Cost effective sustainable slope protection solution of rural roads at flooding regions

(Thematic Area: Rural Transportation: Engineering Design Improvements)

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Abstract:

Bangladesh is a sandwich country between the Himalayas and the Bay of Bengal. The rivers of the country carry a huge amount of upstream water and therefore the rural roads along the rivers and the alluvial plains are often subjected to floods and erosion. Protection of road embankment slopes was difficult and sometimes construction of retaining wall was the only solution. LGED with assistance from a JICA Technical assistance project has developed a sustainable and cost effective solution for protection of steep slopes with soil bag. The cost of the slope protection works is nearly 40% of protection with retaining walls.

The foundation of the protection should be in stable earth. Wooden piles may be used beneath the foundation to avoid scouring. The foundation is constructed with brick soling and a lean concrete above it. The protective materials are made of soil/sand bag. The bags can be made of jute or geosynthetic. The soil/sand cement ratio can be varied from 4:1 to 8:1. The stability of the protection work lies in correct positioning and placing of bags. Under different trial situation, the correct positioning of the bags has been found as 10° inclination at the first layer and 18°at all the upper layers. This method of slope protection can be replicated in flooded regions as well as in hilly region where stability of slope is a great concern.

1. Introduction

Bangladesh is the world's biggest Delta. Most of the land is flat and is between 6.5m- 7m above of mean sea level. It is also a sandwich country between the Himalayas and the Bay of Bengal. The rivers of the country carry a huge amount of upstream water and alluvial sediments therefore they are often flooded. Hence flood flow and wind generated flood wave causes serious damage to rural Infrastructure every year. The damage has become accelerated in recent years with the progress of

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Global climate change.

In Bangladesh, annual flood is essential to convey fertile soil to the paddy, big flood occurs once in a decade that inundates more than 1/3 of the land and erodes rural infrastructures in flood prone areas, especially road embankment, approach to bridge abutment, whose main material is flood piled silt. In addition to that, the embankment and the slope of the roads are often eroded by the wave action of flood water making a total collapse of the road. The road agencies of the country adopt effective solutions for slope and embankment protection. They adopt different solutions for different roads depending on steepness of road slopes. The protection of roads with steep slopes was comparatively difficult and sometimes construction of retaining wall along the road was the only solution. Local Government Engineering Department (LGED) in Bangladesh with assistance from a JICA Technical assistance project developed a cost effective solution for slope protection for steep slopes with soil bag. This method has been found effective, sustainable and working since 2010. The cost of the slope protection works is nearly forty percent of construction of retaining wall along the slopes.

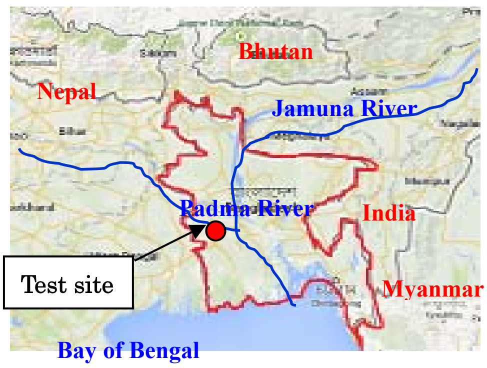
(a) Rural road (b) Approach to bridge abutment (c) Hampered transportation

Picture-1 Serious damage caused by wave erosion

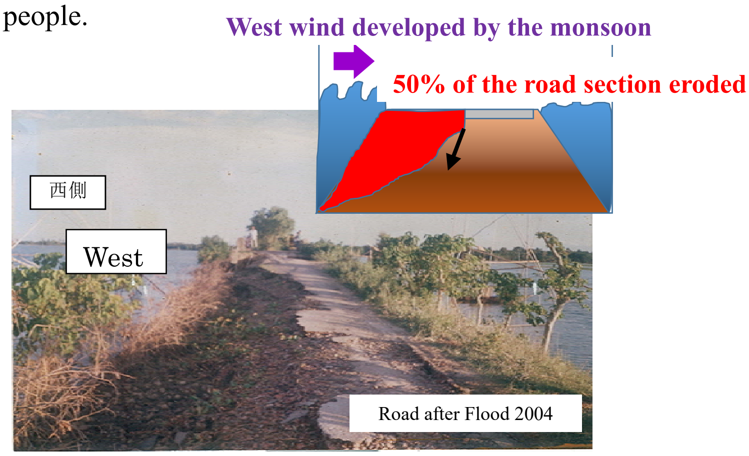
2．Test construction

The construction method was developed to satisfy the following conditions to meet the local needs.

