Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020), 7~9 February 2020, KUET, Khulna, Bangladesh (ISBN-978-984-34-8764-3)

CLIMATE RESILIENT RURAL ROAD CONSTRUCTION IN COASTAL DISTRICT OF BANGLADESH

Md. Jahangir Alam[1], Md. Shamsul Hoque[2] and Muhammad Saiful Islam[*3]

[1]Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh, e-mail: Jahangir.buet@gmail.com
[2]Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh, e-mail: shoque@ce.buet.ac.bd
[3]Research Assistant, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh, e-mail: saifulislamce@gmail.com

***Corresponding Author**

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 paper is to provide proper guideline in rural road construction so that climate resilient road can be constructed. Here, climate resilient road indicates that road which can sustain extreme climatic situations and minimize the life-cycle cost. This paper focuses especially for village and union roads of coastal districts of Bangladesh. Road construction guidelines are suggested for two cases including general situation (say Paddy land in both side) and challenging situation (say pond or khal at one side of road where pond or khal bottom slope is steep). In those situations, different side slope, ground treatment processes are recommended. Also considering soft soil layer thickness, different types of pile design are formulated.

Keywords: *Rural road, Soft soil, Pond side road, Khal side road, Palisading, Road manual.*

1. INTRODUCTION

The road which can sustain extreme climatic situations and minimize the life-cycle cost may be termed as 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. (Alam, Tanvir & Hoque, 2017).

This manual is primarily based on LGED works in Bangladesh. In most of the cases, LGED upgrade existing earthen 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, guidelines of constructing climate resilient road is described in this paper.

2. CHALLENGES OF MAKING CLIMATE RESILIENT RURAL ROAD

Challenges of climate resilient road construction are summarized in this section.

2.1 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 compactors 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 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. In challenging situation, cost estimations should be done after proper design of slope protection.

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. These are the situations where road widening is very difficult and expensive. 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 that time. Compaction is also extremely difficult during rainy season.

2.2 Unsuitable Materials

Locally available soil and materials are not suitable for subgrade and pavement layers. Locally available borrow pit soils are mostly silty clay, clayey silt, sandy silt and silty fine sand. As per specification of tender documents and Road Design Standard of LGED (LGED and JICA, 2005), borrow pit soils don't meet the requirements for subgrade, Improved Subgrade (ISG) and sand required for subbase.

2.3 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:

i. Improper location of borrow pits
ii. Lack of vegetation
iii. Steep side slope
iv. Vertical cliff created by farmers at toe of side slopes
v. Current and wave action of water during rainy season
vi. Lack of layer by layer compaction and moisture control
vii. Dispersive nature of local soils which are used for embankment fill
viii. Absence of clay cladding at sand filled side slopes
ix. Road widening without following benching and compaction
x. Lack of proper drainage and channelization of rainwater

3. 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. Based on investigation, road construction guidelines are suggested for two cases including general situation (say Paddy land in both side) and challenging situation (say pond or khal at one side of road where pond or khal bottom slope is steep).

