Comparative Analysis of Compressive Strength of Concrete by Replacing of Cement by Fly Ash with Conventional Concrete

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Abstract: ***Today, the development of infrastructure, industry and housing is necessary. Without concrete, the built environment would fail to accommodate our modern and demanding lifestyles. Given our reliance on concrete, it will inevitably play a major role to pursue sustainable development in any country. At its most basic, concrete is a mixture of aggregates, cement, sand and water. With appropriate mix design, concrete can be tailored for any construction requirement. Understanding the role of aggregates in concrete is fundamental to the production of good concrete as aggregates have their greatest influence on the performance of fresh concrete. Study all of constitutes in concrete mixtures, including aggregates, in order to obtain a comprehensive understanding of the behaviour of the final product. As a result of such considerations, it is clear that the role of aggregates is crucial to ensure satisfactory performance of mixtures since they govern the volumetric stability of concrete. In addition, aggregates have an important effect on concrete strength by providing rigidity to the material which governs resistance to applied loads and undesired deformations. The aim of the study is to assess the effect of use of fly ash in concrete as compare to cement concrete elements in marine condition of. To compare the compressive strength of concrete by replacing 100% percentage of cement by fly ash with conventional concrete at constant molarity , as well as to study, the effect of varying curing time period under normal condition.***

Keywords: Concrete, cement, fly ash, sand and water

1. Introduction

Mix design can be defined as "the process of choosing the ingredient of concrete and determining their quantities with the object of producing as economically as possible of certain concrete of certain minimum properties such as consistence, strength, and durability" (Neville, 1995).

The Global use of concrete is second only to water as the demand of concrete as a construction material increases so also a demand of Portland cement. It is estimated that the production of cement has been increased from about 2.2 million tons in 2010 to 3.5 million tons in 2016. By 2025, cement production will reach to 550 million tonnes (Business Standard, Ministry of External Affairs, TechSci Research, Ministry of External Affairs).

Concrete has an excellent structural performance and durability, but is affected by early deterioration when subjected to a marine environment. On the other hand the climate change due to global warming has become a major concern. Because of production of 1 tones of Portland cement emits approximately 0.8 tones of CO2 into the atmosphere (Davidovits, 1994' McCaffrey, 2002). The cement industry is held responsible for some of the carbon dioxide emission. In this respect the geopolymer technology shows considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of global warming the geopolymer technology significantly reduce the carbon dioxide emission to the atmosphere caused by the cement industry.

1.1 Aim and Objectives

The aim of the study is to assess the effect of use of fly ash in concrete as compare to cement concrete elements.

- To compare the compressive strength of concrete by replacing 100% percentage of cement by fly ash with conventional concrete at constant molarity , as well as to study, the effect of varying curing time period under normal condition.

2. Material Used

In the present experimental work, low calcium, Class F will use as the base material.

Fly ash

According to the American Concrete Institute (ACI) Committee 116R, fly ash is defined as '*the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gasses from the combustion zone to the particle removal system'* (ACI Committee 232 2004). Fly ash is removed from the combustion gases by the dust collection system, either mechanically or by using electrostatic precipitators, before they are discharged to the atmosphere. Fly ash particles are typically spherical, finer than Portland cement and lime, ranging in diameter from less than 1μm to no more than 150 μm.

Alkaline Liquids

The most common alkaline liquid used in geopolymerisationis a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. A combination of sodium silicate

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solution and sodium hydroxide solution are chosen because they were cheaper than Potassium based solution. The type of alkaline liquid plays an important role in the polymerisation process. Reactions occur at a high rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides.

Table 2.1: Specification of Sodium Silicate

Colour	Colorless
Density (Kg/m^3)	1450-1550
Total Solid Content, by mass %	45:52

The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in water. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, NaOH solution with a concentration of 8M consisted of 8x40 = 320 grams of NaOH solids (in flake or pellet form) per litre of the solution, where 40 is the molecular weight of NaOH.

