Experimental Developments on Corrosion Resistivity of Low Calcium Fly Ash-Based Geopolymer Concrete

G Rambabu, Divya Anusha Naidu, Dumpa Venkateswarlu

***Abstract*: Portland cement production is an main component in making of concrete, which contributes significant amount of greenhouse gas, because in the process of production of Portland cement also releases about one ton of carbon dioxide gas into the atmosphere. Therefore, the introduction of a novel binder called 'geopolymer' by Davidovits promises a good prospect for application in the concrete industry as an alternative binder to Portland cement .**

In terms of reducing global warming, the technology based on geo-polymer could reduce the C02 emission to the atmosphere caused by aggregates and cement industries by 80%.Fly ash-based geopolymer concrete manufactured using fly ash as its source material and does not use Portland cement at all. Not only fly ash, alkaline solution is being utilized to make geopolymer paste which binds the aggregates to form geopolymer concrete. The geopolymer concrete possess excellent mechanical characteristics and better durability characteristics like permeability, resistance against sulphate and acids.

In reinforcement the corrosion is the single most common source of damage and it is usually clear that lack of concrete, inadequate cover to the reinforcement or the available impurities (and sometimes all three) is the prime cause. In the present work, Open Circuit Potential(OCP) method was able to determine the corrosion activity in the reinforced beams. The effect of corrosion on the tensile behavior of reinforcement under different rates of corrosion was compared. The test results reveals that the Geopolymer concrete performs superior to OPC concrete.

***Keywords* : Open Circuit Potential (OCP), CSHs, CO2, AI.**

I. INTRODUCTION

The standard Portland cement still keeps on being the most as often as possible utilized fastener in the development business. The generation of this Portland cement contributes a significant measure of ozone depleting substance, in light of the fact that the creation of one ton of Portland cement discharges one ton of carbon dioxide gas into the environment. Thusly, the novel fastener called 'geopolymer' by Davidovits guarantees a decent prospect for application in the concrete business as an eco-accommodating option in contrast to the Portland cement. There could be about 80% decrease in CO2 emanations to the climate cause by cement and aggregate industry by the usage of the geopolymer innovation. Subsequently bringing about a noteworthy lessening of a worldwide temperature alteration.

Energized by this creative innovation and the point that fly slag is a waste material abundantly accessible, an endeavor has been made to build up a substitute concrete fastener by applying the geopolymer innovation and utilizing fly fiery remains as the source material to yield the Fly Ash-Based Geopolymer Concrete. This paper displays the study on fly slag based geopolymer concrete, concentrated on the sorptivity coefficient for three evaluations for example Low, Medium and Higher evaluations have been arrived and contrasted and that of customary Portland cement concrete.

ASTM wording characterizes consumption as "the concoction or electrochemical response between a material , as a rule a metal , and its condition that creates a deterioration of the material and its properties ".A uninvolved film frames on the steel surface because of the high basic condition of a decent quality concrete which keeps the steel from eroding. This latent film is annihilated under a chloride assault which results in erosion. Steel consumption in concrete prompts break decrease of bond quality, decrease of steel cross area and loss of serviceability. Reinforced concrete uses steel to give the pliable properties that are required in structural concrete which averts the disappointment of concrete structures that are exposed to ductile forces and flexural forces because of traffic, winds, dead loads and warm cycling. In any case, when reinforcement consumes, the development of rust prompts lost bond between the steel and concrete and ensuing delamination and spalling. Whenever left unchecked, the uprightness of the structure can be influenced. Decrease in the cross-sectional territory of steel lessens its quality limit.

FLY ASH-Based Geopolymer Concrete:-Geopolymer concrete in assembling utilizing source materials wealthy in silica and alumina. While the cement-based concrete uses the development of calcium-silica hydrates (CSHs) for lattice arrangement and quality, geo polymers include the concoction response of

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alumina-silicate oxides with soluble base polysilicates yielding polymeric Si-O-Al securities. In this trial work, fly fiery debris is utilized as the source material to make the geopolymer glue as the fastener, to deliver concrete. The assembling of geopolymer concrete is completed utilizing the typical concrete innovation techniques. As in the Portland cement concrete, in fly fiery debris slam geopolymer concrete, the aggregates possess the biggest volume, for example around 75-80% by mass.

