Assessment of Ageing Impact on Cold Mix Asphalt Concrete

***Saad Issa Sarsam*[1]*, *Zahraa Ahmed Samor*[2]**
[1]*Professor, Department of Civil Engineering, College of Engineering,*
University of Baghdad, Iraq
[2]*Student, Department of Civil Engineering, College of Engineering,*
University of Baghdad, Iraq
Corresponding Author
Email Id: saadisasarsam@coeng.uobaghdad.edu.iq

ABSTRACT

Implementation of cold mixing technique for preparation of asphalt concrete is a sustainable process. However, the durability of the mixture is considered as an essential issue. In this investigation, cold mix asphalt concrete mixtures were prepared for base course construction. Two types of liquid binder, named Medium Setting Cationic emulsion CMS and Medium Curing cutback MC-250 have been implemented in preparation of the specimens. Mixtures were subjected to aeration, and then compacted. Two types of specimens were prepared, the first type was with 102 mm in diameter and 63 mm in height while the second type was with 102 mm in diameter and 104 mm in height. Specimens were subjected to ageing for (1, 7, 14, and 21) days at 40°C before testing. It was concluded that the strength properties of cold mix asphalt concrete increase with ageing period. The resistance to compressive stress increases by (402 and 112) % for CMS and MC-250 treated mixtures respectively. On the other hand, the resistance to shear stress increases by (400 and 120) % for CMS and MC-250 treated mixtures respectively. It can be recommended that ageing has a positive influence on the required strength properties of cold mix asphalt concrete and satisfies the specification requirements for base course.

Keywords: *Ageing, Compressive, Shear, Cold Mix, Asphalt Concrete, Cement, Lime.*

INTRODUCTION

Cold mix asphalt (CMA) provides several benefits that make it a good alternative to hot mix asphalt and warm mix asphalt. Such benefits include great reduction in the heating energy and emissions, as well as providing longer working time for transportation and placement of the mixture. Ling and Bahia, [1] stated that the challenges faced in the mix design procedure to control the volumetric properties and performance of CMA can limit the widespread use of CMA.

Oruc *et al.*, [2] reported that the production of cold mixed asphalt concrete has environmental and economic advantages when compared to hot asphalt mixtures. However, the emulsion asphalt mixture may exhibit inadequate performance, and it is susceptible to early service damage due to precipitation. Li *et al.*, [3] stated that cold mix asphalt is generally characterized as a sustainable material, with its mechanical strength increasing with curing time. It was concluded that the mechanical performance of CMA was considerably improved by the addition of cement, and there were liner relationships between the Marshall stability and indirect tensile strength irrespective of cement content.

Brown and Needham, [4] stated that cold mix asphalt concrete mixtures are inferior regarding mechanical properties, high air voids, rain sensitivity and the long curing time needed to achieve their final strength.

