Participatory project to improve trafficability of unpaved road at delta in rural area of Bangladesh

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ABSTRACT

Bangladesh is almost a complete delta area located at the apex of the Bay of Bengal in the Indian sub-continent of South Asia. The land is composed of around 80% clay soil, such that rural soil roads are impassable in the rainy season. For this reason, the locally available geotextile technology, called Do-nou technology in Japanese and consisting of the piling up of soil-filled sacks, was applied to build a base course by members of the community. Do-nou technology has been adopted to reinforce the bearing capacity of the base course, which normally consists of sandy gravel materials, to improve trafficability. However, in rural areas of Bangladesh, it is difficult to obtain reasonable base course materials. In this study, crushed bricks have been identified as one of the alternatives for base course materials. It is anticipated that reinforcing the shear strength of the inner materials through Do-nou technology will make crushed bricks applicable to the base course of roads. Crushed bricks are available and cheap, and they can be utilized as coarse aggregates of concrete as a substitute for traditionally applied crushed stones. In this paper, the construction costs and the productivity are examined in advance of further research.

Keywords: Base course, Do-nou technology, Crushed brick, International cooperation

1 INTRODUCTION

The focus of previous rural development projects in the field of international cooperation was the expansion of agriculture and education to assist the citizens of rural communities. However, recent trends have been moving toward enlarging the range of activities to include improving the access within these areas, and from the city to these areas, and investing in the rural infrastructure at the initial stage of the projects in order to secure earnings and help citizens benefit more fully.

Our research group was given the chance to assist in the construction of a feeder road in a village in Bangladesh within the framework of a rural development project by the Japan International Cooperation Foundation (hereafter, JICF) following recent trends of JICF to promote cooperative activities, such as rural development, in several areas.

Our research group has been developing Do-nou technology (Do-nou means “soil bag” in Japanese), a participatory method to rehabilitate unpaved soil roads using do-nou bags and mainly man power, in order to help the local people repair the roads through their own efforts and without the need for government assistance. Do-nou bags are typically prepared by digging up local soil, filling the bags with it and then compacting the bags manually following the standard plan for base course materials in Do-nou technology. There are two principal types of spot repairs using do-nou bags (Fig. 1(a)), namely installing the bags to partially problematic areas, like ruts, and creating proper drainage by means of an all-over repair (Fig. 1(b)) by piling up the do-nou bags on the ground to raise the road level. The second type of repair is applied in the case of an inundation in the rainy season or if the base materials are composed of clay (Fig. 2). Moreover, all kinds of materials, except clay, can be applied as the inner materials. On the other hand, if it is difficult to collect sandy gravel materials at the site, they can be purchased.

Bangladesh is located in a delta area formed by the Bay of Bengal in the Indian sub-continent. Approximately 80% of the ground is composed of clay materials. As it is difficult to use the onsite soil materials and it would be expensive to purchase sandy gravel materials, the situation does not seem suitable for the application of Do-nou technology. However, brick material production is prosperous in Bangladesh and crushed brick materials are frequently used as concrete aggregates or the base course with the macadam method. Therefore, crushed brick materials were applied to Do-nou technology in the present project.

This paper discusses: (1) an investigation of local available materials and availability at the project site and (2) the method of application of crushed bricks in Do-nou technology and situation after the construction and rainy season.

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2 LOCALLY AVAILABLE MATERIALS

2.1 Brick materials and crusher

Brick production in Bangladesh is the second largest in the world, with an annual total production of 17.2 billion pcs using 5,000 kilns\(^7\). The bricks are mainly produced in Hoffmann kilns (Fig. 3\(^7\)) which consist of a main fire passage surrounded on each side by several small rooms. Each room contains a pallet of bricks where the bricks are fired. In the main fire passage, there is a fire wagon that holds a continuously burning fire. The fire is kept burning in each room for a specific time, namely, until the bricks have been vitrified properly. Then, the fire wagon is rolled to the next room\(^8\). With this method, however, it is difficult to maintain an even temperature throughout the entire kiln, and thus, a certain percent of the bricks are undoubtedly over-burned during each round of firing. After the bricks have been fired, they are divided into three grades, from A to C, based on their color and weight.

