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CHARACTERIZATION ASSESSMENT OF RECYCLED EMULSION COLD MIXTURES CONTAINING HIGH PERCENTAGES OF RECLAIMED MATERIALS

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ABSTRACT

Cold recycling (CR) is a partial recycling process through which a portion of the existing recycled asphalt pavement (RAP) material is rejuvenated and placed back on the road as a new surface course without introducing heat during the recycling process for low volume roadways .Recycling cold mixtures produced by incorporating milled old asphalt runway pavement into some new aggregate and cement as a filler material . During the past few years, the utilization of new processing machines has created expanding measures of reclaimed asphalt materials (RAP).These quantities of RAP have been obtained by milling of in-service and deteriorated flexible pavement in Najaf city located to south of Baghdad city by 160 km . While numerous agencies all around the world have adopted the practice of recycling, only a rare number of research studies have been performed to characterize and examine the strength, durability, and suitability of recycling techniques on local materials in Iraq. Comparison have been achieved between curing time effect in lab (1, 7 ,14 , 28 , 56 and 90 days) on soaked stability , air voids moisture absorbed (%) and rut depth , and effect of accumulated service time (14,28,56,90,120,150,180and 240 days) on those properties . the rut depth of test road at service time of 240 days gave value is similar to that at curing time of 28 days.

KEYWORDS: Cold recycling , Recycling cold mix , Reclaim asphalts pavement and Rut depth .

1. INTRODUCTION

The recycling of asphalt pavements has been an important option in road due to a greater awareness of the environmental problem s and the need to conserve materials for future generations .The use of recycled emulsion cold mixtures (RECM) provides a sustainable alternative to hot mix asphalt . The use of RECMs has certain advantages over hot bituminous road mixtures with their short-comings which include low early life strength, long curing times, high air voids . The using of RECM in surface course was limited to low or medium road traffic volume [1] . 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 [1]. The several researches evaluated the design of cold recycled mixes through different curing time and temperatures to develop suitable mix design of this mixture types. The curing was necessary to increase the early strength of the cold mixture. The laboratory specimens were compacted with Marshall hammer used in preparing conventional hot mix [2]. The objective of this research is evaluation of a cold-recycled mixture containing high percentage of reclaimed asphalt pavement RAP of (90%) .

2. MATERIALS PROPERTIES

2.1 New Aggregate

The new aggregate used in this research (coarse and fine) were originally obtained from AL Nibaie Quarries. This mineral aggregate is common used in the preparation of locally asphalt paving mixtures .The physical characterizations of two aggregate types are shown in **Table 1** while the filler materials, including type I ordinary Portland cement (OPC), was used in combination with new aggregate . Cement is generally added to cold reused blends to give better unbending nature and enhance the mechanical execution for the duration of the time. The basic properties of these materials are presented in **Table 2.**

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Table (1): Physical characterizations of new aggregates

Property	ASTM Designation	Test results	SCRB specifications
Coarse aggregate			
• Bulk specific gravity	C 127	2.614	….
• Apparent specific gravity	C 127	2.677	….
• Percent wear by Los Angeles abrasion , %	C131	21.3	30 Max.
• Soundness loss by sodium sulfate solution,%	C88	3.4	12 Max.
• Degree of crushing, %		98	90 Min.
Fine aggregate			
Bulk specific gravity	C127	2.664	….
Apparent specific gravity	C127	2.696	….
Sand equivalent, %	D2419	57	**45** Min.

Table (2): The basic properties of ordinary Portland cement *

Physical Properties	
Specific surface area (m^2/kg)	418
Density ($gm./cm^3$)	3.12
Passing sieve No.200	95%
Chemical testing (XRF)	
SiO_2	51.392%
Al_2O_3	8.285%
Fe_2O_3	7.066%
CaO	5.782%
MgO	4.883%
K_2O	3.226%
Na_2O	2.082%

