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

Structural Behaviour Fly ash and Ferrochrome ash Based Geopolymer Concrete with Recycled Aggregate

Srishti Saha, Purnachandra Saha, Tribikram Mohanty

Abstract: Recycled aggregates are the construction demolition wastes which can be used in concrete industry to reduce the carbon footprint of the environment. This paper deals with the structural behaviour of reinforced concrete beam made with different percentages of recycled aggregate as coarse aggregate on a novel geopolymer concrete consist of fly ash and ferrochrome ash as binder. Structural behaviour of RCC beam with 10% and 20% recycled aggregate in geopolymer concrete are studied and compared to the 100% natural coarse aggregate. Experimental results revealed that the up to 10% replacement of recycled aggregate can achieve strength equal to control concrete and it can be the recommended percentage of RCA for concrete industry.

Keywords: Recycled aggregate, construction demolition wastes, Fly ash, Ferrochrome ash, Geopolymer concrete, Structural behaviour.

I. INTRODUCTION

Due to the continued growth of societies and human developments, the reliance on natural and non-renewable resources to encounter consumer demands has increased. This resulted in a continual increase of industrial solid waste materials. Industrial solid waste materials are being deposited on a daily basis in landfills. Waste management techniques aim to decrease the consumption of raw resources and energy and help in saving the exhausted landfills. Concrete is the world's most consumed man-made material which attracts great interest as it may be a possible way to recycle solid waste products. The production of 1 ton of Portland cement generates around an equal amount of CO_2 [1]. It is estimated that the cement industry contributes around 5% to 8% of the annual global greenhouse gas emissions [2]. Paulo B .Cachim [3] reported a study were crushed brick used as a replacement of Natural Coarse Aggregate (NCA) for mechanical properties of brick aggregate containing different w/c ratio and also comparing the result to normal concrete aggregate. Results show that up to 15% replacement of NCA Recycled Coarse Aggregate (RCA), no reduction in strength was observed. Beyond that limit the strength should be reduced depending on the properties of brick aggregate. Yang et.al [4] evaluated the mechanical properties of concrete containing recycled coarse aggregate mixed with 20% and 50% crushed clay brick and compared to the normal concrete with the same w/c ratio. Experimental results show that by increasing the percentages of brick aggregate, the strength reduction up to 10.7% at 28 days curing. Braga et.al [5] reported that by adding 15% RCA to the NCA, as a result the properties of mortar are also improved. Patro et.al [6] reported a study of r/f concrete beams by using ferrochrome slag as coarse aggregate. Ultimate failure load are compared between the conventional reinforced concrete beam and ferrochrome slag based reinforced concrete beam. Ultimate flexural strength, shear strength, short term deflection were observed and compared to the predicted value obtained from IS 456. Afrifa et.al [7] studied the flexural behaviour of Phyllite aggregate. It was observed from the study that highest flexural capacity of this aggregate are 115% of the predicted theoretical capacity. Flexural cracks and shear cracks are not satisfying the allowable limit of code. J. Brito et.al [8] reported a study on mechanical behaviour of made by recycled ceramic aggregate as a coarse aggregate and reported that reduction in strength due to the increasing the percentages of ceramic aggregate but the property of abrasion resistance was higher for recycled ceramic aggregate as compared to the concrete made of limestone aggregate. Anna Halica et.al [9] studied the effect of concrete with alumina and ceramic waste recycled aggregate. By using these ceramic waste materials could be useful in the production of concrete and high strength and high abrasion resistance of concrete can be produced. C. Thomas et.al.[10]investigated the effects of mechanical and durability properties of recycled aggregate as a precast waste in the concrete industry. Precast waste was replaced with different percentages of recycled aggregate and experimental results show that up to 20% replacement can be achieved maximum strength of concrete. Geopolymer is emerging cement less binder supposed to provide a sustainable and environmentally friendly alternative to OPC. It is an inorganic alumino silicate polymer is synthesized to silicon and aluminium materials or form by-product of fly ash.