3.1 Pavement Widening General Guideline

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

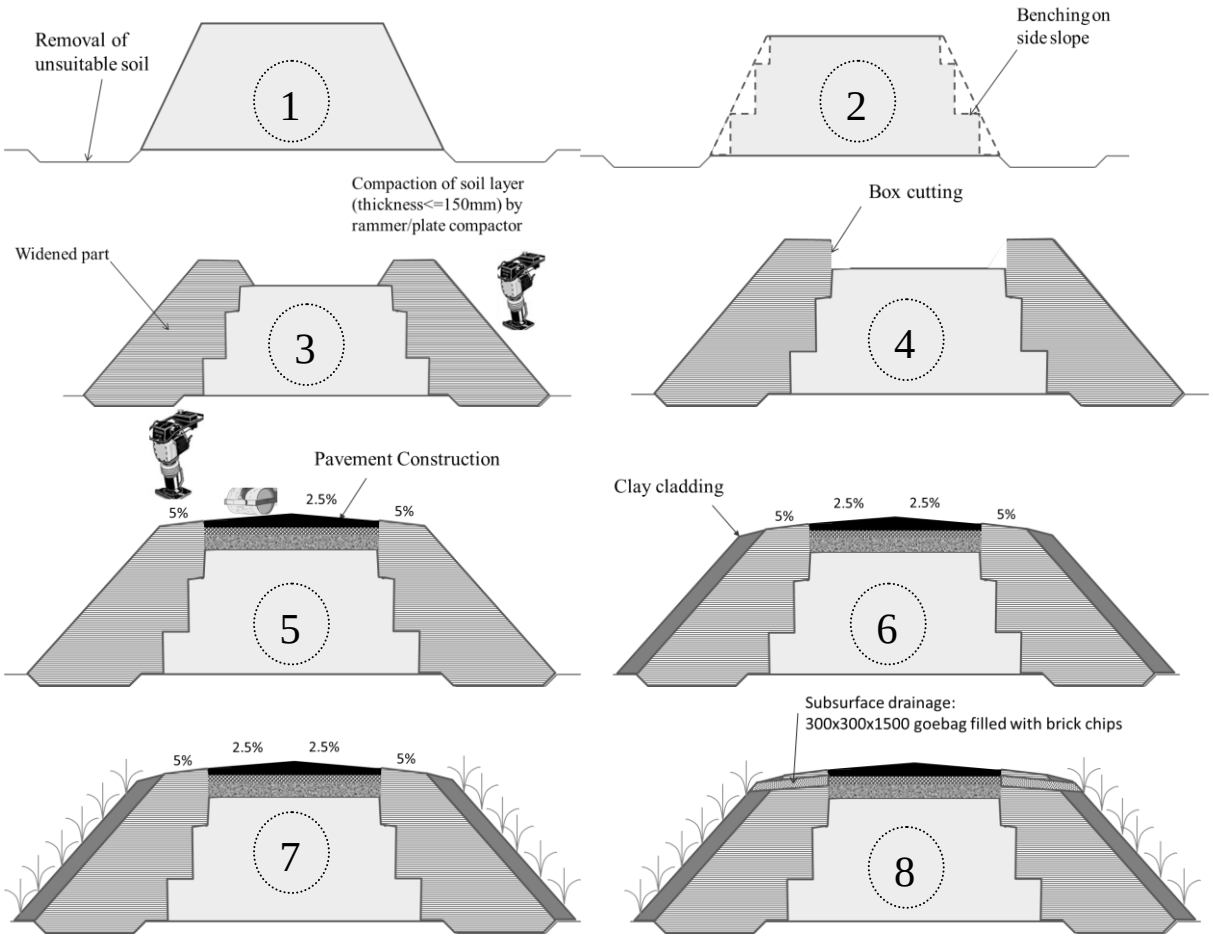


Figure 1: Step by step procedure for general road widening

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.

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.

III. **Construction of widening part:** Compaction and treatment of widening part shall be properly done. 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 soil treatment.

Table 1: 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.

V. **Pavement construction:** Pavement construction shall be done as per design. 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 1. 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 design requirement.

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.

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.

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.

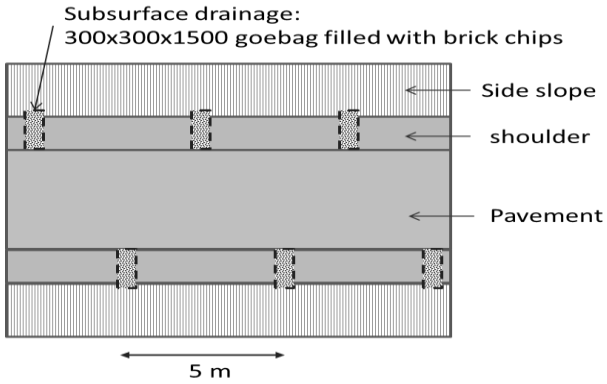


Figure 2: Typical layout of subsurface drainage of road

3.2 Challenging Situations of Rural Road Upgradation

Various situations are being encountered during up gradation of existing road in the coastal districts of Bangladesh. Such as pond or khal (canal) at one side of road as per figure below where 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) (figure 3).

