ENVIRONMENTAL PERFORMANCE INDICATORS FOR GREEN CONCRETE CONTAINING HIGH VOLUME OF RECYCLED MATERIALS

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1. Introduction

To face the reality of global warming, the concrete industry can play an important role. Carbon dioxide (CO_2) is the primary GHG contributing to climate change, and some researchers estimate that the manufacture of Portland cement is responsible for roughly 7% of the worldôs total emissions [1]. The consumption of natural resources like aggregate, water, and sand is another important item, due to the limited resources.

To reduce the environmental impact, we are developing concrete which replaces cement with fly ash and normal aggregate with recycled aggregate. The inclusion of these materials may reduce the mechanical performance of concrete, so it is necessary to implement a new assessment factor, ñenvironmental indicator,ò which considers both the mechanical performance and the CO_2 emissions [2].

2. Experimental program

2.1 Concrete preparation

Cement mortar and concrete was prepared using tap water (W), Type 1 Portland cement (C), river sand (S), fly ash type II (FA), recycled fiber (RF), normal (NG) and recycled aggregates (RG), and air entraining (AE) and super plasticizer (SP) admixtures. Mix proportions are given in Table 1. The term binder (B) is used to represent all cementitious materials ï in this case, fly ash and Portland cement. All mixes used a constant water-binder weight ratio of 30%.

Cylinder (10Øx20cm) and beam (10x10x40cm) specimens were cast following JSCE-F 552-1999. After casting, molded specimens were covered in plastic wrap and cured in the molds for 24 hours, then removed from the molds and moved to water curing. Tests were conducted 28 and 91 days after casting.

2.2 Concrete testing

Compressive strength (f_c) was measured according to JIS A 1108-2006, and flexural strength (f_b) was determined according to JSCE-G 552-1999. For all tests, reported values are the average of three specimens.

3. Environmental performance indicator

The environmental performance indicator was calculated as the ratio of the mechanical performance to the CO_2 footprint (MPa / $kg\ of\ CO_2/m^3$). The CO_2 footprint is calculated from the mix proportions (Table 1), and the emissions of Portland cement, sand, aggregates, and fly ash (Table 2).

Table 2 CO_2 emissions by material [3]

Material	CO_2 emissions (kg CO_2/ton)
Portland cement	765.5
Fly ash	17.9
Natural river sand	3.4
Normal/Recycled aggregate	2.8

Table 1 Mix proportions

Series	Material ratios (%)				Mix proportions (kg/m^3)						Admixtures (% binder)		RF (%vol)
	W/B	S/B	FA/B	s/a	W	C	FA	S	NG	RG	AE	SP	
FA50-M	30	80	50	-	266	443	443	709	-	-	0.06	0.4	2.0
FA50-sa60-NG				60	226	377	377	603	416	-	0.015	0.6	
FA50-sa60-RG					226	377	377	603	-	373	0.015	0.6	
FA50-sa80-RG				80	253	422	422	675	-	156	0.025	0.5	
FA30-sa60-RG			30	60	231	539	231	616	-	381	0.015	0.6	
FA70-sa60-RG			70		221	221	516	589	-	364	0.015	0.6	

Keywords: green concrete, environmental indicator, fly ash, recycled aggregate.
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4. Results and discussion

4.1 Compressive and flexural strength

Compressive and flexural strength are shown in Figure 1. It can be seen that increasing the amount of aggregate does not have a significant effect on strength behavior, and the compressive strength is highest for normal aggregate. On the other hand, the fly ash/binder ratio has a much greater effect. Increasing the fly ash/binder ratio results in a constant decrease in strength.

