Muthanna Journal of Engineering and Technology, Vol. (9), Issue (2), Year (2021)

Muthanna Journal of Engineering and Technology

Website: https://muthjet.mu.edu.iq/

Research paper, Short communication, Review, Technical paper

Developing a warm asphalt mixture using locally emulsion and old paving waste

Jaber Hussein[a]

[a] *Department of Civil Engineering, College of Engineering, Al-Muthanna University, Al-Muthanna, Samawah, Iraq.*
[*]Corresponding author E-mail: jaber.awadth@mu.edu.iq

DOI:10.52113/3/eng/mjet/2021-09-02/01-08

Abstract

Due to the amount of polluting emissions to the environment that are produced by hot mixtures during mixing in factories or their brushing on site, or their effect as waste after removal, it has become necessary to produce alternatives such as cold mixtures or semi-cold (warm) mixtures to reduce the amount of emissions of old pavement waste in Iraq. In this work, the old paving residues were shredded with locally produced emulsion in mixing ratios ranging from 2% to 4% of the total weight of the mixture and the fillers were replaced with Portland cement. The results showed that mixing the old worn pavement residues with the locally produced emulsion of 3.5% of the total weight of the mixture gives an increase in Marshall stability, Marshall flow and good volumetric properties when mixed at 85 ℃. At 25 ℃ the mechanical and volumetric properties are optimal in a curing period of 28 days. When the mixture is made at a temperature of 160 ℃, we get better volumetric and mechanical properties, but they are certainly less environmentally friendly.

Keywords: *Old pavement, Emulsion, Curing period, Marshall Stability, Marshall flow.*

1. Introduction:

Asphalt mixtures are divided into three groups according to temperatures of mixing; cold (CMA), warm (WMA) and hot (HMA) mixtures. Emulsions asphalt are used in cold mixtures whereas asphalt cement used in hot and warm asphalt mixtures [1, 2]. Asphalt emulsion is a combination of three basic ingredients, asphalt, water, and small amount of an emulsifying agent. The using of asphalt emulsions is developing and 10-20% of all asphalt is used in the form of asphalt emulsions. Asphalt emulsions are divided according to the electrical charges surrounding the asphalt particles into three groups; anionic, cationic, and nonionic. Asphalt emulsions are also classified according to how quickly they coalesce; Rapid Setting (RS), Medium Setting (MS), slow setting (SS), and Quick Setting (QS). Relative viscosity represented by the letters “h” and “s” which indicate whether a hard or soft asphalt is used to produce the asphalt emulsions [3, 4].

Recently, recycled materials are widely used in all the asphalt pavement layers. The technology of recycling of old pavement has many advantages, such as speed in a paving, low energy supply, and reduce environmental emissions [4, 5]. Technology of recycling is used for the rural road pavements via cold (CIR) or hot-in place (HIR) recycling. It involves the addition of a very small amount of emulsion materials to the asphalt mixtures [6, 7]. According to the Federal Highway Administration (FHWA) up to 100 million tons of HMA asphalt are removed annually [8]. The main reason for using old pavement waste is to reduce the amount of aggregates and asphalt in form of new recycle asphalt mixtures [9]. The old pavement waste consists of good quality, well graded aggregates covered with asphalt cement and a percent of moisture content [10]. These properties of old pavement waste make it a good substitute for fresh or virgin materials which reduce the need for using virgin aggregates. This makes reclaimed asphalt pavement an eco-friendly and cost-effective alternative for virgin aggregates when mixing at low temperatures [11]. Using of recycled old pavements with a small percent of emulsions also will reduce cost amount of new asphalt binders used in asphalt paving mixtures [12, 13, 14].

The CIR technique is widely used due to large amounts of old pavement waste which are represent a suitable substitution for virgin aggregates [14, 15, 16]. So, a similar technique can be developed to product a warm mix asphalt WMA.

