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Experimental Exploration of Pine Needle Reinforcement in Concrete under Compression

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ABSTRACT

Ordinary concrete has low tensile strength and brittleness. To enhance the flexibility and resilience of concrete, incorporating fibers is a viable method to develop a composite material. Wide range of concrete properties containing compressive strength, flexural strength, toughness indices, and energy absorption improve with addition of fibers. Pine needles are effective in application to concrete structures. 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 50 mm are used for preparation of pine needle reinforced concrete. Improvement observed in compressive energy absorption by 3.5 times, toughness index 4.5 times, maximum deformation up to 21 mm, decrease in compressive strength observed by 5% and increased ductility with respect to the reference specimens. The novelty of current research is to develop low cost-efficient concrete using waste pine needles. The outcomes of this experimental investigation contribute to the on-going efforts towards more sustainable and innovative approaches in the construction industry.

KEYWORDS: Ductile behaviour, Energy absorption, Pine needles. Compressive strength, toughness

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. 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 [1]. The low tensile and flexural strength contribute to cracking issues, but using fibers could enhance these strengths alongside impact and toughness [2]. Altering the concentrations of pine needle content, this research seeks to evaluate the optimal dosage that leads to the most substantial enhancement in the flexural strength of RCC columns [3].

A research carried by focusing on utilizing Masson pine needle fiber (MPNF) to investigate its impact on the mechanical characteristics of concrete[4]. 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% [5]. An investigation carried for the study of the impact of pine needled fiber on the mechanical characteristics of concrete by testing Masson Pine Needle Fiber (MPNF) [6]. A research carried for investigation of dynamic behavior of coir fibre reinforced concrete (CFRC) for low-cost but safe buildings in earthquake prone regions. In this work, the effect of fibre content on properties of CFRC is studied. To evaluate the efficiency of coir fibres in improving the properties of the concrete the performance of plain concrete (PC) is used a reference. Damping increased up to 229 % and natural frequency is decreased up to 63 %, when CFRC beam with 3 % fibre content goes from uncracked to cracked stage [7].

Integration of steel fibers in concrete results into high-strength. In Steel Fiber Reinforced Concrete (SFRC) the compressive strength also observed an upturn [8]. In a study it was revealed that an increase in flexural strength (up to 7.5%), energy absorption (up to 30.4%), and toughness indices (up to 11.1%) along with better crack arresting mechanism by incorporation of wheat straw in reinforced concrete[9]. Utilization of pine needle reinforcement in mud houses in Kashmir, Pakistan, resulting enhancement of durability and structural strength [10]. In an investigation it was revealed that fibers act as reinforcement within the concrete matrix, helping to distribute the stress more evenly and resisting crack formation and growth, thereby increasing the concrete's resistance to bending and improving its modulus of rupture [11]. In a study it was revealed that coco fiber reinforced concrete with coir rope rebars has the potential to be used as main structural members due to its increased damping and ductility [12].

Pine needles is a promising material for application to reinforced concrete structures are effectitve to enhance a wide range of concrete properties, 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 50 mm are used for preparation of pine needle reinforced concrete. Improvement observed in compressive energy absorption by 3.5 times, toughness index 4.5 times, maximum deformation up to 21 mm and decrease in compressive strength observed by 5%. Ductile behaviour also observed with respect to the reference specimens. The novelty of current research is to develop low cost-efficient concrete using waste pine needles. This investigation focuses 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 Reinforced Concrete (PNRC), same ingredients were used with addition of pine needle (available locally in Northern Punjab regions of Pakistan (i.e. Islamabad) fibers having length 50 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 50 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 conforming to ASTM standard C143 [13]. Compressive Strength of Concrete was carried conforming to ASTM standard C39 [14].

3 ANALYSIS OF TEST RESULTS

3.1 Slump

Slump test values for PC is 57 mm and PNRC is 50 mm. Note from Table 1. that in case of PNRC there is less slump then that of PC. Water cement ratio remained 0.82 of Plain concrete and PNRC. Increased water cement ratio of PNRC was observed as compared to PC because more water required to make it workable. The less value of slump for Mix pine needles fiber is due to absorption of water by pine needles which resulted in reduced workability. Moreover fiber length was more than the aggregate size resulting in the increased congestion.

Table 1. Slump values

Sr#	Concrete	W/C	Slump (mm)
1	PC	0.82	57
2	PNRC	0.82	50

3.2 Compressive behaviour

The compressive behaviour for PC and PNFRC is shown in Fig1a).5% decrease in compressive strength was observed for PNFRC as compared to PC. In an investigation it was reported that strength reduces by use of natural (jute) fiber reinforced concrete [15]. In a another study same phenomena reported that the flexural toughness index increase while the modulus of rupture of banana fiber reinforced concrete decreases as compared to ordinary concrete[16]. A Study carried found that while flexural strength initially increases, it eventually reaches a limit and starts decreasing [17]. Abrupt failure was observed in PC but PNRC keeps on taking load after maximum load. Deformation up to 21 mm was also observed for PNRC samples as shown in Figure 1 b). The observed ductility in PNRC was due to fibers created the bridging.

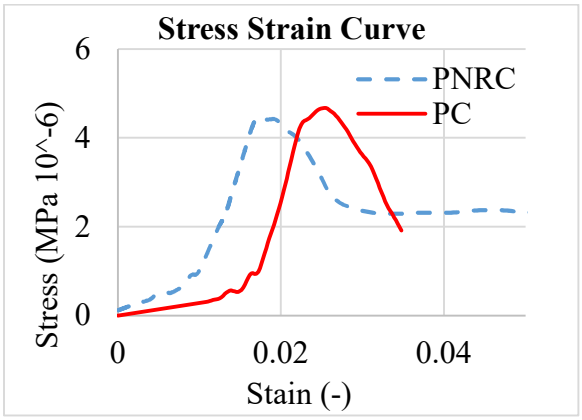

Fig 1: a) Stress Strain Curve *b) Tested Specimen*

3.3 Compressive Energy Absorption

Energy absorption is very important aspect especially in case of PNRC. It is found by calculation the area under load-deformation curve. Table 2. shows that PNRC made by pine needle reinforced concrete absorbed 3.5 times more energy than that of ordinary PC. Toughness index also remained 4.5 times higher than that of PC.

Table 2. Max load, Max. deformation Compressive strength, Energy Absorption and TI

Sr. No.	Concrete type	Max. Load(Kn)	Max. Comp Strength (MPa)	Deformation (mm)	Em (Nm)	Eu (Nm)	TE (Nm)	TI (-)
1	PC	36.7	4.67	7	47.94	51.94	99.84	2.08
2	PNRC	34.95	4.45	21	38	320.3	358.3	9.4

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 Research implementation

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 techniques for enhancing the bond between the pine needles and the concrete matrix could also be beneficial. Detailed investigation delves 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.

By linking with construction industry 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

- Slump for PNRC decreased by 7 mm as compared that of PC
- PNRC made by pine needle reinforced concrete absorbed 3.5 times more energy than that of ordinary PC. And toughness index observed to be 4.5 times higher than that of PC.
- Compressive strength decreased by 5%.
- Long-term durability, resistance to environmental factors, and potential applications of PNRC in various structural elements

Incorporation of 50 mm fibers of pine needle to concrete increases the energy absorption and ductility while decreases the compressive.

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REFERENCES

1. Long, W., Wang, Y. (2021). "Effect of pine needle fibre reinforcement on the mechanical properties of concrete". Construction and Building Materials, 278, 168-189.
2. Wang, Y., & Long, W. (2021). Complete stress–strain curves for pine needle fiber reinforced concrete under compression. Construction and Building Materials, 302, 124134
3. Rana, A. K., Guleria, S., Gupta, V. K., & Thakur, V. K. (2023). Cellulosic pine needlesbased biorefinery for a circular bioeconomy. Bioresource Technology, 367, 128255.
4. Long, W., Wang, Y. (2021). "Effect of pine needle fibre reinforcement on the mechanical properties of concrete". Construction and Building Materials, 278, 168-189.
5. Farooqi, M.U., and Ali, M. (2019). "Effect of pre-treatment and content of wheat straw on energy absorption capability of concrete". Construction and Building Materials, 224, 572-583.
6. Long, W., Wang, Y. (2021). "Effect of pine needle fibre reinforcement on the mechanical properties of concrete". Construction and Building Materials, 278, 168-189.
7. Ali, M., Liu, A., Sou, H., & Chouw, N. (2010, March). Effect of fibre content on dynamic properties of coir fibre reinforced concrete beams. In Proceedings of NZSEE Conference (pp. 1-8).
8. Song, P. S., & Hwang, S. (2004). Mechanical properties of high-strength steel fiber-reinforced concrete. Construction and Building Materials, 18(9), 669-673.
9. Farooqi, M.U., and Ali, M. (2018). "Contribution of plant fibers in improving the behavior and capacity of reinforced concrete for structural applications". Construction and Building Materials, 182, 94-107.
10. Hayat, A., Khan, H., Haq, R. U., & Ali, M. Use of Pine-Needle Reinforced Composites in Kashmir, Pakistan–A Critical Review.
11. Gul, M., Bashir, A., & Naqash, J. A. (2014). Study of modulus of elasticity of steel fiber reinforced concrete. Int. J. Eng. Adv. Technol, 3(4), 304-309.
12. Ali, M., & Chouw, N. (2009, December). Coir fibre and rope reinforced concrete beams under dynamic loading. In Annual Australian Earthquake Engineering Society Conference,"Newcastle Earthquake–20 years on.
13. ASTM, 1998. Annual Book of ASTM Standards. Designation: C 143/C 143M- 97 Standard Test Method for Slump of Hydraulic-Cement Concrete, vol. 04.02, Concrete and Aggregates, ASTM, 89 – 91.
14. ASTM C39/C39M-03, "Standard test method for compression strength of cylinder specimens." West Conshohocken, PA, 2003.
15. Nambiar, R. A., & Haridharan, M. K. (2021). Mechanical and durability study of high performance concrete with addition of natural fiber (jute). Materials Today: Proceedings, 46, 4941-4947.

16. Afraz, A., & Ali, M. (2021). Effect of Banana Fiber on Flexural Properties of Fiber Reinforced Concrete for Sustainable Construction. Engineering Proceedings, 12(1), 63.
17. Chaudhary, S., Goyal, K., & Shukla, A. (2015). Study of the Properties of Concrete using Pine Needles a natural supplement