Manuscript published on November 30, 2019.
* Correspondence Author
Srishti Saha*, Postgraduate 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. Tribikram Mohanty, Associate Professor School of Civil Engineering, KIIT Deemed to be University, Bhubaneswar, Odisha, India. Email: tmohantyfce@kiit.ac.in

Duxson et.al [11] found that the production of fly ash-based geopolymer require around 60% less energy and has at least 80% less CO_2 emissions than that of OPC. Anuar et.al [12] studied that fly ash and slag based geopolymer concrete used in recycled aggregate. Result shows that at 28 days curing age, the compressive strength increased by up to 10% and a higher concentration of NaOH solution gives higher strength of geopolymer concrete. Shuang et.al [13] investigated on properties of fly ash based geopolymer concrete containing 0%, 50%, 100% RCA and results are compared to the normal concrete. Results show that compressive strength and modulus of elasticity are higher for geopolymer concrete containing recycled aggregate. A.Akbarnezhad et. al.[14] found the effects of the recyclability of low calcium fly ash geopolymer concrete (GPC) as a potential sustainable alternative to OPCC. Basic properties of recycling geopolymer concrete (RGA) consisting of 24h water absorption, bulk density and Los Angeles abrasion loss in addition to the results of length of RGA on these properties had been investigated. The alkaline solution was made from a combination of 12 M sodium hydroxide (NaOH) solution and sodium silicate (Na_2SiO_3) solution with Na_2O = 14.7%, SiO_2 = 29.4% and H_2O =55.9% by mass. A constant mass ratio of sodium silicate to sodium hydroxide solution of 2.5 was used and the mass ratio of alkaline solution to alumino silicate material changed into 55 percentage. Nuaklong et.al [15] reported a study on high calcium fly ash geopolymer concrete by inclusion of OPC and nano-silica and reported by adding of 15% OPC with fly ash blend mixture gives higher compressive strength which was 38% lower as compared to Natural Aggregate with Geopolymer Concrete (NAGC) and 1% nano-silica gives considerably higher strength for recycled aggregate geopolymer concrete than that of NAGC. F.U.A Shaikh [16] also reported that mechanical and durability properties of fly ash based geopolymer concrete containing up to 50% of recycled aggregate and also compared to the natural aggregate. Result shows that strength of geopolymer concrete for 100% natural coarse aggregate is increased up to 9% from 7 to 28 days. Acharya et.al.[17] stated that of ferrochrome ash as partially replaced by cement to improve the strength and durability properties. At 47% replacement of cement, 40% by ferrochrome ash and 7% by lime more strength are achieved. Very few literature exist which ferrochrome ash has been used as partial replacement of cement, however, no combination has been found utilizing ferrochrome ash with fly ash in geopolymer concrete. There is a scope to utilize RCA in geopolymer concrete due to the rapid growth of geopolymer concrete in the construction industry.

This paper deals with the structural behaviour of reinforced concrete beam made with different percentages of recycled aggregate as coarse aggregate on a novel geopolymer concrete consist of fly ash and ferrochrome ash as binder. Structural behaviour of RCC beam with 10% and 20% recycled aggregate in geopolymer concrete are studied and compared to the 100% natural coarse aggregate.

II. EXPERIMENTAL SETUP

A. Materials

Ferrochrome ash :

Ferrochrome ash is an industrial waste which is produced from gas cleaning plant of Ferroalloy industries and it is shown in figure 1. This waste material available plant in Odisha is not very harmful to the environment but it required a more large land area for disposal. Ferrochrome ash is blended with fly ash as binder in geopolymer concrete.

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

Fly ash:

Fly ash is a throwaway material which is produced in thermal power plants, is a powder, fine, soft and glassy materials and it is together from the enervate gases by a bag filter. Fly ash is construction materials which can be used in mix concrete and it will make a low maintenance cost as shown in figure 2. It is also a friendly environmentally way out, which meet the show specifications. It contributes to leadership in energy and environmental design points. The physical properties and chemical composition of fly ash and ferrochrome ash as shown in table 1 and 2.

