IMPROVING THE MECHANICAL PROPERTIES OF CBEMs USING WASTE FLY ASHES

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Abstract
The central intention of this work is to offer new Cold Bituminous Emulsion Mixtures (CBEMs) alternative for road and airfield pavement having less cost and environment impacts, as well as disclose high engineering properties. This paper displays the experimental tests and results obtained from incorporating two types of waste fly ashes into CBEMs; pozzolanic and hydraulic fly ashes. Whereas, waste fly ashes material have been examined to prove their validity to improve the mechanical properties of CBEM's.

Fundamental experiment tests were used to evaluate the new CBEMs for road paving and compared the mechanical properties to traditional Hot Mix Asphalt (HMA). The mixtures' mechanical properties of the new CBEMs are promising as an energetic alternative for highway and airfield pavement market. The new CBEMs that comprised hydraulic fly ash as a replacement of conventional mineral filler showed high stiffness modulus and creep stiffness in compared with the soft and hard HMA. Furthermore, the pozzolanic fly ash proved its validity when activated by the hydraulic fly ash and consequently further improvement achieved.

Keywords: cold bitumen emulsion mixtures, fly ash, stiffness modulus, creep stiffness.

1. INTRODUCTION

Environmental and economic challenges are increasing day by day, especially in construction area. So, a huge impacts on highway engineers and researchers to creating new construction methods and developing new materials to overcome these challenges. Cold Bituminous Emulsion Mixtures (CBEMs) could be a vital alternative for Hot Mix Asphalt (HMA) if their inferior characteristics could improve. Predominantly, such mixtures suffered from low early strength, long curing time, and low resistance to rainfall (Needham, 1996, Oruc et al., 2007, Read J and Whiteoak, 2003). But in contrast to traditional HMA, such mixtures introduce low

CO_2 and other fumes emission, low energy required, and high safety during application (Bouteiller, 2010, Wang and Sha, 2010)

Among many other methods of upgrading CBEM, using the Ordinary Portland Cement (OPC) has successfully proven. Head (1974) reported that the Marshall Stability of treated CBEM increased by 250-300% with the addition of 1% OPC compared with un-treated mix. These improvements in mechanical properties have been also proven by other researchers; (Brown and Needham, 2000, Oruc et al., 2007, Al-Khateeb and Al-Akhras, 2011). On the other hand Thanaya (2003) suggested minimizing the curing time by using rapid setting cement. However, the warrants of using OPC or other hydraulic filler are the impact of cost and CO_2 emission during OPC or other filler manufacturing. Thus, low cost and carbon footprint filler is in high demand. Fly ashes could be nominated alternatives, as these ashes normally costless and fly ashes are waste or by-product materials; no manufacture process and consequently no CO_2 emission. Actually, environmental benefit also could gain as majority of those materials to date send to landfills.

Fly ashes have been utilized in a variety of applications, e.g. grouting (Pekrioglu et al., 2003), soil stabilization (Trzebiatowski et al., 2005) and OPC supplementary (Jerath and Hanson, 2007). In general, fly ashes have been used in pavement applications mainly as a binder for stabilizing unbound materials. Fly ashes having either pozzolanic or hydraulic property, fly ash with pozzolanic property needs hydraulic material like OPC to activate hydration process and hardening, while the hydraulic fly ash can produce hydration alone in the present of water.

This paper presents the test results obtained from replacing the conventional mineral filler (CMF) with two type's fly ashes in Cold bituminous Emulsion Mixture (CBEM). The two fly ashes used were Pulverized Fuel Aha (PFA) that has pozzolanic property, and other fly ash (FA) that has hydraulic property. Both ashes are waste material resulting from combustion during electric generation.

2. MATERIAL AND METHODS

2.1. Materials

The aggregates used in this study were crushed granite; their gradation and physical properties are given in Table 1and 2, respectively. Three type fillers, namely: CMF, PFA and FA with two bitumen binders were used to prepare soft and hard HMA, also slow setting cationic bitumen emulsion was used to prepare CBEMs, all binders properties are given in Table 3.

