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Research On Waste Bakelite As A Partial Substitution Of Coarse And Fine Aggregate In Concrete Mix

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Abstract—Bakelite being a plastic material creates an environmental problem and causes health issues to public during its disposal process. In order to overcome this problem, many researchers involved in making waste Bakelite as a useful material for Civil engineering field. This study describes about the basic concept and application of Bakelite which is made into different forms of construction material. In order to reduce the waste management problem created by disposal of waste Bakelite into direct land filling and open burning, this study reveals the use of Bakelite as fine aggregate as well as coarse aggregate in construction field. Paver Blocks & Solid Blocks are manufactured using waste Bakelite as a partial replacement of fine and coarse aggregate with the percentage of 3%,6%,9%12% respectively and partial replacement of coarse aggregate with the percentage of 6%,12%,18%,24%. Tests are conducted to examine its strength and compared with conventional material.

Keywords— Bakelite, coarse aggregate, concrete cubes, solid block, compressive strength

INTRODUCTION:

Ensuring that every nation's citizen lives in a sustainable and clean environment is one of the most critical challenges facing governments today [1]. The rise in construction activity has exponentially increased the demand for river sand, depleting and exploiting natural sand resources and having negative environmental repercussions like river edges slipping and a falling water table [2,3]. So, searching a different filler material that may be used in place of aggregate while making concrete is critical. Moreover, the most significant component of concrete by volume is composed of coarse and fine aggregates, which give the material its stiffness and dimensional stability [4,5]. Thus alternatives to fine and coarse aggregates are crucial in the current situation. It is calculated that nearly 180,000 tons of Bakelite was formed in world per year and Bakelite was used in lots of Products to make thermal resisting material such as cooker handle, electric switch etc [6]. Due to rising industrialization and urbanization, dumping and landfilling plastic product pose a serious risk to human health and the environment. Therefore, there is a need for proper disposal method and also use of these wastes in the recycled form in various field are to be developed.

poly-oxy-benzyl-methylene-glycolanhydride (Bakelite) was invented in 1907 by a Belgian chemist, Leo Baekeland. By handling the pressure and temperature in the reaction of phenol and_formaldehyde, Baekeland produced a hard malleable material which named is "Bakelite" was formed. The composition of Bakelite was formed by polycondensation reaction between phenol (C_6H_5OH) and formaldehyde (HCOH) which formed a viscous liquid. In the year 1993, the world's first synthetic plastic was invented in the National Historic Chemical Landmark by the American Chemical Society. Due to its thermal resistance and electrical nonconductivity, Bakelite plastic was used to create the E-elements [7,8]. As a result, many heavy metals, electronic components, glassware, ferrous, polymers and nonferrous metals, hazardous chemicals, cell phone casings, housewares, plastic containers, pipe stems, and other plastic materials are made of synthetic Bakelite plastic [9]. Due to making these products Bakelite waste are also increased and the presence of methyl and ethyl alcohol in waste Bakelite, it causes some toxic effects to the environment as well as health problems. Landfilling is still a typical technique for Bakelite plastic waste, although when biodegradation does not continue, landfills do not offer an environmentally favourable alternative [10]. The impact of Bakelite on water quality can be analysis in an increasing of the Oxidiseability and the presence of phenol in the water. So dumping of waste Bakelite should be avoided to prevent water contamination. According to statistics, India manufactured 318 million tons of plastic in 2020 and generated 80,000 tonnes of Bakelite waste, with an estimated rise to 70,00,000 tons by 2050 [11]. Several of these were burned in kilns and disposed of in landfills, potentially causing environmental deterioration and posing a health risk to the workers handling them. Dumping of Bakelite is challenging task for safe environment and dumping of waste Bakelite is also a critical task. Waste Bakelite are used as an component of aggregate in the concrete block forming to be an reach to decrease Bakelite waste. Construction industries plays a significant role in uses of natural resources at a huge quantity. The huge amount of manufacturing of concrete in construction using standard coarse aggregate such as granite immoderately decreases the natural stone accumulation and affect the environment after that may cause ecology discrimination [12]. Increasing demand of standard aggregates show that pulverized stone demand will be increases nearly 2100 metric ton in 2020[13]. India is the largest worldwide purchaser of aggregates and worldwide demand for construction by concrete is estimate to increase 2.3% per year nearly 50 billion metric tons in year 2023, due to continued strong evolution in worldwide construction activity [14]. Therefore it is crucial to develop alternative materials due to the future demand for construction and the diminishing supply of natural building materials. The enormous demand for naturally occurring aggregate raises serious questions about the availability in long-term development for natural aggregate [15–17]. By substituting wasted Bakelite material for natural aggregate when making concrete, the environment is therefore protected, and concrete is now a durable and advantageous building material for the construction [18,19]. In this we review the most related knowledge about the structural characterstics and the performance of concrete using Bakelite waste will be deliberate, so this study focus on the Bakelite waste potential to be quitely used as a stand in to coarse aggregate in the cement concrete and check their physical properties such as compressive Strength, Density and water absoption.