The chemical composition of the sodium silicate solution was Na2O=14.7%, SiO2=29.4%, and water 55.9% by mass. The other characteristics of the sodium silicate solution were specific gravity=1.53 g/cc and viscosity at 20^{o}C=400 cp.

Table 2.2: Proportion of NaOH Solution per kg

Sr No	Molarity	Mass of NaOH (gm)	Mass of water (gm)
1	8 M	262	738
2	12 M	361	639
3	16 M	444	556

Aggregates

Fine and coarse aggregates locally available were tested and confirmed the requirements as per Indian Standards (BIS 2386-1963, BIS 383-1970). The size distribution of the aggregate determines how much binder is required. Aggregate with a very even size distribution has the biggest gaps wheras adding aggregate with smaller particles tends to fill the gaps between the aggregate as well as pasting the surface of the aggregate together, and is typically the most expensive component. Thus variation in size of the aggregate reduce the cost of concrete. The aggregate is nearly always stronger then the binder, so its use does not negatively affect the strength of concrete.

Figure 2.1: Aggregate

Aggregate properties

Properties	*Fine Aggregate*	*Coarse Aggregate*
Specific Gravity	2.32	2.60
Fineness Modulus	2.82	7.10
Water Absorption	1.50%	0.80%

Superplastisizer

Superplasticizers, also known as high range water reducers, are chemical admixtures used where well-dispersed particle suspension is required. These polymers are used as dispersants to avoid particle segregation (gravel, coarse and fine sands), and to improve the flow characteristics of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to fly ash ratio without negatively affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. The strength of concrete increases when the water to fly ash ratio decreases.

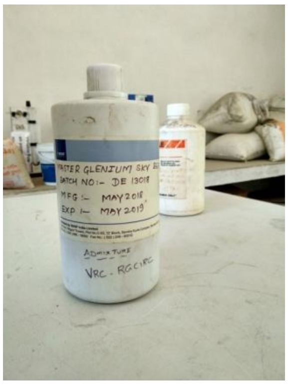

Figure 2.2: Plastisizer

Figure 2.3: Sodium Chloride and Magnesium Sulphate

Curing Compound

For the Marine Condition, Sodium Chloride Solution with concentration 19gm/ltr and 38 gm/ltr and Magnesium Sulphate Solution with concentration 2gm/ltr and 4gm/ltr is prepared.

3. Literature Review

3.1 Introduction

This Chapter presents the background to the needs for the development of alternative binders to manufacture concrete

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and the use of fly ash in concrete. The available published literature on geopolymer technology is also briefly reviewed.

3.2 History of Geopolymer

In 1978, Davidovits proposed that a binder could be produced by a polymerisation process involving a reaction between alkaline liquids and compounds containing aluminium and silicon. The binders created were termed "geopolymers". Unlike ordinary Portland/pozzolanic cements, geopolymers do not form calcium-silicate-hydrates (CSHs) for matrix formation and strength, but silica and alumina reacting with an alkaline solution produce an aluminosilicate gel that binds the aggregates and provides the strength of concrete. Source materials and alkaline liquids are the two main constituents of geopolymers, the strengths of which depend on the nature of the materials and the types of liquids.

Table 2.1

S.No.	Topic	Author	Conclusion
1	Drying Shrinkage of Heat Cured Fly Ash Based Geopolymer Concrete	Wallah (2009)	Heat cured fly ash-based geopolymer concrete undergoes very low drying shrinkage
2	Strength and Water Penetrability of Fly Ash Geopolymer Concrete	Olivia and Nikraz (2011)	The water absorption of low calcium fly ash geopolymer was improved by decreasing the water/binder ratio, increasing the fly ash content, and using a well-graded aggregate. No significant change was observed in water permeability coefficient for the geopolymer with different parameters
3	Study of Properties of Fly Ash Based Geopolymer Concrete.	Yasir and Iftekar (2015)	Geopolymer concrete possesses good compressive strength and offers good durability characterstics. With the increase of alkaline liquid to fly ash ratio, strength decreases and alkaline liquid to fly ash ratio less than 0.3 is very stiff.
4	Review On The Study Of Fly Ash Based Geopolymer Concrete	Ramesh and Joy (2017)	Proper oven curing leads to good strength properties, otherwise the strength attainment may consume time.

