each of pulverized soil passing through 425µm IS Sieve and oven-dry.

ii. Pour each soil specimen into a graduated glass cylinder of 100ml capacity.

iii. Pour distilled water in one and kerosene oil in the other cylinder upto 100ml mark.

iv. Remove entrapped air by gently shaking or stirring with a glass rod.

v. Allow the suspension to attain the state of equilibrium (for not less than 24hours).

vi. Final volume of soil in each of the cylinder should be read out.

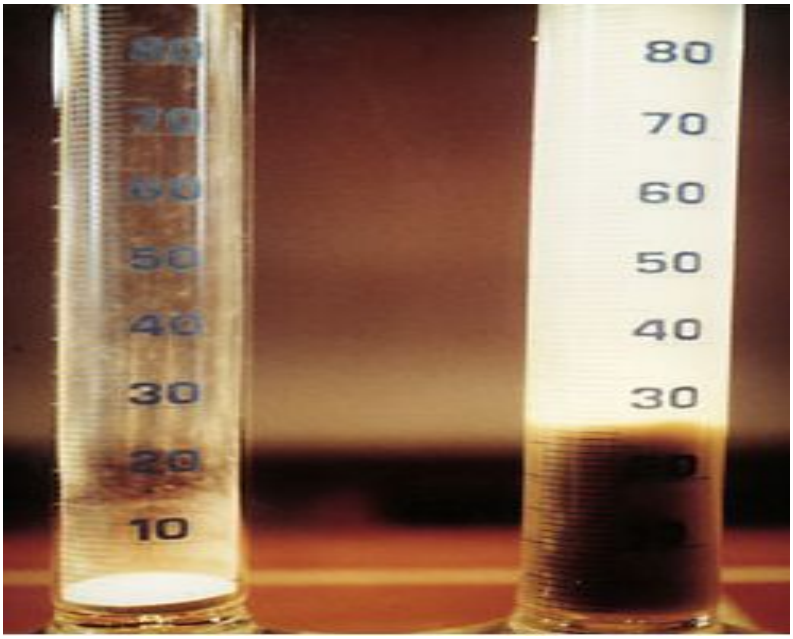
Reporting of results:

Free swell index = $[V_d - V_k] / V_k \times 100\%$

Where,

V_d = volume of soil specimen read from the graduated cylinder containing distilled water.

V_k = volume of soil specimen read from the graduated cylinder containing kerosene.



Determination of dry density and optimum moisture content of soil:

This test is done to determine the maximum dry density and the optimum moisture content of soil using heavy compaction as per IS: 2720 (Part 8) – 1983.The apparatus used is

i. Cylindrical metal mould – it should be either of 100mm dia. and 1000cc volume or 150mm dia. and 2250cc volume and should conform to IS: 10074 – 1982.

ii. Balances – one of 10kg capacity, sensitive to 1g and the other of 200g capacity, sensitive to 0.01g

iii. Oven – thermostatically controlled with an interior of non corroding material to maintain temperature between 105 and 110^{o}C

iv. Steel straightedge – 30cm long

v. IS Sieves of sizes – 4.75mm, 19mm and 37.5mm

Preparation of sample:

A representative portion of air-dried soil material, large enough to provide about 6kg of material passing through a 19mm IS Sieve (for soils not susceptible to crushing during compaction) or about 15kg of material passing through a 19mm IS Sieve (for soils susceptible to crushing during compaction), should be taken. This portion should be sieved through a 19mm IS Sieve and the coarse fraction rejected after its proportion of the total sample has been recorded. Aggregations of particles should be broken down so that if the sample was sieved through a 4.75mm IS Sieve, only separated individual particles would be retained.

