Effect of Nano Compound Addition on the Properties and Microstructure of Cement Mortar with Mixed Fine Recycled Aggregate

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Abstract. The high-water absorption and poor mechanical properties of mixed fine recycled aggregate, which will lead to weakened interfacial transition zone (ITZ) between cement paste and aggregate, seriously hinder the recycling of mixed fine recycled aggregate. The effect and enhancement mechanism of nano compound addition (NCA) on the properties and microstructure of cement mortar was studied in this paper. The results indicated that the compressive and bending strength of cement mortar with 100\% fine mixed recycled aggregate increased about 10\% at most of the curing ages and the shrinkage of cement mortar decreased from 2.5\% at 1 day to 21\% at 28 days by NCA. Scanning electron microscope (SEM) microphotography indicated that the early hydration rate of cement could be accelerated and the density of cement mortar at late ages may well be increased by NCA.

Keywords. Nano compound addition, cement mortar, mixed fine recycled aggregate.

1. Introduction
The continuous and massive consumption of natural aggregates and the overproduction of waste from construction and demolition likewise are serious threats to the environment and the economy. Definitely, the pace of demolition is still accelerating and the supply of appropriate natural aggregates is sharply decreasing owing to their exhaustive exploitation, so it’s necessary to reuse construction and demolition waste (CDW) effectively in order to preserve natural aggregates. In addition, the utilization of recycled aggregates (as substitutions for natural aggregates) collected from CDW in concrete is acknowledged to be environmentally and economically friendly, since it greatly shortens the transportation distance of aggregates [1]. Nevertheless, the recycled aggregate concretes (RAC) exhibit weakened mechanical properties compared to the natural aggregate concretes [2, 3]. Indeed, the multitudinous interfacial transition zones (ITZ) with high level of porosity and the weakened properties of the attached mortar are considered as the main factors explaining the reduced mechanical properties of the RAC [3-6]. On the other hand, the physical performances and the existence of unhydrated cement inside the recycled aggregate impacted the properties of concrete [7]. It is worth mentioning that the recycled aggregate could be divided into two particle sizes: coarse and fine. However, most of the work on using recycled aggregate in concrete has focused on replacing the coarse aggregate, there are relatively few literatures on mixed fine recycled aggregate. Moreover, the high-water absorption and poor mechanical properties [8-12] of mixed fine recycled aggregate, which
will lead to weakened ITZ between cement paste and aggregate, seriously hinders the recycling of mixed fine recycled aggregate. Most of the studies on mixed fine recycled aggregate have focused on the mechanical properties and microstructure of recycled aggregate concrete/mortar. However, there are few researches to improve the performance of recycled aggregate concrete/mortar from the perspective of improving the performance of mixed fine recycled aggregate. Therefore, it is an urgent need to find a treatment for improving the properties of mixed fine recycled aggregate. In this paper, the effect and enhancement mechanism of nano compound addition (NCA) on the properties and microstructure of cement mortar was studied by mechanical strength test, shrinkage test and scanning electron microscope (SEM).

2. Experiment

2.1. Materials
P.O42.5 standard cement according to Chinese standard GB 175-2007 produced by Lafarge Cement Company, mixed fine recycled aggregate supplied by Hangzhou Xiaoshan Fulihua new building materials, naphthalene-based superplasticizer with water reduce ratio of 25% produced by Wulong Company in Zhejiang were used in this research. NCA was made by Institute of Building Materials of Zhejiang University and sprayed on the surface of fine mixed recycled aggregate before the cement mortar was mixed. Table 1 showed the mix proportion of cement mortar.

| Sample | cement (Kg) | MFRA (Kg) | SP (Kg) | NCA (Kg) | Water (Kg) |
|--------|-------------|-----------|---------|----------|------------|
| W      | 450         | 1350      | 5.4     | 0        | 260        |
| Q      | 450         | 1350      | 5.4     | 13.5     | 260        |

MFRA means mixed fine recycled aggregate.
SP means superplasticizer.

