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

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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(%).

| SiO₂ | Al₂O₃ | Fe₂O₃ | SO₃ | 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/m³).

| 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/m³) | Aggregates size (mm) |
|---------------|----------------------|
| 0.5           | 5-10                 |
| 0.7           | 5-15                 |
| 0.9           | 5-20                 |

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 |
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.

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