Malaysian Journal of Civil Engineering 27 Special Issue (1):112-124 (2015)

INTERACTION BETWEEN BEDDING SAND THICKNESS AND SHELL GROOVE-UNDERSIDE SHAPED CONCRETE BLOCK PAVEMENT

Azman Mohamed[1]*, Hasanan Md Nor[2], Mohd Rosli Hainin[2], Haryati Yaacob[2], Che Ros Ismail[2] & Nur Hafizah Abd Khalid[3]

[1]*Department of Engineering, Razak School of Engineering and Advanced Technology, Universiti Teknologi Malaysia, International Campus, Jalan Semarak, Kuala Kumpur, Malaysia.*
[2]*Department of Geotechnic and Transportation, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.*
[3]*Construction Research Centre (UTMCRC), Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia*

*Corresponding author: *az_man@ic.utm.my*

Abstract: Underside Shaped Concrete Block (USCB) has groove shaped at the underside block surface to produce resistance in horizontal plane and to grip onto the bedding sand layer. However, the horizontal movement of block units is the major problem in pavement due to vehicle braking and accelerated action. This paper presents the laboratory evaluation on vertical and horizontal displacement of shell groove-USCB pavement laid onto different bedding sand layer thickness. A pavement laboratory test was conducted to investigate the interaction between USCB type of the Shell-Rectangular 15 mm (Shell-R15) and bedding sand on three different loose bedding sand layer thicknesses of 50 mm, 70 mm and 90 mm respectively. Then, push-in loading test and horizontal loading test were performed. The results showed that interaction between USCB Shell-R15 and bedding sand layer thickness had significant influence to the vertical and horizontal displacement compared to control of 50 mm loose bedding sand layer thickness. The loose bedding sand layer thickness of 70 mm performed better compared to others.

Keywords: *Underside shaped concrete block, concrete block pavement, bedding sand thickness*

1.0 Introduction

In Concrete Block Pavement (CBP) the load spreading capacity of concrete block layer depends on the interaction of individual blocks with jointing sand, which is aimed to build up resistance against applied load. The shape, size, thickness, laying patterns, and etc. are some important block parameters that can influence the overall performance of the pavement. The same applies to the shape of the block. It is postulated that the effectiveness of load transfer depends on the vertical surface area of the blocks (Panda and Ghosh, 2001).

Nevertheless, one of the major problems with this pavement is the concrete blocks' horizontal movement because of the horizontal resistance caused by moving vehicles. Horizontal forces that occurred due to the moving vehicles and braking action will cause the concrete blocks to experience horizontal displacement. Interlocking characteristic of the blocks will then decrease and subsequently cause the concrete blocks to rupture if they run over each other continuously. As a result, the pavement will no longer be able to bear the traffic load applied. Therefore, Underside Shaped Concrete Block (USCB) was introduced to enhancing interlocking between pavers and bedding sand with improved mechanical properties.

The bedding sand layer is considered an essential component in a concrete block pavement. Bedding sand layer provides uniform support for the blocks and to avoid stress concentrations which could cause damage to the blocks. Bedding sand gives a frictional force between concrete blocks to prevent the block moving towards. Thus, it fills the lower part of the joint space between adjacent blocks in order to develop interlock. Changing in the thickness of the bedding sand will effect to the strength and performance of CBP. The behavior of block pavement depends to a significant degree on the shape of concrete blocks. Different types of block shapes will give different load impact on CBP. Block shapes do contribute larger impact to the structural performance of concrete block pavement (Azman *et al.*, 2013).

Adequate compaction is required to minimize the settlement of CBP. The laying course material and blocks should be compacted using a vibrating plate compactor. Some blocks may require a rubber or neoprene faced sole plate to prevent damage to the block surfaces (Interpave, 2006). The block paved area should be fully compacted right after the full blocks and cut blocks have been laid to achieve finished pavement tolerances from the design level of ± 10 mm under a 3 meter straightedge (ICPI, 2004). Normally two cycles of compaction are applied. The first cycle compacts the bedding sand and causes this material to rise up the joints and the second cycle is applied once the joint sand is brushed into the joints.