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

Table- I: Physical Properties of fly ash and ferrochrome ash

Physical Properties	Fl y ash	Ferrochrome ash
Specific gravity	2.64	2.24
Specific surface Area (m^2/Kg)	332	571
Colour	Dark gray	Gray

Table-II: Chemical Composition of fly ash and ferrochrome ash

Constituent	*Fly ash (%)*	*Ferrochrome ash(%)*
SiO_2	55	27.5
Al_2O_3	26	24.7
CaO	18.1	9.06
Fe_2O_3	19.48	4.02
MgO	3.3	22.5
SO_3	1.5	1.92
Na_2O	------	1.3
K_2O	1.79	0.46
P_2O_5	-----	0.313
TiO_2	1.02	2.196

Alkaline material :

The geopolymer mixture does not contain cementitious materials made with activated pozzolanic material and aggregate. Dipolymers are formed by polycondensation of silica and alumina activated with an alkaline material. Sodium hydro-oxide (NaOH) and sodium silicate (Na_2SiO_3) are selected in this study as alkaline material to prepare the alkaline solution. Sodium hydroxide and Sodium Silicate pellets are shown in figure 3-4 and table 3 shows their chemical composition.

Fig.3. NaOH Pellets

Fig.4. Na_2SiO_3 Pellets

Table-III: Chemical composition of sodium hydro-oxide and sodium silicate (% by weight)

Component	**NaOH (%)**	**Na_2SiO_3 (%)**
Assay	97	98
Na_2CO_3	0.2	-------
Cl	0.01	0.05
SO4	0.05	0.05
Pb	0.001	-----
Fe	0.001	-----

Coarse Aggregates:

The coarse aggregate used in this research is the construction demolition waste sourced from demolished structures near KIIT Deemed to be University as recycle coarse aggregate (RCA). The demolished concrete has been crushed and watered properly with maximum aggregate size of 40 mm. As per the procedure of ASTM C 128, specific gravity of recycled coarse aggregate is ranged between 2.2-2.6 and natural coarse aggregate is 2.7. The difference was mainly occurred because of the old adhered mortar attach to the RCA. Crushed granite of 10 mm & 20 mm size are used as coarse natural aggregate.

Fig.5. C & D Waste

Fig.6.Recycled aggregate

Fine Aggregates:

The fine aggregates used was clean river sand passing through 4.75 mm sieve with a specific gravity of 2.5 and grading zone III conforming to IS 383: 1870. Physical properties of fine and coarse aggregate as shown in Table 4.

Table IV: Physical Properties of Aggregate

Properties	*Recycled aggregate*	*Natural coarse aggregate*	*Fine aggregate*
Bulk density (Kg/m^3)	1409	1522	1652
Specific gravity	2.48	2.77	2.63
Water absorption (%)	4.47	0.66	0.73
Fineness modulus	7.47	6.56	2.39

Steel Reinforcement:

10 mm dia of HYSD reinforcements bars were used as longitudinal tension reinforcement in beams as per design requirement and 8 mm dia mild steel was used as stirrups [15]. Details of reinforcement shown in figure 7.

Fig.7. Reinforcement arrangement

Water:

Water was taken from the laboratory of School of Civil Engineering Department of KIIT Deemed to be University and it is tested as per the requirements of IS: 456-2000.The test results are presented table 5.

Table –V: Properties of water

Properties	*Observed Value*
pH value	7.1
Dissolved solids(mg/l)	290
Suspended Solids	Nil
Chlorides(mg/l)	20
Sulphates(mg/l)	74
MPN Value/100 ml	Nil

Superplasticizer:

With the addition of fly ash and ferrochrome ash, the water demand is increased and the workability is reduced. Similarly, replacement of cement with fly ash and ferrochrome ash caused low workability. Keeping the w/c ratio constant for all mixes, a naphthalene based superplasticizer is added in order to improve the workability. Properties of above superplasticizer are obtainable in Table 6.

