Highway construction is generally preceded by detailed surveys and subgrade preparation.[[3]](https://en.wikipedia.org/wiki/Highway_engineering#cite_note-McGraw-3) The methods and technology for constructing highways has evolved over time and become increasingly sophisticated. This advancement in technology has raised the level of skill sets required to manage highway construction projects. This skill varies from project to project, depending on factors such as the project's complexity and nature, the contrasts between new construction and reconstruction, and differences between urban region and rural region projects.

**1.Construction of W.B.M Roads**

 WBM Stands for Water Bound Macadam which is the most commonly used road construction procedure for over more than 190 years.Pioneered by Scottish Engineer John Loudon McAdam around 1820 Macadam is a type of Road Construction. The broken stones of base and surface course,if any are bound by the stone dust is presence of moisture is called WBM Roads.
Macadam means the pavement base course made of crushed or broken aggregate mechanically interlocked by rolling and the voids filled with screening and binding material with the assistance of water.WBM may be used as a sub-base,base or a surface course.The thickness of each compacted layer of WBM ranges from 10cm to 7.5cm depending on size and the gradation of [aggregate](http://civil-online2010.blogspot.in/2010/02/aggregates.html) used.

ConstructionProcedure:
1.PreparethefoundationforreceivingtheWBMcourse.
2.Lateral confinement may be done by compacting the shoulder to advance,to a thickness equal to that of the compacted WBM layer and by trimming the inner side vertically.
3.Spreading of [Coarse Aggregate](http://civil-online2010.blogspot.in/2010/02/aggregates.html)

4.Compaction of [coarse aggregate](http://civil-online2010.blogspot.in/2010/02/aggregates.html) is done by wheeled power roller of capacity 6 to 10 tonnes or alternately by an equivalent vibratory roller.

5.Dry screening is applied gradually over the surface to fill the interstices in these.
6.Thesurfaceissprinkledwithwater,sweptandrolled.
7.Binding material is applied at a uniform and slow rate at two and more layers.
8.WBM Coarse is allowed to set overnight.

**2.CONSTRUCTION OF BITUMEN MACADAM**

Sub-grade act as a cushion for other layers i.e. In order to achieve durable road sub-grade should be strong. Sub-grade is provided by digging up the sub-soil and the level of the sub-grade is decided by subtracting the total thickness of the pavement from the finished level of the road pavement. The sub-grade is thoroughly compacted by rollers weighing 8 tonnes by sprinkling water one night before. Low spots which develop during rolling must be made up and brought to the grades as required. In rocky regions the sub-grades are not rolled whereas in region of clay soils, a layer to natural sand, moorum or gravel, is provided over sub-grade and is duly packed.

On a well compacted sub-grade, spread 10 to 20 cm size boulders or broken stones, or over burnt bricks in layers of 15 cm thickness and total width of the sub-base to be kept 60 cm wider than pavement width, projecting 30 cm on each side. The sub-base should be compacted by a roller to provide an even surface.

On the prepared sub-base or directly on the sub-grade, as the case may be, the specified materials of the base course is spread and proper grade, thickness and cross sections maintained as per design shown on the supplied drawings.

This course may be laid in one or two layers according to the total designed thickness and the thickness of each layer should not exceed 10 cm. this component being very important, the following steps may be taken systematically.

Check the defective portions/patches of the newly laid base course i.e. soling and rectify them

Provide either bricks on end edging or earthen kerbs strong enough to prevent the new road material from spreading outward and also to retain water used in consolidation of the wearing course.

Spread the road metal evenly over the prepared base to the specified thickness and hand pack them so that the finished surface is brought to the required camber.

Spread the coarse aggregate over the surface and roll it dry with a suitable roller till interlocking of the aggregate is achieved with sufficient void space. The rolling is started from the edges and gradually shifted towards the centre.