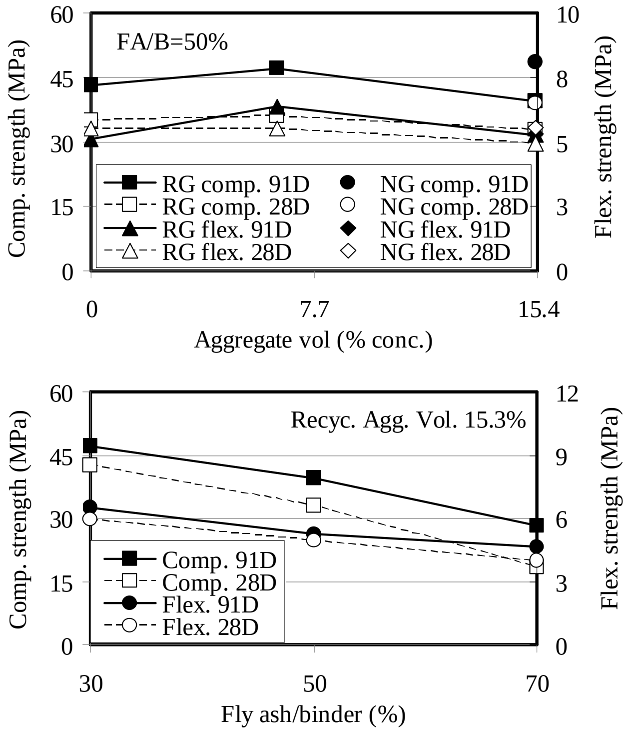

Figure 1 Compressive and flexural results by aggregate volume and type (top) and fly ash/binder ratio (bottom)

4.2 Environmental performance indicators

Environmental indicators were calculated for 91 days tests, and the results are displayed in Figure 2. For variable aggregate volume and type, the trend is similar to the mechanical performance, so there is little change when normalized by the environmental impact. For variable fly ash/binder ratio, normalized by the environmental performance indicator results in a reverse of the trend shown by the mechanical performance.

The usage of fly ash has a more noticeable effect on the environmental indicator compared with recycled aggregates. Recycled aggregates have the same CO_2 emissions as normal aggregates, so the effect of aggregate type is difficult to evaluate by CO_2 alone. However, the effect of fly ash can be explained by the large difference in CO_2 between Portland cement and the other materials, and the effect is greater when more cement is replaced.

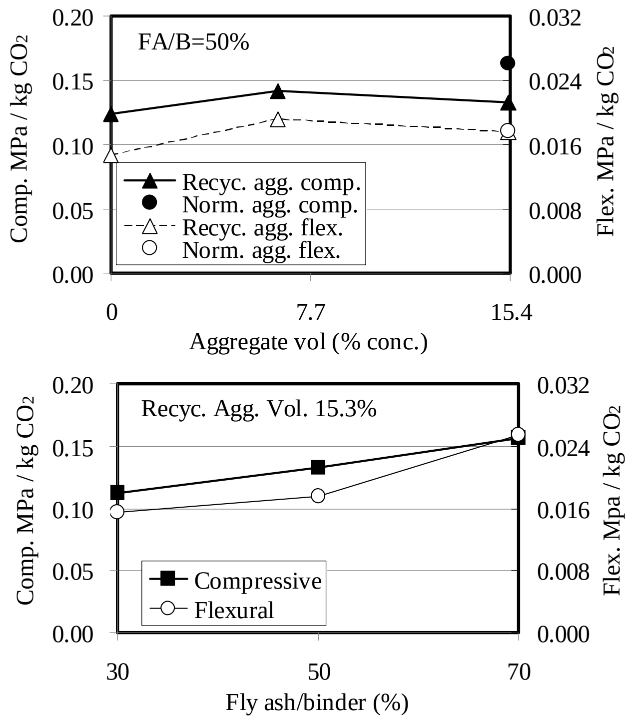

Figure 2 Environmental indicators by aggregate volume and type (top) and fly ash/binder ratio (bottom)

Conclusion

In this paper, environmental performance indicators were used to evaluate the mechanical & environmental performance of concrete containing high volume of recycled materials. It was seen that implementing the environmental indicator is a useful tool in order to assess both the mechanical performance and the CO_2 emissions of the concrete, and make it clear that concrete quality can be appraised taking into account the environmental impact as well. To evaluate the effect of aggregate type it is necessary to introduce an additional factor which considers the effect of preserving raw materials as well.

References

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