Table-VI: Properties of Superplasticizer

Properties	*Observed Value*
Chemical base	Modified Napthalene Formaldehyde Sulphonate
Appearance	Brown liquid
pH value	>6
Specific gravity	1.04

B. Preparation of alkaline activator solution

In this study, caustic soda solution of 13M is used. Under the mix design condition, sodium hydroxide quantity was 89.75kg/m^3 at 13 M and sodium silicate was 224.3 kg/m^3 at 13.3 M. Clear drinking water is used to prepare the solution. A mixing of solution Na_2SiO_3 and NaOH, sodium hydroxide of 97% in pure flaking form and sodium silicate were used for the preparation of activator. Ferrochrome ash as a source material which was obtained from the gas cleaning plant of ferrochrome industry in Balasore, and fly ash was collected from fly ash brick in Bhubaneswar, Orissa were used to make the geopolymer binder and alkaline activator solution. Chemical composition of activator were Na_2O = 77.75%, SiO_2 = 77.75%, and water 33.765% by mass. Solution molarity was maintained at 13M during the entire work. The solution was prepared for at least 24 hours before being used to prepare geopolymer concrete. The coarse aggregate used in this research is the construction demolition waste sourced from demolished structures near KIIT Deemed to be University as recycle coarse aggregate (RCA).

C. Mix proportion

In this research, three types of mixtures are taken into consideration. Table 7 gives the idea of mix proportion and detailed analysis of experimental results of all three types. In the first mix which is known as control series, where 100% natural coarse aggregate geopolymer with 50% fly ash and 50% ferrochrome ash are utilized and it was denoted as GFF 0% mixture and other types of mixtures which are contains 10%, 20% (% by wt) of recycled aggregate and denoted as GFF 10%, GFF 20%, respectively. The ratio of activator to fly ash was taken 0.35 for all concrete mixes. The colour of fly ash and ferrochrome ash based geopolymer concrete is light black. The total quantity of water holds the most significant role in the mix. If mixing of concrete is carried out for a long time, the content bleeds out when the water is high during the mixing period, and the aggregate segregates to give a paste. It is observed from the past study by T. Mohanty [15] 50% fly and 50% ferrochrome ash gives better result. Hence in this study this combination is followed.

Table-VII: Mix proportion for geopolymer concrete using recycled aggregate

Mix	*GFF 0% RCA*	*GFF 10% RCA*	*GFF 20% RCA*
Fly ash (Kg/m^3)	189(50%)	189(50%)	189(50%)
Ferrochrome ash (Kg/m^3)	189(50%)	189(50%)	189(50%)
RCA	0	135.08	270.17
NCA	1350.88	1080.7	1051.17
FA (Kg/m^3)	727.4	727.4	727.4
NaOH	27.29	27.29	27.29
Na_2SiO_3	27.29	27.29	27.29
Superplasticizer	6.05	6.05	6.05

C. Preparation of sample

First, recycled aggregates and fine aggregates were mixed in a 200 L volume laboratory inclined mixer for about 4-5 minutes, then fly ash and ferrochrome ash are added according to the specified amount and mixing was continued for about 3 minutes. After dry blending, the alkaline solution was added to the dry material along with the superplasticizer and again mixed for another 5 minutes. After completion of mixing, mix concrete was poured in a beam. All specimens were cast properly and horizontally in three layers. Each layer was tamped properly and for proper placing of concrete used needle vibrator. The test piece was allowed to stand for 3 days in a specimen at room temperature to cure. Specimens were placed in a hot air curing chamber to cure the beams at temperatures between 60° C and 70 ° C for 24 hours. The specimens were then demoulded and cured keeping under open air in the laboratory till the date of testing. The sample size for flexural strength test was having breadth and height of 100 mm and having a length of 500 mm. In the first stage, three beams were prepared with 50% fly ash & 50% ferrochrome ash with 100% NCA and other six beams are made with 10% and 20% recycled aggregate and compared to the 100% NCA beams.

