Strength Properties of the Geopolymer Concrete as Partial Replacement of Recycled Aggregate

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Abstract – Due to the critical shortage of natural aggregate, the availability of demolished concrete for use as recycled concrete aggregate (RCA) is increasing. Using the waste concrete as RCA conserves natural aggregate, reduces the impact on landfills, decreases energy consumption and can provide cost savings. Recycled aggregates are the materials for the future. The application of recycled aggregate has been started in many countries for construction projects. This Research Paper reports the basic properties of recycled coarse aggregate. It also compares these properties with natural aggregates. Basic changes in all aggregate properties were determined. Basic concrete properties like compressive strength, workability etc. are explained here for different combinations of recycled course aggregate with natural aggregate. In general, present status & utilization of recycled coarse aggregate in India with their future need is discussed.

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 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.

Index Terms – Recycled Course Aggregate, Recycled Course Aggregate Concrete, Compressive Strength, Workability.

1. INTRODUCTION

Cement is only a constituent of concrete and global emissions estimates have not been made for the concrete industry but the author would estimate this to be in the range of 10 to 14 percent. The growth of the concrete industry is being fuelled by key world economics resulting in an increased demand for construction materials, in particular concrete. An average concrete mix requires approximately 350kgs of cement per cubic meter, the heavy usage of cement in concrete resulted in the increase of carbondioxde in the world. It is widely accepted that concrete is the most extensively used construction material. Currently, the world production of concrete is about one tone per year for every living person.

2. RECYCLED COARSEAGGREGATES (RCA)

Recycled coarse aggregates are obtained from the construction demolished waste which requires huge land to dispose off. Instead disposing we try to replace natural aggregates in different proportions. These may does not give the total strength if we use entire aggregates as replacement

FIG 1 : RCA

The utilization of the recycled aggregates created from processing C&DW in new construction has become more important over the last two decades. There are many factors contributing to this, from the availability of new material and the damage caused by the quarrying of NA and the increased disposal of costs of waste materials. C&DW are generated mainly from demolished concrete and masonry structures.

3. OBJECTIVE OF THE STUDY

The objective of this study is to assess the utility and efficacy of silica fume and alkaline liquids as a geopolymer concrete as an alternative to ordinary Portland cement concrete. The properties of materials have to be known before it can be used as an alternative of ordinary concrete.

This study focuses on replacement of normal cement with silica fume as termed to be geopolymer concrete. If geopolymer concrete emerges successfully and attain the properties as normal concrete, it would be a milestone achievement for the local construction industries. Therefore, the main objective of this research is to determine the feasibility of pozzolanic materials as in geopolymer concrete. The objectives of the study are briefly summarized below.

- To make a concrete without using cement (i.e. Geopolymer concrete).
- To evaluate the optimum mix proportion of Geo-polymer concrete with silica fume replaced of cement and also the mix proportion of OPC.
- To study the different Strength, Durability properties of Ordinary and Geo-polymer concrete.
- To make the study of the concrete this has been casted in different moulds and cured in both normal and elevated temperatures

4. LIETERATURE REVIEW

This chapter presents a review of recent research on geopolymers and geopolymer concrete, with an emphasis on low calcium fly ash-based geopolymer paste and concrete.

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.

Ramamurthy and Gumaster (1998) , the compressive strength of recycled aggregate concrete was relatively lower and variation was depended on the strength of parent concrete from the obtained aggregate.

Sawamoto and Takehino (2000) found that the strength of the recycled aggregate concrete can be increased by using Pozzolanic material that can absorb the water.

Giaccio and Zerbino R , conducted an extensive research programme on the residual behaviour of concrete exposed to high temperature. Their objectives were to obtain criteria for the evaluation of concrete structures exposed to high temperature and those affected by fire and to analyze the failure mechanisms in damaged concrete considering temperature as a damaging agent. They studied the effect of high temperatures on the stress strain behaviour under compressive and tensile loading, and the suitability of NDT methods for fire damaged concrete. They also studied the performance of FRC at high temperature. Their study includes the contribution of fibre reinforcement in both conventional and high strength concrete exposed to temperatures up to 500°C.

5. GROUND GRANULATED BLAST FURNACE SLAG (GGBS)

Ground granulated blast furnace slag (GGBS) is produced by rapid cooling of the material molten iron slag (a by - product of iron and steel making) from a blast furnace in water or steam , to produce a glassy, granular product that is then dried and ground into the fine powder. Main components of blast furnace slag are calcium oxide, silica dioxide , alumina oxide ,magnesium oxide.

