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EFFECT OF SALINITY OF WATER ON STRENGTH OF CEMENT CONCRETE AND GEOPOLYMER CONCRETE

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ABSTRACT

Concrete users around the world are second only to water consisting main ingredient as cement. Ordinary Portland Cement is conventionally used as the primary binder to produce concrete production of cement, produce one ton of emission of CO_2 every ton of cement produced. To produce cement, electricity is also required to run the cement production plant. Generation of electrical power produces fly ash as a waste material in thermal power plants Thin cycle is causing environmental pollution, waste disposal problem also. The project aims at replacing the cement. Besides the government has restricted to use the river sand in concrete.

KEYWORDS— Cement Concrete, Geopolymer Concrete, Salinity of water, Sea Water, Compressive Strength, etc.

INTRODUCTION

Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced, in addition, the extent of energy required to produce OPC is only next to steel and aluminium [1].

The name geopolymer was formed by a French Professor Davidovits in 1978 to represent a broad range of materials characterized by networks of inorganic molecules . The geopolymers depend on thermally activated natural materials like Meta kaolinite or industrial by products like fly ash or slag to provide a source of silicon (Si) and aluminum (Al)[5]. These Silicon and Aluminium is dissolved in an alkaline activating solution and subsequently polymerizes into molecular chains and become the binder. “the polymerization process involves a substantially fast chemical reaction under alkaline conditions on silicon-aluminum minerals that results in a three dimensional polymeric chain and ring structure. (1).” The ultimate structure of the geopolymer depends largely on the ratio of Si to Al (Si:Al), with the materials most often considered for use in transportation infrastructure typically having an Si:Al between 2 and 3.5. The reaction of Fly Ash with an aqueous solution containing Sodium Hydroxide and Sodium Silicate in their mass ratio, results in a material with three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds [6].

The use of cement as a binder in a concrete mixture is often criticized by circles concerned with environmental conversation. With the increased use of cement in concrete there have been environmental concerns both in terms of damages caused by the interaction of raw materials and the emission of CO2 during cement manufacture.

Geopolymer cement is an innovative material & real alternative to conventional Portland cement for use in transportation, infrastructure, construction and off shore applications. It relies on minimally processed natural materials or industrial by products to significantly reduces its carbon footprint, while also being very resistant to many of the durability issues that can be plague conventional concrete. India produces 130 million tonne of fly ash annually which was expected to reach 175 million tonne by 2012. Disposal of fly ash is a growing problem as only 15% of fly ash is currently used for high value addition applications like concrete and building blocks the remainder being used for land filling. Globally less than 25% of the annual fly ash produced in the world is utilized [8].

The use of concrete has recently gained popularity as a resource-efficient, durable and cost effective. High Volume Fly Ash constitutes about 50% fly ash, a lower water content, low cement content and a low water-cement ratio (W:C) (about 0.4-0.45%). A concrete mix with fly ash can provide environmental and economical benefits. Fly Ash concrete enhances the workability, compressive strength, flexural strength and also increases its pump ability, durability and concrete finishing. It also reduces corrosion, alkali silica reaction, sulphate reaction shrinkage as it decreases its permeability and bleeding in concrete [9].

1.2 SOURCE MATERIALS

1.2.1 Fly ash

1. Bottom ash
2. Pond ash
3. Mound ash

MANUFACTURING

In India coal power thermal station there are main source of electricity generation. In these process of electricity generation fly ash comes as a by product. Fly ash is a very good resource material. It can be one storage use in cement concrete works as well as applications this will use in cement concrete works. This kind of ash is extracted from flue gases through Electrostatic Precipitator in dry form. This ash is fine material & possesses good pozzolanic property.

TYPES OF FLY ASH

a. Class F-Fly ash

The sum of these three principal (silica, alumina, ferric oxide) constituents is 70% or more and reactive calcium oxide is less than 10% - technically the fly ash is considered as siliceous fly ash or class F. Fly ash normally produced from burning anthracite or bituminous coal falls in these category. This class of fly ash exhibits pozzolanic property but rarely possesses self hardening property.

b. Class C-Fly ash

The sum of these three (silica, alumina, ferric oxide) constituent is equal or more than 50% and reactive calcium oxide is not less than 10%, fly ash will be considered as Calcareous fly ash also called as class C fly ash. This class of fly ash has both pozzolanic and varying degree of self cementious properties.

c. Class N-Fly ash

Raw or calcined natural pozzolans such as diatomaceous earths, and shale, volcanic ashes and pumice come in this category. Calcined kaolin clay and literite shale also fall in this category of pozzolans.

1.2.2 Silica Fume

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses of silica fume is in concrete. Because of its physical and chemical properties. It is a very reactive pozzolan. Silica fume is available from supplier of concrete admixtures and when specified is simply added during concrete production. Silicon metal and alloys are produced in electric furnaces. The raw materials are quartz, coal & woodchips. The smoke results from furnace operation is collected and sold as silica fume, rather than being landfilled. Perhaps the most important use of this material is as a mineral admixture in concrete.

1.2.3.Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast furnace Slag (GGBS) is a byproduct from the blast furnace used to make iron. These operate at a temperature of about 1500°C and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining material from a slag that floats on top of the iron. This slag is periodically tapped of as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volume of water. The quenching optimizes the cementious properties and produces granular similar to a coarse sand. This granulated slag is then dried and ground to a fine powder.

1.2.4. Slag

Slag is a byproduct of metal smelting, and hundreds of tons of it are produced every year all over the world in the process of refining metals and making alloys. Like other industrial by products, slag actually has many uses, and rarely goes to waste. It appears in concrete, aggregate, road materials, as ballast, and it sometimes used as a component of phosphate fertilizer. In appearance slag looks like a loose collection of aggregate, with lumps of various sizes. It is also sometimes reffered to as cinder, in a reference to its sometimes dark and crumbly appearance.

1.2.5. Metacaolin

Metacaolin is a commonly used material for laboratory synthesis of geopolymer, and is generated by thermal activation of kaolin. Geopolymer concrete can also be made from natural source of pozzolonic materials, such as lava or fly ash from coal. Most studies on geopolymer concrete have been carried out using natural or industrial waste source of metacaolin and other aluminosilicates.

