Characteristics of Alternative building materials

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Abstract - Cement concrete is the most consumed materials on the earth next only to water. The ingredients used in preparing concrete are not sustainable. The ingredients are responsible for causing global warming. The most commonly used binder - conventional Portland cement releases considerable amount of carbon dioxide during its manufacture. The mining of popular fine aggregate, sand is causing many environmental imbalances. The coarse aggregates are obtained from quarrying which results in depletion of hard rocks. In view of this, there is a need of developing alternative materials. This paper addresses the technology of alternative building materials to cement, aggregate and masonry units. The use of waste materials like fly ash, slag, and recycled aggregate are illustrated. Mortar and concrete were prepared only by using alternative materials including the water. It was found that these materials have high potential in replacing the conventional materials without compromising the strength and durability.

***Index Terms*—**Cement, Alternative material, concrete, geopolymer, Fal_G.

I. Introduction

Concrete is widely used construction material around the world. It is due to its wide ranging performance properties, suitability and the ease with which it can be produced regionally. Concrete usage worldwide is second only after water. According to *[Plunge (01)]***,** one tonne of concrete is produced every year per person on this planet. According to another estimate, approximately 17,000 million tonnes of concrete is produced annually world-wide *[Mehta (02)]*. Concrete is associated with Portland cement, the main ingredient of conventional concrete. Portland cement is undisputedly the most widely used binder in making concrete. With the infrastructure development growing and housing sector booming, the demand for concrete is bound to shoot-up. Annual incremental increase of Portland cement is about 3% as estimated by *[McCaffrey (03)]*.

The world cement production was about 1 billion tonnes in 1990 *[Mehta (02)]*, 1.5 billion tonnes in 1995 and was about to cross 2.2 billion tonnes in 2010 as reported by *[Malhotra (04)]*. It was reported that by the year 2020, conventional cement requirement is estimated as 3.5 billion tonnes *[Mehta (02)]*

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A real sustainability meets the requirements of the present without compromising the future generations to meet their own needs *[Gajanan M. Sabnis et. al. (5)]*. Sustainable development is related to the socio-economic along with environmental aspects. The construction industry is uniquely positioned to meet the challenges of sustainable development *[Gajanan M. Sabnis et. al. (5)]* by reducing the quantity of cement in concrete and by using alternate building materials. It is an established fact that fly ash, Ground Granulated Blast Furnace Slag (GGBFS) can replace cement partially or completely. Similarly conventional aggregates can replace the recycled aggregates with some modifications.

In case of blended cement, pozzolans like fly ash and GGBFS can be used in place of cement partly. In case of high volume fly ash concrete more than half of the cement is replaced by fly ash. Whereas in geopolymers *[Davidovits (6, 7)]* and FaL-G *[Radhakrishna, (8)]*, the conventional cement is completely replaced by industrial by- products.

Around 90% of concrete and masonry waste are dumped at various places without recycling. Use of this waste is the most important strategy but very much neglected in most of the cases. One of the challenges in achieving consistent quality of recycled aggregates is lack of a suitable mix design method and rational approach. According to [*Fathifazl et al. (9)]*, recycled aggregates can be proportioned by using natural aggregate concrete mix proportioning methods, treating recycled aggregates akin to natural aggregates. In an investigation on the hardened concrete properties, it was revealed that concrete with recycled aggregates can be conviently used with natural aggregates**.** *[Fathifazl et al (10)]*. The reinforced recycled aggregate concrete beams showed similar crack patterns and failure feature, irrespective of the percentage of recycled aggregate *[Li et al. (11)]*. It was found that the mode of failure in shear in case of recycled aggregate concrete was similar to that of conventional concrete with natural aggregates. But, the shear strength was comparatively less in concrete with recycled aggregates *[Guo, and Shi,(12)]*.

II. Objectives Of The Research

The objectives of the proposed research work were as follows:

- To determine the mechanical properties of geopolymer mortar and concrete prepared by conventional aggregates.
- To determine the mechanical properties of mortar and concrete prepared fly ash, GGBFS, manufactured sand, recycled aggregates and recycled water.
- To compare the properties of conventional and geopolymer composites.

III. Materials And Methods

The following materials were used to prepare geopolymer concrete:

1. Fly ash and GGBFS,
2. Manufactured sand, natural sand,
3. Recycled aggregates, natural coarse aggregates,
4. Recycled water,
5. Sodium hydroxide and
6. Sodium silicate.

