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MECHANICAL AND DURABILITY PROPERTIES OF GEOPOLYMERCONCRETE USING GRANITE WASTE

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ABSTRACT

Construction industry is exploring Green-concrete to reduce the use of concrete mixture (OPC). Global warming is caused by the CO2 emissions during cement production. Geopolymer concrete (GPC) has been put into practice as a replacement of conventional concrete. Granite waste is one of the industrial waste produced by the mining activity. Later, granite waste deposits become a problem for the environment. For the case of reducing granite waste, it must be used as a binder or fine aggregate in concrete. In the present analysis, fly ash in the range of 0, 5, 10, 15 and 20% is partially replaced by granite waste. Identify the effect of granite waste at 7 and 28 days of age on mechanical properties such as compressive strength and split-tensile strengthin the initial stage. In the final stage the effect of granitewaste has been studied at different ages on durability properties such as Sulphate attack, chloride attack, acid attack, Sorptivity, water absorption and carbonation. The non-destructive tests such as the Rebound hammer and the UPV tests were carried out at 28 days. Micro- structure of all mixes is studied by Electron MicroscopyScanning (SEM)

Keywords: granite wastes, concrete geopolymers, properties of strength.

INTRODUCTION

The use of traditional concrete in the building industry has increasingly become popular. It has destroyed natural resources such as calcareous and aggregate. The natural resources must be secured and the alternative must be found. CO2 emissions during Portland cement processing contribute to an increase in greenhouse gases in the atmosphere and global warming. Keeping all these considerations in mind, geopolymer concrete was developed as an alternative to the traditional concrete. The use of industrial waste such as flyash, GGBS and granite waste as binding materials can make the material sustainable. Upon processing and polishing of granite, land filling of granite waste must be raising. This industry dumps the waste over the land causing air pollution in the area and raises the soil alkanity because of the granite waste 's land origin. Therefore, researchers are working on the use of granite waste in the concrete in order to control granite waste landfill. Several studies were performed on the use of granite waste as a partial substitute for fine aggregates and a concrete binder. Granite waste can be used in concrete in order to form C-S - H gel..

GEOPOLYMER CONCRETE.

In 1972, Davidovit coined the term Geopolymer. Geopolymer cement can be formulated in two phases: one is to combine the rich contents of silicone with aluminum products, such as flyash, GGBS and metakaolin with the combination of sodium hydroxide , sodium silicate, potassium hydroxide and potassium silicate. During the second stage, alumina and silica during flyash, GBBS or metakaoline trigger and form a contact pulp with the 3D polymer chains or ring structure of -Si-O-Al-O by means of a polymerisation process .

For this analysis, geopolymer concrete mechanical and toughness properties are used as a partial substitute for flyash by granite waste. Several research on the use of granite waste as mineral admixture and partial replacement of binders and finer aggregates in concrete have been carried out. In this research, this is the first attempt to replace the binding agents of geopolymer concrete with granite waste.

OBJECTIVES

This study's main aims are:

1. The mechanical properties of GPC should be examined by replacing fly ash with granite waste in different proportions (0, 5 , 10 , 15 and 20 percent).
2. The Durability properties of GPC to substitute binder with granite waste should be tested and compared.
3. To investigate the micro-structural properties of GPC with specific granite waste replacements.

LITERATURE REVIEW

UbollukRattanasak and PrinyaChadraprasirt (2009) studied the effect of newly implemented long-term geopolymer preparation mixing process and compared it to the standard mixing process. The considered parameters are the ratios of alkaline (0.5, 1,1.5and 2) and molarity (5, 10and 15 M). The findings of the leaching test were strong for NaOH 10M. In compression strength and infrarot spectroscopy, the newly proposed, long-term blending technique gave a better result.The compressive strength and microstructure properties (using SEM, EDS and infrared spectroscopy) on geopolymer pastes were investigated by KiatsudaSomna et al . (2011). Two types of fly ash used here were ordinary fly ash, and one field fly ash and enabled with specific NaOH concentrations (4.5,7, 9.5, 12, 14 and 16.5 M). From the results obtained ground fly ash mix with an alkaline ratio between 9.5 M and 14 M gave reasonable increments in compressive power. It was cleared from the analysis on microstructure that ground fly ash has higher polymerization compared to the ordinary one.

