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Research Article

The Effect of Joint Width on Structural Performance of Asphalt Block Pavements

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Abstract: Asphalt blocks have been occasionally used around the world as a road pavement, but there have been very limited studies being done to evaluate the effect of joint width (spacing) between the blocks on the structural performance of asphalt paving blocks. This study explains the experimental study to assess the performance and properties of asphalt paving blocks laid with different joint widths between the blocks i.e., 0, 2 and 3 mm, respectively. A total of 250 asphalt paving blocks was manufactured and tested in the laboratory to ascertain the density, air voids, the compressive strength and the rut depth and displacement occurred in asphalt paving block. The design compressive load of single asphalt paving block is 166 kN. The test results showed that the joint width plays a vital role on the performance of asphalt block pavement. Asphalt paving blocks were laid as closely in contact as possible (0 mm) yields the best structural performance.

Keywords: Asphalt blocks, deformation, density, joint width, pavement

INTRODUCTION

The block pavement is very distinctive paving alternative presenting many excellent benefits (Shackel, 1979). The most popular type of blocks used for road pavement is Concrete Block Pavement (CBP). The major advantages of using the concrete blocks are attractive, easy to be applied along the road, have the capability to resist the heaviest loads and are suitable for steep road (Gencel *et al*., 2012). The asphalt blocks have been known for the first time as road pavement in Canada in 1964 (Baillairgé, 1964) and are still in use in some places in Germany (Hanover, 2011).

Joint width (spacing) between the blocks plays an important role in the mechanism and performance of block pavement. In concrete block pavement, many studies have been conducted to show the effect of joint width on pavement resistance to rutting. One study Ling *et al*. (2009) has shown that a joint width of 5 mm between concrete blocks yielded the best performance in terms of resistance the deflection. Few studies being conducted to show the effect of joint width in asphalt block pavement. A first study (Baillairgé, 1964) has been done on asphalt paving blocks, a gap of 3 mm between the asphalt paving blocks filled with dry sand was found to give the most satisfactory results. Another study Hanover (2011) has recommended that asphalt blocks must be laid with a joint wider than 1.5 mm. However, there have been very limited studies being done to show in depth the effect of using different joint widths on the performance of asphalt block pavements. The main aim of this study is to develop asphalt blocks for road pavement. The objectives of this research are to ascertain the deflection and displacements occurred in asphalt block pavement with varying the design joint widths between the blocks i.e., 0, 2 and 3 mm, respectively and examine the properties of asphalt blocks.

MATERIALS AND METHODS

Bitumen: The bitumen type used in this study was bitumen penetration grade of 60-80. This type of bitumen is recommended to use for heavy traffic roads as classified under Malaysia (JKR) Standard (Jabatan, 2008).

Aggregates: Aggregates used in the study comprise of coarse aggregates, fine aggregates and filler. A 10 mm of aggregate maximum size was used in this study to produce the samples.

Asphalt mixture design: The dense graded mixture was selected in this study to produce the asphalt paving blocks due to a number of aspects such as the dimensions of the blocks used in this study are not big size. Consequently, it is more suitable to have a mixture with smaller aggregate size.

Test method: A range of tests was carried out to ascertain the properties of asphalt blocks i.e., density (AASHTO T166), voids analysis and compressive

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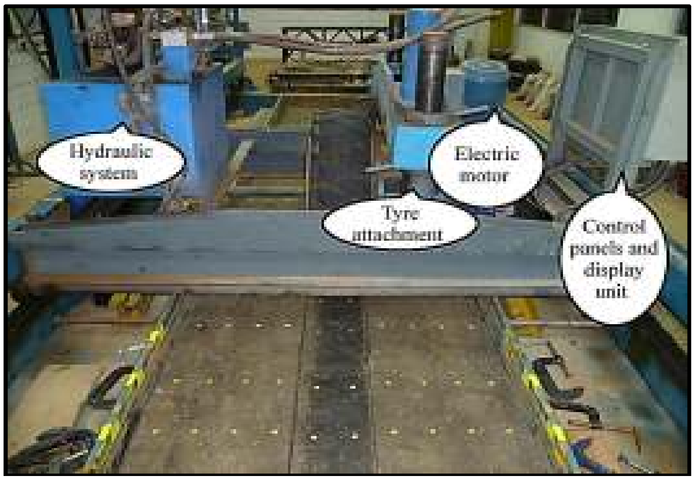