2. Methodology

Mostly emissions of asphalt mixtures occur as a result of heating and mixing components. Therefore, in order to prevent these emissions, the use of asphalt emulsions that are mixed at natural air temperatures. In this work, the scraps of the old paving will be disposed of along with the emulsions produced inside Iraq are mixed to prepare warm mix asphalt WMA.

3. Materials

3.1. Emulsion

Emulsion was an Iraqi product as shown in Figure.1 with the following properties:

Fig. 1: Emulsion

1- Water based thixotropic binder.
2- No flammable or noxious solvents.
3- Adheres to most materials and withstand all climatic conditions.
4- Protect against chemical attack and physical degradation.

Results of bitumen test after drying for 24 hrs. at 105 ℃ are shown in Table.1:

Table.1: Emulsion properties

Property	Specification ASTM 2013*	Result	Specification limits
Pent. Grade: 1/10 mm, 100 gm, 5 sec, 25 ℃	ASTM D5-06	40	40/50
Softening point, ℃	ASTM D36-95	60	35—70
Flash point, ℃	ASTM D93-05	300 ℃	≥232
Water Content, %		45	---

* [17,18]

3.2. Mineral Filler

Ordinary Portland cement (OPC) with following properties used as mineral filler with the following properties shown in Table 2.

Table 2: Ordinary Portland cement (OPC) properties

Sieve size mm	% Passing
0.6	100
0.3	100
0.075	85
Unit weight	3.1

3.3. Old pavement waste

The waste pavement crumble and pass on the sieves of asphalt concrete mixture as shown in Table 3. Figure 2 shows the crumble old pavement.

Fig. 2: Crumble old pavement

Table 3: Sieve analysis of crumble old pavement

Sieve size (mm)	Sieve size in.	% Passing
25	½	100
19	¾	96
12.5	½	73
9.5	3/8	44
4.75	No.4	13
2.36	No.8	6
0.3	No.50	0.4
0.075	No.200	0.2

Marshall samples of the mixture were prepared by using old paving residues and asphalt emulsions with percentages of (2, 2.5, 3 ,3.5 and 4) %, as shown in the Table 4.

Table 4: Preparation of Marshall samples for different emulsion percentage

Sieve size, mm	% Passing	% Retained	0.02%	0.025%	0.03%	0.035%	0.04%
37.5	100	0	0	0	0	0	0
25	100	0	0	0	0	0	0
19	100	0	0	0	0	0	0
12.5	95	5	58.8	58.5	58.2	57.9	57.6
9.5	83	12	141.12	140.4	139.68	138.96	138.24
4.75	59	24	282.24	280.8	279.36	277.92	276.48
2.36	48	11	129.36	128.7	128.04	127.38	126.72
0.3	13	35	411.6	409.5	407.4	405.3	403.2
0.075	7	6	70.56	70.2	69.84	69.48	69.12
Cement		7	82.32	81.9	81.48	81.06	80.64
AC			24	30	36	42	48
Total weight			1200	1200	1200	1200	1200

Firstly, Marshall samples were made for the surface layer mixture by mixing the components for each percentage of the asphalt emulsion at a temperature of 25 C°. Portland cement was used as a filler until a processing process for the models occurred at intervals of 3, 7, and 28 days to allow the evaporation of water and its interaction with the cement. Also, Marshall samples were made for mix at 85 ℃ and 165 ℃.

For each sample of the above, the volumetric properties were calculated as Unit weight, VTM%, VFB%, VMA% and mechanical properties, Marshall stability and Marshall flow. Then the results were compared with the standard specifications of surface pavement layer type III.

4. Results and discussions

Mixing the emulsion and crumbling pavement at a temperature of 25 ℃ using emulsion asphalt ratios ranging from 2 to 4% and after leaving it for treatment periods of 3, 7 and 28 days. It showed that the specific weight of the asphalt mixture increases with the increase in the treatment period (the highest is at 28 days). This is at a percentage of 3 % as an optimal ratio because it gives the highest specific weight of 2.235, which is a very convincing value. As shown in Figure 3.

