

***Civil and Architectural Engineering***

**Assessing the Moisture and Aging Susceptibility of  
Cold Mix Asphalt Concrete.**

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**ABSTRACT**

Laboratory experience in Iraq with cold asphalt concrete mixtures is very limited. The design and use of cold mixed asphalt concrete had no technical requirements. In this study, two asphalt concrete mixtures used for the base course were prepared in the laboratory using conventional cold-mixing techniques to test cold asphalt mixture (CAM) against aging and moisture susceptibility. Cold asphalt mixtures specimens have been prepared in the lab with cutback and emulsion binders, different fillers, and curing times. Based on the Marshal test result, the cutback proportion was selected with the filler, also based on the Marshal test emulsion. The first mixture was medium setting cationic emulsion (MSCE) as a binder, hydrated lime, and ordinary portland cement as a filler (7.95% MSCE + 2%HL + 3% OPC). The second mixture used was medium curing cutback (MC-250) as a binder and ordinary portland cement as a filler (5.18% MC 250 + 5% OPC). The indirect tensile strength (ITS) of the samples was measured at 25 ° C. It was found that the cold mix with the MSCE binder had a high ITS value relative to the cold mix with the cutback asphalt binder (MC-250). The dry mixture of MSCE ITS was approximately 3.77 times the dry mixture of MC-250. The MSCE wet mix was about 4.2 times the wet MC-250 mix. Tensile strength ratio result (TSR %) for the MSCE binder mix and the cutback MC-250 binder mix showed that the MSCE mix has a reasonable moisture resistance (77% ) compared to the MC-250 mix (69.2 %). The aging test and aging ratio result showed that asphalt binder oxidation has a significant effect on age-related pavement degradation as it changes the time-temperature relationship depending on the viscoelastic properties of the asphalt binder. The result clearly showed that the MSCE binder mix had a high resistance to aging (440 Kpa) compared to the cutback (MC-250) binder mix (110 Kpa). In contrast, the MSCE aging ratio (90 %) was higher than the MC-250 ratio (85 %).

**Keywords:** Indirect Tensile Strength, Ageing, Cold Mixture, Cutback, Asphalt Concrete, Emulsion.

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## تقييم تأثير الخلطة الإسفلتية الباردة بالرطوبة والتقدم

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### الخلاصة

في العراق تتوفر مختبرات وخبرات عملية محدودة للغاية لمخاليط الأسفلت الباردة. ومع ذلك، لم يتم إنشاء أي قسم تجريبي بعد والذي يعتمد مثل هذه التقنيات المستدامة. حتى وقت قريب، لم تكن هناك مواصفات فنية تعطي قواعد لتصميم واستخدام الخلطات الإسفلتية الباردة. في هذه الدراسة، تم تحضير نوعين من الخلطات الإسفلتية الباردة لطبقة الأساس في المختبر لتقييم مقاومتها لتأثير الرطوبة والتقدم. إحدى الخلطات تم فيها استخدام المستحلب الأيوني ومادة الجير المطفأ والاسمنت البورتلاندي الاعتيادي ونسب (7.95% + 2% + 3% على التوالي) وفي الخلطة الثانية تم استخدام الاسفلت السائل مع الاسمنت البورتلاندي الاعتيادي فقط بنسب (5.18% + 5% على التوالي). تم إخضاع العينات لقوة الشد غير المباشرة (ITS) عند درجة حرارة 25 درجة مئوية. وخلص إلى أن المزيج البارد مع المستحلب الأيوني له قيمة قوة شد غير مباشره تعتبر عالية مقارنة بالمزيج البارد مع الاسفلت السائل. حيث ان نسبة ال ITS للعينات الإسفلتية الجافة للمستحلب الأيوني بلغت حوالي 3.77 مرة من العينات الإسفلتية الجافة للإسفلت السائل. بينما نسبة ال ITS من العينات الإسفلتية الرطبة للمستحلب الأيوني كانت حوالي 4.2 مرة من العينات الإسفلتية الرطبة للإسفلت السائل. كذلك أظهرت نتائج نسبة مقاومة الشد (TSR %) للخلطة الإسفلتية الباردة للمستحلب الأيوني (77%) وهي اعلى من نسبة مقاومة الشد للخلطة الإسفلتية الباردة للإسفلت السائل البالغة (69.2%) مما تقدم اعلاه تبين ان الخلطة الإسفلتية الباردة باستخدام المستحلب الأيوني ومادة الجير المطفأ والاسمنت البورتلاندي الاعتيادي لديها مقاومة لتأثير الرطوبة اعلى من الخلطة الإسفلتية الباردة باستخدام الاسفلت السائل والاسمنت البورتلاندي الاعتيادي. أظهرت نتيجة اختبار التقدم ونسبة التقدم أن أكسدة مادة الأسفلت الرابطة له تأثير كبير على تلف خلطه الرصف الإسفلتية. حيث ان تقدم الخلطه الإسفلتية يعتمد على عاملين هما تغيير درجة الحرارة والوقت (عمر الخلطة الإسفلتية) لتأثيرهما المباشر على مرونة الخلطه الإسفلتية (اللزوجة). مما تقدم من النتائج توضح انه الخلطه الإسفلتية للمستحلب لديها مقاومة عالية للتقدم (440 كيلو باسكال) مقارنة بخلطه الاسفلت السائل (110 كيلو باسكال) بينما كانت نسبة التقدم لخلطه الاسفلت المستحلب (90) % أعلى من نسبة خلطه الاسفلت السائل (85) %.

