Significance of Flexural Behavior of Blast Furnace Slag Concrete

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Abstract— **The study presents the experimental investigation carried out to evaluate effects of replacing coarse aggregate with that of blast furnace slag on various concrete properties. The basic objective of this study was to identify alternative source of good quality aggregate because the natural stone quarries are depleting very fast due to rapid pace of construction activities in India .The effect of replacing natural coarse aggregate by slag on the compressive strength of cubes, split tensile strength of cylinders and flexural strength of beams are evaluated in this study. Use of slag – a waste industrial by product of iron and steel production provides great opportunity to utilize it as an alternative to normally available aggregate. The test results of concrete were obtained by adding slag to coarse aggregate as a replacement of stone aggregate in various percentages of 0%, 20%, 40%, 60% and 100%. All specimens were cured for 28 days before testing. From the study it has been observed that the blast furnace slag aggregate could be a good replacement of stone aggregate.**

Key Words : 1.Aggregate 2. Concrete 3.Slag 4. Flexural Strength
Sub Area : Construction Technology & Management
Broad Area : Civil Engineering

I. INTRODUCTION

Concrete is an age old material. It can be used easily in any shape and size of structural member. The main ingredients of concrete are cement, sand and aggregate. So concrete can be considered to be an artificial stone obtained by binding together the particles of relatively inert coarse and fine materials with cement paste. The aggregates are generally cheaper than cement and impart greater volume stability and durability to concrete. The aggregate is used primarily for the purpose of providing bulk to the concrete. The aggregate provides about 70-75% of the body of the concrete and hence its influence is extremely important. The stone aggregate produced by crushing of stone obtained from mountains. The quarrying of stone causes number of environmental problem. Hence to replace these aggregate by slag not only allow the use of waste product but also avoid environmental problem. Slag is a waste produced during manufacturing of pig iron and steel. It consists of oxides of calcium, magnesium, manganese, aluminum, nickel and phosphorous. The major component in the blast furnace slag is SiO_2. The physical properties of slag depends upon change in process of cooling, however the chemical composition remain unchanged. The slag produced in blast furnace during pig iron manufacturing is called blast furnace slag and slag produced at steel melting plant is known as steel slag. Large amount of industrial waste produced every year in developing countries. Total world steel production crossed 1200 million metric tons. In India, Slag output obtained during pig iron and steel production is variable and depends on composition of raw materials and type of furnace. For ore feed containing 60 to 65% irons, blast furnace slag production ranges from about 300 to 540 kg per ton of crude iron produced. Lower grade ores yield much higher slag fractions, sometimes as high as one tone of slag per ton of pig iron produced.

The slag is produced in large amount and creates problem to environment when it is dumped, like, it affect the permeability of soil and increases the water logging problem, It causes respiratory problem to nearby residents and pollute ground water and adversely affects the landscape of the area. The industries have to pay huge amount for the disposal of this material. Hence, Problem of disposing slag is very serious and can be sort out by using it in concrete. Slag can be used in concrete to improve its mechanical, physical and chemical properties and it is the one of the waste products which could have a better future in construction industry as partial or full substitute for either cement or aggregate.

II. NEED OF PRESENT STUDY

Large amount of industrial waste produced every year in developing countries. Therefore, utilization of secondary material is being encouraged in construction field .The blast furnace slag is a solid waste from iron production. The amount of deposited blast furnace slag leads to the pollution of groundwater, farm land and soil. Therefore, improving the utilization of slag is an exclusive way for the iron industries to realize sustainable development. The large amount of required material in construction led researchers to use a substitute for aggregate which satisfy the required specification and also assure the serviceability during the design period. In the present study the use of blast furnace slag as replacement of coarse aggregate has been discussed. Therefore, the study introduced the effect of use of blast furnace slag as a replacement of stone aggregate partially or fully in making concrete. In the present study the flexural behavior of RCC beam casted with blast furnace slag has also been observed.

The plain cement concrete has high compressive strength and very low tensile strength. Normally, the tensile strength of concrete is about 10-15% of its compressive strength. Hence, if a beam is made of plain cement concrete, it has a very low load carrying capacity since its low tensile strength limits its overall strength. So, reinforcement is used to increase its

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tensile strength. The concrete reinforced by steel bars is called reinforced cement concrete. The joint action of steel and concrete section is dependent on the following important factors

1. Bond between concrete and steel bars
2. Absence of corrosion of steel bars embedded in concrete
3. Practically equal thermal expansion of both concrete and steel.

