Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (40) No. (1) January, 2018

Effect of Hydrated Lime on Asphalt Cement and Asphalt Mixtures Properties

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ملخص البحث

تمثل جودة الإسفلت عامل مهم في أداء الخلطة الاسفلتية. في بعض الاحيان لايفي الاسفلت المستخرج من مصادر انتاج الاسفلت بمصر بحدود المواصفات اسفلت 70/60 المستخدم في مصر .مما يؤدي إلى إنتاج خلطة اسفلتية ذات ثبات اقل وكذلك زيادة في قيم الانسياب وحدوث مشاكل مستقبلية تتمثل في حدوث شروخ وتخدد للطبقة الاسفلتية . الهدف من الدراسة هو دراسة إمكانية تحسين خصائص الاسفلت الغير مطابق للمواصفات والخلطة الاسفلتية باستخدام الجير المطفأ ثم مقارنة نتائج الخلطة الأسفلتية المعدلة بالجير المطفأ مع خلطة أسفلتية تم خلطها بعينة أسفلت تفي بحدود مواصفات أسفلت 70/60 . ولتحقيق أهداف الدراسة تم إعداد خطة عمل معملية تتمثل في اختيار واختبار مواد الخلطة الاسفلية من الركام والاسفلت .تم استخدام عينتين من الاسفلت في الاختبارات احداهما مستخرجة من معامل تكرير الاسفلت من السويس والاخري من الاسكندرية. إضافة نسب مختلفة من الجير المطفأ إلى عينة الأسفلت الغير مطابقة للمواصفات وإجراء بعض الاختبارات المعملية لتحديد خصائص الأسفلت المعدل. ثم إعداد خلطات أسفلتية تحتوي على النسب المختلفة للأسفلت المعدل بالجير المطفأ . ثم إجراء اختبارات مارشال لتحديد خصائص خليط الأسفلت ومحتوى الأسفلت الأمثل لكل نسبة مئوية من الجير المضاف. تم إجراء اختبار فاقد الثبات واختبار قوة الشد غير المباشرة واختبار عجلة المسار على خليط الأسفلت المعدل وغير المعدل لتقييم أداء الخلطة الأسفلتية. بعد تحليل النتائج، كشفت الدراسة أن النسبة المثلي للجير المطفأ المستخدم في الخلطة الاسفلتية هي 5٪ من وزن الأسفلت.

ABSTRACT

Quality of asphalt cement plays an important role in the performance of asphalt mixes. Sometimes asphalt cement obtained from Egyptian refineries does not meet the specification limits of asphalt 60/70 which used in Egypt . This asphalt cement leads to produce low stability and high flow mixes and future rutting and cracks problems . The objective of study is to investigate the possibility of improving the characteristics of asphalt cement and asphalt mixture by using hydrated lime (HL) then compare the results of (HL) modified asphalt mixture with asphalt mixtures prepared by asphalt specimen meet specification of asphalt 60/70 . To achieve the study objectives, an experimental program was designed. Study materials were selected and tested .Two asphalt specimens are used Alexandria asphalt and Suez asphalt . Adding different percentages of (HL) to Alexandria asphalt cement and performing some tests to determine the properties of modified asphalt. Then, preparing different asphalt mixes containing modified asphalt. Performing Marshall test to determine the asphalt mix properties and optimum asphalt content for each percent of added hydrated lime. Loss of stability test, indirect tensile strength test, and wheel tracking test were performed on the modified and unmodified asphalt mixes to evaluate the performance of asphalt mix. After analyzing the results, the study reveals that the optimum HL percent to be used in mixture is 5 % by weight of asphalt.

KEY WORDS :Asphalt cement, Viscosity, Penetration, Hydrated lime (HL) , Wheel tracking test, Indirect tensile strength, Loss of stability

1 INTODUCTION

Cracks and rutting were the most distresses noticed on several highways network. These distresses due to many factors such as heavy traffic load and mixture design. The performance of cracks and rutting have a close relationship with rheological properties of asphalt such as penetration and viscosity [1].

Asphalt cement is a viscoelastic material with rheological and mechanical properties for traditional paving due to its good adhesion properties to aggregates [2]. The chemical composition of the asphalt cement has a great effect on its viscoelastic properties and then on its performance as road paving material. Several additives have been used to improve asphalt cement properties such as hydrated lime.The useful nature of hydrated lime in asphalt concrete is related to both the particular chemistry of the system and the mechanical nature of fine particles in an asphalt binder matrix. Also, hydrated lime is considered as an agent to reduce moisture a filler and stripping[3].

Several studies had been made to investigate the benefits of using HL in asphalt mixtures. Mohamed et al have concluded that using HL increases asphalt cement viscosity and cohesion by the all particles where its large particles acts as a filler to improve asphalt mix stiffness [4]. Al- Tameemi et al showed that HL can improve asphalt mix to resist permanent deformation, cracks, and moisture damage [5].Satyakumar et al concluded that adding 1.5 % of HL by the total weight of specimens increases the stiffness modulus of asphalt mix up to 55 %. This might be due to that the HL stiffens the asphalt film coating on the aggregates surface and enhances the bonding between aggregates and asphalt [6].Al-Suhaibani found that the HL improves the resistance of asphalt mix to permanent deformation [7]. Using HL to improve asphalt mix characteristics for practical pavement applications, more information and experimental data are still needed for the sake of the development of design standards. Therefore, there is a bad need for sufficient studies on the combined effects of asphalt mix with different percentages of HL contents for different applications.

2 STUDY OBJECTIVES

The main objectives of this study is to investigate the effect of using hydrated lime on waxy asphalt cement and asphalt mix properties.