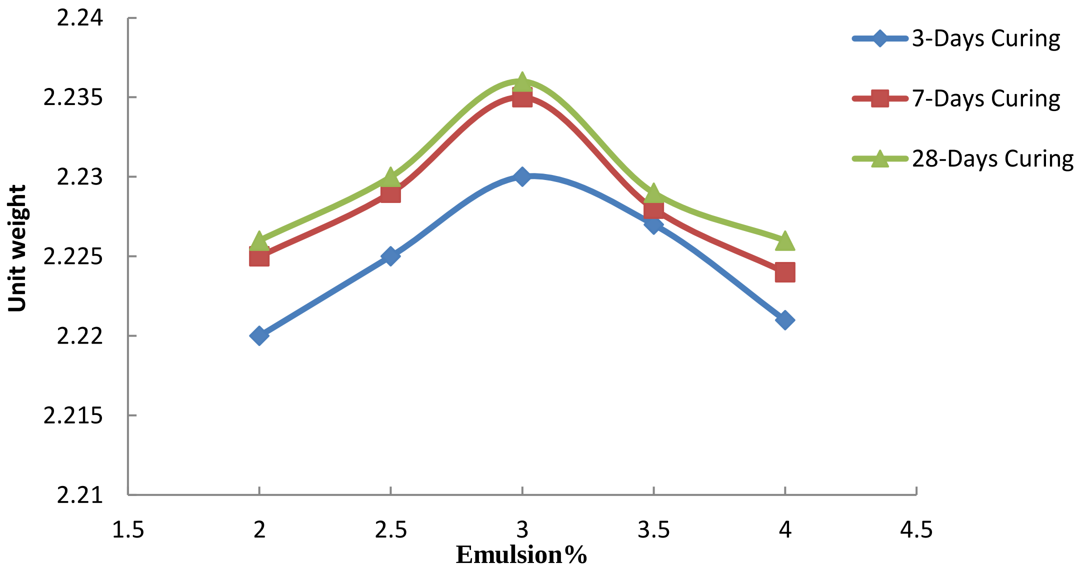

Fig. 3: Effect of emulsion% on unit weight for deferent curing period

The value of Marshall stability increases with the increase in the treatment period, as the treatment period of 28 days gives the highest Marshall stability and at an optimum ratio of 3% of asphalt emulsion. The stability is approximately 12 KN, which is higher than the minimum set in the standard specification, as shown in Figure 4.