Fig. 1: Accelerated trafficking test

Fig. 2: Asphalt blocks are laid with different joint widths

strength. The structural performance of asphalt block pavement was evaluated by using the accelerated trafficking load test and pull-out test:

The accelerated trafficking load test: The accelerated trafficking load test was used to generate realistic dynamic wheel loads on the pavement. This experiment was conducted to ascertain the deformation level in asphalt block pavement. The test was done in a huge steel mold with dimensions of 1 m in width and 5.5 m in length. Bedding sand of maximum particle size of 5 and 30 mm thick was laid in the steel mold. Asphalt blocks were then laid in a stretcher pattern as shown in Fig. 1 with different design joint widths between the blocks i.e., 0, 2 and 3 mm, respectively. Dry sand of a maximum particle size of 2 mm was used to fill the gaps between the blocks. Figure 2 shows that the asphalt blocks were laid with different design joint widths i.e., 0, 2 and 3 mm, respectively. The wheel axle load of 2000 kg with a tire pressure of 600 kPa was set to the loaded wheel to simulate the traffic load. The speed of the wheel was set to 0.2 m/s throughout the entire test. The test was run up to 20,000 cycles.

Pull-out test: The pull-out test was used to allow an individual block to be extracted from the block pavement in order to certify that the adjacent blocks are not being rotated during the extraction process and thereby grip the blocks from being extracted. The test equipment applied its reaction load straight onto the neighboring blocks (Husin, 2001). The upwards load measured by the apparatus in extracting the blocks is considered to be equal to a downward load (Clifford, 1984). This test was carried out on asphalt blocks with different design joint widths i.e., 0, 2 and 3 mm, respectively. Figure 3 shows setup of the test and the movements of paving blocks during the extraction process.

RESULTS AND DISCUSSION

Production and evaluation of asphalt blocks: Marshall Test was conducted to obtain the optimum bitumen content of asphalt mixture. A bitumen content of 6.1% (of the mixture weight) was found to be optimal. The steps of producing asphalt blocks were taken as follows:

- The aggregate was heated to the temperature of 150-170°C Asphalt Institute (1988). The bitumen was then heated to the mixing temperature of 150 to 160°C (Liu *et al*., 2010). The loose mixture was also being prepared near the optimum bitumen

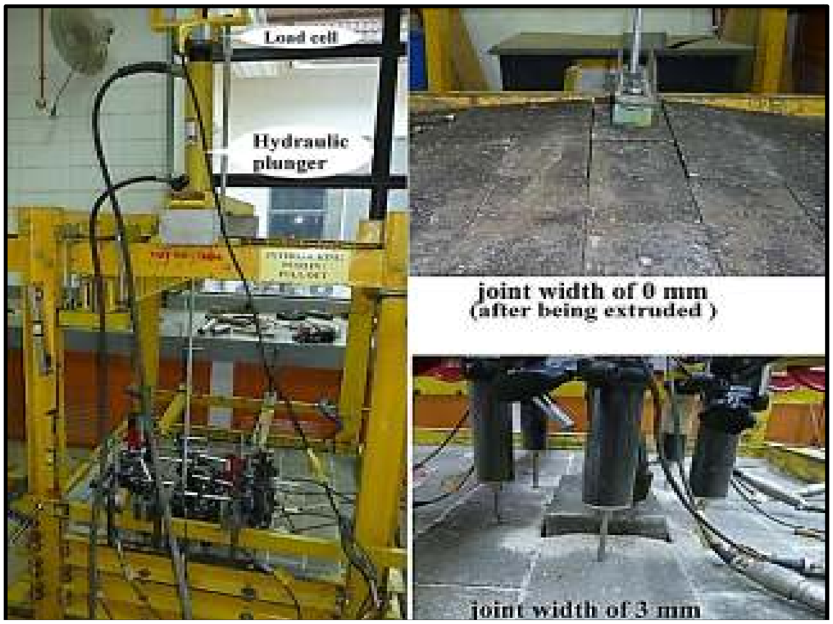

Fig. 3: Pull-out test setup

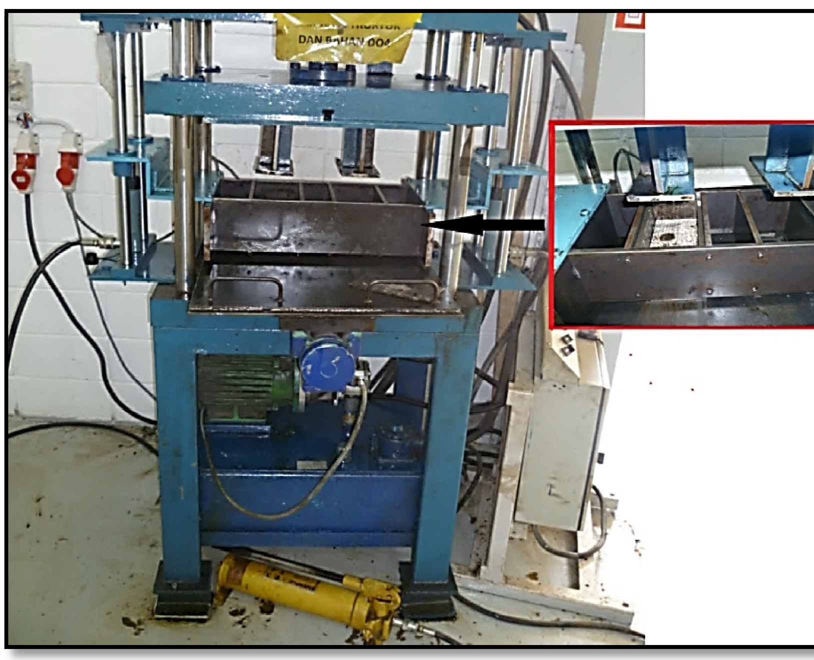

Fig. 4: A machine used to produce blocks

content to measure the Theoretical Maximum Density (TMD) (Croney and Croney, 1998). The aggregates and bitumen were mixed thoroughly until it is a well coated to the temperature not more than 163°C (Asphalt Institute, 1988).

- The hot mixtures were poured into a preheated steel mold. Wax discs were used to keep the mixture from sticking to the base plate. Asphalt blocks are rectangular-shaped with dimensions of 200 mm in length, 100 mm in width and 80 mm in thickness. The total mixture weight to achieve the thickness of 80 mm was 3731.4 g.
- The temperature of the mixture was checked and left to cool down to the compaction temperature of 130°C (Mills-Beale and You, 2010). Subsequently, the mixture was compacted by the machine as shown in Fig. 4 with a compacting pressure of 32 MPa to provide air Voids in Total Mix (VTM) not less than 3% (Taha *et al*., 2013), as most of state highway agencies have recommended (Zulkati *et al*., 2012). This percentage is significant to resist