1) It must be effective under severe wave condition.
2) The construction material must be locally available.
3) It must be labor-intensive.
4) The technology is easy to use for local people.
5) It must be economically viable.



Picture-2 Location of the test site



Picture-3 Wave damage of the test site

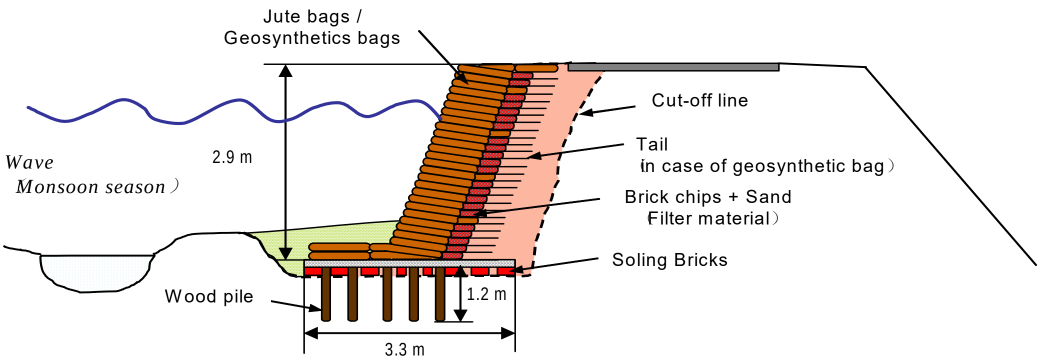
(1) Outline of the test site

The test site is set at the rural road located in the district of Manikgonj, 2 km apart from the intersection of two large international rivers, namely the Padma River (Upstream is the Ganges river in India) and the Jamuna river, where flood damage is serious every year (Picture-2). Picture-3 shows the damage of road embankment at the test site. The road embankment material is silt sand and more than 50% of the cross section is eroded by wave. Silt sand is available at river area but it is likely to be eroded with water invasion by losing its adhesion.

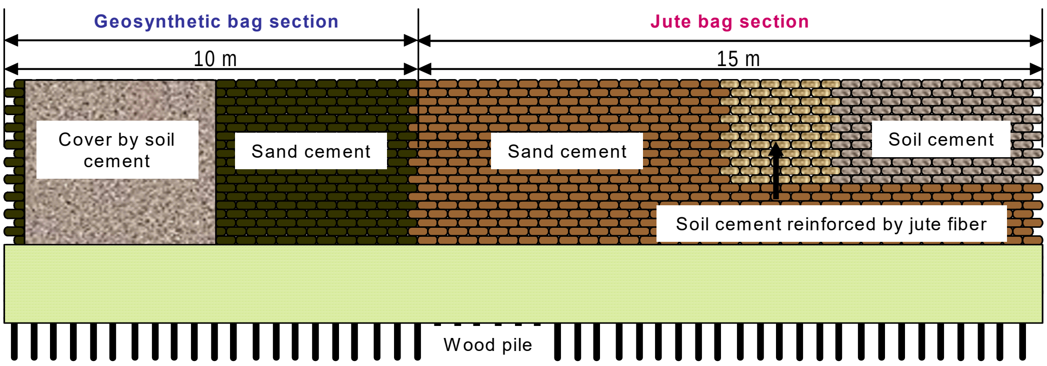
(2) Outline of the construction method

The cross section and the front view of the construction method are shown in Picture-4. The height is 2.9m, the slope is 1.0V: 0.6H. 26 soil bags are piled on the slope. The length of the test construction is 28.0m of which the Jute bag area is 15.0m and the Geo-synthetic bag area is 13.0m. Geo-synthetic bag was imported from Japan.

Jute bag is cheap and locally available, but is biodegradated within a few years. While Geo-synthetic bag is expensive, it is durable and reinforces the stability of embankment by adopting special shape with tail and wing which act as supporter. The bags were also used as mold (Picture-5).

