Feasability Study on the use of Geopolymer Concrete in coastal environment

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Abstract - India holds second largest producer of cement in the world. The current capacity of cement production is 366 million tonnes. It is expected to reach 550 – 600 million tonnes by the year 2025. Approximately 1 ton of cement production liberates 0.8 ton of Co2 to the atmosphere, which pollutes the environment. In this scenario, the geopolymer concrete plays into role, this doesn't use any quantity of cement.The Main aim of this project is to find out the Strength and Durability characteristics of Geopolymer Concrete especially in Coastal Environment by using combination of Fly Ash, GGBS and M – Sand. The characteristic of fly ash, GGBS and M – Sand is studied and M – Sand was confirmed in Zone III. In this a Mix Design was adopted using M25 grade and then a mix proportion of 1:1.31:1.96 was formulated. The different Molarities of sodium hydroxide solution of 8M and 12M were taken for the preparation of different mixtures. The Test specimens of size 100 x 100 x 100mm Cube, 100 x 200mm Cylinder and 500 x 100 x 100mm Beams were carried out. For the above process steam curing method was used. The Compressive strength of Geopolymer concrete specimen was at 7, 14 and 28 days. The Durability characteristics were also studied.

Keyword: Geopolymer concrete, M Sand, Coastal Environment, Compressive Strength.

I. INTRODUCTION

Concrete is a very strong and versatile mouldable construction material. It consists of cement, sand and aggregate mixed with water. The cement and water form a paste or gel which coats the sand and aggregate. When the cement has chemically reacted with the water (hydrated), it hardens and binds the whole mix together. The initial hardening reaction usually occurs within a few hours. It takes some weeks for concrete to reach full hardness and strength. Concrete can continue to harden and gain strength over many years

India holds second largest producer of cement in the world. The current capacity of cement production is 366 million tonnes. It is expected to reach 550 – 600 million tonnes by the year 2025. Approximately 1 ton of cement production liberates 0.8 ton of Co2 to the atmosphere, which pollutes the environment. In this scenario, the geopolymer concrete plays into role, this doesn't use any quantity of cement.

Concrete production is the process of mixing together the various ingredients—water, aggregate, cement, and any additives—to produce concrete. Concrete production is time-sensitive. Once the ingredients are mixed, workers must put the concrete in place before it hardens. In modern usage, most concrete production takes place in a large type of industrial facility called a concrete plant, or often a batch plant.

Concrete can be damaged by many processes, such as the expansion of corrosion products of the steel reinforcement bars, freezing of trapped water, fire or radiant heat, aggregate expansion, sea water effects, bacterial corrosion, leaching, erosion by fast-flowing water, physical damage and chemical damage (from carbonization, chlorides, sulphates and distillate water). The micro fungi Aspergillums' Alternaria and Cladosporium were able to grow on samples of concrete used as a radioactive waste barrier in the Chernobyl reactor; leaching aluminium, iron, calcium and silicon.

Concrete can be viewed as a form of artificial sedimentary rock. As a type of mineral, the compounds of which it is composed are extremely stable. Many concrete structures are built with an expected lifetime of approximately 100 years, but researchers have suggested that adding silica fume could extend the useful life of bridges and other concrete uses to as long as 16,000 years. Coatings are also available to protect concrete from damage, and extend the useful life. Epoxy coatings may be applied only to interior surfaces, though, as they would otherwise trap moisture in the concrete.

II. GEOPOLYMER

The last few years have seen spectacular technological progress in the development of Geosynthesis and geopolymeric applications. New state of the art materials designed with the help of geopolymerization reactions are opening up new applications and procedures, and transferring ideas that have been taken for granted in inorganic and mineral chemistry. Since the discovery of the geopolymer chemistry by Prof. Joseph Davidovits already find out applications in all fields of industries. These applications are to be found in the automotive and aerospace industries, non – ferrous foundries and metallurgy, civil engineering, cement and concretes, ceramics and plastic industries, waste management, art and decoration, retrofit of buildings etc. It is widely known fact that the production of Portland cement consumes considerable energy and at the same time contributes a large volume of CO2 to the atmosphere. However, Portland cement is still the main binder in concrete construction prompting a search for more environmentally friendly materials. One possible of the alternative is the use of alkali – activated binder using industrial by – products containing silicate materials called Geopolymer concrete.

