Eng. & Tech. Journal, Vol.31.Part (A), No. 21, 2013

1st International Conference for Geotechnical Engineering and Transportation ICGTE in24-15/4/2013

Studying the Properties of Cationic Emulsified Asphalts Paving Mixture at Iraqi Environmental Conditions

Dr. Shakir .A. Al-Mishhadani
Building and Construction Engineering Department, University of Technology/ Baghdad
Email:uot_magaz@yahoo.com
Dr. Hasan. H. Al-Baidhani
Building and Construction Engineering Department, University of Technology/ Baghdad
Hussein Hamel Zghair
Building and Construction Engineering Department, University of Technology/ Baghdad

ABSTRACT

Emulsified asphalt mixture is generally a mix made of emulsified asphalt with aggregate. Emulsified asphalt is manufactured from base asphalt, emulsifier agent and water. This study aims to study and improve the emulsified asphalt mixtures with using of ordinary Portland cement as filler materials for road construction and maintenance in Iraq as an alternative to the hot asphalt mixtures, due to its economical, practical and environmental advantages. Beside this study focused to test and evaluates the emulsified asphalt material properties to be used as paving mixture. The tested properties of emulsified asphalt mixture were bulk density, air voids, dry Marshall Stability, wet Marshall Stability, retained Marshall Stability, flow tests with different compaction efforts differ from standard Marshall Limitations and compared with the common used specification. The results indicate that the emulsified asphalt type cationic slow setting low viscosity (CSS-1) is very suitable with quartz type of aggregate from Al-Nibaay quarry. From many trial mixes it is found that the best percentages of initial residual bitumen content to produced adequate results for coating test ,mixing ,compaction ,curing and Marshall stability were ranged from (2.5%, 3%,3.5%,4% and 4.5%), and the optimum percentage is (3.5%).Finally it can be conducted that the emulsified asphalt mixture contained Portland cement filler material is a suitable alternative mixture to the hot asphalt mixture for road construction and specially maintenance of roadways in Iraq.

Keywords: Cold Mix, Emulsified asphalt, Mix Design and Marshall Stability Test.

دراسة خواص خلطات رصف المستحلب الإسفلتي الكاتيونك للظروف البيئية في العراق

الخلاصة

خلطة المستحلب الاسفلتي هي بشكل عام خلطة مكونة من المستحلب الاسفلتي مع الركام . يصنع المستحلب الاسفلتي من اسفلت اساس وماء بوجود عامل مشتت.تهدف هذة الدراسة الى دراسة وتحسين خلطات المستحلب الاسفلتي باستخدام الاسمنت البورتلندي الاعتيادي كمادة فلر لانشاء وصيانة الطرق في العراق كبديل لخلطات الاسفلت الحار , نتيجة لفوائده من النواحي الاقتصادية

,العمليـة والبيئيـة.بجانـب هـذة الدراسـة ركـزت علـى فحـص وتقيم خـواص مـادة المسـتحلب الاسـفلتي لغرض استخدامها كخلطة في رصف الطرق. الخـواص التـي تـم فحصـها لخلطـة المستحلب الاسفلتي هي فحوصات الكثافة الكتلية , الفجوات الهوائية,, ثباتية مارشال الجافة , ثباتية مارشال الرطبـة ,ثباتيـة مارشال المتبقية وفحص الزحف لا بجهود رص مختلفة تختلف عن حدود مواصفة مارشال ومقارنتها مع المواصفات الشائعة الاستخدام.اشارت النتائج ان المستحلب الاسفلتي(Css-1) نـوع موجب بطيـئ التجمد قليـل اللزوجـة كـان ملائـم جدا مـع الركـام ذوالنـوع المعـروف بـالكوارتز المـاخوذ مـن مقلـع النباعي. وبعمل العديد من الخلطات التجريبية وجد ان افضـل نسب لمحتوى الاسفلت المتبقي الاولـي للحصول على افضـل نتائج لفحص الطـلاء ,الخلط,الرص ,المعالجة وثباتيـة مارشـال والتـي تتـراوح (2.5%, 3%, 3.5%,4% و4.5%).وان افضـل نسـبة مثاليـة لمحتـوى الاسـفلت المتبقـي الاولـي كانت (3.5%). أخيرا يمكن ان نستنتج وبناءا على النتائج المستخلصة ان خلطات المستحلب الاسفلتي التي تحتوي على الاسمنت البورتلندي كمادة فلر كانت ملائمـة كبديل لخلطـات الاسفلت الحـار لانشـاء الطرق و خصوصا صيانة الطرق في العراق.

