International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Structural Behaviour of Concrete with Fly-Ash and Ferrochrome Ash as Partial Replacement of Cement

Tribikram Mohanty, Srishti Saha, Purnachandra Saha, Bitanjaya Das

Abstract: ***A large quantity of waste materials such as fly ash, silica fume, rice ash husk, and ferrochrome ash etc. are produced as a result of rapid industrialization. Ferrochrome ash is derived from the ferro-alloy industry and fly-ash is developed in thermal power plants as substitute products that can be used as a mineral admixtureinconcrete.***

The present study considers concrete's structural behavior using different percentage of

fly ash and ferrochrome ash as a partial replacement of cement. Experiments were performed tosubstitute cement with 10% fly as h, 20%, 30% and 3% ferrochrome ash. Beam specimens are prepared by following standard procedures. It can be inferred from the study that the sample with 30% fly ash and 3% ferrochrome ash as partial replacement of cement gives maximum load carrying capacity among all the beam specimens. Further, it is observed that the beam specimen with fly ash and ferrochrome ash gives more ductility than of conventional concrete. Hence 30% fly ash and 3% ferrochrome ash as partial replacement of cement has been strongly recommended.

Keywords: ***Fly ash, Ferrochrome ash, Industrial waste utilization, Structural behaviour.***

I. INTRODUCTION

Concrete is one of the used materials for construction globally. In India, there is a progressive increase in the investment in infrastructure development which generated a huge demand for construction materials across the country. Currently, there has been a growing prominence towards familiarizing alternative materials in construction to balance the economic purpose, to reduce the pressure on good quality natural materials and of course to take care of the environmental issues. Alternative materials which come as the industrial waste like slag of copper, fly ash, blast furnace slag, dust of quarry, glass waste, rubber waste, red mud, silica fume, GGBS, ferrochrome ash, steel fiber etc. can be utilized as the construction materials. Currently the field of concrete technology has witnessed many efforts of exploration and research on the use of by-products of industrial sector and waste resources for concrete manufacture. Proper utilization of the mentioned materials can decrease the cost of concrete production, improve the characteristics of fresh and hardened concrete, and decrease the environmental impact [1-6]. This work emphasizes by using the combination of fly ash and ferrochrome ash as partial replacement of cement.

Patra et.al [7] examined the structural behavoiur of the ferrochrome slag based reinforced concrete beam as a partial substitution of the coarse aggregate. Pellegrino et.al [8] studied that the behaviour of Electric Arc Furnace (EAF) slag as aggregate in reinforced concrete structures and concluded that the behaviour of ultimate flexural capacity and shear capacity was higher compared with the normal concrete . Asamoah et.al [9] stated that flexural behaviour of Phyllite aggregate's for example load-deflection relationship, displacement ductility and crack widths as per BS 8110. Phyllite aggregate concrete beam's experimental flexural load strength was approximately 115 percent of the theoreticalcapacityexpected.The deflection was within the li mitation of design code, but the beam ductility was very sma llGunasekaran et al. [10] compared concrete beams with conventional concrete beams based on the coconut shell aggregate. In both compression and tension, they examined the moment strength, cracking, deflection and ductility. No horizontal cracks were found in the tension zone, suggesting a good bond between coconut shell concrete and reinforcement. Choi et.al [11] observed the 380-days long-term deflection of Recycled Aggregate Concrete (RAC) beam and the flexural activity of RAC beams following exposure to continuous loading. Immediately cracks were observed in all beams after applying the superimposed load, but the beam cracks with recycled aggregates were longer as compared to the controlled beams. Alengaram et al.[12] studied that the moment capacity of concrete shell beams in the palm kernel was about 3 percent higher than concrete beams. In ductile failure, however, Palm kernel shell concrete beams failed, the power concrete beams failed in fragile failure. Palm kernel shell concrete beams deflection and crack width were more than conventional Concrete beams.
The similar behavior of the oil palm shell aggregate in concr ete beams was also observed by Teo et al[13].

