SILICAFUME BASED GEOPOLYMER CONCRETE-DURABILITY PROPERTIES FOR M60 GRADE

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Abstract: The present technology which is in use for the manufacturing of ordinary Portland cement concrete is used. In order to activate the geopolymerization process for binding the concrete,the basic material namely silica fume has been used for replacing the ordinary Portland cement completely. A combination of NaOH solution and Na_2SiO_3 is used for activating the silicon content in silica fume.The steps involved in the manufacturing process such as preparation of material, mixing of material, placing of material, compaction of material and curing are given in this paper. In order to enhance the workability of fresh silica fume based geopolymer concrete, the super plasticizer which is naphthalene based is used. It can also be improved by adding 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(Ordinary 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 analyzed. The comparision is made for the two cases of the durability properties.

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

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1. INTRODUCTION

Concrete, composite construction material which is a mixture of cement, fine aggregate, coarse aggregate and water and a small quantity of air. For over a century the concrete has been using as a leading construction material. It has been estimated that the production of concrete is approximately 2.5 tones i.e.; 1 m^3 per capita. After 2025 the overall world wide usage of natural aggregate will be in the range of 10-13 billion tones. As the concrete can be moulded to any form or shape so it can be used as a desirable building material. Concrete can be used for constructing various structures such as bridges, buildings, dams, barrages, highways etc. The various other parameters such as durability, strength and economy has made the concrete as the most desirable material. Based on the materials which are used in the concrete the concrete can withstand the compression of about 7000 kg/cm^2 or more. The concrete is strong in compression and the tensile strength of concrete is much lower when compared to the compressive strength.

Concrete is the leading construction material throughout the world and is generally used in all types of construction works like high and low raise building and many other infrastructural developmental works. It essentially consists of a mixture of cement, fine aggregate, coarse aggregate, water and admixtures. The major part of aggregate is formed by the materials like sand and gravel. According to the strength parameters and grade of concrete, the mixing of these materials are done in the required proportions

Since the start of the mechanical transformation in 1760 there has been an expansion in the utilization of non-renewable energy source vitality coming about in intensified emanations of GHG's (Greenhouse Gases) (Slanina, 2004). This expanded worldwide dependency on oil, coal and gaseous petrol has brought about the discharge more than 1100 Gt (Giga ton) of CO2 outflows to the atmosphere (IPCC, 2001). The arrival of GHGs adds to anthropogenic prompted a dangerous atmospheric devation with the most critical of these gases being CO2 (Carbon dioxide) (IPCC, 2001). This is because of the sheer amounts that are being transmitted, despite the fact that it doesn't have the most elevated radioactive compelling potential. The cement production releases the large amount of CO2 and forms the major cause for the emissions of green house gases.

Worldwide on an average the amount of CO2 released in to amosphere is of about 5 to 8 percent from the cement industry. The total production of CO2 throughout the world is 42 billion tones in 2014. Out of this there are 3 major contributors namely China producing 12 billion tones (46 %), United States of America producing 6 billion tones (16 %) and India producing 2.6 billion tones (6 %). Cement industry is the major producer of CO2. On an average the cement manufacturing activity contributes to about 6 to 8 % of global anthropogenic CO2 emissions. Cement is only a constituent of concrete and is responsible for 20 to 35 % of the world's GHG's.

Because of concrete magnificent strength, durability properties and its availability, it is used commonly in the construction activity. In reality, the world's most devoured man-made material is concrete and its utilization is increased drastically.

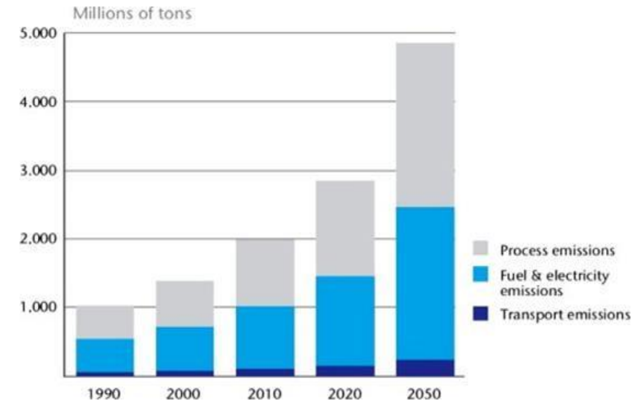
From the above discussions it is been clear that the concrete industry producing vast amount of CO2 around the world and production of concrete is not environmentally friendly, so there is emergency to reduce the usage of cement and this can be achieved by different alternatives

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

3CaCO3 + SiO2 → Ca3SiO5 + 3CO

2CaCO3 + SiO2 → Ca2SiO4 + 2CO2

In order to scale back additional the GHG emissions related to concrete additional viable different to interchange OPC are being examined with geopolymer materials thought-about to be one such alternative.