INTRODUCTION

Cold mix Asphalt Concrete, or cold placed mixture, is generally a mix made from emulsified asphalt with aggregate material where that may be a dense-graded crushed aggregate or open -graded crushed aggregate. Mixing methods may be performed either in the roadway, on the side of the roadway, or in a stationary mixing facility. Where the resultant mixtures usually are spread and compacted at atmospheric temperatures. Cold mix asphalt may be used for surface, binder, base courses if the pavement is properly designed. Cold mix for surface course is suitable for light and medium traffic; however, they normally require a seal coat or hot asphalt concrete overlay as surface protection and when used in the binder or base, they may be suitable for all types of traffic[(1)].

Environmental conservation campaigners have more recently escalated their efforts and have provided added pressures on the road industry to tackle environmentally unfriendly processes. The targeted plans of environmental conservation to worked minimizing land-filling, reducing $C0_2$ emissions during hot bituminous mixture production and laying, control of dust, utilization of bulk inert wastes and /or recycled materials. Additionally, issues of energy saving and safety at work have stimulated efforts to introduce alternative methods of producing bituminous mixtures. One possible and attractive method is using 'Cold Mixture Technology', in which the bituminous mixtures are produced at ambient temperatures by utilizing liquid asphalts (emulsion bitumen's). Liquid bitumen's are obtained by reducing the straight run bitumen viscosity in several different ways. One of which is by emulsifying the bitumen in water in a process known as 'bitumen emulsification [2].In recent years, because of environmental restrictions and economics, emulsified asphalt have become the predominant binder used in cold mix applications [3].

Cold bituminous mixtures are easier to mix and handle the size and the time for the process of installation of a mixing plant is smaller and shorter respectively compared to a hot mix plant [4].

The main objective of this research is to study the fundamental material properties that are used in production of emulsified asphalt mixtures and to investigate some properties of cold emulsified asphalt mixture in order to extend the existing knowledge to improve the road paving layers.

EXPERIMENTAL PROCEDURE

Material Used

The aggregate used in this study is crushed gravel quartz brought from locally asphalt concrete mix plant was its source is Al-Nibaay quarry. Physical properties of the aggregate as shown in Table (1).The maximum aggregate size selected for all the cold mixes was. (19.0mm) this gradation is within the limits recommended by the specification limits of the State Corporation for Roads and Bridges in Iraq (SCRB) [(5)]. Type of mineral filler was used ordinary Portland cement, commercially know (Al-mass) and the specific gravity for limestone of filler was (3.13).

Table (1) Physical Properties of Nibaay Aggregates.

Property	ASTM Designation	Test Results	SCRB Specification
Coarse Aggregate :			
1.Bulk Specific Gravity	C-127	2.623	……
2.ApparentSpecific Gravity	C-127	2.65	……
3.Water Absorption,%	C-127	0.45	……
4.Percent Wear by Los Angeles Abrasion ,% *	C-131	16	35 Max
5.Soundness Loss By Sodium Sulfate Solution,% *	C-88	3.21	10 Max
Fine Aggregate :			
1.Bulk Specific Gravity	C-128	2.63	……
2.Apparent Specific Gravity	C-128	2.673	……
3.Water Absorption,%	C-128	0.5	……

*** Physical tests were made by the National Center for Construction Laboratories and Researches.**

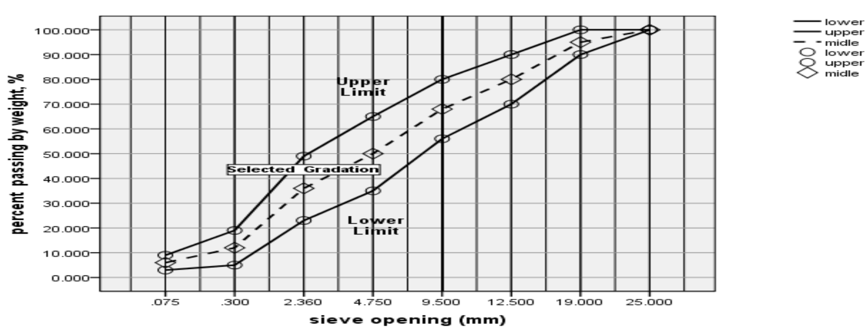

Figure (1) Aggregate Gradation Chart.