Serfass *et al.*, [5] reported that the cold mix asphalt concrete provides a sustainable, cost-effective and energy efficiency alternatives to the traditional hot mixture because no heating is required to manufacture the mixture. However, these mixtures have a comparatively low initial strength and are an evolutionary material, mainly in its early life where the initial cohesion is low and builds up slowly. Lundberg *et al.*, [6] found that asphalt concrete made with cold technology was seen to have a high durability. Despite high void content in the asphalt, which is usually considered to make the asphalt susceptible to aging as well as cracking, the observed road surfaces were in good condition and very few cracks could be noticed even 15 years after paving. Fang *et al.* [7] mentioned three reasons for the hardness of Cement Asphalt Emulsion Composites (CAEC), namely: breaking of the emulsion, water evaporation and cement hydration. Two possible benefits of A Novel Cold Asphalt Concrete Mixture for Heavily Trafficked Binder Course CAEC were demonstrated, which are the lower temperature susceptibility compared with asphalt concrete and the flexibility, which is higher than that of cement concrete. Dulaimi *et al.*, [8] investigated cold mix asphalt concrete binder course with cationic emulsions by means of stiffness modulus whereas water sensitivity was assessed by measuring the stiffness modulus ratio before and after sample conditioning. The results indicate that a substantial enhancement in the stiffness modulus and a considerable improvement of water sensitivity resistance is achieved by implementing additive to the cold asphalt mixtures as a supplementary cementitious material after 2-day curing compared to that obtained with Portland cement, which occurs after 7-day curing. Meijide and I. Pérez, [9] studied different mechanical properties of CAM, such as unconfined compression strength (UCS), indirect tensile strength (ITS) and indirect tensile stiffness modulus (ITSM). It was concluded that after reaching optimal bitumen content, not all properties perform in the same way. As reported by Thanaya, [10], when cold mixes were brought to full curing condition by oven drying at 40°C for 18–21 days (until achieving a constant weight), the samples should have undergone some level of oxidation, hence stiffening the bitumen. Oruc *et al.* [11] conducted experiments to assess the mechanical properties of emulsified asphalt mixtures including 0-6% OPC which was substituted for mineral filler. Significant improvement was revealed with high percentage of OPC addition and they reported that cement-modified asphalt emulsion mixtures might be used as a structural layer. Haque *et al*, [12] evaluated the performance characteristics of cold mix asphalt using reclaimed asphalt mixture. It was observed that the reclaimed asphalt was having a positive impact on strength by 10% while it increases the crushing strength by 8.2%. The aim of the present investigation is to evaluate the influence of ageing periods on behavior of cold mix asphalt concrete prepared by implementation of two types of liquid asphalt (cationic medium setting emulsion and medium curing cutback) under compressive and shear stress.

MATERIALS AND METHODS

The materials used in this investigation are locally available while the aggregates are usually used for asphalt pavement construction in Iraq.

Coarse and Fine Aggregates

Coarse and fine aggregates were obtained from Badra quarry; such aggregates are widely used in the middle and south parts of Iraq for asphalt pavement construction. The coarse and fine aggregates were separated to different sizes by sieving and recombined in the proper proportions to meet the requirement for base course with maximum size of 37.5 mm as per SCRB, [13]. Table 1 illustrates the important physical properties of aggregates. Figure 1 exhibit the aggregates combined dense gradation implemented for base course.

Table 1. Physical Properties of Aggregate

Property	ASTM, [14] Designation	Coarse Aggregate	Fine Aggregate	SCRB, [13] Specification
Bulk specific gravity gm./cm^3	C127, C128	2.46	2.54	------
Apparent specific gravity gm./cm^3	C127, C128	2.57	2.61	------
% water absorption	C127, C128	0.96	0.74	------
Abrasion (Los Angeles)	C131	23 %	------	Max 30%
Flat and elongated particles,%	D4791	0.6%		10% Max

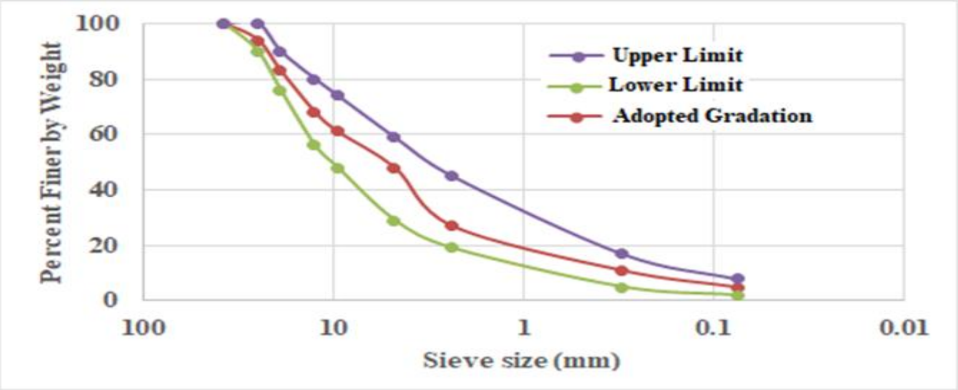

Fig. 1. Aggregate gradation with SCRB specification limits for Base course.

