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Effect of Jointing Sand Sizes and Width on Horizontal Displacement of Concrete Block Pavement

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Graphical abstract

Abstract

This research studies the performance of Concrete Block Pavement (CBP) through the load distribution between the blocks and the jointing sand. Presence of jointing sand in joint provides frictional resistance to prevent the blocks from displaced or moved when the load is applied. Three different sizes of jointing sand (less than 2 mm, 5 mm and 7 mm) with three different jointing widths (2 mm, 4 mm and 6 mm) were used. Laboratory tests were conducted using horizontal load test to compare and investigate the effect by using different jointing sand sizes with different joint widths on the performance of concrete block pavement. It was found that the wider joint width requires coarse jointing sand for good performance of concrete block pavement. Results show that at 2 mm jointing width, it is more appropriate to use jointing sand with a size less than 2 mm and at a 6 mm jointing width it is better to use jointing sand with a size less than 7 mm. It seems to give better results in resisting the horizontal load that been applied before the blocks starts to displace and the pavement failed.

Keywords: Concrete block pavement; jointing sand; joint width; horizontal load test

1.0 INTRODUCTION

Concrete block pavement (CBP) differs from other forms of pavement in wearing surface is made from small paving units bedded and jointed in sand rather than continuous paving [1]. CBP can be categorized as a flexible pavement due to units of the block can be easily removed (take out) if there is another installation needed under the pavement after complete construction. The strength, durability and aesthetically pleasing surface of paver have made CBP ideal for many commercial, municipal and industrial application such as parking area, pedestrian, traffic intersection, container yards, etc. [2].

The surface of CBP comprises concrete blocks bedded and jointed in the sand. The laying bedding sand thickness differs between countries. Most European countries use the 50 mm thick compacted bedding sand [3-5]. In addition, previous study recommended a minimum compacted sand depth of 40 mm to accommodate free movement of blocks under initial traffic [6]. Other than that, the jointing sand and joint width also an important component to ensure better performance of the pavement.

Jointing sand and joint width is the main component in CBP. The size of jointing sand and width of joint space is the main factors need to focus. This is because these two components play a major role in promoting load transfer between blocks ultimately in spreading the load to large areas in the bottom layers. It also acts as a bridge to transfer the loads between the blocks when the blocks under the loading blocks. The frictional resistance develops in the joints under load; this prevents the blocks from undergoing excessive relative displacements and transmits part of the load to adjacent blocks [7]. Once the jointing sand was swap away from the joint, the interlocking characteristics of the blocks will decrease and the blocks start to move away from each other, as a result the pavement will no longer able to bear the applied traffic load. It causes failure to the CBP. Some of the failures of CBP are the blocks move due to vehicle acceleration or braking action, settlement, rutting and etc. According to Shakel and Lim, for optimum load spreading by friction, it is necessary to provide uniform, narrow and fully filled joints of widths between 2 mm to 4 mm [8]. Knapton and O'Grady recommended joint widths between 0.5 mm to 5 mm for better pavement performance [9]. However, joint widths ranges from 2 mm to 8 mm are often used depending on the shape of blocks, laying pattern, application and aesthetic.

This study investigates the possible and the effect of using different sizes of jointing sand with different sizes of joint width. Furthermore, tests were carried out to see whether the pavement can resist the horizontal load before it start to fail.

2.0 EXPERIMENTAL

2.1 Materials

In this study, the natural river sand was used as the bedding layer. It also used as jointing sand in the most of the pavement [10]. However, in this study, three groups of jointing sand sizes (less than 2 mm, 5 mm and 7 mm) and joint widths (2 mm, 4 mm and 6 mm) were selected to investigate the performance of CBP. For bedding sand the grading requirement followed as in Table 1. Concrete blocks with dimension of 200 mm in length, 100 mm in width and 80 mm in thickness, respectively, with the length to width ratio as 2 were used in this study [11].

Table 1 Grading requirement for bedding sand [12]

Sieve Size		Percent Passing
3/8 in.	(9.5 mm)	100
No. 4	(4.75 mm)	95 – 100
No. 8	(2.36 mm)	80 – 100
No. 16	(1.18 mm)	50 – 85
No. 30	(0.600 mm)	25 – 60
No. 50	(0.300 mm)	10 – 30
No. 100	(0.150 mm)	5 – 15
No. 200	(0.075 mm)	0 – 100

2.2 Construction of Test Section

Test of blocks was carried out in a rigid steel box with 1000 mm x 1000 mm square in plan. Bedding sand layer thickness of 70 mm with a moisture content in range 4 % to 8 % (value of 6 % was a satisfactory target value) were spread out uniformly in the steel box. Then the blocks were laid in a stretcher bond laying pattern on the bedding sand layer with three different sizes of joint widths; 2 mm, 4 mm and 6 mm. Bamboo sticks were used to make sure the joint width between the blocks are uniform (Figure 1). The grid line was marked to measure the settlement of the bedding sand and block displacement as in Figure 2. Then the blocks were compacted by using 90 kg plate vibrator of 800 N for two cycles. After each compaction process, the displacements of the blocks were measured to obtain the settlement of bedding sand. After measuring the displacements of the blocks completed, eleven points were marked to measure the displacement of concrete blocks (Figure 3).