The fresh and mechanical characteristics of GPC and geopolymer morter (2014) have been studied by Pradip Natha and Prabir Kumar Sarker. The component was

GGBS (10 , 20 and 30%), alkaline (1,5,2 and 2,5) and activator (35, 40 and 45). The consequence slump and the initial setting time with the GGBS and the alkaline ratio have been reduced but the slump and the initial setting time have been increased as the activator content increased. The increase in the GGBS concentration and the decrease in alkaline ratio and activator content increased the compressive power. With through GGBS material, the microstructure was well compacted.

Dattatreyaet al.(2011) Conducted experimental studies on the flexural behavior of the reinforced geopolymer concrete beam .In his study the binder materialchosen was fly ash and GGBS in different percentages and these geopolymer concrete beams (GPC)are compared with the conventional OPC beams. The fly ash (FA)and GGBS percentages are 75%FA-25%GGBS, 0% FA-100%GGBS,25%FA- 75% GGBS, 50% FA-50% GGBS and the NaOH is taken in 8molarity. The size of the beam is 1500 mm × 100 mm × 150 mm and reinforcement bars used in this study is 16 mm, 12 mm and 8 mm stirrups, the tension reinforcement is varied with 3 different percentages. And the specimens were cured under room temperature, after 28 days those specimens were tested under 2 point loading. The author concluded that load Vsdeflection characteristics of the reinforced OPC beams and reinforced geopolymer concrete beams are almost similar and also the crack patterns were similar with conventional concrete beams.

Duxsonet al.(2006) has presented the history of the geopolymer technology in the form of state of art. In this paper the author has explained about the materials that can be used in the geopolymer concrete preparation. And also the chemical characteristics and the structure of the geopolymer concrete prepared by fly ash, GGBS and metakaolin and the properties of these raw materials were clearly explained. The selection of material and mixing procedure of geopolymer concrete is critical for its setting time, workability and mechanical properties. The author concluded by overview of progress in geopolymer science over last two decades, and the materials that were being used in the geopolymer technology were environmental friendly.

Himath Kumar et al. (2017) conducted study on the strength and durability of the geopolymer concrete, in which geopolymer concrete is made by 100% GGBS and the alkaline solution is taken in 12molarity and 14molarity. For this experimental study standard size of cubes, cylinders and prisms were casted and these specimens were cured under room temperatures and were tested after 3,7,28 days. The cubes were tested for compressive strength and the cylinders were tested for split tensile strength and the prisms were tested for flexural behavior. And durability tests were conducted after 30 days curing in respective chemical solutions. The results have shown, the compressive strength of 14molarity cubes were more than 12molarity cubes, 12molarity specimens have less split tensile strength compared to 14 molarityspecimen and the flexural strength is good for 14 molarity specimens. And the final conclusion is, as the molarities increase the strength increases.

METHODOLOGY AND MIX DESIGN

MIX DESIGN

The mix design has been done for geopolymer concrete on the basis of proposed procedure in the literature. The design grade is M35.

GPC unit weight = 2400 Kg/m3
Assume 75% aggregate in matrix
Aggregate content = 0.75×2400
= 1800 Kg/m3
Coarse aggregate content taken as 60%= 0.60×1800
= 1080 Kg/m3
Fine aggregate content taken as 40%= 0.40×1800
= 720 Kg/m3
M-sand = 720 Kg/m3
Liquid to binder ratio = 0.47
Binder content plus liquid = 2400-1800
= 600 Kg/m3
Binder content = 600/(1+0.47)
= 408.16 Kg/m3
Alkaline ratio = 2.5
NaOH content
=16.772 Kg/m3
Sodium silicate
=38.038 Kg/m3

S.NO	Material	Quantity(Kg/mm^3)				
		MP-1 0%	MP-2 5%	MP-3 10 %	MP-4 15 %	MP-5 20 %
1	Fly ash	326.53	310.204	293.877	277.55	261.224
2	GGBS	81.633	81.633	81.633	81.633	81.633
3	Granite waste	0	16.326	32.653	48.979	65.306
4	Coarse aggregate(20mm)	648	648	648	648	648
5	Coarse aggregate (12.5mm)	432	432	432	432	432
6	M-sand	720	720	720	720	720
7	NaOH	16.772	16.772	16.772	16.772	16.772
8	Na_2SiO_3	38.038	38.038	38.038	38.038	38.038

Material quantities for all five GPC mixes

Flyash is replaced in the range of 0, 5, 10, 15 and 20% by Granite waste were represented as MP-1, MP-2, MP-3, MP-4 and MP-5 respectively.