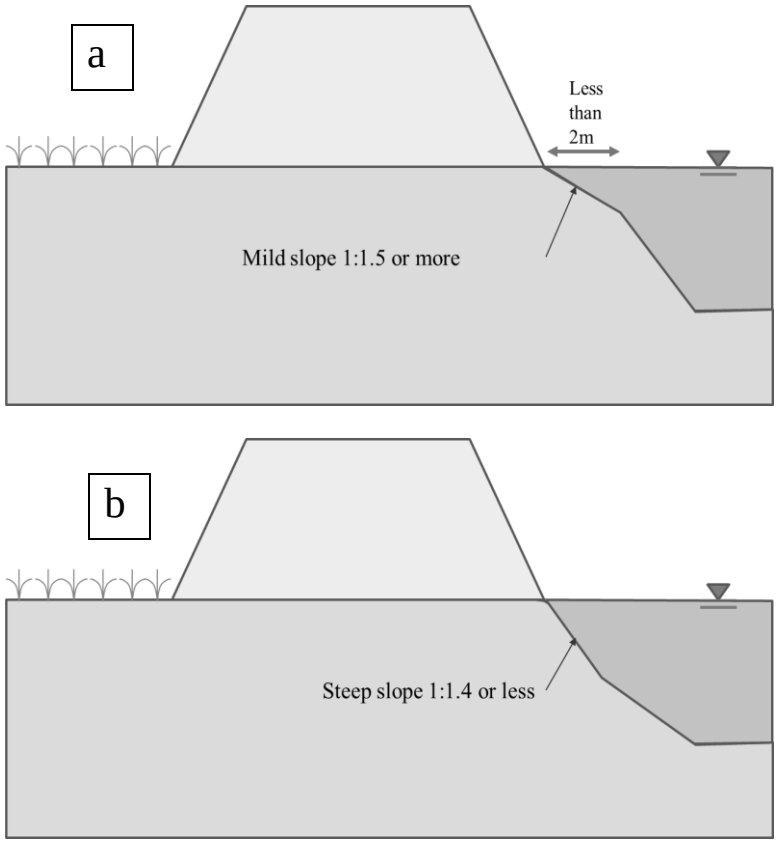


Figure 3: Challenging Condition; (a) situation with less than 2 m wide mild slope under toe of embankment (b) situation with steep slope under toe of embankment