Table : Flexural Behaviour of Beams at 28 Days

specimen	Load (KN)		Energy absorption capacity			Flexural toughness factor
	First crack load	Ultimate load	ACI	JAPANESE (Kn-mm)	INDIAN (Kn-mm)	
0%	61.67	156.8	7.89	306.5	306.5	0.020
20%	64	163	8.22	268.01	268.01	0.018
40%	70	179.3	10.77	179.9	179.9	0.012
60%	72	190	12.31	275.96	275.96	0.018
100 %	47.86	136.9	10.4	177.72	177.72	0.011

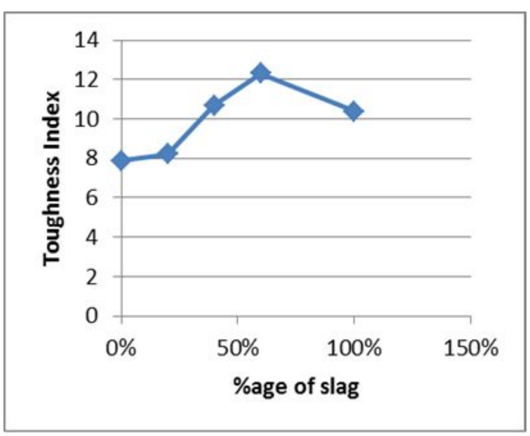

Figure : Variation of Toughness Index of Reinforced Beam

III. FLEXURAL STRENGTH OF BEAMS

Flexural strength or ultimate moment (strength) for reinforced beams is defined as the moment that exists just prior to the failure of the beam. In order to evaluate this moment, we have to examine the strains, stress and forces that exist in the beam.

The load vs deflection curve is drawn for different beams with different percentage ratio of slag. The flexural strength of beams with different quantity of slag are calculated and compared with the beams of control mix. The flexural behaviour of beams at 28 days is shown in Table 3.13 and load vs deflection curve for different beams are shown in Figure 3.7. The first crack is also noticed for each beam.

The flexural test is the most popular because it stimulates more realistically the conditions in many practical situations and is simpler to conduct than the tension test. The results allow toughness characterization through one or more method for example absolute energy absorption, dimensionless indices related to energy absorption capacity, equivalent flexural strength as prescribed post cracking deflection although, intended to characterized the material behavior, results from these test are usually effected by the specimen size and geometry. The ACI 544 toughness index constituted the first major effort in recognizing that energy absorption may be important in addition to strength (related to ductility or brittleness.

The ACI 544 toughness index is defined as the ratio of area under the load-deflection curve up to a deflection of 1.9 mm to the area under the same curve up to the first curve deflection. Among the problem with this approach are that the first crack deflection is difficult to determine reliably, and that the choice of the fixed deflection limit of 1.9 mm is arbitrary. Realistically, deflection limits should be based on serviceability requirements. This types of index provide an upper bound value of 1 (for post cracking strain hardening modulus approaching the initial elastic modulus and a lower bound value of 0.25 (for ideally brittle material).

The Japanese concrete institute (JCI) toughness definition T_{JCI}, is computed for a standard size beam as the area under the load deflection curve up to a limiting deflection curve up to a limiting deflection of L/150. The limitation of JCI toughness definition is that the limiting deflection is large and does not reflect a useful level of serviceability for much application. The Belgian, Dutch and German specifications have partially overcome this limitation by requiring energy absorption computation also at smaller deflection limits. Similarly, energy absorption capacity of the standard size plain concrete beam is idealized as $P_f(\eth_f+l/2000)/2$, where Pr and O_f are first crack load and deflection at first crack load respectively. In addition to the energy-based toughness measure T_{JCI}, the Japanese standard recommends the use of an equivalent flexural strength also called flexural toughness factor which is expressed as $T_{JCI}l/\eth_{limit}bd^2$ where T_{JCI}= toughness of beam, L= span,ð= limiting deflection, b= width of beam and d= effective depth of beam.

According to Indian Standards , the vertical deflection limit of beam may generally be assumed to be satisfied provided that the span to effective depth ratio are not greater than the value obtained as below:-

For span up to 10m

Cantilever 7

Simply Supported 20

Continuous 26

The energy absorption capacity is calculated as area under the load deflection curve up to a limiting deflection of span / depth ratio.

The decrease in energy absorption shows that the ductility decreases with increase in %age of slag aggregate. All the Specimens were casted and tested after 28 days. The compressive strength split tensile strength, first crack load, ultimate load, energy absorption capacity. flexural toughness factor are observed. Flexural behavior of reinforced beams is studied by load deflection curve.