Mineral Filler and Additives

In this investigation, one type of filler was tried which represent conventional mineral filler (limestone dust). Hydrated lime and ordinary Portland cement have been implemented as additives for partial replacement of the mineral filler. Table 3 exhibits the physical properties and chemical composition of mineral filler. The mineral filler and additives implemented are 95% passing sieve No. 200.

Table 3. Properties of Mineral Filler and Additives

Property	Limestone dust	Portland cement	Hydrated lime
Physical Properties			
Specific surface area (m^2/kg)	451	418	280
Density (gm./cm^3)	2.635	3.12	2.12
Chemical composition (XRF)			
SiO_2	51.392%	24.564%	0.74%
Al_2O_3	8.285%	2.135%	0.5%
Fe_2O_3	7.066%	1.131%	0.19%
CaO	5.782%	60.845%	64.23%
MgO	4.883%	1.625%	1.17%
K_2O	3.226%	0.694%	------
Na_2O	2.082%	1.583%	------

Emulsified Asphalt

Medium Setting Cationic emulsion CMS with a residual asphalt content of 54% was obtained from local market and implemented as liquid binder. Table 4 demonstrates its properties as supplied by the manufacturer.

Table 4. Properties of Emulsion

Property	Specification ASTM, [14]	Limits	Test Results
Emulsified asphalt type	D2397	Rapid, medium, slow setting	Medium setting CMS
Color appearance	---	----	Dark brown liquid
Residue by Evaporation %	D6934	Min. 40	54
Specific gravity, gm./cm^3	D70	---------	1.04
Penetration (mm)	D5	100-250	219
Ductility (cm)	D113	Min. 40	46
Viscosity, rotational paddle viscometer 50°C	D7226	110-990	348
Solubility in Trichloroethylene (%)	D2042	Min. 97.5	97.7
Emulsified asphalt/job aggregate coating practice	D244	Good, fair, poor	Fair
Evaluating Aggregate Coating	D6998	Uniform	Uniformly and thoroughly coated

Cutback Asphalt

Medium Curing cutback asphalt MC250 was supplied from AL Dora refinery. The properties as supplied by the refinery are presented in Table 5.

Table 5. Physical Properties of Cutback

Grade	MC 250
Viscosity(cst.) @ 60°C	250-500
Flash point(COC) °C (min)	66
Water %V(max)	0.2
Distillate %of total Distilled	
TO 225 °C (max)	10
TO 260 °C(max)	15-55
TO 315 °C (max)	60-87
Residue from distillation to 360 °C %V(min)	67
Tests on Residue from distillation	
Penetration @25 °C (100g.5sec.0.1mm)	120-250
Ductility @25 °C (cm)(min)	100
Solubility in Trichloro ethylene % wt. (min)	99

Preparation of Cold Mix Asphalt Concrete Mixtures

Coarse and fine aggregates were air dried at 40°C for 24 hours, then were separated to different sizes and stored. Aggregates were recombined, and the filler and additives were added to meet the overall aggregates gradation requirement for base course as per SCRB, [13] specification requirements. Liquid asphalt (cutback or emulsion) was added to the combined aggregates to achieve the desired amount and mixed thoroughly at laboratory environment of 30 ± 1 °C using mechanical mixer for two minutes until all aggregate particles were coated with a thin film of asphalt binder. The details of obtaining the optimum binder and additives content were published elsewhere by Sarsam and Samor, [15]. The liquid asphalt implemented was 7.95% of emulsion CMS with 2% of lime additive and 3% of Portland cement, while 5.18% of cutback MC-250 with 5% of ordinary Portland cement additive were implemented. The cold mixtures were subjected to aeration at 60 °C for two hours. Figure 2 exhibit the aeration process. Similar procedure was reported by AL-Mishhadani et al., [16] and Sarsam, [17]. After the aeration, two types of specimens were prepared, the first type was Marshall Size specimens with 102 mm in diameter and 63 mm in height prepared in accordance with ASTM D1559, [14] using 75 blows of Marshall hammer on each face of the specimen for asphalt base course. The second type was with 102 mm in diameter and 104 mm in height prepared under static compaction to the target density. Specimens were subjected to ageing for (1, 7, 14, and 21) days at 40°C before testing. A total of 48 cold mix asphalt concrete specimens have been prepared and tested. Figure 3 exhibit part of the prepared specimens. Three specimens for each mixture were prepared and tested and the average value was considered.

