Durability Properties of Geopolymer Concrete Using Silica Fume for M_{60} Grade

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Abstract – As far as possible, the technology that is currently in use to manufacture and testing of ordinary Portland cement concrete were used. Silica fume was chosen as the basic material to be activated by the geopolymerization process to be the concrete binder, to totally replace the use of Portland cement. The binder is the only difference to the ordinary Portland cement concrete. To activate the rich silicon content in silica fume, a combination of sodium hydroxide solution and sodium silicate solution was used. Manufacturing process comprising material preparation, mixing, placing, and compaction and curing are reported in the thesis. Naphthalene based super plasticiser was found to be useful to improve the workability of fresh silica fume based geopolymer concrete, as well as the addition of extra water. The M60 grade is used in this paper with different water/binder ratios for case 1, 0.3 for GPC(Geopolymer concrete) and 0.3 for OPC(Orginary portland concrete) case 2 , 0.34 for GPC(Geopolymer concrete) and 0.32 for OPC(Ordinary portland concrete) and the test specimens are prepared and cured in different durability parameters and these specimens are analysed. And made a comparison of two cases of the durability properties.

Index Terms – Geopolymer, Silica Fume, Naphthalene, GPC, OPC.

1. INTRODUCTION

Concrete, artificial engineering material made from a mixture of Portland cement, water, fine and coarse aggregates and a small amount of air. It is the most widely used construction material in the world. Concrete is the only major building material that can be delivered to the job site in a plastic state. This unique quality makes concrete desirable as a building material because it can be molded to virtually to any form or a shape. Concrete provides wide latitude in surface textures and colors and can be used to construct a wide variety of structures such as highways and streets, bridges, dams, large buildings, airport runways, irrigation structure, break waters, piers and docks, sidewalks, soils and farm building homes and even barges and ship. Other desirable qualities of concrete as a building material are its strength, economy and durability. Depending on the mixture of materials used, concrete will support, in compression, 700 or more kg/sq cm, (10,000 or more 1b/sq cm). The tensile strength of concrete is much lower when compared to compressive strength of concrete, but by using properly designed steel reinforcing, the structural members can be made that are as strong as in compression. The durability of concrete is evidenced by the fact that concrete columns built by the Egyptians more than 3600 years ago are still standing.

Concrete is the premier construction material around the world and is most widely used in all types of construction works, including infrastructure, low and high-rise buildings, and domestic developments. It is a man-made product, essentially consisting of a mixture of cement, aggregates, water and admixture(s). Inert granular materials such as sand, crushed stone or gravel form the major part of the aggregate. These materials are blended in required proportions according to the strength parameter and Grade of concrete.

Since the beginning of the industrial revolution in 1760 there has been an increase in the use of fossil fuel energy resulting in amplified emissions of GHG's (Greenhouse Gases) (Slanina, 2004). This increased global dependency on oil, coal and natural gas has resulted in the release in excess of 1100 Gt (Giga tonne) of CO_2e emissions to the atmosphere (IPCC, 2001). The release of GHGs contributes to anthropogenic induced global warming with the most significant of these gases being CO_2 (Carbon dioxide) (IPCC, 2001). This is due to the sheer quantities that are being emitted, even though it does not have the highest radioactive forcing potential. The cement industry is energy intensive and accounts for a significant portion of these anthropogenic GHG emissions.

Globally the cement industry contributes between five and eight percent of all CO_2e (Carbon dioxide equivalent) emissions (CIF, 2003; Flower and Sanjayan, 2007; Ulm, 2007). World production totalled 42 billion tonnes in 2013 with the three major global contributors being China accounting for 11 billion tonnes (46 percent), USA accounting for 6 billion tonnes (16 percent) and India accounting for 2.6 billion tonnes (six percent) (USDoI, 2013).

A major producer of CO_2 is the cement industry. It is estimated that the cement activity contributes five to eight percent of global anthropogenic CO_2 emissions. Cement is only a constituent of concrete and accounts for 15 to 30 percent of the world's GHG's.

Concrete is the most commonly used construction material in the world because of its outstanding strength, durability, and availability. In fact, concrete is the world's most consumed man-made material and its use is expected to increase substantially.

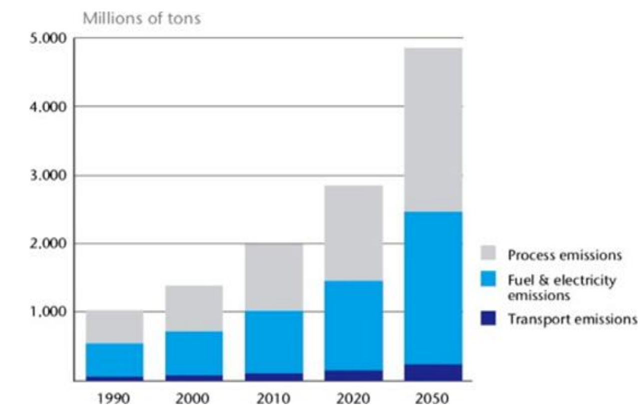
From the above discussions it is been clear that the concrete industry producing vast amount of CO_2 around the world and production of concrete is not environmentally friendly, so there is emergency to reduce the usage of cement and this can be achieved by different alternatives

The manufacture of Portland cement clinker involves the calcinations of calcium carbonate according to the reactions:

$3CaCO_3 + SiO_2 \rightarrow Ca_3SiO_5 + 3CO$

$2CaCO_3 + SiO_2 \rightarrow Ca_2SiO_4 + 2CO_2$

In order to reduce further the CO_2 emissions associated with concrete further viable alternatives to replace OPC are being examined with geopolymer materials considered to be one such alternative.



CO_2 productions in different modes

GEOPOLYMER CONCRETE

In the context of increased awareness regarding the ill-effects of the over exploitation of natural resources, eco-friendly technologies are to be developed for effective management of these resources. Construction industry is one of the major users of the natural resources like cement, sand, rocks, clays and other soils. The ever increasing unit cost of the usual ingredients of concrete have forced the construction engineer to think of ways and means of reducing the unit const of its production. At the same time, increased industrial activity in the core sectors like energy, steel and transportation has been responsible for the production of large amounts like fly ash, blast furnace slag, silica fume and quarry dust with consequent disposal problem.

The geopolymer technology was first introduced by Davidovits in 1978. His work considerably shows that the adoption of the geopolymer technology could reduce the CO_2 emission caused due to cement industries. Geopolymers are members of the family of inorganic polymers. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous. Any material that contains mostly silicon (Si) and aluminium (Al) in amorphous form is a possible source material for the manufacture of geopolymer. Metakaolin or calcined Kaolin, low calcium ASTM Class F fly ash, natural Al-Si minerals, combination of calcined minerals and non-calcined minerals, combination of fly ash and metakaolin, combination of granulated blast furnace slag and metakaolin have been studied as source materials. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide or potassium hydroxide and sodium silicate or potassium silicate.

