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# FLOW AND STRENGTH PERFORMANCE OF GEOPOLYMER MORTAR PARTIALLY REPLACED WITH SUB-SURFACE ROCK POWDER

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## ABSTRACT

Geopolymer is an aluminosilicate compound produced as a result of inorganic polymerization. In the present study the use of geopolymers as binder material in mortar where, fine aggregate was partially replaced with sub-surface rock powder obtained from depths of 200ft, 400ft and 600ft, was tested. The alkali activator used in the present study was 10M Sodium hydroxide (NaOH) solution. The experiments were conducted on fly ash and GGBS (1:1) based geopolymer mortar by varying the ratios of fine aggregate and sub-surface rock powder. The ratio of alkaline liquid (10M NaOH solution) to geopolymer was fixed as 0.1. The admixture Fosroc auramix V200, whose percentage was fixed as 1.2% determined by the marsh cone analysis test, was used for improving the workability of the mortar. The test specimens were ambient cured. The results showed the compressive strength was highest for the GPM 600 60 40 at 16.4 N/mm$^2$ and lowest for GPM 200 0 100 at 6.31N/mm$^2$. The general pattern showed that there was an increase in the compressive strength from 7 days to 28 days of curing. During the 7 days testing GPM 200 showed higher compressive strength but after 28 days of curing GPM 600 had higher compressive strength.

**KEYWORDS:** Fly ash, GGBS, geopolymer mortar, alkaline liquid, compressive strength.

## 1. INTRODUCTION

Concrete is the most widely used construction material. The demand for it is continuously increasing. Due to this the production of cement is also increasing. The production of cement is increasing about 3% annually. The production of 1000 kgs or 1 ton of cement produces about 1 ton of CO2 to atmosphere. Among the other greenhouse gases, CO2 contributes about 65% of global warming.

Mortar is a material comprised of a cementitious binder material, fine aggregate, and water. Here the cementitious material can be OPC, Flyash, GGBS etc. Fine aggregates also play an important role in the strength gain of mortar. But fine aggregates production is also harmful for the environment as it requires breaking down of granite material using crushers. This method is used for production of material called M-sand or manufactured sand.

The geopolymer was synthesized with fly ash, sodium silicate and sodium hydroxide solutions. Geopolymer technology involves more environmentally friendly waste material-based mortar which could be viable solution for conventional cement replacement. Geopolymers are inorganic by-product materials rich in silicon (Si) and aluminum (Al) that react with the alkaline activators to form polymeric chain.

Flyash (FA) and Ground granulated blast furnace slag (GGBS) are the two types of alumino-silicate solid waste materials commonly used in the geopolymer mortar. The geopolymer mortar enhances durability and consistency of effective cost. There is no need of cement content in the geopolymermortar. Geopolymer manufacture is one of the most promising technique that has been developed in the last few years. Utilization of geopolymer materials can reduce 80% of greenhouse gas emission with material production and overcome from the cement production and use of industrial materials by recycling the materials in geopolymer

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manufacture. Porosity of M-sand mortar was found to be higher than that with natural sand whereas the compressive strength of M-sand mortar is higher than that of natural sand mortar. Replacement of natural river sand with crushed limestone sand enhances the long-term performance of mortars exposed to chemical solutions. In the present study properties of M- sand cement mortar and properties of rock powder collected at different depths (200ft, 400ft and 600ft) is evaluated at various replacement levels for flow and compressive strength.

**[1]**(2010) Experimental study on the density and compressive strength of geopolymer concrete. The experiments were conducted on fly ash based geopolymer concrete by varying the types of curing namely ambient curing and hot curing. The compressive strength test was conducted and the results showed that there is an increase in compressive strength with the increase in age of ambient cured specimens.

**[2]** (2013) The study carried out for development of strength for various grades of geopolymer concrete with varying molarity. The geopolymer concrete specimens are tested for their compressive strength at the age of 7 and 28 days. The test results indicate that the combination of fly ash and ground granulated blast furnace slag (GGBS)can be used for development of geopolymer concrete.

**[3]** (2019) The research deals with preparation of geopolymer mortars based on ground granulated blast furnace slag as partial replacement of cement based on using central composite experimental design. The results obtained confirmed that optimum compressive strength was achieved with geopolymer/cement ratio 8.6% and liquid activator/solids 0.52.

