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EVALUATION OF LOW VOLUME RURAL ROAD DAMAGE IN COASTAL AREAS OF BANGLADESH

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ABSTRACT

The developing country, like Bangladesh spends a lot of budget each year for elevating, widening or repairing the existing coastal rural roads. These rural roads are constructed for a design life of 10 years. But these low volume roads loose serviceability within two or three years due to improper construction and design. To find out the reasons of less sustainability, different rural road sites in coastal region were visited by the authors and sandy soil (used for Improved Subgrade) and clayey soil (borrow pit soil used for side slope and shoulder) were collected from 28 sites. And several tests were conducted to identify geotechnical properties. DCP tests were conducted in field and results were analyzed by AfCAP LVR-DCP software which show inadequate value of pavement and shoulder. Several reasons were identified which are responsible for less sustainability of rural roads. The reasons are use of unsuitable material, poor compaction, borrow pit location at toe, vehicle movement over soft shoulder, consolidation settlement due to soft soil under road embankment, inadequate design of palasiding and slope protection, erosion of side slope by wave action

Keywords: *Rural road construction, DCP, Soft soil, Coastal road, Climate impact.*

1. INTRODUCTION

The design life of the rural road pavement is 10 years (Road Design Standards of LGED, 2005). But most of the rural roads damaged within 2-3 years as per road users' opinion. Every year huge amount of money is used to maintain or repair the rural roads. In Figure 1, the total maintenance cost of last ten years is shown.

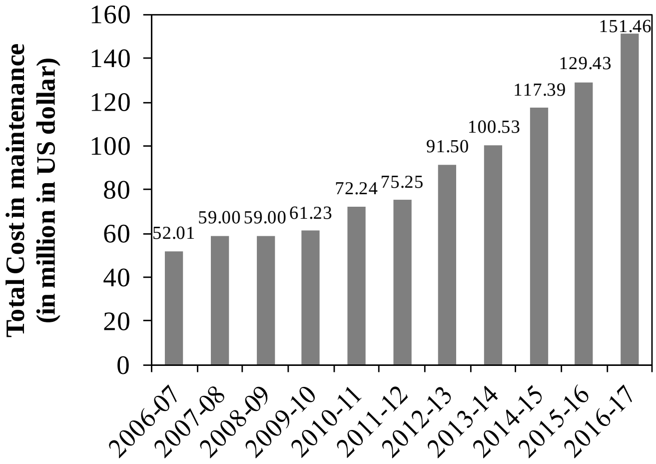

Figure 1. Yearly rural road maintenance cost (LGED, October 2017).

Field investigations have been carried out to identify causes of road damages in coastal regions. A lot challenges were identified in rural road construction in coastal areas of Bangladesh. At the same time, a lot of bad practices also were identified. This paper describes the challenges and bad practices in rural road construction. In this case study, randomly selected roads in rural coastal areas were visited and the reasons of damage were identified based on visual observations and engineering judgement.

Among the many reasons of poor quality of road construction, unavailability of construction materials, lack of compaction or poor compaction and inappropriate design of palisading in challenging roads adjacent to pond or khal or river are three major causes which should be addressed immediately.

2. DAMAGE EVALUATION

Existing earthen roads are upgraded as shown in Figure 2. Earthen roads are widened using borrow pit soil from nearby land. Mud or wet clay from borrow pit are used in widened part without compaction. 300 mm thick Improved Subgrade (ISG) is prepared using available local sand filling into box cut on top of the existing road. 150 mm thick sub-base is prepared using available local sand and brick chips mixed in 1:1 ratio. Then 150 mm thick base is prepared using brick chips only. 25 mm thick bituminous carpeting is done on base.

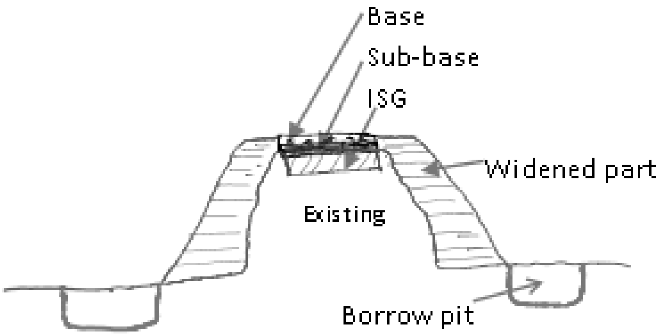

Figure 2. Typical rural road widening.

2.1 Soil sample

Borrow pit samples from randomly selected 28 spots in coastal districts are collected to classify the soil. Location of soil samples are mentioned in the legend of Figure 3 and Figure 4. Sand samples which are used in ISG and sub-base were also collected to see whether those meet the specification prepared by LGED. Grain size distributions of sandy soils are shown in Figure 3. Liquid Limit and Plasticity Index of borrow pit samples are shown in plasticity chart in Figure 4.