After dry rolling, spread the screening materials (stones upto 12 mm size) with uniform rate so that voids of coarse aggregates get filled properly. This is achieved by dry rolling and brooming alternatively, till the voids of the coarse aggregates are filled.

After spreading the screening material, sprinkle sufficient quantity of water, sweep the surface and roll it with roller again.

Now apply the binding material in two to three thick layers at a slow and uniform rate. Each layer of binding material is rolled after adding sufficient water. The slurry is swept in with brooms to fill the void properly. The moving wheel of the roller should be cleaned with water. Continue the operations of spreading of binder, sprinkling of water, sweeping with brooms and rolling till the voids get filled and slurry forms a wave before the moving wheel of the roller.

After proper compacting allow it to dry over night. Spread a layer of sand or earth, about 6 mm thick and roll the surface again after sprinkling water lightly.

The surface may be allowed for 7 to 10 days of curing.

While curing the pavement surface, prepare the shoulders by filling earth to the specified cross slope and compact them properly by rolling or by tamping. Width and thickness of the shoulder should be as per specification.

After properly drying, the road pavement may now be opened to traffic, ensuring that the traffic is distributed uniformly over the full width of the pavement.

1. Preparation of the existing base course layer

The existing surface is prepared by removing the pot holes or rust if any. The irregularities are filled in with premix chippings at least a week before laying surface course. If the existing pavement is extremely way, a bituminous leveling course of adequate thickness is provided to lay a bituminous concrete surface course on a binder course instead of directly laying it on a WBM.

2. Application of Tack Coat

It is desirable to lay AC layer over a bituminous base or binder course. A tack coat of bitumen is applied at 6.0 to 7.5 kg per 10 sq.m area, this quantity may be increased to 7.5 to 10 kg for non-bituminous base.

Bitumen bound macadam (BBM) and compares its performance with that of water bound macadam (WBM) and BUSG, a specification used by the Indian Ministry of Surface Transport. The BBM advantages of the BBM method include: (1) rapid construction; (2) less disturbance to traffic; and (3) relatively low cost. It has already been used successfully at several sites in India. BBM is similar to WBM, except that key aggregates and bitumen are used as binder, instead of screenings and water. The BBM layer can conventionally be laid over an existing bitumen layer, after applying a tack coat. The construction techniques for a layer of BBM are like those for a layer of WBM. BBM was found to be a suitable alternative treatment to WBM and BUSG, and it has a relatively dustproof surface. When overlaid by a hot mix paver treatment, a BBM layer has still better performance and riding conditions. It is predicted that precoating of 12mm size aggregates, in future forms of BBM, will improve the performance of the top layer, and reduce metal 'fly-off' due to traffic. One appendix gives the specification of BBM; the other compares the specifications for BBM, WBM and BUSG.

**Concrete pavement construction process**

The construction of concrete pavement involves sequential construction of subgrade, sub-base/ base and the concrete slab. These are discussed in the following.

**Subgrade preparation**

Subgrade preparation involves cleaning, earthwork (excavation or filling of soil, replacement of weak soil, soil stabilization etc.) and compaction.

Where the concrete layer is laid directly over the subgrade, the subgrade is moist at the time concrete is placed. If the sub grade is dry, water could be sprinkled over the surface before laying any concrete course, however, care should taken so that soft patches or water pools are not formed at the surface ([IRC:15-2002](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#irc2002), [Chakroborty and Das 2003](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#chakroborty)). As an alternative arrangement, concreting could be done over a water proof polyethylene sheet, and in that case moistening the subgrade surface becomes redundant. This polyethylene sheet acts as a capillary cut-off layer ([IRC:15 2002](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#irc2002)). Figure-31 presents a photograph of subgrade construction in progress.



