Comparative study of moisture damage performance test

Adaweiah Taib\textsuperscript{1}, Fauzan Mohd Jakarni\textsuperscript{1}, Muhammad Fudhail Rosli\textsuperscript{1}, Nur Izzi Md Yusoff\textsuperscript{2} and Maniruzzaman Abd Aziz\textsuperscript{3}

\textsuperscript{1}Department of Civil Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
\textsuperscript{2}Department of Civil and Structural Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia 43600 Bangi, Selangor, Malaysia
\textsuperscript{3}Department of Geotechnics and Transportation, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

E-mail: adaweiahtaib@gmail.com & fauzan.mj@upm.edu.my

Abstract. This paper presents a comprehensive literature on moisture damage performance tests of asphalt mixtures. Moisture damage recognized as a cause for pavement distresses. The most common forms of moisture damage are adhesive failure between bitumen and aggregates. Adhesive failure is due to bitumen coating the aggregates are completely displaced by moisture, and stripping becomes visible in the asphalt mixtures. However, both quantitative and qualitative test do not focus on measuring the fundamental properties of the asphalt mixtures related to the moisture damage mechanisms of adhesion and cohesion. The results of the quantitative tests measured quantitatively, minimize the subjective evaluations of the test results. The quantitative are Tunnicliff and Root Conditioning (ASTM D4867) and Modified Lottman (AASHTO T283) test provide evaluation of moisture susceptibility of the asphalt mixture on the basis of strength and/or modulus ratio before and after conditioning. Other tests, such as Hamburg Wheel Tracking Device (HWTD) (AASHTO T324-04) provide measurement of moisture damage in terms of permanent deformation of the specimens. This paper is a review of the effectiveness of the selected available moisture damage performance tests. The analysis was conducted based on the success rate for each moisture damage performance tests.

1. Introduction

Road users in Malaysia feel uncomfortable driving on highway cause by existence of pavement distresses especially after monsoon season. These pavement distresses mostly happen due to moisture damage. Moisture damage or moisture susceptibility in asphalt pavements remain a main concern in the pavement construction almost a few decades ago. The common term used for moisture damage in asphalt pavements is stripping which a primary cause is of distress in asphalt pavement. Stripping commonly occur when moisture infiltrates the pavement and weakening the bond between the aggregate and bitumen. Stripping cause the reduction of pavement shear strength and could lead to several distress such as raveling, rutting, fatigue cracking [1], [28] of the binder to the pavement surface, which could decrease pavement’s skid resistance.

In [1] stated that various tests had been performed to evaluate moisture-susceptible asphalt mixture since 1930s. However, these tests are still producing wavering result in evaluating moisture susceptible in asphalt mixture. Solaimanian [27] pointed out that the tests can be classify into those...
evaluating the affinity between aggregate and asphalt in loose mix condition and those accustomed to evaluate the moisture sensitivity in compacted mix condition. At present accessible moisture damage performance test that had been standardized, for example, Boiling Water test (ASTM D3625) and Static Immersion test (ASTM D1664/AASHTO T182) only depend on subjective evaluation while Modified Lottman test (AASHTO T283) and Immersion Compression Test (AASHTO T165) rely on the principle of relative assessment of mechanical properties (indirect tensile strength, resilient modulus, marshal stability or compression strength) of conditioned sample and unconditioned sample. Meanwhile, other tests such as Saturation Ageing Tensile Stiffness (SATS) test [12], Environmental Conditioning System (AASHTO TP34) and Hamburg Wheel Tracking Test are also recognized to be used in assessing moisture damage performance of asphalt mixture.

This paper discussed the selected test methods for evaluating moisture susceptibility on various combinations of asphalt mixtures.

1 Moisture damage
1.1 General background of moisture damage. Moisture damage is manifested by infiltration of moisture or water through the asphalt binder-aggregate adhesion within an asphalt mixture. This circumstance may lead to a reduction of adhesion among the asphalt binder and aggregate known as stripping and may cause some of distress in pavement such as fatigue cracking and rutting. [10] described that moisture damage is one of the main cause that lead to early rehabilitation of asphalt pavement. They also stated that thermodynamic, chemical, physical, and mechanical processes are likely involved in this action. [26] describes that it is inevitable to dismiss the fact of existing of water in asphalt pavement and found that a few factors can become significant to the existing of water in pavement. Water can penetrate the pavement from the surface through cracking of pavement as explained by [9] that the water on pavement will infiltrate through small crack at the surface of pavement, connection of the air-void mechanism, from the bottom caused by increasing of ground water table, or from the sides. Besides, heating of aggregate throughout mixing process poorly conducted may cause existing of water in pavement.

