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A Study on Carbon Fiber influence to Rebar Corrosion in Concrete

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Abstract. Rebar corrosion test of Carbon Fiber Reinforced Polymer (CFRP) concrete was did. Carbon fiber in concrete improved the compression strength of the concrete, but width and number of concrete cracks was not reduced, carbon fiber has not obvious act for improving concrete corrosion crack behavior. CFRP concrete Corrosion potential was a little high than common concrete, carbon fiber has not obvious act for improving concrete behavior in protecting steel beyond corrosion. The porosity of the carbon fiber reinforced polymer concrete was twice of the common concrete, carbon fiber added to concrete lead to increase porosity and maybe decrease concrete behavior in protecting the embedded steel in corrosion.

Introduction

Carbon Fiber Reinforced Polymer(CFRP) concrete as its electric, compression sensitivity, cracking resistance advantages is widely used in the high building reinforced slabs, electric concrete, electromagnetic shielding concrete and so on. [1] In one hand, the addition of carbon fibers can be effective control cracking, protect the rebar in the concrete apart from air and water, reduced probability of the rebar corrosion. [2] In the other hand carbon fiber has a strong effect on the electrical properties of the composite, concrete resistivity is reduced and it is a disadvantage to rebar corrosion.[3] The addition of carbon fibers led to lots of air bubble in concrete, increase the porosity, reduced concrete impermeability. This study did chloride penetration dry-wet cycles test and inspected the corrosion potential by half cell method, concentrated on the influence of the carbon fiber to improving concrete behavior in protecting the embedded steel in corrosion.

Experiment

Specimens. Concrete prism specimens 100×100×300mm were manufactured with 2 different concrete mixtures in laboratory, and there are 3 same specimens in every group, the mixture proportion of the concrete specimens is showed in table 1, and the sharp of the specimens showed in figure 1.

Table 1 Mixture Proportion of the Concrete Specimens

Group	Cement kg/m^3	Aggregate kg/m^3	Sand kg/m^3	Water kg/m^3	admixtures	W/C	Fiber	Strength MPa
P	418	1164	613	205	-	0.49	-	43.9
C	418	1164	613	205	0.5% dispersant 0.2% Air entrapped	0.49	0.6% Carbon Fiber	44.2

P stand for common concrete specimens; C stand for Carbon Fiber Reinforced Polymer concrete specimens.

CFRP was asphalt-carbon fiber, the average length 7mm, diameter was 12~15μm, tensile strength is 400~600MPa, the tensile modulus is 30~40GPa, density is 1.23~1.91g/cm^3, resistivity is 5.2~6.8Ω·cm, all the rebar in the test was same, diameter was 10mm.

After curing in the standard condition (temperature 20±3°C, relative humidity 95%) 28 days, then all the specimens were exposed to wet-dry cycles (48 hours dry followed by 48 hours wet) in NaCl solution, the specimens immerged about 20cm depth in the solution and the solution concentration was controlled in 3.0%~4.0%.