CBP may carry dynamic loads generated by a variety of vehicles whose configuration varies over a wide range. Shackel (1980) applied a 40 kN maximum wheel load to simulate the wheel loading on the pavement surface to assess the performance and behavior of pavement construction materials during complete life cycles simulation tests.

The laying course thickness differs from country to country. Most European countries use the 50 mm thick compacted bedding sand (Lilley and Dawson 1988; Panda and Ghosh 2002). However, Australia has specified a compacted thickness of 20 mm to 25 mm. This is a very thin layer and will therefore require the surface of the underlying base to be very smooth (Beaty and Raymond, 1992). According to the European practices (Eisenmann and Leykuf, 1988; Lilley and Dowson, 1988; Huurman, 1997) they specify the use of 50 mm as bedding sand thickness after compaction by considering a sub-base tolerance of ± 10 mm. Simmons (1979) recommended a minimum compacted sand depth of 40 mm to accommodate free movement of blocks under initial traffic.

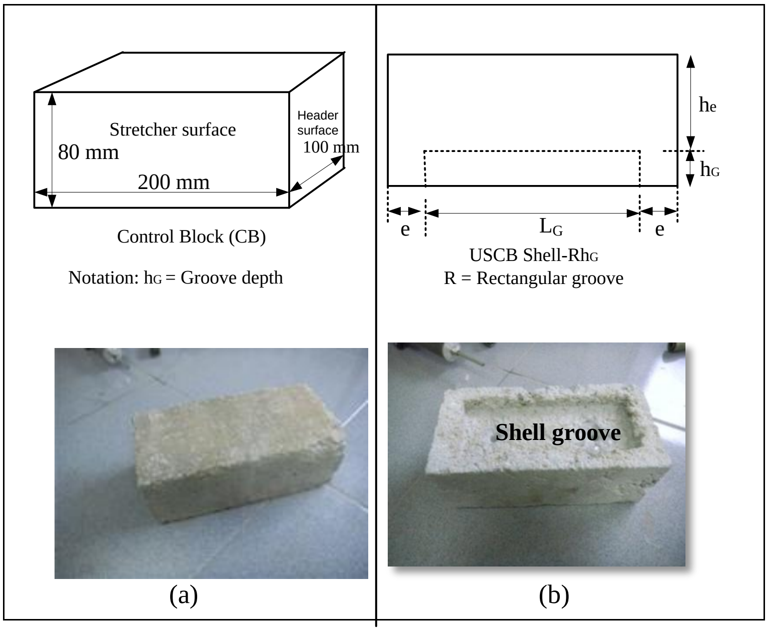
The river sand was used for the bedding layer. It also used as jointingsand in the most of the pavement (Lilley, 1980). Therefore, sand was usedin experimental work follow the grading requirement in Table 1 as bedding layer and joint filler.

Table 1: Grading requirement for bedding sand and jointing sand (BS EN 12620+A1)

Sieve Size	Size Percent Passing For Bedding Sand	Percent Passing For Joint Filler
3/8 in. (9.5 mm)	100	-
No. 4 (4.75 mm)	95 - 100	-
No. 8 (2.36 mm)	80 - 100	100
No. 16 (1.18 mm)	50 - 85	90-100
No. 30 (0.600 mm)	25 - 60	60-90
No. 50 (0.300 mm)	10 - 30	30-60
No.100 (0.150 mm)	5 - 15	15-30
No. 200 (0.075 mm)	0 - 100	5-10

2.0 Materials and Experimental Works

Experimental works are to study the effect of bedding sand thickness to the USCB deflection and friction resistance. The comparables between blocks with no groove (control block) and USCB Shell-R15 with a rectangular groove laid in different bedding sand thickness were performed. The push-in loading test and horizontal loading test were conducted in the laboratory. Figure 1 illustrates the control block (without groove) and USCB Shell-R15 (with rectangular groove), while Table 2 shows the geometrical details.