GEOPOLYMER CONCRETE

Due to increase in the awareness in regard to the adverse effects of over utilization of natural resources, most of the advanced environment friendly methods are to be developed for the effective management of the natural resources. Construction activities are one of the most important one for depleting the naturally available resources like cement, sand, gravel, water etc. Due to the increased cost of materials of the concrete, the engineers have focused on the development of alternate ways for reducing the cost of production of the materials of the concrete.

Industrial activities related to the sectors of transportation, steel and energy are responsible for the formation of large amounts blast furnace slag, silica fume, ash, quarry dust and creating a major problem in their disposal.

Davidovitis was the first man to introduce the geopolymer technology in the year 1978. His research depicts that by using the geopolymer technology in the concrete the emission of CO2 can be reduced in to the environment.Geopolymer belong to the family of inorganic polymers. The geopolymer chemical composition is similar to naturally available zeolitic materials, but in the case of micro structure it is amorphous in nature. Any material which is rich in silica content and aluminum can be used for the manufacturing of geopolymer. The combination of NaOH or KOH and Na_2SiO_3 or K_2SiO_3 is the most commonly used alkaline liquid in the geopolymerization technique.

Materials Required For Geopolymer Concrete

Cementitious binder:

In order to produce geopolymer concrete various naturally available materials and industrial by products are used. The most commonly used cementetious binders are silica fume, GGBS, fly ash, metakaolin, rice husk ash etc.

Alkaline activators:

Alkaline activators are the important ingredient of geopolymer mix. The binding property is obtained by igniting the aluminum and silica present in the cementitious binder by undergoing geopolymerization . It mainly uses high pH activators like NaOH and KOH and Na2SiO3 or K2SiO3

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

2. LITERATURE REVIEW

A review on geopolymers and geopolymer concrete is presented in this chapter focusing on low amount of calcium fly ash based geopolymer paste and concrete. In order to increase the greenness and durability of the structures , new building materials are found out which can also reduce the cost of construction and also reduces the need of replacing the non obsolescent structures thereby saving the environment . In this regard, geopolymers are best suited material which is having high potential for durability and greenness.

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Literature Review On Durability:

Marosszeky M, Munn R,Brungs M andSong X J,, A study on fly ash based geopolymer concrete attacked by sulphuric acid is carried out. They reported that due to sulphuric acid attack there will be corrosion in the geopolymer concrete. This can be controlled by diffusion process.From the SEM analysis it has been observed that there is excellent gel aggregate interface. At the corroded region it is observed that the geopolymer matrix remains similar to the not affected one and for the surrounding aggregates it still functions effectively the binding property.

Sobolev K G,reported that there is an increase in chemical and thermal resistance by adding 50 % of the granulated blast furnace slag by weight in the cement material. It is observed that the permeability is very low and offered a good resistance to freezing and thawing cycles and chemical attack. Even after 140 cycles of freezing and thawing test at -50^{0}C the blast furnace slag destruction has not been observed.

Brito J de , Branco F A and Dos Santos J R, ,identified that when the concrete is subjected to fire attack, there will be a problem in determining the depth of deteriorated concrete and assessment of the concrete structure becomes difficult. So to overcome that a new method called fire behavior test has been developed. By this method the depth of deteriorated concrete is identified by measuring the water absorption and tensile stress failure from the holes drilled in the structure under analysis.

3. METHODOLOGY

MIX DESIGN OF CONCRETE FOR TWO CASES

CASE1

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& 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. TEST RESULTS

TESTS 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 (m^2/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/mm^2)	Compression mould (IS: 4031 Part – 6)	55	53
8	Fineness	Sieve test on sieve no.9 (IS: 4031 Part – 1)	7%	10%

TESTS ON AGGREGATES

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

SILICA FUME AND ITS PROPERTIES

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	_

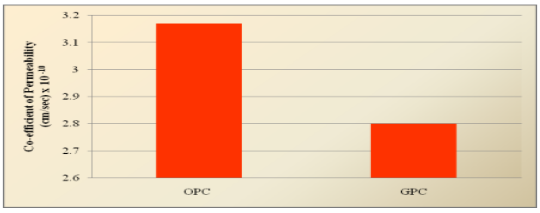
DURABILITY TESTS ON CONCRETE :

PERMEABILITY TEST ON CONCRETE

In this test the concrete specimen or mortar of known dimensions is kept in chamber which is specially designed and subject to a known hydrostatic pressure.