The advantage of replacing some of the cement with metakaolin, rather than simply adding metakaolin to the mix, is that any existing colour formulas or mix designs won’t change, or will only very slightly change. This is because the dosage of pigments and superplasticizers are based on the cement content in the concrete.

1.2.6 Rice Husk Ash (RHA)

Rice Husk Ash (RHA) is a carbon neutral green product. Lots of ways are being thought of for disposing them by making commercial use of this RHA. RHA is a good super pozzolan. This super pozzolan can be used in a big way to make special concrete mixes. There is a growing demand for fine amorphous silica in the production of special cement and concrete mixes, high performance concrete, high strength low permeability concrete, for use in bridges, marine environments, nuclear power plants etc. this market is currently filled by silica fume or micro silica, being imported from Norway, China and also from Burma. Due to limited supply of silica fumes in India and the demand being high the price of silica fume has reach to as much as US $ 500/ton in India. From RHA we manufactured organic micro-silica/ amorphous silica with silica content of above 89%. In very small particle size of less than 35 micron-silpozz for application in high performance concrete.

The furnace can hold up to 60kg of rice husks; it has three small openings through which fire is ignited. They too allow ventilation. A fire source was maintained under the furnace for around 10 minutes, after which the husks slowly burned for more than one day. The ash was left inside the furnace to cool down before it was collected. Ash was ground for 90,180,270and 360 minutes. The RHA ground for 90 minutes was only tested for particle size analysis and surface area to show the effect of grinding time on the average particle size and specific surface area. .

1.3 Alkaline Activators

1.3.1 Sodium Based

The alkaline activator was prepared in the laboratory. In order to avoid the effect of unknown contaminants, laboratory tab water was used to dissolve the sodium hydroxide pellets. The alkaline activator was prepared by mixing the sodium hydroxide solution with sodium silicate solution together before 24 hour of the mixing of mortar to ensure the reactivity of solution. The aim of adding sodium silicate is to enhance the formation of Geopolymer precursors or the polymerization process (Xu et al 2000). Locally available fine aggregate (river sand) in saturated surface dry condition was used.

1.3.1.1 Sodium Hydroxide

Sodium hydroxide solution was prepared by dissolving the sodium hydroxide solids either in the form of flakes. The sodium silicate solution used contained $Na2O = 14.7\%$, $SiO2=29.4\%$ and 55.9% of water by mass. The solution which is combination of NaOH and sodium silicate having ratio of 2.50 and 3.50. It is recommended that alkaline liquid is prepared by mixing both solution together at least 24 hr.

1.3.1.2 Sodium Silicate

The concentration of sodium hydroxide solution can varry in the range between 8 molar to 16 molar, however 8 molar solution is adequate for most application NaOH solution with concentration of 8 molar consist of 320 grams of NaOH solids / liter of the solution . Similarly, mass of NaOH solids per kg of solution for other concentration was measured as 10 molar =314gm, 12 molar =361gm,14 molar =404gm and 16 molar=444gm .

1.4 Application of Geopolymer Concrete

- ➢ Precast structural element for bridges and decks
- ➢ Structural Retrofits
- ➢ Precast pavers and slabs for paving, bricks and precast pipes.
- ➢ Precast Railway sleepers.
- ➢ Sewer pipes.
- ➢ Precast box culverts
- ➢ Precast wall panels
- ➢ In field of industries such as auto mobile and aerospace and plastic industries
- ➢ Interlocking Blocks

1.4.1 Limitations

- ❖ High cost for the alkaline solution.
- ❖ Safety risk associated with the high alkalinity of the activating solution.
- ❖ Practical difficulties in applying steam curing/high temperature curing process.

1.5 Necessity

The literature indicates that some studies are available on GPC but sufficient literature is not available on fly ash based GPC with saline water. Hence an attempt is made in this work to develop fly ash based GPC and conventional concrete with various percentage of saline water and compares its fresh and hardened properties of GPC with conventional concrete.

1.6 Objective

1) To produce GPC with fly ash and varying percentage of salinity with water
Cement ratio 0.40 and solution to fly ash ratio 0.35.
2) To study compressive strength of GPC and conventional concrete with varying
percentage of salinity.
3) To study displacement characteristics of GPC and conventional concrete.

1.7 Theme

The Present experimental work is focused on the study of compressive strength of GPC and conventional concrete by using artificial saline water, which is made in laboratory by using tab water with various percentage of salts such as 0%, 1%, 2%, 3%, 4%, 5% and sea water. For that study used M30 mix proportion for both types of concrete.

REVIEW OF RELATED LITERATURE

From the decades, the concrete has been used as a construction material worldwide, but some of the researcher's introduced a new term 'Geopolymer Concrete'.

The chapter presents the background to the needs for the development of alternative binder to manufacture concrete and the use of fly ash in concrete. The available published literature on geopolymer technology is also briefly reviewed.

Djwantoro Hardjito ***et.*** *al.* [1] reported that to reduce greenhouse gas emissions, Author presents the development of fly ash-based geopolymer concrete. In geopolymer concrete, a by-product material rich in silicon and aluminum, such as low-calcium (ASTM C 618 Class F) fly ash, is chemically activated by a high-alkaline solution to form a paste that binds the loose coarse and fine aggregates, and other unreacted materials in the mixture

Dr. S. L. Patil *et. al*. [2] studied that fly ash, a waste generated by thermal power plants is as such a big environmental concern. The investigation reported is carried out to study the utilization of fly ash in cement concrete as a partial replacement of cement as well as an additive so as to provide an environmentally consistent way of its disposal and reuse.

Fareed Ahmed Memon *et. al*. [3] studied that the effects of silica fume on the fresh and hardened properties of fly ash-based self-compacting geopolymer concrete (SCGC) was investigated.

Ali Allahverdi *et. al.* [4] studied a number of geopolymer cement mixes were designed and produced by alkali-activation of a pumice-type natural pozzolan. Effects of blast-furnace slag on basic engineering properties of the mixes were studied.