Geopolymer is an inorganic polymeric material formed by activating Silica – aluminium rich minerals with Alkaline or Alkaline – Silicate solution at ambient or higher temperature level. These are commonly formed by alkali activation of industrial alumina silicate waste materials such as fly ash, Ground Granular Blast Furnace Slag etc., it is most necessary to find out a suitable alternative material for the existing Portland cement concrete, because cement production consumes lot of energy and pollutes atmosphere on the country. The geopolymer concrete uses the thermal waste material called fly ash. In addition the GGBS is also left out as waste material for first filling. Similarly it is also essential to find out a suitable material for the Natural river sand. The only alternatively is the manufactured sand.

Hence there is a scope for the geopolymerization process for a concrete mix using fly ash, GGBS and Manufactured sand. All the above mentioned three materials have silica and alumina, which are predominated for polymerisation.

III. OBJECTIVE

- Determination of strength characteristic of Geopolymer concretewith Fly ash, GGBS as Binder and M-Sand
- Determination of durability characteristic of Geopolymer concretewith Fly ash, GGBS as Binder and M-Sand

IV. EXPERIMENTAL PROGRAMME

A binder is any material or substance that holds or draws other materials together to form a cohesive whole mechanically, chemically, or as an adhesive. Often materials labelled as binders in different proportions or uses can have their roles reversed with what they are binding

Geopolymer can be produced with the basic raw materials containing silica and alumina rich mineral composition. Several studies have reported that the use of better utilization of these materials in concrete. Most of the studies investigated the use of alkali activators containing sodium hydroxide and sodium silicate or a potassium hydroxide and potassium silicate

Geopolymer Concrete was cast using following materials:

- Fly Ash
- GGBS
- Natural Sand
- M – Sand
- Coarse Aggregate
- Water
- Alkaline (Sodium Hydroxide + Sodium Silicate)

5.1 Mix Design:

The Mix design was carried out as per Indian Standard with the following Data:

- Grade of OPC = M25
- Target Mean Strength = 36N/mm^2
- Density of Concrete = 2400kg/m^3
- Fine Aggregate = 40% of Total volume of concrete
- Coarse Aggregate = 60% of Total volume of concrete
- Alkaline to Binder Ratio is 0.4 (0.35 to 0.55)
- Sodium Silicate to Sodium Hydroxide Ratio is 2 (2 to 2.5)

The Exact quantities for 1m3 of concrete presented in Table 1

Table 1 Mix Design Quantity for 1m^3 of concrete

Binder (Kg/m^3)	**F.A (Kg/m^3)**	**C.A(Kg/m^3)**
514.28	**672**	**1008**
1	**1.31**	**1.96**

The quantity of alkaline solution for 1m^{3}of concrete is presented in Table 2. TheMolarity was calculated as follows:

- 8 Molarity = 8 x 40 = 320 grams of 1 litre of water
- 12Molarity = 12 x 40 = 480 grams of 1 litre of water

Table 2 Molarity Calculation

Molarity	**NaOH (Kg)**	**Water(litres)**
8M	21.94	68.57
12M	43.88	137.14

The following two types of concrete mixes were chosen for casting the specimens

- Geopolymer concrete with Fly Ash (50%) and GGBS (50%) along with M – Sand using 8Molarity of NaOH Solution
- Geopolymer concrete with Fly Ash (50%) and GGBS (50%) along with M – Sand using 12Molarity of NaOH Solution

V. CASTING THE SPECIMENS

The following Sizes of Specimens are casted in Geopolymer concrete:

- Cube – 100x100x100mm
- Cylinder – 100x200mm
- Prism –500x100x100mm

The casted specimens are shown in fig 1

Fig 1 Specimens are casted in Geopolymer concrete using 8M and 12M

VI. CURING

The curing process was adopted by using the method of Steam curing process. These are the process which done for 24 hours only and the remaining period the specimens will be kept in room temperature only. Fig 2 Shows the Steam Curing Process using an Auto clave.

Fig 2 Steam Curing Process

VII. STRENGTH PROPERTIES

After attaining the specified age, the specimens are tested for a strength property as mentioned below

- Compressive Strength

- Split Tensile
- Flexural Strength

VIII. DURABILITY PROPERTIES

The followings were studied in Durability process. They are

- Acid Test
  - Hydro Chloric Acid
  - Sulphuric Acid
- Alkaline Test
  - Sodium chloride
- Sulphate Test
  - Sodium sulphate + Magnesium Sulphate
- Water Absorption test
- Sea water Testing

Durability Test Proportion:

- Acid Test
  - Hydro Chloric Acid 5%
  - Sulphuric Acid 5%
- Alkaline Test
  - Sodium Chloride 5%
- Sulphate Test
  - Sodium Sulphate 5% + Magnesium Sulphate 15%

In this process, 100mm Cube Specimens were immersed in a tub individually in the required solute. It was measured periodically 0 Days, 14 Days, 28 Days and 56 Days respectively. The Test results are provided in Table 6.
In addition to the above Sea water testing was also carried out on two different sources which denotes A and B. A was collected in Bay of Bengal Coasts from Chennai (Marina Beach), and B was collected in Arabian Sea from Kerala (Nattika Beach).