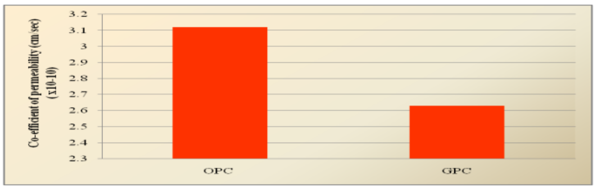
CASE 1

	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}



CASE2

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

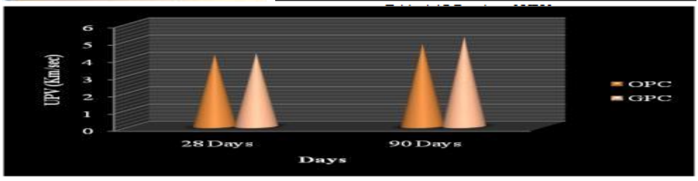


ULTRASONIC PULSE VELOCITY (UPV) TEST

Ultrasonic pulse velocity test is a non destructive test which is conducted according to the IS code 13311:1992. In this test the strength of the material is estimated by measuring the sound speed which is travelling through the materials.

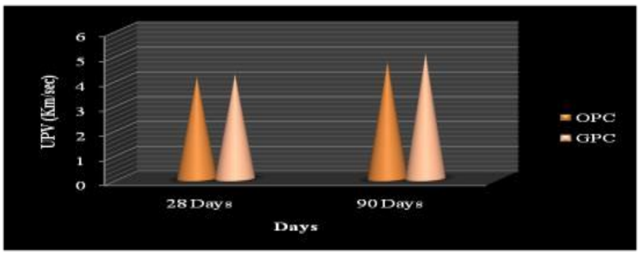
CASE 1

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



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

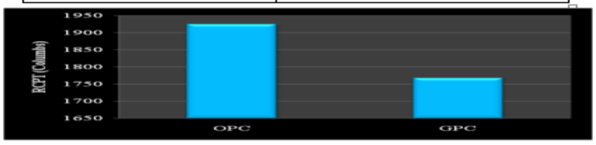
CASE 2



RCPT (RAPID CHLORIDE PENETRATION TEST)

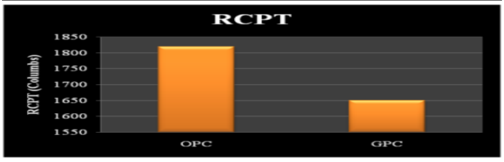
CASE1

	RCPT Value (Columbs)
OPC	1925
GPC	1768



CASE2

	RCPT Value (Columbs)
OPC	1820
GPC	1650

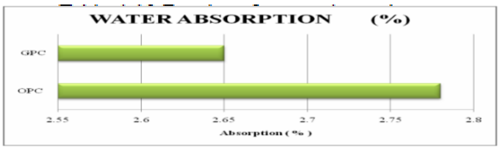


WATER ABSORPTION TEST

As per the code ASTM C 642 this test is conducted on 150mm x 150mm x 150mm concrete cubes for various mix proportions and the water absorption values are calculated.