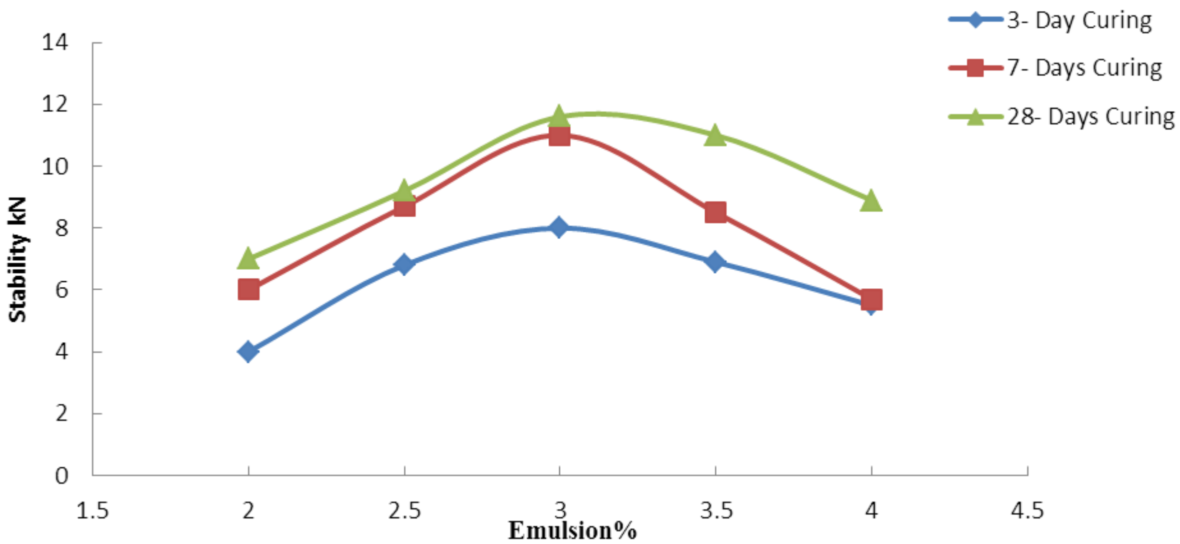

Fig. 4: Effect of emulsion% on Marshall stability for deferent curing period

The percentage of voids in the total mixture is optimal at 3% of the asphalt emulsion in a 3-day treatment period, but the water will evaporate as the treatment progresses. Therefore, the voids percentage depends on a 28-day treatment period and it is also within the specification limits (4.8%), as shown in Figure 5.

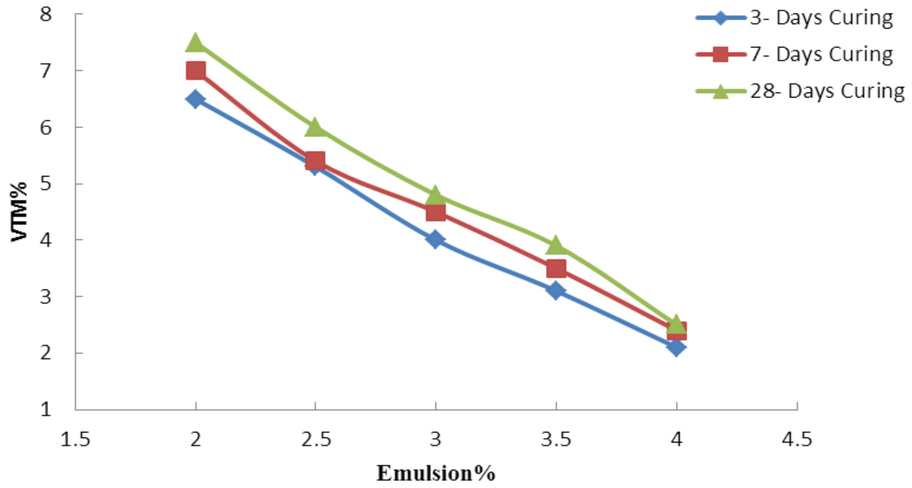

Fig. 5: Effect of emulsion% on %VTM for deferent curing period

The voids filled with asphalt will increase by increasing the percentage of asphalt emulsion and it will be optimal and conform to the specifications at an emulsion percentage of 3% and at a treatment period of 28 days. As for the lower treatment periods, the VFB will be high, but it is within the permissible limits and according to the specification, from 70-85%, as shown in Figure 6.

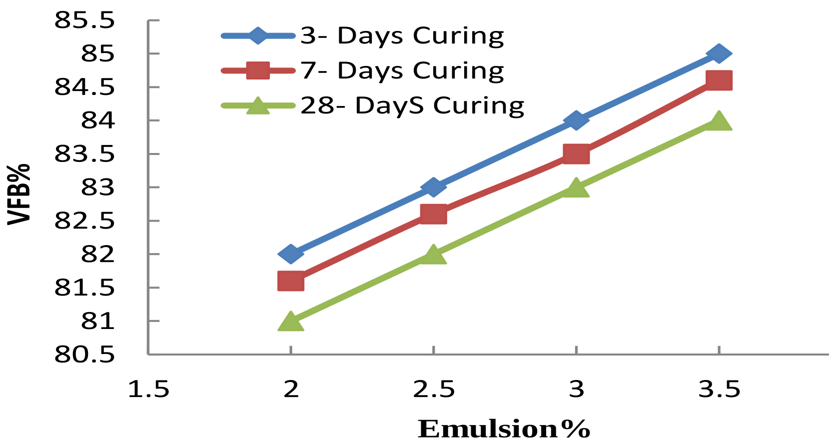

Fig. 6: Effect of emulsion% on %VFB for deferent curing period

The amount of Marshall flow is high in the few treatment periods 3 and 7 days and then decreases to be within the specification limits (2-4) mm at a treatment period of 28 days and with a percentage of asphalt emulsion of 3%, as shown in Figure 7.