Among the 28 sand samples, 5 samples are poorly graded sand, 5 samples are sandy silt and other 18 samples were silty sand as per the Unified Soil Classification System (USCS) (Figure 4). The Fineness Modulus (FM) of 4 samples are more than 0.80, 2 samples between 0.50 and 0.80. Other samples have the FM ranged from 0.00 to 0.50. As per AASTHO, 14 samples are of group A-4, 7 samples of A-3 and of A-2-4 group 6 samples. Fines content of the sandy soil varied from 0 to 82%. Most of the sand samples did not meet the requirement of LGED specification. Due to unavailability of specified sand of FM greater than 0.80, contractors frequently use locally available very fine sand, silty sand and sandy silt in ISG and sub-base with poor compaction control. This is one of the reasons of unsustainable rural roads in Bangladesh.

Among 28 borrow pit samples, 6 samples were silt, 6 samples were fat clay and 18 samples were lean clay (as per USCS) (Figure 4). These soils are used in widened part and shoulder of embankment without compaction. Benching and layer by layer compaction is not done in widened part. So, this is not integrated with existing embankment. As a result, shoulder and widened part of embankment is soft where vehicle runs frequently during passing over.

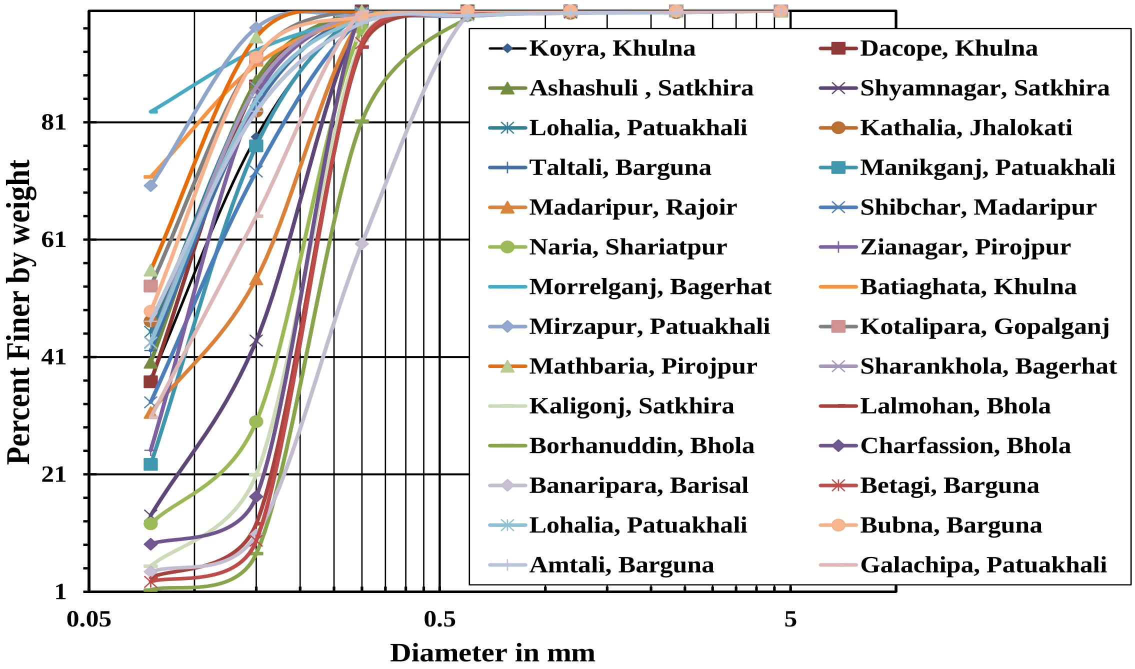

Figure 3. Grain size distribution of sands used for ISG and subbase in coastal districts of Bangladesh.

2.2 Sub-base and Base

Recommended size of the clay burned brick chips for subbase and base is 38mm down well graded brick chips (Road Design Standards of LGED, 2005). In many cases, it was found that 70% (by weight) of the total brick chips are larger than 38mm (see Figure 5). As per LGED specification, the ratio of the brick chips and sand should be 1:1 in subbase. In such a mixture, the brick chips become isolated and suspended in the fine sand matrix where property of sand dominates in stress-strain behaviour of the mixture. This ratio need to be revised based on experimental study using different mix ratios. In the field, more than 65% fine sand was found in sand-brick chips mixture. In the base, used brick chips are made from 2nd class clay bricks which are not properly burned in many cases. This type of brick chips are easily break-down during vehicle movement resulting rutting at wheel position of the road. These sub-base and base are responsible for rural roads with rutting, a lot of pot holes and damage.

