The study of developing asphalt patch slabs on repairing pavement potholes

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Abstract. The research objective was to improve pavement maintenance work of repairing potholes by replacing the cold asphalt patch materials with the laboratory-designed and hot-mixed asphalt patch slabs. The circular asphalt patch slab was designed 50 mm or 60 mm in height and 150 mm in diameter. The dense graded asphalt concrete mixture was designed and proportioned in accordance with Asphalt Institute MS-02 standard and the designed porosity was six to eight percent in this study. The Marshall hammer and Universal Testing Machine were utilized to compact the slabs to assess. The designed porosity was achieved and it took three to five minutes to complete the production of one slab. The rutting resistance of asphalt patch slabs was evaluated by the Hamburg wheel-tracking device in the laboratory. It unveiled that the rut depth was 12.5 mm, while 8,000 wheel numbers passed. The outcome of this study shed lights on a potentially effective method of repairing potholes with the asphalt patch slab. More details about field assessments will be reported in the near future.

Keywords: Universal Testing Machine, asphalt patch slab, pot hole, rut depth.

Introduction

The recent climate change has caused various effects to weather patterns observed in Taiwan, especially in the storm rainfall ratio and strength. Along with the expansions of the municipals and districts in urban area, the impermeable pavements grow. As such causes the incompetence of urban drainage system to drain the exceeding storm water. The sustained surface run-off may increase the likelihood of damaging the existing pavement. Moisture susceptibility is one of the major durability concern in asphalt pavements, mainly due to the moisture infiltrating or penetrating through cracks into the mixture. As cracks propagate, the presence of stripping, potholes, or fatigue cracking inevitably occurs. For the pavement maintenance and rehabilitation point of view, surface treatments, creak seals, and patching are among popular methods of repairing distresses.

The field distresses evaluation, made by the Institute of Materials Testing of the Directorate General of Highways (DGH), revealed that potholes could be induced by taking cores, poor patching job, and materials aging on the surface layer. The regular maintenance work to repair potholes are to fill with the patch materials which is normally the cold asphalt mixtures along with manual, machinery compacting, or Throw-and-Roll process. This is a quick repairing job for eliminating potholes in emergency. A full retrofitting job of patching HMA or cold mix in a large area may come later after the pavement is completely dry. However, the patching job has found to fail very often in practice, due to the difficulties in controlling appropriate compacting level. Figures 1 and 2 show the pothole induced by the moisture damage and the patching job in the field.

Fig. 1 Pothole (taken by DGH)

Fig. 2 Patching (taken by DGH)

In Taiwan, the roadway agencies, for instance DGH, require contractors to take cores every 1000 m^2 in area of pavement that is paved for the need of field quality control. The cores can later be brought to examine the consensus properties of sieve analysis, binder content, thickness, and volume of voids. This QC job inevitably causes the discontinuity of the pavement, owing to the cores taking. Would the empty volume of core not be filled and compacted appropriately, the likelihood of presence of pothole in that section increases. There is a need to develop a suitable technique to repair potholes and maintain the serviceability of pavement for the safety concern.

Experimental Program

The size of pot holes, reported by DGH, range from 100- to 200-mm in diameter and 30- to 70-mm in depth in Taiwan. The objective of this study was to develop and evaluate the circular asphalt patch slabs in the laboratory. One dense graded asphalt concrete (DGAC) mix design was selected to produce asphalt slabs. The asphalt slabs were brought to examine including the bulk specific gravity, voids, thickness, slab-producing time, and rutting depth. The mix design and the following tests were performed at the certified asphalt laboratory of the Institute of Materials Testing of DGH at Shin-Chuang, New Taipei, Taiwan.

Materials and mix design. The coarse and fine aggregates were obtained from the Yu-Loh River located at the Hsinchu County in North Taiwan. The asphalt binder—AC20 was selected and obtained from the Taiwan CPC Corporation. The mix design of DGAC was executed and followed by Asphalt Institute MS-02, or the Marshall Mix Design [1]. The Job Mix Formula was determined with the binder content (5.0% for mixtures) by voids (4.2%), density (2329 kg/m^3), stability (1165 kgf), flow (10.3 per 0.25mm), VMA (13.7%), and VFA (70%). The theoretical maximum specific gravity (G_{mm}=2430 kg/m^3) was also determined. Fig. 3 shows the selected gradation of the job mix formula.

Production of asphalt patch slabs. There were two methods of making asphalt patch slab to assess in this study, namely compaction and compression methods. The compaction method was in use of the Marshall hammer to drop and fabricate asphalt patch slabs, while the compression one was in use of the UTM machine to produce these. It was to utilize with the Humboldt T/H-1364 model and the UTM is a Tokyo Koki CM 200/TK 10B model located at the Institute of Materials Testing, DGH, shown in Figures 4 and 5. The asphalt patch slab was designed by 150 mm in diameter and 50- and 60-mm in thickness. When the voids was targeted in 6%, it was needed to obtain about 2000-, and 2400-g of asphalt mixtures by calculations to manufacture 50- and 60-mm of patch slabs, respectively. It has to be noted that the slab with 50 mm in thickness was designated for the following examination, including a comparison between two methods to make slabs, bulk specific gravity, voids, and gradation check after dissembling slabs, while that with 60 mm in thickness was customized for the laboratory rutting test.

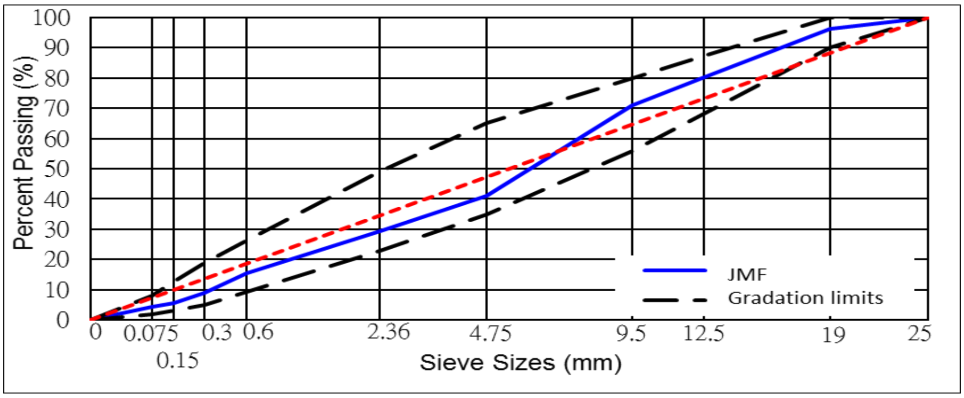


Fig. 3 Gradation selected for Job Mix Formula

Fig. 4 Marshall hammer (taken by DGH)

Fig. 5 UTM machine (taken by DGH)

Test Results and Discussions

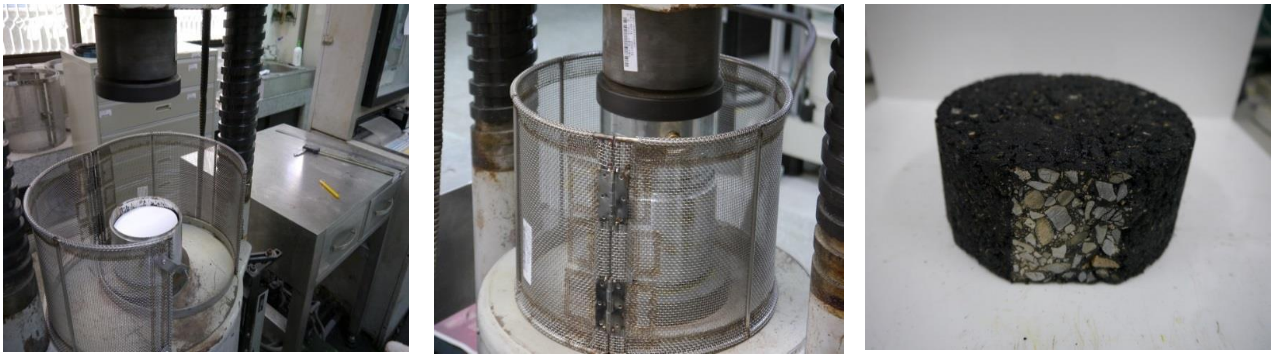
Comparisons of compaction and compression methods.

The voids of making asphalt patch slab through Marshall hammer drops was investigated. It was found that the more drops went on the asphalt mixtures, the less voids the slabs were. Table 1 shows relationship of the voids versus hammer drops for making an asphalt patch slab designated for 50mm in thickness. When it came to make slabs with 60 mm in thickness, it was found that the asphalt patch slab with 3-5% or 6-8% of voids needs about 70 or 21 hammer drops, respectively. Empirically speaking, the compaction effort is sufficient to achieve the same level of voids for two different thickness.

Table 1 Voids of making asphalt patch slab through Marshall hammer drops

Drops	7	14	21	28	42	56	84	112
Voids (%)	8.7	8.2	7.3	6.7	5.4	4.3	3.1	2.7

The double-side of fabricating slab by compression was developed. For instance, when putting loosen 2000 g of asphalt mixture into the mold, it was about 80 mm height, the double-side compression approach proceeded by compressing 15mm from one side and another 15 mm from the other. The procedure facilitated to achieve the slab thickness to 50 mm. It was similar to produce slab with 60 mm in thickness. The asphalt patch slab was suggested to produce by a double-side compression approach, due to the fact that it was found some loosen asphalt mixtures on one side of slab when as such was compressed by one-side compression approach. Figure 6 (a)(b)(c) show the double-side compression approach to produce the asphalt patch slab.



(a) (b) (c)

Fig. 6 (a)(b) the double-side compression approach; (c) the asphalt patch slab through compression method. (taken by DGH)

Further examinations [2,3] on asphalt patch slabs made with 60 mm in thickness, though compaction and compression methods, were conducted shown in Table 2. The bulk specific gravity of slabs were about 2.25 to 2.32, while the slab thickness were about 59.4 to 61.0-mm. However, the voids control varies from one to anther production method. For the compaction method through different Marshall hammer drops, the slab with 70 or 21 drops achieved 4.53% or 7.4% of average voids, respectively. On the other hand, the compression method through UTM machine, either one-side or double-side approach, reached to 6.8% or 6.45%. It has to be noted that all resulting voids of aforementioned production methods fitted with the target voids. In comparison of the production time, to compact a slab with 70 hammer drops took 5-8 minutes, while compaction with 21 drops and compression with either one- or double-side spent 3-5 minutes.

Table 2 Comparisons of compaction and compression methods

Production Method	Compaction		Compression	
	70 drops	21 drops	One-side	Double-side
Target Voids (%)	3-5	6-8	6-8	6-8
Bulk Specific Gravity	2.32	2.25	2.27	2.26
Slab Thickness (mm)	60.4	61.0	59.9	59.4
Voids (%)	4.53	7.40	6.80	6.45
Time for production (min)	5-8	3-5	3-5	3-5

The aforementioned asphalt patch slabs were later disassembled and the asphalt binders were extracted out of mixtures. The left-over aggregates, including coarse and fines, were proceeded to perform the sieve analysis [4]. The extracted binder content for every slabs was more and less the same around 5%. Although it can be observed that the portion of fines aggregates (<4.75 mm) in compression methods was marginally higher than that in the compaction method, every asphalt slabs including compression methods of one-side and double-side and compaction method of 21 drops were found within the gradation limit.

Table 3 Sieve analysis on asphalt patch slabs

Sieve sizes (mm)	Percent Passing (%)					
	JMF	Loosen mixtures	Compression one-side	Compression double-side	Compaction 21 drops	Gradation limit
25	100	100	100	100	100	100
19	96.2	96	96	96	95	90-100
12.5	80.1	81	85	84	81	-
9.5	70.9	71	77	75	72	56-80
4.75	41.1	42	54	50	45	35-65
2.36	29.5	30	39	35	33	23-49
1.18	21.3	23	30	26	25	-
0.60	15.5	17	23	19	19	-
0.30	9.0	10	15	13	11	5-19
0.15	5.5	7	10	9	8	-
0.075	4.3	5.3	7.1	6.8	5.8	2-8
Binder content (%)	5.0	4.8	4.9	4.9	4.9	-

Laboratory rutting test.

The laboratory wheel track test was performed by a CONTROLS 77-PV33A06 model with steel wheel in accordance with AASHTO T324 [5]. It is a Hamburg wheel tracking device with the approach of testing the specimen with water. The testing temperature was set at 50±1 ℃ with the presence of water. The asphalt patch slabs with 60 mm in thickness and target voids 3-5% or 6-8% was designated to fabricate slabs through compaction and compression methods. Table 4 shows test results of laboratory rutting test in rut depth and stripping inflection point associated with the number of wheel passes. Generally speaking, the lower target voids, the more number of wheel passes for both methods. The asphalt patch slab with 3-5% target voids made by compaction method of 70 drops was among the best performance in the laboratory rutting test. The slabs made of 21-drop compaction and double-side compression were more and less equal in performance, while that made of one-side compression was worst. It has to be noted that every slabs were tested with the presence of water and the performance was expected to be much poor than when those were tested in the dry condition. The purpose was to simulate the moisture damage as posed to the asphalt patch slabs.

Table 4 Test results of laboratory rutting test

Production method	Compaction		Compression	
	70 drops	21 drops	One-side	Double-side
Target voids (%)	3-5	6-8	6-8	6-8
Rut depth at 20mm (Number of wheel passes)	21595	12704	7110	14204
Rut depth at 12.5mm (Number of wheel passes)	16320	8867	5000	8775
Stripping inflection point, SIP (Number of wheel passes)	10939	7738	3920	6972

Summary

This study evaluated the asphalt patch slabs made by either compaction or compression methods, examined the volumetric properties, and rutting resistance. The conclusion are as follows:

- The asphalt patch slab is feasible to manufacture through either compaction methods by the Marshall hammer drops or compression method by the UTM machine.

- The volumetric properties of asphalt patch slab such as thickness and voids can be controlled through careful mix design and calculation of how many asphalt mixtures to add in the mold
- It was found that 70-drop and 21 drop of Marshall hammer can produce either 50- or 60-mm of asphalt patch slab with 3-5% and 6-8% voids, respectively.
- It was found that one-side and double-side of compression method can manufacture 50- or 60-mm of asphalt patch slab with 6-8% voids, respectively.
- In terms of post gradation check-up, compression methods were generating slightly more fine aggregates than compaction ones as well as in comparison with the JMF. However, it was too severe to cause the significant gradation change.
- The production time of slab with 70-drop compaction was the most time consuming for five to eight minutes. The rest of production methods, including 21-drop compaction, one-side, and double-side of compression, consumed about three to five minutes to fabricate one patch slab.
- The slab of 3-5% voids made through compaction method was the best performance in wet rutting test performed by the Hamburg wheel tracking device. The slabs of 6-8% made either compaction or double-side compression were seemingly equal in performance of rutting test. However, the slab of 6-8% made through one-side compression was not as good as that made through double-side compression.
- The future work aim to evaluate the field performance and the asphalt patch slabs have been installed on the field in comparison with difference field maintenance approaches. More details will be reported in the near future.

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