An Experimental Study on Geopolymer Concrete using Ceramic Waste as a Fine Aggregate

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Abstract— Concrete being most widely used construction material across the world need to be sustainable. Concrete has occupied an important place in construction industry in the past few decades and it is used widely in all types of constructions ranging from small buildings to large infrastructural dams or reservoirs. Cement is major ingredient of concrete. The cost of cement is increasing day by day due to its limited availability and large demand. At the same time the global warming is increasing day by day. Manufacturing of cement also releases carbon dioxide. In the present study an attempt been made on concrete and also an experimental investigation on the concrete using by replacing cement with Fly ash and alkaline liquid to decrease the usage of cement as well as emission of concrete. The ever increase in the demand of sand and decrease in its availability, there is an immediate need for finding suitable alternatives which can replace sand partially or at a high proportion. In this Research study investigates the effect of waste products as ceramic tiles partial replacement of sand. Use of crushed ceramic tiles as a fine aggregate. So here in this research study partially replacement of a fine aggregate in geopolymer concrete. The percentage of fine aggregate replaced by a ceramic waste up to 5%, 10%, 15%, 20%, 25%, 30% and investigate a fresh and hardened property of a geopolymer concrete. In fresh concrete investigate slump test and compaction factor test and in harden concrete investigate Cube, Beam and Cylinder casted and tested for compressive test, flexural strength & split tensile strength.

Key words: Geopolymer concrete (GPC), Ceramic Fine aggregate (C.F.A), Fine aggregate (F.A), Sodium hydroxide (NAOH), sodium silicate (Na2Sio3), Alkaline liquid (AL)

I. Introduction

Aggregate is a readily available in a financial rate basically concrete is a man-made product consist with a mixture of cement, aggregate, sand, water and admixture. Admixtures are chemical added to the concrete for the purpose of a workability of a concrete. Granular material like sand, gravel and crushed stone is a major part and required quality.

Concrete is one of the most widely used construction materials. It is usually associated with Portland cement as the main component for making concrete. The demand for concrete as a construction material is on the increase On the other hand, the climate change due to global warming, one of the greatest environmental issues has become a major concern during the last decade. The global warming is caused by the emission of greenhouse gases, such as CO2, to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming. The cement industry is responsible for about 6% of all CO_2 emissions. Although the use of Portland cement is still unavoidable until the foreseeable future, many efforts are being made in order to reduce the use of Portland cement in concrete. These efforts include the utilization of supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin, and finding alternative binders to Portland cement. In terms of reducing the global warming, the geopolymer technology could reduce the CO_2 emission to the atmosphere caused by cement and aggregates industries by about 80% fly ash-based geopolymer concrete has excellent compressive strength, suffers very little drying shrinkage and low creep, excellent resistance to sulfate attack, and good acid resistance. It can be used in many infrastructure applications. The special properties of geopolymer concrete can further enhance the economic benefits.

Ceramic unit generated about 30% waste from the production of tiles. The cost of a ceramic aggregate for waste production is saved and also saved natural resources will be replaced so it is lead to saving energy and protect environment. These ceramic materials have a high strength, nontoxic, chemical resistance, long life and electrical resistance to make the durable concrete.

So finally the geopolymer is a new development in the world of concrete in which cement is totally replaced by pozzolanic materials like fly ash and activated by highly alkaline solutions to act as a binder & Ceramic Fine aggregate in the concrete mix.

II. Objective

To evaluate the fresh properties (Slump test & Compaction factor test) of Geopolymer Concrete (GPC) with use of Ceramic fine aggregate (CFA) up to 30% Replacement with the increment of 5%.

To achieve the harden properties (Compressive strength, Split tensile Strength and Flexural Strength) of Geopolymer Concrete (GPC) with use of Ceramic fine aggregate (CFA) up to 30% Replacement with the increment of 5%.

To check the durability Properties, Acid attack (H_2SO_4) of Geopolymer Concrete (GPC) with use of Ceramic fine aggregate (CFA) up to 30% Replacement with the increment of 5%.

III. Material used in Geopolymer Concrete (GPC)

A. Fly ash

The fly ash was obtained from Wanakbori Thermal Power Station, Gujarat, India. This fly ash is of “class F”. It is obtained in powdered form and its colour is light grey. Fly ash of class F is used as it has high amount alumina content and so it works as a binding material. This fly ash has rich content of silica.