***** These tests were accomplished in the materials laboratories of Karbala cement factory in Karbala governorate.

2.2 Reclaimed asphalt pavement (RAP)

The reclaimed asphalt pavement (RAP) materials milled from deteriorated asphalt runway and stockpiled as shown in **Figure 1**.The asphalt content of the RAP material was 3.97 % by weight of total mix (tested using a centrifuge extractor ASTM D 2172).The results of extracted asphalt cement are conducted on samples at university of Kufa /Civil engineering department and they are listed in **Table 3** . RAP cannot be simply treated as black aggregate in the cold recycled asphalt mixture. The specific surface area of RAP is much smaller than the aggregate in RAP that affects the bonding between RAP and new binder. Adequate crushing of RAP, addition of new aggregates, and fine gradation design can increase the tensile strength of cold recycled asphalt mixture by reducing agglomeration of RAP and improving the bonding between RAP and binder [3].

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Fig. (1): Reclaimed asphalt pavement (RAP) from Al-Najaf airport

Table (3): Test results of extracted asphalt cement

Property	ASTM Designation	Test Results
ation at 25 ^{o}C ,100 g, (0.10mm)	D5	28
2. Ductility at 25 ^{o}C , (cm)	D113	53
3.Specific gravity at 25 ^{o}C	D70	1.03
4.Softening point –ring and ball , (^{o}C)	D136	64.7

2.3 Asphalt Emulsion

The cationic slow setting emulsified asphalt (CSS-1) is more popular than other emulsion type and is very suitable with aggregate graduation requirements [4]. The test results showed that the emulsified asphalt contained of asphalt residue is about (61%) where this value is within the range adopted by the manufacture Company Richmond company in EAU.The base asphalt penetration of the emulsion was 120 penetration units .The physical properties of the emulsion show in **Table 4.**

Table (4): Test results of cationic asphalt emulsion.

Property	ASTM Designation and number	Result	Specification Limits (D2397) for CSS-1	
			Min.	Max.
Viscosity, Saybolt Furol at 25°C SFS	D244	26	20	100
Particle Charge Test	D244	positive	positive	
Residue by Distillation, %.	D6997	61	57	……
Sieve Test,%	D6933	0.03	……	0.10
Cement mixing test, %	D6935	0.732	……	2.0
Storage stability test-24 h, %	D6930	0.04	……	1
Tests on Residue from distillation test				
Penetration, 25°C (77°F), 100 g, 5 s	D5	57	40	90
Ductility, 25°C (77°F), 5 cm/min,	D113	100	40	……
Solubility in trichloroethylene, %	D2042	99	97.5	……

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3. PREPARATION OF RECYCLED EMULSION COLD MIXTURES

In the current investigation , RECMs has been designed for grading requirements of State Commision of Roads and Bridges (SCRB) specifications for surface course [5]. The gradation of RAP material and new aggregate was done and is summarized in **Table 5 and Figure 2**.

Table (5) : Percentages of the RAP and new aggregate to meet specification

Sieve (mm)	Specification for surfacing course		Selected gradation	RAP gradation	90% RAP Aggregate	10% new aggregate and filler
19	100.0		100.0	100.0	90.0	9.3
12.5	90.0	100.0	95.0	95.2	85.7	8.9
9.5	76.0	90.0	82.0	81.2	73.1	9.0
4.75	44.0	74.0	50.0	45.6	41.0	8.9
2.36	28.0	58.0	32.0	25.7	23.1	8.5
0.3	5.0	21.0	12.0	3.9	3.5	5.8
0.075	4.0	10.0	7.0	1.3	1.2	9.3

