PAVEMENT CONSTRUCTION

UNIT - 6

SUBGRADE: Earthwork grading and construction of embankments and cuts for roads.
Preparation of subgrade, quality control tests. 6 Hours

Highway construction is generally preceded by detailed surveys and subgrade preparation. 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.

There are a number of elements of highway construction which can be broken up into technical and commercial elements of the system. Some examples of each are listed below:

Technical Elements
- Materials
- Material quality
- Installation techniques
- Traffic

Commercial Elements
- Contract understanding
- Environmental aspects
- Political aspects
- Legal aspects
- Public concerns
Typically, construction begins at the lowest elevation of the site, regardless of the project type, and moves upward. By reviewing the geotechnical specifications of the project, information is given about:

- Existing ground conditions
- Required equipment for excavation, grading, and material transportation to and from the site
- Properties of materials to be excavated
- Dewatering requirements necessary for below-grade work
- Shoring requirements for excavation protection
- Water quantities for compaction and dust control

**Subbase course construction**

A subbase course is a layer designed of carefully selected materials that is located between the subgrade and base course of the pavement. The subbase thickness is generally in the range of 4 to 16 inches, and it is designed to withstand the required structural capacity of the pavement section. Common materials used for a highway subbase include gravel, crushed stone, or subgrade soil that is stabilized with cement, fly ash, or lime. Permeable subbase courses are becoming more prevalent because of their ability to drain infiltrating water from the surface. They also prevent subsurface water from reaching the pavement surface. When local material costs are excessively expensive or the material requirements to increase the structural bearing of the sub-base are not readily available, highway engineers can increase the bearing capacity of the underlying soil by mixing in Portland cement, foamed asphalt, or with emerging technologies such as the cross-linking styrene acrylic polymer that increases the California Bearing Ratio of in-situ materials by a factor 4 – 6.

**Base course construction**

The base course is the region of the pavement section that is located directly under the surface course. If there is a subbase course, the base course is constructed directly about this layer. Otherwise, it is built directly on top of the subgrade. Typical base course thickness ranges from 4 to 6 inches and is governed by underlying layer properties. Heavy loads are continuously applied to pavement surfaces, and the base layer absorbs the majority of these stresses. Generally, the base course is constructed with an untreated crushed aggregate such as crushed stone, slag, or...
gravel. The base course material will have stability under the construction traffic and good drainage characteristics.

The base course materials are often treated with cement, bitumen, calcium chloride, sodium chloride, fly ash, or lime. These treatments provide improved support for heavy loads, frost susceptibility, and serves as a moisture barrier between the base and surface layers.

**Surface course construction**

There are two most commonly used types of pavement surfaces used in highway construction: hot-mix asphalt and Portland cement concrete. These pavement surface courses provide a smooth and safe riding surface, while simultaneously transferring the heavy traffic loads through the various base courses and into the underlying subgrade soils.

**Road surface or pavement** is the durable surface material laid down on an area intended to sustain vehicular or foot traffic, such as a road or walkway. In the past, gravel road surfaces, cobblestone and granite setts were extensively used, but these surfaces have mostly been replaced by asphalt or concrete laid on a compacted base course. Road surfaces are frequently marked to guide traffic. Today, permeable paving methods are beginning to be used for low-impact roadways and walkways.

**Asphalt** (specifically, asphalt concrete), sometimes called flexible pavement due to the nature in which it distributes loads, has been widely used since the 1920s. The viscous nature of the bitumen binder allows asphalt concrete to sustain significant plastic deformation, although fatigue from repeated loading over time is the most common failure mechanism. Most asphalt surfaces are laid on a gravel base, which is generally at least as thick as the asphalt layer, although some 'full depth' asphalt surfaces are laid directly on the native subgrade. In areas with very soft or expansive subgrades such as clay or peat, thick gravel bases or stabilization of the subgrade with Portland cement or lime may be required. Polypropylene and polyester geosynthetics have also been used for this purpose and in some northern countries, a layer of polystyrene boards have been used to delay and minimize frost penetration into the subgrade.

