Investigating the Ability of Using Eggshell Powder as a Filler in Hot Mix Asphalt Mixture

IOP Conf. Series: Materials Science and Engineering **518** (2019) 022047 doi:10.1088/1757-899X/518/2/022047

Investigating the Ability of Using Eggshell Powder as a Filler in Hot Mix Asphalt Mixture

Ghadah Ghassan Masued[1]

1Highway and Transportation Engineering Department, college of Engineering, Mustansiriyah University, Baghdad, Iraq
E-mail: ghadahghassan2013@gmail.com

Abstract. Nowadays, many studies have been conducted to find low cost waste materials that can be used in asphalt mixtures. Therefore, the idea of this study involves using one of these waste materials, which is Eggshell. Moreover, evaluate the ability to use eggshell powder, in hot mix asphalt mixtures as filler is the main objective of this study. This research was conducted by comparing the performance of mixtures of different eggshell powder percentages, 0, 3, 6, 9, 12, 15, 20, 25 and 100% and finding optimal eggshell content (OESC). To achieve this objective, Asphalt concrete mixtures, were prepared, and subjected to a series of laboratory experiments. Stability, flow, bulk density and indirect tensile strength are the experiments that have been implemented. In addition, the materials used are: - asphalt cement, Portland cement, chicken eggshell, coarse aggregate, fine aggregate. Where, eggshell powder used as an alternative to Portland cement in a part or as a replacement to cement. For all tests made in this study, the comparison is made against the conventional specimen with optimum asphalt content (found to be 4.85% for wearing layer) to find an optimum blend mixture of eggshell. The results showed that the effective eggshell content was 6% and the eggshell is one of the substances that can be used as a filler in asphalt mixture blend and realize Iraqi specifications. Furthermore, money can be saved by using this low-cost material instead of cement. For 6% ESP content rate, the stability & flow values has been checked with Iraqi specifications and showed that 6% ESP was the best ratio which has (12.83 KN) stability and (2.45) mm flow values. Higher density was found at 6% ESP and it has (2.32 gm/cm3). The results of indirect tensile strength (ITS) of 6% ESP showed reduction in ITS than 0% ESP specimen. While Tensile strength ratio (TSR) of 6% ESP is higher than 0% ESP that is (95.16 %) & (87.88 %) respectively, therefore 6% ESP specimen is better than the other by resistance to moisture damage.

1. Introduction

Nowadays, waste by-product materials have become widespread in the world and to get rid of these materials, different disposal systems as burning and land filling are used. These systems lead to accumulate waste materials in the environment that can cause unwanted appearance, air and ground water pollution. Therefore, recycling these materials is the best solution to attain the maximum benefit from their and in the same time, this solution will lead to reduce the amount of pollution [1]. These waste materials have become commonly used in the pavement fields, where used as an additive, modifier or construction materials (e.g. recycling asphalt materials, silica fume, rubber and others). In addition, many advantages can be obtained from using them like decreasing the construction cost or improving chemical or physical properties of other materials. Finding available, inexpensive and durable material is the hope of all engineers. Availability of eggshell, chemical composition, resistance of its powder to fire & climate change, all these characteristics encouraged the using of eggshell in

pavement field. Eggshell has good physical properties and low absorption values as proved in the results of some studies [2].

2. Related Studies

For a long time, the use of eggshells was unknown and disposed of in a landfill resulting in more environmental pollution. Nevertheless, this problem began to be solved when the eggshells using become known in some fields like engineering. As an example in engineering fields, the eggshells used, as a cement replacement in concrete mixture and the results were encouraging as illustrated in Mohamed, et.al research [3]. Various studies have been conducted to identify the waste materials that can be used in the asphaltic pavement and as known from many researches and studies, improved or enhanced asphalt properties can be done by these waste materials. Many types of materials are available to improve asphalt like filler, fibers, wax, solvents emulsifiers, wetting agents and other chemical modifiers [4].

