Experimental research on durability of recycled aggregate concrete under freeze-thaw cycles

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Abstract. The freeze-thaw durability of recycled aggregate concrete has significance for the concrete buildings in the cold region. In this paper, the rapid freezing and thawing cycles experience on recycle aggregate concrete was conducted to study on the effects of recycle aggregate amount, water-binder ratio and fly ash on freeze-thaw durability of recycle aggregate concrete. The results indicates that recycle aggregate amount makes the significant influence on the freeze-thaw durability. With the increase of recycled aggregates amount, the freeze-thaw resistance for recycled aggregate concrete decreases. Recycled aggregate concrete with lower water cement ratio demonstrates better performance of freeze-thaw durability. It is advised that the amount of fly ash is less than 30% for admixture of recycled aggregates in the cold region.

1. Introduction
Recycled aggregate concrete, as a kind of green sustainable building materials, can effectively alleviate the plight that a mass of construction waste is difficult to handle in cities. According to statistics, 3.5 billion tons of construction waste outputs every year in China, but the comprehensive utilization rate is less than 5%. About anti-freeze performance of the recycled concrete has been carried on by many scholars[1-6], but their research results presents inconsistent, and even opposite conclusions. Based on the fast freeze-thaw test, this paper will investigate the influence of admixture amount of recycled aggregates, water-binder ratio and fly ash content on the durability performance of recycled concrete, which can provide basis data and reference for the popularization and application of recycled concrete in cold areas.

2. Experimental program

2.1. Materials
P.O. 42.5 ordinary Portland cement was used. fly ash is chose by II grade fly ash. fine aggregate is the river sand, natural coarse aggregate is calcareous rock, efficient AE water reducer is used as the additive. Recycled coarse aggregate was prepared by waste concrete (original strength grade C30) that was crushed by the crusher shattered, then handled by 5 mm diameter of sieve screening process, meanwhile ensuring the aggregate controlled in 5-30 mm of diameter. The recycled coarse aggregate after screening was conducted by some program such as washing and drying to make it have excellent properties. Table 1 is the mix proportion of different categories of recycled aggregate concrete. to ensure the quality of recycled aggregate concrete specimens, the production program was conducted according to the Chinese rule DB11/T 803-2011. To ensure the quality of recycled concrete block, forced small mixer was used to
mix recycled aggregate concrete and recycled aggregate will be in the water-saturated state after prewetting processing. AE efficient water reducing agent, cement, aggregate, water and natural regeneration aggregate is successively put into the mixer. Mixed Materials are placed into the standard moulds after the testing recycled aggregate concrete workability.

**Table 1. Mix proportion of specimens**

| Number | water-binder ratio | recycled aggregates amount | parameters of fly ash |
|--------|--------------------|----------------------------|-----------------------|
| A1     | 0.45               | 0                          | 30%                   |
| A2     | 0.45               | 50%                        | 30%                   |
| A3     | 0.45               | 100%                       | 30%                   |
| B1     | 0.35               | 50%                        | 30%                   |
| B2 (A2)| 0.45               | 50%                        | 30%                   |
| B3     | 0.55               | 50%                        | 30%                   |
| C1     | 0.45               | 50%                        | 0                     |
| C2     | 0.45               | 50%                        | 10%                   |
| C3 (A2)| 0.45               | 50%                        | 30%                   |
| C4     | 0.45               | 50%                        | 50%                   |

2.2. **Test measurement**

In the light of designed mix proportion, the specimens (100mm×100mm×100mm and 100mm×100mm×400mm) will be conducted by mass measurement and dynamic elasticity modulus measurement respectively. Before freezing-thawing cycled experiment, the specimens need to be placed into the water(15℃~20℃) to reach the water-saturated state. Then, the fast freezing-thaw cycled experiment is conducted by the Chinese rule GB82-85. The duration of each freeze-thaw cycle is 4 hours. The specific procedure is shown in Table 2. Mass and dynamic elastic modulus is measured after every completed 25 times freeze-thaw cycle. It is a total of 300 freeze-thaw cycling test. The test will be stopped when the specimen with a 5% drop on mass or dynamic elastic modulus decreased to less than 60%.

**Table 2. Procedure for freeze-thaw cycles**

| Type   | Initial time | Final time | Temperature (℃) |
|--------|--------------|------------|-----------------|
| Stage 1| 0:00         | 0:10       | 15              |
| Stage 2| 0:10         | 0:40       | 15~20           |
| Stage 3| 0:40         | 2:10       | -20             |
| Stage 4| 2:10         | 2:30       | 20              |
| Stage 5| 2:30         | 4:00       | 20              |

3. **Results and analysis**

The different performance degradation rule of recycled aggregates concrete specimens after 300 times fast freeze-thaw test is shown. And the relative results with the consideration of recycled aggregates, water-binder ratio, fly ash admixture are presented in the following parts.