Manuscript published on November 30, 2019.
* Correspondence Author

Dr. Tribikram Mohanty*, Associate Professor, School of Civil Engineering, KIIT Deemed to be University, Bhubaneswar, Odisha, India. Email: tmohantyfce@kiit.ac.in

Srishti Saha, Post graduate student, School of Civil Engineering, KIIT Deemed to be University, Bhubaneswar, Odisha, India.
Email: srishti.civil94@gmail.com

Dr. Purnachandra Saha, Associate Professor,School of Civil Engineering, KIIT Deemed to be University, Bhubaneswar, Odisha, India. Email: dr.purnasaha@gmail.com

Dr. Bitanjaya Das, Senior Professor, School of Civil Engineering, KIIT Deemed to be University, Bhubaneswar, Odisha, India.
Email: bdasfce@kiit.ac.in

Retrieval Number: D4552118419/2019©BEIESP
DOI:10.35940/ijrte.D4552.118419
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Extensive literature studies show that there has been no investigation in structural behaviour of RCC beam by using fly ash and ferrochrome ash as replacement of cement in concrete industry. The objective of this paper is to study the influence of flexural strength of various percentages of fly ash and ferrochrome ash replacement over ordinary cement.

A. Materials

Cements, aggregates, water, and plasticizer:

Ordinary Portland cement (OPC), 53 grade was used according to IS 8112:1989 [14]. As per IS 383:1870, natural river sand (fine aggregate) falling under grading zone III [15] and natural stone aggregates (coarse aggregate) are used as aggregates. For the preparation and curing of samples in compliance with IS 456: 2000, pure drinking water free of impurities and chemical compounds is used [16]. To order to improve the workability, a poly-carboxylic based superplasticizer was used in the tests to keep the water/cement ratio set for all concrete mixes.

Ferrochrome ash

Ferrochrome (F.Ash) is the dust obtained from the ferrochrome industrial unit cleaning process as shown in Fig.1. The gaseous material produced from smelting furnaces of iron or Ferro alloy includes various impurities such as dust particles, poorly burned materials such as timbers.

Fig.1.Ferrochrome ash (source, Balasore Alloys Ltd. Balasore, Odisha)

Fly ash (FA):

Fly ash (FA) as shown in Fig.2. A bag filter extracts from a corrosive liquid is a combination of powder, fine, soft and glass. It can be used to substitute of portland cement in mixed concrete to create low maintenance cost and environmentally friendly alternative that meets the quality requirements. It is possible that if fly ash is included by replacing concrete by 20 to 30 percent, then at various cure age it would yield better results.

Table 1displays chemical composition of OPC, F.ash and fly ash.

Fig.2. Fly ash (source, Sai Ram Fly Ash Brick, Ranga Bazar, Khurda)

Table-I: Chemical Composition of OPC, FA & FLY ASH (% by weight)

Sl.No	Constituent	OPC	Ferrochrome ash (F.Ash)	Fly Ash (FA)
1	SiO_2	20.61	19.6	59
2	Al_2O_3	5.028	11.1	24.18
3	CaO	62.61	4.22	6.9
4	Fe_2O_3	3.329	6.06	3.7
5	MgO	2.237	15.6	3.3
6	SO_3	2.723	1.92	1
7	Na_2O	0.328	1.3	-
8	K_2O	0.577	0.46	0.9
9	P_2O_5	0.32	0.06	-
10	TiO_2	0.27	2.196	1.02

Steel Reinforcement:

In addition, the content of carbon, sulphur and phosphorus is also small, which is useful for earthquake resistance and earthquake resistance of steel materials in the future. These types of steel bars are manufactured under-controlled manufacturing processes and can be effortlessly bent. There is a great relationship among iron and concrete. Since concrete has high compressive power, when united with TMT steel rods, they become ductile together, and the tensile strength becomes stronger. The TMT bar can be used for various projects such as bridges, dams, flyover, buildings, and railroads.

