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# EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH COCONUT SHELL

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## ABSTRACT

The high cost of environmental construction material affects economy of structure. With increasing concern over the excessive exploitation of natural aggregates, lightweight aggregate produced from environmental waste is a viable new source of structural aggregate material. Recently in the environmental issues, restrictions of local and natural access or sources and disposal of waste material are gaining great importance. Today, it becomes more difficult to find a natural resources. Use of the waste materials not only helps inn getting them utilized in cement, concrete and other construction materials, but also has numerous indirect benefits such as reduction in land fill cost, saving in energy, and protecting environment from possible pollution effect. It also helps in reduction the cost of concrete manufacturing. In the present work, coconut shell as partial replacement for coarse aggregate in concrete is studied.

Experimental investigation were carried out by preparing concrete block of 150×150×150mm and compressive strength tests were conducted on these blocks by replacing coarse aggregate in concrete mix by 10%, 20% and 30% with coconut shells. From this experimental investigation it was found that coconut shells can be used as an alternative in concrete mixes by adjusting the water cement ratio and admixtures contents of the mix.

**Key Words:** Coconut Shell, Concrete, Compressive strength, Construction Material

## INTRODUCTION

Infrastructure development across the world created demands for construction material. In this constructed environment, the rising cost of building construction materials is the factor of great concern. The cost of building materials are raising day by day. Now a days most of the researchers have focus on use of the

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waste materials in concrete according to their properties. Fly ash, Rice husk, Slag and Sludge from the treatment of industrial and domestic waste water has been found suitable as a replacement for cement in concrete. The coconut shell is also a material used as a replacement for cement in concrete.In this work we are partially replacing the coarse aggregate with coconut shell. This reduces the land fillings caused due to deposition of the waste material in concrete. Coconut shells show very high resistance to impact load when compared with conventional concrete. The main objective of this replacement work is to utilize the agro waste to produce light weight concrete. In addition, it is done to compare characteristics of M20 or other grades conventional concrete. The replacement is done by gradually increasing the percentage of addition of coconut shells to the coarse aggregate. India is a divine land in every occasion perhaps coconut is the main item of worshipping. So India produces a huge amount of waste from coconut. With the use of coconut shells as a replacement material in the construction history, indirectly reduce the costs production of concrete because of the characteristics found in it better than material that commonly used in production of concrete. Besides, coconut shell is potential materials for the development of new composite material in concrete mix design because of their high strength and modulus properties. By replacing coconut shells with coarse aggregate it develops its strength. And coconut shells concrete has better workability because of smooth surface of one side of the shell. The impact resistance of coconut shell concrete is high when compared with conventional concrete. Moisture retaining and water absorbing capacity of coconut shell are more compared to conventional concrete. Using alternative material in place of natural aggregate in concrete production makes concrete as sustainable and environment friendly construction material

## LITERATURE REVIEW

The components of concrete include broken stone or gravel, sand, cement, and water. Concrete is a type of construction material. It is the second most used substance on the planet because of its versatility in being manufactured from locally accessible resources, its simplicity in shaping it into any form or size, and the cost-effectiveness of its production. Concrete is manufactured in greater quantities than any other man-made substance. Every individual on the globe receives one ton of annual output, which is a significant amount. It is extremely adaptable and may be found in virtually all major building projects due to its versatility. Aggregates are utilized in concrete for a variety of functions that are quite specialized. When it comes to concrete, aggregates generally account for 50 percent to 70 percent of the total volume

