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LABORATORY EXAMINATION FOR THE EFFECT OF ADDING HYDRATED LIME ON THE MOISTURE DAMAGE RESISTANCE OF ASPHALT CONCRETE MIXTURES

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Abstract

The main objective of this study is to investigate the effect of adding hydrated lime on the moisture damage resistance of asphalt concrete mixtures. In this study two samples of asphalt concrete mixture were prepared, the first sample represent control mixture, and the second sample contain hydrated lime with rate (0.5, 1, 1.5, 2.0, 2.5%) by the total weight of aggregate. The properties of control mixture and Lime-asphalt concrete mixture were evaluated by Marshall tests results, Indirect Tensile Strength (ITS) results, and retained Marshall Stability (RMS) test results. The results for these tests indicated improvement in mixture proprieties, increased resistance of asphalt concrete against moisture damage, and reduced effect of water on the properties of asphalt concrete. As a final result, the use of (2%) hydrated lime enhanced asphalt concrete properties and produce durable mixtures for highway construction.

Keywords: Asphalt Concrete, Hydrated Lime, Indirect Tensile Strength, Moisture Damage, Retained Marshall Stability.

الدراسة المختبريه لتأثير اضافة مادة الجير المطفأ على مقاومة الاثر الاتلافي للماء على الخلطات الاسفلتية

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الخلاصة

ان الهدف الرئيسي من هذه الدراسة هو لتقيم تاثير اضافة مادة الجير المطفأ على مقاومة الاثر الاتلافي للماء على الخرسانه الاسفلتية. في هذه الدراسة تم انتاج نوعين من الخلطات الإسفلتية النوع الاول الذي يمثل الخلطة القياسية , والنوع الثاني الذي يحتوي على مادة الجير المطفأ وبنسب(0.5,1.0,1,5,2.0,2.5%) من وزن الركام الكلي. خصائص الخلطات تم تقيمها من خلال فحوصات مارشال ألقياسية , مع الاضافة الى فحص مقاومة مارشال ألمسترجعه وفحص مقاومة الشد الغير المباشرة. وتشير نتائج هذه الفحوصات الى تحسن خصائص الخلطات مع ازدياد نسبة الجير مطفأ, وكذلك ازدياد مقاومة الخلطات لتأثير الماء من خلال تحسن نتائج الفحوصات المستخدمه لتقيم مقاومة الخلطات للتأثير الرطوبي. ونتيجة لذلك ان استخدام مادة الجير المطفأ كمادة مالئة وكمضاف وبنسبة(2.0%) من وزن الركام ادى الى انتاج خلطات اسفلتية ذات خصائص جيده وديمومة عالية تستخدم في انشاء الطرق.

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1. Introduction

Flexible pavement or asphalt concrete is one of the most commonly types of pavement used in highway construction projects in the world. The term of asphalt concrete describes the flexible pavement layer that constructed through mixing asphalt binder with aggregate, and resting on the subbase and subgrade soil layers. Environmental stresses resulting mainly by the water (moisture damage), and temperature (temperature cracks) which influence on the pavement performance **(Paul H Wright, et al, 2004).** Moisture damage effects represent on the stripping action of water that entered the asphalts concrete and destroy the bonding forces between the asphalt binder film and aggregate, which lead to reduce pavement durability against distresses. The asphalt concrete materials such as asphalt properties, and aggregate characteristics & composition, in addition to environmental factors, are the main factors effecting on the moisture damage resisting **(Stuart KD, 1990).** To improve the resisting of asphalt concrete to moisture damage, many method where obtained, which depend on the modified asphalt concrete properties. The modification include on using anti- striping materials with asphalt mixtures to reduce the moisture damage effects. The rule of anti-striping additives is to increase physico-chemical bond between the bitumen and aggregate, and to improve wetting by lowering the surface tension of the bitumen **(Majidzahed K, et al, 1968).**

Hydrated lime has been used in asphalt mixtures for a long time as mineral filler and anti-striping additives. The hydrated lime structure consists of large and small particles, which make hydrated lime works as filer and as anti-striping additives **(Amjad, 2011).** Researchers observed that when hydrated lime coats aggregate particles, it induces polar components in asphalt cement to bond to the aggregate surface. The effect also inhibits hydrophilic polar groups in asphalt from congregation on the aggregate surface **(McGennis et al, 1984).**

The main objective of this study is to investigate the effect of hydrated lime on the moisture damage resistance of asphalt concrete mixture depending on the flowing tests (Marshall tests), (retained Marshall stability), and (indirect tensile strength test). The lime-HMA contains hydrated lime at (0, 0.5, 1, 1.5, 2, and 2.5%) by the dry wet of aggregate and as partial replacement of filler material.

