International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 10 | Oct 2020 www.irjet.net p-ISSN: 2395-0072

SYNTHESIS OF KUDREMUKH IRON ORE TAILING BASED GEOPOLYMER COARSE AGGREGATE USING FLY-ASH AS PRECURSOR IN THE CONSTRUCTION INDUSTRY-A CRITICAL REVIEW

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ABSTRACT*: Fact that the large-scale dumping of the mining and industrial waste causes the various environmental impacts and health diseases in human and animals. It was necessary to use the wastes in effective manner to prevent such environmental problems. Fly ash and iron ore tailings are the two major wastes of such kind. Even though these two wastes are using in the various sector, the utilisation of the waste is lesser than the waste generating. This study mainly concerns with the usage of fly-ash and iron ore tailings in construction industry in sustainable manner. Geopolymer coarse aggregates are synthesised by using the fly-ash and iron ore tailing with alkaline activator solution which activates geopolymeric source. The cubes of side 75*75*75 are prepared by mixing fly-ash and IOT in proportion 70:30 respectively with varying molarity of alkaline activator as 6M, 8M, 10M up to 12M. Compression test are carried out on the prepared cubes. It has observed that as increasing the molarity of alkaline activator the compressive strength also increases. 10M of Alkaline activator is used for the synthesis of geopolymer coarse aggregates. Aggregates are prepared by crushing of cubes. XRD and SEM analysis are preferred for the characterisation of raw materials.*

Key words: Geopolymer, IOT, Alkaline activator, aggregates, Molarity, Compressive strength.

1. INTRODUCTION

In the recent years, the production of the Steel has been increased to meet the demands of construction industry. This has resulted the large amount of iron ore tailing (IOT) and this is disposed in the rivers, quarries, oceans and in the landfills as wastes. It has estimated that there are 370 billion tons of unrefined Iron in the world. India is also one of the major producers of Iron. These tailings cause the various environmental problems. Fly ash is also one of such wastes producing by the thermal power plants although it has the cementitious properties it can be utilized in the construction industry. It was reported that use of such waste materials in concrete products will leads to the sustainable concrete and greener environment.

The recent studies shows that the iron ore tailing and fly-ash have the potential which can be utilised in the production of the concrete. Carrasco et al. [1] Studied characterization of mortars with iron ore tailing using the destructive and non-destructive test. Mortar mix analysed allowed for producing high strength mortar with the better performance in cracking and deformity. F.L. Da Silva et al. [2] Carried out the research on the using of IOT in the production of ceramic the results shown that 5% of IOT is highly feasible for the production of red ceramic, addition of IOT to the ceramic mass increases in the flexural strength and decreases density, water absorption. Joshi et al. [15] carried out the study on the fly-ash based geopolymer concrete and observed that compressive strength of geopolymer concrete increases with increase in the molar concentration of the alkaline activator solution. Average compressive strength is observed at 8M to 10M and 12M to 14M. Okoye et al. [8] carried out the research on the alkali activated fly-ash/kaolin based geopolymer concrete and observed that the compressive strength increases as increase in the temperature and curing time and type of alkali activator. Osinubi et al. [9] carried out the investigation on the Cement modification of tropical black clay using the iron ore tailing as the admixture and found that decrement in the fine fraction, shrinkage, plastic and liquid limits and increment in the dry density. Ravi Kumar C.M et al. [10] carried out the investigation on the Iron ore tailing based interlocking paver blocks and experimental values shown that 5 to15% usage of iron ore tailing increases the compressive strength than conventional concrete. Shetima et al. [15] carried out the study on the replacement fine aggregate by iron ore tailing. The workability reduces as increasing the IOT percentage and 25% of the IOT replacement gives the higher compressive strength compared to the conventional concrete. Talha Junaid et al. [6] studied the performance of fly-ash based geopolymer concrete made using non pelletized fly ash aggregates after exposure to the high temperature. Results shown that OPC losses the structural integrity substantially at the temperature over 40^0C. On the other hand, GPC retains over 60% of its strength and micro structure of GPC occur in the initial hours of exposure. Ugma et al. [19] carried out the study on the effect of the IOT on the concrete and concluded that workability decreases as increasing the percentage of IOT and 20% of IOT has no much difference than the concrete with river sand. In the use of Grounded iron ore tailings and $BaCO_3$ to improve the sulphate resistant paste, $BaCO_3$ and GIOT can improve the capacity of paste against to external sulphate attack, the paste interaction of $BaCO_3$ and GIOTs present the higher