Class-F fly ash and ground granulated blast furnace slag (GGBFS) were used as binders in making the mortar and concrete. The specific gravity of fly ash and GGBFS were 2.42 and 2.87 respectively. The ratio of SiO_2 and Al_2O_3 of the fly ash was around 2, suitable to use for making low CO_2 elements. Natural river sand and manufactured sand were used as fine aggregates. The specific gravity of manufactured sand and natural river sand were found to be 2.64 and 2.68 respectively. The fineness modulii of natural sand and manufactured sand were found to be 2.8 and 3.5 respectively. Both fine aggregates fall in zone-II as per IS : 383. The moisture content of manufactured sand and natural sand were found to be 0.42% and 0.22% respectively. The grain size distribution of Natural River sand and M- sand are shown in *Fig. 1*.

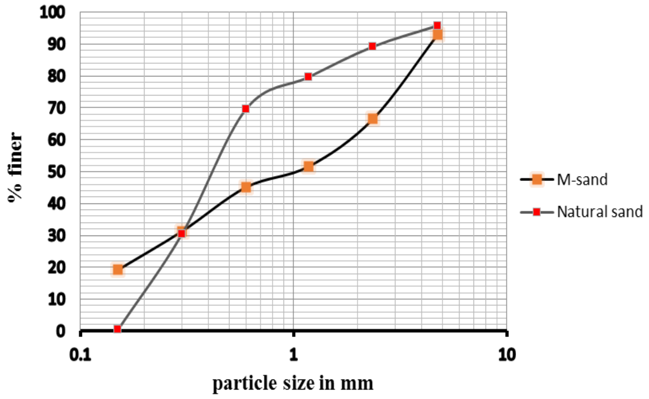

Fig.1. Grain size distribution of natural sand and M-sand

The natural coarse aggregates were derived from granite rock which were locally available having specific gravity of 2.67. The moisture content was 0.4 %. The grain size distribution of natural coarse aggregates is shown in *Fig. 2.*

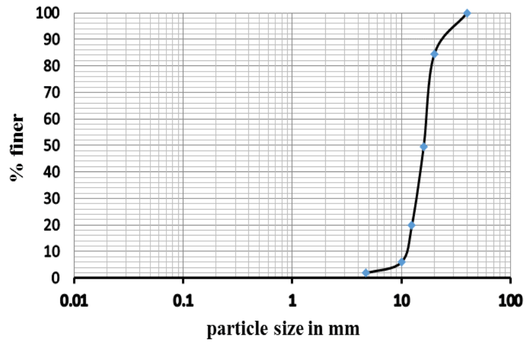

Fig. 2. Grain size distribution of coarse aggregates

The recycled aggregates used in the research were prepared from the demolition waste and were procured from the construction sites. The maximum size of the recycled coarse aggregates was maintained at 20mm. The specific gravity and the water absorption were found to be 2.4 and 3.80 % respectively.

Recycled water was used in this research. The properties of the recycled water are shown in *Table I.*

TABLE I
PROPERTIES OF RECYCLED WATER

Parameters	Values
Colour	Colourless
Odour	Odourless
pH	7.62
Chlorine in mg/l	0.12
Total suspended solids in mg/l	21
BOD in mg/l	26
COD in mg/l	66

The alkaline activator solution used in geopolymerization is a combination of sodium hydroxide and sodium silicate. The concentration of alkali solution affects the dissolution of the binders in the composites. Sodium hydroxides in the form of flakes were used in the research. Currently no standardized methods of mix design for geopolymer concrete are available. Standard concrete mix of M25 grade was designed using IS 10262:2009 for 100 mm slump. The mix ratio was 1:1.8:2.97 and the fly ash to ground granulated blast furnace ratio was 60:40. The final mix proportions are given in *Table II.*

TABLE II
MIX PROPORTION (KG/M^3) AND MIX RATIO

Ingredients	Fly ash	Ground granulated blast furnace slag	Natural sand/ manufactured sand	Natural coarse aggregate/ recycled coarse aggregate
Mix proportion	236.4 kg	157.6 kg	709.2 kg	1170.2 kg

In the proposed research, the properties of geopolymer concrete were examined for the mix of molarity 12. The ratio of sodium silicate to sodium hydroxide was maintained at 2.5. The molecular weight of sodium hydroxide was 40. To prepare the fly ash, GGBFS, M-sand and recycled aggregates were first mixed thoroughly in dry condition and then alkali solution was added to prepare geopolymer concrete. The ratio of alkali solution to fly ash, GGBFS is 0.5 to 0.7 to keep the workability at 100±10 mm. The geopolymer concrete was placed in 150 mm cube, cylinder of diameter 150 mm, and beam of 100X100X500 mm.