Depending on the temperature at which it is applied, asphalt is categorized as hot mix, warm mix, or cold mix. Hot mix asphalt is applied at temperatures over 300 °F (150 °C) with a free floating screed. Warm mix asphalt is applied at temperatures of 200–250 °F (95–120 °C),
resulting in reduced energy usage and emissions of volatile organic compounds. Cold mix asphalt is often used on lower volume rural roads, where hot mix asphalt would cool too much on the long trip from the asphalt plant to the construction site.

An asphalt concrete surface will generally be constructed for high-volume primary highways having an average annual daily traffic load greater than 1200 vehicles per day.[5] Advantages of asphalt roadways include relatively low noise, relatively low cost compared with other paving methods, and perceived ease of repair. Disadvantages include less durability than other paving methods, less tensile strength than concrete, the tendency to become slick and soft in hot weather and a certain amount of hydrocarbon pollution to soil and groundwater or waterways.

**Hot-mix asphalt (HMA) layers**

Hot-mix asphalt surface courses are referred to as flexible pavements. The Superpave System was developed in the late 1980s and has offered changes to the design approach, mix design, specifications, and quality testing of materials. The construction of an effective, long-lasting asphalt pavement requires an experienced construction crew, committed to their work quality and equipment control.

Construction issues:

- Asphalt mix segregation
- Laydown
- Compaction
- Joints

A prime coat is a low viscosity asphalt that is applied to the base course prior to laying the HMA surface course. This coat bonds loose material, creating a cohesive layer between the base course and asphalt surface.

A tack coat is a low viscosity asphalt emulsion that is used to create a bond between an existing pavement surface and new asphalt overlay. Tack coats are typically applied on adjacent pavements (curbs) to assist the bonding of the HMA and concrete.
Portland cement concrete (PCC)

Portland cement concrete surface courses are referred to as rigid pavements, or concrete pavements. There are three general classifications of concrete pavements - jointed plain, jointed reinforced, and continuously reinforced.

Traffic loadings are transferred between sections when larger aggregates in the PCC mix interlock together, or through load transfer devices in the transverse joints of the surface. Dowel bars are used as load-transferring devices to efficiently transfer loads across transverse joints while maintaining the joint's horizontal and vertical alignment. Tie-bars are deformed steel bars that are placed along longitudinal joints to hold adjacent pavement sections in place.

Built up spray grout [BSG] – it consists of 2 layer composite construction of compacted crushed aggregates with application of bituminous binder after each layer with key aggregates at top to provide a total thickness, 75mm. It is used for strengthening of existing bituminous pavement. A suitable wearing course is invariably provided over this & opened to traffic.

Subgrade is that portion of the earth roadbed which after having been constructed to reasonably close conformance with the lines, grades, and cross-sections indicated on the plans, receives the base or surface material. In a fill section, the subgrade is the top of the embankment or the fill. In a cut section the subgrade is the bottom of the cut (Figure 1). The subgrade supports the sub base and/or the pavement section. To ensure a stable, long-lasting, and maintenance free roadway, the subgrade is required to be constructed using certain proven procedures that provide satisfactory results.

After the rough grading is completed, the fine grade stakes are set and the final processing of the subgrade may begin. The rough grade is the top grade of the embankment as built using the information provided on the grade sheets. The grade is normally with in 2 in. at this point. The finish grading operation consists of trimming the excess material down to the final grade. Filling any low spots with thin lifts of materials tends to slide these lifts around if not properly worked into the underlying materials.
Construction Procedure –

Setting out – After the site has been cleared, the work should be setout. The limits of embankment are marked by fixing batter pegs on both sides at regular intervals. The subgrade should be wider than the design dimension so that surplus material may be trimmed.

Dewatering – If the foundation of the embankment is in an area with stagnant water, it is feasible to remove it by bailing out or pumping.

Stripping & Storing top soil – In localities where most of the available embankment materials are not conductive to plant growth, the top soil from all areas of cutting shall be stripped to specified depths not exceeding 150mm & stored in stock piles of height not exceeding 2m for covering embankment slopes.