**Construction of Base/ Sub-base**

A base/ sub-base to the concrete pavement provides uniform and reasonably firm support, prevents mud-pumping , and acts as capillary cut-off. Sub-base for concrete pavement could be constituted with brick flat soling, WBM, granular aggregates, crushed concrete, slag, stabilized soil etc. As per[IRC: 15 (2002)](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#irc2002), sub-base could be of three types with (i) Granular material (for example, brick soling with one layer of sand under it, WBM, well graded granular materials etc.) (ii) Stabilized soil (iii) Semi-rigid material, (for example, lime burnt clay puzzolana concrete, lime fly-ash concrete, lean cement concrete roller compacted concrete etc.). Following contains a brief discussion on dry lean cement (DLC) concrete as sub-base, which is popularly being adopted for the current concrete pavement construction in India.

**Dry lean cement concrete as sub-base**

The thickness of DLC, generally recommended is 100mm or 150mm ([IRC:SP-49 1998](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#irc49)). The maximum aggregate to cement ratio is 15:1. The average compressive strength of DLC cubes at 7 days, as recommended by Indian guidelines ([IRC:SP-49 1998](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#irc49)) should not be less than 10 MPa, tested on 5 samples and individual compressive strength should not be less than 7.5 MPa, at 7 days [(MORT&H 2001](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#morth), [IRC:SP-49 1998](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#irc49)).



Before construction of DLC sub-base, the prepared subgrade is sprinkled with water to moisten the surface. The material is to be laid uniformly by a paver without any segregation . The paving machine should have high amplitude paving bars. The curing of DLC can be done by spraying liquid curing compound, or by covering the surface by gunny bags. As per Indian guidelines, the construction of cement concrete pavement can only start after 7 days of DLC construction ([MORT&H 2001](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#morth), [IRC:SP-49 1998](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#irc49)).

Figure-32 presents a schematic diagram of the sequence of rolling for DLC construction, and Figure-33 presents a photograph of DLC construction.

**Construction of concrete slab**

General

The concrete surfacing could be made up of plain concrete or reinforced concrete. Reinforced concrete has been discussed later in a different lecture. The proportions between cement, aggregate and water is determined by standard concrete mix design technique.

Premature setting and segregation is to be avoided while transporting the concrete mix through the access haul road and continuous stirring may be helpful in such a case. The spreading of concrete should be done uniformly such that no segregation of materials takes place. A separation membrane, made up of impermeable plastic/ polyethylene sheet (of thickness of the order of 150 micron) is sometimes laid over the sub-base, without creases, on to which concrete slab is laid (IRC:15 2002). Figure-34 presents a photograph of laying polyethylene sheet over DLC.



Compaction and surface finishing

Concrete is spread evenly and is rodded with suitable equipment such that formation of honey-combing or voids can be avoided. At the same time, over-compacting needs to be avoided, which can cause segregation and loss of entrained air ( [Swampland and Vanikar 2002](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm%22%20%5Cl%20%22swanlund)). The working of fixed form and slip form pavers are different - and have been discussed briefly in the following:

**Fixed form paving system**

In fixed-form paver system, generally, separate powered machines for spreading, compacting and finishing are used. The spreader spreads concrete evenly through reversible auger to the desired surcharge level ([O'Flaherty 2002](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#flaherty)). The rotary strike-off paddles trim minor irregularities in the surface of the surcharge concrete and adjusts with the carriage-way cross-slope . The compaction beam applies vibration to the concrete with pre-designed amplitude and frequency ([O'Flaherty 2002](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#flaherty)). This vibration also helps to put the dowel and tie bars at their desired positions (for a single layer construction).

The wet formed joint groove is made by introducing vertical cut immediately after compaction is over and inserting a preformed cellular permanent strip . As an alternative, saw joint groove can be made after the concrete is sufficiently hardened and can maintain the sharp edge itself ([O'Flaherty 2002](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#flaherty)).

The finishing of the surface is made, generally, with a pair of finishing beams . The leading beam vibrates and smoothens the surface, and the rear beam acts as float . The beams are oriented obliquely so that it causes less damage to the joints ([O'Flaherty 2002](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#flaherty)).

