International Journal of Research
Available at https://journals.pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 04
April 2019

An Experimental Study on Construction of Soil Embankment

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Abstract- *An embankment refers to a volume of earthen material that is placed and compacted for the purpose of raising the grade of a roadway (or railway) above the level of the existing surrounding ground surface. A fill refers to a volume of earthen material that is placed and compacted for the purpose of filling in a hole or depression. Embankments or fills are constructed of materials that usually consist of soil, but may also include aggregate, rock, or crushed paving material. It is proposed to construct a "four laning of yadagiri-warangal section of NH-163 (new NH-202) from km54+000 to km150+000 (design length 99.103km) under NHDP PHASE-IV to be executed under EPC mode in the state of TELANGANA".*

I. INTRODUCTION

An embankment refers to a volume of earthen material that is placed and compacted for the purpose of raising the grade of a roadway (or railway) above the level of the existing surrounding ground surface [1]. A fill refers to a volume of earthen material that is placed and compacted for the purpose of filling in a hole or depression [2]. Embankments or fills are constructed of materials that usually consist of soil, but may also include aggregate, rock, or crushed paving material.

Normally, the coarser fill materials are placed at or near the bottom or base of the embankment in order to provide a firm foundation for the embankment and also to facilitate drainage and prevent saturation [3]. The top portion of an embankment usually is constructed of relatively high-quality, well-compacted subgrade material that is capable of supporting the overlying pavement layers and imposed wheel loadings without deflection or undesirable movement.

II. LITERATURE REVIEW

Mahbub et al. (2013) in "Slope stability analysis of embankment of Jamuna River" have analyzed the stability of different slopes and to find the pattern of slope failure under different field conditions. They have used the program STB2010 to analyze the slope stability. It has been concluded that the safety factors at high flood level for slope 1:2 were found significantly less than the desired point of the factor. The highest flood level conditions were the most vulnerable and threatening for the embankment. They have advised a slope of 1:1.5 and considered that slope to be a balanced design for embankment slope.

Santosh et al. (2016) in "Slope stability analysis with GEO5 software for Malin landslide in Pune, Maharashtra" has analyzed the slope stability of the landslide to find out the causes of the landslide and remedial measures to avoid landslide by applying the GEO5 slope stability software.

Harabinova and Panulinova (2017) in "Assessment of slope stability", have assessed the slope stability on the road II/595 near the village Zlatno, Slovakia before and after the landslide of 2010 using the GEO 5 slope stability software. The critical factors of safety has been determined by the methods of Petterson, Bishop and Sarma. They have used four variants- original condition (dry state), condition

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after landslide (saturated state) and reinforced slopes with ground anchors [4]. By finding the most unfavorable slip surface the proposal of remedial measures has been given, which is using geogrid with tensile strength 173 KN/m.

Michalski (2016) in "Slope stability analysis with GEO 5 software for 'Laski' landslide in Miedzybrodzie Bialskie" has computed the factor of safety by using the slide surfaces which have been identified in drill cores. He has carried out the calculations in three scenarios- first with normal water level, second with water level lowered to 5 m and third one was without the water level with the worst courses of sliding surfaces. It has been found that despite of water lowering and stabilization of the existing surfaces, there was a considerable risk of a new sliding surface occurrence.

Hossain et al. (2010) in "River embankment and bank failure in Bangladesh: A study on geotechnical characterization and stability analysis" has investigated the geotechnical properties of failed Jamuna and Padma river embankment materials. The study result has shown that the soil of Jamuna river embankment was not well graded sand and the permeability was moderately high which increased rapidly in submerged condition [5]. Also the slope was not well protected which made the embankment vulnerable to erosion. The study has shown that the factor of safety has been over estimated by about 22-24% if seepage analysis has not been considered in designing embankment.

III. SITE CLEARANCE

CLEARING AND GRUBBING:

Fig.1: Clearing and Grubbing

Preservation of Properties/Amenities:

Roadside trees, shrubs, any other plants, pole lines, fences, signs, monuments, buildings, pipelines, sewers and all highway facilities within or adjacent to the highway which are not to be disturbed shall be protected from injury or damage. The Contractor shall provide and install at his own cost, suitable safeguards approved by the Engineer for this purpose.