The Slow-setting cationic emulsified asphalt low viscosity type (Css-1) was used in this study, because of its compatibility with a wider range of aggregate and its common utilization as liquid binder all over the world. It is used in this work to produce a dense – graded mixture. It is observed that the produce mixtures are workable sufficiently during mixing with a very adequate coating **[2]**. From laboratory tests results of emulsified asphalt physical properties which is done according to the specifications **(**ASTM D2397**)** [11] are presented in Table (2) along with their specification limits, because there are no Iraqi specifications for such tests.

The test results showed that the emulsified asphalt contained of asphalt residue is about (55.3%) where this value is within the range adopted by the manufacture Company. However this value is deviated slightly from the limits of ASTM specification (ASTM D2397) and it is used in this study as available material for emulsified asphalt. This is considered as economical advantage, due to the low asphalt residue content that entry in manufacture of emulsified asphalt. So the sieve test result which represents the emulsified asphalt contained of asphalt residue is about (0.02) which is within the range of specifications limits for emulsified asphalt. This means that the emulsified asphalt contains little discreet solids retained on 850 μm sieve mesh and this will facilitates handling and applications of materials without difficulties and problems. The cement mixing result which represented the asphalt emulsion is (0.732%). Where it is within the range of specifications limits for emulsified asphalt. This represents a good indication for slow setting emulsified asphalt to mix with a high surface area material such as Portland cement Type III without breaking. Settlement test result is (0.1%) by weight where this value is within the specification limits(0-1)% and which represented ability of an emulsified asphalt to remain as a uniform dispersion during storage for 5 days. According to that it is found that the storage stability test result is (0.04%) by weight where this value is within the specification limits (0-1) %. This represents the ability of emulsified asphalt to remain as a uniform dispersion during storage for 24 hr. The solubility test results is (99%) this value is within the specification limits (minimum 97.5%).This test gives indication about the amount of impurities in the asphalt material. The penetration test result is (133) where this value is within the specification limits (100-250). This means that the asphalt that entry in manufactured emulsified asphalt is (100-200) penetration grade. The result of ductility test was (185cm) and this value is within the specification limits (minimum40cm/min) and represents good tensile properties of bituminous materials.

Table (2) Physical Properties of asphalt emulsion cationic slow setting low viscosity (CSS1).

Test	ASTM Designation (D244)	Test Result	Specification Limits (D2397) for CSS-1	
			Min.	Max.
Particle Charge Test	D244	positive	positive	
Viscosity, Saybolt Furol at 25°C (77°F)	D244	26	20	100
Residue by Distillation, %.	D6997	55.3	57	……
Residue By Evaporation	D6934	54.9	50	……
Sieve Test,%	D6933	0.02	……	0.10

Cement mixing test, %	D6935	0.732	……	2.0
Settlement Test,5day,%	D6930	0.1	0	1
1 Day Storage stability test, %	D6930	0.04	0	1
Penetration, 25°C (77°F), 100 g, 5 s	D5	133	100	250
Ductility, 25°C (77°F),5 cm/min,	D113	185	40	……
Solubility in trichloroethylene, %	D2042	99	97.5	……
Specific Gravity at 25°C	D70	1.02	……	……

MIXTURE PRODUCTION AND MECHANICAL PROPERTIES TESTS

Currently there is no universally accepted Specification for cold bitumen emulsion mixtures mix design or testing. Mixture design and testing procedures vary amongst the various road authorities, research institutions and asphalt researchers[2,4, 17&18]. In general the design procedures cover the following steps:

1. Determination of Aggregate Gradation. Was taken as a mid-term between upper and lower limits of aggregate gradation for Iraqi specification for binder course**.** Where this gradation used is a job mix formula.
2. Estimation of Initial Residual Bitumen Content (IRBC) and Initial Emulsion Content (IEC). These estimation done by adopting trial mixes derivative according to the specification of the State Organization for Roads and Bridges in Iraq [(5)]with asphalt cement content (%weight of total mix) for binder course (4%, 4.5%, 5%, 5.5%, and 6%) to determined Initial Residual Bitumen Content. Were these mixes tested for gain some variables such as coating test,mixing ,compaction , curing and Marshall stability .From through these variables to verify the mixes that containing on Initial Residual Bitumen Content for these percentage (5%,5.5%,6%) need to long curing period and have been weak early strength ,but they exhibit a good coating , good mixing , high effort for compaction. For the above reasons, these percentage can be adopted for determine Initial Residual Bitumen Content by range(2.5%,3%,3.5%,4%,4.5%) and testing these mixes for different variables such as coating test ,mixing ,compaction , curing and Marshall stability. These variables used to verify the mixes practicability that were characterized by adequate tests of the above variables. To do these tests must be determining the Initial Emulsion Content by mass of total mixture by equation:

$$IEC= \left(\frac{P}{X}\right)*100\% \qquad ... (1)$$

Where: P =% Initial Residual Bitumen Content by mass of' total mixture for percentages (2.5%, 3%, 3.5%, 4%, 4.5%), X value was (55%). The initial emulsion content (IEC) for emulsion type used was calculated from the above equation and the results found as (4.54%, 5.45%, 6.36%, 7.27%, 8.18%) by mass of' total mixture.

3. Binder Coating Test to Obtain the Best Aggregate Coating, where this test is also known as the 'binder compatibility test'. The test indicates the degree of affinity and compatibility between the emulsion and the mineral aggregates and provides a means for selecting the most suitable emulsion type according to the aggregate type being used. The optimum asphalt emulsion content that gave the best asphalt coating on aggregate (in which the mixture is not too sloppy or too stiff) then can be determined. The degree of coating should not be less than 50% by visual observation [10&2].
4. Determination of Adequate Compaction Level to Satisfy Final Air-Void Requirements, where the Compaction of the cold mix specimens was carried out using a Marshall Hammer compactor with the following compaction effort setting; hammer of (4.356kg) sliding weight, and a free fall of (457.2mm) on the top and bottom of each specimen. In this study and for determined the suitable compaction effort, the compaction was carried out at Heavy Compaction effort: 150 Marshall blows each end. The results show that the procedure of compaction given a best results corresponding to the air voids percent within allowable range about (5-10%) [2&18].
5. Curing of Compacted Specimens. The curing procedure adopted at this stage of investigation was referred to as Design Curing. Design curing was carried out in two stages:
   I. Design Curing Stage A; Oven Curing of Compacted Samples for Dry Stability Test.This curing procedure consisted of keeping the newly compacted samples for one day in their compaction molds. The samples were then extruded and kept for one more day in an oven at 40°C .They were then removed from the oven and stored for one day at room temperature (25°C)**(2),**but this curing period can be avoided by more densification that depending on the environmental conditions. Some of the samples were subsequently tested for Marshall Stability at room temperature and the results obtained were referred to as (dry stability values).
   II. Design Curing Stage B; Water Conditioning (capillary soaking) Samples for Soaked Stability Test.

After having been subjected to oven curing as explained earlier in Design Curing Stage A, the remainders of the un-tested dry samples were water conditioned. In this procedure (also referred to as capillary soaking) half thickness of each compacted specimen was soaked in water at room temperature for 24 hr. And the specimen then inverted and the other half was soaked for a further 24 hr. During soaking, the samples would rest on a bed of approximately 15 to 20mm coarse aggregate. The samples were subsequently to be well dried, their mass in air (before and after capillary soaking) was measured to determine the amount of water absorption and they were then tested for Marshall Stability at room temperature. The Marshall Stability test results obtained referred as (soaked stability values) **[2]**.

DENSITY AND POROSITY CALCULATIONS

For determine these properties, the samples are weighed dry in air and when fully immersed in water. Where these values with other known parameter used to calculate (bulk density, Air Voids and maximum specific gravity of paving mixture).