**Slip form paving system**

Slip-form paving machine is a self-propelled system that can automatically spread, trim, compact and finish the surface in a synchronized manner through its feedback sensors. Placing of dowel/ tie bars at their pre-designed locations are done by the slip-form pavers. The introduction of joint grooves, surfacing texturing and spraying of curing compound etc. are done by the equipment  those follow the paver ([O'Flaherty 2002](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#flaherty)).

Slip-form paver requires guide-wires, parallel to edge of construction and maintained at fixed height, installed on the both side. The alignment of the slip-form paver is controlled automatically with respect to the guide-wires. Correct and precise alignment of the guide-wires is therefore extremely important. The hopper/ spreader maintains a constant surcharge of the concrete above the conforming plate level. The conforming plate, vibrators, strike off paddles and the finishing screed gives the final shape of the concrete pavement (O'Flaherty 2002). Figure-35 explains schematically the operation of a typical slip-form paver, and Figure-36 a photograph of concrete pavement construction by a slip form paver.



**Texturing**

Finished concrete has a smooth surface; texturing of concrete surface is done to impart required skid resistance to the concrete surface. The texturing is done by means of wire brushing or grooving along the transverse direction. Initial texturing may be done at the time of construction of the paver itself (refer Figure 37). Final texturing is done no sooner the sheen of the concrete surface goes off ( [Swanlund and Vanikar 2002](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm%22%20%5Cl%20%22swanlund) ).



**Concrete curing**

Curing is a process in which requisite moisture content and temperature is maintained so that concrete achieves its design strength through hydration of cement. For initial curing, curing compound with high water retentivity may be spread over the finished surface to prevent rapid drying of water. For final curing, continuous ponding or moistened hessain/ gunny bags should be kept for about a fortnight (refer Figure 38). As an alternative arrangement to ponding, impervious liquid maybe spread over the surface so as to restrict evaporation of water from the laid concrete. Forms are removed from the freshly prepared concrete layer after about curing of fourteen hours [(IRC:15 2002](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#irc2002), [Chakroborty and Das 2003](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm%22%20%5Cl%20%22chakroborty)).



Opening to traffic

After curing period is over, and before opening the road to traffic, the temporary seal material is to be removed, and the joints are to filled with recommended joint sealing compound. The pouring of sealing material is monitored carefully such that it is not spilled over the pavement surface. Construction of joints and joint sealing have been discussed separately ([IRC:15 2002](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#irc2002),[Chakorborty and Das 2003](http://nptel.ac.in/courses/105104098/TransportationII/module4b/7slide.htm#chakroborty)).

### Highway maintenance

The overall purpose of highway maintenance is to fix defects and preserve the pavement's structure and serviceability. Defects must be defined, understood, and recorded in order to select an appropriate maintenance plan. Defects differ between flexible and rigid pavements.

There are four main objectives of highway maintenance:

* repair of functional pavement defects
* extend the functional and structural service life of the pavement
* maintain road safety and signage
* keep road reserve in acceptable condition

Through routine maintenance practices, highway systems and all of their components can be maintained to their original, as-built condition.

**Necessity of road maintenance**

Roads are among the most important public assets in many countries. Road improvements bring immediate and sometimes dramatic benefits to road users through improved access to hospitals, schools, and markets; improved comfort, speed, and safety; and lower vehicle operating costs. For these benefits to be sustained, road improvements must be followed by a well-planned program of maintenance. Without regular maintenance, roads can rapidly fall into disrepair, preventing realization of the longer term impacts of road improvements on development, such as increased agricultural production and growth in school enrolment

Postponing road maintenance results in high direct and indirect costs. If road defects are repaired promptly, the cost is usually modest. If defects are neglected, an entire road section may fail completely, requiring full reconstruction at three times or more the cost, on average, of maintenance costs. The South African National Road Agency Ltd. (SANRAL) estimates that repair costs rise to six times maintenance costs after three years of neglect and to 18 times after five years of neglect.

