STRENGTH OF CONCRETE BY USING COCONUT COIR FIBER AS PARTIAL REPLACEMENT OF CEMENT

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Abstract

The increasing demand for sustainable construction materials has led to the exploration of industrial waste as potential alternatives in concrete production. This study investigates the feasibility of using coconut coir fiber as a partial replacement for cement in concrete to enhance workability and strength characteristics. Various concrete mixes were prepared by replacing cement with coconut coir fiber at proportions of 1.5%, 2.5%, 3.5% by weight. Comprehensive tests were conducted to evaluate the workability, compressive strength, split tensile strength, and durability of the mixes at different curing periods. The results indicate that the incorporation of coconut coir fiber up to an optimal percentage, can significantly enhance the mechanical properties of concrete while promoting the reuse of industrial waste. This experimental study demonstrates the potential of coconut coir fiber as a sustainable material in cementitious applications, contributing to environmental conservation and resource efficiency in the construction sector.

The rapid growth of the construction industry has significantly increased the demand for cement, contributing to environmental challenges such as high energy consumption, greenhouse gas emissions, and depletion of natural resources. In response, this study explores the use of coconut coir fiber as a partial replacement for cement in concrete.

This experimental investigation involves the preparation of concrete specimens in which Pozzolanic Portland cement (PPC) is partially replaced with cococnut coir fiber in varying proportions: 0% (control mix), 1.5%, 2.5%, 3.5% by weight.. The mechanical and durability properties of the concrete are evaluated through standardized tests, including slump test for workability, compressive strength test, split tensile strength test, and water absorption test at 7 and 28 days of curing.

The results reveal that coconut coir fiber can be effectively utilized as a supplementary cementitious material up to an optimum replacement level—typically around 1.5-2.5%—without compromising, and in some cases even enhancing, the strength and durability of concrete. Beyond the optimal percentage, however, further replacement leads to reduced mechanical performance due to increased porosity and lower cement content.

Overall, this research demonstrates that coconut coir fiber, offers a viable and eco-friendly alternative to partial cement replacement. This approach not only reduces the environmental burden associated with coconut coir fiber disposal but also contributes to sustainable construction practices by lowering the carbon footprint of concrete production.

Key Words – Cement, coconut coir fiber, compressive strength, flexural strength.

Introduction-

The construction industry is a well-recognized contributor to various environmental challenges, including air pollution, climate Change, drinking water contamination, and substantial landfill waste. The severity of these environmental threats has prompted growing interest in exploring sustainable solutions to mitigate the Environmental footprint of the construction industry, including the utilization of natural fibres. As the primary building material in construction, concrete plays a pivotal role in shaping the environmental impact of the industry. However, traditional concrete often lacks the desired mechanical properties required for sustainable and environmentally Friendly construction. To address this limitation, researchers have to enhance concrete performance by incorporating natural Fibres. India is a major producer of coir fibre, with a production of approximately 280,000 metric tons of coir fibre.

Coconut coir fiber has high tensile strength making it suitable for heavy duty application. The density of coconut coir fiber is 1.4g/cm^3.

This study aims to assess the feasibility of using coconut coir fiber as partial replacement for cement to make construction environmmentally and sustainable construction.the replacement is in varying propotional ex. 1.5%,2.5%,3.5%.

The research objective of this study are as follows:

1.to examine the physical and chemical properties of coconut coir fiber

2.to determine the suitanbility as cement replacement.

3.to develop concrete mix.

4.to indentify the optimaum replacement level of coconut coir fiber.

5.to promot sustainable construction.

Literature Review

1)Krishna Guruswamy, Kirti Jalgaonkar [2024]: This research explores the potential of coir fibre as a sustainable and effective reinforcement Material to enhance the compressive strength (CS) of concrete. The influence of the fibre volume Fraction (FVF) and fibre length (FL) on the CS of the coir fibre reinforced concrete was studied Using the response surface method (RSM). The selected range for the FVF was from 4 % to 12 %, And the FL varied from 0.4 cm to 1.2 cm, as per the experimental design. The research determined That the coir fibre with an FVF of 4 % and an FL of 10 mm yielded the maximum CS for the Reinforced concrete cubes, measuring 34 N/mm2. Furthermore, an increase in fibre content was Observed to lead to a decrease in the workability of coir fibre-reinforced concrete. Furthermore, Fourier transform infrared spectroscopy (FTIR) and X-ray diffraction (XRD) analyses of the Control and coir fibres extracted from the concrete cubes after a period of 1 year indicated no Significant changes in the functional properties, thermal properties and crystallinity of the fibres.