Study by [25] summarized that moisture damage is a very indescribable type of distress and symbolizes an acclimatizing phenomenon when the pavement is exposed to the water or moisture. When water or moisture is in contact with bitumen and aggregates, the asphalt mixtures will lose its structural strength and stiffness. This problem will lead to pavement distress such as ravelling, stripping, fatigue cracking, surface wear and rutting, for longer term may lead to extensive damage and the serviceability of the pavement may be reduced.

As a conclusion, even though numerous research have concluded that moisture damage of asphalt mixture is tend to the adhesive failure than the cohesive failure, the basic understanding regarding to these failure are very indescribable to illustrate and researches on these two failure are limited. Thus, moisture damage mechanisms continue to become the most complicated distress and not completely understood.

1.1.2 Moisture damage mechanism. birgis [23] found that there were a few contributing factors that known to be as the failure mechanism in asphalt mixtures include pore pressure, hydraulic scour, detachment, displacement, spontaneous emulsification, and environmental factors. [8] explained that these mechanisms may act independently or coincides with each other that lead to adhesion failure in asphalt mixtures. Moreover, their studies also describe that other possible mechanism for stripping probably due to osmotic cause by the existing of salts or salt solution in the aggregate pores that forms an osmotic pressure gradient that sucks moisture through the bitumen. Two major failure types: loss of adhesion or loss of cohesion occurs from the action of these mechanisms [9].
### Table 1. Factor influencing moisture damage

| Factors                  | Determining Characteristics | Favourable Properties                                                                 | References |
|--------------------------|-----------------------------|---------------------------------------------------------------------------------------|------------|
| Aggregate Properties     | Surface texture, mineralogy, porosity, surface moisture, surface chemical composition and surface coating | Rough surface texture, carbonaceous aggregate, low silica content, optimum amount of porosity, surface dry aggregate, no coating | [18], [16], [17], [11] |
| Bitumen Characteristics  | Asphalt film thickness, viscosity, physical and chemical structure | High asphalt film thickness, High viscosity, existence of phenol and nitrogen | [18], [8], [11] |
| Construction Method      | Compaction method, drainage system, air void mechanism, | Adequate compaction, proper drainage system, low air void percentages, adapt water resistance additives on each layer of pavement | [16], [8], [11], [21] |
| Environmental Condition  | Climates, Environmental temperature | Warm climates, mild temperature (low rate of changing in temperature), no freeze-thaw cycles | [18], [11] |
| Imposed traffic load     | Traffic load                | Low traffic                                                                           | [18]       |

1.2 A Review on Moisture Susceptibility Test

Development of tests to evaluate moisture susceptibility of asphalt mixtures have been started since 1930s [29]. It has been conclusively been shown that since that time, a number of tests had been implemented in order to identify the proneness of asphalt mixtures to moisture damage [4], [11]. The test procedures in the present have tried to resemble the loss of strength that possibly occurs in the pavement so that the premature distress of asphalt mixtures can be recognized prior to construction. Diab and You (2013) expressed that even though continuous improvement on moisture susceptibility tests has been made in clarifying and understanding the mechanisms of moisture damage, a reliable and practical laboratory method that can simulate moisture damage in the field is still needed for agencies such as state highway agencies.

It is generally difficult to develop a laboratory test procedure that can fully simulate the field condition such as environmental condition, traffic and construction practices. Diab and You (2013) in his research state that some efforts have been made so far to develop a test procedure that would precisely determine the susceptibility of an asphalt pavement to moisture damage, however none of the moisture susceptibility test have been accepted widely due to lack of repeatability, difficulty of the process, expensive equipment, or lack of quantitative results. In [4] described that moisture susceptibility tests have a “conditioning and “evaluation” phase. The conditioning phase is a process to simulate the deterioration action on asphalt pavement in the field including environment condition, traffic load repetition, climate condition (humid and hot climate), air void level and others. For evaluation phase, the asphalt mixtures sample will then be assessed by visual evaluation (qualitative evaluation) and physical test (quantitative evaluation). In the visual evaluation, the percentages of retained asphalt coating is then determined after the conditioning process. While, physical test evaluation consist of strength or modulus and a ratio between the result from conditioned sample by the result from un conditioned sample is computed. If the ratio is less than standardized value, the sample will be clarified as moisture susceptible.
And [13] described in [27] that moisture susceptibility tests can be divided into two categories which is test on loose mixtures (qualitative test) and test on compacted mixtures (quantitative test). Following tests are national standard that currently been used widely by public agencies including AASTHO and ASTM.