2.3 Test Procedures

2.3.1 The Settlement of Bedding Sand

Before laying the blocks, the measurements were made on the bedding sand to obtain the thickness, h_1. After laying the blocks, the level of the blocks was measured, h_2. Then, measure level of the blocks again after the first cycle of compaction, h_3 and the second cycle of compaction h_4.

Figure 1 Bamboo sticks were used to uniform the joint width

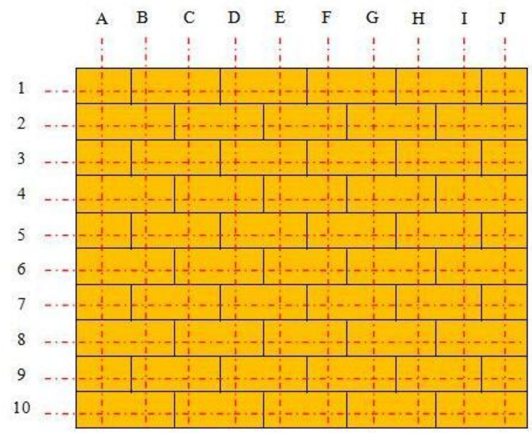

Figure 2 The grid lines.

Figure 3 Eleven points were marked for horizontal loading test.

2.3.2 Horizontal Loading Test

A hydraulic jack fitted on one side of the frame was used to apply a central load in the middle of the entire concrete block pavement in horizontally for horizontal loading test as shown in Figure 4. While the loading was applied, the horizontal displacements were measured to an accuracy of 0.01 mm by using eleven Linear Variable Differential Transducer (LVDT) connected to a data logger. It was placed in horizontal direction and touched the marked points (Figure 5).

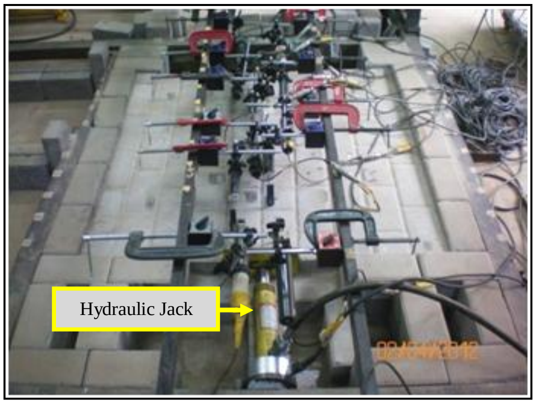

Figure 4 Hydraulic jack fitted at one side of the frame for the horizontal test

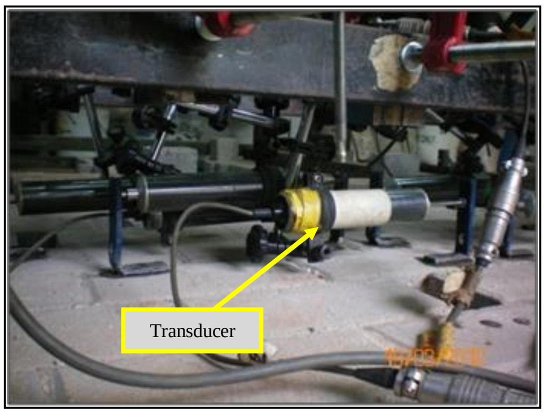

Figure 5 Setup for the LVDT.

3.0 RESULTS AND DISCUSSIONS

3.1 Effect of Compactions Process on Bedding Sand

Figure 6 shows the settlement and compacted bedding sand layer after completed two cycles of compaction process. From the results, settlement of bedding sand was in the range: 15 mm to 23 mm. These results show the same value from a previous study that the settlement is in between 15 mm to 20 mm and 20 % to 35 % from the initial thickness of the bedding sand [13, 14]. However, Australia has specified a compacted thickness of bedding sand is 20 mm to 25 mm [15]. This is to ensure that the blocks interlock into the bedding sand and that the blocks would not move or displaces when traffic load being applied.

Figure 6 Settlement of concrete paving blocks after two cycles of compaction.

