4.2 CBR TEST FOR SUBGRADE

Apparatus for CBR Test

Loading machine-any compression machine can operate at constant rate of 1.25mm per minute can be used. Cylindrical moulds- moulds of 150mm diameter and 175mm height provided with a collar of about 50mm length and detachable perforated base. Compaction rammer, surcharge weight-annular weights each of 2.5kg and 147mm diameter. IS sieve 20mm, Coarse filter paper, balance etc.

California Bearing Ratio (CBR) test was developed by the California Division of Highway as a method of classifying and evaluating soil-sub grade and base course materials for flexible pavements.

✓ CBR test, an empirical test, has been used to determine the material properties for pavement design. Empirical tests measure the strength of the material and are not a true representation of the resilient modulus.

✓ CBR decreases as the penetration increases. The ratio at 2.5 mm penetration is used as the CBR. In some case, the ratio at 5 mm may be greater than that at 2.5 mm. If this occurs, the ratio at 5 mm should be used. The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions.

✓ The test procedure should be strictly adhered if high degree of reproducibility is desired. The CBR test may be conducted in re-moulded or undisturbed specimen in the laboratory. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement.

Test Procedure

✓ The laboratory CBR apparatus consists of a mould150 mm diameter with a base plate and a collar, a loading frame and dial gauges for measuring the penetration values and the expansion on soaking.

✓ The specimen in the mould is soaked in water for four days and the swelling and water absorption values are noted. The surcharge weight is placed on the top of the specimen in the mould and the assembly is placed under the plunger of the loading frame.

✓ Load is applied on the sample by a standard plunger with dia of 50 mm at the rate of 1.25mm/min. A load penetration curve is drawn. The load values on standard

crushed stones are 1370 kg and 2055 kg at 2.5 mm and 5.0 mm penetrations respectively.

✓ CBRvalueisexpressedasapercentageoftheactualloadcausingthepenetrationsof 2.5 mm or 5.0 mm to the standard loads mentioned above. Therefore, Two values of CBR will be obtained. If the value of 2.5 mm is greater than that of 5.0 mm penetration, the former is adopted. If the CBR value obtained from test at 5.0 mm penetration is higher than that at 2.5 mm, then the test is to be repeated for checking.

✓ If the check test again gives similar results, then higher value obtained at 5.0 mm penetration is reported as the CBR value. The average CBR value of three test specimens is reported as the CBR value of the sample.

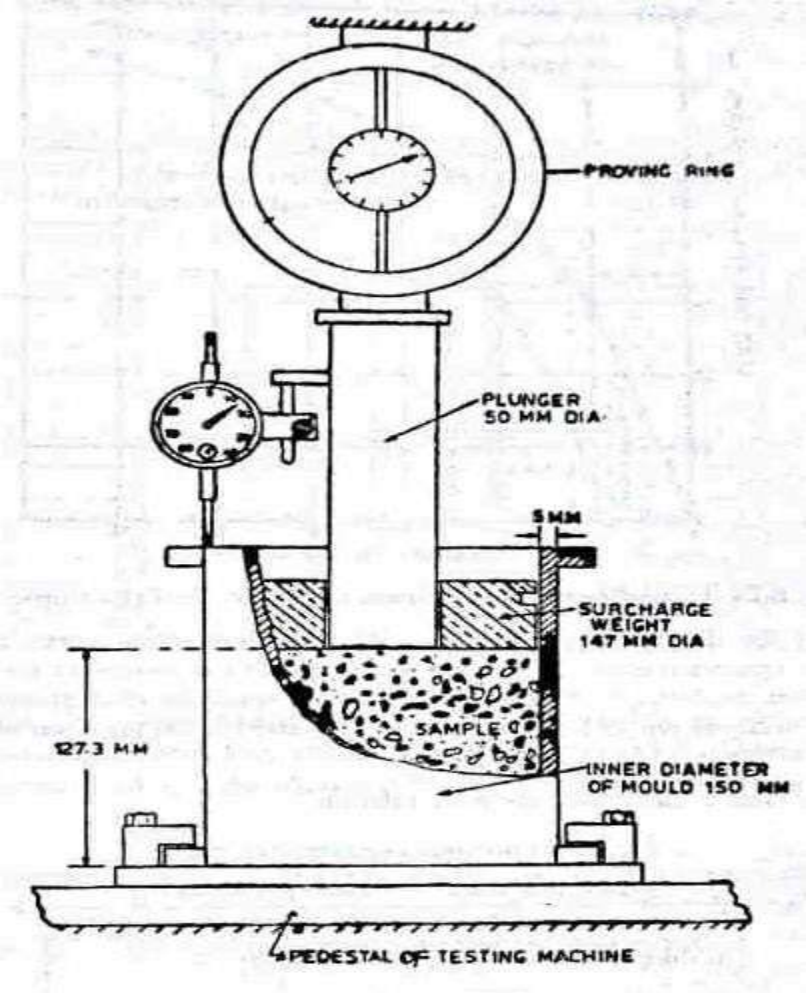


Figure 4.2.1 CBR Test

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 289]

4.7 CONSTRUCTION PRACTICES

WATER BOUND MACADAM ROAD

Excavation

The box cutting shall be done in such a way, that the width of cutting is exactly that of the sub-base width. The depth of cutting shall be total thickness of sub-base, consolidated soling, road metalling and bituminous wearing course.

Preparation of the Subgrade

After the box cutting is completed the formation shall be watered and rolled to a proper gradient and camber with a road roller of 8 to 10 tonnes weight minimum, for thorough compaction, care shall be taken to avoid excessive rolling of the formation

Preparation of the Sub-base

- After rolling of the subgrade is completed, the granular sub-base material shall be laid in two separate layers of 150mm and 200mm respectively and consecutively or as specified in the drawing and as instructed by Engineer In Charge.
- The first layer of 150mm, shall be laid over the compacted sub-grade between the edges of box-cutting, watered and rolled to a proper gradient and camber with a road roller of 8 tonnes weight minimum for thorough compaction to achieve a CBR value greater than 20%.
- Subsequently the second layer of 200mm shall also be laid over the first layer, watered and rolled to a proper gradient and camber with 8 tonnes road roller and thoroughly compacted with a CBR valve of 10% is achieved. Excessive rolling shall be avoided.

Base Course

- The stones shall be laid closely packed to the profile of the finished road surface in such a way that these shall not move under pressure.
- A thin cushion of murrum shall be placed over the sub-base and packed with the stone. The joints shall preferably be staggered. Soling shall commence from edges and proceed towards the center.
- The profile of the soling shall frequently be checked with templates as the laying progresses. When a sufficient length of soling has been laid this shall be watered and packed with a power road roller of not less than 8 tonnes capacity and the surface shall be evened by blinding with small pieces of stone and chipping during rolling.
- A final thin cushioning with murrum shall be spread over the surface and watered and lightly rolled. Rolling shall be continued till the required compacted thickness is obtained.

Wearing course

- Road metal from road side stacks shall be raked on to the carriage way soling course directly. Spreading shall be done to the specified camber and thickness, but never more than 100mm at a time to make a consolidated thickness of at least 75mm after rolling.
- Two such layers shall be spread and consolidated separately but consequently to form a total compacted thickness of 150mm.
- The surface so laid in each layer shall be checked up by means of wooden templates and spirit levels placed every 6 to 7 meters, the top surface being dressed up and hand packed with smaller pieces of stone between successive templates. Transition strips and curves shall be checked up very carefully

Dry-Rolling

- When spreading has been done for a sufficient length (not less than 15M) and checked up with templates, dry rolling shall be started with a power road roller of 8 tonnes minimum weight, to obtain perfect inter locking of the adjacent pieces of stones.

