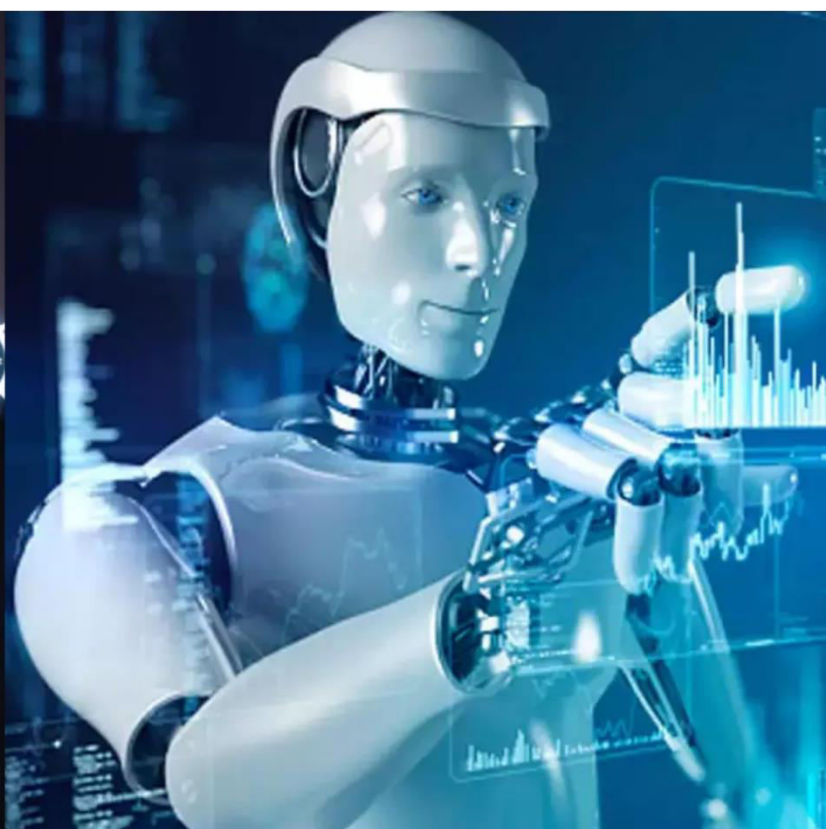




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Experimental Investigation on Compressive Strength of Alccofine Based Polypropylene Fiber Reinforced Concrete Using M-Sand

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ABSTRACT: The increasing demand for sustainable and high-performance cementitious composites has accelerated the use of supplementary cementitious materials (SCMs) and discrete fiber reinforcement to enhance the mechanical performance and durability of concrete. This experimental investigation evaluates the influence of Alccofine 1203 and polypropylene (PP) fibers on the fresh and hardened properties of M30 grade concrete incorporating manufactured sand (M-sand) as a complete replacement for natural river sand. Concrete mixtures were prepared by partially replacing Pozzolana Portland Cement (PPC) with Alccofine at 0%, 7%, 14%, and 21% by weight of cement, while maintaining a constant polypropylene fiber dosage of 0.5% (12 mm length) and a water-to-cement ratio of 0.42. A total of 24 cube specimens and 24 beam specimens were cast and cured for 7 and 28 days to evaluate compressive and flexural strength, respectively, in accordance with relevant Indian Standard specifications. The workability of fresh concrete was assessed using the slump cone test. The incorporation of Alccofine refined the pore structure through its ultrafine particle packing and high pozzolanic reactivity, promoting additional calcium silicate hydrate (C–S–H) gel formation and improving the interfacial transition zone (ITZ). Polypropylene fibers effectively bridged microcracks, delayed crack initiation and propagation, and enhanced the post-cracking response and flexural toughness of concrete. The combined action of Alccofine and polypropylene fibers produced superior mechanical performance compared with the control mixture while maintaining satisfactory workability. The findings demonstrate that Alccofine-based polypropylene fiber reinforced concrete using M-sand is a technically viable and environmentally sustainable alternative for structural applications requiring enhanced strength, crack resistance, and long-term durability.

KEYWORDS: Alccofine 1203, Polypropylene Fibers, M-Sand, M30 Concrete, Compressive Strength, Sustainable Concrete.

I. INTRODUCTION

Concrete is the principal construction material used in structural engineering owing to its high compressive strength, durability, mouldability, and economic viability. However, its quasi-brittle nature, low tensile strength, and limited fracture toughness make it susceptible to microcrack initiation and propagation under mechanical loading and environmental exposure. The progressive development of these microcracks accelerates the ingress of chlorides, sulphates, and moisture, resulting in deterioration of the cementitious matrix and premature corrosion of embedded reinforcement. Furthermore, the cement industry is responsible for a significant proportion of global anthropogenic CO₂ emissions, while excessive extraction of natural river sand has caused serious ecological degradation. These challenges have intensified research on sustainable cement-based composites incorporating supplementary cementitious materials (SCMs), fiber reinforcement, and manufactured aggregates to improve structural performance while minimizing environmental impact.

Among the emerging SCMs, Alccofine 1203 is an ultrafine, low-calcium slag with high specific surface area and pozzolanic reactivity that enhances cement hydration kinetics through the micro-filler effect and secondary hydration reactions. The formation of additional calcium silicate hydrate (C–S–H) gel refines the pore structure, densifies the interfacial transition zone (ITZ), and improves the mechanical and durability characteristics of concrete.

Simultaneously, the incorporation of polypropylene (PP) fibers provides multidirectional crack-bridging, restrains plastic and drying shrinkage cracking, enhances fracture energy, and improves post-peak ductility without being susceptible to corrosion. The replacement of natural river sand with manufactured sand (M-sand) further contributes to sustainable construction by providing better particle packing, improved aggregate interlocking, and consistent grading characteristics. The synergistic interaction between Alccofine, polypropylene fibers, and M-sand is therefore expected to produce a dense, crack-resistant, and mechanically superior cementitious composite suitable for structural applications.

The present investigation experimentally evaluates the influence of Alccofine 1203 as a partial cement replacement at 0%, 7%, 14%, and 21% by weight of cement in M30 grade polypropylene fiber reinforced concrete produced with 100 % manufactured sand as fine aggregate. Polypropylene fibers of 12 mm length were incorporated at a constant dosage of 0.5% by volume, while maintaining a water-to-cement ratio of 0.42. Fresh concrete performance was assessed through slump measurements, whereas hardened properties were characterized using compressive and flexural strength tests at 7 and 28 days. The study aims to establish the optimum Alccofine replacement level and to evaluate the combined effectiveness of ultrafine mineral admixture, synthetic fiber reinforcement, and manufactured sand in developing sustainable, high-performance concrete with enhanced strength, crack resistance, and long-term durability.

1.1 Materials Used:

1.1.1 PPC Cement:

Pozzolana Portland Cement (PPC) conforming to IS 1489 (Part 1) was used as the primary binding material. PPC was selected because of its improved durability, lower heat of hydration, and enhanced long-term strength. It also contributes to the formation of additional calcium silicate hydrate (C-S-H) gel, resulting in a denser and more durable concrete matrix.

1.1.2 Coarse Aggregate:

Crushed angular coarse aggregate of 20 mm nominal maximum size, conforming to IS 383:2016, was used. The aggregate was clean, durable, and free from deleterious materials, providing adequate strength and stability to the concrete.

1.1.3 Fine Aggregate (M-Sand):

Manufactured sand (M-sand) conforming to Zone II of IS 383:2016 was used as the fine aggregate. M-sand provides better particle grading, improved interlocking, and consistent quality compared to natural river sand, making it a sustainable alternative for concrete production.

1.1.4 Alccofine 1203:

Alccofine 1203, an ultrafine slag-based supplementary cementitious material, was used as a partial replacement for cement. Its high pozzolanic reactivity and micro-filling ability enhance hydration, refine the pore structure, and improve the compressive strength and durability of concrete.



Fig. 1 Alccofine 1203

1.1.5 Polypropylene Fibers:

Polypropylene fibers of 12 mm length were incorporated at a constant dosage of 0.5% by volume of concrete. The fibers improve crack resistance, ductility, flexural strength, and post-cracking behaviour by bridging microcracks within the cementitious matrix.

II. LITERATURE SURVEY

Sheetal R. Kathikara et al. (2025) Sheetal R. Kathikara et al. investigated sustainable high-performance concrete incorporating fly ash, GGBS, and polypropylene fibers. Their results indicated that the combined use of supplementary cementitious materials with 1.5% polypropylene fibers significantly improved compressive and split tensile strength at 28 days, while enhancing the overall sustainability of concrete.

Rameshwaran S. et al. (2025) Rameshwaran S. et al. evaluated the durability and microstructural characteristics of concrete containing Alccofine and polypropylene fibers. Their investigation demonstrated that the combined incorporation of these materials reduced porosity and water absorption while improving compressive strength and resistance to acid and sulphate attack through refinement of the concrete microstructure.

K. Meenatchi et al. (2023) K. Meenatchi et al. studied ternary blended concrete containing Alccofine, zeolite, and polypropylene fibers. The authors reported that the inclusion of 15% Alccofine and 0.3% polypropylene fibers considerably enhanced compressive strength, flexural strength, modulus of elasticity, and durability by reducing pore connectivity.

B.L.N. Sai Srinath et al. (2022) B.L.N. Sai Srinath et al. investigated the influence of Alccofine 1203 as a partial cement replacement in M40 concrete. Their experimental results showed that Alccofine substantially increased compressive strength because of its high pozzolanic activity and particle packing effect, with optimum performance observed at approximately 10–15% replacement.

Md. S. Shoaib Hussain et al. (2021) Md. S. Shoaib Hussain et al. examined concrete incorporating Alccofine and fly ash as partial cement replacements. The study concluded that the combined replacement improved workability, compressive strength, and split tensile strength, with the optimum performance achieved at 25% total replacement due to the complementary effects of Alccofine and fly ash.

Altamashuddin Khan Nadimalla et al. (2020) Altamashuddin Khan Nadimalla et al. investigated the feasibility of replacing natural river sand with manufactured sand. Their findings revealed that 55–100% M-sand replacement enhanced compressive and flexural strength while providing a sustainable alternative to conventional fine aggregate.

Sayali Baitule (2018) Sayali Baitule presented a comprehensive review on the application of Alccofine in concrete. The review highlighted that Alccofine improves workability, strength development, and durability, with 10–15% cement replacement identified as the optimum range for achieving superior concrete performance.

2.1 PROBLEM STATEMENT

The growing demand for durable and environmentally sustainable concrete has highlighted the limitations of conventional cement-based composites. Although ordinary concrete provides adequate compressive strength, its low tensile capacity, brittle fracture behaviour, and susceptibility to crack propagation often reduce structural durability and service life. Moreover, the high carbon footprint associated with Portland cement production and the continuous depletion of natural river sand have intensified the need for alternative materials that can improve concrete performance while reducing environmental impacts. Recent advances indicate that supplementary cementitious materials, synthetic fibers, and manufactured aggregates can significantly enhance the engineering properties of concrete when appropriately combined.

Despite the proven benefits of Alccofine 1203, polypropylene fibers, and manufactured sand (M-sand), existing research has predominantly investigated these materials individually or under high-strength concrete applications. Comprehensive studies addressing their combined influence on the fresh and mechanical properties of M30 grade concrete prepared with Pozzolana Portland Cement (PPC) remain limited. In particular, there is insufficient

understanding of the optimum Alccofine replacement level that can simultaneously improve compressive strength, flexural performance, crack resistance, and workability in fiber-reinforced M-sand concrete.

Therefore, the present investigation aims to experimentally evaluate the synergistic effect of Alccofine 1203, polypropylene fibers, and M-sand on the performance of M30 grade concrete. The study seeks to establish an optimum mix proportion capable of enhancing structural efficiency, durability, and sustainability while reducing cement consumption and dependence on natural river sand, thereby contributing to the development of high-performance concrete suitable for modern structural engineering applications.

2.2 SCOPE OF STUDY:

The scope of the present investigation is confined to evaluating the influence of Alccofine 1203 and polypropylene fibers on the fresh and mechanical properties of M30 grade concrete incorporating 100% manufactured sand (M-sand) as fine aggregate. The study focuses on determining the optimum Alccofine replacement level by partially replacing cement at 0%, 7%, 14%, and 21%, while maintaining a constant polypropylene fiber dosage of 0.5% by volume of concrete.

The experimental programme includes the assessment of workability using the slump cone test and the evaluation of hardened concrete properties through compressive strength tests at 7 and 28 days of curing. The research aims to analyze the combined effect of Alccofine, polypropylene fibers, and M-sand on strength development and crack resistance, thereby identifying a sustainable and high-performance concrete mix suitable for structural engineering applications. The study is limited to laboratory-scale investigations under controlled conditions and does not include durability tests, microstructural characterization, or long-term field performance evaluation.

III. METHODOLOGY

3.1 MIX DESIGN PROCEDURE:

The concrete mix was designed in accordance with IS 10262:2019 and IS 456:2000 for M30 grade concrete. A water-to-cement ratio (w/c) of 0.42 was adopted to achieve the target mean compressive strength while ensuring adequate workability and durability. Pozzolana Portland Cement (PPC) was used as the primary binder, and manufactured sand (M-sand) was employed as the fine aggregate. Alccofine 1203 was incorporated as a partial replacement of cement at 0%, 7%, 14%, and 21% by weight of cement, while polypropylene fibers (12 mm) were maintained at a constant dosage of 0.5% by volume of concrete for all modified mixes.

The mix proportions for 1 m³ of concrete are presented in Table 1.

3.2 MIX DESIGN:

Mix Calculations

- i. Cement = 469.43 Kg/m³
- ii. FA = 628.23 Kg/m³
- iii. CA = 1146.83 Kg/m³
- iv. Water = 197.16 Kg/m³
- v. W/C Ratio = 0.42

Table 1: Mix Proportion for 1 m³

Water (Kg/m ³)	Cement (Kg/m ³)	M-Sand (FA) (Kg/m ³)	Coarse Aggregate (Kg/m ³)
197.16	197.16	628.23	1146.83
0.42	1	1.33	2.44

IV. RESULTS AND DISCUSSION

4.1 GENERAL:

The experimental programme was conducted to evaluate the influence of Alccofine 1203 and polypropylene fibers on the fresh and mechanical properties of M30 grade concrete incorporating 100% manufactured sand (M-sand) as fine aggregate. Concrete mixtures containing 0%, 7%, 14%, and 21% Alccofine as partial cement replacement, with a constant polypropylene fiber dosage of 0.5%, were investigated. The performance of each mixture was assessed through slump, compressive strength, and flexural strength tests at 7 and 28 days of curing. The experimental observations provide valuable insight into the combined effect of ultrafine mineral admixture and fiber reinforcement on the behaviour of concrete.

4.2 QUANTITIES AND ESTIMATION:

Sr. No.	Materials	Total Weight (kg)	Cost per Kg	Total Cost per Material (Rs.)
1.	Cement	192.66	7	1348.62
2.	Fine Aggregate	288.24	1	288.24
3.	Coarse Aggregate	525.12	0.7	367.584
4.	Water	90.36	2	180.72
5.	Alccofine	22.572	66	1489.75
6.	Polypropylene Fiber	1.553	388.9	603.95
Total Cost (Rs.) =				4278.864

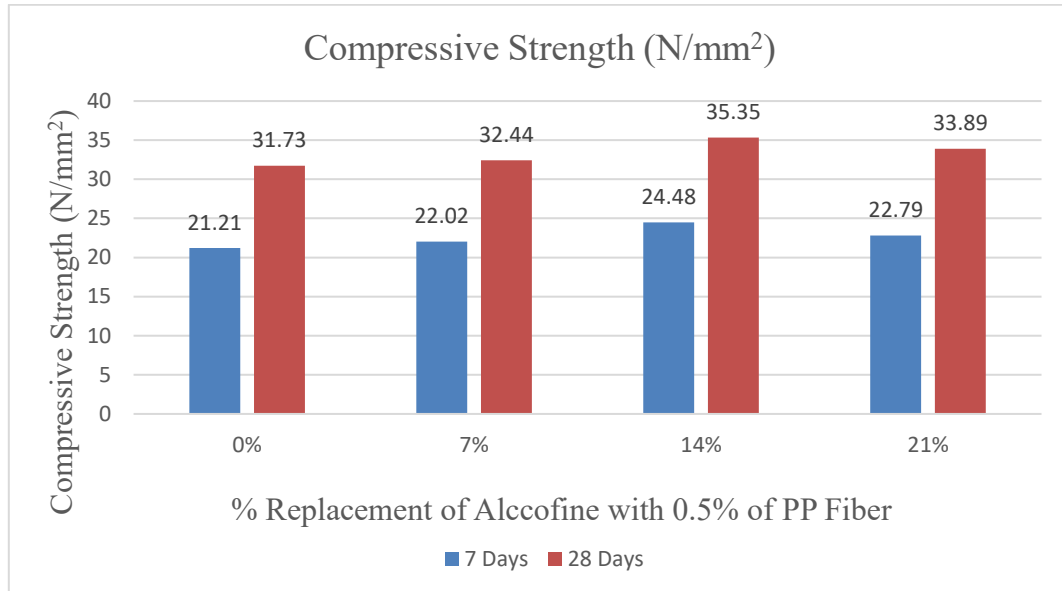
4.3 COMPRESSIVE STRENGTH TEST:

The compressive strength results demonstrated a consistent improvement with the incorporation of Alccofine up to the 14% replacement level. The enhancement in strength is primarily associated with the high pozzolanic reactivity and micro-filling capability of Alccofine. Its ultrafine particles occupied micro-voids within the cement paste, resulting in improved particle packing density and accelerated hydration. The additional formation of calcium silicate hydrate (C-S-H) gel refined the pore structure and strengthened the interfacial transition zone between aggregates and the cementitious matrix.

Among all mixtures, the A14 mix achieved the highest compressive strength at both 7 and 28 days, indicating that 14% Alccofine provided the optimum balance between cement replacement and hydration efficiency. Although the A21 mixture also exhibited higher strength than the control concrete, a slight reduction compared to A14 was observed. This reduction may be attributed to the dilution effect caused by excessive cement replacement, which reduced the availability of calcium hydroxide required for complete pozzolanic reactions. Overall, the modified concrete mixtures exhibited superior strength development compared with conventional concrete, demonstrating the beneficial role of Alccofine in producing a dense and mechanically efficient cementitious matrix.



Fig. 2: Compressive Test of Cube Specimen



Graph 1: Compressive Strength Results

4.3 TENSILE STRENGTH TEST:

The split tensile strength test was conducted to evaluate the tensile behaviour of concrete containing different percentages of Alccofine 1203 and a constant dosage of 0.5% polypropylene fibers. The results indicated that the incorporation of Alccofine and fibers significantly improved the tensile strength compared with the control mix. The improvement is mainly attributed to the combined effect of the pozzolanic activity of Alccofine and the crack-bridging capability of polypropylene fibers.

At 7 days, all modified concrete mixes exhibited higher split tensile strength than the control concrete due to accelerated hydration promoted by the ultrafine Alccofine particles. The enhancement became more pronounced at 28 days, where continued pozzolanic reactions generated additional calcium silicate hydrate (C-S-H) gel, resulting in a denser cement matrix and a stronger interfacial transition zone (ITZ). Simultaneously, polypropylene fibers effectively bridged microcracks, delayed crack propagation, and enhanced stress transfer across the matrix, thereby increasing the tensile resistance of concrete.

The A14 mixture (14% Alccofine + 0.5% polypropylene fiber) achieved the highest split tensile strength among all mixes, indicating that this replacement level provides the optimum balance between matrix densification and cement hydration. Although the A21 mixture also exhibited higher tensile strength than the control concrete, a slight reduction compared with A14 was observed due to the dilution effect associated with excessive cement replacement. The experimental results confirm that the combined use of Alccofine and polypropylene fibers substantially enhances the tensile performance and crack resistance of M30 grade concrete prepared with M-sand.

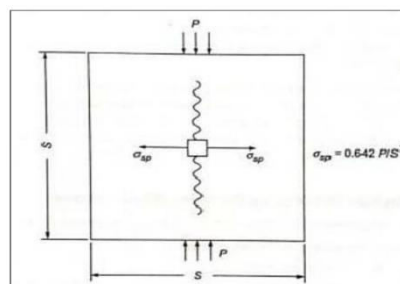
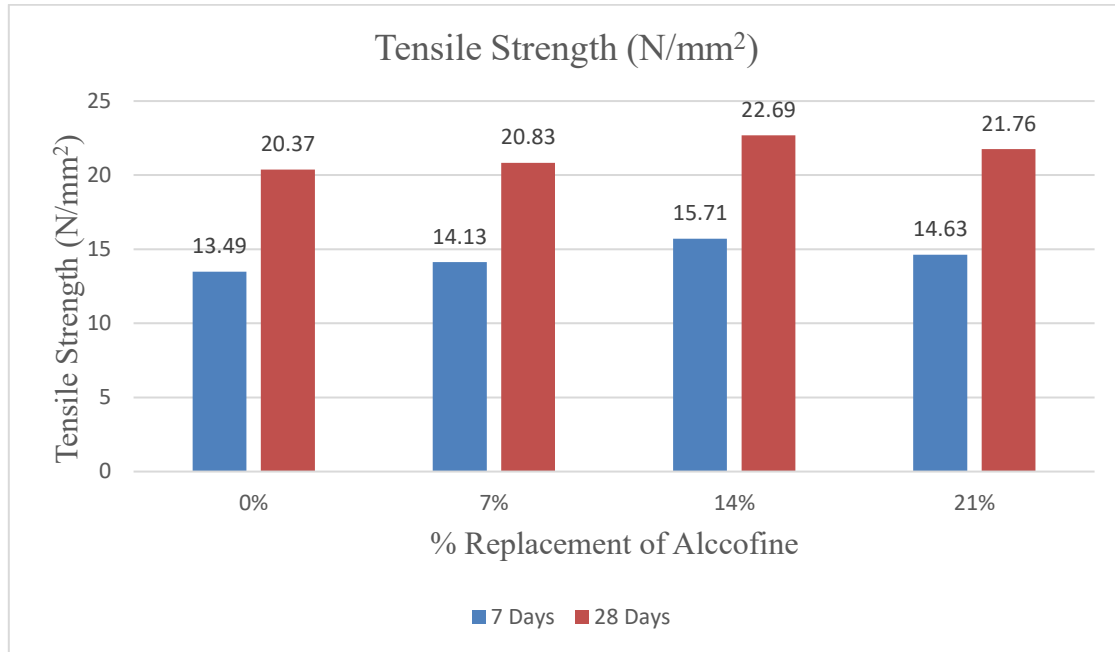


Fig. 3: Tensile Strength



Graph 2: Tensile Strength Results

V. CONCLUSION

- The Compressive Strength at the Age of 7 Days
 - a. Compressive strength of ordinary concrete is found to be 21.20 N/mm² by using concrete mix having w/c ratio.
 - b. The compressive strength of mix of 7% Alccofine + 0.5% of PP fiber found to be 22.03 N/mm². The compressive strength of mix concrete is increased by 3.91% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42.
 - c. The compressive strength of mix of 14% Alccofine + 0.5% of PP fiber found to be 24.48 N/mm². The compressive strength of mix concrete is increased by 15.47% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42
 - d. The compressive strength of mix of 21% Alccofine + 0.5% of PP fiber found to be 22.79 N/mm². The compressive strength of mix concrete is increased by 7.5% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42.
- The Compressive Strength at the Age Of 28 Days
 - a. Compressive strength of ordinary concrete is found to be 31.73 N/mm² by using concrete mix having w/c ratio 0.42.
 - b. The compressive strength of mix of 7% Alccofine + 0.5% of PP fiber found to be 32.44 N/mm². The compressive strength of mix concrete is increased by 2.23% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42.
 - c. The compressive strength of mix of 14% Alccofine + 0.5% of PP fiber found to be 35.39 N/mm². The compressive strength of mix concrete is increased by 11.53% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42.
 - d. The compressive strength of mix of 21% Alccofine + 0.5% of PP fiber found to be 33.84 N/mm². The compressive strength of mix concrete is increased by 6.65% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42.
- The Tensile Strength at the Age of 7 Days
 - a. Tensile strength of ordinary concrete is found to be 13.49 N/mm² by using concrete mix having w/c ratio 0.42.
 - b. The tensile strength of mix of 7% Alccofine + 0.5% of PP fiber found to be 14.13 N/mm². The compressive strength of mix concrete is increased by 4.74% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42.

- c. The tensile strength of mix of 14% Alccofine + 0.5% of PP fiber found to be 15.71 N/mm². The compressive strength of mix concrete is increased by 16.46% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42.
- d. The tensile strength of mix of 21% Alccofine + 0.5% of PP fiber found to be 14.63 N/mm². The compressive strength of mix concrete is increased by 8.45% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42.
- The Tensile Strength at the Age of 28 Days
 - a. Tensile strength of ordinary concrete is found to be 20.37 N/mm² by using concrete mix having w/c ratio 0.42.
 - b. The tensile strength of mix of 7% Alccofine + 0.5% of PP fiber found to be 20.83 N/mm². The compressive strength of mix concrete is increased by 2.25% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42.
 - c. The tensile strength of mix of 14% Alccofine + 0.5% of PP fiber found to be 22.69 N/mm². The compressive strength of mix concrete is increased by 11.39% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42.
 - d. The tensile strength of mix of 21% Alccofine + 0.5% of PP fiber found to be 21.76 N/mm². The compressive strength of mix concrete is increased by 6.82% as compare to ordinary concrete by using concrete mix having w/c ratio 0.42.

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