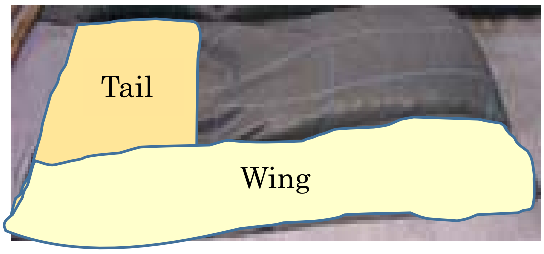


(a) Cross section



(b) Front view (not include transition part 3.0m)

Picture-4 Construction structure



Geos-synthetic bag


Different types of Jute bag

Picture-5 Soil bags

The technical features are as follows,

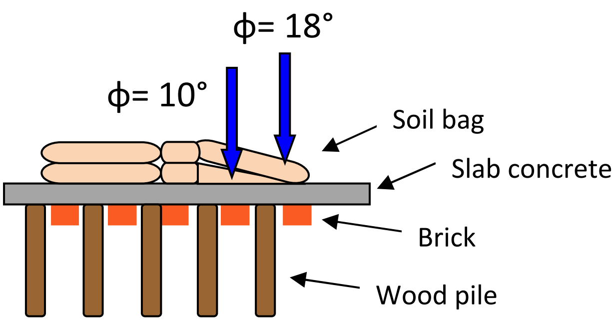
ⅰ) Wide basement of 3.3 m was placed, wood piles were driven and they were covered by the base concrete for scour protection (Picture-4(a).

ⅱ) Long soil bags of 850mm were stacked inclined backwards to increase the structural stability (Picture-6).

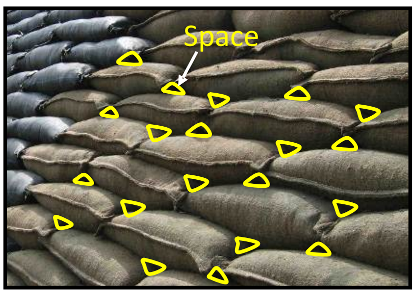
ⅲ) The space between soil bags functions as drain holes. Since the drain holes are inclined backwards, the suction of backfilled materials along with the water drainage is prevented (Picture-7).

ⅳ) Filter materials(mixture of crushed brick and sand, which ratio was 2:1) was placed at the back of soil bags to prevent the suction of backfilled materials.

ⅴ) The proper mixing ratio of the filled material was tested through 3 kinds of trial, (a) Cement: Sand=1:6, (b)Cement: Soil=1:4, (C)Cement: Sand=1:8(LGED standard).



Picture-6 Inclined soil bag



Picture-7 Space between soil bags

(3) Work process and quality management

a) Work process

Construction process is shown in Picture-8.

① Cut-off eroded loosen embankment manually.

② Set up a bamboo scaffold and strike wood piles into the basement by falling a weight of 100kg. The head of the wood pile is stopped at 160mm above the basement so as to unify the wood pile and the base concrete.

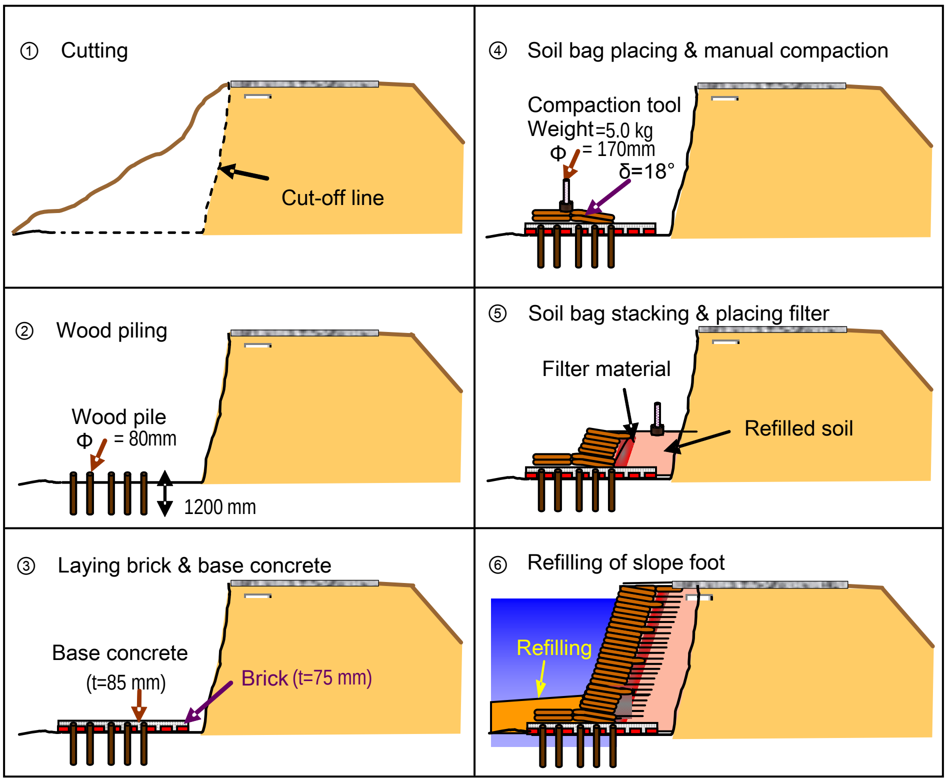
③ Bricks are placed between wood piles, then base concrete is placed.

