Study on Improvement in Performance of Moisture Damage in Asphalt Mixtures with Various Anti-Stripping Agents

SK.R.AFFRIN, Y.ANAND BABU

Abstract— One of the main causes of distress in asphalt pavements is moisture damage. In this study, the effectiveness of hydrated lime in improving the resistance of asphalt mixtures to moisture susceptibility is evaluated to determine the influence of compaction technique (Marshall and roller compaction) on the moisture susceptibility of asphalt mixtures. The asphalt mixtures were prepared using aggregate (granite), and asphalt binder (VG-30). In addition, one of the common anti-stripping additive, hydrated lime is used to improve the asphalt mixture resistance to moisture damage. Asphalt mixes prepared at optimum binder content are tested for indirect tensile strength and retained stability. Mixes modified with hydrated lime improved the stability and indirect tensile strength when compared to the control mix. Marshall compacted samples performed well than the roller compacted samples. An Optimum hydrated lime content of 2 percent is expected to improve the resistance of asphalt mixtures to moisture induced damage.

Keywords- *Compaction technique; Asphalt mixture; Hydrated lime; Indirect tensile strength; Marshall compaction; Roller compaction*

1. INTRODUCTION

Moisture damage is a primary issue in asphalt distresses. The unfavorable effects of water in asphalt mixtures have been studied widely from last 35 years. The moisture damage is generally referred to as degradation of the mechanical properties of the material due to the presence of moisture.
First of all it is important to identify the sources of water ingress and egress from pavement. Generally water finds its way into the pavements through the pavement surfaces and shoulders, capillary action, and seasonal changes in the water table. The significance of the particular routes depends on the materials and climate. A major route of water entry into pavement is also through the crack and shoulder infiltration, and to some extent sub grade capillary action, which affinity towards stripping. Stripping is the physical separation of bitumen from the aggregate produced by the loss of adhesion between the bitumen and the aggregate surface primarily due to the action of water or water vapour (Kamaruddin and Napiah, 2011).

Tensile Strength Ratio (TSR) is used to measure the stripping potential of various HMA mixtures. According to AASHTO T283 process limiting TSR values of 0.8 is used simultaneously for comparison of different mixes. Normally the results are reported in terms of percentage retained strength of the specimens. The retained strengths are determined by comparing the dry tensile strength to the wet conditioned tensile strength of the bituminous mixtures. Anti-stripping agents are necessary if a particular mix plan has been showing susceptible to moisture-induced damage. Liquid anti-stripping agents and lime additives are the most commonly used types of anti-stripping agents. Various studies indicate that anti- stripping additives can positively affect the binder-aggregate bonding characteristics and mixture performance by reducing mixtures moisture susceptibility. Moisture damage causes deterioration of asphalt pavements, which leads to an annual extra vehicle operating costs and has a considerable cost-effective impact in terms of excessive maintenance and rehabilitation costs.

2. MATERIALS USED

2.1 Physical Properties of Aggregate, Binder and Hydrated lime used

Physical properties of Aggregate

Property	Method of test	Specifications
Aggregate Impact Value	IS 2386 Part IV	max 30%
Los Angeles Abrasion Value	IS 2386 Part IV	max 30%
Water Absorption Value	IS 2386 Part III	max 2%
Specific Gravity	IS 2386 Part III	2.5-3
Combined (EI + FI) Index	IS 2386 Part I	max 30%

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R.SK.AFFRIN, *Student, M.Tech (Transportation Engineering) MVR College of Engineering and Technology, Vijayawada, Andhra Pradesh, INDIA, ph no: 8428098811*
Y.ANAND BABU, *M.Tech, Associate Professor (Dept. of CIVIL Engg), MVR College of Engineering and Technology, Vijayawada, Andhra Pradesh, INDIA, ph no: 9160327543*

Physical Properties of the asphalt as per IS: 73 (2006)

Property	BIS Test	VG -30
Penetration 25˚C (100 g, 5 s),0.1mm	IS 1203-1978	50-70
Softening point(Ring and ball), ˚C, minimum	IS 1205-1978	47 min
Ductility at 27 ˚C (5 cm/min pull), minimum	IS 1208-1978	40
Specific gravity	IS 1202	0.99