Materials Required For Geopolymer Concrete

- **Cementitious binder**

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

- **Alkaline activators:**

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

- **Aggregates:**

Aggregates used to produce geopolymer concrete should be chosen and tested as per IS standards.

- **Super plasticizer:**

This is used in concrete to accelerate or decelerate the setting time and also to attain good workability conditions in a concrete

The geopolymer concrete mix was prepared as follows

NaOH (in water) + Na2SiO3 → Alkaline Liquid

Alkaline Liquid +Super plasticizer + → Geopolymer Concrete.

Extra water + Aggregate + silica fume

2. LITERATURE 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. New building materials that enhance both greenness and durability could reduce long-term costs by eliminating the need for the replacement of non-obsolescent structures and thereby reduce the environmental impact. In this connection, geopolymers promise to have a great potential for greenness and durability.

Literature Review On Durability:

Song X J, Marosszeky M, Brungs M and Munn R , carried out a study on the sulphuric acid attack on fly ash-based geopolymer concrete. They find that the sulphuric acid ingress in geopolymer concrete is controlled by a diffusion process. Excellent gel-aggregate interface was observed from SEM micrographs, where the geopolymer matrix at the corroded region remains identical to the unaffected one and still serves the binding function to the surrounding aggregates.

Sobolev K G , studied the effect of adding up to 50% by mass of granulated blast furnace slag in the cementitious material that resulted in the increase of chemical and thermal resistance. The very low permeability of the concrete obtained, provided high resistance to chemical attack and to freezing and thawing cycles. There was no visible destruction of blast furnace slag concrete samples after 140 cycles of freezing and thawing at -50ºC, and they also demonstrated high resistance to elevated temperatures.

Dos Santos J R, Branco F A and Brito J de , pointed out that the main problem in the assessment of concrete structures that have been subjected to fire is determining the depth of deteriorated concrete. In order to do that, a new method, the fire behaviour test (FB Test), has been developed. With it, the depth of deteriorated concrete is quantified by resorting to the measurement of the water absorption and tensile failure stress characteristics in discs obtained from cores drilled from the structure under analysis.

3. MIX DESIGN OF CONCRETE FOR TWO CASES

CASE 1

FINAL PROPORTION OF OPC CONCRETE & FINAL PROPORTIONS OF GPC CONCRETE

	Cement	F.A	C.A	Water	Super plasticizer
Ratio	1	1.16	2.45	0.3	0.03

	Silica Fume	F.A	C.A	Water	NaOH	Na_2Sio_3	Super plasticizer
Ratio	1	1.3	3.05	0.09	0.06	0.23	0.015

AMOUNT OF MATERIALS USED IN OPC & GPC COMPOSITION OF SILICA FUME

	OPC (Kg/m³)	GPC (Kg/m³)
Cement	493	_
Silica fume	_	424.62
Fine Aggregate	575	555
Coarse aggregate	1210	1295
NaOH	_	28.31
Na_2SiO_3	_	99.08
Water	133	42.46
Super plasticizer	15	12.73

CASE 2

FINAL PROPORTION OF OPC CONCRETE & FINAL PROPORTIONS OF GPC CONCRETE

	Cement	F.A	C.A	Water	Super plasticizer
Ratio	1	1.3	2.6	0.32	0.03

	Silica Fume	F.A	C.A	Water	NaOH	Na_2Sio_3	Super plasticizer
Ratio	1	1.36	3.16	0.04	0.1	0.25	0.03

AMOUNT OF MATERIALS USED IN OPC & GPC COMPOSITION OF SILICA FUME

	OPC (Kg/m³)	GPC (Kg/m³)
Cement	463	_
Silica fume	_	409
Fine Aggregate	600	555
Coarse aggregate	1210	1295
NaOH	_	41
Na_2Sio_3	_	103
Water	148	16
Super plasticizer	14	13

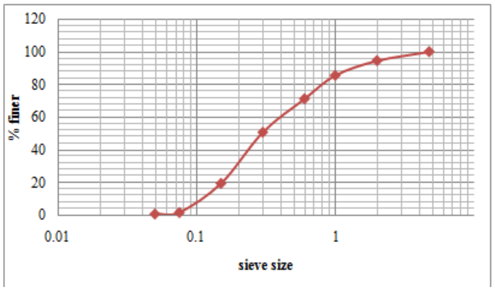
4. RESULTS AND ANALYSIS

TEST ON THE CEMENT :

S.No	Property	Test method	Test Result	Requirements of IS 12269-1987
1	Standard consistency	Vicat Apparatus (IS: 4031 Part - 4)	32%	–
2	Specific gravity	Sp. Gravity bottle (IS:4031 Part - 4)	3.15	–
3	Initial setting time (min)	Vicat Apparatus (IS: 4031 Part - 4)	33	Minimum 30
4	Final setting time (Hours)	Vicat Apparatus (IS: 4031 Part - 4)	8 hrs	Maximum 600
5	Specific Surface Area (m²/Kg)	Blaine's Air permeability (IS:5516-1996)	385	Minimum 225
6	Soundness (mm)	Le-Chatlier's method (IS: 4031 Part – 3)	2	Not more than 10mm
7	Compressive strength (N/mm²)	Compression mould (IS: 4031 Part – 6)	55	53
8	Fineness	Sieve test on sieve no.9 (IS: 4031 Part – 1)	7%	10%

TEST RESULTS AGGREGATES

GRADING OF FINE AGGREGATES



TESTS ON AGGREGATES

SILICA FUME AND ITS PROPERTIES

S. No	Property	Method	Fine Aggregate	Coarse Aggregate
1	Specific Gravity	Pycnometer IS:2386 Part 3 - 1986	2.6	2.66
2	Bulk Density (Kg/m³)	IS:2386 Part 3 - 1986	1650	1780
3	Fineness Modulus	Sieve Analysis (IS:2386 Part 2 - 1963)	2.76	6.04
4	Absorption (%)	IS:2386 Part 3 - 1986	0.1	0.52
5	Moisture content (%)	IS:2386 Part 3 - 1986	0	0

S.No	Property	Test method	Test Result	Requirements of IS 15388: 2003
1	Specific gravity	Sp. Gr bottle (IS:4031 Part - 4)	1.62	-
2	Specific Surface Area (m²/Kg)	Blaine's Air permeablity (IS:5516-1996)	18000	Minimum 15000
3	Bulk Density (Kg/m³)	IS:2386 Part 3 - 1986	650	-
4	Physical Appearance	-	Powder form	-

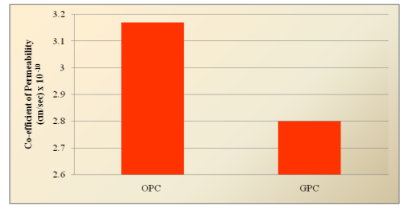
DURABIITY TESTS ON CONCRETE

PERMEABILITY

The test consists in subjecting the mortar or concrete specimen of known dimensions, contained in a specially designed cell, to a known hydrostatic pressure.