sulphate resistance under both level of sulphate attacks [22]. Sintered fly-ash is used as light weight aggregate and possessed the higher water absorption, the durability properties of fly-ash aggregates concrete indicates that is satisfactory for the structural applications [7]. Iron ore tailing used as fine aggregates in the fly-ash based geopolymer mortar and Observed that setting time has been reduced due to the use of IOT in the production of the geopolymer mortar, compressive strength of geopolymer mortar with the natural sand and the iron ore tailing in the ranges from 2.9 to 4.9 MPa and 3.47 to 8.27 MPa respectively [14]. In developing the geopolymer concrete using the cold blonded fly-ash aggregates and nano silica and the steel fibre results showed that high compressive strength as high as 28.23 and 36.62 at 28 and 90 days respectively and 2% of nano silica and 1% of steel fibre were improve the investigated properties significantly [18]. Best performance is obtained for the composition with 40% tailing and 60% clay in the preparation of the construction bricks using the IOT and clay. These all researches ensure that IOT and Fly-ash are effectively used in the construction industry.

2. MATERIALS AND METHODOLOGY

Fly ash: Fly ash used is of class C type which is obtained by burning lignite. Which is also called high calcium fly ash as it contains more than 15% of calcium oxide. Fly ash has taken from KPCL Bellary thermal power station. By hydrometer analysis, fly ash consist of 74% of silt (0.074mm to 0.002mm), 24% of fine sand (0.075 to 0.424 mm) and 2% of clay (<0.002 mm).

Table 1: Fly ash properties

Property	Result
Specific gravity	2.21
Power of hydrogen (pH)	11.5
Electrical conductivity	729 µS/cm
Total dissolved solids	461 mg/L

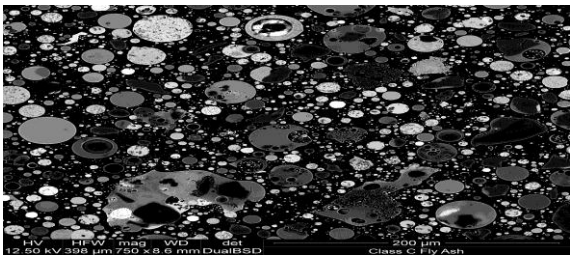

Fig 1: SEM image of fly ash

Iron ore tailing: Iron ore tailing has collected in Lakhya dam which is generated by Kudremukh Iron Ore Company Limited. Properties of iron ore tailing has found out. IOT has specific gravity of 3.16, pH of 9.56, electrical conductivity of 141µS/cm and it has the total dissolved solids 88.9 mg/l. Iron ore tailings contains the irregular shaped particles. In Fig 3 XRD pattern shows that quartz is the major mineral phase present in it.

Table 2: Physical properties of Iron ore tailings

Sl no	Properties	Values
1	Water content	1.2 %
2	Specific gravity	2.7
3	Maximum dry density	2.08 gm/cm^3
4	Optimum moisture content	14.34 %
5	Coefficient of Permeability	0.011 cm/sec
6	Bulk density	2.38 gm/cm^3
7	Fineness modulus	3.06

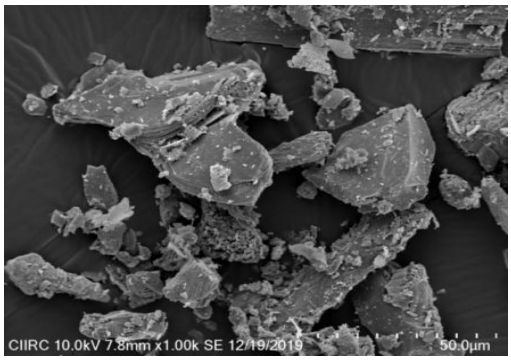

Fig 2: SEM image of IOT 100µm

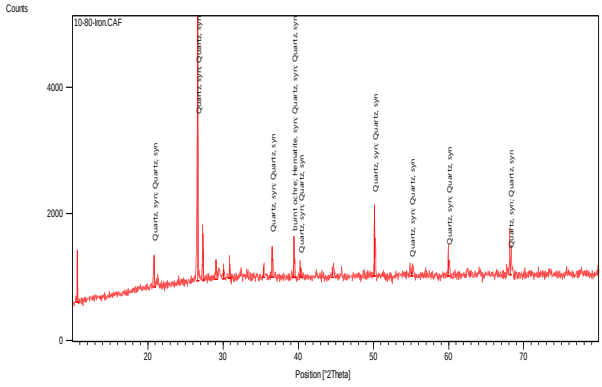

Fig 3: X Ray diffraction pattern of Iron Ore Tailings

A. Preparation of Alkaline activator: Alkaline activator solution is prepared using NaOH, Na_2SiO_3 and distilled water to avoid the mineral interference in required mix proportion. The weighted NaOH pellets are dissolved in the distilled water of certain weight to form NaOH solution then the mixing of weighed Na_2SiO_3 solution into it. The solution is