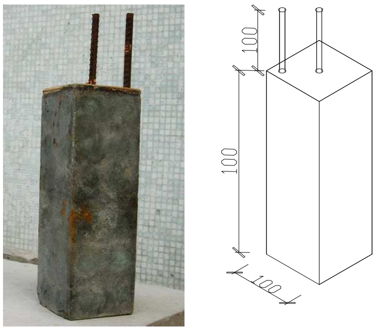


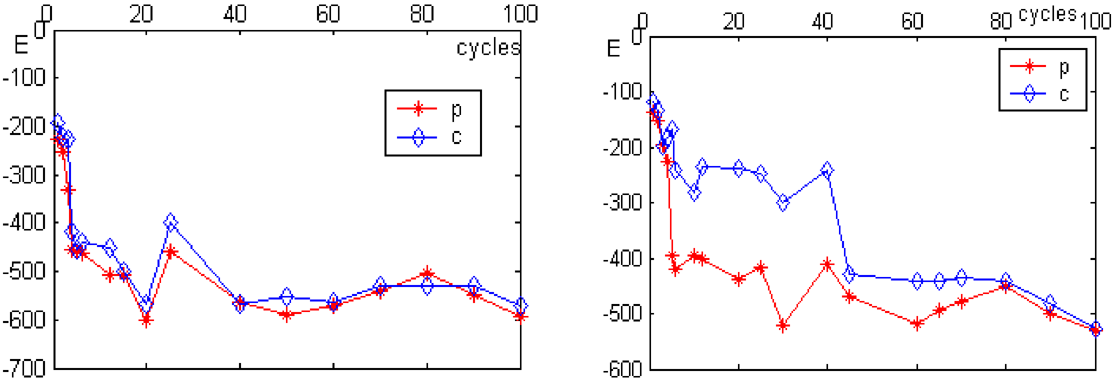
Figure 1 Sharp of the specimens

Half Cell Potential Measurements. The test device is CANIN produced by Switzerland. The corrosion potential E (half-cell rebar / concrete) is measured as potential difference (or voltage) against a reference electrode (half-cell). In this paper, all the reference electrodes are copper-copper sulfate. Interpretation of potential measurement is show in table.2. The corrosion potential E was gotten by the device after every wet-dry cycles at the first 6 cycles, and then corrosion potential was collected every 5 cycles, after 25 cycles the frequency reduced to every 8 cycles until 100 cycles the test was stopped.

Table 2 Interpretation of half-cell potential measurements[4]

Measured potential E(mV vs CSE)	Probability of corrosion
E>-200	<10%
-200>E>-350	unknown
E<-350	>90%

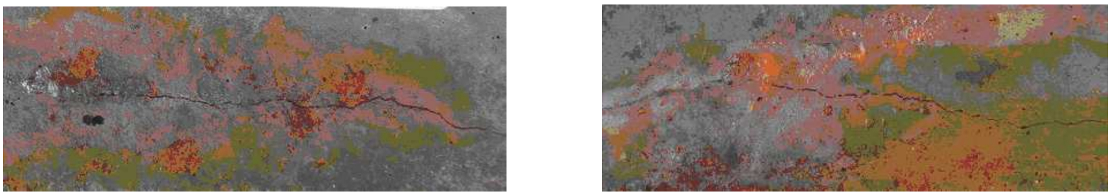
Result Analysis



(a)concrete cover thickness is 10mm (b) concrete cover thickness is 25mm

Figure 2 Corrosion potential various curve of the rebar in CFRP concrete

Potential. In all the specimens there had enough water and air near the water level, the corrosion was most seriously, so all corrosion potential was collected from this area. Inspected the corrosion potential as the wet-dry cycles test, the data curves are showed as figure 2, concrete cover is 10mm and 25mm. At the beginning of the test the corrosion potential reduced rapidly, after 32 times cycles the corrosion potential was lower than -500mV, the corrosion was too much seriously. So both the concrete cover thickness 25mm and 10mm are not enough for protect steel beyond corrosion in the chloride aggressive environment.



(a) P (concrete cover thickness is 10mm) (b) C (concrete cover thickness is10mm)

(c) C (concrete cover thickness is 25mm)

Figure 3 The crack and character of the specimens in the end of the test

In the group of concrete cover thickness 10mm, after 5 times wet-dry cycles, the corrosion potential of group P and C both were lower than -350mV, the probability of the corrosion were larger than 90%, and the corrosion become seriously as the wet-dry cycles was continue. And the potential of the group P was a little lower than C.

In the group of concrete cover thickness 25mm, there was some discrepancy between group P and C, during 10 to 60 wet-dry cycles, the potential of the group P was lower than C. After 60 wet-dry cycles, corrosion potential of group P and C were fairly close.

Carbon fiber in concrete has not obvious act for improving concrete behavior in protecting the embedded steel in corrosion, in some case, CFRP concrete has a little better behavior than common concrete.

The surface crack of the concrete after 100 cycles as figure 3, The width of cracks were not obvious different between P and C on the of cover 10mm concrete specimen, and cover 25 mm were narrow than cover 10 mm in the group C. There were not obvious different in the number of the cracks between the two types. So carbon fiber in concrete has not obvious act for improve concrete crack behavior.