Physical Properties of Anti stripping agents (Hydrated lime)

The most widely used antistripping additive is hydrated lime. Lime treatment helps mitigate adhesive and cohesive failure, tends to stiffen the mix, thus extending pavement life. The effect of hydrated lime as anti-stripping agents on moisture susceptibility is tested using indirect tensile test and retained stability test methods. The structure of hydrated lime consists of different size fractions. The larger size fraction performs as filler and increases the stiffness of the bituminous mixture. The smaller size fraction increases binder film thickness enhancing viscosity of the binder, and improving the binder cohesion and stiffness. Hydrated lime content is added in dosages of (0%, 1%, 1.5%, 2%, and 2.5%) by weight of aggregate. The hydrated lime was added to the heated aggregates before the addition of the asphalt binder.

3. EXPERIMENTAL WORK

One type of mix is investigated in this study i. e Bituminous Concrete (BC) which is most widely used in Indian roads. Bituminous concrete (BC) generally used as wearing and profile corrective courses with single layer thickness of a of 25 mm to 100 mm. Specifications for bituminous concrete mix design as per MoRTH (Ministry of Road Transport and Highways) with composition of BC gradation is shown in Table 3.1

Mix Preparation

First series of specimens as specified in the experimental plan are prepared. Enough material is mixed to produce atleast 2 specimens at every mix for repeatability. Extra mixture will be needed for trials to establish the compaction required and for determining the optimum binder content of the mix.

Table 3.1 Composition of BC

Mix designation	Grading 1	Grading 2
NMAS	13 mm	10 mm
Layer thickness	35 to 40 mm	25 to 30 mm
Sieve size, mm	Percent passing	
26.5	100	100
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content by weight of total mix	5.0 to 6.0	5.0 to 7.0
Bitumen grade	VG 20, 30	VG 20, 30

4. DETERMINATION OF OPTIMUM BINDER CONTENT

The test is conducted in accordance with ASTM D 6926-10: “Standard practice for preparation of bituminous specimens using Marshall apparatus” is to be followed. General size of the specimens used is 101.7 mm diameter by 63.5 mm in thickness. The preparation of specimens for Marshall mix designs requires representative samples of the aggregates to be used. The two prime features of the Marshall method of designing mixes are density, Stability. The samples of approximately 1200 g in weight shall be combined to the desired gradation. Test procedure consists of Marshall mix design, specimen collection, compaction. By conducting Marshall Stability test optimum binder content (OBC) is determined. Using this optimum binder content samples are prepared in according to the test matrix of experimental plan provided in the table 4.1

Table 4.1 The test matrix

Test method	Process	Hydrated lime content, %				
		0	1	1.5	2	2.5
Indirect tensile strength test	Wet	2	2	2	2	2
	Dry	2	2	2	2	2
Retained stability test for Marshall compacted samples	Wet	2	2	2	2	2
	Dry	2	2	2	2	2
Retained stability test for roller compacted samples	Wet	2	2	2	2	2
	Dry	2	2	2	2	2
Total		12	12	12	12	12

5. DETERMINATION OF OPTIMUM MOISTURE CONTENT

In this test, firstly it is important to attain the compaction effort that yields 6 to 8% air voids: Standard test procedure for indirect tensile strength requires that the test specimens are to be compacted for 6 to 8% voids. As such the number of blows to be applied on the test specimen during its preparation has to be recognized. To ascertain this, four test specimens at optimum binder content of 5.5% (by weight of mix) are prepared by applying 20, 30, 40 and 50 blows of Marshall hammer on each face of the specimen. Then the percentage of air voids in the compacted test specimen is calculated. From the data, graph is plotted for the number of blows versus air voids as shown in Figure5.1. From the graph it can be observed that 6 to 8% air voids are achieved at 40 to 47 blows.

