A Geotechnical Study of Bock Paved Road at Sunamganj, Bangladesh

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Abstract: The International Fund for Agricultural Development (IFAD) has been providing assistance to the Government of Bangladesh to implement the Community Based Resource Management Project (CBRMP) in the district of Sunamganj. The project implementation period was 12 years. The project has many facets. Firstly, the region remains under water for a significant part of a year. The blocks remain in place under water during that time of the year without any visible damage. Secondly, the blocks are constructed employing the villagers using a unique “Labour Contracting Societies”, which enhances the local social facets in a dramatic way. Thirdly, it is maintained by another innovative local road-segment ownership method. Consultants of BRTC, BUET have undertaken the task of conducting an all-around study of the block-road.

Key Words: concrete block, paved rural roads, submerged roads, LCS.

1. OBJECTIVES

In this research, the technical viability of the block road has been envisaged. Concrete block paved roads are not very new in the history of paved roads construction. But the use of this technique at Sunamganj, Bangladesh is unique due several reasons. The objectives of this study are

1) Block geometry optimization for better performance in terms of long term stability. In this regard effect of
   (i) Block size
   (ii) Block shape and
   (iii) Block depths on bearing capacity and settlement are studied.

2) Improving riding quality by improving block to block locking mechanism.
2. LABORATORY INVESTIGATION

A detailed laboratory investigation was carried out on the soil samples and blocks collected from two places of Sunamganj. One place was Haluaghat Moinpur road and the other was Voisharpar East, Shahebnagar Road. Two blocks along with soils beneath those blocks were received in our laboratory in a sealed container. Both geotechnical and concrete quality investigation were carried out simultaneously on those samples. Some of the results are summarized in table 1. All other results can be found in the report, 2010.

<table>
<thead>
<tr>
<th>Place / Name of tests</th>
<th>Direct shear (dry)</th>
<th>Direct shear (soaked)</th>
<th>Liquid &amp; Plastic Limits</th>
<th>Specific gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haluaghat Moinpur road, Block-1</td>
<td>C=9.09 kN/m², ϕ=38°</td>
<td>C=8.42 kN/m², ϕ=32°</td>
<td>LL=34, PL=23</td>
<td>2.67</td>
</tr>
<tr>
<td>Haluaghat Moinpur road, Block-2</td>
<td>C=10.42 kN/m², ϕ=34°</td>
<td>C=9.87 kN/m², ϕ=32°</td>
<td>LL=30, PL=20</td>
<td>2.64</td>
</tr>
<tr>
<td>Voisharpar East, Block-1</td>
<td>C=6.0 kN/m², ϕ=37°</td>
<td>C=7.98 kN/m², ϕ=32°</td>
<td>LL=28, PL=18</td>
<td>2.61</td>
</tr>
<tr>
<td>Voisharpar East, Block-2</td>
<td>C=7.98 kN/m², ϕ=32°</td>
<td>C=7.54 kN/m², ϕ=34°</td>
<td>LL=27, PL=20</td>
<td>2.61</td>
</tr>
</tbody>
</table>

3. NUMERICAL ANALYSIS OF SINGLE BLOCK

A three dimensional Finite Element Analysis is carried out for single block surrounded by soil (Ascher, et al 2007, Inuzuka, 1996). The boundary conditions consists of two sets. (i) All x-directions are prevented on the sides and (ii) all y-directions are prevented at the bottom to move. The block is considered to be made of concrete of appropriate strength and it is modeled by linear elastic concrete parameters. Surrounding soil is considered to be a mixed silt type soil and modeled by nonlinear elastic-perfectly plastic material parameters (Oeser et al, 2007, 2009). The analysis is carried out using a 3D FE analysis package called “Plaxis” (Scarpas et al). Concrete strength is considered to be 1000 psi (lowest possible value). Soil parameters are determined from laboratory tests results, which came out to be C=10 kN/m² and ϕ=25 deg. A line load of 200 kN/m (standard rural road loading) is applied in the middle of the block along the shorter side. Actual load on any block is about 20 kN/m. The geometry of actual block (BxLxd) is 9x15x6 inches. Table 2 shows the various block sizes for the parametric study. Figure 1 and 2 shows the Finite Element meshes used for the analysis of single block for the parametric study.

<table>
<thead>
<tr>
<th>Type of variations (Serial)</th>
<th>Size variations, Depth=6 inches (inches)</th>
<th>Shape-variations Depth=6 inches (inches)</th>
<th>Depth-variations (BxLx=9x15 inches (inches))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.25/3.75</td>
<td>3/15 -- &gt; 0.2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4.5/7.5</td>
<td>6/15 -- &gt; 0.4</td>
<td>4</td>
</tr>
<tr>
<td>3 (Field)</td>
<td>9/15</td>
<td>9/15 -- &gt; 0.6</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>12/20</td>
<td>12/15 -- &gt; 0.8</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>15/25</td>
<td>15/15 -- &gt; 1.0</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>18/30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. RESULTS OF THE ANALYSIS OF SINGLE BLOCK

The results of the parametric analysis are shown in Figs 3 through 8. The Figs 3 and 4 show the effect of (1) block size, figs 5 and 6 show the effect of (2) block shape and figs 7 and 8 show the effect of (3) block depths on the applied load (bearing capacity) of those blocks. Figs 3, 5 and 7 show the variations of applied load versus vertical displacement along the middle of long section of the block. Fig. 3 show the variation of applied load versus vertical displacement for the block size and it does not have any lasting effect. The same result is observed for the case of block shape analysis result. This variation is pronounced only in the case of very thin block. Due to the thin formation of the block, its load-displacement curves
vary a lot along the middle section, indicating the possibility of uneven settlement in course of time.