4. Methodology

a) Sieve Analysis
b) Compression Testing Machine (CTM)
c) Mould (150 x150 x 150)mm

4.1 Sieve Analysis

The sieve analysis was carried out on fine aggregate using I.S. sieve. The fine aggregate being used satisfies the guideline of code IS 373:1970. A sieve analysis (or gradation test) is a practice or procedure used to assess the particle size distribution (also called *gradation*) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common.

4.2 Compression Testing Machine (CTM)

Compression tests are used to determine how a product or material reacts when it is compressed, squashed, crushed or flattened by measuring fundamental parameters that determine the specimen behavior under a compressive load.

Figure 4.1: Compression Testing Machine

Compression tests can be undertaken as part of the design process, in the production environment or in the quality control laboratory, and can be used to:

- Check the compressive strength of fly ash based geopolymer mortar samples at interval of 3, 7 and 28 days
- Assess the strength of components e.g. automotive and aeronautical control switches, compression springs, bellows, keypads, package seals, PET containers, PVC / ABS pipes, solenoids etc.
- Characterize the compressive properties of materials e.g. foam, metal, PET and otherplastics and rubber.

4.3 Mould

These ISI Cube Moulds are use for making Concrete /cement Cubes which are use for preparation of concrete cube specimens of high strength materials for compression testing.

Figure 4.2: Casting Mould (150x150x150)mm

Hypothesis

This study is design to assess the hypothesis that a good binding material can be formed for the production of concrete by a polymerisation process involving a reaction

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between alkaline liquids and compounds containing aluminium and silicon. In this paper portland cement which is used as binding material, is 100% replaced by fly ash and various test is performed for study the behavior of the geopolymer concrete under certain condition to check whether the hypothesis we made is correct or not. This paper study adopted is experimentation on high performance concrete (HPC) with super plasticizer with the aim to report its suitability for concrete structure. The flow chart of the thesis is shown in Fig. below

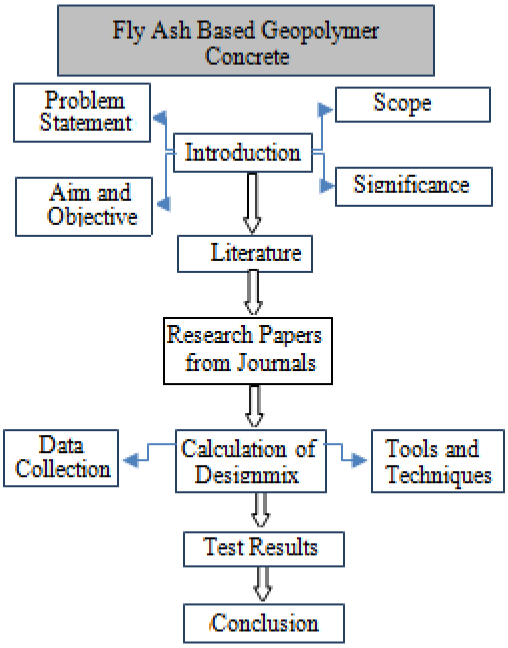

Figure 4.3: Flow Chart

Experiment Procedure adopted

1) Prepare the NaOH solution 24 hours prior to casting.
2) Two hours before the casting prepare the sodium silicate solution by mixing it with the Sodium hydroxide solution.
3) Take predetermined quantities of the Fly ash, Coarse Aggregate, Fine Aggregate and Alccofine.
4) Pre weight all the material.
5) Mix all above well.
6) Add the predetermined quantity of superplasticizer that is 2% of Fly ash.
7) Mix all components together by adding extra water and stir thoroughly.
8) Pour the mix into Cubes (150mm*150mm*150mm size cubes). Leave the cubes for 24 hours so that they can settle well.
9) After 24 hours Demould the cubes and keep the cubes into the oven for the heat curing of 24 hours at 90 degrees.
10) After 24 hours of heat curing remove the cubes from oven.
11) Test the cubes accordingly.