Sodium-based activators were picked in light of the fact that they were less expensive than Potassium-based activators. The sodium hydroxide was utilized in piece or pellet structure. It is suggested that the soluble fluid is set up by mixing both the arrangements together at any rate 24 hours preceding use. The mass of NaOH solids differed relying upon the concentration of the arrangement communicated as far as molar, M. The concentration of NaOH arrangement can fluctuate in the scope of 8M to 16M. The mass of water is the real segment in both the basic arrangements. So as to improve usefulness, a Naphthalene Sulphonate Formaldehyde (SNF) based super plasticizer has been added to the mixture.

II. LITERATUREREVIEW

A.Corrosion:-Corrosion is the steady annihilation of materials, (typically metals), by substance response with its condition. In the most widely recognized utilization of the world, this implies electrochemical oxidation of metals in response with an oxidant, for example, oxygen. Rusting, the development of iron oxides is a notable case of "electrochemical corrosion. This sort of harm regularly creates oxides or salts of the first metal. Corrosion can likewise happen in materials other than metals, for example, earthenware production or polymers, in spite of the fact that in this specific circumstance, the term corruption is increasingly normal. Corrosion corrupts the helpful properties of materials" and structures including quality, appearance and penetrability to fluids and gases. Numerous structural combinations erode only from presentation to dampness in air, yet the procedure can be unequivocally influenced by introduction to specific substances. Corrosion can be focused locally to shape a pit or split, or it can stretch out over a wide region pretty much consistently consuming the surface. Since corrosion is a dispersion controlled procedure, it happens on uncovered surfaces. Accordingly, techniques to diminish the action of the uncovered surface, for example, passivation and chromate transformation, can build a material's corrosion obstruction . Be that as it may, some corrosion components are less noticeable and less unsurprising. Iron is insecure in nature, and on the grounds that strengthening steel utilized in precast concrete is made generally of iron, it, as well, ends up flimsy when presented to destructive specialists, for example, salt, carbonation, and even air. Iron, as we normally remember it, isn't commonly found in nature in view of its flimsiness. It takes a lot of vitality to create iron from its metal, and, after its all said and done it is unstable to the point that it must be covered to shield it from returning to its metal structures (hematite, magnetite, and limonite)."

The two most regular reasons for reinforcement corrosion are

- localized breakdown of the aloof film on the steel by chloride particles and general breakdown of aloofness by balance of the concrete, prevalently by response with environmental carbon dioxide.

`hardened concrete is a perfect domain for steel however the expanded utilization of deicing salts and the expanded concentration of carbon dioxide in present day conditions. Mainly because of mechanical contamination, has brought about corrosion of the rebar turning into the essential driver of disappointment of this material. The size of this issue has achieved disturbing extents in different pieces of the world.

B. Corrosion Of Steel A Concern:-Fortified solid uses steel to give the elastic properties that are required in structural concrete. It keeps the disappointment of solid structures which are subjected to pliable and flexural worries because of movement, twists, dead loads, and warm cycling. In any case, when fortification consumes, the development of rust prompts lost bond between the steel and the solid and in this way delamination and spalling as shown in Fig.1. On the off chance that left unchecked, the honesty of the structure can be influenced. Decrease in the cross sectional territory of steel lessens its quality limit. This is particularly impeding to the execution of tensioned strands in pre-focused on concrete.

C.Reasons ForCorrosion:- Steel in concrete is usually in a non-corroding, passive condition . However, steel reinforced concrete is often used in severe environments where sea water or deicing salts are present . When chloride moves into the concrete, it disrupts the passive layer protecting the steel, causing it to rust and pit. Carbonation of concrete is anothercause of steel corrosion. When concrete carbonates to the level of the steel rebar the normally alkaline environment, which protects steel from corrosion, is replaced by a more neutral environment. Under these conditions the steel is not passive and rapid corrosion begins. The rate of corrosion due to carbonated concrete cover is slower than chloride-induced corrosion. Occasionally, a lack of oxygen surrounding the steel rebar will cause the metal to dissolve, leaving a low pH liquid

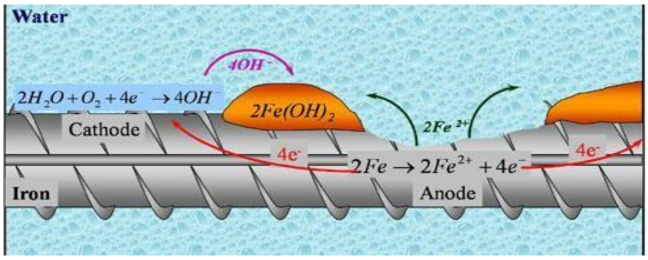

Fig.1. Showing the reasons for corrosion.