Fig. 5: Extruding of asphalt block from steel mold by jacking

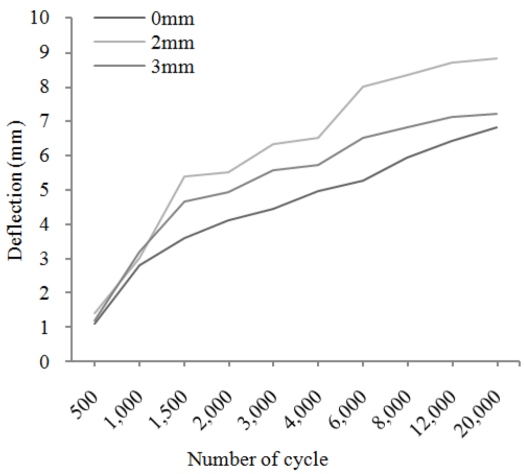

Fig. 6: Deformation (rutting) occurred in asphalt block pavement

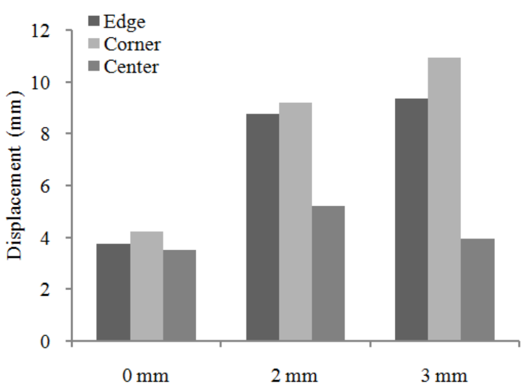

Fig. 7: The displacement occurred in the block pavement

Table 1: The properties of asphalt paving blocks

Bitumen types used in block mixture	Density (g/cm^3)	Compaction (%)	VTM (%)	VMA (%)	VFA (%)	Compressive strength (MPa)
Bitumen penetration grade of 60-80	2.291	96.1	3.10	12.79	75.76	8.3

premature distress such as bleeding (flushing) which is occurred as a result of an additional compaction by the vehicles (Brown, 2004).

- The compacted samples in the steel molds were then extruded by using a jack as shown in Fig. 5. The properties of asphalt paving blocks are shown in Table 1.

The compaction percentage of asphalt block was selected based on compaction time in order to get air voids (VTM) not less than 3% (dense graded mix) and meet the standard specifications. The compaction percentages and air voids analysis of asphalt blocks have met the standard specification of highway state agencies. Asphalt Institute (1988). Furthermore, asphalt paving blocks demonstrated that they have the ability to resist a static load (compressive load) up to 166 kN. Based on AASHO Road Test and other studies (Shackel, 1994), the heaviest permitted axle load in the U.S and other countries is an 80 kN equivalent single axle load (Garber and Hoel, 2009). Accordingly, Asphalt paving blocks are adequate enough to carry a static vehicle axle load.

Accelerated trafficking load test: The accelerated trafficking load test was run up to 20,000 cycles in order to ascertain the rutting occurred in pavement model. As revealed earlier in Fig. 1, the main deformation occurred along the loaded wheel path. Figure 6 shows the rut depth in asphalt block pavement which was laid with three different joint widths i.e., 0, 2 and 3 mm, respectively.

Based on Fig. 6, the results clearly show that the deformation is significantly affected by joint width between the blocks. Joint width of 2 mm was found to yield the highest value of deformation and that may due to some of the sand grains coarser than the joint width (2 mm), thus the sands were prevented from entering through the gaps. On the other hand, the blocks placed as closely in contact as possible (0 mm) had the lowest level of deformation and that may due to the friction between the surfaces of asphalt blocks are higher than with sand. Accordingly, the joint width of 0 mm provided the best resistance to the deformation.

Pull-out test: Pull-out test was done at three different locations i.e., edge, corner and centre. Fig. 7 shows the final displacement occurred in the block pavement as a result of extracting the individual block from pavement model.

As revealed in Fig. 7, the performance of asphalt block pavement is highly influenced by the joint width (spacing) between the blocks. The result showed that the blocks which were placed as closely in contact as possible (0 mm), had the lowest value of the displacement, hence the blocks are more likely to be prevented from being rotated or extracted from the pavement during the movements of vehicles. However, the result demonstrated that the cohesion of asphalt blocks were very high. Figure 8 illustrates the interconnections of asphalt blocks after being compacted. On the other hand, the block pavement with a joint width of 2 mm had the highest level of displacement (extruding).

Fig. 8: The interconnections of asphalt blocks

CONCLUSION

This research examined the effect of joint widths on the performance of asphalt paving blocks. As mentioned earlier in the introduction, the purpose of this study was to assess pavement resistance to deformation and displacement. The following conclusions can be drawn:

- Asphalt blocks resisted a static vertical load as little as 166 kN.
- Asphalt blocks laid as closely in contact as possible (0 mm) was found to yield a higher resistance to the deformation and displacement.

The rutting occurred in asphalt block pavement is considered significantly higher compared to conventional asphalt pavement and that because of using an additional layer beneath the blocks. However, the conventional asphalt pavements are constructed by using heavy machines thereby; it would be beneficial to have alternative method of paving particularly for narrow roads. Lastly, same study needs to be conducted by changing a number of variables. The block thickness and the bedding sand should be varied to evaluate their effect on performance of asphalt block pavement.

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