Shear Resistance of Spike Underside Shaped Concrete Block on Bedding Soil

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Abstract :

Spike Underside Shaped Concrete Block (SUSCB) has groove patterns beneath the surface to produce shear resistance and to grip onto the bedding soil layer. This paper describes the laboratory evaluation on the effect of shear resistance between SUSCB laid onto bedding soil of different thickness levels. Attention was also given to the friction angle between the SUSCB and bedding soil when it was arranged parallel to the load applied. This study used SUSCB-15 with dimension of 200 x 100 x 80 mm with 15 mm-depth grooves as well as thecontrolling block at the size of 200 x 100 x 80 mm. To test the shear resistance of the SUSCB towards the load applied, it was subjected to 3 different loads, 10 kN, 20 kN and 40 kN at three different loose bedding soil thickness: 50 mm, 70 mm, and 90 mm. When the blocks were subjected to Large Shear Box Test, the results showedthat the SUSCB-15 sustained maximum shear resistance when the bedding soil thickness was set to 70 mm. Averagely, it exhibits 40% more resistance towards normal load compared to the controlling block. This SUSCB-15 also averagely produced 24.3% higher friction angle compared to the control block when subjected to normal load at different loose bedding soil thickness. It was found that the introduction of spikes under the concrete block improves the shear resistance and friction angle regardless of the bedding soil thickness.

Key Words : Underside Shaped Concrete Block; Groove; Shear Resistance; Bedding Soil

1. Introduction

Use of Conrete Block Pavement (CBP) has been dated back to 1924 since the first application in Netherlands. Main difference of the CBP to the asphalt and concrete pavement is the use of individual and relatively small concrete block arranged side by side to function as pavement surface and as aesthetic finishes. Apart from the concrete block, the other important elements of the CBP are the jointing and bedding soil. Today, concrete block isproduced in a rectangular shape with the size of 200 mm x 100 mm, having a thickness in between 60-80 mm [1], with average compressive strength of 30 MPa. Similar to the CBP, the Spike Underside Shaped Concrete Block (SUSCB) used in this study has a standard rectangular dimension, with 15mm depth spikes underneath. It is denoted as SUSCB-15, which was introduced to enhance interlocking between pavers and bedding soil. The interlocking of the CBP is defined as the inability of the individual block to move freely due to horizontal, vertical and rotational movement known as the interlocking components [2].

05_ Skid resistance of BP

The main structure of the CBP consists of concrete block arranged over one or more layers of bedding soil, base, and subgrade layer. The success rate of the bedding soil depends on its function to distribute traffic loads to the lower layers uniformly. In addition, it is also an important component in CBP as it provides a shearing resistance towards concrete block horizontal movement. Hence the quality of bedding soilmaterials in terms of its angle of internal friction is critically important [1,3]. Other than that, to guarantee the effectiveness of the CBP to carry, sustained, and to distribute traffic load uniformly to the lower layers, it is essential to prepare the bedding soil with an excellent workmanship and readily even surface. European countries commonly use 50 mm thick bedding soil whilethe Australian Standard prefer a thinner layer in between 20–25 mm [3]. In this study, three varying bedding soilthickness used was 50 mm, 70 mm, and 90 mm to test their influence over the strength and performance of the CBP.

Although the concrete block and bedding soil is not a single unit structure, both of these CBP elements depend on one another. Uneven bedding soilsurface causes one or more individual concrete blocks to protrude or settle. This situation leads to localised stress of the concrete block and affects the surrounding interlocking block. Similarly, the thickness of the concrete block may affect the performance of the bedding soil under traffic load [1]. Therefore, this paper presents the interaction of the SUSCB–15 with the loose bedding soil thickness in terms of the shearing resistance and friction angle when subjected to horizontal movement.

2. Methodology

This study was fully conducted in a laboratory where the SUSCB–15 was subjected to Large Shear Box Test as previously conducted by [4]. Throughout the presentation of methodology, results and analysis in this paper, control block with 70 mm thick bedding soil, SUSCB–15 with 50 mm, 70 mm, and 90 mm thick bedding soil aredenoted as CB(70), USCB(50), USCB(70), and USCB(90) respectively. The normal load applied to each of the bedding soilthickness is 10 kN, 20 kN, and 40 kN.

2.1 Soil Preparation

Sieve analysis was performed for both jointing sand and bedding soil according to [5], and Atterberg Limit Test was performed to obtain the Plasticity Index (PI) of the bedding soil. The bedding soil was further subjected to compaction test to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). The soil properties determination is crucial as to ensure the reliability and consistency of the test results.