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D.Prevention OfCorrosion:-Quality Concrete and Concrete Practices.The first resistance against corrosion of steel in concrete is quality concrete and adequate concrete spread over the fortifying bars. Quality concrete has a water-to-cementious material ratio (w/c) that is low enough to hinder the penetration of chloride salts and the advancement of carbonation. The w/c ratio ought to be under 0.50 to moderate the rate of carbonation and under 0.40 to limit chloride penetration. Concretes with low w/c ratios can be delivered by (1) expanding the cement content; (2) decreasing the water content by utilizing water reducers and super plasticizers; or (3) by utilizing bigger measures of fly fiery remains, slag, or differentcementious materials. Also, the utilization of concrete fixings containing chlorides ought to be limiteds. Furthermore, the utilization of solid fixings containing chlorides ought to be constrained. The AI 318 Building Code gives limits on the most extreme measure of solvent chlorides in the concrete mix.

HOW TO LIMIT CORROSION:

- Utilize great quality concrete air-entrained with a w/c of 0.40 or less.
- Use a base concrete front of 1.5 inches and at any rate 0.75 inch bigger than the ostensible most extreme size of the coarse aggregate.
- Increase the base spread to 2 crawls for deicing salt presentation and to 2.5 inches for marine presentation.
- Ensure that the concrete is satisfactorily relieved.
- Use fly fiery debris, impact heater, slag, or silica rage and additionally a demonstrated corrosion inhibitor.

III.EXPERIMENTALPROGRAMMEE

The principle goal of the present exploratory examination is to acquire explicit test information, which analyzes the corrosion movement of standard Portland cement beams and geopolymer concrete beams.

A. Materials

Cement: Standard Portland cement of 53 grade, accessible in nearby market is utilized in the examination. The cement utilized for all tests is from a similar clump. The cement utilized has been tried for different properties according to May be: 4031-1988

Grade: OPC53

Brand: Bharati Cement

Fine Aggregate: Locally available RIVER SAND is used as fine aggregate and is tested for various properties required. The sand passing through IS sieve 2.36mm was taken.

Coarse Aggregate: The coarse aggregate utilized is locally accessible squashed rock stone of 20mm size. Tests are led to decide its physical properties. The aggregates going through IS 20mm strainer and holding on 12.6mm sifter were taken for the exploratory methods

Size of aggregate: 20mm.

Water: Water used for mixing and curing is fresh potable water, conforming to IS: 3025 - 1964 part 22, part 23 and IS: 456 - 2000.

FLY ASH: Fly Ash is from the National Thermal Power Corporation (NTPC), Ramagundam, Telangana.

TABLE I: Typical Oxide Composition of Indian Fly Ash

SNo	Characteristics	Percentage
1.	Silica, SiO2	**49-67**
2.	Alumina Al2O3	**16-28**
	Iron oxide Fe2O3	**4-10**
4.	Lime Ca0	**0.7-3.6**
5.	Magnesia Mg 0	**0.3-2.6**
6.	Sulfur Trioxide SO3	**0.1-2.1**
7.	Loss on Ignition	**0.4-1.9**

TABLE II: Chemical Requirements Of Fly Ash

S.No.	Characteristics	Requirements (% by weight)	Fly Ash used (% by weight)
1	Silicon dioxide (Si02)plus aluminum oxide A1203 plus iron oxide Fe203	70 (minimum)	94.78
2.	Silicon dioxide (Si02)	35 (minimum)	66.81
3	Magnesium Oxide (MgO)	5 (max.)	2.55
4.	Total sulphur as sulphur trioxide (SO3)	2.75 (max.)	0.87
5.	Loss on ignition	12 (max.)	18

Sodium Silicate: The Sodium Silicate liquid used in this study was provided in liquid form by Kiran Global Chems Limited, Chennai.

TABLE III: Properties of Sodium Silicate Solution

Specific gravity	1.6
Molar mass	122.06 gr/molar
Na2o (by mass)	14.7 %
Sio2 (by mass)	29.4 %
Weight of solids (by mass)	44.5%
Water (by mass)	55.90%
Weight Ratio (sio2 to na2o)	2
Molar ratio	2.06

Sodium Hydroxide: Sodium Hydroxide was provided by Genesynth Fine Chemicals, Hyderabad. The chemical was given in pellet/flakes form with 98% purity.