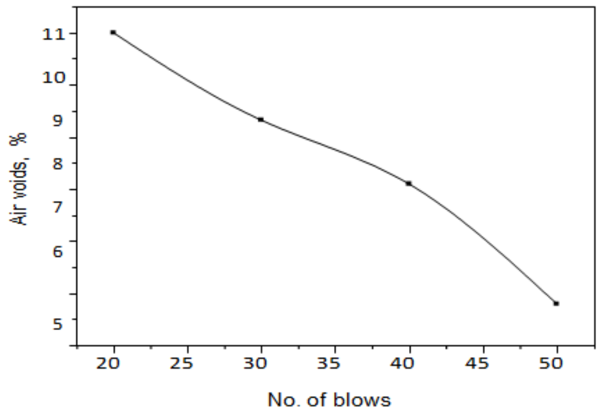

Figure 5.1 Variation of air voids as a function of number of blows

6.INDIRECT TENSILE STRENGTH TEST RESULTS

6.1 Variation of indirect tensile strength as a function of hydrated lime content for conditioned and uncondioned samples

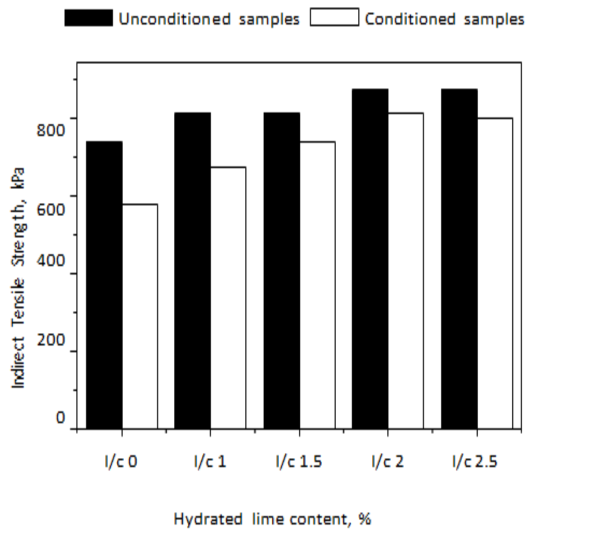

Figure 6.1 Variation of indirect tensile strength as a function of hydrated lime content for conditioned and unconditioned samples

6.2 Variation of tensile strength ratio as a function of hydrated lime content

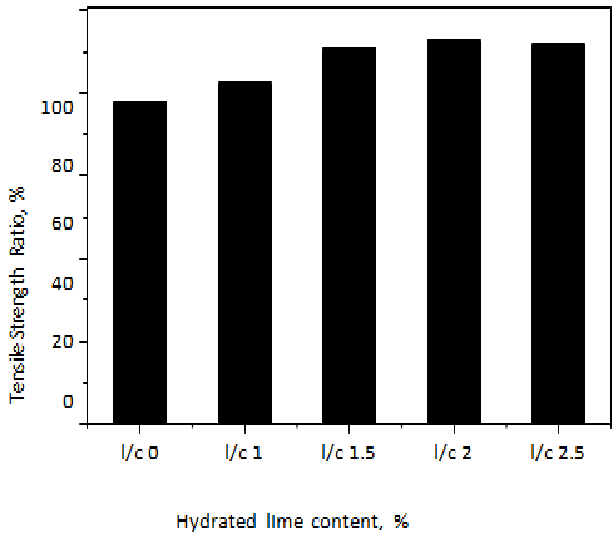

Figure 6.2 Variation of tensile strength ratio as a function of hydrated lime content