Chua Chung Cheak *et. al.* [5] reported that the geopolymer is a novel binding material produced from the reaction of fly ash with an alkaline solution.
N. A. Lloyd *et. al*. [6] Geopolymer results from the reaction of a source material that is rich in silica and alumina with alkaline liquid. It is essentially cement free concrete. This material is being studied extensively and shows promise as a greener substitute for ordinary Portland cement concrete in some applications.

B. Vijaya Rangan *et. al.* [7] studied that in recent years, attempts to increase the utilisation of fly ash to partially replace the use of Portland cement in concrete are gathering momentum

M. A. Bhosale *et. al*. [8] investigated that the alkali activation of waste materials is a chemical process that allows the user to transform glassy structures into very compact well-cemented composites. Nowadays, the knowledge concerning the mechanisms controlling the alkali activation process is considerably advanced; however, there are still many things to investigate. In the investigation, the mechanism of activation of a fly ash (no other solid material was used) with highly alkaline solutions is described.

Damian Robert Selby [9] tested the bond performance of three ribbed and three smooth black steel reinforcement specimens in both geopolymer and OPC concretes of similar compressive strengths in order to produce results that were useful on a relative basis

Yash Shrivastava *et. al*. [10] reported that, concrete used in the field suffers from lack of durability and homogeneity. Since cement is the only binding material in concrete and due to recent hike in its price, researchers have been looking for apt substitutes

Ammar Motorwala *et. al*. [11] considering the increasing demand for developing alternative construction materials, due to the growing environmental concerns, the report discusses the feasibility of alkali activated geo-polymer concrete, as a future construction material. The main objective of this study involves observation of structural behaviours of the fresh fly ash-based geo-polymer concrete.

Bennet Jose Mathew *et. al.* [12] reported that the need to reduce the global anthropogenic carbon dioxide has encouraged researchers to search for sustainable building materials. Cement, the second most consumed product in the world, contributes nearly 7% of the global carbon dioxide emission.

W. Lokuge *et. al.* [13] researched that geopolymer concrete has become a potential candidate to replace Ordinary Portland Cement concrete in the construction industry due to its lower greenhouse gas emissions. It further proves to be environmentally friendly because it uses fly ash which is a by-product of coal that would otherwise end up as landfill.

Claudio Ferone *et. al.* [14] In this study the development of a metakaolin based geopolymeric mortar to be used as bonding matrix for external strengthening of reinforced concrete beams is reported.

Suresh Thokchom *et. al.* [15] presents results of an experimental study performed to investigate effect of incorporating silica fume on physico-mechanical properties and durability of resulting fly ash geopolymers

Ganapati Naidu *et. al.* [16] studied that fly ash based geopolymer concrete is introduced in 1979 by Davidovits to reduce the use of OPC in concrete. Geopolymer is an inorganic alumino-hydroxide polymer synthesized form predominantly silicon and aluminum materials of geological origin and by product materials such as fly ash (with low calcium).

Lohani T.K *et. al*. [17] Geopolymer concrete is an advance technology in concrete technology by partial replacement of bonding material (cement) with fly ash after geopolymerization. The geopolymerization chemistry has been conducted by heating the mixture of a specified proportion of fly ash (carbon content <5%), sodium hydroxide (NaOH) and water (H2O) to a temperature of 600C to 800C.

D. S. Cheema [18] reported that Geopolymer is a material resulting from the reaction of a source material that is rich in silica and alumina with alkaline solution. This material has been studied extensively over the past few decades and shows promise as a greener alternative to ordinary Portland cement concrete.

Concluding Remark

It is observed that from the literature survey, that the use of GPC is more advantageous due to enhancement of overall properties of concrete. Sufficient literature is available on GPC but literature is not available on GPC with varying percentage of salinity.

MATERIALS AND METHOD

Evolution of GPC is discussed in the chapter of literature review and objectives of the proposed work are also specified. The same are mentioned below.
1) To produce GPC with fly ash and varying percentage of salinity with water cement ratio 0.40 and solution to fly ash ratio 0.35.
2) To study compressive strength of GPC and conventional concrete with varying percentage of salinity.
3) To study displacement characteristics of GPC and conventional concrete.

Experimental programe to meet these objectives is presented
In6 this chapter.
Materials for CC and GPC

Materials used for making CC and GPC are tested as per relevant standards and the results are presented here with,
1) Cement
2) Fine Aggregate
    a) River sand
3) Coarse Aggregate
4) Water (With Various Salinity)
5) Source Material (Fly ash)
6) Alkaline Activator (Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3))

3.1 Tests on Materials

The ingredients of concrete i.e. cement, fine aggregate (River sand), coarse aggregate are tested before use in concrete. The relevant Indian Standard Codes were followed for conducting various tests on the material.
3.3.1 Cement

The cement use in this experimental work is **"53 Grade Ordinary Portland Cement".** Test results are presented in table (3.1).

Table 3.1: Physical Properties of Cement

Sr.no	Description of Test	Results
01	Fineness of cement (residue on 45µ sieve	2.9%
02	Standard consistency of cement	24%
03	Setting time of cement a) Initial setting time b) Final setting time	 39 minute 99 minute
04	Specific gravity	3.15
05	Soundness test of cement	3.0 mm
06	Compressive Strength of cement a) 7 days b) 28 days	 47.6 N/mm 65.3 N/mm

3.3.2 Aggregates

Natural river sand from locally available is used. Various tests such as specific gravity, water absorption, sieve analysis *etc*. have been conducted. The tests results are presented in table (3.2), (3.3) and (3.4). Crushed well graded aggregate black trap basalt of size 16mm was used, and confirming the requirement of IS 383-1970 as coarse aggregate.