Pore Structural Analysis. At casting the test specimens, cast 100 mm×100 mm×100mm cube specimens, cured 28 days, did materials test to determine standard compressive strength, volumetric mass, water absorbency and porosity [5]. The cube specimens test data show as table.3.

Table.3 Concrete material test data

Group	28d compressive strength MPa	Volumetric mass Kg/m^3	Water absorbency %	Porosity %
P	41.7	2314	5.49%	10.4%
C	42.0	2274	5.67%	23.2%

Pore structural consist of porosity, pro diameter, distribution of the pro size, pro morphology. Pore structural have important for the concrete strength and durability. Pore structural analysis can confirm harmful pro and un-harmful pro and the influence to concrete behavior in protecting the embedded steel in corrosion. Pro class to four types as follows:[6]

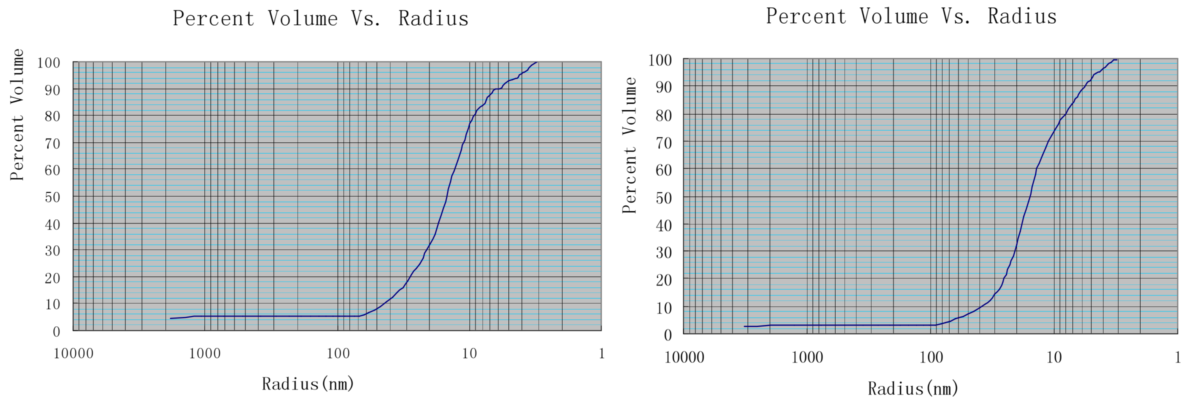
un-harmful pro	diameter less than 20nm
little harmful pro	diameter between 20nm to 100nm
harmful pro	diameter between 100nm to 200nm
much harmful pro	diameter more than 200nm

Broken test specimens, chose concrete 20~30 fragments, diameter about 5mm, without aggregate far from the rebar. The distribution of the pro showed in table 4. Porosity of the fragments from P and C were 10.4% and 23.2%, group C is twice of group P. In all the specimens un-harmful pro was most, harmful pro and much harmful pro was less. Much harmful pro of group C is twice of the P. Figure 4 is percent volume—pro diameter curve in concrete, pro diameter less than 100nm is the most either group P or C.

Carbon fiber added to concrete lead to increase porosity and maybe decrease concrete behavior in protecting the embedded steel in corrosion.

Table 4 Distribution of the pro size in the fragments

fragments	Porosity	un-harmful pro <20nm	little harmful pro 20~100nm	harmful pro 100~200nm	much harmful pro >200nm
P	10.4%	7.09%	2.71%	0	0.626%
C	23.2%	15.8%	6.04%	0	1.29%



(a) P (b) C

Figure 3 Percent volume—pro diameter curve of the concrete fragments

Conclusions

(1) Corrosion potential of steel in the CFRP concrete had a little high than common, but not obviously. Carbon fiber in concrete has not obvious act for improving concrete behavior in protecting the embedded steel in corrosion.

(2) Carbon fiber in concrete can improve the compression strength of the concrete, but has not obvious act for improving concrete crack behavior including width and number of the crack.

(3) The porosity of the CFRP was twice of the common concrete, pore structural analysis result is carbon fiber added to concrete maybe lead to increase porosity and decrease concrete behavior in protecting the embedded steel in corrosion.

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