3 MATERIALS AND EXPERIMENTAL TESTING PROGRAM

To achieve the objectives of this study, an experimental program was designed. Figure (1) shows the steps of this experimental program

3.1 Laboratory Tests

Three types of laboratory tests were applied. The first type is the qualification tests. It is conducted to identify the different properties of materials used in this study as shown in tables from (1) to (4) . While the second type is the tests performed on the modified asphalt as shown in tables . The third type of laboratory tests is the main tests used to measure the intended properties of the investigated mixtures such as Marshal test, indirect tensile test, loss of stability test, and wheel tracking test .

3.1.2 Preparation of Modified Asphalt Sample

Modified hydrated lime asphalt was prepared using wet process technique. The asphalt was heated in oven till fluid condition. The hydrated lime percentage (as a percent of asphalt binder weight) was slowly added and temperature was kept between 150 C and 160 C. Mixing by high shear mixer to produce homogenous blend [8]. After adding five percentages of hydrated lime to Alexandria waxy asphalt, some tests were performed on the modified asphalt to measure different properties of modified asphalt. These tests are penetration test , viscosity and softening point .

3.1.3 Laboratory Tests on Asphalt Mixes Specimens

Laboratory tests performed on the two asphalt mixes samples are Marshall test, loss of stability test, indirect tensile test, and wheel tracking test.

3.1.3.1 Marshall Test

Marshall test was conducted on the used asphalt mix to obtain the optimum asphalt content and the properties of asphalt mix such as stability, flow, air voids, voids in mineral aggregates, and unit weight. The test was performed with 75 blows Marshall compaction according to AASHTO T – 245. Also, rigidity and voids filled with asphalt was calculated at different % of added hydrated lime.

3.1.3.2 Loss of Stability Test

This test was performed to measure mix durability by evaluating the resistance of the asphalt mix to moisture damage. Test was performed according AASHTO T-165. In this test, asphalt mix specimens are placed in water bath with a temperature 60 C and tested in several times (0.5, 24 hours) to measure the loss in mix stability of asphalt mixes containing Alexandria asphalt, Suez asphalt and modified asphalt.

3.1.3.3 Indirect Tensile Strength Test

This test was used to evaluate the tensile strength of asphalt mix. After determination of optimum asphalt content, the asphalt mix was prepared for indirect tensile strength (ITS) test according to manual of testing procedures, 1968 (Texas highway department). The following equation can be used to calculate the value of indirect tensile strength of the specimen[9]:

$$St = \frac{2000\ P}{\prod\ t\ D}$$

St = IDT strength, kPa
P = maximum load, N
t = specimen height immediately before test, mm
D = specimen diameter, mm

3.1.3.4 Wheel Tracking Test

Wheel tracking test was used to measure the rut depth of the asphalt mix.Test was performed according to AASHTO T 324. In this test, a loaded wheel is run over an asphalt mix sample (33.5 cm * 44.5 cm * 5 cm) at 60 C. The device applies a (53.5 kg) vertical force through 335 mm wide steel wheel with 5 cm thickrubber contact surface. Rut depth, temperature, and elapsed time during the test were recorded to plot rut depth versus time via displacement instrumentation on each loaded wheel. The rate of loading is 23 cycles per minute, which corresponding to 46 wheel passes per minute. The total test time was 60 minutes. Since the height of test specimens is expected to vary by 5 cm.

5 Results and analysis

The effect of adding hydrated lime on the properties of asphalt cement and asphalt mix is discussed in this part.

4.1 Effect of Hydrated Lime on Asphalt Cement Properties

Table (6) shows the results of tests conducting on Suez, Alexandria, and modified asphalt. These tests are penetration, kinematic viscosity, and softening point tests.

4.1.1 Effect of Hydrated Lime on the Penetration Test Values of Asphalt Cement

Figure (2) shows the effect of adding different percentages of hydrated lime to Alexandria asphalt cement on the penetration test values. From this figure, it is noticed that, increasing the added percentage of hydrated lime reduces the penetration test values (inverse relationship). As the adding percentage of hydrated lime increases from 5 % to 25 %, the penetration test value decreases from 67 to 57. The value of penetration test of pure Alexandria asphalt cement is 74 (out of specification limits) while the value of penetration test of pure Suez asphalt cement is 67.

4.1.2 Effect of Hydrated Lime on the Kinematic Viscosity Test Values of Asphalt Cement .

The effect of adding different percentages of HL to Alexandria asphalt cement on viscosity test values is shown in figure (3). It is noticed that, increasing the added percentage of hydrated lime increases the kinematic viscosity test values .This may be due to HL reacts with the acids, anhydrides and 2-quinolones,absorb the oils resins and other components which are typically concentrated in the heaviest components of bitumen called the asphaltenes. This absorption decease the bad side effect of waxy asphalt ,enhance increase asphalt viscosity.

4.1.3 Effect of Hydrated Lime on the softening Point Test Values of Asphalt Cement .

Figure (4) shows the effect of adding different percentages of hydrated lime to Alexandria asphalt cement on softening point test values. From this figure, it is noticed that, increasing the added percentage of hydrated lime increases the softening point test values . This increase in softening point value means that the modified asphalt cement with hydrated lime will have good adhesive properties and thus good performance in service.

4.2 Effect of Hydrated Lime on Marshall Test Results .

4.2.1 Analysis of Mix Stability Results .

Figure (5) shows the effect of using different percentages of HL on the stability values of asphalt mixtures at different percentages of asphalt content. Figure (6) shows the value of stability of modified asphalt mix at optimum asphalt content for each percent of added HL as shown in table (7). At optimum asphalt content, the values of stability of modified asphalt are within the specification limits. But the value of the stability, at the optimum asphalt content, of Alexandria asphalt is out of the specification limits. Specification limits is the stability value not less than 1200 kg. . So, the value of maximum stability of modified asphalt, at each percent of added HL, is greater than the maximum stability value of Alexandria asphalt. This might be due to the increase in the viscosity of the modified asphalt mixtures which leads to the formation of more thick mixture film of asphalt.