  AddingScreenings

- When the desired degree of compaction has been obtained by dry rolling screenings of approved stone chippings shall be spread uniformly over the surface by brooming and these shall be pushed into the interstices by rolling, successive layers of screenings being added till no more chippings are taken up by the surface.
- Anyunevenness observed shall be rectified by removing stones to a depth of 50 to 75mm, refilling the same, hand packing and re-rolling. No watering shall be done till the process is complete.

Spreading of blindage and wet rolling

- Approved quality blindage such as murrum or sandy loam shall then be spread uniformly over the surface to a thickness of about 12mm, copiously watered and rolled.
- The roller wheels as well as the road surface shall be constantly watered during the wet rolling and nay stone piece picked up shall be replaced by hand.
- The rolling shall be continued until a slurry is formed over the entire surface and the same moves in a wave in front of the roller wheels as it moves, when rolling may be stopped and the surface allowed to dry.
- The finished surface shall be smooth and uniform, free from waviness and corrugations and as per specified profile and camber.

Finishing, curing and opening up the road to traffic

- After 24 hours of wet rolling, the surface shall be covered with a thin layer of sand (about 12mm thick) for curing.
- Ordinarily the newly consolidated surface shall not be opened to traffic till it is dry which may take 2 to 4 days depending on weather conditions. As the surface dries up the road maybe opened to traffic

BITUMINOUS ROAD

Preparation of Existing Water Bound Macadam Surface:

- The existing water bound macadam surface shall be brushed, cleaned properly with wire brushes and coir brooms, so as to free from all loose materials, murrum, earth, silt and caked mud etc.
- If during the process of cleaning the sub grade (water bound macadam), soft spots and pockets, hollows etc. are found, such spots/pockets will be filled with approved precoated bituminous chips, consolidated and finished to proper level, rolled with power roller if necessary.
- The pot holes shall be excavated properly in a rectangular or rhomboidal shape with vertical edges.
- The bottom and sides shall be cleaned as stated above. The sides and bottom shall then be thoroughly painted with heated 80/100 penetration bitumen.
- The pot hole shall thereafter be filled with premixed bituminous chips so that after thorough tamping and rolling, the surface is flush with surrounding road surface.

HOT MIXED HOTLAID BITUMINOUS ROAD:

Tack Coat: Bitumen of the grade as specified in the Schedule of Quantities shall be heated to a temperature of 1630 C to 1770 C (3250 F to 3500 F) in a bitumen boiler and the hot bitumen shall be applied evenly to the thoroughly cleaned and prepared road surface (as specified here-in-before) @ 8.5 kg. per 10 sqm.

- Leaving no part of the surface unpainted. Application shall be done by a mechanical pressure sprayer or if permitted, by perforated pouring cans.
- The tack coat shall be applied just before the macadam is laid. Application of tack coat shall be only slightly in advance of laying premixed chips. In case of surface already asphalted application of tack coat is not necessary.

Compaction : The base bituminous macadam course shall be compacted thoroughly and evenly with 8 to 10 tonne power roller immediately after it is laid. Compacted thickness shall be as specified in schedule of quantity.

- The surface shall be checked for correct grade during and after rolling.
- Any irregularities shall be corrected by adding precoated chips or removing the surplus.
- The disturbed surface shall be well compacted again. If necessary,
- the roller wheel shall be coated with oil to prevent the coated chip from sticking to the wheels.
- Rolling shall be continued till no wheel marks are left on the surface.

CEMENT CONCRETE ROAD

The various construction steps for laying of cement concrete pavement slab are describe below:-

- Preparation of sub grade
- Preparation of base course
- Placing of form work
- Watering of surface
- Mixing and placing of concrete
- Compaction and finishing
- Belting, Brooming and Edging
- Curing
- Opening to traffic

Preparation of sub grade

The sub grade is the natural soil which is properly compact by rollers and is brought to require camber and gradient. The cross and longitudinal profile should be check by suitable templates.

Preparation of base course

Over the prepare subgrade, base course or sub base course is sometimes providing. In certain cases, where the bearing capacity of subgrade soil is high, base or sub base layer may be omitting. The base for a concrete road may be WBM surface, compact granular material layer or stabilise soil base. The base or sub base layer not only provides a smooth level surface and a supporting layer, but it also reduces the thickness of concrete slab.

Placing of form work

After preparing the base, form work for concrete slab pavement is lay. The forms can be of steel or timber. The depth of form work should be equal to the thickness of slab. Form work should be rigidly fix in position and must be well in advance from the point where concrete mix is to be place. It should be oil properly from inside and must be check to line and grade.

Watering of surface

After laying form work, the surface of base or subgrade must be wet with water before placing of concrete mix. Water should not be allowed to stand on the surface during wetting operation. The main function of watering is to saturate the surface completely so that it should not absorb any water from the concrete mix.

Mixing and placing of concrete

The ingredients of concrete such as cement, sand and coarse aggregates are mix in a dry state in the ratio 1 2: 4. The mixing should be doing preferably in a concrete mixer. The

water should be adding in a measure quantity to obtain the design water cement ratio.

The concrete mix is place in the lay form works by manual labour and it should be deposit in layers of thickness not more than 50 mm to 80 mm. The concrete mix should be lay on the entire width of the form work and always proceed lengthwise. The technique of construction may be alternate bay or continuous bay method. The top most layer should be lay 6 mm to 12 mm higher than the specify profile for further tamping work. The require transverse and longitudinal joints should be provide and it should be ensure that the top layer is lay to the desired camber and gradient.

Compaction and finishing

After placing of concrete mix, it should be compact by vibrating hand screeds or hand tampers. For large scale construction work, power drive vibrators or machines may be use. The hand tampers are use across the bay and tamping of the surface is doing along the length of the bay.

Hand tampers for compaction of concrete mix

For finishing the concrete surface, wooden hand floats are usually used. The main function on floating is to develop a uniform and even surface pavement devoid of any waves or corrugations. The floating is always doing in longitudinal direction. Float is held in position parallel to the centre line of pavement and move gradually from one side to the other. Straight edge with 2 handles is use to check the finish pavement surface for its grade and level in longitudinal direction.

Belting, Brooming and Edging:

Belting is do in transverse direction to the carriage way by a 150 to 300 nm wide strip of canvas or rubber fit with handles at both ends. The belting is doing to finish the surface of concrete just before the concrete sets or hardens.

Canvas belt for finishing

After belting, brooming of pavement surface is carrying out immediately with a fibre broom brush. Brooming is carrying out, to make the pavement surface rough and non-slippery having skid resistance. After brooming, edging tool is use for rounding the transverse and longitudinal edges of the pavement slab. The process of edging is carrying out before the concrete mix develops initial Setting.

Curing

Initial curing of finish pavement is carry out after 12 hours by covering the surface with gunny bags which are keep wet for at least one day. For final curing, gunny bags are removing and surface is cover with a sandy layer which is keep wet for at least 14 days.

Curing of finish pavement may also be carry by:

Application of liquid impervious membrane.

Ponding method in which whole surface is dividing into small bays by forming earthen banks which are fill with water. After curing is complete, a surface is clean properly and washes.

Opening to traffic

Road pavement is open to traffic after 28 days of curing slab or even earlier when the concrete has attained require strength. During this period, brick edging is constructing to protect the slab. Earth may be spread on the berms up to the top of brick edging to disallow the traffic.