During clearing and grubbing, the Contractor shall take all adequate precautions against soil erosion, water pollution, etc., and where required, undertake additional works to that effect vide. Before start of operations, the Contractor shall submit to the Engineer for approval, his work plan including the procedure to be followed for disposal of waste materials, etc., and the schedules for carrying out temporary and permanent erosion control works as stipulated.

Methods, Tools and Equipments:

Only such methods, tools and equipment as are approved by the Engineer and which will not affect any property to be preserved shall be adopted for the Work. If the area has thick vegetation/roots/trees, a crawler or pneumatic tyred dozer of adequate capacity may be used for clearance purposes. The dozer shall have ripper attachments for removal of tree stumps.

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All trees, stumps, etc., falling within excavation and fill lines shall be cut to such depth belowground level that in no case these fall within 500 mm of the bottom of the subgrade. Also, all vegetation such as roots, under-growth, grass and other deleterious matter unsuitable for incorporation in the embankment subgrade shall be removed between fill lines to the satisfaction of the Engineer. All branches of trees extending above the roadway shall be trimmed as directed by the Engineer.

All excavations below the general ground level arising out of the removal of trees, stumps,etc., shall be filled with suitable material and compacted thoroughly so as to make the surface at these points conform to the surrounding area.

Ant-hills both above and below the ground, as are liable to collapse and obstruct free subsoil water flow shall be removed and their workings, which may extend to several meters, shall be suitably treated.

Disposal of Materials:

All materials arising from clearing and grubbing operations shall be taken over and shall be disposed of by the Contractor at suitable disposal sites with all leads and lifts. The disposal shall be in accordance with local, State and Central regulations.

Fig.2: Disposal of materials

IV. DISMANTLING CULVERTS, BRIDGES AND OTHER STRUCTURES/PAVEMENTS

Dismantling Culverts and Bridges:

The structures shall be dismantled carefully and the resulting materials so removed as not to cause any damage to the part of the structure to be retained and any other properties or structures nearby.

Unless otherwise specified, the superstructure portion of culverts/bridges shall be entirely removed and other parts removed up to at least 600 mm below the sub-grade, slope face or original ground level whichever is the lowest or as necessary depending upon the interference they cause to the new construction. Removal of overlying or adjacent material, if required in connection with the dismantling of the structures, shall be incidental to this item.

Pipe culverts shall be carefully removed in such a manner as to avoid damage to the pipes. Steel structures shall, unless otherwise provided, be carefully dismantled in such a manner as to avoid damage to members thereof. If specified in the drawings or directed by the Engineer that the structure is to be removed in a condition suitable for re-erection, all members shall be match-marked by the Contractor with white lead paint before dismantling; end pins, nuts, loose plates, etc. shall be similarly marked to indicate their proper location; all pins, pin holesand machined surfaces shall be painted with a mixture of white lead and tallow and all loose parts shall be securely wired to adjacent members or packed in boxes.

Timber structures shall be removed in such a manner as to avoid damage to such timber or lumber having salvage value as is designated by the Engineer.

Dismantling Pavements and Other Structures:

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In removing pavements, kerbs, gutters, and other structures like guard-rails, fences, manholes, catch basins, inlets, etc., where portions of the existing construction are to be left in the finished work, the same shall be removed to an existing joint or cut and chipped to a true line with a face perpendicular to the surface of the existing structure. Sufficient removal shall be made to provide for proper grades and connections with the new work as directed by the Engineer.

All concrete pavements, base courses in carriageway and shoulders etc., designated for removal shall be broken to pieces whose volume shall not exceed 0.02 cu.m and used with the approval of the Engineer or disposed off.

Fig.3: Dismantling of Pavements

Fig.4: Dismantling of Other Structures

Back-filling:

Holes and depressions caused by dismantling operations shall be backfilled with excavated or other approved materials and compacted to required density as directed by the Engineer.

