IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Impact of Aggregates Size and Fibers on basic Mechanical Properties of Asphalt Emulsion—Cement Concrete

To cite this article: Jun Fu *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **303** 012009

IOP Conf. Series: Materials Science and Engineering **303** (2018) 012009 doi:10.1088/1757-899X/303/1/012009

Impact of Aggregates Size and Fibers on basic Mechanical Properties of Asphalt Emulsion—Cement Concrete

Jun Fu[1,*], Zhihong Liu[1] and Jie Liu[1]

[1]School of Transportation, Wuhan University of Technology, Wuhan 430063, China

*fjgrant@whut.edu.cn

Abstract. Asphalt Emulsion—Cement Concrete (AECC) is currently considered as a typical semi-flexibility material. One of the disadvantages of this material is brittle fracture and lacking ductility. This study aims at accelerating the basic mechanical properties of AECC using fibers and different aggregates size. The mix of AECC was introduced and the different content of fibers and aggregates size were studied. The results showed that the smaller aggregates size could improve the young's modulus and compressive strength as well as fiber. The modulus-compressive strength ratio of fiber reinforced AECC is always below 500.

1. Introduction

Cement-Asphalt Emulsion Mixture (CAEM) is made of by Portland cement, emulsified asphalt, aggregates and some admixtures. CAEM is currently considered as easily cool-mixed and cool-spread, so AECC have environmental, economical, and logistical advantages over Hot Mixture Asphalt (HMA)[1].Research on these composite materials, also called Cement-Asphalt Emulsion Composite (CAEC)[2,3], Cold Bituminous Emulsion Mixture (CBEM)[4,5], Cement-Emulsion Treated Mixture (C-ETM)[6] or Cement–Bitumen Treated Material (CBTM)[7]. According to different mix design method, CAEM could be classified with CAEC and AECC. CAEC is always designed with grading aggregates and cold roller compacted in pavement while AECC is casting without accurate grading aggregates.

Some research has also been carried out on emulsified asphalt cement concrete [8,9], in which cement is the primary binder and bitumen an additive. Cold Bituminous Emulsion Asphalt (CBEA) shares characteristics of both cement and asphalt concrete [10,11]. In particular, compared with conventional HMA, CBEA has higher deformation resistance and lower temperature susceptibility [12]. Additionally, the introduction of cement in cold mix asphalt accelerates emulsion breaking [13], because cement hydration consumes water in the emulsion and meanwhile it increases its alkalinity.

However, AECC is still brittle fracture and lacking ductility. This study focused on accelerating the basic mechanical properties of AECC using fibers and different aggregates size.

2. Material and Specimen

2.1 Material

The material used in this study is aggregates, emulsified asphalt, Portland cement, PVA fiber, fly ash, water and additives. The slow-cracking anionic emulsified asphalt is used in this study and the character is given in Table 1. The properties of Portland cement are shown in Table 2. The fly ash content and properties tested is shown in Table 3. The aggregates are limestone from local and the test results is shown in Table 4. The mineral filler is from limestone whose size is smaller than 0.6 mm after sieving. Water reducer agent is early strength Poly carboxylic acid and water meets concrete water standards. Figure 1 and Figure 2 are PVA fiber and fly ash respectively.

Table 1. Emulsified Asphalt Characteristics.

properties	specification limitation	Property index
Sieve residue(1.18mm)/%	<0.1	0.04
particle diameter/μm	average particle diameter≤7 Module size≤5	average particle diameter:6.2 Module size:4.3
adaptability to cement	≥70	100
Residual content/%	≥60	60.8
Penetration (25℃、100g,5s /0.1mm)	40~120	65
Solubility(chlorylene) /%	≥42	46
ductility(25℃、5cm/min)/cm	≥100	126

Table 2. Portland cement properties.

properties	specific surface area(m2/kg)	initial setting time(min)	final setting time(min)	compressive strength(Mpa) 28d	Bending strength(Mpa) 28d
P.O 42.5	310	118	360	45.7	7.5

Table 3. Fly ash content and properties(%).

SiO_2	Al_2O_3	Fe_2O_3	SO_3	CaO	others	Ignition loss	Water demand ratio	Compressive strength ratio
57.67	28.31	3.92	0.43	2.86	1.86	4.95	90	75

Table 4. Aggregates properties.

properties	apparent density（g/cm3）	water absorption（%）	needle-like particles（%）	crushing value（%）	liquid limit（%）	plasticity index	uniformity coefficient
value	2.75	2.5	3.2	12	30	10	13

Figure 1. PVA fiber.

Figure 2. Fly ash.

2.2 Specimen

After initial determination of the mix ratio of emulsified asphalt concrete, the above mix ratio is used as the basis ratio, and the influence of the particle size and PVA fiber on AECC is analyzed emphatically. The basic mix design and variable parameters are shown in table 5 and table 6. Specimen and mix are shown in Figure 3 and Figure 4. Emulsified asphalt is organic cementitious materials and cement is inorganic cementitious materials, which both form a solid, flexible and rigid integral composite material.

Table 5. Basic mix parameters（kg/m^3）.

Water	Cement	Emulsified asphalt	Fly ash	sands	Coarse aggregate	Fiber	Water reducing agent	Defoamer
115	217	102	38	1089	730	0.9	14	0.012

Table 6. variable parameters.

Fiber（kg/m^3）				Aggregates size （mm）		
0.5	0.7	0.9	1.1	5-10	5-15	5-20

Figure 3. Specimen of AECC.

Figure 4. Mix of AECC.

3. Results and Discussion

As shown in Table 7 and Figure 5, the compressive strength and young's modulus of AECC is negative correlation with the aggregate size， so the small aggregate size is beneficial to improving the strength and young's modulus of AECC. Comprehensive consideration of economic cost and performance, the aggregate of 5-15mm is a relative optimization. The effect of fiber content in AECC is significant from Table 8 and Figure 6. In different age of AECC, with more fiber content, the compressive strength and young's modulus is increased. But in the process of mix, the fiber should be controlled to avoid cluster and preventing the agglomeration. As for modulus-compressive strength ratio, the value for fiber reinforced AECC always be less than 500, which means plastic and suitable ductility to some degree.

Table 7. Test results of concrete with different particle size.

Number	particle size （mm）	Compressive strength （Mpa）			Elastic modulus(Gpa)			Modulus-strength ratio		
		14d	28d	90d	14d	28d	90d	14d	28d	90d
Xq1	5-10	11.6	13.1	18.4	2.25	4.27	7.57	194.0	326.0	411.4
Xq2	5-15	10.5	12.2	17.2	2.13	4.15	7.46	202.9	340.2	433.7

Xq3	5-20	9.5	11.4	16.3	1.97	4.02	7.32	207.4	352.6	449.1

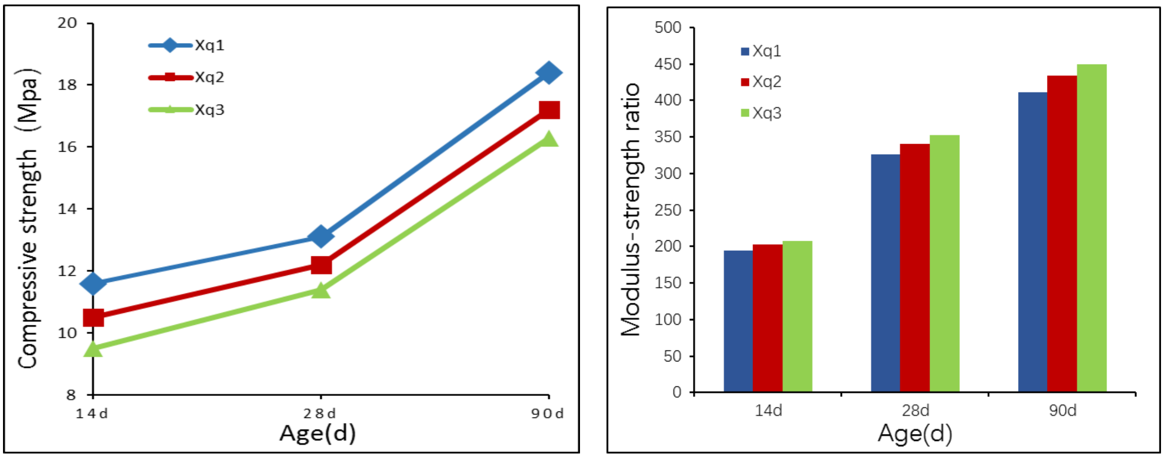

Figure 5. Effect of different particle size on compressive strength and modulus-strength ratio of concrete.

Table 8. Test results of concrete with different fiber content.

Number	Fiber content kg/m^3	Compressive strength (Mpa)			Elastic modulus(Gpa)			Modulus-strength ratio		
		14d	28d	90d	14d	28d	90d	14d	28d	90d
Xq4	0.5	7.1	8.9	13.1	1.75	3.78	7.08	246.5	424.7	540.5
Xq5	0.7	8	10.1	14.2	1.86	3.87	7.17	232.5	383.2	504.9
Xq6	0.9	8.9	11	15.4	1.96	3.99	7.27	220.2	362.7	472.1
Xq7	1.1	9.8	11.8	16.6	2.07	4.11	7.36	211.2	348.3	443.4

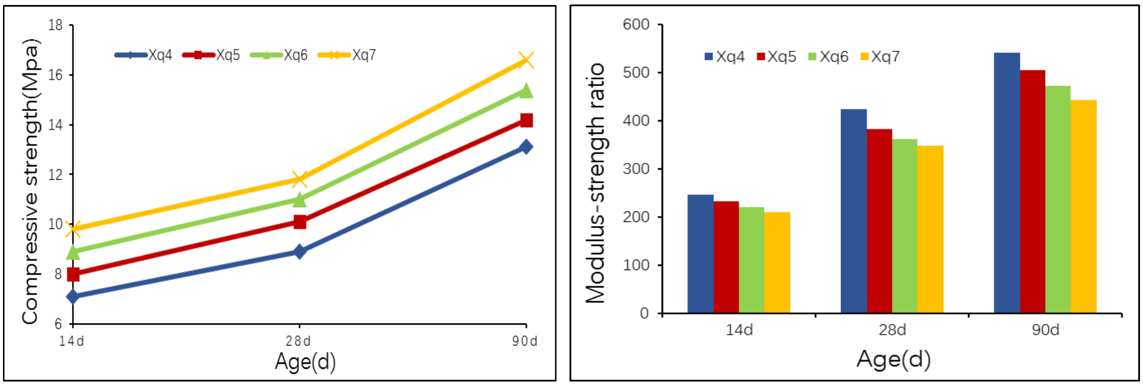

Figure 6. Effect of different fiber content on compressive strength and modulus-strength ratio of concrete.

3. Conclusions

Fiber reinforced AECC is middle and low strength concrete. The compressive strength and elastic modulus will increase when aggregates size is getting smaller. And the PVA fiber can raise the compressive strength and elastic modulus for AECC. Especially, with smaller modulus-compressive strength ratio, the fiber reinforced AECC is better in deformation and ductility than normal Cement Concrete.

4. Acknowledgements

The authors would like to acknowledge support by the National Natural Science Foundation of China (Nos.51072149). Additional Supported by Chinese Department of Transportation Planning Project of Science and Technology (Nos.2015319811320).

5. References

[1] Effect of Cement on Emulsified Asphalt Mixtures. Seref Oruc, Fazil Celik, and M. Vefa Akpinar. JMEPEG (2007) 16:578–58
[2] G. Li, Y. Zhao, S.-S. Pang, and W. Huang, Experimental study of cement-asphalt emulsion composite, 26 Cem. Concr. Res., vol. 28, no. 5, pp. 635–641, 1998. 27
[3] S. Oruc, F. Celik, and M. V. Akpinar, Effect of cement on emulsified asphalt mixtures, J. Mater. Eng. 28 Perform., vol. 16, no. October, pp. 578–583, 2007. 29
[4] H. Al Nageim, S. F. Al-Busaltan, W. Atherton, and G. Sharples, A comparative study for improving the mechanical properties of cold bituminous emulsion mixtures with cement and waste materials, Constr. 1 Build. Mater., vol. 36, pp. 743–748, 2012.
[5] I. N. A. Thanaya, Improving the performance of cold bituminous emulsion mixtures (CBEMs) : 7 incorporating waste, PhD thesis, The University of Leeds, 2003.
[6] R. J. Schmidt, L. E. Santucci, and L. D. Coyne, Performance characteristics of cement modified asphalt 30 emulsion mixes, Proc. Association of Asphalt Paving Technologists, 1973, pp. 300–319.
[7] M. Bocci, A. Grilli, F. Cardone, and A. Graziani, A study on the mechanical behaviour of cement-1 bitumen treated materials, Constr. Build. Mater., vol. 25, no. 2, pp. 773–778, 2011. 2
[8] H. A. Khalid and O. K. Monney, Moisture damage potential of cold asphalt, Int. J. Pavement Eng., vol. 11 10, no. November 2014, pp. 311–318, 2009.
[9] Jun Fu, Xiaoqiang Zhang, and Fazhou Wang.The Meso Structure and Strain Distribution Analysis of Cement Emulsified Asphalt Concrete. International Journal of Pavement Research and Technology,2015,8(3):179-184
[10] M. N. Partl, Sustainable development through asphalt recycling in Switzerland, in International 15 Workshop ISAP Technical Committee APE Asphalt Pavements and Environment, 2010.
[11] A. D. James, D. Needham, and P. S. F. Brown, The benefits of using Ordinary Portland Cement in 17 solvent free dense graded bituminous emulsion mixtures, Proc, International Symposium on Asphalt 18 Technology, 1996.
[12] S. Al-Busaltan, H. Al Nageim, W. Atherton, and G. Sharples, Mechanical Properties of an Upgrading 3 Cold Mix Asphalt Using Waste Materials, J. Mater. Civ. Eng., no. December, p. 463, 2012.
[13] J. Chehovits and L. Galehouse, Energy usage and greenhouse gas emissions of pavement preservation 19 processes for asphalt concrete pavements, Proc. 1st International Conference on Pavement Preservation, 20 2010, pp. 27–42.