Effect of sand percentage on early-age cracking behaviors of concrete

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Abstract: It was analyzed by using flat-type specimens that studied the influence of sand percentage on early-age cracking behaviors. The results showed that concrete early cracking area was decreased first and then increased, while early cracking area was the smallest, as sand ratio of C30 and C50 were separately 44% and 41%. The C30 compressive strength was continuously increasing, and compressive strength of C50 first increased and then dropped.

Introduction

Except corresponding requirements of special positions, the concrete strength and work performance were used as quality index to judge its advantage in the actual application process of concrete, but these indicators didn't consider the volume stability of concrete[1]. Poor volume stability led to concrete cracking that formed concrete cracks, which provided channels for harmful substances permeate or migrate from external to internal, accelerated cracking damage process of concrete, decreased concrete durability[2-4].

Sand ratio, refers to the percentage that sand quality accounts for aggregate in concrete. Therefore, sand percentage lead to surface area and porosity of aggregate are both changed, affecting workability and durability of concrete. He Jinyun[5] had studied that sand ratio was the main factor to affect the normal concrete workability, which wasn't a simple linear relationship on concrete. Niu Yinglan[6] and Wei Jiayang[7] had obtained the reasonable sand ratio can make good aggregate gradation, small porosity, positive workability, and easy to stir and mold, form relatively dense concrete, finally improve concrete durability.

The paper studied that crack development regularity under different sand ratio in the maintenance from 3h to 24h by plate induced cracking, calculated the number of cracks after 24h, then surveyed crack length and width. Meanwhile combining with mechanical properties to explore the influence and mechanism of sand percentage on early-age cracking behaviors of concrete.

Test conditions

Raw materials. Cement that selected P·O 42.5 ordinary Portland cement, Tab.1 had shown physical properties. Fly ash that selected II-level fly ash, Tab.2 had shown performance test results. Mineral powder that selected S95 mineral powder, Tab.3 had shown performance test results. Fine aggregate that selected fine river sand and mechanism sand, Tab.4 had shown performance test results. Coarse aggregate that selected 5～31.5mm continuous-gradation gravel, Tab.5 had shown the performance test results. Admixture that selected polycarboxylate type superplasticizer, solid content was 19.7%, and water-reducing rate was 20.0%. Water that selected running water.

Tab.1 Basic physical and mechanical properties

water requirement of normal consistency/%	surface area/(cm²/g)	setting time/min		flexural strength/MPa		compressive strength/MPa	
		initial setting	final setting	3d	28d	3d	28d
27.2	3480	160	205	6.5	8.6	30.1	49.4

Tab.2 Test results of fly ash performance

grade	density /(g/cm³)	fineness(45μm sieve residue)/%	Water demand ratio /%	ignition loss /%	SO_3 /%
II-level	2.7	19.2	96	2.0	0.7

Tab.3 Test results of slag performance

grade	surface area /(cm²/g)	density /(g/cm³)	activity index/%	
			7d	28d
S95	4230	2.86	82	98

Tab.4 Test results of fine aggregate performance

fine aggregate	fineness modulus	mud content/%
mechanism sand	2.9	1.9
fine river sand	1.8	1.2

Tab.5 Test results of coarse aggregate performance

coarse aggregate	particle size /mm	mud content /%	elongated particle content /%	crush value/%
gravel	5～31.5	0.3	3	9.0

Proportion of concrete. In order to study the influence of sand percentage on early-age cracking behaviors, Tab.6 had given eight concrete proportion of different sand ratio on C30 and C50.

Tab.6　C30、C50 concrete mix proportion（kg/m³）

test number	sand ratio /%	cementing materials			fine aggregate		gravel	water	admixture
		cement	fly ash	mineral powder	mechanism sand	river sand			
3001	42	175	105	70	464	309	1067	170	3.8
3002	44	175	105	70	486	324	1030	170	3.8
3003	46	175	105	70	504	336	1000	170	3.8
3004	48	175	105	70	530	353	957	170	3.8
5001	37	240	96	144	391	260	1109	160	5.4
5002	39	240	96	144	412	274	1074	160	5.4
5003	41	240	96	144	432	288	1040	160	5.4
5004	43	240	96	144	454	303	1003	160	5.4

Test methods. The method for measuring concrete early-age cracking resistance referred to GB/T 50082-2009, testing early-age cracking resistance of concrete under constraints. The experiments used flat thin plate specimens with seven crack inducers, the size of plate was 800 mm x 600 mm x 100 mm. Putting briquettes in curing room on (20±2)℃ and humidity on (60±5)% after being compacted and smoothed, then adjusting the fan speed to keep wind speed on the surface center reach (5±0.5)m/s until specimens had shaped 30mins. In the process of experiments, some cracks must be recorded when specimens had respectively molded 3h, 4h, 5h, 6h, 8h, 24h. At last, using 80X reading microscope to measure the crack width along the direction of crack inducers. The mechanical properties of concrete refers to GB/T 50081-2002, measuring 7d and 28d compressive strength of concrete standard specimens.