allowed to cool for the 24hours before using the solution in the mix. The solution is mixed for the different molar concentration as 6M, 8M, 10M up to 12M. The quantity of the chemical required for 1Molar is as below. Alkaline activator will activate the geopolymeric source when it reacts with fly ash and iron ore tailings.

Example for one molar, for one litre solution:

Distilled water =1 litre

Sodium hydroxide = 1 x 40 x 1 = 40 gms

Sodium silicate = 1 x 122 x 1 =122 gms

The distilled water has been measured for the required quantity, NaOH pellets are mixed with the distilled water and stirred properly to avoid the solidification at the bottom of the container. Na_2SiO_3 is added to the prepared solution this process is exothermic releases the heat more than 50^0 to 60^0 C. Nature of solution is soapy. Proper care and precaution should be taken while preparing solution because if even one drop of solution comes in contact with skin it may cause irritation.

B. Fixing of the optimum molar concentration of Alkaline activator:

Prepared the cubes of 75*75*75 mm by using the fly ash and iron ore tailing with the proportion 70:30 respectively. With the prepared Alkaline activator solution. Prepared 3 cubes for each molarity of Alkaline activator. Carried out the compressive test on the prepared cubes to find out the maximum strength among the cubes. Respective Molarity of alkaline solution of the cube with maximum compressive strength is used to preparation of the Geopolymer coarse aggregate. Here as increasing the molarity of Alkaline activator solution, the strength also increases gradually. 10M of alkaline activator solution is used for the preparation of geopolymer coarse aggregates.

fig 4: 75mm cubes of different molarity

Fig 5: compression testing of cubes

Fig 6: cube after compression

C. Preparation of Geopolymer coarse aggregates:

Alkaline activator is prepared for 10M by mixing of NaOH and Na_2SO_3 with a distilled water. Required quantity of the fly-ash and iron ore tailing was weighed. Fly ash and IOT has mixed with the alkaline activator solution. Mixing was carried out by hand with proper care and precaution. Prepared slurry was added to the mould of 150mm side and the cubes are allowed for the oven curing for 4 hours at 100^0 C and demoulded later. Those cubes are kept outside for a week to gain the strength in a dry atmospheric condition then the aggregates prepared by crushing of the cubes after a week. Obtained the various sizes of coarse aggregates. Those aggregates are used for the preparation of concrete.

3. RESULT AND DISCUSSIONS

Tests on Geopolymer coarse aggregates

The Prepared geopolymer coarse aggregates are tested and compared with the natural aggregates and the test results are reported in the table 3. The water absorption gives the idea of the strength of aggregates and aggregates are more porous as having more water absorption compared to natural aggregates. Results shows that geopolymer aggregates has more impact value than natural aggregates. According to IS code the if impact value lies between the 30-45% those are considered as the good quality aggregates. The crushing values of good quality aggregates should be lie below 30-40 %.

Table 3: Comparison of test results of Geopolymer coarse aggregates and Natural coarse aggregates

Sl. no	Tests conducted	Geopolymer Coarse Aggregates	Natural Coarse Aggregates
1	Specific gravity	1.91	2.73
2	Water absorption	7.08%	0.35%
3	Impact strength	28.32%	15.39%
4	Crushing strength	23.96%	17.82%
5	Apparent specific gravity	2.05	2.5

Tests on the concrete with partial and fully replacement of NA with GPA:

The natural aggregates replaced by the geopolymer aggregates as 100:0, 70:30, 60:40 etc. and the concrete has prepared for the different proportion of GPA and NA. Cubes are prepared and cured for the required number of days and compressive strength has been checked. The maximum strength observed at ratio of 60:40.