**الكلمات الرئيسية:** قوة الشد الغير مباشر، التقدم، الخلطة الباردة، اسفلت سائل، الخلطة الإسفلتية، المستحلب.

## INTRODUCTION

No heating is required to produce a cold asphalt mixture (CAM) that provides a safe, cost-effective, and energy-efficient alternative to conventional hot mixtures. It is called an evolutionary technique because it has low initial strength and early life, with poor initial cohesion and slow development (Serfass, et al., 2004). The main components of cold asphalt mixtures are liquid bitumen and aggregates, which can be blended and compacted at room temperature. Straight-run penetration grade bitumen suitable for pavement applications typically have high viscosity. There are many ways to minimize bitumen viscosity, such as; mixing with flux oil (cut back bitumen), emulsion, and foamed bitumen (Thanaya, 2003). Cold mixtures have three main concerns; high air-void content of compacted mixtures, long curing times, and low early life strength, making the mixture inferior compared to the hot mixture (Leech, 1994). Mechanical properties of CAM, such as unconfined compressive strength (UCS), indirect tensile strength (ITS), and indirect tensile stiffness modulus (ITSM), were studied not only independently but also by a global approach. After reaching the optimum bitumen content, it was concluded that not all the properties of the asphalt mixture perform in the same way and that ITS is a mechanical property that is less sensitive to bitumen content compared to ITSM and UCS (Fang, et al., 2016). The tensile strength test can characterize two properties of the bituminous mixtures that are very useful for use. The first is to assess the water susceptibility of the asphalt concrete mixtures, where the tensile strength is calculated



before and after the samples' water conditioning to determine the retained tensile strength as a percentage of the original tensile strength. The second is derived from this test, the tensile strain at failure, which is more useful in predicting cracking potential(O'Flaherty, 2007). The objective of this investigation is to assess the moisture damage and the aging characterization of the cold asphalt concrete mixture of the base course (in this study, the base course layer, which is a structural layer with less requirements than other road layers, was chosen) by using two types of binders medium setting cationic emulsion (MSCE) and medium curing cutback (MC-250) through a proper mechanical investigation.