Fig. 2. Aeration Techniques Adopted


Fig. 3. Part of the prepared specimens

Ageing of Cold Mix Asphalt Concrete Specimens

The prepared asphalt concrete specimens were subjected to ageing process at 40°C for (1, 7, 14, 21) days so that mare volatiles can evaporate, and more strength could be gained as recommended by Lundberg et al., [6]. Figure 4 exhibit the ageing process.

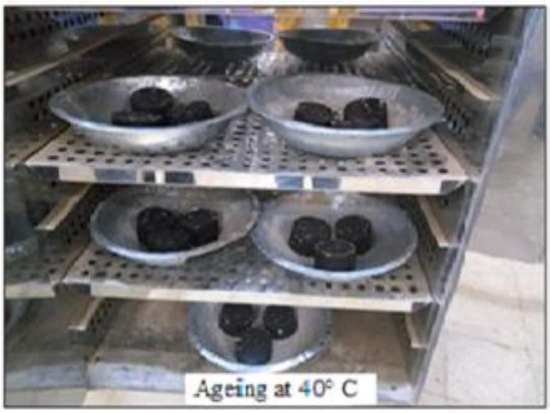

Fig. 4. Ageing Technique Adopted

Testing of Cold Mix Asphalt Concrete Specimens

Specimens of 102 mm in diameter and 63 mm in height were tested for double punch shear strength at various ageing periods. The double punch shear test is used to evaluate the shear resistance of the mixture. This test was reported by many studies, Sarsam and AL-Shujairy,[18] and Sarsam and AL-Zubaidi, [19]. In this test, specimens were conditioned at 40ºC for two hours. The test was implemented by centrally loading of the cylindrical specimen, by means of two cylindrical steel punches seated on the top and bottom of the specimen, the specimen was fixed between the two punchers (2.54cm in diameter), perfectly allied one above the other, then subjected to punching shear stress. The second type of the prepared specimens with 102 mm in diameter and 104 mm in height were tested for compressive strength at various ageing periods.

RESULTS AND DISCUSSION

Influence of Ageing on Compressive strength

As demonstrated in Figure 5, the compressive strength of cold mix asphalt concrete increase with ageing periods regardless of the liquid binder type. However, specimens prepared with cationic emulsion exhibit superior resistance to compressive stress when compared to the specimens prepared with cutback asphalt. The compressive strength of the specimens prepared with emulsion increases by (311, 331, and 400) % after (7, 14, and 21) days of ageing. This may be attributed to the breaking of emulsion and consumption of water through the hydration of lime and Portland cement. Similar findings were reported by Fang et al. (2015). On the other hand, the compressive strength of the specimens prepared with cutback asphalt increases by (62, 97, and 112) % after (7, 14, and 21) days of ageing. This could be attributed to the loss of volatiles throughout the ageing periods which enhance the viscosity of the binder. Such finding agrees with Serfass *et al.*, [5] work.