Table-1 shows the results of a survey conducted to investigate four brick companies located in Rajshahi City. In the survey, the price of the bricks refers to their value not including the transport fee; it was calculated by JICA at the exchange rate of 1 BDT = 0.013 US$ in Dec. 2014. The grade A bricks make up 80% of the total, while grades B and C comprise 10% each. Along with the lower grade bricks, damaged bricks are sold at cheaper prices as defective materials. The grade A bricks are purchased by organizations for use in large-scale construction works, while the grade B and C bricks are sold to individual customers for use in building houses and animal sheds. The defective bricks are used after being crushed by an Indian crusher (Fig. 4\(^7\), a diesel-powered dual-axis crushing system commonly applied in Bangladesh. The grade A crushed bricks are applied as concrete aggregates or base course materials and the grade B crushed bricks are applied for slab making. However, the grade C crushed bricks are normally not used for any construction; they are treated as waste materials. Each brick is 0.12 m in length, 0.24 m in width and 0.07 m in height. The minimum selling lot is 1,000 pcs (2.0 m\(^3\)) and the transportation cost for one lot is 14.8 US$ when it is transported less than 30 km transportation from the site.

2.2 Availability and applicable material

The road repair project was launched in the village of Godagari in the sub-district of Upazila in Rajshahi City.
This area is located near the Padoma River which is downstream of the Ganges River. The ground is classified as Fluvisol by FAO and is composed of mainly kaolinite clay.\(^9\) \(^10\)

Figure 5 shows a map of the construction site. There are many brick factories near the Padoma River, and at least 4 of them are located less than 30 km from the site. The national road was paved with asphalt, so there is no problem with transportation along it. The tools and materials, including the brick crusher, can be procured from a nearby city. Table 2 presents a price list of the fundamental materials required for the construction. It is possible to procure the sandy gravel materials; however, they cost 28.5 US$ /m\(^3\) and the supply is unstable. Thus, grade C crushed brick materials are applied for the materials inside the do-nou and on the surface in order to keep the costs at a level that will continue to be practical for the villagers in the future.

3 CONSTRUCTION PROJECT

3.1 Target road situation and standard section

The target road, with farm land on both sides, is 800 m in length and approximately 3 m in width with an unpaved clay embankment (Fig. 6). The surface of this road becomes muddy in the rainy season, but only around 100 mm of it, which results in low trafficability. Over a year’s time, the daily traffic never exceeds 20 vehicles. This traffic is composed of tractors, trikes, motorbikes, ox-carts and bicycles.

Figure 7 shows the suggested repair for a standard road section, namely, the repair of only the muddy clay surface. The number of layers of bags is set at 2, but 1 line of bags is also added in the center of the road to guarantee an 8% cross slope, thereby creating more surface drainage and allowing the water to be absorbed into the ground. For the lines of bags of the first layer, excluding the edges, and the center of the second layer, do-nou with clay are used. The other bags contain crushed brick to cut costs. The road to be repaired is 800 m in length. A 231-m section was applied on 3.20 m standard road section (Fig. 7(a)), and other 569 m was applied on 2.75 m standard section (Fig. 7(b)).

3.2 Results of road construction

The construction was conducted during the dry season from Nov. to Dec. of 2014. The mobilization target was set at 60 people per day and the work time

| Item                  | Remarks                  | Price [US$/pc] |
|-----------------------|--------------------------|----------------|
| Do-nou bag            | W 0.50 × L, 0.70 m      | 0.1 /bag       |
| String                | 50 m roll                | 0.3 /roll      |
| Nail                  | 100 mm length            | 0.7 /roll      |
| Sandy gravel          | including transport      | 28.5 /m\(^3\) |
| Grade C brick         | including transport      | 14.3 /m\(^3\) |
was set at 8 hours per day. A daily allowance of 2.90 US$ was paid; this is the local average pay for daily workers. The workers were mainly composed of farmers and daily laborers, so it would have been difficult to mobilize them without an allowance. Table 3 shows a list of the materials and the budget for the project, while Fig. 8 shows the progress of the construction. The unit cost is recorded as 10.9 US$/m, for only the materials, and 15.4 US$/m, when including labour. Table 4 presents a list of the productivity of each type of work, which was surveyed on site by checking the work time for completing each task for certain soil volumes, and the standard productivity from the data on the labour based on the International Labour Organization\(^{[1]}\). Table 5 shows the workability of the crusher. From the results, the 3.20 m and 2.75 m standard sections could be built by 0.736 m/person*day and 0.947 m/person*day, respectively. The price of the crushed bricks and the transportation fee totaled 14.3 US$/m\(^3\) and the price including the crushing work with maintenance was 14.8 US$/m\(^3\). From the crusher workability, in the case of the 3.20 m road section, the amount of daily crushing was 16.72 m\(^3\) which would build 26.8 m of road per day and require 36.4 people for labour. When planning for the application of crushed brick into Do-nou technology, it is necessary to consider the crushing work in advance, following the workability of the crusher.

