Asian Journal of Chemistry; Vol. 26, Supplementary Issue (2014), S283-S286

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2014.19066

Optimization of Replacement Level of Steel Slag as Coarse Aggregate in Self Compacting Concrete

R. KRISHNASAMI[1] and R. MALATHY[2,*]

[1]Divisional Engineer, Highways Department, Vilupuram-606 202, India
[2]Department of Civil Engineering, Sona College of Technology, Salem-636 005, India

*Corresponding author: E-mail: malathy1968@hotmail.com

Published online: 24 December 2014; AJC-16491

Self compacting concrete is a highly workable concrete that can flow through densely reinforced complex structural elements under its own weight and adequately fill all voids without vibration or mechanical consolidation. Effective use of industrial waste products in concrete gains many economic, environmental and social benefits rather than disposing of it as waste. The objective of this study is to find out the optimum replacement of blast furnace slag as a partial replacement for coarse aggregate in M20, M30 and M40 grades of fly ash blended self compacting concrete. The coarse aggregate was replaced from 0 to 100 % with an increment of 10 % by blast furnace slag aggregate and the various self compactability and strength properties were determined and compared. From the results, it is found that 32 % of slag aggregate can be replaced for coarse aggregate to attain both self compactability and strength for concrete applications.

Keywords: Self compacting concrete, Fly ash, Blast furnace slag, Coarse aggregate, Strength.

INTRODUCTION

Manufacturing of durable concrete requires adequate compaction by skilled workers. At this situation self compacting concrete (SCC) is an economical alternative to conventional concrete since self compacting concrete eliminates labors demand and use of vibrators for concrete placement and compaction[1,2]. Self compacting concrete should be able to flow under its own weight to fill the form work completely and achieve full compaction with no vibration effort. It should be highly viscous such that segregation and bleeding do not occur[3]. In addition to super plasticizers, supplementary cementitious materials such as limestone powder, natural pozzolans and fly ash are used to increase the workability and viscosity and also to reduce the cost of self compacting concrete[4]. Fly ash has been used as filler material in this experimental work. The use of fly ash reduces the demand for cement and fine fillers that are required in self compacting concrete. Fly ash, a by-product of coal power plants when utilized in concrete, improves the mechanical properties such as durability, freeze and thaw resistance, sulphate resistance, alkali aggregate reaction and abrasion resistance. Also shrinkage and permeability of hardened concrete are decreased due to filling of micro pores[5]. Conplast SP 430 has been used as plasticizer throughout the work to improve the viscosity of the concrete[6]. Many researchers developed mix design for various grades of self compacting concrete[7-10]. Blast furnace slag is a nonmetallic material consisting of silicates and aluminosilicates of calcium and magnesium together with other compounds of sulfur, iron, manganese and other trace elements. It is produced from a molten state simultaneously with pig iron in a blast furnace. The solidified product is further classified according to the process by which it was brought from the molten state. Air-cooled blast furnace slag is produced through relatively slow solidification of molten blast furnace slag under atmospheric conditions, resulting in crystalline mineral formation. It is one of the most commonly utilized reclaimed construction materials, being used as coarse aggregate in concrete, aggregate in hot-mix asphalt, road base material and fill[11,12]. The results herein reveal that utilization of steel slag as aggregate in concrete will have more advantages in high strength concrete than normal strength concrete[13]. This paper deals with the experimental study conducted to investigate the optimum replacement of coarse aggregate by blast furnace slag in M20, M30 and M40 grades of fly ash blended self compacting concrete so as to comply with both self compactability ans strength criteria.

EXPERIMENTAL

Cement used in this investigation was ordinary portland cement of 43 grade. Crushed angular granite aggregate of 12.5 mm size having specific gravity of 2.67 and fineness modulus

5.85 was used as coarse aggregate. River sand conforming to Zone-II having specific gravity 2.56 and fineness modulus 2.77 was used as fine aggregate. Class C fly ash obtained from nearby thermal power plant was used as filler material. The properties of fly ash are conforming to I.S. 3812-1981of Indian standard specification. Conplast SP 430 super plasticizer at the dosage of 2 % by weight of cement was used in this study.

