

Cooling time of porous asphalt pavement affecting compaction process due to various raining condition

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Abstract. While bright sunshine and warm temperatures make for the best paving weather, construction projects can get a bit rough in adverse weather conditions. In this case, porous asphalt is used on paving. Light sprinkles can usually be handled without any serious problems. Moderate rainfall events, on the other hand, will generally require the paving project to be postponed. Steady downpours will cool the porous asphalt mix and make proper compaction extremely difficult to obtain. For the viability of the project, contractors will always wait until the sky clears up. According to the JKR Specification 4(Clause 4.2.6.4), it clearly states that no pavement work should be done during rain. The rain is a cold medium where it will actually cool down everything that make contact with the water. Whereas, the mix porous asphalt (PA) is a hot medium. When these two elements combined, the surface and the PA will harden at a stage where it will not be well compacted. This will cause problems in the future. The test is conducted by pouring water onto the pavement(through raining simulation). Since the rain intensity can be determined by the size of the rain drops, the difference in the shower hole size is good enough to create different rain intensities to predict the PA cooling rate when it makes contact with water. These two variables will work as a comparison in this study between raining and no rain condition. As a result, whenever the water make a contact with the PA, the rates of cooling drops 98% from the normal rates of cooling of PA (without rain) giving the Time Available for Compaction (TAC) to be less than 60 seconds. This study may be a knowledge on how the rates of cooling work if the PA make contact with water. It can also be used as future reference on the study of cooling rates of porous pavement during raining condition.

1. Introduction

Weather in Malaysia needs to be understood when conducting pavement works. Located near the equator, Malaysia's climate is categorized as equatorial, being hot and humid throughout the year. Malaysia is a tropical country that is mainly having two sessions which are the raining session and dry session. However, the amount of water pouring on this land during the dry session can also be considered large. In order to encounter the problem of pavement works in this country, civil engineering work plays an important role. In this study, porous asphalt (PA) can be proposed. It is a special-purpose wearing course. The production of this course uses open-graded aggregate mixed with modified binder and also contain a relatively high air voids after compaction. In order to ensure drain ability, the design and in-place air voids shall be in the range of 18 to 25 percent [1].



Porous asphalt (PA) is an innovative road surfacing technology which allows water to percolate into the PA pavement. The inter-connected voids inside the PA allowed water to infiltrate through the pavement and is usually laid on an impervious compacted base course such as roadways, roof tops and parking lots. Porous asphalt is also included in the pavement works which in the process, brought by lorry and being compacted on site. Around 135-163°C (275 to 325°F), within 6°C (10 °F) is the temperature at discharge from the mixing plant to minimise drainage of bitumen out of the mix during handling and transport. After the asphalt mixture has been spread, struck off, and surface irregularities adjusted, immediately it shall be thoroughly and uniformly compacted by rolling. The compaction objective is 16% - 19% in place void content. Breakdown rolling shall occur when the mix temperature is between 135-163°C (275 to 325°F). Intermediate rolling shall occur when the mix temperature is between 93-135°C (200 to 275°F). Finish rolling shall occur when the mix temperature is between 66-93°C (150 to 200°F). The finishing temperature occurs at approximately 79°C (175°F), at which point the mix becomes resistant to compaction [2].

If compaction has not been done at temperatures greater than the finishing temperature, the pavement will not achieve adequate durability [3]. As such, the pavement will deteriorate shortly, resulting to problems like cracking, which is among major road defects in Malaysia. The surface shall be rolled when the mixture is in the proper condition and when the rolling does not cause undue displacement, shoving, or cracking. Water is the universal agent of cooling where it transfers the heat from high temperature area of mix to the lower temperature area (surrounding). As a result of raining, the water infiltrates and cools down the pavement, thus reducing the Time Available for Compaction (TAC).

JKR does not specify any indications or rules to the placement of pavement in raining situation or any similar test to be done related to this matter. The pavement rapidly become stiff and instantly can be used by road users. It is actually possible and not that hard in the placement of pavement in raining condition. However, JKR also does not specify the safe time duration to compact the pavement before it cannot being compacted. The objective of this study is to determine the design binder content of Porous Asphalt, to determine the cooling rate of the Porous Asphalt in raining condition and to evaluate Time Available for Compaction.