5. Result and Discussion

Calculation

a) Design mix for M35 Conventional Concrete

Table 5.1: Mix Quantity of CC

Constituent of Mix	Quantity (kg/m3)
Cement	385
Water	158
Plasticizer	1.54
Fine Aggregate	724
Coarse Aggregate (10mm)	703
Coarse Aggregate (20mm)	468

b) Design mix for 12 Molarity NaOH solution

Table 5.2: Mix Quantity of GPC

Constituent of Mix	Quantity (kg/m3)
Fly Ash	380
Water (alkaline liquids)	192
Plasticizer	7.6
Fine Aggregate	690
Coarse Aggregate (10mm)	414
Coarse Aggregate (20mm)	621
Total	2304.6

Physical Observation

Table5.3: Weight gain of GPC in different condition

	Average Weight Gain (GPC)		
Solutions	3 Days	7days	28days
Sodium Chloride			
19gm/ltr	7.12	7.24	7.49
38gm/ltr	7.18	7.32	7.58
Magnesiumsulphate			
2gm/ltr	7.03	7.11	7.30
4gm/ltr	7.04	7.15	7.38
NORMAL WATER			
	7.04	712	7.25

Table 5.4: Weight gain of CC in different condition

	Average Weight Gain (CC)		
Solutions	3 Days	7days	28days
SODIUM CHLORIDE			
19gm/ltr	8.43	8.70	8.88
38gm/ltr	8.49	8.76	9.05
MAGNESIUM SULPHATE			
2gm/ltr	8.33	8.42	8.67
4gm/ltr	8.37	8.47	8.71
NORMAL WATER	8.45	8.53	8.70

Compressive Strength

Loadreading= 390 KN

$$\text{Compressive Strength} = \frac{\text{Load}}{\text{Area of Cube Surface}}$$

$$= \frac{390 \times 1000}{150 \times 150} = \mathbf{17.3\ N/mm2}$$

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Table 5.5: Compressive Strength of GPC in different condition

	(GPC) Compressive Strength (N/mm2)		
Solutions	3 Days	7days	28days
SODIUM CHLORIDE			
19gm/ltr	17.3	23.7	39.65
38gm/ltr	15.2	21.4	37.37
MAGNESIUM SULPHATE			
2gm/ltr	15.8	21.3	38.73
4gm/ltr	16.6	20.45	37.45
Normal Water			
	17.73	25.5	42.8

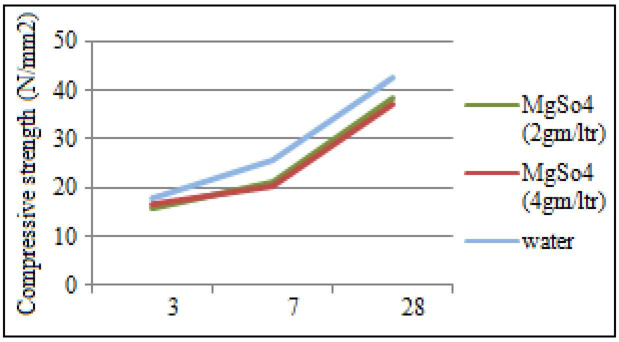

Figure 5.1: Compressive strength of GPC cured under sulphate solution

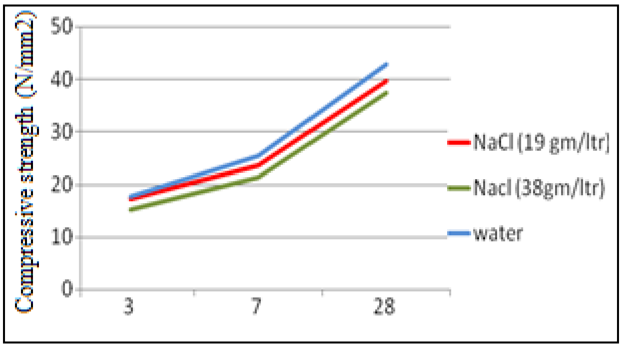

Figure 5.2: Compressive strength of GPC cured under chloride solution

Table 5.6: Compressive Strength of CC in different condition

	CC Compressive Strength (N/mm2)		
SOLUTIONS	3 Days	7days	28days
SODIUM CHLORIDE			
19gm/ltr	15.5	22.15	37.75
38gm/ltr	13.8	19.7	36.1
MAGNESIUMSULPHATE			
2gm/ltr	14.1	19.6	36.9
4gm/ltr	15.2	18.7	35.75
Normal Water			
	15.9	23.7	40.8