Prosperities of blast furnace slag: Steel slag from Agni Steels Pvt. Ltd., Ingur, Perunthurai, Tamil Nadu, India was used in this work. The important compounds in the steel slag are dicalcium silicate, tricalcium silicate, tricalcium aluminate, dicalcium ferrite, merwinite, oxides of Iron and free lime and magnesia. The physical properties and chemical composition of steel slag are given in Tables 1-2.

TABLE-1
PHYSICAL PROPERTIES OF STEEL SLAG

Serial no.	Test particulars	Results
1	Specific gravity	2.48
2	Bulk density (kg/m^3)	1650
3	Aggregate impact value	13.00
4	Aggregate crushing value	26.73
5	Water absorption (%)	2.50

TABLE-2
CHEMICAL COMPOSITION OF STEEL SLAG

Serial no.	Compound	Composition (%)
1	CaO	38.80
2	SiO_2	37.60
3	Fe_2O_3	0.26
4	MgO_3	6.20
5	Al_2O_3	15.60
6	P_2O_5	0.68
7	SO_3	0.72

Mix design: The mix design for self compacting concrete M20, M30 and M40 grades are arrived based on the mix design procedure suggested by Malathy and Govindasamy[14], and the obtained mix proportions are given as Pie chart in Fig. 1

Methodology: Self compacting concrete cubes of size 150 × 150 × 150 mm and cylinders of size 150 mm diameter and 300 mm long with 0 to 100 % of slag as partial replacement for coarse aggregate were cast for compressive, flexural and split tensile strength tests. After 24 h the specimens were demoulded and subjected to water curing. After 28 days the specimens were tested as per IS:516-1964. Flow properties of concrete at green stage are significantly governed by paste content, aggregate volume and admixture dosage. The flow properties of self compacting concrete were determined in the fresh state by slump-flow, V-funnel and L-box and U-box tests, respectively. Number of trial mixtures was tried for their permissible limits and then the final proportions of ingredients and admixtures have been finalized for M20, M30 and M40 grades of concrete.

The coarse aggregate was replaced by blast furnace slag at 10, 20, 30 and upto 100 %. The self compactability and strength of three mixes with different replacements are studied and the optimum replacement of coarse aggregate by blast furnace slag is to be determined.

RESULTS AND DISCUSSION

Self compactability studies: Self compactability tests such as slump flow by Abrams cone test, L Box test, V Funnel test, U Box test and J Ring test were conducted as per European guidelines and the results are presented in Figs. 2-6.

Slump flow by abrams cone: The slump values for self compacting concrete M20, M30 and M40 grade concrete with various replacements of coarse aggregate by steel slag was obtained and the results are graphically represented in Fig. 2.

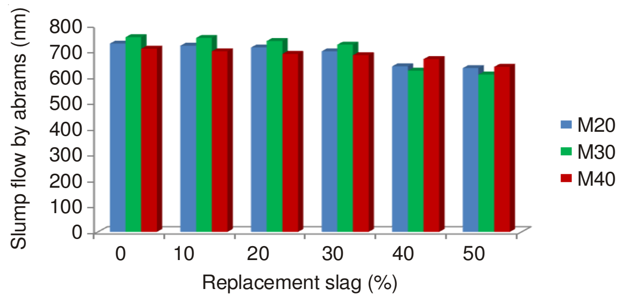

Fig. 2. Slump flow by Abrams Cone for M20, M30 and M40 grades

L Box test: The blocking ratio of self compacting concrete M20, M30 and M40 grade concretes determined by L Box tests for various replacements of coarse aggregate by steel slag was obtained and the results are represented in Fig. 3.