2.2. Experiment Method
The cement mortar was molded and conserved on the 20°C condition. The bending and compressive strength tests of cement mortar were conducted according to GB/T 17671-1999. Small rectangle specimens (40 mm×40 mm×160 mm) were molded at 20°C and cured at 20°C and RH of 60%. The length of specimen was tested when the curing days were 3, 7, 14, 28 and 45, respectively and the dry shrinkage of different specimen was calculated.

The specimens for Scanning Electron Microscopy (SEM) observation was molded and conserved on the 20°C condition. Then the cement mortars were broken into small fragments and finished hydrated reaction by pure alcohol at specific age. Those small fragments were sprayed with gold for 60s in SBC-12 Small Particles Sputtering Apparatus to make specimens conductive. Microscopic structure of specimens was observed with scanning Electron Microscope instrument which type is HITACHI S-570 s.

3. Results and Discussion

3.1. Compressive and Bending Strength
Table 2 showed the compressive and bending strength of different cement mortar. Results indicated that compressive and bending strength of cement mortar with 100% fine mixed recycled aggregate had good performance in early curing ages, because interfacial transition zone (ITZ) between cement paste and aggregate could be strengthened by the increasing fluidity of cement paste with super plasticizer. However, the rate of strength growth of cement mortar was slow in the late curing ages. When the fine mixed recycled aggregate was strengthened by NCA, the compressive and bending strength of cement mortar showed a little increase in the early ages and a great increase of strength development in the
late ages. It is shown that 11% enhancement in bending strength and 9% enhancement in compressive strength could be gained at 28 days by spraying NCA.

| Sample | Compressive strength | Bending strength |
|--------|----------------------|------------------|
|        | 3 days | 7 days | 28 days | 3 days | 7 days | 28 days |
| W      | 3.50   | 5.10   | 7.06    | 31.1   | 39.7   | 59.3    |
| Q      | 3.36   | 5.15   | 7.83    | 31.0   | 43.9   | 64.6    |

3.2. Dry Shrinkage
Figure 1 showed the results of dry shrinkage test of different cement mortar. Results showed that the dry shrinkage was very large on account of the high-water absorption of fine recycled aggregate [6-8]. The shrinkage extended to more than 1400 με at 28 days. It is easy to induce the micro-crack in cement paste and weaken the durability of cement mortar. After spraying NCA, the dry shrinkage of cement mortar reduced about 2.5% at 1 day and 21% at 28 days. The whole dry shrinkage of cement mortar with NCA was less than 1050 με. This is effective to control the formation of cracks, decrease the permeability and improve the durability of cement mortar.

3.3. SEM Observation
Figure 2 and figure 3 showed the SEM photos of cement mortar with and without NCA at 7 days and 28 days, respectively.
Figure 2 showed that the addition of NCA will increase the hydration products of cement due to the acceleration of cement hydration rate. However, the whole density of specimen could not gain better enhancement because of the high volume of hole in cement mortar at early ages. Thus, the strength and shrinkage could not improve much by spraying NCA at early ages, which was also shown in table 2 and figure 1.

As the curing age increases, the density of cement mortar was increasing very fast, especially for the specimen with spraying NCA. Figure 3 showed that specimen with NCA was more compact than specimen without NCA. Therefore, the strength and shrinkage could gain better improvement at late ages by spraying NCA, which was also shown in table 2 and figure 1.

4. Conclusion
The effect of NCA on the properties and micro-structure of cement mortar with 100% fine mixed recycled aggregate was studied.

(1) The compressive and bending strength of cement mortar with 100% fine recycled aggregate were increased almost 10% at late ages by spraying NCA.
(2) The dry shrinkage of cement mortar with 100% fine recycled aggregate decreased about 21% by spraying NCA.
(3) SEM observations results indicated that more hydration products could be created at early ages and the density of specimen were obviously increased at late ages.

Acknowledgments
Authors wishing to acknowledge assistance from the National Defense Innovation Special Zone Project (18 163-13-ZT-007-003-01).

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