Procedure to determine the maximum dry density and the optimum moisture content of soil:

A) Soil not susceptible to crushing during compaction:

i. A 5kg sample of air-dried soil passing through the 19mm IS Sieve should be taken. The sample should be mixed thoroughly with a suitable amount of water depending on the soil type (for sandy and gravelly soil – 3 to 5% and for cohesive soil – 12 to 16% below the plastic limit). The soil sample should be stored in a sealed container for a minimum period of 16hrs.

ii. The mould of 1000cc capacity with base plate attached should be weighed to the nearest 1g (W_1). The mould should be placed on a solid base, such as a concrete floor or plinth and the moist soil should be compacted into the mould, with the extension attached, in five layers of approximately equal mass, each layer being given 25 blows from the 4.9kg rammer dropped from a height of 450mm above the soil. The blows should be distributed uniformly over the surface of each layer. The amount of soil used should be sufficient to fill the mould, leaving not more than about 6mm to be struck off when the extension is removed. The extension should be removed and the compacted soil should be leveled off carefully to the top of the mould by means of the straight edge. The mould and soil should then be weighed to the nearest gram (W_2).

iii. The compacted soil specimen should be removed from the mould and placed onto the mixing tray. The water content (w) of a representative sample of the specimen should be determined.

iv. The remaining soil specimen should be broken up, rubbed through 19mm IS Sieve and then mixed with the remaining original sample. Suitable increments of water should be added successively and mixed into the sample, and the above operations i.e. ii) to iv) should be repeated for each increment of water added. The total number of determinations made should be at least five and the moisture contents should be such that the optimum moisture content at which the maximum dry density occurs, lies within that range.

B) Soil susceptible to crushing during compaction:

Five or more 2.5kg samples of air-dried soil passing through the 19mm IS Sieve, should be taken. The samples should each be mixed thoroughly with different amounts of water and stored in a sealed container as mentioned in Part A)

C) Compaction in large size mould:

For compacting soil containing coarse material upto 37.5mm size, the 2250cc mould should be used. A sample weighing about 30kg and passing through the 37.5mm IS Sieve is used for the test. Soil is compacted in five layers, each layer being given 55 blows of the 4.9kg rammer. The rest of the procedure is same as above.

Reporting of results:

Bulk density Y(gamma) in g/cc of each compacted specimen should be calculated from the equation,

$Y(gamma) = (W_2-W_1)/ V$

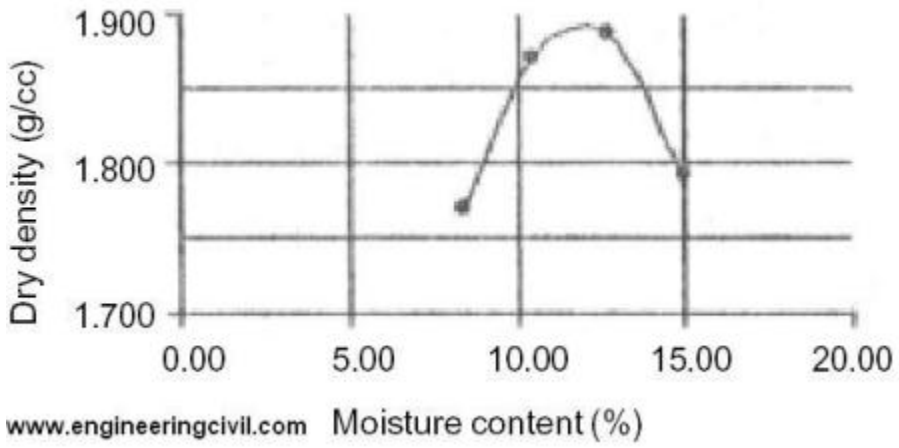
where, V = volume in cc of the mould.

The dry density Yd in g/cc

$Yd = 100Y/(100+w)$

The dry densities, Yd obtained in a series of determinations should be plotted against the corresponding moisture contents. A smooth curve should be drawn through the resulting points and the position of the maximum on the curve should be determined.

A sample graph is shown below:



The dry density in g/cc corresponding to the maximum point on the moisture content/dry density curve should be reported as the maximum dry density to the nearest 0.01. The percentage moisture content corresponding to the maximum dry density on the moisture content/dry density

curve should be reported as the optimum moisture content and quoted to the nearest 0.2 for values below 5 percent, to the nearest 0.5 for values from 5 to 10 percent and to the nearest whole number for values exceeding 10 percent.