Test sieve aperture size mm	% by mass passing specification range	% by mass passing mid
14	100	100
10	95-100	97.5
6.3	55-75	65
2	19-37	28
1	10-30	20
0.063	3-8	5.5

Table (1): Aggregate grading for 0/10 mm size.

properties	value
Coarse aggregate	
Bulk specific gravity, gm/cm^3	2.79
Apparent specific gravity, gm/cm^3	2.82
Water absorption %	0.4
Fine aggregate	
Bulk specific gravity, gm/cm^3	2.74
Apparent specific gravity, gm/cm^3	2.77
Water absorption %	0.4

Table (2): Physical properties aggregates.

Bitumen emulsion		Bituminous binder 100-150		Bituminous binder 40-60	
properties	value	properties	value	properties	value
Appearance	Black to dark brown liquid	Appearance	Black	Appearance	Black
Boiling Point ° C	100	Penetration , 25 ° C	143	Penetration , 25 ° C	43
PH	5	Softening point ° C	43.6	Softening point ° C	52.4
Relative Density at 15 ° C g/ml	1.05	Kinematic viscosity at 135°C	175	Kinematic viscosity at 135°C	325
Residue by distillation,%	56	Density at 25°C	1.00	Density at 25°C	1.01

Table 3: Bituminous Emulsion and Bitumen binder Properties.

2.2. Experimental setups

CBEMs samples were prepared according the method adopted by the Asphalt institute (Marshall Method for Emulsified Asphalt Aggregate Cold Mixture Design (MS-14)) (Asphalt Institute, 1991). Accordingly for the selected materials characteristics, pre-wetting water content was observed to be 4%, the optimum bitumen emulsion was 11.5% and optimum total liquid content at compaction was 14.5%.

Specimens of CBEM's were prepared using different ratios of fly ash fillers (0-5.5%) as a replacement for conventional mineral filler. Moreover, conventional hot mixture samples were prepared with the same aggregate type and gradation, 5.3% binder content was used. The cold mix specimens were mixed and compacted at lab temperature (20-25 °C), while hot mix specimens were compacted at (135-140 °C).

Two fundamental tests were used to identify the mechanical properties of CBEMs and HMA. These tests are as follows:

- Indirect Tensile Stiffness Modulus (ITSM): The test was conducted in accordance with BS EN 12697-26 (British Standard Institution, 2004).
- The Uniaxial Compressive Cyclic Test (UCCT) : The test was conducted in accordance with BS EN 12697-25 (British Standard Institution, 2005).

The tests were conducted using UTM machine manufactured by Cooper Research Ltd, tests details are described elsewhere (Al-Busaltan et al., 2012).

3. RESULTS AND DISCUSSION

3.1. ITSM test results

The CBEM specimens were prepared and compacted, and then a curing protocol was achieved for all CBEM specimens. This protocol included two curing stage; stage one specimen was left in mold for 24 hours at 20˚C to ensue no disintegration due to specimen extraction, stage two comprised cure the specimen at 40˚C for extra 24 hours. According to Jenkins (2000) this will represent 7-14 days of sample age. Specimens then tested after 2, 7, 14, 28, 90, 180 and 360 days.

ITSM test results of specimens comprised different PFA content is shown in Figure 1. Generally, there were improvements in stiffness modulus due to increase the percentage of replacement CMF by PFA especially at early ages. Those variations in ITSM became un-noticeable at late ages, but it should say that the PFA filler at all ages have shown improvement in stiffness in contract with control CBEM comprised CMF. On the other hand, in contrast with ITSM values of soft and hard HMA, CBEMs comprised PFA still show inferior ITSM values.

On the other hand, incorporate FA in CBEMs demonstrate an outstanding ITSM values. As can be seen in Figure 2, increase FA content is lead to significant improvements in stiffness modulus of CBEM. Additionally, comparative values to HMA have been achieved. Actually and for the first time with waste materials, stiffness modulus values reached to acceptable ranges within reasonable curing time.