**2. Materials**

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

**2.1 Fine and Coarse Aggregates**

There were two types of aggregates, coarse and fine were used for this investigation. Badra's quarry supplied us with a crushed and fine aggregate. This kind of aggregate is commonly used for asphalt pavement in the central and southern areas of Iraq. The coarse aggregate is an angular shape of the particles and tends to be black. Two types of sands were used as fine aggregates in conjunction with crushed sand and standard sand, considering that normal sand had a weight of about (25 %) of fine aggregates. The general specification for roads and bridges was included in this investigation.

The aggregates used were sieved and recombined in the correct proportion, according to (SCRB., 2003). **Table 1.** illustrates the physical properties of aggregates. **Table 2.** exhibits the aggregates of the combined gradation applied for the base course. It was classified as a dense gradation.

**Table 1.** Aggregate Physical Properties.

Property	ASTM Designation	Coarse aggregate	Fine aggregate	SCRB specification
Bulk specific gravity gm./cm <sup>3</sup>	C127[109] C128[110]	2.46	2.54	-----
Apparent specific gravity gm./cm <sup>3</sup>	C127 C128	2.57	2.61	-----
% of water absorption	C127 C128	0.96	0.74	-----
Abrasion (Los Angeles)	C131[111]	23 %	-----	Max 30%
Angularity	D5821[112]	93 %	-----	Min 90%
Flat and elongated particles,%	D4791[113]	0.6%		10% Max



**Table 2.** Aggregate gradation with specification limits for base course.

(% passing by weight of total aggregate + filler)			
Sieve size		SCRB Specification limits	Gradation
Standard sieves (mm)	English sieves (in)		
37.5	1.5 "	100	100
25	1"	90-100	94
19	3/4	76-90	83
12.5	1/2	56-80	68
9.5	3/8	48-74	61
4.75	No.4	29-59	48
2.36	No.8	19-45	27
300 um	No.50	5-17	11
75 um	No.200	2-8	5

**2.2 Filler**

The aggregate passing through 0.075 mm (N ° 200 size) is described as the filler. The filler may be inert or active. An active filler is known as the filler, which provides hydration in the presence of water in the asphalt mix and can improve the concrete mixture's mechanical properties specifically. In this investigation, two types of fillers were used. The Iraqi cement company supplied us with hydrated lime filler while the Karbala factory's cement filler was supplied. **Table 3.** shows the chemical composition and physical properties of the filler.

**Table 3.** Mineral filler properties.

Property	Portland cement	Hydrated lime
Physical Properties		
Specific surface area (m <sup>2</sup> /kg)	418	280
Density (gm./cm <sup>3</sup> )	3.12	2.12
Chemical composition (XRF)		
SiO <sub>2</sub>	24.564%	0.74%
Al <sub>2</sub> O <sub>3</sub>	2.135%	0.5%
Fe <sub>2</sub> O <sub>3</sub>	1.131%	0.19%
CaO	60.845%	64.23%
MgO	1.625%	1.17%
K <sub>2</sub> O	0.694%	-----
Na <sub>2</sub> O	1.583%	-----



**2.3 Emulsified Asphalt**

Medium setting cationic emulsion MSCE has a residual asphalt content of 54 percent. Liquid asphalt binder was supplied from the local market. **Table 4.** demonstrates the properties as supplied by the manufacturer.

**Table 4.** Emulsion Properties.

Property	Specification ASTM, (2013)	Limits	Test Results
Emulsified asphalt type	D2397	Rapid, medium, slow setting	Medium setting
Color appearance	---	----	Dark brown liquid
Residue by Evaporation %	D6934	Min. 40	54
Specific gravity, gm./cm <sup>3</sup>	D70	-----	1.04
Penetration (mm)	D5	100-250	219
Ductility (cm)	D113	Min. 40	46
Viscosity, rotational paddle viscometer 50	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

**2.4 Cutback Asphalt**

Medium curing asphalt cutback MC-250 was supplied from the AL Dora refinery. Cutback properties are given in **Table 5.**