4.2.2 Analysis of Mix Flow Results .

The effect of using different percentages of HL on the flow values of asphalt mixtures at different percentages of asphalt content is shown in figure (7). Figure (8) shows the value of flow of modified asphalt mix . From these figures, it can be noticed that, at optimum asphalt content for each percent of added hydrated lime, the flow value increases with the increasing of added percentage of HL . So, these values of flow of modified asphalt mixes are higher than the value of Alexandria asphalt mix as shown in table (7). This might be due to HL affects the internal friction of asphalt mixture in negative manner.

4.2.3 Analysis of Mix Density Results .

Figure (9) shows the effect of using different percentages of HL on the density values of asphalt mixtures at different percentages of asphalt content. Figure (10) and table (7) shows the value of density of modified asphalt mix at optimum asphalt content for each percent of added HL . From these figures, it can be seen that, at a specific percent of asphalt content for all percentages added of HL , the value of density decreases with the increasing of the percent of added hydrated lime mixes. This might be due to two reasons. The first reason is the high porosity and low density of HL . While the second reason is related to the increase of air voids. In general, the addition of HL tends to increase the viscosity and makes the asphalt mixture more stiff. So, the degree of compaction may decrease with the increasing of HL content.

4.2.4 Analysis of Air Voids Results .

The effect of using different percentages of HL on the air voids values of asphalt mixtures at different percentages of asphalt content is shown in figure (11). Figure (12) ad table (7) shows the value of air voids % of modified asphalt mix at optimum asphalt content for each percent of added HL. From these figures, it can be noticed that, at a specific percent of asphalt content, the value of air voids % increases with the increasing of the percent of added HL. Also, at optimum asphalt content for each percent of added HL , the air voids % values increase with the increasing of added percentage of HL. This might be due to the high dry porosity (rigden air voids) of HL .

4.2.5 Analysis of Voids in Mineral aggregates Results .

Figure (13) shows the effect of using different percentages of hydrated lime on the voids in mineral aggregates percentage (VMA %) values of asphalt mixtures at different percentages of asphalt content. Figure (14) and table (7) shows the value of VMA % of modified asphalt mix, at optimum asphalt content for each percent of added HL .From these figures, it can be seen that, at a specific percent of asphalt content, the value VMA% increases with the increasing percentages of added HL .Also, at optimum asphalt content for each percent of added HL , the VMA% value increases with the increasing of added percentage of HL . This might be due to the high dry porosity (rigden air voids) of hydrated lime and this is expected as the mixtures with the hydrated lime has higher voids in the total asphalt mix.

4.3 Analysis of Loss of Stability Test Results .

The loss of stability test was performed on asphalt concrete samples prepared at optimum asphalt content obtained on Marshall test. Figure (15) and table (7) show the effect of using different percentages of HL on the loss of stability values of asphalt mixtures at optimum asphalt content . It can be seen that, the loss of stability percentage value decreases with the increasing of the percent of added HL . Which indicate that HL tends to reduce the effect of water action(stripping action), increase stiffness, and increase cohesive strength between asphalt binder and the aggregate particles.

4.4 Analysis of Indirect Tensile Test Results

Indirect tensile strength test (ITS) was performed on asphalt mix samples prepared at the optimum asphalt content obtained from Marshall test. ITS test is considered an important measure for the ability of the asphalt mix to resist cracking. In this study, the ITS test was performed on asphalt mixes containing 0 %, 5 %, 10 %, and 15 % added percentages of hydrated lime. The results of ITS test are shown in figure (16) and table (8). From the figure and the table, it is clear that, as the percentage of added HL increases the value of ITS increases , at each percent of added HL, the values of ITS of modified asphalt mixes is greater than the value of ITS of unmodified asphalt. This might be due to that, at high percentages of added HL asphalt mixes become too stiff, making these asphalt mixes prone to cracking. Therefore, it is recommended that the optimum percent of HL to be used in asphalt mixes is 5 % by weight of asphalt.

4.5Analysis of Wheel Tracking Test Results

Wheel tracking test (WTT) was performed on asphalt mix samples prepared at the optimum asphalt content obtained from Marshall test. WTT test is considered an important measure for the ability of the asphalt mix to resist rutting. In this study, the WTT test was performed on asphalt mixes containing 0 %, 5 %, 10 %, and 15 % added percentages of HL . The results of WTT test are shown in figure (17) and table (9). From the figure and the table, it is clear that, for each percentage of added HL , rut depth increases with the increasing of time (direct relationship). The rut depth values, at the end of the test, of modified asphalt mixes are 2.032, 2.88, and 5.9 mm. for 5 %, 10 %, and 15 % of added HL respectively. The value of rut depth, at the end of the test, of Alexandria asphalt mix, at optimum asphalt content, is 8.3 mm. Also, The value of rut depth, at the end of the test, of Suez asphalt mix, at optimum asphalt content, is 5.1 mm. Also, at a specific time, the value of rut depth increases with the increasing of the added percentages of HL. So, the least values of rut depth occur at 5 % added of HL , then at 10 % and 15 % added of HL , respectively .In general, the values of rut depth of modified asphalt is less than the values of rut depth of unmodified asphalt, at any specific time of test .This might be due to the increasing of added percentage of HL increasing air voids which caused increasing in rut depth.