From the observation of the figures 4, 6 and 8, it is clear that the effect of size of the block is highly pronounced. The effect of block shape and block depth are not so pronounced at this stage of the analysis. Although theoretically there are effects of block shape and block depth, but considering the conservativeness of this analysis, these effects can be safely ignored.

Fig. 3 Variation of applied load with vertical settlement for biggest block size along the middle of long section of the block (marked A,B,C,D,E)

Fig. 4 Variation of applied load with vertical settlement for various block sizes

Sizes of the block (B/L) inches
- 2.25/3.75
- 4.5/7.5
- 9/15
- 12/20
- 15/25
- 18/30
Fig. 5 Variation of applied load with vertical settlement for square block shape along the middle of long section of the block (marked A,B,C,D,E)

Fig. 6 Variation of applied load with vertical settlement for various shapes of blocks
Fig. 7  Variation of applied load with vertical settlement for the thinnest block along the middle of long section of the block (marked A,B,C,D,E)

Fig. 8  Variation of applied load with vertical settlement for various depths of blocks
5. ANALYSIS OF A ROAD SECTION

In order to complete the analysis, a section of road is taken for the three dimensional analysis. The section is shown in Fig. 9. The section is consisted of blocks of standard sizes (9”x15”x6”). Blocks are jointed by a very weak mortar. Fig. 10 shows the results of the analysis. It has been found that the road section can carry much higher load. It can carry the LGED designated load for rural roads.

![Fig. 9](image1) A typical road section taken for FE analysis

![Fig. 10](image2) Variation of applied load with vertical settlement for a road section

LGED designated load=8.2 ton
About 500 kN/m of block load
6. ANALYSIS OF LOCKING MECHANISM

One of the objectives of this analysis was to improve the riding quality of the block-paved roads at Sunamganj (Songlin et al., 2009). In order to improve the riding quality of the road, it is necessary to improve the locking mechanism of the road. Currently blocks are jointed by mortar of 1” thickness. It can be improved by designing the blocks with a particular sloped side. A Finite Element parametric study is conducted on the effect of side slope of the blocks on the bearing capacity of the block (Walter et al., 2004). A 2D analysis is carried out for six side slopes. A typical locking mechanism with its Fe representation is showed in Fig. 11. Fig. 12 shows the deformed shape of the block-road section in amplified scale.

![Fig. 11 A 2D road section taken for FE analysis](image1)

![Fig. 12 A 2D road section deformation pattern after the ultimate load is applied](image2)

Figs 13 and 14 show the effect of slope on the bearing capacity of the blocks. It is obvious
from these figures that the bearing capacity increases exponentially with the increase in slopes of the sides of the blocks. But with the increase in slope of the block, its vulnerability of breakage will also increase. So it will need some field trial, before deciding a particular slope.

Fig. 13 Applied loads versus vertical settlement for various side slopes of blocks

Fig. 14 Bearing capacity versus side slopes of blocks
7. DEVELOPMENT OF A DESIGN PROCEDURE

Fig. 15 shows the variation of block settlement with its surface areas. It has been understood that settlement increases at a faster rate up to the block size of 12”x20”. After that rate of settlement increase remains constant. Fig. 16 shows the variation of block bearing capacity with its surface area or weight. It has been observed that the actual load on the block pavement is far below the smallest block.

Fig. 15 Variation of settlements with surface area of blocks

Fig. 16 Variation of applied loads with surface area/weights of blocks
So the bearing capacity of the current block is underutilized. It can be seen from the top axis of the figure that weight increases along with the increase in bearing capacity or surface area. The current block has a weight of 32 Kg. The next size is 12”x20” but it will have a weight of 58 Kg, which may not be suitable for carriage by human labour.

Fig. 17 shows a unique way of designing blocks considering its size, depth, weight and bearing capacity. Any of the three axes can be starting variable for the design. As for example, someone starts for a 40 kg block, then he has a choice of taking either 2” depth block with corresponding size on the bottom axis and bearing capacity on the right. Similarly he might choose 4” depth as well with a different size of the block and bearing capacity. In this way, a block designer may have a plethora of options for the size, depth, weight and bearing capacity of the blocks.

Fig. 17 A design graph for the designing of optimum blocks usable by human labor only.

8. CONCLUSIONS

From the discussion of the results of the analysis, it is clear that size of the blocks has the most prominent effect on the bearing capacity and settlement of the block. Increase in block size will increase the bearing capacity, reduce the settlement and hence increase the riding quality to some extent. But the increase in weight will create distress among the labour. The current size of the block is just right in size. Size can be increased by reducing the depth to keep the weight good for LCS by using the design graph. Riding quality can be improved by increasing the side slope of the block, but it needs field trial before a particular side slope is approved.
REFERENCES


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