CASE 1

	Volume of water collected (ml)	Time (Hrs)	Height of Sample (m)	Area of Sample (cm2)	Pressure Head (m)	Coefficient of permeability (cm/sec)
OPC	9	96	0.1	78.53	100	3.17×10^{-10}
GPC	6	96	0.1	78.53	100	2.8×10^{-10}



- CASE 2

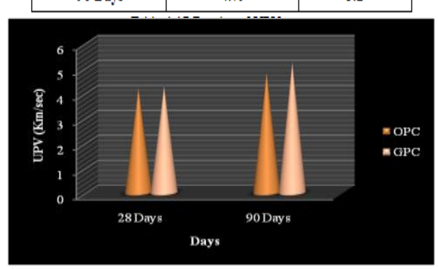
	Volume of Water Collected (ml)	Coefficient of Permeability (cm/sec)
OPC	9.5	3.12×10^{-10}
GPC	7	2.63×10^{-10}

UPV(ULTRASONIC PULSE VELOCITY) TEST

This test was conducted as per the procedure given in IS: 13311:1992. Ultrasonic pulse velocity (UPV) is a non destructive technique that involves measuring the speed of sound through materials in order to predict material strength.

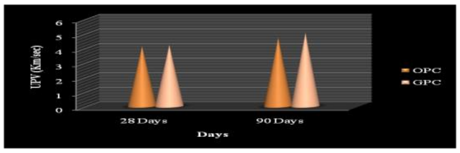
CASE 1

	PULSE VELOCITY (V) (Km/Sec)	
	OPC	GPC
28 Days	4.18	4.25
90 Days	4.79	5.2



- CASE2

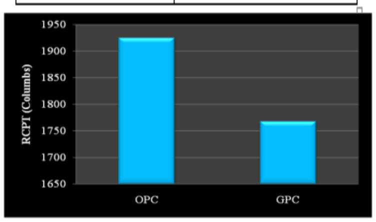
	Pulse Velocity (V) (km/sec)	
	OPC	GPC
28 Days	4.11	4.2
90 Days	4.692	5.036



RCPT(RAPID CHLORIDE PENETRATION TEST)

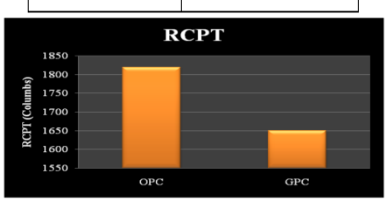
- CASE 1

	RCPT Value (Columbs)
OPC	1925
GPC	1768



- CASE 2

	RCPT Value (Columbs)
OPC	1820
GPC	1650

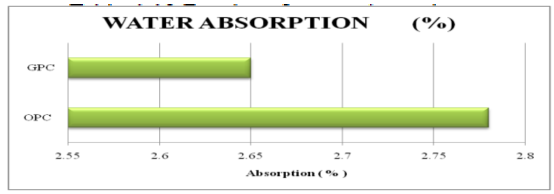


WATER ABSORBTION TEST

The water absorption values for various mixtures of concrete were determined on 150mm x 150mm x 150mm cubes as per ASTM C 642

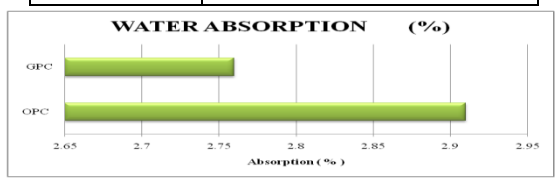
CASE 1

	Water Absorption (%)
OPC	2.78
GPC	2.65



- CASE 2

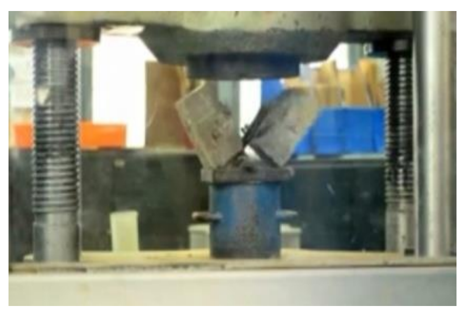
	Water Absorption (%)
OPC	2.91
GPC	2.76



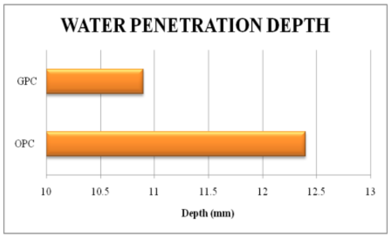
WATER PENETRATION TEST

This test is the method of determination of depth of water penetrated in the concrete hardened surface which is cured in water for 28 days.

CASE 1

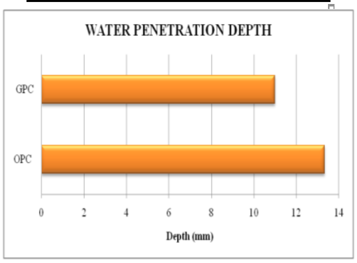


	Water Penetration Depth (mm)
OPC	12.4
GPC	10.9



- CASE 2

	Water Penetration Depth (mm)
OPC	13.33
GPC	11.00

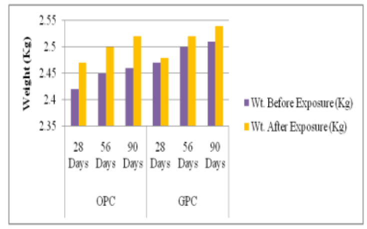


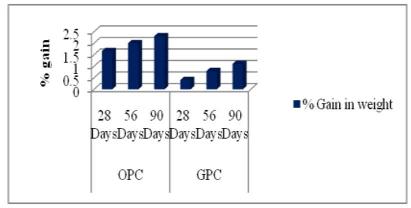
SULPHATE RESISTANCE TEST

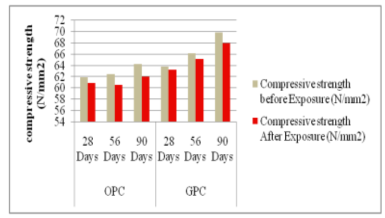
The test was performed to study the effect of sulphate on concrete. Sulphate may be present in soil or ground water which comes in to the contact of concrete and affect it.

