Experimental Study of Natural Fibre Reinforced Concrete (NFRC) Pavements

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Introduction & Background

- Concrete production is responsible for 8-10% of all human-induced CO_2 emissions.
- Limitation of concrete is that it is strong in compression and weak in tension.
- Natural Fiber Reinforced Concrete (NFRC) is gaining significant attention as an eco-friendly alternative.
- Natural Fibers have potential to enhance the tensile strength, toughness, and durability of concrete.
- Examples of natural fibers such as coir, sisal, bamboo, flax, hemp, palm and wheat.
- **Flax fibers** have emerged as promising natural reinforcement material in concrete pavements due to their high tensile strength, low density, and renewable nature.
- **Flax fibers** help improve tensile and flexural performance, enhance crack resistance, and mitigate shrinkage effects.
- Controlling micro-cracking and enhancing toughness can extend service life under heavy traffic and variable environmental conditions

Aim, Objectives, and Scope

The primary objectives of the overall study are:

- **Phase I**: To optimize the use of flax fibres as a partial replacement for fine aggregate and cement to enhance the mechanical properties of concrete.
- **Phase II:** To evaluate the load transfer efficiency and bond strength between dowels (steel or GFRP) and concrete in both conventional and natural fibre reinforced concrete (NFRC) pavements.

This paper presents the findings from **Phase I** of the overall study.

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Research Design and Methodology

Phase I

- Preparation of design mix.
- Preparation of concrete specimens with flax fibers.
- Compressive and flexural strength test.
- Optimization of fiber content in concrete.
- Design of concrete pavement.

Phase II

- Pullout test of steel and GFRP dowels in conventional and natural fiber reinforced concrete.
- Analysis of load transfer efficiency between steel and GFRP dowels.
- Investigating the results and drawing out conclusions.

Research Design and Methodology

Table 1. Mix design (per cubic foot).

Materials	Weight (lb)
Cement	24.94
Coarse Aggregate	65.14
Fine Aggregate	44.13
Water	11.23
Superplasticizer	1.75 ml/lb

Fig. 1. Preparation of fibres:

a) Cutting down fibres to a length less than the maximum size of coarse aggregate, ¾ in.
b) Soaking fibres for 24 hrs in 4% Sodium Hydroxide ($NaOH$) solution
c) Rinsing and Drying of fibres
d) Separating of fibres before mixing.

Table 2. Concrete Specimens

Sample ID	Flax fibre content	Flax fibre content (lb/yd^3)	Partial replacement
CC	0%	0	-
FRC-A1	0.5%	3.24	By weight of cement
FRC-A2	1%	6.48	By weight of cement
FRC-R1	0.5%	8.18	By volume of fine aggregate
FRC-R2	1%	16.36	By volume of fine aggregate

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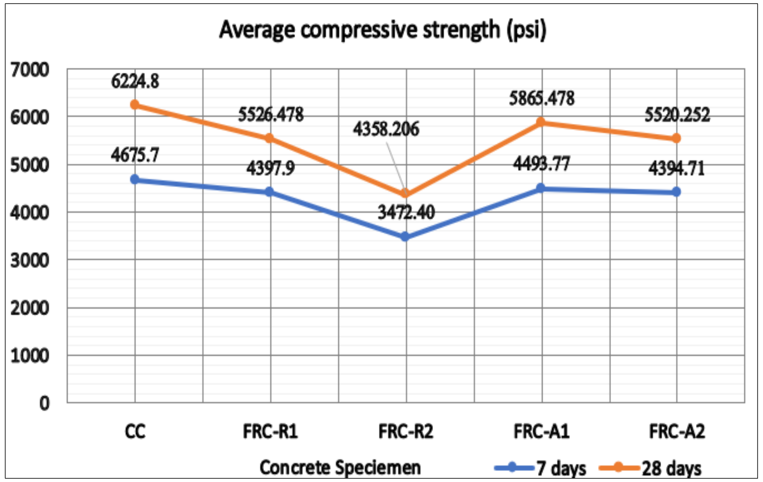
Results & Discussions

1- Slump Test Results

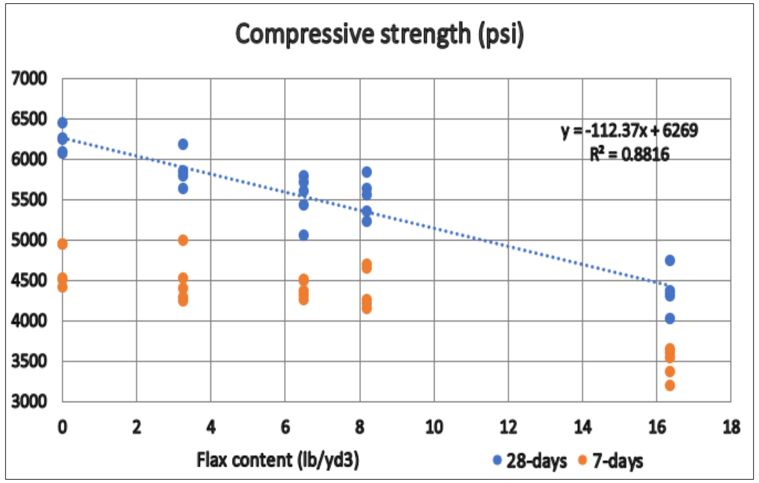
- Due to their high-water absorption, natural fibre reduces concrete workability.
- Fibre length and balling also significantly affect slump

2- Concrete Compressive Strength Test Results (ASTM C39)

- Strength decreased with increased flax content.
- Partial cement replacement shows less strength reduction.

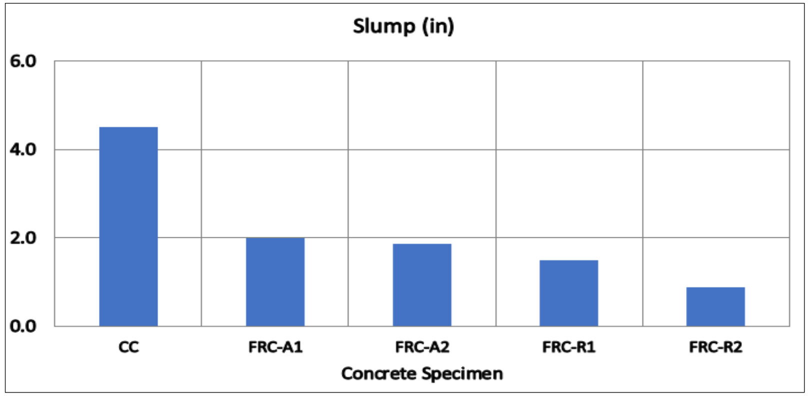


a)



b)

Fig. 4. (a) Average compressive strength, and (b) Compressive strength vs. Flax content.



a)

b)

Fig. 2. (a) Slump test results, (b) Slump measurements

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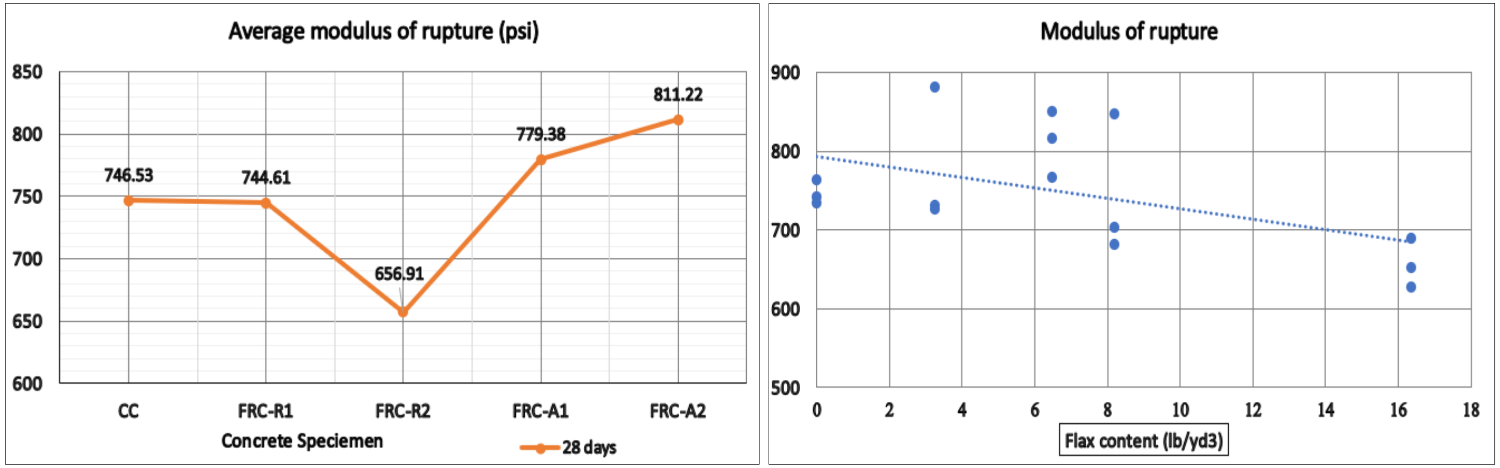
Results & Discussions

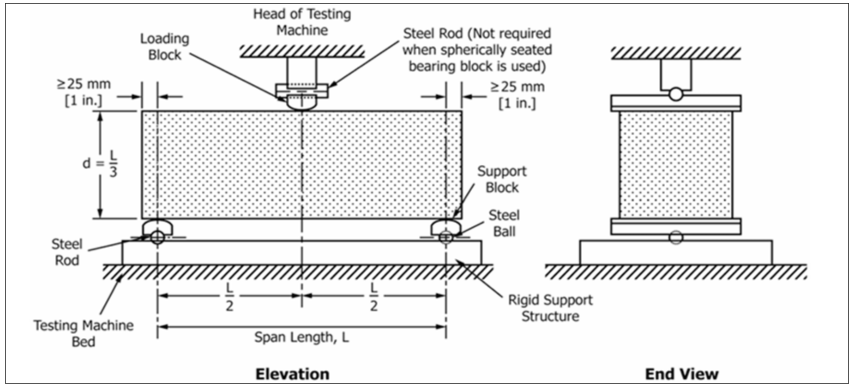
3- Flexural Strength Test Results (ASTM C293)

- Improved flexural strength at lower fibre contents, despite reduced compressive strength
- Partial cement replacement shows higher modulus of rupture improvement.



a) **b)**

Fig. 3. (a) Average modulus of rupture, and (b) Modulus of rupture vs. Flax content.



$$\text{Modulus of rupture, } R = \frac{3PL}{2bd^2} \quad [psi]$$

where,

P = Maximum applied load, N [lbf], L= Span length, mm [in.], b = Average width of specimen at the fracture, mm [in.], d= Average depth of specimen at the fracture, mm [in.].

4- Design of Pavement Thickness

- Study adopted the existing pavement thickness, dowel bar diameter and spacing, and traffic data from Section 16-3017 in Pocatello, Idaho, for phase II of research along with the concrete mechanical properties obtained in Phase I.

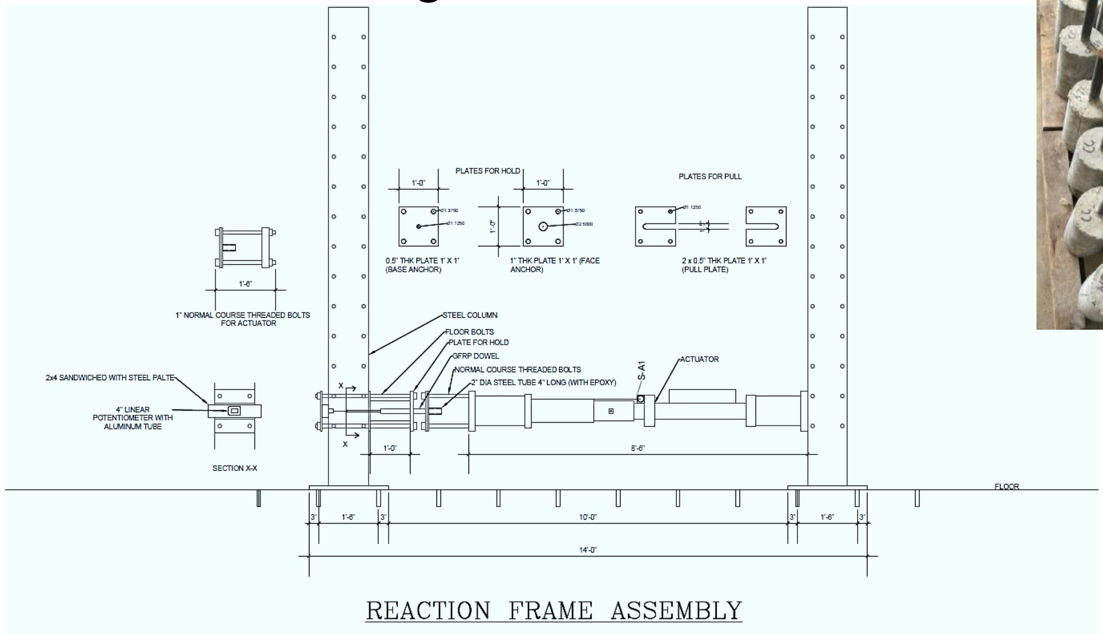
Conclusions & Recommendations

- Mechanical performance of concrete with flax fibre reinforcement was significantly influenced by both fibre content, replacement procedure and surface treatment.
- On surface treatment of flax fiber, the fiber had the tendency to tangle up and exhibit a balling phenomenon. The treated fibers had to be manually separated before adding them into the concrete mix.
- Natural Fiber Reinforced Concrete (NFRC) demonstrated promising mechanical properties.
- Based on the mechanical properties, **FRC-A1 and/or FRC-A2** are recommended for use in the phase II of the project.
- Use of flax fibers in concrete offers a sustainable alternative for construction by reducing reliance on synthetic or steel reinforcements and utilizing renewable materials.

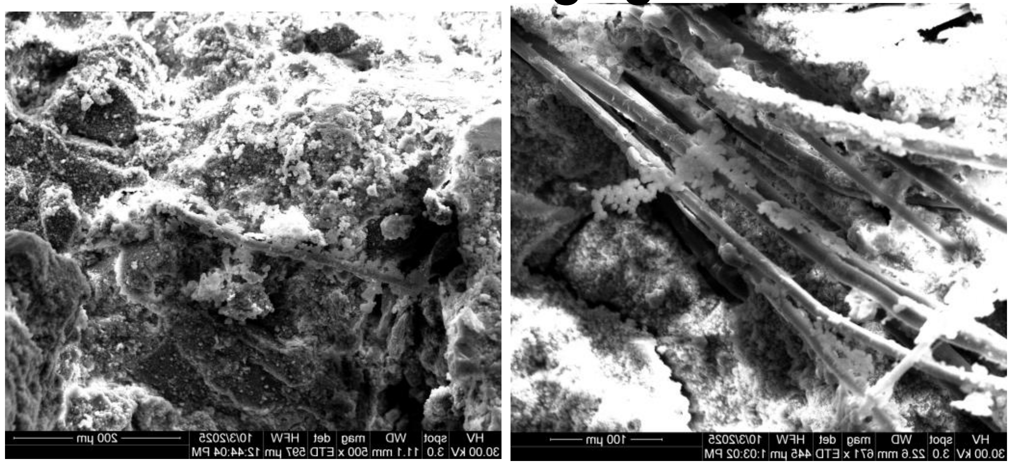
Conclusions & Recommendations

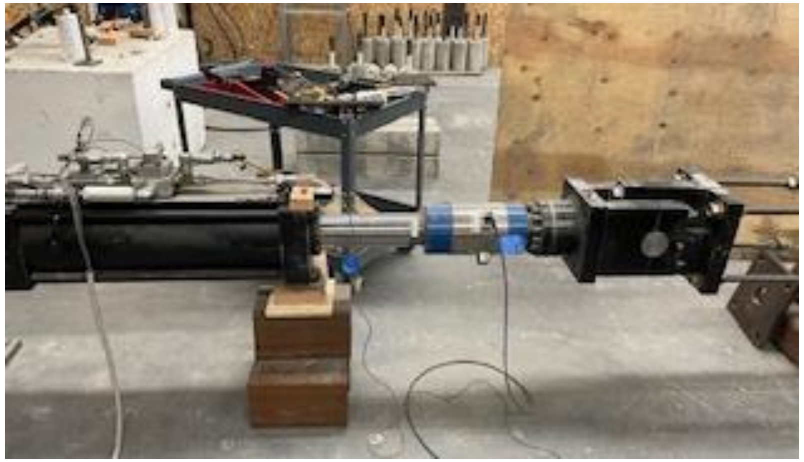
Phase II Ongoing Testing

- Scanning Electron Microscopy (SEM)
- Pullout Strength Test

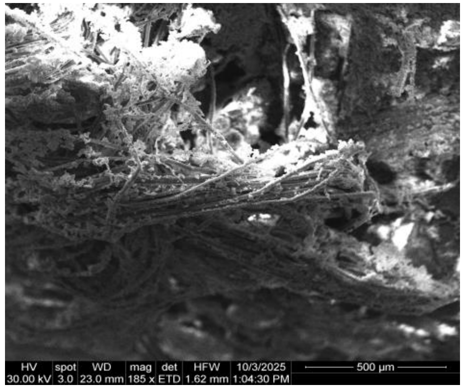


Possible fiber bridging





Possible fiber balling



Next:

- Preparing Large Slabs for ACPA T 253-21 Load-Deflection Test Settings

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