(a) (b)

Figure 1: (a) Control block and (b) USCB:Shell-R15

Table 2: Details of blocks used in study

Block type	Groove width, B_G (mm)	Groove length, L_G (mm)	Groove depth, h_G (mm)	Effective thickness, h_e (mm)	Number of grooves, n_G	Internal web, d (mm)	Edge web, e (mm)	Groove volume, V_G (cm^3)	Block volume, V_B (cm^3)	Average block weight (kg)
CB				80				0	1600.0	3.558
USCB: Shell -R15	60	160	15	65	1	0	20	144.0	1456.0	3.168

CB – Control block
USCB: Shell-R15 – Underside shaped concrete block with shell rectangular of 15 mm depth

2.1 Materials

The USCBs (Shell-R15) were manufactured in the laboratory. The length, width and thickness of rectangular concrete blocks were 200 mm, 100 mm and 80 mm, respectively, with the length to width ratio as 2 for this study (BS 6717, 2001). The blocks were air cured for 28 days. Concrete blocks were tested to ensure that the concrete mix satisfied the specification. The blocks were tested at the age of 28 days with average compressive strength meeting the minimum requirement of 25 MPa, as suggested by Shackel (1990).

2.2 *Test Setup*

The tests of blocks were carried out in a rigid steel box with 1000 mm x 1000 mm square in plan. A reaction steel frame was used to apply vertical and horizontal load on the 12 mm (thick), 100 mm (width) and 200 mm (length) steel plate. The loading was applied vertically straight at the center of the block in the middle of the pavement sample as shown in
Figure 1. Meanwhile,
Figure 2 illustrates the horizontal loading test setup with load horizontally straight applied at the center of one side of pavement sample using hydraulic jack with load cell of 200 kN capacity attached.