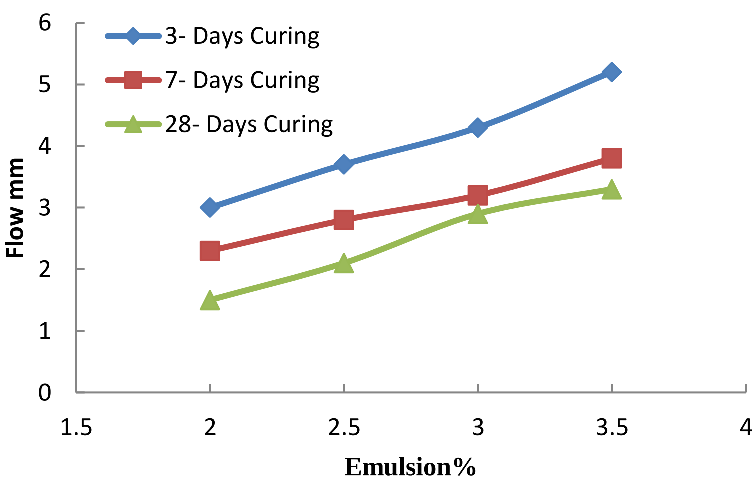

Fig. 7: Effect of emulsion% on Marshall flow for deferent curing period

When mixing the components of the asphalt mixture at a temperature of 60 °C and 100 °C and comparing it with cold mixing at 25 °C, it was noticed that the highest specific weight was at 3.5% of the asphalt emulsion and at a mixing temperature of 100 °C, but at a mixing temperature of 60 °C, the value of the specific weight was Less than it at a temperature of 25 °C and a treatment period of 28 days, as shown in Figure 8.

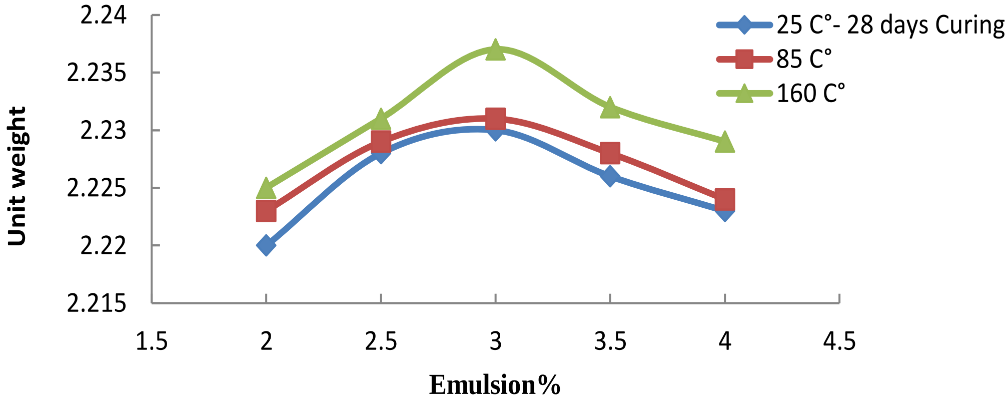

Fig. 8: Effect of emulsion% on unit weight for deferent mixing temp

Marshall stability value for mixed samples at a temperature of 100 °C is the highest value for it by 3% of asphalt emulsion at warm temperatures of 25 °C and cold mixtures of 25 °C with a treatment period of 28 days. This is due to the high bonding as a result of high temperatures. Very acceptable and higher than the minimum set within the limits of the standard specification, as shown in Figure 9.