2.2 Large Shear Box Test

The apparatus used for this test are the 2 units of steel shear box mould, 2 units of 50 kN load cells, 2 units of Linear Variable Differential Transducer (LVDT), steel ball, steel cube, and the shear box test machine. Preparation of control block, SUSCB,and bedding soil was conducted before the Large Shear Box test was performed. The 2 block samples were arranged parallel to each other in a steel shear box mould with dimension 200 mm x 200 mm x 80 mm. Gaps between the concrete blocks were filled with jointing sand with average diameter of equal and less than 2.36 mm. Excessive jointing sand was removed from the block surface.

Dry bedding soil was weighed and added with 19% water before it is placed loosely in the shear box mould and levelled using a plywood to 50 mm height (preparation of bedding soil for USCB(50)). The bedding soil was covered with load cap and 50 kN vertical load applied onto it. After 10 minutes, the new thickness of the bedding soil was measured and recorded.

The shear box test was started by setting up the LVDT and the load cell horizontally. All blocks were arranged in the direction parallel to the direction of the horizontal force. The vertical load was maintained through the entire process. Horizontal load was applied until the mould moved about 25 mm from its original position.The setup was removed and new thickness of the bedding soil was measured. A sampling soil was taken for moisture content determination. These processes wererepeated for CB(70), USCB(70), and USCB(90) with other value of the normal stress. Figure 1 shows the test setup for Large Shear Box test.

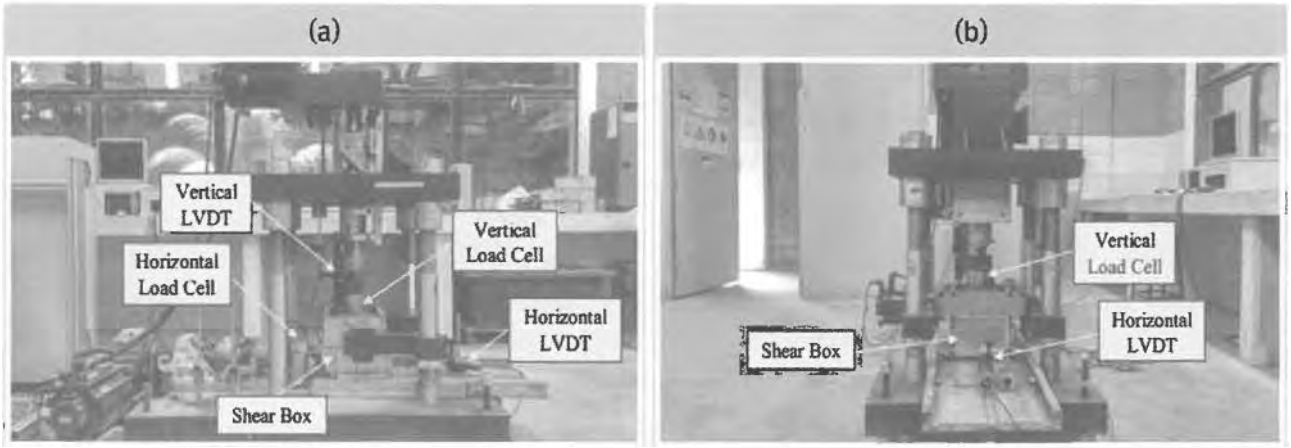

Figure 1. (a) Large Shear Box Test setup front view; (b) Large Shear Box Test setup side view

3. Results and Discussion

The soil properties were determined before the start of the Large Shear Box test. The useful result for the soil properties is presented in Table 1.

Table 1. Soil properties of the bedding soil

Item	Unit	Description	Remarks
Particle size	%	99.8% pass through sieve size 4.75 mm	Sandy soil
Liquid Limit (LL)	%	46	Soil type – silty soils
Plastic Limit (PL)	%	34	
Plasticity Index (PI)	%	12	
Moisture Content (ω)	%	19	Optimum Moisture Content (OMC)
Density (ρ)	kg/m^3	1460	Maximum Dry Density

3.1 Bedding Soil Thickness and Density

Figure 2 shows the bedding soil layer thickness before (h1) and after (h2) compaction. It is worth to note that the percentage of settlement gradually increaseswhen the thickness of the bedding soil increase. The settlement differencebetween CB(70) and the rest of the USCBs shows that the shape of the block has an effect on the settlement. The bedding sand easily fills in the gap between spikes, and hence causing more settlement of the bedding soil [6]. The information from this bedding soil settlement is useful data to determine the relative density of the bedding soil.

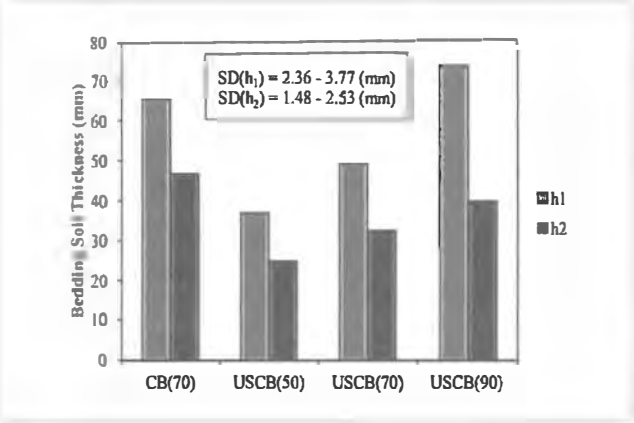

Figure 2. Bedding soil thickness before and after compaction

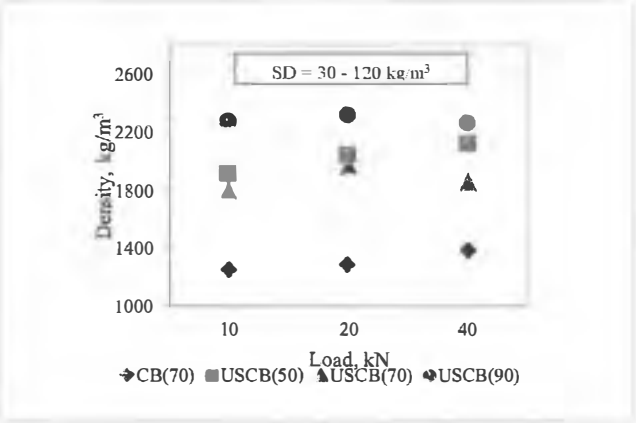

Figure 3. Bedding soil density against applied load

The density of the bedding soil is defined as the mass per unit volume. It may also refer to as the easy-compactness of the USCB blocks. The compaction effort is highly dependent with the bedding soil density. Figure 3 shows the density of bedding soil when subjected to load. The minimum and maximum density of bedding soil layers were averagely ranged between 1875 kg/m^3 to 2278 kg/m^3 for the USCBs. The density is 44% to 75% higher compared to the CB(70) where the standard deviation ranged between 30 kg/m^3 to 102 kg/m^3 for all blocks tested. This has proven that the introduction of spikes underneath of the concrete block has enhanced the easy-compactness of the USCB pavements ascompared to the control block.

3.2 Effect of USCB-15 towards Shear Resistance

Figure 4(a) to Figure 4(c) shows the effect of shear stress towards the displacement for all tested blocks that has been subjected to 10 kN, 20 kN, and 40 kN. Overall, regardless of the bedding soil thickness, all of the SUSCB-15 sustained higher shear stress compared to control block, CB(70). Among all of the SUSCB-15, USCB(70) sustained the highest maximum shear stress for normal load 10 kN and 20 kN with 56% and 27% higher compared to CB(70) at 2.98 mm and 7.19 mm displacement, respectively. However, when 40 kN normal load was applied, the highest maximum shear stress occured for USCB(90) with 37% higher from CB(70) at 11.14 mm displacement. It shows that at higher normal load, thicker loose bedding soil is able to resist higher shear stress.