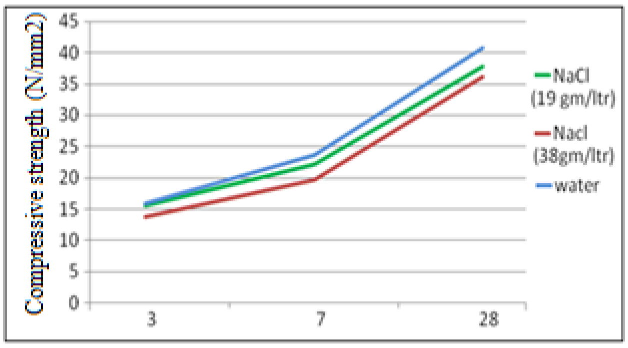

Figure 5.3: Compressive Strength of CC Cured under chloride slout ion

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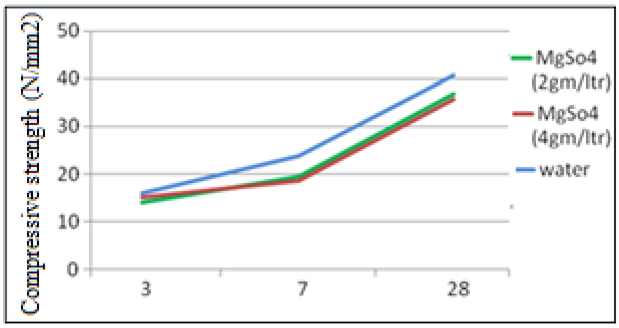