To avoid such escalating costs, SANRAL first “allocate its available funding resources to ideal maintenance actions (e.g., reseals and overlays), and thereafter to more extensive maintenance actions (e.g., rehabilitation), and finally to new construction”

Delayed maintenance has indirect costs as well. Neglected roads steadily become more difficult to use, resulting in increased vehicle operating costs (more frequent repairs, more fuel use) and a reluctance by transport operators to use the roads. This imposes a heavy burden on the economy: as passenger and freight services are curtailed, there is a consequent loss of economic and social development opportunities

Countries need a core road network that carries about 80 percent of national traffic, including key roads in urban areas and roads providing sufficient access to rural areas. Some part of the overall road budget thus has to be spent on construction and some part on maintaining the core network. But many countries have tended to favor new construction, rehabilitation, or reconstruction of roads over maintenance. This has led to a steady increase in the backlog of road repairs and a loss of development impact. In Sub-Saharan Africa for every kilometer of road rehabilitated, an estimated three kilometers of road fall into disrepair, leading to a net deterioration in the total road network (World Bank 2003). The situation is similar in many other developing country regions. Much of the capital cost of road construction is financed by donor funds, with low perceived cost to the country but high real costs, while maintenance is funded locally, requiring difficult and unpopular tax mobilization.

**Scope of maintenance**

The goal of maintenance is to preserve the asset, not to upgrade it. Unlike major road works, maintenance must be done regularly. Road maintenance comprises “activities to keep pavement, shoulders, slopes, drainage facilities and all other structures and property within the Page 2 Transport Note No. TRN-4 June 2005 road margins as near as possible to their as-constructed or renewed condition” (PIARC 1994). It includes minor repairs and improvements to eliminate the cause of defects and to avoid excessive repetition of maintenance efforts. For management and operational convenience, road maintenance is categorized as routine, periodic, and urgent.

* **Routine maintenance** which comprises small-scale works conducted regularly, aims “to ensure the daily passability and safety of existing roads in the short-run and to prevent premature deterioration of the roads” (PIARC 1994). Frequency of activities varies but is generally once or more a week or month. Typical activities include roadside verge clearing and grass cutting, cleaning of silted ditches and culverts, patching, and pothole repair. For gravel roads it may include regrading every six months.
* **Periodic maintenance** which covers activities on a section of road at regular and relatively long intervals, aims “to preserve the structural integrity of the road” (WB Maintenance website). These operations tend to be large scale, requiring specialized equipment and skilled personnel. They cost more than routine maintenance works and require specific identification and planning for implementation and often even design. Activities can be classified as preventive, resurfacing, overlay, and pavement reconstruction. Resealing and overlay works are generally undertaken in response to measured deterioration in road conditions. For a paved road repaving is needed about every eight years; for a gravel road re-graveling is needed about every three years.
* **Urgent maintenance** is undertaken for repairs that cannot be foreseen but require immediate attention, such as collapsed culverts or landslides that block a road.

**HIGHWAY DRAINAGE**

**INTRODUCTION:**

Highway drainage is the process of removing and controlling excess surface and sub-surface

water within the right way. This includes interception and diversion of water from the road

surface and sub-grade. The installation of suitable surface and sub-surface drainage system

is an essential part of highway design and construction. During rain, part of the rain water flows on surface and part of it percolates through the soil. mass as gravitational water until it reaches the ground water below the water table. Removal and diversion of surface water from the roadway and adjoining land is termed as surface drainage, while the removal of excess soil-water from the sub-grade is termed as sub-surface water.

**NECESSITY OF HIGHWAY DRAINAGE**

Highway drainage is important from various view points:

 Excess moisture in soil sub-grade causes instability under the road surface. The pavement may fail due to sub-grade failure. In some clayey soil variation in moisture content causes considerable variation in volume of sub-grade. This sometimes contributes to pavement failure.

