Performance of porous asphalt pavement using clay brick dust as mineral filler

M I Joohari¹, N A Aziz¹, N M Daud¹, S Mansor¹ and M A Abdul Halim¹

¹Faculty of Civil Engineering, Universiti Teknologi MARA, Cawangan Pulau Pinang, 13500 Permatang Pauh, Pulau Pinang
*jat_joe@hotmail.com

Abstract. High demand of recycling waste materials are able to solve disposal problem which created opportunities for researcher to use it in their product. Waste clay brick dust is one of the material can be improvised to be tested for the performance of porous asphalt pavement towards rutting problem. In this study, crushed dust of clay brick was used in porous asphalt mixture as mineral filler. 15 samples were produced in different proportions (4%, 4.5%, 5%, 5.5% and 6%) of bitumen content and each proportion have three samples. The optimum bitumen content (OBC) obtained was 4.75% for modified and 5.9% for conventional porous asphalt. Rutting Test was then tested to evaluate the performance of porous asphalt after being modified with clay dust and compared with conventional mixture of porous asphalt. Modified mixture showed a slight higher in rutting depth of 2.2 mm compared to the conventional mixture of 1.6 mm. This means that modified mixture is less in rutting strength. However, the drain down test showed that modified samples are more intact between binder and aggregate and able to sustain in high temperature. Further modifications are required to enhance rutting strength for modified mixture.

1. Introduction
Porous asphalt is considered as an open-graded asphalt blended with fine particles and less sand compared to conventional asphalt. It is laid on top of squashed stone aggregate layer to provide water infiltration. The key to progress is to furnish the water with a spot to go, generally as an underlying, open-reviewed stone bed. As the water depletes through the permeable asphalt and into the stone bed, it gradually penetrates into the soil. The stone bed size and depth must be structured with the goal that the water level never ascends into the asphalt. This stone bed, frequently 18 to 36 inches inside and out, gives a colossal sub-base to the asphalt paving. Water can penetrate the asphalt because of expanded void space of roughly 16% contrasted with 2-3% for conventional asphalt [1].

Porous asphalt pavement offers designers and developers another instrument in their toolbox for managing stormwater. These asphalts, utilized for the most part for parking areas, enable water to deplete through the pavement surface into a stone energize bed and infiltrate into the soil underneath the pavement. Such asphalts have been demonstrating their value since the mid-1970s, and late changes in stormwater guidelines have incited many consulting engineers and public works authorities to look for data about them [2].

During the most recent two decades, numerous structures achieved their planned lifetimes or defected during construction execution. Colossal amounts of construction and destruction waste are created each year and presently turning it into a serious environmental issue. In this research, the emphasis was on
utilizing waste crushed clay brick as shown in figure 1 as a part of blending material for the asphalt mixture.

![Figure 1. Clay brick dust.](image)

Clay brick dust is one of the industrial activity residue acquired from the process of producing clay brick at the factory. As of now, the waste stockpiling disposals in Malaysia are turning into an environmental issue, particularly in the urban areas. This is mainly due to lack of disposal sites because of urbanization and modernization. So as to lessen waste materials being disposed to disposal sites, the researchers need to locate ways to make all waste material can be recyclable and re-useable again. The utilization of waste clay brick dust as mineral filler in porous asphalt is a viable alternative in order to protect the environment and preserve natural resources. For the most part, mineral admixture has a favourable influence on quality and sturdiness of the concrete. Moreover, clay in the block structure likewise gives numerous advantages like imperviousness to fire as well as heat insulation, sound insulation, and absorption of dampness. From the previous researches, the utilized of clay brick dust was more on the admixture of concrete. There was no investigation on utilizing of clay brick dust as a replacement of aggregate dust in porous asphalt.

The most significant characteristic of pavement is the bonding of aggregate and asphalt since it is the essential characteristic that impacts the integrity of the pavement. This bonding must be built up at the underlying phases of contact between asphalt and aggregate. It should be able to endure during the lifetime of the pavement. Loss of bonding may result in lower performance.

Stripping issue happens when the total bond between asphalt and aggregate is acquainted with the water. This is because porous asphalt allows the water to stream down to underneath layer of pavement and creating a condition for the water to breakdown the bond [3]. Another problem in porous asphalt is the ravelling. Ravelling is the detachment of aggregate from the pavement surface because of insufficient bonding between aggregate and asphalt binder [4].