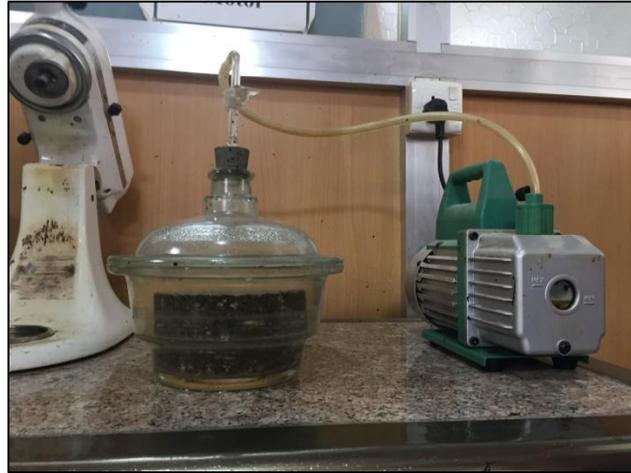
**Table 5.** Cutback Physical Properties.

Grade	MC 250
Viscosity(cst.) @ 60°C	250-500
Flashpoint (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 the distillation	
Penetration @25 °C (100g.5sec.0.1mm)	120-250
Ductility @25 °C (cm)(min)	100
Solubility in Trichloroethylene % wt. (min)	99

### 3. Preparation of Cold Mix Asphalt Concrete Mixtures.

#### 3.1 Preparing specimens for Tensile Strength Ratio and Indirect Tensile Strength Test

Coarse and fine aggregates were dried at 40 ° C for 24 hours, then separated into different sizes and stored. The aggregates were recombined, and the filler was added to meet the overall gradation requirements for coarse base aggregates as per SCRB (2003) specification requirements. Liquid asphalt (cutback or emulsion) was added to the aggregate and mixed in a  $30 \pm 1$  ° C. Mix laboratory environment until all aggregate particles have been coated with a thin film of liquid asphalt for two minutes. The range of liquid asphalt used was cutback (5.18%MC250 + 5 % OPC) and cationic emulsion (7.95 %MSCE+2 % HL+3 % OPC). The cold mixture was aerated four hours at (25 ° C) for the emulsion binder and (60°C) for the cutback. (Al-Mishhadani, *et al.*, 2014) after aeration. Marshall samples were prepared in accordance with ASTM D1559. Compacting sample 75 blows per face (**heavy traffic surface and base, Asphalt Institute 1979**) use Marshall hammer for asphalt concrete base course. Specimens were cured with an oven for 24 hours at a temperature of 60 ° C. For the preparation and testing of asphalt concrete samples, the indirect tensile strength test was used to assess the water impact on the tensile strength of the asphalt concrete pavement. (**AASHTO T 283 and ASTM D 4867** ). Six specimens were prepared for each binder (six for MC -250 and six for MSCE), three for dry condition and three for partial saturation and moisture condition. Diameters 100 mm (4 in) and 62.5 mm (2.5 in) were compacted by Marshall compact (**Sarsam, 2019**). Saturate the condition set (55 to 80 %) to be moisturized using vacuum chambers such as 70 Kpa or 525 mmHg (20 in high) for five minutes, as shown in **Fig.1**.



**Figure 1.** Saturate sample by using vacuum.

The conditioned set was frozen at least 16 hours at a temperature of  $0\pm 5^{\circ}\text{F}$  ( $-18\pm 3^{\circ}\text{C}$ ), as shown in **Fig.2**. After that, the conditioned collection of each binder (emulsion and cutback) was subjected to the cycle thaw by placing it in a water bath for  $24 \pm 1$  hour at  $140 \pm 2^{\circ}\text{F}$  ( $60 \pm 1^{\circ}\text{C}$ ), as shown in **Fig.3**.



**Figure 2.** ITS test/ specimens freezing at a temperature of ( $-18\pm 3^{\circ}\text{C}$ ).

**Figure 3.** ITS test/conditioned set in a water bath for 24 hours at  $60^{\circ}\text{C}$ .

The loading rate of 51 mm per minute, all samples were tested. Maximum displacements have been reported. **Fig.4**. The indirect tensile strength testing device is shown.



