ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

EXPERIMENTAL ANALYSIS OF FLY ASH SLAG BASED GEOPOLYMER CONCRETE WITH PARTIALLY REPLACED RECYCLED COARSE AGGREGATE

NELLA SHIVA KUMAR[1], GONE PUNNESHWAR[2]

[1]M. Tech (Structural Engineering), Department of Civil Engineering, CMR Institute of Technology kandlakoya,medchal road, Hyderabad, Telangana, 501401, India

[2]M. Tech (Structural Engineering), Department of Civil Engineering, CMR Institute of Technology kandlakoya,medchal road, Hyderabad, Telangana, 501401, India

ABSTRACT

Recycled coarse Aggregate (RCA) is sourced from local construction and demolition waste. The RCA is used as a partial replacement of natural coarse aggregate (NCA) in fly ash slag based geo polymer concrete at 0%, 10% , 20% , 30% , 40% and 50% by wt. While the fly ash slag based geopolymer concrete containing 100% NCA is control and is considered as the first series. Fly ash & GGBS is used as the source material for the geo polymer and 10 M sodium hydroxide and sodium silicate alkali activators are used to synthesize the fly ash slag based geopolymer in this study. In all replacements a constant alkali activator to fly ash ratio is used. Compressive strength, tensile strength and elastic modulus of above geo polymer concrete are measured at 7 , 28 and 56 days, while sorptivity, immersed water absorption and volume of permeable voids of above geopolymer concrete are measured at 28 days.

Results show that the compressive strength, tensile strength and elastic modulus of geo polymer concrete decrease with an increase in RCA contents, which is also true for both 7 and 28 days. Relation between compressive strength with indirect tensile strength and elastic modulus are also observed in fly ash slag based geo polymer concrete containing RCA . Natural coarse aggregates does not give proper relations of indirect tensile strength , elastic modulus, respectively of fly ash slag based geo polymer concrete containing RCA. .

Keywords: Geopolymer; Fly ash & ground granulated blast furnace slag; Recycled coarse aggregate; Construction and demolition waste; Mechanical properties and durability properties

I.INTRODUCTION

Concrete is the second most consumed material apart from water. Despite current global financial crisis resulting in reduced demand for construction materials, a long term projection is that by 2030 the concrete industry is expected to have grown roughly five times larger than in 1990, with close to five billion tones sold annually worldwide. Concern about human induced climate change and its impacts are increasing. It is a manmade product, essentially consisting of a mixture of cement, aggregates ,water and admixtures . Sand, crushed stone or gravel form the major part of the aggregate. These materials are blended in required proportions according to the strength parameter and grade of concrete.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

On the other hand the disposal of construction and demolished waste is also been a major environmental issue that has prompted many researchers worldwide to investigate new means of recycling it , with the aim of alleviating the pressure on the scare landfill space available and also asa means to reduce the current reliance on natural aggregates and minerals . Given that coarse and fine aggregates occupy 75-80 % of recycled coarsed aggregates (RCA) has huge potential. Although this is not a new concept , many researchers around the world have investigated the resulting properties and there is wide arrangement that the concrete containing RCA represents inferior properties compared to conventional concrete incorporating natural aggregates estimates an average consumption of aggregate , the incorporation of C&D waste as substitute to natural coarse aggregates in concrete has many economic and environmental benefits.

RECYCLED COARSE AGGREGATES (RCA)

The quality of the recycled aggregates has been improved significantly during the last decade as a result of good deconstruction practice and advances in stationary or transportable crushing machinery, as well as the recycling process itself *i.e* .screening and separation. As a result, improved quality aggregates are available now-a-days, at prices competitive to NA. However, despite the enhanced quality of the recycled aggregates, the uptake of this alternative is still in fact too low(Dhir 2001; Wrap 2007).this limited use is largely due to the past experience formed when low strength cements and low quality recycled aggregates were used as well as the restrictions imposed by standards. Therefore, in view of current concreting technologies and advances in materials production, there is a need to reform the negative impression, prevalent for a relatively longtime, to increase the use of recycled aggregates in construction.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

