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Behavior of Fiber Reinforced Concrete to Enhance Concrete block, Pavers and Kerbstones Performance

Rashid Ahmad[1,*], Majid Ali[1]

[1]Capital University of Scince and Techonology, Islamabad, Pakistan

*Corresponing author: engr.rashid8@gmail.com

ABSTRACT

At present, concrete blocks serve as the primary construction material in civil engineering due to their convenient material selection and impressive compressive strength. However, their limitations in terms of low tensile strength, poor toughness, and susceptibility to cracking hinder their progress. To enhance the flexibility and resilience of concrete, incorporating fibers is a viable method to develop a composite material. Pine needles is a promising material for reinforcing concrete blocks, pavers, and kerbstones. It has been shown to enhance a wide range of concrete valuables, containing tensile strength compressive strength, flexural strength, toughness indices, and energy absorption. In current study mix design of 1:4:2:0.8 (cement: sand: aggregate: water) is used for preparing PC. Pine needle fibres lengths of 37 mm are used for preparation of pine needle reinforced concrete. Improvement observed in compressive energy absorption by 2.25 times, toughness index 3.05 times, maximum deformation up to 13 mm and decrease in compressive strength observed by 23%. Ductile behaviour also observed with respect to the reference specimens. In general, pine needles are effective in utilization in concrete structure has the potential to be used in cement concrete composites for different structural. The current investigation focuses on to develop low cost-efficient concrete keeping compressive performance.

KEYWORDS: Concrete block, paver, kerbstone, Fiber reinforcement, pine needles.

1 INTRODUCTION

Construction due to their favourable characteristics, including ease of material selection and high compressive strength. However, their drawbacks, such as limited tensile strength, reduced toughness, and susceptibility to cracking, impede further progress. The incorporation of fibers into concrete offers a chance to bolster its ductility and toughness, creating a composite material. Concrete blocks currently serve as a primary construction material in civil engineering, boasting high compressive strength but lacking in tensile strength, toughness, and prone to cracking. The addition of pine fibers offers notable advantages and has the potential to enhance the concrete's strength. The increasing use of fiber-reinforced concrete in global civil infrastructure aims to improve toughness, flexural strength, tensile strength, impact resistance, and alter failure modes compared to conventional concrete (Long and Wang, 2021). The low tensile and flexural strength contribute to cracking issues, but using fibers could enhance these strengths alongside impact and toughness (Yonggang and Long, 2021).

Wheat straw (Farooqi and Ali, 2018, Farooqi and Ali, 2019, Al-Kheetan, 2022), millet husk ash (Bheel et al., 2021), wheat straw ash (Bheel et al.,2021), polypropylene fibre (Saberian et al., 2023), human hair (Aziz et al., 2023), 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. The compressive strength of the masonry composite relies on the compressive strength of its individual components within the masonry (Mohamad at al., 2007). First crack initiation loads were reported to increase and crack numbers, length and width were reported to decrease with the adding of wheat straw in concrete. Addition of wheat straw also results in an improvement in energy absorption, and toughness indices along with better crack arresting mechanism (Al-Kheetan, 2022).These needles hold promising potential for development into natural plant fiber materials.

(Long And Wang 2021) tested the research focused on utilizing Masson pine needle fiber (MPNF) to investigate its impact on the mechanical characteristics of concrete. 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). (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). Recycled PET bottle fibers were also reported to improve workability (measured through slump test) of concrete (Javaid and Ali, 2023). Sheep wool was observed to cause a similar improvement in workability (Alyousef et al., 2020). %. Song and Hwang (2004) observed that integrating steel fibers into high-strength. In Steel Fiber Reinforced Concrete (SFRC) the compressive strength also observed an upturn.

Pine needles is a promising material for reinforcing concrete blocks, pavers, and kerbstones. It has been shown to enhance a wide range of concrete valuables, containing tensile strength compressive strength, flexural strength, toughness indices, and energy absorption. 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 37 mm are used for preparation of pine needle reinforced concrete. Improvement observed in compressive energy absorption by 2.25 times, toughness index 3.05 times, maximum deformation up to 13 mm and decrease in compressive strength observed by 23%. Ductile behaviour also observed with respect to the reference specimens. In general, pine needles are effective in using in concrete structure has the potential to be used in cement concrete composites for different structural. This investigation focuses on to develop low cost efficient concrete keeping compressive performance.