Table 4: compressive strength values of concrete with different ratio of GCA and NCA

Sl.No	GCA:NCA	Age of M40 concrete in Days	Average Compressive Strength (N/mm^2)
1	100:0	7 21 28	13.26 18.67 22.42
2	70:30	7 21 28	19.51 26.70 29.48
3	60:40	7 21 28	27.64 35.68 38.42
4	50:50	7 21 28	22.14 29.32 31.60

4. CONCLUSIONS

This paper presents the synthesis of iron ore tailing based geopolymer coarse aggregates using fly-ash as the precursor in the constructions in the industry on the synthesised geopolymer aggregates, water absorption, specific gravity, and apparent specific gravity impact value test and crushing value test were conducted and the results were compared with the natural coarse aggregates. Following conclusion were made:

1) Fly ash has the pH value of 11.6.its shows that the fly-ash is Alkaline in nature

2) By hydrometer analysis, fly ash contains 24% of sand content, 74% of silt content and 2% of clay content

3) Specific gravity of geopolymer coarse aggregates is 1.90 shows that the aggregates are light in weight.

4) Geopolymer aggregates gives the 24 % of crushing value and 28% of impact value shows the lesser value than the natural aggregates.

5) The water absorption of geopolymer aggregates is 7.07 % which is more than the IS specification.

6) The good compressive strength has obtained in concrete of 40% replacement of natural aggregates with GPA.

AKNOWLEDGEMENT

The author is grateful to Kudremukh Iron Ore Company Limited (KIOCL). Bengaluru., Karnataka and Ministry of Steel for procurement of Iron ore tailings and Bellary thermal power station (BTPS), KPCL Bellary, Karnataka for providing the fly-ash to carry out the research work. This project is supported by Kudremukh Iron Ore Company Limited (KIOCL) and Ministry of Steel.

REFERENCES

1. Carrasco, E. V. M., Magalhaes, M. D. C., Santos, W. J. D., Alves, R. C., & Mantilla, J. N. R. (2017). "Characterization of mortars with iron ore tailings using destructive and non-destructive tests".Construction and Building Materials,131,31–38. https://doi.org/10.1016/j.conbuildmat.2016.11.065

2. Da Silva, F. L., Araújo, F. G. S., Teixeira, M. P., Gomes, R. C., & Von Krüger, F. L. (2014). "Study of the recovery and recycling of tailings from the concentration of iron ore for the production of ceramic". Ceramics International, 40(PB), 16085–16089. https://doi.org/10.1016/j.ceramint.2014.07.145

3. Junaid, M. T., Khennane, A., & Kayali, O. (2015). "Performance of fly ash based geopolymer concrete made using non-pelletized fly ash aggregates after exposure to high temperatures". Materials and Structures/ Materiaux et Constructions, 48(10), 3357–3365. https://doi.org/10.1617/s11527-014-0404-6

4. Kathirvel, P., & Kaliyaperumal, S. R. M. (2016). "Influence of recycled concrete aggregates on the flexural properties of reinforced alkali activated slag concrete". Construction and Building Materials, 102, 51–58. https://doi.org/10.1016/j.conbuildmat.2015.10.148

5. Khan, M. S. H., Castel, A., Akbarnezhad, A., Foster, S. J., & Smith, M. (2016). "Utilisation of steel furnace slag coarse aggregate in a low calcium fly ash geopolymer concrete". Cement and Concrete Research, 89, 220–229. https://doi.org/10.1016/j.cemconres.2016.09.001

6. .Talha Junaid, Amar Khennane and Obada Kayali. (2014) "Performance of flyash based Geopolymer concrete made using non Peletized flyash aggregates after exposure to high temperatures". Materials and structures.

7. Nadesan, M. S., & Dinakar, P. (2017). "Structural concrete using sintered flyash lightweight aggregate: A review". Construction and Building Materials, 154, 928–944. https://doi.org/10.1016/j.conbuildmat.2017.08.005

8. Nuaklong, P., Sata, V., & Chindaprasirt, P. (2018). "Properties of metakaolin-high calcium fly ash geopolymer concrete containing recycled aggregate from crushed concrete specimens". Construction and Building Materials, 161, 365–373. https://doi.org/10.1016/j.conbuildmat.2017.11.152

9. Okoye, F. N., Durgaprasad, J., & Singh, N. B. (2015). "Mechanical properties of alkali activated flyash/Kaolin based geopolymer concrete". Construction and Building Materials, 98, 685–691. https://doi.org/10.1016/j.conbuildmat.2015.08.009

10. Osinubi, K. J., Yohanna, P., & Eberemu, A. O. (2015). "Cement modification of tropical black clay using iron ore tailings as admixture". Transportation Geotechnics, 5, 35–49. https://doi.org/10.1016/j.trgeo.2015.10.001

11. Ravi Kumar, C. M., Kumar, A., Prashanth, M. H., & Reddy, D. V. (2012). "Experimental studies on Iron-ore tailing based interlocking paver blocks". International Journal of Earth Sciences and Engineering, 5(3), 501–504.