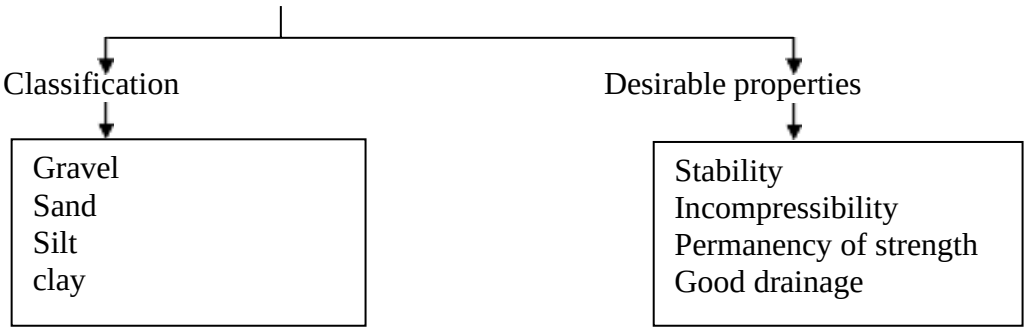
4.1 HIGHWAY CONSTRUCTION MATERIALS

Good quality construction material makes superior pavements. Thickness, performance and efficiency of pavements depend upon quality of highway materials. Highway materials include:

1. Sub-grade soil
2. Stone aggregates
3. Bituminousmaterials
4. Cement and cement concrete

Classification,Characteristics and Desirable Properties:

1. Sub-grade soil



2. Stone aggregates

3. Types of bituminous material:

- ✓ Asphalt
- ✓ Bitumen
- ✓ Cutback bitumen
- ✓ Bitumen emulsion

Desirable Properties of Aggregates

1. Strength
2. Hardness
3. Toughness
4. Durability
5. Shape of aggregates
6. Adhesion with bitumen

1. Strength

- ✓ The aggregates to be used in road construction, particularly the aggregates used in the wearing course of the pavement should be sufficiently strong/ resistant to crushing to withstand the high stresses induced due to heavy traffic wheel loads.

2. Hardness

- ✓ The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic.
- ✓ Abrasive action may be increased due to the presence of abrasing material like sand between the tyre of vehicle and the aggregates exposed to the top surface.
- ✓ It should be hard enough to resist the wear due to abrasive action of traffic.

3. Toughness

- ✓ Aggregates in the pavement are also subjected to impact due to moving wheel loads.
- ✓ The magnitude of impact increase with roughness of road and speed of vehicle. Severe impact is common when heavily loaded steel tyre vehicles move on WBM.
- ✓ The resistance to impact or toughness is thus another desirable property of aggregates

4. Durability

- ✓ The aggregates are subjected to physical and chemical actions of rains and ground water, the impurities in them and that of atmosphere.
- ✓ The road stones used in the construction should be sound enough to withstand the weathering action. The property of aggregates to withstand the adverse actions of weather may be called soundness.

5. Shape of Aggregate

- ✓ Road aggregates may be rounded, angular, flaky or elongated.
- ✓ Flaky and elongated particles have less strength than rounded and cubical particles. Thus, too flaky and too much elongated particles should be avoided.

6. Adhesion with Bitumen

- ✓ The aggregates in bituminous pavements should have less affinity with water when compared with bitumen, otherwise the bituminous coating on the aggregates will be stripped off in presence of water.

4.6 Highway Drainage

Highway drainage may be defined as the process of interception and removal of water from over, under and the vicinity of the road surface. Road drainage is very important for safe and efficient design of the road way and hence is an essential part of highway design and construction

Effects of Improper Drainage

One of the major causes of road failure is its improper drainage. Improper drainage of the road causes destruction in the following ways:

- ✓ Road surface if made of soil, gravel or water bound macadam, it will becomes soft and losses strength
- ✓ .The road sub-grade may be softened and its bearing capacity reduced.
- ✓ Variation in moisture content in expensive soils, causes variation in the volume of sub-grade and thus causes failure of roads.
- ✓ Failure of formation slopes is also attributed to poor drainage.

Highway Drainage Requirements

- ✓ Surface water should not be allowed to remain standing on the road pavement and shoulders. Measures should be taken to drains off this water,immediately.
- ✓ The surface rain water from the adjoining area, should not be allowed to come towards the road surface. For this, general slope of the ground adjoining road, should be made slopping away from the road. This objective can be achieved by aligning road on ridge.

Types of Highway Drainage

1. Surface Drainage

It is the road drainage in which the surface water of the road is collected and disposed within right-of-way of the road.

Surface drainage is basically designed to prevent the flow of surface water to the shoulders, sub-grade or any other layer of the road surface.

Basic Functions of Surface Drainage :

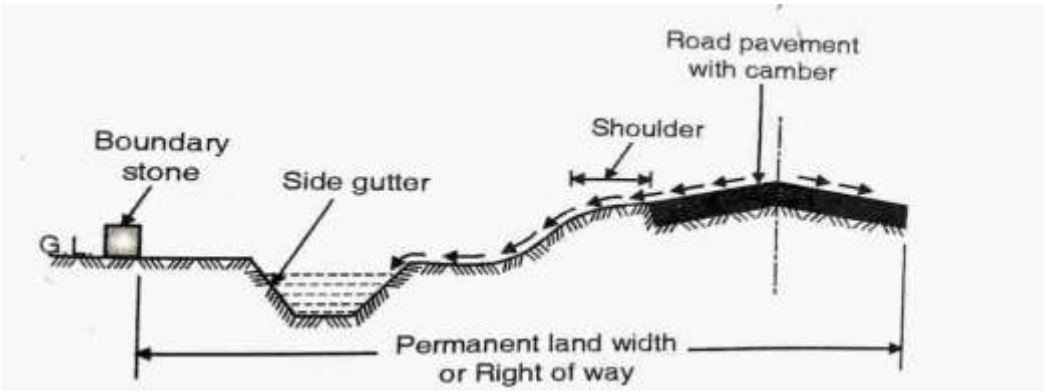
- The maintain the road surface completely dry from water.
- To collect the drained off water from the road surface.
- Increase the stability of the road or highway.

- By using the gravitational force, carrying of collected water into nearby stream or river or nallah.

1a. Side Gutter :

Side gutters are generally constructed parallel to the side of the road and it disposes the surface water efficiently.

Below figure shows the side gutter or side drain in cutting and embankment provided for proper surface drainage. The section of side drain is generally trapezoidal, but generally triangular side gutters are also provided in cutting.
They are basically provided parallel to the road surface only when the designed depth of the side drains is less and the road is subjected to light traffic.



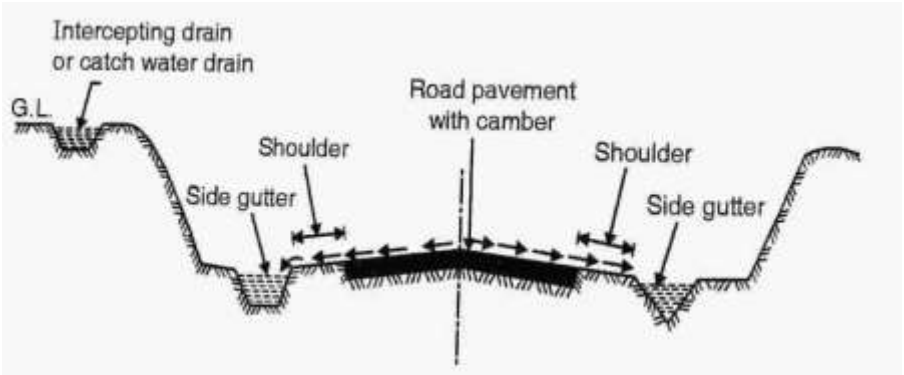


Figure 4.6.1 Side Gutter

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 530]

Functions of Side Gutter :

- The main function is to collect the surface water and further these side drains ultimately join the natural streams and nalla or rivers.
- They can be constructed and maintained in very low budget. But they give unpleasant look due to deep ditch. Hence they are not adopted when the traffic is heavy.