④ Place the first base soil bag.

⑤ Soil bags are stacked with the inclination of 18°backwards and tamp well with a compaction tool. At the back of soil bags, filter material and refilled soil are placed and tamp well with a compaction tool.

⑥ After slope protection work is constructed, refill the slope with soil.

The most important thing is to compact the soil bag well to make solid cement as shown in Picture-9. Then, since the filter material and the refilled soil are compacted after the soil bag is placed/compacted; effective compaction of the protection work develops. At the same time, since compaction is made by every layer whose height is same as a soil bag height (=125mm), easy and sure compaction becomes possible. These are the big advantages of this method which overcomes the insufficient compaction problem frequently observed in other existing slope protection methods.



Picture-8 Construction process

(a) Soil bag (b) Filter & refilled soil

Picture-9 Compaction work

Picture-10 Field compaction test

(b) Quality management

Following management was conducted to secure the quality.

1) Compaction management of back-filled materials (Picture-10)

Compaction guideline was fixed as 5 times fall of local compaction tool from the height of 30 cm based on the field compaction test.

2) Cement and material mixing management

Mixing quantity was fixed by the times of casting with an overhead soil convey basket into the mortal mixer.

3) Mixing field soil management

Field soil block was subdivided into small pieces smaller than 1 – 2 cm so as to improve the mixture with the cement.

4) Cement curing management

After the cement mixed mortar was made, all the works of filling the bag, conveying it, placing it, compacting it were completed within 40 minutes and its wet condition was kept by timely watering to gain the required strength.

(4) Advantages of the method

①High technology and special construction machines are not necessary.

②Locally available materials can be used.

③Work process is simple and easy to follow (if guided by experts)

④Back-fill materials are well compacted.

⑤Land for construction can be saved since the slope is steep. (Picture-11)

(a) Easy slope (b) Steep slope

Picture-11 Comparison image

(5) Limitation

The main limitation of the method is that it requires careful monitoring by skilled professional during the whole construction procedure. However, it can be managed by providing training regarding the method.

(6) Economic consideration

The cost of the slope protection works is nearly forty percent of construction of retaining wall along the slopes. Considering the soil bags; cost of construction with geo-synthetic bag is 1.5 times higher than the ordinary soil bag (jute bag) available in Bangladesh. The local soil bags last only 1 – 3 years. Since the test construction works last more than 5 years already (Picture-12), it can be concluded to be more cost effective. The cost using Geo-synthetic bag is 10 times higher. Since the bag is durable, no deterioration after 5 years at all, if it is mass produced for the vast demand in Bangladesh, the cost will be greatly decreased.

(a) Soil bag (A little deteriorated)

(b) Geo-synthetic bag (No deterioration)

Picture-12 Present situation (After 5 years)

3．Other Methods of Slope Protection in Bangladesh

The popular method in Bangladesh is placing cement concrete blocks in a mild sloped embankment. One of the limitations of cement concrete block is their lack of interlocking. Now, special blocks are manufactured with interlocking properties and holes within the blocks. Vetiver plantation (a special plantation with deep root-effective against wave) is another promising method. It is being tested and has found effective in a number of sites. A new method with interlocking blocks combining with vetiver plantation is now under trial. However, in case of steep slopes, soil bag method described above is a cost effective and sustainable alternative.

4. Conclusion

Rural infrastructure faces serious wave erosion in Bangladesh. This slope protection method appeared to be one of the promising repair methods against wave erosion.

About the Author-

1. Mr. Md. Abul Kalam Azad obtained his graduation in Civil Engineering in Bangladesh and MSc in Highway Engineering in UK. He is one of the prominent figures in Rural Road projects in Bangladesh. During his 32 years of Government service he has been involved in planning and implementation of numerous road infrastructure development projects all over the country. He had significant contributions in developing new and sustainable construction methodologies, techniques of flexible pavement in the context of rural Bangladesh. He has attended numerous road conferences, workshops in many countries of the world.

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