2. *Literature Review*

(Al-Suhaibani,1992) evaluated the mineral properties of hydrated lime and other local fillers available is Saudi Arabia. The mechanical properties of the mixes were studied using tests such as the resilient modulus test, the indirect tensile strength test, Hveem stability, and Marshall Criteria. The research results revealed that the amount and characteristics of the mineral fillers can have an effect on flexible pavement properties, and the using of hydrated lime showed positive effect on rutting resistance and moisture damage resisting.

(Tebid, et al,2006) evaluate the laboratory performance- based properties of asphalt mixtures modified by hydrated lime. They used two different types of hydrated lime application dry and wet method. The results indicate that the performance of hydrated lime modified asphalt mixture in moisture damage and rutting resistance improved comparing with control mixture.

(AL-Jumaily, 2008) studied the effect of filler types on fundamental engineering properties of asphalt mixtures. Three types of filler (soft sand stone, Portland cement, hydrated lime) were used, and the asphalt mixtures were evaluated by (Marshall Tests, index of retained strength, permanent deformation characteristics, and fatigue resistance). He concluded that asphalt mixtures modified by hydrated lime have improved the permanent deformation characteristics, fatigue life, and decrease moisture susceptibility of asphalt mixtures.

(Amjad, 2011) studied the effect of hydrated lime on the mechanistic properties of asphalt concrete mixtures modified by hydrated lime. In this study seven replacement rate of hydrated lime were used and the modified mixtures were evaluate through (Marshall Tests, moisture damage, fatigue cracking, permanent deformation). He found that hydrated lime improve the Marshall Properties, increase moisture damage, fatigue cracking, and permanent deformation resistance, with hydrated lime content (2%).

Also **Hicks, 1991**; **Little, et al, 1993**; **Petresen, 2005;Peter, 2007**; they studied effect of adding hydrated lime to asphalt mixtures. They founded beneficial application of hydrated lime on the moisture damage resisting and improved asphalt concrete properties.

3. Materials Properties

3.1 Asphalt Cement

One kind of asphalt cement is used with (40-50) penetration grade brought from AL-Daurah refinery. The physical properties of asphalt cement were evaluated according ASTM standards **(ASTM, 2003)** and compared with Iraqi Specification known as State Commission of Roads and Bridge specifications **(SCRB/R9, 2003),** as shown in **Table 1**.

3.2 Aggregate

The aggregate used in this study (coarse and fine) were originally obtained from AL-Najaf quarries. The aggregate were sieved and recombined to meet the requirements of wearing course gradation according to SCRB specification **(SCRB, 2003)**. The physical properties of aggregate are shown in **Table 2**, while **Table 3** shows the aggregate gradation.

3.3 Filler

Filler materials represent mineral particles that passes sieve No .200. Filler used in this study, was ordinary Portland cement (Tasluja), at (7%) content, which represent average value of SCRB specifications **(SCRB, 2003)**.

3.4 Hydrated Lime

The Hydrated lime used in this study was brought from Al-Noora plant in Karbala Province. Hydrated lime was used in dry state with the percentage (0, 0.5, 1, 1.5, 2, and 2.5%) by weight of total aggregate and as partial replacement of the used filler material with remain(7%) constant; **Table 4** shows the properties of cement filler and hydrated lime.

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4. Experimental Work

4.1Asphalt Concrete Mix Design

The asphalt concrete mixtures design started by mixing mixture components (aggregate, filler material, and asphalt cement), and determining the optimum asphalt content using the Marshall Mix design method in accordance with ASTM D1559**(ASTM,2003).** The optimum content was found to be (4.9%) by the weight of aggregate. This value (4.9%) will be used for the asphalt concrete mixtures content hydrated lime to eliminate the effect of asphalt content on the results analysis, Table5 shows the asphalt concrete mixtures properties.