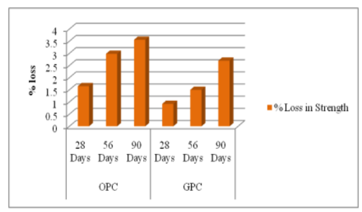
- CASE 1
- *SAMPLES CURED IN Na_2SO_4*

	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.42	2.45	2.46	2.47	2.5	2.51
Wt. After Exposure (Kg)	2.47	2.5	2.52	2.48	2.52	2.54
% Gain in weight	**1.66**	**2**	**2.3**	**0.4**	**0.79**	**1.1**
Compressive strength before Exposure (N/mm²)	61.9	62.45	64.23	63.78	66.1	69.88
Compressive strength After Exposure (N/mm²)	60.87	60.58	61.94	63.19	65.1	68
% Loss in Strength	**1.65**	**2.98**	**3.56**	**0.92**	**1.5**	**2.7**



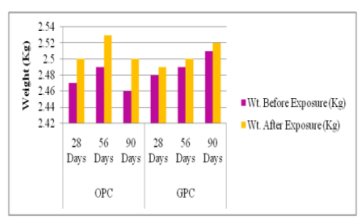


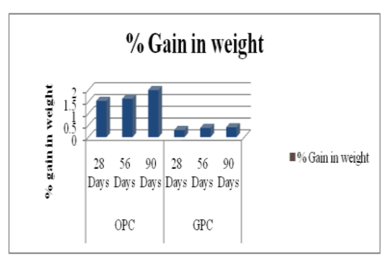


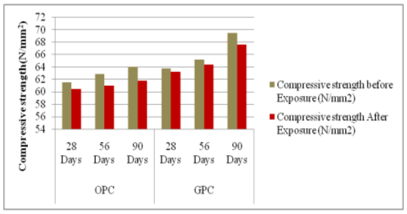


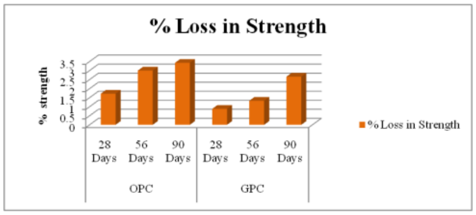
- CASE 2

	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.47	2.49	2.46	2.48	2.49	2.51
Wt. After Exposure (Kg)	2.5	2.53	2.5	2.49	2.5	2.52
% Gain in weight	1.54	1.63	2	0.3	0.39	0.42
Compressive strength before Exposure (N/mm²)	61.5	62.9	64	63.8	65.22	69.5
Compressive strength After Exposure (N/mm²)	60.44	61.01	61.8	63.23	64.35	67.65
% Loss in Strength	1.72	3	3.43	0.88	1.33	2.66





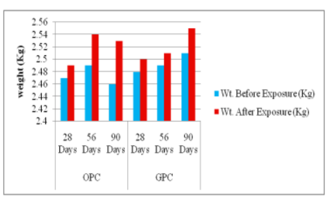


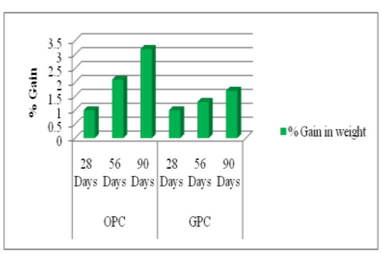


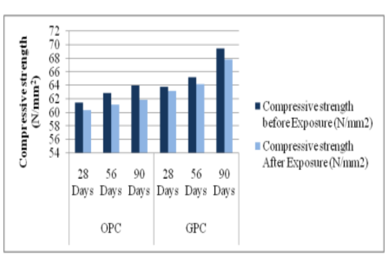
- *SAMPLES CURED IN $MgSO_4$*

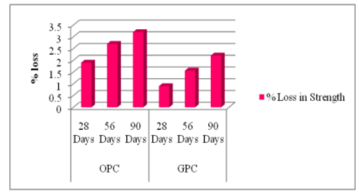
CASE 1

	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.47	2.49	2.46	2.48	2.49	2.51
Wt. After Exposure (Kg)	2.49	2.54	2.53	2.5	2.51	2.55
% Gain in weight	1	2.1	3.2	1	1.3	1.7
Compressive strength before Exposure (N/mm²)	61.5	62.9	64	63.8	65.22	69.5
Compressive strength After Exposure (N/mm²)	60.33	61.2	61.9	63.22	64.2	67.9
% Loss in Strength	1.9	2.7	3.2	0.9	1.56	2.2



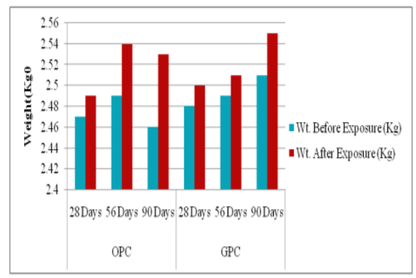


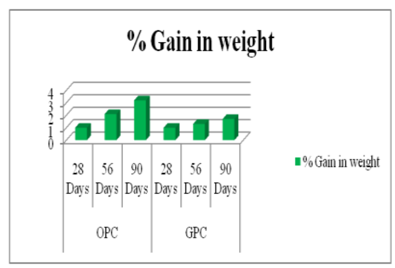


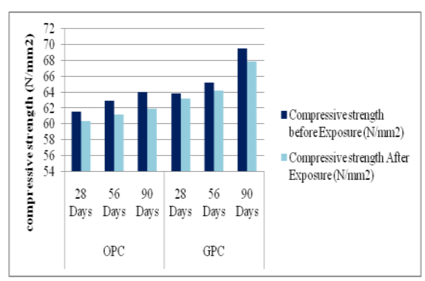


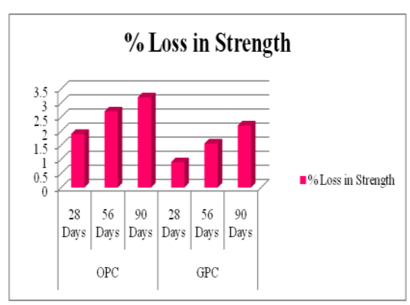
CASE 2

	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.47	2.49	2.46	2.48	2.49	2.51
Wt. After Exposure (Kg)	2.49	2.54	2.53	2.5	2.51	2.55
% Gain in weight	1	2.1	3.2	1	1.3	1.7
Compressive strength before Exposure (N/mm²)	61.5	62.9	64	63.8	65.22	69.5
Compressive strength After Exposure (N/mm²)	60.33	61.2	61.9	63.22	64.2	67.9
% Loss in Strength	1.9	2.7	3.2	0.9	1.56	2.2



