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# The characteristics of ITZ between function aggregate and cement paste

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ABSTRACT: Function aggregate (FA) is composed of a porous matrix with high strength and low water absorption, and a reactive layer coated by the matrix, which can improve ITZ between aggregate and cement paste and control curing range of cement paste. The ITZ between function aggregate and cement paste is studied by SEM images and microhardness method. The width of the ITZ between hardened cement paste (hcp) and FA pellet is about 40μm. Compared to the matrix pellet, the interfacial bond between FA pellet and hcp is stronger. Further research should be focused on the mechanism of ITZ between hcp and FA pellet.
Keywords: function aggregate; ITZ; surface activity

## 1 INTRODUCTION TO FUNCTION AGGREGATE

As is known to all, aggregate and interfacial transition zone (ITZ) between aggregate and cement paste play a very important role in concrete, which was the weakest link of the chain. In the past few decades, much work has been devoted to improve the ITZ. Some researchers tried to optimize the composition of cement paste by mineral admixtures, i.e. fly ash, slag, silica fume, etc., leading to a denser ITZ structure with a smaller thickness and a lower content of $Ca(OH)_2$. However, it is difficult to eliminate wall effect, and maybe enlarges the difference between cement paste and ITZ. Researchers also turned to surface modification of aggregate through thermal treatment, chemical dissolution and silica fume coating, which was effective in increasing the bonding strength between cement paste and aggregate, but failed to eliminate the gradient distribution in ITZ. Artificial aggregate was another route as an internal curing agent to enhance this vulnerable part. But the surface of high performance lightweight aggregate always is coated by a deep glaze during the sintering process, which weakens the bonding strength between cement paste and aggregate.

We tried to make some efforts on modification of aggregate. The composition, structure and properties of aggregate were designed to form a strong bond between aggregate and cement paste. Based on artificial aggregate, we proposed the concept of function aggregate in 2009 annual meeting of Chinese Materials Research Society. Function aggregate (FA) is composed of a porous matrix with high strength and low water absorption, and a coating layer which can hydrate in cement paste. And its ideal model is illustrated in Figure 1. It can improve ITZ between aggregate and cement paste and control curing range of cement paste.

Based on the design idea, function aggregate was produced by optimization of raw materials and processing techniques. In the study, scanning electron microscopy images and microhardness method were employed to investigate the ITZ between cement paste and FA.

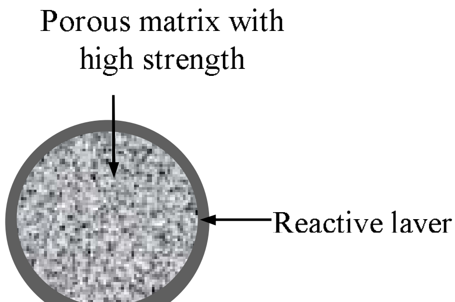



Figure 1. Ideal model of function aggregate pellets.

## 2 MATERIALS AND EXPERIMENTS

### 2.1 *Materials*

(1) cement

Ordinary Portland cement (P·O 52.5 type according to GB175-2007) was used. The chemical composition is listed in Table 1.

Table 1. Chemical composition of cement. wt.%

| $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | LOI |
|---|---|---|---|---|---|---|
| 21.35 | 4.67 | 3.13 | 62.60 | 3.08 | 2.25 | 0.95 |