The above results encouraged the research team to explore the ability of FA to activate PFA to hydrate. Figure 3 shows the results of CBEMs comprising 5.5 % FA with different extra percentage of PFA. It is obviously showed the positive effect of incorporating FA with PFA. For example, there is an increase in ITSM of 2 days values ranged from 5-77 % according to increase in PFA from 1.375 to 5.5 %. Also, the improvements were increase as PFA % increased for all curing ages.

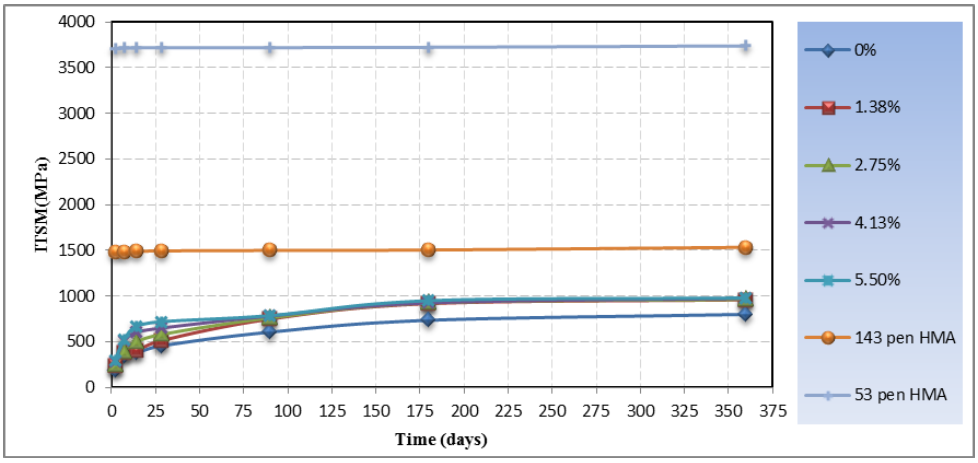

Figure (1) Effect of PFA % on ITSM (24hrs. 20 ˚C +24 hrs. 40˚C)

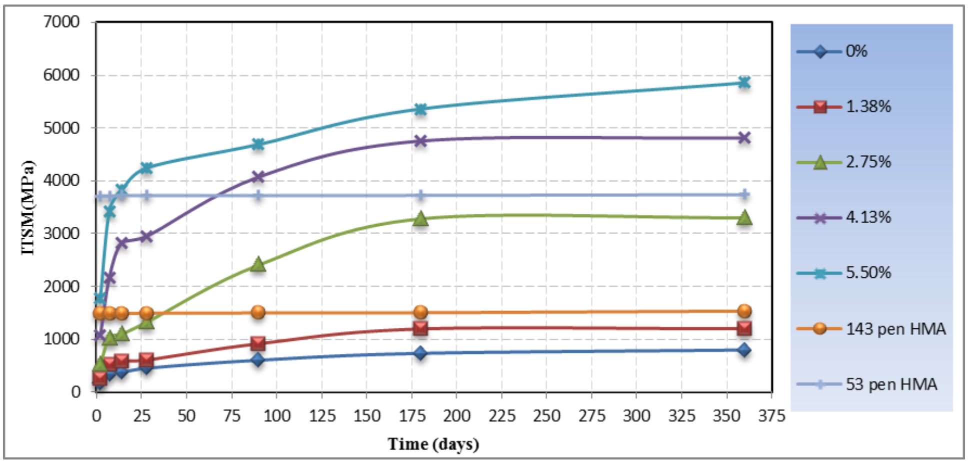

Figure (2) Effect of FA % on ITSM (24hrs. 20 ˚C +24 hrs. 40˚C)