- AASHTO T 165/ASTM D 1075 Effect of Water on Compressive Strength of Bituminous Mixtures
- AASHTO T 283/ASTM D 4867 Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage
- ASTM D 3625 Effect of Water on Bituminous-Coated Aggregate using Boiling Water
- ASTM D 4867 Effect of Moisture on Asphalt Concrete Paving Mixtures
- AASHTO T 324 Hamburg Wheel-Track Testing of Compacted Hot-Mix Asphalt.

1.2.1 Test on Loose Mixture (Qualitative Test). These types of tests are conducted on bitumen-coated aggregates by immersing samples into water. Some examples of these tests are boiling test, film strip, and static/dynamic immersion tests. Benefit of these tests is they are only consuming short time and less costly to conduct comparing with tests on compacted samples. However, these tests are not able of simulate pore pressure, traffic condition, and mix design properties to justify moisture susceptibility of asphalt mixture. The results are mostly qualitative and clarification of the results tends to be subjective as it is reliant on the evaluator’s judgement and experience. Besides, correlation between these types of tests to field performance of asphalt pavement is still unreliable.

In addition, these tests are suitable to be used for comparison between different aggregate-bitumen mixtures or uses of different anti-stripping additive to evaluate compatibility, stripping and strength of adhesion of asphalt mixtures. Mixtures that not achieved required standard of these tests will be considered fail and have higher probability to strip and should not be used. Though, successful results not necessarily mean that the mix can be used, as the effects of other factors are not taken into consideration in these tests. Most popular test conducted on loose samples currently used such as Static Immersion test (AASHTO T182) and Boiling Water test (ASTM D3625). Table 2 will provide explanation on the only established standard test on loose mixture according to AASTHO and ASTM.

1.2.2 Test on Compacted Sample (Quantitative Test). Stated in [27] that this type of test are performed on laboratory-compacted samples or taken from field in the form of cores or slabs. Some of the tests that currently established as standard tests and widely used according to ASTM or AASHTO are immersion-compression test (ASTM D1075/AASHTO T165), Modified Lottman test (AASHTO T183) and Tunnicliff-Root test (ASTM D4867). Other tests such as Hamburg wheel tracking test (AASHTO T324), Environmental conditioning system (ECS) (AASHTO TP34), Simple performance test (SPT), Asphalt Pavement Analyser (APA), moisture induced sensitivity test (MIST) and saturated ageing tensile stiffness (SATS) are also taken into consideration but rarely used due to lack of standardization in the procedures used in term of sample preparation and complexity of the procedures. The main benefits of these tests is that it can assess the physical and mechanical properties while the traffic action and pore pressure effects can also be considered [27]. The results provided are measured quantitatively and this will reduce the higher variability of the test results due to visual evaluation. However, the weaknesses from these tests are it involved very expensive and complex testing equipment, take longer time to perform and demanding more laborious test procedures. Summarize for some of these tests that currently been widely used by highway authority is briefly explained in the following table 3.

1.3 Comparison of Previous Moisture Susceptibility Test on Various Asphalt Mixtures
From table 4 to table 6, it can be concluded that asphalt mixture consist of limestone aggregate will give more resistant to moisture damage. This can be seen from result shown in table 4 provided by [19], asphalt mixture consist of limestone aggregate produce the highest tensile strength ratio (TSR)
which is 61.7% compare to asphalt mixture consist of slate aggregate which is 48.6% and granite which is 58.5% with the same type of bitumen without any anti-stripping additives after conditioning by Modified Lotmann test. While in table 5 after immersion compression test, it can be seen from data provided by [21] that asphalt mixture consist of limestone give the highest Marshall stability ratio which is 98% compare to asphalt mixture consist of granite (89.1%), sandstone (87.8%) and Harwar Quartzite (86.5%). Whereas in table 6, after boiling water test being conducted on loose asphalt mixture, the result by [7] shown that asphalt mixture consist of limestone produce the highest percentage of aggregate remain coated by bitumen which is 98.7% and 98.4% compare to other asphalt mixture which consist of quartzite (59.7%), granite (84.2%) and andesite (13.5%).