Sustainable engineering is one approach that used these waste materials to improve the pavement performance. Some studies followed this approach by using waste materials like coconut shell, egg shell, rubber, sugar cane and others in the asphalt mixture. Erfen and Mohd [2] have used egg shells in their study to evaluate the effect of eggshell as filler in hot mix asphalt. Their results showed the effective eggshell content was in the range of 3% to 5% and using eggshell as a filler will reduce the specific gravity. At last, they gave a summary that the eggshell is one of the substances that can be used as filler in the asphalt mixture. Egg shell used also as filler in Kiruthiha, et, al. [5] project, to fill the air voids of the asphalt mixture. They found that the eggshell is suitable to be applied in the road construction and its addition in the range of 10-15% in the bituminous mix with OBC of 6 – 6.5% gives better strength compared to conventional mix.

In 2015, some researchers used eggshell in their project by different percentages (0, 3, 6, 9, 12, 15, 20, 25 & 100%) from aggregate of sieve size No.200. The main goal was to determine the optimal eggshell content in the asphaltic mixture, and a comparison of feature parameters between conventional and modified samples had been made based on stability, flow, density, void in mineral aggregate, void filled with asphalt and total void in the mixture [6]. The results obtained from this project were: mixtures containing eggshell displayed maximum density at 12% eggshell content then decreased by increasing the shell's content of more than 12% where, this decreasing may be due to the low density of eggshell. Stability results increased at 12% eggshell specimens and decreased to its lowest value at 100% eggshell specimens. While flow results showed the maximum value at 100% eggshell specimens and decreased to its lower value at 10%. Stability & flow results gave the best range of eggshell content that can be used in asphalt mixture, which was (3 - 12) percentage.

Finally, all the results of voids in mineral aggregate for all eggshell specimens have been conformity Iraqi Specifications [7] and on the contrary in voids in total mix & voids filled with asphalt; results where only specimen of (12) % eggshell content have been conformity . Therefore, the result of the project was, 12% eggshell content was the optimal content among all selected percentage. The properties of asphaltic mixture are depended on several things, and filler type is one that plays important role. Filler serves various purposes when added, the first one compose a mortar by which stiffness of the mix is improved, also plays as contact points between bitumen and aggregate particles, fill voids that reduce bitumen content and that lead to increasing the stability [8].

3. Study Objective

Using eggs in many homes, restaurants and chicken hatcheries generate big quantities of eggshells to the surrounding environment as domestic waste materials. Therefore, the main goal of this study is to analyze the effect of using eggshell as filler in hot mix asphalt concrete because, the eggshell materials are inexpensive when compared to other filler type used in Iraq. In addition, the suitable mix proportion that can withstand against the development of distress has to be found out by various laboratory experiments. In order to realize this objective, the design of conventional and modified asphalt mixtures with eggshell have been provided then a comparison is made between these mixtures to determine the optimal eggshell content at optimum bitumen content. A series of laboratory experiments have been implemented on specimens of different eggshell powder percentages. The

implementation of study done by preparing specimens with eggshell content start from 0%, 3%, 6%, 9%, 12%, 15%, 20, 25 and 100% and at the last, the comparison has done for stability, flow, bulk density, indirect tensile strength and tensile strength ratio values.

4. Materials and Experimental Work

4.1 Materials

This study is made to investigate the effect of eggshells powder (ESP) when used as filler in Marshall Specimens. Therefore and for this reason, different percentages of this powder used (0, 3, 6, 9, 12, 15, 20, 25 and 100%). Full details, materials characterization used, specimen preparation and testing procedure are presented below.

4.1.1 Asphalt Cement:

The asphalt cement used in this study is taken from Al-Daurah refinery. The physical properties of the petroleum asphalt are presented in Table 1.

Table 1. Physical Properties of Asphalt Cement.

Test	Results	SCRB Specification
Penetration (25°C, 100g, 5sec) ASTM [D5] (1/10 mm)	48	40-50
Ductility (25°C, 5cm/min). ASTM D 113 (cm).	165	≥100
Flash point ASTM D 92 (C^O).	252	≥232
Softening point (ring & ball). ASTMD 36 (C^O).	52	50-60
Solubility in trichloroethylene (%)	99.4	> 99
Specific gravity ASTM D 70	1.041	-----

4.1.2 Aggregate:

The aggregate used is coarse and fine aggregate. The aggregate brought from the hot mix plant of Al-Nibaee quarry at Al-Taji and crushed aggregate is selected only. The physical properties and chemical composition of the aggregate are shown in Table 2.

Table 2. Physical Properties of Nibaee Aggregates.

Property	Coarse Aggregate	Fine Aggregate
Bulk Specific Gravity (ASTM C127 and C128).	2.6303	2.630
Apparent Specific Gravity (ASTM C127 and C128).	2.669	2.680
Percent Water Absorption (ASTM C127 and C128).	0.45	0.53
Percent Wear (Los-Angeles Abrasion) (ASTM C131).	20.12	……
Chemical Compound	% Content	
Silica,SiO_2	82.52	
Lime, CaO	5.37	
Magnesia, MgO	0.78	
Sulfuric Anhydride, SO_3	2.71	
Alumina, Al_2O_3	0.48	
Ferric Oxide, Fe_2O_3	0.69	
Loss on Ignition	6.55	
TSS(total soluble salts)%	1.9	

Organic matter (%)	0.5
Gypsum content (%)	0.45
Mineral Composition	
Quartz	80.3
Calcite	10.92

The test was done in cooperation with National Center for Construction Laboratories and Researches (Baghdad).

Wearing course is Prepared under the standard specifications which is established by The State Corporation for Roads & Bridges specifications of Iraq [7]. The mid of this specification is adopted in this study as shown in Table 3 and Figure 1 for hot mix bituminous paving mixtures.

Table 3. Gradation of Aggregate for Wearing Course, [7].

Sieve Size	Sieve Opening (mm)	Percentage Passing by Weight of total Aggregate & filler	
		Wearing Course	
		Specification Limit (S.C.R.B)	Selected gradation of Aggregate
¾	19.0	100	100
1 /2	12.5	90-100	95
3/8	9.5	76-90	83
No.4	4.75	44-74	59
No.8	2.36	28-58	43
No.50	0.300	5-21	13
No.200	0.075	4-10	7

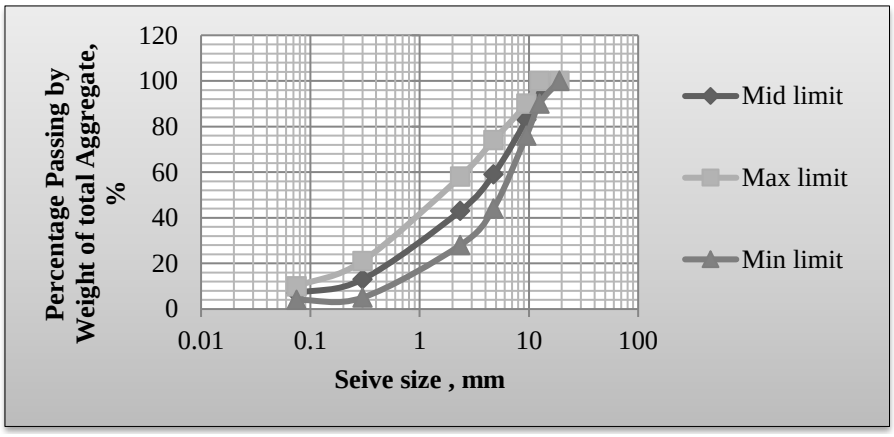

Figure 1. Specification Gradation Limits for Wearing Course.

4.1.3 Cement: The chemical composition and physical properties of Portland cement are shown in Table 4. The reason of using cement as fillers in this study is, many researchers used eggshells with concrete mixture and outputs results of their study showed the compatibility of these shells with cement.

Table 4. Chemical Composition & Physical Properties of Cement Used[a].

Chemical Compound	% Content[a]
Silica,Sio_2	21.54
Lime, CaO	62.2
SiO_3	……
Sulfuric Anhydride, SO_3	1.5
Alumina, $Al2O_3$	4.4
Magnesia (MgO)	3.7
Ferric Oxide, Fe_2O_3	5.3
K_2O	0.58
Na_2O	
Loss on Ignition (L.O.I)	0.3
I.R	0.48
$Ca(OH)_2$	……
Total	100
Physical properties	
%Passing Sieve No. 200	98
Apparent Specific Gravity	3.1

[a] From Local Market (Tests are carried out by NCCL)

4.1.4 Egg Shell:

The eggshell powder consists of a set of elements and Calcium is the main element that forms it. The similarity of eggshell powder (ESP) in its chemical composition to industrial lime and cement made it a good replacement to them [5] **.** Literature study has shown that ESP primarily contains CaO and the remaining elements are Al_2O_3, Cr_2O_3, SiO_2, Cl, MnO and CuO [9] as well as with cement and lime where the CaO is greater content as compared with other elements. The eggshell texture is brittle, easily crumbled and owns white or brown color and specific restriction should be taken when decided to use in the asphalt mixture. The steps that have been followed in this study included collecting the eggshells from residues of the house, washing the shells very well, drying by leaving in an air, removing unwanted materials from all shells and grinding. After obtaining the pulverized eggshells, sieve process on No. 200 made to ensure it free from unwanted materials and has the filler gradation, and the portion passing this sieve is used as filler as shown in Figure 2. Eggshell powder has become widespread in the field of engineering where used in the concrete mixture when a part of cement is replaced by it to improve mixture's properties.

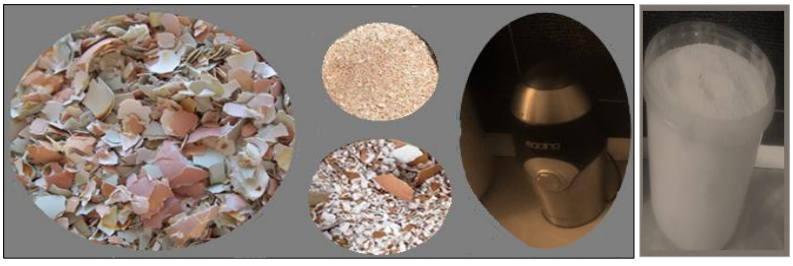

Figure 2. Eggshell's filler Preparation.

5. Sample Preparation

Marshall Design method is generally used to set the aggregate mixing and obtain the optimum bitumen content. All details of the selection aggregate, bitumen and gradation are done according to the Iraqi specification. As well as specimens mixing and compacting (75 blows for each face) are done under the test conditions. To prepare eggshell as powder, followed the same steps of preparation mentioned above to be ready for use in Marshall Specimen.

The optimum asphalt content (OAC) should be obtained and it is found to be (4.85%) for wearing layer based on Marshall testing analysis. All the ratio of eggshell powder added to the specimen depended on OAC and the graphs & results for determining OAC are presented in Figure 3. Results from these curves checked with SORB specification limits in Table 5, to know either these results are accepted or not. For finding this optimum, 15 samples are made with three samples for each percentage.

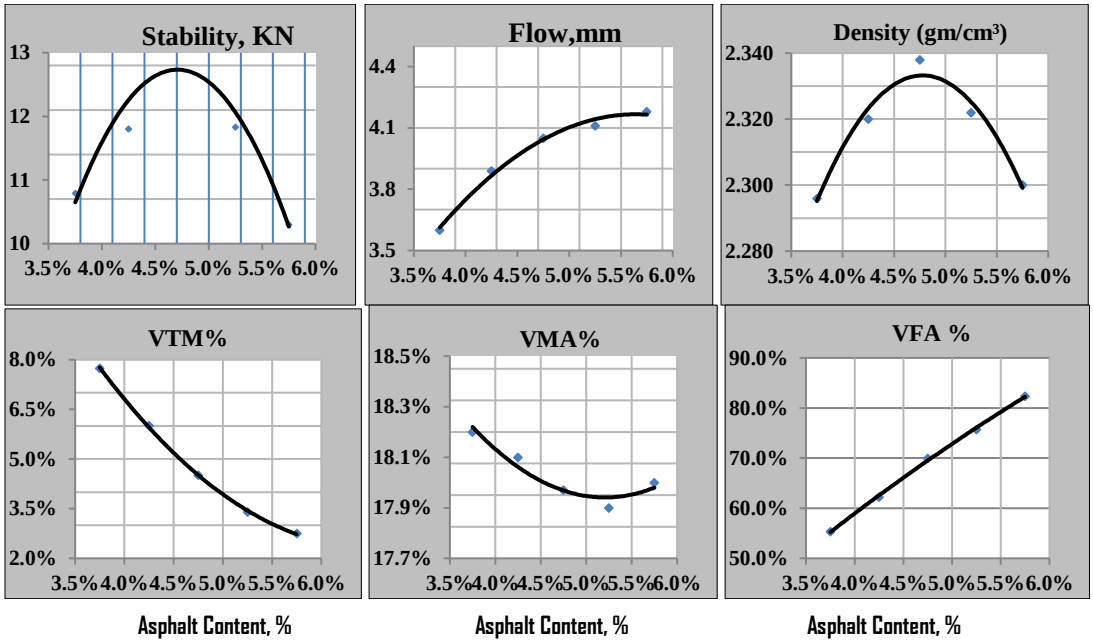

Figure 3. The Graph with Parameter Needed To Obtain the Optimum Asphalt Content for Wearing Course Layer.

Table 5. Properties of Wearing Asphalt Mixture According To Iraqi Specification Limits (SORB).

Property	Values of OAC	Surface Course	Check Results
Marshall stability (KN)	12.75	8 (min)	✓
Marshall flow, (mm)	3.98	2-4	✓
Voids in Marshall specimen, (%)	4.25	3-5	✓
Voids in mineral aggregate, (%)	17.97	14 (min)	✓
Optimum Asphalt Content, (%)	4.85	4-6	✓

6. Test Methods

6.1 Stability & Flow

Marshall Stability and flow test is done to determine the strength of the bituminous mixture and then predict its performance according to ASTM D 1559 [10]. The results of maximum load resistance and the corresponding flow value are reported as the average of three specimens for each percent. Marshall Stability values are taken at the rate of (2 in/min.). Different specimens prepared and the comparison between Marshall specimens (with and without ESP) is explained by stability value in Figure 4.

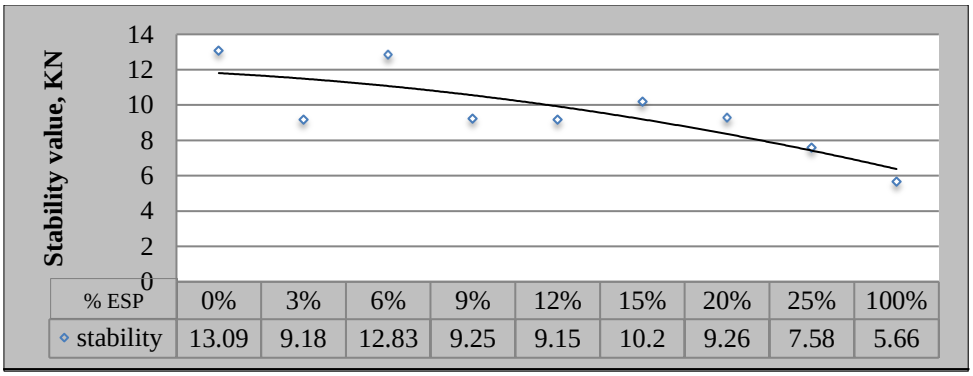

Figure 4. Stability Values of Marshall Specimens with ESP.

