An experimental study on structural behavior of Cement Concrete manufactured by partial replacement of Coarse Aggregate with Bakelite waste

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Abstract: Bakelite is used in the manufacturing of various components of cars and consumer goods industry. The growth of bakelite consumption has resulted in the increase of Bakelite waste. Disposal of Bakelite watses by direct land filling and open burning is also prohibited due to its ill effects on the soil and atmosphere by hazardous emissions respectively. A large amount of this waste needs large space of warehouse area for keeping which becomes a waste management problem. The purpose of this research is the use of post-milling waste bakelite as a coarse aggregate (WBCA) was mixed in cement mortar with the proportions. The mortar sample was tested for compressive strength follow ASTM standard. The compressive test result of mortar sample will be compared between conventional mortar (0% WBCA) and waste bakelite mortar (WBM) as well as comparing with the mortar standard. From the analysis cement mortar mixture can predict the strength of WBM. Hence, efforts have been taken to identify the potential application of waste bakelite in civil engineering projects. In this content, our presentation aims to study and compare the properties of conventional materials used in concrete. A total of 3 cubes are casted of M_{20} grade by replacing 5,10,15,20,25 and 30 percent of bakelite and compared with M_{20} grade concrete made with natural coarse aggregates. Hardened concrete strengths were identified.

***Index Terms* – Waste, bakelite, coarse aggregate, structural behavior**

1. INTRODUCTION

During the past few decades the global demand for plastics had grown significantly over with the worldwide consumption approaching 100 million tons per year. **Bakelite** or **polyoxy-benzyl-methylen-glycolanhydride** was developed in 1907 by a Belgian chemist, Leo Baekeland. By controlling the pressure and temperature applied to phenol and formaldehyde, Baekeland produced a hard moldable material which he named "Bakelite". The chemical formula of Bakelite was found that combining phenol (C_6H_5OH) and formaldehyde (HCOH) formed a sticky mass. In 1993, it was designated a National Historic Chemical Landmark by the American Chemical Society in recognition of its significance as the world's first synthetic plastic. It is a thermostat phenol formaldehyde resin commonly used for parts of automobiles, electric insulators components, telephone casings and heat resistant properties in kitchenware. It cannot be re-melted to form a new product, and are land filling or incinerated, both of which lead to environmental problems. Moldings are smooth, retain their shape and are resistant to heat, scratches, and destructive solvents. It is also resistant to electricity, and prized for its low conductivity. Phenolic resin products may swell slightly under conditions of extreme humidity or perpetual dampness. Toxic effects of Bakelite are caused by the presence of phenol as well as methyl and ethyl alcohols.

Figure1. Raw Bakelite waste

The influence of Bakelite on water quality can be observed in an increasing of the oxidiseability and the appearance of phenol in the water. Hence disposal of bakelite should be avoided to prevent water pollution.Bakelite describes loosely discarded, surplus, obsolete, broken, electrical or electronic devices. The Bakelite need to be disposed per year. Traditional landfill or stockpile method is not an environmental friendly solution and the disposal process is also very difficult. How to reuse the non disposal Bakelite becomes an important research topic. In this work the most relevant knowledge about the structural behavior and the

durability of concrete manufactured using bakelite will be studied. Also this project focuses on the potential of bakelite waste to be partially used as a replacement to coarse aggregate in cement concrete. Further investigations are needed to clarify for instance which are the characteristic that maximize concrete performance.

2. LITERATURE REVIEW

SereeTuprakay (2017) This research focused on the use of waste Bakelite aggregate milling machine for Bakelite waste size reduction and use of the post-milling waste Bakelite as a fine aggregate to replace natural sand material in cement mortar. The waste Bakelite fine aggregate (WBFA) was mixed in cement mortar mixture with the proportion 0% 20% 40% 60% 80% and 100% by volume for cement mortar sample preparation. The mortar sample was tested for compressive strength as per ASTM standard and found that the replacement can be done upto 20%.