2)Shri Rama Chand Madduru [2020]: Now a days the cost of construction increases along with gradual effect on the environment and it has led the researchers to the acceptance of natural fibers such as coconut fibers for improving the strength in concrete. Coconut fibres that are abundantly accessible at the test site making it relatively applicable as a reinforcing material in concrete. Concrete with different fiber contents was evaluated with conventional concrete or prestressed concrete and different strengths parameters such as bending, compression and tensile strength of coconut fiber varies with a proportion (0.6% and 1.2%) of total weight of the volume of concrete coconut fiber is carried out. The effect of fiber shape on strength property studied by testing with coconut fibre mesh from pre-defined dimension. The optimum percentage of both treated fibre yarn and raw fibre nets was found with trial-and-error process and maximum percentage of superplasticizer needed to both ordinary cement as well as coconut fibers in the concrete for basic operability was also determined. 2020 Elsevier Ltd. All rights reserved. Selection and peer-review under responsibility of the scientific committee of the First International conference on Advanced Lightweight Materials and Structures.

3)Prasana Kumar [2024]: This paper presents an experimental study on coconut fibres grains using partial replacement method. The Goal of the project is to improve the strength of concrete and minimize the emission of carbon dioxide. Coconut fibre grains are the natural materials which is plentifully available in tropical region .The coconut Fibre grains are replaced with fine aggregate by a percentage replacement of 1 %,3 %,5 % and 7 %.The Fresh and hardened properties of Conventional Concrete (CC) and Concrete with Coconut Fibre Grains (CCFG) such as Slump test, Compressive strength ,Split tensile strength and Flexural strength Test of Concrete mixes are found for 7 days and 28 days of curing period and results are found and compared with The Conventional Concrete.

4)S.O.Osuji, U.Ukeme [2024]: This work studies the compressive strength of concrete partially replaced at various Percentages of the cement content by volume with coconut (cocos nucifera) fibres. Three common mix ratios of 1:2:4. 1:1.5:3 and 1:3:6 (cement: fine aggregate: coarse Aggregate) ratios by volume were used for the study. Natural river sand and crushed Granite stones were used for the fine and coarse aggregates while the coconut fibres Were sourced from Ugonna Village in Edo State, Nigeria. For the three mixes used Percentage replacement by volume ranged from 5 to 35. The results showed that as the Percentage of fibre increased, the mixes became less workable. In the 1:2:4 mixes at 28 days curing period, the highest average compressive strength was 28.97N/mm2 (0% replacement) while at 35% replacement the lowest average compressive strength Of 17.11/mm2 was recorded. For 1:1.5:3 mix at 28 days curing the corresponding Values were 29.78N/mm and 17.44N/mm respectively for 0% and 35% Replacements. In the 1:3:6 the compressive strength at 28 days were 15.32N/mm and 11.41N/mm respectively. The variation of compressive strength from the control mix (0% replacement) were found to be maximum of 34.12% replacement for 1:2:4 mix, 41.44% for 1:1.5:3 concrete mix and 25.52% for 1:3:6 concrete mix, all at 35% partial Replacement of coconut fibre. Coconut fibre has the enormous advantage of being Sourced cheaply as a waste product. It is therefore recommended that coconut fibre be Utilized as a partial replacement in making concrete where concrete strength required Are met.

5)Aliu Adekunle O., Fakuyi Fummi [2022]: This research is necessary as a result of the constant and sudden failure of concrete structures as well as the prior and obvious cracks in buildings. The use of coconut fibre to increase concrete's bearing capacity was looked into. A concrete beam measuring 50mm x 50mm x 1000mm, coconut fibre was added in varying amounts of 1%, 2%, 3%, 4% and 5% by weight in partial replacement of cement. Load Testing was done on the produced samples on days 7, 14,21, and 28. It was found that concrete made with coconut fibres tends to be more load-resistant, and able to prevent the concrete from breaking apart after failure than conventional concrete. Concrete's future will change as a result of the use of coconut fibre, which has the potential to support is therefore recommended that coconut fibre be Utilized as a partial replacement in making concrete where concrete strength required Are met.

5)Aliu Adekunle O., Fakuyi Fummi [2022]: This research is necessary as a result of the constant and sudden failure of concrete structures as well as the prior and obvious cracks in buildings. The use of coconut fibre to increase concrete's bearing capacity was looked into. A concrete beam measuring 50mm x 50mm x 1000mm, coconut fibre was added in varying amounts of 1%, 2%, 3%, 4% and 5% by weight in partial replacement of cement. Load Testing was done on the produced samples on days 7, 14,21, and 28. It was found that concrete made with coconut fibres tends to be more load-resistant, and able to prevent the concrete from breaking apart after failure than conventional concrete. Concrete's future will change as a result of the use of coconut fibre, which has the potential to support heavier loads while also providing an escape route in the event of failure. Its exhibited property compared to conventional concrete shows that it can be adopted in seismic resistant lightweight structures with the introduction of 2% replacement of cement with coconut fibre to achieve higher strength.

6)Sanjay Kumar Yadav, Avinash Singh [2019]: Fibers have the property to enhance the Toughness of concrete. The cost of construction has Skyrocketed together with the deteriorative impact on setting. This resulted in the adoption of a more balanced approach With the environment as its nerve centre to create a better World to live in. This has led to the adoption of a fibre like Coconut for the strength sweetening in concrete. Coconut fibre Is obtainable in abundance, which makes it quite viable as a Reinforcement material in concrete. This paper presents a Experimental discussion on the subject of coconut fibre Reinforced concrete, CFRC. It discusses usually used terms and Models of behaviour that kind a basis for understanding Material performance with presenting mathematical details. In this research it is shown that flexural strength of coconut Fiber reinforced concrete is directly proportional to the Coconut fibre content and inversely proportional to the Water-cement ratio. This study aimed toward analyzing the variation in strength of Coconut fibre concrete at variable fiber contents and to Establish it with that of conventional concrete. The various Strength aspects analysed are the flexural, compressive and Lastingness of the coconut fiber concrete at variable Percentages (1%, 2%, 3%, 4%, 5%) by the load of cement of Fiber. Result data clearly shows percentage increase in Compressive strength for M20 grade of concrete in 7 days and 28 days with respect to the variation in % addition of coconut Fibers. This research is based on the use of coconut fibres in Structural concrete to enhance the mechanical properties of Concrete.

7)Basi Kalyan [2023]: Concrete needs to be reinforced in order to improve its engineering qualities. Coconut fibres were employed for this study since they are widely accessible and come in big numbers. The study includes a comparison of the qualities of regular concrete and concrete reinforced with coconut fibre based on laboratory experimentation. Better management of these waste fibres will result from the usage of coconut fibres. The study discovered that 1%, 2% and 3% of ideal fibre content (by weight of cement). To identify the ideal range of fibre content so that fibre reinforced concrete can be made, additional effort is needed by adjusting the fibre content and aspect ratio.

8)Girum Urgessa, Yared Shiffraw [2017]: The use of natural fibres in concrete has significantly increased in recent years as a Result of the push for sustainable construction. Coconut fibres, also known as coir Fibers, have been used as natural fibres in concrete, particularly in some parts of Asia. This paper presents an experimental study that investigates the use of coconut fibres in Concrete. Two baseline concrete mix designs were selected based on design standards with a water-cement ratio of 0.4 and 0.5 respectively. For each baseline mix design, 20 cm x 20 cm x 1 cm concrete plates were constructed by varying the percentage Of coconut fibres by weight of cement. The fibre contents studied are 0%, 0.1%, 0.175%, and 0.25%. The concrete plates were then tested to determine the mechanical Properties of the coconut fibre-reinforced concrete and comparisons were made with the mix designs with 0% coconut fibre content. The results show that adding coconut Fibers increases the flexural strength of concrete plates. This is particularly beneficial for low scale construction applications such as those in concrete tile production. For Both mix designs, adding 0.25% of coconut fibres increased the flexural strength of the Concrete plates by 90% when compared to concrete with no coconut fibres.

9)Markssuel Teixeira Marvila [2023]: The use of plant fibres in cementitious composites has been gaining prominence with the Need for more sustainable construction materials. It occurs due to the advantages natural fibres provide to these composites, such

as the reduction of density, fragmentation, and propagation of cracks in concrete. The consumption of coconut a fruit grown in tropical countries, generates shells that are improperly disposed of in the environment. The objective of this paper is to provide a comprehensive Review of the use of coconut fibres and coconut fibre textile mesh in cement-based materials. For this purpose, discussions were conducted on plant fibres, the production and characteristics of coconut Fibers, cementitious composites reinforced with coconut fibres, cementitious composites reinforced with textile mesh as an innovative material to absorb coconut fibres, and treatments of coconut Fibre for improved product performance and durability. Finally, future perspectives on this field of Study have also been highlighted. Thus, this paper aims to understand the behaviour of cementitious Matrices reinforced with plant fibres and demonstrate that coconut fiber has a high capacity to be Used in cementitious composites instead of synthetic fibres.

Material Used-

1.Cement

Cement, one of the most important building materials, is a binding agent that sets and Hardens to adhere to building units such as stones, bricks, tiles, etc. Cement generally refers to a very fine powdery substance chiefly made up of limestone (calcium), sand or clay (silicon), bauxite (aluminum), and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate. The raw ingredients are processed in cement manufacturing plannts and heated to form a rock-hard substance, which is then ground into a fine powder to be sold. Cement mixed with water causes a chemical reaction and forms a paste that sets and hardens to bind individual structures of building materials.

2. Fine Aggregate

Fine aggregates are small-sized particles, each with a specific fine aggregate size classification, used extensively in construction. They typically consist of sand, crushed stone, or crushed slag with a diameter of less than 9.5 mm. These aggregates are essential In mixing concrete and mortar to give the mixtures a smoother consistency. Fine aggregates also help fill the tiny gaps between larger stones in concrete, improving the structure’s overall stability and appearance. They are crucial for achieving the right texture and strength in various construction projects.

3. Coarse Aggregate

Coarse aggregates are granular materials. It is often used in construction for concrete making. Its major composition includes crushed stone, gravel, or recycled concrete. Coarse aggregates typically accounts for more than 60-80% of the volume of the concrete. Their durability depends on the quality of the coarse aggregate, significantly impacting the strength and workability of the concrete. Coarse aggregates are classified as those larger than 4.75 mm according to sieve analysis, with a common diameter range between 3/8 inch (approximately 9.5 mm) and 1.5 inch

4.Coconut coir fiber

The most well-known fibrous by-product of coconut farming is coconut fibre. Coconut fibres are inexpensive and are generally regarded as waste. Coconut fibre has the greatest toughness among all known natural fibres, which is the main reason for its selection. Coconut fibre is very cheap and locally available in developing countries. The world produces at least 30 million tons of coconuts annually, which are widely available in tropical countries coastal regions. The coconut husk has high lignin and phenolic content and is made up of 70% pith and 30% fibre. The individual fibre cells are each about 1 mm long and 10–20µm in diameter. They are hollow, narrow, and made of cellulose. The length and diameter of the raw coconut fibres range from 15 to 35 cm and 50 to 300µm, respectively. There are two types of coconut fibres, brown fibre extracted from matured coconuts and white fibres extracted from immature coconuts. Coconut fibres are stiff and tough and have low thermal conductivity. Coconut fibres are commercially available in three forms, namely bristle (long fibres), mattress (relatively short) and decorticated (mixed fibres). Coconut coir has a tensile strength of 15 to 327 MPa, an elongation of 10 to 75%, and has various sizes. Their diameter is from 0.1 to 0.6 mm, and its length is from 50 to 350 mm. It consists of 40% lignin, 54% cellulose, and 6% other water-soluble substances. Due to the high lignin content, coconut coir degradation can occur up to 10 years, taking longer than other natural fibres. Celluloseprovides higher mechanical strength (tensile and flexural) and rigidity than other fibers. Coir fibres maintain their tensile strength in wet conditions, have a higher coefficient of friction. Coir also called coconut fibre, is a natural fibre extracted from the outer husk of coconut.

AIM

The aim of this project is to study the behaviour of the coconut coir fibre, when it mixes with the concrete. That is when coconut fibre is replaced with cement in some percentage in concrete then the behaviour of the concrete is try to understand. That is study of strength of concrete also behaviour of concrete its compression and flexural strength.

OBJECTIVES

1] To study the workability of concrete.

2] To study the compression strength and flexural strength and slump test.

3] To achieve low-cost concrete.

4] To achieve lightweight structure.

5] To do propre utilization of natural waste.

6] To make more durable and sustainable concrete.

7] To make ecofriendly concrete.

8] To give proper toughness to the concrete.

9] To make beneficial for low scale construction application.

10]To improve performance and durability of concrete

Concrete Mix

The physical properties of blended cement (Portland cement replaced by 0%, 1.5%, 2.5%, 3.5% With constant water ratio concrete design mix of grade M30 was prepared and design mix was studied for compressive.

Cement	Fine Aggregate	Coarse Aggregate	Water
1	1.65	2.24	0.43
450 (kg)	746(kg)	1008 (kg)	197(kg)

Test for concrete

Compressive Strength

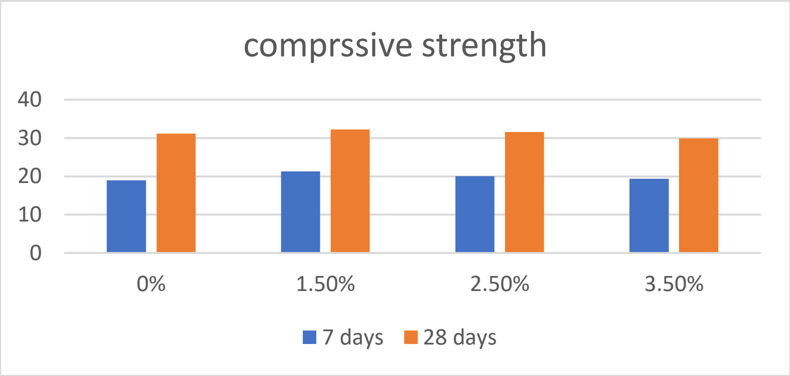
The compressive strength test on concrete cubes is one of the most commonly used methods to assess the load-bearing capacity and overall quality of concrete. This test involves casting standard cube specimens, usually of size 150 mm × 150 mm × 150 mm, using freshly mixed concrete. The cubes are filled in three layers, each layer compacted either manually with a tamping rod or using a vibration table to remove air voids. After casting, the specimens are kept at room temperature for 24 hours and then cured in water for specified periods, typically 7, 14, and 28 days. Once the curing period is complete, the cubes are taken out, allowed to surface dry, and tested using a compression testing machine (CTM). The cube is placed centrally in the machine, and a gradually increasing compressive load is applied until the specimen fails. The maximum load at failure is recorded, and the compressive strength is calculated by dividing this load by the cross-sectional area of the cube. The results help determine whether the concrete mix meets the required strength specifications for structural applications. Usually, the average strength of three cubes is taken for accuracy, and results are compared against standard values based on the concrete grade, such as M20 or M25, as per codes like IS 516 or IS 456.

 # Calculations

Compressive Strength = P/A

Compressive Strength

%Replacement (coconut coir fiber)	7days Compressive Strength (N/mm^2)	28days Compressive Strength (N/mm^2)
0%	18.94	31.14
1.5%	21.28	32.29
2.5%	20.09	31.55
3.5%	19.36	29.95



Tensile Strength

The tensile strength of concrete is commonly determined using the split tensile strength test, which is an indirect method due to the difficulty of applying a pure tensile load on concrete. Although cylinders are the standard specimen type, concrete cubes can also be used in this test with some adjustments. In this method, the cube is placed horizontally in a compression testing machine, and a compressive load is applied along one of its vertical diameters. As the load increases, it induces tensile stress perpendicular to the loading direction, ultimately causing the specimen to split vertically.

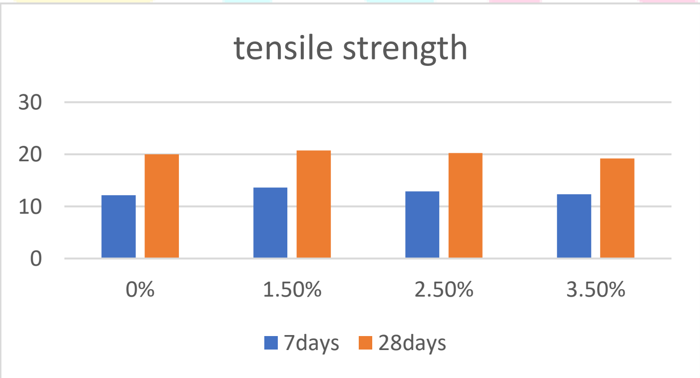
Where P is the maximum applied load in Newtons, L is the length of the specimen (in mm), and d is the width (in mm). For cube specimens, L and d are typically equal (e.g., 150 mm for a 150 mm cube). This formula assumes the tensile failure occurs along the vertical plane due to the induced lateral tension. The result gives the indirect tensile strength of the concrete, which is essential for understanding how the material will perform under cracking or flexural stresses in real structures. This method is simple and effective, providing a good approximation of tensile strength for quality control and research purposes.

#Calculation

Tensile Strength = 0.642P/A

Tensile Strength

%Replacement (coconut coir fiber)	7days Tensile Strength (N/mm^2)	28days Tensile Strength (N/mm^2)
0%	12.15	19.99
1.5%	13.66	20.73
2.5%	12.89	20.25
3.5%	12.37	19.22



Flexural strength

The flexural strength test, also known as the modulus of rupture test, is performed to determine the ability of concrete to resist bending or flexural tension. This test is typically carried out on concrete beam specimens, usually measuring 100 mm × 100 mm × 500 mm or 150 mm × 150 mm × 700 mm. After proper casting and curing, the beam is placed in a flexural testing machine where a load is applied either at one-third points (two-point loading) or at the center (single-point loading), depending on the standard being followed (e.g., IS 516 or ASTM C78). As the load increases, the beam experiences tension at the bottom and compression at the top. The specimen eventually fails due to tensile stresses at the bottom surface.

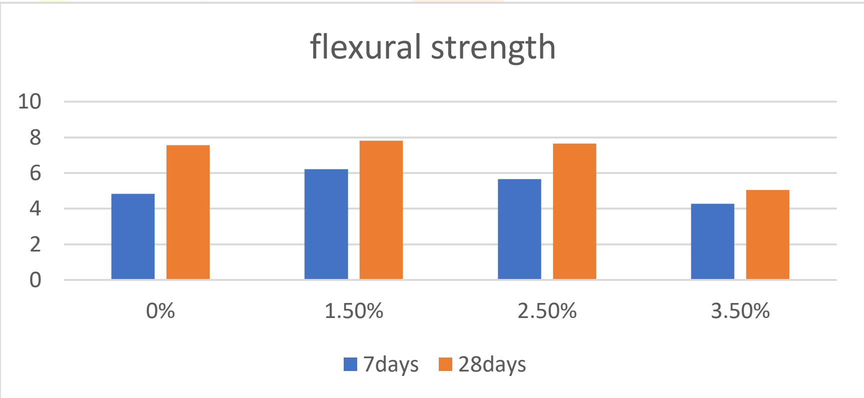
For single-point loading, where P is the maximum applied load (N), L is the span length between supports (mm), b is the width, and d is the depth of the beam. In two-point loading, a different formula is used depending on the loading points. This test provides valuable data for the design of concrete pavements, beams, and other structural elements subjected to bending. Flexural strength is typically 10% to 20% of compressive strength, and although concrete is weak in tension, this test helps predict its cracking behavior under flexural loads.

#Calculation

Flexural Strength = PL/BD^2

Flexural Strength

%Replacement (coconut coir fiber)	7days Flexural Strength (N/mm^2)	28days Flexural Strength (N/mm^2)
0%	4.83	7.56
1.5%	6.21	7.81
2.5%	5.66	7.65
3.5%	4.28	5.04



Conclusion

1. Compressive Strength of M30 grade of concrete for 7days at 0%,1.5%,2.5%,3.5% is 18.94N/mm2, 21.28N/mm2, 20.09N/mm2, 19.36N/mm2.

2. Compressive Strength of M30 grade of concrete for 28days at 0%,1.5%,2.5%,3.5% is 31.14N/mm2, 32.29N/mm2, 31.55N/mm2, 29.95N/mm2.

3. Tensile Strength of M30 grade of concrete for 7days at 0%,1.5%,2.5%,3.5% is 12.15N/mm2, 13.66N/mm2, 12.89N/mm2, 12.37N/mm2.

4. Tensile Strength of M30 grade of concrete for 28days at 0%,1.5%,2.5%,3.5% is 19.99N/mm2, 20.73N/mm2, 20.25N/mm2, 19.22N/mm2.

5. Flexural Strength of M30 grade of concrete for 7days at 0%,1.5%,2.5%,3.5% is 4.83N/mm2, 6.21N/mm2, 5.66N/mm2, 4.28N/mm2.

6. Flexural Strength of M30 grade of concrete for 28days at 0%,1.5%,2.5%,3.5% is 7.56N/mm2, 7.81N/mm2, 7.65N/mm2, 5.04N/mm2.

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