Determination of plastic limit and liquid limit of soil:

This test is done to determine the plastic limit of soil as per IS: 2720 (Part 5) – 1985.The plastic limit of fine-grained soil is the water content of the soil below which it ceases to be plastic. It begins to crumble when rolled into threads of 3mm dia. The apparatus used:

i) Porcelain evaporating dish about 120mm dia.
ii) Spatula
iii) Container to determine moisture content
iv) Balance, with an accuracy of 0.01g
v) Oven
vi) Ground glass plate – 20cm x 15cm
vii) Rod – 3mm dia. and about 10cm long

Preparation of sample:

Take out 30g of air-dried soil from a thoroughly mixed sample of the soil passing through 425μm IS Sieve. Mix the soil with distilled water in an evaporating dish and leave the soil mass for naturing. This period may be upto 24hrs.

Procedure to determine the plastic limit of soil:

i. Take about 8g of the soil and roll it with fingers on a glass plate. The rate of rolling should be between 80 to 90 strokes per minute to form a 3mm dia.
ii. If the dia. of the threads can be reduced to less than 3mm, without any cracks appearing, it means that the water content is more than its plastic limit. Knead the soil to reduce the water content and roll it into a thread again.
iii. Repeat the process of alternate rolling and kneading until the thread crumbles.
iv. Collect and keep the pieces of crumbled soil thread in the container used to determine the moisture content.
v. Repeat the process at least twice more with fresh samples of plastic soil each time.

Reporting of results:

The plastic limit should be determined for at least three portions of the soil passing through 425µm IS Sieve. The average water content to the nearest whole number should be reported.

This test is done to determine the liquid limit of soil as per IS: 2720 (Part 5) – 1985. The liquid limit of fine-grained soil is the water content at which soil behaves practically like a liquid, but has small shear strength. Its flow closes the groove in just 25 blows in Casagrande's liquid limit device. The apparatus used :-

i. Casagrande's liquid limit device
ii. Grooving tools of both standard and ASTM types
iii. Oven
iv. Evaporating dish
v. Spatula.
vi. IS Sieve of size 425µm.
vii. Weighing balance, with 0.01g accuracy.
viii. Wash bottle.
ix. Air-tight and non-corrodible container for determination of moisture content.

Preparation of sample:

i) Air-dry the soil sample and break the clods. Remove the organic matter like tree roots, pieces of bark, etc.

ii) About 100g of the specimen passing through 425µm IS Sieve is mixed thoroughly with distilled water in the evaporating dish and left for 24hrs for soaking.

Procedure to determine the liquid limit of soil:

i. Place a portion of the paste in the cup of the liquid limit device.
ii. Level the mix so as to have a maximum depth of 1cm.
iii. Draw the grooving tool through the sample along the symmetrical axis of the cup, holding the tool perpendicular to the cup.
iv. For normal fine grained soil: The Casagrande's tool is used to cut a groove 2mm wide at the bottom, 11mm wide at the top and 8mm deep.
v. For sandy soil: The ASTM tool is used to cut a groove 2mm wide at the bottom, 13.6mm wide at the top and 10mm deep.
vi. After the soil pat has been cut by a proper grooving tool, the handle is rotated at the rate of about 2 revolutions per second and the no. of blows counted, till the two parts of the soil sample come into contact for about 10mm length.
vii. Take about 10g of soil near the closed groove and determine its water content.
viii. The soil of the cup is transferred to the dish containing the soil paste and mixed thoroughly after adding a little more water. Repeat the test.

