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EXPERIMENTAL STUDY ON ASSESSMENT OF FLY ASH AND GGBS BASED GEOPOLYMER MORTAR WITH BRICK WASTE AS REPLACEMENT TO FINE AGGREGATES

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A B S T R A C T

Construction and demolition waste (CDW) valorization in a new production process has been widely studied. However, up to now, valorization has been limited to use one type of waste. Hence, the environmental and economic benefits remain quite narrow, particularly in countries with high waste production. It is reviewed that during manufacturing 1ton of cement, 1ton of CO2 is released into the atmosphere. Thus, to make up hand with the recent researches in the field of geopolymer concrete a small study has been carried out, which is further stated. This report generally consists of fly ash and GGBS based geopolymer mortar with replacement of sand with brick waste. Fly ash and GGBS percentage was varied as 0:100, 30:70, 50:50, 70:30, 100:0 %. Study was carried on different molarities of sodium hydroxide (NaOH) i.e. 4M, 6M, and 8M. Percentage of replacement of sand with brick waste was kept as 10%, 20% and 30%. Sodium silicate and sodium hydroxide were used as alkaline activators. Ratio of Sodium silicate to sodium hydroxide was kept 2.5. Initial tests like normal consistency, final setting time, etc. were carried on each mix. Flow test was taken to fix a unique solution to binder ratio. Ambient curing of 70.6 x 70.6 x 70.6 mm cube for 28days was performed and later tested for compressive strength. 100% of GGBS in geopolymer mortar shown optimum results. Further, an equation was developed to determine the predicated value of compressive strength which was obtained by experimental study. For that regression analysis was performed.

***Keywords**: Fly Ash, GGBS, Waste, Aggregate.*

1. INTRODUCTION

In the last few decades there has been a rapid growth in industrialization and urbanization due to which infrastructure development has been boosted. This has led use of conventional construction materials for the development of infrastructure. Using conventional materials has led to many problems in the recent periods. Cement industries has been growing at a faster rates which have made their large impact on the environment and society.

As demand of concrete for construction has been increasing, production of cement has been also increasing at a faster rate. This has led to increase in demand of Ordinary Portland Cement (OPC). In recent years significant increase in the construction activities for urban development has increased. This has led to depletion of natural resources to a large extent. On the other hand, old constructions is been demolished to a greater extent. This resulted in problem of disposing the demolished waste. Research are been carried out on a large scale to make this waste useful in construction activities and put some efforts to make it eco-friendly.

One of the main environmental problems is the disposal or recycling of big volumes of waste materials from construction and demolition. One of the most common materials in these residues are waste clay bricks bonded with cement mortar (masonry waste-MW). Only a city as Bogotá, Colombia, produces approximately 15 million cubic meters each year of debris from construction. Investigations have been carried out on production of cement and its side effects on environment.

It has been concluded that, a huge amount of Carbon Dioxide (CO2) is released into the atmosphere during its production. Carbon Dioxide is the major gas responsible for greenhouse effect. Approximately, cement production accounts for 5% of the total CO2 emission. It has been studied that, 1tonne of cement production releases 1tonne of CO2 into the atmosphere (Neville 2012). It has been seen that the demand for cement is increasing day by day and will become close to a number of 500 million by 2025. But it is observed that the trend in demand and production will fall behind by 230 million (Singh et al. 2015).

Considering to all of the above problems there should be some studied carried on the replacement of cement either partially or fully.

In general, the demolition wastes are estimated to be from 1.0 to 2.0 ton/m2 of the total ground level area. The volume of construction waste generated worldwide every year, according to a report from Transparency Market Research, will nearly double to 2.2. Billion tons by the year 2025, according to Construction & Demolition Recycling. The disposal of construction waste is often a safety issue. In December 2015, a pile of construction debris caused a landslide in Shenzhen, China that killed more than 70 and left 900 individuals displaced.

The slide also demolished a host of buildings, including 33 factories, workers' living quarters and apartments. Rapid industrial growth has witnessed the ever increasing utilization of river sand for building purposes where river beds are worn-out. Several problems are emerged including the increase of river bed depth, lowering of the water table, increasing salinity and destruction of river embankments. . Thus, exploration of alternative materials as a fine aggregate in concrete to replace the river sand became an absolute necessity. In this regard, brick waste is emerged as a promising candidate to fulfil such requirements.

2. LITERATURE REVIEW

Muthulakshmi and Nivedhitha (2012) investigated through their experiments to gauge the effect of partial replacement of natural coarse aggregates (NCA) and natural fine aggregates (NFA) by recycled coarse aggregates (RCA) and recycled fine aggregates (RFA) on compressive strength, tensile strength and flexural strength of recycled concrete. 10%, 20%, 30% of NCA and NFA were replaced with RCA and RFA respectively. The results obtained from compressive strength test, split tensile test and flexural test were compared with the conventional concrete. From the experimental study, it was observed that compressive strength & tensile strength of concrete with recycled aggregates increased up to 20% replacement of natural aggregates with recycled aggregates whereas the flexural strength of recycled concrete was found to decrease with increase in percentage of RCA & RFA.

Nili et al (2012) worked on the concrete potential as a friendly environmental construction material to use different type of waste materials as a partial replacement for aggregates and even cement. Six type of waste materials include: recycled concrete aggregate (RCA), waste glass of all kinds mostly (container glass, thin film transistor liquid crystal display [TFTLCD], crushed clay brick aggregate, various plastic types such as polyethylene (PET), scraped PVC pipes and rubbers , recycled ceramic materials from sanitary installation and recycling ornamental stones (Granite and Marble). For all six categories of recycled materials, mechanical and durability properties are discussed. Also reuse of these materials in concrete were evaluated from the viewpoints of environmental aspect and cost efficiency. It is concluded that by introducing of some outstanding features of these materials, a new perspectives to concrete technology and efficiently may be expected.

Kumar and Siva (2015) carried out laboratory experiments to scrutinize a concrete made of partial replacement of coarse aggregate with construction and demolition waste materials like ceramic tiles waste, plastic debris, crushed bricks. The resultant concrete thus produced was tested on the following parameters like compressive strength, workability, flexural strength. The results thus obtained are compared with a plain cement concrete. By using low weight materials like plastic debris they got a light weight concrete. The workability of concrete produced with construction waste when compared with plain cement concrete is not reliable but it produced a considerable increase in the compressive strength.

Dinesh Kumar et al (2016) focused on the usage of coal bottom ash in replacing the fine aggregate. Bottom ash forms up to 25% of the total ash while the fly ash forms the remaining 75%. Their research experimented the behaviour of concrete using coal bottom ash at different replacement level of sand. The study evaluated the potential of coal bottom ash as a partial replacement of sand in concrete by 0%, 10%, 20%, 30%, 40%, and 50%. In order to study the mechanical properties of concrete, M25 grade was fixed. At the point when the bottom ash is utilized as a part of the concrete, the workability of existing is diminished because of the water request. At last, the utilization of coal bottom ash in concrete is prescribed as a different option for fine aggregates in concrete but limited to 20% by weight of fine aggregate**.**

Jayakumar et al (2016) aimed finding the optimum concrete mixture encompassing of cement mortar and brick bat debris as a substitute for fine aggregate. The basic properties of cement mortar debris and brick bat debris as fine aggregate was studied and it is compared with the traditional fine aggregate. It was tried in different proportions on strength and was recorded at the curing age of 7, 14 and 28 days. The results concluded that particular proportions of cement mortar debris and brickbat debris displayed enhancing effect on the compressive strength.

N A Lloyd and B V Rangan (2010) presented the study of fly ash based geopolymer concrete. The author discussed the properties of geopolymer concrete, design of geopolymer mixtures, use of geopolymer concrete for precast sections. The economic benefits and contributions of geopolymer concrete to sustainable development have also outlined. This paper showed a great interest on Geopolymer concrete properties and is well-suited to manufacture precast concrete products that are needed in rehabilitation and retrofitting of structures after a disaster. Further scope of research is also discussed regarding the durability aspect of geopolymer concrete in aggressive soil conditions and marine environments. Past (2005) research of author also concluded that higher concentration (in terms of molar) of sodium hydroxide solution and also higher ratio of sodium silicate solution-to-sodium hydroxide solution ratio by mass results in higher compressive strength of geopolymer concrete

3. EXPERIMENTAL SETUP

- This experiment generally deals with the Fly ash and GGBS based geopolymer mortar.
- As studied in the reviews, there has been limited research carried on brick waste. Some studies have been carried on replacing the cement with waste clay brick powder partially. This study deals with replacing the fine aggregates with brick waste in limited proportion.
- From studies, 0%, 10%, 20%, 30% replacement of fine aggregates with brick wastes has been finalized for the experimental work.

- With variation in the brick waste, there are variations among the fly ash and GGBS content to find the optimum percentage of GGBS and Fly ash in accordance with the previous studies.
- It was finalized to take 0:100, 30:70, 50:50, 70:30, 100:0 % of GGBS: Fly ash ratio.
- Alkaline activators are the main constituent in the geopolymer paste, as it is responsible for polymerization.
- Sodium Silicate and Sodium Hydroxide (NaOH) were considered as the alkaline activators. The ratio of Sodium silicate: Sodium Hydroxide was kept as 2.5 from the study carried out in the reviews section.
- Considering the molarity aspect, we considered 4M, 6M, 8M solution of sodium hydroxide, as limited research were there at lower molarity.
- Solution to binder ratio was finalized as 0.55 from initial test carried on different mortars.
- Initial test were carried out on normal consistency, Initial setting time, final setting time and physical parameters of fine aggregates and brick waste. Solution to binder ratio was determined for each mixes and later unique ratio was maintained among all mixes for comparing the results.
- Finally, compressive strength was determined for 28days for each mixes and results were later compared and optimum mix was found out for this experiment.

4. MATERIALS

Fly Ash and GGBS:

These are the main content of geopolymer mortar which holds replacement of cement as sustainable development. Fly Ash was obtained from Ramagundam Thermal Power Plant, India as known from the Phd scholars. It has a specific gravity of 2.17 (83). GGBS was made available from Andhra Cements, Vishakhapatnam, India. Its specific gravity was 2.9 (83). The chemical composition of Fly ash and GGBS was taken from research paper (83) which was carried out earlier in the institute and is mentioned in Table no.1

Table no.1 Chemical composition of Fly Ash and GGBS

Chemical composition	Fly Ash	GGBS
SiO_2	60.11	34.06
Al_2O_3	26.53	20
Fe_2O_3	4.25	0.8
SO_3	0.35	0.9
CaO	4.00	32.6
MgO	1.25	7.89
Na_2O	0.22	NIL
LOI	0.88	NIL

Alkaline Solution:

This is the main content which binds the geopolymer paste and is responsible for polymerization. In this study Sodium Hydroxide and Sodium Silicate were used as alkaline activators which were made available from Pure chemical Co., Chennai, Tamil Nadu, India. Sodium hydroxide was made available in the form of pellets and with 98% purity level given by the manufacturer. Sodium silicate solution was made with mass ratio of 2.61 (SiO2 to Na2O) with approximate proportion of SiO2 =30.0%, Na2O=11.5% and water=58.5%. For making the solution, firstly NaOH pellets were weighed appropriately by fixing molarity and then dissolved in 1ltr distilled water and kept it for 1hr. After 1hr if the weight decreased, it was making up to 1ltr afterwards. After making this, Sodium Silicate was added to it by considering ratio of 2.5 and then solution was kept for 24hrs at 25 ± 2 ◦C and relative humidity of 65% and used in the mix.

Fine aggregates and Brick Waste:

Fine aggregates (Sand) were available in the laboratory, which was later sieved from 4.75mm sieve to separate out the coarser particles from them. Specific gravity of which was 2.73 confirming to Zone II as per IS: 383 [20]. Brick waste was made available from a renovation site which was near to Hanamkonda Bus Stand, Warangal, Telangana. Later physical tests were carried on as carried on Sand.

Fig. no.1 Demolition site near Hanamkonda bus stand, Warangal

5. FUTURE SCOPE

- In this study, alkaline solution used is of sodium hydroxide and sodium silicate while other alkaline solution can also be used e.g. Potassium activators. Further, some research is also carried on single alkaline activator (NaOH). This study can also be carried out with single alkaline solution.
- Sodium silicate to sodium hydroxide ratio is kept 2.5 in this ratio which can be changed and results of which can be manipulated with this experimental results.
- Limited molarities of sodium hydroxide are taken for this study which can be further increased till 16M at 2M interval. As some research, shows that compressive strength increases till 16M and further decreases.
- Durability plays an important role which is not studied in this experiment. Further, study can be carried out to determine the durability of geopolymer mortar with brick waste replacement.
- Ambient temperature curing condition is used to cure the mortar cubes and test was done on them after 28 days. Oven curing can be done for these cubes and mechanical properties of the cubes can be studied.
- After seeing the % finer passing graph of brick waste, it can be said that brick waste particles are coarser than sand and gap graded nature of brick waste particles are also seen. By taking well graded particles of brick waste and confirming to zone II, study can be carried further to determine mechanical properties.
- Fracture characteristics of geopolymer concrete such as, characteristic length, fracture energy, critical mouth opening displacement (CMOD), tip mouth opening displacement (TMOD), critical stress intensity factor (K), etc. can be studied by casting the beams of required dimension. These factors can be correlated with the compressive strength of mortar.

6. CONCLUSION

The fresh and mechanical properties of a fly ash and GGBS geopolymer mortar with replacement of sand with brick waste showed encouraging results and led to pointing out interesting aspects to use as a possible solution in building industries. Following are some of the conclusion made by studying different research papers and correlating it with the experimental results

- From the results, normal consistency of the solution is affected by the content of fly ash and GGBS. It is seen that as fly ash content increases normal consistency decrease i.e. requirement of alkaline solution decreases. This is due to the microscopic structure of fly ash being spherical shape (i.e., curved, cubic shape with rounded angularity) with smooth surface texture, making fewer surfaces in contact and reduces viscosity.

- Final setting time of geopolymer paste decreases with increase in GGBS content. This shows that, GGBS reacts readily with the alkaline activators as compared to fly ash. As GGBS contains high amount calcium as compared to fly ash, it reacts readily with alkaline activators to form dense structure and settle quickly. It is found that increase in the concentration of sodium hydroxide solution resulted in increased final setting time.

- Flow test was also conducted to determine the solution to binder ratio for each mix. Test results also shown the same variation as for normal consistency. As the fly ash content increased amount of alkaline solution required decreased and vice versa for GGBS. Results varied from 0.4 – 0.6. By considering these values unique solution to binder ratio was taken (0.55).

- Compressive strength of geopolymer mortar increased with increase in molarity of sodium hydroxide. This trend was observed for all combination of fly ash and GGBS. Increase in GGBS content increases the compressive strength. Optimum results were obtained for 100% GGBS content with 8M solution.

- Result shown that compressive strength decreases with 10% fine aggregate replacement and then increases for 20% replacement and then decreases. It can be concluded that 20% replacement would be better in all combinations to achieve strength close to 0% replacement.

- Hence, 100% GGBS with 8M alkaline solution and 20% replacement of sand with brick waste would be best combination to achieve a sustainable geopolymer mortar mix.

- By analysing the results it can be said that replacement of fine aggregate with brick waste can achieve remarkable strength close to no replacement condition. Adding to this Method of curing plays an important role in achieving good strength. Further, study can be carried on oven curing.

- Regression analysis data shows a satisfactory correlation between the obtained experimental results and the predicted results.

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