MATERIALS AND PROPERTIES

S.NO	Material	Colour	Specific gravity
1.	Fly ash	Grey	2.34
2.	GGBS	White	2.46
3.	Granite waste	Grey	2.64

Physical properties of binder materials

AGGREGATE

Material	Specific Gravity	Water Absorption(%)
M-Sand	2.69	2.95
Coarse aggregate of 20mm	2.76	0.38
Coarse aggregate of 12.5mm	2.65	0.32

Physical properties of Aggregate

ALKALINE ACTIVATOR

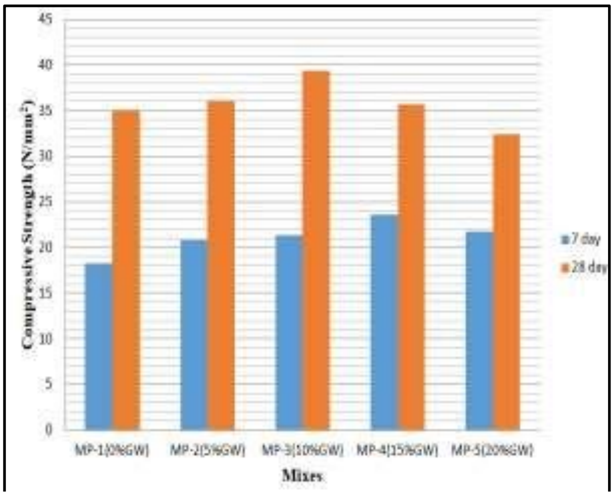
Activator	Colour	Specific Gravity	Form
Sodium Hydroxide	White	1.35	Solid flakes
Sodium Silicate	yellowish	1.51	Liquid

Physical properties of activators

Compressive Strength Test Setup

S.No	Mix-Id	Compressive Strength Of Cubes (N/mm^2)	
		7 Day	28 Day
1.	MP-1	19.31	34.12
2.	MP-2	20.82	36.20
3.	MP-3	22.35	39.20
4.	MP-4	23.61	35.62
5	MP-5	21.58	32.54

Compressive strength of all mixes at 7 day and 28 day



Compressive strength of all mixes at 7 day and 28 day

RESULTS AND DISCUSSIONS

As per IS 516-1959 the compressive strength of concrete can be found by applying compressive force on cube (150*150*150mm) by compression testing machine at 5KN/sec. After some time crushing of concrete takes place due to fail of bond between matrix. The following Fig. 5.1 showed compression testing of sample.

The compressive strength can be calculated through the following formula.

Compressive strength = L/A

Where 'L'-Failure load, 'A'- Area of the specimen.

SPLIT TENSILE STRENGTH

Using compression testing machine of 2000KN capacity apply the load 2 KN/sec after placing the cylinder parallel the plates of machine. Due to the application of compressive load on the surface of cylinder causes development of the tensile stresses in cylinder later it split into two halves. Fig. 4.2 shows split-tensile testing of sample.

Tensile strength can be calculated by using the following formula.

$Cs=2p/\pi Ld$

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Split Tensile Test Setup

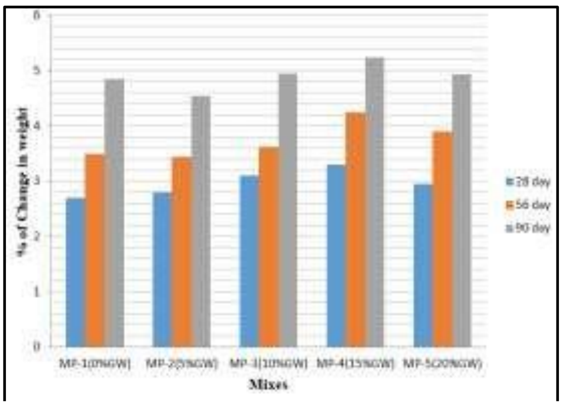
S.No	Mix-Id	Split Tensile Strength Of Cylinders (N/mm^2)	
		7 Day	28 Day
1.	MP-1	1.85	3.52
2.	MP-2	2.35	3.52
3.	MP-3	2.32	4.25
4.	MP-4	2.44	4.20
5.	MP-5	2.55	3.10

