An Experimental Study of concrete by Partial Replacement of Fine Aggregate with Bakelite Waste

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Abstract. Bakelite is an industrial waste produce in manufacturing process like in Auto Industries etc. Nowadays the waste increases rapidly because of these modern living and thus creates a waste management problem. It is necessary to overcome such waste related problem in a meaningful manner. The purpose of this study is to find whether the Bakelite gives us that much Compressive strength as compared to conventional M25 grade concrete by replacing fine aggregate with Bakelite waste. So, this research examines the utilization of waste Bakelite in concrete with varying percentage like 0%,17%,20%,30%,40%,50%,60% and 70%. Different percentages of Bakelite are added and tests like the slump cone test, compaction factor test were conducted to investigate the fresh properties like workability and compression test were performed to find out the 7, 14 and 28 days compressive strength. It is found that the replacement of fine aggregate with Bakelite can be done up to 20% without compromising the compressive strength of the M25 grade concrete.

Keywords: Bakelite, Compressive Strength, Fine Aggregate.

1. Introduction

1.1 General

Bakelite is a kind of thermoset plastic that is the product of an elimination reaction where phenol reacts with formaldehyde\cite{1}. Bakelite is mostly used in kitchenware appliances for heat resistance, automobile parts, and telephone casings. The reason behind providing the heat resistance is that Bakelite cannot be remelted into another product\cite{11}. Just like every coin has two sides, Bakelite has it too. Advantages and disadvantages go hand in hand. There are a few disadvantages, that include the presence of methyl and ethyl alcohol\cite{1,2}. These chemicals are harmful to the environment and also can lead to severe health issues. Disposal of Bakelite into the water bodies is also creating a hazardous environment for the aquatic ecosystem\cite{6}. To avoid such health hazards there is an efficient alternative used which acts as a partial replacement for the sand in concrete i.e the Bakelite granules (Figure 1).
Bakelite or polycrylbenzylmethylenglycolanhydride happens to be the very first plastic, produced from synthetic components[2]. It is also known as the thermosetting formaldehyde resin which is the product of the condensation reaction of phenol with formaldehyde[4]. A Belgian- American chemist named Leo Beakeland is the one who developed the product in the year 1907 [3]. Later in December 1909, Bakelite was patented. This invention acted as a boon for electrical insulators, the radio, telephone casings, kitchenware, jewellery, pipe stems, children's toys, and firearms[14]. Vital properties of the product were the electrical conductivity and heat resistance that eventually widened the usage value.

The objectives of the research are to determine % of fine aggregate which can be replaced by Bakelite waste without compromising the compressive strength of the conventional concrete of the grade M25, to study the effect of Bakelite waste on the slump value, compaction factor and compressive strength of the M25 grade concrete, utilization of waste Bakelite to reduce the dumping problem (Figure 2).
1.2 Literature Review

Sakthi Sasmita, Dr. R. N. Uma (2019), carried out a study on concrete and paver blocks. Here, the coarse aggregate was replaced by Bakelite. The study stated the properties, strength, and use of Bakelite as a construction material in paver blocks of grade M25. The optimum modifier content of waste Bakelite came out to be 8% for paver blocks and 35% for solid blocks. This study concluded that it will help to reduce the cost of construction to some extent and will solve the problem of waste plastic disposal.

Clement M, Rohini K, Krishna Kumar P, Boopathi M (2018) carried out a study on the structural behavior of cement concrete made by using partial replacement of coarse aggregate with Bakelite by casting 21 cubes of size 150 mm x 150 mm x 150 mm with different percentages of waste Bakelite. The cubes made with different percentages of waste Bakelite and conventional concrete were both compared to check their strength for 7, 14, and 28 days respectively. So was the fine aggregate, coarse aggregate, Bakelite, and cement tested based on the ISI standards. 3 cubes of M20 grade were cast by replacing 5, 10, 15, 20, 25, and 30 percent of Bakelite. This was compared with M20 grade concrete which was made with natural coarse aggregates. The experiment came to a conclusion where the waste Bakelite up to 10% can be used as a substitute for aggregates in concrete. It will not hamper the compressive strength. It has also stated that it will always act as a better choice to avoid waste disposal and environmental hazard.

Arun Raja (2016) did a study on the mechanical and flexural strength of specimens by using E-plastic waste (Bakelite) in concrete as a partial replacement of fine aggregate. E-plastic waste was used instead of fine aggregate. The percentage of Bakelite used was 2%, 4%, 6%, 8%, and 10% by weight of total fine aggregate. The results stated that E-plastic waste up to 8% can act as a good substitute for fine aggregate in concrete. It will not compromise the compressive and flexural strength.