LITERATURE REVIEW:

RR Bhopi and M Sinha partially replace the fine aggregate with Bakelite. 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 up to 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.

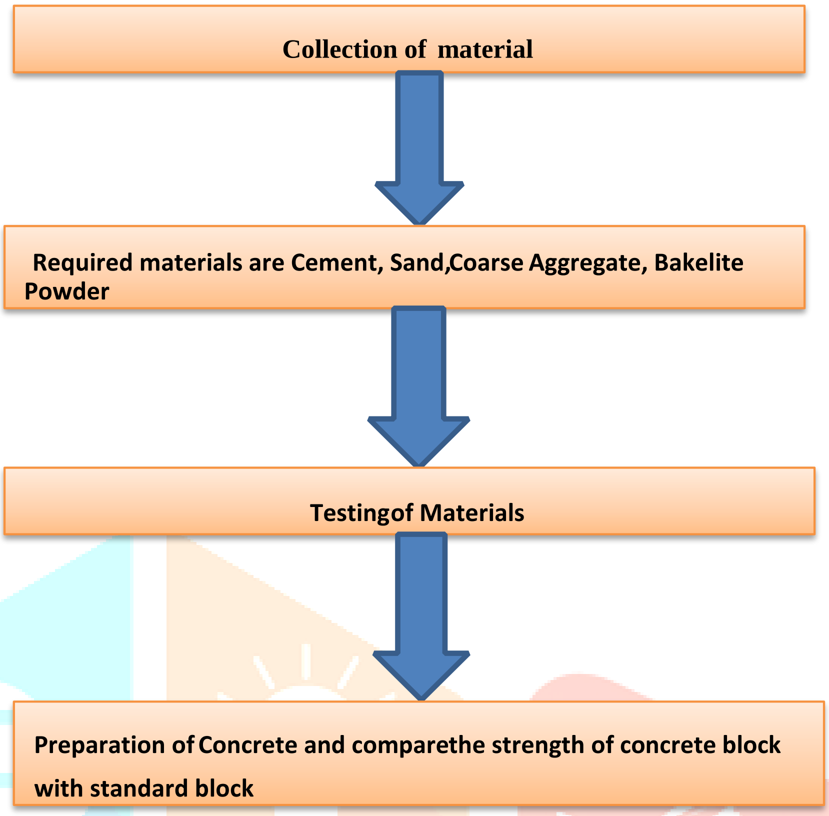
Akhil Verma Determine strength of concrete cubes using Bakelite powder instead of natural sand. The optimum result is found to be after replacement of Bakelite powder Strength of concrete with Bakelite powder replacements at optimum ratio was tested to be 24.51 MPa 4. This concrete can be used up to 3 floor house/buildings, surface water tanks and for structure of aesthetic value. High quality control with respect to material and casting is required for this type of concrete manufactures.

L Arun Raja and P Kumar Study on Flexural behaviour of Concrete by Partially Replacing Fine Aggregate with E-Plastic Waste. It is also concluded that the use of industrial wastes such as E-Plastic waste in concrete provides some advantages, like reduction in the use of natural resources, disposal of wastes, prevention of environmental pollution and energy saving.

Gyandeep Gupta, Mr. Rajneesh Partial Use of Bakelite Powder in Concrete Structures as an Alternative to Natural Sand. Partial Use of Bakelite Powder in Concrete Structures as an Alternative to Natural Sand at 20% replacement of natural sand with Bakelite powder the compressive strength of the concrete decreases but it is still better from the normal M25 concrete with 0% replacement, but at 30% replacement the compressive strength 9f the concrete is below 25Mpa so we can replace the sand with Bakelite powder to an extent of 20% only. The range of replacement of natural sand with Bakelite powder should be between 5% to 20% in which maximum compressive strength is obtained at 15% replacement.

S. Sakthi Sasmitha , Dr. R.N Uma A Critical Review on the Application of Bakelite as a Partial Replacement of Fine and Coarse Aggregate. The present study reveals the properties and use of Bakelite as a construction material in Cement, and solid blocks with appropriate specifications. The use of waste material into construction industry creates a challenging job and better performance along with the development of construction sector. Incorporation of plastic waste in building material gives a cost effective and light weight sustainable component in construction which alters the strength and durability property. This study helps to develop a replaceable material (waste Bakelite) for fine and coarse aggregate in order to minimize disposal of plastics which creates a waste management problem.

Methodology:



Material used in concrete and its properties:

1. **Bakelite:**
   The commercial name of Bakelite is thermosetting phenol formaldehyde resin formed from the polycondensation reaction of formaldehyde with phenol. Its main chemical composition of Bakelite consist of hydrogen(H), carbon(C) and oxygen(O). Compounds found in the Bakelite formation by X-Ray diffraction technology are reported in Table 1 so calcium oxide is the main composition with contain a small amount of silica and Sulphur trioxide [20].

Compound	Percentage by weight (%)
CaO	94.23
SiO2	5.14
SO3	0.33

Table-1 Chemical compounds in Bakelite.

The Bakelite materials are classified based on their size. By means of coarse aggregates the Bakelite material should passed through 12.5 mm IS sieve and retained on 10 mm IS sieve.
The properties of Bakelite in the form of coarse aggregate were tested based on the Codal provisions and results are in table-2 [21].

Property	Waste Bakelite
Type	bakelite (10 mm)
Specific gravity	1.36
Water Absorption	1.18 %
Crushing Value	8.9 %
Impact Value	4.3 %
Bulk Density	1003.42kg/m^3
Abrasion Value	13.8 %

Table-2 Properties of Bakelite as a Coarse Aggregate

Properties [22]:

- It is a cross linked polymer
- Strong, rigid and light in weight
- Can be Mold easily
- It cannot be remelted
- Resistance to heat, electricity and chemical action

2. Aggregate:

Aggregate is an inert granular material such as sand, gravel, crushed stone, etc. which gives volume, stability, resistance to wear and tear. Both fine and coarse aggregate plays a major part in the manufacturing of various construction members. The grading of aggregate should be properly done and an appropriate size is to be preferred for construction. The aggregate which is not pass on IS sieve 4.75mm is a coarse aggregate. In the work we decide to use the maximum size of coarse aggregate, the maximum size of 20mm was used in the construction work. The aggregates were tested as per Indian Standards Specification IS: 2386-1963.

Properties:

- Particle size and gradation
- Resistance to wear
- Durability
- Chemical stability
- Specific gravity and absorption

Property	Coarse Aggregate
Type	Crushed stone (10 mm)
Specific gravity	2.70
Water Absorption	2.4 %
Crushing Value	29.22 %
Impact Value	27.8 %

Bulk Density	1580.24kg/m^3
Abrasion Value	49.15 %

Table-3 Properties of Coarse Aggregate[21]

METHODOLOGY

TEST ON AGGREGATE

A. .Crushing Test

One of the model in which pavement material can fail is by crushing under compressive stress. A test is standardized by **IS: 2386 part-IV** and used to determine the crushing strength of aggregates. The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied crushing load.

The test consists of subjecting the specimen of aggregate in standard mould to a compression test under standard load conditions (See Fig-1). Dry aggregates passing through 12.5 mm sieves and retained 10 mm sieves are filled in a cylindrical measure of 11.5 mm diameter and 18 cm height in three layers. Each layer is tamped 25 times with at standard tamping rod. The test sample is weighed and placed in the test cylinder in three layers each layer being tamped again. The specimen is subjected to a compressive load of 40 tonnes gradually applied at the rate of 4 tonnes per minute. Then crushed aggregates are then sieved through 2.36 mm sieve and weight of passing material (**W2**) is expressed as percentage of the weight of the total sample (**W1**) which is the aggregate crushing value.

Aggregate crushing value = (W1/W2)*100

A value **less than 10** signifies an exceptionally **strong aggregate** while **above 35** would normally be regarded as **weak aggregates**.

Also Read: Crushing Test Procedure of Aggregate

B. 2.Abrasion Test

Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. Los Angeles abrasion test is a preferred one for carrying out the hardness property and has been standardized in India (**IS: 2386 part-IV**).

The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge.

Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated (see Fig-2). An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g is placed in the cylinder along with the aggregates. The number of the abrasive spheres varies according to the grading of the sample. The quantity of aggregates to be used depends upon the gradation and usually ranges from 5-10 kg. The cylinder is then locked and rotated at the speed of 30-33 rpm for a total of 500 -1000 revolutions depending upon the gradation of aggregates.

After specified revolutions, the material is sieved through 1.7 mm sieve and passed fraction is expressed as percentage total weight of the sample. This value is called Los Angeles abrasion value.

A maximum value of **40 percent** is allowed for **WBM base course** in Indian conditions.
For **bituminous concrete**, a maximum value of **35 percent** is specified.

C. *3.Impact Test*

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 numbers of blows (see Fig-3). Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 numbers of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. And the impact value is measured as percentage of aggregates passing sieve (**W2**) to the total weight of the sample (**W1**).

Aggregate impact value = (W1/W2)*100

Aggregates to be used **for wearing course**, the impact value **shouldn't exceed 30 percent**. For **bituminous macadam** the **maximum** permissible value is **35 percent**. For **Water bound macadam** base courses the maximum permissible value defined by IRC is **40 percent.**

D. *5.Shape Tests*

The particle shape of the aggregate mass is determined by the percentage of flaky and elongated particles in it. Aggregates which are flaky or elongated are detrimental to higher workability and stability of mixes.

The **flakiness index** is defined as the percentage by weight of aggregate particles whose **least dimension is less than 0.6 times their mean size**. Flakiness gauge (see Fig-4) is used for this test. Test procedure had been standardized in India (**IS: 2386 part-I**).

The **elongation index** of an aggregate is defined as the percentage by weight of particles whose **greatest dimension (length) is 1.8 times their mean dimension**. This test is applicable to aggregates larger than 6.3 mm. Elongation gauge (see Fig-5) is used for this test. This test is also specified in (**IS: 2386 Part-I**). However there are no recognized limits for the elongation index.

6.Specific Gravity and Water Absorption

The specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. Because the aggregates may contain water-permeable voids, so two measures of specific gravity of aggregates are used:

1. Apparent specific gravity and
2. Bulk specific gravity.

Apparent Specific Gravity, $\mathbf{G_{app}}$, is computed on the basis of the net volume of aggregates i.e the volume excluding water-permeable voids. Thus

$$\mathbf{G_{app} = [(M_D/V_N)]/W}$$

Where,

M_D is the dry mass of the aggregate,

V_N is the net volume of the aggregates excluding the volume of the absorbed matter,

W is the density of water.

Bulk Specific Gravity, **G_{bulk}**, is computed on the basis of the total volume of aggregates including water permeable voids. Thus

$G_{bulk} = [(M_D/V_B)]/W$

Where,

V_B is the total volume of the aggregates including the volume of absorbed water.

Water Absorption: The difference between the apparent and bulk specific gravities is nothing but the water permeable voids of the aggregates. We can measure the volume of such voids by weighing the aggregates dry and in a **saturated surface dry condition**, with all permeable voids filled with water. The difference of the above two is M_W.

M_W is the weight of dry aggregates minus weight of aggregates saturated surface dry condition. Thus,

Water Absorption = $(M_W/M_D)*100$

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 2.9. Water absorption values ranges from 0.1 to about 2.0 percent for aggregates normally used in road surfacing.

TEST ON CUBE

E. *Compression strength*

The Compressive tests are required to determine the strength of specimen which is one of the important tests for solid block to determine its suitability in construction field. The casted specimens were tested for 7, 14 and 28 days compressive strength by using hydraulic compressive testing machine strength and the test results are tabulated.

Test results for Compression Strength

F. *Slump Test*

A concrete slump test is conducted in-field on fresh concrete mix. It helps to determine if the, soon to be poured, concrete will meet its specified standard. It is a simple test that can confirm, over multiple batches, that the concrete is consistent – providing a chance to amend the mix before it is poured on site.

By measuring the overall ‘slump’ of the concrete, you can tell whether the water-cement ratio is too high, and whether a mix will have high workability or not.

Interpreting Slump Test Results

True Slump – Here the general mass of the concrete drops evenly without any disintegration. This is the desired test result.

Shear Slump – Here one side of the concrete shears or falls from the main portion of concrete. This is an indication that the concrete lacks cohesion.

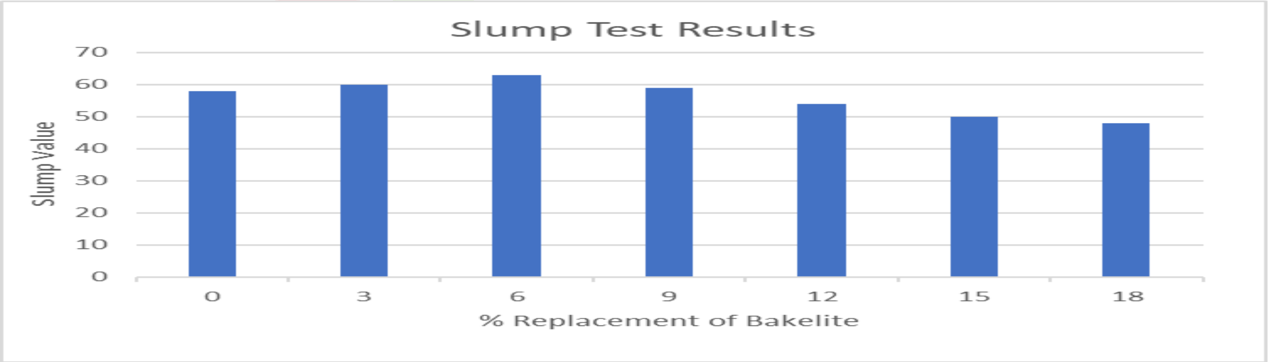
Collapse Slump – Here the concrete completely collapses. This is an indication that the mix is too wet.

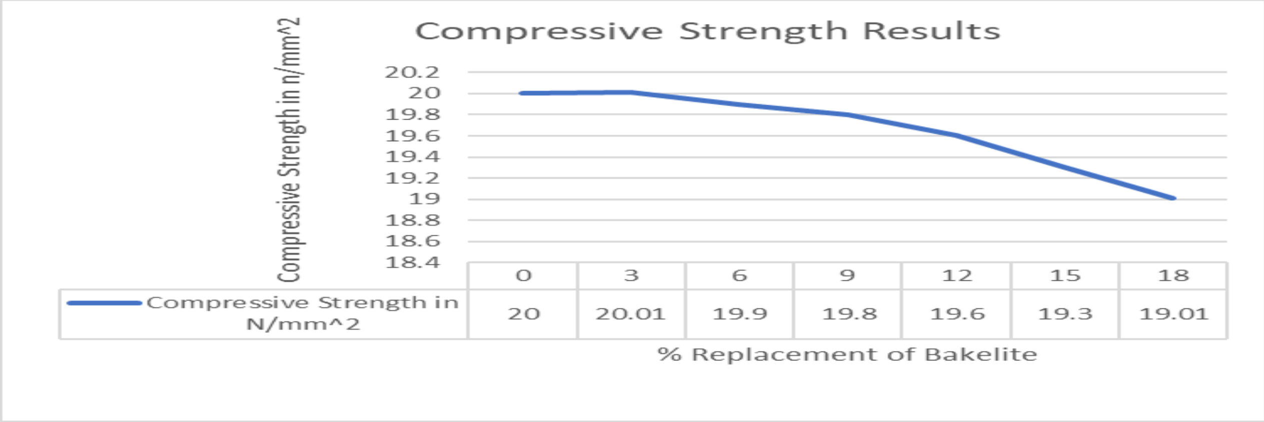
Zero Slump – Here the concrete maintains the shape of the mold. This type of concrete is too stiff and has almost no workability.

If shear slump, collapse slump or zero slump are found, the slump test should be repeated. If the second test also results in a failed slump test, then that batch of concrete should be rejected according to the established safety standards.

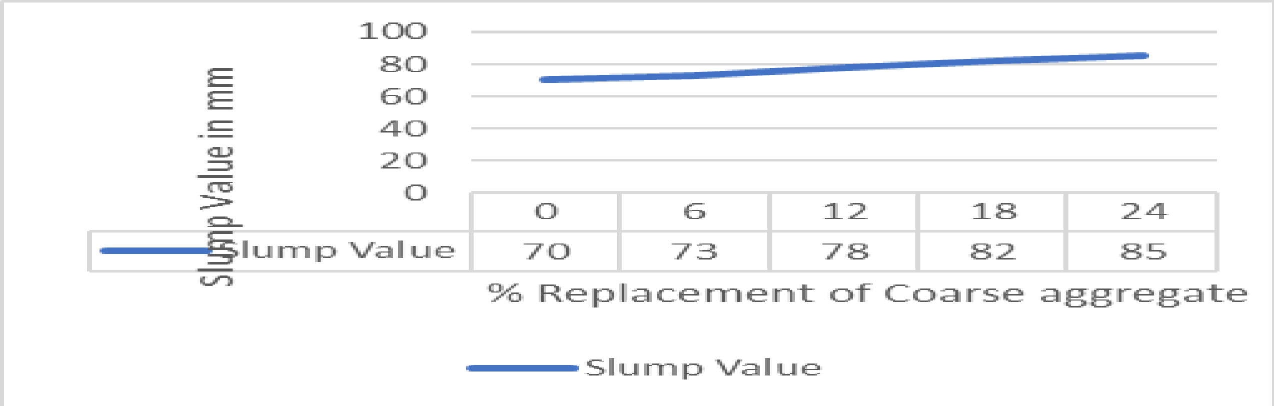
RESULT

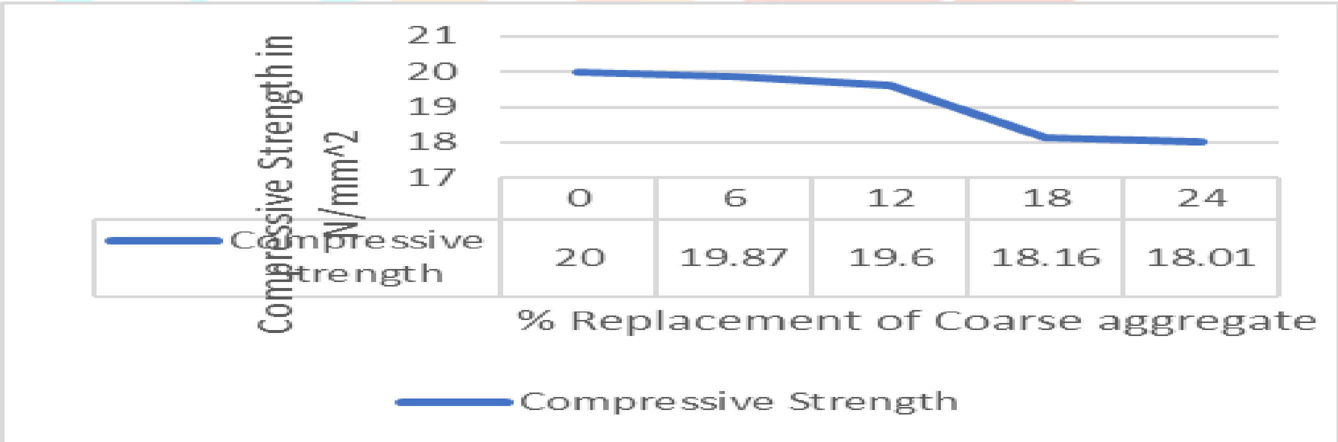
Result For Fine Aggregate Replacement-





Result For Coarse aggregate Replacement-





CONCLUSION-

The study elucidates the properties and applications of waste Bakelite in building construction materials, specifically within concrete mixtures, cube formation, paver blocks, and solid blocks, adhering to appropriate specifications. The utilization of waste Bakelite material in construction presents a challenging yet promising task, contributing to enhanced performance and the overall advancement of the construction sector. The integration of Bakelite waste into building materials offers a cost-effective and lightweight sustainable component in construction, impacting compressive strength, water absorption, density, and durability properties. This research contributes to the development of a substitute material (waste Bakelite) as a coarse aggregate, aiming to mitigate the challenges associated with plastic waste disposal and contributing to improved waste management practices.

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