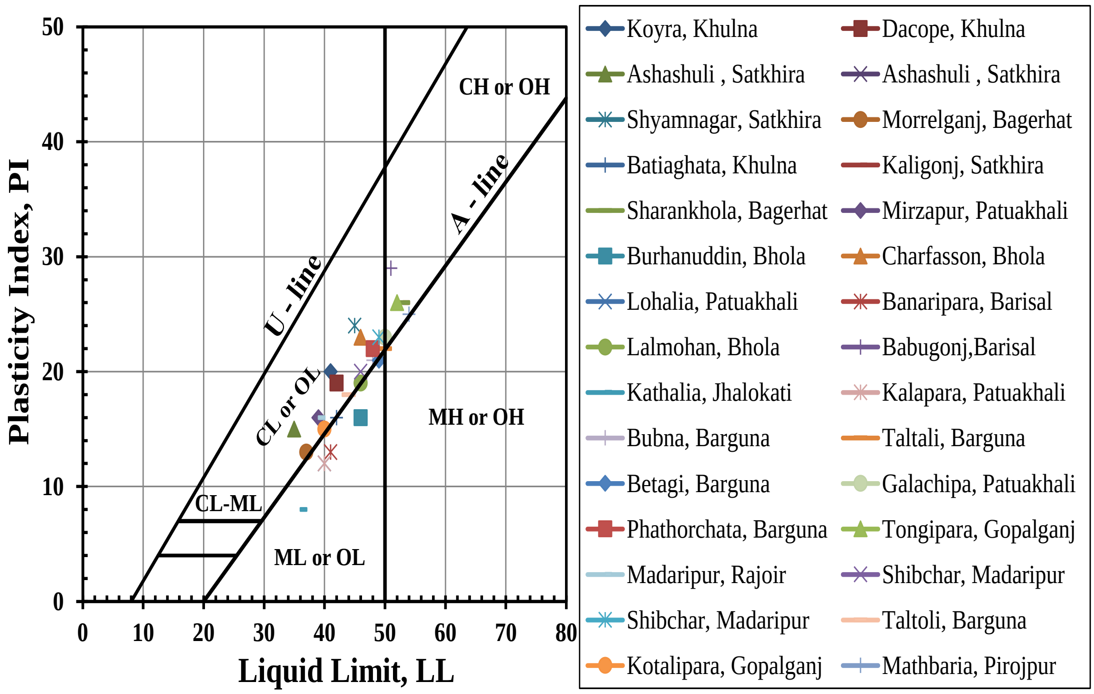

Figure 4: Position of borrow pit soil samples of coastal districts in the plasticity chart

Figure 5: Sub base and base sample collected from kaliganj, Satkhira

2.3 Moisture Content

During site visit, it is found that workers do not have any training or knowledge about optimum moisture content. It is possible to get better CBR value by maintaining the moisture content and proper compaction. So, better performance of road can be achieved by supplying the portable moisture meter and giving training to the workers, how to measure the moisture content and do better compaction.

2.4 Side Slope

Side slopes of roads were found steeper (1V:1H) than the design value (Rural Road Design Standards of LGED (2005) is 1V:1.5H for clayey soil, 1:2 clayey sand and 1:3 for sand or silty sand). Figure 6 shows a road at Bilaspur, Kaziarchar, Shariatpur. As the slope is steeper and the height of the road is more than 3.66 m, a surface crack was observed on the slope. Due to the steeper side slope and poor compaction, the crack also appeared on the shoulder of the road at Uttarpara, Uzirpara, Barisal (see Figure 7).

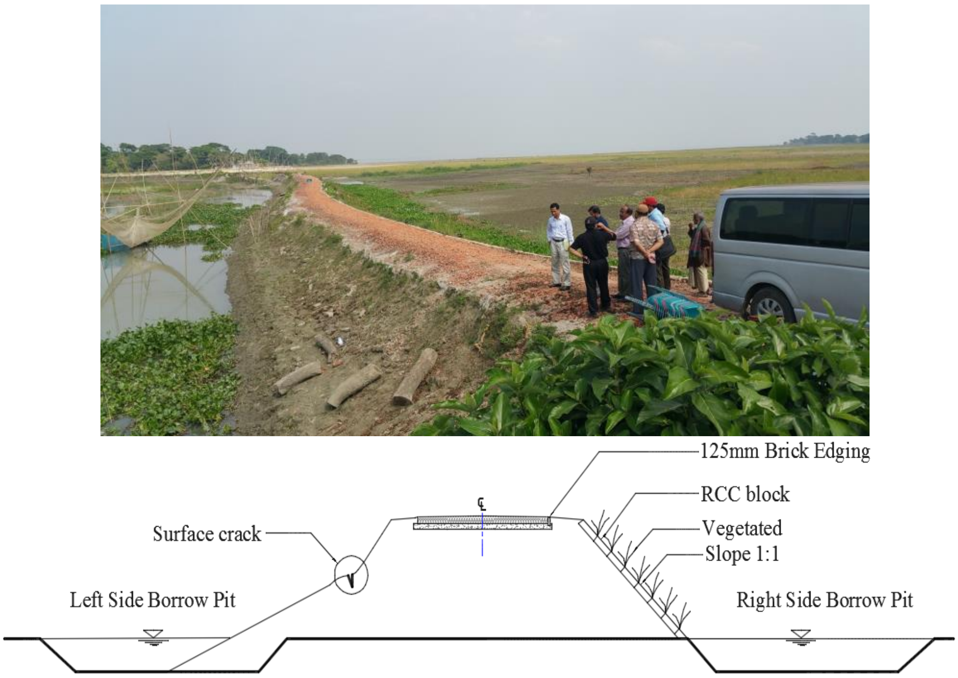

Figure 6: Failure line is observed in a road of Bilashpur, Kaziarchar, Shariatpur: Photograph, schematic diagram.