2. Background

2.1 Pavement temperature relation with water

Liquid water which comes from the rainfall act as a universal heat conductor. It carries low or cold temperature with them. As the water continues to pour on to the surface of the pavement, it carries the heat inside the pavement as well [4]. The capacity of the water flows play a major role in cooling the PA. The larger amount of rain dissipates, the more intense the water pours. This means that the amount of conductor which brings out the heat from the Mix tend to cause the rate of water to become faster. The assumption of the temperature drop down the graph is shown in Figure 1.

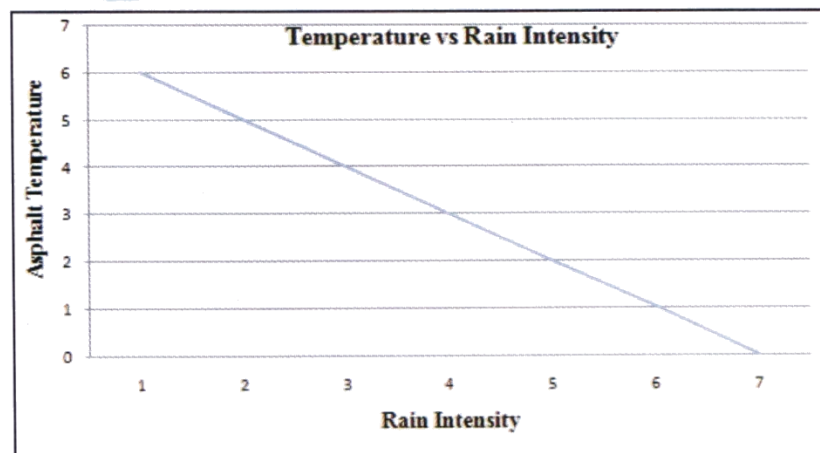


Figure 1. Temperature vs Rain Intensity

2.2 Factors affecting cooling of aggregate

Since the aggregates are in granular shape, the composition has some disadvantages on water absorption. As a result of having pores inside, it can absorb water very efficiently. If the aggregate continues to vaporize the water, the water will continuously cool the aggregate rapidly. When the water percolates around the aggregates, the effectiveness of the aggregates to keep its temperature will decrease. This happens because as the water flows, the heat inside the aggregates will be carried out by the water that has a cooling element.

2.3 Compaction of PA

In pavement construction, the compaction of aggregates is very crucial. Once the mix got laid at site at the site, it needs to be compacted and the time is sort of limited. This is because the mix gets cooled slowly after it was discharge from the plant. In order to determine the sufficient time to compact the mix, Time Available for Compaction or TAC is very important. It is done before the mix reaches 79°C to 80°C because the mix will not be suitable anymore to be compacted. In the quality of the pavement, temperature plays a major role. It was measured when the compaction work is done. The efficiency work of the asphalt binder and how dense the pavement will be depends mainly on the temperature. When pavement was compacted, the temperature of the mix can dictate the air void of the pavement itself.

In peak season, the amount of total monthly rainfall that Malaysia receives is up to 318.0 mm in a month [5]. This data shows that the constructions in Malaysia are always facing problems. There are no other alternatives in the pavement construction when it is raining. The lorry that is carrying the porous asphalt as well as the work that needed to be done either have to work in the rain or postpone the work. A lot of money may be lost if the supply of the porous asphalt is to return back to the facilities. This condition may indicate that the exposed surface area where the precipitation comes to contact with, experienced higher rate of cooling, hence establish weak bond between aggregate particles.

3. Methodology

3.1 Laboratory works

This study approach mainly involved laboratory experimental works. The study focuses on the properties evaluation and the raining test. The Marshall Mix design procedure involved material selection and volumetric proportioning as a first approach in producing a mix that will perform successfully. Optimum binder content (OBC) for the PA was acquired as the designed binder

reference to be used in preparing the raining test sample [6]. Density-void analysis, binder-drain down and Cantabro test were conducted prior to the determination of OBC [7].

The material used are aggregates and porous asphalt binder, the aggregate are taken from quarry in Kajang and the mix grade of aggregate for these study are according to JKR specification section 4 which indicates combined aggregates of coarse and fine aggregates (Grading B) and the asphaltic binder used is 60/70 penetration grades.