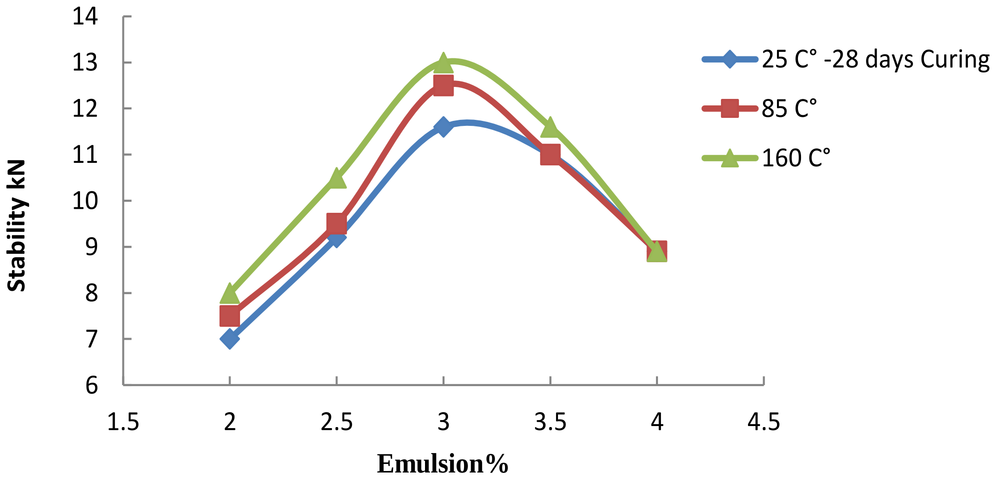

Fig. 9: Effect of emulsion% on Marshall stability for deferent mixing temp

It is very normal for %VTM to be higher at lower mixing temperatures due to the lack of workability of the mixture and therefore the lack of interference well. The results showed that %VTM is within the limits of the standard specifications for hot, warm and cold mixing with a treatment period of 28 days and as shown in Figure 10.

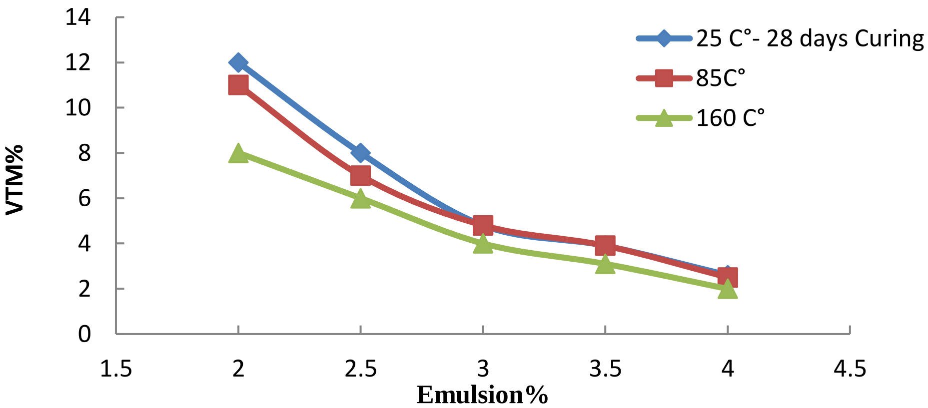

Fig. 10: Effect of emulsion% on %VTM for deferent mixing temp

The results of calculating the %VFB for all the mixing temperatures adopted for mixing the mixture showed that increasing the temperature to 60 ℃ or more leads to an increase of %VFB and it is optimal at a percentage of asphalt emulsion of 3% as shown in Figure 11.