5 Conclusions

Based on the analysis and discussion of the study results, the following conclusion may be obtained:

1- The viscosity is increase as the HL percent increases ,increase the HL percentage from 0% to 25% by weight of asphalt cement increase the viscosity from 340 to 527.

2- The penetration is decrease as the HL percent increases ,increase the HL percentage from 0% to 25% by weight of asphalt cement decrease the penetration from 74 to 57 .

3- The softening point is increase as the HL percent increases ,increase the HL percentage from 0% to 25% by weight of asphalt cement increase the softening point from 48 to 54 .

4 – The maximum stability value occur at 5 % added of HL .Then as the percent of added HL increases the stability value decreases . While as the percent of added HL increases the optimum asphalt content increases . In general, the stability value of modified asphalt, at each percent added of HL and at the optimum asphalt content, is higher than the stability value of unmodified asphalt.

5 – At optimum asphalt content for each percent of added HL, the flow value increases with the increasing of added percentage of HL . at 5 % added of HL is within the specification limits. While the flow values, at the optimum asphalt content, for the rest percentages of added HL, are out of the specification limits.

6 -At a specific percent of asphalt content for all percentages added of HL, the value of density decreases with the increasing of the percent of added HL . Also, at the optimum asphalt content for each percent of added HL , as the percent of added HL increases the value of density of modified asphalt mix decreases. So, at the optimum content for each percent of added HL of modified asphalt mixes, the density value is less than the density value of unmodified and Suez asphalt mixes.

7 - At a specific percent of asphalt content, the value of air voids % increases with the increasing of the percent of added HL . Also, at optimum asphalt content, air voids value % of unmodified asphalt mix is greater than the values of air voids % of modified asphalt mixes at 5 % and 10 % added of HL and visa versa for the rest percentages of added HL .

8 - At a specific percent of asphalt content, the value VMA% increases with the increasing percentages of added HL . Also, at optimum asphalt content for each percent of added HL , the VMA% value increases with the increasing of added percentage of HL . In general, at optimum asphalt content for each percent of added HL, the value of VMA % of modified asphalt is greater than the value of VMA % of unmodified asphalt.

9 - The loss of stability percentage value decreases with the increasing of the percent of added HL . Also, the % value of loss of stability of modified and Suez asphalt mixtures is less than the value of loss of stability of Alexandria asphalt mixture. In general, The rate of percent of improvement of loss of stability value is high between Alexandria asphalt and 5 % added HL. After that the rate of percent of improvement of loss of stability between 5 % and the subsequent percentages values of added HL is small.

10 - As the percentage of added HL increases the value of ITS increases . Also, at each percent of added HL , the values of ITS of modified asphalt mixes is greater than the value of ITS of unmodified asphalt. In general, the rate of improvement in ITS values is high at 5 % added percentages of HL, After that,

at 10 % and 15 % of added HL, the rate of improvement in ITS values becomes small.

11 - For each percentage of added HL , rut depth increases with the increasing of time . Also, at a specific time, the value of rut depth increases with the increasing of the added percentages of HL .In general, the values of rut depth of modified asphalt is less than the values of rut depth of unmodified asphalt, at any specific time of test. Also, the least value of rut depth occur at 5 % added of HL , then at 10 % and 15 % added of HL , respectively.

12 – Only 5 % added of HL ,to asphalt cement and asphalt mix, satisfies the requirements of specification limits for all parameters of asphalt cement and asphalt mix such as penetration, kinematic viscosity, ductility, stability, flow, air voids %, VMA %, VFA %, loss of stability, and rigidity. So, the optimum HL percent to be added to asphalt mix and used in pavement is 5 % by weight of asphalt at optimum asphalt content 5.76 .

6 REFERENCES

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Table(1): Aggregate gradation

Type	Coarse Aggregate (Pin 2)	Coarse Aggregate (Pin1)	natural sand	silicous sand	Mineral filler	Design gradation mix	Specification limits (4C)
Sieve size	Passing %						
1	100	100	100	100	100	100	100
3/4	67	100	100	100	100	93.4	80/100
1/2	10	97	100	100	100	80.8	___________
3/8	4	72	100	100	100	69.9	60/80
No. 4	1	20	97	100	100	48.5	48/65
No. 8	0	11.8	93	82	100	40.7	35/50
No.16	0	9.3	82	58	100	33	___________
No. 30	0	7.7	57	43	100	24.9	19/30
No. 50	0	6.1	17	43	100	14.6	13/23
No. 100	0	3.5	4.2	24.6	98	10	7/15
No. 200	0	2.2	3	18	91	7.7	3/8

Table(2):Properties of coarse aggregate

Test No.	Test	Type of Aggregate	AASHTO Designation No.	Results	Specifications Limit
1	Abrasion value after 100 revolution	Pin 2	AASHTO T 96-02	5%	≤ 10 %
		Pin1		5%	
2	Abrasion value after 500 revolution after washing	Pin 2		23%	≤ 40 %
		Pin1		23%	
3	Water absorption values	Pin 2	AASHTO T (85-10)	2%	≤ 5 %
		Pin1		2.80%	
4	Fragmentation	Pin 2	AASHTO T (112-00)	0.20%	_________
		Pin1		0.40%	______
5	Specific gravity Bulk	Pin 2	AASHTO T (85-10)	2.602	
	saturated			2.654	
	apparent			2.745	
	Bulk	Pin 1		2.583	
	saturated			2.656	
	apparent			2.785	
6	plastic limit & liquid limit	Pin2&Pin 1	AASHTO T (90-00)& (89-10)	No-plasticity	

Table(3):Properties of fine aggregate

Test No.	Test	Type of Aggregate	AASHTO Designation No.	Results	Specifications Limit
1	Water absorption values	silicous sand	AASHTO T (85-10)	2.80%	≤ 5 %
2	Specific gravity	silicous sand			
	Bulk			2.602	
	saturated			2.675	
	apparent			2.807	