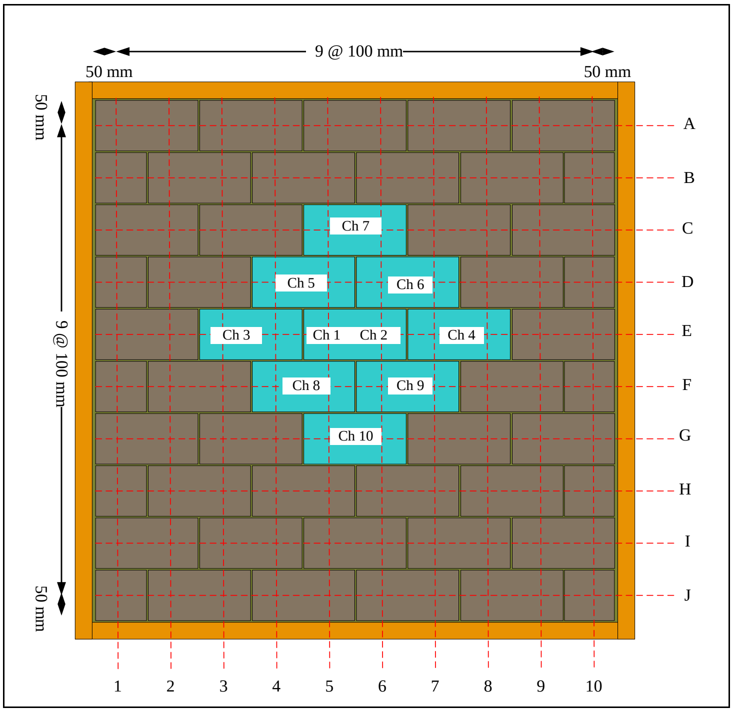


Figure 1 : Grid line layout and push-in loading test point

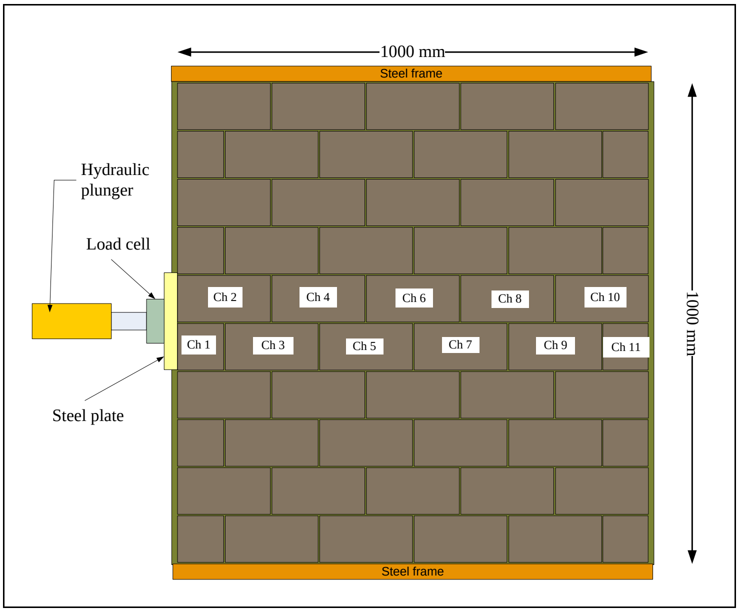


Figure 2 : Horizontal loading test layout

2.3 Construction of Test Section

Bedding sand layer thickness of 50 mm, 70 mm and 90 mm with moisture content of 4 % to 8 % were spread out on the neoprene layer. Then, the blocks were laid in a stretcher bond laying pattern on the bedding sand layer. The grid lines and testing points were marked to measure the bedding sand settlement and block displacement as shown in Figure 1 above. The blocks were compacted by using plate vibrator of 800 N. The laying process was followed according CCAA, TN 56 (1986). During the compaction process, the displacements of blocks were measured to obtain the settlement of bedding sand. After the compaction process was completed, the height of the bedding sand and displacement of concrete blocks were measured.

2.4 Test Procedures

The measurements were made on bedding sand to obtain the desired thickness and the level of blocks before compaction, h_1, first cycle of compaction, h_2, and second cycle of compaction, h_3, throughout hundreds of measurement points.

A hydraulic jack fitted to the reaction frame was used to apply a central load in the middle of the entire block pavement in vertically for push-in loading test (with 10 channels as shown in Figure 4-a) and horizontally for horizontal loading test (with 11 channels as shown in Figure 4-b). While the loading was increased up to 25 kN, the displacements were measured to an accuracy of 0.01 mm using Linear Variable Differential Transducer (LVDT) connected to a data logger.


(a) (b)

Figure 3: (a) Push-in loading test and (b) Horizontal loading test

3.0 Results and Discussions

3.1 *Effects of USCB Shell-R15 on Bedding Sand*

Figure **4** shows the settlement and compacted bedding sand layer thickness of the control blocks and USCB Shell-R15 after compaction. Settlement of bedding sand for control block was15 mm (30 %) in the range of 15 mm to 20 mm studied by Azman (2004) and 20 % to 35 % by Shackel (1990). Meanwhile, settlement of loose bedding sand layer of 50 mm, 70 mm and 90 mm for USCB Shell-R15 were 18 mm (36 %), 25 mm (35 %) and 30 mm (34 %), respectively. Thickness of loose bedding sand observably influences the percentage of bedding sand settlement. It showed that the bedding sand has ability filled the groove with sufficient compaction during the laying process. All the blocks (control block and Shell-R15) showed the compacted thickness of bedding sand between 35 mm to 46 mm except 60 mm for 90 mm loose bedding sand was in the range of 25 mm to 50 mm bedding sand thickness commonly used.

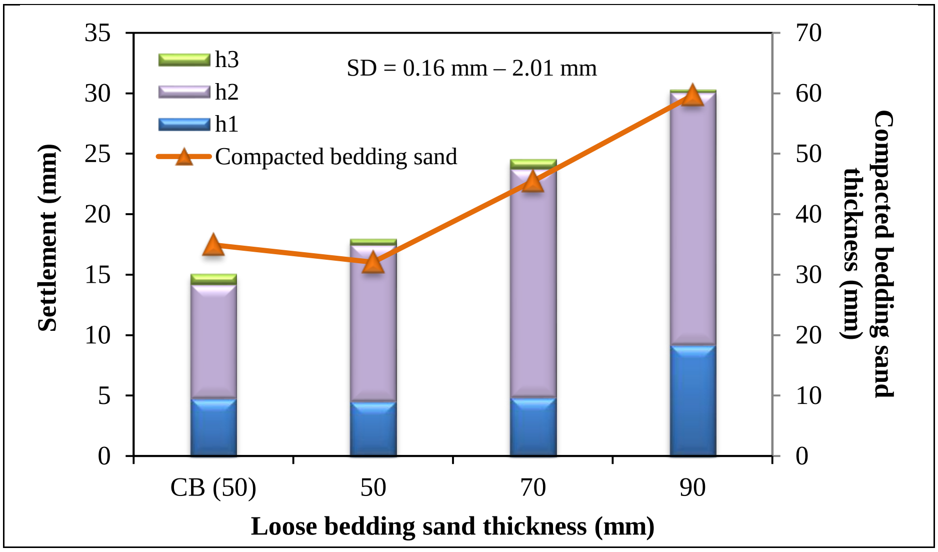


Figure 4 : Settlement and compacted bedding sand

h_1= Height of bedding sand after blocks laid, mm.
h_2 = Height of bedding sand after first cycle compaction, mm.
h_3 =Height of bedding sand after second cycle compaction, mm.