Geopolymer mortar was also prepared with natural sand and m-sand. Fly ash and GGBFS to fine aggregate ratio was 1:6. For geopolymer mortar and cement mortar flow test, compressive strength and bond strength test were conducted. Geopolymer mortar was used as masonry mortar of thickness 15 mm to assemble the geopolymer blocks and tested for bond shear strength.

IV. Results And Discussion

Two types of building materials were investigated in this research – Concrete and Mortar.

A. *Concrete*

The compressive strength of different concrete cubes is shown in *Fig. 3 and 4* for different ages. The geopolymer concrete specimens which were cured in open air, developed a strength of 60-70% of the corresponding 28 days strength at 7 days.

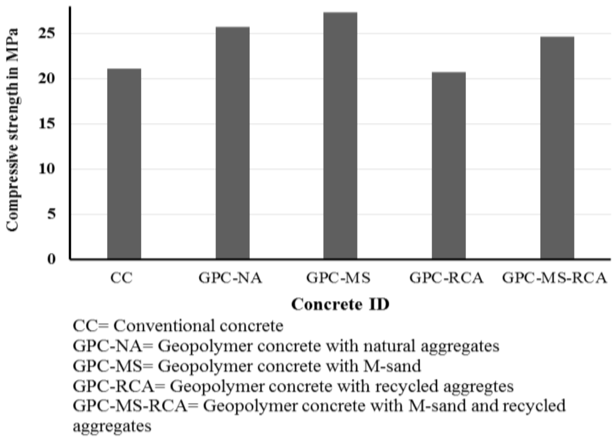

Fig. 3. Compressive strength of different geopolymer and standard concrete at 7 days

The compressive strength of all the types of geopolymer concretes were marginally higher compared to the conventional concrete, except geopolymer concrete with recycled aggregates. It may be due to the poor grain size distribution in recycled aggregate. This is true for 7 and 28 days age.

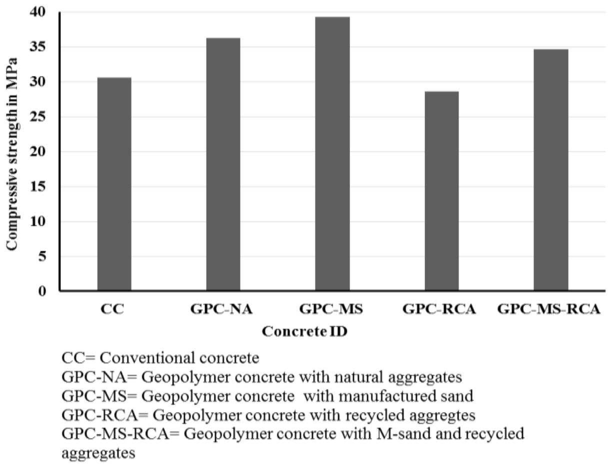

Fig. 4. Compressive strength of various geopolymer and conventional concrete at 28 days

The split tensile strength of the concrete cylinders are shown in *Fig 5*. It can be seen that the split tensile strength is marginally higher for all geopolymer concrete cylinder compared to the conventional concrete except in the case of geopolymer concrete with recycled aggregate and geopolymer concrete with M-sand and recycled aggregate.

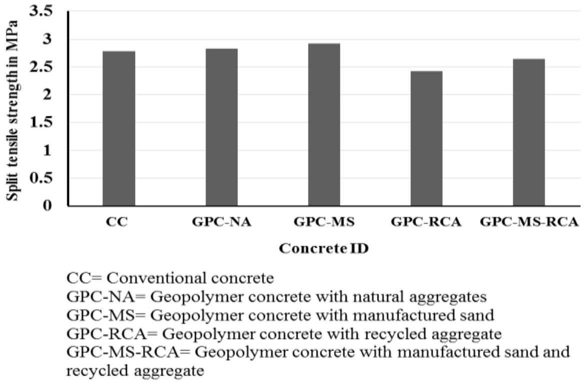

Fig. 5. Split tensile strength of various geopolymer concrete and conventional concrete

The flexural strength of the concretes is shown in *Fig.6***.** It can be seen that the flexural strength of geopolymer concrete was marginally higher compared to conventional concrete.

