BEAM DESIGN, COST & CO_2 ASSESSMENT FOR GREEN CONCRETE CONTAINING HIGH VOLUME OF RECYCLED MATERIALS

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1. Introduction

It is well known the increasing necessity of taking care of our planet in order to preserve it for the future generations which has been commonly understood as sustainable development. On this regard 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 world's total emissions [1]. The consumption of natural resources like aggregate, water, and sand is another important item, due to the limited resources.

In order to reduce the carbon dioxide emissions and preserve raw materials, we are developing concrete which replaces cement with fly ash, and normal aggregate with recycled aggregate. For this we cast different concrete series with different proportions, evaluating their strength, CO_2 emissions, and cost and compared them with a control series which is considered to have the normal proportions of common concrete used for common constructions in Japan. Then a simple supported beam design was conducted and the results analyzed to evidence that this kind of concrete containing high volume of recycled materials is possible to use in the real construction industry, even having some extra benefits as it will be shown.

2. Concrete mixes

2.1 Mix proportions

The concrete mixes used for the beam design are given in Table 1, Water (W), ordinary Portland cement (C), type-II fly ash (FA), river sand (S), normal aggregates (NG), and grade-L recycled aggregates (RG) were used. Different factors were compared among series such as fly ash content effect (none vs. 50%), the effect of aggregate type (normal vs. recycled), and the effect of combining fly ash and recycled aggregates. The series control is the one chosen as normal with water-binder ratio 0.5, for all other series water-binder ratio is 0.3.

Table 1 Mix proportions

Series	kg/m^3					
	W	C	FA	S	NA	RA
Control	171	342	-	746	1015	-
NB-NA	165	550	-	624	1009	-
NB-RA	165	550	-	624	-	905
NB-NA-FA50	165	275	275	590	955	-
NB-RA-FA50	165	275	275	590	-	856

2.2 Mechanical properties

The properties of concrete mixes are given in Figure 1. The compressive strength values were taken at 28 days from casting under water curing conditions. For this calculation were used 28 days results for being more traditional in current construction industry, though it is known that concrete with fly ash develops more strength in time than other concrete, improving its mechanical performance.

2.3 Environmental impact

For the environmental impact were considered the carbon dioxide emissions (CO_2) and volume of recycled materials used to replace the virgin ones as the percentage per cubic meter. The CO_2 emissions for each mix were determined based upon the mix proportions and the emissions per component materials given by Japan Society of Civil Engineers [2]. The values per every series are shown in Figure 1.

2.4 Cost

The costs were calculated using the mix proportions and material costs obtained from a catalog of material costs in Japan (Sekisan-shiryou). In the case of fly ash, the cost may vary so a private company was contacted and the cost of fly ash estimated based on their response. The cost for recycled aggregates was estimated from the price of recycled crushed stone used in road beds, and the cost of water was taken from Tokyo Metropolitan Bureau Waterworks. The cost per mix is shown in Figure 1.

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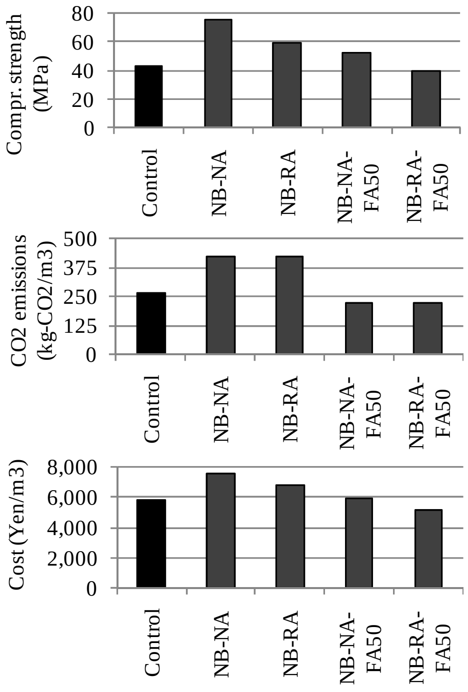

Figure 1 Concrete properties; top: compressive strength; middle: CO_2 emissions; bottom: cost

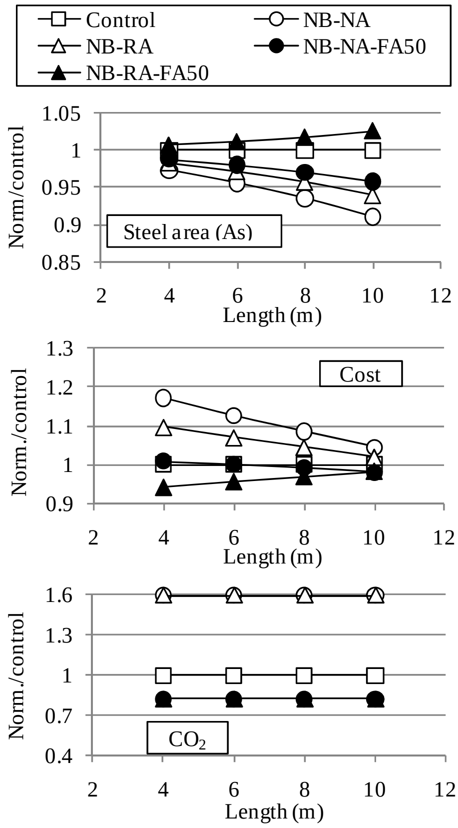

Figure 2 Results for Case 1 with variation in the beam length (L)

3. Structural design

3.1 Design methodology & parameters

The structural design was conducted for a simple supported beam with central point load. For the calculations were assumed the Whitney rectangular stress distribution theory accepted by the American Concrete Institute (ACI), and the reduction factors and other coefficients stipulated by the ACI for designing this type of elements [3]. Just the moment capacity was evaluated since the shear capacity has similar trend; also fracture was not consider. For the CO_2 calculations were just considered the contribution of concrete, since the contribution of steel is very low as compared with that from concrete for a single beam and also for simplicity. All the results were normalized by the control series.

3.2 Beam design

In this the length (L) is varied and the steel area (As) required calculated, then also the CO_2 emissions and cost were calculated. The results normalized by control series are plotted in Figure 2.

All the series requires less steel area than control series, except for NB-RA-FA50 series, being the gap bigger while increasing the length (L). The cost is lower or similar than control series for concrete using fly ash, however while increasing the length (L) all series tend to decrease in cost except for NB-RA-FA50 series. From CO_2 emissions it can be seen that the only series with less emissions are those with fly ash.

4. Conclusions

After analyzing the results obtained and the factors evaluated we can conclude that utilizing recycled materials for developing concrete is a good alternative, due to its good performance compared to normal concrete when evaluating mechanical performance, environmental impact and cost.

Although this and previous research have shown the benefits of using this kind of materials, there is still a big concern and general fear of using them, mainly because the lack knowledge and information, which is the big barrier for making the concrete a more sustainable industry.

References

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