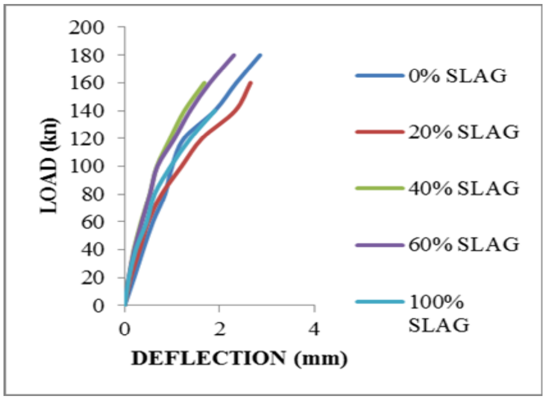

Figure :Load vs deflection of beams with different %age of slag

IV. ANALYSIS OF R/F BEAM

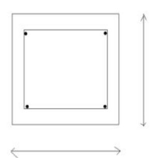

Figure : Cross Section of Beam

150×150 mm

b= 150mm, d= 125mm , d'= 25 M25, Fe 500

A_{st}= 226 mm^2 (12mm dia)

A_{sc}= 226 mm^2 (12mm dia)

Solution by limit state method

1. Choose a suitable neutral axis (NA) depth

Limiting x/d for Fe 500, $X_u = 0.46$

X = 57.5m, Adopt x=55mm

2. Strain and Stress in steel

$\epsilon_{st} = 0.0035(125–55)/55$

=0.0058

3. Total tension in steel

$T = 0.87×500×226×10^{-3} = 98.3$

4. Strain in compression steel

$\epsilon_{sc} = 0.0035(55–25)/55$

= 0.0019

5. Corresponding stress in steel = 360N/mm^2

$C_s = f_s × A_s$

$= 360×226×10^{-3}$

= 81.36KN

6. Compression in concrete and its point of action

$C_c = 0.36f_{ck}×b×x$

$= 0.36×25×150×55×10^{-3}$

= 74.25KN

7. Total Compression

$C = C_s + C_c$

= 81.36 + 74.2

= 137.48KN

Check Tension = Compression

T = 98.3KN, C = 137.48KN

8. Ultimate Moment of Resistance

M_u= [81.36(125-25)+74.25(125-23.10)]× 10^{-3}

= 8136+ 7566

=15702.07 =15.72 KN-M

9. Factored load

$W = 3\ M_u/l = 3× 15.72×10^3/540$

= 87.3 KN

Load = 58.2

Total = 116.4 KN

10. Check for deflection

Actual span/depth ratio = 540/125 = 4.6

p =226×100/150×125

=1.21

Modification factor =1 (assume), f_s= 290

Allowable span/depth ratio= 1×20

20 > 4.6 O.K

CONCLUSION

Concrete is an age old material. Mainly it is constituted of cement , sand and aggregate made up of natural stone. In the present study, natural stone coarse aggregate is replaced by blast furnace slag's aggregate in proportion of 0%, 20%, 40%, 60% and 100% in concrete. The various structural characteristics e.g. compressive strength, split tensile strength and flexural strength of concrete made up of blast furnace slag has been evaluated in this study. The flexural behavior of reinforced beam with different slag ratio has been studied and energy absorption capacity, first crack load, ultimate load, flexural toughness factor are observed experimentally and theoretically. The following conclusion has been made from the present study.

1. The compressive strength of concrete made up op 100% slag aggregate has been increased upto 10% in comparison to conventional concrete having stone aggregate.
2. The split tensile strength of cylinders with 40% slag aggregate has been decreased upto 48% in comparison to conventional concrete and further increase in quantity of slag beyond 40%, the split tensile strength increases about 10%.
3. The maximum value of first crack load has been observed as 72KN with 60% replacement of slag

correspondence to 61.67 KN in case of conventional concrete with stone aggregate.

4. The ultimate flexural load was observed maximum with 60% slag aggregate i.e. 190 KN and the ultimate flexural load in case of conventional concrete beam with stone aggregate was observed as 156.8KN.
5. The energy absorption capacity and flexural toughness factor of concrete having 100% slag aggregate has been decreased up to 42% and 45% respectively which shows the brittle behaviors of slag concrete .
6. The moment of resistance of reinforced beam is obtained as 28.22 kn-m experimentally and the moment of resistance is calculated analytically as 20.95 Kn-m.