Arun Raja (2016) has made an investigation regarding mechanical and flexural strength of specimen by using E-plastic waste (Bakelite) in concrete as partial replacement of fine aggregate. The E-plastic waste was used to replace fine aggregate and the percentage of replacement carried out as 2%, 4%, 6%, 8% and 10% by weight of total fine aggregate which results that the E-plastic waste up to 8% may be used for replacement of fine aggregate in concrete without any reduction in compressive strength and flexural strength.

Pugal (2015) has conducted a study on plastic waste as a coarse aggregate for structural concrete. The replacement of plastic waste was carried out as 0%, 5%, 10% and 15% by the total weight of coarse aggregate. It results that the compressive strength and split tensile strength of containing plastic aggregate is retained more or less in comparision and also the strength is decreased when the plastic content was more than 20%.

3. METHODOLOGY

The structural behavior of cement concrete made by using partial replacement of coarse aggregate with Bakelite is studied by casting, 21 cubes of size 150 mm x 150 mm x 150 mm with different percentages of waste Bakelite. The strength of cubes made up with different percentage of waste Bakelite is compared with the strength of conventional concrete for 7, 14 and 28 days respectively. Similarly fine aggregate, coarse aggregate, Bakelite and cement were tested as per the IS standards.

Fine, Coarse aggregate and waste Bakelite:- The test like sieve analysis, water absorption specific gravity are common to the above aggregates. Sieve analysis is the particle size distribution is determined by the following formulae based on IS 2386 part I – 1963.

Percentage retained = $\frac{Wsieve}{Wtotal} X\ 100$ where W_{sieve} = weight of aggregate in the sieve.

W_{total} = the total weight of the aggregate.

Water absorption test helps to determine the water absorption of coarse aggregate, fine aggregate and Bakelite as per IS 2386 part I 1963

Water absorption = $\frac{W1 - W2}{W2} X\ 100$ where,

W_1 = Weight of saturated surface-dried sample

W_2 = weight of oven-dried sample

Specific gravity of aggregate sample by determining the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water as per the IS 2386 part III 1963.

Specific gravity = $\frac{A}{(B-C)}$ where,

A = mass of oven-dry sample in air.

B = mass of SSD sample aggregate.

C = mass of SSD sample in water.

Aggregate impact value test is done to determine the aggregate impact value as per IS 2386 part IV- 1963 Aggregate impact value = $\frac{B}{A} X\ 100$ where,

A = Initial eight of the aggregate

B = Friction passing through a 2.36 mm sieve size.

3. OBJECTIVE

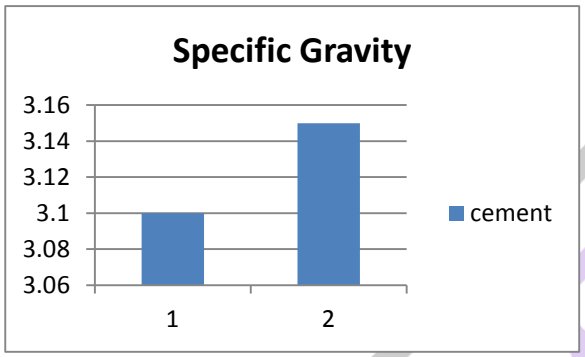
- To study and compare the structural properties of Natural Coarse Aggregate (NCA) and Sized Raw Bakelite Coarse Aggregate (SRBCA) by experimental investigation.

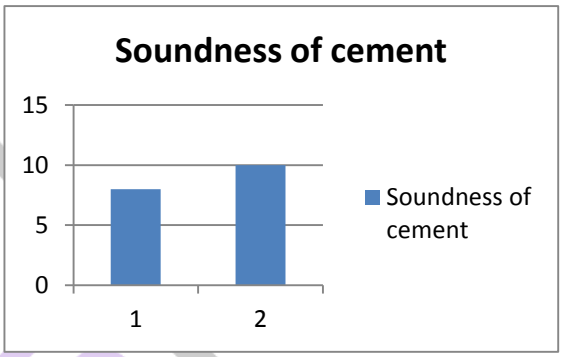
- To study the structural behavior of concrete manufactured by using sized bakelite waste.
- To experimentally determine the optimum percentage replacement of NCA with SRBCA in conventional concrete mixes for effective management of bakelite wastes.