D. Details specification and setting up of beams

The detail specification of beams is shown in Table 8. As all beams are simply supported over the dimension of 1000 mm length, 150 mm width and 150 mm overall depth and 2-10 mm diameter bars are provided at the top and bottom reinforcement and also 8 mm dia bars are provided for shear reinforcement at 90 mm centre to centre spacing. All beams were tested under two-point loading system. The experimental set up and placing of the beam has been shown in Fig 8. Two 30 mm diameter rollers were placed symmetrically over the beam at distance 1/3rd of the span from left and right side of the support.

The steel beam I section ISMB 300 is provided over the roller to transfer the load on the beam through rollers. Load cell with 100KN capacity is placed at the center of the I section. RCC beams by using recycled aggregate of geopolymer concrete can be tested after the curing age at 28 days. Three dial gauges were placed below the beam to measure deflection due to loading. First shear crack and peak load of all beams were observed and compared among all type of beams. Crack development on the surface of concrete beams was observed and also marked.

Fig.8. Experimental set up and placing of beam

Table-VIII: Details specification of normal aggregate and recycled aggregate beams

Mix	*GFF 0% RCA*	*GFF 10% RCA*	*GFF 20% RCA*
Beam dimension (mm)	1000mm length,150mm Width,150mm overall depth	1000mm length,150mm Width,150mm overall depth	1000mm length,150mm Width,150mm overall depth
Overall length (mm)	1000	1000	1000
Clear span (mm)	950	950	950
Width (mm)	150	150	150
Overall depth (mm)	150	150	150
Area of r/f (mm^2)	157	157	157

E. Behaviour of recycled aggregate based RCC beam specimens

All beam specimens are tested for flexure due to the application of load. The load is applied through two similar rollers mounted at the third part of surrounding span. The loads are divided equally between the two loading rollers and rollers are mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or resistance. When the load is applied to the beam, it started deflecting in the load direction and cracks start developing along the tension zone. For GFF0%, GFF10%, GFF20% RAC beam specimens failed in shear failure. The first cracking event was noted by the yielding of the tensile reinforcement. Concrete crushing started first connected with enlarging of concrete cover-up and break down of the compression zone.

F. Comparision of natural coarse aggregate and recycled aggregate based RCC beams

The load deflection behaviour for with and without recycled aggregate RCC beams are shown in Fig 9-12. All types of beams, load can be applied gradually at an interval of 2KN, first crack of all beams are observed, corresponding deflections and loads are also noticed. For GFF0% RCA, first crack was observed at 10KN, at 12KN load can gradually releases and at 13KN the specimen can failed under shear failure. GFF10% RCA and GFF20% RCA both are occurs first crack at 8 KN and finally specimens can failed12KN and 11KN respectively under shear failure. It can be observed that at a constant load, GFF0% RCA deflected more as compared to GFF10% and GFF20% RCA. The behaviour of recycled coarse aggregate than that of NCA are comparable but due to the presence of old adhered mortar, the beam with RCA become more porous and weak and cause micro gaps in transition zone, these factors create direct impact on RCA. The results indicate that proper treatment of RCA is required to enhance its strength.

G. Crack Pattern and mode of failure for beams containing with and without recycled aggregate:

For 0%, 10% and 20% recycled aggregate the beam specimens failed due to shear failure and some crack occurs due to vertical cracks. The cracks at the mid-span were wider close to the failure of the beam, and deflect a lot, so representing that the tensile stress has to have yielded failure. The last breakdown of the beams occurred when the concrete in the compression zone start crushing, accompanied by buckling of the compressive steel bars. The breakdown mode was characteristic of that of an under-reinforced concrete beam. Shear strength is the power of a substance or part relative to the type of yield or structural failure when the material or component breaks at shear. The shear load is a power that tends to cause descending failure in a substance all along a plane similar to the track of force. In simple terms, the shear stress is maximum at 45 degrees in the c/s of the beam, so the oblique cracks are a shear fracture. Failure and crack pattern of beam specimens are shown in Figure13.
Corresponding load, deflection, shear force, bending moment for NCA and RCA based RCC beams shown in Table 9.