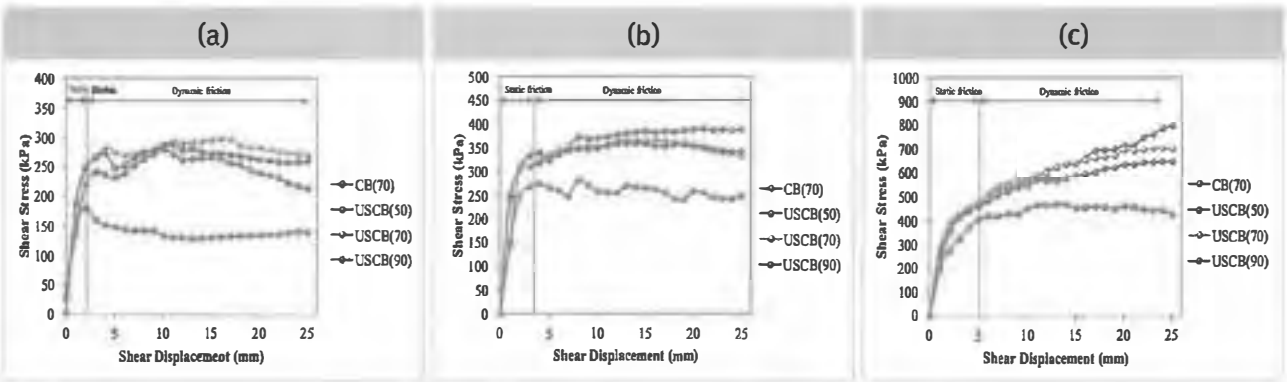

Figure 4. Shear stress against shear displacement for normal load; (a) 10 kN; (b) 20 kN; (c) 40 kN

All graphs in Figure 4 shows the development of static and dynamic friction. In static friction zone, all the blocks in resting area resists the horizontal movement in between the bedding soil and the bottom surface of the blocks known as the horizontal interlocking mechanism. In addition, the interlocking mechanism develop in between sides of the adjacent blocks. In dynamic friction zone, CB(70) sustained the least shear stress compared to USCB(50), USCB(70), and USCB(90). It proved the failure of horizontal interlocking system in between the bottom surface and bedding soil and only depending on the friction exist between sides of the blocks [5,6].

3.2 Effect of SUSCB-15 towards Friction Angle

Figure 5 shows the friction angle for all four blocks arrangement. It shows that USCB(50), USCB(70), and USCB(90) has higher internal friction angle compared to CB970) with 24%, 21%, and 28% respectively. From this result, it has proven that SUSCB-15 allows for a better grip in between the loose bedding soil and the spikes underneath. It is also worth to note that thicker loose bedding soil causes more loose soil particles to fill in the gaps between the spike, leading to highest friction angle as presented by the result of USCB(90).

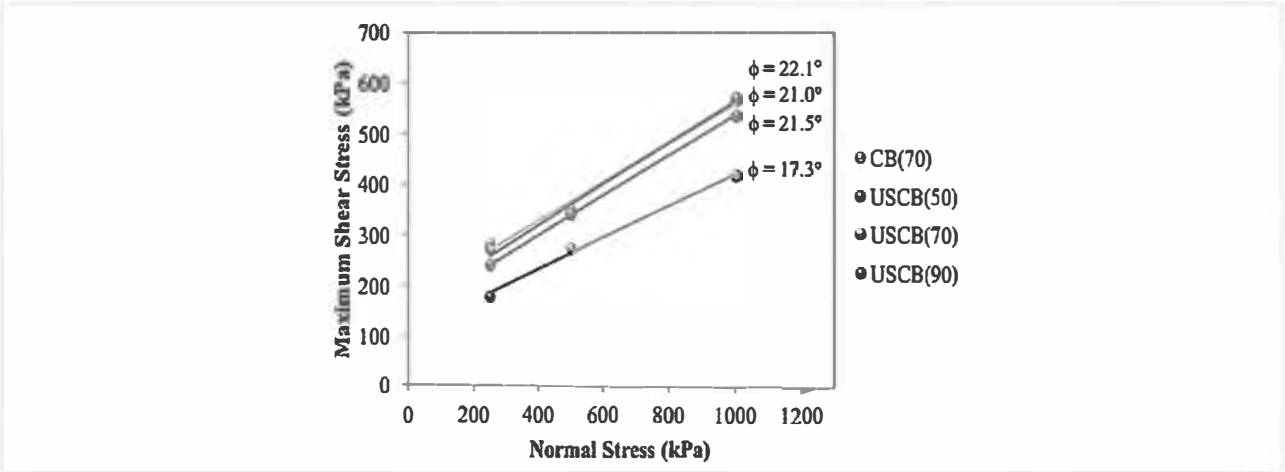

Figure 5. Friction angle of control block and SUSCB-15 under maximum shear stress against normal stress

4. Conclusion

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

1) Increasing the thickness of the loose bedding soil would increase the bedding soil settlement of SUSCB-15.
2) For normal load 10 kN and 20 kN, SUSCB-15 with 70 mm thick bedding soil is able to sustain the best shear stress.
3) At 40 kN applied normal load, the SUSCB-15 with 90 mm thick bedding soil shows highest shear resistance with highest displacment compared to all other blocks.
4) The SUSCB-15performed better shear resistance due to higher internal friction angle as compared to the controlling block.

Acknowledgements

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