Table 3.2: Physical Properties of Fine and Coarse aggregates

Sr. No.	**Properties**	**Results**	
		River Sand	**Coarse Aggregate**
	Particle Shape, Size	**Rounded, 4.75mm**	**Angular, 1**
01	Fineness Modulus	2.465	2.5
02	Specific Gravity	2.6	3.91
03	Silt/Dust Content	3.3%	Nil
04	Surface Moisture	Nil	Nil
05	Water Absorption	1.43%	1.51%
06	Bulk Density	1723 kg/m^3	1620 kg/m^3

Table 3.3: Sieve Analysis of Fine Aggregate

Sr. No.	**Sieve Size**	**% Passing**
		River Sand
01	4.75 mm	99.5
02	2.36 mm	98.4
03	1.18 mm	85.4
04	600µ	54.1
05	300µ	12.4
06	150µ	3.3
	F.M.=	2.465

Table 3.4: Sieve Analysis of Coarse Aggregate

Sr. No.	Sieve Size	Weight Retained
		Coarse Aggregate
01.	16 mm	0
02.	12.5 mm	2.557
03.	10 mm	0.889
04.	4.75 mm	0.554
	F.M.=	2.5

3.3.3 Properties of Alkaline Activator

Sodium Hydroxide (NaOH) flake form of 98 % purity (supplied by Shree Royal Seema Alklies and Allied Chemicals Ltd,) and Sodium silicates (Na_2SiO_3) liquid form (Supplied bySamarth Chemical Khamgaon) is used as an alkaline activator. The properties of sodium hydroxide and sodium silicates are given in table (3.5) and (3.6).

Table 3.5: Chemical Properties of Sodium Hydroxide (NaOH)

Sr. N	Properties	Details
01	Purity of NaOH	97.4 %
02	Iron as Fe (ppm)	14.6 %
03	Chloride as NaCl (%)	0.044 %

Table 3.6: Chemical Properties of Sodium Silicate (Na_2SiO_3)

Sr. No.	Properties	Details
01	Na_2O	14.3 %
02	SiO_2	32.9 %
03	Total	47.2 %
04	Specific gravity	1.58 %
05	Water	52.8 %

3.3.4 Properties of Fly Ash

Fly Ash from India bulls Pvt. Ltd., Amaravati is used in concrete in dry powder form. Colour of Fly Ash is light gray. The Physical and Chemical composition of Fly Ash as reported by manufactured are shown in Table (3.7) and (3.8).

Table 3.7: Physical Properties of Fly Ash

Sr. No.	Physical Properties	Values	Requirement as per IS-3821:2003
01.	Fineness –Specific surface,m^2/kg (By Blains permeability method)	437	320 Minimum
02.	Retention in 45 microns, percent	2.1	34 Maximum
03.	Lime reactivity-Average compressive strength MPa	4.8	4.5 Minimum

04.	Compressive strength at 28 days ,as percent of strength of corresponding plain cement mortar cube	86	No less than the 80% of strength of corresponding plain cement mortar cubes
05.	Soundness by autoclave Expansion (%)	0.04	0.8 Maximum

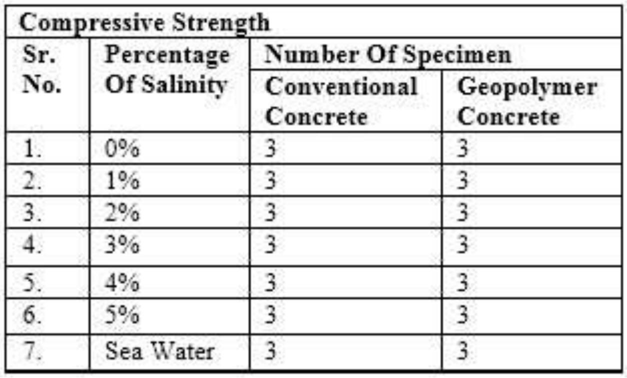
Table 3.8: Chemical Composition of Fly Ash (% by mass)

Sr. No.	**Oxides**	**Values**
01.	SiO_2	61.85
02.	Al_2O_3	27.36
03.	Fe_2O_3	5.18
04.	CaO	1.47
05.	Na_2O	0.08
06.	K_2O	0.63
07.	TiO_2	1.84
08.	MgO	1.00
09.	P_2O_5	0.54
10.	SO_3	0.05

3.4 Test on Concrete in the Fresh State

3.4.1 Slump Cone Test

A mould of 1.18 mm thick galvanized metal in the form of the lateral surface of the frustum of a cone with the base 200 mm in diameter, the top 100 mm in diameter and the height 300 mm. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mold shall be provided with a foot piece on each side for holding the mold in place, and with handles for lifting the mold from the sample.



Compressive Strength			
Sr. No.	Percentage Of Salinity	Number Of Specimen	
		Conventional Concrete	Geopolymer Concrete
1.	0%	3	3
2.	1%	3	3
3.	2%	3	3
4.	3%	3	3
5.	4%	3	3
6.	5%	3	3
7.	Sea Water	3	3

Tamping Rod- a round, straight steel rod 16 mm in diameter and approximately 600 mm in length. The tamping end shall be a hemisphere 16 mm in diameter.

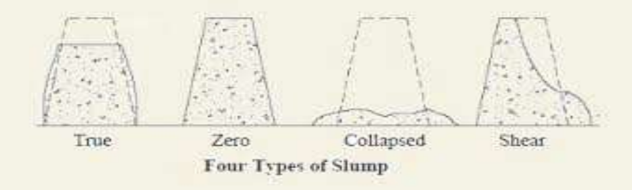
Procedure

Sample Preparation

The sample of concrete from which test specimens are made must be representative of the entire batch. It shall be obtained in accordance with STP 106.

Test Procedure

1) Dampen the mold and place it on a flat, moist, non-absorbent rigid surface.
2) Hold firmly in place by standing on the two foot pieces.
3) Fill the cone 1/3 full and uniformly rod the layer 25 times to its full depth.
4) Fill the cone with a second layer until 2/3 full by volume and rod 25 times uniformly, ensuring that the rod just penetrates into the first layer.
5) Overfill the cone with the third layer and rod uniformly, 25 times, with the rod just penetrating into the second layer.
6) Strike off the excess concrete level with the top of the cone by a screening and rolling motion of the tamping rod.
7) Remove any spilled concrete from around the bottom of the cone.
8) Immediately remove the mold from the concrete by raising it carefully in a vertical direction without lateral or torsional motion.
9) Measure the difference between the height of the mold and the height of the specimen at its highest point to the nearest 6.3 mm. This distance will be the slump of the concrete.