Furthermore, addition of anti-stripping additive will increase asphalt mixture resistant to moisture damage exponentially. It can be seen from the research carried by [5] in table 4 that the TSR value recorded by asphalt mixture with addition of anti-stripping additives such as limestone dust is very high which is 96% compare to asphalt mixture without anti-stripping additives which is recorded to be 48% and 60% with constant type of bitumen and aggregate. This circumstance also can be seen in research by [19] that also shown high TSR ratio ranging from 72% to 95.2% in asphalt mixtures with addition of anti-stripping additives compare to without any additives which is in range of 48% to 61.7%. While in other test such as immersion compression test, addition of antistripping additive also give the same result. With respect to the table 5, it was found that with the same type of aggregate and bitumen, the TSR value for asphalt mixtures in addition of anti-stripping additives is higher than without any addition of anti-stripping additives [21]. By referring to table 6, result from boiling water test also shown the same situation. Percentage of aggregate remain coated with bitumen is higher in asphalt mixtures with the addition of anti-stripping additives compare to the asphalt mixture without any additives with the fixed aggregate and bitumen.

Table 2. Test methods on loose asphalt mixture

| Test name                      | Measured parameter | Approach of the test | Description of test procedure |
|--------------------------------|--------------------|----------------------|-------------------------------|
| Static immersion (AASHTO T1&2) | Percentage of aggregate remain coated after static immersion in water | Focusing on adhesion bond failure | This test required a sample of asphalt mixture been immersed in a jar filled with 600 mL of distilled water after been cured for 2 hours at 60oc and cooled to room temperature. The jar is then capped left settled in a 25oc water bath for 16 to 18 hours. The degree of stripping is visually evaluated while the mixture still in the jar. |
| Boiling water (ASTM D3625)     | Percentage of aggregate remain coated after boiling in water | Focusing on adhesion bond failure | The test involves placing loose sample of asphalt mixtures into boiling water and being stirred using glass rod. After 10 minutes, the mixture is left to cool while the stripped bitumen is detached away. Then, the mixture is removed from the water and being dried in room condition |

In general, types of bitumen also have a significant impact in moisture resistant to moisture damage. Uses of modified bitumen will increase the moisture resistant towards moisture damage. This view is supported by [3] who writes that increasing of binder grade will then lead to reducing of retained stiffness of bitumen. This circumstance will result in reduction of resistant towards moisture damage on asphalt mixture.
Table 3. Test methods on compacted asphalt mixture

| Test name                                  | Measured parameter                                                                 | Description of test procedure                                                                                                                                                                                                                                                                                                                                 |
|--------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Immersion compression test (ASTM D1075/AASHTO T165) | The ratio of average strength of conditioned specimens over controlled specimens is being used as a parameter to measure loss of strength caused by moisture damage | Core specimens are compacted with a double plunger at 3,000 psi for two minutes to achieve air void content at 6%. The procedure involves six specimens which have been divided equally into two groups known as control group and conditioned group. The control group is kept dry while the specimens in conditioned group are immersed in a water bath at 120°F (49°C) for four days or at 140°F (60°C) for one day. Then, the compressive strength of the specimens from both groups is being measured at 77°F (25°C) at a loading rate of 0.05 in./min per inch of height. So, for Marshall mix design specimen with 4 inches diameter, loading rate of 0.2 in./min will be used. |
| Lottman test                               | Ratio of test values conditioned specimen to control group specimen (tensile strength ratio, TSR) including freeze and thaw cycle | Nine compacted Marshall specimens of 100mm in diameter and 63.5mm in height which are being divided into 3 groups equally.  
  • Group 1: Control group, dry  
  • Group 2: Vacuum saturated at 660mmHg with water for 30-minutes.  
  • Group 3: Vacuum saturation followed by freeze cycle at -18°C for 15 hours and then subjected to a thaw at 60°C for 24 hours. After the conditioning procedure, the Resilient Modulus (MR) and/or Indirect Tensile Strength Test (ITS) are conducted on each specimen. The loading rate for testing at 55°F (13°C) is 0.065 in./min while 0.150 in./min are being used for testing at 73°F (23°C). |
| Tunnicliff – Root Test (ASTM D4867)        | Ratio of test values conditioned specimen to control group specimen (tensile strength ratio, TSR) without freeze and thaw cycle | Improvising from Lottman test  
  • Load rate increases to 2 in/min from 0.065 in/min  
  • Test temperature increases from 55°F (12.8°C) to 77°F (25°C)  
  • Presaturation of 55% -80% compared to an infinite level in Lottman test  
  • Removing freeze cycle condition |
| Modified Lottman Test (AASHTO T283)       | Ratio of test values conditioned specimen to control group specimen (tensile strength ratio, TSR) with/without freeze and thaw cycle | The procedure combines features of both the Lottman and Tunnicliff and Root procedures. The Lottman procedure attempts to achieve a 100 percent saturation level in its specimens, while the Tunnicliff and Root procedure attempts to control the level of saturation between 55 and 80 percent. Concern that oversaturation induces damage in specimens that is not associated with moisture damage but rather with the oversaturation of the specimen, meant that for the Modified Lottman procedure the degree of saturation was decreased to between 60 to 80 percent. As the saturation level achieved by partial vacuum is primarily responsive to the magnitude of the vacuum and relatively independent of the length of time, this reduced saturation was achieved by reducing the partial vacuum from 600 mm Hg to 508 mm Hg. |
### Table 4. Modified Lottman test