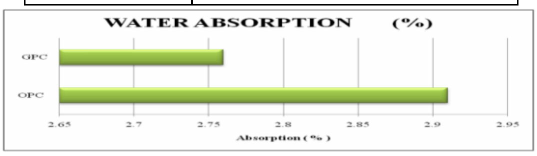
CASE1

	Water Absorption (%)
OPC	2.78
GPC	2.65



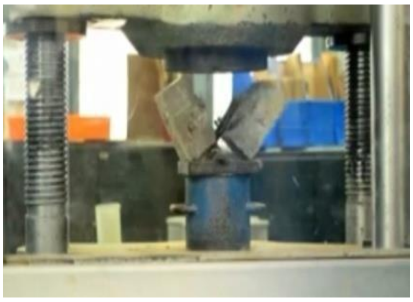
CASE2

	Water Absorption (%)
OPC	2.91
GPC	2.76



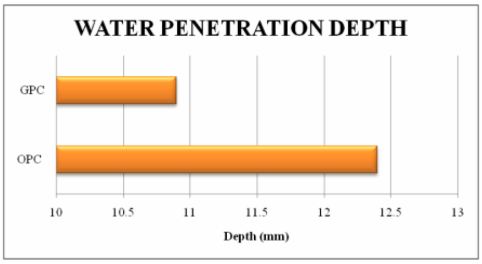
WATER PENETRATION TEST

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



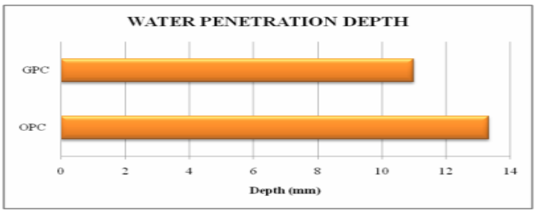
CASE 1

	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

Generally sulphates which are present in the ground water and soil come in contact with concrete and causes effect. So in order to study the effect of sulphates on concrete sulphate resistance test is conducted.

SAMPLES CURED IN Na_2SO_4

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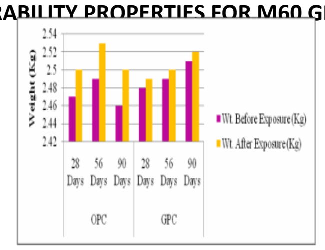
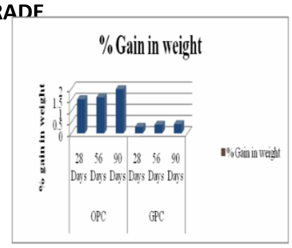
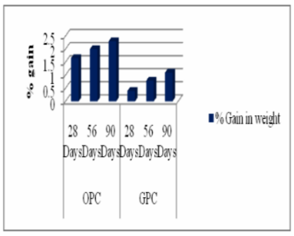
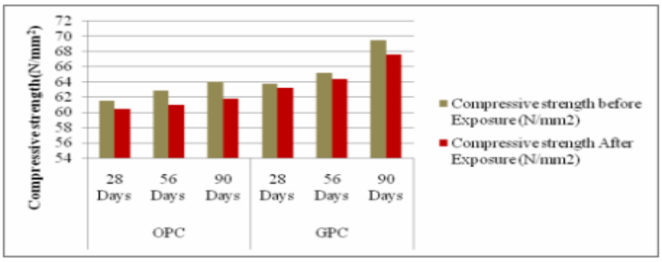
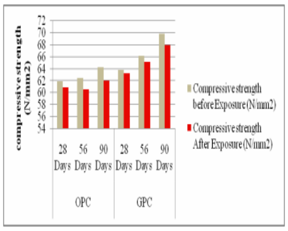
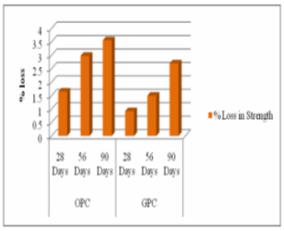


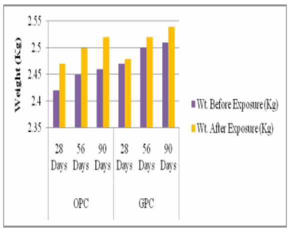












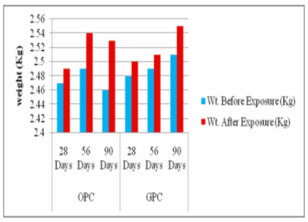
SAMPLES CUREDINMgSO $_4$ 5420

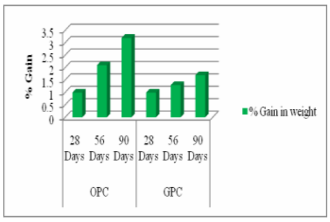
CASE1

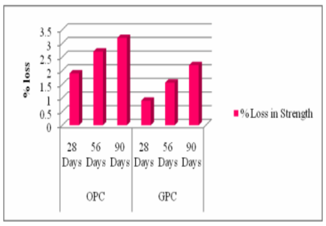
	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.47	2.49	2.46	2.48	2.49	2.51
Wt. After Exposure (Kg)	2.49	2.54	2.53	2.5	2.51	2.55
% Gain in weight	1	2.1	3.2	1	1.3	1.7
Compressive strength before Exposure (N/mm²)	61.5	62.9	64	63.8	65.22	69.5
Compressive strength 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

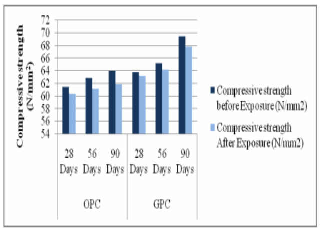
CASE2

	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



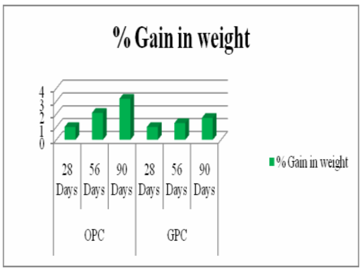


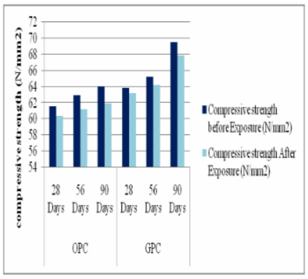


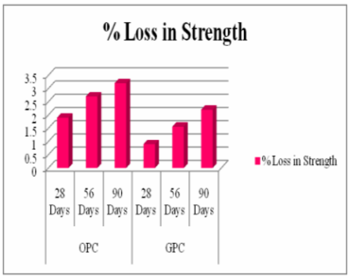


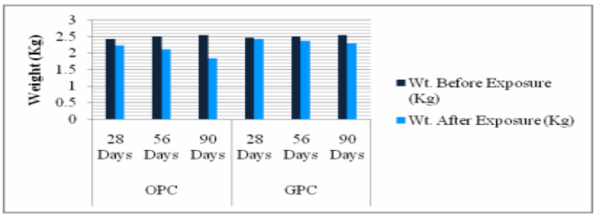
CASE2

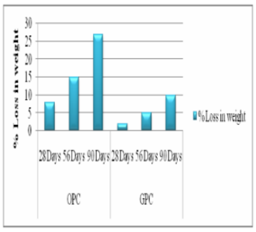
	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.47	2.49	2.46	2.48	2.49	2.51
Wt. After Exposure (Kg)	2.49	2.54	2.53	2.5	2.51	2.55
% Gain in weight	1	2.1	3.2	1	1.3	1.7
Compressive strength before Exposure (N/mm²)	61.5	62.9	64	63.8	65.22	69.5
Compressive strength 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

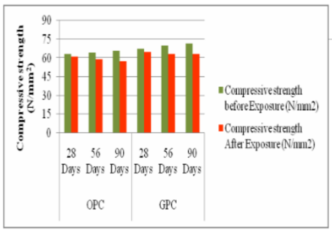












ACID RESITANCE ATTACK

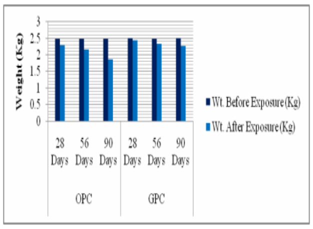
➢ ***SAMPLES CURED IN H_2SO_4***

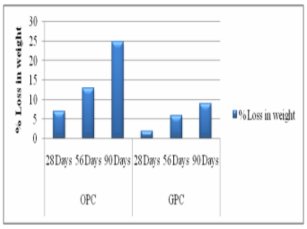
CASE 1

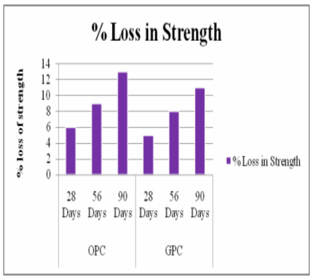
	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.44	2.5	2.54	2.48	2.51	2.55
Wt. After Exposure (Kg)	2.24	2.125	1.85	2.43	2.38	2.295
% Loss in weight	**8**	**15**	**27**	**2**	**5**	**10**
Compressive strength before Exposure (N/mm²)	63.4	64.01	65.9	67.2	69.8	71.6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

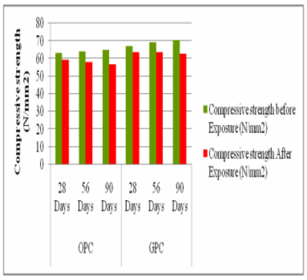
CASE 2

	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









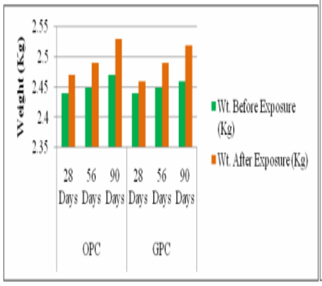
CHLORIDE RESISTANCE ATTACK

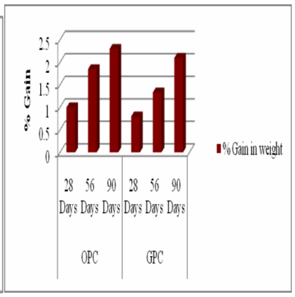
The structures which are near to the sea coast are subjected to chloride attack. Due to the penetration of chloride in to the concrete the reinforcement is ubjected to corrosion. So by chloride resistance test the effect of chloride on geopolymer concrete and normal concrete were studied and compared.

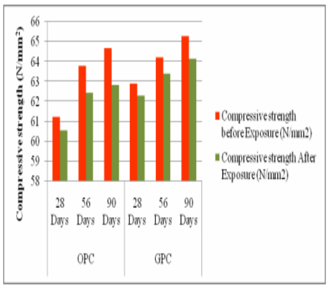
➢ ***SAMPLES CURED INNacl***

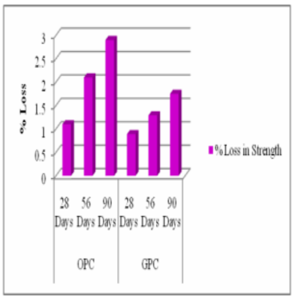
CASE 1

	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**



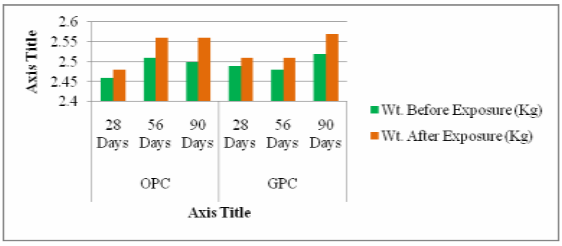


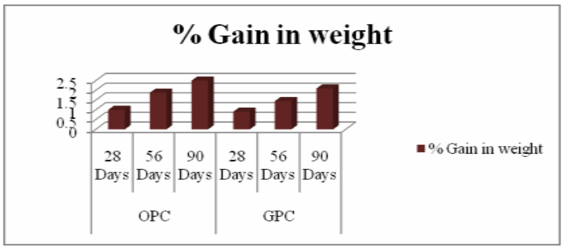


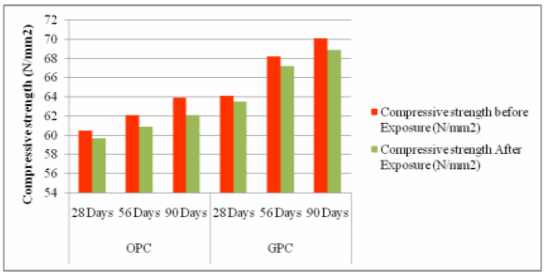


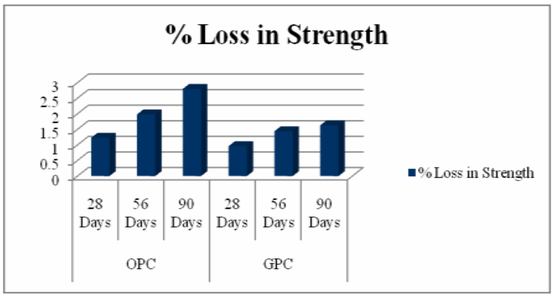
CASE 2

	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









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SORPTIVITY

Sorptivity is the rate of absorption of water in to the concrete. This test is based on Darcy's law and was developed by Hall. It is simple and rapid test for determining the tendency of concrete to absorb water by capillary suction.

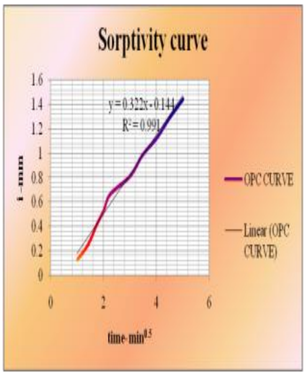
CASE 1

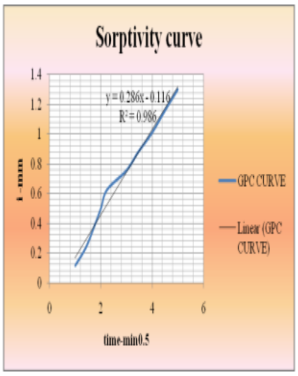
TIME (min)	WEIGHT (gm)	GAINED WEIGHT (gm)	CUMILATIVE WEIGHT GAINED (gm) (W)	VOLUME OF WATER (mm3) (V)	SURFACE AREA (mm2) (A)	i=w/(A*Density) (mm)	√ (TIME) (√min)
0	776.1	0	0	0	7853.98	0	0
1	777.19	1.09	1.09	1090	7853.98	0.13	1
2	778.21	1.02	2.11	2110	7853.98	0.26	1.41
3	779.41	1.2	3.31	3310	7853.98	0.42	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

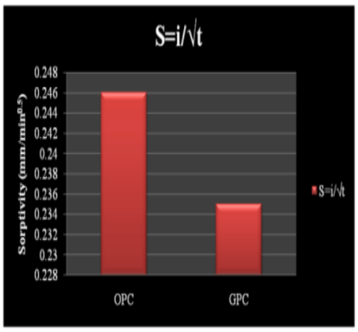
Table 4.25 Sorptivity results of OPC

TIME (min)	WEIGHT (gm)	GAINED WEIGHT (gm)	CUMILATIVE WEIGHT GAINED (gm) (W)	VOLUME OF WATER (mm3) (V)	SURFACE AREA (mm2) (A)	i=w/(A*Density) (mm)	√ (TIME) (√min)
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





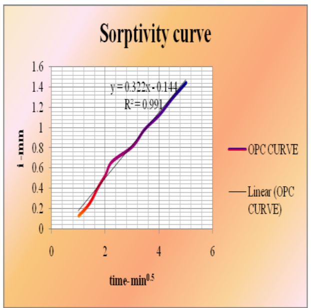


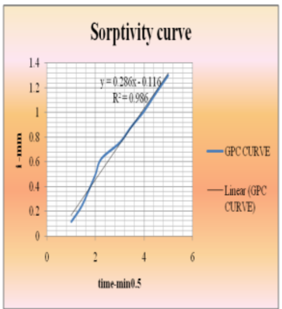
CASE 2

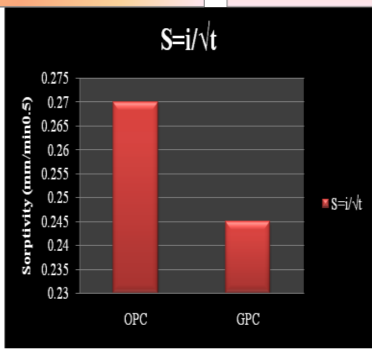
TIME (min)	WEIGHT (gm)	GAINED WEIGHT (gm)	CUMILATIVE WEIGHT GAINED(gm) (W)	VOLUME OF WATER (mm3) (V)	SURFACE AREA (mm2) (A)	i=w/(A*Density) (mm)	√ (TIME) (√min)
0	776.1	0	0	0	7853.98	0	0
1	777.19	1.09	1.09	1090	7853.98	0.13	1
2	778.21	1.02	2.11	2110	7853.98	0.26	1.41
3	779.41	1.2	3.31	3310	7853.98	0.42	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) (W)	VOLUME OF WATER (mm3) (V)	SURFACE AREA (mm2) (A)	i=w/(A*Density) (mm)	√ (TIME) (√min)
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

When the concrete is wet and especially in the presence of deicing chemicals the most destructive factor is freezing and thawing. The deterioration of the concrete is caused mainly because of freezing of water and at the same time expansion in the aggregate particles, paste or both.

CASE1

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

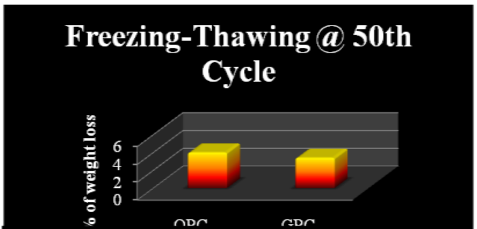
Table 4.28 Results of durability factor of GPC