Figure 4 shows the stability values for all ESP ratio where it is (13.09) KN for 0% ESP and (5.66) KN for 100% ESP. From this figure, it is noted that at 100% ESP the stability value decreases to about more than half value than at 0% ESP. For ESP specimens, the stability results have the highest value for the specimen of 6% ESP and the lowest value for 100%. For all ESP ratios, except 25 & 100%, the stability values checked with Iraqi specification in Table 5 and all gave values more than (8) KN. Whenever the stability of specimens is increased, a better mixture will be obtained and therefore, 6% ESP specimens is the best ratio than others stability.

Figure 5 shows a comparison between specimens with and without ESP by flow values. From this figure, the flow value of 0% ESP is (3.54) mm and (3.25) mm for 100 % ESP. it is noted that at 6% ESP the flow value decreases more than all percents of ESP. Moreover, the flow value of 15% ESP represents the highest value as compared to other. From figure 5 note that the variation in the values of flow at most negligible with increases egg shell powder content more than 15%. This may be due to the fact that when increasing the shells powder content beyond 15%, the voids in the specimen will be more filled with the shells powder and thus will be reduced the compressibility of the specimen. Finally, from the results it becomes clear that, (6%) ESP is the best ratio in stability and flow.

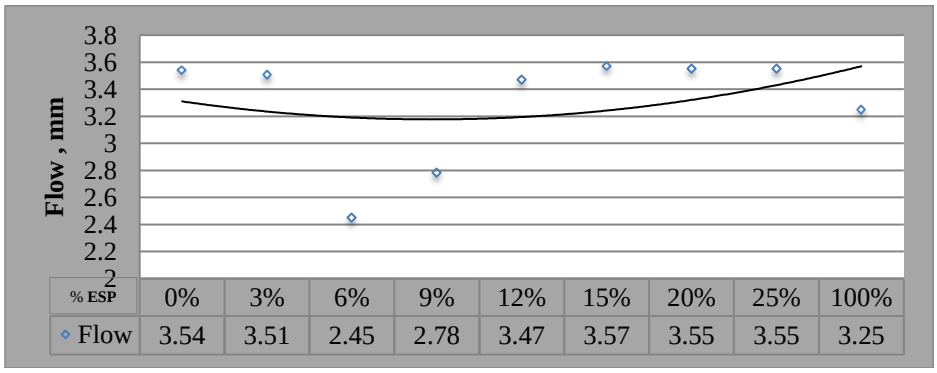

Figure 5. Flow Values of Marshall Specimens with ESP.

6.2 Density

The bulk density value (Figure 6) is obtained according to ASTM D2726 [10]. The weight of all specimens in air, water and saturated surface dried are taken to calculate the bulk specific gravity then bulk density. Figure 6 shows that the density of the admixture is increased to 6% eggshell powder and then after that, density value began to decline. 6% ESP gives a higher density value which is (2.32 gm/cm^3) than another ratio and that means 6% ESP mixture is the densest. From all three figures above, the optimum eggshell content of our study may be the (6%) where the stability, flow and density value higher than all ratios and the higher stability means the ability of the mixture to resist the deformation due to traffic loads acting on.

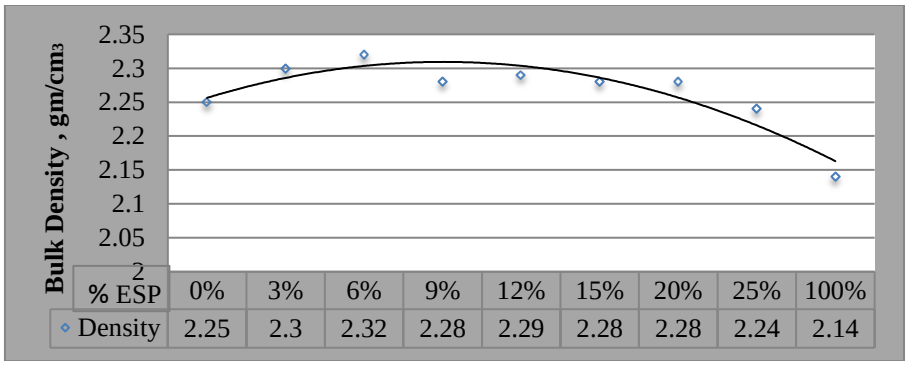

Figure 6. Bulk Density Values of Marshall Specimens with ESP.

