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Characterization of Hot Mix Asphalt Modified by Egg Shell Powder

Ahlam K. Razzaq[1]
[1]Lecturer at Civil Engineering Department, Facility of Engineering, University of Kufa /Al-Najaf / Iraq.

Rana A. Yousif [2]
[2] Highway and Transportation Engineering Department, Facility of Engineering, Mustansiriyah University, Baghdad, Iraq.

Sady A. Tayh[3*]
[3]Highway and Transportation Engineering Department, Faculty of Engineering, Mustansiriyah University, Baghdad, Iraq.*

Abstract

Construction of asphalt pavement involves a large outlay of finance. Addition of some waste materials such as coconut shell, saw dust, steel slag, etc., may save a huge amount of investments as provides efficient performance. This research has the interest to introduce the egg shell powder as a sustainable modifier to fulfil the objectives of reducing the weight percentile, reducing costs and improving the economic viability of hot mix asphalt. This research was conducted performing a number of experimental tests on virgin and modified asphalt by adding egg shell powder (3, 5, 7, 10, and 15%) by weight of asphalt to evaluate the physical properties of asphalt cement as well as the mechanical properties of hot mix asphalt. The results of the study demonstrated a decrease in penetration and the rotational viscosity as well as a valuable increase in flash point versus increasing percent of the waste material. Although, 3-5% egg shell still give the asphalt cement good ductility. The mechanical tests showed improvement in stability-flow results with increasing egg shell percent. This paper recommends that egg shell can be used successfully for producing asphalt concrete.

Keywords: DSR, egg shell, hot mix asphalt, rheological properties, viscosity.

I. INTRODUCTION

A few years ago, many studies towards the use of alternative materials for road construction and some of them have shown positive and encouraging results. This promoted the use of organic and inorganic materials as modifiers or additives in asphaltic pavement such as plastics, polymers, glass, oils, fibers, etc. With this, not only can solve the problem of the lack of original material in asphaltic pavement construction, but also give alternatives by recycling process [1].

It is estimated that roughly 100 million tons of hen egg shell is generated throughout the world every year without realizing that it has many uses in other areas, perhaps most distinguishes the eggshell is fit on mineral salts such as calcium, phosphorus, manganese, molybdenum, iron, copper, chromium, fluorine, zinc. The researchers chose this material in order to investigate its effect on bitumen as long as it's having an effect on the chemically cement material. These egg-shells waste are non-biodegradable and the majority of eggshell waste is deposited as landfills. Egg-shell waste in landfills attracts vermin due to the attached membrane in landfills and causes problems associated with human health and environment. So this egg-shell waste is useless as a landfill material [2].

Throughout the world, asphalt concrete is being widely used for the construction of roads. Hence, it has been properly labelled as a significant role in the infrastructure development of a nation. Sustainable construction has become an interest in the engineering community and several techniques have been developed to assess the environmental impact of new construction materials. Researches have shown that it's doable to use recycled materials to interchange a number of the normal asphalt mixture elements to provide more sustainable asphalt pavement materials. One of those materials that can be recycled and have the possibility of use in asphalt concrete applications is egg shell powder. Eggshell waste is considered as food waste, that is that if subjected to adequate scrutiny, may well be appropriate alternative material for road pavement construction [3].

Materials usually used in the flexible pavement are bitumen, aggregate, and filler. The filler material is used as an addition to these components in order to avoid the voids formed in wearing coat. When it is mixed with bitumen and aggregate it fills the cavities and avoids the formation of cracks thereby creating a dense mix and increasing the viscosity of bitumen. It also acts as a reinforcement material and increases the compaction effects required to compact the specimen. Modified binders with suitable modifiers are found to result in longer life for wearing courses relying upon the proportion and type of modifier used. Since the eggshell has an identical composition as that of limestone, it will be utilized in the pavement as they're cheap when put next to others. Overloading of trucks and vital variations in daily and seasonal temperature of pavements are liable for development of distress symptoms like raveling, undulations, rutting, cracking, bleeding, shoving and potholing of bituminous surfaces. So as to find the suitable mixture proportion which may with efficiency withstand the issues, optimum asphalt content (OAC) and optimum eggshell content must be seen by experimental studies [4].

Raji and Samuel have listed the benefits of egg shell as follows: Considerable reduction in alkali-silica and sulfate expansions; meets the foremost tight environmental laws nationwide; ideal for painting in occupied areas; excellent sturdiness and washable finish; resist mould and mildew on the paint film; saves money; less material needed; and meets strict performance and aesthetic necessities [5].