Different recycled aggregate parameter changes impact on the quality of concrete specimens after freezing and thawing cycle. It can be seen from the Fig 1, Fig.2 and Fig.3 that concrete mass loss after freeze-thaw cycle increases with the amount of recycled aggregates parameter rising. There are no more than 5% mass loss in A2 group after 300 times of freeze-thaw cycle. It is indicated that the recycled aggregate concrete in the terms of mass loss can be accepted. When amount of recycled aggregate reaches to 100%, the mass loss is so severe for A3 after 300 times freeze-thaw cycles. mass loss is not more than 3% for different water-binder ratio of recycled concrete specimens after 300 times fast freeze-thaw cycle which presents well freeze-thaw performance. But it can be seen that water-binder
ratio has a great influence on the quality loss. The smaller water-binder ratio of recycled aggregates concrete is and the smaller mass loss is. For the specimens of C3 group (30% fly ash amount), the mass loss is not more than 5%. When fly ash amount is 50% for C4 group, the mass loss is more than 5%. Thus, it is obvious that the no more than of amount of fly-ash for recycled aggregate concrete is advisable.

The Fig.4 shows the effects of recycled aggregates, water-binder ratio and fly ash on dynamic elasticity modulus. It can be observed that these factors have different extents influence. When the amount of recycled aggregates is 50% for A2 group. The dynamic elasticity modulus still stays the level of 0.9. It demonstrates that freeze-thaw resistance of recycled aggregates concrete seems is similar with ordinary concrete. With the increase of amount of recycled aggregates, the decline rate of dynamic elasticity modulus of recycled aggregates concrete for in the later stage of freeze-thaw cycles (200 times) is obviously faster when the amount of the recycled aggregates is 100% for A3 group, the relative dynamic elasticity modulus is lower 0.9. It shows that the freeze-thaw performance is weaker than the ordinary concrete. In order to obtain the well performance concrete, lower 50% the amount of recycled aggregate is advisable.

As Fig.5 shown, the recycled concrete after freeze-thaw cycle 300 times relative dynamic elastic modulus were above 0.9 as shown in Figure 5, antifreeze performance is still good. Water-binder ratio on dynamic elastic modulus of smaller, but still show some regularity, dynamic elastic modulus increases with the smaller of water/cement ratio. The relative dynamic elastic modulus of after 300 times freeze and thaw cycles keep above 0.9 as shown in Figure 5, which shows the well freeze and thaw performance for recycled aggregates concrete. The water-binder ratio has small effects on the dynamic elastic modulus, but there is obvious rule that dynamic elastic modulus increase with the water-binder ratio decrease.

In the Fig.6, when recycled concrete admixture amount of fly ash in more than 50% (C4) specimen, the freeze-thaw cycle elastic modulus decreased after 300 times larger, and even destruction of specimen. But other groups of specimens (C1, C2 and C3 and C4), the relative dynamic elastic modulus were above 0.9, shows that still has better performance of antifreeze. Experimental data show that in the process of 300 freeze-thaw cycles, not with fly ash of relative dynamic elastic modulus of recycled concrete specimens of lower speed no faster, with 10% and 30% fly ash of the recycled concrete specimens after freezing and thawing cycle 200 times, its relative dynamic elastic modulus decreased obviously accelerated, and fly ash admixture amount for 50% of C4 group of specimens, the relative dynamic elastic modulus after freezing and thawing circulation of 150, presents the obvious acceleration tendency.
4. Conclusion
The general rule of mass loss and dynamic elasticity modulus is obtained based on the 8 groups of recycled aggregates concrete specimens under freeze-thaw cycles test. The amount of recycled aggregates has an important role in the freeze-thaw performance of recycled aggregates concrete, which makes the declining tendency decreases with the enhancement of recycled aggregates. The concreted with 50% recycled aggregates shows the well performance in all the specimens. Water-binder ratio is also an essential factor on the freeze-thaw performance of recycled aggregates concrete. The specimens with lower water-binder ratio presents the well freeze-thaw performance, whose mass loss increase and dynamic elasticity modulus decrease with the amount of fly ash enhancing. It is advised that the amount of fly ash is less than 30% for admixture of recycled aggregates in the cold region.

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