Table- IX: Summary of corresponding load, deflection, shear

Mix	*GFF0% RCA*	*GFF10% RCA*	*GFF20% RCA*
Load at which first crack observed (KN)	10 KN	8 KN	8 KN
Corresponding	2.15	1.65	1.51
Corresponding	12.57	11.14	10.19
Peak load (KN)	13 KN	12 KN	11 KN
Shear force (KN)	6.5	6	5.5
Bending moment	2.6	2.4	2.2

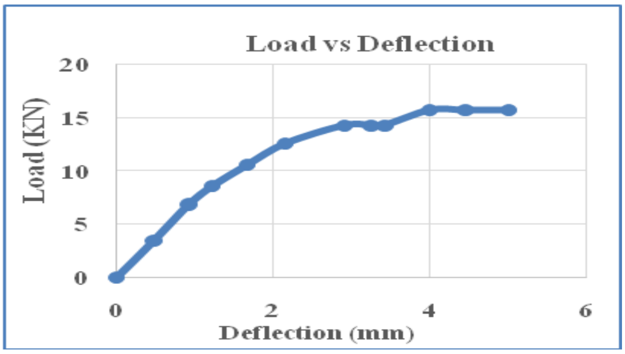

Fig.9. Load vs Deflection for GFF0% RCA beam

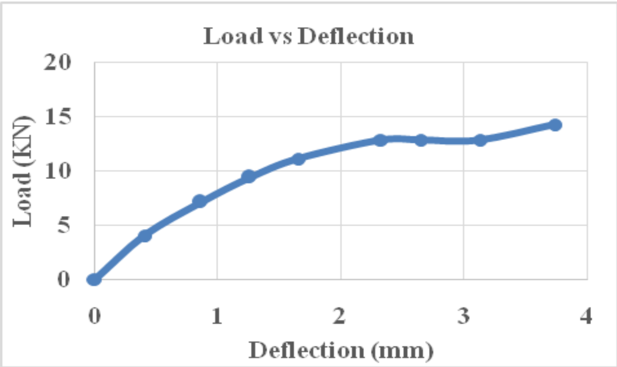

Fig.10. Load vs Deflection for GFF10% RCA beam

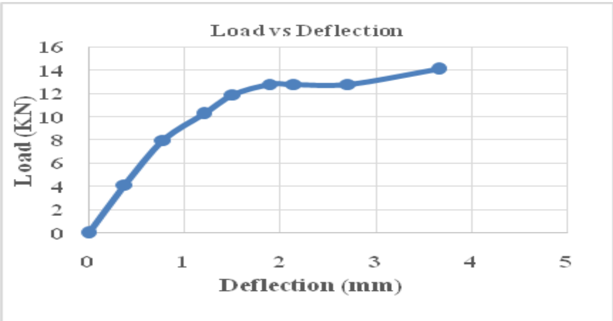

Fig.11. Load vs Deflection for GFF20% RCA beam

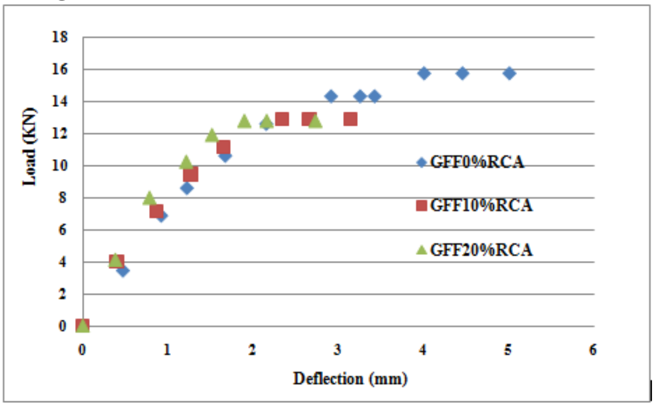

Fig.12: Comparision of NCA and RCA based RCC beam GFF20% RCA beams

Fig.13. Crack pattern and failure mode for RCA as well as NCA based beams

III. CONCLUSION

The paper studies the structural behavior of fly ash and ferrochrome ash based geopolymer concrete by using recycled aggregates as coarse aggregate. Beams were prepared with 0%, 10% and 20% as partial replacement by recycled aggregates and tested for flexures. From the test results obtained, following conclusions are deduced:

- All specimens failed due to shear failure since the length of the beam is so small. The entire beam shows good ductility and conveyed adequate warming before failure. Among the beam samples with recycled aggregates, specimen with 10% recycled aggregate provides maximum strength.
- Recycled aggregates, fly ash and ferrochrome ash, all three are waste materials used for making geopolymer concrete, experimental results revealed that the up to 10% replacement of recycle aggregate have comparable strength of natural coarse aggregate and it is the recommended percentage of RCA suitable in concrete industry.