| Mixture Design | Aggregate       | Bitumen   | Anti-stripping additives | Strength/Criteria Ratio | References |
|----------------|-----------------|-----------|--------------------------|-------------------------|------------|
|                | Granite         | Pen 60/70 | Quarry dust              | Min. Req. (%)           | Test result (%) |               |
| M              | Granite         | Pen 60/70 | Ordinary Portland Cement | 70                      | 82.0        | 70.9         | [6]           |
| M              | Granite         | Pen 60/70 | Polymer Modifier          | 70                      | 86.2        | 76.7         | [6]           |
| M              | L(MLDG)        | Pen 60/70 | Calcium Hydroxide Limestone dust | 80                      | 68          |              | [5]           |
| M              | L(MLDG)        | Pen 60/70 | No additives              | 80                      | 48          |              | [5]           |
| M              | L(MLDG)        | Pen 80/100 | Calcium Hydroxide Limestone dust | 80                      | 60          |              | [5]           |
| M              | L(MLDG)        | Pen 80/100 | No additives              | 80                      | 40          |              | [5]           |
| SP             | Granite        | PG 64     | Not available             | 80                      | 97.3        |              | [2]           |
| SP             | Granite        | PG 70     | Not available             | 80                      | 94.7        |              | [2]           |
| M              | Granite        | PG 64     | Not available             | 80                      | 99.8        |              | [2]           |
| M              | Granite        | PG 70     | Not available             | 80                      | 97.3        |              | [2]           |
| SP             | Slate          | PG 64-22  | No additive               | 80                      | 48.6        |              | [19]          |
| SP             | Slate          | PG 64-22  | Hydrated lime             | 80                      | 80.8        |              | [19]          |
| SP             | Slate          | PG 64-22  | Amine                     | 80                      | 95.2        |              | [19]          |
| SP             | Slate          | PG 64-22  | Phosphate Ester           | 80                      | 83.5        |              | [19]          |
| SP             | Limestone      | PG 64-22  | No additive               | 80                      | 61.7        |              | [19]          |
| SP             | Limestone      | PG 64-22  | Hydrated lime             | 80                      | 80.9        |              | [19]          |
| SP             | Limestone      | PG 64-22  | Amine                     | 80                      | 81.2        |              | [19]          |
| SP             | Limestone      | PG 64-22  | Phosphate Ester           | 80                      | 72.0        |              | [19]          |
| SP             | Granite        | PG 64-22  | No additive               | 80                      | 58.5        |              | [19]          |
| SP             | Granite        | PG 64-22  | Hydrated lime             | 80                      | 85.7        |              | [19]          |
| SP             | Granite        | PG 64-22  | Amine                     | 80                      | 81.2        |              | [19]          |
| SP             | Granite        | PG 64-22  | Phosphate Ester           | 80                      | 79.0        |              | [19]          |
| SP             | L+G (less angular) | PG 64-22 | No additive               | 80                      | -           | 69           | [20]          |
| SP             | L+G (less angular) | PG 64-22 | Hydrated lime             | 80                      | -           | 77           | [20]          |
| SP             | L+G (more crushed) | PG 70-28 | No additive               | 80                      | -           | 79           | [20]          |
| SP             | L+G (more crushed) | PG 70-28 | Hydrated lime             | 80                      | -           | 85           | [20]          |
| SP             | L+G (more crushed) | PG 70-28 | Fly ash                   | 80                      | -           | 91           | [20]          |