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TABLE IV: Properties of Sodium Hydroxide

Molar mass	40 gm/mol
Appearance	White solid
Density	21 gr/mol
Melting point	318° c
Boiling point	1390 °c
Amount of heat liberated when dissolved in water	266 cal /gr

Super Plasticizer: Naphthalene Sulphonate Formaldehyde (SNF) based super plasticizer was provided by BASF chemical company by the product name - Rheobuild - 920SH.

B. Compressive Strength Of Cement

CODE: IS 4031Part-VI

Description: Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. It provides data of force vs. deformation for the conditions of the test method as shown in Fig.2.

Apparatus: Mould of (7.06*7.06) cm dimensions, CTM

Cement Mortar: 1:3 cement and sand

Water Percentage: (P/4 +3) %(weight of sample)

Result: Compressive strength of OPC 53 grade for 3 days is 26Mpa.

Is Limit: As per code compressive strength of cement when tested shall be minimum 53Mpa (for 28 day).

Fig.2.Compressive Strength of Cement

TABLE V: Physical Properties Of Cement

PHYSICAL TESTED	IS SPECIFICATIONS	RESULTS
Fineness of cement	% Residue <10% % Fineness :- >90%	3% 97%
Specific gravity	3.15	3.1
Standard consistency	30-32%	32%
Initial setting time	>30 minutes	55 minutes
Final setting time	<600 minutes	350 minutes
Compressive strength test	53 MPa for 28 days	26 MPa for 3 days

C. Tests On FineAggregate

1. Specific Gravity Of FineAggregate:

CODE: IS 2386 Part-Ill

Description: Specific gravity test is used to find the specific gravity of fine aggregate sample by determining the ratio of weight of given volume of aggregate to the weight of equal volume of water. Aggregate specific gravity is needed to determine weight-to-volume relationships.

2. Fineness Modulus Of FineAggregate:

CODE: IS 2386 Part-1

Description: Fineness modulus (FM) is defined as an empirical figure obtained by adding the total percentage of the sample of an aggregate retained on each of a specified series of sieves, and dividing the sum by 100. In general fineness modulus is defined as size of the aggregate.

TABLE VI: Fineness Modulus Of Fine Aggregate

SI no.	IS Sieve Size	Weight retained gm.	Cumulative Weight retained gm	Cumulative %Weight retained	Cumulative % Passing	Grading Limits IS 383-1970 Zone II
1	10 mm	0	0	0	100	100
2	4.75mm	4	4	0.4	99.6	90-100
3	2.36mm	40	44	4.9	94.9	75-100
4	1.18mm	184	228	22.8	75.9	55-90
5	600microns	355	583	58.3	39.9	35-59
6	300 microns	310	909	90.9	8.9	8-30
7	150 microns	75	984	98.4	1.4	0-10
8	<150microns	14		—	-	-
9	Total	1000		275.7		

Result: The fineness modulus of fine aggregate is 2.7.

Is Limits: As per code fineness modulus should range from 2-4

HENCE OK

TABLE VII: Physical Properties Of Fine Aggregate

PHYSICAL PROPERTY TESTED	IS SPECIFICATIONS	RESULTS OBTAINED
Specific gravity	2.5-26	2.55
Fineness modulus	2-4	2.7

D. Tests On CoarseAggregate

1. Specific Gravity Of Coarse Aggregate: Code: IS 2386 Part-Ill

Description: Specific gravity test is used to find the specific gravity of coarse aggregate sample by determining the ratio of weight of given volume of aggregate to the weight of equal volume of water as shown in Fig.3. Aggregate specific gravity is needed to determine weight-to-volume relationships.

Apparatus: Pycnometer

Result: Specific gravity of coarse aggregate is 2.62

Is Limit: As per code specific gravity of coarse aggregate has to range between 2.6-2.7

HENCE OK.

