Optimisation of bio medical waste ash in GGBS based of geopolymers concrete

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Abstract: Bio-Medical Waste Ash (BMWA) in Geopolymer Concrete (GPC) has been studied for its potential use as a substitute for Ground Granulated Blast Furnace Slag (GGBS). The raw materials were determined to have physical and chemical characteristics. Bio-medical waste ash was used for GGBS at 0%, 1%, 2%, 3%, 4%, 5% 6%, 7%, 8%, 9% and 10% by weight replacement. The mixing proportion of the GGBS, M-Sand, and Alkaline solution is 1:2.21:3.48, respectively. A compressive strength test was performed for all of the specimens. Results showed that up to 10% of BMWA replacement for GGBS had higher compressive strength than a standard mix (0% BMWA). Use 7% BMWA after 28 days of curing, the maximum compressive strength of 39.8 N/mm² was achieved. After 28 days of curing, specimens prepared using 13 M NaOH yielded a better compressive strength than the normal mix. At 28 days of curing time, the average compressive strength of 40.12 N/mm² was reached.

1. INTRODUCTION

In the construction industry, demand for cement is steadily increasing worldwide. Ordinary Portland Cement (OPC) has historically been used in concrete as a binder, but it does have a more negative environmental impact. Nevertheless, recent research has confirmed that the cement industry is worldwide responsible for CO₂ emissions (around 5%). By 2050, cement production and demand will grow from 2836 million tons worldwide to a capacity of 4380 million tonnes. In addition, the raw materials needed for the production of 1 ton of Portland cement are 1.5 tons and nearly 1 ton of CO₂ is released into the surrounding region [1,18,19,21,22]. Air pollution and mining practices resulting from cement processing affect the environment and the ecosystem. Global concrete intake increases due to the growing population and the need for new structures. All the materials, in concrete terms, are natural except cement. Efforts must therefore be made to reduce the production of cement based on reduced cement consumption [2,15,16,17,20].

Another big issue is the pollution caused by waste. As the world is experiencing rapid urbanization and industrialisation, there is an increasing trend in the need for energy and waste discharges. Waste discharge in any form (liquid or gas) causes serious health problems, emissions of greenhouse gasses, water pollution and acid rain [3,23,24,26].

Environmental pollution is primarily caused by waste generated from thermal power plants, steel factories, municipal waste and hospital waste. Waste generation has increased a lot around the world in the last few decades. Biomedical activities have increased considerably compared to all the waste generated and are toxic, more hazardous and even harmful. The waste produced by biomedical activities is also a real problem of living nature and the human world. Biomedical waste can thus be...
considered hazardous waste. Therefore, all biomedical waste must be disposed of in a way that is least harmful to humans and the environment [4,9,10]. A proper waste management system should be needed to dispose of hazardous biomedical waste, and the best available technology for reducing the volume of this hazardous waste should be incineration. The method of incineration kills contaminants and eliminates the amount of waste by 90% and weight by 75% [5,11,12]. Incineration usually involves the combustion of mingled solid waste with the presence of air or sufficient oxygen. The incinerator temperature usually reaches 850°C, and the waste is converted to carbon dioxide and water. Hospital waste incineration not only releases harmful acid gases (CO, CO\textsubscript{2}, NO\textsubscript{2}, SO\textsubscript{2}, etc.) into the atmosphere but also leaves a solid material called ash, as the mixture contains bottom ash and fly ash, which raises the amounts of heavy metals, inorganic salts and organic compounds in the environment[13,14,24,25].

Therefore, a new type of alternative binders using industrial by-products is needed to mitigate all these problems and thus increase the construction industry's sustainability. A number of studies have been carried out since the early 1970’s to develop a new class of binder material known as Geopolymer [6,15,27].

Geopolymer is a new concrete alternative binder that makes use of industrial by-product materials as source material. A base material rich in Silica (SiO\textsubscript{2}) and Alumina (Al\textsubscript{2}O\textsubscript{3}) is conventionally reacted by an alkaline solution for the processing of the geopolymer binder [7,28]. There is now a massive shortage of river sand and river sand mining also contributes to deterioration of the environment [8]. Nevertheless, the performance of hybrid industrial by-product ash consisting of Ground Granulated Blast Furnace Slag (GGBS) and Bio-Medical Wood Ash (BMWA) has been investigated in very limited research. Therefore, the impact of BMWA on compressive strength, workability on Geopolymer Concrete based on GGBS, is present in this research. In addition, this research aims at developing a new form of concrete using M-Sand.