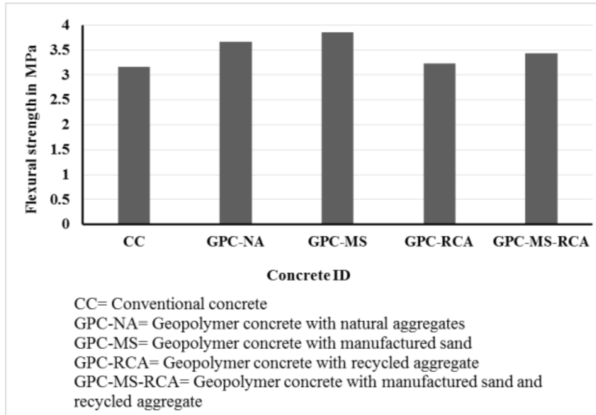

Fig. 6. Flexural strength of various GPC and standard concrete

B. *Mortar*

Geopolymer mortar was tested for flow, compressive strength and shear bond strength in masonry. It was found that for a flow of 100%, the w/c was 1.2, 1.25 & 1.4 for plain cement mortar, geopolymer mortar with natural sand and geopolymer mortar with manufactured sand respectively. The results of the tests are shown in *Table III.*

TABLE III
FLOW VALUES OF MORTAR

	Cement mortar (mm)	Geopolymer mortar with natural sand (mm)	Geopolymer mortar with M-sand (mm)
Flow values	169	166	164

The compressive strength of all the mortars considered at the age of 28 days is shown in *Fig.7*. It was interesting to note that geopolymer mortar with natural sand possess double the strength of cement mortar. The compressive strength of geopolymer mortar with M- sand was marginally higher compared to geopolymer mortar with natural sand.

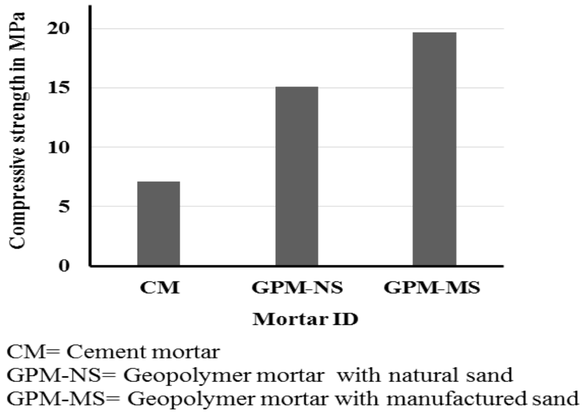

Fig.7. Compressive strength of different mortar

Figure 8 shows the bond shear strength of different mortar. The bond shear strength was found to be higher in geopolymer mortar with natural sand and manufactured sand compared to plain cement mortar.

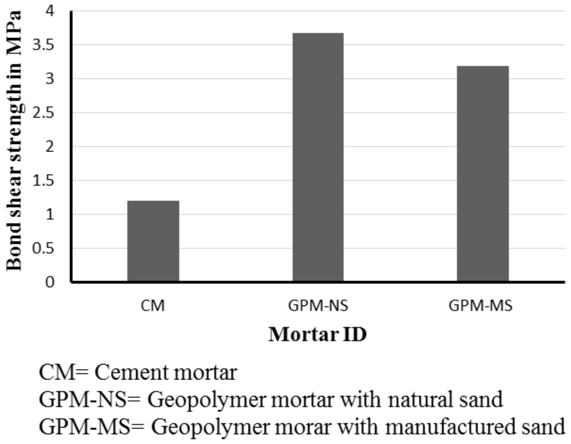

Fig.8. Bond shear strength of different mortar

Hence, this mortar can be recommended for masonry mortar in structural masonry.

V. Concluding Remarks

Based on the limited study, the following conclusions can be made.

- Structural concrete can be prepared by replacing all the ingredients by recycled/ waste material including the water.
- The mechanical properties of geopolymer concrete were higher than concrete conventional concrete.
- It is possible to prepare geopolymer mortar which can be used as masonry mortar and plastering as it exhibits excellent relevant properties.

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