The crushed bricks were also applied for the surface, but this type of material is hard to compact. Moreover, due to the low traffic friction, the trafficability in the dry season is reduced. Thus, clay materials were distributed 3 times on the surface, as a countermeasure, 9 months after the end of construction. As a result, the surface materials were well compacted. Figure 9 shows the difference in particle distribution between right after the crushing and 9 months later. The surface materials right after crushing did not include any portion of fine grain, but the materials 9 months later showed 8.8% of fine grain contents. In the rainy season, this road maintains high trafficability (Fig. 8(d)). Actually, the hearing survey from villagers said that the road situation had been changed into well compacted after 1 month later of project end and 1 time maintenance had been carried out and also the tractor and tractor passing affect to compact and transporting fine grain for the surface.

Accordingly, the proposed grade C crushed bricks applied Do-nou technology can construct the good trafficability soil road in the rainy season. And it is possible to procure the all of materials for purposes for method if the project site is located in rural area.
4 CONCLUSION

This paper has discussed a road construction project applying locally available materials in a rural area of Bangladesh under the difficult situation of finding suitable soil materials such as sandy gravel materials. The conclusions are as follows:

1) Three grades of bricks are distributed; the damaged ones are sold at a cheaper price, namely, the grade C defective bricks cost 14.3 US$/m², including the transportation fee, when the transport distance is less than 30 km.

2) Many brick factories are found in Bangladesh; there are 17 of such factories in an area less than 50 km from the project site, although the site is located in a rural area.

3) The Indian brick crusher is commonly distributed and it is possible to purchase it in a nearby town. It is possible to crush 2.09 m³ of bricks per hour and this work requires the labour of 6 people. The brick price, including the crushing work, is 14.8 US$/m³.

4) The proposed Do-nou technology is applicable for maintaining trafficability in the rainy season when the daily traffic is less than 20 vehicles. However, road surfaces which use only crushed brick are difficult to compact, so it is necessary to mix in some clay.

5) The unit cost of the proposed method has been recorded as 10.9 US$/m, including only the materials, and 15.4 US$/m, including labour and the materials.

6) The unit productivity of the proposed method has been recorded as 0.736 m/person*day in the 3.20 m road standard, 0.947 m/person*day in the 2.75 m road standard.

7) When planning for the application of the proposed Do-nou technology, it is necessary to consider the crushing work in advance, following the workability of the crusher which generates 16.72 m³ of crushed bricks per day.

8) When mobilizing the people for a social project in rural area of Bangladesh. Because they are mainly farmer or daily work, it is necessary to provide the daily allowance and which price should be around 2.90 US$ per day.

5 FURTHER DISCUSSION

The main issue for the Do-nou technology is to produce the association for rural road improvement by themselves. Therefore this purposed method should be manualized for the further road repair project in the future. In making a manual, the further discussions are shown as follows:

1) The difference of reinforced effect between using sandy gravel and grade C crushed bricks as inner materials should be considered through the Do-nou compression tests.

2) The suitable clay mixing ration and characteristics of mixing clay and crushed bricks materials for surface material should be confirmed through the compaction test and CBR test in each mixing ratio.

3) The difference of improvement effect between the national road standard and the purposed method should be considered with workability and cost performance.

4) The purposed method should be summarized for the local people, at the same time the engineering property should be reported for obtaining governmental approval of lunching the road rehabilitation works by local association.

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