TABLE VIII: Fineness Modulus Of CoarseAggregate

SI. No	IS Sieve size	Weight retained gm.	%weight retained	Cumulative Percentage Weight retained
1	40 mm	0	0	0
2	20 mm	3550	63	63
3	10 mm	1450	37	100
4	4.75 mm	0	0	100
5	2.36 mm	0	0	100
6	1.18 mm	0	0	100
7	600 microns	0	0	100
8	300 microns	0	0	100
9	150 microns	0	0	100
	-			763

Fineness Modulus = 763/100 = 7.63

TABLE IX: Physical Properties Of CoarseAggregate

PHYSICAL PROPERTY TESTED	IS SPECIFICATIONS	RESULTS OBTAINED
Specific gravity test	2.6-2.7	2.62
Fineness modulus	5.5-8	7.63

Fig.3. Coarse Aggregate. Code: IS 2386 Part-1

III. PROCEDURE

A. Mixing

Intensive mixing is fundamental for the generation of uniform, brilliant concrete. Hence hardware and strategies ought to be able to do adequately mixing concrete materials containing the biggest determined aggregate to deliver uniform mixtures of the most reduced droop reasonable for the work. A concrete mixer is utilized for this reason.

B. Geopolymer ConcreteMixing

The essential contrast between Geopolymer concrete and Portland cement concrete is the fastener. The silicon and aluminum oxides in the low - calcium fly-ash responds with the basic fluid to from the geopolymer glue that ties the free coarse and fine aggregates and other unreacted materials to frame the geopolymer concrete. The Sodium Hydroxide chips are to be disintegrated in refined water in right amounts relying on the molarity required for each mix design. This NaOH arrangement is to be mixed and arranged 24hours before use.

The fly fiery debris, coarse aggregate and fine aggregates are first mixed together in the mixer for three minutes or until the dry materials are altogether mixed together. The Sodium Hydroxide and Sodium Silicate arrangements are mixed together alongside the super plasticizer and water and after that additional to the dry materials in the mixer. The whole mixture is permitted to mix for four minutes. The crisp concrete is to be tried for droop in a droop cone mechanical assembly which has been appropriately lubed and fitted.

C. Casting

GPC Specimens: After the sample has been mixed and tried for slump, fill the beam forms in the wake of applying oil to every one of the appearances. The concrete is to be poured in three layers and compacted with manual strokes by applying twenty-five hits to each layer with the assistance of a packing pole. While completing off the outside of the concrete, if the form is too full the abundance concrete ought not be evacuated by scratching off the top surface as this removes the cement glue that has made advances on the top and leaves the concrete shy of cement.

The right route is to utilize a side of trowel and uncover a reasonable sample of the concrete all in all, at that point complete the surface by trowelling.

OPC Specimens: After the sample has been mixed and tried for slump, fill the beam forms in the wake of applying oil to every one of the appearances. The concrete is to be poured in three layers and compacted with manual strokes by applying twenty-five hits to each layer with the assistance of a packing pole.

While completing off the outside of the concrete, if the shape is too full the overabundance concrete ought not be evacuated by scratching off the top surface as this removes the cement glue that has made advances on the top and leaves the concrete shy of cement. The right path is to utilize an edge of trowel and uncover a reasonable sample of the concrete in general, at that point complete the surface trowelling.

D.Demoulding

The Conventional concrete beams ought to be demoulded between 20-24 hours after they have been made. The Geopolymer concrete beams are to be demoulded after proper warmth restoring has occurred. When expelling the block from the shape, dismantle the form totally. Take care not to harm beam in such a case that any breaking is caused, the compressive quality might be diminished. Subsequent to demoulding, each beam ought to be set apart with neat recognizable proof on top or base utilizing a waterproof pastel or ink. The shape must be altogether cleaned in the wake of demoulding and guarantee that oil or soil does not gather between the ribs, generally the two parts won't fit appropriately and there will be spillage through the joint and a sporadically formed beam may result.

E. Curing

Care must be taken to appropriately fix concrete, to accomplish best quality and hardness, during this period concrete must be held under controlled temperature and damp environment. Appropriately relieving concrete prompts expanded quality and lower penetrability and abstains from splitting where the surface dries out rashly. Ill-advised relieving can cause scaling, decreased quality, poor scraped area obstruction and breaking.

After the Geopolymer concrete molds are casted, the specimens are restored at a temperature of 60°C for 24hours. Two kinds of restoring were connected, Heat relieving and Ambient restoring. For warmth restoring, the specimens werecovered with a polythene sheet andcured in a broiler and for Ambient relieving the specimens were left to air for wants period. Theheat relieved specimens were left to air-dry in the research center for another 24hours or until testing. It is to be noticed that the specimens are still in their molds during the 24hours time of Heat restoring. The specimens can be demoulded, after warmth relieving, and left for Ambient restoring.