TESTS FOR MARSHALL STABILITY AND FLOW

The test of stability and flow properties for CBEMs samples utilizes the same Marshall stability apparatus used for testing hot bituminous mixtures. The procedure, however, had been modified so that the samples are tested at room temperature(17), instead of at 60°C, so the number of Marshall blows for compaction about 150 blows instead of 75 blows at each end as is specified for hot mixtures and has been renamed the Modified Marshall test. Different asphalt emulsion content where chosen, (4.54%, 5.45%, 6.36%, 7.27%, and 8.18%) by total weight of mixtures, as mentioned previously. The fifteen specimens were prepared and tested and the optimum asphalt emulsion is found as a percentage by weight of the mixture. The procedure of testing is carried out according to method described by D6927 (19)**.** The specimens left in mold for 24 hr. and then extruded and kept for 24 hr. in an oven at 40°C. Then removed from the oven and stored for24 hr. at room temperature (25°C),but this curing period can be avoided in the field by more densification that depending on the environmental conditions. Followed placed the specimens in a water bath at 25 °C for 30 to 40 min. before testing Marshall Stability and flow, were this procedure for dry curing condition to obtain dry stability and density. For capillary soaking curing another set of specimens are kept in mold for 24 hr. and then extruded and kept for 24 hr. in an oven at 40°C. Then removed from the oven and stored half thickness of each compacted specimen soaked in water at room temperature for 24 h, the specimen was then inverted and the other half was soaked for a further 24 h. The specimens were subsequently to well dried, their mass in air (before and after capillary soaking) were measured to determine the amount of water absorption and they were then tested for Marshall stability at room temperature. The Marshall Stability test results obtained were referred as wet (soaked) stability.

RETAINED STABILITY

The retained stability, i. e. the ratio of wet stability to dry stability is required only for mixtures at Optimum Residual Bitumen Content (ORBC) .Where the minimum of three samples are required for determination of an average dry stability value. These samples are obtained after conducting design dry curing stage. The stability of the soaked samples that had been obtained are used for comparison. A minimum of 50%retained Stability shall be achieved following this design curing procedure at early age three days **[2]**.

DETERMINATION OF OPTIMUM RESIDUAL BITUMEN CONTENT (ORBC)

The ORBC is determined based on soaked samples by optimizing the two main parameters namely: Soaked Stability, Bulk Density, Retained stability, Furthermore air voids and water absorption values must be evaluated with reference to specifications. All parameters shall be plotted in graphical format against the Residual Bitumen Content (RBC) [2, 4&20].

Based on Figure (2) for bulk density and Figure (5) for wet stability it can be conducted that the optimum percentage of initial asphalt emulsion content is (6.36%) and Initial Residue Bitumen Content is (3.5%).

Results and Discussion

The bulk density of emulsified asphalt mixture obtained at various binder contents as shown in Figure (2). It can be seen that as the binder content increases the bulk density also increases until maximum is reached. The maximum value is obtained at 3.5 percent binder content. One possible way to explain the bulk density trend to binder content for emulsified asphalt mixture follows the same trend observed for hot asphalt mixture [21], which show increasing with increase the percentage of initial emulsified asphalt content which lead to be the aggregate particles closer one from the another, also the result is showing of reduction in the volume and increasing in weight of sample and that mean increasing density. And after certain percentage which known an optimum percentage ,the binder material (emulsified asphalt) which starting to form film with much thickness which leading to reduce the contact distance between aggregate particles andthat resulting increase the volume of the sample which means decreasing in sample density.

Figure (3) shows that, initially, as the binder content increases, the air voids decrease rapidly, up to a certain percentage of binder content. The relations between air voids and binder content follows the same trends observed for hot asphalt mixtures. It may be explained by the fact that as more binder is added into the matrix more voids are filled with binder and therefore the percentage of air voids decreases.

In general, the range of air voids percent for emulsified asphalt mixture about (5-10) % **[2]** and another range of air voids percent for emulsified asphalt mixture about (6-12) % **(4)**.It is found that all air voids percent for emulsified asphalt mixture are within these limits.