6.3 Indirect Tensile Strength & Tensile strength ratio (TSR)

For all eggshell specimens, except 6%, some of their results have not coincided with Iraqi specification and only 6% ESP specimens is conform with this specification and has the best stability, flow and density results . This is the reason to choose only 6% ESP specimens in indirect Tensile strength test to complete checking of this best ratio. As known, the pavement structure is subjected to many problems and cracking is one of these problems. Therefore, the indirect tensile strength test is used in this study to determine the tensile properties of the specimen according to ASTM D 6931 [10]. All figures above show the specimens of 6% ESP is the optimum so that and for more checking ITS test is done on this ratio only. Then a comparison is made with a conventional specimen of 0% ESP. The indirect tensile strength test is done for these specimens without and with water to investigate the effect of eggshells powder under weather condition and then to evaluate the moisture susceptibility of the mixture. The indirect tensile strength results of 0 & 6% ESP for both conditioned and unconditioned specimens are given in Figure 7.

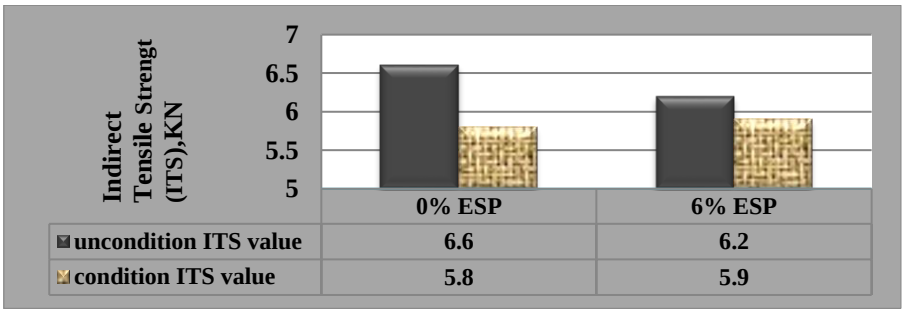

Figure 7. Effect of Egg Shell Powder (ESP) On Tensile Strength of Asphalt Mixtures.

The results were (6.6 & 6.2) KN indirect tensile strength (ITS) for unconditioned specimens of (0 & 6) % egg shell content. And after soaking the specimens in water the results reduced to be (5.8 & 5.9) KN for (0& 6) % eggshell specimens. From these results noted that reduction in indirect tensile strength of 6% eggshell specimen is lower than 0% shells specimen. And that may be give a good indication to the resistance of egg shells specimen for the water effect. To prove that, Tensile strength ratio (TSR) calculates later.

Tensile strength ratio (TSR) is also calculated in this study to obtain the resistance of specimens to moisture damage and then estimate the water sensitivity. The indirect tensile strength of the specimen under the condition to that of unconditioned result is considered the tensile strength ratio, as shown in Figure 8. Higher tensile strength ratio means good strength of mixture to resist moisture damage. A total of 12 specimens are prepared for this test on two groups with 3 specimens for each ratio to obtain the result as the average value. The specimens of the first group (6 specimens) put it in a water bath at a temperature of 60°C for 24 hrs then removed and kept at 25°C for 2 hrs. Other specimens of the second group are kept in the oven at 25°C for 2 hrs.

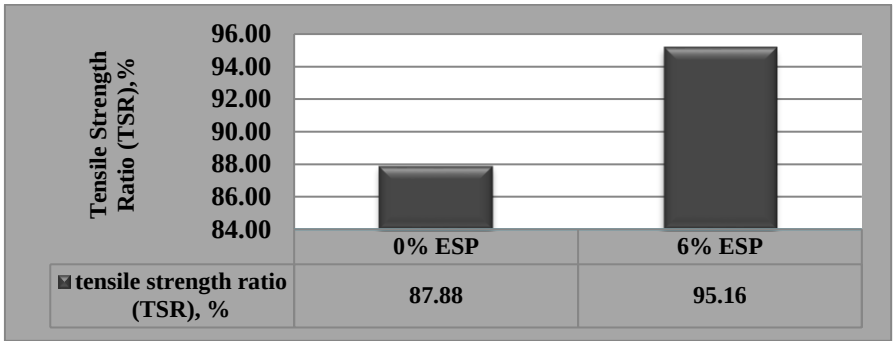

Figure 8. Effect of Egg Shell Powder (ESP) On Tensile Strength Ratio of Asphalt Mixtures.