Fig 2 :fly ash and GGBS

Ground Granulated Blast furnace Slag (GGBS) is a byproduct from the blast furnaces used to make iron. These operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials from a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimizes the cementitious properties and produces granules similar to coarse sand. This „granulated" slag is then dried and ground to a fine powder. Although normally designated as "GGBS" in the UK, it can also be referred to as "GGBS" or "Slag cement" Concrete is basically a mix of fine aggregate, coarse aggregate and cement.

PROPORTIES OF GGBS

S NO	PROPERTY	TEST METHOD	TEST RESULT
1	Specific gravity	Sp. Gr bottle (IS:4031 Part - 4)	2.9
2	Specific Surface Area (m^2/Kg)	Blaine's Air permeability (IS:5516-1996)	800
3	Bulk Density (Kg/m^3)	IS:2386 Part 3 - 1986	1400
4	Physical Appearance	–	Powder form

Table 1:properties of GGBS

FLY ASH

Fly ash is a by-product of the combustion of pulverized coal in thermal power plants. The dust-collection system. Fly ash is a by-product of the combustion of pulverized coal in thermal

power plants. The dust-collection system removes the fly ash, as a fine particulate residue, from the combustion gases before they are discharged into the atmosphere. Fly ash particles are typically spherical, ranging in diameter from\1 lm up to 150 lm. The type of dust collection equipment used largely determines the range of particle sizes in any given fly ash.

Fig 3:Fly ash

PHYSICAL PROPORTIES OF FLY ASH

S NO	PROPERTY	TEST METHOD	TEST RESULT
1	Specific gravity	Sp. Gr bottle (IS:4031 Part - 4)	2.2
2	Specific Surface Area (m^2/Kg)	Blaine's Air permeablity (IS:5516-1996)	550
3	Bulk Density (Kg/m^3)	IS:2386 Part 3 - 1986	1100
4	Physical Appearance	–	Powder form

Table 2 :properties of fly ash

6. SCOPE OF THE PROJECT

- To find an alternative for the ordinary Portland cement.
- To find replacement for natural aggregates.
- To decrease the landfill area.
- Utilizing the construction and demolished waste.
- To reduce CO_2 emission and produce eco-friendly concrete.
- To develop a cost efficient product.
- To provide high strength concrete than ordinary Portland concrete.

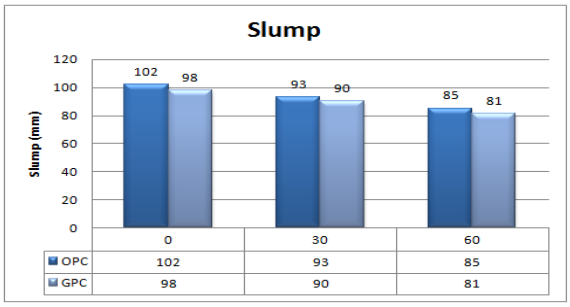
7. RESULTS AND ANALYSIS

Tests on Fresh Concrete

Slump test:

Slump test is used in determining the workability of concrete this test is performed either in laboratory or at site of work. This test is not recommended in very wet or very dry concrete.

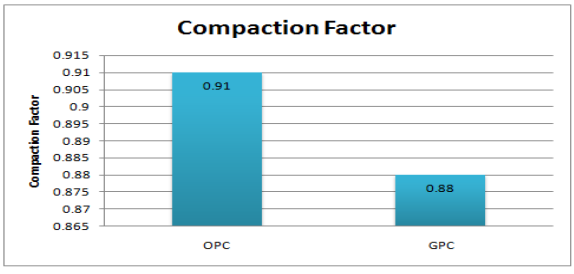
	Slump @ 0 min	Slump @ 30 min	Slump @ 60 min
OPC	102	93	85
RCA GPC	98	90	81



Compacting Factor Test

The compaction factor test is designed primarily for use in the laboratory. It is more precise and sensitive than the slump test and is mostly useful for very low workability concrete Principle.