Figure 7: Steep side slope of rural roads in the study area (Location: Uttarpara, Uzirpar, Barishal).

2.5 Borrow pit location

Borrow pit locations were found at the toe of embankment. Borrow pit location should be at least 3 m or 1.5 times of road height (which one is greater) away from toe line (Road Design Standards of LGED, 2005). But in Figure 8, it is observed that the location of the borrow pit is at the toe of embankment. This is a reason of unsustainable rural road.

Figure 8: Borrow pit was at the toe of the road. (Location: Babubazar, Barishal).

2.6 Road along Bank or River/Khal

Some rural roads run along the bank of river or khal (Figure 9). This kind of road needs slope protection works for sustainable road construction. Sometimes, slope protection work is done using CC block revetment as shown in Figure 10. This is a typical design which is followed everywhere without any slope stability analysis. That is why sometimes slope failures are observed as shown in Figure 11. Limited fund of rural road construction is a reason of not doing any proper slope protection design.

Figure 9: Road along khal/river

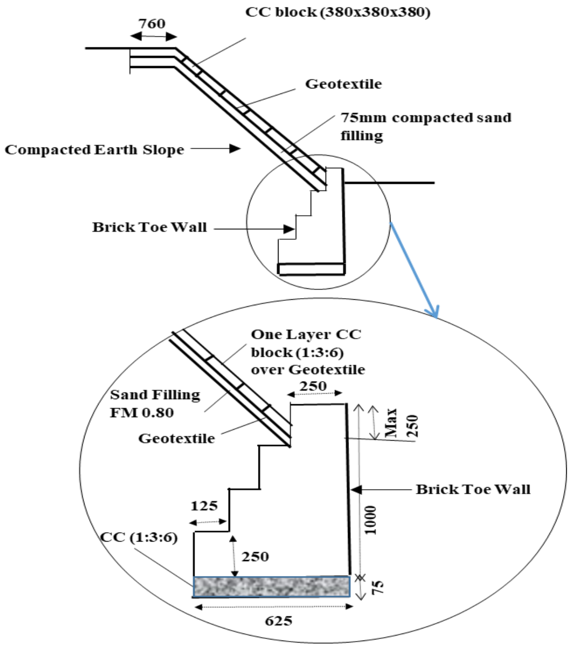

Figure 10: Schematic diagram of designed slope protection.

Palisading is done to stabilize the slope. In most of the cases palisading does not work properly. Figure 12 shows the design of palisading followed by LGED. Firstly, the precast piles of 3 m length are driven into the existing soft soil at a c/c distance of 0.90 m. Thereafter the RCC precast plates are hooked using nuts and bolts. After one or two years of construction the nuts and bolts become corroded and slipped from hooked piles (see Figure 13). Besides, in between two vertical RCC plates small gap exist through which the soil washed away day by day and erode the slope (Figure 13). Later this design is modified by LGED. They used cast in place plates instead of precast plates. However, this system is not stable in many soil conditions of coastal districts. The posts are inserted within the soft soil layer. Existing typical design and construction methodology of palisading need to be revised. Palisading design need to be modified with proper stability analysis.

Figure 11. Embankment slope failed.