4. MATERIALS USED AND THEIR PROPERTIES

4.1 Cement

Cement is a binding material, which is the combination of raw material called calcareous and argillaceous materials, usually in powder type that may be created into paste by the addition of water. Cement used in construction are usually inorganic often lime or calcium silicate based. The cement used for the present investigation is ordinary Portland cement of Grade 53.





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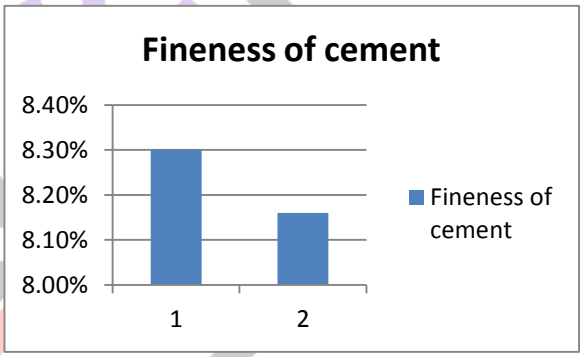

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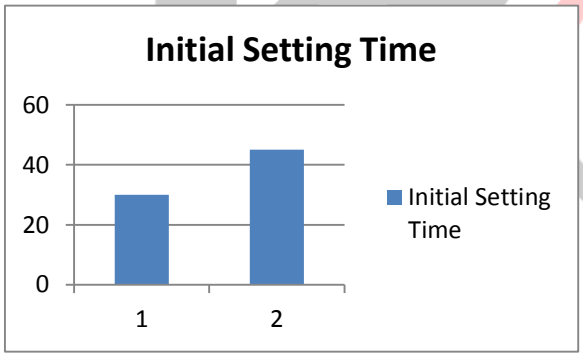
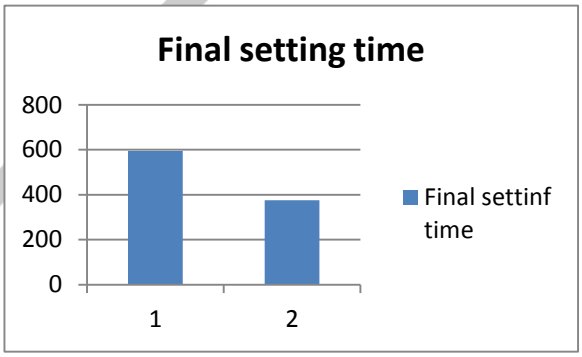




(e) (f)

Figure 2. Cement properties (a)Specific gravity, (b) Soundness, (c) Standard consistency, (d) Fineness of cement, (e) Initial Setting Time, (f) Final Setting Time

Property test results for cement

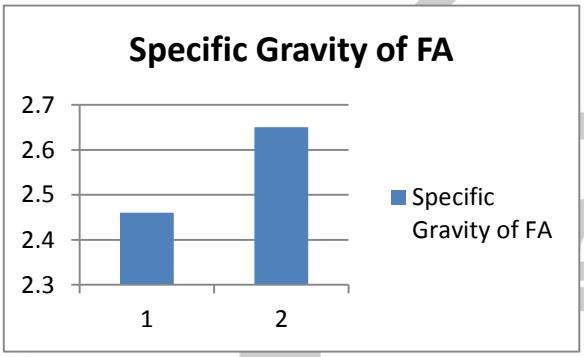
Property tests	Cement	Standard Value
Specific Gravity	3.1	3.15
Standard consistency	29%	30 to 35 %
Soundness	8mm	10 mm
Fineness of cement	8.3%	8.16 %
Initial Setting Time	30mins	≥ 45 mins
Final Setting Time	595mins	≤ 375 mins

4.2 Fine Aggregate

Sand is of zone-II as per IS: 383-1970, crushed aggregate and rubber aggregate both are 20 mm grade aggregates as per IS 383-1970 The physical properties of aggregate were considered according IS: 2386(1963).