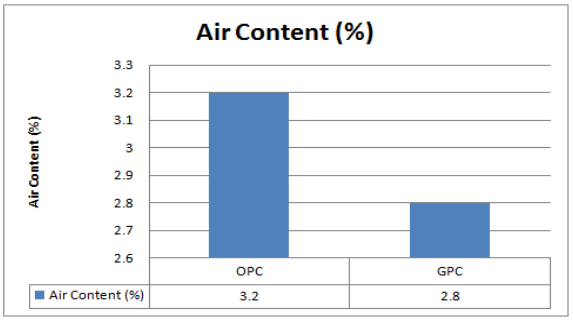
	OPC	RCA GPC
Compaction Factor	0.91	0.88



Air Content

The most dependable and accurate method is the pressure method which is based on the relation between the volume of air and the applied pressure (at constant temperature) given by Boyle's law.

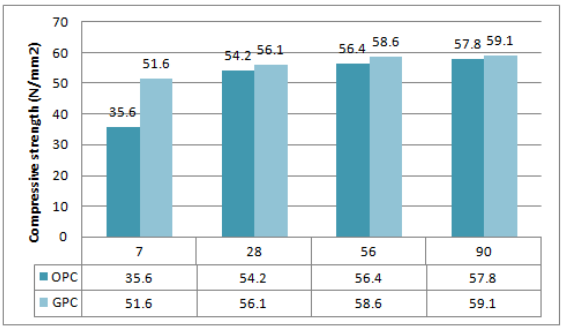
	OPC	RCA GPC
Air Content (%)	3.2	2.8



COMPRESSION TEST

This test is done on hardened concrete . The c test is carried out on specimens cubical in shape or cylindrical in shape. The cube specimen is of the size 150 × 150 × 150 mm. The test is conducted on Universal Testing Machine.

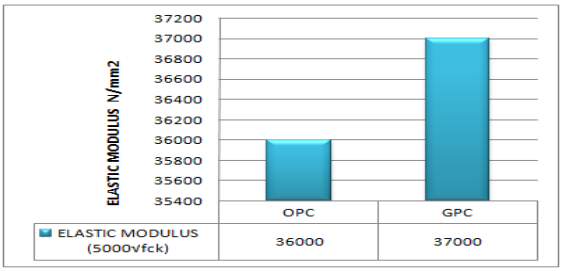
	OPC		RCA GPC	
Days	Density (Kg/m^3)	Compressive strength N/mm(or)Mpa	Density (Kg/m^3)	Compressive strength N/mm^2(or)Mpa
7	2379	35.6	2400	51.6
28	2400	54.2	2417	56.1
56	2410	56.4	2420	58.6
90	2420	57.8	2428	59.1



Elastic modulus

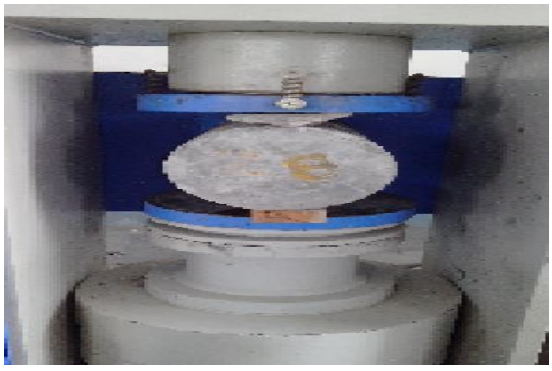
Elastic modulus is a mechanical property of linear elastic solid materials. It defines the relationship between stress and strain in the material. It is obtained from characteristic strength of the concrete which is determined from the compressive strength test on the concrete cylinder.

	DENSITY (Kg/m3)	COMPRESSIVE STRENGTH N/mm^2 (or) Mpa	ELASTIC MODULUS(5000√fck) N/mm^2 (or) Mpa
OPC	2419	54.2	0.36X 10^5
RCAGPC	2428	56.1	0.37X 10^5

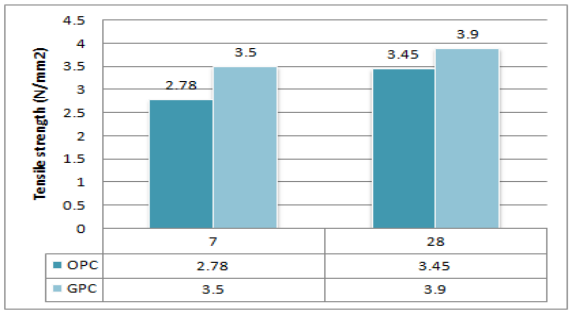


Split Tensile Test

In split tensile test the loading induces tensile stresses on the plane containing the applied load and relatively high compressive stresses in the area immediately around the applied load. Tensile failure occurs rather than compressive failure because the areas of load application are in a state of triaxial compression.