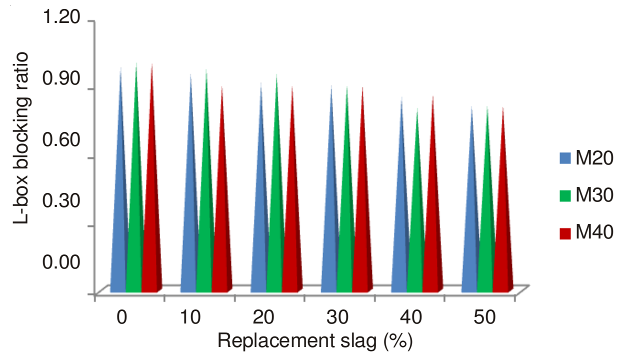

Fig. 3. L Box for M20, M30 and M40 grades

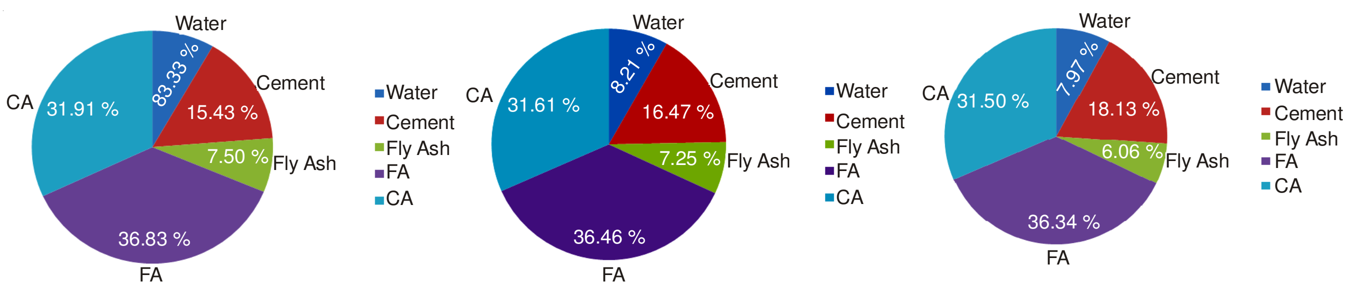

Fig. 1. Mix proportion for self compacting concrete M20, M30 and M40 Grades

V Funnel test: The time required to pass the V Funnel for M20, M30 and M40 grade concretes of self compacting concrete with various replacements of coarse aggregate by steel slag was obtained and the results are represented in Fig. 4.

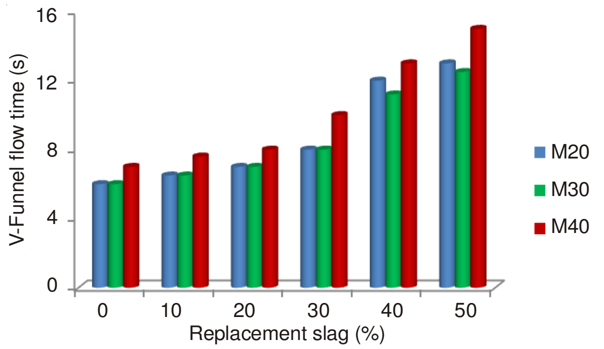

Fig. 4. V funnel flow time for M20, M30 and M40 grades

U Box test: The results obtained to determine passing ability of self compacting concrete using U Box are represented in Fig. 5.

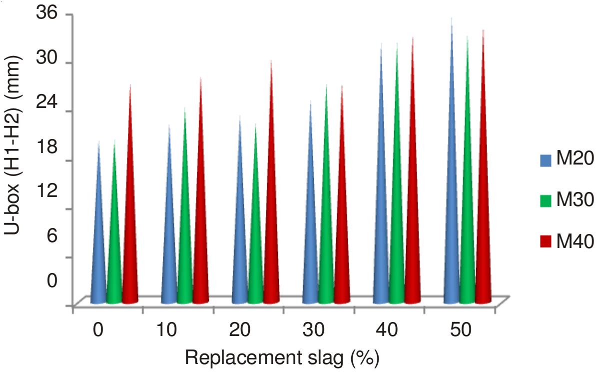

Fig. 5. U Box for M20, M30 and M40 grades

J Ring test: The J ring test results for M20, M30 and M40 grade concretes of self compacting concrete with various replacements of coarse aggregate by steel slag was obtained and the results are represented in Fig. 6.