Fe 500D grade TMT steel rods are used in this study. "Fe" represents iron and the number "500" means the characteristics stress in units of N /mm^2. The letter "D" means ductility, which means that the steel rod has a higher elongation. All these grades are manufactured using Thermo mechanical Treatment (TMT) process. TMT process makes steel bars with an outer tempered martensitic layer (which gives tensile strength) and an inner Ductile Ferrite- Pearlite core. According to the latest version of IS 1786 (2008), Fe 500 D is a new product of deformed steel bar with the specified minimum rate of elongation at the same specification as the specified minimum 0.2% proof stress/yield stress. TMT Bars are shown in Fig. 3.

Fig.3. TMT Bar

B. Mix proportions and Preparation of beam specimen

Different concrete mix specimens using fly-ash, ferrochrome-ash & cement are prepared according to relevant Indian Standard codes and cured for 7 and 28 days.

The sizes of beam specimen used in the research work are 150mm x 150mm in cross section and 1000mm in length. Table 2 shows the mix number and weight of different material for M 30 concrete mix ratio (1: 1.23: 2.29). For the accurate test results of the sample, consistent mixing of concrete was ensured.

Table-2: Mix proportion (Kg/m^3)

Materials	**Contro l**	**Fly ash 10%**	**Fly ash 20%**	**Fly ash 30%**
Mix no	N100	N87FA	N77FA	N67FA
Mix composition	100% OPC	87%OPC +10%FA +3% F.ash	77%OPC+ 20%FA +3%F.ash	67%OPC +30%FA +3%F.ash
Cement	499	434.13	384.23	334.33
Ferrochrom e Ash	-	13.5	13.5	13.5
Fly Ash	-	42.771	85.543	128.314
Water	0.4	0.4	0.4	0.4
Fine Aggregate	613.9	613.9	613.9	613.9
Coarse Aggregate	1144.5	1144.5	1144.5	1144.5

C. Casting of beam

Simply supported reinforced concrete beams have been subjected to pure flexural failure by a two-point load test. 2-12 mm and 2-10mm diameter bars are used through out at bottom and top reinforcement respectively shown in fig 4. For each beam bars of diameter 8 mm, as stirrups 90 mm c/c spaced are used for shear reinforcement. Typical arrangements of beam r/f are shown in the fig 4. For this investigation, all beams are casted using concrete grade of M30.

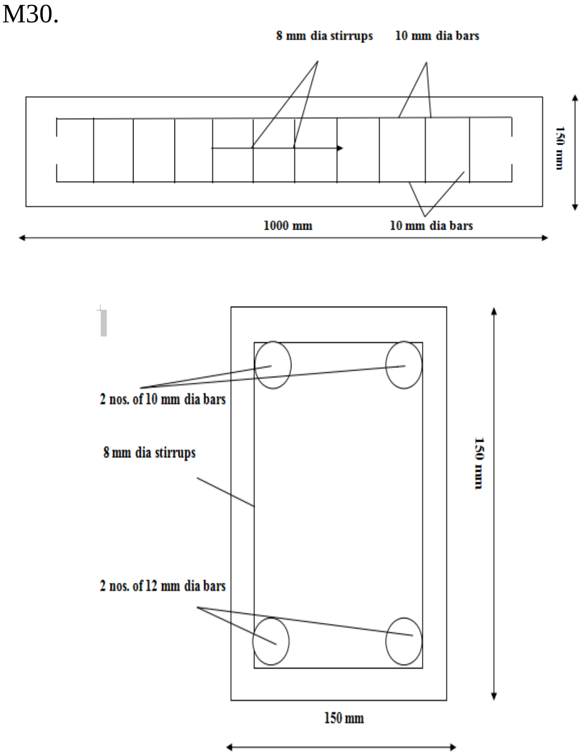

Fig.4. Reinforcement arrangement

D. Set up of Flexural Test of beam:

Since all beams are simply supported over 900 mm span, all beams have been examined under a two point loading system. Two rollers with a diameter of 30 mm are placed at a distance above the beam of 1/3 of the span from the supports. The load on the beam is transferred through the use of rollers, an I section steel beam of size ISMB 300 is placed over the roller. Load cell with the 100 KN capacity is placed at centre of I section. Three dial gauges were placed below the beam to measure the deflection. One was placed in the middle of the section and two more were mounted to the support on the left and right side. Set up of beam representing in fig 5-6.