B. Alkaline Solution

The alkaline solution is a mixture of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). 16M solution is used for the experimental work. The alkaline solution of sodium hydroxide & sodium silicate was mixed together one day or 24 hours before for use of preparing geopolymer concrete. The ratio of sodium hydroxide solution to sodium silicate solution was kept 2.5 in the study.

C. Water

Water used for mixing shall be clean and free from injurious amount of oils, acids, alkalis, salts, organic materials or other deleterious materials.

D. Fine Aggregate

The fine aggregate, which is used in the investigation is clean river sand and conforming to zone II as per IS: 383-1970. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm.

E. Coarse Aggregate

The coarse aggregate use as the crushed stone aggregate passing through 20 mm sieve. The aggregate occupy 70%-80% of the total volume of normal concrete. For the strength Coarse aggregate particles must be roughly equal dimension & shape. Coarse aggregate shall comply with the requirement of IS 383.

F. Ceramic fine aggregate (CFA)

Recycled ceramic waste aggregate is derived from "Marbilano Ceramic privet limited" At 8A national highway morbi-Mandal road. In this research crushing of waste aggregates Ball mill. They were tested for gradation purpose. The sieved aggregate carefully stored in laboratory. Gradation of recycle aggregate is given below.

1) Ceramic Fine Aggregate

Sr.No.	TEST	UNIT	OBTAIN RESULT
1	SiO_2	%	62.0-68.0
2	Al_2O_3	%	22.0-48.0
3	MgO	%	0.4-0.7
4	Na_2O	%	2.0-4.0
5	CaO	%	0.2-0.5
6	K_2O	%	3.0-5.0
7	Fe_2O_3	%	0.4-0.8

Table 1: Chemical Composition of CFA

IV. EXPERIMENTAL PLAN

A. Test Procedure

1) Assessment of mix design from trial and error mix design.
2) Selection of mixing procedures and test methods.
3) Selection of the target properties of Geopolymer concrete for the subsequent tests
4) Selection of constituent materials

B. Mixing, Casting & Curing

GPC was replaced by CFA varying from 5% 30% at the equal interval of 5%.

The hardened properties of each of the concrete mixes will measure, including compressive strength, splitting tensile strength and flexural strength & also measure fresh property.

The mixing of GPC was done in a room temperature. FA and coarse aggregate & fine aggregate were mixed until a uniform mixture. Finally, Alkaline liquid & water was added and mixed uniformly 8-10 min. After mixing, fresh concretes were tested for slump test and compaction factor test. Then cast in molds and compacted on a vibrating table. The 150x150x150 mm cube, 150 mm dia-300mm length cylinder and 100x100x500 mm beam samples were prepared for respectively compressive strength, splitting tensile strength, and flexural strength tests.

After that, the specimens were then cured at 80-85^0 C for 24 h. After the heat curing, the specimens were put in the 25^0 C controlled room to cool down and demolded on the next day. The specimens were then stored in the 25^0 C controlled room until the testing age.

Mix Design	Fly ash (kg)	AL	CA (20mm) (kg)	CA (10mm) (kg)	NFA	CFA
GPC0	400	200	702	468	630	0
GPC5	400	200	702	468	598.5	31.5
GPC10	400	200	702	468	567	63
GPC15	400	200	702	468	535.5	94.5
GPC20	400	200	702	468	504	126
GPC25	400	200	702	468	472.5	157.5
GPC30	400	200	702	468	441	189

Table 2: Mix Proportions

V. RESULTS AND DISCUSSIONS

A. Results of Fresh Properties Test

1) Slump Test Result

From the observation Replacement of C.F.A with N.F.A in geopolymer concrete the slump was decreased. The percentages of C.F.A was increases from 0% to 30%, the slump was decreases from 1.88% to 18.86% as compare to normal Geopolymer concrete test result.

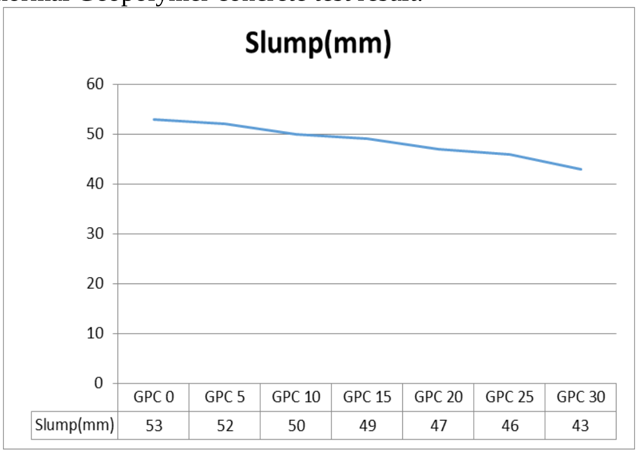

Chart-1 Slump Flow Chart

2) Compaction Factor Result

From the observation Replacement of C.F.A with N.F.A in geopolymer concrete the Compaction factor was decreased. The percentages of C.F.A was increases from 0% to 30%, the compaction factor was decreases from 2.22% to 11.11% as compare to normal Geopolymer concrete test result.

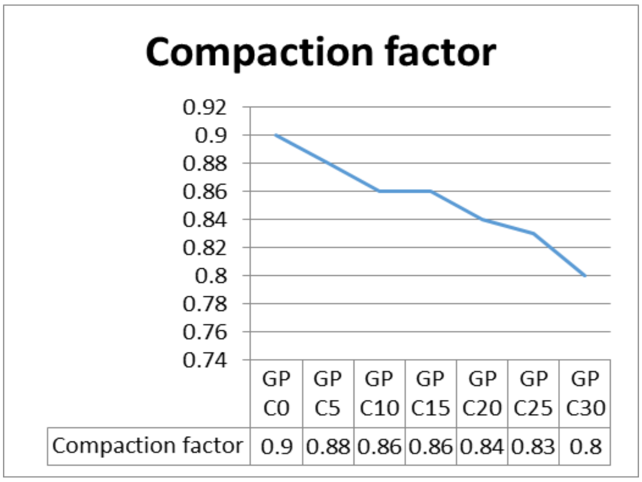

Chart-2 Compaction Factor Flow

B. *Result of Harden Property*

1) *Compressive Strength of GPC*

MIX	3 days(mpa)	7 days(mpa)	28 days(mpa)
GPC 0	25	29.7	36.2
GPC 5	24.28	28.74	35.18
GPC 10	23.29	27.88	34.06
GPC 15	21.98	25.91	32.04
GPC 20	22.78	24.98	30.63
GPC 25	22.04	23.91	29.06
GPC 30	20.92	22.65	27.85

Table 3: Compressive Strength Result

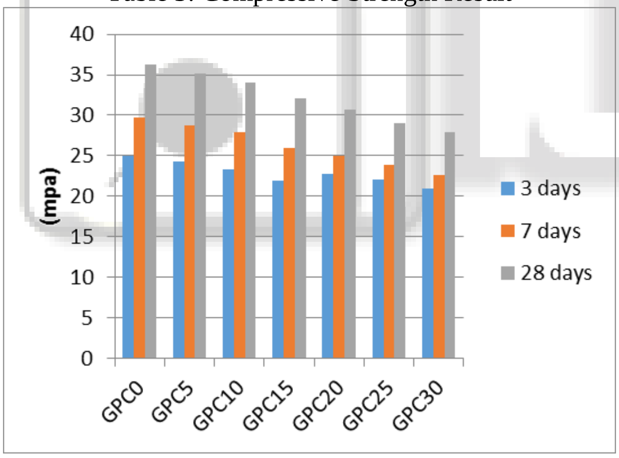

Chart-3 Compressive Strength

C. *Split Tensile Strength Of GPC*

MIX	28 days(mpa)
GPC 0	3.1
GPC 5	3.0
GPC 10	2.9
GPC 15	2.9
GPC 20	2.8
GPC 25	2.6
GPC 30	2.6

Table 4: Split Tensile Strength Result

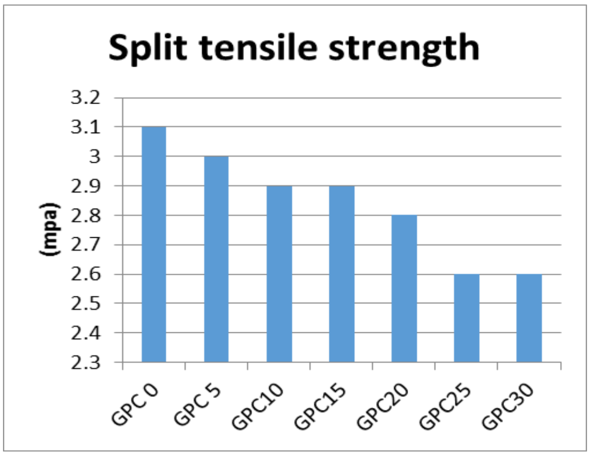

Chart-4 Split Tensile Strength

D. *Flexural Strength of GPC*

MIX	28 days(mpa)
GPC 0	4.2
GPC 5	4.2
GPC 10	4.1
GPC 15	3.9
GPC 20	3.8
GPC 25	3.7
GPC 30	3.7