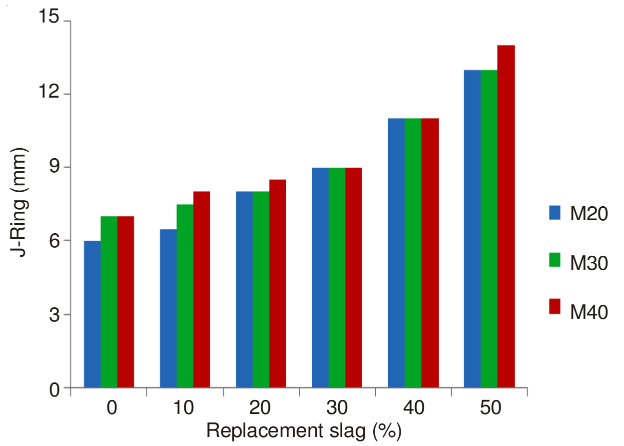

Fig. 6. J Ring for M20, M30 and M40 grades

Figs. 2-6 represent the self compactability test results of self compacting concrete M20, M30 and M40 grades. From these figures, it is observed that up to 30 % replacement of slag, the slump value, V funnel time, L box, J ring and U tube parameters are satisfying the European guidelines. Beyond which all the three grades (M20, M30 and M40) are not performing well regarding all the self compactability criteria and the mix become harsh and unworkable because of the increased quantity of slag aggregate and its angularity.

Hardened concrete properties: The main objective of this investigation is to compare the effectiveness of the blast furnace slag as partial replacement of coarse aggregate in M20, M30 and M40 grades of self compacting concrete. The compressive and split tensile test results of self compacting concrete for M20, M30 and M40 grades of concrete for various replacement of slag are obtained.

Fig. 7 shows the comparison of compressive strengths of three grades of concrete M20, M30 and M40 with 0 to 100 % replacement of slag. From the results it is observed that the compressive strength increases by 13.83, 7.34 and 0.87 % for M20, M30 and M40 mixes, respectively at 30 % replacement level. Beyond which even though the strength reduces but upto 50 % replacement, the strength matches with the strength of conventional concrete.

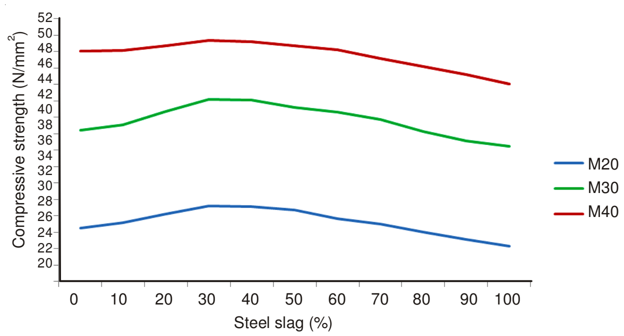

Fig. 7. Comparison of compressive strength of M20, M30 and M40 grade concretes

Fig. 8 shows the comparison of split tensile strength of M20, M30 and M40 grades of self compacting concrete. Split tensile strength tests were conducted on the specimens after 28 days curing. From the results, it is observed that the split tensile strength of self compacting concrete with partial replacement of steel slag as coarse aggregate increases from 10 to 30 % and the values starts decreasing beyond the replacement of 30 %. For M20 grade concrete the increase in split tensile strength is 7.5 %, for M30 grade concrete it is 0.80 % and

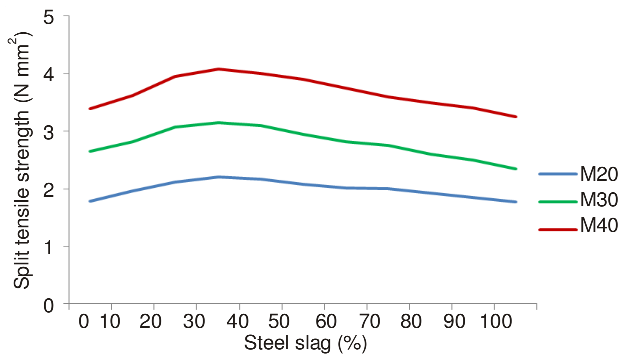

Fig. 8. Comparison of Split tensile strength of M20, M30 and M40 grades self compacting concrete

for M40 grade concrete it is 1.15 at 30 % replacement of coarse aggregate by steel slag. The decrease in split tensile strength may be attributed by the more voids present in the coarse aggregate.