Figure (4) Show that the dry Marshall stability decreases continuously as the binder content increases. The difference in dry stability within mixtures with regard to added binder content can be principally attributed to the degree of coating, since all the other factors which might influence the dry stability were kept constant, i. e. moisture content at compaction, compaction level, type of binder and aggregate gradation. As the percentage of emulsion content was increased, the rate of "breaking" of the emulsion was reduced and hence the coating of the aggregates was improved. The slow rate of breaking results in a better distribution of binder and a reduction in the number of uncoated aggregates both of which contribute towards better stability**[**4]. Although an increase in the amount of emulsion content improves the coating of the aggregate and results in better dry stability, an excessive amount of emulsion content will produce a very wet mix which has two distinct disadvantages. These are the prolonged curing time. The wetter mixtures will certainly require longer time for the water to evaporate in order to reach certain content for compaction, and consequently a longer time for the emulsion to break completely.

The wet stability continues to increase as the binder content increases until a maximum is reached. The maximum value is obtained at 3.5 percent residue binder content (6.36 percent initial emulsion content) and the wet stability continues to decrease as the binder content increases, and that can be attributed to the effect of moisture on mixture and causing prevented the evaporation water from mixture, delay the curing process and developed strength of mixture at early age (3days).Thus the wet stability continues decrease as the binder content increases after reached a maximum at the optimum asphalt emulsion content as show in Figure (5). the variability of the low wet stability values is attributed to the fact that the specimens, the immersion period capillary soaking, absorbed an appreciable amount of water. The absorbed water may have penetrated between the binder film, and the aggregate surface, causing a reduction in the bonding and adhesion between the aggregate particles.

Figure (6) Show that the retained stability increases as the binder content increases until a maximum is reached at the optimum asphalt emulsion content and the retained stability continues to decrease as the binder content increases where that can be attributed to the effect of moisture on the mixture. In some cases, the Retained Marshall Stability values were found to be slightly greater than 100%. This was attributed to the development of pore water pressure within the sample during load application [2].

The Flow values for asphalt emulsion mixtures are represented in Figure (7) it is found that the flow values started to decrease with increasing of binder content until (5.45%) where beyond this percentage the flow began to increase with increasing of binder content and it reached to maximum value at the higher percentage of binder.

CONCLUSIONS

1. The emulsified asphalt type cationic slow setting low viscosity (Css-1) is very suitable with aggregate graduation requirements according to Iraqi specification. On the other hand, the asphalt residual content about (55%) and water content about (45%) is more suitable and more economical as compared with hot asphalt mixtures because it is not required to dry the aggregate during mixing process.
2. The quartz type of aggregate from Al-Nibaay quarry is suitable for emulsified asphalt mixture, due to containing a negative charge according to chemical composition producing good bond with positive charge for emulsified asphalt.
3. From many trial mixes it is found that the best percentages of initial residual bitumen content to produced adequate results for coating test ,mixing ,compaction ,curing and Marshall stability are ranged from (2.5% to 4.5%). And hence the optimum percentage is (3.5%).
4. The suitable and effective mixing procedure for emulsified asphalt mixtures consists from mixing the coarse aggregate with asphalt emulsion at first and after that the fine aggregate is added to mixture. This procedure produces appropriate coating degree for aggregate.
5. The compaction procedure required to obtain porosity within allowable range (5-10) % is about 150 blows for each face for emulsified asphalt mixture Marshall Specimen.
6. The curing period appropriate (3day) at early age consisted on (1day) in mold, (1day) in oven at 40°C and followed then removed from the oven and stored for1 day at room temperature (25°C)**,**but this curing period in the field can be avoided by more densification that depending on the environmental conditions.
7. For early age (3 days) Marshall Stability test it is required to place the samples in water bath at 25°C for 30-40min. This requirement is related to the gain in strength with age.
8. The emulsified asphalt paving mixture is very suitability to Iraqi environmental conditions .Where no heating for asphalt emulsion is required and no drying for aggregate is required. And finally there is not required to control the temperature of the mixtures as in the case of hot asphalt mixtures which is considered a very big problem in road construction in Iraq.

REFERENCES

[1].Asphalt Paving Association of Iowa," A Basic Asphalt Emulsion Manual, Manual Series No. 19 (MS-19)". College Park, Maryland, 1987, pp.2-6.

[2].Thanaya, N. A.," Improving the Performance of Cold Bituminous Emulsion Mixtures (CBEMS) Incorporating Waste Materials ", Ph.D. Thesis, University of Leeds School of Civil Engineering, 2003, pp.6-23, pp.105-137, pp.173-175, pp.203-205.