4.2 Retained Marshall Stability Test

Retained Marshall Stability (RMS) test is used to determine retained Marshall Stability for Marshall Compaction specimens after curing for 24 hours in a water bath at 60^{o}c.It is one of tests required by SCRB to be performed on asphalt mixes used in surface course in addition to Marshall Tests, in accordance with method ASTM D 1075. The specimens were divided into two groups; the first group (un conditioned) were immersed in water at 60 C^{o}for 30 min, and then loaded to failure by using curved steel loading plated along with a diameter at a constant rate of compression of 51mm/min. The second group (conditioned) was placed in water bath at 60 C^o for 24hr. The retained Marshall stability (RMS) was calculated according to the following equation.

$$RMS = \frac{MS_{cond}}{MS_{uncond}} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq.(1)$$

Where:
RMS = retained Marshall stability.,
MS_{cond} = Marshall stability for conditioned samples.
MS_{uncond} = Marshall stability for unconditioned samples.

4.3 Indirect Tensile Strength Test

The indirect tensile strength test was conducted in accordance with **AASHTO T283**, as standard test method to measure the resistance of compacted bitumen mixtures to moisture damage. A static load is increasingly applied at rate of 2.0"/min to the sample until failure. In the test, two groups of samples were used, the first one represent control samples (un conditioned) samples which were tested at 25 C^o. The second one are (conditioned) samples, which they are submerged in water at 60 C^o for 24hr, and then tested at 25 C^o.All samples were compacted to attain 7% air voids ±0.5%.For both types of samples the indirect tensile strength is calculating according equation (2). The tensile strength ratio *(TSR)* (i.e., ratio of *ITS* of conditioned samples to the *ITS* of un conditioned samples) were calculated according to equation (3), and used as moisture damage resistance index for asphalt mixtures. The higher *TSR* is better in the moisture damage resistance.

$$ITS = \frac{2p}{\pi t d} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq.(2)$$

$$TSR = \frac{ITSc}{ITSuc} \quad .... eq.(3)$$

ITS: Indirect tensile strength.
P: Applied load.
t: Thickness of sample.
d: Diameter of sample.
TSR: Tensile strength ratio.
ITS_c: indirect tensile strength of conditioned samples.
ITS_{uc}: indirect tensile strength of unconditioned samples

5. Analysis and Discussion of Test Results

5.1 Effect of hydrated Lime on Marshall Stability and Air Voids

The effects of hydrated lime on the Marshall Stability and air void values are shown in Figure1, and Figure2. It clear in these figures that, the Marshall stability increases with increased hydrated lime content. The maximum increase was, at hydrated lime content equals to (2.5%). Air voids values decreased with increased hydrated lime content to the optimum content (2%), and then increased for hydrated lime content (2.5%). As the beneficial application of (2%) hydrated lime to asphalt mixtures improves mixture properties by increasing Marshall Stability, reducing air voids, which effect on the mixtures durability against environmental effects (moisture damage).

5.2 Effect of Hydrated Lime on the Retained Marshall Stability

Index of retained Marshall stability (RMS) can be used to measure the effect of water damage on the Marshall stability for the asphalt concrete mixtures exposed to moisture conditions. The results for this test are listed in **Table 6**, and shown in Figure 3. As shown the Marshall Stability values decrease for the mixtures which they exposed to moisture conditions. The retained Marshall Stability values were calculated for each mixtures type, and it found to be equal to (60.6%) for control mixture and increase for the mixtures contain hydrated lime. The optimum increase at(2.5%) hydrated lime, where RMS equal to (75%), which indicate that hydrated lime tends to reduce the effect of water action(stripping action), increase stiffness, and increase cohesive strength between asphalt binder and the aggregate particles.

5.3 Effect of Hydrated Lime on the Indirect Tensile Strength Ratio

The results of indirect tensile strength are listed in Table **7**, the indirect tensile strength for both types of samples (un conditioned and conditions) were calculated and the TSR were determined. As shown in Figure4, the TSR value for control mixture equal to(72.3%) and this value meets the specification limit(TSR=70%, as minimum value), and for lime-HMA the TSR increase with the increase in hydrated lime content to the optimum content (2%) and then decrease. The results for this test indicate that hydrated lime had improved the moisture damage through increasing TSR.