The fundamental idea of this study is to evaluate the cooling rate of PA caused by rain water. Having to test sample on-site during actual raining condition will lead to sample being affected by other environmental element such as wind. Therefore, a raining condition was simulated in the laboratory by using a shower of different holes sizes. Data collected was then analyzed to compare the cooling rate between the control sample (without raining condition), and samples of three different raining condition. A temperature detector was used to achieve the objective of this study. All of these is best shown by the flowchart in Figure 2.

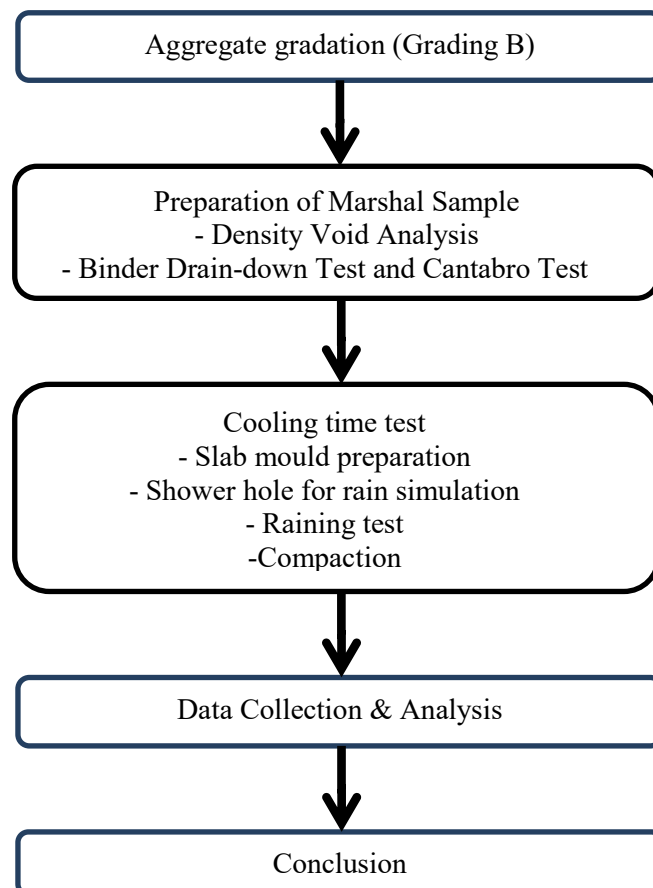


Figure 2. Flowchart of Study

3.1.1. Sample mold preparation.

The mold made of wood are prepared once the optimum binder content is determined. This designated mold is drilled at the center of the mix so that the thermometer can enter through it. This is done to observe the changes in the temperature of the mix. A rectangular shape is chosen for the temperature mold to operate the experiment, as shown in Figure 3. This is because this shape could distribute heat more efficiently than any other shape. When the surface area is straight, heat reflects much more efficient. In comparison to circular shape, the heat distribution disperse to various points in the mold. This produce less effective heat distribution [8]. This could lead to unstable temperature distribution in

the mold. The 50 mm height of the mold is chosen because the wearing course in JKR specification is 50 mm in minimum. A minimum thickness of 50 mm is essential to provide adequate drainage within the porous asphalt layer.