Photograph 3.1: Types of Slump

3.5 Schedule of Casting

The Specimen were casted as per the relavent standard. For each parameter (Test) Three specimen were cast and average of these three specimen were considered. The specimen series from A to G were casted for Cement Concrete and series H to N were used for Geopolymer Concrete. The details of dimension of cube parameters and number of specimen casted is given in table 3.9.

Cube: 100 mm × 100 mm × 100 mm

Table 3.9: Schedule of Specimen Preparation

Total number of specimen used are,
1) Conventional Concrete = 21
2) Geopolymer Concrete = 21

Total = 42

Mixing and Placing of Concrete

The fresh concrete was placed in the moulds by scoop. It was ensured that the representative volume was filled evenly in all the specimens to avoid segregation, accumulation of aggregate *etc*. While placing concrete, no compaction in vertical position was given to avoid gaps in moulds. Moulds are cleaned and oiled from inside smooth demoulding. Concrete is mixed thoroughly and placed in the mould without vibration.

After filling the mould, the concrete is not worked with trowel to give uniform surface. It level surface automatically. Care is taken not to add any extra cement, water or cement morter for achieving good surface finish. The density of fresh concrete is taken with the help of weigh balance. Identification marks are given on the specimens by embossing over the surface after initial drying.

Curing of Specimen

Curing of conventional cement concrete is done after 24 hours of casting by demoulding it and poured in water for 28 days.

Curing for GPC cubes is done for 24 hours at 60˚C temperature keeping it to the oven and after 24 hours, curing is done at natural temperature for 28 days.

EXPECTED RESULT

4.1 Tests on Harden Concrete

Compression test specimens are tested according to IS: 516-1975(36).

4.1.1 Tests for Compressive Strength

Compression test was carried out as per IS: 516-1975. Total 42 cubical specimen of 100 mm side were tested. The compression testing machine of 3000 kN capacity was used. The rate of loading was kept at 1.5kN/sec and deflection were measured using dial gauge with least count of 0.01 mm. Result are presented in Table (4.2).

The compressive strength of specimens, calculated by following formula,

$$f_{c\,k} = P_c / A_c$$

where,

P_c = Load at failure in kN
A_c = Loaded area in mm^2

4.1.2 Modulus of Elasticity

Modulus of elasticity is one of the important properties of material, which is required in the analysis and design of structures. It varies with the types of material. In the present work short term Static Modulus of elasticity of GPC and Conventional concrete is calculated as per the following equation given in IS 456-2000.

$$E_c = 5000\sqrt{fck}$$

Where,

E_c = Modulus of Elasticity
$F_{ck\,=}$ Cube compressive strength of concrete in MPa

OBSERVATION AND RESULTS

The selection of material and mix proportioning of Cement Concrete (CC) and Geopolymer Concrete (GPC) was done to achieve objectives, namely development of Geopolymer concrete, its workability and compressive strength for various percentages of salinity of water, by carrying number of trails on mix design and adding cement with various percentage of salinity. The mix proportion of GPC for the same grade by varying percentage of salinity had conducted. Properties of fresh state of cement concrete and geopolymer concrete are calculated by using slump cone tests and its results are given in this chapter, also the results of compressive strength of CC and GPC are shown and discussed.

5.1 Test Results on Fresh Concrete

5.1.1 Slump Cone Test

The slump cone test were carried out in laboratory on cement concrete and geopolymer concrete as per IS 456-2000. The results of slump cone test are given in Table 5.1, and the graphical variation of workability of CC and GPC for all percentage of salinity of water is shown in figure 5.1.

Sr. No.	**Types of Concrete**	**Slump (mm)**							
		Percentage of Salinity of Water (%)							
		0	**1**	**2**	**3**	**4**	**5**	**6**	**Sea Water**
01	Cement Concrete	98	96	92	86	80	74	66	94
02	Geopolymer Concrete	95	85	79	72	67	62	58	82

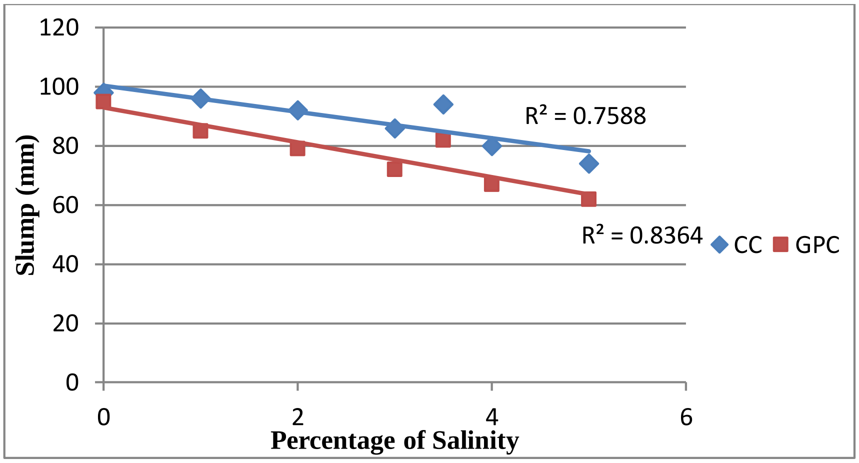


Fig. 5.1: Variation of Slump with Respect to Percentage of Salinity of Water

Relation between Slump of Concrete and Percentage of Salinity
From the figure 5.1 it is found that the slump of cement concrete and geopolymer concrete were medium as per the standard guidelines of IS 456-2000. The slump of cement concrete and geopolymer concrete of 0% salinity was found to be similar. The slump of cement concrete was more than that of gropolymer concrete at all percentage of salinity of water. The rate of decrease of slump with respect to percentage of salinity of water of geopolymer concrete is decreases as compared to cement concrete.