In the paper, evaluation indexes of slab cracking were carried out to according to "Concrete structure durability design and construction guide" which had been proposed by the Civil Engineering Society of China, formulas were shown as follows. In the formulas, W_i was the maximum width of crack I (mm), L_i was the length of crack I (mm), N was total number of cracks (root), S was $0.36m^2$.

Average cracking area of cracks:
$$A = \frac{1}{2N}\sum_{i}^{N} Wi \cdot L_i \,(mm^2/root)$$
. （1）

Number of cracks per unit area:
$$B = \frac{N}{S} \,(root/m^2)$$
（2）

Total cracking area per unit area:
$$C = A \cdot B.$$
（3）

Test results and analysis

The experiment of concrete cracking behaviors. The experiment studied the influence of sand percentage on early-age cracking behaviors by plate induced cracking. The paper comprehensively evaluated cracking resistance of concrete on measuring cracks length along the direction of crack inducers, reading cracks width, calculating total cracking area.

Development trend of early-age cracks in concrete. It was observed that concrete surface cracks with the same strength grade were in the same trend. Putting briquettes at (20±2)℃ and humidity on (60±5)% that would find no cracks on concrete surface between forming 3h and 6h, C30 surface along the direction of crack inducers after 8h that began to appear subtle cracks, but C50 specimens had subtle cracks between 6h and 8h. With the extension of time, apparent cracks could be seen after 24h, then respectively testing surface cracks of C30 and C50 specimens, results were shown in Fig.1 and Fig.2 that the width of C30 surface cracks were in the range from 0.05mm to 0.50mm, and the width of C50 surface cracks were between 0.15mm and 0.38mm.

Analysis and performances of concrete cracking Tab.7 had given concrete cracks with different numbers. From the results of C30 and C50 early-age cracking can be seen that the total cracking area per unit area decreased with sand ratio increasing in a certain range, but the fracture area increased with sand ratio increasing when sand ratio exceeded a certain critical value.
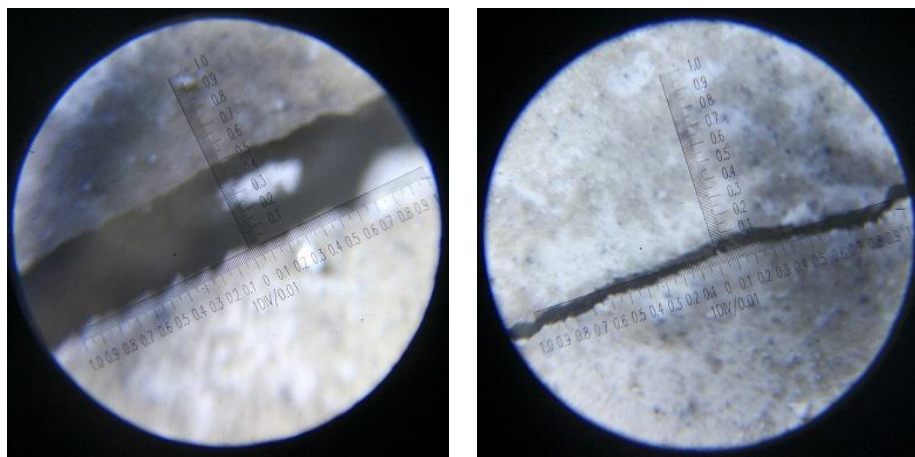
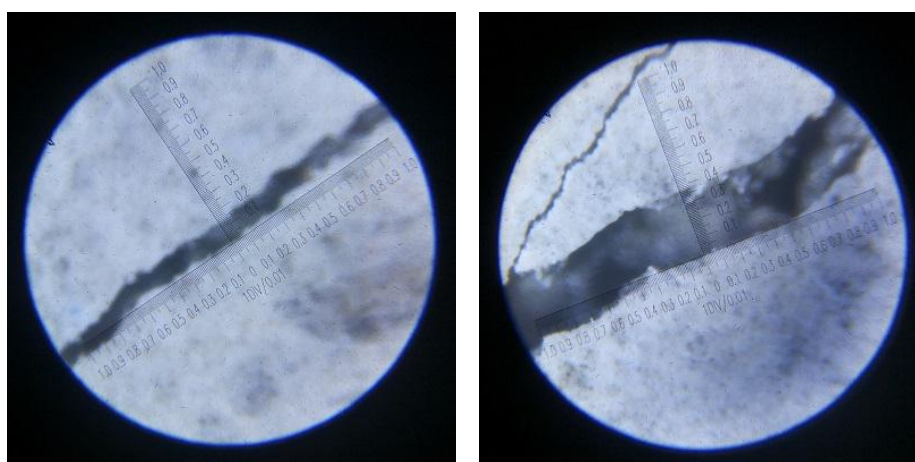Fig.1   Crack micrograph of curing NO.3002 concrete after 24h

