3rd International Conference on Advances in Civil and Environmental Engineering (ICACEE-2024)

University of Engineering & Technology Taxila, Pakistan

Conference dates: 21st and 22nd February 2024; ISBN: 978-969-23675-2-3

Optimizing RCC Slabs Using Compressive Strenght of Fiber Reinforced Composites

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ABSTRACT

FRC can yield a favorable influence on the compressive strength of reinforced concrete slabs. Fiber Reinforced Concrete (FRC) is extensively employed in the realm of construction due to its remarkable mechanical and enduring properties, whereby diverse fiber variants manifest distinct impacts on strength and durability. The effect of dissimilar fiber types and environmental conditions on the strength and durability of standard concrete, including steel fiber, polypropylene (PP) fiber, and natural palm tree fiber, varies. In current investigation mix design of 1:4:2:0.8 (cement: sand: aggregate: water) is used for preparing PC. Pine needle fibres lengths of 50 mm are used for preparation of pine needle reinforced concrete. The natural fibre reinforced concrete (NFRC) has been very well known for its better flexural strength and toughness. But at the same time, there is little compromise on its compressive strength. The conventional design of RCC slab primarily uses the compressive strength (fc') of plain concrete (PC). There is a need to evaluate the slab design using the compressive strength of NFRC. Therefore, in this current work, the compressive strength of NFRC is experimentally investigated first and then slab design using NFRC is discussed. For reference purposes, the properties of PC are taken. It is concluded that the slabs can be designed using the compressive strength of NFRC. The objective of this investigation is to scrutinize the compressive strength of FRC through conventional material examinations.

KEYWORDS: Fiber-reinforced-concrete, RCC Slab, Compressive Strength

1 INTRODUCTION

The use of fiber reinforced concrete (FRC) can have a positive impact on the compressive strength of reinforced concrete slabs. Mittal et al., (2023) reported that Fiber Reinforced Concrete (FRC) is widely used in construction due to its exceptional mechanical and durable properties, with different types of fibers having varying effects on strength and durability. The impact of different types of fiber and environmental conditions on the strength and durability of ordinary concrete, such as steel fiber, polypropylene (PP) fiber, and natural palm tree fiber, varies. The study aims to analyze the compressive strength of FRC through conventional material tests. The addition of small amounts of PP fiber can significantly increase compressive strength and durability in 28 days of water curing, while steel fiber performs better than PP fiber in 6 months of wet-dry and heat-cool cycles. The study provides valuable insights for the material proportion design of concrete, as the results can be used as a testimonial for optimizing the use of different types of fibers in FRC.

Zainal et al., (2023) reported that fibers are effective in restricting crack propagation and improving the failure mode of cement composites. (Long And Wang, 2021) investigated the impact of pine needled fiber on the mechanical characteristics of concrete by testing Masson Pine Needle Fiber (MPNF). Addition of millet husk ash and wheat straw ash to concrete outcome in an increase in flexural strength, compressive strength, and split tensile (Bheel et al., 2021). Song and Hwang (2004) observed that integrating steel fibers into high-strength. Initiation of fist crack is increasing the crack numbers this can decrease with the use of fibers can improve compressive, flexural, splitting tensile toughness up to 105% Tests performed by Farooqi and Ali (2019). PET bottle (Javaid and Ali, 2023), sheep wool (Alyousef et al., 2020), coconut-fiber rope (Ali et al., 2013) have been used as an additive in concrete, among others. Wheat straw, of approximately 18 mm in length and 1% content (by mass of wet concrete) were used and concluded with 34% and 16% more energy absorption capacity and load transfer efficiency, respectively by Farooqi and Ali (2023). The study is concluded with 34% and 16% more energy absorption capacity and load transfer efficiency, respectively. The study aims to enhance the performance of Reinforced Concrete (RC) slabs by embedding synthetic fibers. Uniaxial tests were conducted to observe the stress-strain behavior of Hybrid Fiber Reinforced Concrete (HyFRC).

The obtained data were used for numerical analyses using Finite Element (FE) modeling. The numerical results were verified with experimental data for cracking behavior, load capacity, mid-span deflection, and steel reinforcement strain. HyFRC slabs showed positive improvements in load-carrying capability, reduced stress in concrete and rebars, lower deflections, improved crack resistance, and high flexural stiffness compared to the control slab. The developed FE models had a low margin of error compared to experimental data. The use of synthetic fibers in Reinforced Concrete (RC) slabs resulted in positive improvements in load-carrying capability, reduced stress in concrete and rebars, lower deflections, improved crack resistance, and high flexural stiffness compared to the control slab. Concrete structures face early deterioration due to steel corrosion, especially in cold areas. Saeed et al., (2023) reported that fiber-Reinforced Concrete (FRC) is a cost-effective substitute for conventional concrete, enhancing durability and crack resistance.

Cement manufacturing emits greenhouse gases, necessitating the development of environmentally friendly alternatives. Ferrocement, a versatile building material, is considered an economical alternative for roofing systems due to its impact resistance, ductile performance, and strength. Adding fibers to concrete improves its ductility. The incorporation of 10% silica fume (SF) in the concrete improved the compressive strength and bond between cement paste and aggregates. Adding polypropylene fibers (PPF) and multiple layers of wire mesh in slabs compensated for ductility loss and resulted in a higher cracking load compared to control slabs with normal concrete. To the best of author's knowledge, to analyse the compressive strength of FRC through conventional material tests. It finds that adding small amounts of PP fiber can significantly increase compressive strength and durability after 28 days of water curing. However, steel fiber outperforms PP fiber in durability over 6 months of wet-dry and heat-cool cycles. These findings offer valuable insights into optimal material proportions.

2. EXPERIMENTAL PROCEDURES

2.1 Raw Materials

For the preparation of plain concrete, ordinary Portland cement, local sand, normal size aggregate was used. Preparation of Pine Needle Fiber Reinforced Concrete (FRC), same ingredient were used with addition of pine needle fibers having varying length 37mm, 50 mm and 62.5mm. The natural fibers utilized were removed from the pine needle trees. Firstly, the pine needles were washed to remove the dust on the surface of pine needles and were well dried. Secondly, the fibers were cut manually into length of 37 mm, 50mm and 62.5mm respectively.

2.2 Mix proportions and casting procedure

The mix proportion for PC was 1:4:2 (cement: sand: aggregate). For making FRC the pine needles were added in 05% by mass of cement. The w/c ratio of 0.82 is kept same for both PC and FRC. For the preparation of PC mix all the ingredients were simultaneously put into the drum type mixer and the mixer was rotated for one minute. The water in required quantity was then poured into the mixer and the mixer was rotated again for five minutes until a homogeneous mixture was obtained. In case of FRC, one-third of cement, sand, aggregates and pine fibers were put in the mixer in four layers. The remaining quantities were then added using the same layering technique. After that, two-third of water was added, and the mixer was rotated for about four minutes. The one-third of the remaining water was added, and the drum mixer was again rotated for two minutes. For preparation of FRC specimens, the prepared homogeneous mixture is then poured in the respective moulds. Each mould is filled in three layers with compaction of 25 blows per layer with the help of temping rod.

2.3 TESTING PROCEDURE

Slump tests were performed for both PC and FRC as per ASTM standard C143. Compressive Strength of Concrete was carried conforming to ASTM standard C39.

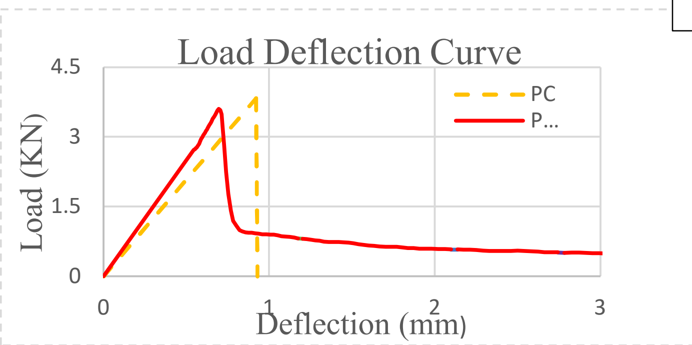
3 ANALYSIS OF TEST RESULTS

3.1 Slump

Slump test values for PC is 57 mm and FRC is 25 mm. It is to be noted that FRC has less slump than that of PC. Increased water cement ratio of FRC was observed as compared to PC because more water was required to make it workable. The less value of slump for pine needles fiber is due to absorption of water by pine needles which resulted in reduced workability.

3.2 Compressive Strength

The compressive behavior of Plain Concrete (PC) and Pine Needle Fiber Reinforced Concrete PNFRC exhibited approximately a 23% reduction in compressive strength compared to PC. This aligns with findings by Nambiar and Haridharan (2021), who also reported a decrease in strength for natural (jute) fiber reinforced concrete. While PC demonstrated abrupt failure, PNFRC continued to bear load beyond the maximum load point, with deformations reaching up to 12.72 mm. This enhanced ductility in PNFRC is attributed to the presence of fibers. Figure (b) shows the failure modes of the specimens."



Compressive strength test under Load

Fig a) Load Deformation Curve **b) Tested Specimen**

Fiber-reinforced concrete, on the other hand, may exhibit a slightly softer initial stiffness due to the energy-absorbing nature of the embedded fibers. This can result in greater deformation before reaching the yield point. Once plain concrete cracks, it tends to experience a sudden drop in load-carrying capacity. Crack propagation is often more abrupt, leading to a brittle failure mode. Fiber-reinforced concrete demonstrates better post-cracking behavior. The embedded fibers arrest crack propagation and distribute stress, allowing the material to carry loads even after the initiation of cracks. This results in a more gradual reduction in load-carrying capacity, indicating increased ductility.

4 CONCLUSIONS

An experimental work was carried out to study the effect of Pine Needle Fibers mechanical properties of concrete following conclusions were made from the results obtained:

- Improved Compressive Strength: The inclusion of fibers has effectively contributed to the overall structural performance, resulting in a robust and durable slab.
- PC has a slump of 57 mm, while FRC has 25 mm, indicating FRC's lower slump. FRC required a higher water-cement ratio for workability, as pine needles absorb water, reducing workability.
- FRC made by pine needle reinforced concrete absorbed 2.25 times more energy than that of ordinary PC.

Fibers improved compressive strength, resulting in a robust and durable slab. PC slump is 57 mm; FRC is 25 mm, needing a higher water-cement ratio due to pine needle absorption. Pine needle FRC absorbed 2.25 times more energy than ordinary PC.

5. ACKNOWLEDGMENT

The authors are grateful to every person who provided support thorough out the research work and the staff of Concrete Lab.

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