Compacting ground supporting embankment / subgrade – where necessary, the original ground shall be leveled to facilitate placement of first layer of embankment, scarified, mixed with water and then compacted by rolling so as to achieve minimum dry density as given in table. In case difference in subgrade level and ground level is less than 0.5m & the ground does not have 97% relative compaction, the ground shall be loosened up to a level 0.5m below the subgrade level, watered & compacted in layers to not less than 97% of dry density.
Spreading material in layers & bringing to appropriate moisture content –

1. The embankment & subgrade material shall be spread in layers of uniform thickness not exceeding 200mm compacted thickness over the entire width of embankment by mechanical means, finished by a motor grader & compacted.
2. Moisture content of the material shall be checked at this site of placement prior to commencement of compaction, water shall be sprinkled from a water tanker filled with sprinkler capable of applying water uniformly.
3. Moisture content of each layer should be checked with respect to table – 1 in accordance with IS – 2720.
4. Clods or hard lumps of earth shall be broken to have max size of 75mm when placed in embankment & max size of 50 mm when placed in subgrade.
5. Embankments & other areas of unsupported fills shall not be constructed with steeper side slopes, or to greater widths.
6. Whenever fills is to be deposited against the face of a natural slope, steeper than 1 verticle on 4 horizontal, such faces shall be benched.

Compaction –

a. Smooth wheeled, vibratory, pneumatic tyred, sheep foot or pad foot rdlers of suitable size and capacity should be used for different types & grades of materials.
b. Mostly compaction will be done with vibratory roller of 80 to 100KN static weight or heavy pneumatic tyred roller.
c. Each layer of the material shall be thoroughly compacted to the densities in table – 1, subsequent layers should be laid only after the finished layer has been tested.
d. The measurement of field dry density is recorded by nuclear moisture / density guage.
e. When density measurement revel any soft areas in embankment, further compaction is carried out.

Drainage – The surface of embankment at all times during construction shall be maintained at such across fall as will shed water and prevent pending.
Repairing of damages caused by rain / spillage of water –

a. The soil in the affected portion shall be removed in such areas before next layer is laid & refilled in layers & compacted using small vibratory roller, plate compactor or power rammer to achieve the required density.

b. Tests shall be carried out to ascertain the density requirements of the repaired area.

Finishing operations –

a. It shall include the work of shaping & dressing the shoulders / verge / road bed & side slopes to conform to alignment, levels, cross sections & dimensions.

b. Both the upper & lower ends of side slopes shall be rounded off & to merge the embankment with adjacent terrain to improve appearances.

c. The top soil, removed & conserved earlier shall spread over the fill slopes, before spreading the slopes should be roughened and moistened slightly to provide bond and is provided at a depth of 75mm to 150mm for plant growth.

d. When earthwork is completed, the road area shall be cleared of all debris & ugly scars.

Fine Grading

Fine grade is required to be provided for the final trimming and checking of the cross section and grade. Stakes are usually set at 50 ft intervals near each edge of the subgrade with a grade mark established at some known distance above the actual finish subgrade elevation. A string line is stretched across the grade marks on two adjoining stakes and the subgrade 7-3 elevation is checked by measuring down the known offset distance from the stringline to the dirt grade. The appropriate corrections for a crown in the typical cross section are used in calculating the correct offset distance. The tolerance for finishing the earth subgrade is 1/2 in. from the true grade. Any low areas in the grade requiring less than 3 in. additional fill material are scarified prior to placing the fill material so the thin layer of fill is tied into the previous layer when compacted.

Fine Grading the subgrade for aggregate or asphalt base courses is usually conducted with a motor grader and checked with a stringline, but may be conducted with an automatic grading machine controlled from a stringline. The automatic grading machine is required to be used for preparing the subgrade for concrete base and pavement. When underdrains are specified, special care is required to be taken to ensure that there is no damage to the drains and that the aggregate backfill does not become contaminated with soil.
Drainage
Providing surface drainage for the undercut areas is usually not possible. The size of the undercut areas is limited, and the undercutting schedule regulated so that an area is not left open when rain is likely. Water ponding in the undercut area would likely worsen the excess moisture problems that the undercut was designed to alleviate. The final moisture and density testing, and proof rolling are conducted on the top 8 in. of the completed subgrade near the beginning of the paving operation.