Fig.5: Back filling

V. EXCAVATION OF ROAD IN SOIL/ROCK

Fig.6: Excavation for Roadway

Fig.7: Excavation for Drains

BLASTING OPERATIONS:

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Fig 8: Blasting operations

The blasting shall be carried out during the pre-determined hours of the day preferably during the mid-day luncheon hour or at the close of the work as ordered in writing by the Engineer. The hours shall be made known to the people in the vicinity.

Red danger flags shall be displayed prominently in all directions during the blasting operations. The flags shall be planted 200 m from the blasting site in all directions. People, except those who actually light the fuse, shall be prohibited from entering this area and all persons including workmen shall be kept away from the flagged area, and all persons including workmen shall be removed from the flagged area at least 10 minutes before the firing. A warning siren shall be sounded for the above purpose.

The charge holes shall be drilled to required depths and at suitable places. Blasting should be as light as possible consistent with thorough breakage of the material necessary for economic loading and hauling. Any method of blasting which leads to overshooting shall be discontinued.

At a time not more than 10 such charges will be prepared and fired. The man in charge shall blow a siren in a recognized manner for cautioning the people. All the people shall then be required to move to safe distances. The charges shall be lighted by the man-in-charge only. The man-in-charge shall count the number of explosions. He shall satisfy himself that all the charges have been exploded before allowing the workmen to go back to the work site.

V. EARTHWORK IN EMBANKMENT (FILLING)

Fig 9: Embankment Filling

Compaction Requirements:

The Contractor shall obtain representative samples from each of the identified borrow areas and have these tested at the site laboratory following a testing programme approved by the Engineer. It shall be ensured that the subgrade material when compacted to the density requirements as in Table shall yield the specified design CBR value of the sub-gradas.

S.NO.	Type of work/material	Relative compaction as percentage of max. laboratory dry density as per 15:2720 (Part 8)
1.	Subgrade and earthen shoulders	Not less than 97%
2.	Embankments	Not less than 95%
3.	Expansive Clays a) Subgrade and 500 mm portion just below the subgrade b) Remaining portion of embankment	 Not allowed 90-95%

Table-1: Compaction Requirements for Embankment and Sub-grade

The Contractor shall at least 7 working days before commencement of compaction submit the following to the Engineer for approval:

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i. The values of maximum dry density and optimum moisture content obtained in accordance with IS:2720 (Part 8), appropriate for each of the fill materials he intends to use.
ii. A graph of dry density plotted against moisture content from which each of the values in (l) above of maximum dry density and optimum moisture content were determined.

The maximum dry density and optimum moisture content approved by the Engineer shall form the basis for compaction.

VI. CONSTRUCTION OPERATIONS

Setting Out:

After the site has been cleared to Clause 201, the work shall be set out. The limits of embankment/sub-grade shall be marked by fixing batter pegs on both sides at regular intervals as guides before commencing the earthwork. The embankment/sub-grade shall be built sufficiently wider than the design dimension so that surplus material may be trimmed, ensuring that the remaining material is to the desired density and in position specified and conforms to the specified side slopes.

Dewatering:

If the foundation of the embankment is in an area with stagnant water, and in the opinion of the Engineer it is feasible to remove it, the same shall be removed by bailing out or pumping, as directed by the Engineer and the area of the embankment foundation shall be kept dry.

Care shall be taken to discharge the drained water so as not to cause damage to the works, crops or any other property. Due to any negligence on the part of the Contractor, if any such damage is caused, it shall be the sole responsibility of the Contractor to repair/restore it to original condition or compensate for the damage at his own cost.

Stripping And Storing Top Soil:

When so directed by the Engineer, the topsoil from all areas of cutting and from all areas to be covered by embankment foundation shall be stripped to specified depths not exceeding 150 mm and stored in stockpiles of height not exceeding 2 m for covering embankment slopes, cut slopes and other disturbed areas where re-vegetation is desired. Topsoil shall not be unnecessarily subjected to traffic either before stripping or when in a stockpile.

Stockpiles shall not be surcharged or otherwise loaded and multiple handling shall be kept to a minimum.

Compacting Ground Supporting Embankment/Ground:

Where necessary, the original ground shall be levelled to facilitate placement of first layer of embankment, scarified, mixed with water and then compacted by rolling.