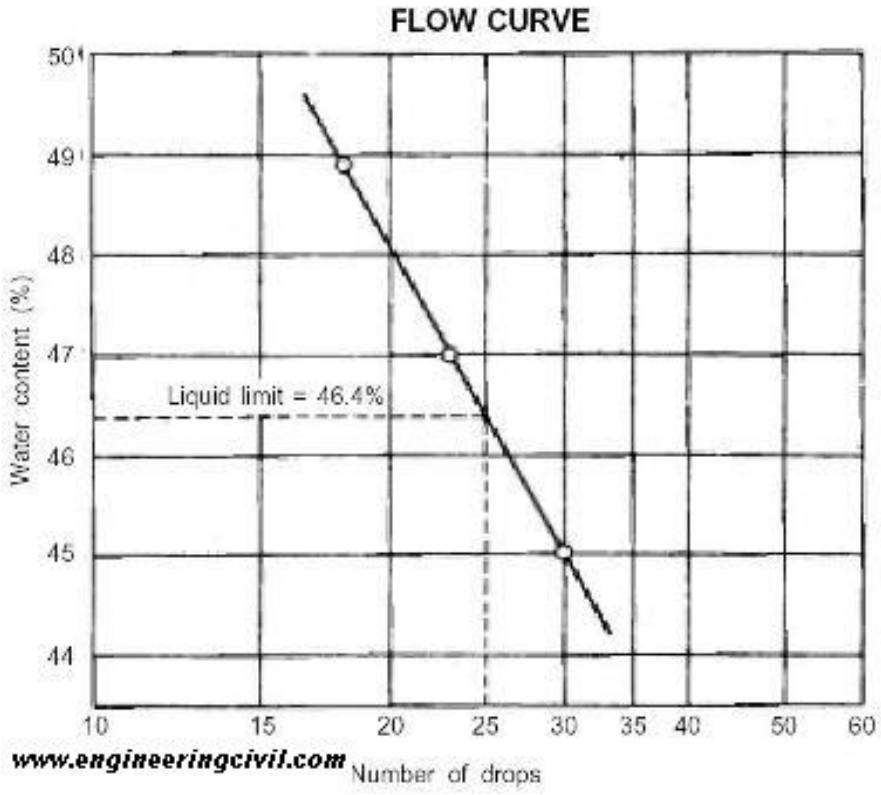
ix. By altering the water content of the soil and repeating the foregoing operations, obtain at least 5 readings in the range of 15 to 35 blows. Don't mix dry soil to change its consistency.

x. Liquid limit is determined by plotting a 'flow curve' on a semi-log graph, with no. of blows as abscissa (log scale) and the water content as ordinate and drawing the best straight line through the plotted points.

Reporting of Results:

Report the water content corresponding to 25 blows, read from the 'flow curve' as the liquid limit.

A sample 'flow curve' is given as:



Flakiness index and elongation index of coarse aggregates:

Aim:

i. To determine the elongation index of the given aggregates.
ii. To determine the flakiness index of the given aggregates.

Apparatus:

The apparatus for the shape tests consists of the following:

i. A standard thickness gauge.
ii. A standard length gauge.
iii. IS sieves of sizes 63, 50 40, 31.5, 25, 20, 16, 12.5,10 and 6.3mm.
iv. A balance of capacity 5kg, readable and accurate up to 1 gm.

Theory:

The particle shape of aggregates is determined by the percentages of flaky and elongated particles contained in it. For base course and construction of bituminous and cement concrete types, the presence of flaky and elongated particles are considered undesirable as these cause inherent weakness with possibilities of breaking down under heavy loads. Thus, evaluation of shape of the particles, particularly with reference to flakiness and elongation is necessary. The Flakiness index of aggregates is the percentage by weight of particles whose least dimension (thickness) is less than three- fifths (0.6times) of their mean dimension. This test is not applicable to sizes smaller than 6.3mm. The Elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than nine-fifths (1.8times) their mean dimension. This test is not applicable for sizes smaller than 6.3mm.

Procedure:

i. Sieve the sample through the IS sieves (as specified in the table).

ii. Take a minimum of 200 pieces of each fraction to be tested and weigh them.

iii. In order to separate the flaky materials, gauge each fraction for thickness on a thickness gauge. The width of the slot used should be of the dimensions specified in column (4) of the table for the appropriate size of the material.

iv. Weigh the flaky material passing the gauge to an accuracy of at least 0.1 per cent of the test sample.

v. In order to separate the elongated materials, gauge each fraction for length on a length gauge. The width of the slot used should be of the dimensions specified in column (6) of the table for the appropriate size of the material.

vi. Weigh the elongated material retained on the gauge to an accuracy of at least 0.1 per cent of the test sample.