Table(4): Physical properties of HL

Specific gravity(gm./cm3)	2.43
No 100	100
No 200	99

Table(5):Properties of asphalt cement specimens

Test No.	Test	AASHTO Designation No.	Suez asphalt	Alexandria asphalt	Specifications Limit
1	Penetration 0.1 mm	AASHTO T 49	67	74	60-70
2	softening point	AASHTO T 53	53	52	45-55
	flash point	AASHTO T 48	275	265	250
	Kinematic viscosity	AASHTO T 201	375	340	320

Table (6):Results of penetration ,kinematic viscosity and softening point testing for Suez and modified asphalt cement

Hydrated lime %	Penetration(1/10 mm)	Kinematic Viscosity ,cst	Waxyening point
Suez asphalt	67	375	53
Alexandria asphalt	74 *	340	48.0
5.0	65.000	410	49.0
10.0	65.000	438	50.0
15.0	61.000	442	51.0
20.0	62.000	444	53.0
25.0	57.000	527	54.0

Note : * the value does not met the specifications limits.

Table (7):Values of Marshall parameters for different % of hydrated lime at OAC.

Marshall properties	HL %							
	Suez	Alex	5%	10%	15%	20%	25%	specification limits
O.A.C	5.33	5.58	5.78	5.82	5.82	5.83	6	
Stability (kg)	1530	1060 *	1500	1450	1390	1440	1400	≥1200
Density (gm/cm3)	2.405	2.355	2.354	2.353	2.341	2.328	2.313	
Air voids %	3.3	4.4	4.1	4.3	4.7	5.4 *	5.6 *	3 : 5
Flow (mm)	3.5	3.7	3.8	4.1 *	4.25 *	4.35 *	4.9 *	2 : 4
V.M.A %	15.1	16.6	16.75	16.85	17.25	17.75	18.5	≥15
Loss of stability %	12.4%	22.0%	17.4%	16.5%	15.2%	13.1%	13.8 %	≤ 25 %

Note : * the value does not met the specifications limits.