1b. Catch Water Drain :

When the gutters or drains are additionally provided parallel to the road at higher level for collecting and disposing the surface water is known as catch water drain.

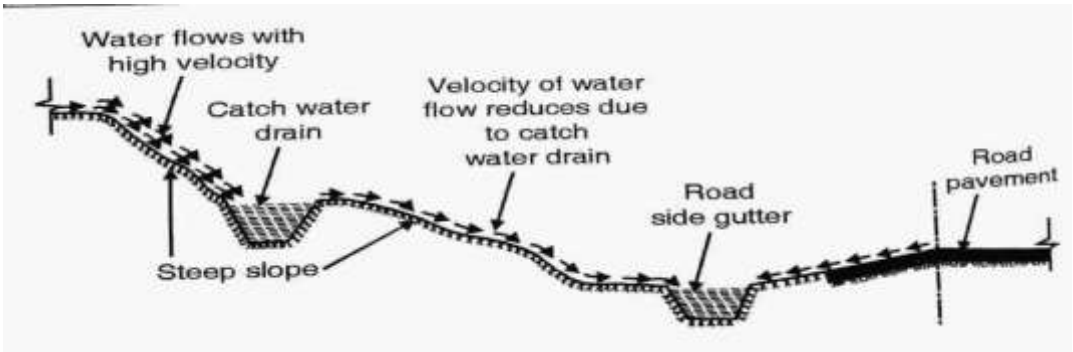


Figure 4.6.2 Catch Water Drain

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 532]

Generally catch water drain is provided under following conditions :

- When the adjoining ground is steep towards roadside.
- In case of hill roads, when the rainfall is heavy.
- When the quantity of water flow on sloping ground is more.

Functions of Catch Water Drain :

The catch water drain intercepts the large quantity of the surface water flow and also breaks the continuity of flow and thereby reduces the velocity of water and prevents the erosion and landslides and thereby protect the road pavement. Catch water also help in reducing the size of side gutters or side drains.

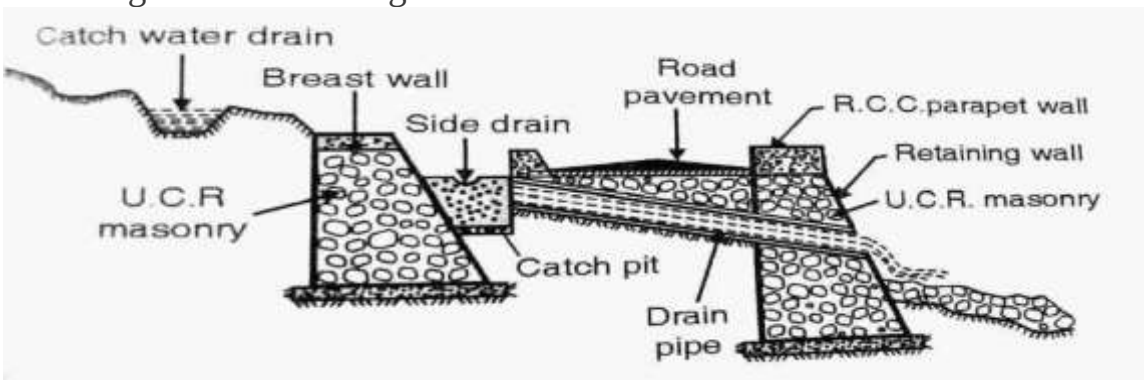


Figure 4.6.3 Sectional Area Catch Water Drain

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 532]

Sectional area of catch water drains are generally 0.9 m*0.9 m* and should be constructed normally at 4.5 m from the road edge.

If surface water flowing from the high level ground towards the road is large then it is desirable to take this water across the road at regular intervals and then allow this water to flow through the pipe drain constructed through the road embankment to the natural stream.

2. Sub-surface Drainage of Road

Sub-surface drainage is the system in which the sub-soil water from underside of road pavement is collected and removed efficiently. It is generally adopted to control the moisture content of road sub-grade.

If the moisture content in the sub-soil increases, it can weaken the road structure. Hence it becomes more important to control the moisture of road sub-grade.

Factors increasing the sub-soil moisture content are as follows :

- Increase in ground water table.
- Water seepage from adjoining areas.
- Surface water percolation through joints and cracks.
- Rise of the moisture above ground water table which is caused by the capillary action.

Thus longitudinal drains, cross drain and impervious bituminous layer are provided to prevent the rise in sub-soil moisture or sub-surface moisture and its specially provided to control the capillary rise.

Functions of sub-surface drainage :

- It prevents and controls the moisture content of the road sub-grade.
- To maintain the bearing capacity of the sub-grade soil by restricting the entry of water into it.
- To reduce the capillary rise, because sometimes due to capillary action, the water rises into the sub-grade from the ground water.

Longitudinal Drains (L-Drains) and Cross Drains :

Water table can be lowered by providing longitudinal drains and cross drains below the pavement structure at the specified depth.

Longitudinal pipes are placed with open joints butting against each other and laid on a bed of sand, crushed stone of 150 mm thick.

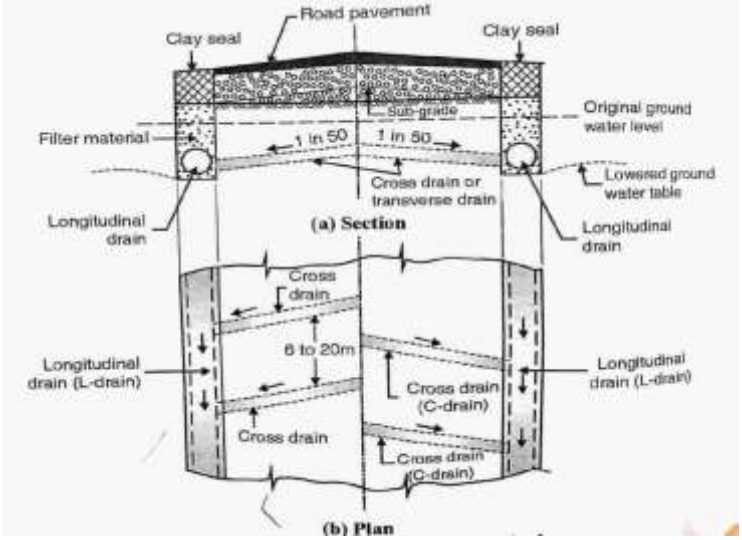


Figure 4.6.4 Longitudinal Drains(a)

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 534]

The diameter of L-drain pipes varies from 150 mm to 200 mm. In addition to longitudinal drains, Cross drains (C-drains) or transverse drains consisting porous pipes or perforated pipes are laid cross from the center of the road and opened to the L-drains with slope of 1 in 50.

The diameter of C-drains varies from 60 to 100 mm. There arc two cases of providing the longitudinal and cross drains.