3.2 Effect of Concrete Blocks Pavement under the Horizontal Force

Figure 7, 8 and 9 show the results of the horizontal displacement and horizontal loading at three different joint widths for each jointing sand size. Figure 7 shows at 2 mm and 4 mm joint width, the results shows that it is better to use jointing sand with sizes less than 2 mm as filler. It results in higher horizontal load resistance; 2.58kN and 2.51kN before the pavement failed and the blocks start to displace. This is because the individual blocks transfer the applied load to the adjacent blocks. Mudiyono reported that the optimum joint width was 3 mm, as the joint width decreases the deflection of pavement also decreases [16, 17]. However, the opposite situation gives different result when the joint width is wider. It showed that by using jointing sand sizes less than 7 mm as filler give better results in resist the horizontal load as in Figure 9. This is supported by Knapton that large joints require coarse sand and tight joints require fine sand for good performance of pavement [9].

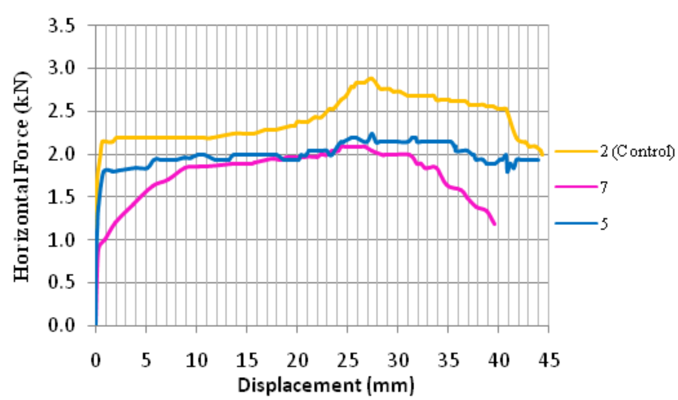

Figure 7 Result on the horizontal force with different jointing sand sizes in joint width 2 mm

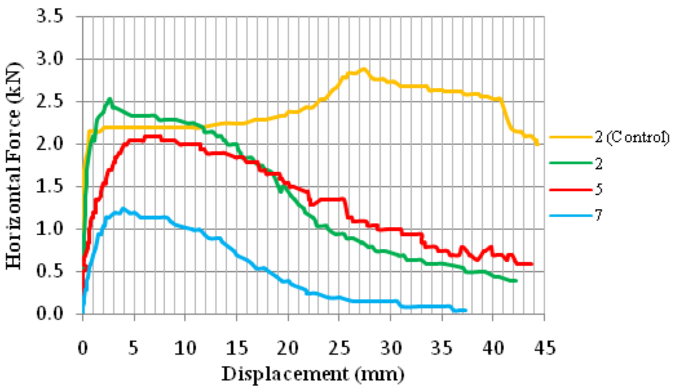

Figure 8 Result on the horizontal force with different jointing sand sizes in joint width 4 mm

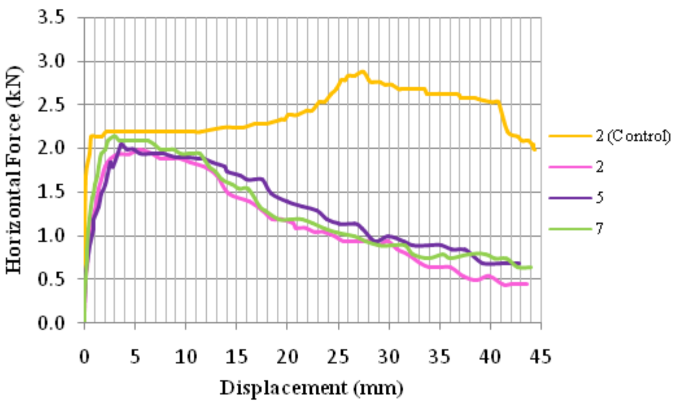

Figure 9 Result on the horizontal force with different jointing sand sizes in joint width 6 mm

4.0 CONCLUSIONS

The main conclusions can be drawn from this study are as follows:

a. The uniformity of the compaction process in CBP is important because it will affect on the interlocking of the blocks. The blocks were bedded and interlock by the bedding sand in optimum thickness between 15 mm to 20 mm to prevent the blocks from sliding (due to vehicle braking and accelerated action) and rotated under vehicular load.
b. The optimum joint width for CBP is in between 2 mm to 4 mm with jointing sand size less than 2 mm, preferred 4 mm due to results in highest frictional force. However, joint width should not be less than 2 mm because the jointing sand was unable to enter between the blocks and this will reduce the friction resistance between the blocks.
c. However, larger joint widths of CBP require coarse jointing sand and tight joints of CBP require fine jointing sand to get better performances.

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