6. Conclusions

Depending on the test program results the following points were concluded:

1. Using hydrated lime as additives and as a partial replacement of filler material had improved properties of asphalt concrete mixtures at different content.
2. Marshall Stability increases with the increase of hydrated lime content, with rate equal to (40%) for (2.5%) hydrated lime content.
3. Air voids decreased with increasing hydrated lime content, especially at the optimum content (2%) hydrated lime and the rate of decrease equals to (17%), and then air voids increase.
4. According to retained Marshall stability test, hydrated lime tend to reduce the effects of water and temperature on the cohesion and stiffness of mixtures, where RMS value increase with increase hydrated lime dosage, where the maximum value equal to(75%) for(2.5%) hydrated lime content.
5. The addition of hydrated lime had improved the tensile strength for unconditioned and conditioned specimens; as a result the TSR values increase from (72%) to (81 %) which improves moisture damage resistance.
6. Finally the using of hydrated lime as partial replacement of filler material improved Marshall stability, reduce air voids, increase cohesive strength, and tensile strength, which make asphalt mixtures more stiffness and durable against environmental effects, and the optimum hydrated lime content will be (2%) as indicate from the tests results.

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Table 1 Physical Properties of Asphalt Cement used in this Study.

Property	ASTM Designation	Test Result	SCRB Specification
Penetration(25C°,100gm,5sec),(0.1mm)	D-5	48	40-50
Ductility (25 C°, 5 cm/min). (cm)	D-113	109	>100
Flash point(Cleveland open cup), (C^0)	D-92	290	Min.232
Softening Point (C°)	D-36	49	------
Specific gravity at 25 C°	D-70	1.03	1.01-1.05

Table 2 Physical Properties of the Aggregate.

Property	ASTM Designation	Coarse Aggregate	Fine Aggregate
Apparent Specific Gravity	C-127 C-128	2.66	2.67
% Water Absorption	C127 C-128	1.42	2.8
%Wear(Los Angeles)	C-131	25%, Max 30%	----------

Table 3 Aggregate Gradation (Surface Course, Type A)

Sieve size (mm)	19	12.5	9.5	4.75	2.36	0.3	0.075
%Passing(SCRB)	100	90-100	76 -90	44 -74	28-58	5-21	4 -10
%Passing Selected	100	95	80	60	45	15	7

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Table 4 Physical Properties of Filler and Additive Material.

Property	Cement filler	Hydrated lime
Specific gravity	3.13	2.76
Fineness (cm^2/gm)	3123	3850
% Passing Sieve No. 200	95	100

Table 5 Properties of Asphalt Mixtures

Property	Asphalt Mixture Type						SCRB Specification
	0% HL	0.5% HL	1% HL	1.5% HL	2% HL	2.5% HL	
Marshall Stability,KN	10.2	11.45	12.4	12.9	13.3	14.2	Min,8kn
MarshallFlow,mm	3.8	3.75	3.7	2.9	2.71	2.63	2-4mm
Air Voids, %	4.5	4.12	3.92	3.8	3.72	4.1	3-5%
Density, gm/cm^3	2.321	2.329	2.334	2.347	2.348	2.341	——
Stiffness, Kn/mm	2.24	2.36	2.51	3.4	3.7	4.37	——
Optimum Asphalt Content,%	4.9	4.9	4.9	4.9	4.9	4.9	4-6%

Table 6: Retained Marshall Stability Test Results.

Type of mixtures	Marshall stability, KN (30min,60 C^o)	Marshall stability, KN(24Hr,60 C^o)	Retained Marshall Stability (RMS,%)
Control	9.3	5.64	60.60
0.5% Hydrated Lime	10.00	6.13	61.30
1% Hydrated Lime	10.75	6.85	63.70
1.5% Hydrated Lime	12.00	8.42	70.20
2% Hydrated Lime	12.50	9.21	73.70
2.5% Hydrated Lime	13.00	9.75	75.00

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Table 7 Indirect Tensile Strength Test Results.

Type of Mixtures	T mm	$P_{uncond,}$ N	$P_{cond,}$ N	$ITS_{uncon,}$ MPa	$ITS_{con,}$ MPa	TSR%
0%Hydretd Lime	63.5	11516	8326	1.137	0.822	72.3
0.5%Hydrated Lime	64	12118	8432	1.187	0.826	69.6
1.0%Hydrated Lme	66	12738	9254	1.210	0.879	72.63
1.5%Hydrated Lime	65	13157	9725	1.269	0.938	73.92
2.0%Hydrated Lime	64	13445	10934	1.317	1.071	81.3
2.5%Hydrated Lime	65	13976	11063	1.348	1.067	79.16