The focal point of this research was on the issue identified with rutting. Rutting or ruts is characterized as a small tranche on the pavement surface created by the movement of wheels. Ruts can be formed by wear, as from the vehicles’ tires commonly in hot climate areas. They can also shape through deformation of asphalt pavement or sub-based material.

1.1. Modification of porous asphalt mixture
The major drawback appears from porous asphalt is lack of structure’s stiffness due to surface depression in the wheel path produced from heavy traffic [5]. The uplift may happen to the pavement along the sides of the rut. When they are loaded up with water after the downpour, and the heavy vehicle passed through the porous asphalt for at least 800 cycles, ruts can be obviously seen on the surface. Modification of porous asphalt might, therefore, be able to combat this problem. Thus, an investigation was done in this research by replacing the aggregate dust with crushed dust of clay brick as a mineral filler in porous asphalt mixture to see whether it can improve the stiffness to porous asphalt.

1.2. Objectives
The objective of this research was to assess on the workability performance of modified porous asphalt mixture using Marshall Mix Design in order to obtain the optimum bitumen content (OBC) and compared with the conventional porous asphalt. Thereafter, the amount of optimum bitumen content
obtained was used in the mixture for both conventional and modified specimens. The specimens were then tested to analyze the rutting resistance as well as binder draindown.

2. Experimental method

2.1. Marshall mix design method
In this research, the aggregate size of porous asphalt was chosen based on Public Works Department PWD) Malaysia’s Standard Specification for Road Works [6]. The aggregate size use was 14mm, 10mm, 5mm, 2.36mm and 0.075mm. Marshall Mix Design was conducted to obtain OBC. A total of 30 specimens for both conventional and modified mixture were prepared; having 3 specimens for each percentage of bitumen used ranging from 4% to 6% with 0.5% increment. Each specimen was subjected to the volumetric analysis in order to determine the OBC. The OBC obtained for both conventional and modified mixture was then used for rutting test and binder draindown. Figure 2 shows the Marshall stability and flow equipment used to obtain volumetric data.

2.2. Performance test (Rutting)
The test accordance to AASHTO TP63 [7], was performed by using an Asphalt Pavement Analyzer (APA) machine as shown in figure 3 that is use to evaluate the rutting characteristics of porous asphalt pavement. The specimen was restrained in a 300 mm x 300 mm x 50 mm plastic mould. The gyratory compactor was used to compact the specimens until 7.0 + 0.5 percent of air voids and they were then preheated in the test chamber for 6 hours with the calibrated temperature. A motor was driven by the wheel and a reciprocating device loaded the pavement bi-directionally. The rate of the wheel was 42 cycles/min with the test length of 8000 cycles. The wheel covered a loading distance of 230 + - 10 mm. The vertical deformation in the middle of the pavement was recorded. The standard loading pressure for this test was 700 kPa at temperature 60°C under dry conditions.

![Figure 2. Marshall stability and flow equipment.](image)
2.3. Binder draindown test
This test was developed by AASHTO T305 [8] to stimulate the condition of the mixture and is likely to encounter as it is produced, stored, transported and placed. It is conducted at typical and construction temperatures. The thick film of asphalt binder common to porous asphalt pavement has the propensity to drain from the aggregate structure. The test carried out for the purpose to evaluate the potential of binders draining down from coarse aggregate using a standard basket. A wire basket held in position on a pre-weighed dry paper plate for the loose mixture. The entire apparatus placed in an oven at a controlled temperature of 175°C for 60 to 180 minutes (3 hours). The basket containing the specimen was then removed from an oven along with the paper plate and weighed to get the amount of draindown occurred. According to PWD Standard Specification for Road Works, the amount of allowable for a binder to drain down must not more than 0.3% from the total weight of bitumen.

3. Result and analysis

3.1. Volumetric properties
Marshall Mix Design was carried out to analyze volumetric properties and directly able to determine the optimum bitumen content for both conventional and modified mixture. Stability of Marshall Mix can be determined at the maximum load carried by the specimen at a standard test temperature of 60°C. The stability for conventional mixture recorded 12500 N while 21300 N for the modified mixture. The deformation of the test specimen is stated in the form of flow value and the specimen undergoes during the loading up to the maximum load. The flow recorded for conventional and modified mixture were 3 mm and 3.7 mm respectively. As a result, the OBC for modified mixture recorded 1.15% lower than the conventional mixture of 5.9%. All of the results met the requirement by PWD Specification. Table 1 shows the result for volumetric properties.
### Table 1. Test and analysis properties.