In case where the difference between the sub-grade level (top of the sub-grade on which pavement rests) and ground level is less than 0.5 m and the ground does not have 97 percent relative compaction with respect to the dry density, the ground shall be loosened upto a level 0.5 m below the sub-grade level, watered and compacted in layers to achieve dry density not less than 97 percent relative compaction as given in Table.

Any foundation treatment specified for embankments especially high embankments, resting on suspect foundations as revealed by borehole logs shall be carried out in a manner and to the depth as desired by the Engineer. Where the ground on which an embankment is to be built has any of such material types (a) to (f) at least 500 mm of such material must be removed and replaced by acceptable fill material before embankment construction commences.

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Spreading Material in Layers and Bringing to Appropriate Moisture Content:

The embankment and sub-grade material shall be spread in layers of uniform thickness in the entire width with a motor grader. The compacted thickness of each layer shall not be more than 250 mm when vibratory roller/vibratory soil compactor is used and not more than 200 mm when 80-100 kN static roller is used. The motor grader blade shall have hydraulic control suitable for initial adjustment and maintain the same so as to achieve the specific slope and grade. Successive layers shall not be placed until the layer under construction has been thoroughly compacted to the specified requirements and got approved by the Engineer. Each compacted layer shall be finished parallel to the final cross-section of the embankment.

Moisture content of each layer of soil shall be checked in accordance with IS:2720 (Part 2), unless otherwise mentioned, shall be so adjusted, making due allowance for evaporation losses, that at the time of compaction it is in the range of 1 percent above to 2 percent below the optimum moisture content determined in accordance with IS:2720 (Part 8) as the case may be. Expansive clays shall, however, be compacted at moisture content corresponding to the specified dry density, but on the wet side of the optimum moisture content obtained from the laboratory compaction curve.

After adding the required amount of water, the soil shall be processed by means of graders, harrows, rotary mixers or as otherwise approved by the Engineer until the layer is uniformly wet.

Clods or hard lumps of earth shall be broken to have a maximum size of 75 when being placed in the embankment and a maximum size of 50 mm when being placed in the subgrade.

Embankment and other areas of fill shall, unless otherwise required in the Contract or permitted by the Engineer, be constructed evenly over their full width and their fullest possible extent and the Contractor shall control and direct construction plant and other construction vehicles. Damage by construction plant and other vehicular traffic shall be made good by the Contractor with material having the same characteristics and strength of the material before it was damaged.

Embankments and unsupported fills shall not be constructed with steeper side slopes or to greater widths than those shown in the drawings, except to permit adequate compaction at the edges before trimming back, or to obtain the final profile following any settlement of the fill and the underlying material. Whenever fill is to be deposited against the face of a natural slope, or sloping earthworks face including embankments, cuttings, other fills and excavations steeper than 1 vertical to 4 horizontal, such faces shall be benched immediately before placing the subsequent fill.

All permanent faces of side slopes of embankments and other areas of fill shall, subsequent to any trimming operations, be reworked and sealed to the satisfaction of the Engineer by tracking a tracked vehicle, considered suitable by the Engineer, on the slope or any other method approved by the Engineer.

Only the compaction equipment approved by the Engineer shall be employed to compact the different material types encountered during construction. Static three-wheeled roller, self propelled single drum vibratory roller, tandem vibratory roller, pneumatic tyre roller, pad foot roller, etc., of suitable size and capacity as approved by the Engineer shall be used for the different types and grades of materials required to be compacted either individually or in suitable combinations.

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Earthmoving plant shall not be accepted as compaction equipment nor shall the use of a lighter category of plant to provide any preliminary compaction to assist the use of heavier plant be

When density measurements reveal any soft areas in the embankment/sub-grade/earthen shoulders, further compaction shall be carried out as directed by the Engineer. If inspite of that the specified compaction is not achieved, the material in the soft areas shall be removed and replaced by approved material, compacted using appropriate mechanical means such as light weight vibratory roller, double drum walk behind roller, vibratory plate compactor, trench compactor or vibratory tamper to the density requirements and satisfaction of the Engineer.