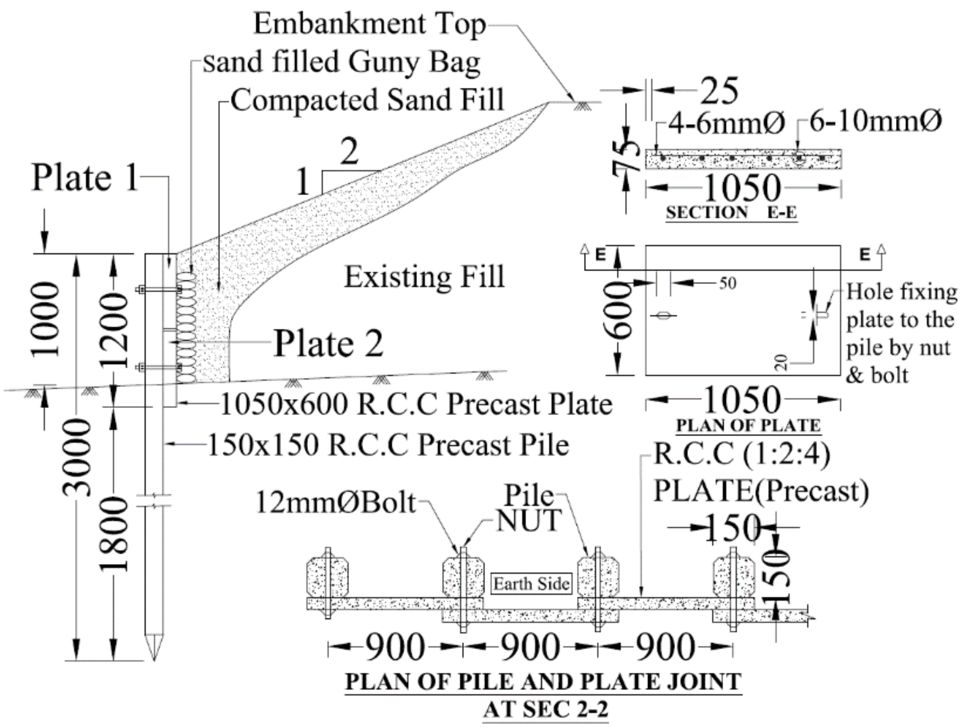

Figure 12: A typical design of palisading implemented by LGED.

Figure 13: Nut corroded, and Soil washed out in between the plates.

2.7 Fish Farming along Road

Crab, lobster and other fish farming in the coastal area are very common in Bangladesh. So, in the both side of the road the water exists throughout the year. Due to shallow water, wind generated waves erode side slopes (see Figure 14). In such location, soil is not available for widening and elevating road. To overcome this problem, dewatering of fish farm is done for road construction and the muds of the fish farms are used for road widening. Figure 15 shows damaged slope repairing using mud of dewatered fish farm. The soil is too wet to compact.

Figure 14: Side slope of rural road washed away by wave action.

Figure 15: Mud dumping at side slope from dewatered fish farm (Location: Dumuria,Khulna)

2.8 Approach road

Approach road must be designed and constructed in proper way to avoid differential settlement between abutment and approach road. In Figure 16, photograph are added to show the settlement of approach road. Geotextile and CC blocks were used for slope protection at approach embankment. Consolidation settlement of underlying soft soil, lack of compaction of approach embankment and inadequate wing wall are the major reasons of approach road damages.

2.9 Rain Cut Erosion and Slip Circle Failure

Vegetation don't naturally grow immediately after construction. Bare soil is vulnerable to rain cut erosion during rainy season immediately after completion of construction. Figure 17 shows such a situation.

Figure 16: Damages of an approach road of a bridge.

Figure 17: Rain cut erosion in shoulder without vegetation

Vegetation is eco-friendly and has a very beneficial effect on the side slope protection. But, due to lack of maintenance and inadequate sunlight, it does not grow properly to protect the slope (Figure 18). Sometimes, deep seated slope circle failure occur which cannot be protected by vegetation only.

2.10 Overloading

When a road network is developed in rural area, economic activity increases. Some people build multi-storied buildings beside road. So, loaded trucks enter into rural roads for which the road is not designed. During passing other vehicle, wheels of truck go on soft shoulder causing initiation of damage at pavement edge and shoulder (Figure 19). Because of frequent movement of loaded truck the small damage becomes greater.

Figure 18: Slope failed in a vegetated slope

Figure 19: Truck position at the edge of pavement and shoulder

2.11 Road Settlement

Nearly 85 percent of Bangladesh is underlain by deltaic and alluvial deposits of Ganges, Branhmaputra, and Meghna river systems (Alam et al, 1990). In the previous studies of the coastal region of Bangladesh, it was found that the sub-surface soil is soft (Kabir et al, 2000; Nath et al, 2017). At least 4-8 m soft clay exists at top layer of subsoil in coastal districts. Figure 20 shows a bore log of plot for Civil Surgeon office, Gopalganj. In another research report on "Ground Improvement on Khulna Soft Soil" revealed that more than 15 m soft clay layer exist at top of subsoil in Khulna region (AsCAP final report, 2017). The soft soils consist of silt or clay. Besides, in that region, in some places, an organic clay layer of 3-5m thickness was found. This organic layer was formed from the decomposition of mangrove vegetation of the largest mangrove forest of Bangladesh (Kabir et al, 2000). As the soils of the coastal area are soft and sometimes those are organic, settlement of the newly constructed road or widened or elevated road continues more than 10 years. This settlement is not uniform along longitudinal direction of road.