REFERENCES

1. Addullahi M. (2012) "Effect of aggregate type on compressive strength of concrete" international journal of civil and structural engineering vol. 2, pp-791-800
2. Aguilar R.A., Diaz O.B. and Garcia J.I.E (2010) " light weight concretes of activated metakaolin-fly ash binders, with blast furnace slag aggregates" construction and building materials vol. 24, pp-1166-1175
3. Anastasiou E., Geosgiadis K. and Stefanidou M. (2014) "utilization of fine recycled aggregate in concrete with fly ash and steel slag" construction and building materials vol. 50, pp-154-161
4. Ameri M., Shahabishahmiri H. and Kazemzadehazad S. (2012) "Evaluation of the use of steel slag in concrete" 25^{th} ARRB conference
5. Arivavalagan S. (2013) "experimental study on the flexural behavior of reinforced concrete beams as replacement of copper slag as fine aggregate" civil engineering and urbanism vol. 3 pp. 176-182
6. Choi W.C. and Yun H.D. (2013) "Long-term deflection and flexural behavior of reinforced concrete beams with recycled aggregate" materials and design vol. 51 pp-742-750
7. Chunlin L., Kunpeng Z., Depeng and C. Chen (2011) "possibility of concrete prepared with steel slag as fine and aggregates: A preliminary study" procedia engineering vol. 24 pp 412-416
8. Ducman V and Mladenovic A. (2011) "The potential use of steel slag in refractory concrete" material characterization vol. 62 pp 716-723
9. Gonzalez-Ortega M.A., Segura I., Cavalaro S.H.P., Toralles-Carbonari B., Aguado A. and Andrello A.C. (2014) "radiological protection and mechanical properties of concrete with EAF steel slags" construction and building materials vol.51 pp-432-438
10.. IS 456:2000, "Plane and Reinforced Concrete- code of practice (Fourth Revision), Bureau of Indian Standards, New Delhi, India
11. Kamanli M., Kaltakci M.Y., Bahadir F., Balik F.S., Korkmaz H.H., Donduren M.S. and Cogurcu M.T. (2012) "Predicting the flexural behavior of reinforced concrete and light weight concrete beams by ANN" Indian journal of engineering & material science vol.19 pp-87-94
12. Khalifa S., Jabri al, Abdullah H., Saidy Al, and Ramzi T. (2011) " effect of copper slag as a fine aggregate on the properties of cement mortar and concrete" construction and building materials vol. 25 pp- 933-938
13. Lee N.K. and Lee H.K. (2013) "setting and mechanical properties of alkali-activated fly ash/slag concrete manufactured at room temperature" construction and building materials vol. 47 pp- 1201-1209
14. Lim I., Chern J-C., Liu T., Chan Y-W. (2012) "effects of ground granulated blast furnace slag on mechanical behavior of PVA-ECC" journal of marine science and technology vol. 20 pp-319-324
15. Li Q., Li Z. and Yuan G. (2012) " effects of elevated temperature on properties of concrete containing ground granulated blast furnace slag as cementitious material" construction and building materials vol. 35 pp- 687-692
16. Matias D., Brito de j., Rosa A. and Pedro D. (2013) "mechanical properties of concrete produced with recycled coarse aggregate – influence of the use of super plasticizer" construction and building materials vol. 44, pp 101-109
17. Miyazawa S., Yokomuro T., Sakai E., Yatagi A., Nito N. and Koibuchi K. (2014) " properties of concrete using high C_3S cement with ground granulated blast furnace slag" construction and building materials vol. 61 pp-90-96
18. Saifullah I., Nasir-uz-zaman M., Uddin S.M.K., Hossain M.A. and Rashid M.H. (2011) "experimental and analytical investigation of flexural behavior of reinforced concrete beam" International journal of engineering and Technology vol. 11 pp-146-152
19. Sangeetha S.P., and Joanna P.S. (2014) " flexural behavior of reinforced concrete beams with partial replacement of GGBS" Americal journal of engineering research(AJER) vol. 3 pp-119-127
20. Sarkar R., Singh N. and Das S. (2010),"utilization of steel melting electric arc furnaces slag for development of ceramic tiles" bull. Mater science vol. 33 pp. 293-298
21. Shaowei H. (2014) "experimental and analysis of flexural capacity and behavior of pre-stressed composite beams" automation in construction vol.37 pp-196-202
22. Shukla M. (2011) "behavior of reinforced concrete beams with steel fibers under flexural loading" international journal of earth sciences and engineering vol. 4 pp-843-846
23. S. Rafat and Kaur D. (2012) "properties of concrete containing ground granulated blast furnace slag (GGBS) at elevated temperature" journal of advanced research vol. 3 pp-45-51
24. Teng S., Darren Lim T.Y. and Divsholi B.S. (2013) " Durability and mechanical properties of high strength concrete incorporating ultra fine ground granulated blast-furnace slag" construction and building materials vol. 40 pp-875-881
25. Yang I.H., Joh C., Kim B.S. (2011) " flexural strength of ultra high strength concrete beams reinforced with steel fibers" procedia engineering vol. 14 pp- 793-796
26. Yi H., Xu G., Cheng H., Wang J., Wan Y. and Chen H. (2012) "An overview of utilization of steel slag" procedia environmental sciences vol. 16 pp 791-801