Split-tensile strength of all mixes at 7day and 28 day

DURABILITY TEST RESULTS

S.No	Mix-Id	% Of Weight Variation (Loss)		
		28 Day	56 Day	90 Day
1.	MP-1	2.5	3.44	4.65
2.	MP-2	2.6	3.54	4.32
3.	MP-3	3.3	3.80	4.72
4.	MP-4	3.5	4.23	5.30
5.	MP-5	2.75	3.60	4.83

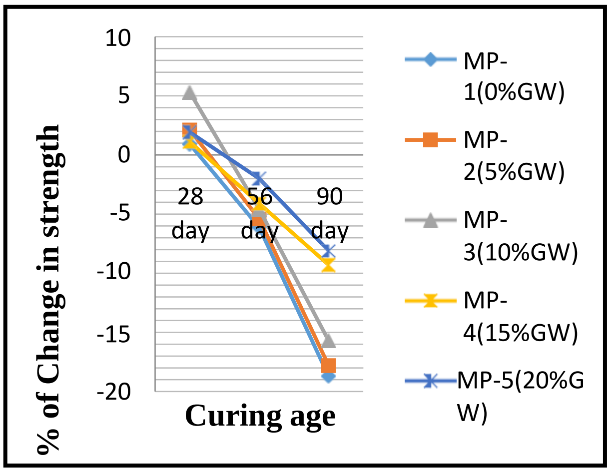
Percentage of weight variation due to Sulphate attack



Weight loss of all mixes under sulphate curing

Mix-Id	Compressive Strength At Different Ages (N/mm^2) gain(+) loss(-)					
	28 Day	% Of Variation	56 Day	% Of Variation	90 Day	% Of Variation
MP-1	34.45	0.9	32.97	-6.1	28.54	-18.7
MP-2	35.8	2.1	34.13	-5.4	29.65	-17.8
MP-3	40.5	5.3	37.58	-4.6	33.21	-15.7
MP-4	34.12	1.1	34.25	-4.1	32.41	-9.3
MP-5	32.05	1.9	31.79	-2	29.8	-8.1

Variation of Compressive Strength for all mixes in sulphate attack



For all mixes under sulfate healing variance of intensity

CHLORIDE ATTACK

S.No	Mix-Id	% Of Weight Variation (Loss)		
		28 Day	56 Day	90 Day
1.	MP-1	2.4	3.71	4.53
2.	MP-2	2.2	3.47	4.32
3.	MP-3	2.3	3.3	4.21
4.	MP-4	2.6	3.22	4.1
5.	MP-5	2.9	3.86	5.2

Percentage of weight variation due to Chloride attack

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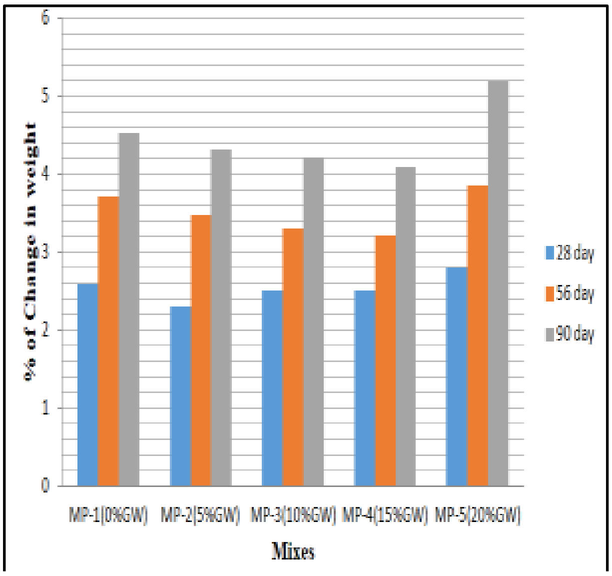
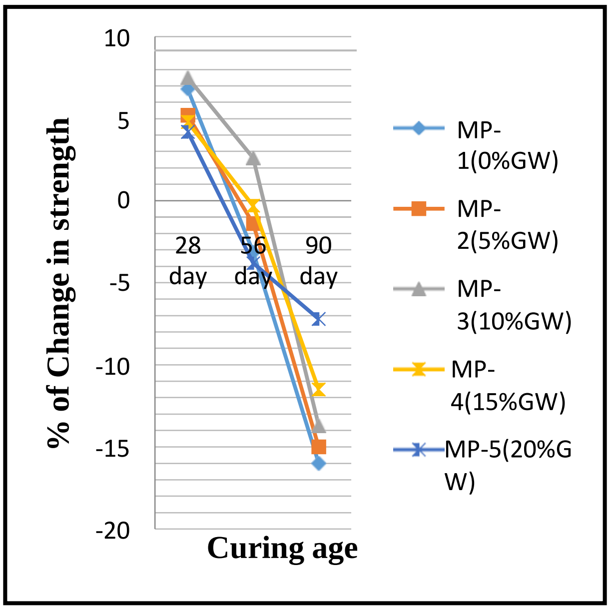