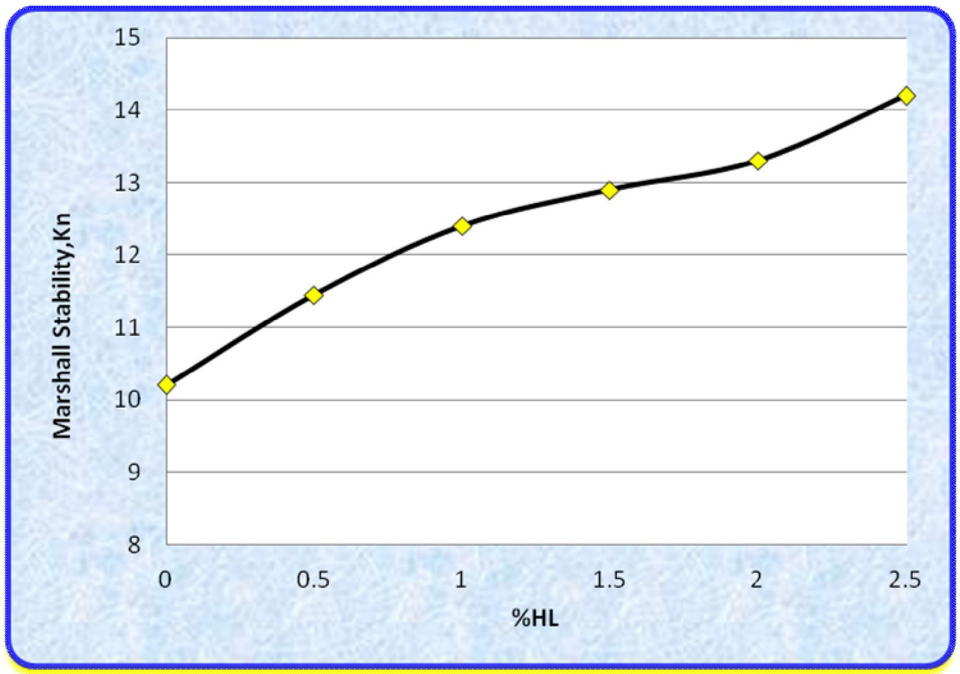

Fig.1 Effect of Hydrated Lime on Marshall Stability.

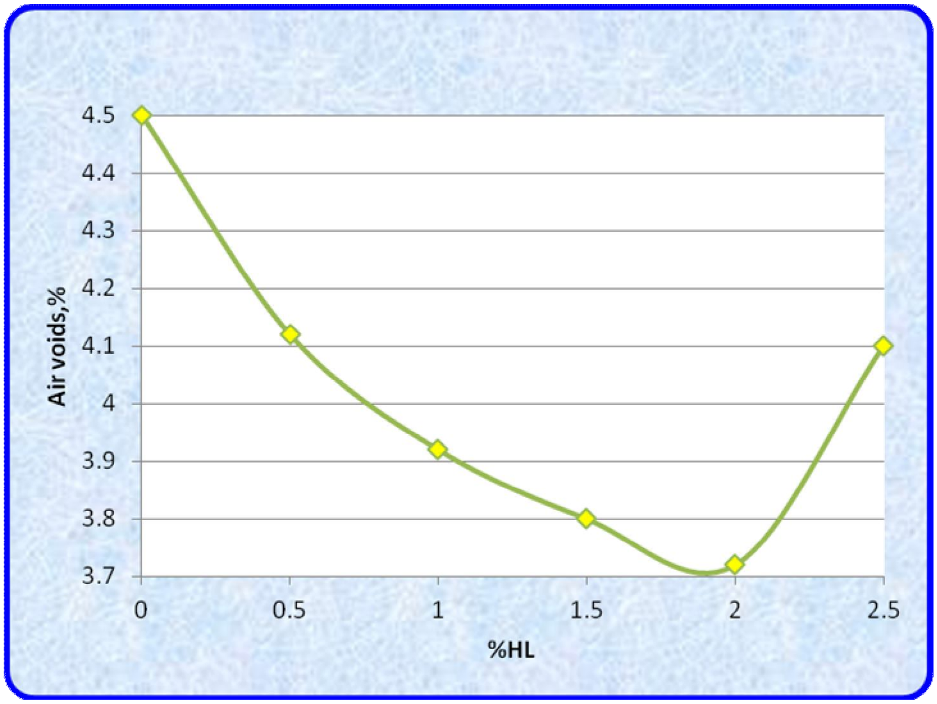

Fig.2 Effect of Hydrated Lime on the Air Voids Value.