12. Shaikh, F. U. A. (2016). "Mechanical and durability properties of fly ash geopolymer concrete containing recycled coarse aggregates". International Journal of Sustainable Built Environment, 5(2), 277–287. https://doi.org/10.1016/j.ijsbe.2016.05.009

13. Shankar, A. U. R. (2017). "A Study on Utilization of Iron Ore Tailings as Partial Replacement for Fine Aggregates in the Construction of Rigid Pavements A Study on Utilization of Iron Ore Tailings as Partial Replacement for Fine Aggregates in the Construction of Rigid Pavements". Procedia Engineering, July 2018.

14. Sharath, B. P., Shivaprasad, K. N., Athikkal, M. M., & Das, B. B. (2018). "Some Studies on Sustainable Utilization of Iron Ore Tailing (IOT) as Fine Aggregates in Fly Ash Based Geopolymer Mortar". IOP Conference Series: Materials Science and Engineering, 431(9). https://doi.org/10.1088/1757899X/431/9/092010

15. Shettima, A. U., Hussin, M. W., Ahmad, Y., & Mirza, J. (2016). "Evaluation of iron ore tailings as replacement for fine aggregate in concrete". Construction and Building Materials, 120, 72–79. https://doi.org/10.1016/j.conbuildmat.2016.05.095

16. S V Joshi, M.S kadu. (2012) "Role of Alkaline activator in development of eco-friendly fly ash based Geopolymer concrete", international journal of environmental science and development vol.3, no.5, pp.417-421

17. Temuujin, J., Minjigmaa, A., Davaabal, B., Bayarzul, U., Ankhtuya, A., Jadambaa, T., & Mackenzie, K. J. D. (2014). "Utilization of radioactive high-calcium Mongolian flyash for the preparation of alkali-activated geopolymers for safe use as construction materials". Ceramics International, 40(PB), 16475–16483. https://doi.org/10.1016/j.ceramint.2014.07.157

18. Their, J. M., & Özakça, M. (2018). "Developing geopolymer concrete by using cold-bonded fly ash aggregate, nano-silica, and steel fiber". Construction and Building Materials, 180, 12–22. https://doi.org/10.1016/j.conbuildmat.2018.05.274

19. T.I. Ugama, S.P. Ejeh,D,Y Amartey. (2014) "Effect of iron ore tailing on the properties of the concrete".ISSN vol.6, no 10

20. Tiwari, S., Rai, A., & Bajpai, Y. K. (2017). Effect of Iron Ore Tailing on the Flexural Strength. 5(Xii), 2773–2778.

21. Wang, C. L., Ni, W., Zhang, S. Q., Wang, S., Gai, G. S., & Wang, W. K. (2016). "Preparation and properties of autoclaved aerated concrete using coal gangue and iron ore tailings". Construction and Building Materials, 104, 109–115. https://doi.org/10.1016/j.conbuildmat.2015.12.041

22. Xiong, C., Li, W., Jiang, L., Wang, W., & Guo, Q. (2017). "Use of grounded iron ore tailings (GIOTs) and BaCO3 to improve sulfate resistance of pastes". Construction and Building Materials, 150, 66–76. https://doi.org/10.1016/j.conbuildmat.2017.05.209

23. Young, G., & Yang, M. (2019). "Preparation and characterization of Portland cement clinker from iron ore tailings". Construction and Building Materials, 197, 152–156. https://doi.org/10.1016/j.conbuildmat.2018.11.236

24. Zuccheratte, A. C. V., Freire, C. B., & Lameiras, F. S. (2017). "Synthetic gravel for concrete obtained from sandy iron ore tailing and recycled polyethyltherephtalate". Construction and Building Materials, 151, 859–865. https://doi.org/10.1016/j.conbuildmat.2017.06.133

IS CODES

1. IS:383-1970, "Specification for Coarse Aggregate and Fine Aggregates from Natural Sources for Concrete", Bureau of Indian Standards, New Delhi
2. IS:456-2000, "Indian Standard Code of Practice for Plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi
3. IS:10262-2009, "Indian Standard Code for Guidelines of Concrete Mix Proportioning", Bureau of Indian Standards, New Delhi