Fig.2   Crack micrograph of curing NO.5003 concrete after 24h

Tab.7 Concrete cracking cases of different grade

test numbers	Average cracking area of cracks （mm²/root）	Number of cracks per unit area （root/m²）	Total cracking area per unit area （mm²/m²）
3001	32	6.3	201.6
3002	85	2.1	178.5
3003	34	8.3	282.2
3004	76	4.2	319.2
5001	37	6.3	233.1
5002	27	4.2	113.4
5003	3	2.1	6.3
5004	18	4.2	75.6

When sand ratio was small as the total amount of aggregates was kept constant, coarse aggregates in concrete was too much, and the amount of cement mortar was relatively small, which let mortar insufficiently coat the surface of coarse aggregates. All those aspects that reduced concrete density, accelerated the moisture in concrete along the capillary migration rate to outside, dropped the ability of concrete to resist deformation, led to a larger area of early-age cracking.

As sand rate increasing and gradually approaching the critical value, the amount of fine aggregates was increased and the amount of mortar was enough to coat the surface of coarse aggregates that improved concrete density, enhanced resistant capability, and decreased early-age

cracks area. Total surface areas of aggregates could be increased when sand rate was larger than the critical value. Thanks to the strength of cement mortar was less than aggregates, elastic modulus and thermal expansion coefficients were different, existing radial stress on interface between cement pastes and aggregates had a negative effect on concrete early-age cracking resistance. The volume stability of concrete can be reduced with the proportion of coarse aggregate decreasing, resulting in dropping concrete cracking resistance. These factors led to concrete early-age cracking area increase.

Results and analysis of concrete mechanical properties. Fig.3 and Fig.4 respectively showed the 7d and 28d compressive strength of C30, C50. From concrete compressive strength trends of number 3001 to 3004 and number 5001 to 5003 can be seen that compressive strength gradually increased，while sand ratio increasing within a certain range. However, concrete compressive strength was decreased by number 5003 and 5004 specimens.

Maintaining a stable amount of cementing material in concrete molding process, the amount of mortar couldn't completely wrap the surface of coarse aggregate and the gap between aggregates when sand ratio was small. With the increasing of sand ratio, concrete encapsulation and workability were obviously improved, and the compactness was also enhanced, which made compressive strength increase. But sand rate was much larger than the normal value that can be increased aggregate surface areas and porosity, thinned the aggregate thickness of aggregate layer, weaken the internal bonding capacity of concrete. In addition, high sand ratio may be caused poor performance of concrete, difficult to form the ideal structure with embedded lock-type, decreasing the density of hardened concrete, finally reducing concrete strength. At the same time, higher sand ratio destroyed the mechanical cohesion between coarse aggregates, which was one of the main reasons for decreasing of concrete strength[8].
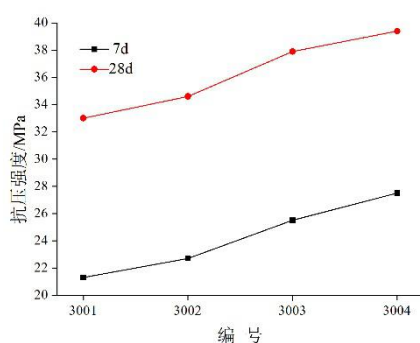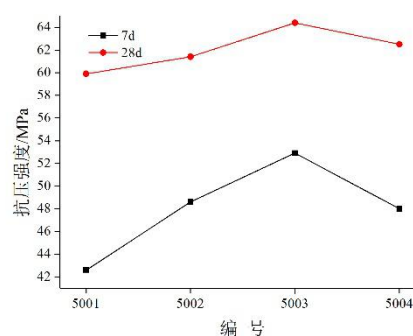

Fig.3 The compressive strength of C30 concrete

Fig.4 The compressive strength of C50 concrete

Conclusions

1）Putting briquettes at (20±2)℃ and humidity on (60±5)% that would find C30 specimens surface along the direction of crack inducers after forming 8h that began to appear subtle cracks, but C50 specimens had subtle cracks between 6h and 8h. With the extension of time, apparent cracks can be seen after 24h.

2）As sand ratio of concrete was in a certain critical value, the crack area was the biggest after curing 24h at (20±2)℃ and humidity on (60±5)%.

3) With sand ratio growing, C30 compressive strength was continuously increasing, and the compressive strength of C50 first increased and then dropped.

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