According to Figure 8, the tensile strength ratio (TSR) of eggshell's specimen (95.16 %) is higher than the other without shell (87.88 %). In general, the higher tensile ratio means that the mixture has a good performance, lower reduction of specimen's strength in water and more resistant of the mixture in water soaking condition. Therefore, shell's specimen is the best than the other in resistance to moisture damage where it has the higher tensile ratio.

7. Conclusions

From all test results obtained in this study about the used eggshell powder as filler material in hot mix asphalt concrete, the main conclusion can be summarized as:

1. Adding 6% ESP to asphalt mixture gives a higher density, higher stability, lower flow and higher tensile ratio value and that means, 6% ESP is a better ratio than others (within the limits of this study).
2. From all results above, adding eggshell powder to asphalt mixture should be taken with a range of (1-6) percent, where using ratio higher than this range may give somewhat unsatisfactory results.
3. Tensile strength ratio (TSR) of eggshell's specimen is higher than the specimen without shell. The higher tensile ratio means that the mixture has a good performance, lower reduction of specimen's strength in the water and more resistant of the mixture in water soaking condition. Therefore, the shell's specimen is the best than the other in resistance to moisture damage where it has the higher tensile ratio.
4. Adding eggshell powder to asphalt mixture makes the reduction in indirect tensile strength (ITS) very less and this behavior usefulness in specified situations when the resistance for the water effect is required.

Reference

[1] Hassan H H B 2014 Eggshell Perpustakaan Ump E Mix. *Report submitted in partial fulfillment of requirements for the award of the degree of Bachelor of Engineering (Hons.)* Civil Engineering Faculty of Civil Engineering and Earth Resources Universiti Malaysia Pahang.

[2] Erfen Y B and Mohd Yunus K N B 2015 The Appropriateness of Egg Shell as Filler in Hot Mix Asphalt. *researchGate*.

[3] Mohamed A M, Dinesh K M, Milan Ch J and Vani G 2016 Replacement of Cement using Eggshell *SSRG International Journal of Civil Engineering (SSRG-IJCE)* **3** 1-2.

[4] Federal Highway Administration Research and Technology 1997 Retrieved from User Guidelines for Waste and Byproduct Materials in Pavement Construction.

[5] Kiruthiha K, Loshini G and Thivya M 2015 Strengthening of Flexible Pavement using Egg Shell as a Filler *International Journal of Engineering Trends and Technology (IJETT)* **21** 483-486.

[6] Ahmed K M and Adnan M Q 2017 Using Egg Shells to Improved H M A A project Submitted to the Highway and transportation Department/Faculty of Engineering/ Mustansiriya University

in a partial Fulfilment of the Requirements For the Degree of *B.Sc. in Highway and Transportation*, Iraq.

[7] Iraqi General Specification for Roads and Bridges 2003 Standard Specification for Roads and Bridges *The state Corporation for Road and Bridges* Revised Edition.

[8] Sarsam S I and Sultan K H 2015 Impact of Aggregate Gradation and Filler Type on Marshall Properties of Asphalt Concrete *Journal of Engineering* **21** 34-46.

[9] Jassim N W 2012 Influences of Fly-Ash and Eggshell Powder on Some of Engineering Properties of Al-Umara Soil *Journal of Engineering and Development* **16** 211-219.

[10] ASTM, 2009 *Road and Paving Materials* Annual Book of ASTM Standards Volume **04.03** *American Society for Testing and Materials* West Conshohocken, USA.