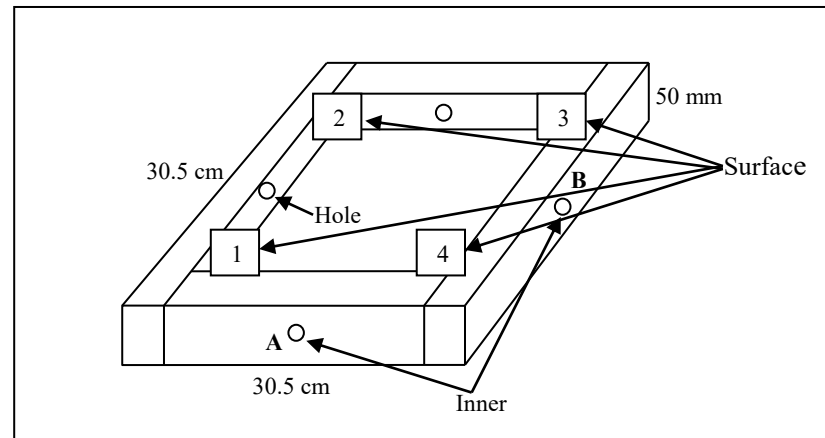


Figure 3. Sample of Mould

3.1.2. Rain Simulator

The size of the water drops act as variables to run the test. The size of the shower head holes varies from 2,3 and 5 mm which represents the water drop size, as shown in Figure 4. The determination of the water size drops as the basic principle is the size of the hole of the shower where the water comes out. Rain drops are usually varies from 2 to 5mm according to its intensity [9]. From this principal, the water drops which acts as variables are changeable in this test. The larger the variables, the more accurate the result will be. During the test, there will be no wind environment included. This is because wind acts as another factor of cooling the pavement. In addition to that, the cooling rate of the pavement will increases if wind is introduced in the test. Thus, the cooling rate of the mix will also increases dramatically. In fact, the TAC will also shorten due to the other cooling factors.

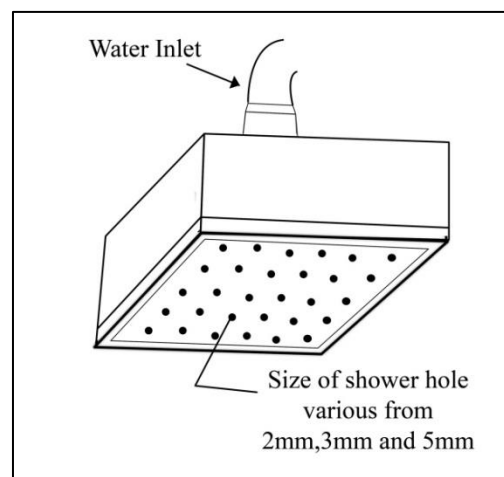


Figure 4. Shower Head

4. Results and discussions

A result between rain and no rain condition is shown in Figure 5. All of the test under rain condition happened in a unit of seconds. Meanwhile, the test without rain happened in a unit of minutes. It shows a huge gap differences between these two sets of data. The difference of TAC between without

rain and 2mm rain (Light Rain) was 32.48 minutes. Furthermore, the difference for 3mm rain (Medium Rain) and 5mm rain (Heavy Rain) compared to without rain were 32.78 minutes and 32.84 minutes each.

