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To Study the Partial Replacement of Cement with Bamboo Leaf Ash and Eggshell Powder with Addition of Coted Pet Fiber

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Abstract: Concrete, the most widely used construction material globally, plays a vital role in infrastructure development due to its versatility, strength, and durability. However, the production of Ordinary Portland Cement (OPC), a key ingredient in concrete, is associated with high energy consumption and significant carbon dioxide (CO_2) emissions. In pursuit of sustainable alternatives, this study explores the partial replacement of cement with Bamboo Leaf Ash (BLA) and Eggshell Powder (ESP), along with the incorporation of coated Polyethylene Terephthalate (PET) fibers to enhance mechanical and durability performance. BLA, a silica-rich agro-waste, exhibits pozzolanic activity and improves long-term strength development, while ESP, primarily composed of calcium carbonate, functions as a micro-filler that contributes to matrix densification. Additionally, coated PET fibers, derived from recycled plastic bottles, are introduced to improve tensile behavior, reduce crack propagation, and enhance ductility. This research supports the development of eco-friendly, cost-effective, and sustainable concrete, contributing to resource conservation and environmental protection in the construction industry. The experimental investigations are administered for compressive strength, split tensile and flexural strength for curing period of 7, 14, 28 days. Workability gets reduced at higher replacement of materials and the experimental results shows test are satisfactory up to the combined replacement percentage with cement of 11% BLA&ESP with addition of 2% coted PET fibers in concrete. The values of compressive strength, flexural strength and split tensile strength were higher compared to alternative replacement percentages.

Keywords: BLA (Bamboo Leaf Ash), ESP (Eggshell Powder), PET (Polyethylene Terephthalate) workability, compressive strength, Split Tensile strength, Flexural strength

I. INTRODUCTION

Cement is a green concrete. Consumption of cement has increased dramatically year by year due to infrastructure development. When cement is widely used in concrete, the risk of environmental impact on the earth increases. There is a perpetual need for building materials that meet all the strict requirements for the structure's short- and long-term performance because of the ongoing and continuous engineering development activities as well as the expanding construction activities. Future buildings will be larger and more intricate, thus the materials used in their construction must meet higher performance standards and requirements than those currently in use. Alternative materials must be tested to ensure they are a feasible choice for use in building as the current supply is running low. Since the natural resources utilized in construction are becoming saturated, the amount of building materials will not rise.

A. Silica fume

In case of silica fume the American Concrete Institute defines that its ‘‘very fine non-crystalline silicon oxide made in arc furnaces as a by-product of making of elemental silicon or alloys containing silicon’’. Silica Fume (SF), conjointly called micro silica, Condensed silicon oxide Fume (CSF), silicon oxide dust, volatilized silicon oxide and micropoz (trademark name), is a by-product obtained from the producing of silicon metal, ferrosilicon alloy. Silicon oxide Fume holds very fine particles, spherical in form, with surface area around 20,000 m2/kg (Measured by nitrogen adsorption Method). The common particle diameter is 0.1μm that is 100 times finer than a median hydraulic cement particle. Outsized particles (larger than 45μm) are usually composed of non-silica elements. Because of its high glass content and fineness, SF exhibits a high pozzolanic reactivity that is extremely effective once employed in concrete.

B. (PET) fibers

Polyethylene Terephthalate (PET) fibers are synthetic fibers produced from recycled plastic waste, commonly from used water or soda bottles. These fibers have gained attention in concrete technology due to their lightweight, corrosion resistance, and ability to enhance crack resistance and tensile strength. However, raw PET fibers have a smooth surface and low bonding affinity with the cement matrix, which can reduce their effectiveness. To overcome this limitation, surface coating or treatment of PET fibers is applied to improve their interfacial bonding with the cement paste.