Curing Of Normal Concrete Specimens: The beams must be restored before they are tried. The blocks ought to be put following demoulding in the restoring tank. The restoring temperature of the water in the relieving tank ought to be kept up at 27-30°C. Relieving ought to be proceeded for 28 days or up to the season of testing. So as to permit acceptable course of water, sufficient space ought to be given between the beams, and between the beams and the side of the tank.

A.Testing

The beam specimens are to be tested for compressive strength in the Compressive Testing Machine (CTM) and then tested for Corrosion in Open Circuit Potential Method.

Open Circuit Potential Method: Open circuit potential (OCP) alludes to the distinction that exists in electrical potential. It typically happens between two gadget terminals when segregated from a circuit including no outside burdenIt is the potential in a working terminal similar to the cathode in reference when there is no present or potential existing in the cell. When a potential with respect to the open circuit is made present, the whole framework checks the capability of the open circuit preceding turning on the cell. This is trailed by the use of potential with respect to the current estimation. On the off chance that the essential potential is in excess of 300 mV, the underlying potential ought to be in excess of 400 mV. Open circuit potential is also known as open circuit voltage (OCV).

IV. ANALYSIS & DISCUSSION OFRESULTS

Based the Experimental examinations did on Ordinary, Standard and High quality geopolymer concrete and Conventional concrete (OPC), the compressive quality Outcomes are exhibited in the accompanying tables.

TABLE X: Test Results Of Portland Cement Concrete Mixtures

Grade of Concrete	M20	M40	M60
Compressive strength (7 days curing) N/mm^2	18.55	33.77	50.08
Compressive strength (28 days) N/mm^2	23.77	43.55	66.12
Workability (Slump)	Very stiff	High	Moderate

TABLE XI: Test Results Of Fly Ash-Based Geopolymer Concrete Mixtures

A. OPC Test Results

Grade of Concrete	G20	G40	G60
Compressive Strength (7 days) N/mm^2	27.55	40.88	62.22
Compressive Strength (28 days) N/mm^2	29.25	45.77	67.85
Workability (Slump)	High	High	Very stiff

TABLE XII: Corrosion Condition (ASTM C 876-1991)

(mV vs SCE)	(mV vs CSE)	Corrosion Condition
<-426	<-500	Severe corrosion
<-276	<-350	Eligh(<90% risk of corrosion)
-126 to-275	350 to - 200	Intermediate corrosion risk
>- 125	>-200	Low(10 % risk of corrosion)

The test outcomes got were contrasted and the values given by ASTM C 876-91 guideline and the likelihood of reinforcement corrosion is anticipated. From the table, it tends to be seen that GPC carries on in a superior way contrasting and OPC for a similar chloride arrangement.

TABLE XIII: Corrosion Probability

SET	Cement type	Specimen no.	Average open circuit potential values of 3 specimens (mV)	Corrosion condition
1	OPC	M20	-89	Intermediate
	OPC	M40	-122	intermediate
	OPC	M60	-169	High
2	GPC	G20	-84	Intermediate
	GPC	G40	-105	Intermediate
	GPC	G60	-155	Intermediate

The effect of corrosion on the tensile behaviour of reinforcement under different rates of corrosion is compared. There is not much noticeable change in the yield strength. Long duration test may be required to analyze the strength of beams.

TABLE XIV: Results Of Tension Test

Set	Cement type	Specimen no.	Yield stress with corrosion	Ultimate stress with corrosion	Yield stress without corrosion	Ultimate stress with out corrosion
1	OPC	M20	394.26	471.85	426	492.86
		M40	398.13	479.89	426	492.86
		M60	405.26	486.28	426	492.86
2	GPC	G20	402.96	476.94	426	492.86
		G40	406.09	481.58	426	492.86
		G60	412.23	489.18	426	492.86

The table shows the influence of chloride content on OPC and GPC in the potential values which is the indication

V. CONCLUSION

1. Geopolymer concrete acts like OPC concrete.
2. Water to geopolymer solids ratio and antacid fluid to flyash ratio are the administering factors for the advancement of geopolymer concrete
3. The execution of geopolymer reinforced concrete beams presented to chloride condition is better than OPC reinforced concrete beams.
4. As the evaluation of concrete increment the corrosion opposition likewise increments; for both OPC and GP concretes.
5. Yield pressure and extreme pressure values for OPC and GPC diminishes as for unexposed reinforced bar.

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