Drainage:

The surface of the embankment/sub-grade at all times during construction shall be maintained at such a crossfall (not flatter than that required for effective drainage of an earthen surface) as will shed water and prevent ponding.

Repairing of Damages Caused by Rain/Spillage of Water

The soil in the affected portion shall be removed in such areas as directed by the Engineer before next layer is laid and refilled in layers and compacted using appropriate mechanical means such as small vibratory roller, plate compactor or power rammer to achieve the required density. If the cut is not sufficiently wide for use of required mechanical means for compaction, the same shall be widened suitably to permit their use for proper compaction. Tests shall be carried out as directed by the Engineer to ascertain the density requirements of the repaired area. The work of repairing the damages including widening of the cut, if any, shall be carried out by the Contractor at his own cost, including the arranging of machinery/equipment for the purpose.

Finishing Operations:

Finishing operations shall include the work of shaping and dressing the shoulders/verge/roadbed and side slopes to conform to the alignment, levels, cross-sections and dimensions shown on the drawings or as directed by the Engineer subject to the surface tolerance. Both the upper and lower ends of the side slopes shall be rounded off to improve appearance and to merge the embankment with the adjacent terrain.

The topsoil, removed and conserved earlier shall be spread over the **fill** slopes as per directions of the Engineer to facilitate the growth of vegetation.

Slopes shall be roughened and moistened slightly prior to the application of the topsoil in order to provide satisfactory bond. The depth of the topsoil shall be sufficient to sustain plant growth, the usual thickness being from 75 mm to 150 mm.

Where directed, the slopes shall be turfed with sods. If seeding and mulching of slopes is prescribed.

When earthwork operations have been substantially completed, the road area shall be cleared of all debris, and ugly scars in the construction area responsible for objectionable appearance eliminated.

Earthwork for Widening Existing Road Embankment:

When an existing embankment and/or sub-grade is to be widened and its slopes are steeper than 1 vertical on 4 horizontal, continuous horizontal benches, each at least 300 mm wide, shall be cut into the old slope for ensuring adequate bond with the fresh embankment/subgrade material to be added. The material obtained from cutting of benches could be utilized in the widening of the embankment/subgrade. However, when the existing slope against which the fresh material is to be placed is flatter than 1 vertical on 4 horizontal, the slope

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e-ISSN: 2348-6848
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surface may only be ploughed or scarified instead of resorting to benching.

End dumping of material from trucks for widening operations shall be avoided except in difficult circumstances when the extra width is too narrow to permit the movement of any other types of hauling equipment.

Fig 10: Earthwork for Embankment and Sub-Grade to be placed Against Sloping Ground

Where an embankment/subgrade is to be placed against sloping ground, the latter shall be appropriately benched or ploughed/scarified before placing the embankment/sub-grade material. Extra earthwork involved in benching or due to ploughing/scarifying etc. shall be considered incidental to the work.

For wet conditions, benches with slightly inward fall and subsoil drains at the lowest point shall be provided as per the drawings, before the fill is placed against sloping ground.

Where the Contract requires construction of transverse subsurface drain at the cut-fill interface, work on the same shall be carried out to Clause 309 in proper sequence with the embankment and sub-grade work as approved by the Engineer.

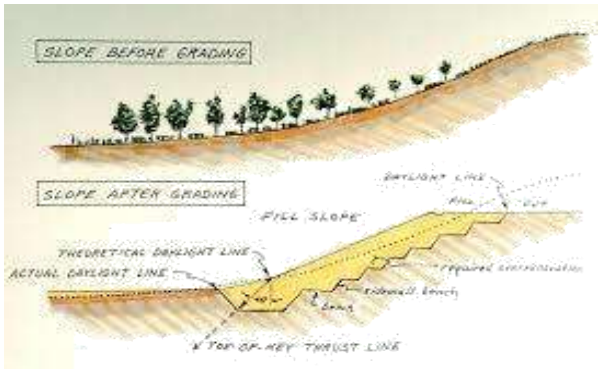

Fig 11: Benching

Earthwork over Existing Road Surface

Where the embankment is to be placed over an existing road surface, the work shall be carried out as indicated below:

i. If the existing road surface is of granular type and lies within 1 m of the new formation levels, it shall be scarified to a depth of 50 mm or as directed so as to provide ample bond between the old and new material ensuring that at least 500 mm portion below the top of new sub-grade level is compacted to the desired density;

ii. If the existing road surface is of bituminous type or cement concrete and lies within 1m of the new formation level, the bituminous or cement concrete layer shall be removed completely;

iii. If the level difference between the existing road surface and the new formation level is more than 1 m, the existing surface shall be roughened after ensuring that the minimum thickness of 500 mm of subgrade is available.

Embankment and Sub-Grade around Structures:

To avoid interference with the construction of abutments, wing walls or return walls of culvert/bridge structures, the Contractor shall, at points, to be determined by the Engineer suspend work on embankment forming approaches to such structures, until such time as the construction of the latter is sufficiently advanced to permit the

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completion of approaches without the risk of damage to the structure.

Unless directed otherwise, the filling around culverts, bridges and other structures upto a distance of twice the height of the road from the back of the abutment shall be carried out independent of the work on the main embankment. The fill material shall not be placed against any abutment or wing wall, unless permission has been given by the Engineer but in any case not until the concrete or masonry has been in position for 14 days. The embankment and sub-grade shall be brought up simultaneously in equal layers on each side of the structure to avoid displacement and unequal pressure.

Construction of Embankment over Ground Incapable of Supporting Construction Equipment:

Where embankment is to be constructed across ground which will not support the weight of repeated heavy loads of construction equipment, the first layer of the fill may be constructed by placing successive loads of material in a uniformly distributed layer of a minimum thickness required to support the construction equipment as permitted by the Engineer.

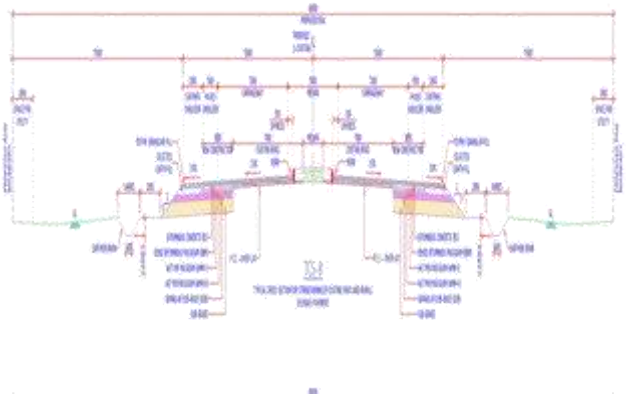

Fig 12: TYPICAL CROSS-SECTION

VII. LABORATORY VALUES

MDD, OMC& NMC

a)Assume dimension :100*14.2*0.25=355cum (674500kg)

MDD – maximum dry density (1.8-1.9,2.01)

OMC –optimum moisture content (10,9+2%)

NMC – Normal moisture content (4%-5%)

RMC=OMC-NMC =9-5 =4%

Water content = 674500*4% =26,980 liters (1 tank = 12,000 liter) = (i,e2 tanks)

VIII. CONCLUSIONS

1. The compacted thickness of each layer shall not be more than 250mmthick when a vibrator roller soil compactor used and not more than 200mm when 80-100KN static roller used to achieve 95 % of MDD.
2. Each pass of roller shall overlap 1/3rd of the preceding pass. 4.7 Acceptance Criteria.
3. Field Dry Density Shall be greater than 95% of MDD.
4. Optimum moisture content shall be +1% to -2% during the time of compaction.
5. If the moisture content (NMC) is less than OMC, the water shall be added above1% to 2% by sprinkling considering evaporation losses.
6. If NMC is more than OMC, the material can be allowed to dry by exposure to the sun.

REFERENCES

1. MORT&H specification of clause No: 201.
2. MoRT&H specification clause No: 301 to 303 and technical specifications of Contract.
3. IRC:SP:84-2009, MoRT&H Specifications, Clause no: 305, IRC-36-2010.
4. Highway engineering text book of S. K. Khanna and C. E. G. Justo
5. Highway Engineering by T. D. Ahuja.