From Fig. 9, it is found that, considering self compactability as well as strength point of view 32 % replacement of coarse aggregate with steel slag gives optimum percentage replacement.

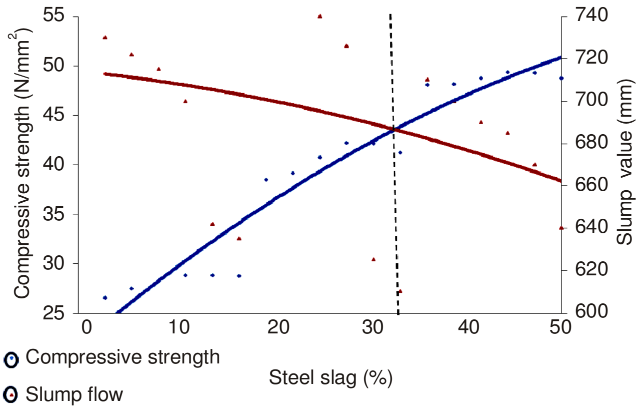

Fig. 9. Optimum replacement of slag with respect to to self compactability and strength

Conclusions

- For self compacting concrete, the replacement of coarse aggregate by steel slag is effective upto 30 to 40 % with respect to self compactability parameters given by European guidelines.
- From the strength results obtained, it has been found that steel slag can be utilized as partial replacement for coarse aggregate in self compacting concrete up to 30 % and could enhance strength properties in M20, M30 and M40 grades of self compacting concrete beyond which upto 50 % replacement the strength is on par with the conventional concrete.
- When compared with self compacting concrete with conventional coarse aggregate, self compacting concrete with slag aggregate gives the higher strengths on longer duration.
- From the results obtained on both strength and self compactability criteria, it is concluded that 32 % replacement is found to be optimum replacement.

REFERENCES

1. H. Okamura and M. Ouchi, *J. Adv. Concrete Technol*., **1**, 5 (2003).
2. M.S. Jagadesh Vengala, *Indian Concr. J*., **77**, 1261 (2003).
3. P. Bhuva, Evaluation of Properties of Fresh Self Compacting Concrete, Second National Conference on Emerging Vistas of Technology in 21st Century, pp. 27-36 (2010).
4. C. Naveen Kumar and V. Kiran, *Indian Concr. J*., **80**, 33 (2006).
5. J. Vengala and Ranganath, INCONTEST, **10-12**, 341 (2003).
6. M. Ouchi, M. Hibino, T. Sugamata and H. Okamura, A Quantitative Evaluation Method for the Effect of Super-plasticizer in Self Compacting Concrete, Transaction of JCI, pp 15-20 (2001).
7. H. Okamura and K. Ozawa, Mix Design for Self-Compacting Concrete, Concrete Library of Japanese Society of Civil Engineers, pp. 107-120 (1995).
8. S. Subramanian and D. Chattopadhyay, *Indian Concr. J*., **76**, 13 (2002).
9. N. Su, K.C. Hsu and H.W. Chai, *Cement Concr. Res*., **31**, 1799 (2001).
10. The European Guidelines for Self Compacting Concrete, (BIBM, CEMBUREAU, EFCA, EFNARC, ERMCO); www.efnarc.org (2005).
11. M. Kamal, A.H. Gailan, A. Haatan and H. Hameed, Aggregate made from Industrial Unprocessed Slag, Proceeding of the 6th International Conference on Concrete Technology for Developing Countries, Amman, Jordan (2002).
12. M. Ouchi and Edamatsuy, A Simple Evaluation Method for Interaction Between Coarse Aggregate and Mortar Particles in Self Compacting Concrete, Transaction of JCI, pp. 50-55 (2002).
13. P.S. Rao and S.S. Tirumala, *J. Future Eng. Technol*., **3**, 78 (2007).
14. R. Malathy and T. Govindasamy, *Indian Concrete Inst. J*., 19 (2006).