5.2 Analysis of Test Result on Harden Concrete

5.2.1 Compressive Strength

The results of compression test on cement concrete and Geopolymer concrete are presented in Table (5.2). column 2 of table represents percentage of salinity. Column 3 and 4 represents the corresponding compressive strength of Cement Concrete and Geopolymer Concrete at 28 days. The variation of compressive strength of Cement Concrete and Geopolymer Concrete with respect to percentage salinity is presented in column 5. The strength of Cement Concrete is more than Geopolymer Concrete by 4.55%, 2.93%, 5.90%, 5.60%, 5.48%, 4.02%, and 6.05% at varying salinity percentage as 0%, 1%, 2%, 3%, 4%, 5% and sea water respectively. Graph (Figure 5.2) is plotted between % salinity on x-axis and 28 days compressive strength of CC and GPC on y-axis. It shows that the variation of compressive strength with respect to % salinity is approximately linear for the number of salinity percentage variations considered in the study. Graph also indicates that the rate of decrease of compressive strength of CC and GPC is approximately same.

Table 5.2: Compressive Strength of Cement Concrete and Geopolymer Concrete

Sr. No.	**Percentage of Salinity (%)**	**Compressive strength At 28 Days (N/mm^2)**		**Percentage Variation in Strength (N/mm^2)**
		CC	**GPC**	
1	**2**	**3**	**4**	**5**
1	0	25.47	24.36	4.55
2	1	24.9	24.19	2.93
3	2	23.3	22.00	5.90
4	3	22.6	21.40	5.60
5	4	20.2	19.15	5.48
6	5	18.1	17.4	4.02
7	Sea Water (3.5)	21.9	20.65	6.05

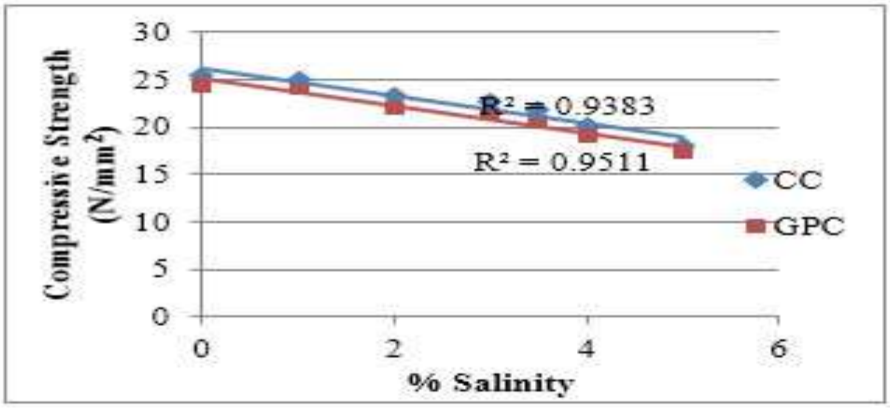


Fig. 5.2: Variation of Compressive Strength with Respect to % Salinity

5.2.2 Load Deflection Relationship

The result of compressive load and its corresponding deflection of Conventional Concrete and GPC are presented in Table (5.3) to Table (5.9) and its corresponding graphs were shown in Fig. (5.3) to Fig. (5.9). The load and deflection were measured at an interval of 25 KN. Column number 2 and 3 of the table represents compressive load and its corresponding deflection of Cement Concrete and column number 4 and 5 of tables represents compressive load and its corresponding deflection of GPC. All graphs are plotted between deflection on X-axis and compressive load on Y- axis of CC and GPC. In figures deflection occurs up to failure in GPC is greater than cement concrete.

Table 5.3: Load –Deflection of Cement Concrete and GPC at 0% Salinity

Sr. No.	**CC**		**GPC**	
	Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
1	**2**	**3**	**4**	**5**
1	0	0.01	0	0.01
2	25	0.54	25	0.89
3	50	0.78	50	1.19
4	75	0.94	75	1.38
5	100	1.13	100	1.66
6	125	1.36	125	1.97
7	150	1.6	150	2.16
8	175	1.83	175	2.39
9	200	1.99	200	2.53
10	225	2.23	225	2.76
11	250	2.43	243	3.06
12	254	2.71		

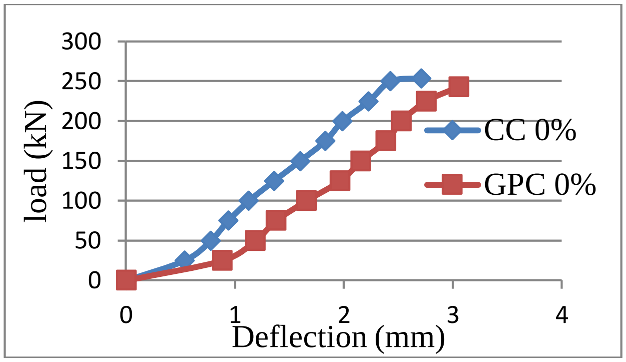


Fig. 5.3: Variation of Load Deflection of Cube with 0% Salinity

Fig. 5.3 shows the load –deflection variation for 0% salinity of water. The graph shows that the load bearing capacity of geopolymer concrete is less than that of cement concrete. Graph indicates that the rate of increase of load with increase in deflection is higher in case of GPC than CC. From the graph it is observed that in Geopolymer Concrete the rate of increase of deflection is increase when increasing the load as compared to cement concrete.

Table 5.4: Load – reduction in height of cube and GPC at 1% Salinity

Sr.No.	**CC**		**GPC**	
	Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
1	**2**	**3**	**4**	**5**
1	0	0.01	0	0.01
2	25	0.1	25	0.14
3	50	0.18	50	0.24
4	75	0.29	75	0.42
5	100	0.43	100	0.66
6	125	0.61	125	0.85
7	150	0.83	150	1.13
8	175	1.02	175	1.46
9	200	1.17	200	1.74
10	225	1.3	225	2.12
11	249	1.45	241	2.36

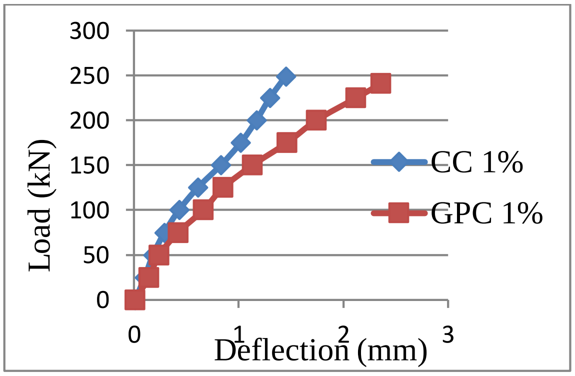


Fig. 5.4: Variation of Load Deflection of Cube with 1% Salinity

Fig. 5.4 shows the load –deflection variation for 1% salinity of water. The graph shows that the load bearing capacity of geopolymer concrete is less than that of cement concrete. Graph indicates that the rate of increase of load with increase in deflection is higher in case of GPC than CC. From the graph it is observed that in Geopolymer Concrete the rate of increase of deflection is increase when increasing the load as compared to cement concrete.