6.3 Variation of stability as a function of hydrated lime content for condioned and uncondioned samples

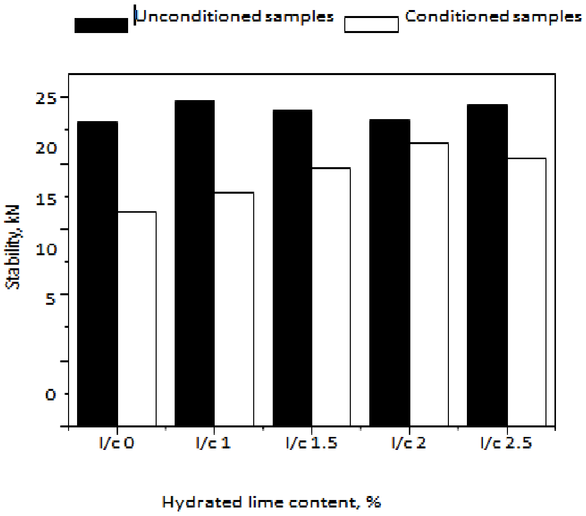

Figure 6.3 Variation of stability as a function of Hydrated lime content for unconditioned and conditioned samples

6.4 Variation of retained stability as a function of hydrated lime content

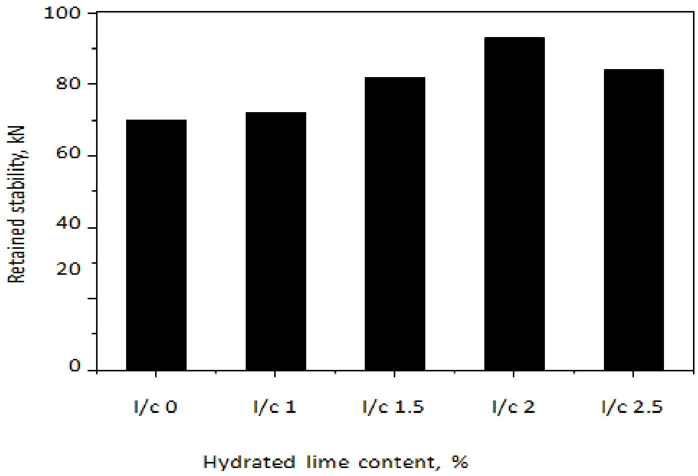

Figure 6.4 Variation of retained stability as a function of Hydrated lime content

6.5 Variation of stability as a function of hydrated lime content unconditioned and conditioned samples

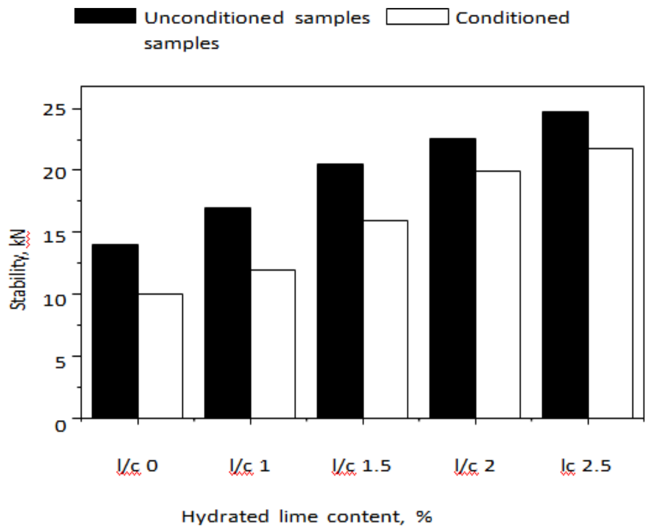

Figure 6.5 Variation of stability as a function of hydrated lime content unconditioned and conditioned samples

6.6 Variation of retained stability as a function of hydrated lime content

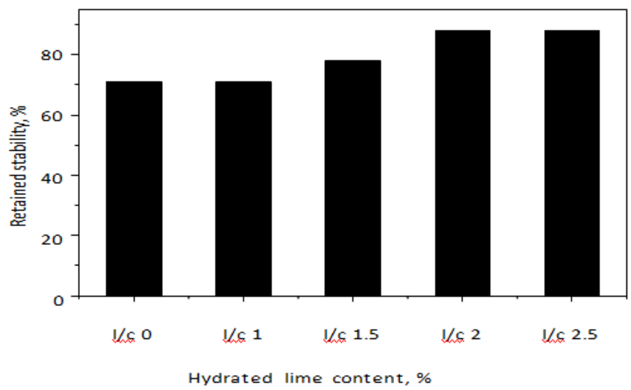

Figure 6.6 Variation of retained stability as a function of hydrated lime content

7. COMPARISON OF THE TEST RESULTS OF MARSHALL AND ROLLER COMPACTED SAMPLES

The unconditioned and conditioned stability and retained stability values of samples prepared from Marshall compaction are compared with that of roller compaction for each identical mix. From the comparison, it was observed that Marshall compacted samples are considerably better performing than roller compacted samples. Almost all the mixes of Marshall Compaction showed significantly higher stability and retained stability values when compared to roller compacted samples. It was observed noticeably from the Figure 7.1 to 7.3.