Observations:

Flakiness Index = $(X_1 + X_2 + \ldots..) / (W_1 + W_2 + \ldots.) \times 100$

Elongation Index = $(Y_1 + Y_2 + \ldots) / (W_1 + W_2 + \ldots.) \times 100$

Result:

i. Flakiness Index =

ii. Elongation Index =

Aggregate impact value test:

This test is done to determine the aggregate impact value of coarse aggregates as per IS: 2386 (Part IV) – 1963. The apparatus used for determining aggregate impact value of coarse aggregates is:

i. Impact testing machine conforming to IS: 2386 (Part IV)- 1963.

ii. IS Sieves of sizes – 12.5mm, 10mm and 2.36mm.

iii. A cylindrical metal measure of 75mm dia. and 50mm depth.

iv. A tamping rod of 10mm circular cross section and 230mm length, rounded at one end and Oven.

Preparation of sample:

i. The test sample should conform to the following grading:
   - Passing through 12.5mm IS Sieve – 100%
   - Retention on 10mm IS Sieve – 100%

ii. The sample should be oven-dried for 4hrs. at a temperature of 100 to 110^{o}C and cooled.

iii. The measure should be about one-third full with the prepared aggregates and tamped with 25 strokes of the tamping rod.

A further similar quantity of aggregates should be added and a further tamping of 25 strokes given. The measure should finally be filled to overflow, tamped 25 times and the surplus aggregates struck off, using a tamping rod as a straight edge. The net weight of the aggregates in the measure should be determined to the nearest gram (Weight 'A').

Procedure to determine aggregate impact value:

i. The cup of the impact testing machine should be fixed firmly in position on the base of the machine and the whole of the test sample placed in it and compacted by 25 strokes of the tamping rod.

ii. The hammer should be raised to 380mm above the upper surface of the aggregates in the cup and allowed to fall freely onto the aggregates. The test sample should be subjected to a total of 15 such blows, each being delivered at an interval of not less than one second.

Reporting of results:

i. The sample should be removed and sieved through a 2.36mm IS Sieve. The fraction passing through should be weighed (Weight ‘B’). The fraction retained on the sieve should also be weighed (Weight ‘C’) and if the total weight (B+C) is less than the initial weight (A) by more than one gram, the result should be discarded and a fresh test done.

ii. The ratio of the weight of the fines formed to the total sample weight should be expressed as a percentage.

Aggregate impact value = (B/A) x 100%.

iii. Two such tests should be carried out and the mean of the results should be reported

Determination of bituminous content:

i. This test is done to determine the bitumen content as per ASTM 2172. The apparatus needed to determine bitumen content are:-Centrifuge extractor.

ii. Miscellaneous – bowl, filter paper, balance and commercial benzene.

iii. A sample of 500g is taken.

Procedure to determine bitumen content:

i. If the mixture is not soft enough to separate with a trowel, place 1000g of it in a large pan and warm upto 100^{o}C to separate the particles of the mixture uniformly.

ii. Place the sample (Weight ‘A’) in the centrifuge extractor. Cover the sample with benzene; put the filter paper on it with the cover plate tightly fitted on the bowl.

iii. Start the centrifuge extractor, revolving slowly and gradually increase the speed until the solvent ceases to flow from the outlet.

iv. Allow the centrifuge extractor to stop. Add 200ml benzene and repeat the procedure.

v. Repeat the procedure at least thrice, so that the extract is clear and not darker than the light straw colour and record the volume of total extract in the graduated vessel.

vi. Remove the filter paper from the bowl and dry in the oven at 110 + 5^{o}C. After 24hours, take the weight of the extracted sample (Weight ‘B’).

Reporting of results:

i. Bitumen content = [(A-B)/B]×100 %

ii. Repeat the test thrice and average the results.

Bibliography:

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