Table 5.5: Load –Deflection of Cement Concrete and GPC at 2% Salinity

Sr. No.	**CC**		**GPC**	
	Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
1	**2**	**3**	**4**	**5**
1	0	0.4	0	0
2	25	0.84	25	1.21
3	50	1.12	50	1.67
4	75	1.35	75	1.99
5	100	1.56	100	2.25
6	125	1.75	125	2.6
7	150	1.9	150	2.86
8	175	2.03	175	3.05
9	200	2.15	200	3.25
10	225	2.28	220	3.41
11	233	2.42		

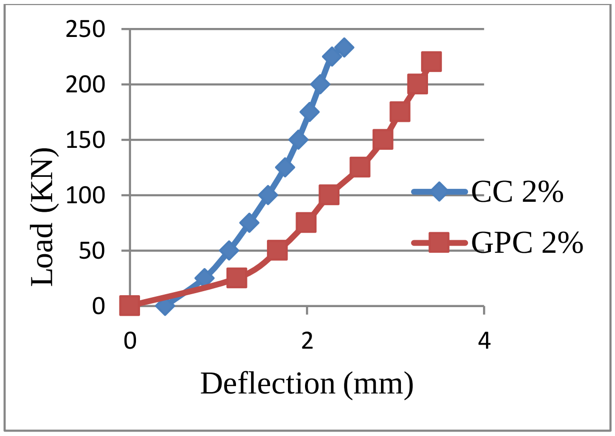


Fig. 5.5: Variation of Load Deflection of Cube with 2% Salinity

Fig. 5.5 shows the load –deflection variation for 2% salinity of water. The graph shows that the load bearing capacity of geopolymer concrete is less than that of cement concrete. The rate of change of deflection increases with increase in load. From the graph it is observed that the rate of increase of deflection is increase when increasing the load as compared to cement concrete.

Table 5.6: Load –Deflection of Cement Concrete and GPC at 3% Salinity

Sr. No.	**CC**		**GPC**	
	Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
1	**2**	**3**	**4**	**5**
1	0	0.1	0	0.01

2	25	0.57	25	0.76
3	50	0.86	50	1.26
4	75	1	75	1.59
5	100	1.13	100	1.86
6	125	1.25	125	2.02
7	150	1.39	150	2.23
8	175	1.52	175	2.47
9	200	1.66	200	2.78
10	225	2.01	214	2.98
11	226	2.34		

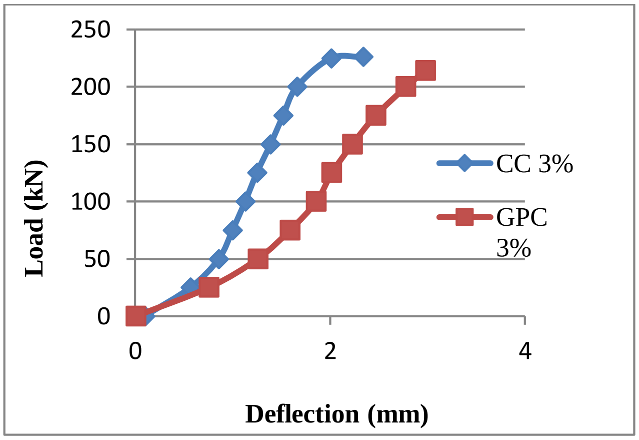


Fig. 5.6: Variation of Load Deflection of Cube with 3% Salinity

Fig. 5.6 shows the load –deflection variation for 3% salinity of water. The graph shows that the load bearing capacity of geopolymer concrete is less than that of cement concrete. The rate of change of deflection increases with increase in load. From the graph it is observed that the rate of increase of deflection is increase when increasing the load as compared to cement concrete.

Table 5.7: Load –Deflection of Cement Concrete and GPC at 4% Salinity

Sr. No.	**CC**		**GPC**	
	Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
1	**2**	**3**	**4**	**5**
1	0	0.01	0	0.01
2	25	0.46	25	0.8
3	50	0.78	50	1.26
4	75	0.96	75	1.55
5	100	1.16	100	1.69
6	125	1.34	125	1.91
7	150	1.49	150	2.11

8	175	1.69	175	2.24
9	200	1.86	191.5	2.54
10	202	2.16		

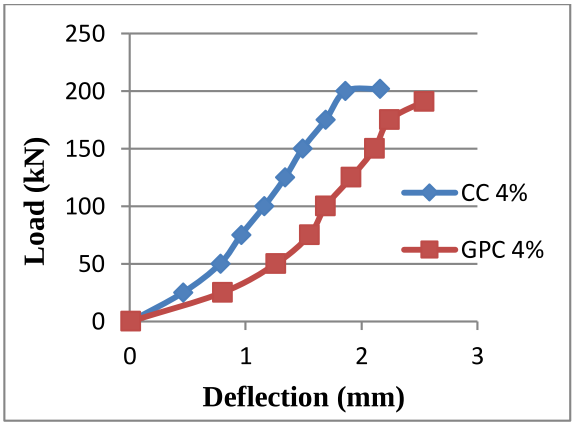


Fig. 5.7: Variation of Load Deflection of Cube with 4% Salinity

Fig. 5.7 shows the load –deflection variation for 4% salinity of water. The graph shows that the load bearing capacity of geopolymer concrete is less than that of cement concrete. The rate of change of deflection increases with increase in load. From the graph it is observed that the rate of increase of deflection is increase when increasing the load as compared to cement concrete.