AGGREGATES

S. No	Property	Method	Fine Aggregate	Coarse Aggregate	Recycled Aggregrate
1	Specific Gravity	Pycnometer IS:2386 Part 3 - 1986	2.6	2.77	2.45
2	Bulk Density (Kg/m^3)	IS:2386 Part 3 - 1986	1600	1650	1800
3	Fineness Modulus	Sieve Analysis (IS:2386 Part 2 - 1963)	3.07	6.7	7.6

COMPARISION OF RECYCLED AND NATURAL AGGREGATES

1.Property	Natural aggregate	Recycled aggregate
Texture	Natural aggregate is smooth and rounded compact aggregate.	Recycled aggregate has the rough – textured, angular and elongated particles. The rough – texture, angular and elongated particles require much water
Quality	The quality of natural aggregate is based on the physical and chemical properties of sources sites.	The quality of recycled aggregate is depended on contamination of debris sources.
Density	Natural aggregate has higher density compared to recycled aggregate.	Recycled concrete aggregate have lower density because of the porous and less dense residual mortar lumps that is adhering to the surfaces.
Strength	Strength of natural aggregate is higher than recycled aggregate.	The strength of recycled aggregate is lower than natural aggregate. This is due to the weight of recycled aggregate is lighter than natural aggregate. This is the general effect that will reduce the strength of reinforcement concrete.
Location	Natural aggregate are derived from a variety of rock sources. The processing plant for natural aggregate depends on the resource. It usually occurs at the mining site and outside the city.	Recycled aggregate are derived from debris of building constructions and roads. The locations of recycling plants are depended on where the structures are demolished. The recycling process is often located in the urban area.

GEOPOLYMER CONCRETE

In the context of increased awareness regarding the ill-effects of the over exploitation of natural resources, eco-friendly technologies are to be developed for effective management of these resources. Construction industry is one of the major users of the natural resources like cement, sand, rocks, clays and other soils. The ever increasing unit cost of the usual ingredients of concrete have forced the construction engineer to think of ways and means of

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

reducing the unit const of its production. At the same time, increased industrial activity in the core sectors like energy, steel and transportation has been responsible for the production of large amounts like fly ash, blast furnace slag, silica fume and quarry dust with consequent disposal problem..

Materials Required For Geopolymer Concrete

- **Cementitious binder**

Various industrial by-products and naturally available materials can be used to produce geopolymer concrete. Commonly used cementitious binders are fly ash, GGBS, silica fume, Metakaolin, rice husk ash, etc.

- **Alkaline activators:**

Alkaline activators are the important ingredient of geopolymer mix, it undergoes geopolymerisation and gives binding property by igniting the Al and Si present in the cementitious binder. It mainly uses high pH activators like combination of sodium hydroxide or potassium hydroxide and sodium silicate or potassium silicate.

NaOH

The sodium hydroxide (NaOH) with 97-98% purity, is generally available in flake or pellet form. These pellets are dissolved in water to make a solution with the required concentration. Concentration of NaOH solution can vary however, 8 Molar solutions are adequate for most applications. The mass of NaOH solids in a solution varies depending on the concentration of the solution. For

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

instance, NaOH solution with a concentration of 8 Molar consists of 8x40 = 320 grams of NaOH solids per litre of the solution, where 40 is the molecular weight of NaOH. Remember that mass of water is the major component in both the alkaline solutions.

Figure 3.15 NaOH flakes

S.No	Property	Test Result
1	Specific gravity	1.52
2	Bulk Density (Kg/m³)	2130
3	pH	14

Na_2SiO_3

Sodium silicate is also called as water glass or liquid glass , these materials are available in aqueous solution and in solid form. The present composition are colourless or white , but commercial samples are green or blue in colour due to presence of impurities.

These solution is commercially available in different grades in market. The sodium silicate solution A53 with silicon dioxide to sodium oxide ratio by mass of approximately 2, i.e., SiO_2 = 29.4%, Na_2O = 14.7%, and water = 55.9% by mass, is generally used.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

Na_2SiO_3solution

Sl.No	Property	Test Result
1	BULK DENSITY(Kg/m^3)	2600
2	COLOUR	WHITE TO GREEN OPAQUE

Properties of Na_2SiO_3

- **Aggregates:**
  Aggregates used to produce geopolymer concrete should be chosen and tested as per IS standards.
- **Super plasticizer:**
  This is used in concrete to accelerate or decelerate the setting time and also to attain good workability conditions in a concrete
  The geopolymer concrete mix was prepared as follows

Aims and Objectives:

The main objective of project is as follows:

1. To obtain the fresh concrete properties of Natural Aggregate and various proportions Recycled Aggregate (slump, compaction factor, stability and air content tests)
2. To evaluate the mechanical properties of Recycled Aggregate Concrete.

3. To determine strengths of the Recycled Aggregate Concrete with different proportions (0%, 25%, 50%, 75%, 100%).

4. To compare the strength characteristics of Natural Aggregate Concrete and Recycled Aggregate Concrete.

Scope of the Present Work:

The scope of this project:

The project is proposed to cast the specimens of natural and recycled aggregate concrete, of (0%, 25%, 50%, 75%, and 100%) proportions. Cubes (150mm x 150mm x 150mm), Cylinders (150mm dia x 300mm height), Beams (150mm x 150mm x 700mm) by using natural and recycled aggregate, which will give a better understanding on the properties of concrete with RAC.

- Each proportion of concrete consists of 12 cubes, 8 cylinders and 2 prisms by using natural and recycled aggregate concrete. Total number of specimens prepared using natural and recycled aggregate is 110 specimens.
- Investigation and laboratory testing on high strength concrete with recycled aggregate.
- Analyze the results and recommendation for further research area.

II. LITERATURE REVIEW

Tavakoli (1996) , the strength characteristics of recycled aggregate concrete were influenced by the strength of the original concrete, the ratio of coarse aggregate to fine aggregate in the original concrete, and the ratio of top size of the aggregate in the original concrete in the recycled aggregate. He also mentioned that water absorption and Los Angeles abrasion loss will influence the water cement ratio and top size ratio for the strength characteristic of recycled aggregate.

Davidovits J and Sawyer J L, used ground blast furnace slag to produce geopolymer binders. This type of binders patented in the USA under the title Early High-Strength Mineral Polymer was used as a supplementary cementing material in the production of precast concrete products. In addition, a ready-made mortar package that required only the addition of mixing water to produce a durable and very rapid strength gaining material was produced and utilized in restoration of concrete airport runways, aprons and taxiways, highway and bridge decks, and for several new constructions when high early strength was needed. Geopolymer has also been used to replace organic polymer as an adhesive in strengthening structural members. Geopolymers were found to be fire resistant and durable under UV light.

Ganapati Naidu.et presented in this paper to study strength properties of geopolymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Higher concentrations of GGBS result in higher compressive strength of geopolymer concrete 90% of compressive strength was achieved in 14 days

Joseph Davidovits , proposed a new type of concrete without Portland cement which is called as geopolymer concrete. Geopolymer, an inorganic alumina-silicate polymer, is synthesized from predominantly silicon (Si) and aluminium (Al) material of geological origin or by-product material. The chemical composition of geopolymer materials is similar to zeolite, but they reveal an amorphous microstructure. During the synthesized process, silicon

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

and aluminium atoms are combined to form the building blocks that are chemically and structurally comparable to those binding the natural rocks. Geopolymer cements are acid resistant cementitious materials with zeolitic properties developed for the long term containment of hazardous and toxic wastes. Geo polymer even with alkali contents as high as 9.2% and higher which do not generate any dangerous alkali aggregate reaction. Addition of GGBS accelerates the setting time of concrete and improves compressive and flexural strength of geo polymer concrete.

III. METHODOLOGY AND RESULTS

DESIGN OF ORDINARY PORTLAND CEMENT FOR M_{50} GRADE

The proportioning of concrete mix is a process by which one arrives at the right combination of cement, aggregates, water and admixtures for making concrete according to the given specifications. Main reason of mix proportioning is to produce a product that will perform according to certain determined requirements, the most essential requirements being the workability of fresh concrete, and strength and durability of hardened concrete.

Target mean strength from IS 10262:2009 taken as follows:

	Cement	F.A	C.A	Water	Super plasticizer
Ratio	1	1.51	2.27	0.27	0.03

RATIO: - Cement: fine aggregate: coarse aggregate = 1:1.51:2.27

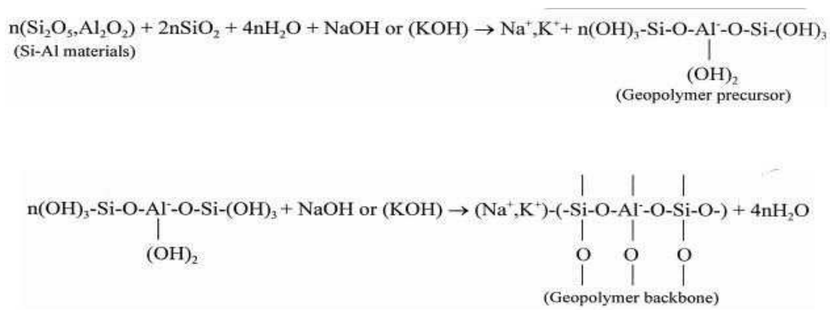
DESIGN OF GEOPOLYMER CONCRETE MIXTURES

The Indian Standard (IS) mix design procedure of normal strength concrete is not suitable for design of GPC using admixtures. The American Concrete Institute (ACI) mix design method available for high strength concrete considers only the use of fly ash and super plasticizer. Since there is no specific method of mix design found suitable for GPC by incorporating all these mineral admixtures like fly ash, GGBS and silica fume, a simplified preliminary mix design procedure was formulated by combining the IS method, ACI method of mix design for high strength concrete and the available literatures. The same has been used to arrive at a mix proportion

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

for the control mix of grade M_{60} and the proportioning was adjusted for various combinations of admixtures by simple cement replacement method.



(1)

(2)

Making the Parameters Constant in Mix Design

- Density of concrete 2400Kg/m^3
- Alkaline liquid to GGBS &Fly Ash ratio = 0.3
- Sodium Silicate to Sodium Hydroxide ratio = 3.0
- Morality= 10 M
- Rest Period = 1day
- Admixture Dosage = 3 %
- Water to binder ratio = 0.162

QUANTITY OF MATERIAL REQUIRED TO PRODUCE M_{50} GRADE CONCRETE

	OPC (Kg/m³)	GPC (Kg/m³)
Cement	493	-
GGBS	-	121.84
FLY ASH	-	284.30
Fine Aggregate	747.94	561.6
Coarse aggregate	1122	917.26
Recycled coarse aggregate	-	393.12
NaOH	-	30.46
Na_2SiO_3	-	91.39
Water	133	30.0
Super plasticizer	14.79	12.8

Material requirements for 1 m³

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

Water to Geo polymer binder ratio

Water to geo polymer binder ratio plays an important role in finding out the design compressive strength . As per B V Vijaya Rangan , he gave a relation between water to geopolymer binder ratio , workability and design compressive strength . As the W/GS ratio increases compressive strength decreases similarly workability will be high as the water to binder ratio increases for example consider W/GS =0.16 workability is very stiff & compressive strength shows 60 MPa from the graph and table .

Water to Geo polymer Solids ratio by mass	Workability	Design Compressive Strength (MPa)
0.16	Very Stiff	60
0.18	Stiff	50
0.20	Moderate	40
0.22	High	35
0.24	High	30

Water to GS ratio v workability v compressive strength

Additional water may be added if required in order to increase the workability of geo polymer concrete but the additional water in geo polymer concrete does not play any role in concrete as in ordinary Portland cement. Here the role is limited to increase the workability but does not have any role of hydration or does not make any reactions. [5] proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction. Utilizing the versatile back venturing method, every one of the six DOF are effectively followed utilizing just four control inputs while within the sight of un demonstrated flow and limited unsettling influences. Elements and speed vectors

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

were thought to be inaccessible, along these lines a NN eyewitness was intended to recoup the limitless states. At that point, a novel NN virtual control structure which permitted the craved translational speeds to be controlled utilizing the pitch and the move of the UAV. At long last, a NN was used in the figuring of the real control inputs for the UAV dynamic framework. Utilizing Lyapunov systems, it was demonstrated that the estimation blunders of each NN, the spectator, Virtual controller, and the position, introduction, and speed following mistakes were all SGUUB while unwinding the partition Principle.

Sl.No	Molarity	$Na_2SiO_3/NaOH$	Extra water (Kg/m^3)
1	8	1.0	19.23
2		1.5	22.41
3		2.0	24.57
4	10	1.0	22.42
5		1.5	25.04
6		2.0	26.74
7	12	1.0	25.55
8		1.5	27.47
9		2.0	28.76
10	13	1.0	27.88
11		1.5	28.96
12		2.0	30.01

Morality v extra water

Mix proportions of fly ash slag GPC containing RCA

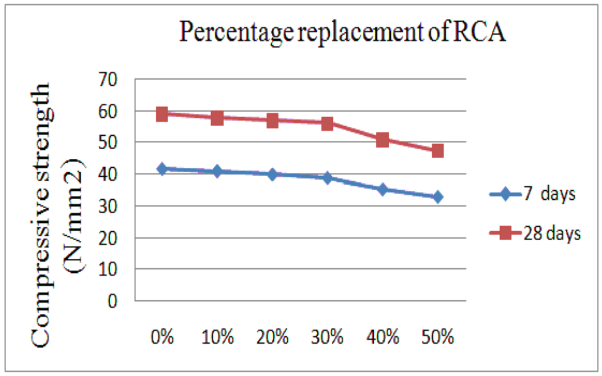
%Replacement RCA	GGBS + FLY ASH	Fine Aggregates	Coarse Aggregate	Recycled CA	Water	NaOH	Na_2SiO_3	Super plasticizer
0%	1	1.38	3.22	0	0.07	0.07	0.22	0.03
10%	1	1.38	2.90	0.32	0.07	0.07	0.22	0.03
20%	1	1.38	2.58	0.64	0.07	0.07	0.22	0.03
30%	1	1.38	2.25	0.96	0.07	0.07	0.22	0.03
40%	1	1.38	1.93	1.29	0.07	0.07	0.22	0.03
50%	1	1.38	1.61	1.61	0.07	0.07	0.22	0.03

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

Compresssive Strength of FA SLAG GPC RCA at Different Proportions

	0%	10%	20%	30%	40%	50%
7days (N/mm²)	41.75	41.1	40.0	38.9	35.3	32.9
28days (N/mm²)	58.9	57.6	57.0	56.1	50.9	47.44



COMPARISION OF OPC & % RCA REPLACED GPC COMPRESSIVE STRENGTHS

	7days (N/mm²)	28days (N/mm²)
30% RCA replaced GPC	38.9	56.1
OPC M_{50} GRADE	35.6	54.2

REFERENCES

[1] Bakharev, T. (2005a). Durability of geopolymer materials in sodium and magnesium sulfate solutions. Cement And Concrete Research, 35(6), 1233-1246.

[2] Bakharev, T. (2005b). Geopolymeric materials prepared using Class F fly ash and elevated temperature curing. Cement And Concrete Research, 35(6), 12241232.

[3] Bakharev, T. (2005c). Resistance of geopolymer materials to acid attack. Cement And Concrete Research, 35(4), 658-670.

[4] Balaguru, P., Kurtz, S., & Rudolph, J. (1997). Geopolymer for Repair and Rehabilitation of Reinforced Concrete Beams. The Geopolymer Institute. Retrieved 3 April, 2002, from the World Wide Web: www.geopolymer.org

[5] Christo Ananth,"A Novel NN Output Feedback Control Law For Quad Rotor UAV",International Journal of Advanced Research in Innovative Discoveries in Engineering and Applications[IJARIDEA],Volume 2,Issue 1,February 2017,pp:18-26.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

[6] Comrie, D. C., Paterson, J. H., & Ritchey, D. J. (1988). Geopolymer Technologies inToxic Waste Management. Paper presented at the Geopolymer ’88, First European Conference on Soft Mineralurgy, Compiegne, France.

[7] B. Nematollahi and J. Sanjayan, "Effect of Superplasticizers on Workability of Fly Ash Based Geopolymer," pp. 713-719, 2014.

[8] P. J. Lloyd RR, van Deventer JSJ., "Microscopy and microanalysis of inorganic polymer cements. 1: remnant fly ash particles," J Mat Sci, vol. 44, pp. 608–19. , 2009.

[9] S. H. Guo X, Chen L, Dick WA. , "Alkali-activated complex binders from Class C fly ash and Ca-containing admixtures," J Hazard Mater vol. 173, pp. 480–6, 2010.

[10] v. R. A. Temuujin J, Williams R. , "Influence of calcium compounds on the mechanical properties of fly ash geopolymer pastes," J Hazard Mater, vol. 167, pp. 82–8., 2009.