Table (8): Effect of different HL percentage on I.T.S values

HL %	I .T.S(Kpa)
0% alex	1122
5%	1152
10%	1156
15%	1159

Table (9): Effect of different HL percentage on WTT values

HL %	W.T.T(mm)
0% Suez	5.1
0% Alex	8.38
5%	2.032
10%	2.88
15%	5.9

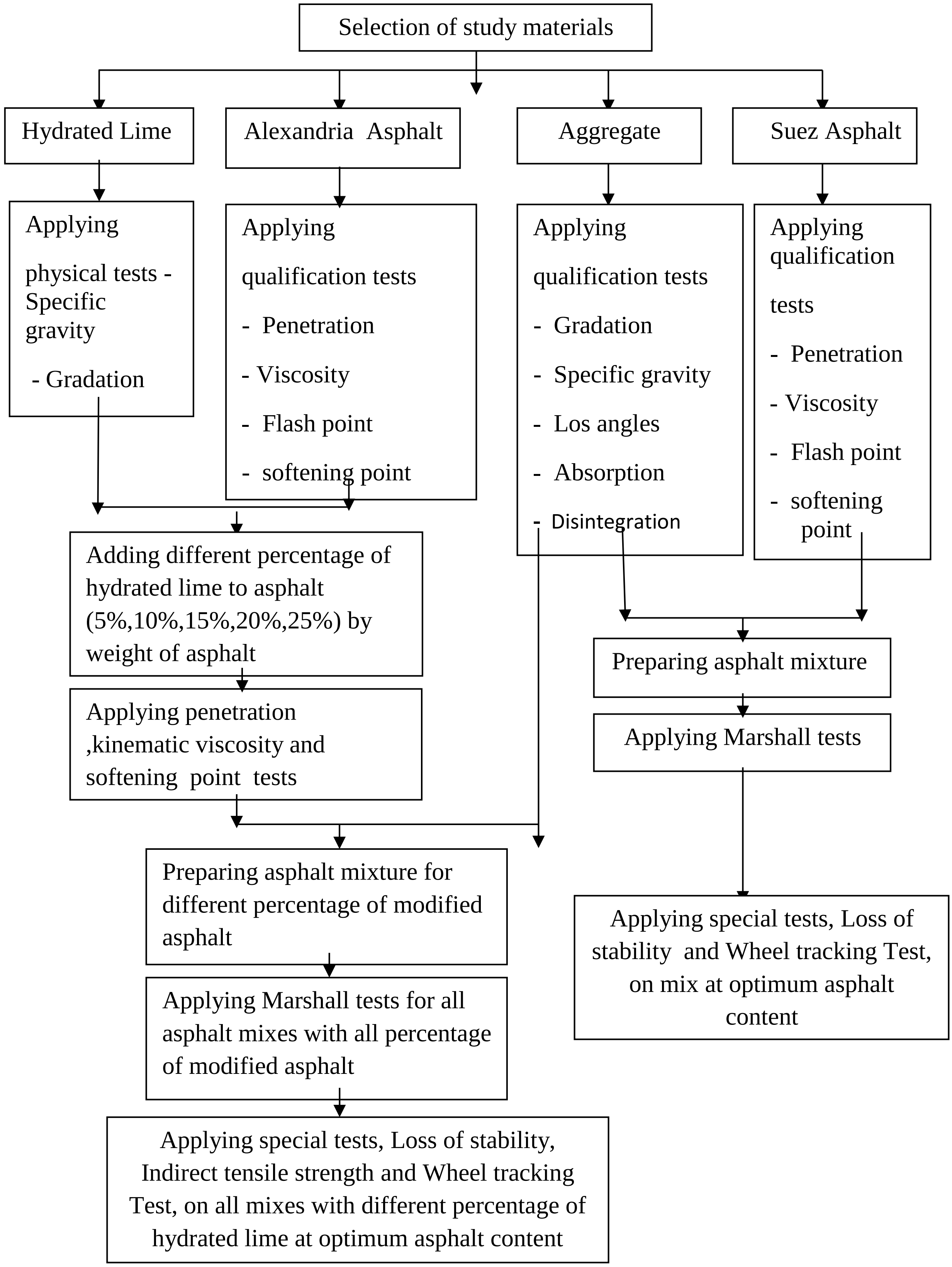


Figure (1): Experimental program

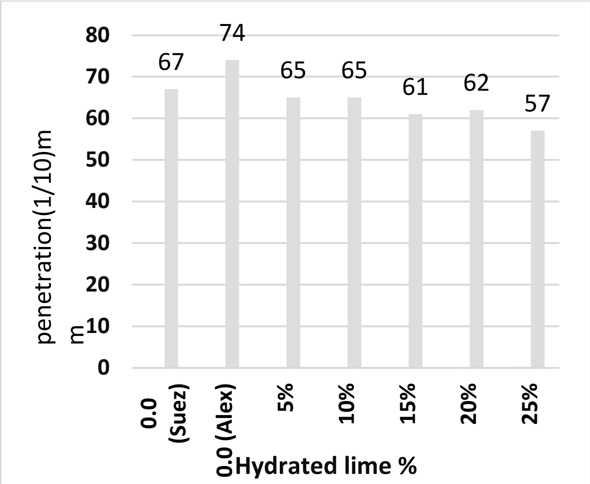


Figure (2) : Effect of hydrate lime on the penetration test values of AC.

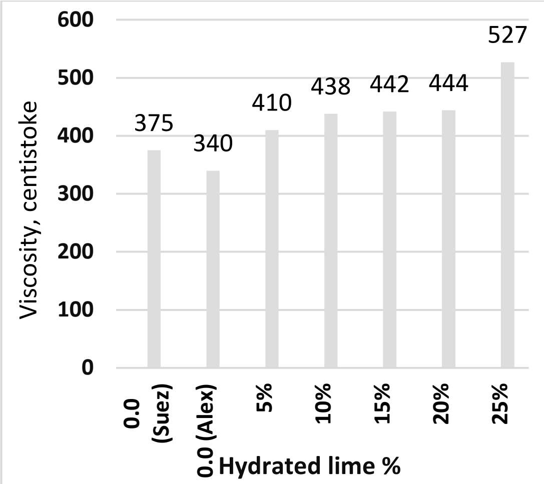


Figure (3) : Effect of HL on kinematic viscosity test values of AC

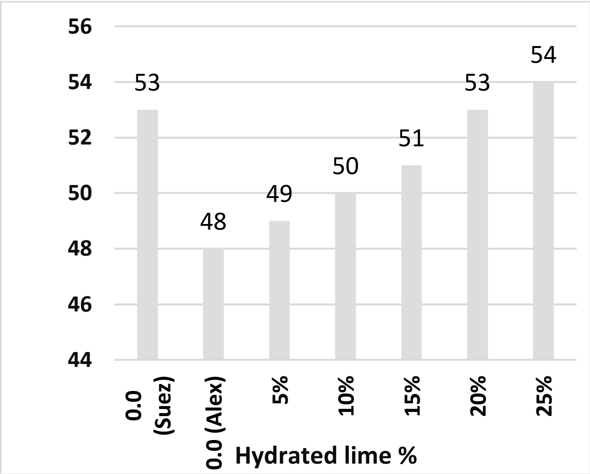


Figure (4) : Effect of hydrate lime on softening point Test values of AC.

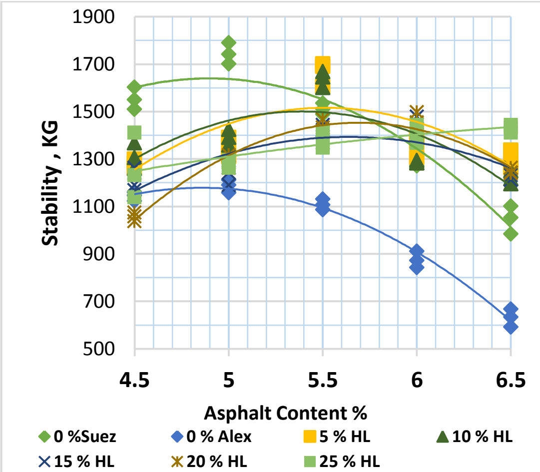


Figure (5) : Effect of adding different percentage of HL on stability values at different asphalt content.

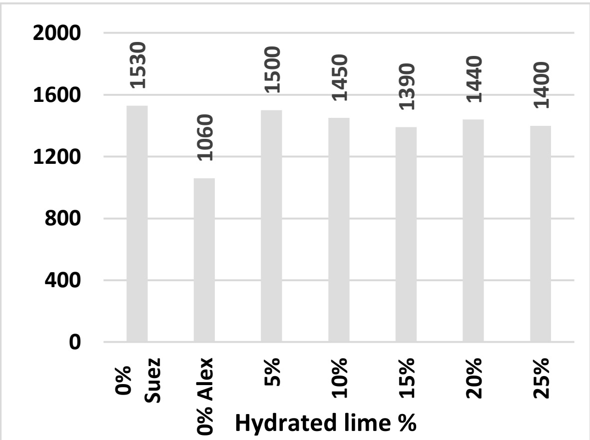


Figure (6) : Effect of adding different percentage of HL On stability Values O.A.C

