Freezing-thawing resistance of recycled coarse aggregate concrete containing fly ash

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This paper presents the freezing-thawing resistance of recycled coarse aggregate concrete containing fly ash (FA). Concretes with a w/b ratio of 0.4 containing FA (i.e. of 15% and 30% by weight) as partial replacement of Portland cement (PC) were studied under freezing–thawing cycles. The performance of recycled coarse aggregate including gradation, voidage and crushing value index was examined along with the evaluation of the properties of concretes (i.e. compressive strength, relative dynamic elastic modulus (RDEM) and microstructure). It was found that RCA-1 was the optimum grain composition of coarse aggregate with the minimum voidage. Without FA, concretes suggested a slight decrease in compressive strength as the content of recycled coarse aggregate increased (from 80% to 100%). The concrete containing 100% recycled coarse aggregate and 0% FA had the optimum freezing-thawing resistance up to 75 times freezing-thawing cycles. As for the concrete without FA and 30% FA, RDEM increased up to 75 cycles as the RCA increased.

1. Experimental program

1.1 Materials

P.O.42.5R OPC conforming to Chinese standard GB175-2007 [1]and similar to the 42.5 R Portland cement conforming to EN197-1:2009, was used for preparing concrete in this research. The fly ash (FA) used in this study was supplied by Lingwu power plant and certified for application in concretes. Recycled coarse aggregates (RCA) crushed by jaw crusher from the concrete of the dismantled building and crushed nature limestone aggregates (NCA) were used as coarse aggregates, and washed mountain sand as fine aggregates. A commercially available water reducer (i.e. SM) was used to keep concrete slump between 60 and 80 mm.

1.2 Mix proportion and specimen preparation

Recycled coarse aggregates (RCA) with different particle sizes were separated by sieves and the particles with sizes less than 4.75mm and greater than 37.5mm were discarded. According to continuous grading, the three groups of RCA mixtures proportion were determined and listed in Table 1.

Table 1 Mix proportions and properties of- RCA investigated in this study

	particle size (mm)						voidage	crushing value index
	4.75	9.5	16	19	26．5	31.5	(%)	(%)
RCA-1	20	25	25	12	15	3	1.15	15.9%
RCA-2	10	25	20	20	20	5	8.06	16.8%
RCA-3	30	30	25	7	8	0	5.79	14.3%

The actual mix proportions (1 m^3 in total) and properties of concretes investigated in this study are given in Table 2. In order to investigate the effect of FA and RCA on the compressive strength and freezing-thawing resistance of concrete, six groups of concrete mixtures were prepared with a w/b ratio of 0.4. In each group, concrete mixtures with three different FA contents (i.e. 0%, 15% and 30% by weight of cementitious materials), two different RCA contents (i.e. 80% and 100% by weight of coarse aggregates) were prepared and tested.

Concrete mixtures were prepared by using a single horizontal-axis forced mixer. After moulded, concrete specimens were placed in the curing room at the temperature of (20±5) ℃ for 24 hours. Then they were demoulded and immersed in limewater at the temperature of (20±2) ℃ for another 27 days. For each mixture, a total of 6 specimens were prepared, among which 3 specimens had the dimensions of 100 ×100 ×100 mm^3 for measuring compressive strength, while the remaining 3 specimens with the dimensions of 100 ×100 ×400 mm^3 were prepared for assessing freezing-thawing resistance. For each test, the results presented were the average of the values obtained from three specimens under identical conditions.

Table 2 Mix proportions and properties of concretes investigated in this study

Fly ash (kg/m^3)	OPC (kg/m^3)	RCA (kg/m^3)	NCA (kg/m^3)	Fine aggregates (kg/m^3)	Water (kg/m^3)	compressive strength (MPa)	RDEM under freezing-thawing (%)		
							25	50	75

								times	times	times
C1	0	450	1094	0	619	180	28.5	76.1	49.7	40.4
C2	0	450	1094	240	619	180	29.7	48.5	20.8	12.9
C3	68	382	1094	0	619	180	31.7	31.3	12.2	7.4
C4	68	382	1094	240	619	180	30.1	35.7	13.0	9.0
C5	135	315	1094	0	619	180	29.9	22.4	7.3	1.9
C6	135	315	1094	240	619	180	26.0	17.9	5.2	0.3

2. Results and discussion

2.1 Grain composition of coarse aggregate

The voidage analysis had shown that the grain composition among three groups of RCA mixtures proportion had evident impact on voidage, and they were 1.15(RCA-1), 8.06(RCA-2) and 5.79(RCA-3), respectively. But the difference of crushing value index was insignificant, and RCA-1 was chosen as the optimum grain composition to conduct the concrete study.

2.2 Compressive strength of recycled coarse aggregate concrete

Compressive strength of the recycled coarse aggregate concrete specimens containing FA is given in Table 2 which demonstrated similar varying features for both 80% and 100% recycled coarse aggregate series concretes, i.e. both series of concrete specimens actually gained strength when the replacement ratio of FA was 15%, while the strength was diminished when the FA replacement ratio was 30%. Regarding the concrete specimens without FA, it was observed a slight decrease in compressive strength as the recycled coarse aggregate increased. Contrarily, there was a slight increase of compressive strength with the increase of the replacement ratio of RCA in concretes containing 15% and 30% FA.

2.3 Freezing-thawing resistance of recycled coarse aggregate concrete

The deterioration in RDEM of concrete under freezing-thawing cycles is depicted in Table 2. There was a relatively larger decrease in RDEM as the FA content increased for 25, 50 and 75 times freezing-thawing cycles, and only C1 RDEM value was greater than 60%. The RCA effect on the RDEM varied greatly. As for the concrete without FA and 30% FA, RDEM increased up to 75 cycles as the RCA increased, while when FA content was 15%, RDEM decreased slightly up to 75 cycles as the RCA increased.

2.4 Microstructure of concrete

Microstructure tests of concrete specimens are in progress.

3. Conclusions

(1) RCA-1 was the optimum grain composition of coarse aggregate and it showed the minimum voidage.

(2) Without FA, concretes demonstrated a slight decrease in compressive strength as the recycled coarse aggregate increase (from 80% to 100%). Contrarily, there was a slight increase as the replacement ratio of RCA increased (from 80% to 100%) in the concretes containing 15% and 30% FA.

(3) The concrete containing 100% recycled coarse aggregate and 0% FA had the optimum freezing-thawing resistance up to 75 times freezing-thawing cycles. As for the concrete without FA and 30% FA, RDEM increased up to 75 cycles as the RCA increased.

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