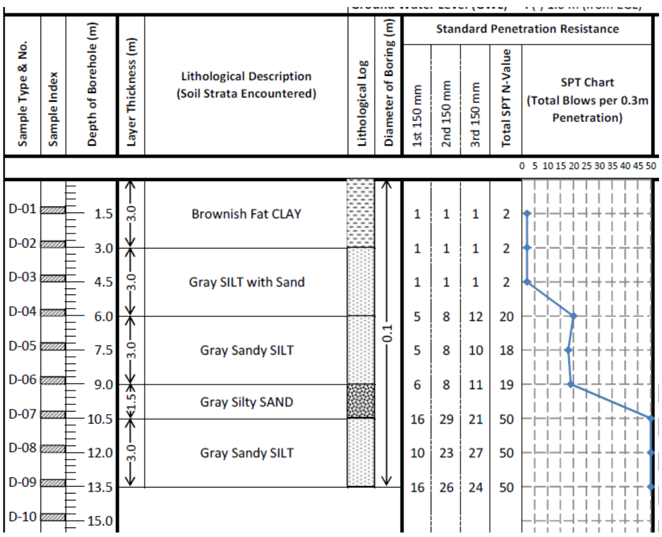

Figure 20: A subsoil bore log at Civil Surgeon Office, Gopalganj, Dhaka

When roads are constructed on this subsoil, consolidation and squeeze out of soft clay cause subsidence, cracking and rutting of constructed road. Subsoil investigation should be mandatory for road project in coastal areas. Special attention should be given in the planning and design phase of road projects. Figure 21 shows the settlement of road on soft soil. In the both sides of the road fish farm is full of water.

2.12 Rutting and Water Logging

When roads are constructed, crown and 3% lateral slope is maintained (Road Design Standards of LGED, 2005). After one year of construction, rutting and subsidence of pavement create water logging on the road pavement. This water logging damages the bituminous carpeting and subsequently base layer. Two photographs of Khulna region are exhibited in Figure 22 shows the field scenario.

Figure 21: A Portion of road settled

Figure 22: Water logging on the settled pavement and wide spread pot holes

3. DCP TEST ON PAVEMENT AND SHOULDER

The recommended CBR value verses DCP penetration per blow for rural road construction was collected from LGED as shown in Figure 23. To compare the LGED recommended DCP values with field DCP values, total 34 DCP (Dynamic Cone Penetration) tests were conducted in rainy season on some village roads in Khulna district, Bangladesh. Test locations are listed in Table 1. Results of DCP tests done on road pavement are shown in Figure 24 whereas results of DCP tests done on shoulders are shown in Figure 25. In Figure 24 and Figure 25, the black lines are the LGED recommended maximum DCP penetration per blow (denoted as DN in mm/blow) for various layers of pavement. Where DN exceeded black line indicates not meeting the requirement set by LGED.

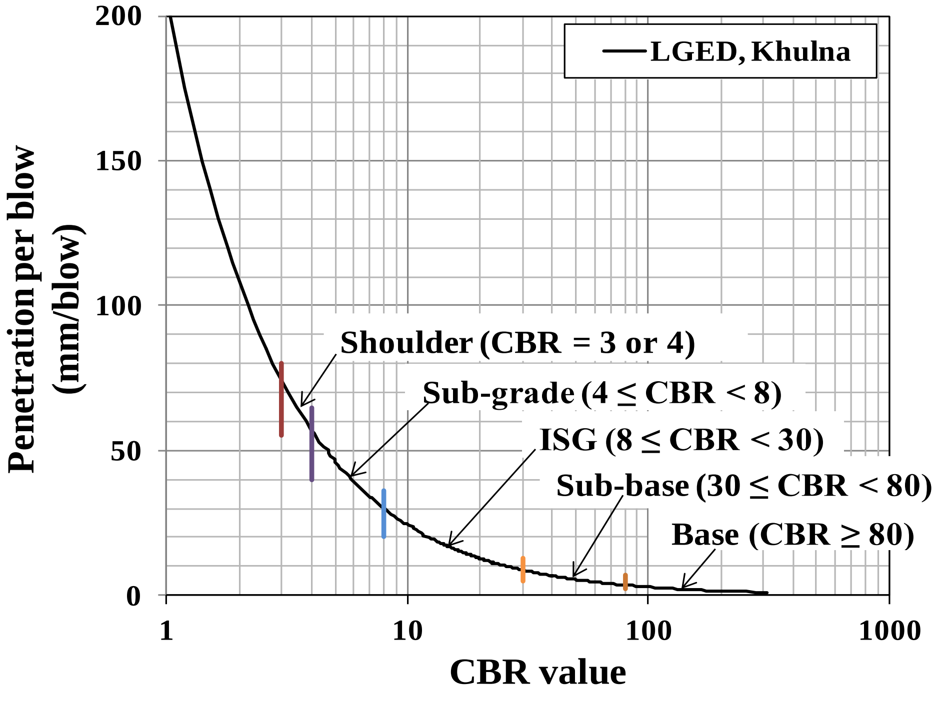

Figure 23. CBR verses DCP penetration rate (mm/blow) recommended by LGED for rural road.