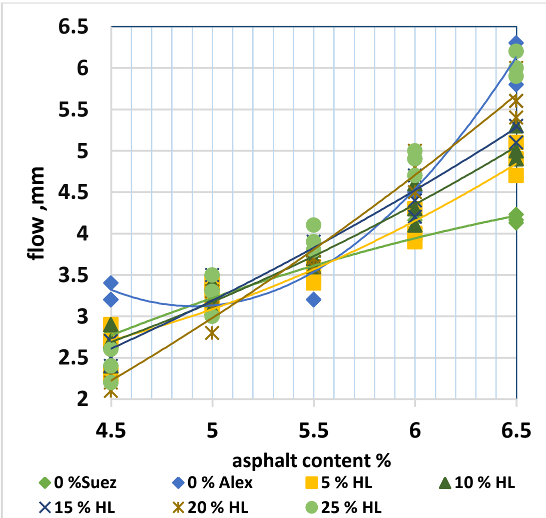


Figure (7) : Effect of adding different percentage of HL On Flow Values at different asphalt content.

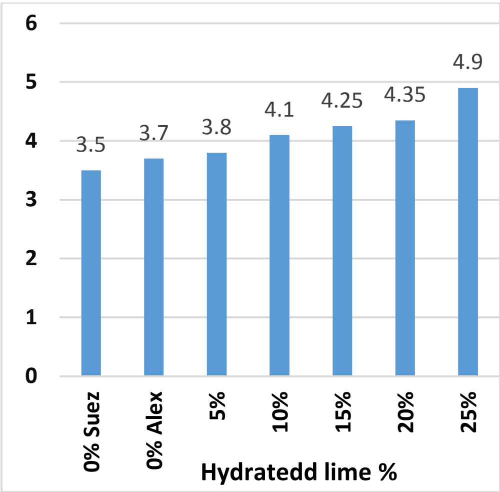


Figure (8) : Effect of adding different percentage of HL On Flow Value At O.A.C

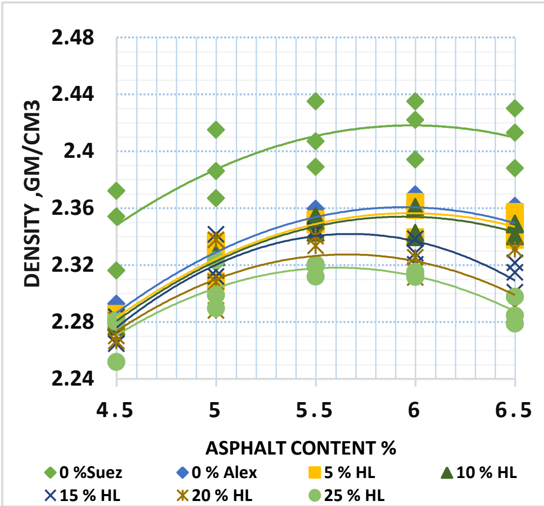


Figure (9) : Effect of adding different percentage of HL On Density Values at different asphalt content.

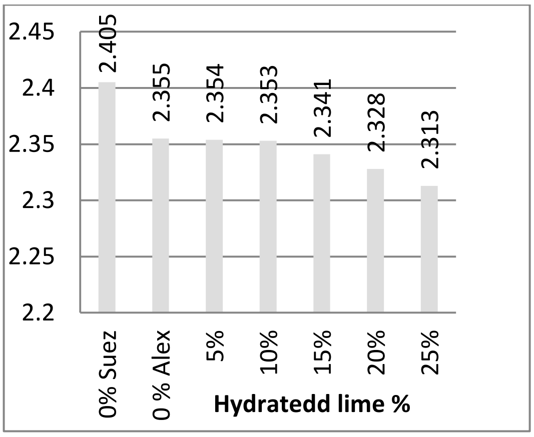


Figure (10) : Effect of adding different percentage of HL on density At O.A.C

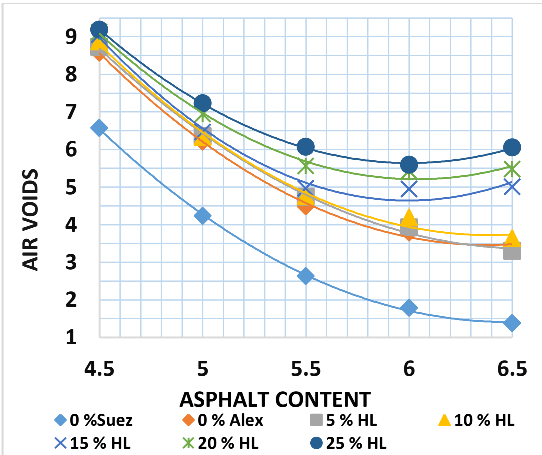


Figure (11) : Effect of adding different percentage of HL On Air voids Values at different asphalt content.