Figure 5.4: Compressive Strength of CC Cured under sulphate solution

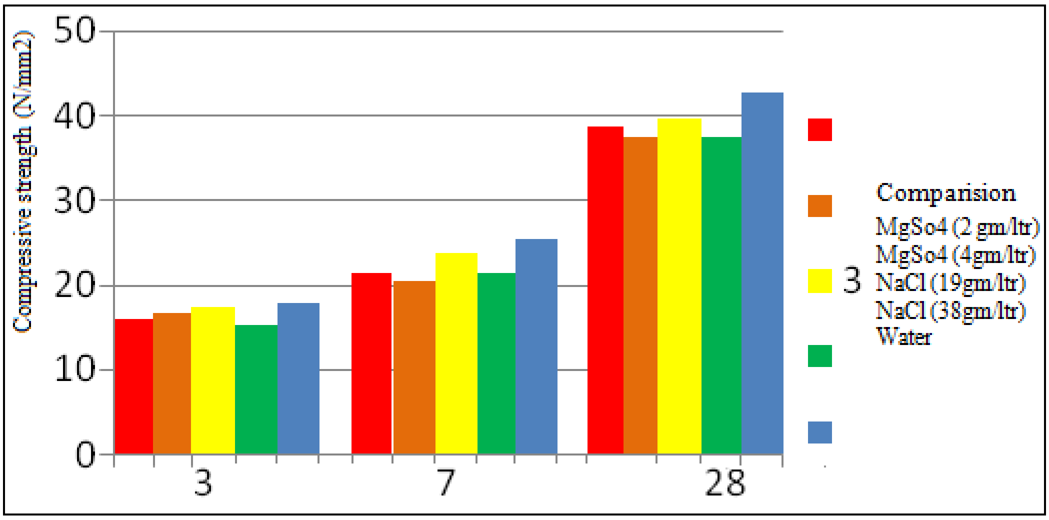

Figure 5.5: Compressive Strength of GPC for different curing condition

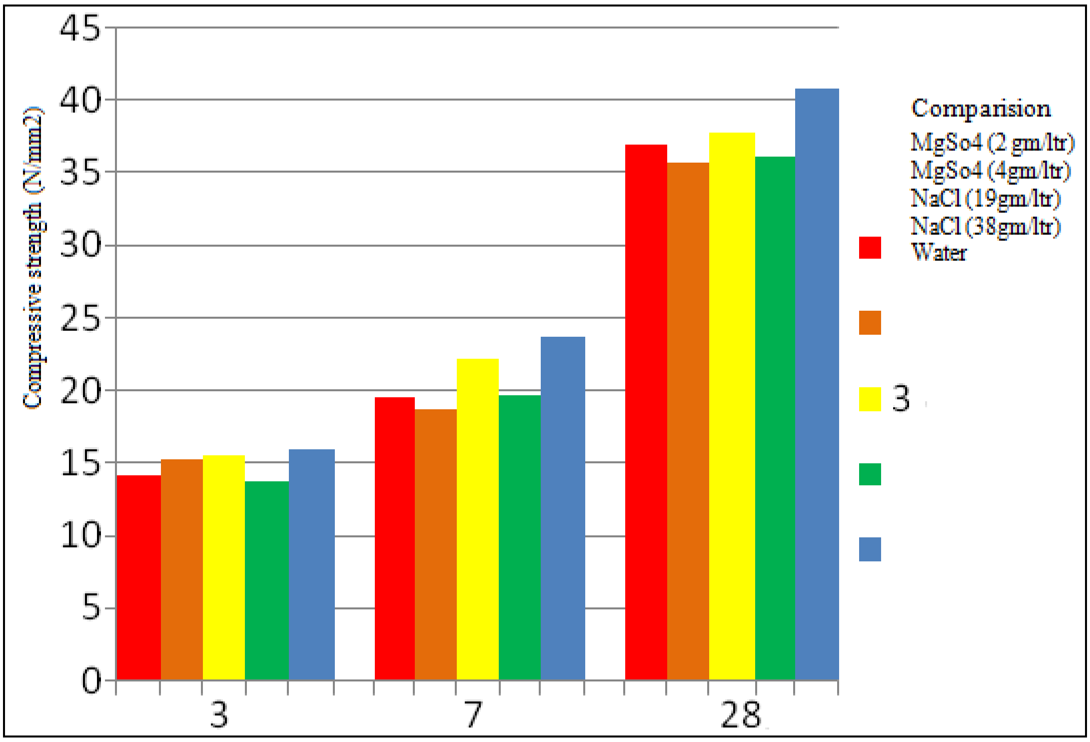

Figure 5.6: Compressive Strength of CC for different curing condition

6. Conclusion

- It is possible to produce geopolymer concrete for general purpose at room temperature (27^{o}C).
- Visual inspection results indicated that FAGPC specimens showed moderate surface deterioration without color change and OPC specimens exhibited greatest surface deterioration with color change from gray to white.
- Geopolymer and OPC specimens were visually observed to remain structurally intact and maintained their initial conditions without color change, spalling and cracking when they were exposed to magnesium sulfate and sodium chloride attack.

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- Weight gain was observed for almost all specimens immersed in chemical solutions due to solution absorption and expansion occurred by gypsum formation. Weight gain was observed to be higher for immersed in sodium chloride solutions.
- Although compressive strength test results after chemical exposure of the OPC specimens were slightly lower than the FAGPC specimens, loss of mechanical strengths due to chemical attack was found to be less on FAGPC specimens, which may be attributed to low calcium amount of the FAGPC specimens.

7. Further Work Plan

Further study should be made on prevention of chemical attack in order to avoid the effect of salt water on other important characteristics of concrete and check the accurate durability of geopolymer concrete as durability cannot be measured in 28 days. It is planned to increase the percentage content of alkaline liquid ratio. This is expected to increase the strength of final product and to study various methods for the measurement of the durability of the geoploymer concrete block.

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