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of the mixture. Because they are the least expensive of all the elements used in concrete, the economic effect is substantial as well. Seventy-five percent of CO2 emissions from buildings are created not by the manufacturing of the materials used in their construction, but rather by the electrical utilities required by the structure during its life-cycle. Concrete is less expensive to make than other equivalent construction materials, and it stays relatively inexpensive when compared to other comparable building materials. A research effort has been undertaken in order to meet the needs of society in terms of trash disposal that is both safe and cost-effective. The utilization of waste materials helps to save natural resources and landfill space, while also contributing to the preservation of a clean environment. It is believed that the existing concrete building method is unsustainable since it not only consumes vast amounts of stone, sand, and drinking water, but it also consumes two billion tons of Portland cement each year, which emits greenhouse gases that contribute to global warming. There have been experiments done on a variety of waste materials, including rubber tires, e-waste, coconut shells, blast-furnace slag, waste plastic, destroyed concrete components, and waste water. Many nations have now established construction waste recycling facilities. However, these facilities only provide a partial answer to the waste problem. The depletion of aggregate reserves, environmental deterioration, and ecological imbalance are all negative effects of the rising demand for concrete, according to the World Bank. Because of the prospect of full depletion of aggregate supplies, the continuous use of aggregates for building is no longer economically feasible. Rapid development in the building sector results in the depletion of conventional natural aggregate sources at an alarmingly rapid rate. A common complaint about conventional concrete is that it is weak in tensile strength and brittle, and that it is easily erodible by chemicals and high-velocity water flow. A position in the concrete construction industry has been established as a result of the strong compressive and tensile strengths of epoxy resin, as well as its outstanding adhesive qualities. Recent years have seen a significant increase in the number of applications using the bonding of concrete to concrete in the restoration of damaged or degraded construction. Despite the fact that epoxy concrete, which is made by mixing an epoxy resin compound with concrete components, has high compressive and tensile strengths, it is not widely used. The demand for building materials has increased as a result of infrastructure development throughout the world. Concrete is the most widely used material in civil engineering. Concrete production necessitates the use of materials such as cement, aggregates, water, and chemical admixtures. Aggregates account for the majority of the total number of components. Approximately two billion tons of aggregate are generated in the United States each year. Production is anticipated to rise to more than a billion tons

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per year by next year in the same way as the consumption of primary aggregate in the United Kingdom increased from 100 million tons in 1960 to over 280 million tons in 2006. The use of natural aggregates at such a high pace raises the question of how long natural aggregate sources will be available for use. Apart from that, the operations related to the extraction and processing of aggregates are the primary sources of environmental pollution. This is reflected in the fact that, in current civil engineering construction, the use of alternative materials in place of natural aggregate in the manufacture of concrete results in concrete being a more sustainable and ecologically friendly building material. Coconut shell, being a durable and not readily degraded material, if crushed to the size of sand, can be used as a viable alternative to sand in construction projects. At the moment, coconut shells are also being burned to generate charcoal and activated carbon, which are used in the production of food and carbonated beverages, as well as the filtration of mineral water. In certain areas, the coconut shell, on the other hand, is still underutilized. The coconut shell has a chemical makeup that is comparable to that of wood. It includes 34 percent cellulose, 40 percent lignin, 30 percent lignin, and 0.5 percent ash, among other things.

**B. Damodhara Reddy and colleagues (2014)** Presented in this study are the physical and chemical characteristics of coconut shell and coconut shell aggregate concrete, as well as the feasibility of using coconut shell aggregate in construction. When compared to conventional aggregate, the moisture content and water absorption were 4.20 percent and 24 percent, respectively. These values are higher than those of conventional aggregates. When crushed, the density of the coconut shell may be as high as 550-650 kg/m3, which is well within the boundaries of what, is required for light weight aggregate.

**Daniel Yaw Osei and colleagues (2013)** According to the findings of his publication, there is potential for the use of coconut shell as a replacement for conventional aggregate in both conventional reinforced concrete and light-weight reinforced concrete. Coconut shell concrete aids in the protection of natural resources.

**Yogesh Narayan Sonawane and colleagues (2016)** In their diary, they talked about a variety of different topics. It has been discovered that coconut shell concrete offers greater workability due to the smooth surface on one side of the shell, which was discovered during the research. As long as the sugar is not in a free sugar form, the presence of sugar in the CS will have no effect on the setting strength of concrete. The shell does not disintegrate quickly due to the strong tissue that it is formed of, and it stays as a solid waste for many years.