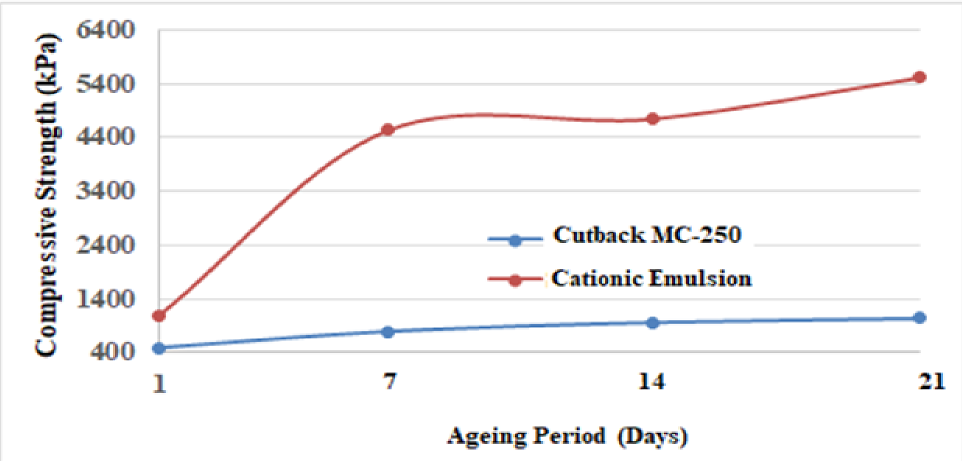

Fig. 5. Influence of Ageing periods on compressive strength

Influence of Ageing on Shear strength

Figure 6 demonstrate the variation in shear strength of cold mix asphalt concrete with ageing. A significant improvement in shear strength could be observed at specimens prepared with cationic emulsion as compared to the specimens prepared with cutback asphalt. The shear strength of the specimens prepared with emulsion increases by (52, 65, and 100) % after (7, 14, and 21) days of ageing. On the other hand, the shear strength of the specimens prepared with cutback asphalt increases by (41, 52, and 55) % after (7, 14, and 21) days of ageing.

Figure 7 exhibit the influence of liquid asphalt type on the strength properties of cold mix asphalt concrete through the ageing process. The medium setting cationic emulsion CMS exhibit superior quality as compared with medium curing cutback MC-250. It can be observed the significant variation could be detected at the early age of cold mix when practicing compressive stresses. The variation ranges between (55-82) % in compressive strength between emulsion and cutback treated mixtures. More ageing period exhibit steady variation. On the other hand, the variation in shear strength was almost steady in the range of (87-90) % among the variation in liquid asphalt type. Similar behavior was detected by Al-Mishhadani et al., [16] and Sarsam, [17].