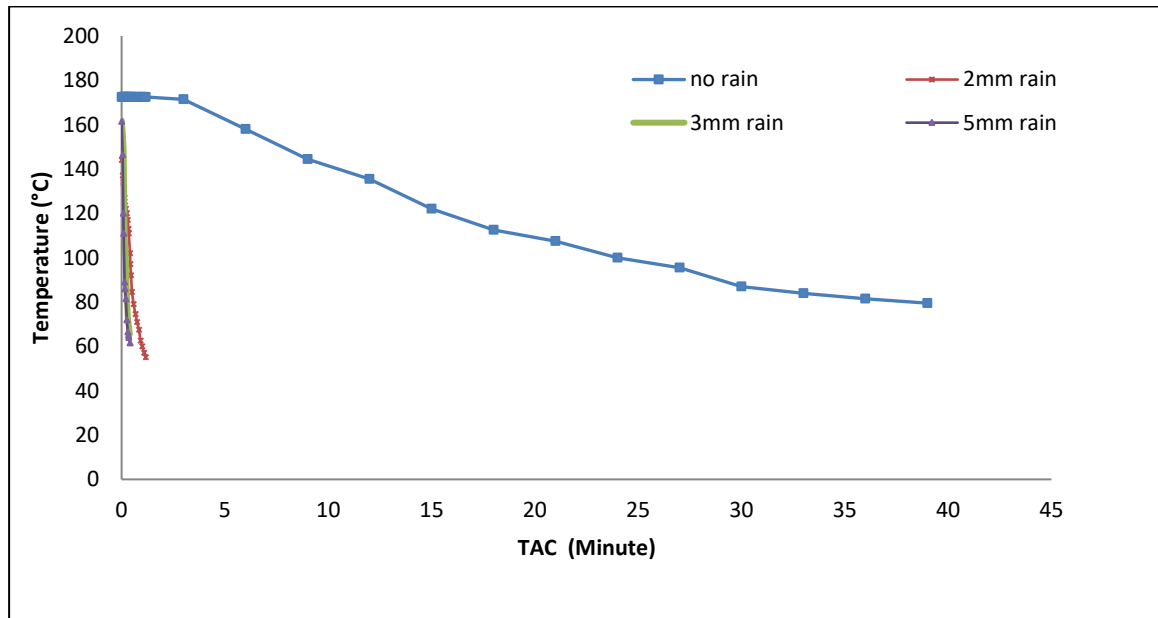


Figure 5. TAC for different raining condition on PA

As shown in the Figure 5, the fastest condition to reach TAC was under the heavy rain which was only in 9.5 seconds. Followed by the second condition which was under medium rain, took about 13 seconds. Lastly, under the light rain, it took longer than the rest for about 31 seconds. However, the differences for TAC between these three conditions did not show a big difference because it happened under the unit of seconds. All of the result is best explained by Table 1.

Table 1. TAC and cooling rate for different raining condition on PA

Size of Rain	Time Available for Compaction (TAC)				Cooling Rate (average in °C/sec)
	Inner (average)	Surface (average)	Average	Reduction (%)	
No Rain	39 minutes	27 minutes	33 minutes	Controlled	0.04
2mm (Light)	35 seconds	27 seconds	31 seconds	98.5%	2
3mm (Medium)	16 seconds	10 seconds	13 seconds	99.3%	6
5mm (Heavy)	13 seconds	6 seconds	9.5 seconds	99.5%	8

As an outcome, the effect of water on the porous asphalt is quite resolute. The heat needed in the mix to be compacted is immediately removed by the water. This is shown as even the lightest rain can absorb all the heat under just 31 seconds. It is nearly 98.5% of the total time of TAC or time available for compaction during a no-rain test. However, in medium and heavy rain, the percentage descent much higher. This has been expected earlier as this type of rain brings much more volume of water. This causes the pavement to cool much faster when the water is poured and the heat being carried out were in a large amount. In the uncompacted mix of porous asphalt, the rate of cooling shall be much faster. This is because it was not well-compacted and there seems to be much void which can be filled with water. In addition to that, this occurrence fasten the rate of cooling in the porous asphalt.

The height placement of the rain simulator were placed at about 1.2m from the ground. However, the height placement of the rain simulator act only as an indicator to simulate the rainfall. The rain water has larger momentum than the testing shower because it falls much higher than in the laboratory. This causes the water to penetrate much deeper into the pavement making it to cool down much faster. Apart from that, the rain test can be used as a guideline on rain effect on compaction process where there are more aspect to be considered that leads to the faster rate of cooling of porous asphalt.

5. Conclusion

In order to determine the actual event that is happening in the field, the rain water test is a success. It only shows small parts of role played by the rain water on cooling the porous asphalt pavement. In this test, the volume of the water carried in its raindrops varies in different sizes of raindrops. The hole of the shower head simulates the diameter size of rain drops. The larger the size of the rain drops, the quicker the time taken to cool down the un-compacted porous asphalt. This happen due to the contact between the water and the pavement. Most of the water making contact with the surface of porous asphalt cools rapidly causing the outer layer to be harden first. Then, the temperature of the inner layer which cools slower than the outer layer will start to decrease rapidly. This is because the water has started to penetrate into the void.

The specified standard mentioned earlier clearly tells that the compaction process shall not be continued in raining condition. This is very reasonable because it is not good in keeping the heat in moist and wet condition. The temperature of the porous pavement descends from 144°C to 79°C in less than 31 seconds clearly shows that the compaction process cannot be conducted in raining condition. This also shows that no matter how fast the paving process is, the duration is too short and impossible for compaction process. With all the aspects to be considered, the aftermath of the process which are not properly taken care of could cause damage to the pavement in the future.

As a suggestion, the compaction process shall not be continued in any circumstances during raining condition. As it will affect the workability of the pavement in the future, the compacting force of cooled porous asphaltic concrete should also not allowed to be practiced in the field. Moreover, as

mentioned earlier, water acts as a coolant medium on porous asphaltic concrete. Therefore, any kind of moist or humid on the surface or the underlying layer shall not be permitted. Upon getting all the results of the test from this report, any pavement work shall strictly not be continued in the rain, moist or any similar condition.

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