Weight loss of all mixes under chloride curing

Mix-Id	Compressive Strength At Different Ages(N/mm^2) gain(+) loss(-)					
	28 Day	% Of Variation	56 Day	% Of Variation	90 Day	% Of Variation
MP-1	37.5	6.8	34.02	-3.13	29.5	-16
MP-2	37.95	5.2	35.54	-1.4	30.65	-15
MP-3	42.35	7.5	40.42	2.6	34.02	-13.7
MP-4	37.45	4.8	35.6	-0.3	31.62	-11.5
MP-5	33.8	4.2	31.2	-3.8	30.12	-7.2

Variation of Compressive Strength for all mixes in chloride attack

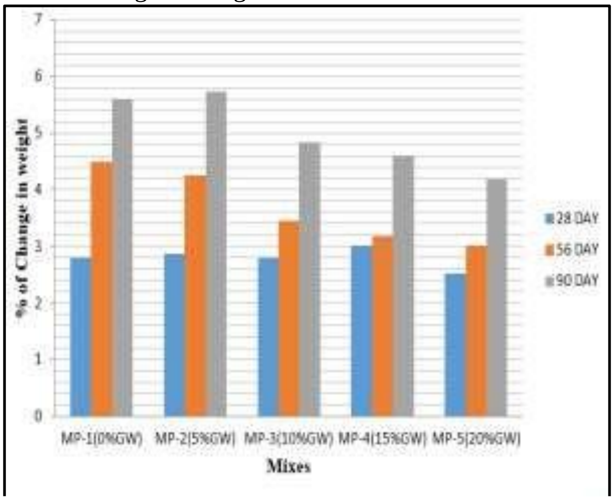


Variation of strength for all mixes under chloride curing

ACID ATTACK

S.No	Mix-Id	% Of Weight Variation (Loss)		
		28 DAY	56 DAY	90 DAY
1.	MP-1	2.8	4.5	5.6
2.	MP-2	2.87	4.25	5.74
3.	MP-3	2.8	3.45	4.83
4.	MP-4	3.01	3.18	4.6
5.	MP-5	2.53	3.01	4.2

Percentage of weight variation due to acid attack



Weight loss of all mixes under acid curing

Mix-Id	Compressive Strength At Different Ages (N/mm^2) gain(+) loss(-)					
	28 Day	% Of Variation	56 Day	% Of Variation	90 Day	% Of Variation
MP-1	34.65	-1.3	32.4	-7.7	27.54	-21.6
MP-2	36.5	1.2	33.45	-7.2	29.09	-19.3
MP-3	41.6	5.6	36.95	-6.2	32.85	-16.6
MP-4	37.12	3.9	33.64	-5.8	31.52	-11.8
MP-5	33.4	3	31.04	-4.3	29.05	-10.5