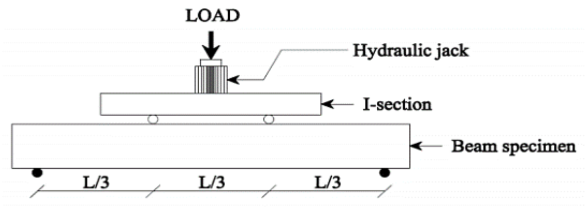

Fig.5.Diagram for Beam Flexural

Fig.6. Setup for Flexural Test

E. Behaviour of Beam Specimen:

When the load is applied gradually beam begins to deflect in the direction of loading and cracks begin to develop along the tension zone. The curves of load vs. deflection represent those events that occurred during testing. First cracking event was recorded, yield of tensile reinforcement; Concrete crushing began associated with concrete cover enlargement and disintegration of the compression zone. Placing of beam as shown in fig 7.

Fig.7. Placing of Beam

Retrieval Number: D4552118419/2019©BEIESP
DOI:10.35940/ijrte.D4552.118419
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

F. **Crack Pattern and Mode of Failure**

All the beam specimen are failed as flexural failure. The flexure cracks start in the pure bending area as load increases. As the load was expended on existing cracks, new cracks formed along the span. Crack pattern for various beam samples representing as fig 8-11. The mid-span cracks opened wide near beam collapse, the beams greatly deflected, suggesting the failure of the tensile steel. The final beam failure occurred when the concrete began cracking in the compression area, followed by the compressive steel bars buckling. Beam failed into shear failure as it shows that this failure occurred due to less bonding of material and shear strength of a material relative to the type of yield or structural failure when the material breaks at shear failure.

Fig.8. Conventional Beam Sample

Fig 9: Cracking Pattern of C + 20% FA + 3% FrA Sample

Fig: 10 Cracking Pattern of C + 20% FA + 3% FrA Sample

Fig.11. Cracking Pattern of C + 30% FA + 3% FrA Sample

G. Cracking Moment

The load is noted where visibly the first flexural crack is observed. The theoretical moments of cracking are determined according to IS: 456-2000 from the available test data. Test result shows that, the first experimental moment of cracking is greater than that of the theoretical moment of cracking measured and both the experimental and theoretical test results are compared. In the C+30%FA+3%FrA beam cracks has occur diagonally to at both support that shows this beam failed in shear. Shear failure occurs at the end of support at 45 degree.

H. Deflection of Beam

Deflection are measured at mid span and 1/6th from the end support. The deflection were recorded till the failure of beams and shown in table 3. For all beams the load vs. mid-span deflection shown in the figure 12, the failure load noted and compared with the test data.