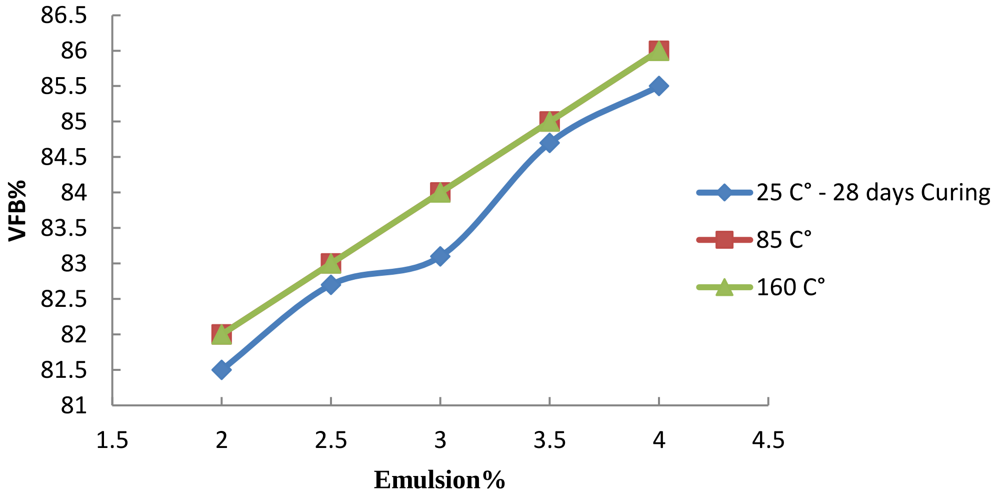

Fig. 11: Effect of emulsion% on %VFB for deferent mixing temp

The value of Marshall flow increases with increasing percentage of asphalt emulsion and increasing temperature. The measured results of Marshall creep are optimal and within the limits of the standard at 3% of asphalt emulsion and at a warm mixing temperature of 60 ℃, as shown in Figure 12.

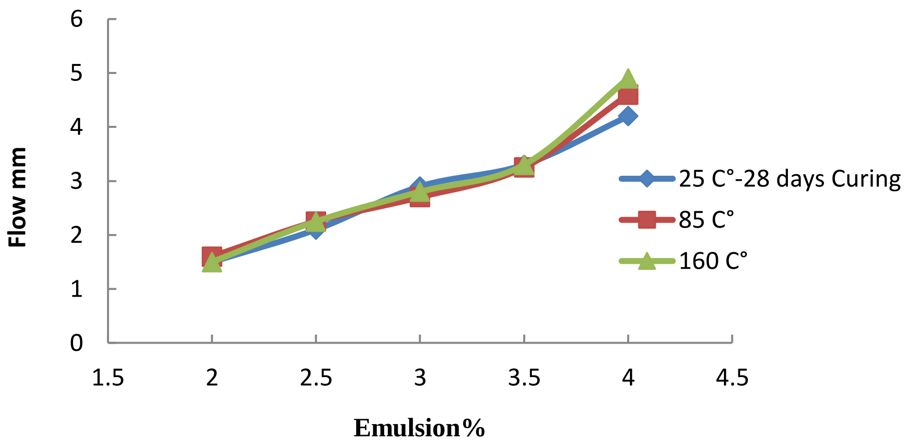

Fig. 12: Effect of emulsion% on Marshall flow for deferent mixing temp

5. Conclusions and recommendations:

1- Asphalt mixtures resulting from mixing old crumbled and emulsified paving and Portland cement as a filler at a temperature of 25 ℃ require a curing period to increase the bonding strength of the components and thus improve their properties. Therefore, it is very environmentally friendly due to lower emissions as a result of lower mixing temperature. But tiling will need time to use it.
2- Mixing crumbled old pavement with emulsion and Portland cement as a filler at a temperature of 85 ℃ gives an asphalt mixture with good volumetric and mechanical properties when the emulsion is 3%. The warm mixing temperature reduces environmental pollutant emissions on the one hand and reduces energy consumption.
3- Mixing the old crumbled paving with the addition of a percentage of emulsion and Portland cement as a filler at a temperature of 160 ℃ will produce a mixture similar to the ordinary mixture without recycling, as the emulsion activates the effective asphalt and water evaporation. But the negative impact of emissions and the increase in the energy consumed to produce them still remains.
4- The recycled aggregate from cracking the old pavement is well graded and covered with a layer of asphalt. Mixing it with the emulsion ensures that all voids are filled with the surface of the aggregate and thus prevents the separation and peeling of the asphalt.
5- The use of a modified emulsion to resist water will give the resulting mixture resistance to the harmful effects of water.

