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PREPARATION OF GEOPOLYMER CEMENT WITH DRY ACTIVATORS BY ONE PART SYSTEM

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Abstract: The geopolymer concrete(GPC) is comparitively more durable and green material with less CO2 emission and less energy consuming as compared to widely used Ordinary Portland cement (OPC). The purpose of this thesis work was an experimental study of the mechanical properties and fire resistant property of geopolymer cement prepared using a class F fly ash and two different alkali-activators (NaOH activator and Na2SiO3 activator). Basically, there are two methods for preparation of geopolymer cement – one part system and two part system. This research work deals with one part system. In one part system, the raw material and alkali activators are mixed and grind at ambient temperature in a ball mill making sure that there is no moisture present in the mix otherwise the end product may stick to the wall of Ball mill. The pellets of NaOH and powder of Na2SiO3 were mixed and grind in a dry form properly in a ball mill, after which moist free Fly-ash Powder is added to it and again grinding the mix for further which as a result forming Geopolymer cement by one part system . The compressive strength and chemical composition, are investigated. Furthermore, the effects of the water to fly-ash ratio, curing methods on the compressive strength and thermal properties of the geopolymer products are studied and analyzed in details. The tested results show that the geopolymer cement cured at appropriate temperature conditions can reach a compressive strength of more than 35MPa in 3 days and it also has an excellent heat resistance to some extent when the geopolymer cement is applied on wood sample. In addition, it is found that the water is used only to facilitate the workability and does not incorporate in the geopolymer crystal which means water is only required for mixing and handling of concrete. This paper presents an optimization of fly ash based geopolymer by one part system using dry activators to analyze on the mechanical properties of concrete produced from the optimal mixes and to conduct fire test after its application on wood samples. The weight losses were lower than that of the OPC concrete only if the cubes are kept at normal room temperature. To avoid this, we have cured the samples by oven drying at considerable temperature and time.

IndexTerms - GPC, Na2SiO3, NaOH activators, Geopolymer, one part system, Fly ash, Water absorption.

I. INTRODUCTION

Geopolymer - A more economical, sustainable and green construction material is the concern of geopolymer applications nowadays. In recent years, the study of Geopolymer concrete also termed as 'green concrete' have drawn attention of many Research Scholars and Engineers widely in the field of construction. Alkali activated binders – also referred to as geopolymers – had been studied over years and have emerged as an alternative to Ordinary Portland Cement(OPC). Geopolymer is generally more eco-friendly than Ordinary Portland Cement as there is negligible CO2 emission in its manufacturing. However, they normally require thermal curing for a certain period of time to gain acceptable compressive strength. Geopolymer was first develop by a French Scientist Joseph Davidovit during the latter half of the 20th century. The concept of Geopolymerisation was firstly described by him in his research papers and patents of inorganic polymers(Si/Al inorganic polymer). Geopolymers cements contain high levels of calcium derived from the blast furnace slag or flyash used as the binder. Currently, the Ordinary Portland Cement is used in construction industry. The lifespan of concrete structures made of Ordinary Portland Cement is less than the expect design time owing to the original design and which depends upon various parameters like construction errors, potential damages caused by mechanical actions and environmental effects and changes in functionality etc. Presently, the World Cement Industry contributes 7 to 10% of global carbon dioxide emissions in chemical reaction of calcining of limestone during the cement manufacturing process. This releases approximately 1 tonne of CO2 for every tonne of Portland cement produced which is a serious concern. The Cement Industries are taking some steps to reduce this figure by improving fuel -burning techniques and by diluting the raw OPC with Supplementary Cementitious Materials such as Power Station fly-ashes red mud metakaolin, natural pozzolan, rice husk ash, and ground granulated blast furnace slag. In most of the publications of research patents on geopolymer studied the behavior of pastes. The present study deals with the manufacture of geopolymer cement by one part system and the influence of several parameters on the compressive strength.

II. OBJECTIVE OF STUDY

The objective of the present studies is to manufacture geopolymer cement by one part system i.e. making geopolymer cement similar to OPC. Secondly, to study thermal property of cement when applied on wood sample and analyze its resistance to fire.

a. To study the basic properties of geopolymer cement – Compressive strength.
b. To study about different grades by optimizing the ratios.
c. To study the scope of application of geoploymer cement.
d. To study the behaviour of geopolymer cement on bonding in concrete mix.

III. EXPERIMENTAL PROCEDURE

A. Materials

i) Fly Ash: FA is a by-product which is derived from coal combustion power plants and other industries where coal is used as fuel. Fly-Ash produced may be Class F or Class-C. Depending upon the class the material is selected.

Image 1. Class F Fly Ash

ii) Sodium Hydroxide: Generally the sodium hydroxide is available in solid state by mean of pellets and flakes .The cost of the sodium hydroxide is mainly varied according to the purity of the Substance. Hence it is recommended to use sodium hydroxide with cost effective and purity .In this Investigation, sodium hydroxide pellets were used.

Image 2. Sodium Hydroxide pellets

iii) Sodium Meta-silicate: In this experiment, it is used as an activator to react with water and Fly-Ash. Sodium Meta-silicate is also used in the detergent company and textile industry to act as bonding agent. Sodium silicates are colourless glassy or crystalline solids available in white powder form. Generally, they are readily soluble in water. Sodium silicates are stable in alkaline solutions and neutral in nature.

Image 3. Sodium Meta-silicate

iv) Water: Tap water supplied in laboratory was used to activate reaction between the chemicals and Fly Ash. Potable Water is used as per IS Code456:2000.

IV. RESEARCH METHODOLOGY

A. **Procedure**:

i) Preparation of Geopolymer Cement: Prior to beginning the mixing and grinding procedure, each component was measured as per the mix ratio of specification and immediately put in a ball mill.

Image 4. Freshly prepared Geopolymer cement

ii) Packaging of geopolymer Cement: The geopolymer cement (in powdered form) has to be packed in air tight bags to avoid lumps formation in cement.

iii) Mixing and Moulding: Due to the tendency of geopolymer based class-F fly ash to set in unfavorable condition, the GPB was mixed By the hand to prevent unnecessary damage to laboratory equipment.

iv) Curing of Cubes: Later than the de-moulds of specimen measured the weight of cubes and after stored in oven for hot curing.

v) Compression Testing on cement cubes: The compressive strength of the specimens in the factorial design was measured on 23 hours, 3,7,28 days. Compressive testing was performed by semi Automatic compressive testing Machine. Its capability of testing is 1 ton according to IS code as per IS 516-1959, and the results were reported in MPa.

vi) Application of geopolymer cement on wood samples: The wood sample of different properties were taken and were coated with double layer of geopolymer cement. And to some extent the fire flames were resistant to entrained inside the sample. These sample were tested when they are completely dried and the geopolymer cement coat adhere to wood sample. Butane torch/ gas torch was used as an fire equipment to test on samples.

Image 5. Application of geopolymer cement on wood sample

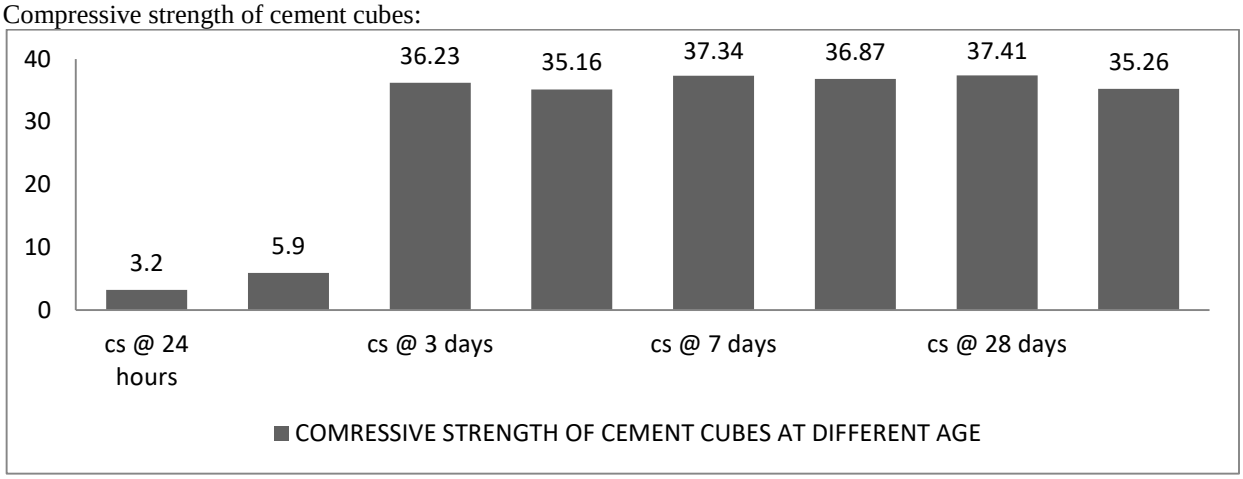
vii) Fire test on wood samples: The sample when dried completely, were flamed by an equipment called gas torch at constant temperature. Somehow the flames entered inside the sample and burnt the wood internally without damaging the outer surface which is coated of geopolymer.

Image 6. Fire test on geopolymer cement coated wood sample

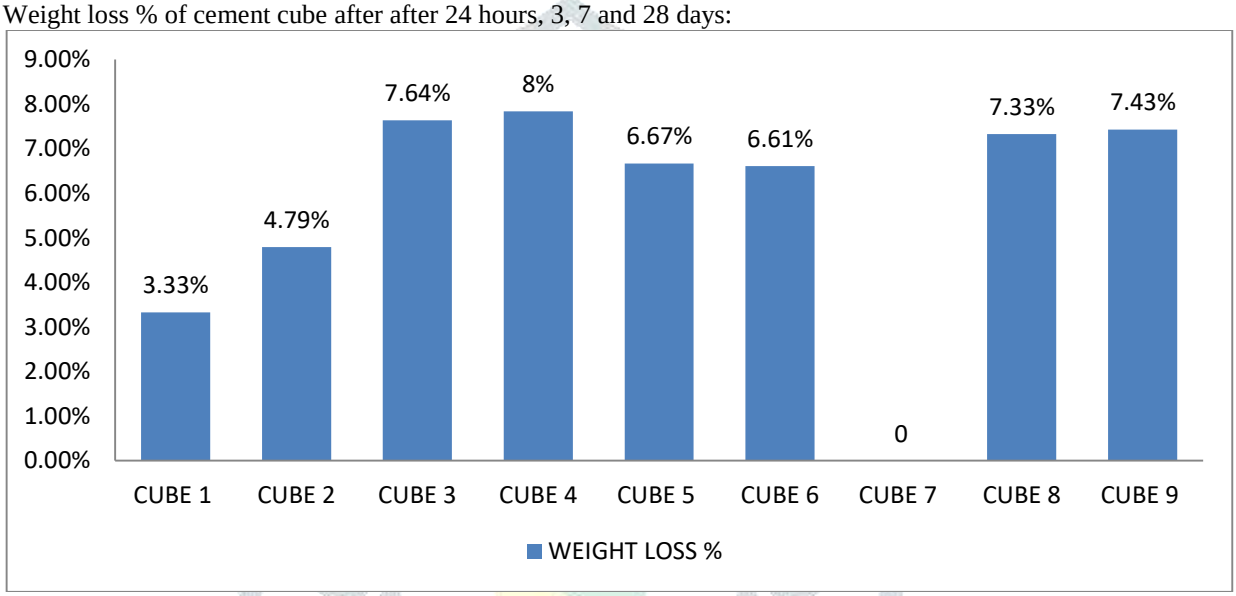
V. RESULTS AND DISCUSSION

A. Results

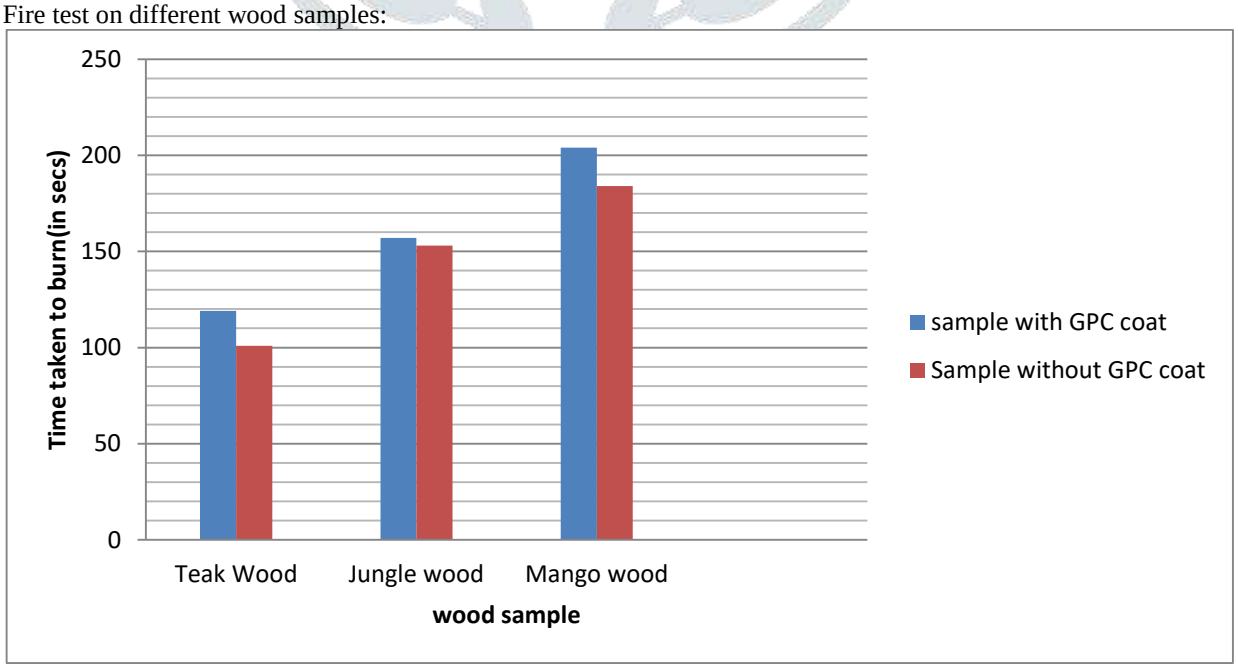
- Compressive strength of cement cubes:



- Weight loss % of cement cube after after 24 hours, 3, 7 and 28 days:



- Fire test on different wood samples:



B. Discussion

1) Preparation of Geopolymer cement by one part system:
- The fly ash used is of Class F type. It is to be noted that the fly ash used should be reactive. If not, it may create trouble in bonding and strength parameters.
- Sodium metasilicate pentahydrate($Na_2SiO_3.H2O$) fine powder is used in this experiment. Selection of settled $Na_2SiO_3.H2O$ should be avoided as it may tougher to grind in ball mill.
- The chips of NaOH used were seal packed and was reactive when grinded. Preferably NaOH which is kept in tight container should be used.

2) Weight loss % of cement cube after after 24 hours, 3, 7 and 28 days:
- Here, weight loss % indicates the quantity of water expelled out of cement cubes.
- Geopolymer cement was made by one part system, it requires time to react when in contact of water initially.
- Heat curing is required to expel water out from cubes so as to gain strength and eliminate plasticity.
- Water is only used to facilitate workability and doesn't involved in chemical reaction. Hence no wet curing is required.
- The temperature was constant throughout.
- The more water expel, the more compressive strength can be achieved.

3) Compressive strength of cement cubes:
- Water in the mix should not be more than twice the weight of NaOH present in Geopolymer cement.
- Size of moulds were 7.06cm x 7.06cm x 7.06cm.
- It is seen that the geopolymer cement settles quickly, therefore care should be taken while handling and placing.
- To avoid initial setting of all cubes all of sudden while handling, moulds should be filled in sets of two rather filling in all moulds at once.
- Vibrator plate is used for compaction.

4) Fire test on different wood samples:
- The aim of fire test on wood is to investigate geopolymer cement fire resistance to its application on different specimen.
- The wood specimens were cured at ambient temperature. No testing was done on partially dried sample.
- Somehow the fire enters the sample and burns internally without damaging the outer layer of geopolymer.

VI. CONCLUSION

- Geopolymer cement can be successfully made by one part system.
- Geopolymers are promising construction material due to its low carbon dioxide emission and it can be used in some application as an alternative.
- Further research may enhance the quality of geopolymer cement.
- Geopolymer cement does not require water for curing.
- The fly ash used to produce the Geopolymer binder phase.
- Fly ash bind to the Geopolymer block with the use of dry activators
- As it requires heat curing, it may not be possible to implement its application in RCC works. Though it can be used in precast concrete work.
- The desirable compressive strength of geopolymers can be achieved at high temperature. The higher the temperature, the more water evaporates thus increase in compressive strength.
- Since in one part system, all the materials used are in dry form. Therefore dry activators may take time to react.
- To make geopolymer more workable, solution of NaOH can be added in minimum quantity.
- The tested results show that the geopolymer cement cured at appropriate temperature conditions can reach a compressive strength of more than 35MPa in 3 days.

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