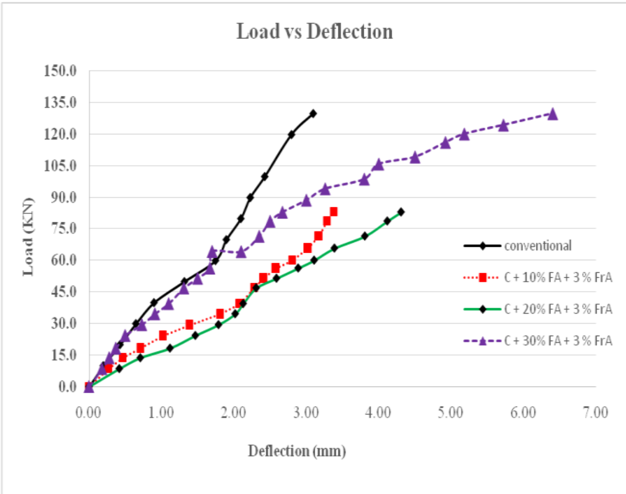

Fig.12. Load vs. deflection of different materials

II. CONCLUSION

In this study an investigation was conducted into observe the structural behaviour of cement concrete beams with different percentages of FA and F.Ash as partial replacement of cement. The cement has been replaced with 10%, 20% and 30% fly ash respectively. The fly ash has been supplemented with 3% of ferrochrome ash in all the specimens. The flexure test on the standard beam specimens has been conducted and from the test results possible to draw the following conclusions:

Retrieval Number: D4552118419/2019©BEIESP
DOI:10.35940/ijrte.D4552.118419
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

- The sample with 30% fly ash and 3% ferrochrome ash as partial replacement of cement gives maximum load carrying capacity among all the beam specimens.
- Further, the sample of the beam is observed with fly ash and ferrochrome ash gives more ductility than of conventional concrete. Hence 30% fly ash and 3% ferrochrome ash as partial replacement of cement has been strongly recommended.

REFERENCES

1. P. K. Acharya, and S. K Patro, "Effect of lime and ferrochrome ash (FA) as partial replacement of cement on strength, ultrasonic pulse velocity and permeability of concrete",*Construction and Building Materials*, (2015), vol 94, pp 448–457.

2. 2. P. K. Acharya, and S. K Patro, "Use of ferrochrome ash (FCA) and lime dust in concrete preparation" , *Journal of Cleaner Production,* (2016a), Vol 131, pp 237-246.

3. 3. F. V Ajileye, "Investigations on Microsilica (Silica Fume) As Partial Cement Replacement in Concrete", *Global Journal of researches in engineering Civil And Structural engineering*, (2012), vol 12, pp 17-24.

4. P. Aggarwal, Y. Aggarwal, and S.M. Gupta "Effect of bottom ash as replacement of fine aggregate in concrete", *Asian Journal of Civil Engineering,* (2007), vol 8(1), pp 49-62.

5. 5.S.A. Barbhuiya, J.K. Gbagbo, M.I. Russel, and P.A.M. Basheer, "Properties of Fly ash concrete modified with hydrated lime and silica fume", *Construction and Building Materials,* (2009), vol 23, pp 3233-3239.

6. 6. P. K. Acharya, and S. K Patro. "Utilization of ferrochrome waste such as such as ferrochrome ash and ferrochrome slag in concrete manufacturing", *Waste Management &Reasearch,* (2016b), vol 34(8), pp 764-774.

7. K J. Prusty, S. K Patro, and T. Mohanty, "Structural Behaviour of Reinforced Concrete Beams Made with Ferrochrome Slag as Coarse Aggregate", *KSCE Journal of Civil Engineering,* (2017), pp 1–12.

8. 8.C.Pellegrino, and F. Faleschini, "Experimental behavior of reinforced concrete beams with Electric arc furnace slag as recycled aggregate," ACI Materials Journal, (2013), vol. 110, No. 2, pp 197-205.

9. 9. M. A. Asamoah, and R. O. Afrifa, "Investigation on the flexural behaviour of reinforced concrete beams using phyllite aggregates from mining waste", *Materials and Design,* (2011), vol. 32, pp. 5132-5140.

10. 10.K. Gunasekaran, R. Annadurai, and P. S. Kumar, "Study on reinforced light weight coconut shell concrete beam behavior under flexure", *Materials and Design,* (2013), vol. 46, pp. 157-67.

11. W. C Choi, and H. D Yun, "Long-term deflection and flexural behavior of reinforced concrete beams with recycled aggregate" , *Materials and Design*, (2013), vol. 51, pp. 742-50.