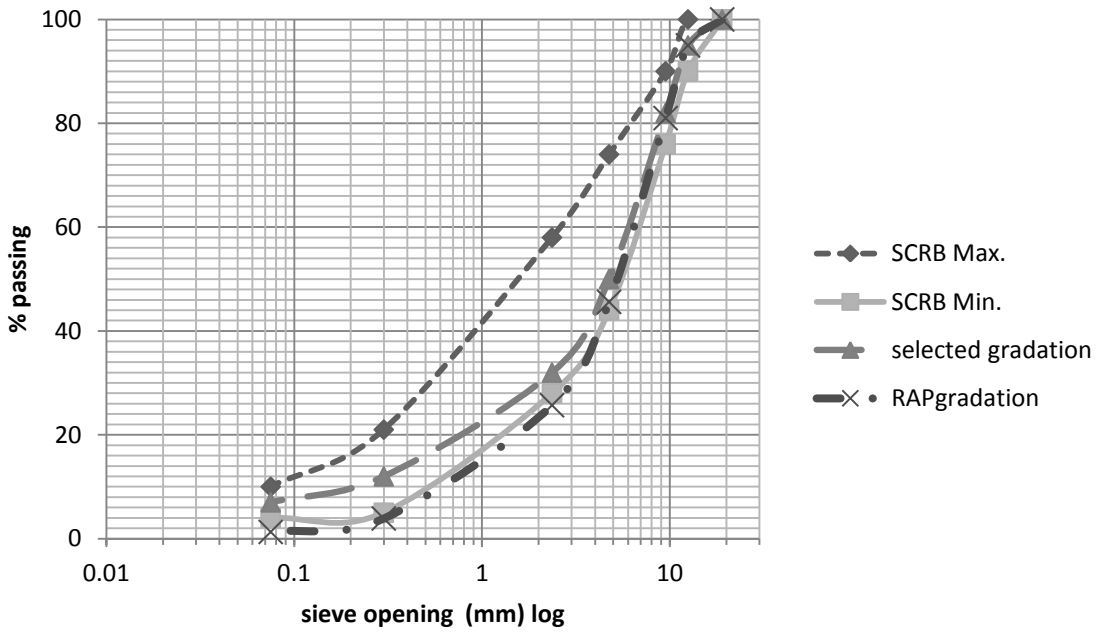

Fig. (2): show Percentages of the RAP and new aggregate to meet specification

To find The initial residual asphalt content was estimated using the following formula [6]:

P= (0.05 A+0.1 B+0.5 C) 0.70 …(1)

P=Percent by weight of initial residual asphalt content by mass of total mixture ; A= percent of mineral aggregate retained on 2.36mm ; B= percent of mineral aggregate passing 2.36 and retained on 0.075mm ; and C= percent of mineral aggregate passing 0.075mm.

With virgin aggregate gradation having A= 68% , B=25% and C=7 , P was 6.6%

The initial emulsion content (IEC) was calculated as below:

$$IEC=\left(\frac{P}{X}\right)100\%$$

Where X =% of asphalt content of the emulsion (0.61%), and IEC was obtained to be 11.0% .

3.1 Optimum Pre-Wetting Water Content for Best Coating (OPWwc) based on Asphalt Institute (MS-14)

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This section details results of a study undertaken to obtain the best sequence for mixing the pre-wetting water content (PWC) and the bitumen emulsion with the aggregate materials. The pre-wetting water lubricates the aggregate materials and activates the surface charges on the aggregate materials prior to the addition of the bitumen emulsion. Optimal pre-wetting water content facilitates good coating, bonding and improved properties of the cold mixes [7]. The optimum pre wetting water was 3.0 % by weight of aggregate.

3.2 Determination of Optimum Residual Asphalt Content (ORAC)

This section details results of a study undertaken to obtain the best sequence for mixing the pre-wetting water content (PWC) and the bitumen emulsion with the aggregate materials. The pre-wetting water lubricates the aggregate materials and activates the surface charges on the aggregate materials prior to the addition of the bitumen emulsion. The residual asphalt content is optimized depending on bulk density and soaked stability of Marshall specimens(100 mm diameter).

3.3 Mixture

Various recycled cold mixtures were prepared by proportioning the RAP and new aggregates to meet the aggregate grading requirements for surface course. The aggregates and cement filler were dry mixed and pre-wetted with water and evenly mixed to moist the aggregate for one minute . After that, the required asphalt emulsion was added and mixed further until the emulsion evenly coated the aggregates at ambient temperature for two minutes. The loose mixture should be observed: if the mixture is too wet, air drying may be required until the mixture is sufficiently loose, neither too dry nor too wet, before being compacted in Marshall mold. Afterward, the samples were compacted at the 75 blows for each face with 150 blows total . After compaction the samples were left inside the mold for 24 hours at room temperature, and were then removed [8].

In this study the IRAC that is calculated from the equation (1) adopted as 7.0 % approximately, increments/decrements of 1% of IRBC which steps in 0.5% and according to the volumetric properties and Marshal tests, for each mixtures were the ORAC are 6.0%, 6.5% , 7%,7.5and 8 % respectively.

For determining the optimum residual asphalt content (ORAC), added residual asphalt content and the Marshall properties of the mixtures according to Asphalt Institute (MS-14) [6] are reported in **Table 6**.

Table (6) : Optimum residual asphalt content (ORAC)

RAC (%)	Bulk density (gm/cm^3)	Dry stability (kN)	Soaked stability (kN)	Stability Loss(%)	Moisture absorbed(%)	Air voids
6	2.136	8.17	5.83	28.6	1.965	9.36
6.5	2.189	9.22	7.43	24.1	1.904	8.42
7	2.161	8.63	6.11	29.2	1.732	7.73
7.5	2.140	7.89	5.74	27.2	1.207	6.64
8	2.122	7.31	4.63	36.7	0.974	6.33
Asphalt Institute specification			2.3Min	50 Max	4 % Max	

By optimizing the density and soaked stability, the ORAC was determined to be at 6.5 %.Show in **Figure 3 and Figure 4**

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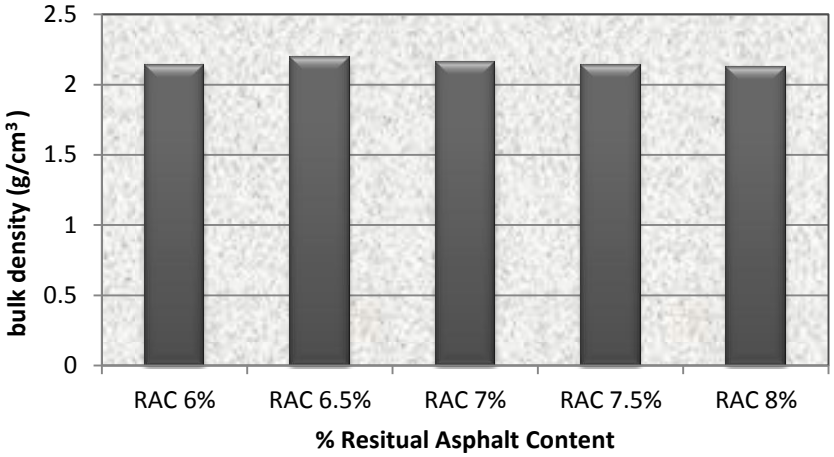

Fig. (3) : Residual asphalt content (ORAC) percentages versus bulk density

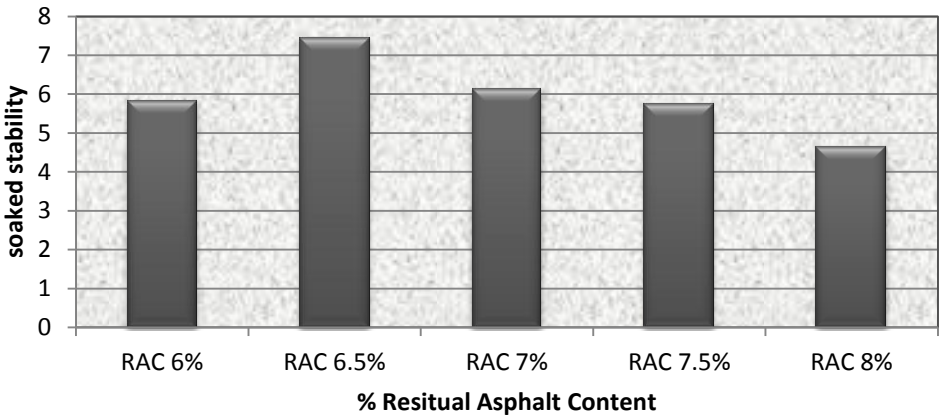

Fig. (4) : Residual asphalt content (ORAC) versus soaked stability

3.3 Curing of cold recycled mixes

Curing is the process in which mixtures lose their moisture content at elevated temperatures. Past studies have proposed different temperatures and curing periods. Accelerated curing plays a major role but the major issue to contend with is the ability to reproduce field curing conditions. Several mix design methods used curing at room temperatures and period between 2 hours to three days [2]. The behavior of cold recycled mixes throughout their curing time (1,7,14,28,56,and 90) has been increase in stiffness of cold recycled mixes specimens when increase days of curing while the moisture absorbed % and air voids decrease as shown in **Table 7 and Figure 5 and 6.** Each property was determined as a average of three specimens.

Table (7): Effect of Curing Time on Soaked stability and moisture absorbed

Curing time (day)	Soaked stability (kN)	Moisture absorbed (%)	Air voids (%)
1	7.43	1.965	8.42
7	9.82	1.843	7.84
14	11.64	1.666	7.32
28	13.36	1.321	6.90
56	14.27	1.278	6.21
90	15.82	0.842	5.17

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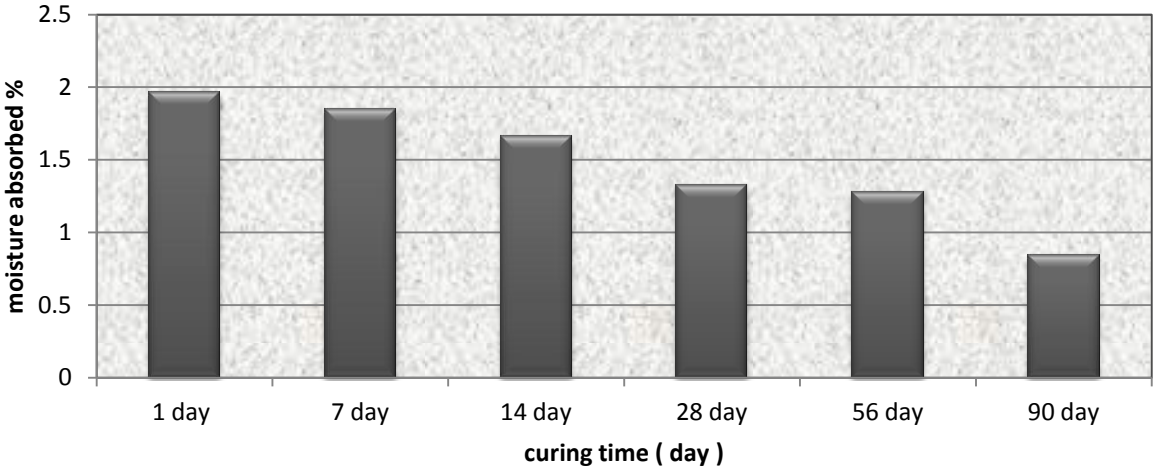

Fig. (5) : Effect of Curing Time and moisture absorbed

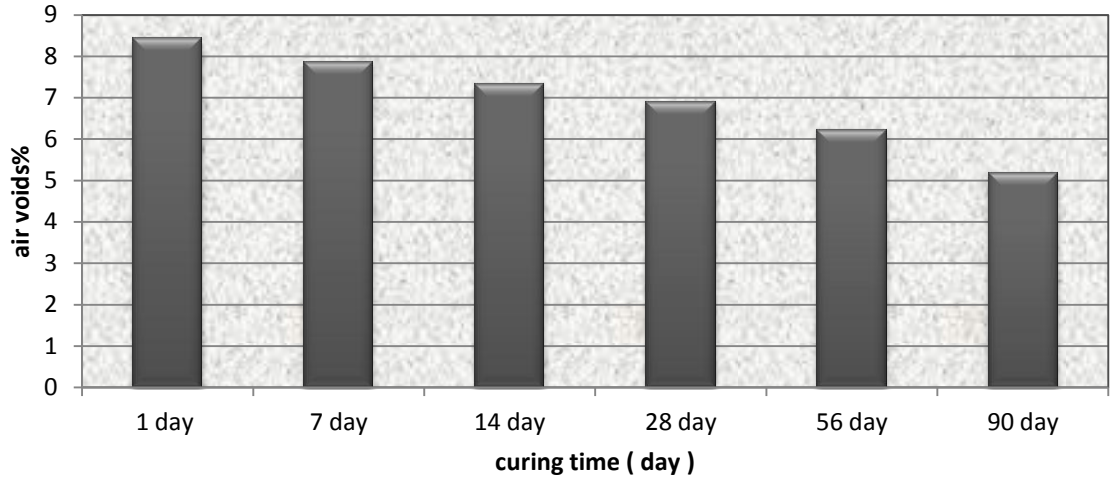

Fig. (6): Effect of Curing Time on Soaked stability and air voids

4. WHEEL TRACKING (RUTTING) TEST

Wheel tracking tests are based on the general operating procedure of tracking a load repeatedly over an asphalt sample to simulation-service behavior. The rut depth value (mm) can be measured by the wheel tracking device as per AASHTO T324[10] . In this loading and environmental conditions were simulated according to the field. A slab with special dimensions (30 cm length and 40 cm width) and 10 cm depth was rolled compacted and made and load was applied through a steel wheel by repeated back and forth movement along its length. Total load of 700 N was applied on steel wheel with 5cm width at the rate of 42 passes per minute. Finally, the total rut depth was recorded. Three replicate samples were tested in all RAP mixtures. The Wheel Track Apparatus (WTA) as shown in **Figure 7.**The wheel tracking test was conducted at 40°C temperature to determine the rut depth after 10000 cycles according to AASHTO Standard T-324 [10].**Table 8 and Figure 8** show the effect of curing time on rut depth when increase curing time in other side decrease rut depth .

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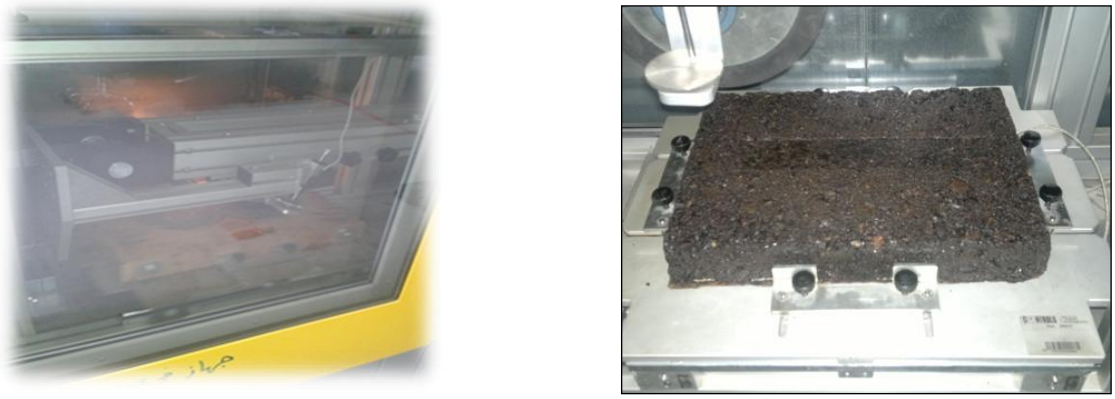

Figure 7 : Wheel Track Apparatus (WTA)

Table 8: Effect of Curing Time on rut depth (mm)