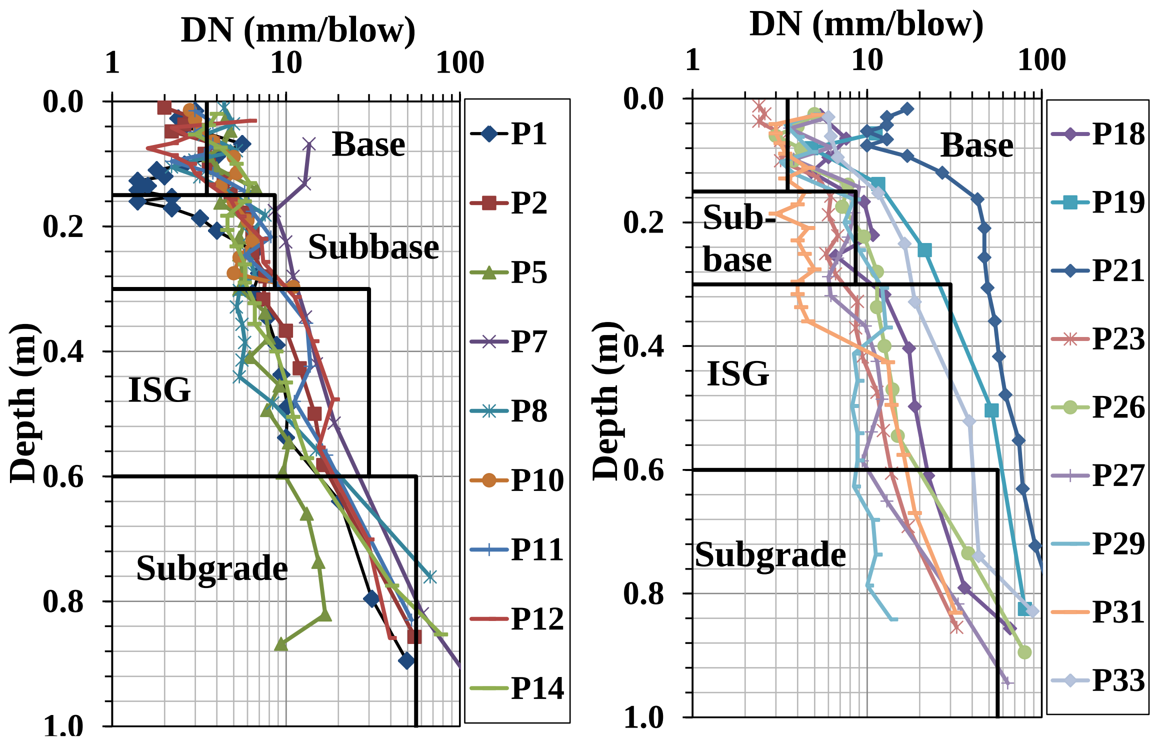

Figure 24. DCP test results conducted on the village road

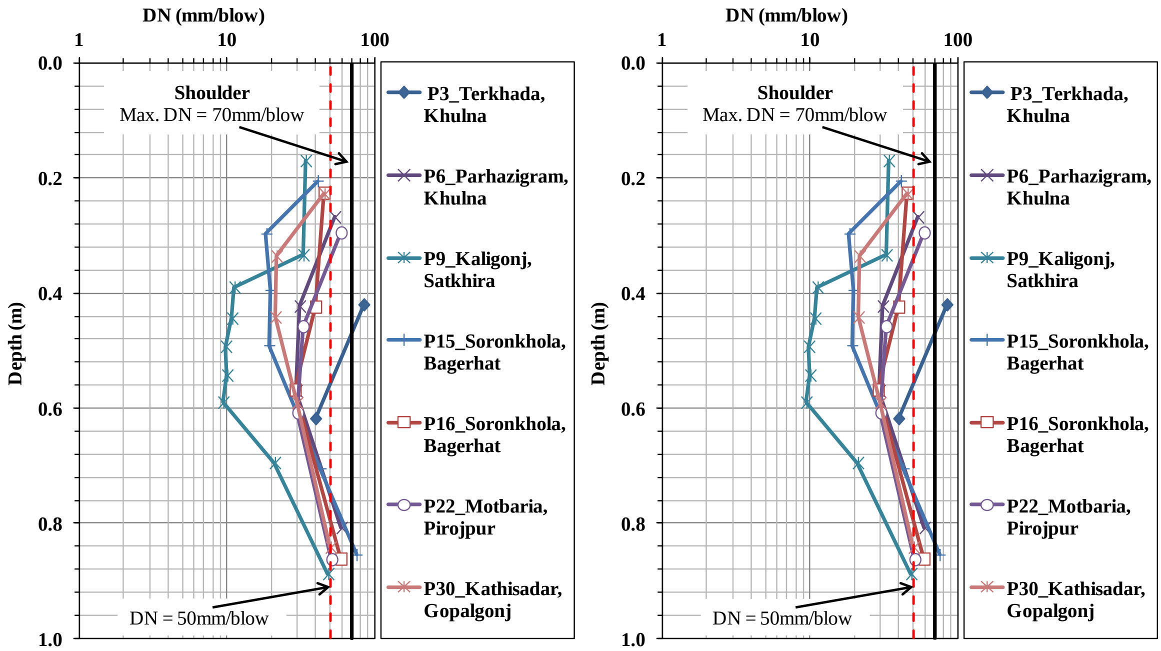

Figure 25. DCP tests conducted on the shoulder of the rural road

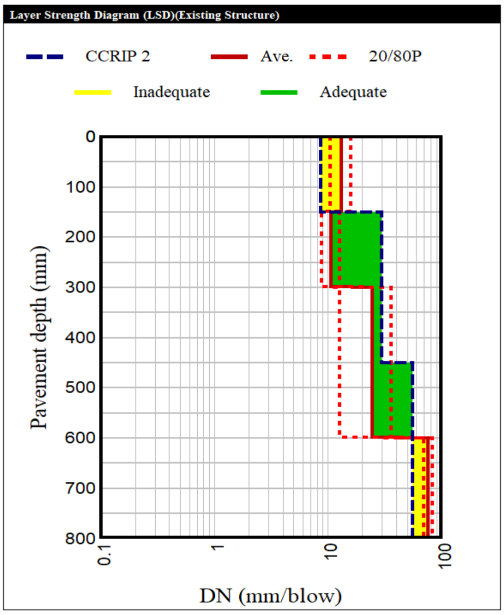

Figure 26. Analysed DCP test result (P7_Modhupur, Khulna): Layer strength diagram

Table 1. Condition) of Road and Shoulder by using AfCAP-DCP software.

No.	Point_Point_Location	Road Pavement*				Shoulder*
		Base	Sub-base	ISG	Sub-grade	
1	P1_P3_Terkhada, Khulna	A	A	A	A	I
2	P2_P4_Terkhada, Khulna	I	A	A	A	I
5	P5_P6_Parhazigram, Khulna	I	A	A	A	A
7	P7_Modhupur, Khulna	I	A	A	A	--
8	P8_P9_Kaligonj, Satkhira	I	A	A	A	A
10	P10_Kaligonj, Satkhira	I	A	A	A	--
11	P11_ Kaligonj, Satkhira	I	A	A	A	--
12	P12_P13_Soronkhola, Bagerhat	I	A	A	A	I
14	P14_P15_Soronkhola, Bagerhat	I	A	A	A	A
16	P16_Soronkhola, Bagerhat	--				A
18	P18_P17_Soronkhola, Bagerhat	I	I	A	A	I
19	P19_P20_Motbaria, Pirojpur	I	I	I	I	I
21	P21_P22_Motbaria, Pirojpur	I	I	A	A	A
23	P23_P24_Motbaria, Pirojpur	I	A	A	A	I
26	P26_P25_Mathbaria, Pirojpur	I	I	A	I	I
27	P27_P28_Kathisadar, Gopalgonj	I	A	A	A	I

No.	Point_Point_Location	Road Pavement*				Shoulder*
		Base	Sub-base	ISG	Sub-grade	
29	P29_P30_Kathisadar, Gopalgonj	I	I	A	A	A
31	P31_P32_Kathisadar, Gopalgonj	I	A	A	A	I
33	P33_P34_Kathisadar, Gopalgonj	I	I	I	A	I

*A=Adequate I=Inadequate

A digital moisture meter was used to measure moisture content of the subbase and ISG after making a small hole on road pavement. Later it was filled with concrete. Moisture contents of roads were between 14 and 18 percent for subbase and ISG. In the shoulder the moisture content was more than 50 percent. The DCP test data were analysed by using the AfCAP LVR-DCP software (A software developed by Africa Community Access Program). In Figure 26, adequacy of each layer is checked by comparing with maximum recommended DN (mm/blow) values shown in Figure 23. Adequate layers are represented by green colour and inadequate layers by yellow colour. Thus, all DCP tests data were analysed and adequacy of layers is listed in Table 1. In most of the cases, bases were found inadequate. 