12. 12.U. J. Alengaram, M. Z. Jumaat, and H. Mahmud "Ductility behaviour of reinforced palm kernel shell concrete beams", *European Journal of Scientific Research,* (2008), vol. 23, No. 3, pp. 406-420.

13. D. C. L. Teo, M. A. Mannan, and J. V. Kurian, "Flexural behaviour of reinforced lightweight concrete beams made with Oil Palm Shell (OPS)", *Journal of Advanced Concrete Technology*, (2006), vol. 4, No. 3, pp. 1-10

14. 14.IS: 8112-1989, *43 Grade Ordinary Portland Cement* – Specification, Bureau of Indian Standards, New Delhi, India,

15. 15.IS: 383-1970, *Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete*, Bureau of Indian Standards, New Delhi, India.

16. IS: 456-2000, *Plain and Reinforced concrete – Code of practice*, Bureau of Indian Standards, New Delhi, India.

AUTHORS PROFILE

Dr.Tribikram Mohanty is a Associate Professor in the school of Civil Engineering in KIIT Deemed -to-be university, Bhubaneswar, Orissa. He has 11 years of teaching experiences and 05 years of industrial experiences. His area of research is sustainable building materials, waste utilization, and geopolymer concrete. He authored more than 10 research articles in journals and conferences and guided 15nos of M.Tech students till date. Apart from academia, he holds a post of Lieutenant in NCC Government of India.

Srishti Saha born in Agartala, She has completed her Bachelor's in Civil Engineering in the year of 2017 from National Institute of Technology Agartala and Masters in Construction Engineering and Management in the year of 2019 from KIIT Deemed -to-be University, Bhubaneswar, Odisha. Title of her master thesis is "Performance of Recycled Aggregate Used in Fly ash and Ferrochrome ash based Geopolymer Concrete" and published one international journal paper and three international conference papers till date.

Dr. Purnachandra Saha's areas of specializations are earthquake engineering, structural control, sustainable materials, green building and he has written 85 research articles till date. He is a member of ASCE and The Faculty Advisor of ASCE KIIT University Student Chapter. He is currently working as an Associate Professor (II) in the school of civil engineering, KIIT Deemed to be University, Bhubaneswar, Odisha, India

Dr. Bitanjaya Das received M. Tech & Ph. D from Asian Institute of Technology, Bangkok, Thailand has 35 years of experience out of which 30 years experience in the area of teaching, training, extension, and research. He is a fellow of Indian Water Resources Association and has guided several Ph. D. Students and conducted research projects. Currently, he is working as Senior Professor in the School of Civil Engineering, KIIT Deemed to be University, Bhubaneswar, Odisha, India. Lieutenant in NCC Government of India.

Table-3: Load and Deflection for all beam samples

Hydraulic jack load (KN)	0	10	20	30	40	50	60	70	80	90	100
Proving Ring (KN) Sample 1	0	8.57	8.71	18.28	24.28	32.57	39.42	46.85	56.28	65.71	71.42
Proving Ring (KN) Sample 2	0	13.71	24.28	34.57	46.85	56.28	65.71	78.57	88.57	98.57	105.71
Proving Ring (KN) Sample 3	0	13.71	24.28	34.57	46.85	56.28	65.71	78.57	88.57	98.57	105.71
Proving Ring (KN) Sample 4	0	13.71	24.28	34.57	46.85	56.28	65.71	78.57	88.57	98.57	105.71
Deflection (mm) Sample 1	0	20	35	30	55	79	102	147	32	33	30
Deflection (mm) Sample 2	0	19	37	55	85	110	131	168	254	332	375
Deflection (mm) Sample 3	0	17	40	76	110	132	157	189	288	365	401
Deflection (mm) Sample 4	0	28	50	91	131	167	235	267	326	400	450

Retrieval Number: D4552118419/2019©BEIESP
DOI:10.35940/ijrte.D4552.118419
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication