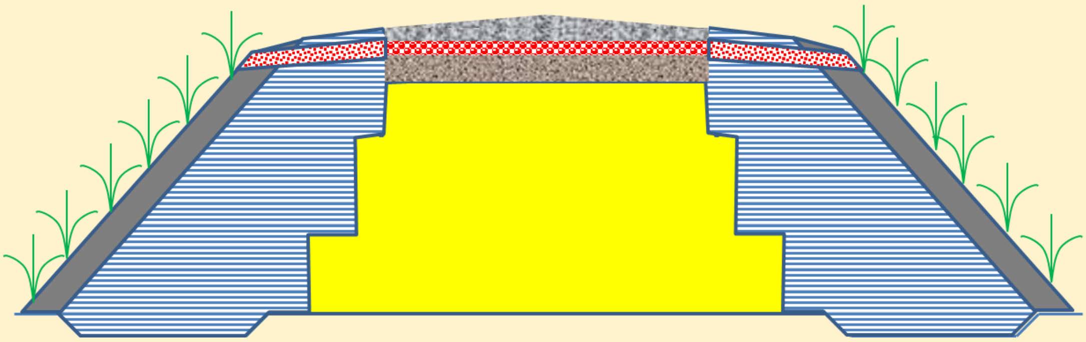
CLIMATE RESILIENT RURAL ROAD MANUAL



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ABSTRACT

Rural roads in coastal districts are subjected to extreme climatic situations such as flooding due to storm surges, submergence due to flooding and sea level rise and erosion due to current and wave actions. Rural road construction in coastal districts of Bangladesh is a challenging job due to scarcity of suitable construction materials, compaction difficulty and lack of skilled manpower. The aim of this manual is to provide proper guideline in rural road construction so that climate resilient road can be constructed by Local Government Engineering Department (LGED). This manual is an outcome of research subproject "Introduction of Quality Test Protocols for Road and Market Rehabilitation" under Coastal Climate Resilient Infrastructure Project (CCRIP) of LGED.

The Road which can sustain extreme climatic situations and minimize the life-cycle cost may be termed as climate resilient road. Climate Resilient Road should be made of using local materials as more as possible. It should be durable within its design life so that life-cycle cost is minimum. Use of recycled materials and industrial by products should be encouraged for climate resilient road construction. To cope with the sea level rise due to global warming, frequent flooding and storm surges, coastal rural roads should be elevated so that it may survive at extreme climates.

Step by step construction sequences are described with pictorial presentation for all the situations in rural areas of coastal districts. Compaction of filling soil maintaining optimum moisture content is the key parameter of quality control of road construction. If the compaction quality is not ensured, road will not be durable. The slogan **"NO COMPACTION, NO ROAD"** should be propagated with notice, signboard and banners in all levels of LGED.

Transportation contributes to the industrial, economic, social and cultural development of a nation. So it is very important to establish transportation system in such a standard way to get maximum output. Considering different types of adverse field condition, different type of solutions are described which would be fruitful for engineers to ensure quality of rural road construction. Climate resilient road can be made if this manual is followed. Training for LGED Engineers and contractors are essential for this purpose.

Contents

CHAPTER 1: INTRODUCTION

1.1 General

Rural roads in coastal districts are subjected to extreme climatic situations such as flooding due to storm surges, submergence due to sea level rise and erosion due to current and wave actions. Rural road construction in coastal districts of Bangladesh is a challenging job due to scarcity of suitable construction materials, compaction difficulty and lack of skilled manpower. The aim of this manual is to provide proper guideline in rural road construction so that climate resilient road can be constructed by Local Government Engineering Department (LGED). This manual is an outcome of research subproject "Introduction of Quality Test Protocols for Road and Market Rehabilitation" under Coastal Climate Resilient Infrastructure Project (CCRIP) of LGED. The research team comprised of Team Leader Professor Dr. Md. Jahangir Alam and Team Member Professor Dr. Md. Shamsul Hoque.

1.2 Defining Climate Resilient Road

The Road which can sustain extreme climatic situations and minimize the life-cycle cost may be termed as climate resilient road. Climate Resilient Road should be made of using local materials as more as possible. It should be durable within its design life so that life-cycle cost is minimum. Use of recycled materials and industrial by products should be encouraged for climate resilient road construction. For example, if locally available unsuitable soil can be used with treatment, this type of construction is environment friendly. Because, transportation of suitable soil from other places would increase cost and greenhouse gas emission. If the road is not durable and it loses serviceability within 2-3 years, within the design life of the road, say 10 years, repair and reconstruction of road will be required 3 times which would increase life-cycle cost 3 times than the durable road. To cope with the sea level rise due to global warming, frequent flooding and storm surges, coastal rural roads should be elevated so that it may survive at extreme climates.

1.3 Challenges of Making Climate Resilient Road

Construction of durable rural road in coastal districts is really challenging task. Lack of suitable materials, wrong methodology of construction and social and management problems made the situation extremely difficult. Causes of road damage are report in the final report of the research subproject (Alam, Tanvir, & Hoque, Final Report of the Sub-Project "Introduction of Quality Test Protocols for Road and Market Rehabilitation", 2017). Challenges of climate resilient road construction are summarized in this section.

1.3.1 Compaction

Layer by layer compaction by maintaining optimum moisture content and layer thickness 150 mm is considered as the most important parameter of quality control of road embankment construction. Compaction is most challenging part in rural road construction. It can be said that **"no compaction, no road"**. Following reasons can be summarized why the compaction is difficult to achieve in coastal districts.

i. Scarcity of compactor: Compactor is not available or number of compactor is limited compared to constructions works going on in those areas. Usually small contractors are awarded these rural road works. They don't have compactors of any kind. They borrow roller compactors from LGED which are not sufficient enough for all the running construction works.
ii. Lower estimation of cost: Estimation of cost was found lower than required in many situations where contractors avoid compaction to minimize their loss or maximize their profit. These situations are road through fish farms or low land areas, road along khals or rivers etc.
iii. Optimum moisture content: contractors are not aware of optimum moisture content during compaction. They collect mud from borrow pit and dump at side slopes without benching and compaction.
iv. Narrow shoulder and widened part: widened part of road and shoulder is so narrow that rollers cannot move there. Plate compactor is needed for these situations. Contractors don't have and never use plate compactor.
v. Water logged area: In the water logged area where two or one side of road is water body. Water body may be pond, khal, fish farm or beel. This is a difficult situation where road widening is very difficult job. Soils are dumped at side slopes without any benching and compaction.
vi. Rainy Season: It is very difficult to maintain optimum moisture content during rainy season. Filling material is not available at this time. Compaction is also extremely difficult during rainy season.

1.3.2 Unsuitable Materials

Locally available soil is not suitable as subgrade material. Locally available borrow pit soils are mostly silty clay, clayey silt, sandy silt and silty fine sand. As per specification of tender documents, these borrow pit soils don't meet the requirements for subgrade, Improved Subgrade (ISG) and sand required for subbase.

1.3.3 Slope Protection

Rural roads on the bank of khal and pond require retaining structure and side slope protection which are expensive. Sometimes, there are fish farms (locally called "Gher") or marshy land on two sides of rural road. These situations make the construction of road extremely difficult. As synthesis of observations in all the site visits, causes of sides slope erosion may be summarized as follows:

1) Improper location of borrow pits
2) Lack of vegetation

3) Steep side slope
4) Vertical cliff created by farmers at toe of side slopes
5) Current and wave action of water during rainy season
6) Lack of layer by layer compaction and moisture control
7) Dispersive nature of local soils which are used for embankment fill
8) Absence of clay cladding at sand filled side slopes
9) Road widening without following benching and compaction
10) Lack of proper drainage and channelization of rainwater

1.4 Climate of Coastal District in Bangladesh

The topography of Bangladesh is dominated by the low lying delta created by three mighty rivers Ganges, Brahmaputra and Meghna which discharge into the Bay of Bengal through its territory. The climate of Bangladesh is semi-tropical and is dominated by the southwest monsoon which provides significant rainfall between the months of June and September. However, cyclonic storms, occasionally of severe intensity, can occur in the months of March-May and October-November. The Coastal Zone of Bangladesh has been defined as the area within which the river flows are influenced by the tide. Given the high tidal range and the very low river gradients, the tide reaches very far landwards, particularly in the dry season. If the upstream freshwater inflows are reduced in the dry season, salinity can also intrude very far upstream within the river system.

The coastal region of Bangladesh covers about 20% of total land area whereas 30% of cultivable land having 710 Km shoreline. The coastal zone of Bangladesh has an area covering 47,211 km^2 facing the Bay of Bengal or having proximity to the Bay. There are 19 coastal districts in Bangladesh with 35 million people living in there including 8 million people are highly exposed to disaster.

1.4 Future Climate Projection and Key Climate Impact in Bangladesh

Temperature rise, sea-level rise and increase in rainfall intensity, flood incidence, and cyclone intensity and intensity are predicted by international researchers. Figure 1 shows Climate Projection and Key Climate Impact in Bangladesh.

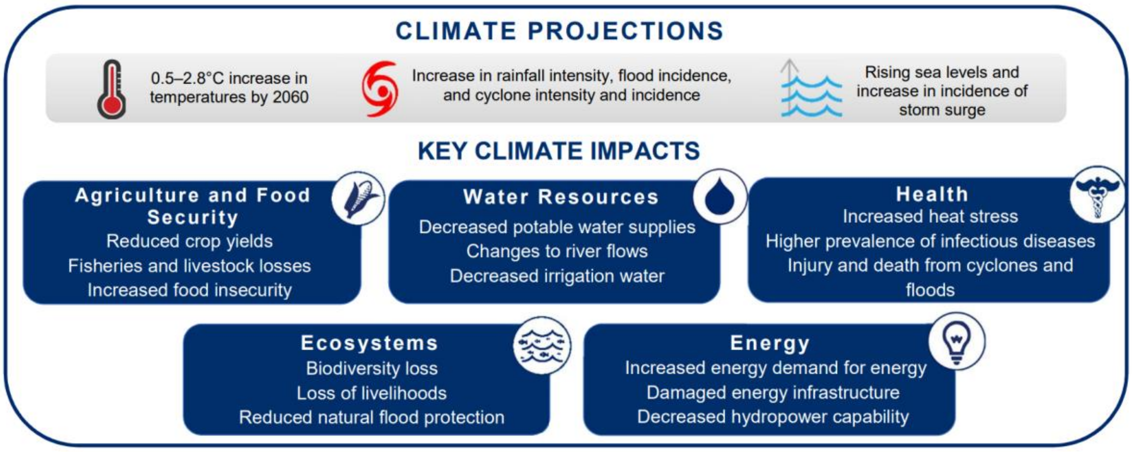

Figure 1: Climate Projection and Key Climate Impact in Bangladesh (USAID, March 2018)

1.5 Geology and Subsoil Condition of Coastal Districts

Table 1 shows the Geology and Subsoil Condition of Coastal Districts of Khulna region of Bangladesh.

Table 1: Geology and Subsoil Condition of Coastal District Khulna region (AsCAP (Asia Community Access Partnership), October 2017)

Parameter	Remarks
Grading Test Data	Typically fine-grained soils ranging between sandy silts (SM) to high plasticity clays (CH). Organic content is variable ranging from 0% to very high organic contents up to 71%.
Plasticity Test Data	Majority of soils of low to high plasticity depending on their clay content. Although the data is limited there is no appreciable difference between the soils composition or moisture content over the ground level (GL) and 3m depth range and the underlying soils between 3m to 6m. Moisture contents from the test sites are lower however, and this may be due to the shallow samples, or some drying experienced during sampling.
Undrained Shear Strength	The very soft to firm range over the upper 3m layer. The 3m to 6m depth range show results in the very soft to soft range.
Specific Gravity	Specific gravity data of 2.50 to 2.77 are recorded.
Groundwater	Close to surface. Within 1 m below ground level

1.6 Districts Where This Manual is Applicable

This manual is made especially for village and union roads of coastal districts of Bangladesh. The applicable area includes 12 (twelve) districts (see Figure 2) of the South-Western Coastal areas of Bangladesh, which are:

a) Dhaka Division:

Gopalgonj, Madaripur and Shariatpur;

b) Khulna Division:

Khulna, Bagerhat and Sathkhira;

c) Barisal Division:

Barisal, Patuakhali, Barguna, Jhalokathi, Bhola and Pirojpur

Figure 2: Applicable districts of this manual

CHAPTER 2: CLIMATE RESILIENT RURAL ROAD MANUAL

2.1 Introduction

In most of the cases, LGED upgrade existing road rather constructing new road. Upgrading an existing earthen road need elevating and widening in either side or one side. Different circumstances and situations are encountered during upgradation of rural road. Considering difficulties of quality control of embankment construction and flexible pavement construction, durability of flexible and rigid pavement, climate and subsoil condition of coastal districts and socio-economic condition of rural areas, this rural road construction manual is prepared. It is expected that if this manual is followed, 90% of the quality control problem would be solved.

2.2 Various Situations of Rural Road Upgradation

Followings are the various situations which may be encountered during upgradation of existing road in the coastal districts of Bangladesh.

i. Type A: This is a general condition where suitable subgrade and ISG materials are not available locally, side slopes are steep (1:1 or less), subsoil is consolidated under existing road embankment. During upgradation work, both sides of road are dry and water table is 1m – 2m below the existing ground level. (see Figure 3).

ii. Type B: Fish farm or marshy land at either side of road, side slopes are steep (1: 1 or less), suitable subgrade and ISG materials are not available. During construction, water table is 1m – 2m below the road crest. Without dewatering, it is quite impossible to construct durable road in this situation. (see Figure 4).

iii. Type C: Pond or Khal at one side of road. Side slope of embankment is steep (1:1 or less). However, below the embankment toe, there is a mild slope (1:1.5 or more) upto 2 m horizontal distance from toe. Beyond the mild slope part, steep slope of pond or khal starts. If the mild slope part below toe is less than 2 m wide horizontally, Type D will be applicable. (see Figure 5).

iv. Type D: Pond or khal at one side of road. Side slope is very steep (1:0.5 or less). Other side of road is paddy land. There is no scope of maintaining slope by filling at the pond side or khal side of road. Below the embankment toe, there is steep slope (1:1.4 or less). (see Figure 6).

v. Type E: Pond or khal at both sides of road. Both the side slopes are very steep (1:0.5 or less). There is no scope of maintaining slope by filling at the pond side or khal side of road. Below the embankment toe, there is steep slope (1:1.4 or less). (see Figure 7).

Step by step procedures climate resilient rural road construction at different situations are described in this chapter.

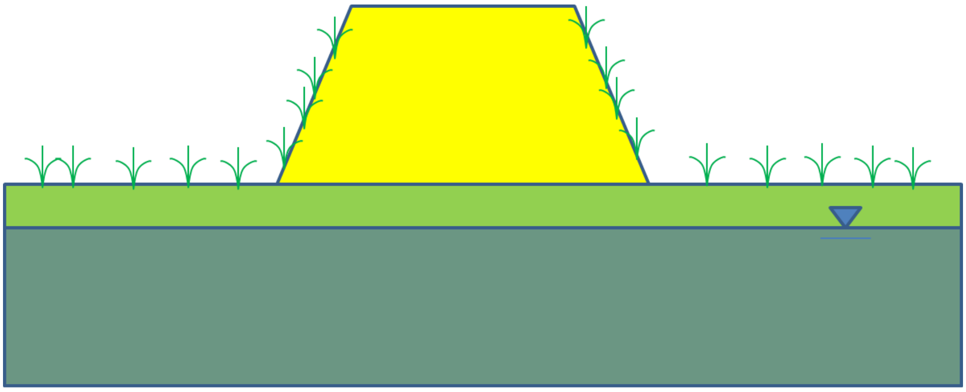

Figure 3: Type A: paddy land at both sides of road

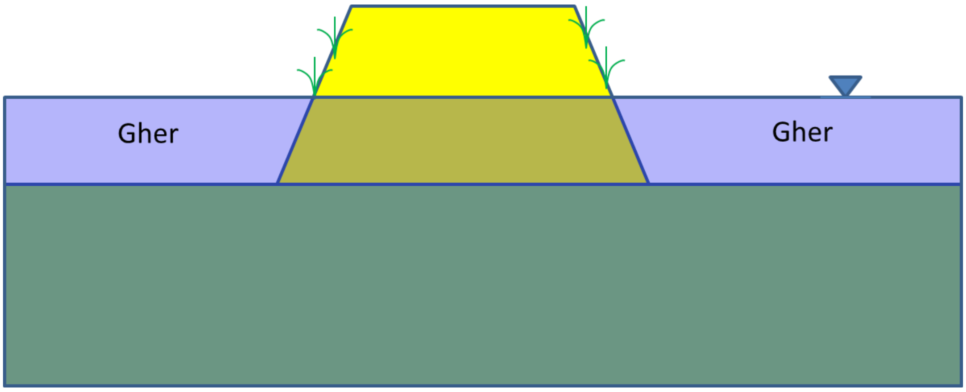

Figure 4: Type B: Gher (fish farms) at both sides of road

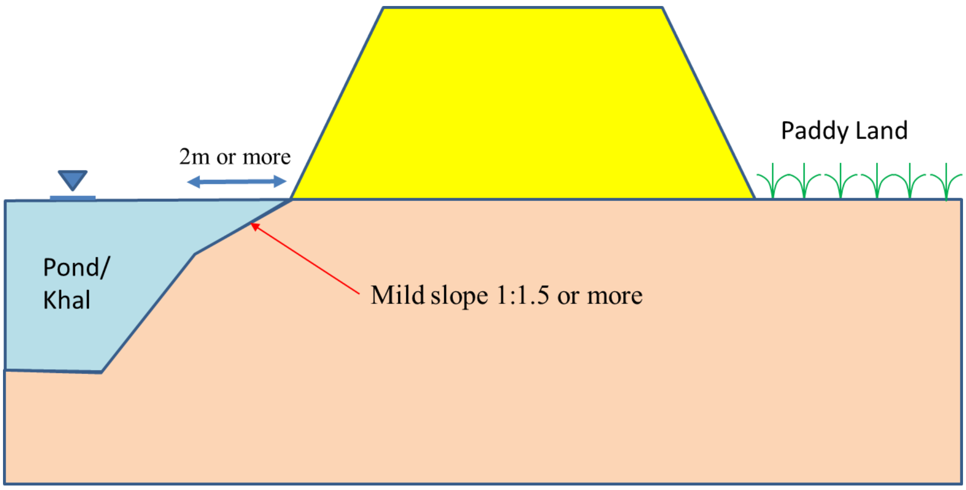

Figure 5: Type C situation with more 2 m mild slope under toe of embankment

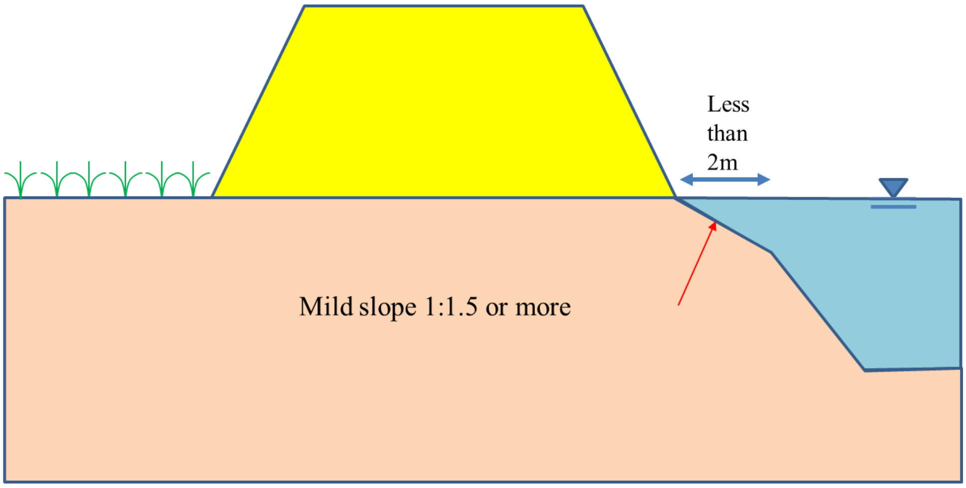

Figure 6: Type D situation with less than 2 m wide mild slope under toe of embankment

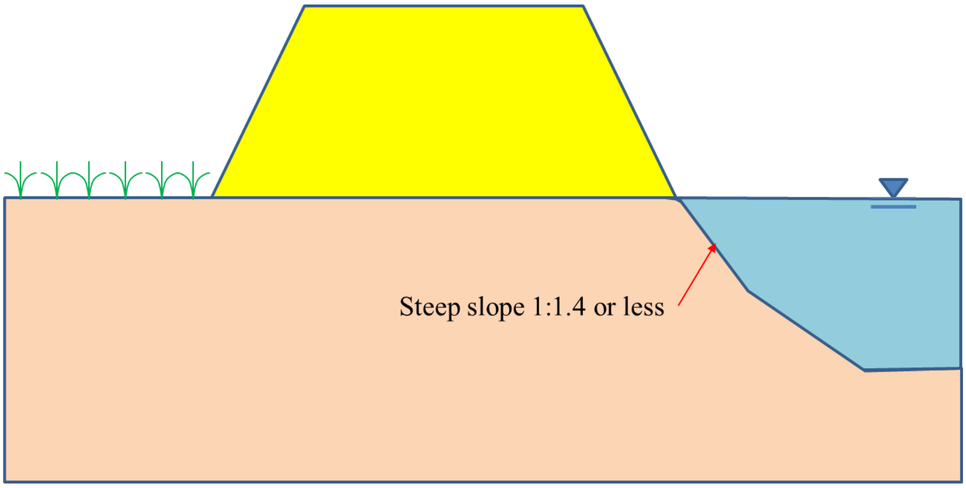

Figure 7: Type E situation with steep slope under toe of embankment

2.3 Compaction and Treatment of Widening Part

Widening part may be constructed using locally available soil with proper compaction and treatment depending on the soil type and moisture content of borrow pit soil. Widening part should be filled with layer by layer compaction. Compacted layer thickness should be less than or equal to 150 mm. If roller compactor cannot be used at this narrow strip of widened part, plate compactor or rammer should be used for compaction. Digital moisture meter shall be used to ensure moisture content near about Optimum Moisture Content. It is encouraged to use the locally available borrow pit soils for filling the widened part. However, Liquid Limit shall be less than 40 and Plasticity Index shall be less than 15. If the borrow pit soil is sandy silt or silty sand or nonplastic silt, side slopes shall be covered by 200 mm thick clay cladding. Side slopes shall be according to soil type as per Table 11. Borrow pit soil types shall be identified as per USCS classification or AASHTO classification. If classified using USCS classification, Fat Clay (LL>50 and PI above A Line) shall be avoided for embankment construction. If classified using AASHTO classification, A-7, A-7-5 and A-7-5 type soil shall be avoided for embankment construction.