10 points out of 16 points on shoulder were inadequate. Some sub-bases were found inadequate and few ISG (Improved Subgrade) were found inadequate.

Rutting on road pavement may be attributed to inadequate base layer. Initiation of damage at the edge of pavement may be attributed to inadequate shoulder. Shoulder and widened part of road acts as confinement to existing road. Soft shoulder is not capable of giving confinement to pavement layers. That is why authors think that shoulder should be hard type with herring bone brick under which there should be a sub-base layer. Dumping of mud at shoulder and side slope must be avoided to make sustainable rural road.

4. CONCLUSION

Based on the test results and field observations, following reasons of road damage were identified.

i. Use of unsuitable soil for ISG, subbase, base and slope.
ii. Lack of training and concern about relation of moisture content and compaction.
iii. The side slope is steeper than the designed slope.
iv. Borrow pit location is along the toe.
v. No extra protection or proper protection for the road embankment along the river or khal.
vi. Erosion of side slopes due to wave action from the shallow fish pond (Gher).
vii. Settlement of the approach road due to underlying soft soil, uncompacted approach embankment and inadequate wing wall.
viii. Rain cut erosion of soft lean clay or silt on the shoulder and slope.
ix. Overloaded vehicle movement on the pavement and on the shoulder.
xi. Soft subsoil under road embankment.
xii. Rutting and water logging on the road.
xiv. Lack of vegetation on side slopes.

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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.

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.

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