[3].Blades C., Kearney E.," Asphalt Paving Principles", New York LTAP Center, 2004, pp.16, pp.50.

[4].Nikola ides , A. F. ,"Construction and Performance of Dense Cold Bituminous Mixtures as Strengthening Over layer and Surface Layer .Proceedings of the First European Symposium on Performance and Durability of Bituminous Materials University of Leeds , 1994 pp.3-7,pp.63-75.

[5].State Organization for Roads and Bridges. "Hot Asphaltic Concrete Pavement", Iraqi Standard Specification, Ministry of Housing and Construction, Department of Design and Study, Section R9 2003.

[6].ASTM C127,"Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate ", Annual Book of Standards American Society for Testing and materials, Vol.04.02, 2001.

[7].ASTM C131,"Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine", Annual Book of Standards American Society for Testing and materials, Vol.04.02, 2001.

[8].ASTM C88,"Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate", Annual Book of Standards American Society for Testing and Materials, Vol.04.02, 1999.

[9]..ASTMC 128,"Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate", Annual Book of Standards American Society for Testing and Materials, Vol.04.02, 2001.

[10].ASTM D244,"Standard Test Methods and Practices for Emulsified Asphalts", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, 2008.

[11].ASTM D2397," Standard Specification for Cationic Emulsified Asphalt", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, 2008.

[12]. ASTM D6997 "Standard Test Method for Distillation of Emulsified Asphalt", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, 2012.

[13].ASTM D6934,"Standard Test Method for Residue by Evaporation of Emulsified Asphalt", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, 2008.

[14].ASTM D6933," Standard Test Method for Oversized Particles in Emulsified Asphalts (Sieve Test)", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, 2004.

[15].ASTM D6935,"Standard Test Method for Determining Cement Mixing of Emulsified Asphalt," Annual Book of Standards American Society for Testing and Materials, Vol.04.03, 2011.

[16].ASTM D6930,"Standard Test Method for Settlement and Storage Stability of Emulsified Asphalts", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, 2010.

[17].The Asphalt Institute, "Asphalt cold-mix manual", Manual Series No. 14 (MS - 14), Third Edition, Lexington, KY 40512 - 4052, USA, 1987.

[18].Ministry of Public Works Republic of Indonesia., "Paving Specifications Utilizing Bitumen Emulsions", Jakarta, 1990.

[19].ASTM D6927," Standard Test Marshall Stability", Annual Book of Standards American Society for Testing and Materials, Vol.04.03, 2010.

[20].Needam, D.," Developments in Bitumen Emulsion Mixtures for Roads", Ph.D. Thesis, University of Nottingham, 1996, pp.12-35.

[21].NicholasJ.Garber,LesterA.
[22].Hoel.," Traffic and Highway Engineering", Fourth Edition, University of Virginia, 2009, pp. 974-980.

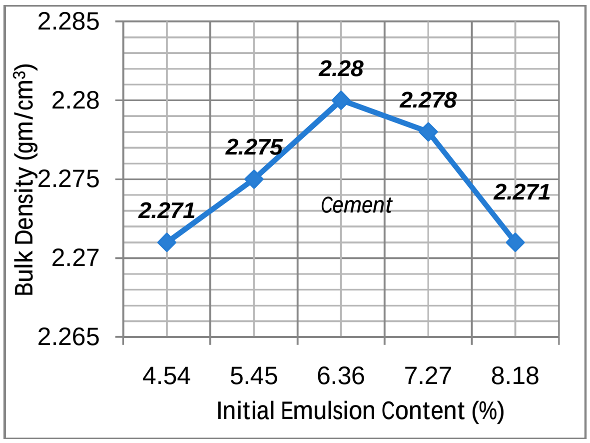

Figure (2) Bulk Density with Initial Emulsion Content,(IEC, %) for Cement Type of Filler.