REFERENCES

1. D.M. Sadek, S.K. Amin, and, N.F. Youssef, "Blended cement utilizing ceramic wall tiles Waste", *International Conference on Construction Materials and Structures (ICCMATS)*, (2014), pp. 152–161.

2. K.B.Najim, I.A. Jumaily, and A.M. Atea, “Characterization of sustainable high performance/self-compacting concrete produced using CKD as a cement replacement material”, Construction Building Materials, (2016), vol.103, pp.123–129.
3. P.B, Cachim, “Mechanical properties of brick aggregate concrete”, *Construction and Building Materials,* (2009), vol.23, pp 1292–1297.
4. J. Yang, D.Qiang, and B.Yiwang, “Concrete with recycled concrete aggregate and crushed clay bricks” *Construction and Building Materials,* (2011), Vol. 25, pp 1935–1945.
5. M. Braga, D. J. Brito, and R.Veiga “Incorporation of fine concrete aggregates in mortars”, *Construction and Building Materials,* (2012) , vol 36, pp 960–968.
6. 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.
7. M.A. Asamoah, 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..
8. D.J. Brito, A.S. Pereira, and J.R. Correia, “Mechanical behaviour of non-structural concrete made with recycled ceramic aggregates”. *Cement and Concrete Composites.,* (2005), vol 27 (4), pp 429-433.
9. A. Halicka, P. Ogrodnik, and A. Zegardlo, “Using ceramic sanitary ware waste as concrete Aggregate”,*Construction and Building Materials,* (2013),vol 48, pp 295–305.
10. C.Thomas, J. Setién, and J.A. Polanco, “Structural recycled aggregate concrete made with precast wastes”,Construction and Building Materials, (2016), vol 114, pp 536–546.
11. P. Duxson, J.L. Provis, G.C. Lukey, and V. Deventer, “The role of inorganic polymer technology in the development of green concrete”,*Cement Concrete Research,* (2007), vol 37 (12), pp 1590–1597.
12. K.A.Anuar, A.R.M. Ridzuan, and S.Ismail, “Strength characteristics of geopolymer concrete containing recycled concrete aggregate”, *Int. J.Civil Environ. Eng,* (2011), vol 11 (1), pp 59–62.
13. S.X. Shuang, W.Q. Yuan, Z.X. Ling, and C. Frank, “Discussion on properties and microstructure of geopolymer concrete containing fly ash and recycled aggregate”, Adv. Mater. Res, (2012), pp 450–451.
14. A. Akbarnezhad, M. Huan, S. Mesgari, and A. Castel, “Recycling of geopolymer concrete”,*Construction and Building Materials,* (2015), vol 101, 152–158.
15. T. Mohanty, “Utilization of industrial waste of normal and geopolymer concrete. PHD Thesis school of civil Engineerig, KIIT Deemed to be University, Bhubaneswar, Odisha, (2018).
16. P. Nuaklong, V. Sata, A. Wongsa, K. Srinavin, and P. Chindaprasirt, “Recycled aggregate high calcium fly ash geopolymer concrete with inclusion of OPC and nano-SiO_2” , *Construction and Building Materials,* (2018), vol 174, pp 244–252.
17. F.U.A. Shaikh, “Mechanical and durability properties of fly ash geopolymer concrete containing recycled coarse aggregates” International Journal of Sustainable Built Environment, (2016), vol 5, pp 277–287.
18. 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*, (2016),vol 34, 764-774.

AUTHORS PROFILE

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.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.