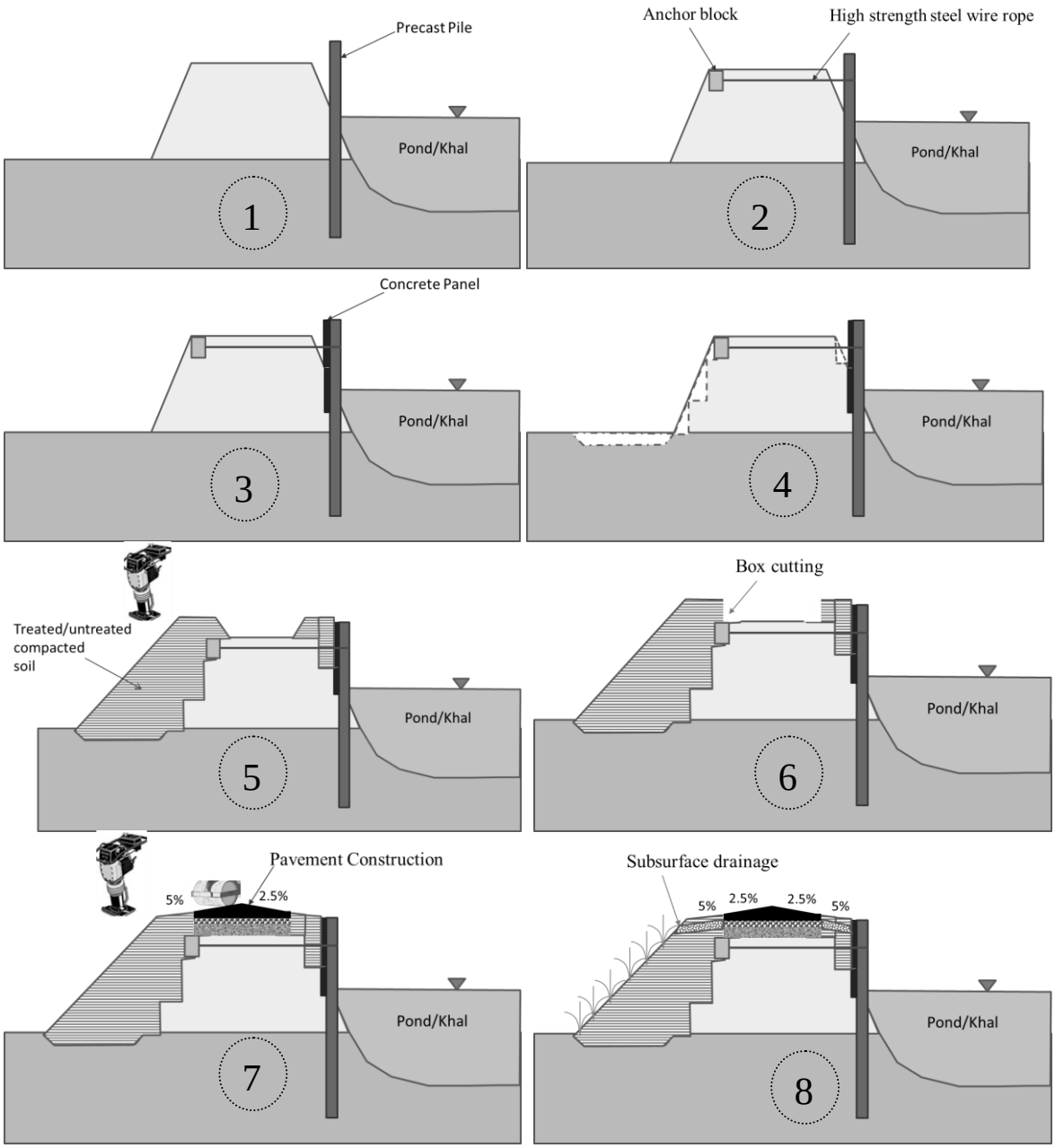
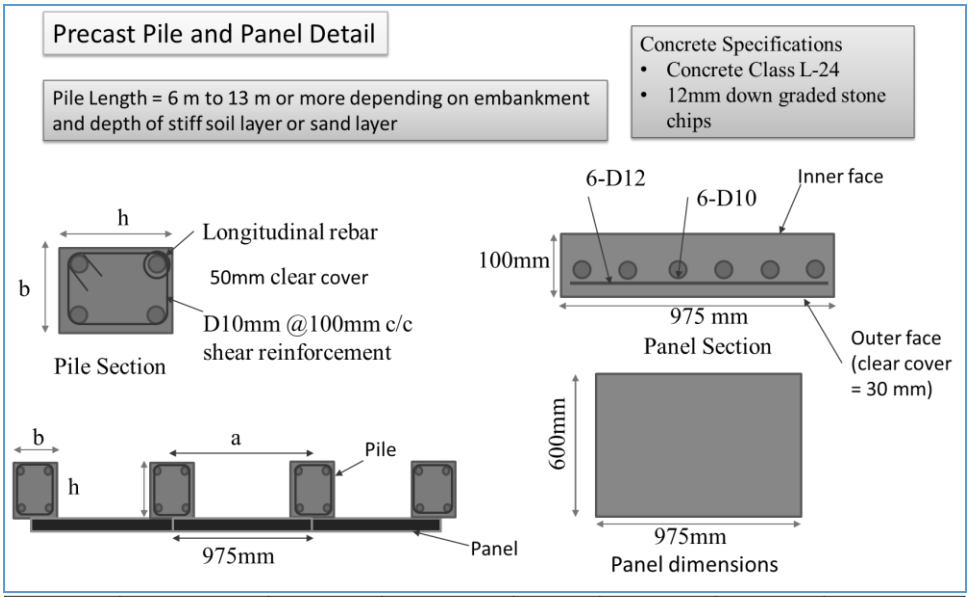


Figure 4: Step by step construction sequences for one side pond/khal situation

Step by step construction sequences for the Type 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 5. Embankment height shall be measured at 2 m distance from the edge of existing road top as shown in Figure 6. Concrete class will be as per climate resilient concrete manual (Alam & Hoque, 2019).



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 5: Details of precast pile and panel for one/both side pond or khal situation

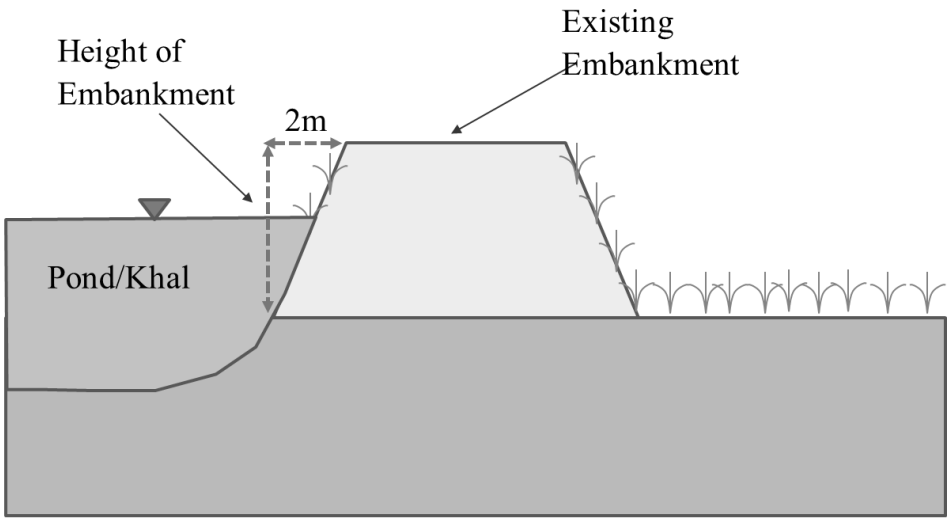


Figure 6: Selection of embankment height

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 7.

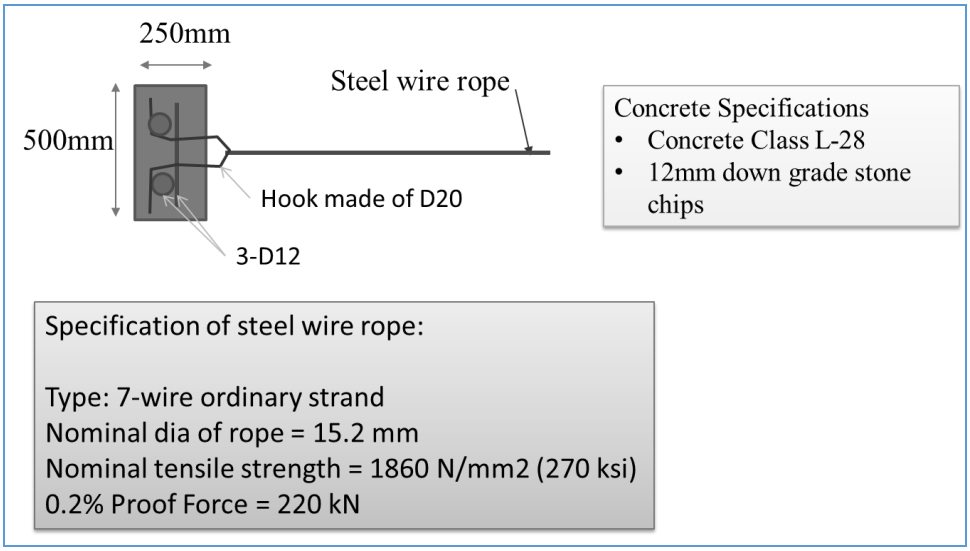


Figure 7: Details of anchor block and steel wire rope

III. **Placement of concrete precast panel:** Details of concrete precast panel are given in figure 5.

IV. Remaining part (other side) of this construction procedure will be as per section 3.1.

4. EFFECTIVENESS OF ANCHOR PLACEMENT AT TOP PORTION OF PILE

To investigate the effectiveness of anchor at top portion of pile a geo5 model is done. From the analysis it is found that for the same soil condition, the structure is unstable without anchoring whereas same structure is stable with anchoring as shown in figure 4. Considering displacement of anchor block and elongation of steel wire, spring constant of anchoring is assumed as 1130.0 kn/m.

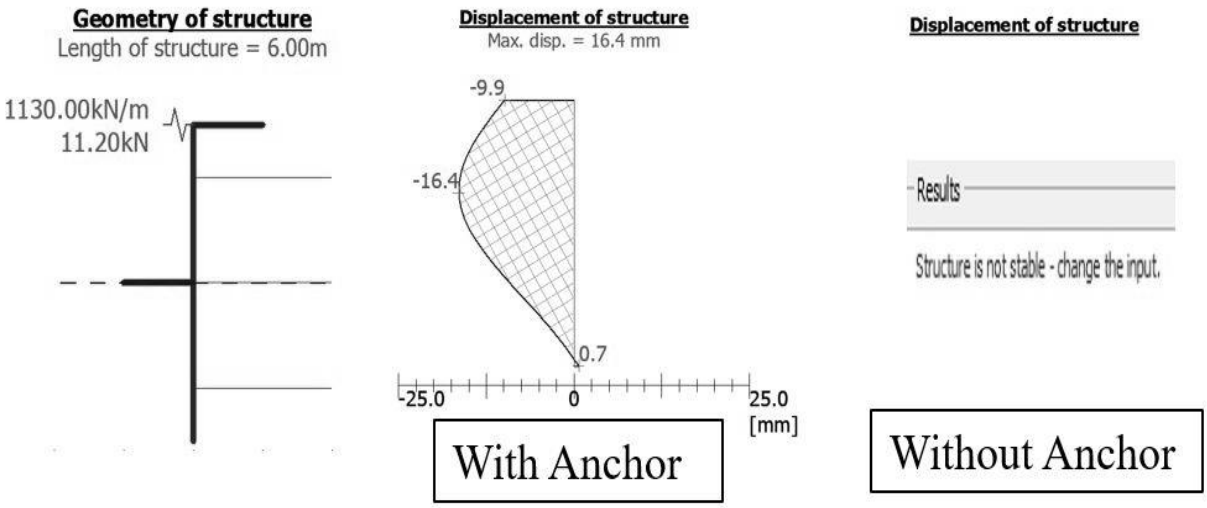


Figure 8: Displacement pattern of pile with anchor and without anchor option

5. CONCLUSIONS

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. Among the different types of adverse field condition, two types of situations are described in this paper. The construction guidelines described in this paper would be useful for engineers and contractors to ensure quality of rural road construction in coastal district of Bangladesh. Climate resilient road can be made if these guidelines are followed.

ACKNOWLEDGEMENTS

Authors wish to express their gratitude to "Introduction of Quality Test Protocols for Road and Market Rehabilitation" under Coastal Climate Resilient Infrastructure Project (CCRIP) (Package No: CCRIP-S-05(C), LGED, GOB) for their financial support.

REFERENCES

Alam, M. K., Hasan, A. S., Khan, M. R., & Whitney, J. W. (1990). Geological Map of Bangladesh. Geological Survey of Bangladesh, Ministry of Energy and Mineral Resources, Government of the People's Republic of Bangladesh.

Alam, Tanvir, & Hoque, (2017) Final Report of the Sub-Project "Introduction of Quality Test Protocols for Road and Market Rehabilitation

Government of the People's Republic of Bangladesh. (2005). Road Design Standards (Rural Road). Bangladesh: Local Government Engineering Department (LGED) and Japan International Cooperation Agency (JICA).

Huq, S., & Rabbani, G. (2011). Adaptation Technologies in Agriculture; The Economics of rice farming technology in climate - vulnerable areas of Bangladesh.

Islam, M. T., Alam, J. M., Taufique, F. M., & Hasan, S. M. (2015). Effect of Sand Content on Plasticity, Compaction and CBR of Sand-Clay Mixture. International Conference on Recent Innovation in Civil Engineering for Sustainable Development (IICSD-2015). Gazipur, Bangladesh: Department of Civil Engineering, DUET.

Kabir, M. H., Alam, J. M., Hamid, A. M., & Akhtaruzzaman, A. K. (2000). Foundations on Soft Soils for Khulna Medical College Buildings in Bangladesh. ISRM International Symposium, 19-24 November, Melbourne, Australia. International Society for Rock Mechanics and Rock Engineering.

Md. Jahangir Alam & Md Shamsul Hoque (2019), Climate Resilient Concrete Manual for Local Government Engineering Department (LGED)

Nath, B. D., Molla, M. K., & Sarkar, G. (2017). Study on Strength Behavior of Organic Soil Stabilized. International Scholarly Research Notices, 2017.