Pugal (2015) did a study on plastic waste as a coarse aggregate for structural concrete. The replacement Percentage used were 0%, 5%, 10%, and 15% by the total weight of coarse aggregate. The conclusion stated that the compressive strength and split tensile strength which contained plastic aggregate were retained in comparison. A decrease in strength was seen when the plastic content was greater than 20%.

2. Materials and Methodology

2.1 Materials

The materials (Figure 3) used for M25 grade concrete are as follows:

- **Cement:** The cement used for this study is JSW ordinary Portland cement (OPC) of 53-grade.[9]
- **Fine aggregates:** The grit powder sieve through BSS10 and retained on BSS20 was used as fine aggregate.
- **Bakelite:** The replacement for fine aggregate i.e. Bakelite. The Bakelite powder sieve through BSS10 and retained on BSS20 was used.
- **Coarse aggregate:** The 20mm size crushed stones were used.
- **Water:** Normal daily used water was used for mixing and curing.
2.2 Methodology
Following the literature research, a significant methodology was prepared to establish the objective of the project. This study is also focused on the effectiveness of Bakelite used in a construction project [7]. In Figure (4) step by step methodology of work is explained.

![Flowchart](image)

**Figure 4.** Methodology Flowchart
2.2.1 Data Collection

The data about the use of Bakelite in concrete is fetched from the site engineer, site supervisor, and contractor. For a detailed study of concrete technology and the use of Bakelite in concrete, books were referred from the college library. For some latest context, we referred to sample research papers like International Research Journals of Engineering and Technology (IRJET), Elsevier, MDPI, etc.

2.2.2 Data Analysis

The data collected was analysed thoroughly. Vital aspects like the quantity of material used, aim, results, conclusions were studied properly. Based on this context, the quantity of Bakelite to be used in concrete was decided. This overall collected data turned out to be our project topic.

Calculation of quantity of materials (Table 1) of M25 grade concrete: The quantities of cement, fine aggregate, Bakelite, coarse aggregate and water were calculated.

Dimensions of concrete block: Length=0.15m
Breadth=0.15m
Height=0.15m

Wet volume of blocks = 0.15*0.15*0.15*3
= 0.010125 cu m

Dry volume of blocks = 1.54*0.010125
= 0.0155925 cu m

Grade of concrete=M25
Ratio of cement: sand: aggregate =1:1:2
Sum of ratio =4

Quantity of cement= (1/sum of ratio) *density of cement*dry volume of blocks
Quantity of sand= (1/sum of ratio) *density of sand*dry volume of blocks
Quantity of aggregates = (2/sum of ratio) *density of aggregate*dry volume of blocks
Water cement ratio=0.45

Water required=0.45*quantity of cement

2.2.3 Mixing and Testing

After calculating all the materials quantity of all samples are mixed in tray (except water) and then water is added to it and again mixed thoroughly. The concrete mixture is then added in slump cone to perform slump cone test. After performing slump cone test, the same mixture is then used for compaction factor test. The same mixture was used to form blocks of size 150mm x150mm x 150mm [10,12]. After performing all the tests the result were tabulated.

Table 1. Quantities of materials

| Sr. no. | Percentage of Bakelite to be used (%) | Quantity of Bakelite (kg) | Quantity of sand actually used (kg) | Quantity of cement (Kg) | Quantity of Aggregates (Kg) | Quantity of water required |
|---------|--------------------------------------|--------------------------|------------------------------------|------------------------|---------------------------|--------------------------|
| 1       | 0                                    | 0                        | 5.6523                             | 5.6133                 | 12.0842                   | 2.5259                   |
| 2       | 17                                   | 0.9608                   | 4.9615                             | 5.6133                 | 12.0842                   | 2.5259                   |
| 3       | 20                                   | 1.1304                   | 4.5218                             | 5.6133                 | 12.0842                   | 2.5259                   |
| 4       | 30                                   | 1.6956                   | 3.9567                             | 5.6133                 | 12.0842                   | 2.5259                   |
| 5       | 40                                   | 2.2609                   | 3.3913                             | 5.6133                 | 12.0842                   | 2.5259                   |
| 6       | 50                                   | 2.8261                   | 2.8261                             | 5.6133                 | 12.0842                   | 2.5259                   |
| 7       | 60                                   | 3.3913                   | 2.2609                             | 5.6133                 | 12.0842                   | 2.5259                   |
| 8       | 70                                   | 3.9565                   | 1.6956                             | 5.6133                 | 12.0842                   | 2.5259                   |
2.2.4 Slump cone test
Slump cone test (Figure 5) is done to determine the consistency or workability of concrete. It is done at construction site or at laboratory to check the uniform quality of concrete during construction [13]. It is helpful to confirm whether the correct water quantity has been added to the mix or not. (Figure 7) shows the slump value (Table 2) of concrete. The mixing is done as per mix. Indian standards IS:1199-1959. It is observed that workability of concrete decreases when the Bakelite added in the mix. For the conventional mix, 60 mm slump value is observed and from sample 1 to sample 7 the slump value decreases with increase in percentage of Bakelite.