**Figure 4.** Indirect tensile strength testing device.

Conditioned and unconditioned specimens have been assessed using Eq.(1) as follows:

$$ITS = \frac{2P}{\pi DT} \quad (1)$$

Where:

ITS= indirect tensile strength, KPa.

P = peak load , N.

D = diameter of the specimen, mm.

T = height of the specimen, mm.

The water susceptibility of asphalt mixture was measured using a % TSR ratio. The ratio of the indirect tensile strength of conditioned set to unconditioned set was determined, which is expected to be at least 80 % (**Asphalt Institute, 2007**). The percent of the tensile strength ratio was measured by Eq.(2).



$$T.S.R = T2 / T1 *100 \tag{2}$$

Where:

TSR = tensile strength ratio, percent .

T1 = average tensile strength of unconditioned set, kPa.

T2 = average strength of conditioned set, kPa.

### 3.2 Preparing specimen for Ageing Test

Aging of asphalt concrete was graded as short-term aging for simulation of the preparation process and long-term aging for simulation of mixture aging for road service existence (**AASHTO R 30**). Since there is no heating in preparing a cold asphalt mixture, the short-term aging test has been ignored (**Al-Busaltan, et al., 2012**). Marshal specimens have been prepared, as stated in **item 3.1**, for Long-term aging. Six specimens of MC-250 binder (three before aging and three after aging) and the same collection for MSCE binder. Three specimens from each binder (MC-250 and MSCE) were placed in the oven at the temperature of  $185 \pm 5^\circ\text{F}$  ( $85 \pm 3^\circ\text{C}$ ) for  $120 \pm 0.5$  h. At room temperature, about 16 hours were cooled after aging (**R30 AASHTO**). The ratio of aging is given in Eq.[3].

$$A.R(\%)=(A.A) / (B.A) \tag{3}$$

where

A.R= Ratio of Aging, percent.

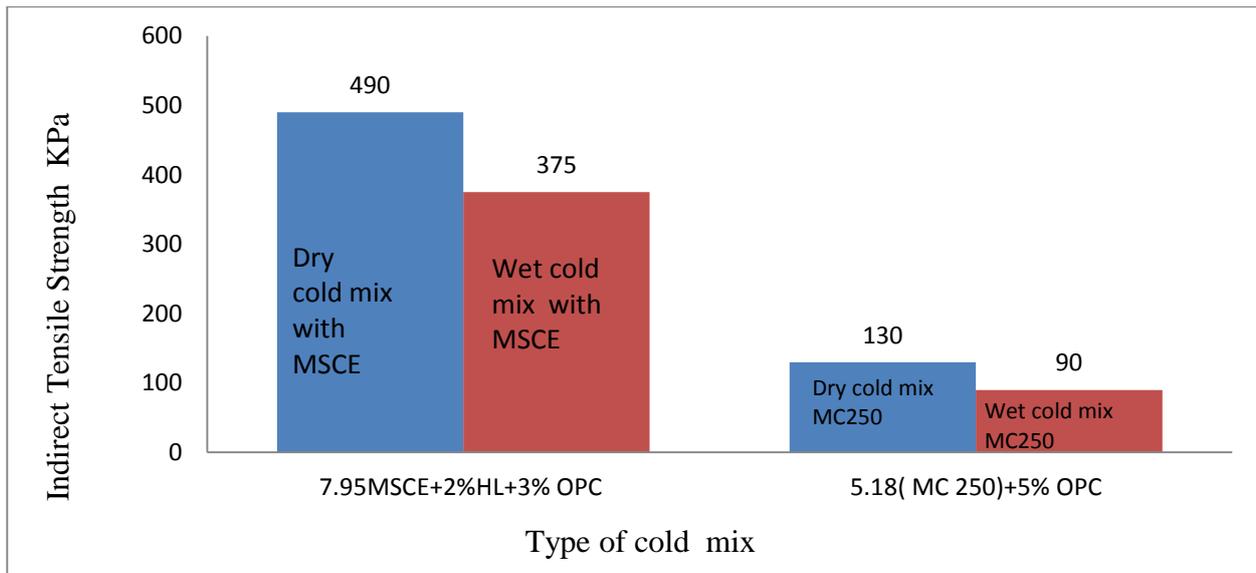
A.A = the ITS after aging, kPa.