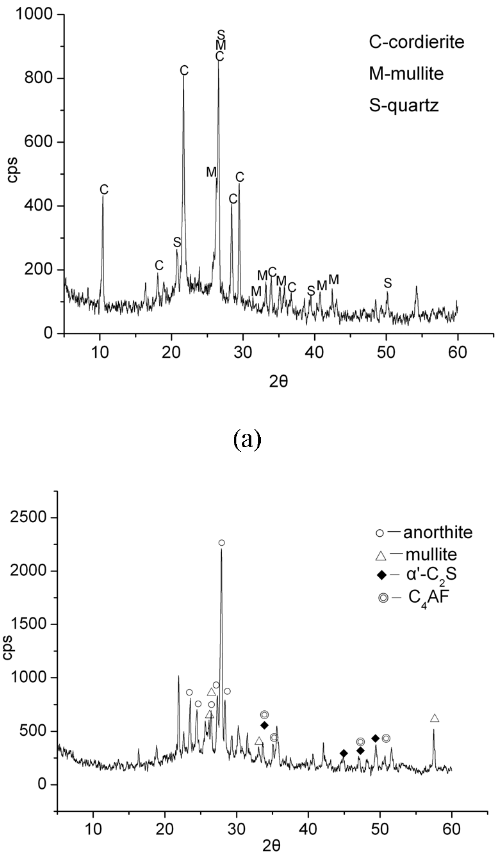
(2) FA and matrix pellets

FA and matrix pellets with a near-spherical shape were sintered by the same process. And the particle size of pellets is within the range of 10-15 mm. The

XRD spectra of FA pellets are given in Figure 2. Mullite, cordierite and quartz are the main phases in the matrix of FA. Previous study showed that cordierite can prevent the generation of cracks within matrix pellets, improving their strength with lower water absorption. Minor components of Portland cement exist in the surface layer. The physical and mechanical properties of matrix pellets are shown as Table 2.

(3) superplasticizer (SP)

Polycarboxylate-based superplasticizer (SP) was used with 30% solid content.




(a)

(b)

Figure 2. XRD spectra of FA pellets, (a)matrix & (b)surface layer.

Table 2. Physical and mechanical properties of FA.

| Apparent denstiy, g/cm$^3$ | Absorption, % | | Compressive Strength*, Mpa |
|---|---|---|---|
| | 24h | vacuum | |
| 1.779 | 1.473 | 5.541 | 42.65 |

*Particle strength of cylindrical sintered samples

## 2.2 *Specimens preparation*

Freshly mixed cement paste (water-cement ratio = 0.30, SP-cement ratio = 0.008) and aggregate were casted into Φ25×30mm cylindrical moulds. Only one pellet was placed in the center of the specimen. After moulding, the specimens were immediately cured at 293±2 K and 95% relative humidity for 24 h. Then, they were demoulded and placed in water at 293 K until the prescribed age.

## 2.3 *Microhardness test*

The specimens were cut into the 10-mm-thickness cylinders. The test surface of the specimens containing the ITZ between aggregate and mortar was ground and polished. Based on the ASTM E 384-07 testing method, a Vickers indenter was used to determine the microhardness in the ITZ between aggregates and hardened cement paste(hcp).

## 2.4 *Microstructure analysis*

In order to analyze the microstructure of the ITZ, the specimens were broken into proper size pieces at selected times. The fractured surfaces along the interface and both the cement paste side and the aggregate side were gold coated and observed using scanning electron microscopy.

# 3 RESULTS AND DISSTRUSSIONS

## 3.1 *Microhardness*

The microhardness of the ITZ with varied distance away from different aggregates at the age of 3,7 and 28 days are shown as Figure 3. It can be seen from that the interfacial Hv increases with a longer age. The interfacial Hv falls down to nadir gradually at the point of 30 μm away from aggregate surface, then it rises up and becomes stable. It gives evidence that the range of the weak zone (ITZ) is about 40 μm. But a gentler slope tendency of Hv exists in the interface between hcp and FA pellet. It also needs to be noted that the interfacial Hv in the weak range between hcp and FA pellet is higher than that between hcp and the matrix pellet at every age, especially at 28 days.