2. EXPERIMENTAL PROCEDURES

2.1 Materials

For the preparation of plain concrete, ordinary Portland cement, local sand, normal size aggregate (≤12 mm with mixed sizes of 12 mm and 6 mm) and drinking water was used. Preparation of Pine Needle Fiber Reinforced Concrete (FRC), same ingredient was used with addition of pine needle (available locally in Northern Punjab regions of Pakistan (i.e. Islamabad) fibers having length 37 mm. 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.

2.2 Mix proportions and casting procedure

The mix proportion for PC was 1:4:2 (cement: sand: aggregate). For making PNRC 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 PNRC. 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 PNRC, 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 PNRC 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 PNRC 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 44 mm. It is to be noted that FRC has less slump than that of PC. Table 1 also shows the w/c ratio of Plain concrete and FRC. Increased water cement ratio for PNRC 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 behaviour

The compressive behaviour for PC and PNFRC is shown in Table 1. Almost 23% decrease in compressive strength was observed for PNFRC as compared to PC. In a study Nambiar and Haridharan (2021) reported strength reduction for natural (jute) fiber reinforced concrete. Abrupt failure was observed in PC but PNFRC keeps on taking load after maximum load. Deformation up to 12.72 mm was also observed for PNFRC samples as shown in Figure 4. The observed ductility in FRC was due to fibers. Failure of specimen is presented in Figure 5.

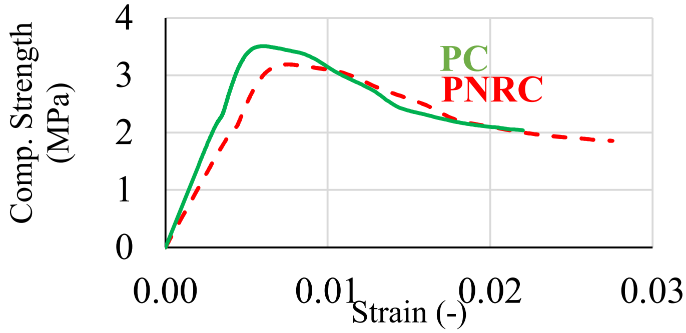

Figure 1: a) Load Deformation Curve

b) Tested Specimen

3.3 Compressive Energy Absorption

Energy absorption is very important aspect especially in case of FRC. It is found by calculation the area under load-deflection curve Table shows that FRC made by pine needle reinforced concrete absorbed 2.5 times more energy than that of ordinary PC. Toughness index also remained 3.05 times higher than that of PC.

Table 1: Energy Absorption and TI

Sr. No.	Concrete type	Max Load	Comp Strength (Mpa)	Deformation (mm)	Em (MJ*10^6)	Eu (MJ*10^6)	TE (MJ*10^6)	TI
1	PC	36.7	4.67	7	3.05	3.3	6.35	2.08
2	PNRC	25.56	3.25	8	2.25	4.7	6.95	3.08

Em= energy absorbed up to max. load, Eu = energy absorbed from max. load to ultimate load, T.E = total energy absorbed, T.T.I = Total toughness Index = T.E / Em

4 Application of Current Research

To capitalize on these positive findings, future research should focus on optimizing the mix design and fiber content to strike a balance between improved mechanical properties and maintaining an acceptable level of compressive strength. Exploring alternative methods for enhancing the bond between the pine needles and the concrete matrix could also be beneficial. Additionally, a detailed investigation into the long-term durability, resistance to environmental factors, and potential applications of PNRC in various structural elements would provide valuable insights for its practical implementation.

Collaboration with industry stakeholders and construction professionals can facilitate the development of guidelines and standards for the use of pine needle reinforced concrete in real-world construction projects, ensuring its successful integration into the construction industry while addressing any concerns related to reduce compressive strength. Overall, the findings open avenues for further research and application of sustainable and energy-absorbing construction materials, contributing to the advancement of eco-friendly and resilient building practices.

5 CONCLUSIONS

PC and PNRC were made with same mix design of 1:4:2:0.8 and 5% pine needles by mass of cement were added to PNRC. Specimen were cast for both PC and PNRC and their behaviour under flexure were studied. After the analysis of experimental results, following conclusions can be made

- FRC made by pine needle reinforced concrete absorbed 2.25 times more energy than that of ordinary PC.
- Toughness index observed to be 3.05 times higher than that of PC.
- Compressive strength decreased by 23%.

Incorporation of 37 mm fibers of pine needle to concrete increases the energy absorption and ductility while decreases the compressive.

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