Grading in civil engineering and landscape architectural construction is the work of ensuring a level base, or one with a specified slope, for a construction work such as a foundation, the base course for a road or a railway, or landscape and garden improvements, or surface drainage. The earthworks created for such a purpose are often called the sub-grade or finished contouring

Construction of Embankments
A road, railway line or canal is normally raised onto an embankment made of compacted soil (typically clay or rock-based) to avoid a change in level required by the terrain, the alternatives being either to have an unacceptable change in level or detour to follow a contour. A cutting is used for the same purpose where the land is originally higher than required.

Materials
Embankments are often constructed using material obtained from a cutting. Embankments need to be constructed using non-aerated and waterproofed, compacted (or entirely non-porous) material to provide adequate support to the formation and a long-term level surface with stability.

Intersection of embankments
To intersect an embankment without a high flyover, a series of tunnels can consist of a section of high tensile strength viaduct (typically built of brick and/or metal) or pair of facing abutments for a bridge.

Cuts for roads: In civil engineering, a cut or cutting is where soil or rock material from a hill or mountain is cut out to make way for a canal, road or railway line. In cut and fill construction it keeps the route straight and/or flat, where the comparative cost or practicality of alternate
solutions (such as diversion) is prohibitive. Contrary to the general meaning of cutting, a cutting in construction is mechanically excavated or blasted out with carefully placed explosives. The cut may only be on one side of a slope, or directly through the middle or top of a hill. Generally, a cut is open at the top (otherwise it is a tunnel). A cut is (in a sense) the opposite of an embankment. When used in reference to transportation routes, it reduces the grade of the route.

Cuts can be created by multiple passes of a shovel, grader, scraper or excavator, or by blasting. One unusual means of creating a cut is to remove the roof of a tunnel through day lighting. Material removed from cuts is ideally balanced by material needed for fills along the same route, but this is not always the case when cut material is unsuitable for use as fill. The word is also used in the same sense in mining, as in an open cut mine.

**Quality Control Tests**  
**Quality control tests for Embankment, Subgrade construction.**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Type of test</th>
<th>Frequency of tests</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Sand content</td>
<td>2 tests per 3000 cubic meter of soil.</td>
</tr>
<tr>
<td>2</td>
<td>Plasticity test</td>
<td>2 tests per 3000 cubic meter of soil.</td>
</tr>
<tr>
<td>3</td>
<td>Density test</td>
<td>2 tests per 3000 cubic meter of soil.</td>
</tr>
<tr>
<td>4</td>
<td>Deleterious content</td>
<td>As &amp; when required.</td>
</tr>
<tr>
<td>5</td>
<td>Moisture content</td>
<td>1 test for 250 cubic meter of soil.</td>
</tr>
<tr>
<td>6</td>
<td>CBR test [soaked &amp; unsoaked]</td>
<td>1 test per 3000 cubic meter of soil.</td>
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</table>

a) **Compaction Control** – At least one measurement of density for each 1000sqm of compacted area, test locations should be chosen with random sampling techniques. Control should be based on the mean value of 5 – 10 density determinations. The number of tests in one set of measurements shall be 6. For earth work in shoulders at least one density
measurement for every 500sqm for the compacted area should be made and the number of tests in each set shall be at least 10.

1. Enumerate the steps in the preparation of sub grade. How is the adequacy of the compaction in the field evaluated? What are the quality control tests or checks at the lab and in the field?

2. Explain the steps in the formation of an embankment.

3. Write a brief note on i) surface dressing ii) Mastic Asphalt iii) Built up Spray Grout.

4. Explain the evaluation of soil strength properties.

**TEXT BOOKS:**


**REFERENCES BOOKS:**


2. RRL, DSIR, ‘Soil Mechanics for Road Engineers’, HMSO Publication.

3. Relevant IRC codes and MoRT & H specifications.