Table 5: Flexural Strength Result

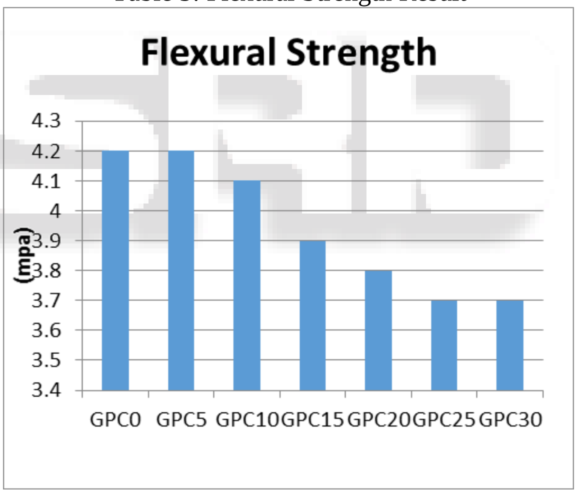

Chart-5 Flexural Strength

E. *Acid Attack Test of GPC*

The cubes were cast at a temperature of 27°C ± 2°C. After 24 hours of oven curing the cubes were removed from the mould and put at normal temperature for 28 days. After The cubes were immersed in a 5% concentrated sulphuric acid (H_2SO_4). After 28 days in acid strength were measured.

MIX	Compressive strength	Compressive strength after acid attack
GPC 0	36.20	31.96
GPC 5	35.18	31.19
GPC 10	34.06	30.34
GPC 15	32.04	28.82
GPC 20	30.63	27.69
GPC 25	29.06	26.43
GPC 30	27.85	25.35

Table 5: Acid Attack Result

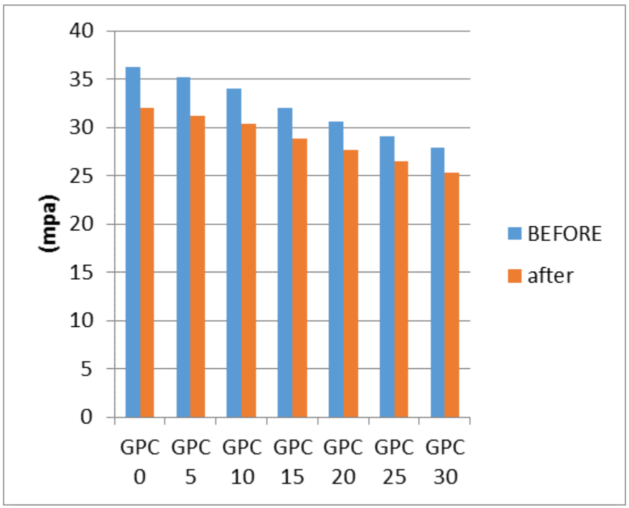

Chart 6 Acid Attack

VI. Conclusions

Based on experimental investigation, following observations are made on the fresh property, hardened properties and durability of GPC

- By replacement of 5%, 10%, 15%, 20%, 25% & 30% C.F.A with N.F.A in geopolymer concrete the slump was decreased up to 18.86%.
- By replacement of 5%, 10%, 15%, 20%, 25% & 30% C.F.A with N.F.A in geopolymer concrete the compaction factor was decreased up to 11.11%.
- By replacement of 5%, 10%, 15%, 20%, 25% & 30% C.F.A with N.F.A in geopolymer concrete the compressive strength was decreased up to 23.06%.
- By replacement of 5%, 10%, 15%, 20%, 25% & 30% C.F.A with N.F.A in geopolymer concrete the split tensile strength was decreased up to 16.12%.
- By replacement of 5%, 10%, 15%, 20%, 25% & 30% C.F.A with N.F.A in geopolymer concrete the flexural strength was decreased up to 11.90%.
- By replacement of 5%, 10%, 15%, 20%, 25% & 30% C.F.A with N.F.A in geopolymer concrete the acid attack resistance improved.
- Hence where the acid attack is a major issue the C.F.A can be use.

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