Curing time (days)	Rut depth (mm)
1	26
7	16
14	11
28	9
56	7
90	6

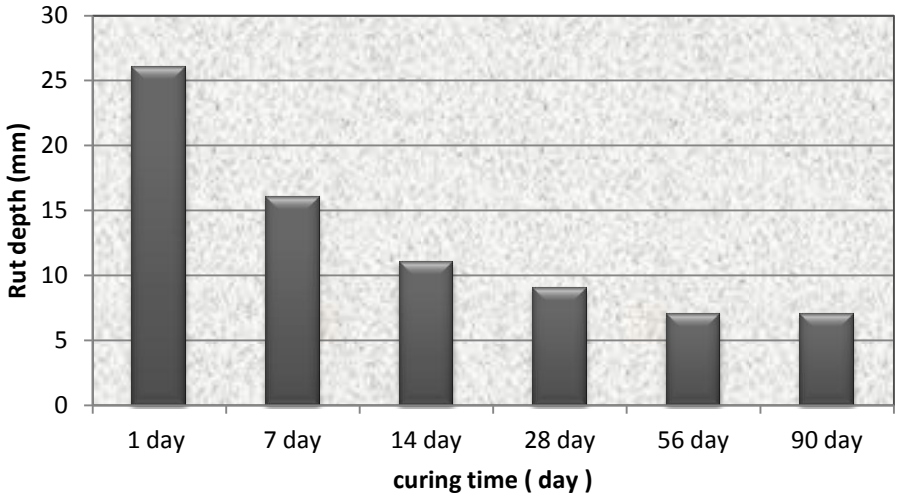

Fig. (8) : Effect of Curing Time on rut depth (mm)

5. TEST ROAD

Al Jamea company for contactors was undertaken a test road on Saturday in 6/2/2016 in Al-Najaf city near cement kufa factory for 300 m length to evaluate the performance of recycling cold mixture surface layer with 10 cm thick .The research involved assessment of performance levels, investigation of factors that most influence pavement performance and the almost traffic was 200 single unit trucks (20 tons) per day . **Figure 4** illustrates the photos of recycled cold mix test pavement. The job mix formula was provided to asphalt plant similar to that used in preparing recycled cold mix at optimum residue asphalt (6.5%) by weight of total aggregate.

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Fig. (4): The photos of recycled cold mix test pavement.

According to test plane the 21 cores with 4 inch diameter have been taken after selected in-service time(14 ,28,56 ,90, 120 ,150 and 180)days , one core per 1000 square meters and three cores for whole test road (see Figure 5)as well as rut depth measurements as shown in **Figure 6** and in **Table 8 , Figure 7** alternative when increase service time to test pavement conversely increase rut depth in (mm). The test road length was divided into sections with 20 meters for each section. The rut depth value at each in-service time was average of 15 readings for 300m totally length of test road.

Fig. (5): Core taken from test road

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Fig. (6) : Rut depth measurements on test road

Table (8) : Recycling cold mix properties of test road pavement at various in-service time

In service time (days)	Soaked stability (kN)	Moisture absorbed (%)	Air voids(%)	Rut depth(mm)
14	10.93	1.831	7.92	1.5
28	13.01	1.470	7.10	3
56	13.94	1.333	6.94	4
90	15.43	0.812	5.45	5
120	15.87	0.803	5.13	6
150	16.12	0.799	5.02	7
180	16.53	0.763	4.81	10

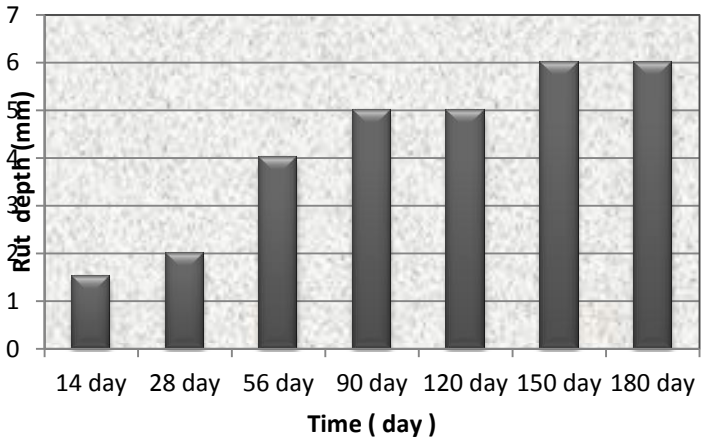

Fig. (7) : Rut depth of test road pavement at various in-service time

6. CONCLUSIONS

The following conclusions can be drawn:

1. Recycling emulsion cold mixture (RECM) involved a high portion (90%) of RAP, where their properties well meet the specifications.

2. The strength of RCAM increases with increasing of curing time. This due to evaporate the water from RCAM and the cement will accelerate to absorb the water to hydration operation .

3. When compared to the results of the laboratory and the result of field note increase rut depth in field when increase service time while otherwise in laboratory .

4. The rut depth of test road at service time of 180 days gave value is similar to that a curing time of 28 days . Additionally , the compatible between recycling cold mix properties after 90 days of curing and those of test road after 120 days of time in service .

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