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Shear strength of reinforced concrete beams with recycled aggregates

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ABSTRACT: In this paper, three reinforced concrete beams using recycled aggregate were tested to evaluate their failure modes, shear behavior and shear strength of reinforced concrete beams. All specimens have a cross section of 170 × 270 mm and a shear span-to-depth of 2. Each specimen was simply supported and subjected to four-point loading. The results showed that the beams with recycled aggregates present the similar shear failure mode as the beam with natural aggregate. The codes are conservative and subsequently can be used for the shear design of reinforced concrete beams with recycled aggregates.

1 INSTRUCTIONS

The construction of highways, bridges and building has been increasing from the beginning of the past century. These infrastructures need to be replaced or repaired because their end of service life is reached or the original design no longer satisfies the needs dues to the growth in population. Large volume of aggregates will be required to rebuild this infrastructure and support new construction and large quantities of demolition wastes are generated. Recycling of waste concrete by converting not only saves landfill space but also reduces the demand for extraction of natural raw material for new construction activity. Various investigations have been carried out to study the mechanical properties of concrete and the structure behavior (under flexure condition, shear, bond, torsion, etc.) with recycled aggregates. However, few investigations have been carried out to study the shear behaviors with recycled aggregates such as low absorption of recycled aggregates. This study discusses the shear performance of reinforced concrete beams with recycled aggregates. Also, the correlation of experimental results with code predictions is essential in order to check the applicability of current design provisions for recycled concrete beams.

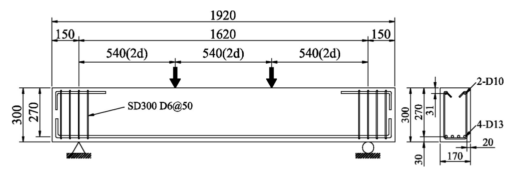

Figure 1. Configuration of beam (mm).

Table 1. Properties of specimens.

Specimens	b × h (d) (mm)	span (mm)	f_{cu} (MPa)	Longitudinal reinforcement, ρ
C30			31.61	
RH30	170 × 300(270)	1,920	36.10	0.011
RL30			39.66	

Table 2. Physical properties of aggregates.

Aggregates	Density (g/cm^3)	Water absorption (%)	Fineness modulus
Natural coarse	2.56	1.39	6.02
Recycled coarse	2.54	1.86	6.72
Natural fine	2.56	1.42	2.84
Recycled fine	2.47	3.64	2.89

2 EXPERIMENTAL PROGRAM

Figure 1 and Table 1 show the details of the three beams with different replacement conditions of aggregates (natural aggregate 100%: C30, recycled fine aggregate 50%: RH30, and recycled coarse aggregate 100%: RL). All specimens had a rectangular cross section with 170 × 300(270) mm and were tested with a shear span-to-depth of 2. The physical properties of the aggregates are given in Table 2. The proportions of

Table 3. Mix proportions of concrete.

	W/C (%)	s/a (%)	Slump (mm)	Unit weight(kg/m^3) C	FA	NF	RF	NC	RC
C30	45	46	230 ± 20	331	58	763	0	927	0
RH30	50	47	150 ± 20	298	53	409	402	979	0
RL30	45	46	230 ± 20	331	58	763	0	0	888

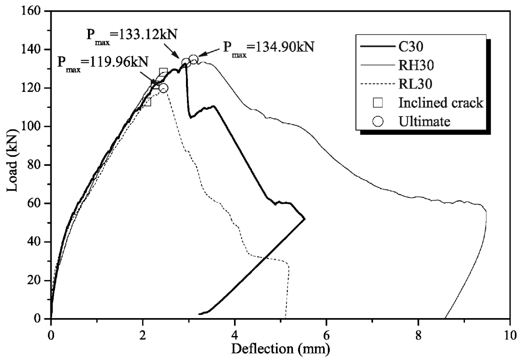

Figure 2. Load-deflection curves.

the mixture of the concrete are shown in Table 3. The beams were tested to failure under four-point loading.

3 TEST RESULTS

3.1 *Failure modes*

Each specimen exhibited an initial flexural crack in the center of the beam and subsequent flexural cracks away from that section. As the applied load was increased, one of the flexural cracks extended into a diagonal crack near one of the supports, or a diagonal crack formed abruptly at the mid-height of the beam within the shear span. After the formation of the diagonal crack, brittle failure occurred.

3.2 *Load-deflection curves*

Figure 2 shows the comparison of the load-deflection curves for test specimens. The specimen exhibited a moderate amount of reserve load-carrying capacity beyond the formation of diagonal cracking and exhibited the formation of arch-action after diagonal cracking; the load capacity decreased quickly beyond the maximum load, in which no difference in failure modes were observed.

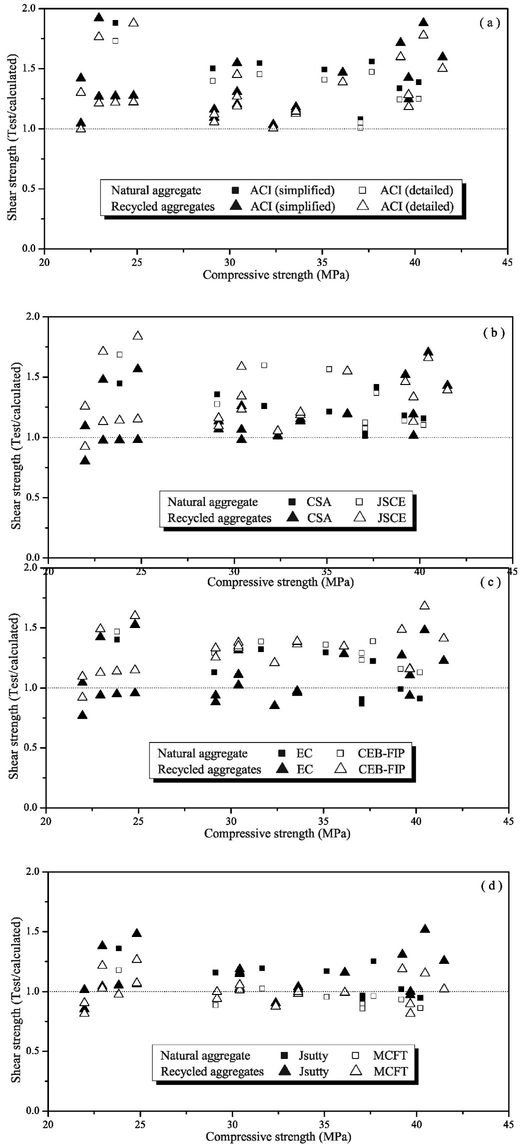

Figure 3. Comparision of test result and calculated values.

3.3 *Comparison of test result and calculated values*

Figure 3 shows the results of this study and previous studies with recycled aggregates concrete were contrasted by the ACI-318, EC, CEB-FIP, JSCE, Jsutty, and MCFT. Results generated by the codes except EC are conservative and subsequently can be used for the shear design of recycled aggregates concrete beams. The predictions using the MCFT agreed with the experimental results better than the codes. However, in some cases MCFT overestimates.

4 CONCLUSIONS

- The reinforced concrete beams using recycled aggregates concrete shows similar shear behaviors as the beam with natural aggregate.
- The codes except EC are conservative and subsequently can be used for the shear design of recycled aggregates concrete beams.

REFERENCES

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