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Pine Needle Reinforcement in Concrete: A Sustainable Approach for Enhancing Mechanical Properties

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ABSTRACT

Ordinary concrete is characterized by brittleness and low tensile strength which makes it unfavourable for applications to civil engineering structure. Unidirectional or bi directional axially loaded columns are subjected to flexure shear failure. Pine needles, abundantly available renewable resources, are considered for their potential for sustainable concrete production. The research aims to assess the effects of varying pine needle proportions on the mechanical, thermal, and durability properties of concrete. The experimental procedure involved the preparation of concrete mixtures with different percentages of pine needle substitution. In current investigation mix design of 1:4:2:0.6 (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. Slump decrease by 13 mm and modulus of rupture 6% for PNRC. Energy absorbed by pine needles reinforced concrete is 2.1 times higher than PC. Bridging due to pine needles reduced the brittleness as compared to the reference concrete specimens. Pine needles are effective in utilization 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 for application to columns. The outcomes of this experimental investigation contribute to the on-going efforts towards more sustainable and innovative approaches in the construction industry.

KEYWORDS: Pine needle, axially loaded column, brittleness, energy absorption.

1 INTRODUCTION

The reinforcement of Reinforced Concrete (RC) structures, particularly columns, has long been a critical aspect of construction engineering to enhance their load-bearing capacity and durability. Axially loaded columns in practical are rarely existing. Unidirectional or bi directional axially loaded columns are subjected to flexure shear failure. Traditional methods often involve the use of steel bars or mesh to strengthen RC columns. Their fibrous nature and composition offer unique structural characteristics that could contribute to enhancing the mechanical properties of concrete when integrated into the Reinforced Concrete Column (RCC) matrix (Wang et al., 2023). The utilization of pine needles as an additive in RCC columns holds promise due to their potential to augment the tensile and flexural strength of concrete. Incorporating these natural fibers within the concrete mix may provide additional reinforcement, potentially reducing crack propagation and enhancing the column's ability to withstand bending stresses. This study aims to investigate the influence of incorporating varying proportions of pine needles into RCC column mixes on their flexural strength and structural performance. By systematically 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 (Rana et al., 2010). Efficient energy absorption and load transfer using wheat straw fiber reinforced concrete as compared to reference concrete (Farooqi and Ali, 2023)

Increase in flexural energy absorption for basalt fiber reinforced concrete with increasing length of basalt fiber as compared to reference concrete observed (Khan et al.,2018). Mashri et al.(2021) noted a 1% increase in optimum flexural strength with brown pine fiber, but higher fiber content decreased strength. Green pine fiber reduced flexural strength, and excessive fiber caused bonding loss. Red pine needles enhanced concrete ductility. The highest strengthening was achieved by using of reinforced concrete, but in this case, it is considerably technologically difficult due to using and preparing reinforcement around the column and using formwork. So, the best method seems to be strengthening by fiber concrete layer, which showed higher load-carrying capacity compared to plain concrete layer and very comparable values to the reinforced concrete layer. It is needed to highlight that the tensile force in fiber concrete is dependent on to amount of the fibers in the concrete mixtures and the fibers in concrete decrease the ductility and fragility during failure of member (Vavruš and Koteš, 2019). This investigation into the efficacy of pine needles as a natural additive in RCC columns aims to expand the repertoire of materials used in structural engineering while addressing the ongoing need for stronger and more durable construction elements (Saini et al., 2024). Ultimately, this research endeavours to contribute to the advancement of sustainable construction practices by harnessing the potential of natural resources to improve structural performance. The uniform appearance will assist the reader to read paper of the proceedings. It is therefore suggested to authors to use the example of this file to construct their papers (Chakraborty et al., 2006).

Axially loaded columns in practical are rarely existing. Unidirectional or bi directional axially loaded columns are subjected to flexure shear failure. This investigation focuses on to develop low cost efficient concrete for application to columns. The experimental procedure involved the preparation of concrete mixtures with different percentages of pine needle substitution. In current investigation mix design of 1:4:2:0.6 (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. Results shown slump decrease by 13 mm and modulus of rupture 6% for PNRC. Energy absorbed by pine needles reinforced concrete is 2.1 times higher than PC. Bridging due to pine needles reduced brittleness as compared to the reference concrete specimens. Pine needles are effective in utilization in concrete structure has the potential to be used in cement concrete composites for different structural. The outcomes of this experimental investigation to produce concrete for application to sustainable civil engineering structures.

2. EXPERIMENTAL PROCEDURES

2.1 Materials

The pine needle fibre collected from the pine trees in irregular size then wash it down with clean water. Then cut it with different sizes 37mm, 50 mm,62.5 mm. The fibre were used about

361 grams is taken in this concrete. Drinking water were used in the concrete mixture, Portland cement, local river sand and 6mm and 12 mm aggregate were used in this concrete.

2.2 Mixing and casting of molds

The mixing ratio for PC was 1:4:2 which was (cement, sand , aggregate) which put in the mixture machine one by one and add some water and then mixture machine started for about 5 minutes after 5 minutes the concrete taken out from the mixture machine and start pouring in cylinders and beams. For PNFRC, the pine needle ratio were added to the mixture 0.5 and 1 % by the mass of wet concrete. Where the w/c ratio kept 0.6 same for the PC and PNRC, in the time of preparation of PC materials were added to the mixture machine simultaneously and the mixture rotated for 1 to 2 minutes. The required water quantity added to the mixer and rotated again for 5 minutes until the homogeneous mixture obtained. At the time of PNFRC making the required materials (fiber, sand, cement, aggregate) added in the mixture machine and the remaining materials were added in four layers with laying technique. For the preparation of specimens, the prepare homogenous mixture is poured in the molds, each mold is filled in three layers with compaction of 25 blows per layers with the help of temping rod.

2.3 Testing methodology

The slump test which is performed as per ASTM C143. ASTM C78 used for testing of beams to find the modulus of rupture (MoR), the first crack occurs to corresponding deflection load and using mid-point for maximum deflection.

3 ANALYSIS OF TEST RESULTS

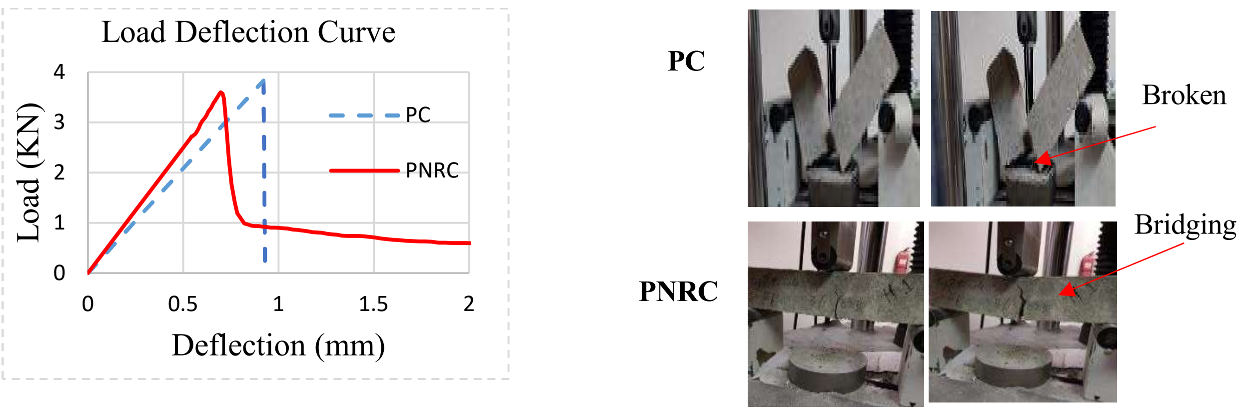
3.1 Slump

The slump test was performed for both PC and PNRC. Test was performed conforming to ASTM standard C143 for. The value of slump noted 44 mm for PNRC and for PC it was 57 mm. There is 13 mm decrease in slump for PNRC. Reduced slump may be due to congestion of pine needles as pine needles length was more than the aggregate size.

Figure 1: a) *Fresh concrete* b) *Slump test*

3.2 Flexural behavior

Load deflection curve is shown in the Fig.1. Note from the Fig. 2 (a) reference concrete (PC) reaches it ultimate failure quickly without going deflection while PNRC shows ductile behavior by bridging effect. From figure 2(b) it is to be noted that tested specimen of broken in to halves while the specimen of PNRC reached ultimate failure and fiber shown bridging effect resulting in ductile failure.



1st Crack ***Ultimate failure***

Figure 2: a) Load Deflection Curve, b) Tested specimen

The modulus of rupture (MOR) in fiber-reinforced concrete (PNFRC) refers to the measure of the material's ability to resist bending or flexural stresses before fracturing. It represents the maximum tensile stress experienced by a specimen at the moment of failure under a bending load. In simpler terms, it's the measure of the material's ability to withstand bending forces without breaking. It's especially crucial in situations where concrete is subjected to bending or flexural loads, such as in beams, pavements, or slabs (Ajrad et al., 2016). For fiber-reinforced concrete, the addition of fibers improves the modulus of rupture by providing additional tensile strength, reducing crack propagation, and enhancing the post-crack behavior of the material. The 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 (Gul et al., 2014). 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 (Ali and Chouw, 2009).

3.3 Flexure energy absorption

Energy absorption is found by calculating the area under load-deflection curve. Table 2. Shows that PNRC made by pine needles absorbed 2.1 times more energy than that of ordinary PC. Toughness index remained 2.1 times higher than that of PC. Addition of fibers made the specimens to withstand the load after the peak value and prevented the brittle failure. It is also to be noted from the Table 2. that load capacity for the PNRC decreased in comparison to that of PC. Resultantly the MoR for the specimen got decreased. PC specimen shown higher load capacity as compared to PNRC but abruptly failed after reaching the maximum load. This strength loss might be due to the weak bonding between fibers and concrete as the fibers were easily pulled out from the failed specimens. In a similar type of investigation (Afraz and Ali, 2021) reported that the flexural toughness index increase while the modulus of rupture of banana fiber reinforced concrete decreases as compared to ordinary concrete. Incorporation of coconut fibers into concrete improve its flexural toughness and can be used for low cost concrete structures (Ali et al., 2012).

Table 2. Max load, Max Deflection, MoR, Flexural Energy and Toughness Index

SR #	Concrete type	Max Load (kN)	MoR (MPa)	Max Deflection	Em (Nm)	Eu (Nm)	TE (Nm)	TI (-)
1	PC	3.83	2.30	7.40	2.28	0	2.28	1
2	FRC	3.63	2.18	6.80	1.53	3.24	4.77	3.11

4 PRACTICAL IMPLEMENTATION

Axially loaded columns in practical are rarely existing. Unidirectional or bi directional axially loaded columns are subjected to flexure shear failure. Incorporating pine needle-reinforced concrete in the construction of residential and commercial buildings enhances their structural strength while reducing the environmental impact. Traditional methods often involve the use of steel bars or mesh to strengthen RC columns. Their fibrous nature and composition offer unique structural characteristics that could contribute to enhancing the mechanical properties of concrete when integrated into the Reinforced Concrete Column. It enhances the longevity and resilience of these structures against environmental stresses.

5 CONCLUSIONS

PC and PNRC were made with same mix design of 1:4:2:0.6 and 5% pine needles by mass of cement were added to PNRC. Specimen were cast for both PC and PNRC and their behavior under flexure were studied. After the analysis of experimental results, following are the conclusions

- Slump for PNRC by 13 mm as compared to that of PC
- MoR values decreased by 6% for PNCR as compared to that of PC
- PNRC absorbed 2.1 times more energy and toughness index 3.11 as compared to PC
- The fibers act as reinforcement within the concrete matrix, helping to distribute the stress more evenly and resisting crack formation and growth

Decreased slump, modulus of rupture and brittleness for PNRC in comparison to that of PC

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