2.3.1 Compaction Methodology

Widening part or embankment construction can be done using borrow pit soil or dredged sand. Digital moisture meter must be used to monitor moisture content of fill soil before compaction.

If the borrow pit soil is lean clay, silty clay or clayey silt with moisture content more than 20%, the soil shall be cut and spread for drying. Moisture content shall be monitored during drying. If the moisture content comes within 12-18%, the soil shall be spread in 200 mm thick layer with lumps not larger than 50 mm. compacted layer thickness shall be less than 150 mm. Plate compactor or rammer shall be used for compaction. If the borrow pit soil contain less than 12% moisture content, water need to be sprinkled after spreading.

If the borrow pit soil is sandy silt or silty sand or nonplastic silt, moisture content shall be maintained within 6-10% before compaction. Loose thickness of one layer shall be 200 mm.

If dredged sand need to be used for filling widening part or top of embankment, dredged sand cannot be directly poured in the embankment from the outlet of dredging pipe. At first, dredged sand shall be dumped in a dumping site. Dredged sand shall be placed in 200 mm thick loose layers in embankment with controlled moisture content 6-10% and then compacted.

In many instances, there is not enough space to maintain the suggested side slopes of rural roads. Treated soil should be used for filling widening part so that steep slope (1:1) can be used. All types of soil can be treated using CEM-II cement or Ground Granulated Blast Furnace Slag (GGBFS). 5% cement or 5% GGBFS shall be mixed with the soil and compacted by rammer or plate compactor. Compaction method is same as mentioned above. Mixing of cement or GGBFS is not an easy task for rural road construction because mixing equipment is not available. Alternative option is to spread the soil in 100 mm layers on which cement or GGBFS shall be sprinkled. Sandy silt, silty sand and nonplastic silt is preferable for this treated soil.

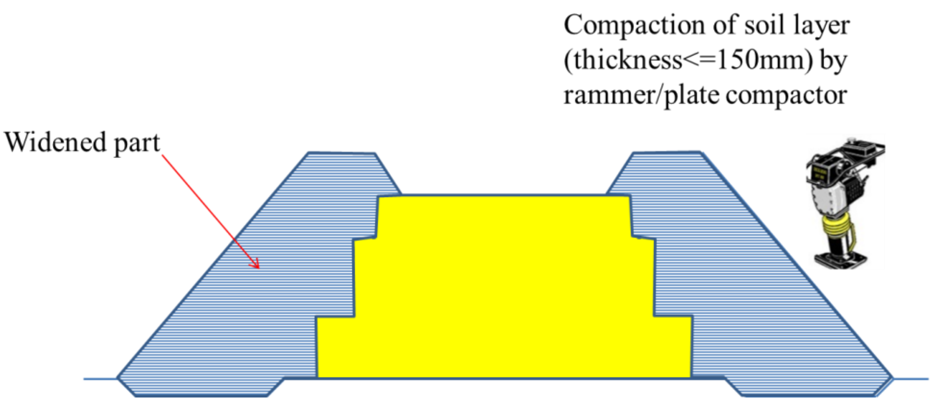

Figure 8: Layer by layer compaction of widening part

2.4 Pavement Recommendation

Depending on the traffic load, layer thicknesses of flexible pavement are determined (ref. BRTC BUET report for LGED). However, durability of this flexible pavement depends on compaction of subgrade, compaction of pavement layers (ISG, subbase, base), confinement by properly compacted shoulder width and drainage of rain water by maintaining proper camber. Considering manpower of LGED compared to work volume and socio-economic and management problem of Bangladesh, flexible pavement should be avoided if other circumstances don't compel to construct flexible pavement. Usually, LGED considers the design life of rural road 10 years. It was observed than flexible pavements of rural roads lose their serviceability within 2-5 years. Therefore, it is highly recommended to use rigid pavement instead of flexible pavement. However, cost of rigid pavement is higher than that of flexible pavement. Table 2 and

Table 3 show the per km cost of flexible and rigid pavement for a typical single lane village road. Total thickness pavement layers is 600 mm. Brick chips is used for rigid pavement. It is found that cost of rigid pavement is 40% higher than that of flexible pavement. However, total project increases only 10-15% due rigid pavement. **Table 4** summarizes the situations where rigid pavement should be selected. After casting rigid pavement concrete, road cannot be used for at least two weeks. This can be solved by casting the concrete half of the road width when other half is used for vehicle movement.

Traditional flexible pavement layers are shown in **Figure 9**. Depending on the traffic volume layers thicknesses of flexible pavement shall be determined as per road design and pavement standards of LGED (BRTC, BUET, 2017). Rigid pavement layers are shown in **Figure 10**. Rigid pavement layer thicknesses and materials for different traffic volume of road are provided in

Table 5, Table 6 and Table 7. Detail specification of concrete classes mentioned here are described in “Climate Resilient Concrete Manual” (Alam & Hoque, Climate Resilient Concrete Manual, 2019). Rigid pavement construction sequence may be as shown in Figure 11. In general, village roads may be considered as low traffic (0-200 CVD), Union roads as medium traffic (201-500 CVD) and Upazilla roads as heavy traffic (500 or more CVD) (see Table 8). It is very important to note that road distress is mainly depends on axle load and number of repetitions of Equivalent Single Axle Load (ESAL) on the road. However, if a truck (5 Ton or more capacity) enter in a village or union road having single lane pavement, tyre goes on edge of pavement or at shoulder during passing over or crossing another vehicle. This is a situation where road damage mainly depends on axle load of vehicle and does not depend on repetitions of ESAL. Therefore, for village road and union road, bus and truck having capacity more than 1.5 Ton must be restricted (see Table 9).

It is assumed that total thickness required for elevating the road is 600 mm. If more than 600 mm thickness is required for elevating the road, subgrade thickness will be increased as required.

Table 2: Cost per km of 3.7 m wide flexible road pavement.

Cost per km of 3.7 m wide flexible road pavement				
item	unit	quantity	unit rate	cost (BDT)
cleaning and grubbing	sqm	3700	8.00	29,600
earthfilling excluding compaction cost	cum	0	165.00	0
mecanical compaction (roller or plate compactor)	cum	0	38.00	0
earthwork in box cutting	sqm	3700	62.00	229,400
Improved Subgrade (ISG)	cum	1110	440.00	488,400
Subbase using brick chips and sand mixed	cum	555	2500.00	1,387,500
base using brick chips	cum	555	4100.00	2,275,500
brick edging	m	2000	150.00	300,000
prime coat	sqm	3700	120.00	444,000
25 mm bituminous carpeting	sqm	3700	410.00	1,517,000
7 mm seal coat	sqm	3700	130.00	481,000
base using stone chips	cum	0	9625.00	0
concrete L-21 or L-21B	cum	0	14000.00	0
Rebar	kg	0	91.00	0
total				7,152,400

Table 3: Cost per km of 3.7 m wide rigid road pavement.

Cost per km of 3.7 m wide rigid road pavement				
item	unit	quantity	unit rate	cost (BDT)
cleaning and grubbing	sqm	3700	8.00	29,600
earthfilling excluding compaction cost	cum	1110	165.00	183,150
mecanical compaction (roller or plate compactor)	cum	1110	38.00	42,180
earthwork in box cutting	sqm	0	62.00	0
Improved Subgrade (ISG)	cum	0	440.00	0
Subbase using brick chips and sand mixed	cum	0	2500.00	0
base using brick chips	cum	555	4100.00	2,275,500
brick edging	m	0	150.00	0
prime coat	sqm	0	120.00	0
25 mm bituminous carpeting	sqm	0	410.00	0
7 mm seal coat	sqm	0	130.00	0
base using stone chips	cum	0	9625.00	0
concrete L-21 or L-21B	cum	555	10500.00	5,827,500
Rebar	kg	17316	91.00	1,575,756
total				9,933,686

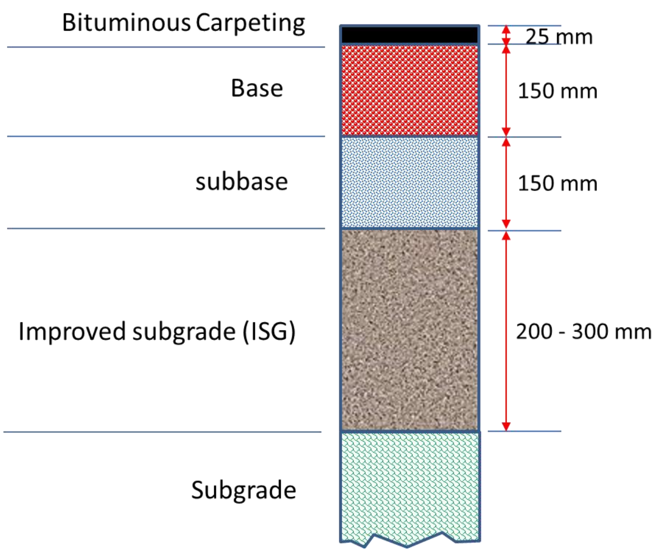

Figure 9: Traditional flexible pavement layers (Typical)

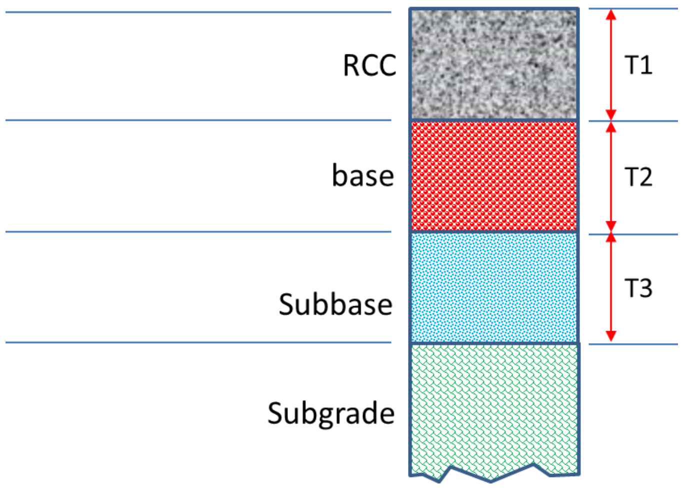

Figure 10: Proposed rigid pavement layers (subbase is required for heavy traffic road only).

Table 4: Situations where rigid pavement should be selected.

Sl. No.	Situations where Rigid Pavement Should be Selected
1	The road is susceptible to submergence during monsoon floods
2	Pond or canal (khal) at one side or both side of road
3	Hat, Bazar or Growth Centers
4	Bridge Approaches
5	At junctions with earthen road where earthen road elevation lower than LGED road
6	Soft clay under the embankment
7	Gher or fish farms at one side or both side
8	Embankment, subgrade, shoulder material don't satisfy the specification (for example, Fat Clay, Organic Clay etc.)

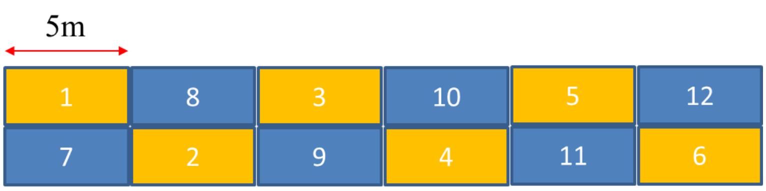

Figure 11: RCC Pavement Construction Pattern

Table 5: Rigid pavement layer thicknesses and materials for low traffic road (0-200 CVD)

Pavement class: **RIGID-LIGHT**		
	Thickness	Material
RCC	150 mm	• Concrete Class-L-21B or L-21 • 1 layer reinforcement • Short direction rebar = D10@200 mm c/c • Long direction rebar = D10@100 c/c (placed at bottom of short direction rebar) • Rebar shall be deformed bar of fy = 420 MPa or more • Epoxy coated rebar shall be used for roads within 20 km from main coast line • Staggered lapping of rebar, lapping length = 40 times bar diameter • No gap at construction joint • Clear cover 50 mm at bottom
Base	150 mm	25 mm down well graded stone chips; well compacted by roller OR 25 mm down well graded slag; well compacted by roller OR Coarse sand of FM > 2.50; well compacted by roller OR 25 mm down well graded brick chips, well compacted by roller
Subbase	0 mm	Not applicable
Improved Subgrade	0 mm	Not applicable
Subgrade	300 mm	Lean clay, silty clay, sandy silt, silty sand with any CBR value

Table 6: Rigid pavement layer thicknesses and materials for medium traffic road (201-500 CVD)

Pavement class: **RIGID-MEDIUM**		
	Thickness	Material
RCC	200 mm	• Concrete Class-L-21B or L-21 • 1 layer reinforcement • Short direction rebar = D10@200 mm c/c • Long direction rebar = D12@100 c/c (placed at bottom of short direction rebar) • Rebar shall be deformed bar of fy = 420 MPa or more • Epoxy coated rebar shall be used for roads within 20 km from main coast line • Staggered lapping of rebar, lapping length = 40 times bar diameter • No gap at construction joint • Clear cover 75 mm at bottom
Base	150 mm	25 mm down well graded stone chips; well compacted by roller OR 25 mm down well graded slag; well compacted by roller OR Coarse sand of FM > 2.50; well compacted by roller OR 25 mm down well graded brick chips, well compacted by roller
Subbase	0 mm	Not applicable
Improved Subgrade	0 mm	Not applicable
Subgrade	250 mm	Lean clay, silty clay, sandy silt, silty sand with any CBR value

Table 7: Rigid pavement layer thicknesses and materials for heavy traffic road (more than 500 CVD)

Pavement class: **RIGID-HEAVY**		
	Thickness	Material
RCC	250 mm	• Concrete Class-L-24 • 2 layer reinforcement • Short direction top and bottom rebar = D10@200 mm c/c • Long direction bottom rebar = D16@150 mm c/c (placed at the bottom most layer) • Long direction top rebar = D10@150 mm c/c • Rebar shall be deformed bar of fy = 420 MPa or more • Epoxy coated rebar shall be used for roads within 20 km from main coast line • Staggered lapping of rebar, lapping length = 40 times bar diameter • No gap at construction joint • Clear cover 75 mm at bottom
Base	150 mm	25 mm down well graded stone chips; well compacted by roller OR 25 mm down well graded slag; well compacted by roller OR Coarse sand of FM > 2.50; well compacted by roller
Subbase	200 mm	10% cement/GGBFS treated compacted locally available fine sand with FM> 0.50
Improved Subgrade	0 mm	Not applicable
Subgrade	0 mm	Lean clay, silty clay, sandy silt, silty sand with any CBR value

Table 8: Traffic Class as per "Road Design Manual for LGED" (BRTC, BUET, 2017)

Commercial Vehicle per Day (CVD)	Traffic Class
0 - 200	Low Traffic
201 - 500	Medium Traffic
500 and more	Heavy Traffic

Table 9: Axle load restriction of different category of roads

Road Category	Restricted Vehicles
Village Road	Bus and Truck of capacity more than 1.5 Ton
Union Road	Bus and Truck of capacity more than 1.5 Ton
Upazilla Road	Bus and Truck of capacity more than 10 Ton

2.5 Shoulder Recommendation

The purpose of shoulder is to provide edge support of the road pavement, assist off tracking vehicles, increase pedestrian safety, provide additional pavement width during vehicle side crossing, provide refuge for disabled vehicles, and prevent erosion from pavement runoff. Plain concrete, asphalt concrete, HBB (Herring Bone Bond), cemented sand and grass are various options for shoulder. After completion of flexible road pavement on poorly compacted subgrade, subbase and base, settlement and rutting of pavement occur whereas grass shoulder elevation remains same. That means pavement elevation become lower than shoulder. This causes water congestion on road pavement resulting damage of road pavement. During vehicle crossing on a single lane road, tyres go on edge of pavement or on shoulder. This is one of the reasons of road damage in rural areas. For this reason, hard shoulder (HBB, plain concrete, asphalt concrete or cemented sand) is better than soft shoulder (grass on soil). However, hard shoulder is more expensive than soft shoulder. Road beside pond or khal (canal) shows severe distress in pavement and shoulder. Hard shoulder should be constructed at road sections beside khal or pond (Type C, D, E). Recommended shoulder options are shown in Table 10.

Table 10: Shoulder recommendation for various traffic volume and embankment type

	Type A, B	Type C, D, E
Low Traffic Road	Grass on Compacted Soil	plain concrete
Medium Traffic Road	Grass on Compacted Soil	plain concrete
Heavy Traffic Road	plain concrete	plain concrete
Specification of plain concrete: Thickness = 100 mm, Mix ratio = 1:2:3.5, Coarse Aggregate = Brick Chips or Slag or Recycled crushed concrete Transverse slope of shoulder = 5%		

2.6 Drainage, Vegetation and Camber

Surface and subsurface drainage is important for durability of road. Surface drainage is expensive and not feasible for rural roads. However, if the vegetation on side slopes, camber (2.5%) and shoulder slope (5%) are done properly, surface drainage is not required. Sheet flow of rain water on vegetated slope shall have no erosion capacity. Subsurface drainage is important to prevent pumping when water enters into pavement layers. Details of subsurface drainage are shown in Figure 20 and Figure 21.

2.7 Embankment Widening Guidelines at Different Situations

During upgradation of any rural road, widening is the most challenging part of construction. Different difficult situations arise during widening of rural road in the coastal districts (see Figure 3 to Figure 7). Step by step construction sequences are described with pictorial presentation for all the situations. Compaction of filling soil maintaining optimum moisture content is the key parameter of quality control of road construction. If the compaction quality is not ensured, road will not be durable. The slogan **"NO COMPACTION, NO ROAD"** should be propagated with notice, signboard and banners in all levels of LGED (Figure 12).

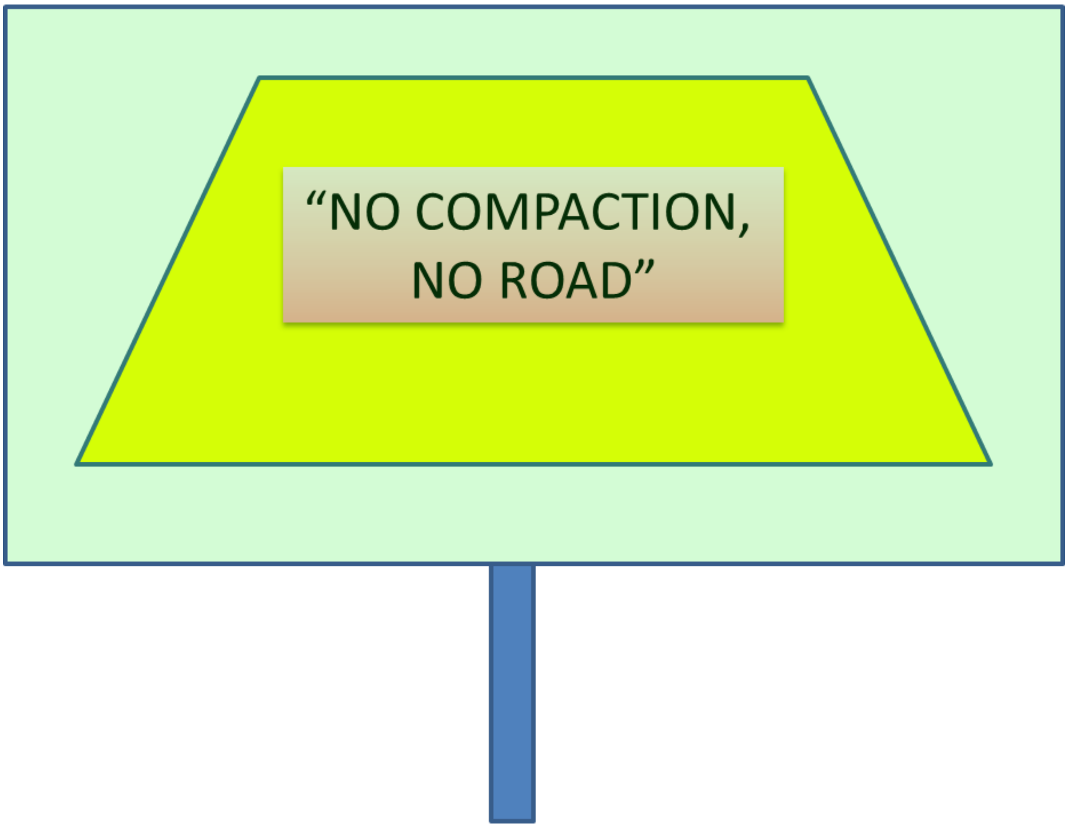

Figure 12: Slogan for rural road construction.

2.7.1 Pavement Widening General Guideline

In general, following steps must be followed during widening and upgradation of road:

- **i. Removal of unsuitable soil of the ground on which widened part will be constructed**
- **ii. Benching on side slopes**
- **iii. Construction of widened part by layer by layer compaction of treated or untreated soil**
- **iv. Box cutting**
- **v. Pavement construction with proper camber and shoulder slope**
- **vi. Covering of sides by clay cladding if the widened part is filled with sand, sandy silt, silty sand, nonplastic silt or treated soil**
- **vii. Vegetation on side slopes**
- **viii. Installation of subsurface drainage**

i. Removal of unsuitable soil:

Grass and topsoil with humus must be removed from the ground on which widened part of embankment will be constructed. If mud or very soft clay exists under the top soil, that part should also be removed. This removed soil may be preserved somewhere, so that it may be used on side slopes after completion of widened part. Vegetation will grow faster on this type of soil.

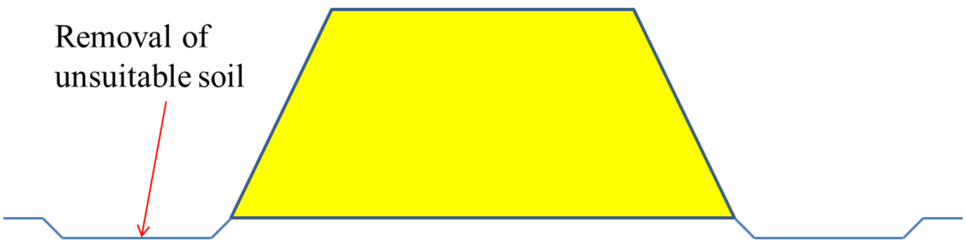

Figure 13: Removal of unsuitable soil

ii. Benching on existing side slopes:

All grasses and trees shall be removed from existing side slopes. Benching shall be done with convenient size of steps.