B.A = the ITS before aging, kpa.

## 4. Results and Discussions

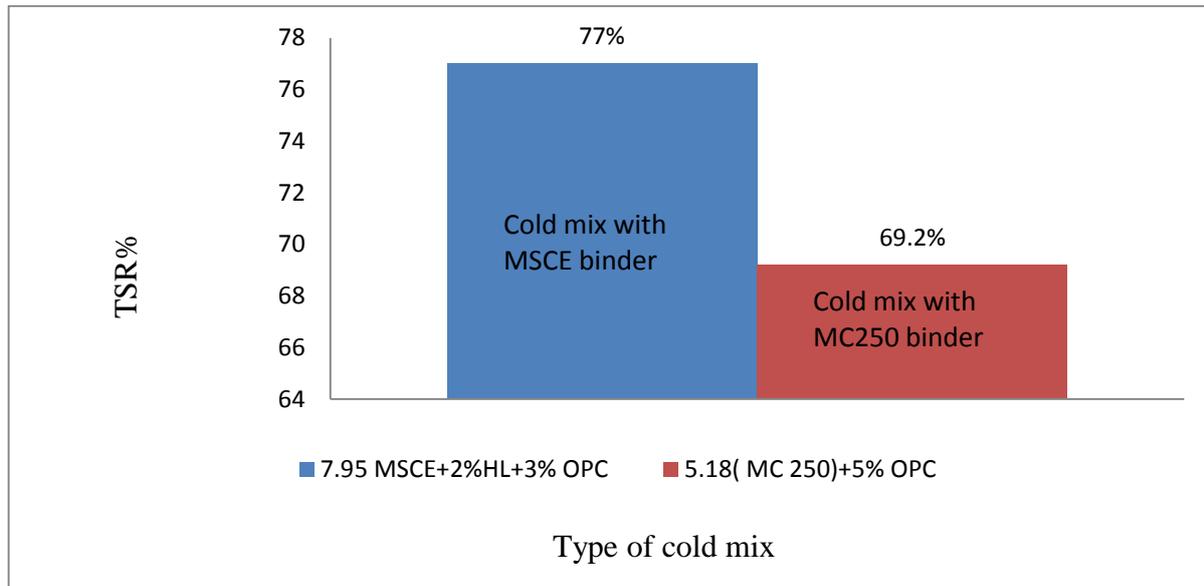
### 4.1 Indirect Tensile Strength (ITS) and Tensile Strength Ratio(%TSR)

In **Fig 5**. for MSCE binder (7.95% MSCE+2 % HL+3 % OPC) and MC-250 binder specimens (5.18 % MC-250 + 5 % OPC), the result of indirect tensile strength (ITS) tests showed that the cold mixture with MSCE binder is high ITS compared to cold MC-250 and MSCE dry mix is approximately 3.77 times dry MC-250. Although the MSCE wet mix of percent ITS is about 4.2 times the MC-250 wet mix.



**Figure 5.** Indirect Tensile Strength result of the cold mix with MSCE binder as compared to the MC-250 binder .

**Fig.6** shows the result of the % TSR for the MSCE binder mix and MC-250 binder mix. MSCE has a high resistance to moisture (77 %) compared to MC-250 (69.2 %). The result explained TSR value of MSCE with 2% hydrated lime represents the ability of hydrated lime to act as an anti-stripping material. Hydrated lime includes polar mechanism coats aggregate elements in asphalt mixture. It results in bonding between the asphalt binder and the aggregate surface. Hydrated lime works as a filler and anti-stripping material because it contains large and small particles and adds 3% ordinary portland cement (OPC) as filler improve resistance to emulsion mix water damage are cement is an effective adhesion agent for emulsion mixture. Similar recommendations were reported by (Mohan and Obaid, 2016) and (El-Behiry, 2013).