IX. RESULTS AND DISCUSSION

A. COMPRESSIVE STRENGTH:

The cube compressive strength was presented in table 3

Table 3 Compressive strength – Cube

S.No	**7 Days (N/mm^2)**		**14 Days (N/mm^2)**		**28 Days (N/mm^2)**	
	8M	**12M**	**8M**	**12M**	**8M**	**12M**
1.	40	43	44	46	46	48
2.	39	42	45	47	48	51
3.	41	40	44	45	52	55
Average					**48.66**	**51.33**

The target Mean strength of M25 using OPCC was 36 N/mm^2. However the GPCM at 28 days has attained strength of 48.66N/mm^2 for 8M concrete and 51.33N/mm^2 for 12M concrete, which was 35.2% and 42.5% higher than the OPCC. Hence GPCM can be replaced against OPCC with respect to strength characteristics. The chart showing the comparison of 8M & 12M are presented in fig 3.

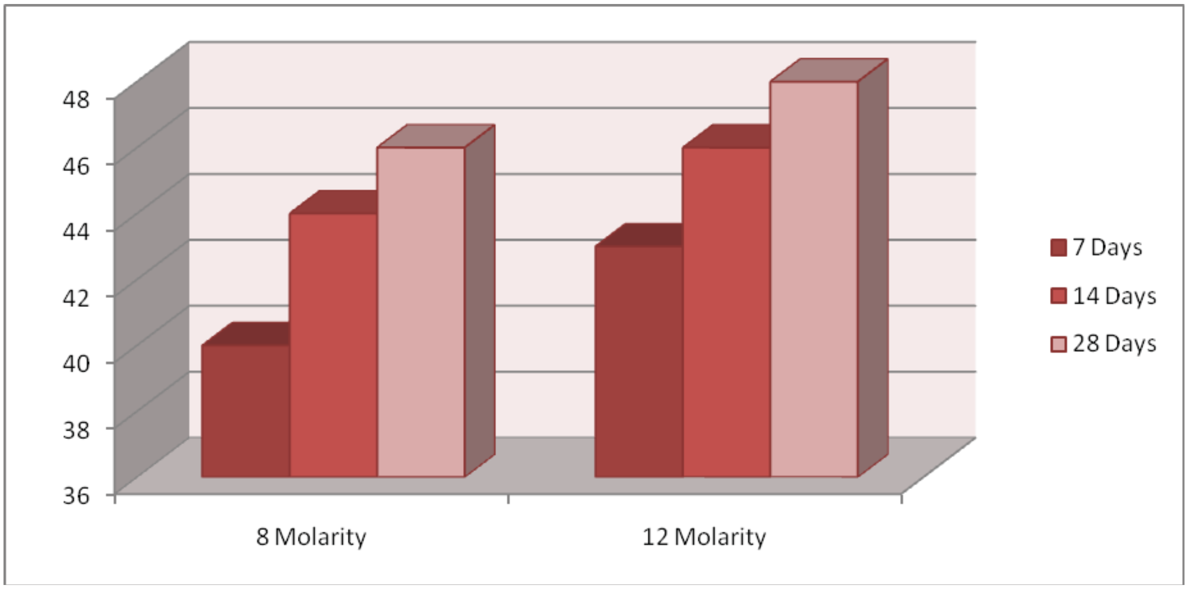


Fig 3 – Comparison between 8M and 12M for Cube

The 8M concrete itself gave sufficient strength compared to OPCC, 8M GPCM shall be used against OPCC. Higher Molar concentration led to higher cost. Since 8M concrete itself has got 35.27% above OPCC, 8M GPCM shall be sufficient to use by considering the economical point of view. If for any structure much higher strength is required then we can use 12M GPCM.