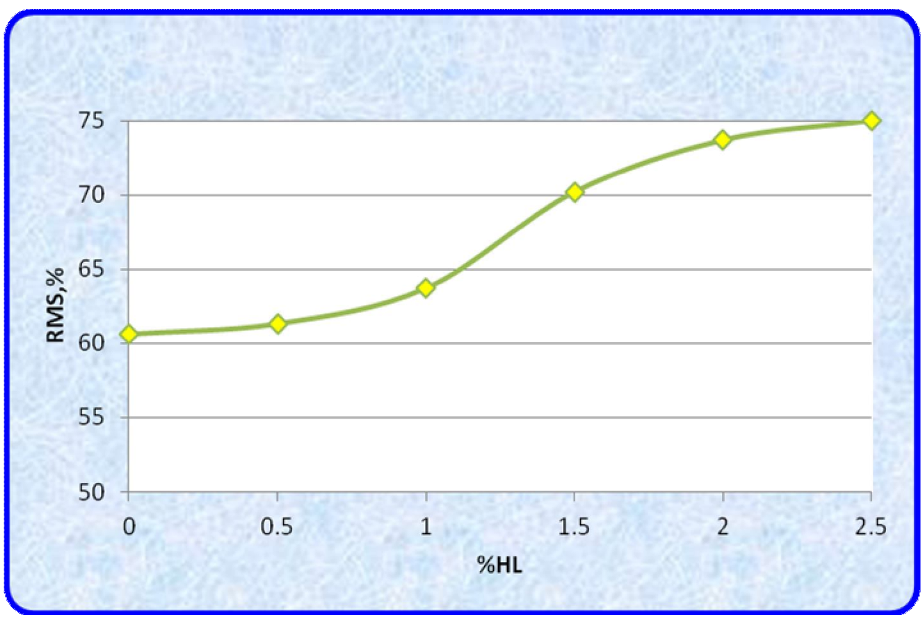

Fig 3 Effect of Hydrated Lime on RMS Value.

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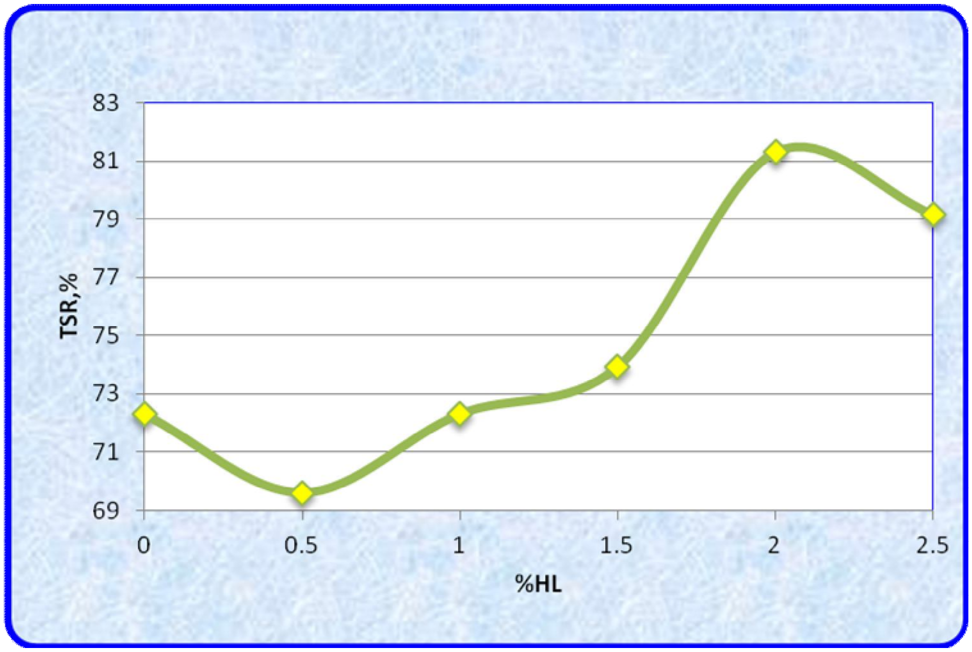

Fig. 4 Effect of Hydrated Lime on TSR Value.