Various studies have been conducted to identify the new materials that can be used as modifiers of bitumen in hot mix asphalt concrete. Modification in the mixture is one approach that can be taken to improve the performance of the pavement. The eggshell powder is an alternative to enhance the properties of conventional asphalt binders in the asphalt mixture. Thus, by using eggshells as a modifier, sustainable performance can be improved. Performance of the mixture specified by obtaining the optimum bitumen content (OBC) and optimal eggshell content (OESC).

This work has investigated the potential use of egg shell as an asphalt binder additive. The egg shells were added to the asphalt binder directly with proportions of (3, 5, 7, 10, and 15%) by weight of asphalt. In the laboratory test, control group binder and asphalt mixtures were tested and compared by those modified by egg shell powder.

The work was limited to one type of gradation and one source of aggregate (Al Nibaee aggregate), and one type of asphalt cement from Al Dora refinery in Baghdad with 40-50 gradation. One nominal maximum size aggregate (12.5mm) was used in these mixes.

II. THE AIM OF THIS STUDY

The essential objective of this study is to investigate the utilization of egg shell powder as an additive for asphalt binder and evaluate its influence on the physical and rheological properties of asphalt binder as well as asphalt mixture.

III. MATERIALS

The materials used in this study are locally available and selected from the current local materials used in roads construction in Iraq.

III.I Asphalt Cement

One type of asphalt cement is used (40/50) Penetration grade from Al-Daurah Refinery was utilized in this study. There are a number of tests to assess the properties of bituminous materials. The following tests are usually conducted to evaluate different properties of bituminous materials such as penetration test, softening point test, ductility test, specific gravity test, viscosity test, flash and fire point test, loss on heating test, and DSR. The properties of asphalt cement were within the required specifications of 40/50 penetration grade asphalt binder as shown in Table 1.

Table 1. Properties of the used asphalt cement

Test	Test results	Specification	
		Min.	Max.
Specific gravity (g/cm³)	1.013	1.01	**1.06**
Penetration (0.1 mm)	42-45	40	**50**
Ring and ball softening point (c°)	51	46	**56**
Ductility (cm)	>130	100	
Flash point (c°)	**309**	**250**	

III.II Aggregate

Aggregates are bodying material in HMA. They play a most crucial role in the performance of bituminous mixture. They comprise about 90 to 95% by weight of the total mixture [6]. Therefore, information on aggregate properties is important to come up with top quality HMA mixtures.

The coarse and fine aggregates used were brought from Al-Nibaee district at the northern of Baghdad. The coarse aggregate is crushed gravel and also the filler used was Portland cement to supplement the fine materials in hot mix asphalt design. The physical properties of al-Nibaee aggregate are listed in Table 2.

Table 2. Physical Properties of Al-Nibaee Aggregates

Properties	Coarse aggregate	Fine aggregate
Bulk Sp.G. (ASTM C127 and C128)	2.610	**2.631**
Apparent Sp.G. (ASTM C127 and C128)	2.641	**2.680**
Percent water absorption (ASTM C127 and C128)	0.423	**0.542**
Percent wear (loss Angeles Abrasion) (ASTM C131)	**20.10**	

The aggregates were washed, dried, sieved and separated into various sizes. In this study, one nominal maximum size was selected (12.5 mm) with one aggregate gradation, Table 3. The aggregate fractions were then recombined in the proper proportions to meet the chosen gradation.

Table 3. Gradation of the aggregate for surface course.

Sieve size	Specification % passing	Selected Gradation
3/4 in.	100	100
1/2in.	90-100	95
3/8in.	76-90	83
No.4	44-74	59
No.8	28-58	43
No.50	5-21	13
No.200	4-10	7

III.III Additive (Egg Shell Powder)

Eggshell consists of several mutually growing layers of $CaCO_3$, the innermost layer-maxillary 3 layer grows on the outermost egg membrane and creates the base on which palisade layer constitutes the thickest part of the eggshell. The top layer is a vertical layer covered by the organic cuticle. The eggshell primarily contains calcium, magnesium carbonate (lime) and protein. In many other countries, it is the accepted practice for eggshell to be dried and used as a source of calcium in animal feeds. The quality of lime in eggshell waste is influenced greatly by the extent of exposure to sunlight, raw water and harsh weather conditions. It is the fine-grained powder with suitable proportion which is sieved to the required size before use with asphalt binder as appeared in Fig. 1.