B. SPLIT TENSILE:

The Cylinder Split Tensile was presented in table 4

Table 4Split Tensile – Cylinder

S.No	**7 Days (N/mm^2)**		**14 Days (N/mm^2)**		**28 Days (N/mm^2)**	
	8M	**12M**	**8M**	**12M**	**8M**	**12M**
1.	2.86	3.81	3.5	4.2	4.31	4.77
2.	2.38	2.71	3.7	4.3	3.5	4.13
3.	2.86	2.54	3.8	4.12	4.45	4.13
Average					**4.086**	**4.34**

The target Mean strength of M25 using OPCC was 3.5 N/mm^2. However the GPCM at 28 days has attained strength of 4.086N/mm^2 for 8M concrete and 4.34N/mm^2 for 12M concrete, which was 16.74% and 24% higher than the OPCC. Hence GPCM can be replaced against OPCC with respect to strength characteristics. The chart showing the comparison of 8M & 12M are presented in fig 4.

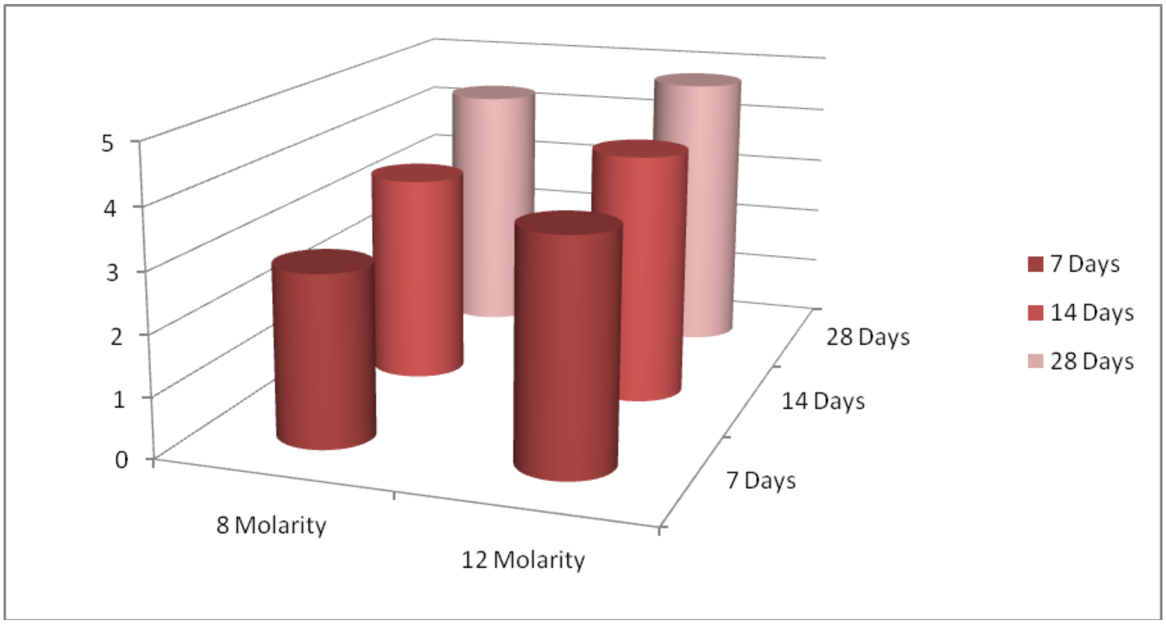


Fig4 – Comparison between 8M and 12M for Cylinder

The 8M concrete itself gave sufficient strength compared to OPCC, 8M GPCM shall be used against OPCC. Higher Molar concentration led to higher cost. Since 8M concrete itself has got 16.74% above OPCC, 8M GPCM shall be sufficient to use by considering the economical point of view. If for any structure much higher strength is required then we can use 12M GPCM.