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**Apeksha Kanojia and colleagues (2015)** According to this publication, the coconut shell has the additional benefit of having a high lignin concentration. It increases the weather resistance of the composites, and because the coconut shell has a low cellulose content, it absorbs less moisture when compared to other agricultural waste. Because the coconut shell is readily accessible due to the fact that its shells are non-biodegradable and because of the smooth surface on one side of the shell, concrete created from coconut shell has greater workability than concrete manufactured from other materials. It can be used as a substitute for aggregates in the production of concrete hollow blocks.

**Dr. B. Rajeevan and colleagues (2015)** According to the authors of this article, when compared to conventional aggregate, coconut shell exhibits greater resistance to crushing, impact, and abrasion than the latter. Because of this, there is no need to prepare the coconut shell before using it as an aggregate, and the coconut shell has the potential to serve as a lightweight aggregate in concrete applications. Additionally, utilizing coconut shell as an aggregate in concrete can help to minimize the cost of materials used in building.

**Dewanshu Ashlawat and colleagues (2014)** According to their findings, the coconut shell is classified as a lightweight aggregate in their research. When dried, the coconut shell includes significant amounts of cellulose, lignin, pentosans, and ash. The weights of the ingredients are used to determine the proportions of the materials. The water cement ratio is determined by the use of a variety of workability tests. Because of the high water absorption capacity of the coconut shell, it was necessary to soak them in water for 24 hours before combining them. According to their experimental setup, they came to the conclusion that, after 10% replacement, concrete achieved 18.91 N/mm2, which was barely less than the minimum recommended for use as structural concrete according to the requirements. As the percentage of replacements grew, the strength of the system diminished. In proportion to the increasing surface area of the coconut shell, the amount of cement required for effective bonding increased. Because the cement concentration remained constant, there was no additional bonding and the strength decreased.

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**Kakade et al. (2015)** state that when coconut shell aggregates are capsulated into a concrete matrix, their sugar content does not affect the setting and strength of the concrete, as long as it is not in a sugar-free form. The conventional increase in strength also indicates that the coconut shell aggregate does not deteriorate once the coconut shell aggregates are capsulated into the concrete matrix, according to Kakade et al. Additionally, due to the increased porosity in the shell structure of the coconut shell aggregate, it has a higher water absorption rate. When compared to crushed stone aggregate, the aggregate impact value of coconut shell aggregates is significantly lower, indicating that the aggregates have high shock absorption. According to the findings of the study, the cost of manufacturing concrete can be lowered by up to 48 percent. Akshay S. Shelke and colleagues (2014) In this investigation, he demonstrates that crushed coconut shell is more resistant to crushing, impact, and abrasion than crushed granite aggregate when compared to the latter. The coconut shell, on the other hand, may be classified as a low- weight aggregate. The densities of coconut shell aggregate after 28 days in the open air are less than 2000 kg/m3, which is within the range of densities for structural light weight concrete. A coconut shell concrete that meets the standards of ASTM C 330 is used in construction.

According to the results of **Parag S.Kambli et al. (2014)**, oil palm shell is a waste product from the agriculture sector that is readily available in huge numbers. In this study, the compressive strength properties of concrete made using crushed, granular coconut as a substitute for typical coarse aggregate with partial replacement were investigated, with the goal of determining how well the concrete performs. The experimental program's goal was to determine the optimal mix proportion of CS used as coarse aggregate in concrete, as well as the feasibility of using CS as coarse aggregate in concrete in the first place. It was determined via experimental research that coconut shell may lower the cost of materials and is more suited for use as a lowstrength, light-weight aggregate in the concrete manufacturing process than other materials.

**S. Prema and colleagues (2017)** came to the conclusion that oil palm shell is a waste product from the agriculture industry that is readily available in huge numbers. In this study, the compressive strength properties of concrete made using crushed, granular coconut as a substitute for typical coarse aggregate with partial replacement were investigated, with the goal of determining how well the concrete performs.

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**Amarnath Yerramala and colleagues (2012)** investigated the strength of concrete with coconut shell (CS) replacement and other types of coarse aggregate replacement, as well as the transport characteristics of concrete with CS as coarse aggregate replacement. They came to the conclusion that increasing the CS% lowered the density of the concrete, and that increasing the CS% improved the 7-day strength gain, which was accompanied by an increase in the equivalent 28-day curing strength.

**According to J.P. RIES (2011),** lightweight aggregate (LWA) plays an important role in today's move towards sustainable concrete. Lightweight aggregates contribute to sustainable development by lowering transportation requirements, optimizing structural efficiency, which results in a reduction in the amount of overall building materials used, conserving energy, reducing labor demands, and increasing productivity in the construction industry. Maninder Kaur and colleagues (2012) published a paper in which they examined a variety of issues. In this study, it was discovered that utilizing coconut shell aggregates in concrete produced adequate strength requirements for structural concrete. The coconut shell-cement composite is friendly to the environment and does not require any pre-treatment. Coconut shell concrete has a high level of impact resistance due to its high density. The moisture-retaining and water- absorbing abilities of the coconut shell are exceptional.

**MIX DESIGN FOR M20 GRADE OF CONCRETE**

Mix design is a crucial process in concrete construction, involving the selection and proportioning of ingredients to achieve the desired properties and performance of concrete. It's a systematic approach that considers factors such as strength, durability, workability, and economy to create a concrete mix tailored to specific project requirements.

**Step 1: Stipulation for proportioning**

a) Grade designation : M20
b) Types of cement : PPC 53 grade

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c) Maximum nominal size of coarse aggregate : 20mm
d) Minimum water content : 345kg/m3 (As per IS: 456-2000)
e) Maximum water cement ratio : 0.5 (As per IS: 456-2000 Table 5)

**Step 2: Test data for materials**

a) Cement used : PPC 53 grade
b) Specific gravity of cement : 2.5
c) Specific gravity of
Coarse aggregate : 2.87
Fine aggregate : 2.67

**Step 3: Determination of target strength**

Standard deviation (σ) for M20 IS 4.0 taken as per IS-10262- 2019 Target Strength = fck + 1.65 ×σ

= 20 + 1.65 × 4.0

= 26.6 N/mm$^2$

**Step 4: Selection of water-cement ratio**

Adopt water-cement ratio = 0.5

**Step 5: Water content**

For 20mm nominal maximum size of aggregate, water content per cubic meter of concrete

= 186L

**Step 6: Selection of cement content**

Water cement ratio = 0.5
Cement content = 186/0.5
= 372 Kg/m$^3$

**Step 7: Volume of Coarse aggregate and Fine aggregate**

As per IS 10262-2009 Table No.3 Volume
of coarse aggregate = 0.62m$^3$
Volume of fine aggregate = (1-volume of C.A)

= 1-0.62

= 0.38m$^3$

**Step 8: Mix Calculation**

Volume of concrete = 1m$^3$

Volume of cement = mass of cement/specific gravity × 1000

= (372/2.5) × (1/1000)

= 0.1488m$^3$

Volume of water = mass of water/specific gravity of water×1000

= (186/1) × (1/1000)

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= $0.186m^3$

Volume of all in aggregate = 1-(0.1488+0.186)

= $0.66m^3$

Coarse aggregate =0.66×0.62×2.87×1000

= $1174.404Kg/m^3$

Fine aggregate = 0.66×0.38×2.67×1000

= $669.636Kg/m^3$

**Step 9: Mix proportion**

For $1m^3$ of concrete

Cement = 372 $Kg/m^3$

Fine aggregate = 669.636 $Kg/m^3$

Coarse aggregate = 1174.404 $Kg/m^3$

Volume of water = 186 L

**For 1 Cubical block (150 × 150× 150mm)**

Cement = 1.360 kg

Fine aggregate = 2 kg

Coarse aggregate = 4 kg

**For 9 cubical block**

Cement = 12 kg

Fine aggregate = 18 kg

Coarse aggregate = 36 kg

**RESULTS AND CONCLUSION**

The compression test is widely regarded as the most common test conducted on hardened concrete due to its direct correlation with many desirable characteristic properties. This test is crucial because the compressive strength of concrete serves as a fundamental indicator of its overall quality and performance in structural applications.

During the compression test, specimens in the form of cubes are subjected to increasing compressive loads until failure occurs. These cube specimens typically have dimensions of 150×150×150 mm, adhering to standard testing protocols. The size and shape of the cubes allow for uniform loading and accurate measurement of compressive strength.

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Compressive strength, measured in megapascals (MPa) or pounds per square inch (psi), represents the maximum load-bearing capacity of concrete under axial compression. It indicates the ability of concrete to withstand applied loads and resist deformation or failure. Various factors, including the quality of materials, mix proportions, curing conditions, and age of concrete, influence the compressive strength.

The results of compression tests provide valuable insights into the structural integrity, durability, and serviceability of concrete elements, such as beams, columns, slabs, and foundations. Engineers use these test results to assess the suitability of concrete mixes for specific design requirements, verify compliance with industry standards and specifications, and ensure the safety and reliability of constructed structures.

In short, the compression test on concrete cube specimens serves as a critical quality control measure, offering quantitative data on compressive strength and guiding engineering decisions throughout the design, construction, and maintenance phases of infrastructure projects.

The study aims to investigate the compressive strength of concrete when natural coarse aggregate is partially substituted with waste coconut shell. The concrete grade selected for this investigation is M-20. The concrete mix proportions are maintained as per standard practice, with the ratio of cement to fine aggregate to coarse aggregate.

Compression strength tests are conducted on cube samples using a compression testing machine. Each batch consists of three samples, and the average strength values are reported in the study. The replacement levels of natural coarse aggregate with coconut shell are set at 10%, 20%, and 30% by weight of M-20 grade concrete.

Cube specimens with dimensions of 150×150×150mm are examined, and the compressive strength results are analyzed after curing periods of 7, 14, and 28 days. Curing is essential for allowing the concrete to gain strength and achieve its full potential properties over time.

The study seeks to understand how the incorporation of waste coconut shell as a partial replacement for natural coarse aggregate affects the compressive strength of the concrete at different curing durations. By evaluating the performance of the concrete mixes at various substitution levels and curing periods, valuable insights can be gained into the feasibility and potential benefits of utilizing coconut shell waste in concrete production.

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Compressive strength= Maximum load/Area

**Table 1: Compressive strength of concrete replaced with coconut shell at 7 days**

| S.N0 | Specimens | Coarse aggregate (kg) | Coconut shell(g) | Date of casting | Date of testing | Weight of cube | Load (KN) | Compressive strength |
|---|---|---|---|---|---|---|---|---|
| 1 | M1 | 3.9 | 100 | 14/05/24 | 20/05/24 | 7252 | 320 | 14.22 |
| 2 | M1 | 3.9 | 200 | 14/05/24 | 20/05/24 | 7310 | 360 | 16.00 |
| 3 | M1 | 3.9 | 300 | 14/05/24 | 20/05/24 | 7289 | 350 | 15.55 |

**Table 2: Compressive strength of concrete replaced with coconut shell at 14 days**

| S.N0 | Specimens | Coarse aggregate (kg) | Coconut shell(g) | Date of casting | Date of testing | Weight of cube | Load (KN) | Compressive strength |
|---|---|---|---|---|---|---|---|---|
| 1 | M2 | 3.8 | 100 | 14/05/24 | 27/05/24 | 7440 | 420 | 18.66 |
| 2 | M2 | 3.8 | 200 | 14/05/24 | 27/05/24 | 790 | 450 | 20.00 |
| 3 | M2 | 3.8 | 300 | 14/05/24 | 27/05/24 | 7435 | 410 | 18.22 |

**Table 3: Compressive strength of concrete replaced with coconut shell at 28 days**

| S.N0 | Specimens | Coarse aggregate (kg) | Coconut shell(g) | Date of casting | Date of testing | Weight of cube | Load (KN) | Compressive strength |
|---|---|---|---|---|---|---|---|---|
| 1 | M3 | 3.7 | 100 | 14/05/24 | 10/06/24 | 8149 | 510 | 22.66 |
| 2 | M3 | 3.7 | 200 | 14/05/24 | 10/06/24 | 8477 | 540 | 24.00 |
| 3 | M3 | 3.7 | 300 | 14/05/24 | 10/06/24 | 8412 | 520 | 23.11 |

**Table 4: Comparison of Compressive strength N/mm$^2$**

| S.NO | Specimens | 07 days | 14 days | 28 days |
|---|---|---|---|---|
| 1 | 10% aggregate replace with coconut shell | 15.55 | 18.66 | 22.66 |
| 2 | 20% aggregate replace with coconut shell | 14.22 | 18.22 | 24.00 |
| 3 | 30% aggregate replace with coconut shell | 16.00 | 20.00 | 23.11 |

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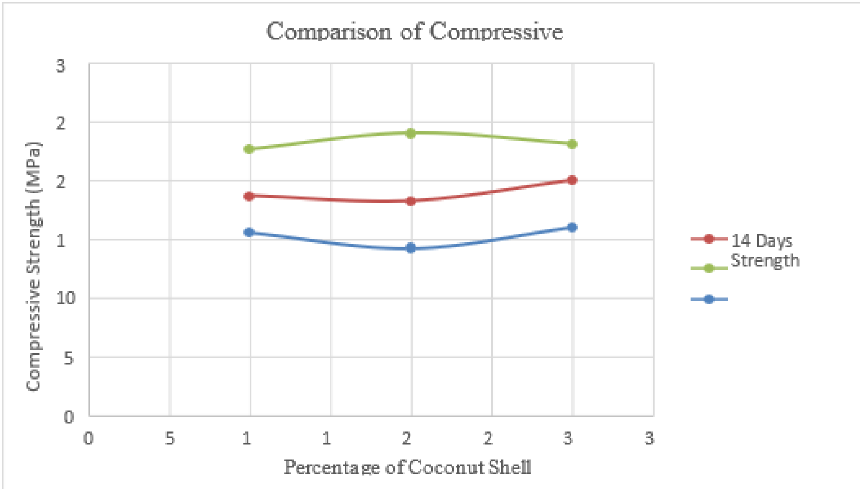


**Figure 1: Comparison of Compressive Strength at different percentage of coconut shell**

**Concluding Remark**

The utilization of waste materials in construction has gained significant attention in recent years due to its potential to enhance sustainability and reduce environmental impact. In the context of concrete production, incorporating alternative aggregates such as coconut shell has been explored as a means to not only mitigate waste disposal issues but also to improve concrete properties. The findings of the tests conducted in this study underscore the promising benefits of replacing coarse aggregate with coconut shell in M20 grade concrete.

Firstly, the test results reveal a notable increase in various properties of the concrete when coconut shell is used as a partial replacement for coarse aggregate. This observation suggests that coconut shell aggregates possess inherent characteristics that positively influence the performance of the concrete mix. Specifically, there is a significant enhancement in workability, indicating improved ease of handling and placement during construction activities. Additionally, there is a substantial increase in compressive strength, which is a critical parameter governing the structural integrity and load-bearing capacity of concrete elements. These findings highlight the potential of coconut shell aggregates to enhance both the fresh and hardened properties of concrete compared to plain cement concrete of M20 grade.

Moreover, the study identifies an optimal range for the replacement of coarse aggregate with coconut shell in M20 concrete, ranging from 10% to 30%. Within this range, the concrete exhibits the most favorable combination of workability and compressive strength. This finding is crucial for concrete producers and construction practitioners as it provides guidance on the appropriate dosage of coconut shell aggregates to achieve desired performance levels in concrete mixes.

Furthermore, the economic implications of incorporating coconut shell aggregates into concrete are also examined. The cost comparison between plain cement concrete of M20 grade and concrete with 10% to 30% replacement of coarse aggregate by coconut shell reveals a significant reduction in cost per cubic meter of concrete. This cost savings could have profound implications for construction projects, potentially leading to overall cost reduction without compromising the quality or performance of the concrete structures.

In conclusion, the findings of this study underscore the potential of coconut shell aggregates as a sustainable alternative to traditional coarse aggregates in concrete production. The observed improvements in workability, compressive strength, and cost-effectiveness highlight the viability of incorporating coconut shell aggregates in concrete mixes, particularly in the context of M20 grade concrete. Moving forward, further research and implementation efforts in this direction could contribute to the development of more sustainable and cost-effective construction practices.

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