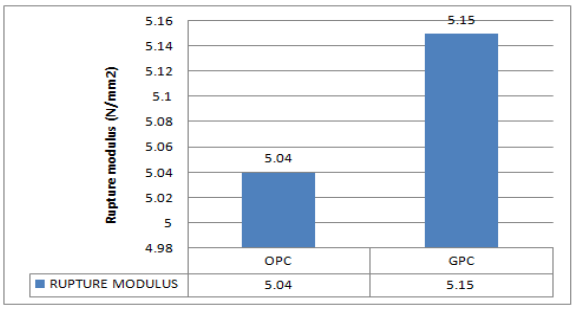
	OPC		RCA GPC	
Days	Density (Kg/m^3)	Tensile strength N/mm^2(or)Mpa	Density (Kg/m^3)	Tensile strength N/mm^2(or)Mpa
7	2420	2.78	2425	3.45
28	2456	3.5	2480	3.9



Rupture modulus

Rupture Modulus is a measure of the ultimate strength of the breaking load by unit area of the specimen, as determined from bending and compression test. It is obtained from characteristic strength of the concrete which is determined from the compressive strength test on the concrete cylinder.

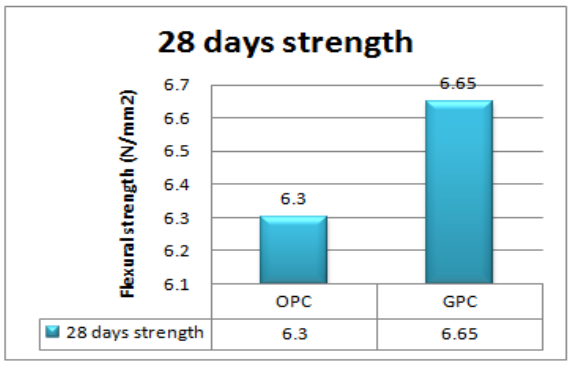
	DENSITY (Kg/m3)	COMPRESSIVE STRENGTH N/mm^2 (or) Mpa	RUPTURE MODULUS(0.7√fck) N/mm^2 (or) Mpa
OPC	2478	52.2	5.04
RCA GPC	2392	54.2	5.15



Flexural strength

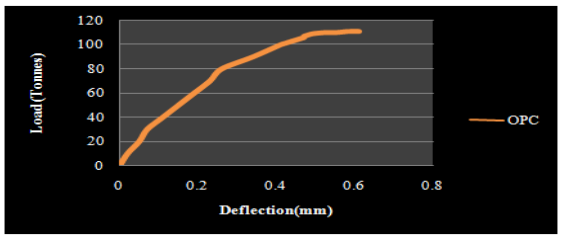
Flexural strength is the measure of modulus of rupture. The systems of loading used in finding out the flexural strength are central point loading and third point loading. In the central point loading, maximum fiber stress will come below the point of loading where bending moment is maximum.

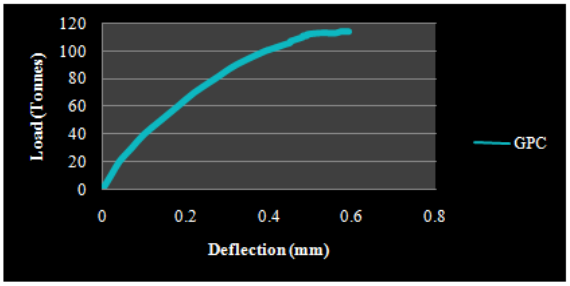
Days	OPC Flexural strength N/mm^2 (or) Mpa	RCA GPC Flexural strength N/mm^2(or) Mpa
28	6.3	6.65

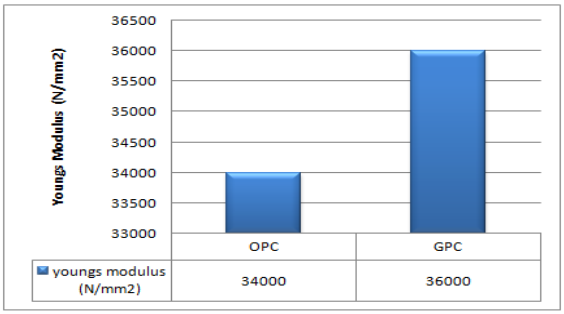


Determination of Young's Modulus by Stress-Strain Parameters

	STRESS--(σ) (N/mm^2)			STRAIN---(e)			
	Load (Tonnes)	Area (mm^2)	Compressive Stress N/Mm^2 (Or) Mpa	Change In Length (mm)	Original Length (mm)	Strain	Youngs Modulus (N/mm^2)
OPC	97.58	17671.45	54.2	0.48	300	0.00159	$0.34X10^5$
GPC	100.70	17671.45	55.90	0.46	300	0.00155	$0.36X10^5$