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



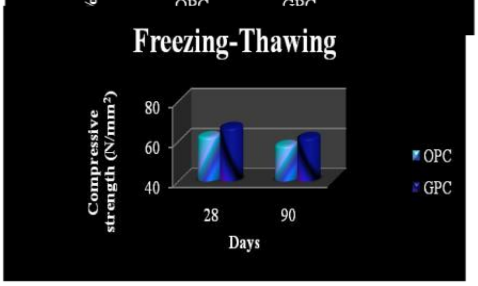
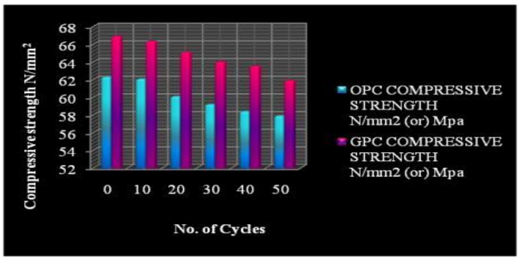
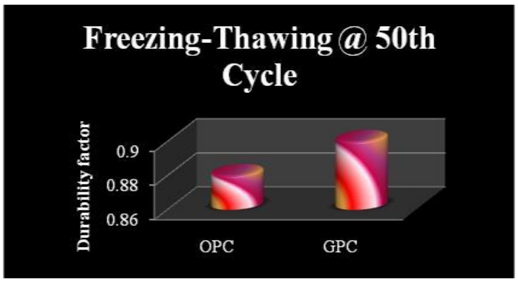
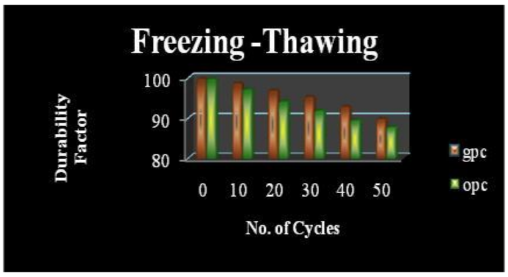


Table 4.29 Variation of compressive strength across cycles of OPC

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







CASE 2

Table 4.27 Results of durability factor of OPC

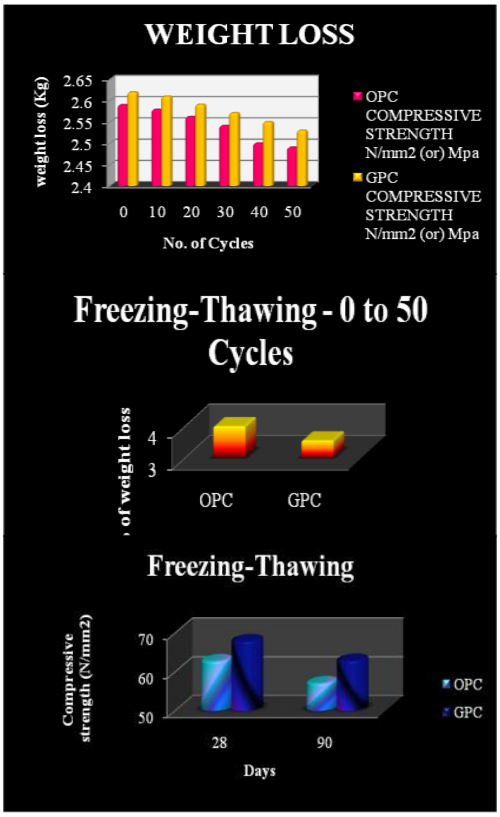
Cycles	Weight (Kg)	Density (Kg/M3)	Ultra Pulse Velocity (V) (Km/Sec)	Dynamic Modulus	Relative Dynamic Modulus (R=En/Eo *100)
0	2.59	2590	4.71	51711	100
5	2.585	2585	4.69	51283	99.1
10	2.579	2579	4.66	50404	97.4
15	2.571	2571	4.625	49495.7	95.7
20	2.562	2562	4.6	48790	94.35
25	2.556	2556	4.575	48148	93.11
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

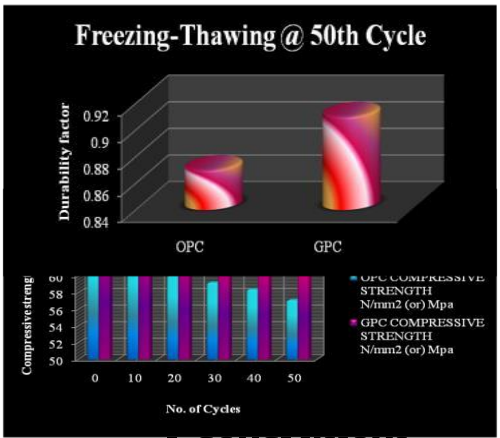
Table 4.28 Results of durability factor of GPC

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 4.30 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 asfollows:

1. The resistance towards the chemical attack on concretehassignificantlyprovenessentialforbothth e concrete, where GPC has resisted well in circumstances like sulphate, chloride and acid attacks compared to OPC
2. ThechloridepenetrationinGPCislesscomparatively than OPC, so it can be used in chloride zonearea.
3. The mix of both the concrete are taken special attraction in this, where it is proven in UPV test and tookhugeamountoftimetotraveltherays.Hencewe 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 evolvedsuccessfulinthatandproventobesuitableinf rozen conditions even by the results

Fromthecumulativeresultswecancometoanconclusionthan 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 theatmosphere.

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