In first case, the main longitudinal drain pipes may be provided on both the sides as shown in fig.

In this case, slope of cross drains is kept 1 in 50 from center towards the sides. This case of providing the L-drains on both the sides is comparatively costly but can be easily constructed and maintained.

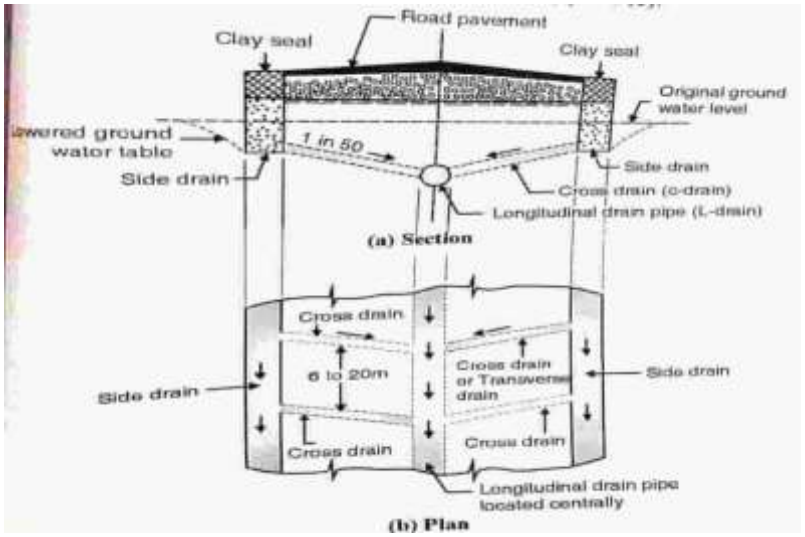


Figure 4.6.5 Longitudinal Drains(b)

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 534]

In second case, the main longitudinal drain pipes may be provided at the center sufficiently below the road pavement and side drains may be opened to the cross drains consisting porous or perforated pipes.

The slope of the cross drains or transverse drains is kept 1 in 50 from side drains towards the main longitudinal drain pipe

4.4 Modern Construction Materials Used for the Construction of Pavements

Steel slag aggregate is a good example of synthetic aggregates obtained from by- products of industrial processes. It has good binding properties with bitumen due to its high calcium oxide content (NatSteel 1993).

The angular shape of the aggregates helps to form strong interlocking structure. Road paving with steel slag aggregate show good skid resistance mechanical strength able to withstand heavy traffic and surface wearing. Also, many industrial and other waste products like fly-ash, cement kiln dust, incinerated refuse etc. have been successfully used to produce synthetic aggregates.

Mixing bitumen with rubber (natural or crumb form) sometimes poses difficulty. As an alternative approach, tiny crumb rubber pieces can be mixed with aggregates - known as dry- process, this process does not require any modification to the existing batch mixing plant.

Polymer Modified Bitumen is emerging as one of the important construction materials for flexible pavements. Use of plastic waste in the construction of flexible pavement is gaining importance because of the several reasons.

- ✓ The polymer modified bitumen show better properties for road construction & plastics waste, otherwise considered to be a pollution menace, can find its use in this process and this can help solving the problem of pollution because most of the plastic waste is polymers.
- ✓ In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate.
- ✓ It also helps to improve the strength of the road. But its resistance towards water is poor. Antistripping agents are being used. A common method to improve the quality of bitumen is by modifying the rheological properties of bitumen by blending with organic synthetic polymers like rubber and plastics.

Geo- textile is any permeable textile material used with foundation, soil, rock, earth, etc. that is an integral part of a constructed project, structure or system.

- ✓ It may be made of synthetic or natural fibers. In contrast; a geo-membrane is a

continuous membrane-type liner or barrier. It must have sufficiently low permeability to control migration of fluid in a constructed project, structure or system.

✓ A geo-textile is designed to be permeable to allow the flow of fluids through it or in it, and a geomembrane is designed to restrict the fluid flow.

Separation

In this function, the geo-textile serves to separate two dissimilar materials, eg, two different soils, landfill material and the native soil, stone material and sub-grade soil, old and new pavement, foundation soils and various types of walls, or one of many other similar situations. In some instances, it is difficult to distinguish between the separation and stabilization functions because in both situations the geo-textile is serving as a separator. However, in stabilization some additional phenomena occur.

Stabilization

In this application, the natural soil on which the geo-textile is placed is usually a wet, soft, compressible material, exhibiting very little strength. By acting as a separator, the geo-textile allows water from the soft natural soil to pass from this soil into a free-draining construction soil, which in turn allows consolidation of the natural soil to take place. As a result of the consolidation process, there is a strength gain in the natural soil, which then provides an adequate foundation for construction to take place.

Reinforcement

✓ The key difference between stabilization and reinforcement is that stabilization is accomplished by providing for drainage of water from the unstable soil, while in reinforcement the strength characteristics (stress–strain) of the geo-textile provide added strength to the whole system.

✓ Another difference is that in stabilization the geo-textile is placed on or around the area being stabilized and thereby also acts as a separator, whereas in the reinforcement application the geotextile is placed within the material being reinforced. This is in line with reinforcement concepts in concrete and other materials.

Filtration

✓ Here the prime function is to retain soil or other fine materials, while allowing water to pass through. Again, it is seen that more than one function is being

performed.

- ✓ If there were no drainage of water taking place, movement, and therefore retention of the soil, would not be of concern. Part of the mechanism by which filtration occurs is through the development of a soil filter behind the geo-textile.
- ✓ As the water passes through, soil is filtered out and collects behind the geo-textile. As buildup takes place, a natural soil filter is developed.

Drainage

- ✓ Drainage parallel to the plane of the geo-textile is described. The property called transmissivity is defined as flow parallel to the plane of the geotextile.
- ✓ This type of flow can occur to some extent in all geo-textiles, but is best achieved in needle-punched non-woven materials.
- ✓ This class of geo-textiles can be manufactured in a range of thicknesses such that this characteristic is optimized.

Moisture Barrier

- ✓ When impregnated with an asphaltic emulsion, geo-textiles become impermeable and can then be used as moisture barriers. The primary application for this type of geo- textile is in pavement rehabilitation.

Fiber Reinforced Bituminous Mix

Addition of various kinds of fibers to the binder and aggregates during mix preparation process results in fiber reinforced bituminous mix (FRBM). Fibers are generally blended with bitumen binder before mixing it with the aggregates to achieve complete coating and even distribution throughout the mix.

Bituminous Recycling

In recycling method, bitumen and aggregates are separated out (partly or fully) and used again. The specific benefits of recycling of bituminous pavement can be summarized as:

- ✓ Conservation of energy and construction material.
- ✓ Prevention of undesirable rise in height of finished surface and preservation of the existing road geometrics.
- ✓ Reuse of deteriorated road materials which in turn solves the disposal problem.
- ✓ Solution to the problem of scarcity of good quality material.

- ✓ Preservation of the environment.
- ✓ Reduction in susceptibility to reflection cracking.

Bitumen ages due to oxidation with atmospheric oxygen as a result of which resins get converted into asphaltenes (Petersen, 1984). By this process bitumen loses its ductility and becomes more brittle. Recycling is based on the fact that bitumen obtained from old deteriorated bituminous pavement, may still has its residual properties and recycling helps in restoring those residual properties of the bitumen.