3.2 Push-in Loading Test

Channel 1 (ch1) and 2 (ch2) were the most received stresses (1.25 N/mm^2) and highest deflection. The stresses were transmitted to the adjacent blocks caused by vertical friction and developed interlocking behavior.

Figure **5** presented the maximum deflection of USCB Shell-R15 at the loading of 25 kN. The deflection for USCB Shell-R15 of 50 mm and 70 mm loose bedding sand thickness was 5 mm (about 6 %) better than control block. While, USCB Shell-R15 of 90 mm loose bedding sand deflected 6.5 mm and 23 % more than control block. The experimental results indicate, the loose bedding sand thickness of 50 mm and 70 mm received stresses with lower deflection compared others. USCB with shell groove of 15 mm performed effectively on this bedding sand thickness. It was acceptance sufficient for loose bedding sand thickness inlay the USCB Shell-R15.

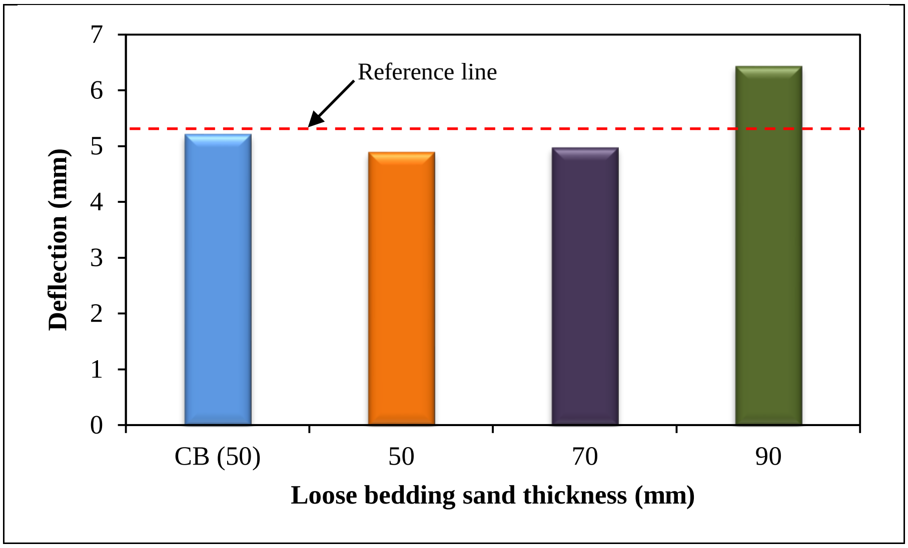


Figure 5: Deflection of USCB Shell-R15 at the middle test point of pavement compared to CB at the loading of 25 kN

3.3 Horizontal Loading Test

The horizontal loading test was conducted to study the friction resistance of USCB Shell-R15 on the various loose bedding sand thicknesses as shown in Figure **6**. The horizontal loading was applied at the maximum of 50 mm displacement because LVDT-50 mm can measure until this limit. This figure portrays the stage of the frictional resistance. The static friction and dynamic friction happened during the testing. In the first stage, the static friction occurred while the blocks sustain the load at the higher resistance before it moving. Then, the blocks moved slowly toward the loading to reach the maximum measuring limit namely dynamic friction. Dynamic friction indicated the block's self weight produce the resistance. The blocks moved without an increasing of loading due to no stress concentration occurred. Whereas, stress concentration will increase the loading because block was concentrated at one block's edge.

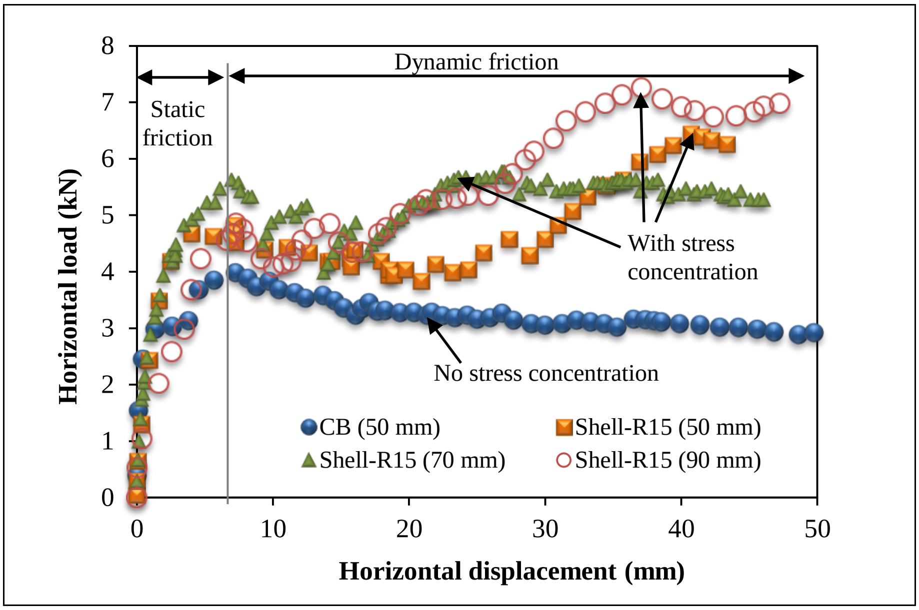


Figure 6 : Horizontal resistance behavior under horizontal loading

Figure 7 shows the horizontal displacement and horizontal loading versus different thickness of loose bedding sand. The horizontal displacement of USCB Shell-R15 of 70 mm loose bedding sand thickness was 6.3 mm about 15 % less than control block. It produced 5.6 kN the highest friction resistance with 41 % better compared to others. Increasing loose bedding sand thickness, lead USCB Shell-R15 to increase the horizontal displacement, but little effect to horizontal loading except for 70 mm loose bedding sand thickness. 50 mm and 90 mm loose bedding sand thickness were increased 21 % and 22 % of friction resistance respectively. USCB Shell-R15 for 70 mm loose bedding sand thickness has shortest static friction, while 90 mm loose bedding sand thickness shows the opposite situation. Therefore, 70 mm loose bedding sand thickness give significant interaction between bedding sand thickness and USCB Shell-R15.

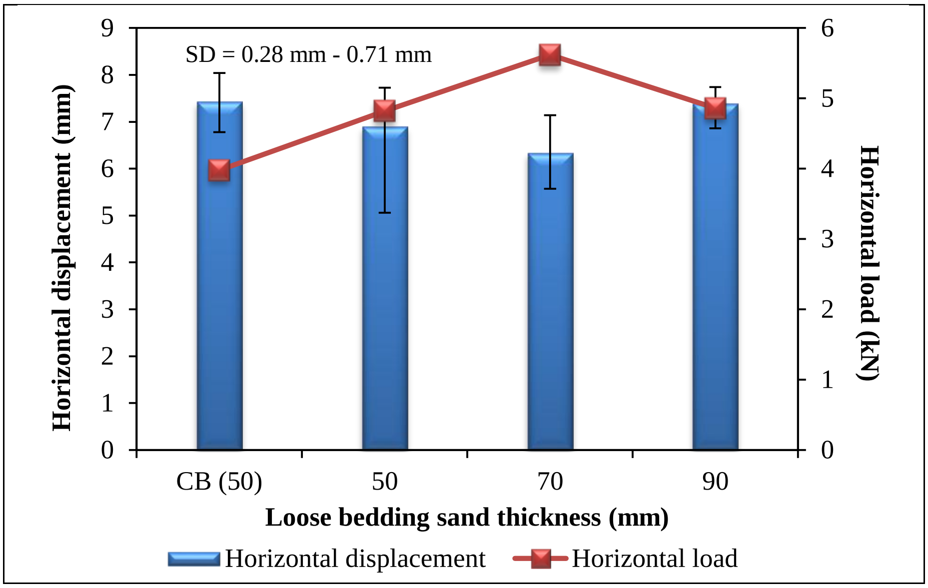


Figure 7 : Average horizontal displacement and maximum horizontal loading at static friction