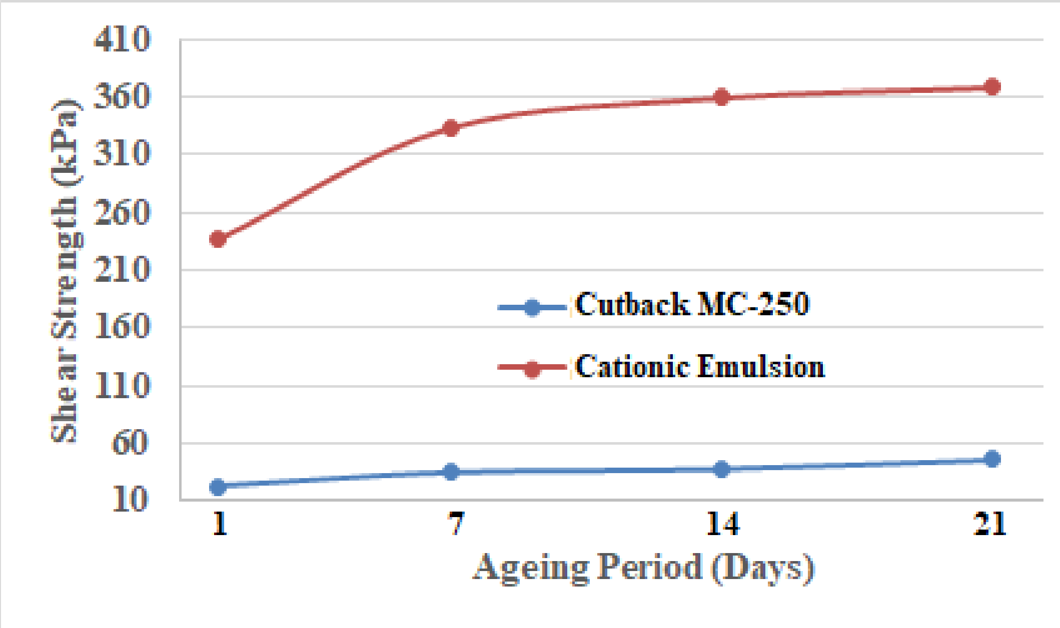

Fig. 6. Influence of Ageing periods on Punching Shear strength

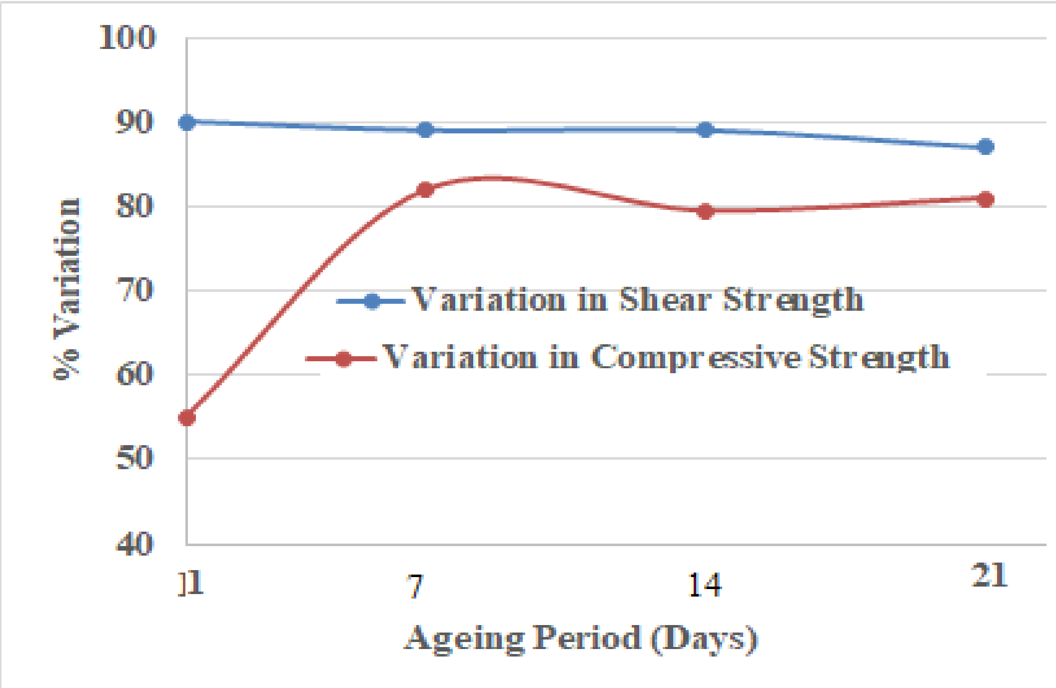

Fig. 7. Influence of Liquid Asphalt Type on Strength Properties of Cold Mix

CONCLUSION

Based on the limitations of materials and testing program, the following conclusions may be drawn.

1) The compressive strength of the specimens prepared with emulsion increases by (311, 331, and 400) % after (7, 14, and 21) days of ageing.
2) The compressive strength of the specimens prepared with cutback asphalt increases by (62, 97, and 112) % after (7, 14, and 21) days of ageing.
3) The shear strength of the specimens prepared with emulsion increases by (52, 65, and 100) % after (7, 14, and 21) days of ageing.
4) The shear strength of the specimens prepared with cutback asphalt increases by (41, 52, and 55) % after (7, 14, and 21) days of ageing.
5) The medium setting cationic emulsion CMS exhibit superior quality as compared with medium curing cutback MC-250.
6) The variation in compressive strength ranges between (55-82) percent while the variation in shear strength was in the range of (87-90) % among the variation in liquid asphalt type.