To judge the suitability for use as a recycled material, aggregates are tested for their gradation and bitumen is tested for its engineering properties. The optimum quantity of reclaimed material to be mixed with fresh material is generally determined from mix design process. Fresh thin (soft grade) bitumen having low viscosity can be used to replenish the aged bitumen. Rejuvenators (like road oils and flux oils) are sometimes added for improvement in properties of reclaimed bitumen.

There are four major technologies exist for bituminous pavement recycling :

(i) Hot mix recycling

Here recycled asphalt pavement (RAP) is combined with fresh aggregate and bituminous binder or recycling agent in a hot mix plant. Mix is transported to paving site, placed, and compacted.

(ii) Cold in-place recycling

In this the existing pavement is milled up to a depth of 75 to 100mm, RAP, if necessary and recycling agent in emulsion form is introduced, then compacted.

(iii) Hot in-place recycling

In hot in-place recycling method the existing asphalt surface is heated, scarified to a depth from 20 to 40 mm, scarified material combined with aggregate and/or bituminous binder and/or recycling agent and compacted. New overlay may or may not be provided.

(iv) Full depth reclamation

Here all the bituminous layers and predetermined thickness of underlying material is pulverized, stabilized with additives, and compacted. A surface course is applied over it.

4.8 Pavement Construction Machinaries

Necessity of Machinary

- Increase the rate of output through work progress
- Reduce the overall construction costs
- Carry out activities which cannot be done manually
- Save construction time
- Maintain the planned rate of production
- Maintain the high quality standards
- Eliminate the various hazards and health issues

Selection of Machinery

The selection of a machinery is based on the following factors;

- Purchase Cost
- Depreciation
- Maintenance
- Fuel

EXCAVATION MACHINERY

1.Excavators

Excavators are being used at site as follows;

- Digging of trenches
- Material handling
- Forestry work
- Demolition
- Heavy lift
- Mining etc.

Performance of excavator can be measured from the production cycle.

- It is the time that an excavator took to load the bucket from source, swing, dump, return back and dig again.
- Therefore, faster the operation speed, the faster will be the complete and hence production cycle will be increase.

2. Chain Excavator

- Chain wheel system
- Used in hilly areas where risks of sliding of machinery are on the verge.
- Chain excavators has low ground pressure because of spreading of load on large area.Therefore,it is also used where soil support is weak.

3. Dragline

Dragline is being used for the following purposes;

- Used to excavate earth and load it into hauling units
- Used to deposit the excavated earth on the banks
- To dig soft or medium hard materials
- Digging is at or well below ground level
- Where materials are to be lifted from a pit
- Where wet conditions exist

Advantages:

- Can do the underwater digging work
- For digging from the pit, need not to go into the pit.

Disadvantages:

- To increase the length of the boom means to decrease the size of the bucket.

4. Dozers

Bulldozers used for the following operations

- Level the earth
- Clear construction site of debris
- Clear floors of the borrow pits
- Back-fill trenches
- Move earth for distances from 80 to 100 meters
- Construct temporary roads through difficult areas.

Classification

On the basis of blades direction

• Bulldozers: These are mounted blades, perpendicular to the direction of travel.

• Angle dozers: These are mounted with the blades set at an angle with the direction of travel . The angle of inclination of the blade is kept up to 65 degree

On the basis of mountings

• Wheel-tractor mounted bulldozer

• Crawler-tractor bulldozer

According to the method of raising and lowering the blades

• Cable controlled and Hydraulic controlled

5.Back hoe

A backhoe, also called a rear actor or back actor, is a piece of excavating equipment consisting of a digging bucket on the end of a two-part articulated arm.

ROAD LEVELING MACHINERY

Grader

A grader,is construction machine with a long blade used for the following purposes;

- For spreading heaped earth into layers
- For maintaining cross section of the embankment
- For shaping the cross section during construction
- The output of a grader in four passes, is about 1300 sq. m per hour.
- Length of blade is about 3.5 meter.
- It is capable of turning, tilting, raising and lowering

General graders used are of power 100 to 150 HP

ROAD COMPACTING MACHINERY

1.Roller

Roller is one of the essential equipment required for road construction. A road roller is a compactor type engineering vehicle used to compact;

- Soil
- Gravel
- Asphalt in the construction of roads

Rollers are of the following types;

- Smooth wheeled rollers
- Pneumatic tyred rollers
- Sheep's foot rollers
- Vibratory rollers

Smooth Wheeled Rollers:

- May be of two axles or three axles
- Three axles rollers are very heavy and generally not used in road construction
- Two axles rollers may be of two wheels or three wheels
- Three wheeled rollers having weight 8-10 tones
- Two wheels rollers are called tandem roller
- Diameter and width of rear roll is 145 cm and 50 cm
- Rolling width is 200 cm

Pneumatic Tyred Rollers:

- Usually used in for compacting asphalt layer in road construction
- The rear axle has one wheel more than the front axle
- Rear wheels are spaced in such manner that these travel over the surface between the front wheels
- Generally four wheels in front and five in rear

Viboratory Rollers:

- These rollers vibrates during the compaction
- Suitable for granular soil
- Steel drum is 1.2 to 1.5 m long and 0.9 to 1.2 m in diameter
- Weighs from 0.5 Ton to 15 Ton
- Help to increase the shear capacity of earth

Sheep's Foot Rollers:

• Consist of hollow circular steel drum with steel projections in the form of sheep's foot

• Projections are called tamping feet

• Steel drum is 1.2 to 1.5 m long and 0.9 to 1.2 m in diameter

• Weighs from 3 Ton to 4.5 Ton

Suitable for cohesive soils

TRANSPORTATION MACHINERY

- The equipment used for transportation of material are known as hauling equipment.
- Haulers may operate on the roadways or railways. It involve
- Transportation of materials.
- Carriage and disposal of excavated earth.
- Haulage of heavy construction equipment.

1. Dump Truck

- A dumper truck is a truck used for transporting loose material such as sand, gravel, or dirt) for construction.
- Dump truck is fitted with a trolley at the rear which can be tilted.
- The trolley is lifted with the help of one or two hydraulic operated pistons.

2.Tractor Trolley

Tractors have many uses as construction equipment, their primary purpose is to pull or push loads. They are used as mounts for many other accessories such as front-end shovels

WATERING MACHINERY

Water Bowser

- Use for watering purpose on road

PAVEMENT MACHINERY

1.Bitumen Sprayer

- This Equipment is used for tack coat and Bitumen Spraying application.
- It is capable of applying a uniform unbroken coating of hot Bitumen on specified surface in prescribed quantity.

2.Paver

- A paver (asphalt finisher, paving machine) is a piece of construction equipment used to lay asphalt on roads, bridges, parking lots and other such places.
- It is very suitable for multi lane roads.
- Can maintain the specified thickness of the layer.
- The paver operates at speed of 1.5 to 10 m per minute.
- The mat width can be adjusted in the range of 2 to 5 meter.

3.Concrete Transirt Mixer

- They are mainly used for transporting concrete from batching point.

capacity:- 3cum- 9cum.

- A concrete plant, also known as batching plant, is a device that combines various ingredients to form concrete.
- A concrete plant can have a variety of parts and accessories, including mixers,conveyors, aggregate bins, cement bins, heaters,batch plant controls.
- The center of the concrete batching plant is the mixer.

4. Vibrator

- To eliminate the air voids in reinforced concrete
- Increases the unit weight of the concrete
- Due to less voids, lesser water absorbs
- Less voids increase the strength of the concrete

4.4 TESTS ON AGGREGATES

Abrasion Test

- The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge.
- Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated.
- An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g is placed in the cylinder along with the aggregates.
- The number of the abrasive spheres varies according to the grading of the sample.
- The quantity of aggregates to be used depends upon the gradation and usually ranges from 5-10 kg.
- The cylinder is then locked and rotated at the speed of 30-33 rpm for a total of 500 - 1000 revolutions depending upon the gradation of aggregates.
- After specified revolutions, the material is sieved through 1.7 mm sieve and passed fraction is expressed as percentage total weight of the sample.
- This value is called Los Angeles abrasion value. A maximum value of 40 percent is allowed for WBM base course in Indian conditions. For bituminous concrete, a maximum value of 35 is specified.

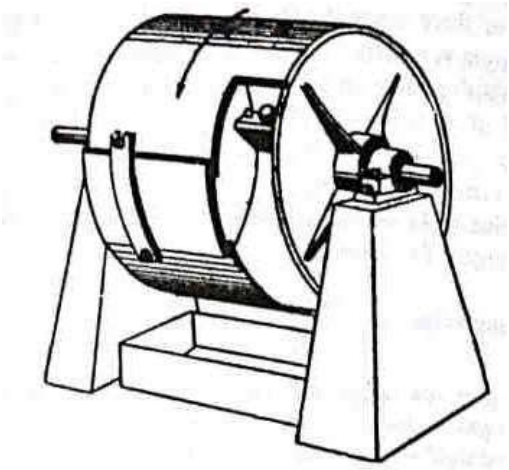
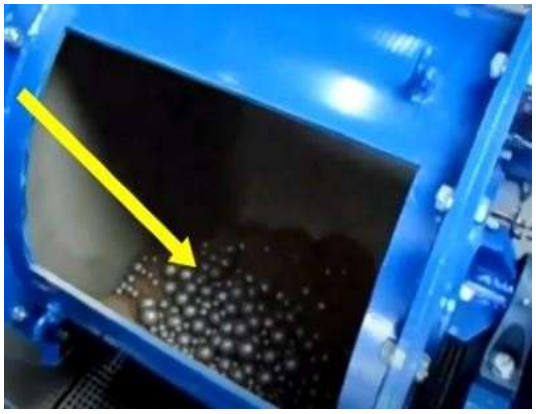


Figure 4.4.1 Los Angeles Abrasion Test Machine

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 296]



Impact Test

- The aggregate impact test is carried out to evaluate the resistance to impact of aggregates.
- Aggregates passing12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth5 cm which is attached to a metal base of impact testing machine.
- The material is filled in 3 layers where each layer is tamped for 25 number of blows. Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a Free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 number of blows.

$$\text{Aggregate impact value} = \frac{W_1}{W_2} \times 100$$

- The crushed aggregate is allowed to pass through 2.36 mm IS sieve.
- And the impact value is measured as percentage of aggregates passing sieve (W2) to the total weight of the sample (W1).
- Aggregates to be used for wearing course, the impact value shouldn't exceed 30 percent.
- For bituminous macadam the maximum permissible value is 35 percent. For Water bound macadam base courses the maximum permissible value defined by IRC is 40 percent

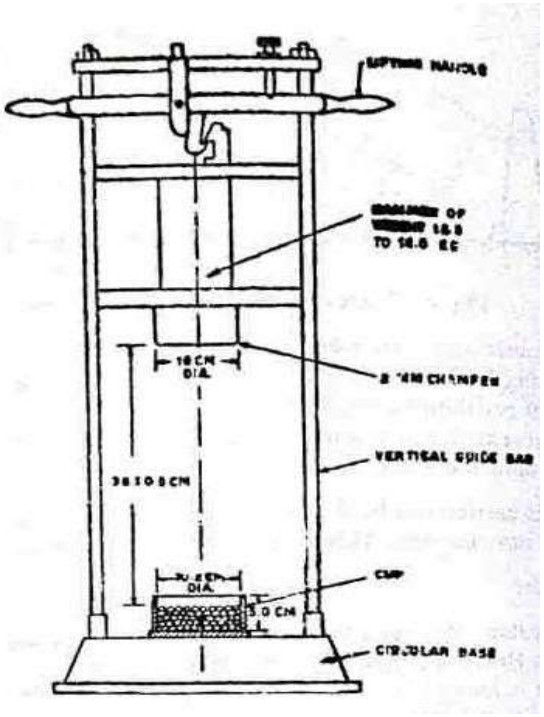
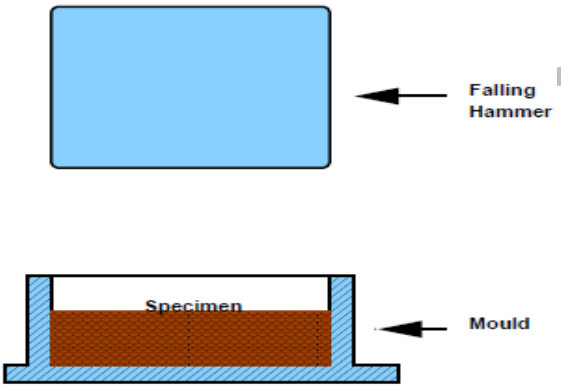


Figure 4.4.1 Aggregate Impact Testing Machine

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 298]



SHAPE TEST

- The particle shape of the aggregate mass is determined by the percentage of flaky and elongated particles in it.
- Aggregates which are flaky or elongated are detrimental to higher workability and stability of mixes.
- The flakiness index is defined as the percentage by weight of aggregate particles whose least dimension is less than 0.6 times their mean size.
- For determining the flakiness index of aggregate. It consists of a panel having accurately cut slots of different standard lengths and width.

- Particle is elongated when its length (longest dimension) is more than 1.8 of the midsize of the sieve fraction.
- Aggregate to be classified is separated into seven sieve fractions from 63 to 6.3mm, and each fraction is examined separately.
- Six labeled openings between pairs of metal pins measure particle from each of the six sieve cuts below 50mm.
- The mass of all elongated particles (failing to pass between pins) as percent of the sample is the elongation index. Meets BS 812.
- Select the length gauge appropriate to the size-fraction under test and gauge each particle separately by hand. Elongated particles are those whose greatest dimension prevents them from passing through the gauge
- From the sum of masses of the fractions in the trays(M1), calculate the individual percentages retained on each of the various sieves. Discard any fraction whose mass is 5% or less of mass M1 . Record the mass remaining (M2)
- Gauge each fraction as follows. Select the length gauge appropriate to the size-fraction under test and gauge each particle separately by hand.
- Elongated particles are those whose greatest dimension prevents them from passing through the gauge.
- Combine and weigh all Elongated particles (M3).

$$\text{Elongation index} = \frac{M3}{M2} \times 100$$

Water Absorption Test

- Water absorption is the difference between the apparent and bulk specific gravities or water permeable voids of the aggregates.
- We can measure the volume of such voids by weighing the aggregates dry and in a saturated, surface dry condition, with all permeable voids filled with water.
- The difference of the above two is MW. MW is the weight of dry aggregates minus weight of aggregates saturated surface dry condition.

$$\text{water absorption} = \frac{M_W}{M_D} \times 100$$

- Water absorption values ranges from 0.1 to about 2.0 percent for aggregates normally used in road surfacing.

4.3 TEST FOR BITUMEN

Penetration Test:

- ✓ The penetration test determines the hardness or softness of bitumen by measuring the depth of a millimeter to which a standard loaded needle will penetrate vertically in five seconds.
- ✓ The sample is maintained at temperature of 25^0C for one hour .The dial is set to zero or the initial reading is taken and the needle is released for 5 seconds. The final reading is taken on dial gauge on dial gauge.

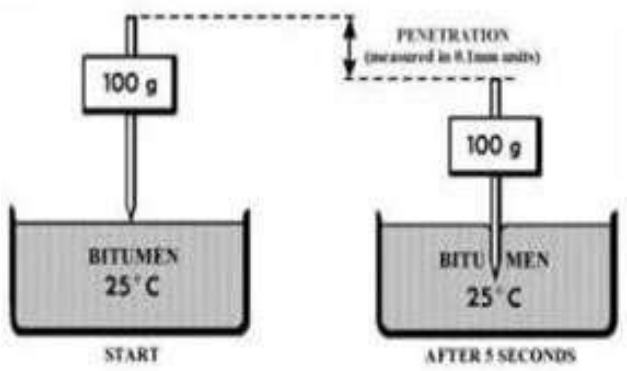


Figure 4.3.1 Penetration Test Concept

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 304]

- ✓ After each test the needle is designed and wiped with benzene and dryed.The depth of penetration is repeated in one tenth millimeter units.
- ✓ The value is influenced by any inaccuracy as regards pouring temperature size of needle, weight placed on the needle and the test temperature.

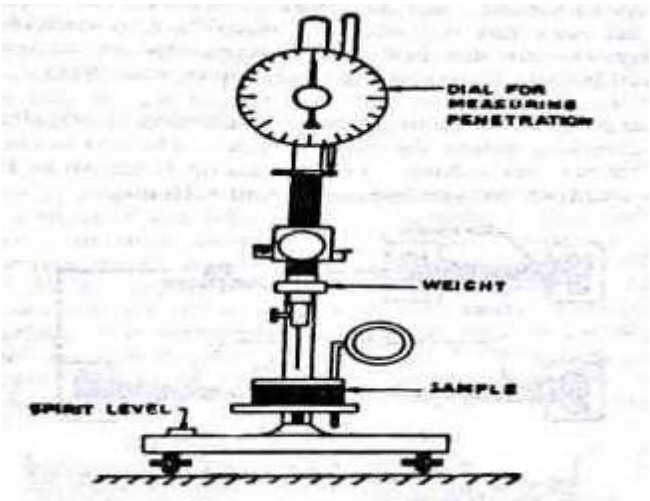


Figure 4.3.2 Penetrometer

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 305]

- ✓ The bitumen grade is specified in terms of penetration value. The penetration test is applied almost exclusively to bitumen. As road tars are soft, the penetration test cannot be carried out on these materials.
- ✓ The penetration values of various types of bitumen used in pavement construction in this country range between **20 and 2254, 30/40 and 80/1000 grade bitumen** are more commonly used, depending on construction type and climatic conditions.

Ductility Test:

- ✓ In the flexible pavement constructions where bitumen binders are used, it is important that the binders form ductile thin films around the aggregates.

  This serves as a satisfactory binder in improving the physical interlocking of the aggregate bitumen mixes.

  Under traffic loads the bituminous pavement layer is subjected to repeated deformation and recoveries.
- ✓ It is carried out on bitumen to test this property of the binder. The test is believed to measure the adhesive property of bitumen and its ability to stretch.
- ✓ Bitumen paving engineer would however want that both test requirements are satisfied in the field jobs.
- ✓ It is expressed as the distance in **centimeters** to which standard briquette bitumen can be stretched before the thread breaks.The test is conducted at 27^0C and at a rate of pull of **50 mm per minute.**
- ✓ The ductility machine functions as a constant temperature water bath with a pulling device at a pre calibrated rate. The **ductility values of bitumen** vary from **5 to over 100** for different bitumen grades.

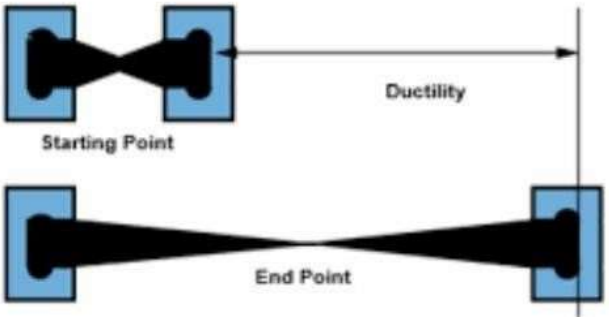


Figure 4.3.3 Ductility Test

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 306]

Viscosity Test:

- ✓ Viscosity is defined **as inverse of fluidity**. Viscosity thus defines the fluid property of bituminous material. Viscosity is the general term for consistency and it is measure of resistance to flow. Many researchers believe that grading of bitumen should be by absolute viscosity units of the conventional penetration units.
- ✓ The degree of fluidity of the binder at the application temperature greatly influences the strength characteristics of the resulting paving mixes.
- ✓ The bituminous binder simply lubricates the aggregate particles instead of providing a uniform film for binding action, similiarly high viscosity also resists the comp active effort and the resulting mix is heterogeneous in character exhibiting low stability values.
- ✓ The viscosity of tar is determined as the time taken in seconds for 50 ml of the sample to flow through 10mm orifice of the standard tar viscometer at the specified temperature of 35,40,45 or 55°C.
- ✓ The viscosity of cutback bitumen is determined as the time taken in seconds for 50ml of the sample to flow through either 4.0mm orifice at **250°C or 10mm orifice at 25 or 400°C**.

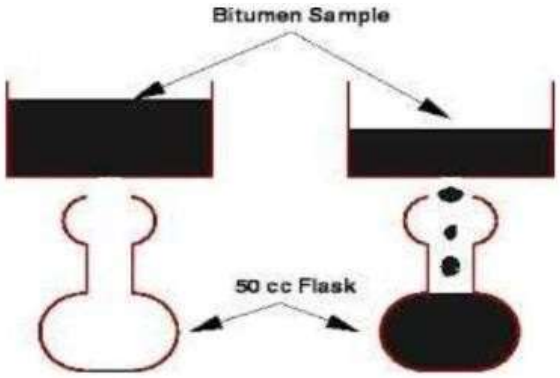


Figure 4.3.4 Viscosity Test

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 307]

5 Softening Point Test:

The softening point is the temperature at which the substance attains a particular degree of softening under specified condition of test.

- ✓ It is determined by ring and Ball test.
- ✓ Generally higher softening point indicates lower temperature sample of bitumen is suspended in liquid like water or glycerin at a given temperature.
- ✓ A steel ball is placed upon the bitumen

  sample and the liquid is then heated at a rate of 5^0C per minute. The temperature at which the softened bitumen touches the metal placed at a specified distance below the ring is recorded a point of bitumen.

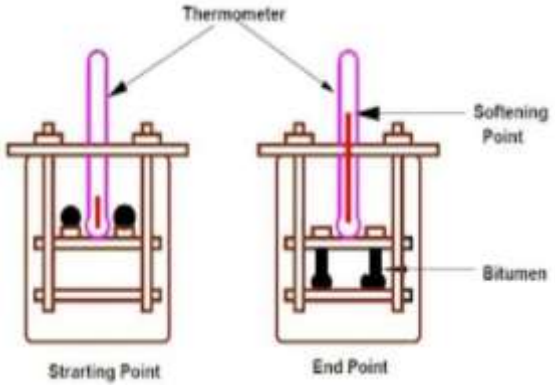


Figure 4.3.5 Softening Point Test

[Source: "Highway Engineering" by S.K.Khanna,C.E.G.Justo, Page: 308]