Variation of Compressive Strength for all mixes in Acid attack

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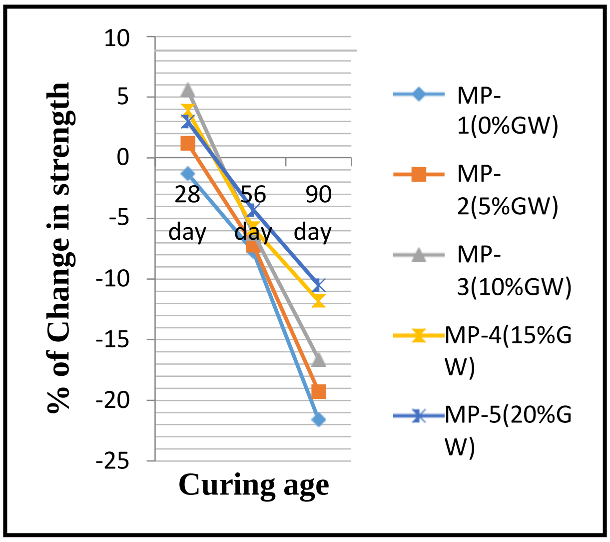
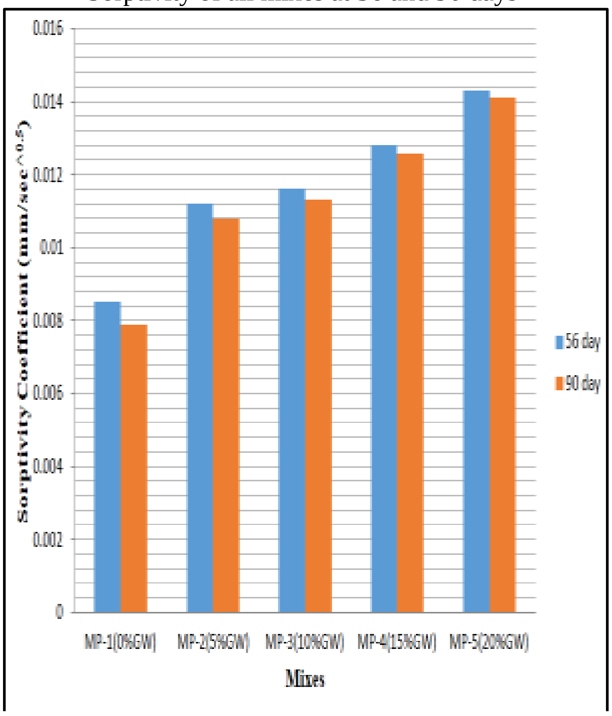


Variation of strength for all mixes under Acid curing

SORPTIVITY

S.No	Mix-Id	Sorptivity(mm/sec^0.5)	
		56 Day	90 Day
1.	MP-1	0.0085	0.0079
2.	MP-2	0.0112	0.0108
3.	MP-3	0.0116	0.0113
4.	MP-4	0.0128	0.0126
5.	MP-5	0.0143	0.0141

Sorptivity of all mixes at 56 and 90 days

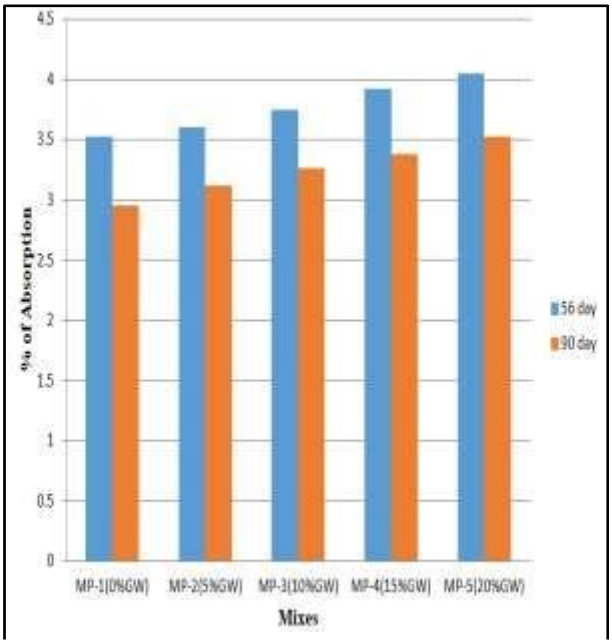


Sorptivity of all mixes at 56 and 90 days

WATER ABSORPTION

S.No	Mix-Id	Percentage Of Water Absorption (%)	
		56 Day	90 Day
1.	MP-1	3.52	2.95
2.	MP-2	3.6	3.12
3.	MP-3	3.75	3.26
4.	MP-4	3.92	3.38
5.	MP-5	4.05	3.52

Percentage of water absorption for all mixes at 56 and 90 days



Percentage of water absorption for all mixes at 56 and 90 days

CARBONATION

S. No	Mix-Id	Carbonation Depth (mm)	
		56 Day	90 Day
1.	MP-1	3.42	3.15
2.	MP-2	5.66	5.43
3.	MP-3	5.87	5.65
4.	MP-4	5.93	5.73
5.	MP-5	6.89	6.74