Note: L(MLDG)=Limestone (Mid limits of dense graded) L+G = Limestone+Gravel
### Table 5. Immersion compression test

| Mixture Design | Aggregate | Bitumen | Anti-stripping additives | Strength/Stability Ratio | References |
|----------------|-----------|---------|--------------------------|--------------------------|------------|
| M Granite      | VG 30     | No additives |                       | 70 | 89.1 | [21] |
| M Granite      | VG 30     | Hydrated lime |                       | 70 | 96.8 | [21] |
| M Limestone    | VG 30     | No additives |                       | 70 | 98  | [21] |
| M Sandstone    | VG 30     | No additives |                       | 70 | 87.8 | [21] |
| M Sandstone    | VG 30     | Hydrated lime |                       | 70 | 97  | [21] |
| M Harwar Quartzite | VG 30 | No additives |                       | 70 | 86.5 | [21] |
| M Harwar Quartzite | VG 30    | Hydrated lime |                       | 70 | 94.5 | [21] |
| SP Crushed stone | PG 64-16 | Class C Fly Ash |                       | 70 | 95  | [9] |
| SP Crushed stone | PG 64-16 | Class F Fly Ash |                       | 70 | 112 | [9] |
| SP Crushed stone | PG 64-16 | Cement Kiln Dust |                       | 70 | 95  | [9] |
| SP Crushed stone | PG 64-16 | Hydrated lime |                       | 70 | 93  | [9] |
| SP Crushed stone | PG 64-16 | HP Plus (amine chemical) |                       | 70 | 97  | [9] |
| SP Crushed stone | PG 64-16 | No additives |                       | 70 | 97  | [9] |

Notes: M = Marshall, PG = Performance grade, SP = Superpave, VG = Viscosity grading

### Table 6. Boiling water test

| Mixture Design | Aggregate | Bitumen | Anti-stripping additives | Strength/Criteria Ratio | References |
|----------------|-----------|---------|--------------------------|--------------------------|------------|
| SP Limestone+Gravel (less angular) | PG 64-22 | No additive |                       | 90 | 85.0 | [20] |
| SP Limestone+Gravel (less angular) | PG 64-22 | Hydrated lime |                       | 90 | 94.0 | [20] |
| SP Limestone+Gravel (less angular) | PG 64-22 | Fly ash |                       | 90 | 95.0 | [20] |
| SP Limestone+Gravel (more crushed) | PG 70-28 | No additives |                       | 90 | 98.0 | [20] |
| SP Limestone+Gravel (more crushed) | PG 70-28 | Hydrated lime |                       | 90 | 99.0 | [20] |
| SP Limestone+Gravel (more crushed) | PG 70-28 | Fly ash |                       | 90 | 99.0 | [20] |
| M Granite      | VG 30     | Hydrated lime |                       | 95 | >95  | [21] |
| M Sandstone    | VG 30     | Hydrated lime |                       | 95 | >95  | [21] |
| M Limestone    | VG 30     | Hydrated lime |                       | 95 | >95  | [21] |
| M Delhi Quartzite | VG 30    | Hydrated lime |                       | 95 | >95  | [21] |
| M Harwar Quartzite | VG 30    | Hydrated lime |                       | 95 | >95  | [21] |
| SP Quartzite   | Pen 60/70 | No additives |                       | 95 | 59.7 | [7]  |
| SP Quartzite   | Pen 60/70 | Hydrated lime |                       | 95 | 96.5 | [7]  |
| SP Quartzite   | Pen 60/70 | Zycosoil |                       | 95 | 98.6 | [7]  |
| SP Granite     | Pen 60/70 | No additives |                       | 95 | 84.2 | [7]  |
2. Conclusions
This study indicates that asphalt mixtures consist of limestone aggregate, modified bitumen and addition of anti-stripping additives will provide more resistant towards moisture damage. This result supported by [22], [30] and [6] in their previous research. Hydrated lime tends to be the most popular among others anti-stripping additives because it had been proven effective in increasing resistance of asphalt mixture towards moisture. While polymer modified bitumen are most popular to be used in asphalt mix design because it can sustain moisture damage more than commonly used asphalt binder. Generally, Modified Lottman test, Immersion Compression test and Boiling Water test can be expected to be reliable test on evaluating the moisture susceptibility of asphalt mixture.

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