REFERENCES

1) Ling C., and Bahia H. *Development of a Volumetric Mix Design Protocol for Dense-Graded Cold Mix Asphalt*. Journal of Transportation Engineering, Part B: Pavements. Volume 144 Issue 4 – December.2018.
2) Oruc S, Celik F, and Akpinar M V. *Effect of Cement on Emulsified Asphalt Mixtures*. ASM International, JMEPEG 16 578–583. 2007.
3) Li R., Leng Z., Wang Y., Zou F. *Characterization and correlation analysis of mechanical properties and electrical resistance of asphalt emulsion cold-mix asphalt*. Construction and Building Materials. Volume 263, 10 December, 119974. DOI: 10.1016/j. conbuildmat. 2020.119974.
4) Brown, S.F. and Needham, D. *A Study of Cement Modified Bitumen Emulsion Mixtures*. In Association of Asphalt Paving Technologists Conference Proceeding (AAPT). 2000. Reno, Nevada.
5) Serfass, J., Poirier, J., Henrat, J. and Carbonneau, X., *Influence of curing on cold mix mechanical performance*. Materials and Structures, 37: pp., 365-368. 2004.
6) Lundberg R., Jacobson T., Redelius P., Östlund J. *Production and durability of cold mix asphalt*. Proceedings, E&E Congress 2016 | 6th Eurasphalt & Eurobitume Congress, 1-3 June, Prague, Czech Republic. DOI: dx.doi.org/10.14311/EE.2016.074. 2016.
7) Fang, X., Garcia, A., Winnefeld, F., Partl, M.N. and Lura, P., *Impact of rapid-hardening cements on mechanical properties of cement bitumen emulsion asphalt*. Materials and Structures, 2015.
8) Dulaimi A., Al Nageim H., Ruddock F., Seton L. *A Novel Cold Asphalt Concrete Mixture for Heavily Trafficked Binder Course.* World Academy of Science, Engineering and Technology. International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:9, No:8, 2015.
9) Meijide B., Pérez I. *A proposed methodology for the global study of the mechanical properties of cold asphalt mixtures*. Materials and Design 57. 2014. 520–527 http://dx.doi.org/10.1016/j.matdes.2013.12.079.
10) Thanaya I. N. A. *Improving the Performance of Cold Bituminous Emulsion Mixtures (Cold mix) Incorporating Waste Materials*. PhD Thesis, School of Civil Engineering, University of Leeds, 2003.

11) Oruc, S., Celik, F. and Akpinar, V., *Effect of cement on emulsified asphalt mixtures*. J Mater Eng. Perform, 2007. Vol. 16 No. 5: p. 578-583.
12) Haque L., Ramachandra S., Betta K., Kumar N., Thankachen N., Kumar V. *Evaluation of Strength and Performance Characteristics of Cold Mix Bitumen using Reclaimed Asphalt*. International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS) Volume VI, Issue IV, April 2017. P 108-114, www.ijltemas.in
13) SCRB, General Specification for Roads and Bridges, *Section R/9 Hot-Mix Asphalt Concrete Pavement*, Reverse Edition, State Corporation of Roads and Bridges, Ministry of Housing and Construction, Republic of Iraq. 2003.
14) ASTM. American Society for Testing and Materials. *Road and Paving Material, Vehicle-Pavement System*, Annual Book of ASTM Standards, Vol.04.03. 2013.
15) Sarsam S. I. and Samor Z. A. *Evaluation of Cold Mix Asphalt Concrete Properties*. J Civil Eng. ID 1(1): 1-7. https://journalofcivilengg.com .
16) Al-Mishhadani S., Al-Baidhani H., Zghair H. *Some Properties of Emulsified Asphalt Paving Mixture at Iraqi Environmental Conditions*. Tikrit Journal of Engineering Sciences Vol. 21 No. 1, 2014. P. 10-18. http://www.tj-es.com.
17) Sarsam S. I. *Comparative Assessment of Tensile and Shear Behaviour of Cold, Warm and Hot-Mix Asphalt Concrete*. International Journal of Transportation Engineering and Traffic System, Vol. 5: Issue 2, Journals pub. 2019. P. 39-47.
18) Sarsam S. and AL-Shujairy A. *Assessing Tensile and Shear Properties of Recycled Sustainable Asphalt Pavement*. Journal of Engineering, Volume 21 Number 6, June 2015.
19) Sarsam S. I. and AL-Zubaidi I. *Assessing Tensile and Shear Properties of Aged and Recycled Sustainable Pavement*. International Journal of Scientific Research in Knowledge, (IJSRK) 2(9), pp. 444-452, 2014.