References:

[1] Mantalovas, K.; Di Mino, G.; Jimenez Del Barco Carrion, A.; Keijzer, E.; Kalman, B.; Parry, T.; Lo Presti, D. European National Road Authorities and Circular Economy: An Insight into Their Approaches. *Sustainability* 2020, *12*, 7160.

[2] N. Garber, L. Hoel, " Traffic and highway engineering", Cengage Learning, 2014.

[3] AEMA, Basic Asphalt Emulsion Manual BAEM (MS-19), Fourth Edition.

[4] Yu Kun ZHAO[1], Qing An LI[2,] The Application of Asphalt Cold Recycling Technology in Lower Yellow River Flood Control Project, MATEC Web of Conferences44, 0 01 59 (2016) DOI: 10.1051 /matecconf/2016440 01 59 Owned by the authors, published by EDP Sciences, 2016.

[5] Mix designs for cold recycled pavement materials considering local weather and traffic conditionsKonrad Mollenhauer1, a, Diana Simnofske1, b, Jan Valentin2, c, Zuzana Čížková2, d, Jan Suda2, e,Fátima Batista3, f, Ciaran McNally4, , Digital Object Identifier (DOI): dx.doi.org/10.14311/EE.2016.357.

[6] Forˇt, J.; Šál, J.; Ševcˇík, R.; Doleželová, M.; Keppert, M.; Jerman, M.; Záleská, M.; Stehel, V.; Cernˇ ý, R. Biomass fly ash as an alternative to coal fly ash in blended cements: Functional aspects. Constr. Build. Mater. 2021, 271, 121544.

[7] Zaumanis, M., Mallick, R. B. & Frank, R. 2014. 100% Recycled Hot Mix Asphalt: A Review and Analysis. Resources, Conservation and Recycling. 94: 230-245.

[8] Federal Highway Administration. 2008. User Guidelines for Waste and By-product Materials in Pavement Construction. Washington, DC: FHWA.

[9] Arshad, A. K., Karim, Z. A., Shaffie, E., Hashim, W., & Rahman, Z. A. 2017. Marshall Properties and Rutting Resistance of Hot Mix Asphalt with Variable Reclaimed Asphalt Pavement (RAP) Content. Paper Presented at the IOP Conference Series: Materials Science and Engineering.

[10] Copeland, A. 2011. Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice. McLean, VA: Turner-Fairbank Highway Research Center, Report Number FHWA-HRT-11021.

[11] Serpell, A. and Alarcon, L. F. 1998. Construction Process Improvement Methodology for Construction Projects. International Journal of Project Management. 16(4): 215221.

[12] Sufian, Z., Aziz, A. N., & Hussain, M. Z. 2005. Cold In-place Pavement Recycling in Malaysia. 2005 International Symposium on Pavement Recycling.

[13] Terrel, R. L., & Hicks, R. G. 2008. Viability of Hot In-place Recycling as a Pavement Preservation Strategy. California Pavement Preservation Center, Chico, California, Report Number: CP2C-2008-106.

[14] Cox, B., & Howard, I. Cold In-Place Recycling Characterization Framework and Design Guidance for Single or Multiple Component Binder Systems. Mississippi State University. Jackson: Mississippi Department of Transportation. (2015).

[15] ARRA, Basic Asphalt Recycling Manual, Asphalt Recycling and Reclaiming Association, U.S. Department of Transportation, Federal Highway Administration, 2015.

[16] ASCE, Infrastructure Report Card: A comprehensive assessment of America's infrastructure. American Society of Civil Engineers, 2017.

[17] ASTM. Standard Terminology Relating to Materials for Roads and Pavements, ASTM International, ASTM (2020). Braham, A. Manufacturing of Asphalt Emulsion (Certificate 3). In Pavement Maintenance and Rehabilitation Professional Development Courses, University of Arkansas, Fayetteville, AR, USA, (2018).

[18] AASHTO. (1993). AASHTO Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials.