FACULTY OF ENGINEERING INTERNATIONAL CONFERENCE (FEIC 2026)

TECHNICAL PRESENTATION

Paper Title: Investigation of Concrete Tensile Strength with Partial Replacement of Cement with Bamboo Stem Ash in Concrete Structures

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Presentation Outline

- Introduction
- Literature Review
- Materials and Methodology
- Discussion of Results
- Conclusion

Introduction

- Concrete is an important construction material with very low tensile strength, also a brittle material possessing little elastic deformation and insignificant plastic deformation

- The study investigates inclusion of bamboo stem ash to partially replace cement in concrete using the split tensile strength experiment

- Including transition from fresh concrete to hardened concrete with corresponding change in concrete molecular bonding

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- Concrete tensile characteristic property (ability to stretch) is influenced by nature of molecular bonding, which depends on chemical bonds, quality of cement paste, applied load and loading rate etc

- Concrete manufacturing process involving combination of constituents in specific mix design ratio, fine aggregates, coarse aggregates and binder matrix or cementitious paste (cement + BSA) produces fresh concrete

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- Fresh concrete transforms hardened concrete through curing over time period, with adequate strength for load bearing purposes

- When concrete is subjected to tension, stress concentrates and the weak bond of aggregate and binder matrix can disintegrate easily leading to brittle failure (yan et al, 2013) due to low intermolecular bond energy

Contd

- Bond mechanism between aggregate and cementitious binder matrix in concrete depends on chemical adhesion, physical friction and mechanical interlock within the interfacial zone (Zeraf, 2016).
- Adhesion between cementitious binder and aggregates (the substrates) occur either by mechanical means or chemical mechanism (Afolabi, 2023)

- The adhesive strength depends on several factors including bonding mechanism, interfacial tension, surface roughness, wettability and curing process etc (Windisch, 2020)

Literature Review

- **Mathematical Model of tensile and compressive stress**

- Hooke's law state that, stress is proportional to strain
- Therefore, at a point within a continuum (Ravi et al, 2009)
- $\sigma = E\varepsilon$ where E = elastic modulus

- Thus, If a structural component is subjected to axial forces in opposite direction
- $\sigma_t = E_t\, \varepsilon_t \quad (due\ to\ tensile\ force\ F_t)$
- $\sigma_c = E_c\, \varepsilon_c \quad (due\ to\ compressive\ force\ F_c)$

Contd

- Hence, If the opposite forces are applied individually at a cross section on the component
- Then, $F_t = F_c$, therefore, $\sigma_t = \sigma_c$
- and $E_t\varepsilon_t = E_c\varepsilon_c$ or $\varepsilon_t = (\frac{E_c}{E_t})\varepsilon_c$

- If, $\frac{E_c}{E_t} = 1$ then, $\varepsilon_t = \varepsilon_c$
- And if, otherwise, $\varepsilon_t \neq \varepsilon_c$
- Therefore, $E_t \neq E_c$ and the material is considered bimodular, having different elastic modulus in tension and compression (Madandous et al, 2017 and Afolabi et al, 2026)

Contd

- Concrete is brittle and usually designed not to resist tension and steel rebars are used to compensate this weakness in reinforced concrete
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- Tension resistance is an important engineering properties with regards to material toughness, cracking and durability etc

- Research indicated that (ASTM-C496), that tensile strength of concrete is about 8% to 11% of concrete compressive strength which explains different in elastic modulus

Materials and Methods

- Concrete constituents used for the study were cement, bamboo stem ash, sand (fine aggregates) and granite (coarse aggregate)

- The bamboo stem ash sourced locally were prepared by air drying to reduce moisture content, and subjected to controlled combustion to produced the ash

Table 3.1: Chemical composition of bamboo stem ash

S/No	Composition	%
1	Silicon dioxide (SiO_2)	24.0 - 68.8
2	Potassium oxide (K_2O)	2.7 – 34.2
3	Calcium oxide (CaO)	1.0 – 11.9
4	Magnesium oxide (MgO)	5.8 – 6.7
5	Sulphur trioxide (SO_3)	0.4 – 14.1
6	Aluminium oxide (Al_2O_3)	0.1 – 0.5
7	Iron oxide (Fe_2O_3)	0.1 – 0.8

Contd.