| Properties          | Conventional Mixture | Modified Mixture | PWD Specification |
|---------------------|-----------------------|------------------|-------------------|
| Stability, S        | 12500 N               | 21300 N          | >8000N            |
| Flow, F             | 3 mm                  | 3.7 mm           | 2 – 4 mm          |
| Stiffness, S/F      | 4167 N/mm             | 5756 N/mm        | >2000 N/mm        |
| Opt. Bitumen Content (OBC) | 5.9%                 | 4.75%            | 4 – 6%            |

3.2. Binder draindown

The allowable drainage is 0.3 % in accordance with PWD Malaysia’s Standard Specification for Road Works. In this research, the percentage draindown for the modified and conventional mixture was 0.08% and 0.3% respectively. The modified mixture recorded less binder drainage. Clay brick dust seemed to provide more intact between the binder and the aggregate as well as the ability to retain asphalt in high temperature. Both results met the requirement by PWD specification despite conventional mixture was at the maximum allowable value. The percentage of binder drainage for both conventional and modified mixture is shown in figure 4.

3.3. Rutting resistance

One of the disadvantages of having a porous asphalt is lower rutting resistance than the gap and dense graded mixture [9]. Therefore, rutting resistance was the focus of this research as both mixtures put into test to analyze their performance. The depth of rutting value for the modified bituminous mixture was 2.2 mm, which slightly higher compared to the conventional mixture of 1.6 mm. The result showed that clay brick dust could not provide enough stiffness to porous asphalt to sustain the load, as it might need to be mixed with other admixture to achieve the desired strength. However, the modified mixture rutting value was still in the range of PWD Specification which is below 4 mm. Figure 5 shows the result of rutting value.

![Figure 4. Percentage of binder draindown.](image-url)
4. Conclusion
The objective of this research was to evaluate the effect of using clay brick powder as a replacement for mineral filler towards the optimum bitumen content, binder draindown, and rutting resistance. Modified mixture with clay brick powder seemed to have a better result on the optimum bitumen content with a percentage of 4.75% compared to 5.9% for the conventional mixture. This proved that the modified mixture containing clay brick dust able to reduce the amount of bitumen used in porous asphalt mixture.

A positive result could also be seen on the binder draindown test as the modified mixture recorded 0.08% whereas 0.3% draindown for the conventional mixture. The presence of clay brick dust as replacement for mineral filler showed the better ability of porous asphalt to retain in hot temperature.

The performance evaluation of porous asphalt towards rutting has been determined by its surface depth deformation. The conventional porous asphalt rutting deformation was 1.6mm slightly lower than modified mixture which recorded 2.2mm.

In conclusion, further study is required to enhance the modified mixture containing clay brick dust to stand against rutting deformation.

Acknowledgement
The Author would like to acknowledge Universiti Teknologi Mara (UiTM) Cawangan Pulau Pinang for financial sponsor of this research paper.

References
[1] Wolf S 2017 Porous Asphalt Paving - Cost and environmental benefits. Retrieved from https://www.wolfpaving.com/blog/bid/55431/porous-asphalt-paving-cost-and-environmental-benefits.
[2] National Asphalt Pavement Association 2019 Porous asphalt. Retrieved from https://www.asphaltpavement.org/index.php?option=com_content&view=article&id=359&Itemid=863.
[3] Mallick R B Kandhal P S Colley J and Watson D E 2000 Design, Construction and Performance of New Generation Open-Graded Friction Course. National Center for Asphalt Technology: Auburn University (NCAT 200-1).

[4] Miradi M 2004 Neural network models for analysis and prediction of ravelling in cybernetics and intelligent systems IEEE Conference on 2004 IEEE.

[5] Erlingsson S 2012 Rutting development in a flexible pavement structure, road materials and pavement design 13:2 DOI: 10.1080/14680629.2012.682383 218-234.

[6] Public Works Department (PWD) Standard Specification for Road Works in Malaysia, Section Four: Flexible Pavements Malaysia Public Works Department 2008.

[7] ASHTO 2006 Standard method of test for determining rutting susceptibility of hot mix asphalt (HMA) using the asphalt pavement analyzer (APA) AASHTO Provisional Standards TP63 AASHTO Washington DC.

[8] AASHTO T305-97 2005 Standard method of test for determination of draindown characteristics in uncompacted asphalt mixtures.

[9] Teong H 2007 Evaluating Rutting on Porous Asphalt Mixes – Comparison between Marshall and Superpave Method in terms of Volumetric Properties. Dissertation from University Technology Malaysia.