8. CONCLUSIONS

Recommendations for Further Studies

Further testing and studies on the recycled aggregate concrete is highly recommended to indicate the strength characteristics of recycled aggregates for application in high strength concrete.

1. Below are some of the recommendations for further studies The Slump of FA Slag GPC containing RCA is almost satisfying the slump of OPC lagging by slump value of 3-4 mm.
2. As per the codifications the compaction factor for the concrete should be greater than 0.85 for good workable conditions. As the compaction factor is satisfying the workability conditions we can replace the usage of OPC with FA Slag GPC containing RCA.
3. As per previous researches when the test has been conducted the %.Air content values will not be exactly 2%, but it varies from 2% - 5%, here GPC value is differed by 0.4 % compared to OPC. Air content of GPC is reducing; it is more beneficial to the property of hardened concrete in terms of durability.
4. The high amount of strength in shorter period is obtained by FA Slag GPC containing RCA when compared to OPC. The value of compressive strength of FA Slag based GPC is nearly more by 2.0 N/mm² compared to OPC.
5. GPC does not require accelerated curing conditions in order to attain early high strength which is different from OPC condition.
6. OPC has attained the strength as per codifications, and gradually increased till 90 days. Coming to FA Slag GPC, it has attained 70% of strength in 7 days itself and it has been gradually increased till 90 days.
7. When compared to OPC, GPC attains tensile strength more in 7 and 28 days where it shows its resistance to the tensile load comparatively more by nearly 0.6 N/mm² than OPC.
8. When compared to OPC, GPC attains flexural strength more by 5 % where it shows its resistance to the flexure load comparatively more than OPC.
9. Both OPC and FA Slag GPC have satisfied the proposed elastic modulus values. Where GPC attains 1 KN/mm² more than OPC.
10. The rupture modulus values obtained for OPC & FA Slag GPC containing RCA are satisfactory. Results obtained for both differ by approximately 2% having GPC greater value than OPC.
11. The value of elastic modulus obtained from the 28 days characteristic strength and the value of young's modulus from load-deflection curve are almost similar for both the concretes.

REFERENCES

[1] Mostafa Tavakoli and Parviz Soroushin(1996), *Strength of recycled aggregate concrete made using field demolished concrete as aggregate*, ACI-Material Journal, volume 93, pp 182 – 190.
[2] Rammurthy and Gumaste(1998), *Properties of recycled aggregate concrete*, Indian Concrete Journal, volume 72, pp 49 – 53.
[3] Sawamoto and Takehino(2000), *usage of admixtures to increase the workability of recycled aggregate concrete*
[4] Limbachiya M.C, Leelawat T and Dhier R.K(2000), *Use of recycled aggregate concrete in high strength concrete*, Material and Structures, volume 33, pp 574 – 580.
[5] Mandal S., Chakarborty S., Gupta A(2000), Some studies on durability of recycled aggregate concrete. *Indian Concrete Journal*.;**76(No. 6)**:385-388.
[6] Sageo , Brown and Taylor(2002), *differences between normal and recycled aggregate*
[7] Hadijieva-Zaharieva R.and Buyle-Bodin F(2000)., *Influence of industrially produced recycled aggregates on flow properties of concrete*, Materials and Structures, Volume 35, p504-509.
[8] Mandal , Chakraborthy and Gupta(2000), studies on the effect of recycled aggregate of the proportions. *Indian Concrete Journal*.;**76(No. 6)**:385-388
[9] Poon C.S.,Fong F.K. Winston, Yeung S.K. Jaime, *Hong Kong experience of using recycled aggregates from construction and demolition materials in ready mix concrete*, viewed 26 Jun 2004.
[10] BCSJ(1978) proposed standard for the *Use of recycled aggregate and recycled aggregate concrete*, Building society of Japan committee on disposal & reuse of construction waste.