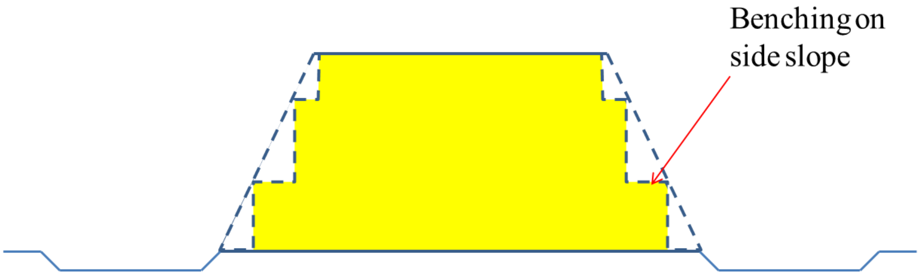

Figure 14: Benching on existing side slopes

iii. Construction of widening part:

Compaction and treatment of widening part shall be as per Section 2.3.

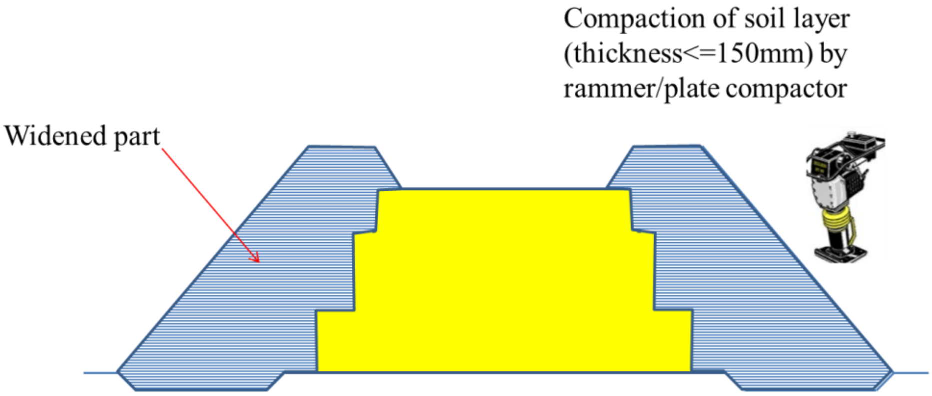

Figure 15: Layer by layer compaction of widening part

Table 11: Recommended side slope for different soil types

Soil Type	Side Slope (Vertical : Horizontal)	Clay Cladding Requirement on Side Slopes
sandy silt, silty sand, nonplastic silt (untreated)	1 : 1.75	Yes
Lean clay, silty clay, clayey silt (untreated)	1 : 1.50	No
All types of soil (treated)	1 : 1.00	Yes

iv. Box cutting:

Box cutting is done for constructing pavement layers.

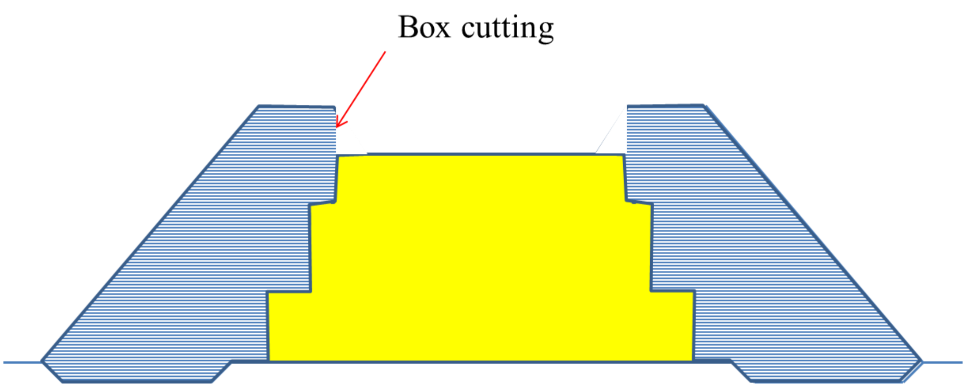

Figure 16: box cutting before pavement construction

v. Pavement construction

Pavement construction shall be done as per recommendation given in Section 2.4. Before constructing pavement layers, compacted sand filling may be required if total thickness of pavement layers don't cover the required elevation of top surface of road. Considering durability, frequent flooding, socio-economic condition of Bangladesh, environment protection, and bad practices and examples of flexible pavement construction, rigid pavement should be constructed instead of flexible pavement. Rigid pavement increases the road construction cost 10-15%. During pavement construction most important point shall be maintaining proper camber and shoulder slope as per **Figure 17**. Transverse slope at pavement shall be 2.5% and at shoulder 5%. If these slopes are properly done, there shall be no requirement of surface drainage. Rain water will sheet flow on vegetated side slopes. Pavement construction includes ISG, subbase, base, bituminous carpeting and seal coat in case flexible pavement. In case of rigid pavement, base and RCC shall be the main two layers for low and medium traffic road. For heavy traffic road, subbase shall be needed. Layer thicknesses shall be as per recommendation given in Section 2.4.

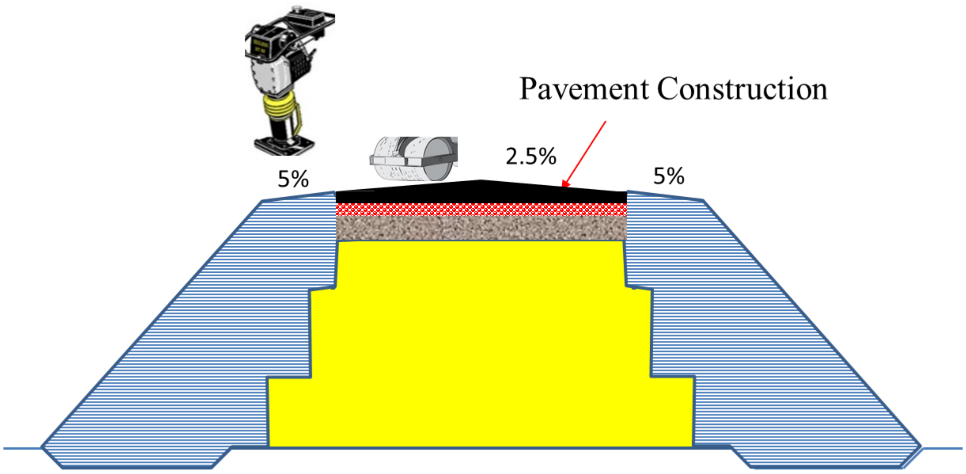

Figure 17: Pavement construction

vi. Clay cladding:

Rain cut erosion need to be prevented in side slopes where widened part is filled with sandy silt, silty sand or nonplastic silt. 200 mm thick clay shall be used cladding on side slopes.

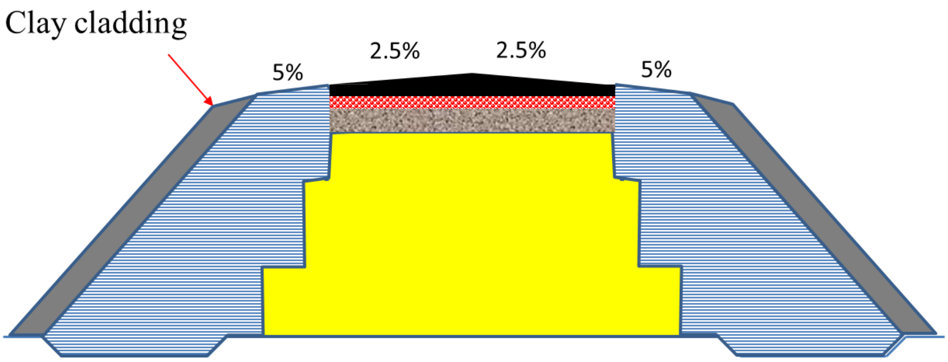

Figure 18: Clay cladding on side slopes if widened part is filled with sandy silt, silty sand or nonplastic silt.

vii. Vegetation on side slopes:

Vegetation is eco-friendly and has a very beneficial effect on the side slope protection. In many cases, it helps to make a sustainable slope. But, due to lack of maintenance and inadequate sunlight, it does not grow properly to protect the slope. At the side slopes, trees are planted to protect slopes. Side slopes must be protected immediately after completion of road construction. Biotechnology shall be the best and environment friendly option for this purpose. Vetiver or local grasses shall be planted on side slopes before commencement of monsoon. Watering shall be done to grow the vegetation in dry season. Large tree plantation shall be avoided on shoulders. Large trees may be planted 1 m below the shoulder level.

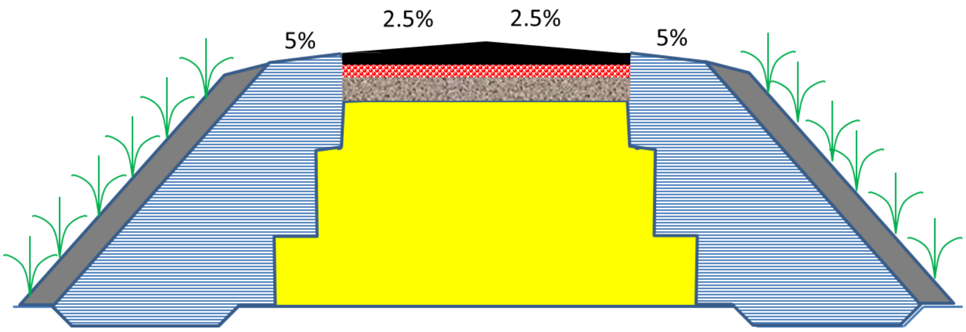

Figure 19: Vegetation on side slope

viii. Installation of subsurface drainage:

Pumping need to be prevented by installing subsurface drainage which will be connected to base layer. Subsurface drainage is geobag of size 300x300x1500 filled with 20 mm down well graded brick chips. 3 mm thick geotextile shall be used to make geobag. 325 mm wide and 450 mm deep trench will be cut on shoulder @ 5m interval. Subsurface drainage shall be placed into the trench and top shall be covered with the compacted shoulder soil.

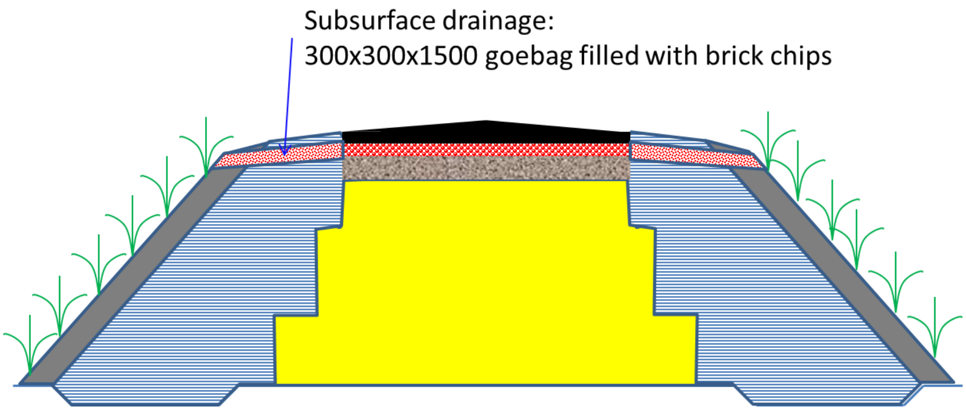

Figure 20: Subsurface drainage under shoulder @ 5m interval along the road

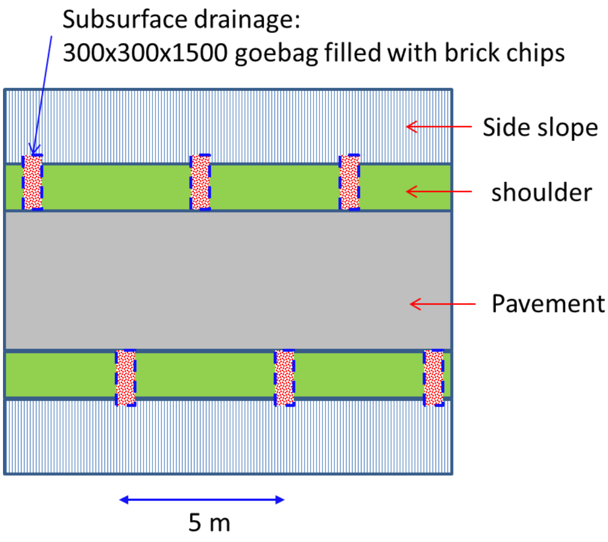

Figure 21: Layout of subsurface drainage under shoulder

2.7.2 Type A: Paddy Land at Both Sides

This is a general condition where suitable subgrade and ISG materials are not available locally, side slopes are steep, and subsoil is consolidated under existing road embankment. During upgradation work, both sides of road are dry and water table is 1m – 2m below the existing ground level. This situation is shown in **Figure 22**. All the construction sequences described in 2.7.1 is applicable for this type A.

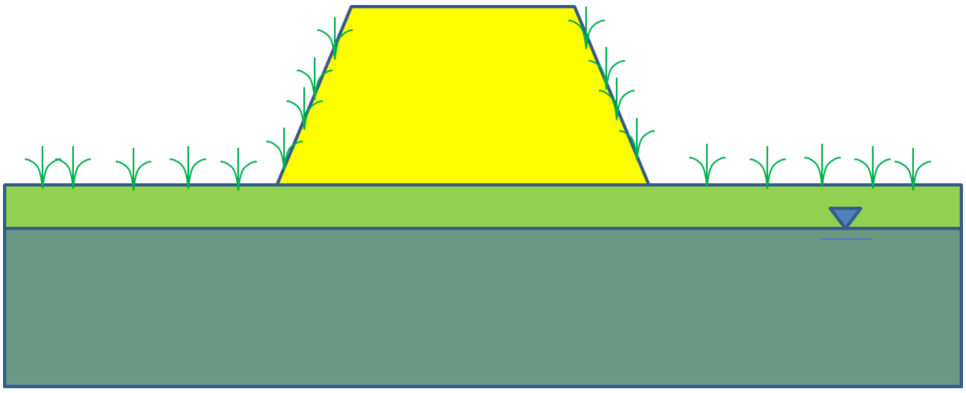

Figure 22: TYPE A: Paddy land at both sides

2.7.3 Type B: Gher (Fish Farm) at Both Sides

This is a condition where gher (fish farm) are located in both sides of road. Fish farm or marshy land at either side of road, side slopes are steep (1: 1 or less), suitable subgrade and ISG materials are not available. During construction, water table is 1m – 2m below the road crest. Without dewatering, it is quite impossible to construct durable road in this situation. After dewatering, all the construction steps are same as type A as described in Section 2.7.1.

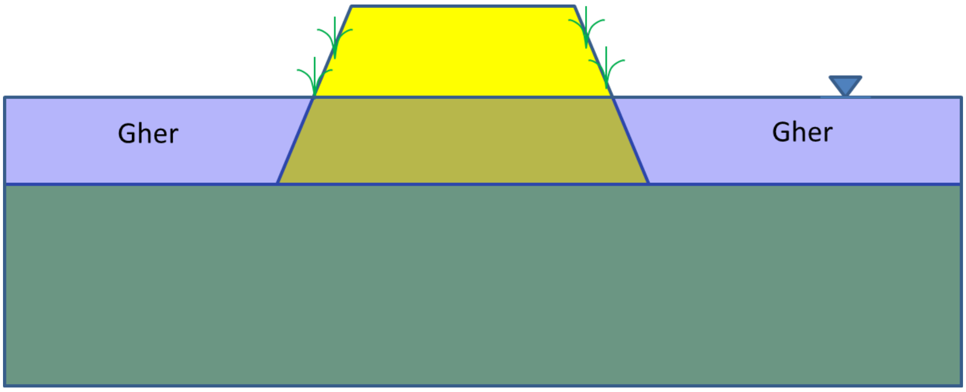

Figure 23: Type B; Gher (Fist Farm) at both side

Construction steps for this Type B are

i. **Dewatering of existing Gher (Fish Farm) (see Figure 24)**
ii. **Removal of unsuitable soil of the ground on which widened part will be constructed**
iii. **Benching on side slopes**
iv. **Construction of widened part by layer by layer compaction of treated or untreated soil**
v. **Box cutting**
vi. **Pavement construction with proper camber and shoulder slope**
vii. **Covering of sides by clay cladding if the widened part is filled with sand, sandy silt, silty sand, nonplastic silt or treated soil**
viii. **Vegetation on side slopes**
ix. **Installation of subsurface drainage**

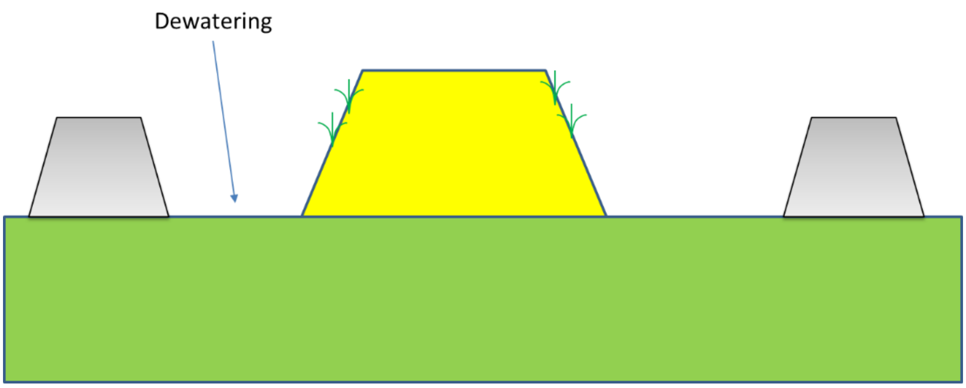

Figure 24: Dewatering of gher (fish farm) before road widening

2.7.4 Type C: Pond/Khal (Canal) at One Side of Road

This is a condition where pond/khal is located in one side of road and on the other side, there is paddy land. Side slope of embankment is steep (1:1 or less). However, below the embankment toe, there is a mild slope (1:1.5 or more) upto 2 m horizontal distance from toe. Beyond the mild slope part, steep slope of pond or khal starts. If the mild slope part below toe is less than 2 m wide horizontally, Type D will be applicable. (see Figure 6).

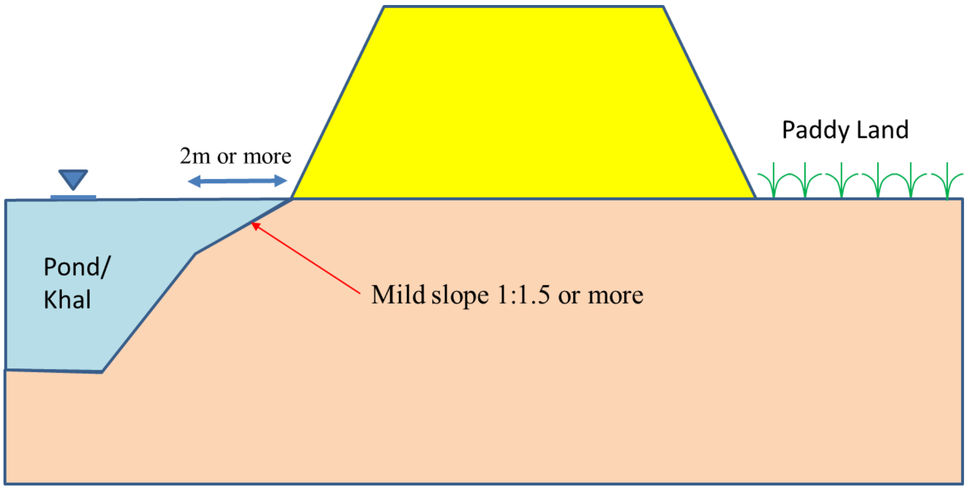

Figure 25: Type C situation with more 2 m mild slope under toe of embankment

Construction steps of Type C are shown below with pictorial presentation:

i. Installation of precast post at pond side and removal of unsuitable soil at paddy land side

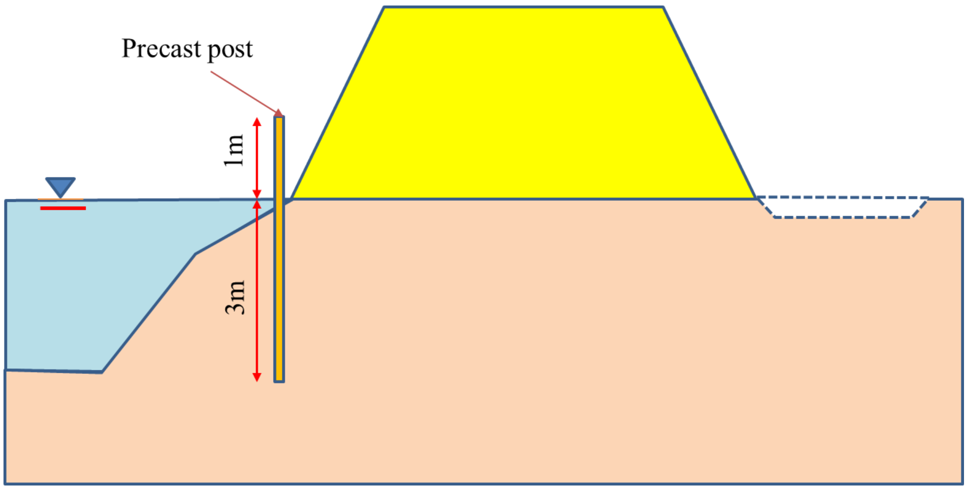

Figure 26: Installation of precast post and removal of unsuitable soil

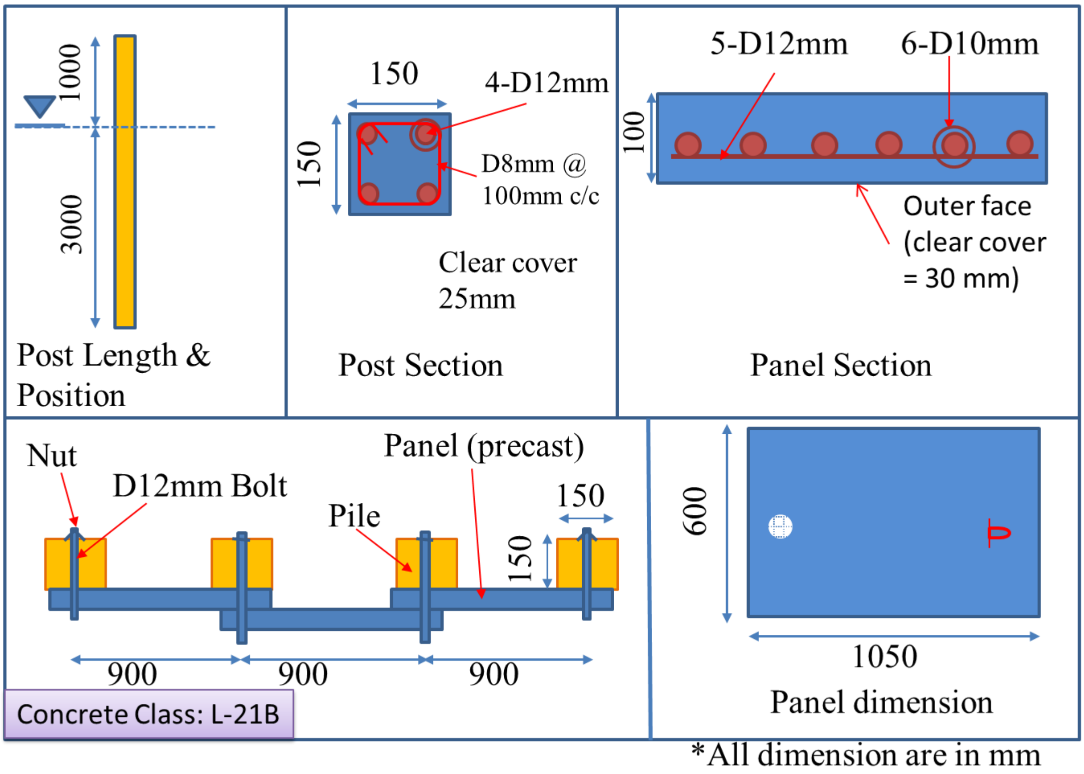

Figure 27: Details of precast concrete post and precast concrete panel for Type C

ii. Placing precast concrete panels

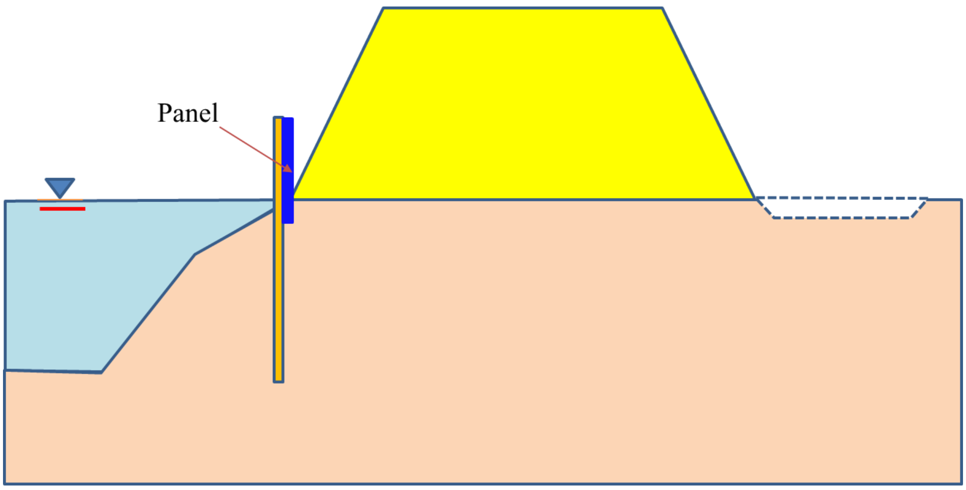

Figure 28: Placing precast concrete panels

iii. Placing sand filled gunny bag

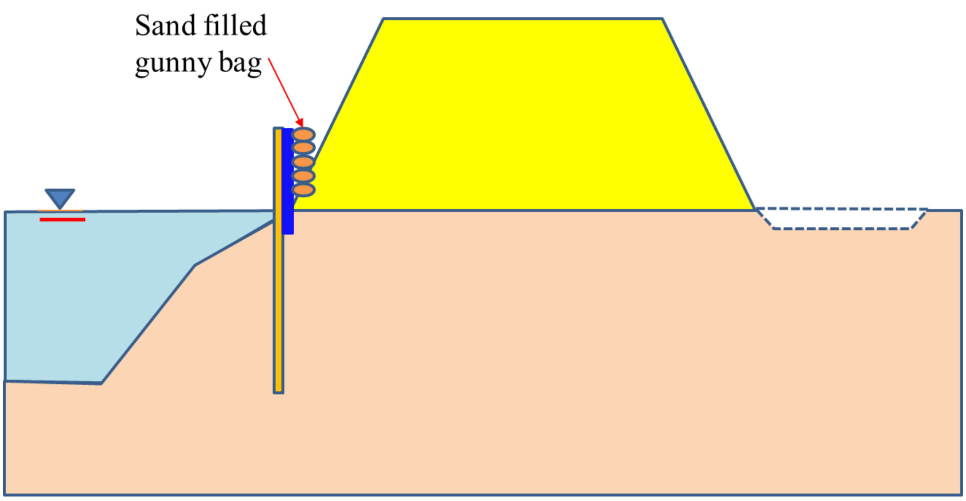

Figure 29: Placing sand filled gunny bag

iv. Benching

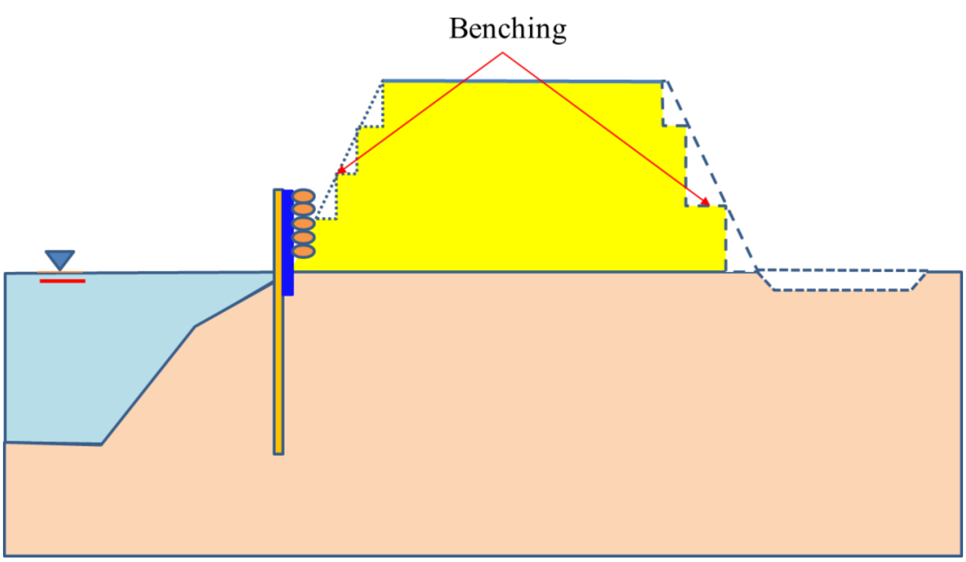

Figure 30: Benching

v. Construction of widening part with layer by layer compaction of soil

Construction of widening part shall be as per Section 2.7.1.

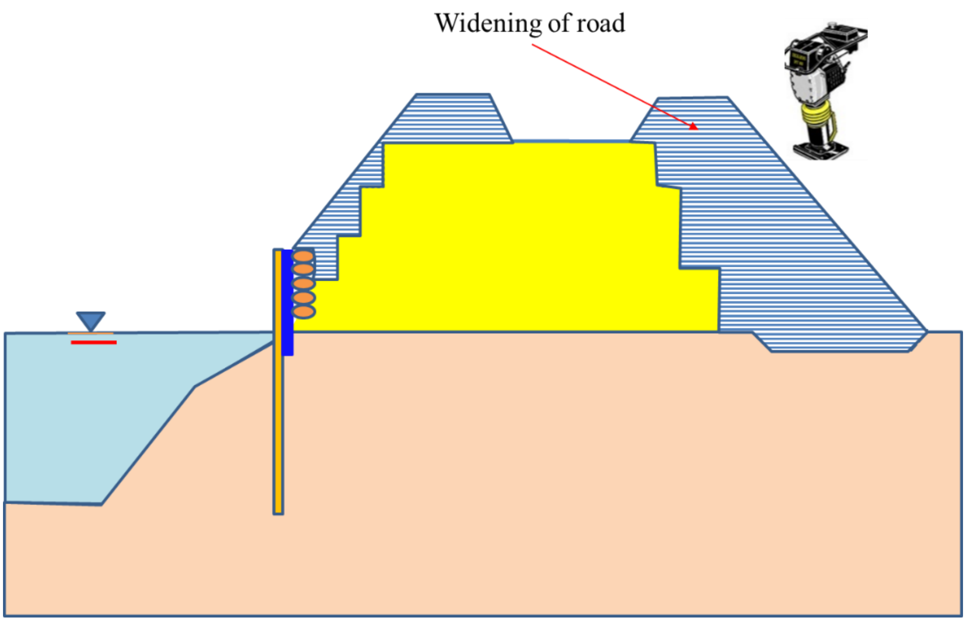

Figure 31: construction of widening part

vi. Box cutting before pavement construction

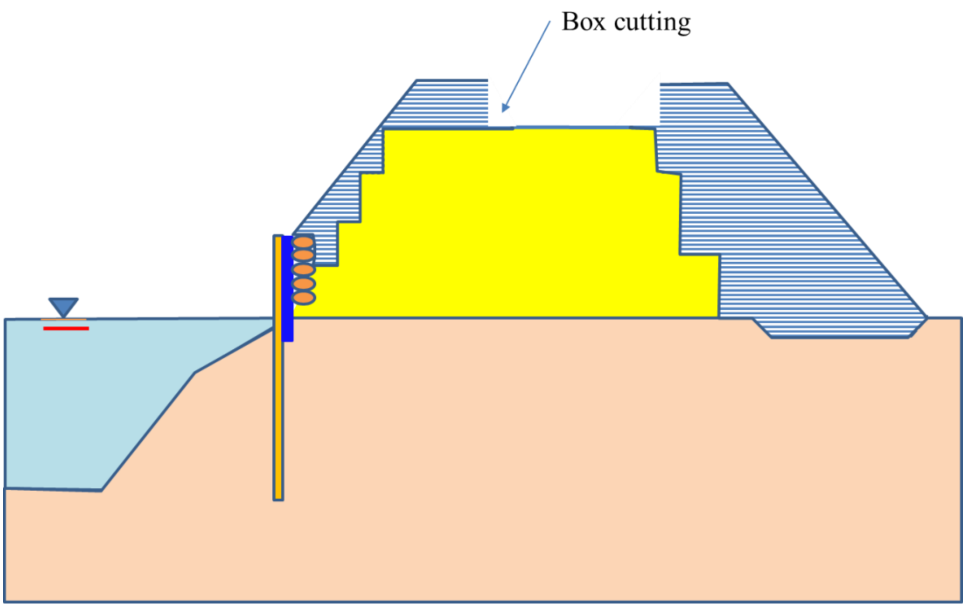

Figure 32: box cutting

vii. Pavement and shoulder construction with proper camber and shoulder slope

Pavement construction shall be as per Section 2.4. Shoulder construction shall be as per section 2.5.

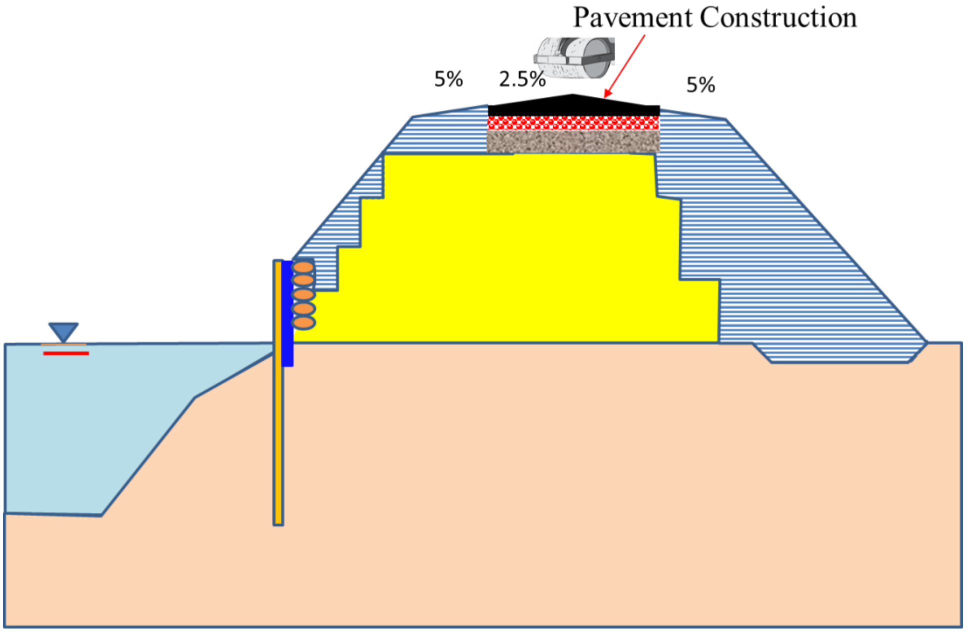

Figure 33: Pavement construction

viii. Vegetation

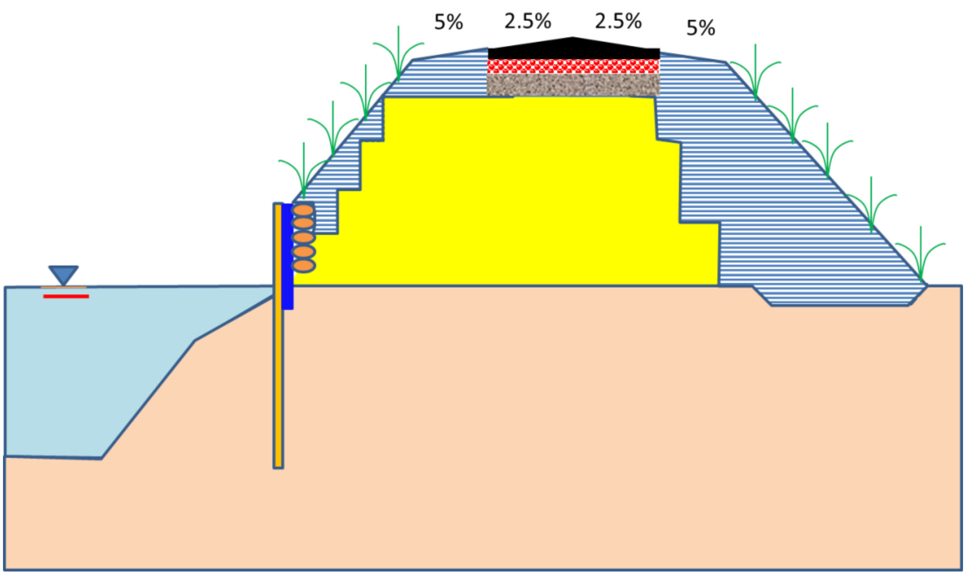

Figure 34: Vegetation on side slopes and shoulder

ix. Installation of subsurface drainage

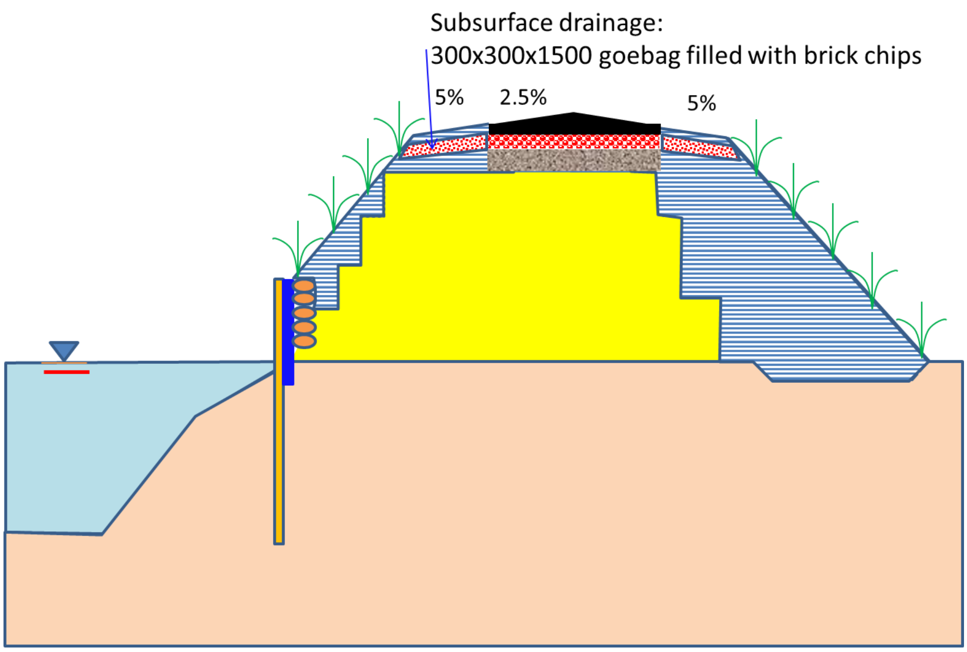

Figure 35: Installation of subsurface drainage

2.7.5 Type D: Pond/Khal (Canal) at One Side of Road

This is a condition where pond/khal is located in one side of road and on the other side, there is paddy land. Side slope of embankment is steep (1:1 or less). This is similar to Type C except the steep slope under toe of embankment. Below the embankment toe, there is a steep slope (1:1.4 or less). If the slope part below toe is mild (1:1.5 or more) but less than 2 m wide horizontally, Type D will be applicable. (see Figure 6).

Two types of solution are given for this type of situation. One is Type D1 where 2 m width of road in the pond/khal side is abandoned for further erosion or damage of road. The road is widened in the other side where paddy land is there. Another is Type D2 where pond/khal side is protected to keep the road straight.

Type D1: Sacrificial Width Solution

Construction steps with pictorial presentation of Type D1 is given below:

1. Selection of 2m Sacrificial width in pond/khal side

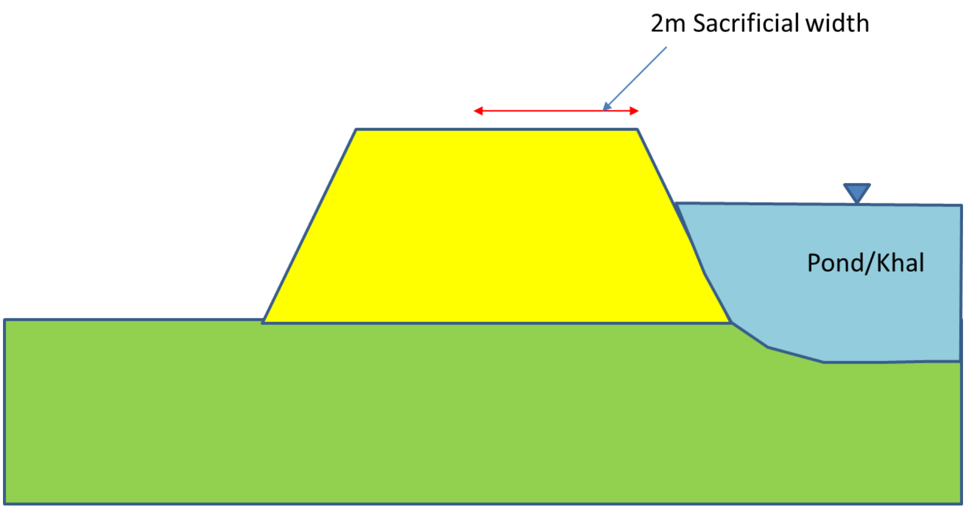

Figure 36: Abandoned 2 m width of existing road at pond or khal side

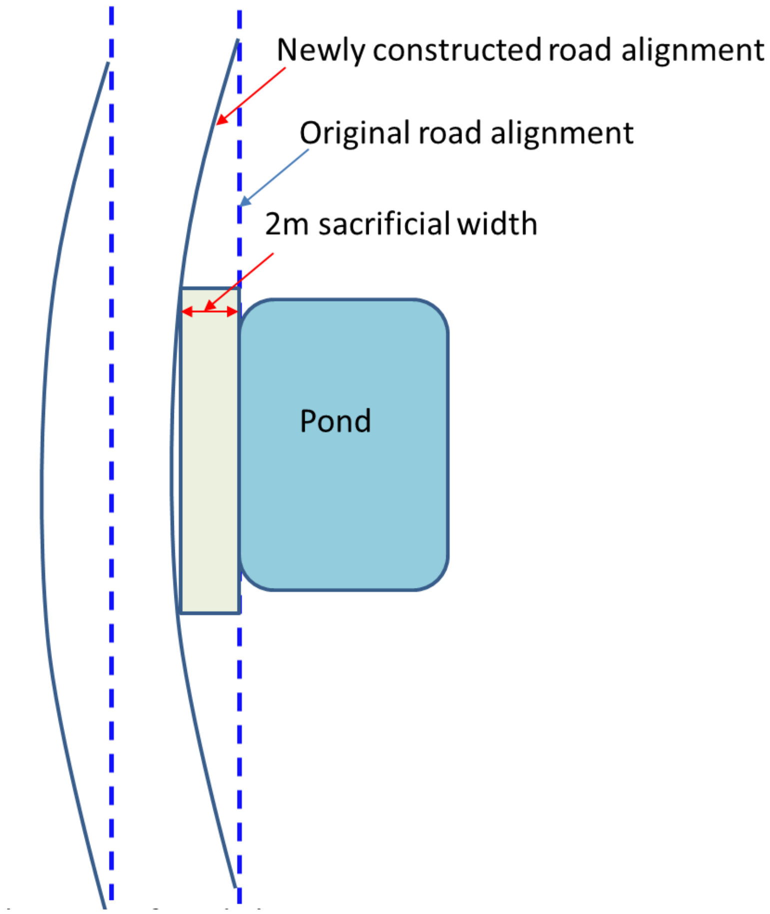

Figure 37: Plan view of shifted curved road alignment where pond at one side

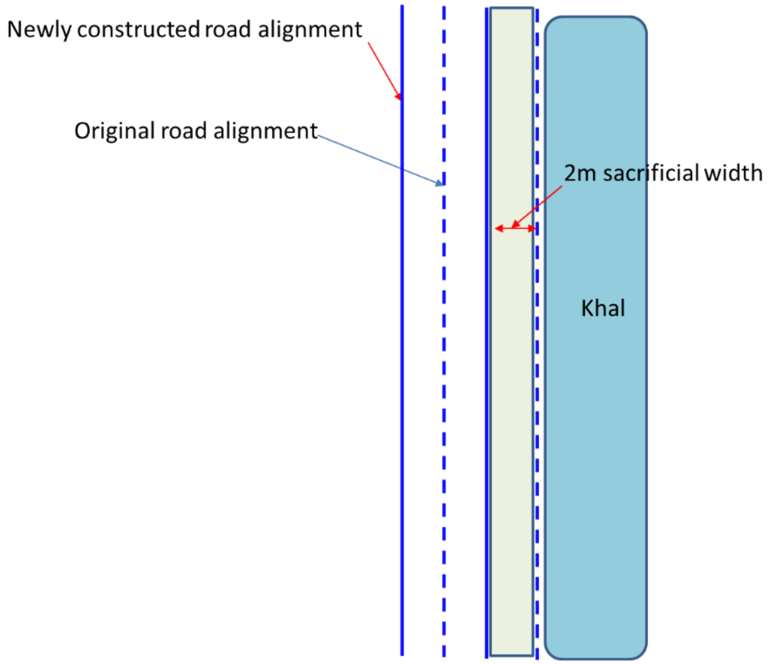

Figure 38: Plan view of road alignment for khal

2. Removal of unsuitable soil at paddy land side

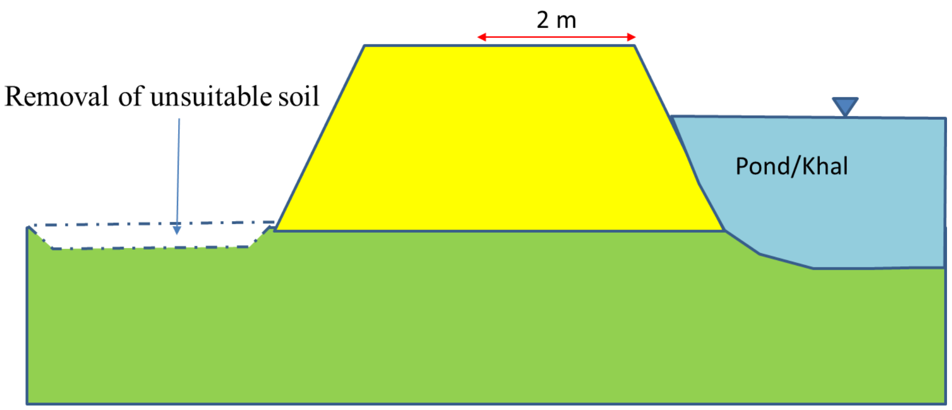

Figure 39: Removal of unsuitable soil at paddy land side

3. Preparation of shoulder at pond/khal side

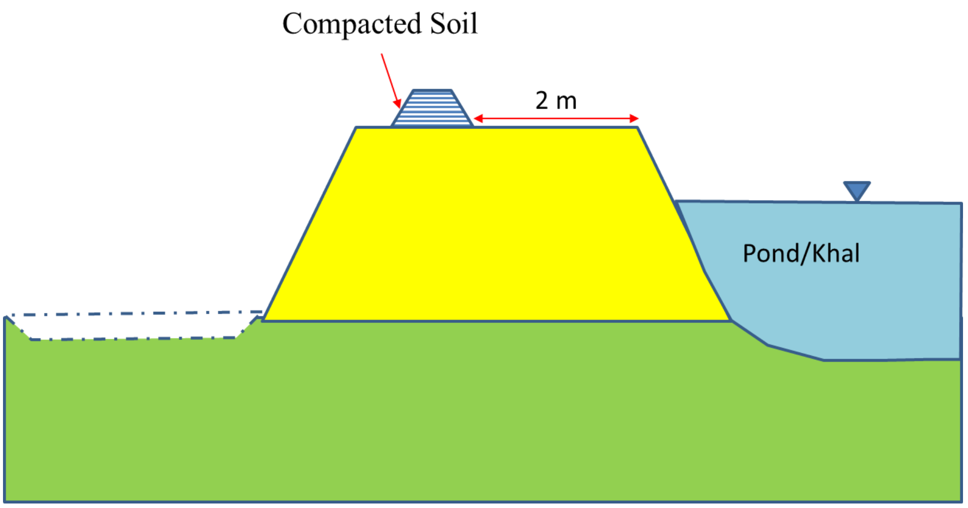

Figure 40: Preparation of shoulder in pond/khal side

4. Benching in paddy land side

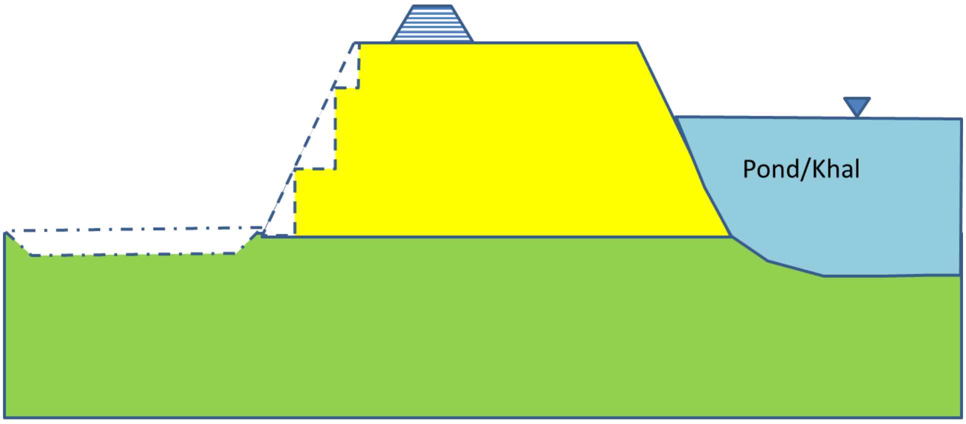

Figure 41: Benching in paddy land side

5. Widening of road at paddy land side

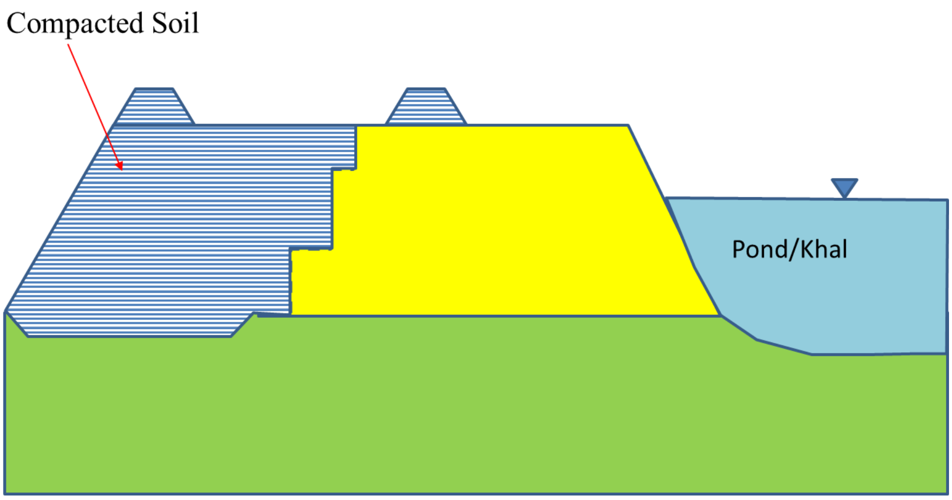

Figure 42: Widening of road using at paddy land side

6. Box cutting

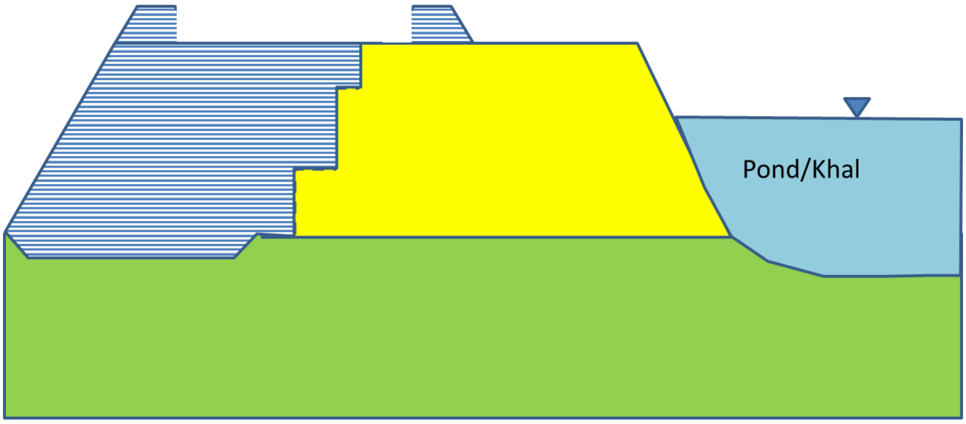

Figure 43: box cutting

7. Pavement and shoulder construction

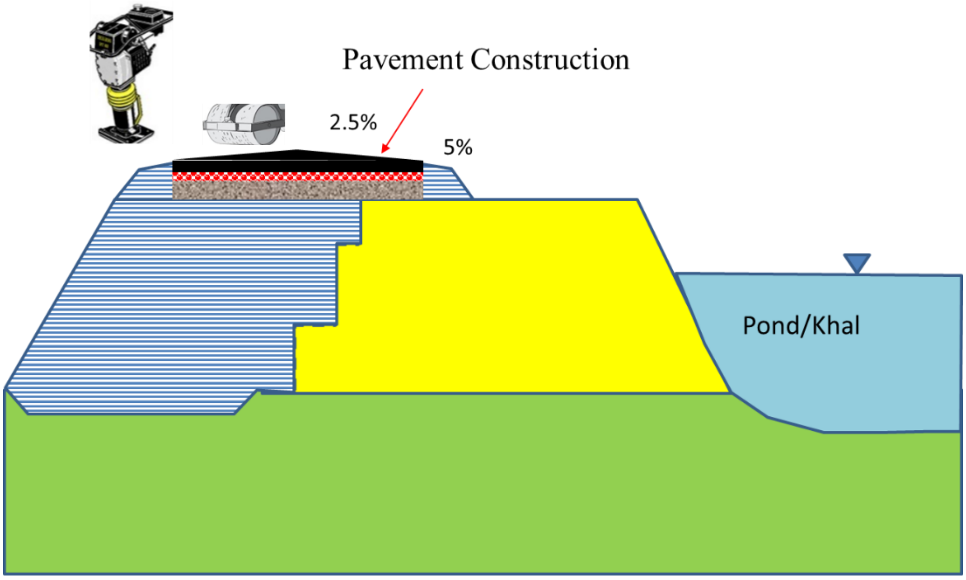

Figure 44: Pavement and shoulder construction

8. Vegetation at side slopes

Clay cladding shall be required for vegetation if widening is done using sandy silt, silty sand or nonplastic silt. Vegetation may be vetiver or locally available any suitable grass.

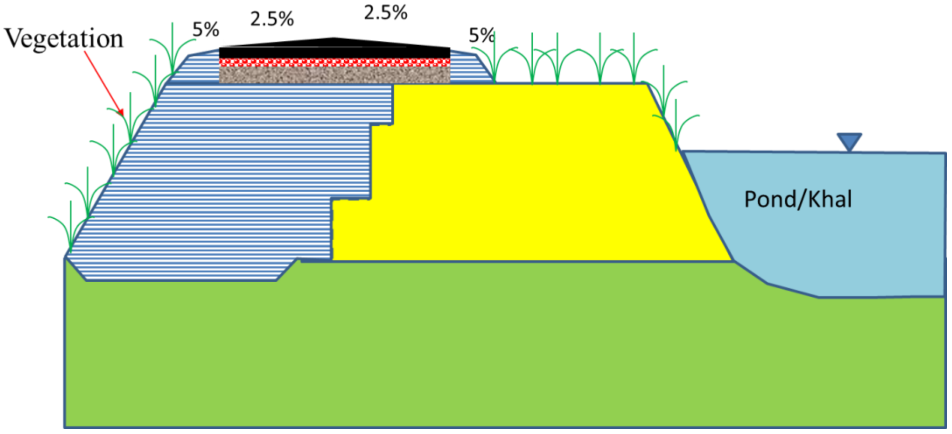

Figure 45: Vegetation at side slopes

9. Installation of subsurface drainage

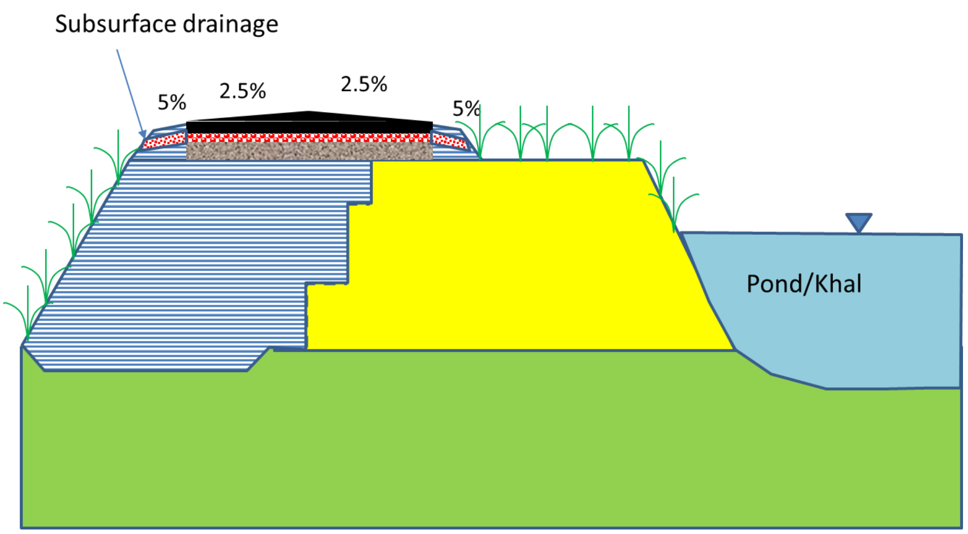

Figure 46: Installation of subsurface drainage

Solution for Type D2: Straight Road Solution

This is the situation where canal or pond at one side of road is deep and don't satisfy the condition of Type C. To keep the road straight or to keep widening at paddy land side minimum, canal/pond side need vertical protection work. Anchored pile is designed for different embankment height and soft soil under embankment. Geotechnical investigation shall be done to determine soft soil layer thickness under embankment. At least 20 m SPT boring and testing shall be done at toe of the embankment at pond/canal side. Step by step construction sequences for the Type D2 are described below.

i. Pile Installation at canal (khal) side

Geotechnical investigation is essential for designing pile size and reinforcement in anchored pile. Depending on the embankment height and soft soil thickness, pile length, section and rebar shall vary. Details of precast pile and panel are given in Figure 48 and Table 12. Embankment height shall be measured at 2 m distance from the edge of existing road top as shown in Figure 49.

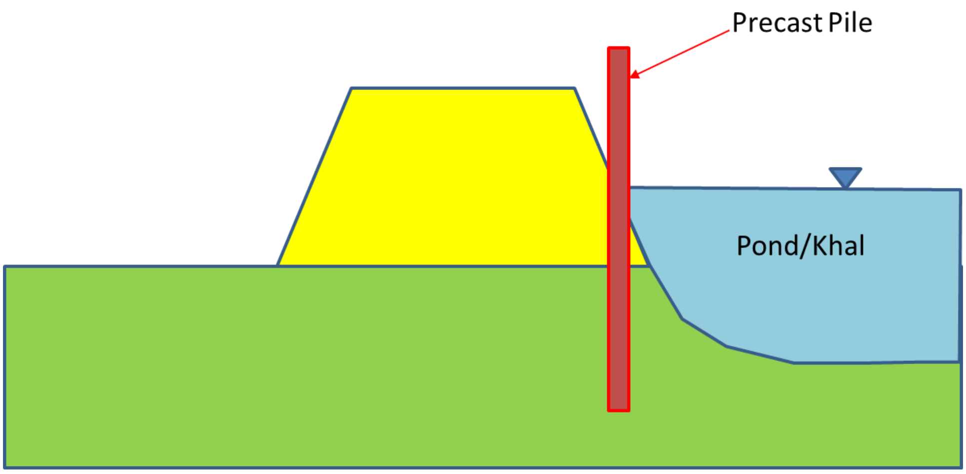

Figure 47: Pile installation at canal side

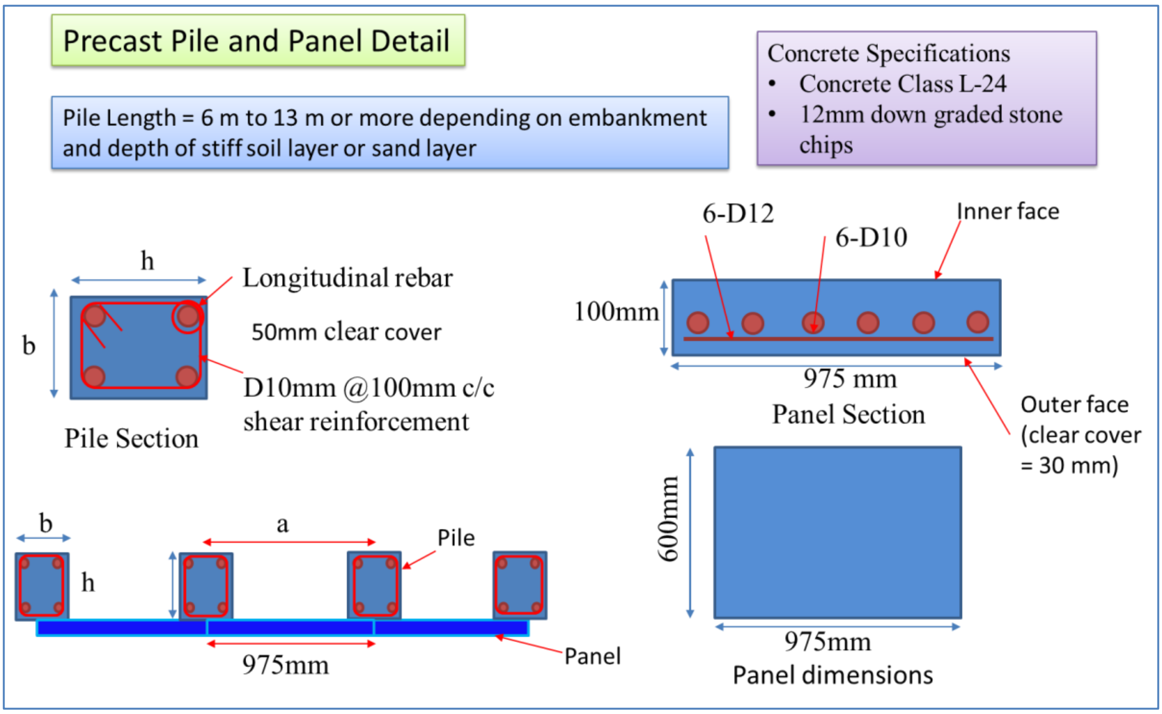

Figure 48: Details of precast pile and panel for Type D and E

Table 12: Details of precast pile depending on height of embankment and thickness of soft soil under embankment for Type D and E

Height of Embankment, m	Soft soil layer thickness below embankment, m	Pile Length, m	Pile Cross-Section, mxm (bxh)	Pile Spacing, m (a)	Longitudinal Rebar	Shear rebar	Concrete Class And Specification
3	2	6	0.20x0.20	1.0	4-D12mm	▪ Shear reinforcement: D10@ 100mm c/c distance	▪ Concrete Class: L-24 ▪ Coarse aggregate: 12mm down grade stone chips
3	3	7	0.25x0.25	1.0	4-D12mm		
3	4	9	0.25x0.30	1.0	4-D12mm		
3	5	10	0.25x0.35	1.0	4-D16mm		
4	2	7	0.25x0.30	1.0	4-D16 mm		
4	3	8	0.25x0.35	1.0	4-D16 mm		
4	4	10	0.25x0.40	1.0	4-D16 mm		
4	5	12	0.25x0.40	0.5	4-D16 mm		
5	2	9	0.25x0.30	0.5	4-D16 mm		
5	3	10	0.25x0.40	0.5	4-D16 mm		
5	4	11	0.25x0.40	0.5	4-D20 mm		
5	5	13	0.25x0.40	0.5	4-D20 mm		

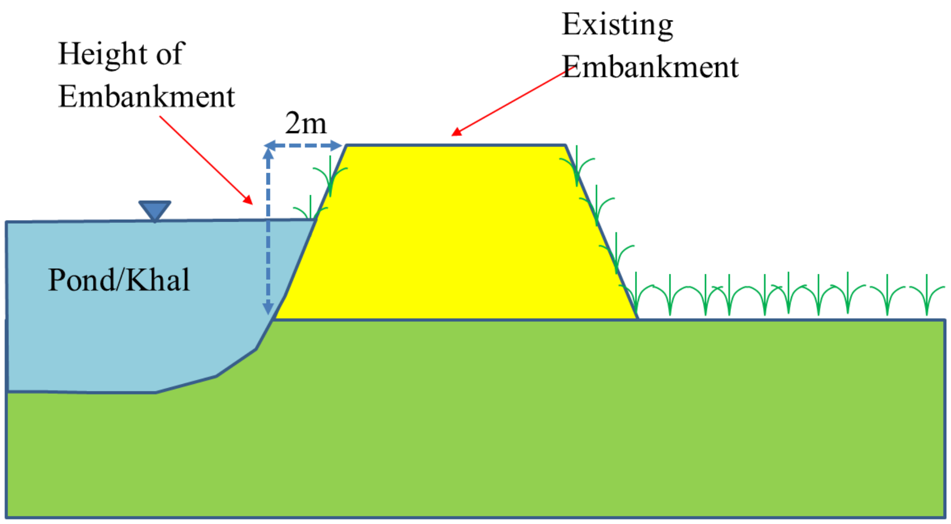

Figure 49: Selection of embankment height

ii. Anchoring precast concrete pile

Precast concrete pile is anchored by high strength steel wire rope. Details of anchor block and high strength steel wire rope is given in Figure 51.

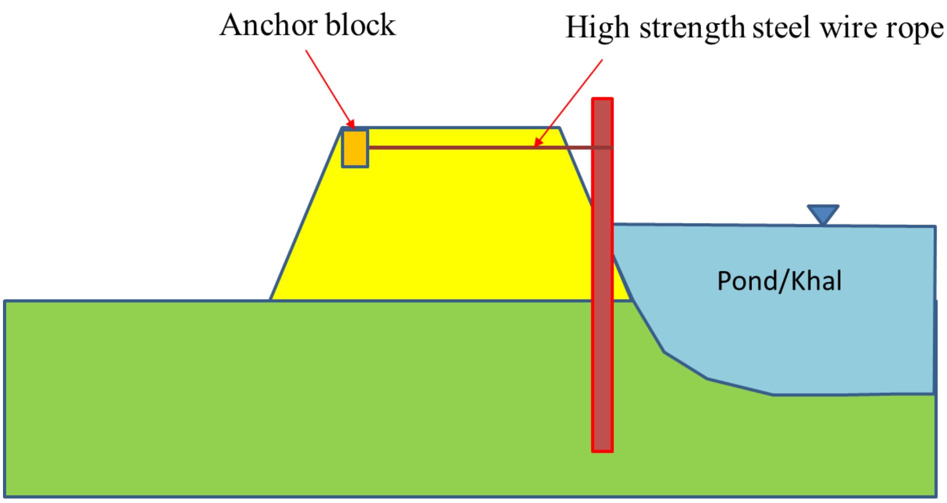

Figure 50: Anchoring Precast Pile

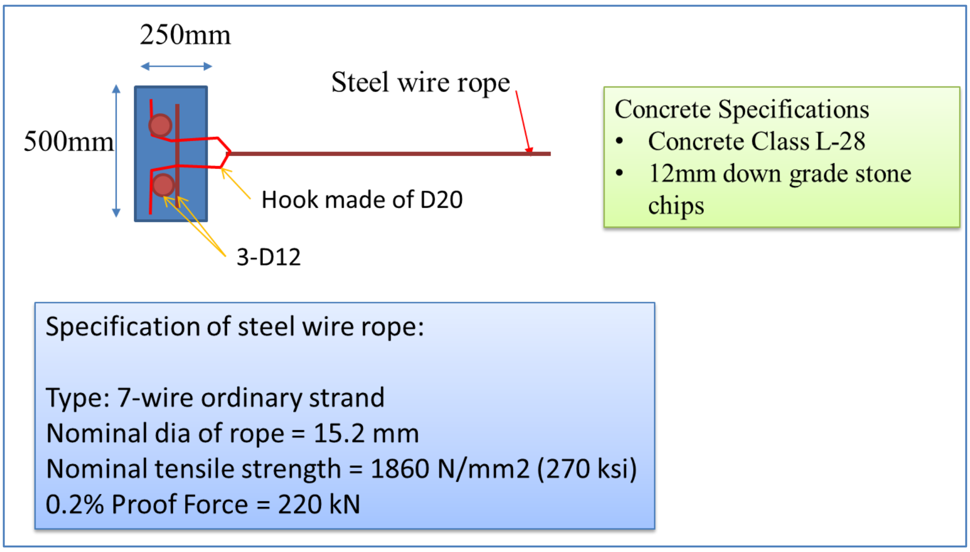

Figure 51: Details of anchor block and steel wire rope

iii. Placement of concrete precast panel

Details of concrete precast panel are given in Figure 48.

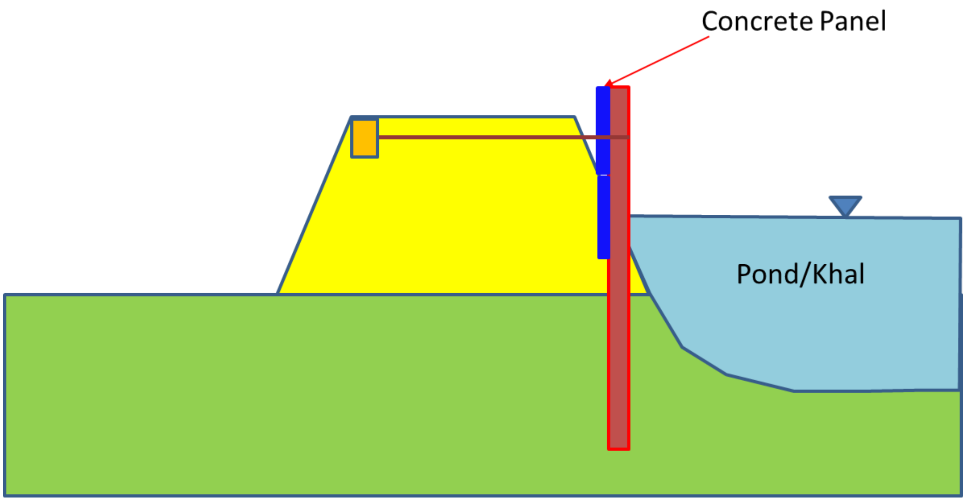

Figure 52: Placement of Panel

iv. Removal of unsuitable soil and benching on bide slope

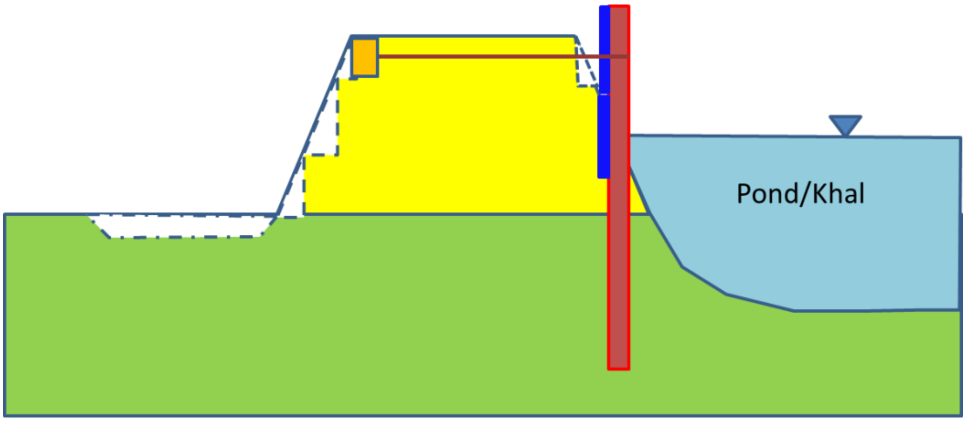

Figure 53: Removal of Unsuitable Soil and Benching

v. Filling widening part

Widening part shall be filled as per recommendation in Section 2.7.1.

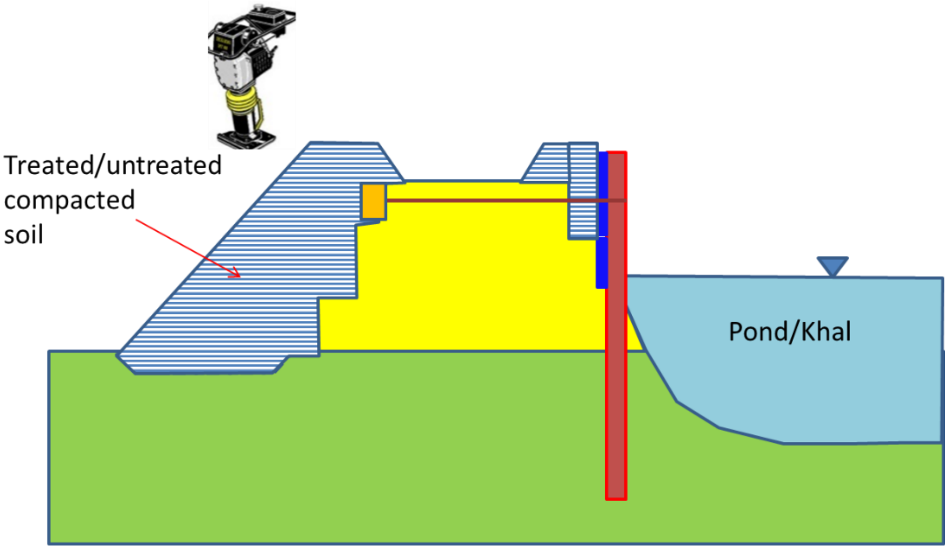

Figure 54: Filling widening part

vi. Box cutting

Box cutting shall be done before pavement construction

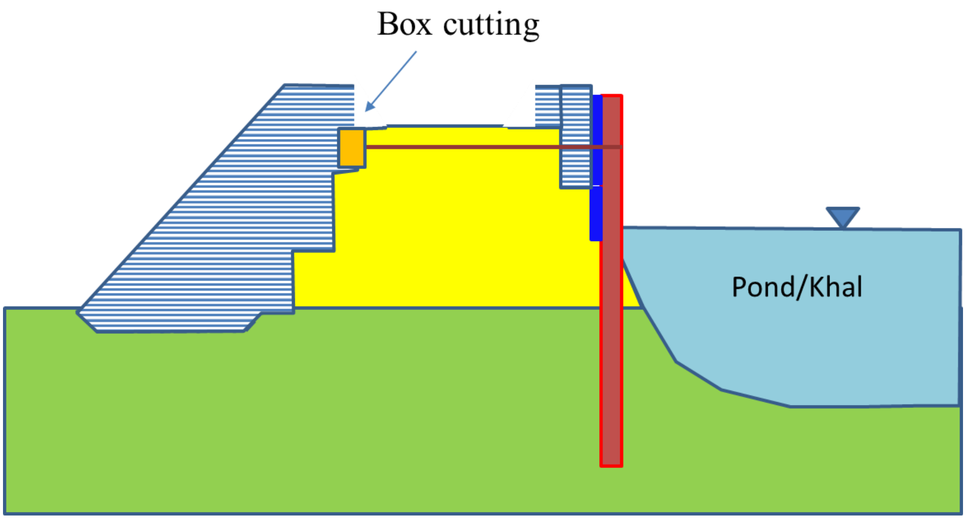

Figure 55: box cutting

vii. Pavement and shoulder construction

Pavement shall be constructed as per Section 2.4. Shoulder shall be constructed as per section 2.5.

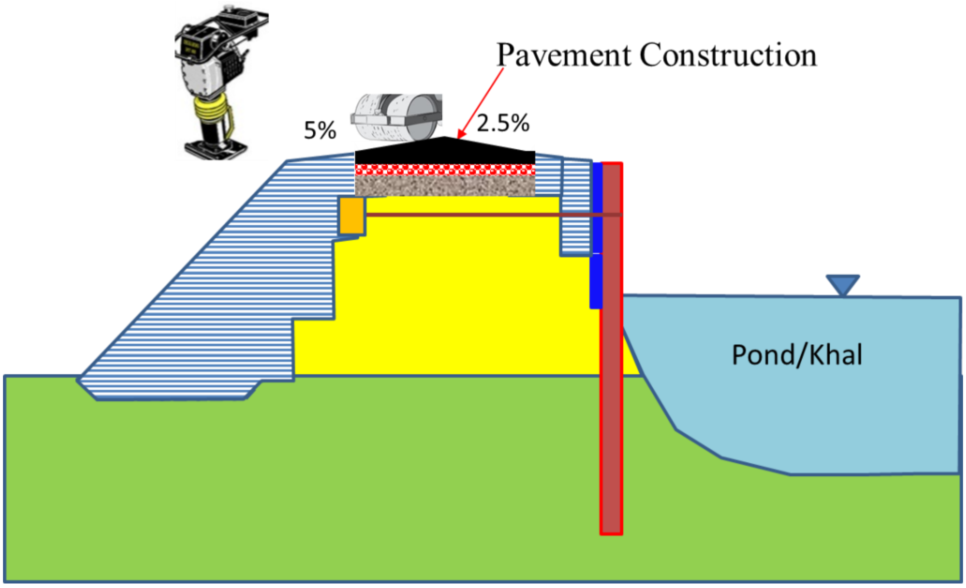

Figure 56: Pavement and shoulder construction

viii. Vegetation at paddy land side

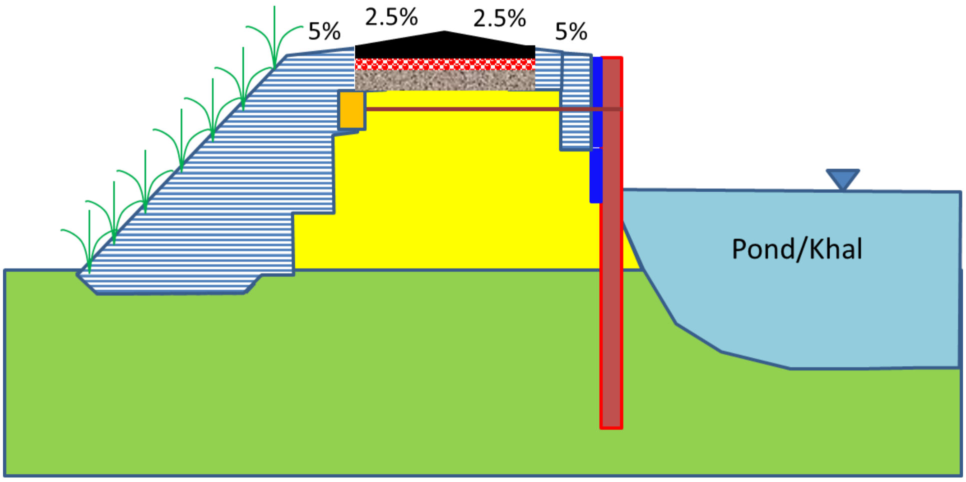

Figure 57: vegetation at paddy land side

ix. Installation of subsurface drainage

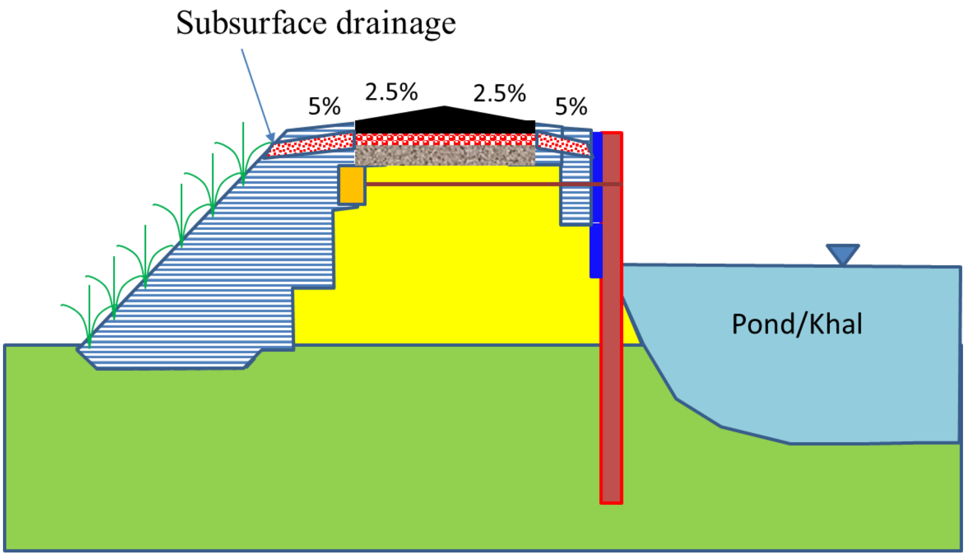

Figure 58: Installation of subsurface drainage

2.7.6 Type E: Khal/Pond at Both Sides

This is the extremely difficult situation where canal/pond at both sides of road. This is the situation where canal or pond at both side of road is deep and don't satisfy the condition of Type C. Road widening is quite impossible at this situation where vertical protection side is needed. Anchored pile is designed for different embankment height and soft soil under embankment. Geotechnical investigation shall be done to determine soft soil layer thickness under embankment. At least 20 m SPT boring and testing shall be done at toe of the embankment at pond/canal side. Step by step construction sequences for the Type E are described below.

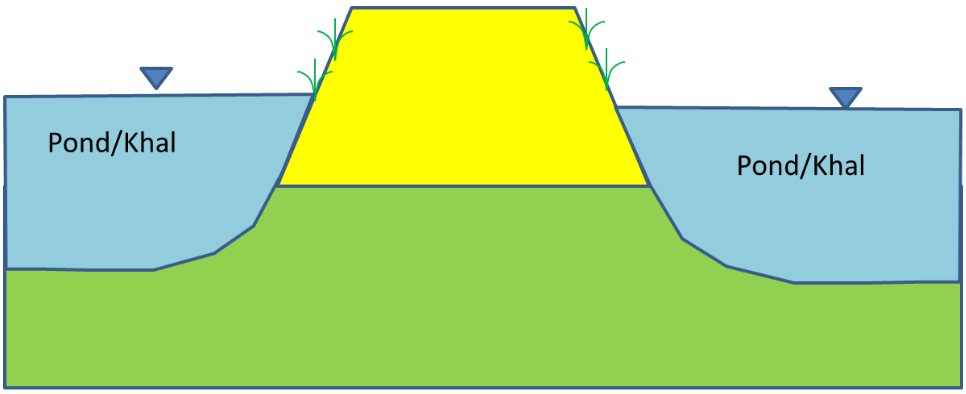

Figure 59: Both side khal Road

i. Pile Installation in both sides of existing road embankment.

Geotechnical investigation is essential for designing pile size and reinforcement of pile. Depending on the embankment height and soft soil thickness, pile length, section and rebar shall vary. Details of precast pile and panel are given in Figure 48 and Table 12. Embankment height shall be measure at 2 m distance from the edge of existing road top as shown in Figure 49.

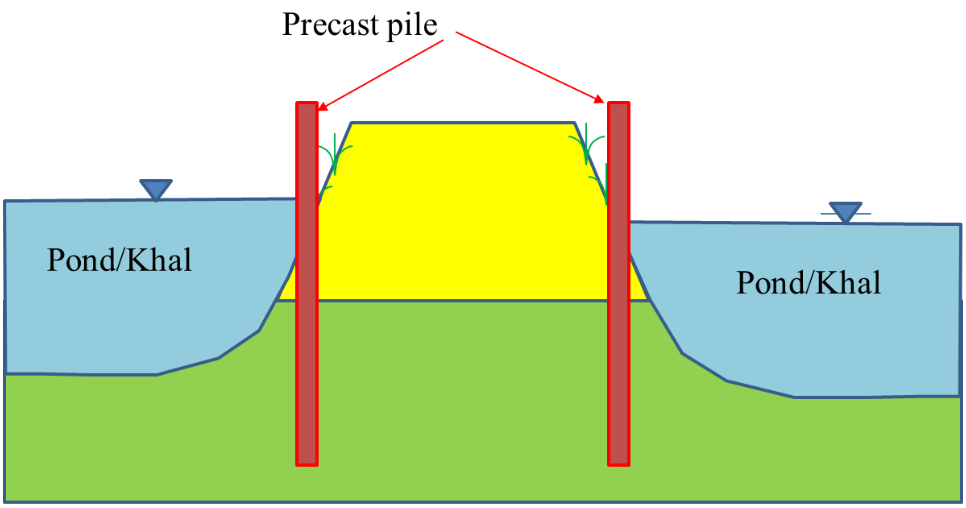

Figure 60: Precast Pile Installation

ii. Tie up both pile using high strength steel wire rope.

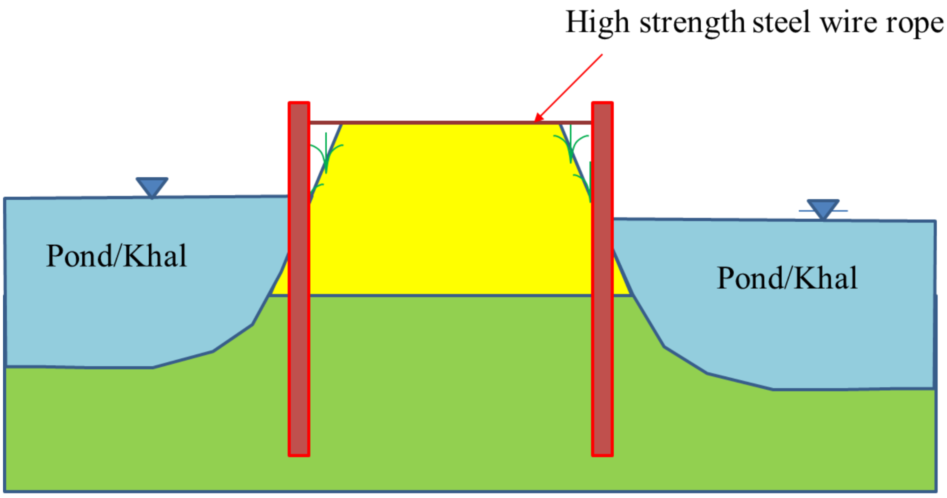

Figure 61: Tie up piles using high strength steel wire rope

iii. Placement of panels

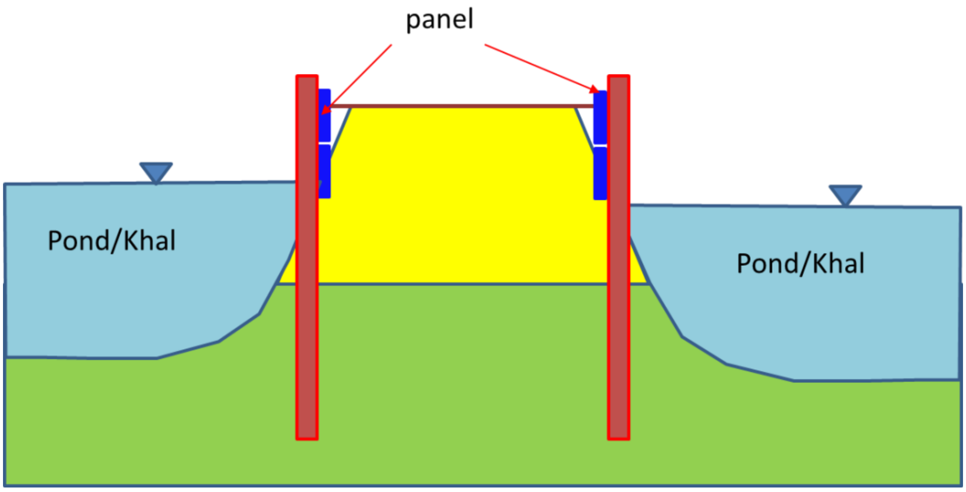

Figure 62: Placement of panels

iv. Benching on side slopes

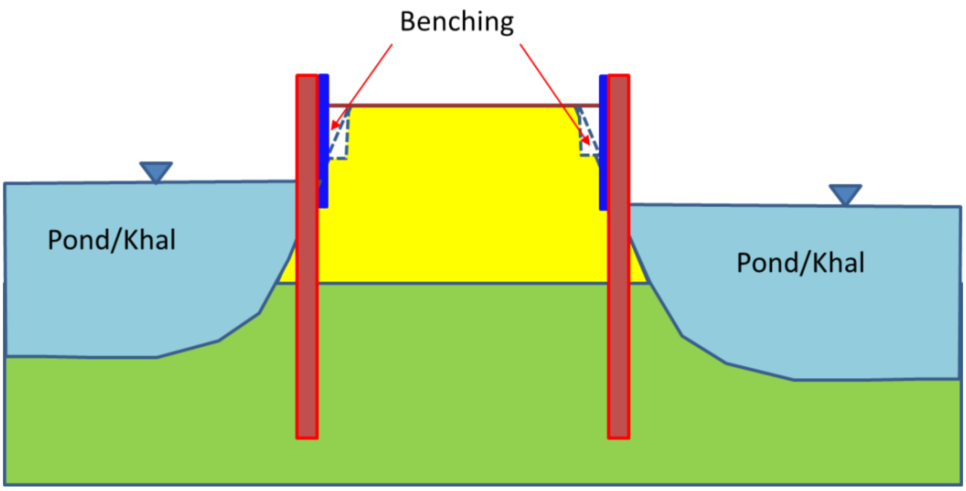

Figure 63: Benching on side slopes

v. Filling using compacted soil

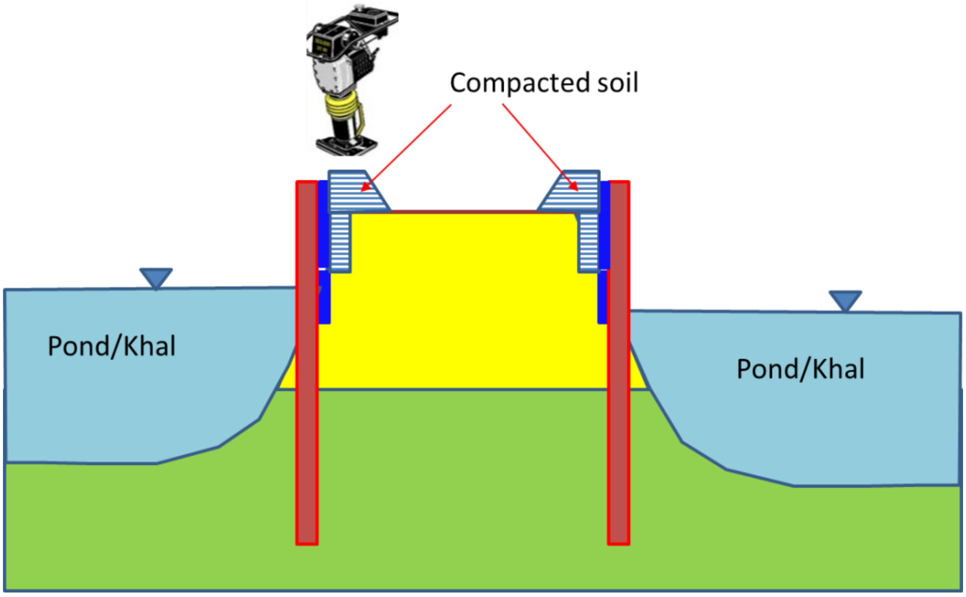

Figure 64: Filling using compacted soil

vi. Box cutting

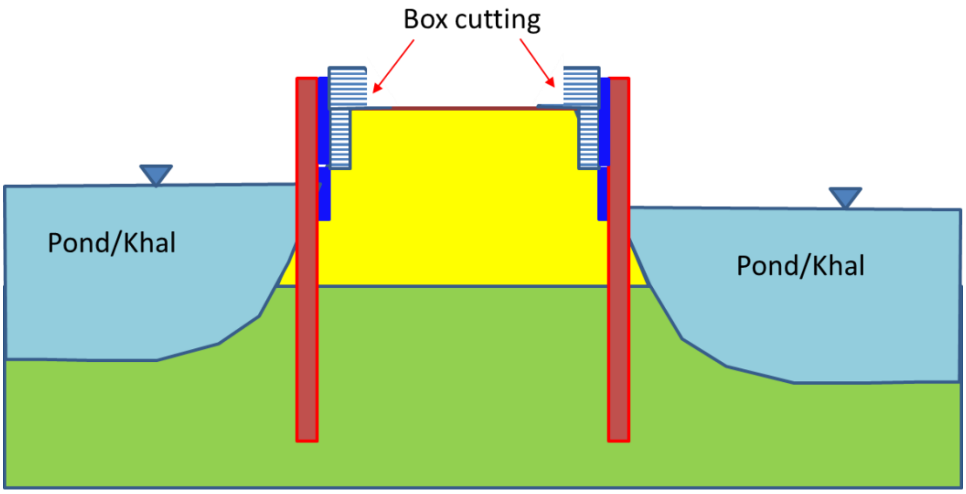

Figure 65: box cutting

vii. Pavement and shoulder construction

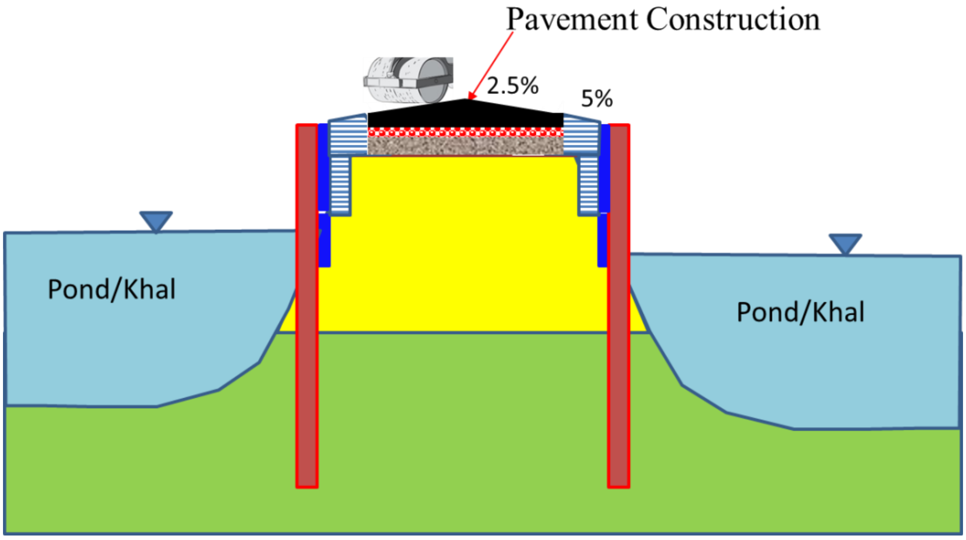

Figure 66: Pavement and shoulder construction

viii. Installation of subsurface drainage

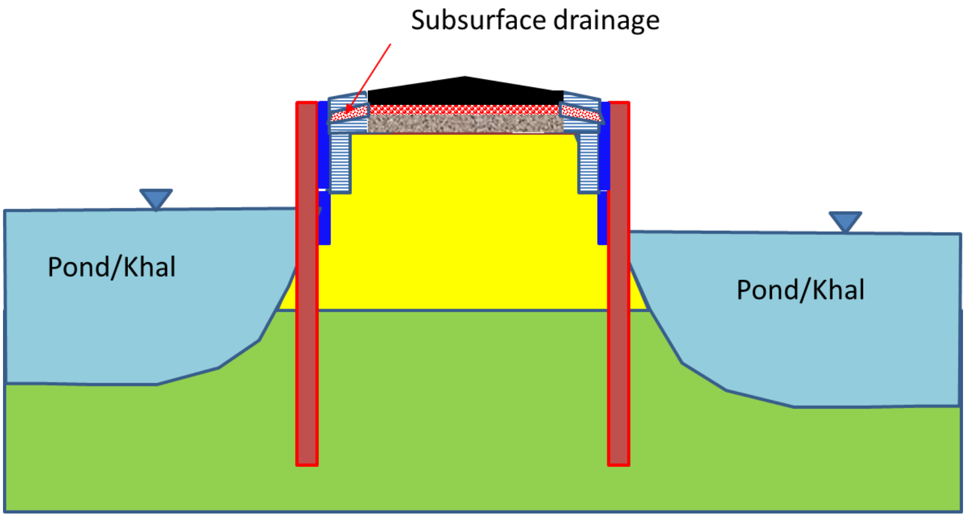

Figure 67: Installation of subsurface drainage

CHAPTER 3: MANUAL FOR BRIDGE APPROACH AND CULVERT

3.1 Introduction

In rural area, subsidence of approach road with respect to Culvert and Bridge is a common problem. Within 1 or 2 years of construction, this type of problem arises. Mainly it occurs because of subsidence of soil due to densification or erosion underneath. This subsidence of road compels to reduce the speed of vehicles or makes vehicle movement difficult. Compaction of soil at approach road must be done properly to mitigate this type of problem. Geometry of wing walls need to be revised to address the subsidence and erosion of soil in bridge approaches. Mechanism of damage of approach road is explained in Figure 68. Causes of approach road damage are summarized as follows:

i. Poor compaction of approach road embankment
ii. Consolidation of soft soil under approach embankment
iii. Erosion of side-slope of approach road
iv. Squeeze out of soft soil under approach road

To reduce the impact of speedy running water which often causes formation of vortex turbulence at the abutment nose, there is a need for correction of the existing abutment base by giving a nice round shaped structural form integrating the wing-wall (Contractor based work) with the slope protection work (LCS based work). To avoid overlapping related problem, a good practice would be to award the culvert/bridge work along with 10m slope protection work.

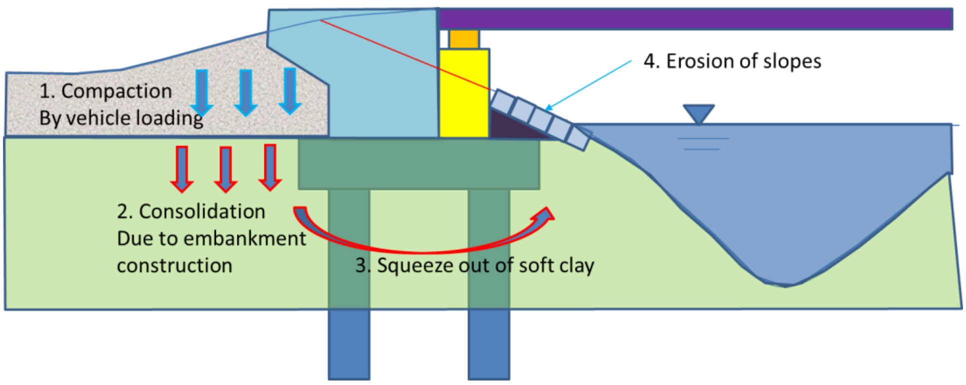

Figure 68: Major causes of distress and failure at bridge approach

3.2 Recommendation for Bridge Approach

Distress and damage of approach road can be minimized by following the recommendation given in this section.

3.2.1 Ground Improvement under Approach Road

In most of the cases, soil under the approach road is soft clay which need to be improved to increase durability of approach road. There are a various methods of ground improvement method techniques such as PVD with preloading, Sand Pile with Preloading, Deep Mixing Method, Jet Grouting, Stone Column, Precast Piling and Sand Compaction Pile. For a bridge site in rural area, all these methods are not feasible because of small volume of work and remote location of site. However, Sand Compaction Pile using local technology would be cost effective solution. Details of Sand Compaction Pile (SCP) are shown in Figure 69. If the soft clay layer thickness is more than 4 m, SCP shall be used. If the soft clay layer thickness is less than 4 m, 2 m soft clay shall be replaced with compacted sand.

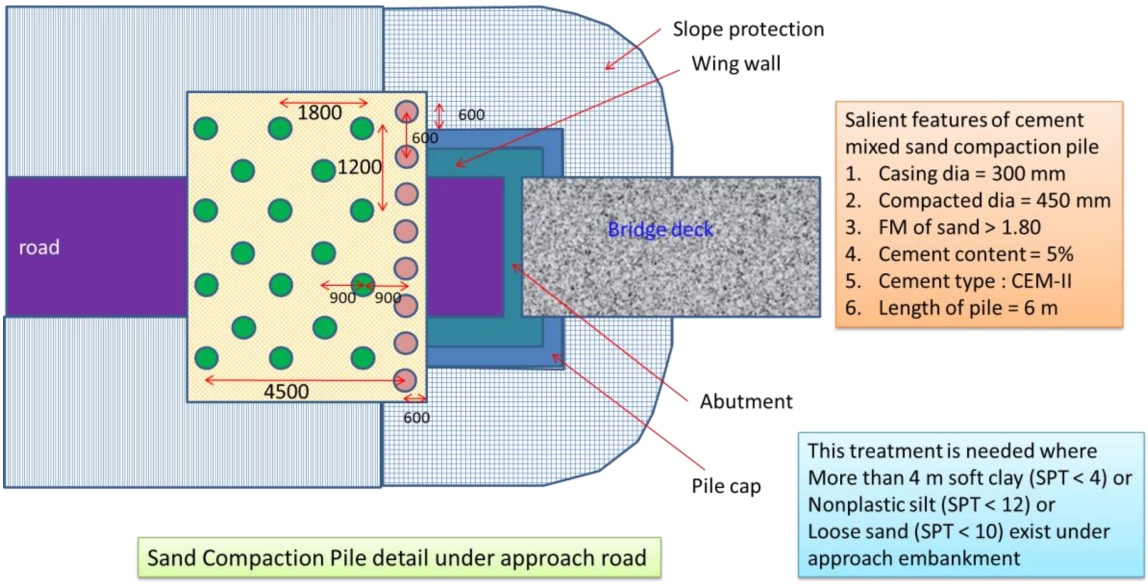

Figure 69: Details of Sand Compaction Pile under approach embankment of bridge

3.2.2 Slope Protection Works

Slope protection works must be done around the abutment and at both side slopes of approach embankment. Round shaped slope protection around abutment will minimize vortex and erosion around abutment. Slope protection zone is shown in Figure 70. Details of slope protection is shown in Figure 71, if the river current velocity is less than 2 m/s and wave height is less 0.5 m. site specific erosion protection shall be needed if current velocity is more than 2 m/s or wave height is more than 0.5 m/s.

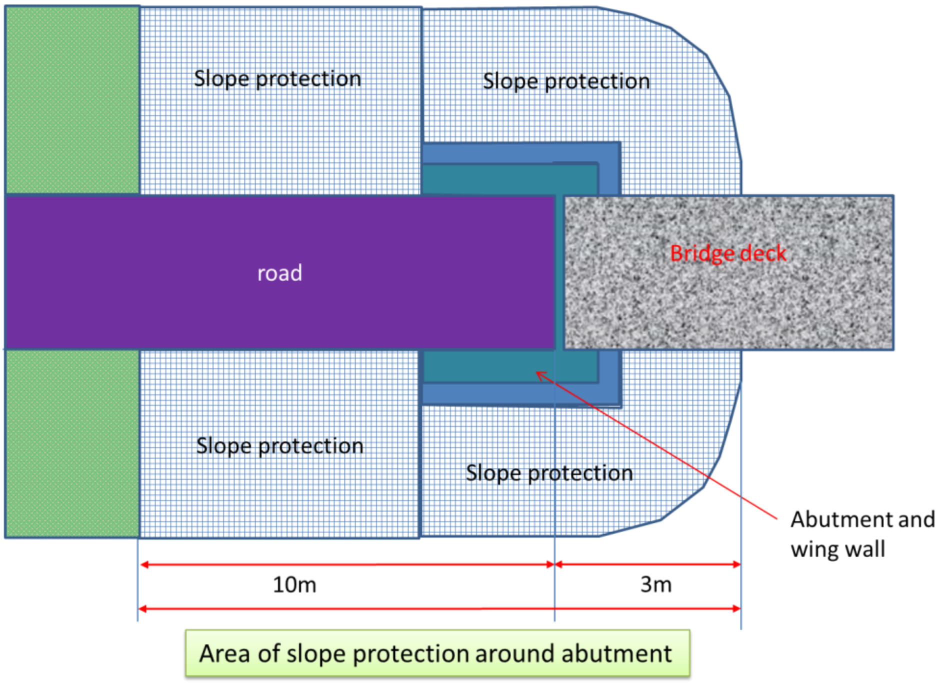

Figure 70: Slope protection zone around bridge abutment

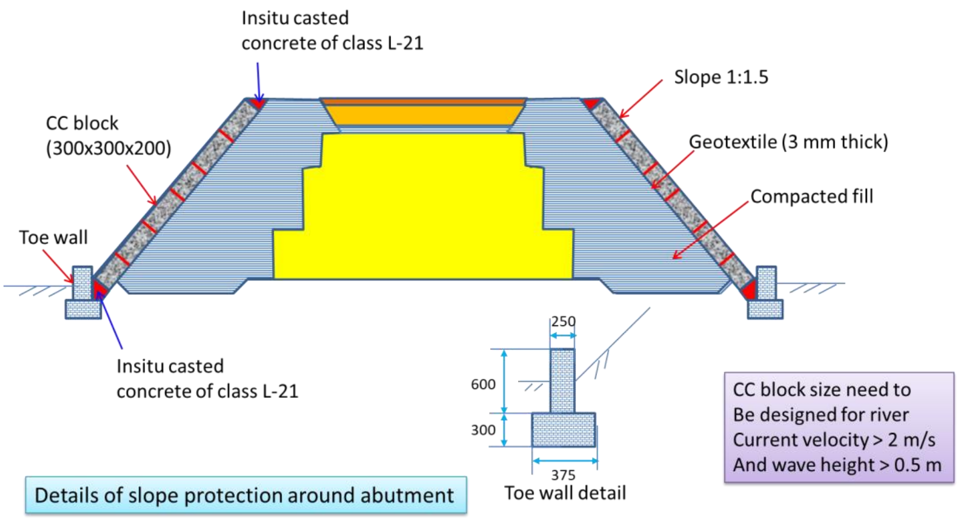

Figure 71: Details of slope protection work at bridge approach and around abutment

3.2.3 Depth of Pile Cap and Length of Wing Wall

Minimum depth of pile cap and length of wing wall is shown in Figure 72.

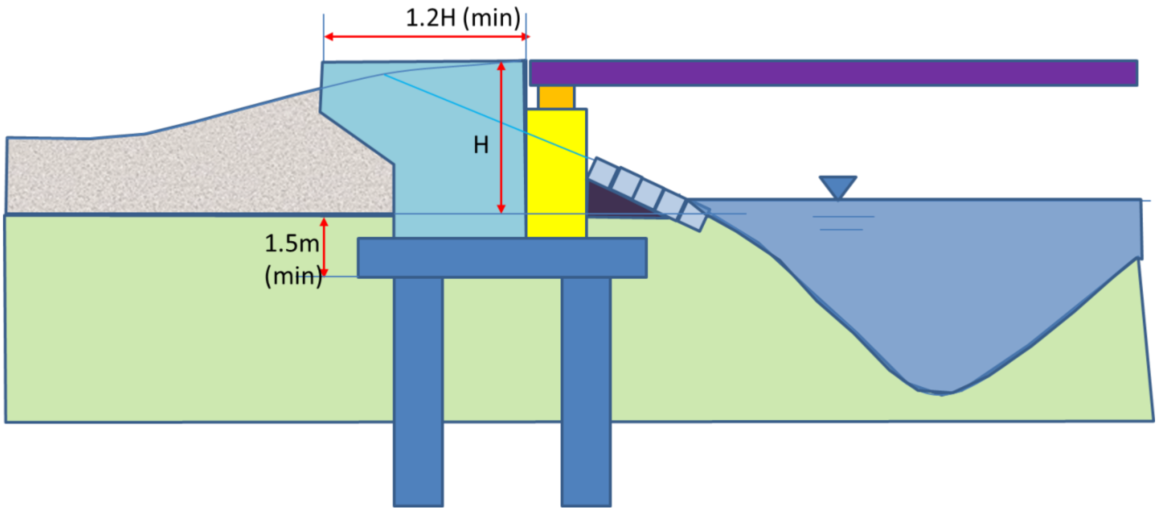

Figure 72: Minimum pile cap depth and wing wall dimension

3.2.4 Pavement at Approach Road

Instead of constructing approach slab before abutment, 15 m long rigid pavement (Figure 73) is suggested in case the road pavement is flexible type. This rigid pavement design shall be as per Section 2.4.

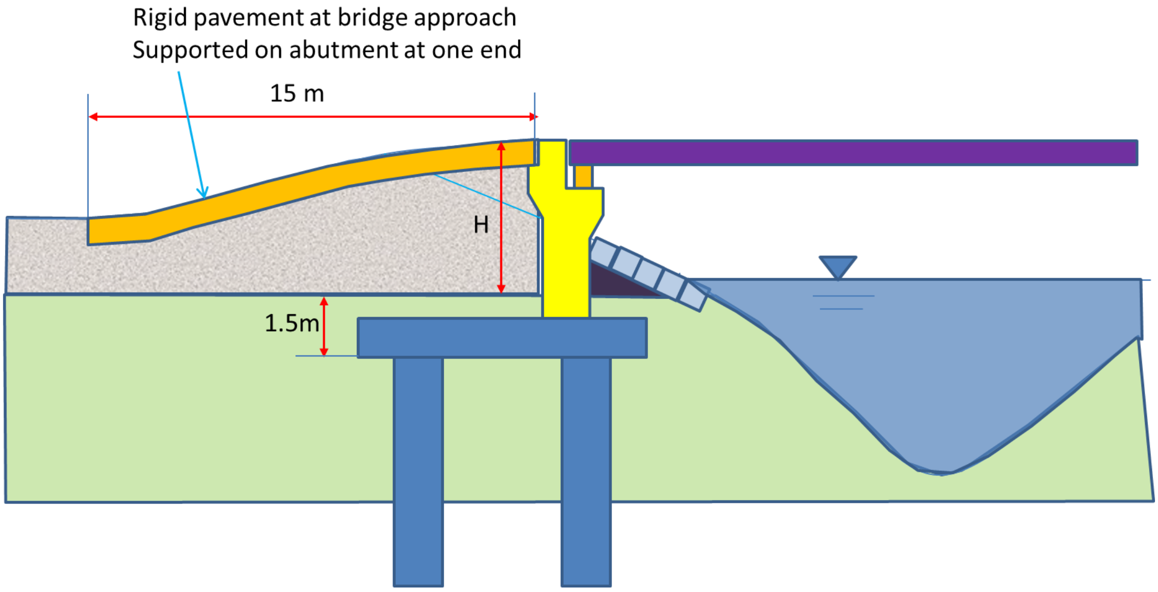

Figure 73: Details of rigid pavement at approach road of bridge

3.3 Culvert Recommendation

A simplified geometry of culvert is suggested for rural areas Bangladesh. Details of single cell and double culvert geometry, sections and reinforcement are shown in Figure 74 to Figure 81. No wing wall is required for this type of culvert. Construction shall be easy and simple.

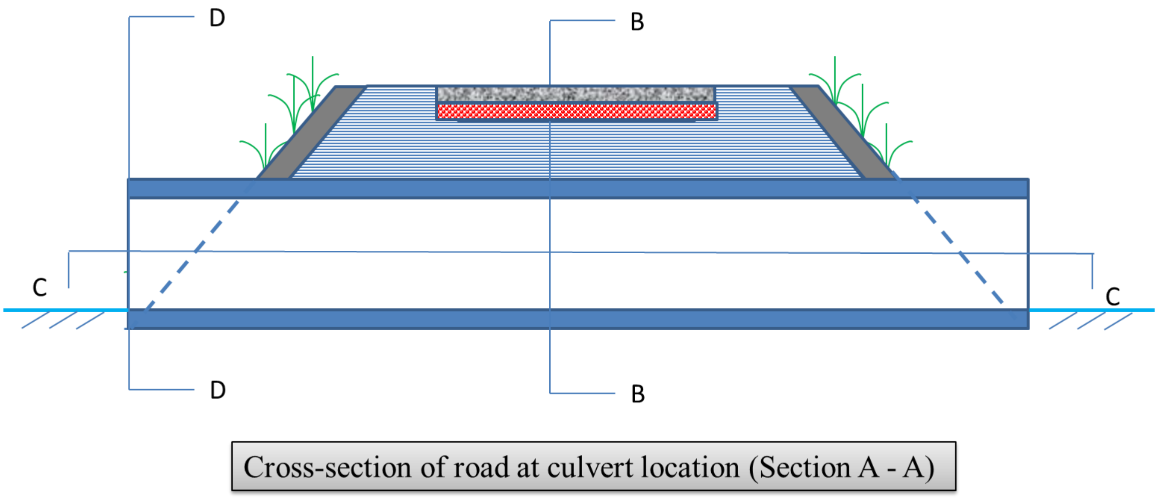

Figure 74: Cross section of road at culvert location

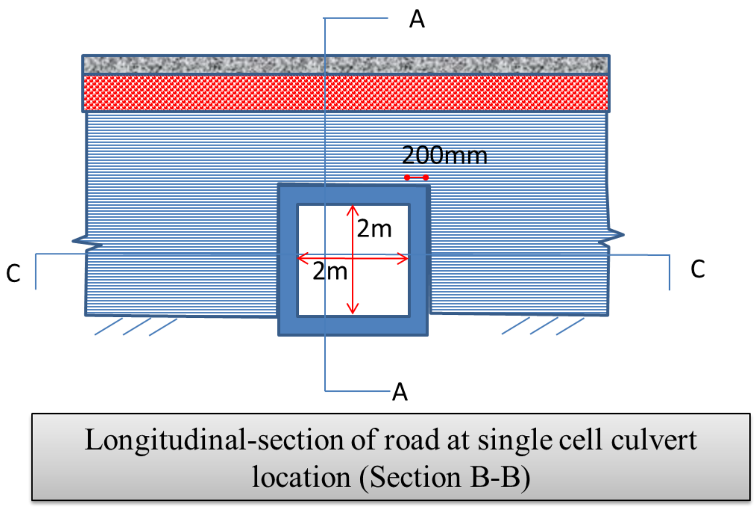

Figure 75: Section B-B of single cell culvert

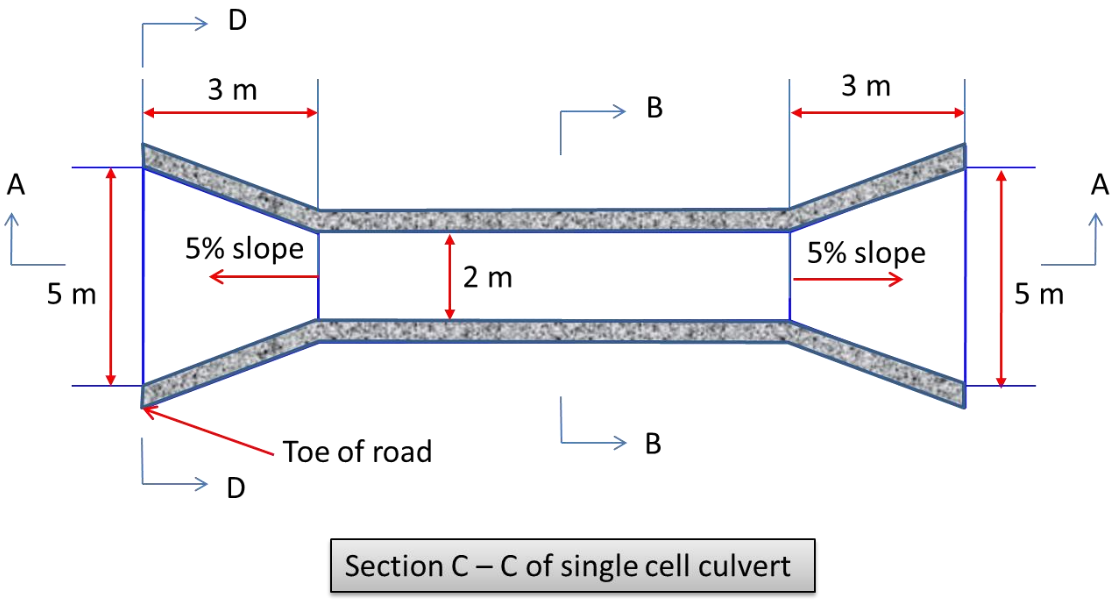

Figure 76: Section C-C of single cell culvert

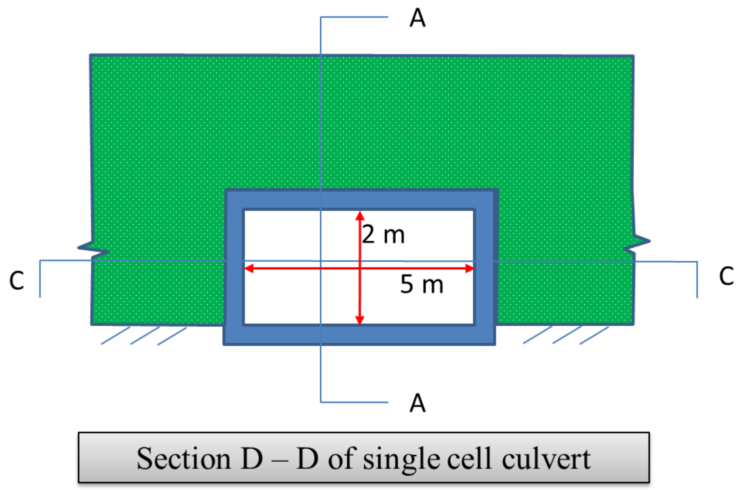

Figure 77: Section D-D of single cell culvert

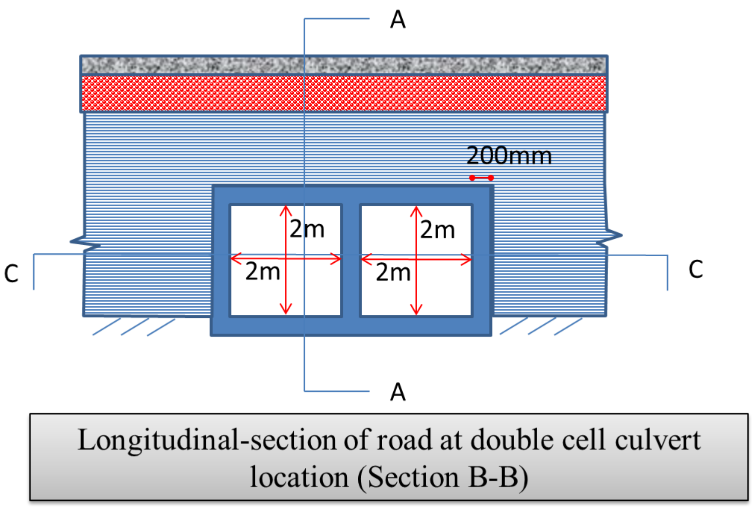

Figure 78: Section B-B of double cell culvert

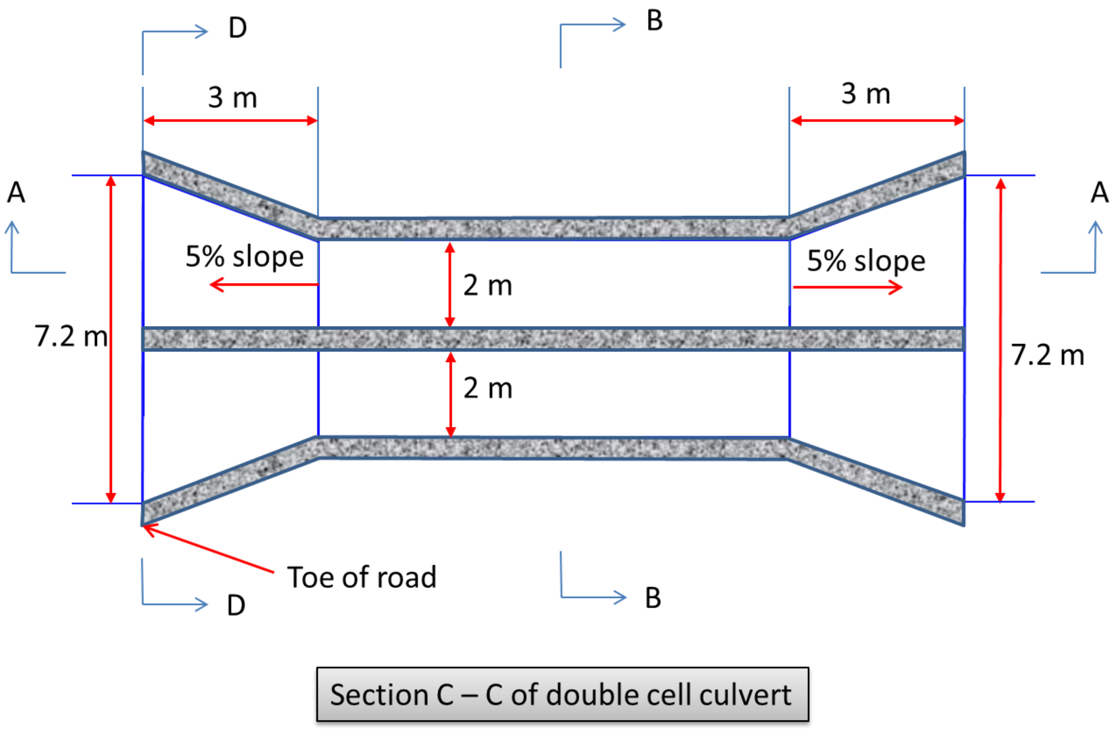

Figure 79: Section C-C of double cell culvert

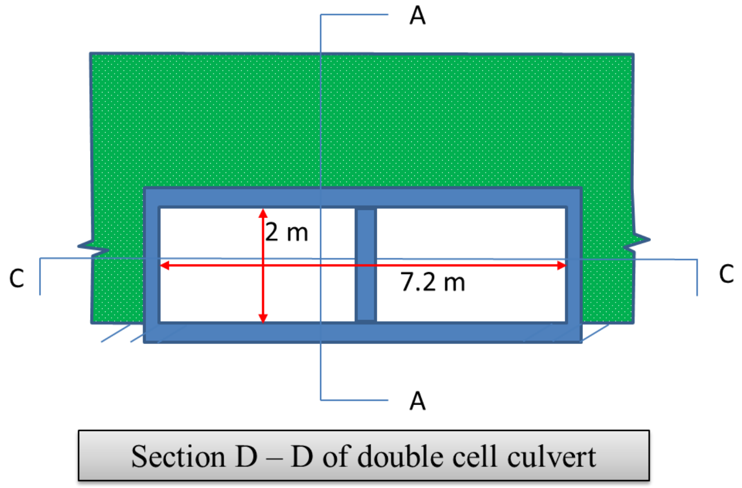

Figure 80: Section D-D of double cell culvert

Inner dimension of one cell = 2 m x 2 m
Concrete class = L-24
Concrete Thickness = 200 mm
Clear cover = 60 mm
2 layer Rebar = D10@125 mm c/c bothway at bothface
Epoxy coated rebar is required at exposure class “SEVERE”
No wing wall is required

Figure 81: Details of reinforcement of single cell and double cell culvert

CHAPTER 4: QUALITY TEST PROTOCOL

4.1 Introduction

Sustainability and durability of road depend on the quality control of design, materials and methodology. Sustainability is the outcome of quality control in every step.

4.2 Quality Control of Design

Design of road embankment and pavement shall be done using this manual and Road Design Manual for LGED by BRTC, BUET (BRTC, BUET, 2017). Special attention shall be given to road sections where pond or canal exists at one side or both side. Subsoil condition shall be assessed by SPT boring at those sections. Bill of quantity preparations should address all the construction challenges. All road designs shall be checked by an independent consultant having experience in designing road. Retaining structures or side slope protection designs shall be checked by a Geotechnical Engineer.

4.3 Quality Control of Methodology

Construction sequence and methodology is important for constructing climate resilient rural road. Construction steps described in Chapter 2 and Chapter 3 must be followed. To ensure the construction sequence and methodology, the contractor shall take photographs with date and GPS location using smart phone at every stages of construction. These photographs shall show the details of construction steps. Each photo shall be tagged with date and GPS location and accompanied by a comment. The photo shall be submitted to respective authority or Engineer. Removal of unsuitable soil, benching, layer by layer compaction, construction of pavement layers, shoulder, vegetation etc. all the steps shall be included in photographs.

4.4 Quality Control of Materials and Compaction

Compaction quality control is the most important parameter to make climate resilient road. Compaction depends on moisture content. Digital moisture meter shall be used to ensure the moisture content of fill within OMC±2. Rammer or plate compactor shall be used at widening part and shoulder and vibratory roller shall be used for pavement layers. Compaction of pavement layers shall be confirmed by field CBR test and Dynamic Cone Penetration (DCP) test. Field CBR and DCP result greatly vary with the moisture content of soil during testing. This need research to quantify the variation of field CBR and DCP result with moisture content for different soils. Moisture content pavement layers shall be determined during field DCP and field CBR test.

Table 13: Materials testing frequency per kilometer of road

Road Component	LL, PL, PI	LAAV or TFV	Grading or FM	Soaked CBR	Field CBR	Field DCP	Moisture Content
Base	None	1	2	1	4	4	8
Subbase	None	1	2	1	4	4	8
ISG	None	None	2	2	4	4	8
Subgrade	2	None	None	2	2	2	4
Shoulder	2	None	None	2	2	2	4
Embankment	2	None	None	2	2	2	4

4.4.1 Concrete

Material specification and quality control of different concrete classes for different exposure category are described in "Climate Resilient Concrete Manual for LGED" (Alam & Hoque, Climate Resilient Concrete Manual, 2019).

4.4.2 Base Materials

Base materials may be crushed stone or crushed fired clay brick. Crushed fired clay brick is called brick chips in Bangladesh. Brick chips as base material is allowed for light and medium traffic road. Stone chips must be used for base material of heavy traffic road. Slag from iron industry may be used as base material for light and medium traffic road.

Brick Chips as Base Material

Use of brick chips is allowed in Light and Medium Traffic Raod if it meets the Specifications requirements. First Class brick or over burned bricks shall be used for making brick chips.

Bricks ships as base material shall conform to the requirements given below:

i. Grading: The grading shall conform to one of the grading envelopes shown in Table 16. The material shall be well graded within the envelope with no excess or deficiency of any size;
ii. Plasticity: The fraction passing the 0.425 mm sieve shall have a plasticity index not greater than 6
iii. CBR: The material shall have a minimum soaked CBR value of 60 at a compaction of 98% of the maximum dry density as determined by BS Vibrating Hammer [BS 1377].
iv. Los Angeles Abrasion Value (LAAV)/Ten Percent Fine Value (TFV): Material retained on 10 mm sieve when sampled and tested shall have a Los Angeles Abrasion Value of not greater than 40% and the Ten Percent Fines value shall not be less than 80 kN.
v. DCP: Dynamic cone penetration rate shall meet the requirement given in Table 14.
vi. Field CBR: Field CBR values shall meet the requirement given in Table 15.

vii. Water Absorption: Water absorption shall not exceed 16%.

Slag as Base Material

Use of slag is allowed in Light and Medium Traffic Raod if it meets the Specifications requirements.

Slag as base material shall conform to the requirements given below:

i. Grading: The grading shall conform to one of the grading envelopes shown in Table 16. The material shall be well graded within the envelope with no excess or deficiency of any size;
ii. Plasticity: The fraction passing the 0.425 mm sieve shall have a plasticity index not greater than 6
iii. CBR: The material shall have a minimum soaked CBR value of 60 at a compaction of 98% of the maximum dry density as determined by BS Vibrating Hammer [BS 1377].
iv. Los Angeles Abrasion Value (LAAV)/Ten Percent Fine Value (TFV): Material retained on 10 mm sieve when sampled and tested shall have a Los Angeles Abrasion Value of not greater than 40% and the Ten Percent Fines value shall not be less than 80 kN.
v. DCP: Dynamic cone penetration rate shall meet the requirement given in Table 14.
vi. Field CBR: Field CBR values shall meet the requirement given in Table 15.
vii. Water Absorption: Water absorption shall not exceed 2%.

Stone Chips as Base Material

Use of stone chips is allowed in Light, Medium and Heavy Traffic Road if it meets the Specifications requirements.

Slag as base material shall conform to the requirements given below:

i. Grading: The grading shall conform to one of the grading envelopes shown in Table 16. The material shall be well graded within the envelope with no excess or deficiency of any size;
ii. Plasticity: The fraction passing the 0.425 mm sieve shall have a plasticity index not greater than 6
iii. CBR: The material shall have a minimum soaked CBR value of 80 at a compaction of 98% of the maximum dry density as determined by BS Vibrating Hammer [BS 1377].
iv. Los Angeles Abrasion Value (LAAV)/Ten Percent Fine Value (TFV): Material retained on 10 mm sieve when sampled and tested shall have a Los Angeles Abrasion Value of not greater than 35% and the Ten Percent Fines value shall not be less than 100 kN.

v. DCP: Dynamic cone penetration rate shall meet the requirement given in Table 14.

vi. Field CBR: Field CBR values shall meet the requirement given in Table 15.

vii. Water Absorption: Water absorption shall not exceed 2%.

Table 14: Maximum field DCP penetration rate for pavement layers at different moisture condition

pavement layer	Maximum Field DCP (mm/blow)				Maximum Soaked DCP (mm/blow	Minimum Soaked CBR
	Very dry	dry	moderate dry	damp		
base (stone chips)	2.5	2.5	2.5	3.2	3.5	80
base (brick chips or slag)	3.0	3.0	3.0	4.0	4.5	60
subbase	5	5	6	7	8	30
ISG	10	12	15	17	22	8
subgrade	7	10	15	20	38	4
shoulder	7	10	15	20	38	4
embankment	10	15	20	30	65	2
Notes: Moisture contents are expressed as ratios of in situ moisture content to Optimum Moisture Content as follows. Very dry = 0.25; Dry = 0.5; Moderate dry = 0.75; Damp = 1.0. This table is only a guide and should be used with discretion. Materials that are highly moisture sensitive may produce different values.						

Table 15: Maximum minimum field CBR for pavement layers at different moisture condition

pavement layer	Minimum Field CBR				Maximum Soaked DCP (mm/blow	Minimum Soaked CBR
	Very dry	dry	moderate dry	damp		
base (stone chips)	125	125	129	94	3.5	80
base (brick chips or slag)	100	100	100	69	4.5	60
subbase	52	52	41	34	8	30
ISG	22	17	13	11	22	8
subgrade	34	22	13	9	38	4
shoulder	34	22	13	9	38	4
embankment	22	13	9	5	65	2
Notes: Moisture contents are expressed as ratios of in situ moisture content to Optimum Moisture Content as follows. Very dry = 0.25; Dry = 0.5; Moderate dry = 0.75; Damp = 1.0. This table is only a guide and should be used with discretion. Materials that are highly moisture sensitive may produce different values.						

Table 16: Grading requirement coarse aggregate used as base and subbase material

Sieve Size (mm)	% Passing by weight	
	Minimum	maximum
38	100	100
20	60	80
12	40	60
4.8	25	45
2.4	15	32
0.6	10	20
0.075	0	15

4.4.3 Subbase Materials

Fine aggregate (sand of FM>0.80) and coarse aggregate (brick chips, slag or stone chips) are mixed in 2:3 by volume to make subbase material. Coarse aggregate shall meet the requirement base material mentioned above. Fine aggregate shall meet the requirement of Improved Subgrade mentioned below. 40% fine aggregate volume and 60% coarse aggregate volume shall be mixed homogenously and well compacted to meet the subbase material requirement given in Table 14 and Table 15. Soaked CBR, field CBR and field DCP shall be used for quality control of compaction of subbase.

Subbase material shall conform to the requirements given below:

i. CBR: The material shall have a minimum soaked CBR value of 30 at a compaction of 98% of the maximum dry density as determined by BS Vibrating Hammer [BS 1377].
ii. DCP: Dynamic cone penetration rate shall meet the requirement given in Table 14.
iii. Field CBR: Field CBR values shall meet the requirement given in Table 15.

4.4.4 Improved Subgrade (ISG) Materials

Locally available fine sand of FM>0.80 is recommended as ISG material. If FM>0.80 sand is not available locally, FM>0.50 sand may be used.

ISG material shall conform to the requirements given below:

iv. Plasticity: The fraction passing the 0.425 mm sieve shall have a plasticity index not greater than 6
v. CBR: The material shall have a minimum soaked CBR value of 8 at a compaction of 98% of the maximum dry density as determined by BS Vibrating Hammer [BS 1377].
vi. DCP: Dynamic cone penetration rate shall meet the requirement given in Table 14.
vii. Field CBR: Field CBR values shall meet the requirement given in Table 15.

4.4.5 Subgrade and Shoulder

Subgrade and shoulder material shall be the same material and standard. The material shall be free from roots, sods and other deleterious material. Compaction of subgrade and shoulder shall be confirmed by field CBR test or Dynamic Cone Penetration (DCP) test. Field CBR and DCP result greatly vary with the moisture content of soil during testing. Research is needed to quantify the variation of field CBR and DCP result with moisture content for different soils.

Subgrade and shoulder material shall conform to the requirements given below:

i. Plasticity: Liquid Limit (LL) of soil fraction passing 0.425 mm sieve not exceed 40 and Plasticity Index (PI) not to exceed 15.
ii. CBR: The material shall have a minimum soaked CBR value of 4 at a compaction of 95% of the maximum dry density as determined by Modified Proctor Test.
iii. DCP: Dynamic cone penetration rate shall meet the requirement given in Table 14.
iv. Field CBR: Field CBR values shall meet the requirement given in Table 15.

4.4.6 Embankment

Embankment material shall be free from roots, sods and other deleterious material.

Embankment material shall conform to the requirements given below:

i. Plasticity: Liquid Limit (LL) of soil fraction passing 0.425 mm sieve not exceeds 50 and Plasticity Index (PI) not to exceed 20.
ii. CBR: The material shall have a minimum soaked CBR value of 2 at a compaction of 95% of the maximum dry density as determined by Modified Proctor Test.
iii. DCP: Dynamic cone penetration rate shall meet the requirement given in Table 14.
iv. Field CBR: Field CBR values shall meet the requirement given in Table 15.

CHAPTER 5: CONCLUDING REMARKS

Transportation contributes to the industrial, economic, social and cultural development of a nation. So it is very important to establish transportation system in such a standard way to get maximum output. Considering different types of adverse field condition, different type of solutions are described which would be fruitful for engineers to ensure quality of rural road construction. Climate resilient road can be made if this manual is followed. Training for LGED Engineers and contractors are essential for this purpose.

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