4.0 Conclusions

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

i. Increasing the thickness of loose bedding sand would increase the bedding sand settlement of USCB Shell-R15.
ii. 70 mm loose bedding sand thickness was the effective thickness of bedding sand with a settlement of 35 %.
iii. USCB Shell-R15 of 50 mm and 70 mm loose bedding sand thickness was 6 % better received stress to reduce the deflection than control block.
iv. The horizontal displacement of USCB Shell-R15 of 70 mm loose bedding sand thickness was 15 % less than control block and produced 41 %friction resistance better compared to others.
v. 50 mm and 90 mm loose bedding sand thickness, lead to increase the horizontal displacement, but little effect to horizontal loading.
vi. 70 mm loose bedding sand thickness gives significant interaction between bedding sand thickness and USCB Shell-R15.

5.0 Recommendation

The selection of suitable loose bedding sand thickness should be limited to 70 mm and USCB Shell-R15 have to further investigate the groove effects in the other environment condition.

6.0 Acknowledgements

The authors are grateful to Research University Grant (RUG) fund vot number 00H93 for supporting this research.

References

Azman, M., Hasanan, M. N., Hainin, M. R., Haryati Yaacob, Che Ros Ismail, and Nur Hafizah, A.K. (2013). *The Effect of Groove-Underside Shaped Concrete Block on Pavement Permanent Deformation*. Jurnal Teknologi (Sciences & Engineering), 61(3), pp 7-14

Beaty, A.N.S. and Raymond, G.P. (1992). *Geotechnical Aspects of Iinterlocking Concrete Block Pavements*. Proceedings of the 45th Canadian Geotechnical Conference, pp. 41-1/41-7.

British Standard Institution (2002). *Aggregates for Concrete*. *BS EN 12620+A1*. London: British Standard Institution.

British Standards Institution (2001). *Precast Unreinforced Concrete Paving Blocks – Requirements and Test Methods*. *BS 6717*. London. British Standards Institution.

Cement And Concrete Association Of Australia (1986). *A Specification for Construction of Interlocking Concrete Road Pavement*. (TN56).

Eisenmann, J., and Leykauf, G. (1988). *Design of Concrete Block Pavement in FRG*. Proc., 3rd Int. Conf. on Concrete Block Paving. Pavi- Italia, Rome, 149–155.

Huurman, M. (1997). *Permanent Deformation in Concrete Block Pavements*. PhD Thesis. Delft University of Technology, Delft, Netherlands.

Interlocking Concrete Pavement Institute (ICPI) (2004). *Mechanical Installation of Interlocking Concrete Pavements*. Tech Spec 11, Washington, DC, U.S.A.

Interpave (2006). The Precast Concrete Paving & Kerb Association. *Specification of Concrete Block Paving*. 60 Charles Street, Leicester LE1 1FB, UK.

Lilley, A. A. (1980). *A Review of Concrete Paving in The UK Over The Las Five Years*. Proc. 1st Int. Conference on Concrete Block Paving. September 2 – 5, Newcastle Upon Tyne, 40 – 44.

Lilley, A. A. and Dowson, A. J. (1988). *Laying course sand for concrete Block Paving*. Proc. 3rd International Conference on Concrete Block Paving. Rome; 457-462.

Panda, B. C. and Ghosh, A. K. (2001). *Source of jointing sand for concrete block pavement*. Journal of Materials in Civil Engineering 13(3):235-237.

Panda, B. C. and Ghosh, A. K. (2002). *Structural behavior of concrete block paving; I:sand in bed and joints*. Journal of Transportation Engineering 128(2):123-129.

Shackel, B (1980). *Loading and Accelerated Trafficking Test In Three Prototype Heavy Duty Industrial Block Pavements*. National Institute for Transport and Road Research, CSIR, Pretoria Tech. Rpt 12.

Shackel, B. (1990). *Developments In The Specification Of Concrete Segmental Pavers For Australian Conditions*. University of New South Wales, Australia: Department of Geotechnical Engineering. 56 – 64.

Simmons, M. J. (1979). *Construction of Interlocking Concrete Block Pavements*. Australian Road Research Report. ARR No. 90.,71-80.