C. Bamboo Leaf Ash

A common crop in many tropical nations is bamboo. The tree's stem is hollow, smooth, and rounded. Because the bottom portions of the tree lack limbs, a third of the tree is covered in light-colored, shiny, tiny, robust, smooth, and dark-green leaves that are covered in numerous spines between nodules. The majority of the leaves fall during the dry season, and the earth gets compacted, rendering the soil and surrounding soil unfit for planting. It has been discovered that the ashes produced by burning and drying the leaves have pozzolanic properties. Bamboo's high carbohydrate content contributes significantly to both its strength and improved health. In addition, silica, potassium, and calcium make up the majority of the inorganic minerals found in bamboo ash. Two other common minerals are manganese and magnesium. The epidermis has the largest silica content, while the nodes have little to no silica penetration. This ash, when burned at high temperatures, reacts with slaked lime to form a substance that is naturally pozzolanic

D. Egg Shell Powder

Among the different wastes eggshell is also one of the wastes. India is third largest egg producer in the world. Every day egg company in the world process nearly one million eggs. If it is to be estimated, about 10,000 tons of eggshells have to be willing each year. Most of the eggshell waste is put out in the landfill without any pretreatment because it is useless and, in many countries, requires pretreatment before dumping. Eggshell waste also attracts vermin due to the membrane attached to it. So, it is a threat to the environment and human health. The utilization of this waste will lead to a sustainable environment. Also, utilizing eggshell powder in place of cement will reduce carbon dioxide emissions during the production of cement and decrease air pollution. This will lead to the economic growth and development of countries. Eggshell waste evolves from poultry farms, restaurants, and hotels where there is the consumption of eggs.

Eggshells are rich in calcium and have the same limestone composition as cement. Researchers have reported that eggshell mainly contains calcium in the form of Calcium Carbonate (90%) and the remaining masses contain Phosphorus, Magnesium, traces of sodium, zinc, manganese, iron, and copper.

II. LITERATURE REVIEW

Catherine Mayowa Ikumapayi 2023 This research examines the impact of BLA on alkali-silica reaction (ASR) in concrete. Concrete bars with varying BLA content were soaked in NaOH at 80°C to assess ASR-induced expansion. Findings revealed that BLA improved workability and had no detrimental effect on linear expansion, although higher BLA content led to reduced compressive strength. A 5% BLA replacement is recommended for areas where strength is not the primary concern.

Abdul Razak B H 2023 This study evaluates BLA as a supplementary cementitious material by replacing ordinary Portland cement (OPC) at 10%, 20%, and 30%. The fresh and hardened properties of concrete were assessed. Results showed satisfactory compressive strength up to 20% BLA replacement, beyond which strength declined below the characteristic value, indicating 20% as the optimal replacement level.

Kamran Basit et al. (July 2019) This paper studies the various strength parameters of concrete made with varying proportions of egg shell powder viz 0%, 5%, 10%, 15% and 20% as replacement of cement and concluded that the highest strength is achieved at 10% replacement of cement with ESP. Also concluded that split elastic qualities of ESP cements were practically similar to traditional cement up to 15% ESP replacement. The workability characteristics of the concrete with varying ratio of ESP were also studied through slump cone test. Compressive strength test, flexural strength test and split tensile strength test were performed to get the results and conclusion of replacement of cement with ESP.

KANAKA RANYA et al. (August 2019) This paper focused on various parameters of M40 concrete made with partial replacement of cement with ESP in the following percentages as 5%, 10% and 15% and percentages of fine aggregates with Quarry dust are 25%, 50% and 75%. compressive strength test, flexural strength test and split tensile strength tests were performed to get the results.

It is reported by the data of test results that the optimum percentages are 10% for ESP replacement with cement and 50% for Quarry dust with fine aggregates. The percentage increase in split tensile strength is 5.5% with 10% ESP and 50% Quarry dust when compared with normal mix and flexural strength is increased by 7.1%.

Aditya Krishna Reddy K 2018 This study investigates the mechanical properties of concrete incorporating coated PET bottle fibers. The fibers were treated with maleic anhydride grafted polypropylene and used in varying percentages (0.25%, 0.5%, 0.75%) by weight of cement. Results indicated that the inclusion of 0.75% coated PET fibers enhanced compressive, split tensile, and flexural strengths compared to conventional concrete. The study concludes that coated PET fibers can improve the mechanical performance of concrete.

III. MATERIALS

A. Cement

The OPC is the basic Portland cement which is best suited for use in general construction work, where there is no exposure to sulphates in ground water or in the soil. Cement is available in three different grades 33, 43 and 53 Grade Cement. The cement of 43 Grade is the most popular Grade of Cement which has low heat of hydration and provides long life strength of Concrete Structures. Ordinary Portland cement of grade- 43 conforming to Indian Standard IS: 8112- 1989.

B. Coarse Aggregates

Coarse aggregate is defined as aggregate that is larger than 4.75 mm or that is retrained on a 4.75 mm IS sieve. Coarse aggregates are materials that are too big to be retained on a 4.75 mm IS sieve and only include the amount of fine particles allowed by the standards. The nominal size of the graded coarse aggregate—40 mm, 20 mm, 16 mm, and 10 mm—defines it. Many of the aggregates' characteristics are derived from the parent rocks since they are created either by the natural disintegration of rocks or by the artificial crushing of rocks or gravel. The coarse aggregate was graded in accordance with IS:383-1970. A graded aggregate is made up of aggregates with nominal sizes of 20 mm and 10 mm. The coarse aggregate parameters were supplied by the relevant lab.

C. Fine Aggregates

Natural river sand or crushed sand particles that have passed through a 4.75mm sieve make up fine aggregate. River sand, which has a particle size of 0.07 mm, is typically utilized as a fine aggregate. The extraction process is carried out from seabeds, lakes, or rivers. Jammu was used to extract the fine aggregate that was on the site. The zone that complies with IS: 383-1970 would be determined using sieve analysis. The relevant lab supplied the physical characteristics of the sand.

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D. Eggshell Powder

Eggshell powder (ESP) is a promising sustainable material made from leftover eggshells. Like limestone, the primary raw material used to make cement, eggshells are mostly constituted of calcium carbonate (CaCO3). ESP can be utilized in concrete in place of some of the cement if it is thoroughly cleaned, dried, and crushed into a fine powder. Using ESP in concrete encourages efficient waste management in addition to cutting cement usage and, consequently, CO_2 emissions. Because of the filler effect and pozzolanic reaction, studies have demonstrated that using ESP in place of up to 10% of cement can improve the mechanical qualities of concrete, including its compressive and tensile strength.

Table no. 1 Properties of ESP

Chemical Composition	Cement (%)	Eggshell Powder (%)
SiO2	21.8	0.09
Cao	60.1	52.1
Al2O3	6.7	0.04
Fe2O3	4.1	0.03
MgO	2.2	0.01
K_2O	0.4	-
Na_2O	0.4	0.15
SO3	2.2	0.62

E. Bamboo Leaf Ash

Bamboo is arguably the most productive and rapidly expanding natural resource and building material that humans have discovered. However, using bamboo results in other wastes, including bamboo leaves, that cannot be turned into fibers. Large volumes of solid waste are produced during the processing of bamboo in several nations. These waste materials are frequently burned in open landfills, which harms the environment. Research on the pozzolanic qualities of bamboo waste is scarce in the literature. After burning bamboo leaves, ash is produced that is amorphous and contains pozzolanic qualities. To create a mound of bamboo leaf ash, the bamboo leaves are sun-dried and then burned outside for two hours.

Table no. 2 Properties of BLA

S.no	Elemental Oxide	BLA (% by mass)
1.	Calcium Oxide (CaO)	4.23
2.	Silicon Dioxide (SiO_2)	72.25
3.	Aluminum Oxide (Al_2O_3)	4.08
4.	Magnesium Oxide (MgO)	1.01
5.	Ferric Oxide (Fe_2O_3)	1.97
6.	Potassium Oxide (K_2O)	3.15
7.	Manganese dioxide (MnO_2)	0.22

F. Coated Pet Fiber
The manufacturing process of silica fume-coated PET fibers for use in concrete begins with the collection and preparation of PET fibers, typically sourced from recycled plastic bottles. These fibers are first cleaned thoroughly with water, detergent, or mild alkaline solutions such as sodium hydroxide (NaOH) to remove contaminants and to roughen the surface, which enhances bonding. After cleaning, the fibers are dried completely. Meanwhile, a silica fume slurry is prepared by mixing fine silica fume powder with water, sometimes with the addition of a dispersing agent to ensure uniformity. The cleaned PET fibers are then immersed into the silica fume slurry and kept there for about 10 to 30 minutes to allow a uniform coating to adhere to their surface. Following immersion, the fibers are taken out and dried, typically by air drying or at a low oven temperature (around 60–80°C), ensuring that the silica fume layer is securely bonded to the fiber

Table no. 3 Properties of Coted PET FIBER

Properties	Specification
Appearance	White staple fiber
Chemical name	Polyethylene terephthalate
Description	Thermoplastic fiber, round, and uncrimped
Fiber diameter	60mm*2mm, 120mm*2mm
Fiber count per gram	231.4 for 12 mm fiber
Specific density	1.34–1.4
Melting point	254°C
Auto ignition temp	515°C
Physical state	Solid
Moisture regain	0.5%
Solubility in water	Not soluble
Solvents	None
Tenacity at break	45 cN/Tex (±5)
Elongation at break	40% (±)
Fiber tenacity at 10% elongation	>10 cN/Tex

IV. METHODOLOGY

A. Mixing Concrete
All of the concrete's constituents are combined, but the mixture should be uniformly colored and consistent. A mixer can be used, or the mixing can be done by hand.

B. Mixing Concrete
Thorough mixing of the materials is essential to produce uniform concrete. The mixing should make sure that the mass become homogeneous, uniform in consistency and colour. There are two methods adopting for mixing concrete one is hand mixing and other is machine mixing.

C. Curing
Specimens are placed in a water tank designed to cure them after the mold has dried for a full day. To ensure that there are no mistakes, the specimens must be marked for identification. Before being placed in the testing apparatus, the specimens are taken out of the tank and allowed to dry. For 7, 14, and 28 days, the specimens are housed in the tank.

D. Workability Test

It can be utilized both in the lab and on-site. Both very low and very high workability concrete cannot pass this test. It is made up of a mold that is shaped like a frustum and has dimensions of 10 cm for the top, 20 cm for the bottom, and 30 cm for the height. If four layers of concrete are placed in the mold, the concrete will be tested. With a tamping rod, each is compacted twenty-five times. When the mold is fully filled, it is instantly raised vertically upward, which causes the concrete to sink.

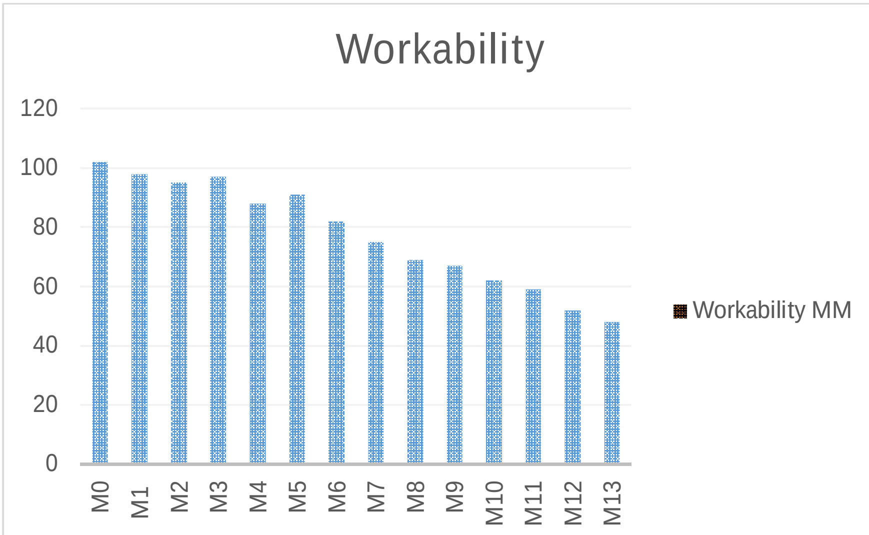

Fig -1: Slump Cone Test

E. Compressive Strength Test

Then fresh concrete is filled in mould in 4 layers and after filling each layer tamping should be done 35 times in case of cube and 25 times in case of cylinder by using standard tamping rod. Once the mould is filled then leveled top surface of concrete with trowel. After the day the mould will removed and specimen are dropped in the curing tank under standard temperature of 27±2° c. After 7,14 days and 28 days in this research.

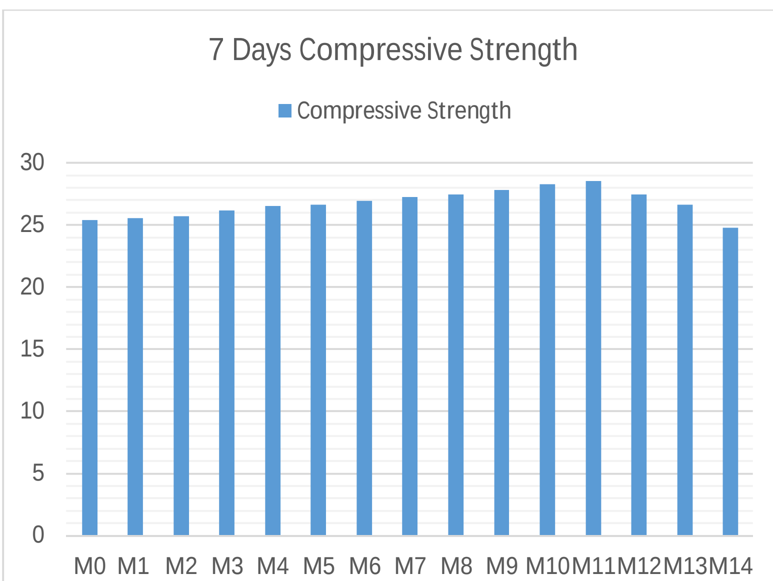

Fig -2: Compressive Strength Test 7

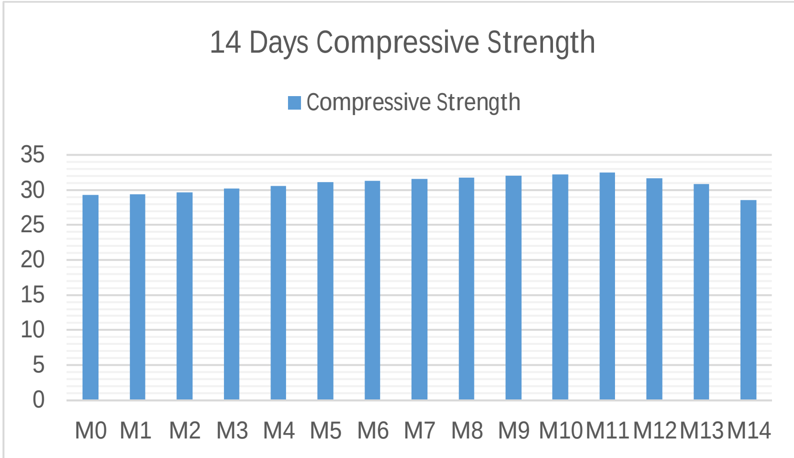

Fig -3: Compressive Strength Test 14

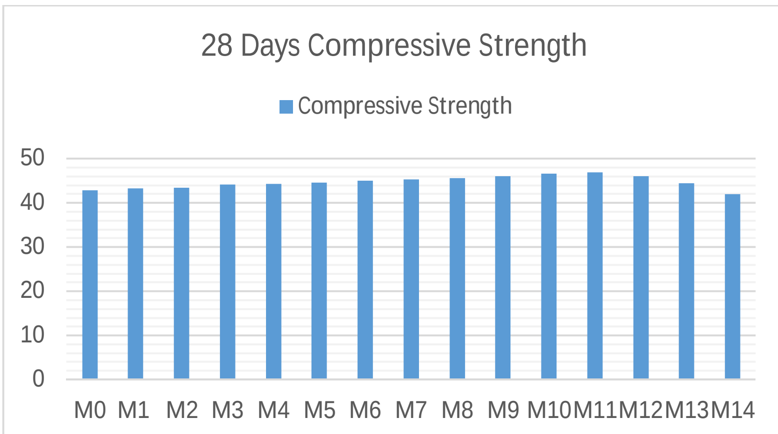

Fig -4: Compressive Strength Test 28

F. Split Tensile Strength Test

The specimen used for this test is cylindrical and its dimension is 150 mm in diameter and 300mm in length. The instrument used for this testing is universal testing machine. The fresh concrete is prepared in according to the required grades and respective mix proportion. The fresh concrete is filled in mould in layers and each layer is tamping with standard tamping rod with 25 blows for each layer. After the day the mould is removed and specimen is placed in the curing tank for 7,14 days and 28 days in this research at the temperature 27+ 2°c. Then draw the line on the specimen.

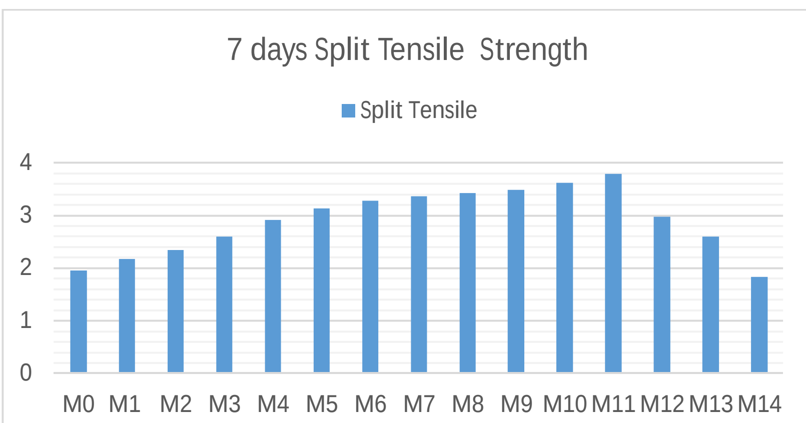

Fig -5: Split Tensile Strength Test 7

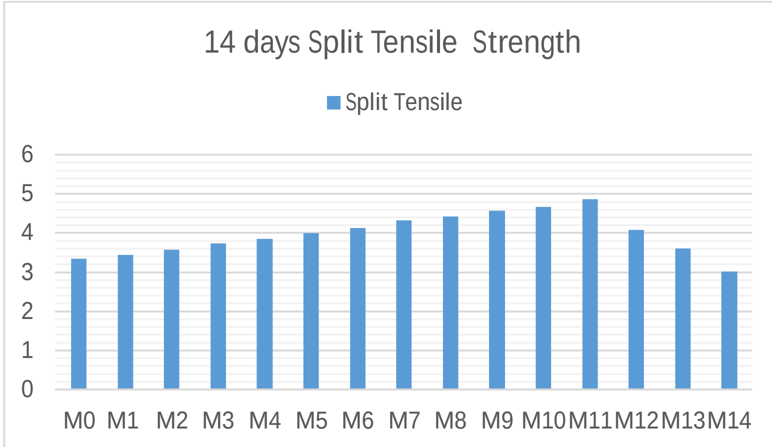

Fig -6: SPLIT TENSILE STRENGTH TEST 14

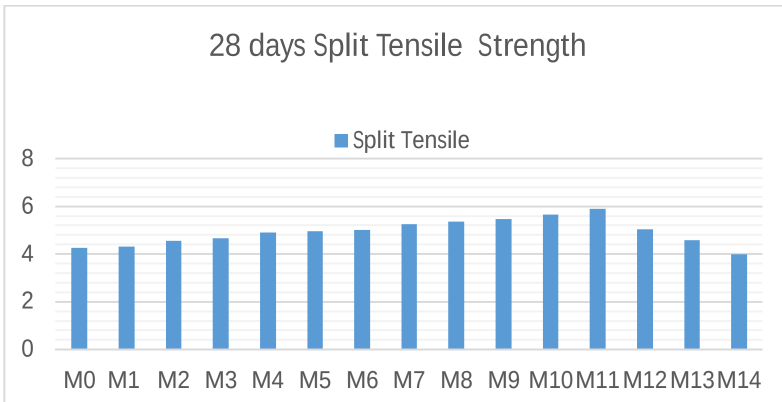

Fig -7: SPLIT TENSILE STRENGTH TEST 28

G. *Flexural Strength Test*

The concrete is prepared at required rate of mass element the mould is filled with concrete in layers and blows 25 times with standard tamping rod. After the day or we can say 24 hours the mould is removed and specimen placed in the water tank for curing at a temperature of 27 + 2 C. Depending upon the requirement the test specimen is removed from the water tank and wipe it properly for 7,14 and 28 days for testing.

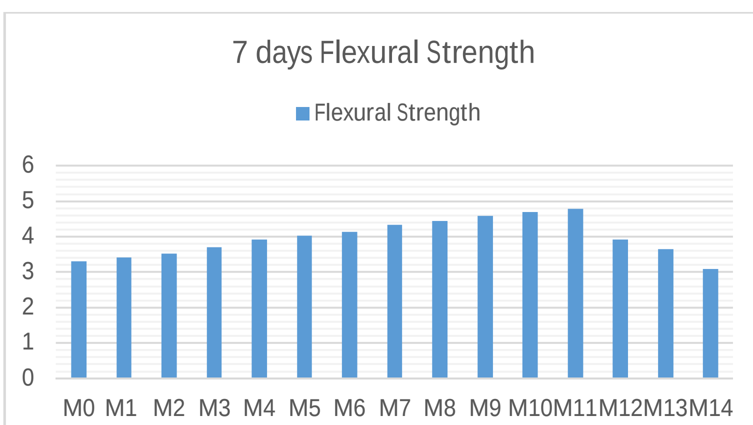

Fig -8: FLEXURAL STRENGTH TEST 7

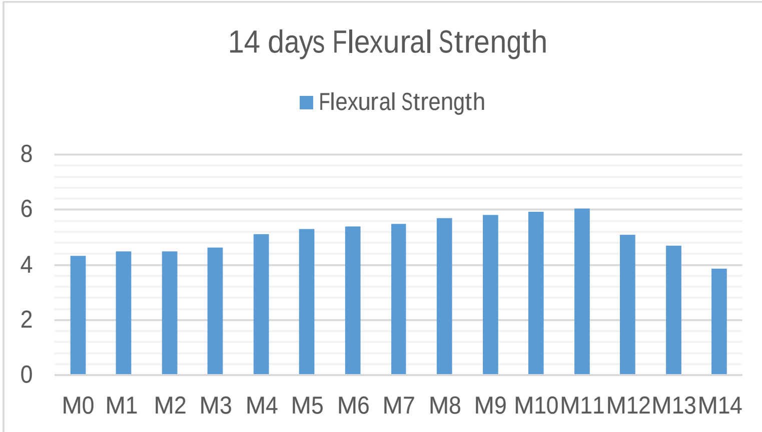

Fig -9: FLEXURAL STRENGTH TEST 14

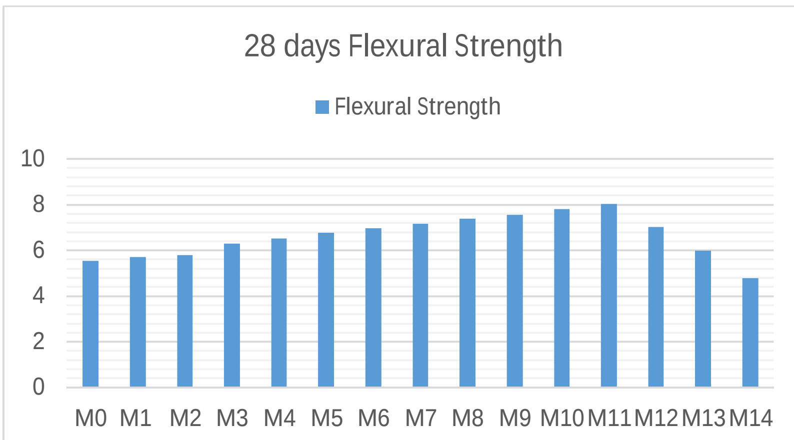

Fig -10: FLEXURAL STRENGTH TEST 28

V. CONCLUSION

On filling up the moulds hand compaction should be opted, as to reduce the segregation of the fibre in the concrete mould. By replacing the cement with the replacement of egg shell powder 5.5% and bamboo leaf Ash 5.5% in cement with addition of 2% coated pet fiber in concrete mix strengths get increased, also the replacement can be taken into consideration up to certain percentage workability factors gets enhanced as well. Coted PET fiber acted as a reinforcement and hence acted as resistance to the cracks, thus increasing the flexural strength.

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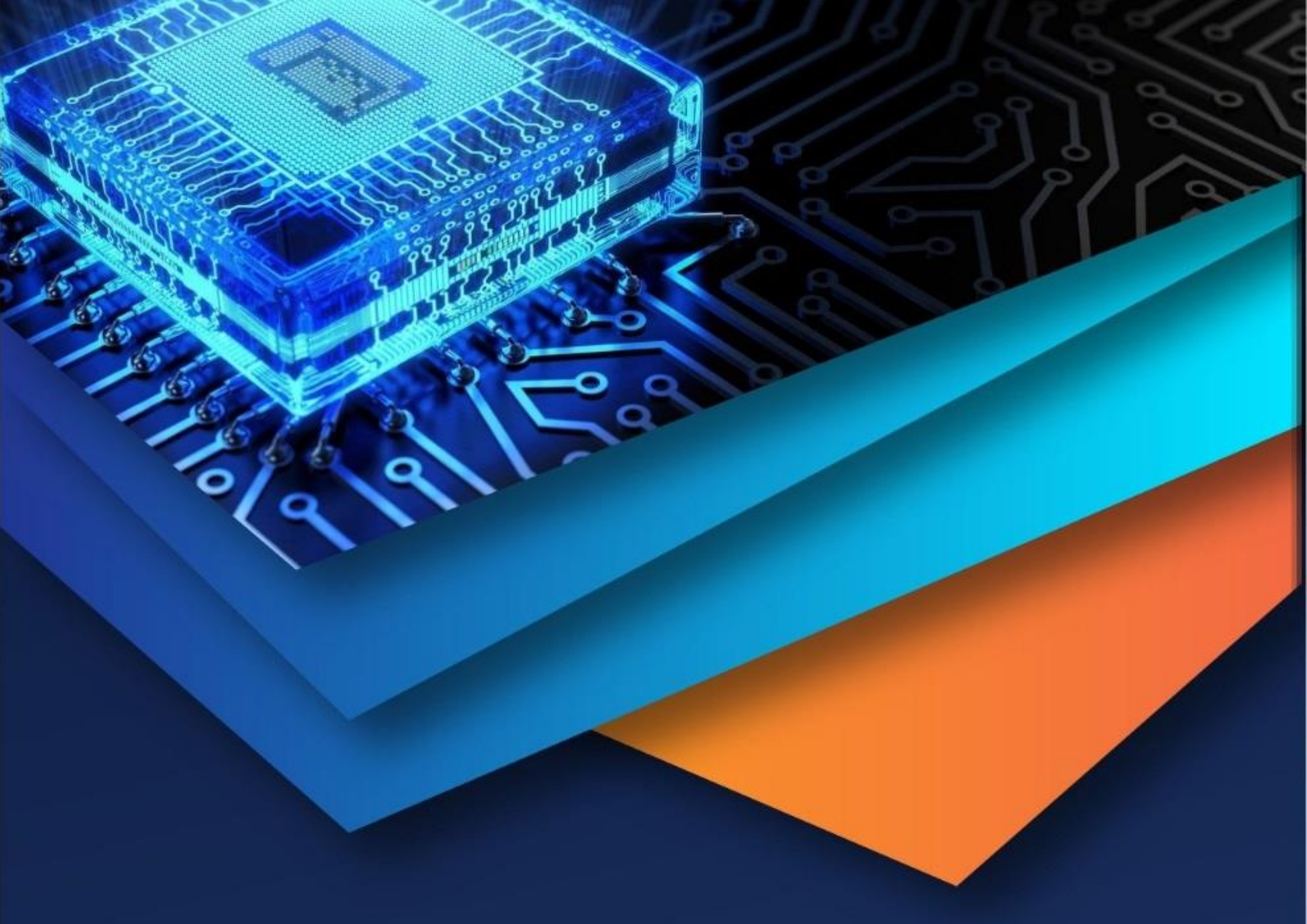

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