**Figure 6.** Tensile Strength Ratio (%) of the cold mixture with the MSCE binder as compared to the MC-250 binder mix.

#### 4.2 Aging

The result of the aging test and the aging ratio was shown in **Fig.7** and **Fig. 8**, indicating that the asphalt binder's oxidation has a significant impact on age-related pavement degradation as it alters the time-temperature dependence of the viscoelastic asphalt binder. The chemical and physicochemical changes that occur in the asphalt due to oxidative aging increase both the viscous and the elastic properties of the binder, contributing to the hardening of the asphalt concrete and demonstrate that the (MSCE) binder mix has a high aging resistance relative to the cutback (MC-250) binder mix that has been confirmed by (**Al-Hdabi, 2014**) reactive filler, such as cement (other cement compounds) when integrated in a cold bitumen emulsion mixture that reacts when in contact with emulsion / any added water as a hydration phase occurs. The main advantage of this incorporation is that it improves the mechanical properties and durability of the cold asphalt mixture. Also (**Lundberg, et al., 2016**) was reported that the mixture of cold asphalt was seen to have high durability. Despite high air void, which is usually considered to make the asphalt susceptible to aging and cracking. (**Choudhary, et al., 2012**) confirmed that after 15 years of pavement with cold asphalt mixture, the road surfaces were good.

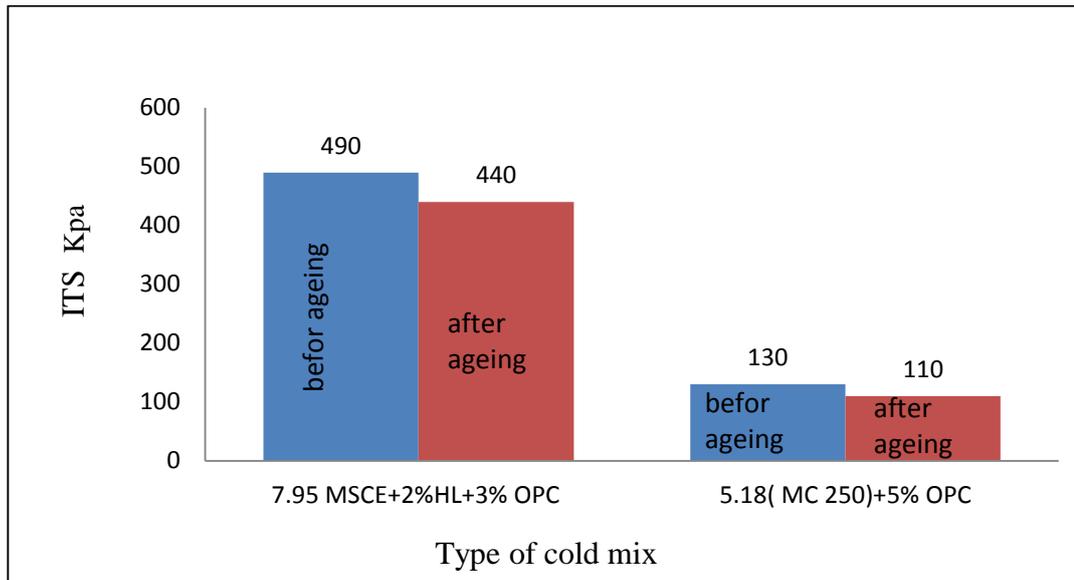


Figure 7. Aging test result of cold mix with MSCE binder as compared to cutback MC-250 binder.