Eggshell is brittle white and has a grainy texture. It is semi-permeable and resistant to fire and climatic changes [4].

Fig 1. Egg shell powder

The main ingredient in eggshells is calcium carbonate (the same brittle white stuff that chalk, limestone, cave stalactites, sea shells, coral, and pearls are made of). The shell itself is about 95% $CaCO_3$ (which is also the main ingredient in sea shells). The remaining 5% includes Magnesium, Aluminum, Phosphorous, Sodium, Potassium, Zinc, Iron, Copper, Ironic acid and Silica acid. Eggshell has a cellulosic structure and contains amino acids; thus, it is expected to be a good bio-sorbent [5], [7] The chemical composition of the eggshell powder is shown in Table 4, while the physical properties are as shown in Table 5.

Table 4. The chemical composition of egg shell powder

Composition	EPS
CaO	47.49%
SiO_2	0.11%
Al_2O_3	Nill
Fe_2O_3	Traces
MgO	Nill
SO_3	0.38%
K_2O	Nill
Na_2O	0.14%

Table 5. Physical Properties of Egg Shell

Physical Properties	**Result**
Moisture content	1.2
Density (g/cm^3)	0.9
Surface area m^2/g	18.5

IV. MIX DESIGN

Marshall mix design technique has been followed throughout this work. Consequently, a mixture of aggregate with one gradation (12.5mm) nominal sieve size and one asphalt cement 40/50 penetration gradation were utilized. Marshall mix design method uses several trial blends (five blends with 3 samples each for a total of 15 samples), each with a definite asphalt binder content. Then, optimum binder content can be calculable by evaluating every trial blend's performance. This technique includes preparation of cylindrical specimen which is 101.6mm diameter and 63.5mm height [4], [8].

V. RESULTS AND DISCUSSIONS

V.I Physical Properties

To identify some properties of asphalt after entering as a component of hot asphalt mixture, physical experimental tests (penetration, softening point, flash point, and viscosity) were conducted using asphalt with penetration of (40-50) as a binder which is modified with eggshell powder of (3, 5, 7, 10, and 15 %) by weight of the asphalt to ensure they conform to the specifications in addition to study their behavior as additive or filler. All above results displayed in Table 6.

Table 6. Modified asphalt cement properties

Properties	ASTM specification	Penetration grade (40-50)						
		Test results						SCRB specification [SCRB,2007]
	Eggshell %	0	3	5	7	10	15	
Penetration(25 °C, 100 gm, 5 sec, 0.1 mm)	D-5	45	43	40	38	36	33	40-50
Softening point , °C	D-36	67	66	66	65.5	65	64	……….
Flash point °C	D-92	234	233	237	240	244	260	Min limit 232 C°
Ductility, cm	D-113	130	118	105	98	86	57	>100
Absolute viscosity at 60°C , poise	D-70	2520	3600	3960	4410	5580	5940	4000±800
Loss in weight, %	D-1754	0.346	0.521	0.411	0.571	0.586	0.778	0.75
residue pent.	D-5	48	48	51	53	53	59	+55
Residue ductility	D-113	78	64	42	44	35	31	+25
Soluble in CCL4	D-2042-97	99.3	99.3	99.6	99.7	99.6	99.2	Min limit 99%

V.II Rheological Properties

The fundamental rheological properties of Egg Shell asphalt binder were measured in terms of the complex modulus (G*), phase angle (δ), temperature sweep test on un-aged and RTFO-aged states. Also, the Egg Shell asphalt binder was tested for fatigue performance after short-term aging procedure (RTFO-aged) utilizing dynamic shear rheometer (DSR).

1- Temperature Sweep Test at High Temperature

In this test G* (complex modulus) and δ (phase angle) of all un-aged Egg Shell modified binder at four different proportion was measured over a temperature range between 40°C and 82°C using DSR to investigate the effect of adding Egg Shell at four different proportions in terms of rutting. Based on the Superpave specification, G*/sin δ represents the asphalt binder resistance to permanent deformation (rutting). A stiff and elastic binder could contribute better to rutting resistance, therefore, increasing G* or decreasing sinδ would lead to more rutting resistance. It is recommended a minimum value of 1.0 kPa for G*/sin δ to ensure that asphalt binder could resist well against permanent deformation at designed performance grade temperature. As a result, 1.0 kPa was selected as failure temperature criteria in this test. Fig. 2 shows the failure temperatures for Egg Shell modified binders in four different proportions.

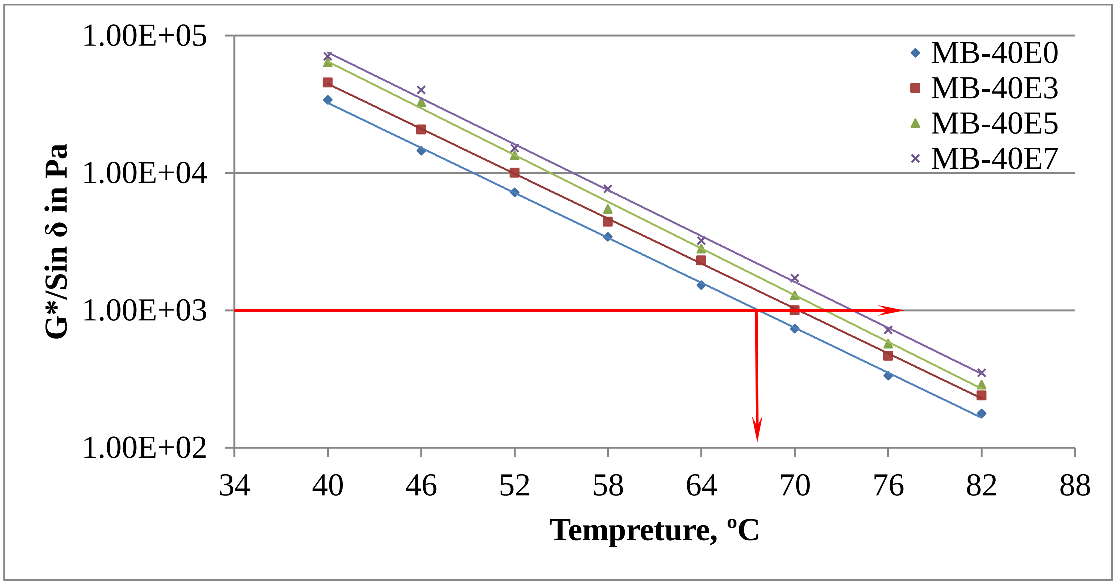

Fig 2. Temperature Sweep Test Results for Unaged Binders

Temperature sweep test on RTFO aged binder were carried out for Egg Shell modified binder at four different proportions as shown in Fig. 3. It is recommended that a minimum value of 2.2 kPa for G*/sin δ to ensure that asphalt binder could resist well against permanent deformation at designed performance grade temperature. As a result, 2.2 kPa was selected as failure temperature criteria in this test.

Figures 2 and 3 shows that regardless of aging state the Egg Shell modified asphalt has the highest stiffness modulus (G*) compared to the neat asphalt. This indicates the improved (reduced) temperature susceptibility of the Egg Shell modified asphalt resulting in both increased flexibility at lower temperatures and increased hardness at high temperatures.

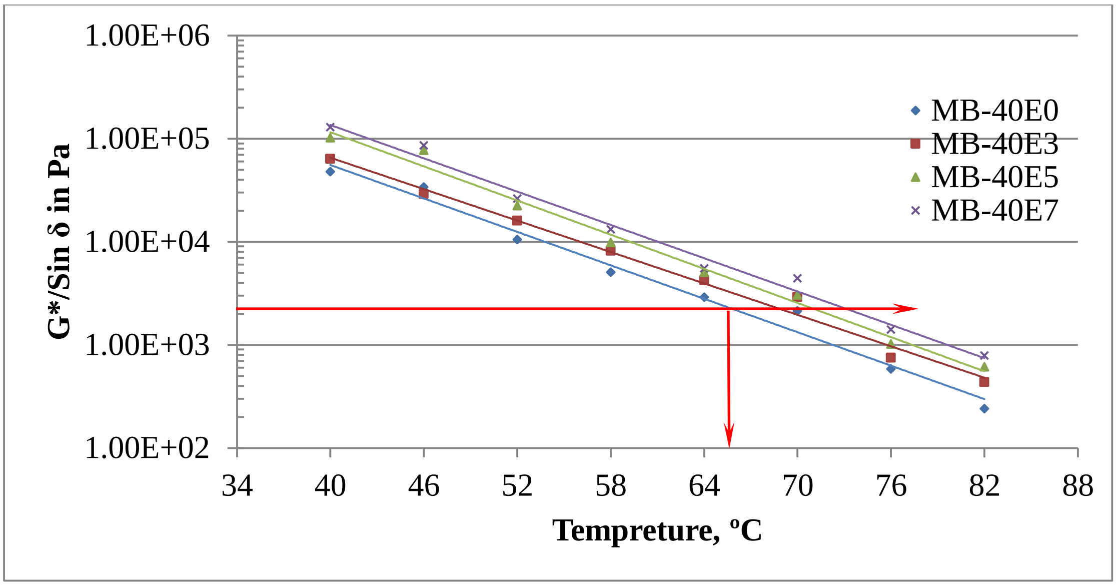

Fig 3. Temperature Sweep Test Results for after RTFO Test

2- Sustenance Measurement

The sustenance measurement of original and modified asphalt binders using temperature sweep test at medium temperature domain as a measure for asphalt binder fatigue resistance using DSR. This test was ideal to observe how asphalt binder changes over time. This test was carried out on PAV aged samples with diameter of 8 mm and thickness of 2 mm at a range of temperatures (10 - 40°C) with a frequency of 10 Hz. The results of temperature sweep test are shown in Fig. 4.

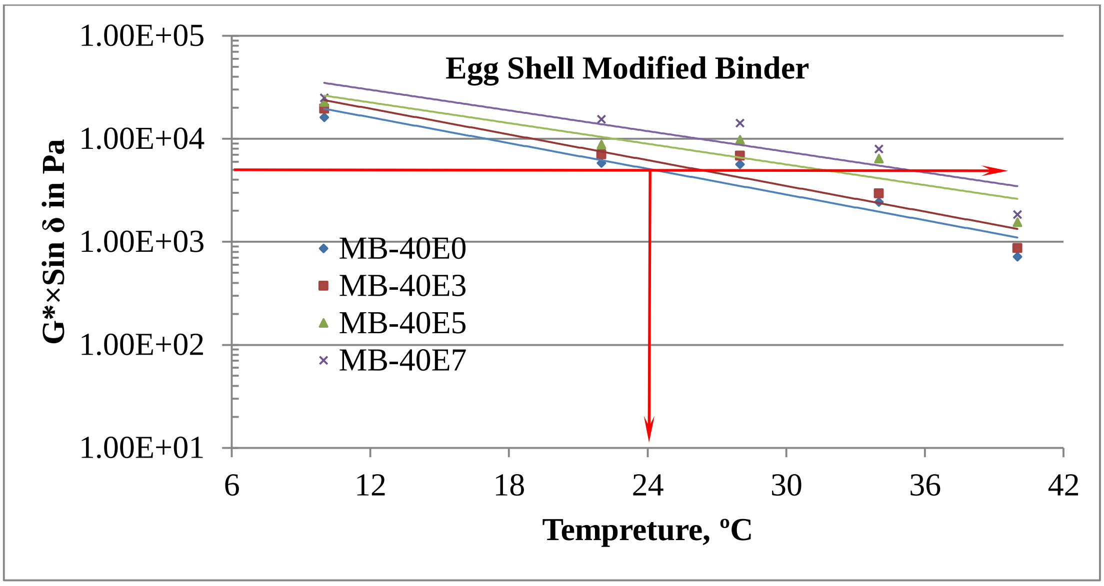

Fig 4. Fatigue Parameter at Low Temperature Domain

The increment of failure temperature is extremely necessary to enhance the high-temperature performance of asphalt binder. It'll facilitate to cut back the high-temperature deformation and rutting damage of asphalt concrete pavement. Table 7 shows the Failure Temperature and PG-Grading for Egg Shell Modified binder at four different proportions.

Table 7. Failure Temperature and PG- Grading

Binder Type	**Failure Temperature (°C)**			**Temperature High and Low PG – Grading**
	Un-aged	**RTFO Aged**	**PAV Aged**	
MB-40E0	67.5	67.6	24.0	PG64-25
MB-40E3	70.0	69.5	26.5	PG64-28
MB-40E5	72.0	72.2	32.0	PG70-33
MB-40E7	74.0	74.5	35.3	PG70-37

3- Mechanical Properties of HMA

The higher value of Marshall Stability and lower value of Marshall flow display the high potential to withstand heavy traffic and a higher resistance against rutting particularly at high temperatures [9].