Carbonation depth of all mixes at 56 and 90 days

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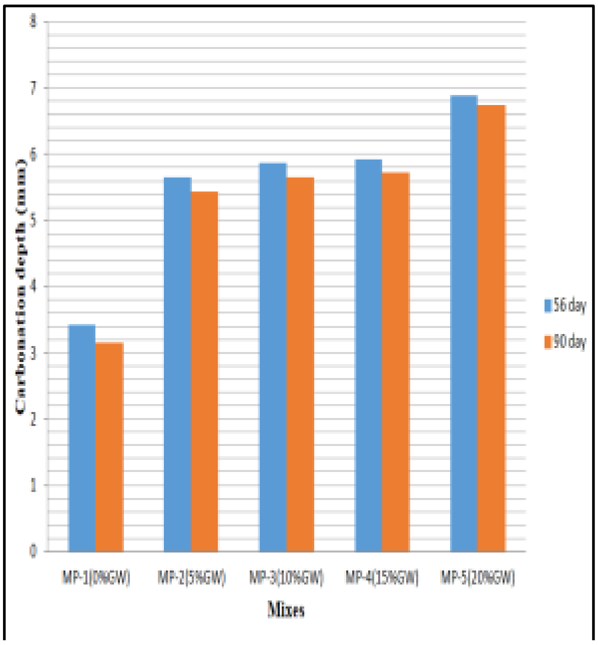


Carbonation depth of all mixes at 56 and 90 days

REBOUND HAMMER

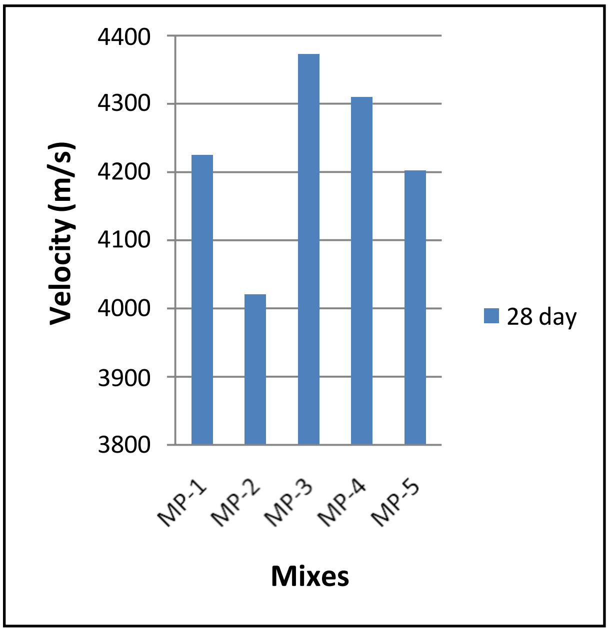
Mix-Id	Rebound Number	Compressive Strength From Rebound Index (N/mm²)	Compressive Strength At 28 Day (N/mm²)
MP-1	29	28.5±6.0	35.12
MP-2	31	32.0±6.5	36.06
MP-3	34	37.0±6.5	39.40
MP-4	32	34.0±6.5	35.72
MP-5	28.5	27.0±6.0	32.44

Rebound number of all mixes at 28 days

ULTRASONIC PULSE VELOCITY

S.No	Mix-Id	Velocity(m/s)	Quality of concrete IS 13311-Part1
1.	MP-1	4225	Good(3500-4500)
2.	MP-2	4021	Good(3500-4500)
3.	MP-3	4373	Good(3500-4500)
4.	MP-4	4310	Good(3500-4500)
5.	MP-5	4202	Good(3500-4500)

Ultrasonic pulse velocity of all mixes at 28 days



CONCLUSION

From this research the following conclusions were drawn.The mechanical characteristics of geopolymer concrete with granite waste are strengthened and the optimal contents of 10% granite waste is best suited for flyash substitution.20 per cent replacement granite wastes have the ability to preserve sulfuric condition compared to control mixture of sodium sulfates, sodium chlorides and hydrogen.Results have shown that the 5 and 10% replacement use of granite waste has comparable results in a durability mix of 56 and 90 days such as sorptive characteristics, waste absorption and coal carbonation10% of granite waste has solid ultrasonic pulse speed and rebound hammer testing, when compared with results of control mix.Geopolymer concrete micro-structure was improved with granite waste of 10 percent.

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