**[4]**(2005) studied on the Marsh Cone as a viscometer: theoretical analysis and practical limits. In this study, we carry out Marsh cone and rheumatic measurements on glycerol-water mixes in a first part. In a second part a simple modelling is proposed linking flow time to Newtonian viscosity. In EN 12 715, the nozzle diameter recommendation of 4.75 mm has then to be followed.

**[5]** (2013) The experimental data generated to formulate a phenomenological model to arrive at the combinations of the ingredients to produce geopolymer blocks to meet the strength development desired at the specified age.It was observed that some of the blocks attained considerable strength within 24 h under ambient conditions. The validity of phenomenological model was examined with an independent set of experimental data. The blocks can replace the traditional masonry blocks with many advantages.

**[6]** (2019) Tests were conducted to examine the microstructure and mineralogical changes. It has been observed that the performance of geopolymer concrete containing fly ash with more glass content was better. The concrete samples were exposed to atmosphere for 180 days under a wide range of temperature (11o to 39oC) and relative humidity. This indicates good durability characteristic of fly ash based geopolymer concrete.

**[7]**(2015) Test conducted cement is replaced by geopolymer material and water is replaced by alkaline activator solution. The parameters considered in this investigation are geopolymer source material (fly ash and GGBS) and alkaline activator consisting of sodium meta silicate and sodium hydroxide of different molarities (8, 12, 16M). The ratio of sodium meta silicate to sodium hydroxide considered in this study is 2.5. The test results indicated that combination of fly ash and GGBS results in decreased final setting time and increased compressive strength. It was also observed that increase in sodium hydroxide increases compressive strength of geopolymer mortar.

**[8]** (2009) This paper describes the development and testing of three novel geopolymer mix designs prepared using metakaolin and fly ash (class C and F) precursors. Specimens prepared using Portland cement-silica fume blend were also tested for comparison purposes. The other geopolymer mix designs were found to perform equally or better compared with the OPC binary blend

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## 2. MATERIALS AND METHODS

### 2.1 Materials

- Binder: Class-F Flyash and Ground Granulated Blast Furnace Slag (GGBS). The binders used in this study were satisfying the requirements of IS:3812:2003.
- Chemical Admixtures: superplasticizer
- Fine Aggregates: Manufactured sand and Sub-surface rock powder. Both of these were tested as per IS:383:2016 to determine if they were acceptable for use as fine aggregates in mortar.
- Alkali activator: 10M Sodium hydroxide (NaOH) solution.

### 2.2 Methodology

- Study on properties of mortar ingredients.
- Marsh cone analysis to check compatibility of blended geopolymeritious material with chemical admixtures and to fix dosage.
- Flow table test to determine the consistency of fresh mortar.
- Experimental investigations on mortar replacing M-Sand with sub-surface rock powder collected at different depths.
- Compressive strength study on ambient cured mortar cubes of standard size by replacing M-sand in different ratios with sub-surface rock powder.

## 3. TEST RESULT AND ANALYSIS

### 3.1 Test on ingredients

#### *3.1.1 Specific gravity*

***Table 1***

| SI NO | MATERIAL | SPECIFIC GRAVITY |
|---|---|---|
| 1 | Flyash | 2.8 |
| 2 | GGBS | 2.85 |
| 3 | M-Sand | 2.70 |
| 4 | Chemical admixture | 1.09 |

#### *3.1.2 Chemical analysis*

***Table 2. For rock powder 200ft depth***

| Sl. No. | Parameters used | Test results | Test method | Requirement as per IS:383-2016(Table2) |
|---|---|---|---|---|
| 1 | pH value | 9.14 | IS:2720(part 26)-1987 | Not specified |
| 2 | Chloride content | 0.0065 | IS:4032-1985(RA2014Z | Not specified |
| 3 | Sulphate content | 0.094 | IS:4032-1985(RA2014) | Not specified |
| 4 | Organic impurities | Not harmful | IS:2386part2-1963(RA2011) | The aggregate shall not contain harmful organic impurities in sufficient to affect the strength of mortar |

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| | | | |
|---|---|---|---|
| 5 | Alkaline aggregate reactivity<br>1. Reduction in alkalinity of 1.0N NaOH<br>2. Silica dissolved | 60.0millimoles/lt<br>13.16millimoles/lt | As per IS: 2386 the sample fall under Innocuous aggregate, the tested sample do not indicate potential deleterious degree of alkali reactivity. |

*Table 2. For rock powder 400ft depth*

| Sl. No. | Parameters used | Test results | Test method | Requirement as per IS:383-2016(Table2) |
|---|---|---|---|---|
| 1 | pH value | 9.20 | IS:2720(part 26)-1987 | Not specified |
| 2 | Chloride content | 0.009 | IS:4032-1985(RA2014Z | Not specified |
| 3 | Sulphate content | 0.084 | IS:4032-1985(RA2014) | Not specified |
| 4 | Organic impurities | Not harmful | IS:2386part2-1963(RA2011) | The aggregate shall not contain harmful organic impurities in sufficient to affect the strength of mortar |
| 5 | Alkaline aggregate reactivity<br>1. Reduction in alkalinity of 1.0N NaOH<br>2. Silica dissolved | 75.0millimoles/liters<br>27.88millimoles/liters | As per IS: 2386 the sample fall under Innocuous aggregate, the tested sample do not indicate potential deleterious degree of alkali reactivity. | |

*Table 3. For rock powder 600ft depth*

| Sl. No. | Parameters used | Test results | Test method | Requirement as per IS:383-2016(Table2) |
|---|---|---|---|---|
| 1 | pH value | 9.05 | IS:2720(part 26)-1987 | Not specified |
| 2 | Chloride content | 0.0071 | IS:4032-1985(RA2014Z | Not specified |
| 3 | Sulphate content | 0.088 | IS:4032-1985(RA2014) | Not specified |

| | | | | |
|---|---|---|---|---|
| 4 | Organic impurities | Not harmful | IS:2386part2-1963(RA2011) | The aggregate shall not contain harmful organic impurities in sufficient to affect the strength of mortar |
| 5 | Alkaline aggregate reactivity<br>1. Reduction in alkalinity of 1.0N NaOH<br>2. Silica dissolved | 75.0millimoles/liters<br>27.24millimoles/liters | As per IS: 2386 the sample fall under Innocuous aggregate, the tested sample do not indicate potential deleterious degree of alkali reactivity. | |

### *3.1.3 Marsh cone analysis*

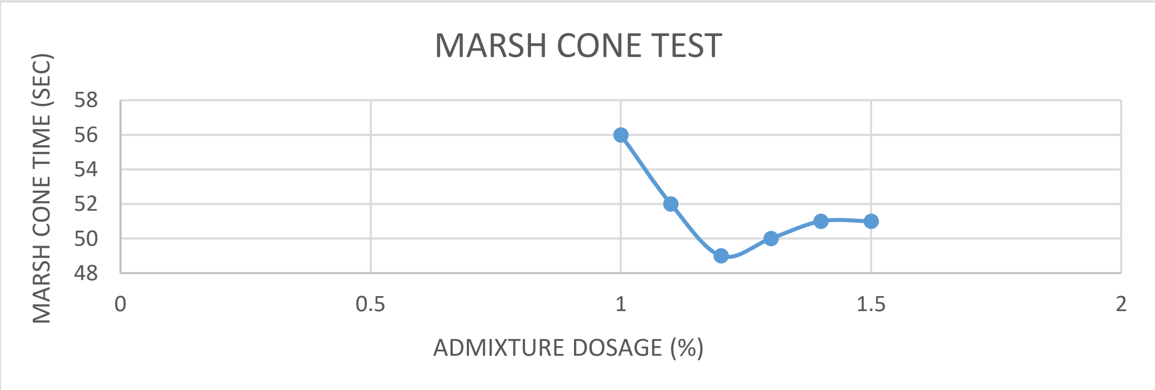


***Fig.1:marsh cone test graph***

### *3.1.4 Flow table test*

***Table 4.flow table test results***

| SI. NO. | MIX | FLOW (mm) | SUITABLE W/C (%) |
|---|---|---|---|
| **1.** | GPM 200 100 0 | 107.40 | 0.48 |
| **2.** | GPM 200 80 20 | 110.66 | 0.46 |
| **3.** | GPM 200 60 40 | 113.75 | 0.48 |
| **4.** | GPM 200 40 60 | 110.70 | 0.46 |
| **5.** | GPM 200 20 80 | 110.75 | 0.46 |
| **6.** | GPM 200 0 100 | 110.70 | 0.48 |
| **7.** | GPM 400 100 0 | 107.40 | 0.48 |
| **8.** | GPM 400 80 20 | 107.40 | 0.46 |
| **9.** | GPM 400 60 40 | 107.40 | 0.46 |
| **10.** | GPM 400 40 60 | 107.40 | 0.46 |
| **11.** | GPM 400 20 80 | 113.70 | 0.46 |
| **12.** | GPM 400 0 100 | 113.70 | 0.48 |
| **13.** | GPM 600 100 0 | 107.40 | 0.48 |
| **14.** | GPM 600 80 20 | 107.40 | 0.46 |
| **15.** | GPM 600 60 40 | 107.40 | 0.46 |

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| | | | |
|---|---|---|---|
| **16.** | GPM 600 40 60 | 107.40 | 0.46 |
| **17.** | GPM 600 20 80 | 113.70 | 0.46 |
| **18.** | GPM 600 0 100 | 110.70 | 0.46 |

***3.1.5 Compressive strength***

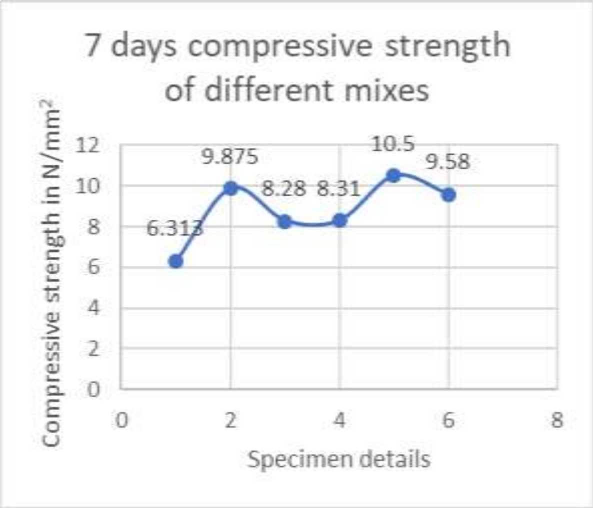


*Fig 2: 200ft depth rock powder specimens (7 days)*

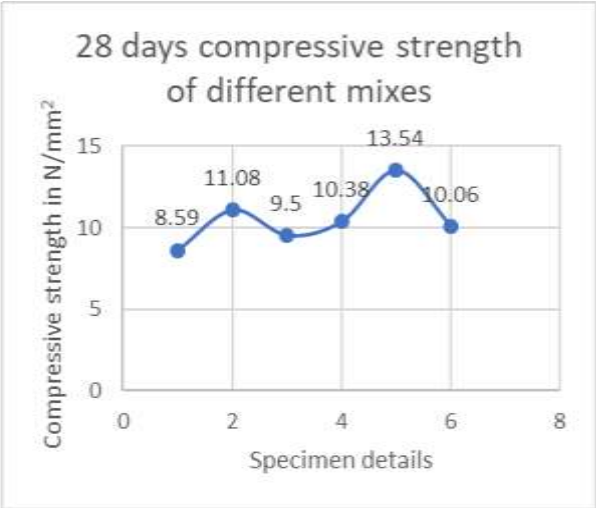


*Fig 3: 200ft depth rock powder specimens (28 days)*

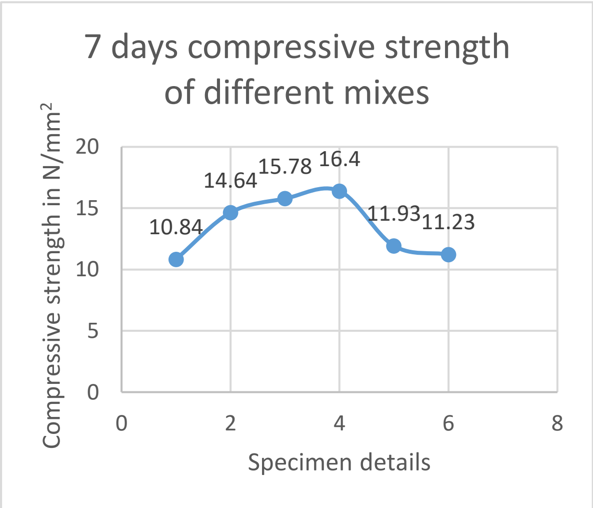


*Fig 4: 400ft depth rock powder specimens (7 days)*

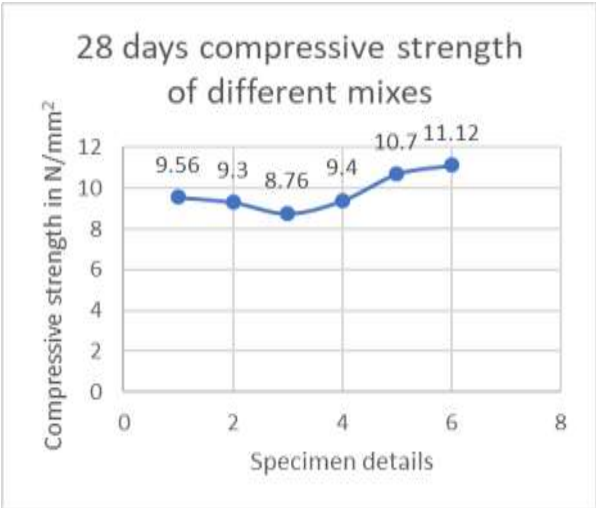


*Fig 5: 400ft depth rock powder specimens (28days)*

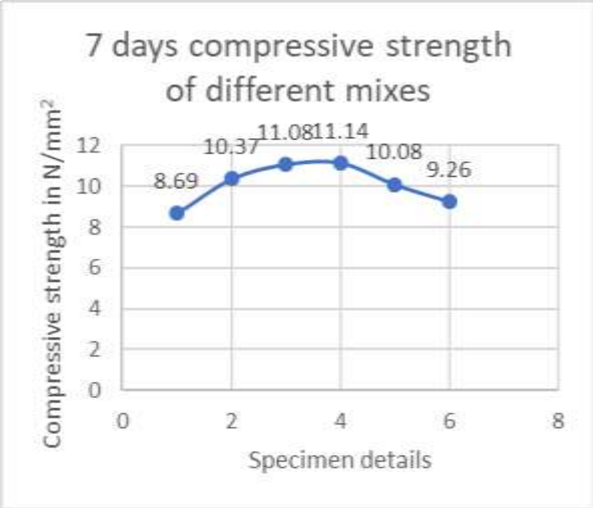


*Fig 6: 600ft depth rock powder specimens (7 days)*

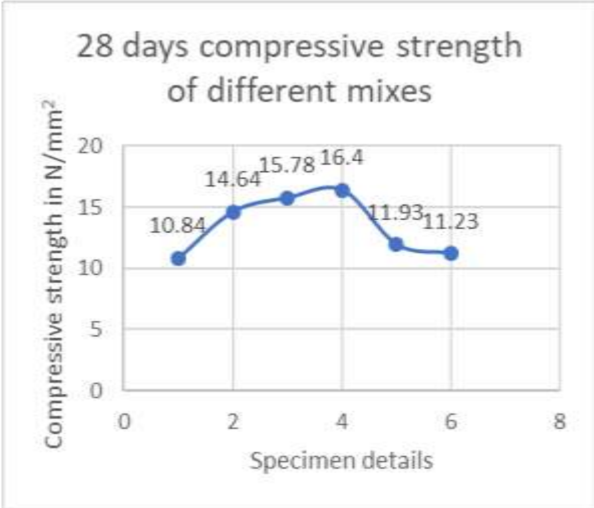


*Fig 7: 600ft depth rock powder specimens (28 days)*

## 4. PHOTOS

*Fig.8:Marsh Cone Analysis*

*Fig.9:Sample In Marsh Cone*

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*Fig 10: Mortar mixer*

*Fig 11: Flow table*

*Fig 12: Compacted mortar*

*Fig 13: Flow table result 1*

*Fig 14: Flow table result 2*

*Fig 15: Cube Vibrating Machine*

*Fig 14: Geopolymer mortar cubes*

*Fig 15: Geopolymer mortar cubes*

*Fig 16: Compression testing machine*


*Fig.17: Test samples of GPM 200, GPM 400 and GPM 600 cubes*

## 5. CONCLUSIONS

- From the above study we can conclude that sub-surface rock powder can be used as a partial replacement for M-sand.
- By using sub-surface rock powder from different depths produced as a waste from bore well digging sites a lot of construction can be reduced. By using the rock powder for geopolymer mortar instead of cement mortar the eco-friendly aspect of the building can be improved.
- As sub-surface rock powder is a limited resource it is only viable for usage in localized projects where the bore well is being dug at that particular site itself.
- The sub-surface rock powder can also be made use in construction of temporary structures like workers sheds and also in non-load bearing structures since it is being made use for geopolymer mortar.
- The fineness of the sub-surface rock powder increases with depth, and it was found that long term strength was higher for 600ft depth rock powder compared to 200ft rock powder.
- The general pattern showed that there was an increase in the compressive strength from 7 days to 28 days of curing.

## 6. ACKNOWLEDGEMENT

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