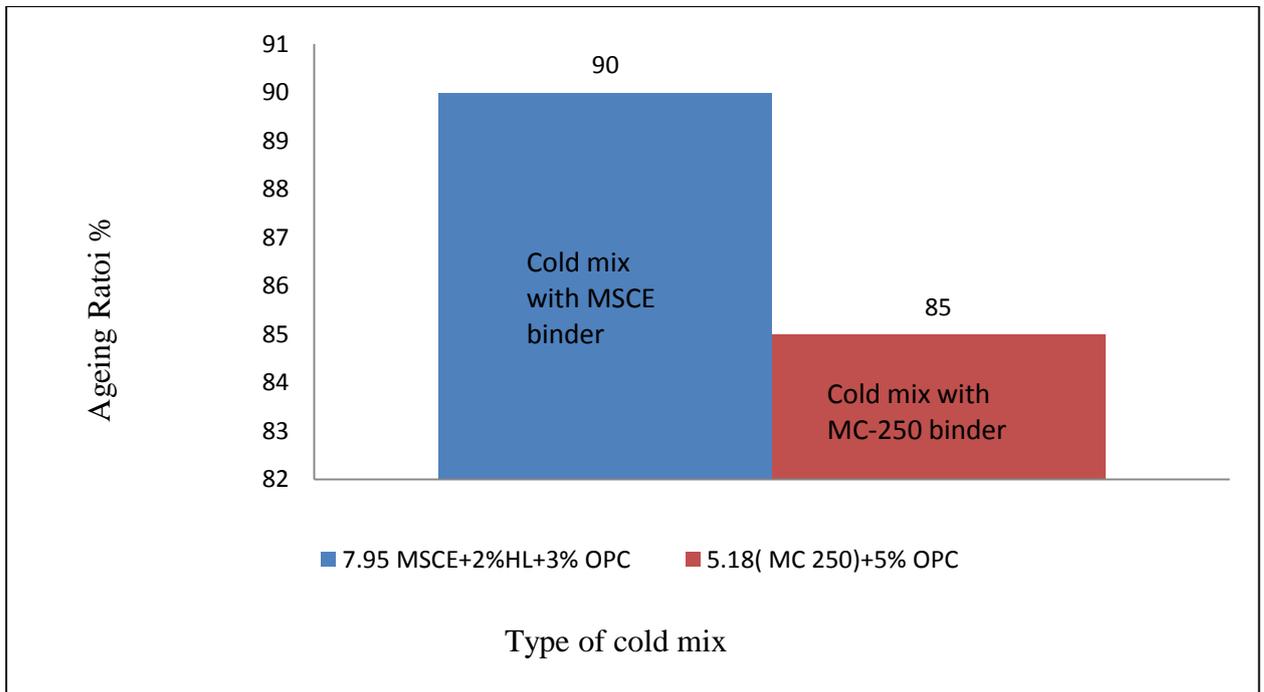


Figure 8. %Aging Ratio of cold mix with MSCE binder as compared to MC-250 Binder.



## 5. CONCLUSIONS

From the results, some conclusions are given:

- 1- The addition of hydrated lime and ordinary portland cement as a cold mixture filler using medium setting cationic emulsion (MSCE) as a binder has enhanced the tensile strength of the cold mixture and made it less susceptible to moisture damage where the OPC is an effective adhesive agent, and HL is an anti-stripping material.
- 2- Cold mixture with medium curing cutback MC-250 as a binder and ordinary portland cement as a filler is an inadequate mixture for moisture damage resistance. It may be enhanced by using a different form of filler or a new curing condition.
- 3- The Tensile Strength Ratio (%TSR) for the cold mixture using medium setting cationic emulsion MSCE as a binder (7%7) is higher than the %TSR for the cold mixture using medium curing cutback MC-250 (69.2%).
- 4- Cold mix with hydrated lime and ordinary portland cement as a filler by using medium-setting cationic emulsion (MSCE) as a binder made it less susceptible to aging and cracking.
- 5- Cold mix with a medium curing cutback MC-250 as a binder and ordinary portland cement as a filler, which is poorly mixed for aging resistance and needs improvement maybe with another filling form or a new cure condition.

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