Property test results for sand

Property tests	Natural Fine, Aggregate	Standard Value
Specific Gravity	2.46	2.65
Sieve Analysis	2.38	2
Bulking Characteristic	14.3%	20 to 30 %
Bulk Density	1765kg/m^3	2.65 g/cc



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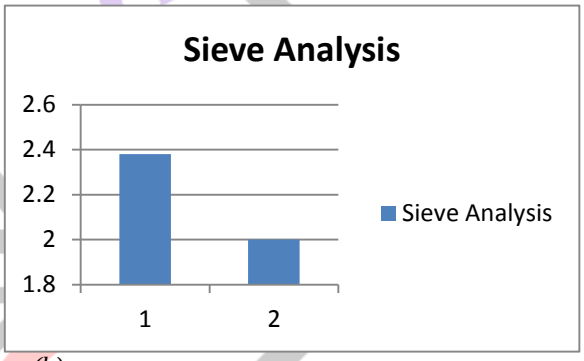

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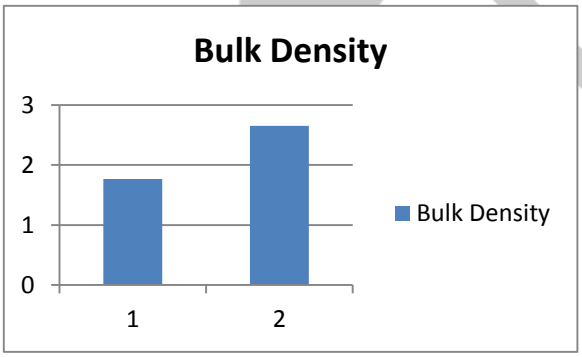

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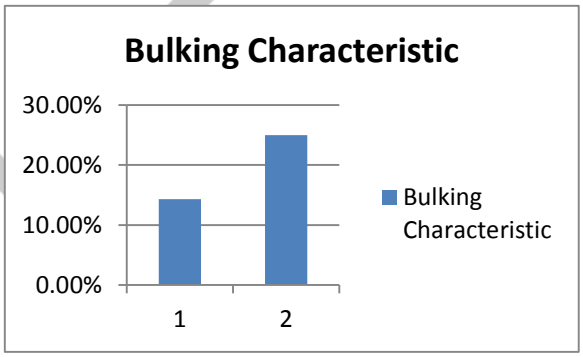


(d)

Figure 3. Sand properties (a)Specific gravity of FA, (b) Sieve analysis, (c) Bulk Density, (d) Bulking characteristic

4.3 Coarse aggregate

The material which is retained on IS sieve 4.75mm is termed as coarse aggregate. The nature of work decides the maximum size of the coarse aggregate, the maximum size of 20mm was used in our work. The aggregates were tested as per Indian Standards Specification IS: 2386-1963.

4.4 Bakelite

Bakelite or **polyoxy-benzyl-methylen-glyco-lanhydride** was developed in 1907 by a Belgian chemist, Leo Baekeland. The crushed Bakelite waste of which is passed from 20mm sieve and retained on 4.75 mm sieve is employed in this research project.