7.1 Variation of stability as a function of hydrated lime content for Marshall compacted versus roller compacted unconditioned samples

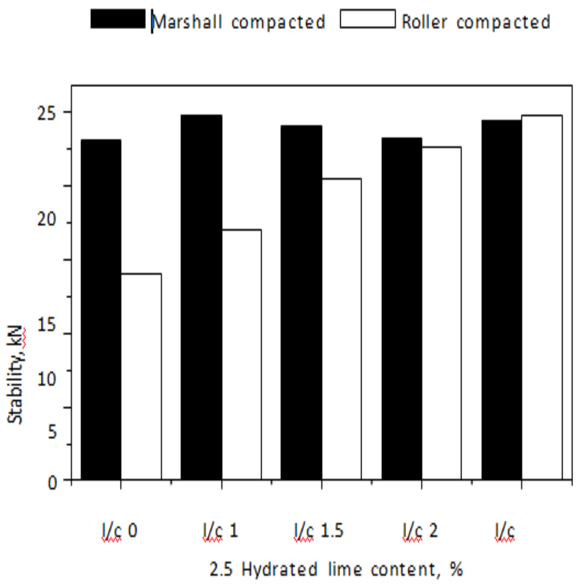

Figure 7.1 Variation of stability as a function of hydrated lime content for Marshall compacted versus roller compacted unconditioned samples

7.2 Variation of stability as a function of hydrated lime content for Marshall compacted versus roller compacted conditioned samples

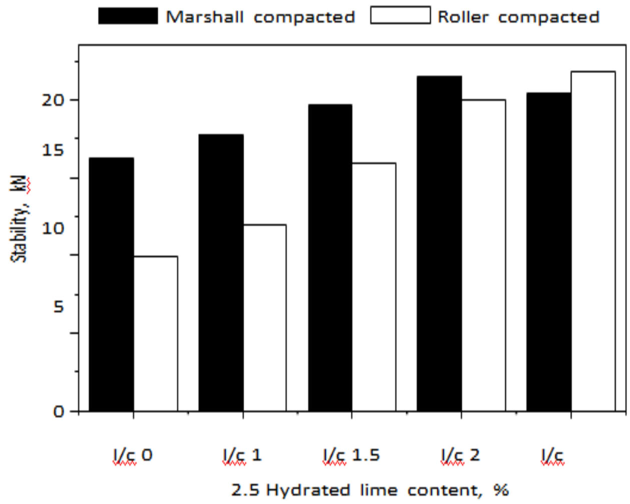

Figure 7.2 Variation of stability as a function of hydrated lime content for Marshall compacted versus roller compacted conditioned samples

7.3 Variation of retained stability as a function of hydrated lime content for Marshall and roller compacted samples

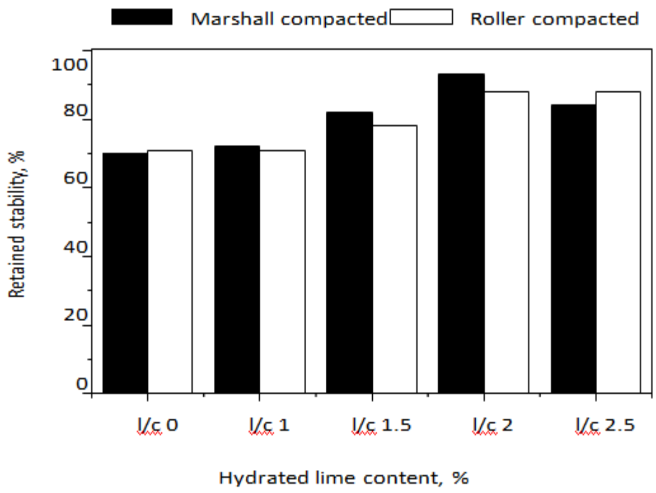

Figure 7.3 Variation of retained stability as a function of hydrated lime content for Marshall and roller compacted samples