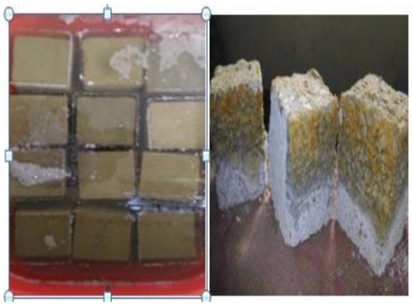




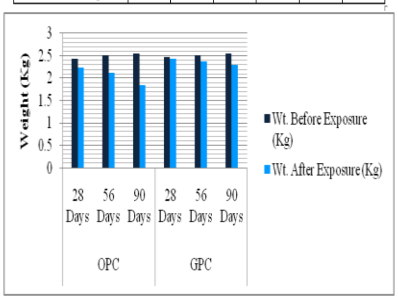


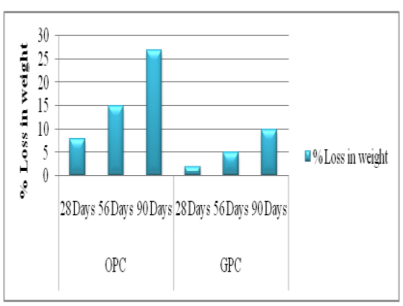
ACID RESITANCE ATTACK

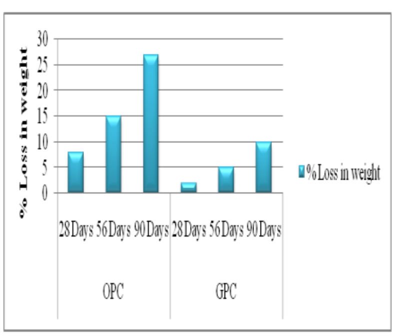
- *SAMPLES CURED IN H_2SO_4*

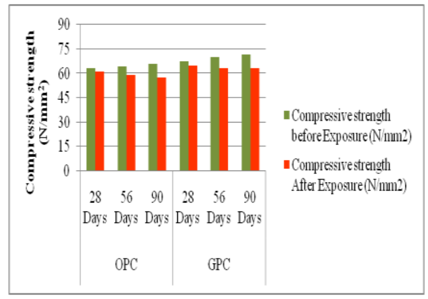


	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.44	2.5	2.54	2.48	2.51	2.55
Wt. After Exposure (Kg)	2.24	2.125	1.85	2.43	2.38	2.295
% Loss in weight	**8**	**15**	**27**	**2**	**5**	**10**
Compressive strength before Exposure (N/mm²)	63.4	64.01	65.9	67.2	69.8	71.6
Compressive strength After Exposure (N/mm²)	60.79	58.88	57.33	64.51	62.9	62.96
% Loss in Strength	**6**	**8**	**13**	**4**	**9**	**12**



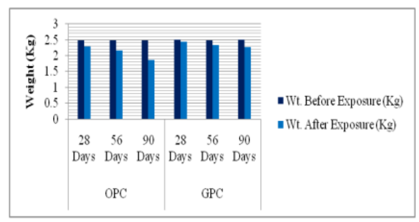


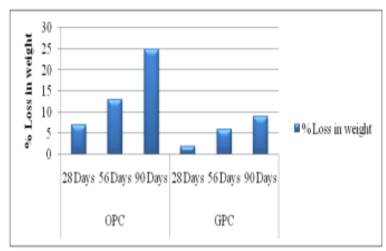


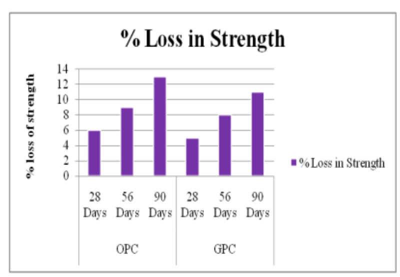


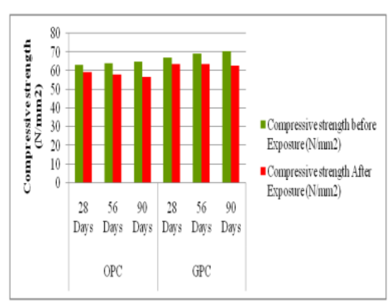
- CASE 2

	OPC			GPC		
	28 Days	**56 Days**	**90 Days**	**28 Days**	**56 Days**	**90 Days**
Wt. Before Exposure (Kg)	2.48	2.49	2.48	2.5	2.49	2.51
Wt. After Exposure (Kg)	2.3	2.16	1.86	2.45	2.34	2.28
% Loss in weight	7	13	25	2	6	9
Compressive strength before Exposure (N/mm²)	63.1	63.9	65	67	69.2	70.3
Compressive strength After Exposure (N/mm²)	59.3	58.15	56.55	63.65	63.66	62.56
% Loss in Strength	6	9	13	5	8	11







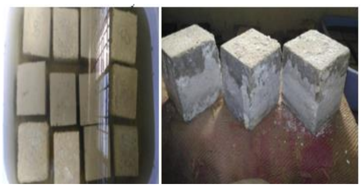


CHLORIDE RESISTANCE ATTACK

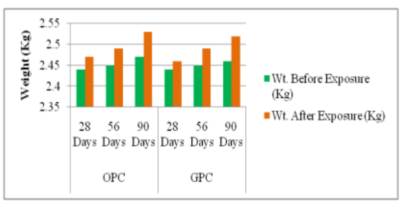
The effect of chloride on geopolymer and control concrete were studied through this test. Marine structures are subjected to chloride attack and due to the penetration of chloride the reinforcement is subjected to corrosion

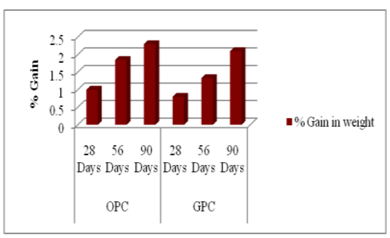
- *SAMPLES CURED IN Nacl*

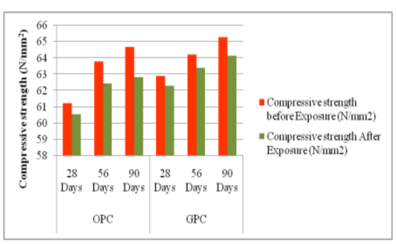
CASE 1

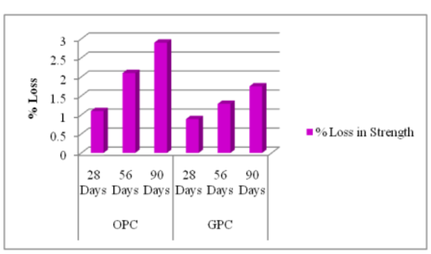


	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.44	2.45	2.47	2.44	2.45	2.46
Wt. After Exposure (Kg)	2.47	2.49	2.53	2.46	2.49	2.52
% Gain in weight	**1**	**1.85**	**2.3**	**0.8**	**1.33**	**2.1**
Compressive strength before Exposure (N/mm²)	61.23	63.8	64.7	62.9	64.22	65.3
Compressive strength After Exposure (N/mm²)	60.55	62.46	62.82	62.3	63.39	64.15
% Loss in Strength	**1.1**	**2.1**	**2.9**	**0.89**	**1.29**	**1.75**



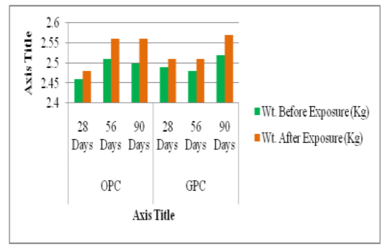


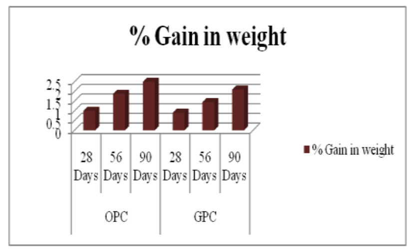


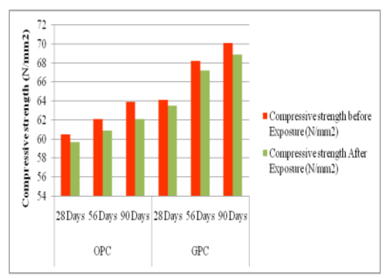


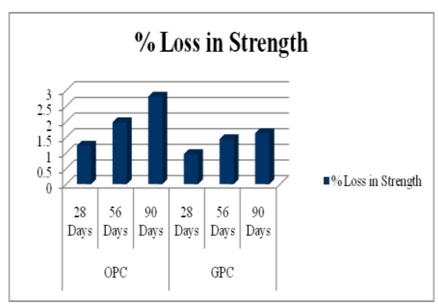
CASE 2

	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.46	2.51	2.5	2.49	2.48	2.52
Wt. After Exposure (Kg)	2.48	2.56	2.56	2.51	2.51	2.57
% Gain in weight	1	1.88	2.5	0.9	1.45	2.1
Compressive strength before Exposure (N/mm²)	60.45	62.1	63.9	64.1	68.23	70.1
Compressive strength After Exposure (N/mm²)	59.68	60.87	62.11	63.48	67.24	68.9
% Loss in Strength	1.23	1.98	2.8	0.96	1.44	1.63









SORPTIVITY

The sorptivity test is a simple and rapid test to determine the tendency of concrete to absorb water by capillary suction. The test was developed by Hall and is based on Darcy's law of unsaturated flow. One of the methods to examine the related permeability of concrete is sorptivity, which is measuring the rate of absorption of water into concrete.

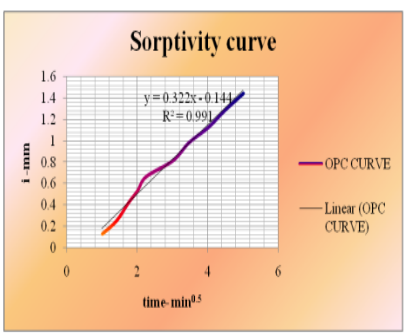
- CASE 1

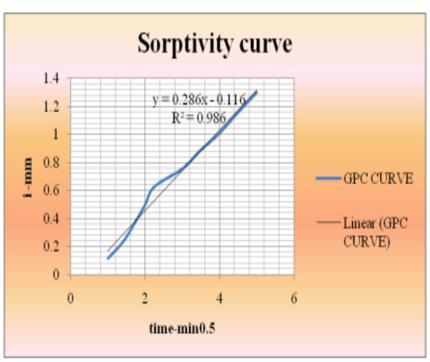
TIME (min)	WEIGHT (gm)	GAINED WEIGHT (gm)	CUMILATIVE WEIGHT GAINED (gm)	VOLUME OF WATER (mm3)	SURFACE AREA (mm2)	i=w/(A*Density) (mm)	√ (TIME) (√min)
			(W)	(V)	(A)		
0	776.1	0	0	0	7853.98	0	0
1	777.19	1.09	1.09	1090	7853.98	0.13	1
2	778.21	1.02	2.11	2110	7853.98	0.26	1.41
3	779.41	1.2	3.31	3310	7853.98	0.42	1.73
4	780.38	0.97	4.28	4280	7853.98	0.54	2
5	781.36	0.98	5.26	5260	7853.98	0.67	2.24
9	782.56	1.2	6.46	6460	7853.98	0.82	3
12	783.87	1.31	7.77	7770	7853.98	0.99	3.46
16	785.01	1.14	8.91	8910	7853.98	1.13	4
20	786.23	1.22	10.13	10130	7853.98	1.29	4.47
25	787.52	1.29	11.42	11420	7853.98	1.45	5

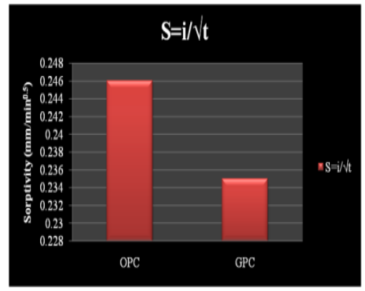
Table 4.25 Sorptivity results of OPC

TIME (min)	WEIGHT (gm)	GAINED WEIGHT (gm)	CUMILATIVE WEIGHT GAINED (gm)	VOLUME OF WATER (mm3)	SURFACE AREA (mm2)	i=w/(A*Density) (mm)	√ (TIME) (√min)
			(W)	(V)	(A)		
0	776.29	0	0	0	7853.98	0	0
1	773.82	0.92	0.92	920	7853.98	0.117	1
2	774.76	0.94	1.86	1860	7853.98	0.236	1.41
3	775.85	1.09	2.95	2950	7853.98	0.375	1.73
4	776.83	0.98	3.93	3930	7853.98	0.5	2
5	777.82	0.99	4.92	4920	7853.98	0.626	2.24
9	778.84	1.02	5.94	5940	7853.98	0.756	3
12	779.84	1	6.94	6940	7853.98	0.88	3.46
16	780.84	1	7.94	7940	7853.98	1.01	4
20	781.94	1.1	9.04	9040	7853.98	1.15	4.47
25	783.08	1.14	10.18	10180	7853.98	1.3	5

Table 4.26 Sorptivity results of GPC





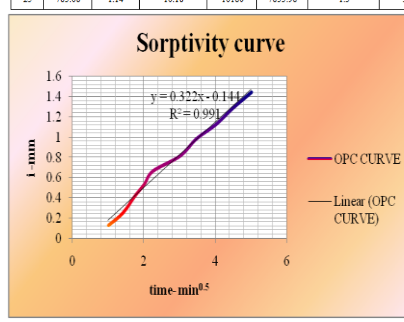


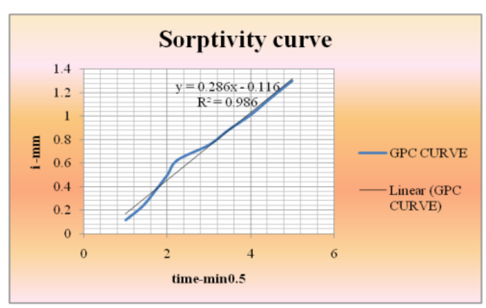
- CASE 2

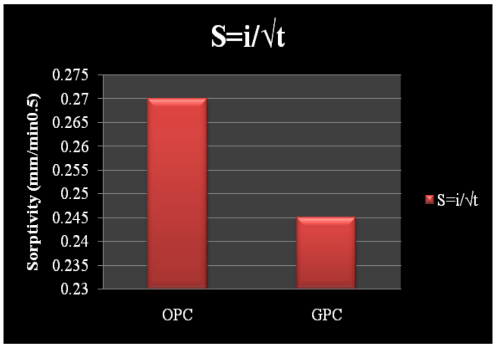
TIME (min)	WEIGHT (gm)	GAINED WEIGHT (gm)	CUMILATIVE WEIGHT GAINED(gm)	VOLUME OF WATER (mm3)	SURFACE AREA (mm2)	i=w/(A*Density) (mm)	√ (TIME) (√min)
			(W)	(V)	(A)		
0	776.1	0	0	0	7853.98	0	0
1	777.19	1.09	1.09	1090	7853.98	0.13	1
2	778.21	1.02	2.11	2110	7853.98	0.26	1.41
3	779.41	1.2	3.31	3310	7853.98	0.42	1.73
4	780.38	0.97	4.28	4280	7853.98	0.54	2
5	781.36	0.98	5.26	5260	7853.98	0.67	2.24
9	782.56	1.2	6.46	6460	7853.98	0.82	3
12	783.87	1.31	7.77	7770	7853.98	0.99	3.46
16	785.01	1.14	8.91	8910	7853.98	1.13	4
20	786.23	1.22	10.13	10130	7853.98	1.29	4.47
25	787.52	1.29	11.42	11420	7853.98	1.45	5

Table 4.25 Sorptivity results of GPC

TIME (min)	WEIGHT (gm)	GAINED WEIGHT (gm)	CUMILATIVE WEIGHT GAINED(gm)	VOLUME OF WATER (mm3)	SURFACE AREA (mm2)	i=w/(A*Density) (mm)	√ (TIME) (√min)
			(W)	(V)	(A)		
0	776.29	0	0	0	7853.98	0	0
1	773.82	0.92	0.92	920	7853.98	0.117	1
2	774.76	0.94	1.86	1860	7853.98	0.236	1.41
3	775.85	1.09	2.95	2950	7853.98	0.375	1.73
4	776.83	0.98	3.93	3930	7853.98	0.5	2
5	777.82	0.99	4.92	4920	7853.98	0.626	2.24
9	778.84	1.02	5.94	5940	7853.98	0.756	3
12	779.84	1	6.94	6940	7853.98	0.88	3.46
16	780.84	1	7.94	7940	7853.98	1.01	4
20	781.94	1.1	9.04	9040	7853.98	1.15	4.47
25	783.08	1.14	10.18	10180	7853.98	1.3	5







FREEZING THAWING

The most potentially destructive weathering factor is freezing and thawing while the concrete is wet, particularly in the presence of de-icing chemicals. Deterioration is caused by the freezing of water and subsequent expansion in the paste, the aggregate particles, or both.

- CASE 1

Environmental testing chamber

Cycles	Weight (Kg)	DENSITY (Kg/m3)	ULTRA PULSE VELOCITY (V) (Km/Sec)	DYNAMIC MODULUS	RELATIVE DYNAMIC MODULUS (R=En/Eo *100)
0	2.59	2590	4.71	51711	100
5	2.585	2585	4.69	51283	99.1
10	2.579	2579	4.66	50404	97.4
15	2.571	2571	4.625	49495.7	95.7
20	2.562	2562	4.6	48790	94.35
25	2.556	2556	4.575	48148	93.11
30	2.541	2541	4.565	47657	92.1
35	2.53	2530	4.555	47243	91.3
40	2.5	2500	4.54	46376	89.68
45	2.496	2496	4.515	45792	88.55
50	2.485	2485	4.51	45505	88

Table 4.27 Results of durability factor of OPC

Cycles	Weight (Kg)	DENSITY (Kg/m3)	ULTRA PULSE VELOCITY (V) (Km/Sec)	DYNAMIC MODULUS	RELATIVE DYNAMIC MODULUS (R=En/Eo *100)
0	2.62	2620	4.95	57776.8	100
5	2.617	2617	4.94	57477	99.4
10	2.61	2610	4.93	57092	98.9
15	2.604	2604	4.915	56614	97.9
20	2.591	2591	4.905	56103	97.1
25	2.58	2580	4.9	55751	96.5
30	2.571	2571	4.885	55217	95.5
35	2.56	2560	4.86	54419	94.1
40	2.55	2550	4.84	53761	93.05
45	2.54	2540	4.82	53109	91.9
50	2.53	2530	4.77	51999	90

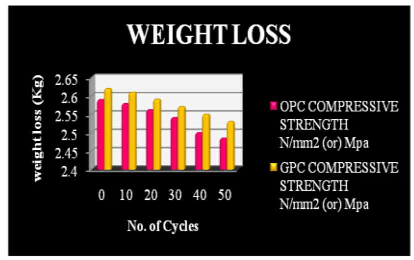
Table 4.28 Results of durability factor of GPC

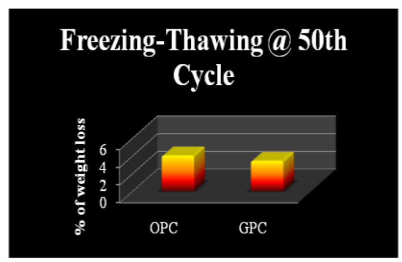
Cycles	0	10	20	30	40	50
COMPRESSIVE STRENGTH N/mm2 (or) Mpa	62.3	62.08	60.09	59.2	58.4	57.9

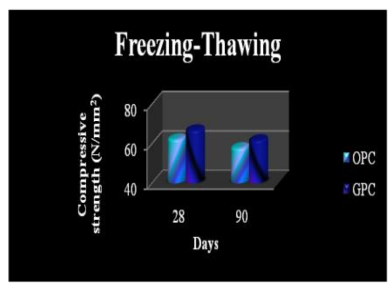
Table 4.29 Variation of compressive strength across cycles of OPC

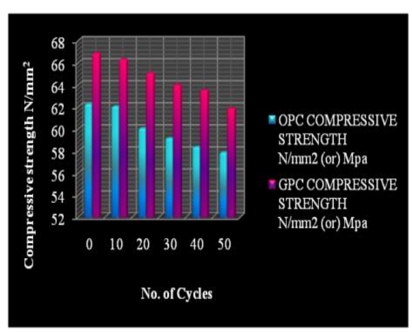
Cycles	0	10	20	30	40	50
COMPRESSIVE STRENGTH N/mm2 (or) Mpa	66.9	66.34	65.1	64.03	63.54	61.89

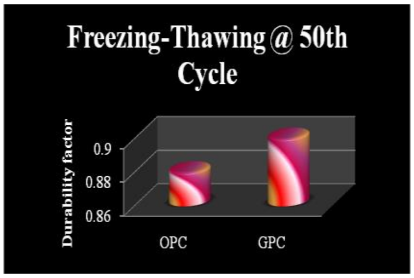
Table 4.30 Variation of compressive strength across cycles of GPC

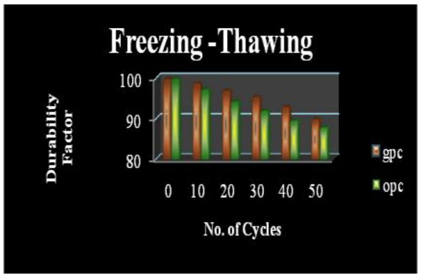












- CASE 2

Table 4.27 Results of durability factor of OPC

Cycles	Weight (Kg)	Density (Kg/M3)	Ultra Pulse Velocity (V) (Km/Sec)	Dynamic Modulus	Relative Dynamic Modulus (R=En/Eo *100)
0	2.59	2590	4.71	51711	100
5	2.585	2585	4.69	51283	99.1
10	2.579	2579	4.66	50404	97.4
15	2.571	2571	4.625	49495.7	95.7
20	2.562	2562	4.6	48790	94.35
25	2.556	2556	4.575	48148	93.11
30	2.541	2541	4.565	47657	92.1
35	2.53	2530	4.555	47243	91.3
40	2.5	2500	4.54	46376	89.68
45	2.496	2496	4.515	45792	88.55
50	2.49	2490	4.48	44988	87

Table 4.28 Results of durability factor of GPC

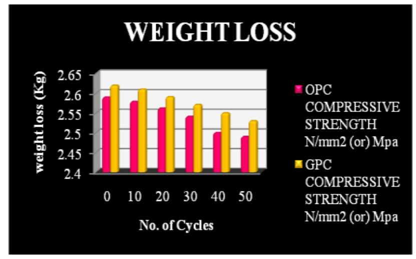
Cycles	Weight (Kg)	Density (Kg/M3)	Ultra Pulse Velocity (V) (Km/Sec)	Dynamic Modulus	Relative Dynamic Modulus (R=En/Eo *100)
0	2.62	2620	4.95	57776.8	100
5	2.617	2617	4.94	57477	99.4
10	2.61	2610	4.93	57092	98.9
15	2.604	2604	4.915	56614	97.9
20	2.591	2591	4.905	56103	97.1
25	2.58	2580	4.9	55751	96.5
30	2.571	2571	4.885	55217	95.5
35	2.56	2560	4.86	54419	94.1
40	2.55	2550	4.84	53761	93.05
45	2.54	2540	4.82	53109	91.9
50	2.53	2530	4.805	52576.8	91

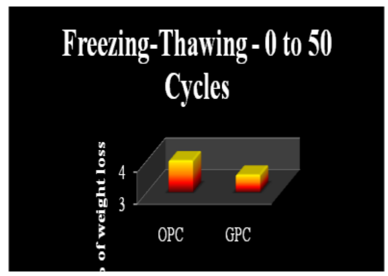
Table 4.29 Variation of compressive strength across cycles of OPC

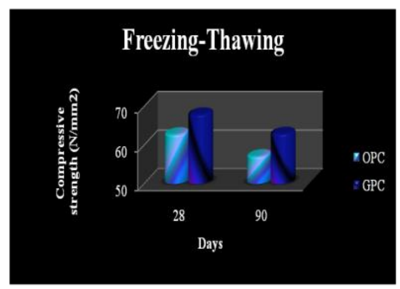
Cycles	0	10	20	30	40	50
COMPRESSIVE STRENGTH N/mm2 (or) Mpa	62.76	62.08	60.09	59.2	58.4	57.1

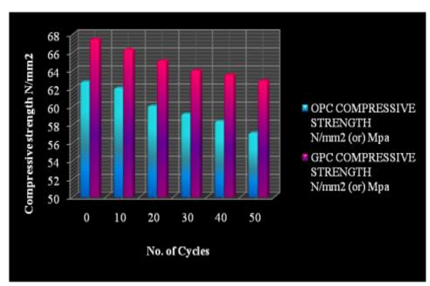
Table 4.30 Variation of compressive strength across cycles of GPC

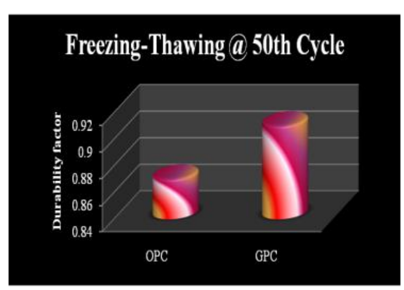
Cycles	0	10	20	30	40	50
COMPRESSIVE STRENGTH N/mm2 (or) Mpa	67.48	66.34	65.1	64.03	63.54	62.88

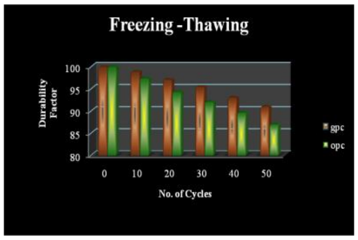












5. CONCLUSIONS

The project achievements are as follows:

1. The resistance towards the chemical attack on concrete has significantly proven essential for both the concrete, where GPC has resisted well in circumstances like sulphate, chloride and acid attacks compared to OPC
2. The chloride penetration in GPC is less comparatively than OPC, so it can be used in chloride zone area.
3. The mix of both the concrete are taken special attraction in this, where it is proven in UPV test and took huge amount of time to travel the rays. Hence we can conclude the materials are conjoined in the specimens.
4. Atmost care is been taken while testing specimen under freezing – thawing conditions and GPC has evolved successful in that and proven to be suitable in frozen conditions even by the results

From the cumulative results we can come to an conclusion than replacement of OPC with GPC can be done, which can bring the dual benefit such as preserving the natural resources and reduce the emission of green house gases into the atmosphere.

REFERENCES

[1] Song X J, Marosszeky M, Brungs M and Munn R , S. Geopolymer Manufacture and Application - Main problems When Using Concrete Technology. Presented at the Geopolymers 2002 International Conference. Melbourne, Australia: 2002. Siloxo Pty. Ltd.

[2] Sobolev K G , Effect of fly ash preliminary calcination on the properties of geopolymer", Journal of Hazardous Materials, Vol. 164, pp. 634-639, 2009.

[3] Khaloo A R and Houseinian M R , Chemical Stability of Cementitious Materials Based on Metakaolin. Cement and Concrete Research, Vol. 29: pp. 997-1004, 1999.

[4] Ray I and Chattopadhyay R , Use of fly ash in structural concrete: Part 1-Why?"Indian Concrete Journal, Vol. 79, No. 5, pp. 13-22, 2005.

[5] Potha Raju M, Shoba M and Rambabu K , Licensed Under Creative Commons Attribution CC BY Geo Polymer Concrete with the Replacement of Granite Aggregate as Fine AggregateInternational Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Index Copernicus Value (2013): 6.14 Volume 4 Issue 9, September 2015

[6] Dos Santos J R, Branco F A and Brito J de , Effect of Alkaline Activator, Water,Superplasticiserand Slag Contents on the Compressive StrengthandWorkability of Slag-Fly Ash BasedGeopolymerMortar Cured under AmbientTemperature World Academy of Science, Engineering and Technology; International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:10, No:3, 2016