2. MATERIALS AND ITS PROPERTIES

2.1. Ground Granulated Blast Furnace Slag (GGBS)
In the present study, the GGBS was used as the aluminosilicate source material for making GGBS based polymer binder. The physical and chemical properties are tabulated in table 1 & 2 respectively.

| Sl.No | Physical Properties   | Test result |
|-------|-----------------------|-------------|
| 1     | Specific gravity      | 2.94        |
| 2     | Consistency           | 36%         |
| 3     | Initial setting time  | 26 min      |
| 4     | Final setting time    | 03 hour     |

| Sl.No | Composition | GGBS Weight (%) |
|-------|-------------|-----------------|
| 1     | Calcium oxide | 39.45           |
| 2     | Silica      | 33.25           |
| 3     | Alumina     | 13.18           |
| 4     | Magnesia    | 8.20            |

2.2. Bio-Medical Waste Ash (BMWA)
In the present study, the BMWA is collected from Ramky Energy and Environment Ltd. Kariapatti, Virudhunagar. The physical and chemical properties of BMWA are tabulated in table 3 & 4 respectively.
Table 3. Physical properties of BMWA

| Sl.No | Physical Properties | Test result |
|-------|---------------------|-------------|
| 1     | Specific gravity    | 2.64        |
| 2     | Consistency         | 34%         |
| 3     | Initial setting time| 28 min.     |
| 4     | Final setting time  | 2 hour 45 min. |

Table 4. Chemical properties of BMWA

| Sl.No | Composition                  | BMWA Weight (%) |
|-------|------------------------------|-----------------|
| 1     | Diphosphorus pentoxide       | 18.2            |
| 2     | Silicon dioxide              | 17.4            |
| 3     | Sodium oxide                 | 16.8            |
| 4     | Sulphur trioxide             | 9.8             |

2.3. Alkaline Solution

The alkaline solution selected for this analysis was a mixture of sodium silicate solution and sodium hydroxide solution since solutions based on sodium are cheaper than solutions based on potassium. At room temperature, the sodium hydroxide and sodium silicate are mixed together to make an alkaline solution. Polymerisation takes place when the solution is mixed together. As polymerization occurs, it releases large quantities of heat. So it is recommended that the alkaline solution be prepared before 24 hours.

Manufacturing Sand (M-Sand)

In this study, M-sand belonging to zone II was used as a fine aggregate and the following tests were performed for compliance with IS:2386-1968 Part III and tabulated in Table 5.

Table 5. Properties of M-Sand

| Sl.No | Physical Properties | Test result |
|-------|---------------------|-------------|
| 1     | Fineness modulus    | 2.78        |
| 2     | Specific gravity    | 2.60        |

Coarse Aggregate

In the present study, locally available coarse aggregate with a maximum size of 10mm was used. The aggregates were washed to remove dust and dirt and dried to surface dry condition. Properties of the coarse aggregate are tabulated in Table 6.

Table 6. Properties of Coarse aggregate

| Sl.No | Physical Properties | Test result |
|-------|---------------------|-------------|
| 1     | Fineness modulus    | 7.04        |
| 2     | Specific gravity    | 2.62        |

3. MIX PROPORTIONING

The mix design is done based on the modified guidelines of flyash based Geopolymer concrete as per IS standards. The mix ratio is given in Table 7.

Table 7. Mix Ratio

| GGBS | M-Sand | Coarse Aggregate | Alkaline Solution Binder ratio |
|------|--------|------------------|-------------------------------|
| 1    | 2.21   | 3.48             | 0.61                  |
The initial hybridization ratio was 100 percent of GGBS as the standard mix and subsequently replaced by total binder weight using BMWA at 1 percent increment interval. Such lead to the ratio of GGBS: HCWA hybridization (weight base) of 100:0, 99:1, 98:2, 97:3, 96:4, 95:5, 94:6, 93:7, 92:8, 91:9 and 90:10 respectively. From an extensive literature survey, BMWA above 10% has no sufficient strength and up to 10% it can be replaced. The quantity of materials used for this study is tabulated in Table 8.