 The waves and corrugations formed in case of flexible pavements also play an important

role in pavement failure.

 Sustained contact of water with bituminous pavements causes failure due stripping bitumen from the aggregates like loosening of some of the bituminous pavement layer and formation of pot holes.

 The prime cause of failures in rigid pavements by mud pumping is due to the presence of water in fine sub-grade soil.

 Excess water on shoulders and pavement edge causes considerable damage.

 Excess moisture causes increase in weight and thus increase in stress and simultaneous reduction in strength in soil mass. This is one of the main reasons of failure of earth slope

and embankment foundations.

 In place where freezing temperatures are prevalent in winter, the presence of water in sub-grade and a continuous supply of water from the ground water can cause considerable damage to the pavement due to in frost action.

 Erosion of soil from top of un-surface roads and slopes of embankment, cut and hill side is also due to surface water.

 Failure due to hydraulic pressure and failure due to binder stripping can be avoided with the help of proper drainage on roads

**ROAD DRAINAGE- importance**

Well designed and well maintained road drainage is important in order to:

 Minimize the environmental impact of road runoff on the receiving water environment.

 Ensure the speedy removal of surface water to enhance safety and minimize disruption to

road users.

 Maximize the longevity of the road surface and associated infrastructures.

There are many different types of drainage systems with different design features and attributes that can be used to manage flows and treat water quality. Drainage which is needed on the Highways Agency network depends not just on any flood risks and pollution risks identified but the characteristics of the natural water catchment area in which the network is based. The size, shape, gradient and geology of a catchment area are all factors which can influence the type of drainage methods used.

**SURFACE DRAINAGE**

The surface water is to be collected and then disposed off. The water on the surface is first collected in longitudinal drains, generally in side drains and then the water is disposed off at the nearest stream, valley or water course. For the preparation of surface drainage, we should keep

 in mind various things like

**COLLECTION OF SURFACE WATER**

Seeing the amount of rainfall and slope a suitable camber is to be provided for collection of surface water. The shoulders of rural roads are constructed with suitable cross slopes so that the water is drained across the shoulders to the side drains. These side drains of rural roads are generally Open (kutcha) drains of trapezoidal shape, cut to suitable cross-section and

longitudinal slopes. These sides are provided parallel to the road alignment and hence these are

also known as longitudinal drains. In embankments the longitudinal drains are provided on one or both sides beyond the toe; in cutting, drains are installed on either side of the formation. In urban roads because of the limitation of land width and also due to the presence of footpath, diving island and other road facilities, it is necessary to provide underground longitudinal drains. Water drained from the pavement surface can be carried forward in the longitudinal direction between the kerb and the pavement for short distances which may be collected in catch pits at suitable intervals and lead through underground pipes. Drainage of surface water is all the more important in hill roads. In hill roads disposal of water is also very important. Certain maintenance problems may arise due to faulty hill road construction.

 **CROSS DRAINAGE**

For streams crossing the runways, drainage needs to be provided. Also often the water from the side drain is taken across by these cross drains in order to divert the water away from the road, to a water course or valley in the form of culverts or bridges. When a small stream crosses a road with linear water way less than amount six meter, the cross drainage structure provided is called culvert; for higher value of linear waterway, the structure is called bridge.

 **SUB-SURFACE DRAIN**

Change in moisture content of sub-grade are caused by fluctuations in ground water table

seepage flow, percolation of rain water and movement of capillary water and even water vapour. Although sub-surface drainage helps in removal of gravitational water, it is designed to keep minimum moisture in sub-grade.

**LOWERING OF WATER TABLE**

The highest level of water table should be fairly below the level of sub grade, in order that the sub grade and pavements layers are not subjected to excessive moisture. From practical considerations it is suggested that the water table