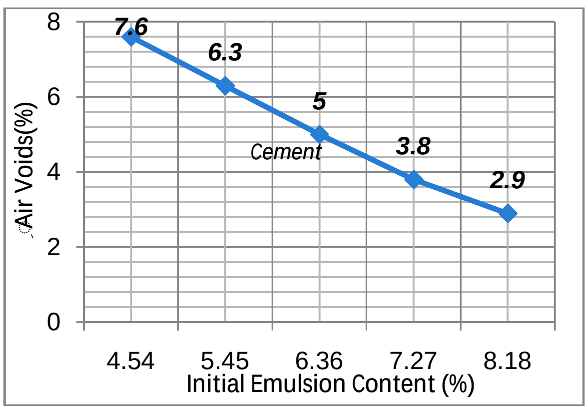

Figure (3) Air voids with Initial Emulsion Content, (IEC, %) for Cement Type of Filler.

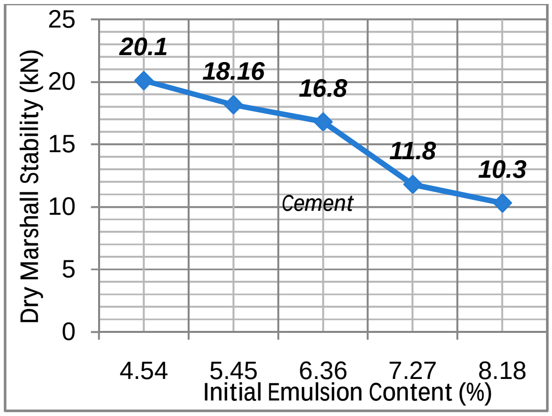

Figure (4) Dry Marshall Stability with Initial Emulsion Content, (IEC, %) for Cement Type of Filler.

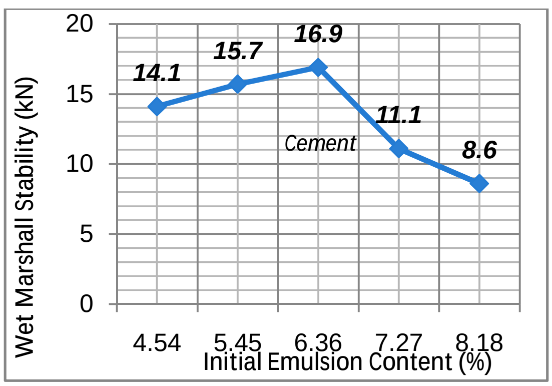

Figure (5) Wet Marshall Stability with Initial Emulsion Content, (IEC, %) for Cement Type of Filler.

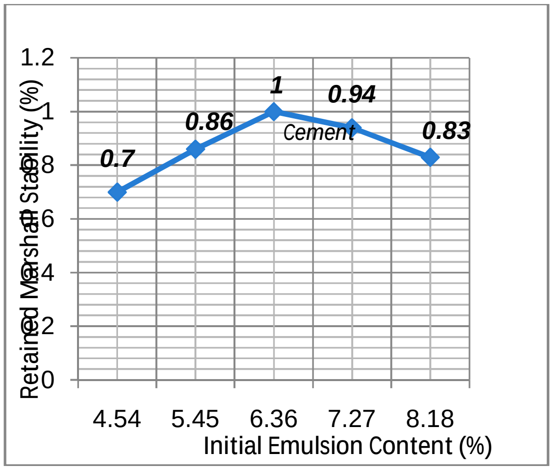

Figure (6) Retained Marshall Stability with Initial Emulsion Content, (IEC, %) for Cement Type of Filler.

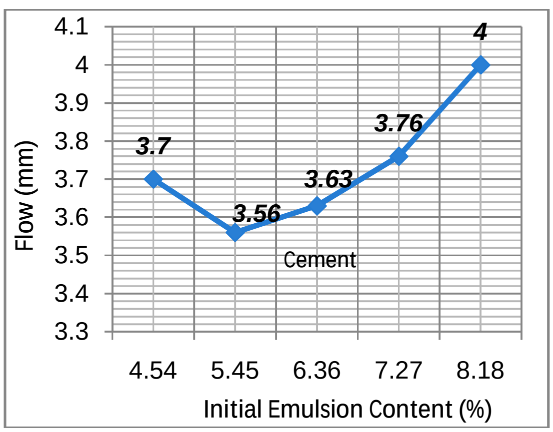

Figure (7) Flow value with Initial Emulsion Content, (IEC, %) for Two Types of Filler.