| Mix ID | % of GGBS | % of BMWA | GBBS (gms) | BMWA (gms) | Fine aggregate (gms) | Coarse aggregate (gms) |
|--------|-----------|-----------|-------------|------------|----------------------|-----------------------|
| GPC    | 100       | 0         | 350         | 0          | 773.5                | 1218                  |
| GPCB1  | 99        | 1         | 346.5       | 3.5        | 773.5                | 1218                  |
| GPCB2  | 98        | 2         | 343         | 7          | 773.5                | 1218                  |
| GPCB3  | 97        | 3         | 339.5       | 10.5       | 773.5                | 1218                  |
| GPCB4  | 96        | 4         | 336         | 14         | 773.5                | 1218                  |
| GPCB5  | 95        | 5         | 332.5       | 17.5       | 773.5                | 1218                  |
| GPCB6  | 94        | 6         | 329         | 21         | 773.5                | 1218                  |
| GPCB7  | 93        | 7         | 325.5       | 24.5       | 773.5                | 1218                  |
| GPCB8  | 92        | 8         | 322         | 28         | 773.5                | 1218                  |
| GPCB9  | 91        | 9         | 318.5       | 31.5       | 773.5                | 1218                  |
| GPCB10 | 90        | 10        | 315         | 35         | 773.5                | 1218                  |

4. EXPERIMENTAL PROGRAM

4.1. Compressive Strength Test

Compressive strength is one of the most important and valuable properties of concrete. In most structural applications concrete is specifically presumed to withstand compressive stress. Geopolymer concrete cubes were cast in this experimental investigation and used to measure compressive strength. Note the load at which the specimen ultimately fails. Compressive strength is determined by load/area of the specimen.

\[
\text{Compressive strength (F_c)} = \frac{P}{A}
\]

Where

- \( F_c \) = cube compressive strength in N/mm\(^2\)
- \( P \) = cube compressive load causing failure in N
- \( A \) = cross sectional area of cube in mm\(^2\)

It was determined by universal testing machine (UTM). Cube specimens of 100×100×100 mm dimension were cast. The specimens were tested as per IS516:1959. The figure 1 shows the specimen before and after testing. The compressive strength was determined at 3, 7, 28 days.
5. RESULT AND DISCUSSION

Compressive Strength
(a) Optimization of Bio-Medical Waste Ash
The behaviour of GGBS based GPC with Bio-Medical Waste Ash of M30 grade was tested under compression. Compressive strength tests at 3, 7 and 28 days were carried out. The content of BMWA used in this investigation is 0 – 10%. The size of cube used for testing is 100x100x100mm, and the test results are given below. Figure 2 indicates the comparison of 3, 7 and 28 days compressive strength.

From the results obtained the following conclusions can be made,
- The compressive strength of BMWA has increased up to 7% replacement of GGBS
- The compressive strength of BMWA has been decreased above 7% replacement of GGBS
- The compressive strength has been increased due to the micro filler effect.

(b) Optimization of Molarity
The behaviour of GGBS based GPC with 7% of Bio-Medical Waste Ash was tested under compression. For 3, 7 and 28 days compressive strength test were carried out. The molarities of NaOH used in this investigation are 6 – 18%. The size of cube 100x100x100mm is used for testing and the test results are given below. Figure 3 indicates the comparison of 3, 7 and 28 days of
compressive strength.

From the results obtained the following conclusion can be made,
- The compressive strength of GPC has been increased up to 13 molarity of NaOH
- The compressive strength of GPC has been decreased above 13 molarity of NaOH because Na ions remains inert in excess molarity.

![Comparison of 3, 7 and 28 days Compressive Strength](image)

**Figure 3.** Compressive strength for 3,7 and 28 days

6. CONCLUSION

- Increasing the addition of Bio-Medical Waste Ash increases the Initial Setting Time of GGBS based GPC.
- Increasing the addition of Bio-Medical Waste Ash increases the strength up to 10% of GGBS based GPC compare to 100% GGBS.
- Addition of BMWA beyond 10% decreases the strength.
- The compressive strength has been increased by 13.07% in addition to 7% of BMWA.
- The compressive strength has increased by increasing the molarity of NaOH up to 13; beyond 13 molarity the compressive strength has been decreased.

Therefore 7% of Bio-Medical Waste Ash can be replaced for GGBS based Geopolymer concrete with 13 molarity of NaOH.

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