C. FLEXURAL STRENGTH:

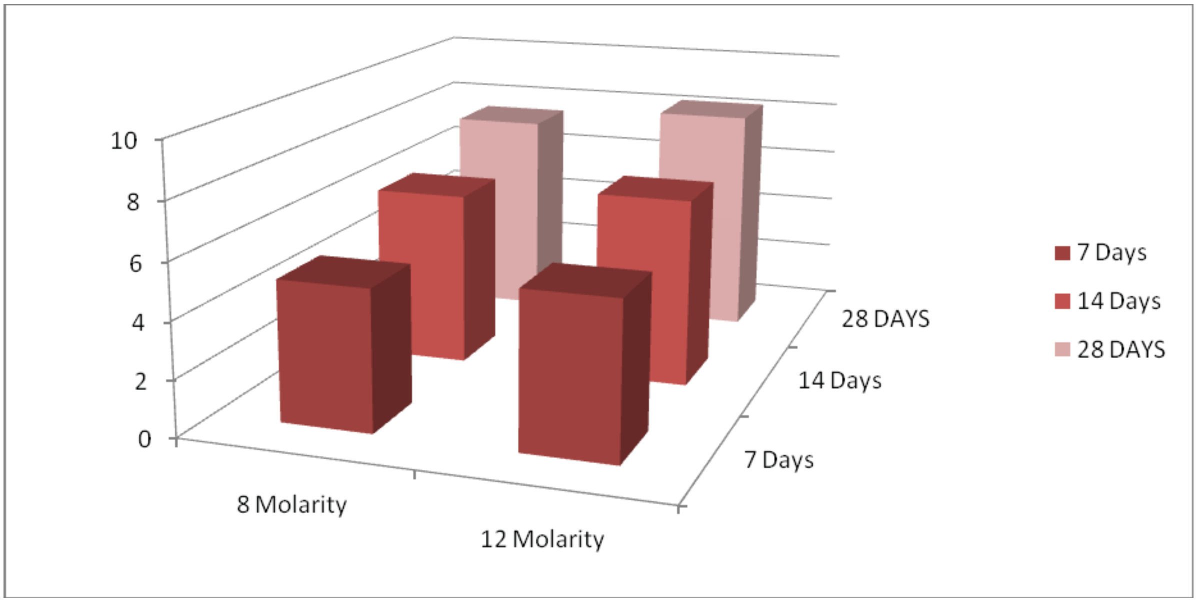
The Prism Flexural strength was presented in table 5

Table 5Flexural strength – Prism

S.No	7 Days (N/mm^2)		14 Days (N/mm^2)		28 Days (N/mm^2)	
	8M	**12M**	**8M**	**12M**	**8M**	**12M**
1.	5.00	5.25	6.25	6.75	7.50	7.75
2.	4.25	5.00	6.10	6.60	6.50	7.50
3.	4.50	5.50	6.40	6.80	7.00	8.25
Average					**7.00**	**7.833**

The target Mean strength of M25 using OPCC was $5.5N/mm^2$. However the GPCM at 28 days has attained strength of $7N/mm^2$ for 8M concrete and $7.833N/mm^2$ for 12M concrete, which was 27.27% and 42.4% higher than the OPCC. Hence GPCM can be replaced against OPCC with respect to strength characteristics. The chart showing the comparison of 8M & 12M are presented in fig

5



Graph 3 – Comparison between 8M and 12M for Prism

The 8M concrete itself gave sufficient strength compared to OPCC, 8M GPCM shall be used against OPCC. Higher Molar concentration led to higher cost. Since 8M concrete itself has got 25.27% above OPCC, 8M GPCM shall be sufficient to use by considering the economical point of view. If for any structure much higher strength is required then we can use 12M GPCM.

D. DURABILITY VALUES:

Table 6 Durability Readings

Samples	0 Days Weight (kg)	14 Days Weight (kg)	28 Days Weight (kg)	56 Days Weight (kg)
Sea water A	2.478	2.489	2.529	2.523
Sea water B	2.468	2.481	2.516	2.504
Sulphuric Acid	2.448	2.450	2.464	2.459
Sodium Chloric	2.379	2.410	2.427	2.422
Sulphate Test	2.417	2.420	2.483	2.478
HCL	2.480	2.495	2.510	2.490

In this Method, Durability properties of the specimen were studied for different days of 14, 28 and 56 days respectively. The weight has been increased gradually up to 28 days as mentioned in above table 6. The specimen has not been affected during the durability process up to 14 and 28 days. Finally the weight of the specimen has been decreased @ 56th day.

The results indicated that for a period up to 28 days water absorption was carried out and after 28 days only the specimen was affected by the salts.

X. CONCLUSION

Based on the experimental results of the study, the following conclusion can be drawn from it.

- The Target Mean Compressive strength of M25 concrete using OPCC was 36N/mm^2. In GPCM @28 Days was attained a Compressive strength of 48.66N/mm^2. Since 8M concrete using has got 35.2% above OPCC, 8M GPCM shall be sufficient to use by considering the economical point of view.
- The Target Mean Tensile strength of M25 concrete using OPCC was 3.5N/mm^2. In GPCM @28 Days was attained a Split Tensile of 4.086N/mm^2. Since 8M concrete using has got 16.74% above OPCC, 8M GPCM shall be sufficient to use by considering the economical point of view.
- The Target Mean Flexural strength of M25 concrete using OPCC was 5.5N/mm^2. In GPCM @28 Days was attained a Flexural strength of 7.00N/mm^2. Since 8M concrete using has got 27.27% above OPCC, 8M GPCM shall be sufficient to use by considering the economical point of view.
- Durability of GPCM was high, Compared to OPCC.
- The specimen was not affected during the durability process up to28 days.
- The durability the specimens was affected from the 56th day around only.

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