The mechanical properties results are presented in Table 8. It should be noted that the values are at OAC in the base asphalt binders for HMA. The results indicate that the Marshall Stability increased with the increasing of eggshell powder content, while density increased in mixtures that contain eggshell powder. On the other hand, the Marshall flow increased with increasing eggshell powder proportion. The HMA Mixtures containing eggshell powder yielded higher values of Marshall Quotient than control mixtures. It is often inferred that these modified HMA give better resistance against permanent deformations due to their higher stability and MQ and additionally indicate that these mixtures are often utilized in pavements wherever higher stiffness asphalt mixture is needed, particularly in warmth regions.

Table 8. Mechanical properties results

Additive	Asphalt Surface course type IIIB Asphalt penetration (40-50)				SCBR specification
Egg shell%	0	3	5	7	
Stability , KN	10.97	11.41	11.65	11.58	Min. limit 8
Flow, mm	3	3.1	3.1	3.3	2-4
Marshall Quotient	3.65	3.68	3.76	3.51	
Density, kg/m^3	2.138	2.104	2.21	2.25	………

To explain the effect of adding the egg shells to hot mix asphalt, Data has tabulated in Table 9 by comparing the results which have recorded with virgin mix has no additive. All values have been obtained to show improving in asphalt concrete characteristics.

Table 9. Comparison of Data from Tests

Test	Differences %				
Egg shells % (by wt of asphalt) Tests	3	5	7	10	15
Penetration	-4.4	-11.1	-15.6	-20.0	-26.7
Softening points	-1.5	-1.5	-2.2	-3.0	-4.5
Flash points	-0.4	1.3	2.6	4.3	11.1
Ductility	-9.2	-19.2	-24.6	-33.8	-56.2
Viscosity	42.9	57.1	75.0	121.4	135.7
Failure temperature at high performance grade	2.5	4.5	6.5		
Failure temperature at low performance grade	2.5	8	11.3		
Stability	3.8	5.9	8.0	……	…..
Flow	3.3	3.3	10.0	……..	…..
Density	2.6	3.4	5.2	……	…..

VI. CONCLUSIONS

After investigating the results of this project, it is concluded that:

1- Despite the apparent decline in the value of penetration, there was a significant increase in viscosity.

2- The flash point temperature was improved with increasing proportion of additive.

3- The additive has no significant effect on the softening point temperature because of small difference values obtained.

4- The addition of 5% eggshell powder has given the best results for the mechanical properties of the hot mixture.

In general, the results recorded have led to the fact that the egg shell powder could be classified as a promise modifier for asphalt mixture.

REFERENCES

[1] Y. Erfen, and K.N.H. Mohd Yunus, (2015). The Appropriateness of Egg Shell as Filler in Hot Mix Asphalt, 2015, 10.13140/RG.2.1.4113.5201.

[2] M. Dexit, A. Meena, A. Malik, Chhinderpal, and K. Sundesha, Effect of Using Egg Shell Powder and Micro Silica Partially in Place of Cement in M25 Concrete, *SSRG International Journal of Civil Engineering, 3(5)*, 2016, 273-282.

[3] D.S. Ing, The Performance of Eggshell as Filler in Concrete Mixtures, Proc. of the 2014 International Conf. on Industrial Engineering and Operations Management Bali, Indonesia, January 7 – 9, 2014.

[4] K. Kiruthiha, G. Loshini, M. Thivya, and V. Kumar, Strengthening of Flexible Pavement using Egg Shell as a Filler, *International Journal of Engineering Trends and Technology, 21(10)*, 2015, 483-486.

[5] S.A. Raji, and A.T. Samuel, Egg shell as a fine aggregate in concrete for sustainable construction, *International Journal of Scientific & Technology Research*, *4(9)*, 2015, 8-13.

[6] F.L. Roberts, P.S. Kandahal, R.E. Brown, D.Y. Lee, and T.W. Kennedy, *Hot Mix Asphalt: Materials, Mixtures, Design, and Construction* (Second Edition) (Lanham, Maryland: National Asphalt Pavement Association Research and Foundation, 1996).

[7] J. Karthick, R. Jeyanthi, and M. Petchiyammal, Experimental study on usage of egg shell as partial replacement for sand in concrete, International Journal of Advanced Research in Education Technology, 1(1), 2014, 7-10.

[8] S.A. Tayh, The effect of additives in hot asphalt mixtures, *Journal of Engineering and Development*, *15(3)*, 2011, 131-150.

[9] M. Ameri, and A. Behnood, Laboratory studies to investigate the properties of CIR mixes containing steel slag as a substitute for virgin aggregates, *Construction and Building Materials, 26(1)*, 2012, 475-480.