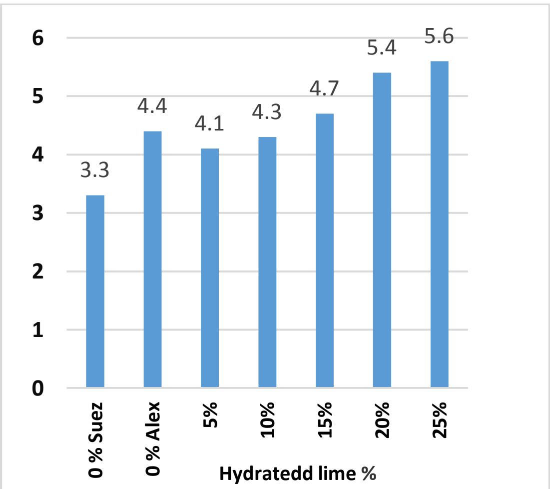


Figure (12) : Effect of adding different percentage of HL On Air voids % Value At O.A.C

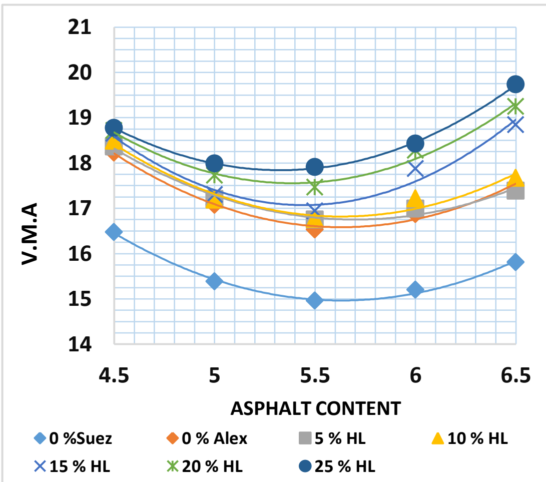
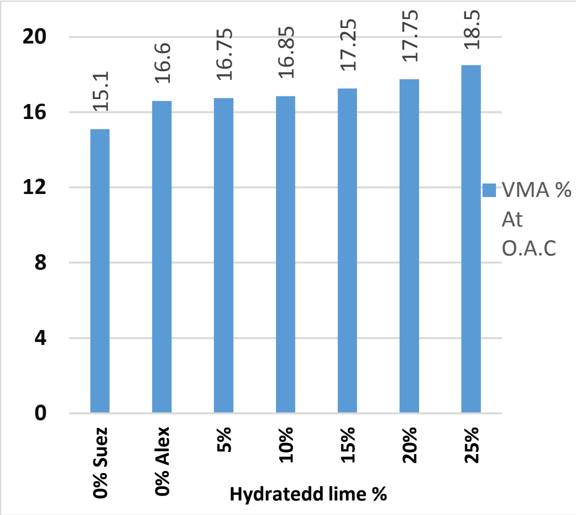


Figure (13) : Effect of adding different percentage of HL On VMA Values at different asphalt content



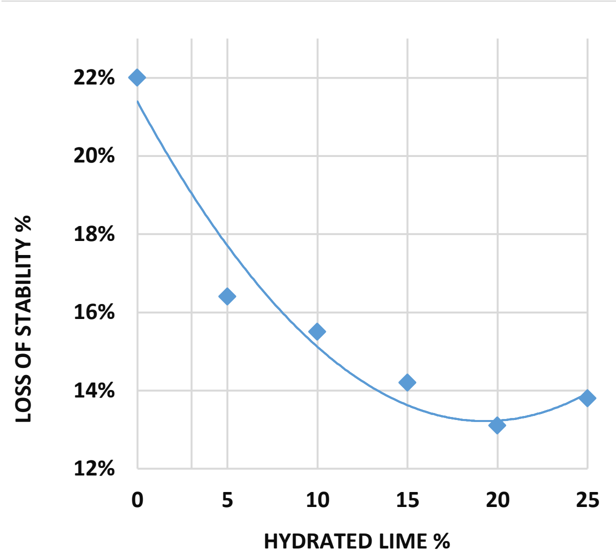
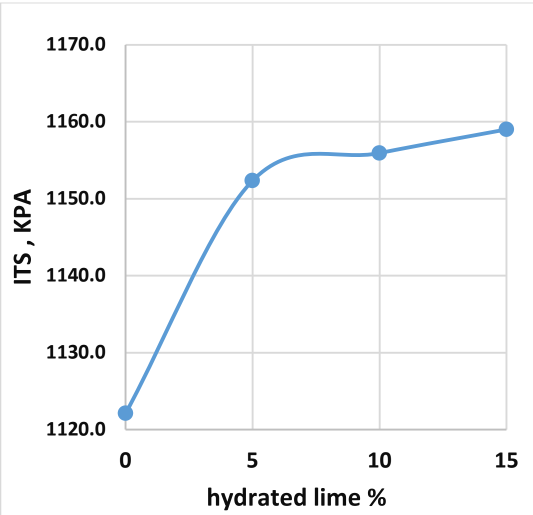


Figure (14) : Effect of adding different percentage of HL On VMA % Value At O.A.C

Figure (15) : Effect of adding different percentage of HL On Loss of stability Value At O.A.C



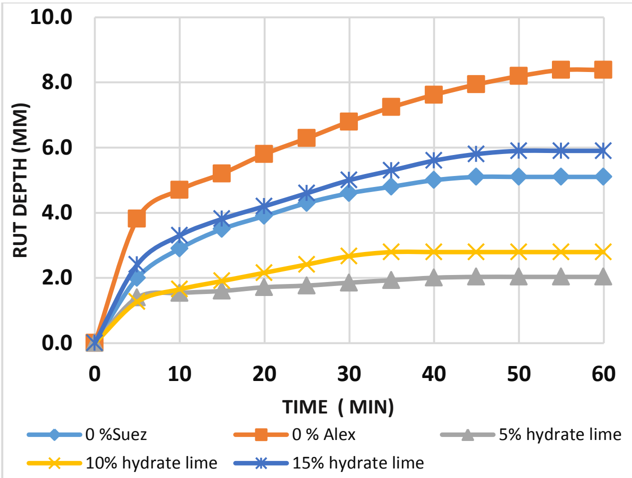


Figure (16) : Effect of adding different percentage of HL On I.T.S Value At O.A.C

Figure (17) : Effect of adding different percentage of HL On WTT Values at different asphalt content