2.2.5 Compaction factor test
The compaction factor test (Figure 6) is executed to estimate the degree of workability of fresh concrete. It is followed as per the Indian standard IS:1199-1959. It is more precise than slump cone test and particularly helpful for concrete mixes of very low workability [13]. (Figure 8) shows the compaction factor value (Table 3) of concrete as per mix. It is observed that, conventional concrete achieved 0.90 compaction factor, which is having medium workability. Whereas, sample-1 achieved maximum compaction factor of 0.958 which treated as good workability. Least compaction factor, 0.769 is for sample-7. On the basis of compaction factor results, it is observed that, as the fine aggregates contents in concrete are reduced by Bakelite, workability of concrete decreases.

2.2.6 Compressive strength test
Compressive strength (Figure 5) is the mechanical test which determines the maximum amount of compressive load a block or cube can carry before breaking. The samples were tested in compression testing machine after specified curing period for different percentage of Bakelite replacement. Compressive strength (Table 4) (Figure 9) of concrete is investigated for all the 8 specimens as per Indian standards IS:516-1959 at 7, 14 & 28 days curing period [17].

Figure 5. Slump cone test and compression test
3. Result and Discussion

The results obtained after performing the various tests on concrete are as follows:

3.1 For Slump cone test

The values of the slump are mentioned for all samples in the tables given below.

| Sample no. | Conventional Mix | 1   | 2   | 3   | 4   | 5   | 6   | 7   |
|------------|-------------------|-----|-----|-----|-----|-----|-----|-----|
| % of replacement |                  | 0   | 17  | 20  | 30  | 40  | 50  | 60  | 70  |
| Slump value(mm)  |                  | 60  | 65  | 62  | 48  | 32  | 25  | 20  | 15  |

Figure 6. Compaction factor test

Figure 7. Comparison of slump value
3.2 For Compaction factor test

Compaction factor = (Weight of the partially compacted concrete with cylinder)/ (Weight of the fully compacted concrete with cylinder)

**Table 3.** Observations for compaction factor test

| Sample no. | Conventional Mix |
|------------|------------------|
|            | 1    | 2    | 3    | 4    | 5    | 6    | 7    |
| % of replacement | 0    | 17   | 20   | 30   | 40   | 50   | 60   | 70   |
| Compaction factor | 0.90 | 0.958 | 0.922 | 0.877 | 0.869 | 0.841 | 0.822 | 0.769 |

The below figure shows the comparison of compaction factor values of all samples of concrete used in the experiment.

**Figure 8.** Comparison of compaction factor

3.3 For Compression Test

Compressive strength = load / cross-sectional Area

Compressive strength in N/mm²

**Table 4.** Calculation for compression test

| Sample no. | Conventional Mix |
|------------|------------------|
|            | 1    | 2    | 3    | 4    | 5    | 6    | 7    |
| % of replacement | 0    | 17   | 20   | 30   | 40   | 50   | 60   | 70   |
| 7th day     | 17.77 | 20   | 13.33 | 18   | 12.22 | 13.33 | 11.11 | 7.11 |
| 14th day    | 19.55 | 20   | 20   | 20   | 16   | 18.22 | 19.11 | 12.88 |
| 28th day    | 26.44 | 26.44 | 26.44 | 24.44 | 22.88 | 24.66 | 25.05 | 17.33 |

The below figures shows the comparison of compressive strength of all samples of concrete used in the experiment.
Figure 9. Compressive strength in N/mm²
4. Conclusion
The conclusions can be drawn from the experimental investigation are when the percentage of Bakelite is increased the value of slump decreases. There is a decrease in the compaction factor when we increase the Bakelite percentage. We can replace the fine aggregate upto 20% with Bakelite waste by weight in the concrete of M25 grade without compromising compressive strength. As the percentage of Bakelite is increased the concrete becomes lighter in weight.

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