Table 5.8: Load –Deflection of Cement Concrete and GPC at 5% Salinity

Sr. No.	**CC**		**GPC**	
	Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
1	**2**	**3**	**4**	**5**
1	0	0.04	0	0.1
2	25	0.34	25	0.57
3	50	0.47	50	1.03
4	75	0.69	75	1.46
5	100	0.86	100	1.79
6	125	1.03	125	1.96
7	150	1.26	150	2.16
8	175	1.48	175	2.36
9	200	1.98	200	2.86
10	219	2.36	206.5	2.99

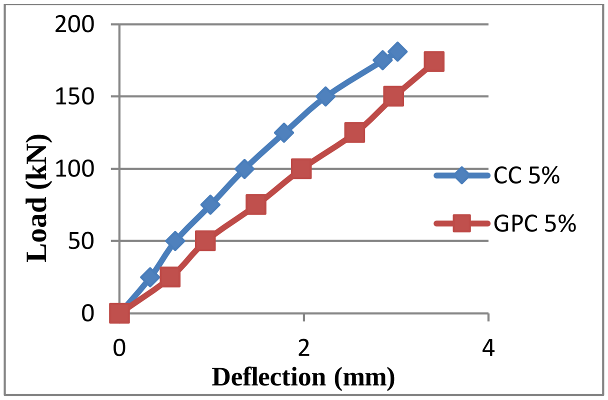


Fig. 5.8: Variation of Load Deflection of Cube with 5% Salinity

Fig. 5.8 shows the load –deflection variation for 5% salinity of water. The graph shows that the load bearing capacity of geopolymer concrete is less than that of cement concrete. The rate of change of deflection increases with increase in load. From the graph it is observed that the rate of increase of deflection is increase when increasing the load as compared to cement concrete.

Table 5.9: Load –Deflection of Cement Concrete and GPC at Sea Water

Sr. No.	**CC**		**GPC**	
	Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
1	**2**	**3**	**4**	**5**
1	0	0.01	0	0.01
2	25	0.34	25	0.56
3	50	0.61	50	0.94
4	75	0.99	75	1.49
5	100	1.36	100	1.98
6	125	1.79	125	2.56
7	150	2.24	150	2.98
8	175	2.86	174	3.42
9	181	3.02		

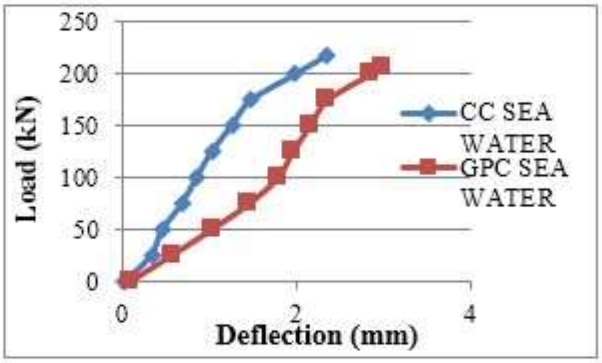


Fig. 5.9: Variation of Load Deflection of Cube with Sea Water

Fig. 5.9 shows the load –deflection variation for sea water. The graph shows that the load bearing capacity of geopolymer concrete is less than that of cement concrete. The rate of change of deflection increases with increase in load. From the graph it is observed that the rate of increase of deflection is increase when increasing the load as compared to cement concrete.

5.3 Modulus of Elasticity

Short term static modulus of elasticity of concrete was calculated as per I.S. Code. The results of Modulus of Elasticity of CC and GPC are determined by using I.S. Code equation and are presented in Table (5.10). Column 2 represents salinity of water, column 3 and 5 represents Compressive strength of CC and GPC at varying salinity percentage. Column 4 and 6 represents Modulus of Elasticity for that compressive strength. Modulus of Elasticity depends on the Compressive strength of concrete, in this study the Compressive strength of CC occurs greater than GPC. Furthermore the Modulus of elasticity of CC occurs more than GPC. Graph (figure 5.10) is plotted between compressive strength on x-axis and Modulus of Elasticity on y-axis. It shows that the variations of Modulus of Elasticity with respect to Compressive strength are approximately linear. Graph also shows that the rate of increase of Modulus of Elasticity of CC and GPC is same.

Table 5.10: Modulus of Elasticity of CC and GPC

Sr. No.	**% of Salinity**	**Cement Concrete**		**Geopolymer Concrete**	
		fck	**E_{CC}**	**fck**	**E_{CG}**
1	**2**	**3**	**4**	**5**	**6**
1	0	25.47	25.23	24.36	24.67
2	1	24.9	24.95	24.19	24.59
3	2	23.3	24.13	22	23.45
4	3	22.6	23.77	21.40	23.13
5	4	20.2	22.47	19.15	21.88
6	5	18.1	21.27	17.40	20.86
7	Sea Water (3.5%)	21.9	23.40	20.65	22.72

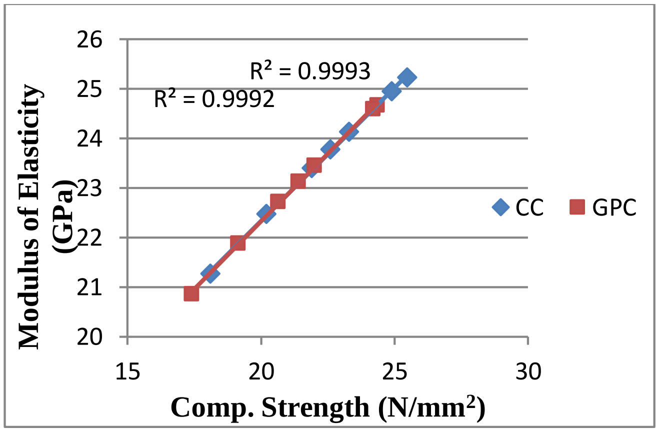


Fig. 5.10: Variation of Modulus of Elasticity with Respect to Compressive Strength

CONCLUSION

The conclusions drawn from the results discussed in the previous chapter are summarized as follows,

1. The workability of Cement Concrete and Geopolymer Concrete decreases when, increasing the salinity of water.
2. In case of sea water concrete the workability of CC and GPC were similar to fresh water concrete.

3. The compressive strength of Geopolymer Concrete is slightly less than that of cement concrete.
4. The compressive strength of Cement Concrete and Geopolymer Concrete get decrease when increasing the percentage of salinity of water.

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