- 150 x 300mm cylindrical concrete specimen were used in casting the concrete mixture in the ratio 1:2:4 (cement : fine aggregate: coarse aggregate)

- Curing were done in air and water, which commences immediately after removal from the cast mould for period of time, before the splitting tensile tests, ie at 7 days, 14 days, 21 days, 28 days and 45 days

- Split tensile strength is an indirect method of determining concrete resistance to pulling force (BS-EN 12390. The test involve using a cylindrical specimen, which splits across vertical diameter at fracture load (ASTM C496)

Split Tensile Test Experiment

According to test set ups the applied load (P) is distributed over the length (P/L) of the cylinder for even distribution of stress developed.

- Split tensile strength is calculated as follows
- stress = applied load/area
- And using max shear stress failure theory, $\tau_{max} = ½ f_y$
- and $f_y = 2 \tau_{max}$
- therefore, $f_{ST} = 2P/AL = 2P/\pi DL$

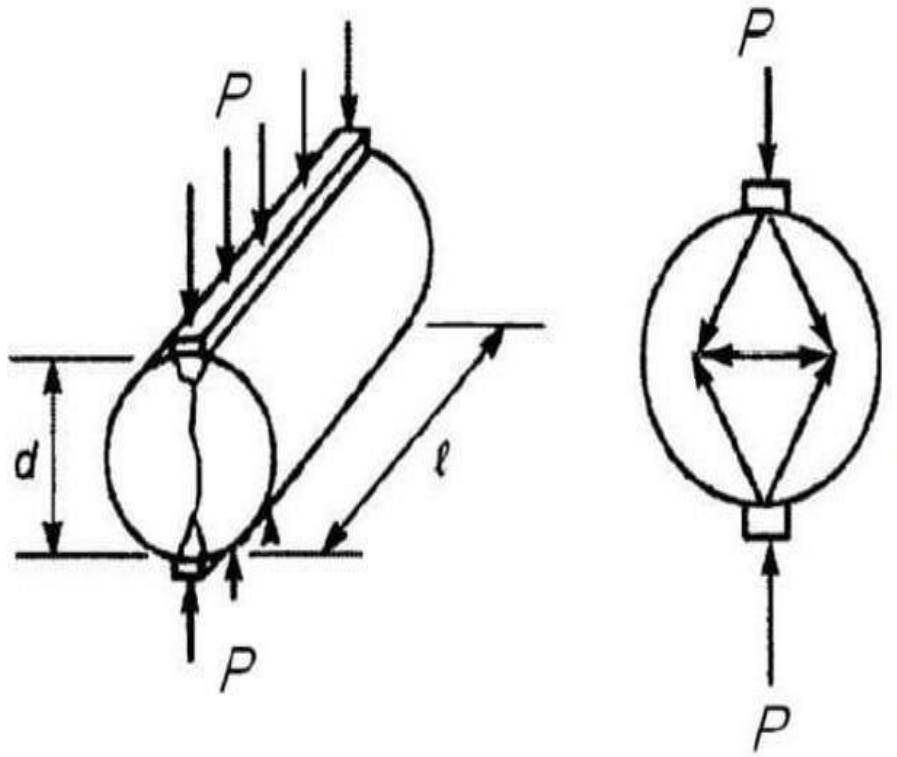


Figure 3.1 Split tensile test

Discussion of Results

Workability

- Property of hardened concrete directly depends on property and quality of fresh concrete produced

- Concrete production process involve transition from plastic state through curing to hardened (solid) concrete (Afolabi and Edidi, 2025)

- Workability test is determined by performing slump test according to standard specifications (BS EN 12350-2).

Table 4.1: Slump test on BSA-cement concrete

Test No	BSA %	Slump	Workability
1	0 %	150 mm	High
2	5 %	50 mm	Low - medium
3	7.5 %	40 mm	Low
4	10 %	60 mm	Medium

- Workability results in indicated that inclusion of BSA improves stability of BSA-cement concrete
- Observed a decrease in slump values between 40mm and 60mm
- which define a workable fresh concrete mixture (BS EN 12350-2:2019)

Table 4.1: Split tensile strength of air-cured BSA-cement concrete

BSA Percent	3 days (N/mm^2)	7 days (N/mm^2)	14 days (N/mm^2)	21 days (N/mm^2)	28 days (N/mm^2)	42 days (N/mm^2)
0%	1.74	1.45	2.16	1.70	1.42	1.60
5%	1.42	1.84	1.75	1.68	1.78	1.73
7.5%	0.86	1.06	0.92	1.08	1.14	1.26
10%	1.00	1.10	1.02	1.22	1.23	1.30

contd

- Transition of fresh concrete from the plastic state involve increase in bond energy to the solid bonds of hardened concrete entailing increase in strength

- Table 4.1 and Figure 4.1 are the results of split tensile strength of BSA-cement concrete cured in air, which indicated that maximum tensile strength of 2.16 N/mm^2 occurs at 14 days for 0% BSA replacement and 1.84 N/mm^2 at 7 days with 5% BSA level

- The result shows an early strength development attaining maximum at 7 days curing period followed by reduction in split tensile strength could be due to type and nature of concrete bonding which involve adhesive forces that binds the aggregates mass together

Figure 4.1: Split tensile strength of air cured BSA-cement Concrete

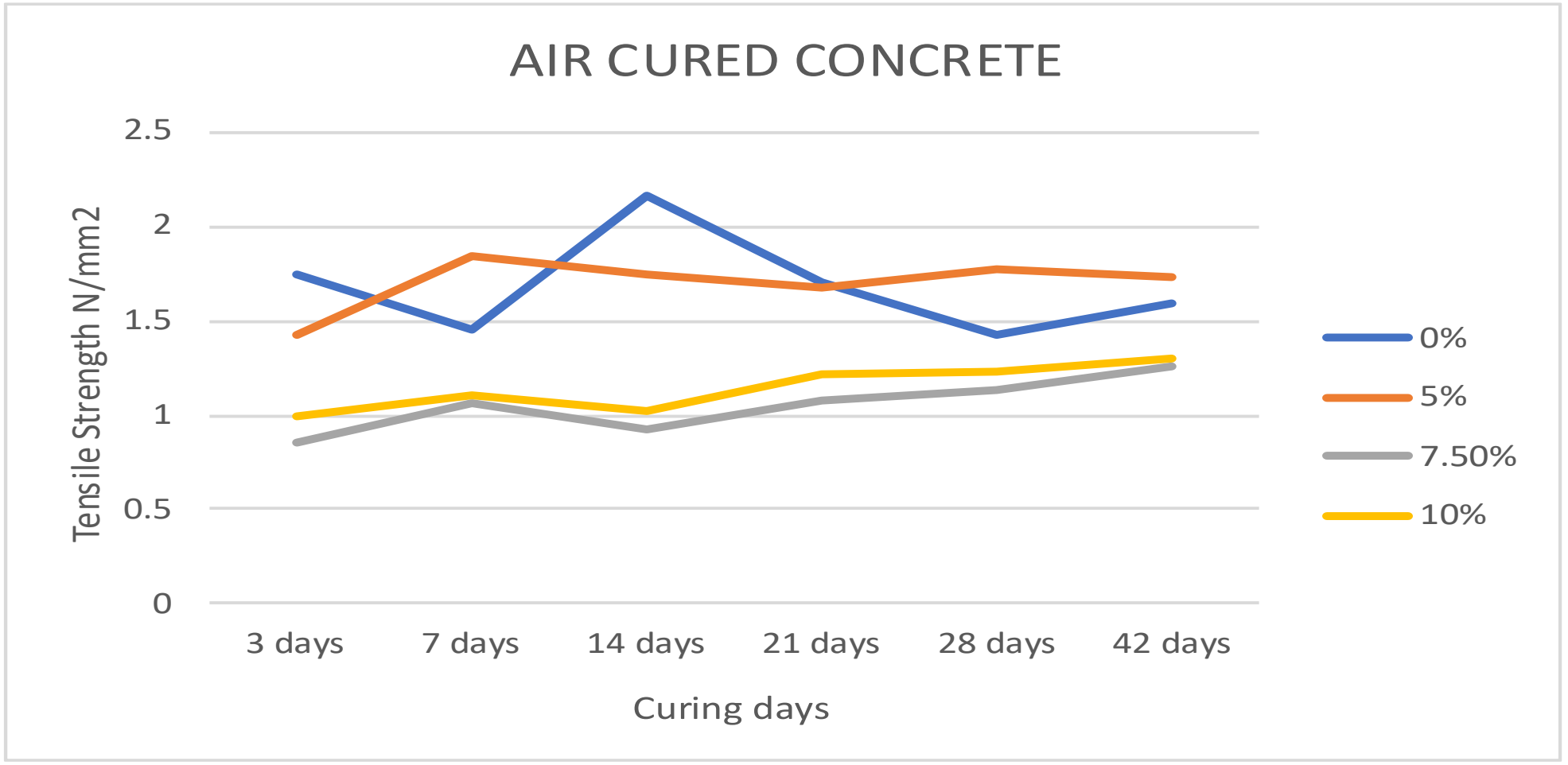


Table 4.2. Result of Split tensile strength test of water cured BSA-Cement concrete

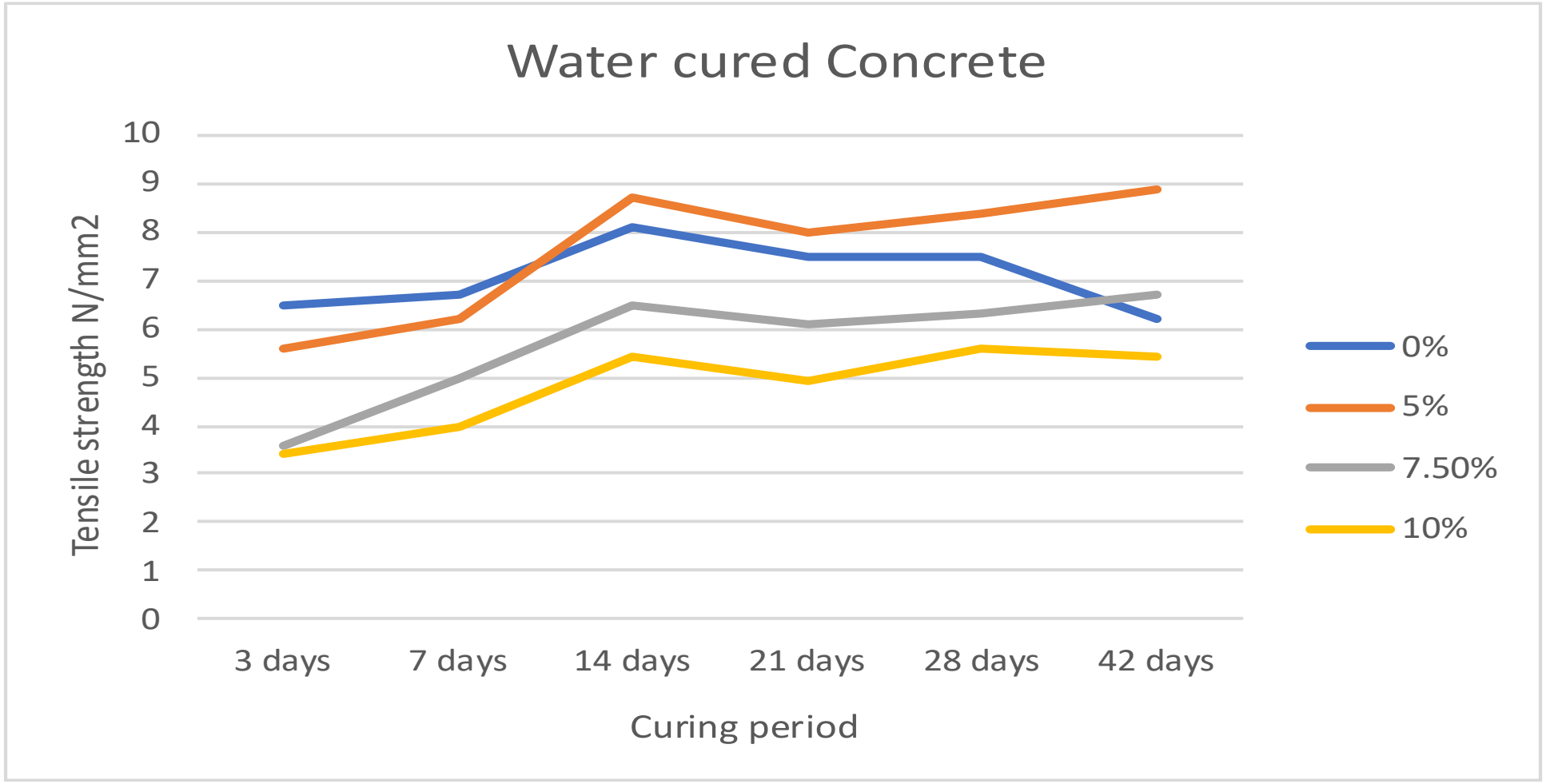
BSA Percent	3 days (N/mm^2)	7 days (N/mm^2)	14 days (N/mm^2)	21 days (N/mm^2)	28 days (N/mm^2)	42 days (N/mm^2)
0%	6.5	6.7	8.1	7.5	7.5	6.2
5%	5.6	6.2	8.7	8.0	8.4	8.9
7.5%	3.6	5.0	6.5	6.1	6.3	6.7
10%	3.4	4.0	5.4	4.9	5.6	5.4

Contd.

- Table 4.2 and figure 4.2 are the split tensile strength results of water cured BSA-cement concrete which were significantly higher than air cured concrete due to effect of water curing, which is an important factor in development of adhesive forces in concrete binder matrix

- Maximum strength of 8.4 N/mm^2 occur at 14 days curing for 0% BSA replacement level., while 5% BSA replacement produced a tensile strength of 8.7 N/mm^2 at the same curing period.

Figure 4.2: Split tensile strength of water cured BSA-cement Concrete



Conclusion

- Tensile strength is the maximum pulling or stretching force a material can resist before fracturing or permanently deforms, and an important property of concrete commonly used in the design of concrete structures, roadway and runway slabs.

- Split tensile strength of BSA-cement concrete cured in air indicated that maximum tensile strength of 2.16 N/mm^2 occurs at 14 days for 0% BSA replacement and 1.84 N/mm^2 at 7 days for 5% BSA level. Low tensile strength of BSA-cement concrete can be as a result type and nature of concrete bonding which involve adhesive forces that binds the aggregates mass together and associated with low adhesive bond-energy

- Split tensile strength of water cured concrete cylinder presented maximum strength of 8.4 N/mm^2 at 14 days curing for 0% BSA replacement level., while 5% BSA replacement produced a tensile strength of 8.7 N/mm^2 at the same curing period. Tensile strength results of water cured BSA-cement concrete were significantly higher than air cured concrete due to effect of water curing and an essential factor in development of adhesive forces in concrete binder matrix

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