Property Test results for normal aggregate and Bakelite

Tests	Normal Coarse Aggregate	Bakelite	Standard Value
Specific gravity	2.5	1.27	2.65
Impact test	22.2%	9.89%	8.65 %
Water Absorption	1.5%	6.19%	2%
Elongation Index Value	12.2%	28%	
Flakiness Index Value	11%	9%	
Bulk density	1.6 gm/cc	1.25gm/cc	1.52 g/cc

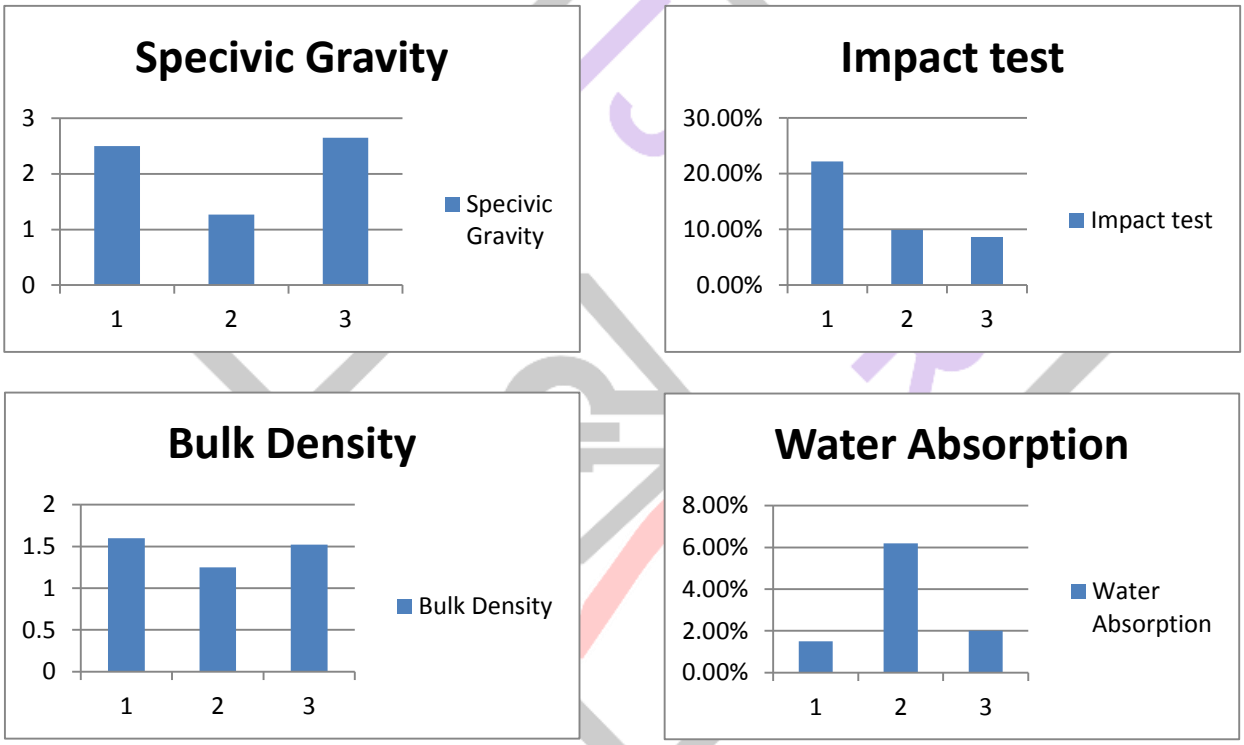


Figure 4. Bakelite properties (a)Specific gravity of FA, (b) impact test, (c) Bulk Density, (d) water absorption

5. MIX PROPORTION

- In this study, the mixes or combination is arrived as per Indian Standard Specification IS: 10262(2009)
- Water cement ratio- the water cement ratio is optimized according to the grade of concrete chosen and the mix design carried out.
- Quality of coarse aggregate- the size of coarse aggregates used is 20mm

5.1 Factor to be considered for mix design

- The grade designation giving the characteristics requirement of concrete.
- The type of cement influences the rate of development of compressive strength of concrete.
- Maximum nominal size of aggregate to be used in concrete may be as large as possible within the limit prescribed by IS 456-2000.
- The cement content is to be limited from shrinkage, creeping and cracking

Water cement ratio	Cement	Fine aggregate	Coarse aggregate
145Kg/m^3	290 Kg/m^3	696 Kg/m^3	1429 Kg/m^3

6. CASTING OF SPECIMEN

The specimens were casted in the laboratory. Steel moulds were used for casting. Required quantities of cement, fine aggregate, coarse aggregate and bakelite is weighed and mix is prepared according to the M_{20} mix proportions. The mix is poured into the cube mould and compacted by using tamping rod. The specimen is kept for 24 hours and curing id done for 28 days.

7. TESTING OF SPECIMENS

7.1 Compressive strength test:

The compressive test is used to determine the hardness of cubical specimens of concrete. The strength of concrete specimen depends upon cement, aggregate, bond, w/c ratio, curing temperature, age and size of specimen. Mix design is the major factor controlling the strength of concrete.

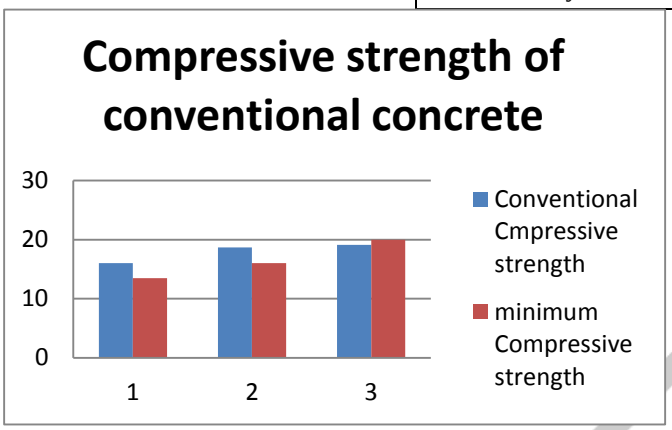
Figure 5. Compressive test of cube

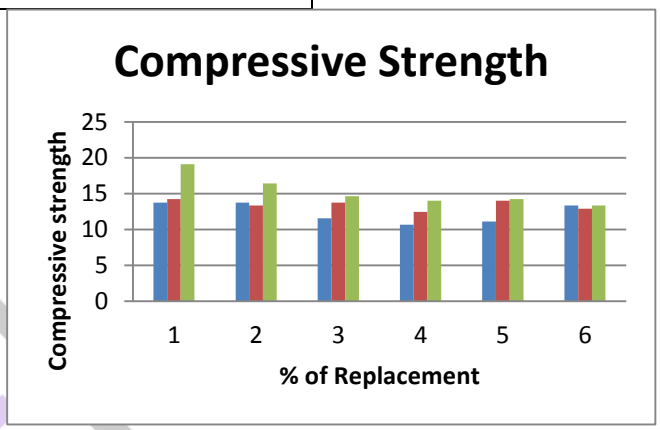
Test results of partial replacement of coarse aggregate with bakelite

% of coarse aggregate with bakelite	Strength of cubes in N/mm^2		
	7 days	14 days	28 days
5%	13.77	14.22	19.11
10%	13.77	13.33	16.44
15%	11.55	13.77	14.66
20%	10.66	12.44	14
25%	11.11	14	14.22
30%	13.33	12.88	13.33

Test results of conventional concrete

Test days	Strength of cubes in N/mm^2
7 days	16
14 days	18.66
28 days	19.11





(a) (b)

Figure 6. (a) Compressive strength of conventional concrete, (b) compressive strength of partial replacement of Coarse aggregate with bakelite

8. CONCLUSION

- From the above findings, it is concluded that the waste Bakelite up to 10% may be used for replacement of aggregates in concrete without any reduction in compressive strength.
- It is also concluded that the use of industrial wastes such as bakelite in concrete provides some advantages, like reduction in the use of natural resources, disposal of wastes, prevention of environmental pollution.

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