7.4 Air voids in Marshall and roller compacted samples

Table 4.4 Air voids in Marshall and roller compacted samples

Marshall compacted		Roller compacted	
Unconditioned	Conditoned	Unconditioned	Conditoned
5.87	5.09	7.26	7.17
3.73	4.9	5.88	6.22
3.52	3.59	4.26	4.85
3.31	3.58	3.34	3.82
2.99	3.31	2.67	2.85

Two reasons were drawn for this differentiation, firstly based on the air voids data shown in Table 4.4, that there is higher percentage of air voids in roller compacted samples as compared to the Marshall compacted samples. Hydrated lime contents also having the influence on the air voids in asphalt mixes. Due to the fact that air voids are too low at 2.5 percent hydrated lime content, addition of hydrated lime higher than this value tend to increase air voids due to insufficient compaction effort in Marshall compacted samples (Albayati, 2012). And secondly, during the coring process the roller compacted slabs causes elongation of aggregate due to the drilling stroke of the core cutting machine. Thus, it can be concluded that the Marshall compacted samples exhibits better performance when compared to the roller compaction.

CONCLUSIONS

Based on the experimental results, following conclusions are drawn from this study:

Hydrated lime is widely used across the world in improving the resistance of asphalt mixtures to the moisture damage. However, it is proved that the use of hydrated lime as anti stripping agent is very effective in improving the resistance of asphalt mixtures to moisture susceptibility in case of unconditioned and conditioned samples in ITS and retained stability test methods. In this study, influence of compaction method on the moisture susceptibility of asphalt mixtures was studied. On behalf of this, the cored samples which are extracted from the roller compacted slabs are compared with Marshall compacted samples for their resistance to the moisture damage performance in asphalt mixtures. It was observed that Marshall compacted samples are considerably better performing when compared to the roller compacted samples. The optimum content of 2 percent hydrated lime is expected to produce long-lasting asphalt mixtures with superior resistance to moisture induced damage.

i. The optimum content of hydrated lime as an additive to improve the tensile strength ratio and retained stability of asphalt mixtures is found to be 2%. At 2% hydrated lime content, indirect tensile strength and stability of the unconditioned and conditioned mixes are attaining higher values. Though 2.5% hydrated lime content resulted having the in relatively higher values of strength, 2% hydrated lime is selected from cost effective point. Further, the tensile strength ratio of BC mix satisfactorily met the MORTH criteria at 2% hydrated lime content. The addition of hydrated lime has improved the indirect tensile strength and stability values for both unconditioned and conditioned mixes.

ii. It is due to its evenly and well distribution of hydrated lime with combining effects like increase in stiffness, strength, and toughness of mix that induces better resistance of mix against degradation in the presence of moisture. Hydrated lime induces asphalt aggregate interfacial bonding that produces better resistance to stripping.

iii. Marshall compacted samples are considerably better performing when compared to the roller compacted samples. Occurrence of this result is due to increase in air voids in roller compacted samples when compared to the Marshall compacted samples. Further, the coring of samples from the roller compacted slabs causes elongation of aggregate due to the drilling stroke of core cutting machine which leads to decrease in stability.

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BIOGRAPHIES

SK.R.AFFRIN *Student, M.Tech (Transportation Engineering) MVR College of Engineering and Technology, Vijayawada, Andhra Pradesh, INDIA, ph no: 8428098811*

Y.ANAND BABU *M.Tech, Associate Proffesor (Dept. of CIVIL Engg), MVR College of Engineering and Technology, Vijayawada, Andhra Pradesh, INDIA, ph no: 9160327543*