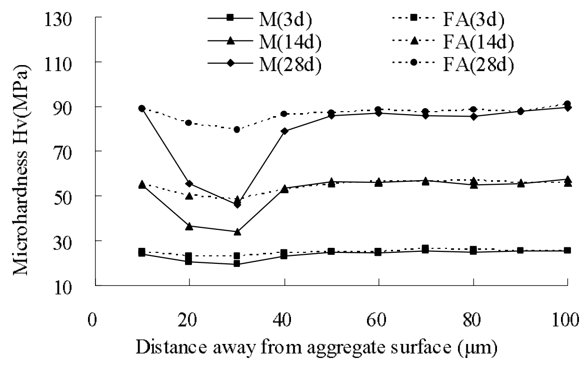



Figure 3. Microhardness profiles in the ITZ between hcp and aggregate at different ages. Herein, M indicates the matrix pellets.

## 3.2 *Microstructure analysis*

Figure 4 shows microstructure of the ITZ between hcp and aggregate at 3 and 28 days. With the age increase, the microstructure of ITZ becomes denser. There exist visible differences in the microstructure of different ITZ at the same age. It can be seen that the interfacial bond between FA pellet and hcp (Fig. 4a, 4c) is closer that between the matrix pellet (Fig. 4b, 4d).

Figure 4b shows that some thin layered crystal adsorbed on the surface of the matrix pellet, resulting a weak bond. It also can be seen from Figure 4(d) that there exists tiny debonding between the matrix pellet and hcp caused by the prominent difference between the ITZ and hcp. However, the bond between hcp and FA pellet becomes stronger with the increase of age. The rough surface of FA pellet plays a positive role in the interfacial bond. It is difficult to estimate the hydration of the components on the surface of FA pellet, which needs to be further studied.

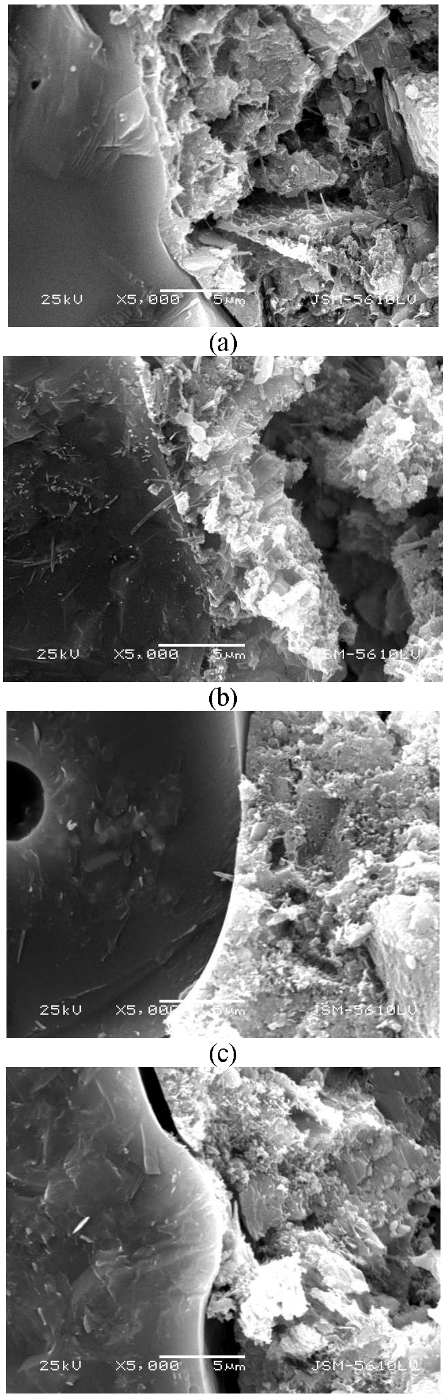


Figure 4. SEM micrographs of the ITZ between hcp and (a)FA & (b)the matrix pellet at 3 days; (c)FA & (d)the matrix pellet at 28 days.

## 4 CONCLUSIONS

(1) The width of the ITZ between hcp and FA pellet is about 40μm.
(2) The bond between hcp and FA pellet is stronger than that between hcp and the matrix pellet, exhibiting a greater difference with a longer age.
(3) It is not adequate to clarify the mechanism of the ITZ between hcp and FA pellet by SEM analysis and microhardness, which needing further research.

## ACKNOWLEDGEMENTS

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