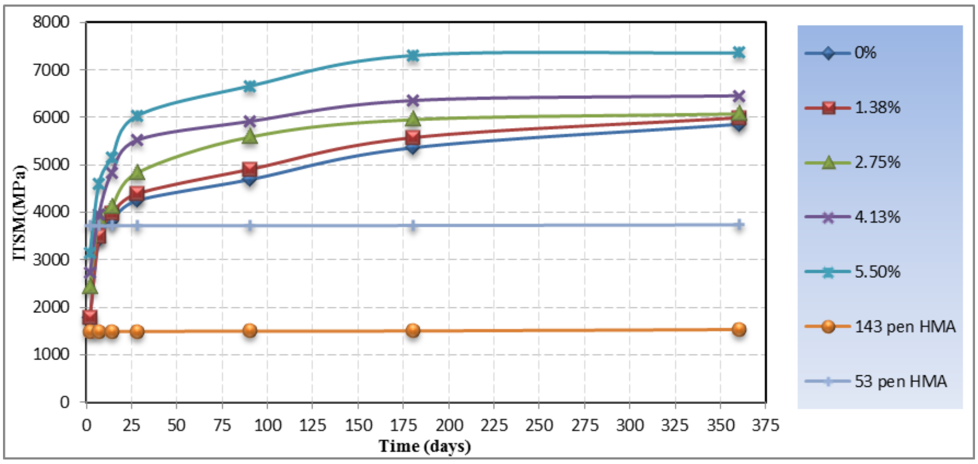

Figure (3) Effect of PFA% with 5.5 % FA on ITSM (24hrs. 20 ˚C +24 hrs. 40˚C)

However, the hydraulic property of FA is the main reason for the improvement in ITSM values. The hydration process due to present of FA in CBEM is resulting double benefits. Firstly the hydration absorbs the trapped water between the bitumen binder itself and bitumen binder and aggregates; this trapped water is the main cause of weakness of CBEM. Secondly, produce hydration products which play two roles; hydration products stiffening and strengthen the bitumen binder, additionally it is itself a binder that works as secondary binder. Thus, the initiated secondary binder and the primary bituminous binder are work together to bind the aggregates skeleton. In case of PFA, the hydration needs activator, which FA plays this role. So, it was recognized clearly when increase PFA content more hydration products generated, resulting more improvement.

3.1. UCCT test results

The CBEM specimens for UCCT were prepared and compacted, then a curing protocol was achieved for all CBEM specimens as recommended by Thanaya (2003) to gain full curing specimens. This protocol included two curing stage; stage one specimen was left in mold for 24 hours at 20˚C to ensue no disintegration due to specimen extraction, stage two comprised cure the specimen at 40˚C for extra 14 days, finally the test conducted.

Test results of CBEM with diffrenet FA content are shown in Figures 4and 5. The results demonstrate the high impact of FA on permanent deformation resistance characteristics; whereas with 2.75 % and more of FA the creep stiffness of CBEM succeeded the HMA values, as can be shown in Figure 4. At the same time, the creep rates showed a huge reduction due to increase in FA content; again, their values are very comparative to HMA values, as can be seen in Figure 5.

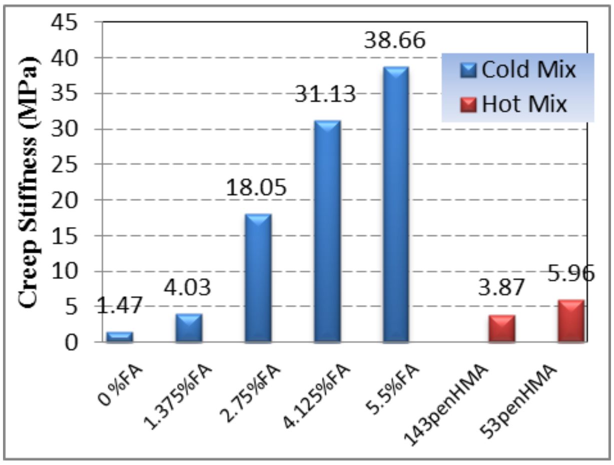

Figure (4) Effect of FA % on Creep Stiffness

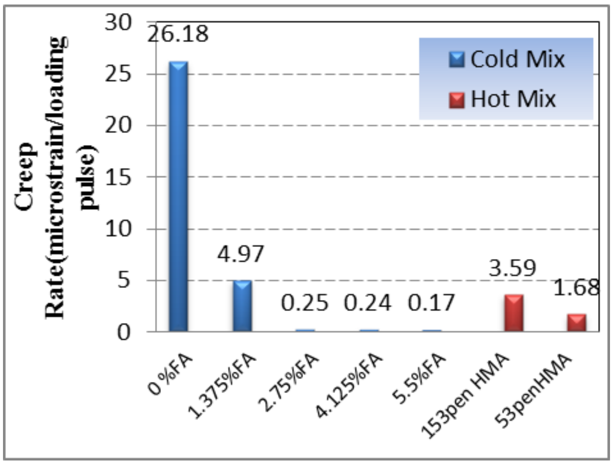

Figure (5) Effect of FA % on Creep Rate

CBEMs compraised 5.5% FA with different PFA content showed an outstanding creep stiffness and creep rate values as can be seen in Figures 6 and 7. the results indicated the overcome of permenent deformation problems of traditional CBEMs . in fact, the same reasons mentioned previously in ITSM improvement can adopted here; hydration products resulting secondary binder and strenghten the bituminous binder.

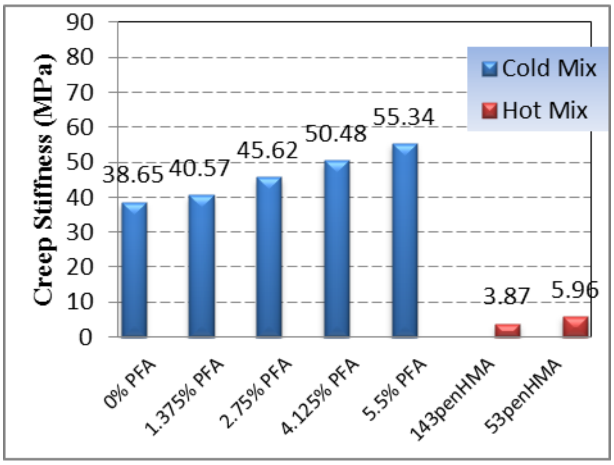

Figure (6) Effect of PFA % with 5.5% FA on Creep Stiffness

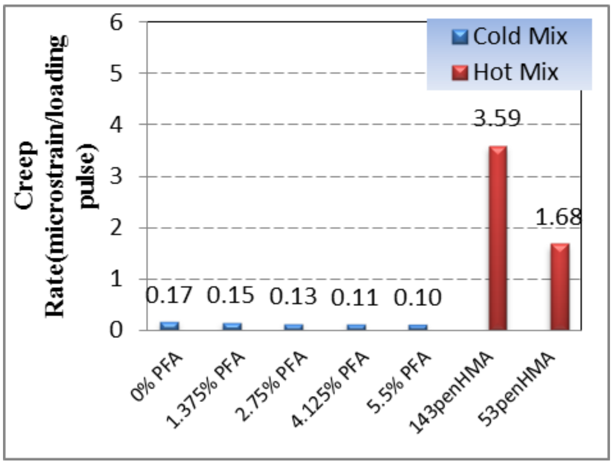

Figure (7) Effect of PFA % with 5.5% FA on Creep Rate

3. CONCLUSIONS

The main conclusions drawn from this study are as follows:

1. Fly ashes can be a vital replacement of conventional mineral filler in Cold Bituminous Emulsion Mixtures.
2. New CBEMs with comparative mechanical properties to soft and hard HMA can be introduced using waste fly ashes.
3. These new CBEMs and for the first time showed acceptable early strength, also such mixtures are address new paving mixtures suitable for heavily trafficked roads further to low and medium trafficked roads.
4. Fly as with hydraulic property showed more advantages than fly ash with pozzolanic property. But, pozzalanic ones can be activated by hydraulic fly ash.
5. The replacement of 2.75% and more of conventional mineral filler with hydraulic fly ash is significantly improved the mechanical properties of CBEM in terms of stiffness modulus, creep stiffness and creep rate.

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