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A Reliability-Based Design of Africa-Birch Timber-Reinforced Concrete Beams

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Abstract. This study investigates the reliability-based design of African-Birch (AB) timber-reinforced concrete beams. This study investigated Some of the physical and engineering properties of the constituent materials for the reinforced concrete beams were tested and preparing the reinforcement in four different composition and configurations (steel-steel, Steel- AB, AB-Steel, and AB-AB) of the beams were prepared, cast and cured for varying durations (3, 7, 14, 21, and 28 days), and the concrete was tested for its flexural strength and deflection and consequently reliability analysis (in terms of flexural strength and deflection) of all the beam configurations using First Order Reliability Analysis-5 (FORM5) to assess the beam performance was carried out. The flexural strength and deflection analysis reveals Steel-AB outperforming other sections and was found to be optimal under various loading conditions. For flexure, Steel-AB achieved a safety index (β) of 1.98 and probability of failure (Pf) of 0.0238 at a span length of 10,000mm and effective depth of 400mm. Similarly, for deflection, Steel-AB demonstrated a safety index (β) of 1.786 and probability of failure (Pf) of 0.037 at a span length of 2500mm. This study demonstrates that African-birch timber is a viable and sustainable alternative to traditional steel reinforcement for structural applications, particularly for medium span and depth beam-configurations.

Key words: African-birch timber, reinforced concrete, sustainable construction, steel reinforcement alternative.

1. Introduction

The widespread use of steel reinforcement in concrete beams poses significant environmental and durability concerns. In search of a sustainable solution, this study investigates African-birch timber as a locally available, cost-effective, and underutilized alternative in Nigeria. Despite its potential, limited research exists on the mechanical properties and reliability of African-birch timber-reinforced concrete beams. This study aims to bridge this knowledge gap by evaluating some of the physical and engineering properties of African-birch timber, its compatibility with concrete, deflection behavior, flexural strength, and structural reliability. The findings of this research will contribute to addressing the environmental, durability, and sustainability concerns associated with steel reinforcement, paving the way for a more sustainable construction material in Nigeria.

Timber reinforcement in concrete structures has regained attention due to its local availability, cost-effectiveness, sustainability, and eco-friendliness (Dejene, 2024). African-birch timber, in particular, offers numerous advantages, including low cost, favorable strength-to-weight ratio, reduced corrosion susceptibility, and ease of handling. However, challenges persist, such as durability concerns, variability in timber quality, and bond strength issues between timber and concrete.

To address these limitations, advancements in timber treatment and engineering techniques have been developed, making timber reinforcement a viable option (Ayanleye *et al.,* 2022).

Proper design, selection, and treatment can optimize performance (Pastori *et al.,* 2022). Furthermore, reliability-based design (RBD) has emerged as a crucial approach in structural engineering, addressing uncertainties in loads, material properties, and other factors (Lobato *et al.,* 2020). RBD ensures structures maintain a specified probability of meeting design requirements throughout their service life (Shadabfar *et al.,* 2022). The First-Order Reliability Method (FORM5) is widely applied for reliability analysis, approximating the limit state function to estimate failure probabilities (Ghalehnovi *et al.,* 2020; Zabojszcza *et al.,* 2021). For example, according to Wilson et al., (2021) the Nigerian-grown African birch timber column was found adequate having varied the depth, length and the axial load supported by a Nigerian-grown African birch timber column and results obtained reveal that the timber is adequate for use as solid timber column at a depth and breadth of 150 mm, an effective height of 3600 mm and an axial load of 260 kN with its probability of failure as 8.85×10^{-3}. Also, in a reliability investigation carried out using the First Order Reliability Method (FORM) to assess the performance of a timber column section of 250 x 250mm and 300 x 300mm for six selected Nigerian-grown timber species. *Lophira alata* being and N1 timber was found to be the most reliable with a Probability of failure Pf = 2.78×10^{-3} and 7.1×10^{-2} under axial loads of 1000kN and 2000kN respectively. This was followed by *Anogeissus leiocarpus* with Pf = 2.53×10^{-2} and 5.26×10^{-3} under axial loads of 1000kN and 1500kN respectively (Wilson *et al.*, 2022a). Using a FORTRAN-based program, an identified I- section of (100 x 400mm) with a probability of failure Pf =1.22×10^{-02} was found adequate and its compressive resistance corresponds to a 200 x 100mm of the solid section (with Pf =7.76×10^{-02}) which is apparently half the dimension of the I-section. This shows that the solid section has a capacity twice that of the 'I'- section of equal dimensions (Wilson *et al.,* 2019).

The African birch timber is known to belong to strength class N2 grade timber by the NCP-2 (1973) system of grading (Wilson *et al.,* 2022a), as well as been known to be applicable as a reliable beam material (Abubakar *et al.,* 2020) and a satisfactory column material (Wilson 2018) hence, it can be explored as a reinforcement material in concrete for structural purpose. In the context of African-birch timber-reinforced concrete beams, FORM5 assesses structural performance and safety under various loading conditions. By employing RBD and FORM5, engineers can design timber-reinforced components meeting specified reliability targets, enhancing safety and reducing failure risks in sustainable construction practices (Leyder *et al.*, 2021).

2. Materials and Method

This section described the materials and methods used, adhering to BS code. Constituent material testing informed mix design, casting, and flexural strength analysis of timber-reinforced concrete beams. The rigorous methodology yielded precise results, evaluating beam performance and determining optimal mix ratios according to BS code guidelines.

2.1. Physical Properties of African-Birch Timber

The physical properties of African-birch timber were characterized according to British Standard (BS) codes (Wilson *et al.,* 2022b). The tests conducted included moisture content, specific gravity, and tensile strength.

a. Moisture Content Test (BS EN 13183-1:2002)

The moisture content of African-birch timber was determined using the oven drying method (Akinyele & Folorunsho, 2021). According to Iorkar & Adedeji, (2022), the samples were cut to 50mm x 50mm x 50mm and weighed to record their initial weight (m1). The samples were then dried at 103°C ± 2°C for 24 hours and re-weighed to record their final weight (m2). The moisture content (%) was calculated using:

$$\mathrm{Mc}\ (\%) = \left\{\frac{(\mathrm{M1}-\mathrm{M2})}{(M1)}\right\} X\ 100$$ ***Equ.1***

b. <u>Specific Gravity Test (BS EN 316:2009)</u>

The specific gravity of African-birch timber was determined by measuring the sample's dimensions (L, W, H) and weight (m). The volume (V) was calculated as V = L × W × H, and the specific gravity (G) was calculated using:

$$\mathrm{G} = \left\{\frac{M}{(V\ X\ \rho\mathrm{w})}\right\}$$ ***Equ.2***

Where;

ρw = density of water (1000 kg/m^3).

c. <u>Tensile Strength Test (BS EN 310:1993)</u>

The tensile strength of African-birch timber was determined using a universal testing machine with a 10mm/min crosshead speed. Samples were cut to 20mm x 20mm x 300mm, and the maximum load (F*max*) at failure was recorded. The tensile strength (σt) was calculated using:

$$\sigma \mathrm{t} = \left\{\frac{(\mathrm{F}max)}{A}\right\}$$ ***Equ.3***

Where;

Maximum load= (F*max*)

Tensile strength= (σt)

A = cross-sectional area.

2.2 Concrete Mix Design (EN 12350-2:2019; Part 2: Slump test)

This study employed a mixed design approach to develop a concrete mix suitable for reinforcing with African-birch timber. The initial water-cement ratio of 0.5 was found to be too coarse, resulting in a mix that was difficult to handle. Therefore, the water-cement ratio was adjusted to 0.6, achieving a slump test value of 50-100 mm, which is ideal for building columns, walls, and general construction due to its ease of handling and moderate flowability (Sonebi & Yahia, 2020).

The mix ratio adopted for the concrete was 1: 2.48: 3.38, representing the ratio of cement, fine aggregate, and coarse aggregate, respectively. This mix ratio was chosen based on the desired strength and workability of the concrete.

a. <u>Specimen Preparation</u>

Four concrete beam configurations were prepared, combining steel (Y12) and African-birch timber (Ayin) reinforcements: The reinforcement used for each beams was four reinforcement (with two reinforcement main reinforcement and another two as hanger bars) for each beam and each configurations as well. Beams were cast in a 150mm x 150mm x 700mm wooden mold, with Y8 bars at 200mm centers holding reinforcements in place.

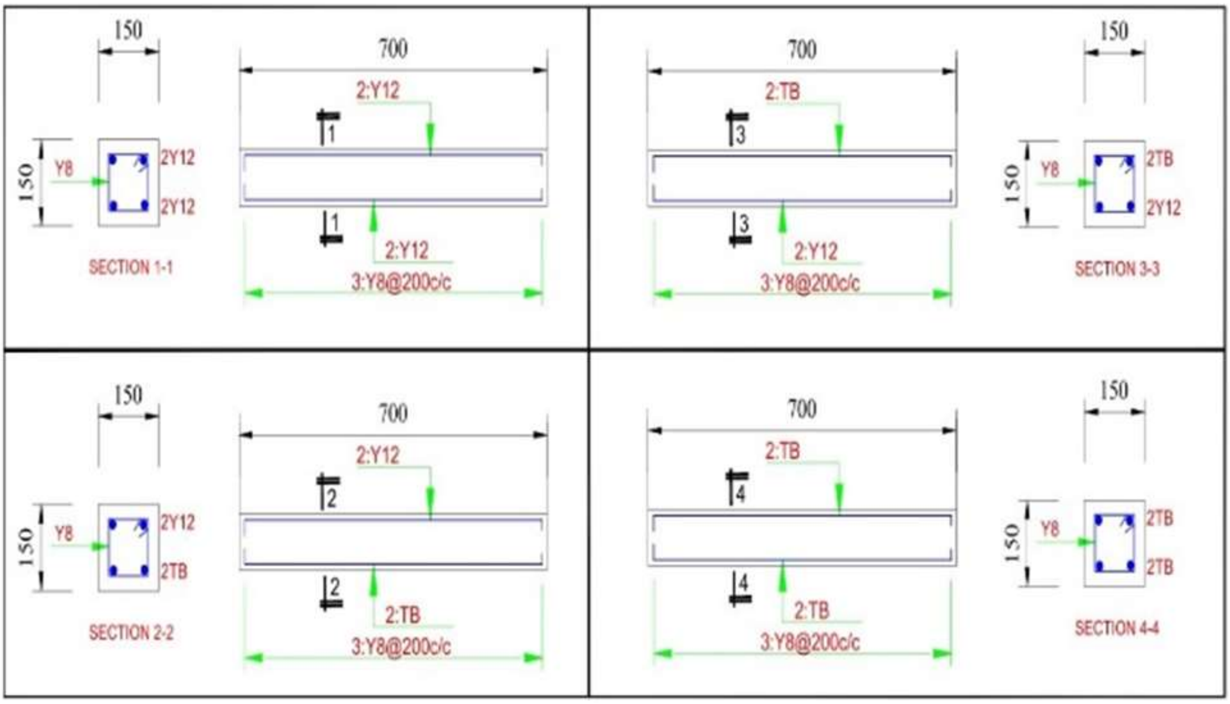

Plate.1. Different reinforcement configurations.

b. ***Specimen Casting, Curing and Testing***

A total of 40 samples were cast and cured for different periods: 3, 7, 14, 21, and 28 days. This allowed for an assessment of the concrete's strength development over time.

After each curing period, the following tests were conducted on the samples:

i. *Flexural Strength Test (Three-Point Bending):*

This methodology outlines the procedures for testing the flexural strength and deflection of concrete beams using a Universal Testing Machine (UTM) in accordance with BS EN 12390-5**.** Concrete beams measuring 150 mm x 150 mm x 700 mm were cured for various durations (3, 7, 14, 21, and 28 days) before testing. Each beam was placed on two roller supports spaced 600 mm apart**,** with a loading head positioned at the midpoint to apply a gradual load until failure. The maximum load and failure mode were recorded, and deflection was monitored using a dial gauge. The flexural strength was calculated using the formula

$$Fs = \frac{3Pa}{bd^2} \qquad \textbf{Equ.4}$$

Where;

P = Load, a = length of the sample, b = breath of the sample and d = depth of the sample.

ii. *Deflection Test:*

A dial gauge indicator was used to measure the deflection of the concrete beams under load (Van *et al*., 2023). This test provides information on the beam's stiffness and deformation characteristics. Methodology ensures a comprehensive assessment of the concrete mixes' performance and structural integrity.

c. ***The Limit State Functions for Reliability Analysis***

The limit state function for flexural failure is defined as:

$$g(M, R) = R - M = 0 \qquad \textbf{Equ.5}$$

Where;

R = maximum moment capacity of a simply supported beam subjected to flexural failure, determined from laboratory tests (Wang & Arora, 2006)

M = applied moment of a simply supported beam subjected to point load

$M = \frac{WL\hat{}2}{8}$ ***Equ.6***

$W = 1.4Gk + 1.6Qk$ ***Equ.7***

$M = (\frac{1.4Gk+1.6Qk}{8})*L^2$ ***Equ.8***

$N = \frac{M}{Z}$ ***Equ.9***

$N = \{ (\frac{WL\hat{}2}{8}) / 0.9d_{eff}\}$ ***Equ.10***

$N = \{ (\frac{1.4Gk+1.6Qk}{8})*L^2 / 0.9*d_{eff}\}$ ***Equ.11***

$g(R-N) = R - N = R - \{ (\frac{1.4Gk+1.6Qk}{8}) * L\hat{}2 / 0.9 * \text{deff} \} = 0$ ***Equ.12***

The limit state function for Deflection is defined as:

$g(D, C) = C - D = 0$ ***Equ.13***

$C = \frac{L}{deff}$ ***Equ.14***

$g(D-C) = (\frac{L}{d}) - D = 0$ ***Equ.15***

where:

D = ultimate deflection, determined from laboratory tests
C = allowable deflection

L = Length (m)

d_{eff} = effective depth (m)

Table 1. Probability distribution and statistical parameters for variables for flexural strength.

S/No	Basic variables	Probability distribution	Mean	Standard deviation	*COV (%)*
1.	Length, L (m)	Normal	5.43	2.82	51.9
2.	Effective Depth, d_{eff} (m)	Normal	1.3	0.76	58.5
3.	Live Load, G_k (kN/m^2)	Log. Normal	10.2	7.61	74.5
4.	Dead Load, Q_k (kN/m^2)	Log. Normal	8.6	6.88	80.0

Table 2. Probability distribution and statistical parameters for variables for deflection.

S/No	Basic variables	Probability distribution	Mean		CoV
1.	Length, L (mm)	Normal	1.5	0.79	52.7
2.	Effective Depth, deff. (mm)	Normal	1.3	0.76	58.5

3. Results and discussion

3.1 Material Properties and Compatibility

The properties of Ayin (African-birch) timber, as measured in this study, include a specific gravity of 0.89, aligning with the findings of Bello & Jimoh (2018), who reported a specific gravity range for African-birch timber of 0.84 to 1.16 and an average of 1.046. This is within the acceptable range for timber used in structural applications but lower than that of typical aggregates, which generally range from 2.30 to 2.90 (Çelik *et al.,* 2021). The moisture content of the timber was recorded at 9.83%, consistent with the findings of Jimoh *et al.,* (2018), who reported values ranging from 6.01% to 12.39%, corresponding to stress grades of 40-50 as supported by Bello & Jimoh (2018). Furthermore, the tensile strength of the African-birch timber was found to be 99.86 N/mm^2, which aligns with previous studies that recorded tensile strengths between 69.61 N/mm^2 and 115.9 N/mm^2 (Bello & Jimoh, 2018), indicating its suitability for lightweight structural applications.

3.2 Analyzing the Relationship between Flexural Strength and Deflection

The graph below illustrates the correlation between deflection and flexural strength for various beam configurations. Among the specimens tested, the Ayin-Steel configuration exhibited the highest deflection at 0.37mm and the highest flexural strength at 23.02 M/mm^2. However, this specimen's performance deviated from a smooth upward trend compared to the Steel - Steel configuration.

The Steel - Steel specimen demonstrated a consistent upward trend in both deflection and flexural strength, reaching 0.36mm and 2539.68 N/mm^2 respectively. This suggests a direct proportional relationship between flexural strength and deflection for the Steel - Steel specimen, indicating that as deflection increases, so does flexural strength.

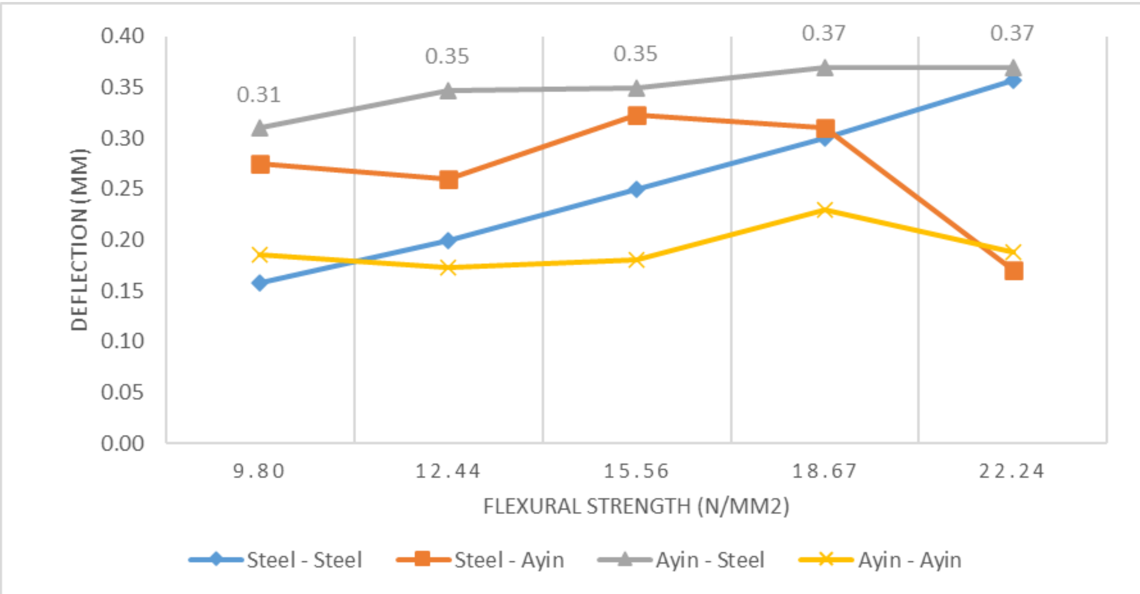

Fig. 1. A chart of deflection against flexural strength for each configuration.

3.3 Reliability Analysis

Using FORM-5, this study evaluated the reliability of beams across four rebar configurations, highlighting the impact of key parameters on structural safety and efficiency (which are Length, width, live & dead loads, effective depth).

a) Varying Length, L (m) and keeping all other variables constant for flexural strength analysis.

The reliability analysis shows Steel-AB offers the highest safety index (β = 1.98) and lowest probability of failure (Pf = 0.0238), outperforming AB-Steel by 8.2% in safety index and 28.1% in reduced failure probability. Steel-Steel also demonstrates strong reliability. These findings suggest that Steel-AB is the optimal combination for reinforced concrete beams with African birch timber, providing excellent safety and durability in construction.

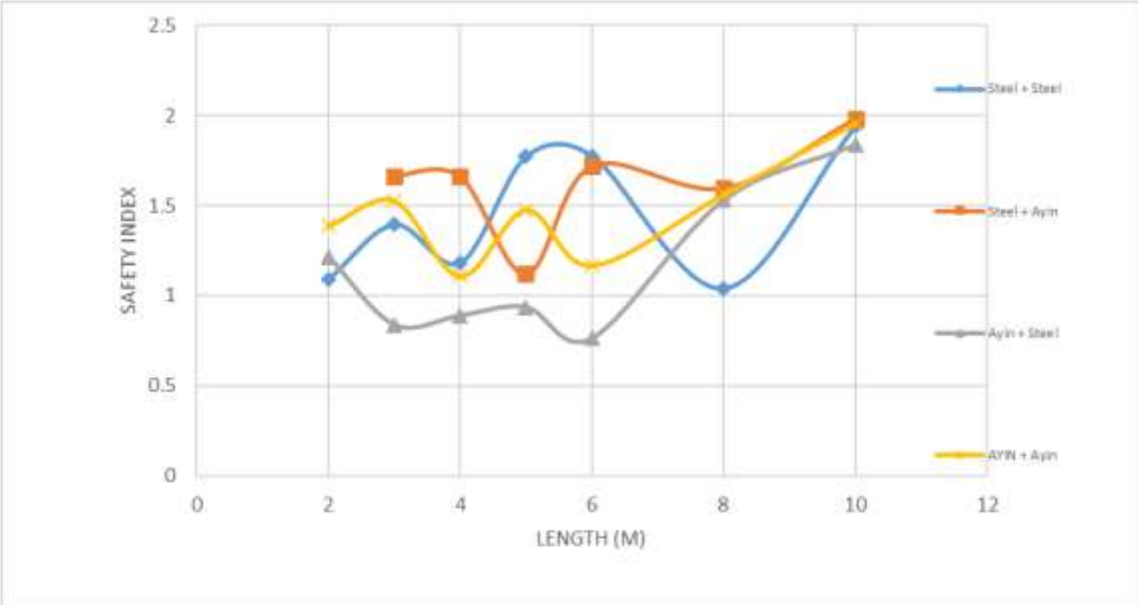

Fig. 2. A graph of safety index against varying Length (m) of the beam.

b) Varying depth, d (m) and keeping all other variables constant for flexural strength analysis.

The study identified Steel-AB as the most reliable combination, with a safety index of 1.947 and 0.0258% probability of failure at 0.15m. It outperformed AB-Steel by 6.85% in safety index and 24.56% in reduced probability of failure, and Steel + Steel, which showed decreased reliability at 0.3m (safety index: 0.934, failure probability: 0.175). Careful material selection and depth consideration are crucial.

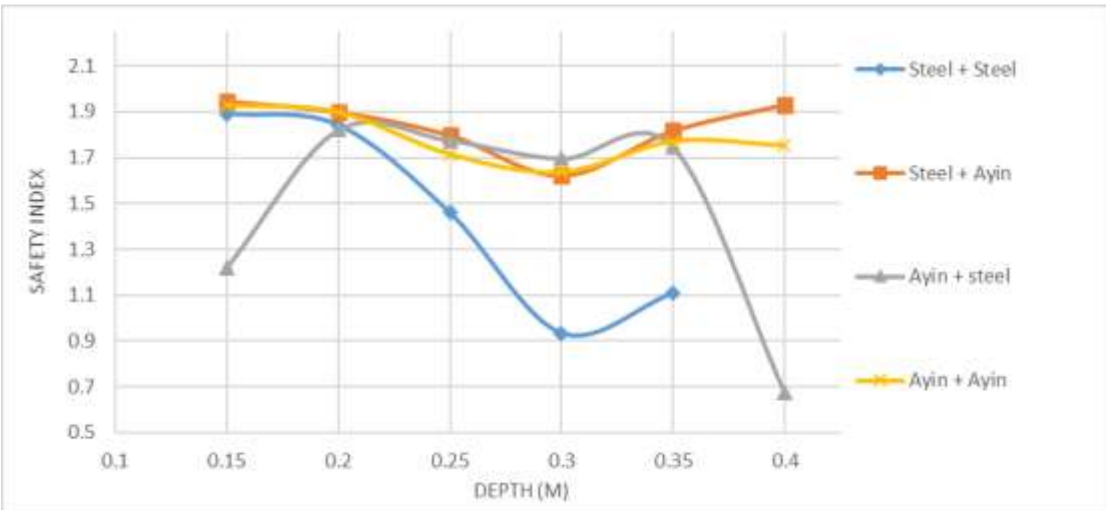

Fig. 3. A graph of safety index against varying depth (m) of the beam.

c) *Varying live load, Gk (kN/m²) and keeping all other variables constant for flexural strength analysis.*

The study revealed varying reliability performances across different material combinations and live loads. Steel-AB's safety index dropped significantly from 1.808 to 0.533 (70.6% decline) as live loads increased from 1 kN/m^2 to 20 kN/m^2, with probability of failure rising from 0.0353 to 0.297. Similarly, Steel-Steel and AB-Steel showed declines of 77.1% and 77.1% respectively. In contrast, AB-AB demonstrated consistent reliability, maintaining a stable safety index of 1.742 across all loads, with minimal change in probability of failure (0.0408).

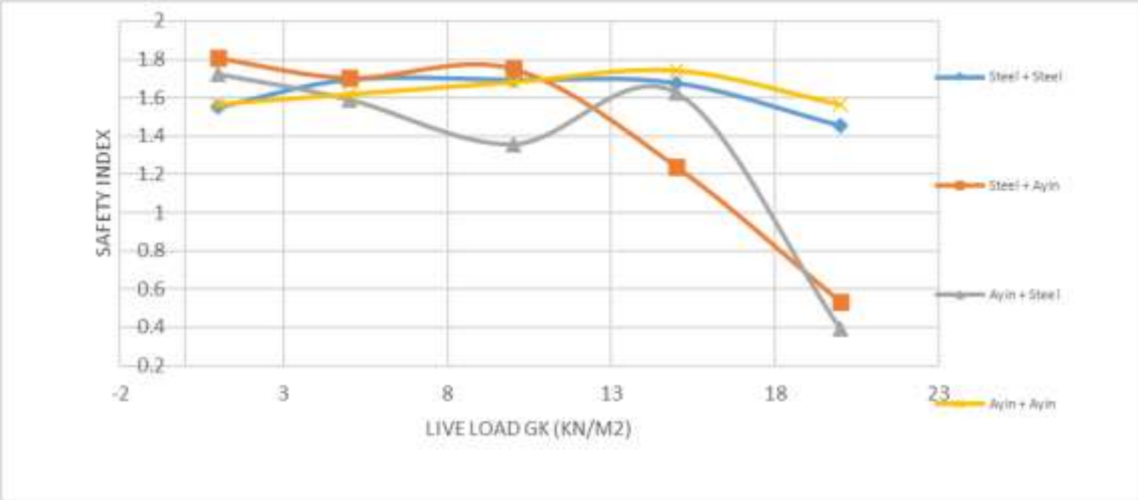

Fig. 4. Safety index against varying live load, Gk (kN/m²) in the beam sample.

d) *Varying dead load, Qk (kN/m²) and keeping all other variables constant for flexural strength analysis.*

The study revealed that AB-AB combination offers the highest reliability, with a safety index of 1.824 and probability of failure of 0.0341. Steel-AB followed closely, with a safety index of 1.635 and probability of failure of 0.0514. AB-AB outperformed Steel-AB by 11.1% in safety index and 29.2% in reduced probability of failure, indicating that using African-Birch alone or with steel as a reinforcement enhances structural safety and reliability.

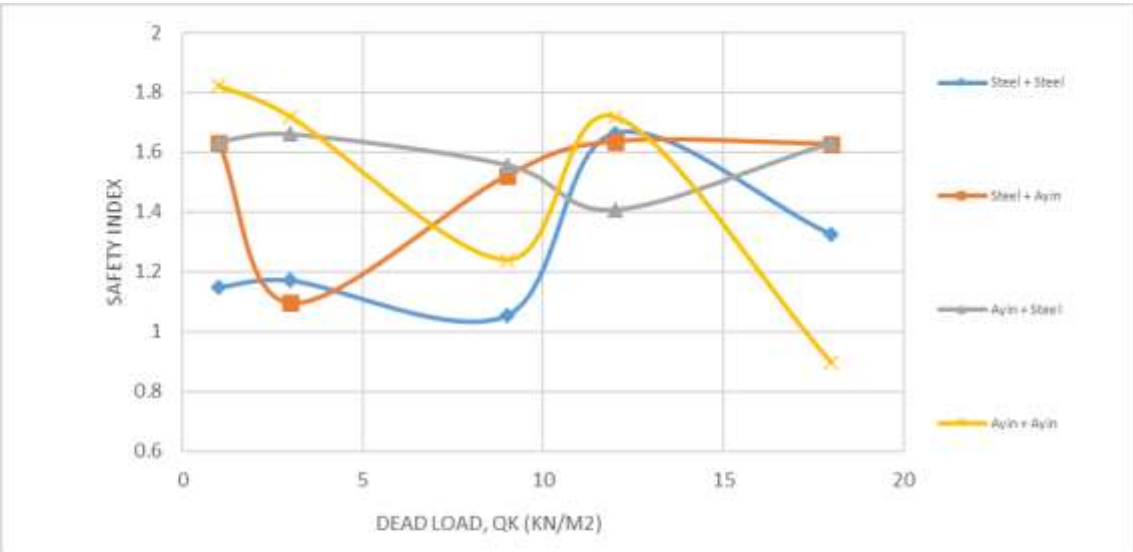

Fig. 5. A graph of safety index against varying dead load, Qk (kN/m2) in the beam.

e) *Varying Length (m) and keeping effective depth (m) constant for deflection analysis.*

The analysis indicates that AB-Steel offers the best structural performance, achieving a safety index of 1.786 and a failure probability of 0.037 at 2.5m, significantly outperforming Steel-Steel, which has a safety index of 1.633 and a failure probability of 0.0513. This represents a 9.36% improvement in safety index and 27.5% reduction in failure probability, demonstrating that longer lengths enhance reliability across all combinations.

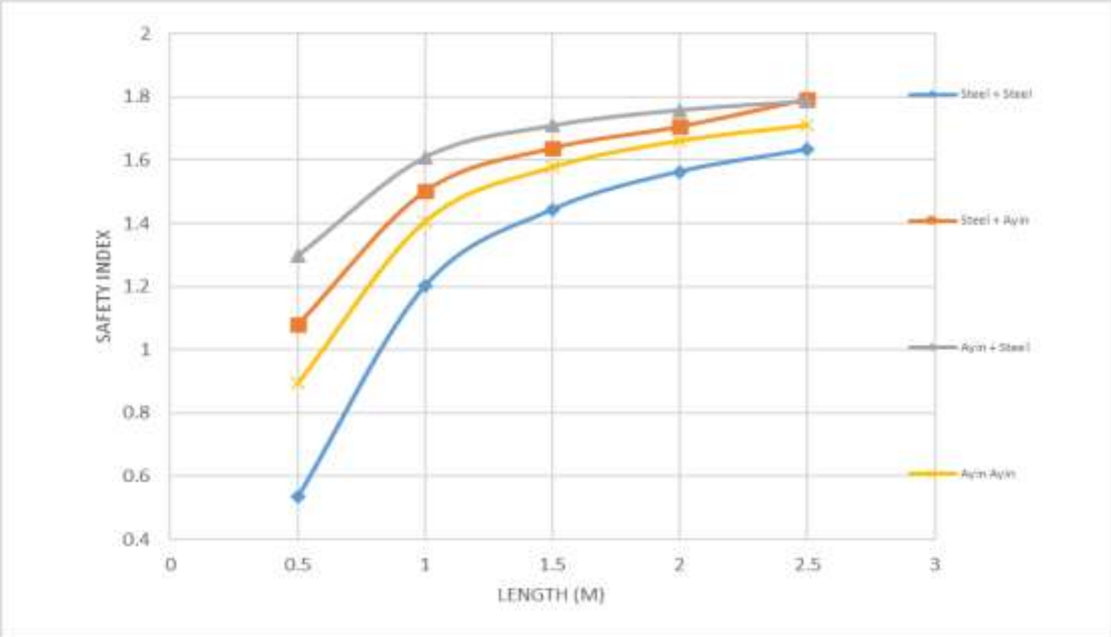

Fig. 6. A graph of safety index against varying Length (m) of the beam.

f) <u>Varying Effective depth (m) and keeping Length (m) constant for deflection analysis.</u>

As effective depth increases, all reinforcement combinations show declining safety. AB-Steel performs best, maintaining the highest safety index of 1.843-1.555 and lowest probability of failure of 0.0327-0.06 across depths of 0.4m-2.3m. In contrast, Steel-Steel is the least reliable, with a 27.1% lower safety index and 77.1% higher failure probability compared to AB-Steel. This emphasizes the critical role of material selection for deeper sections in structural applications, highlighting AB-Steel as the best option.

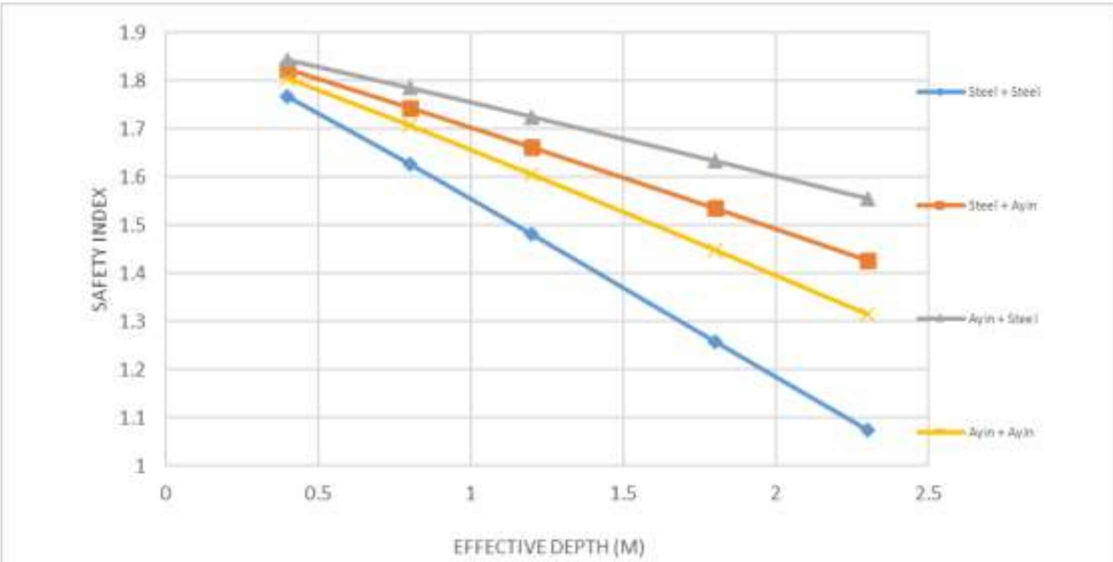

Fig. 7. A graph of safety index against varying Effective depth (m) of the beam.

4. Conclusions

This study investigated African-birch timber-reinforced concrete beams' reliability and structural performance. The findings reveal that incorporating African-birch timber enhances structural safety and reliability, offering a sustainable alternative to traditional Steel + Steel configurations.

Steel + AB and AB + AB combinations outperform Steel + Steel, demonstrating superior reliability and safety. AB + AB exhibits consistent reliability across varying live loads, while AB + Steel achieves a 9.36% higher safety index (1.786) and 27.5% lower failure probability (0.037) at 2.5m.

As effective depth increases, AB + Steel maintains superior reliability. Careful material selection and depth consideration are crucial for optimal performance. The study highlights African-birch timber's potential as a reliable and sustainable reinforcement material, particularly when combined with steel.

These findings provide valuable insights for structural engineers and construction professionals seeking innovative, eco-friendly solutions. African-birch timber-reinforced concrete beams offer enhanced structural safety and reliability.

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APPENDICES

A-1; Table of all mechanical test readings.

<table>
<tr><td colspan="6">GENERAL READING CONSIDERING (AGE, DEFLECTION, DENSITY, LOAD & FLEXURAL STRENGTH).</td></tr>
<tr><td colspan="6">STEEL + STEEL</td></tr>
<tr><td rowspan="6">7a.</td><td>AGE (days)</td><td>DEFLECTION (mm)</td><td>LOAD (KN))</td><td>DENSITY (Kg/m3)</td><td>FLEXURE (N/mm)</td></tr>
<tr><td>3</td><td>0.16</td><td>31.50</td><td>2850.79</td><td>5.60</td></tr>
<tr><td>7</td><td>0.20</td><td>40.00</td><td>2888.89</td><td>7.11</td></tr>
<tr><td>14</td><td>0.25</td><td>50.00</td><td>2793.65</td><td>8.89</td></tr>
<tr><td>21</td><td>0.30</td><td>60.00</td><td>2730.16</td><td>10.67</td></tr>
<tr><td>28</td><td>0.36</td><td>71.50</td><td>2539.68</td><td>12.71</td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">STEEL + AYIN-TIMBER</td></tr>
<tr><td rowspan="6">7b.</td><td>AGE (days)</td><td>DEFLECTION (mm)</td><td>LOAD (KN))</td><td>DENSITY (Kg/m3)</td><td>FLEXURE (N/mm2)</td></tr>
<tr><td>3</td><td>0.28</td><td>55.00</td><td>2647.62</td><td>9.78</td></tr>
<tr><td>7</td><td>0.26</td><td>52.00</td><td>2603.17</td><td>9.24</td></tr>
<tr><td>14</td><td>0.32</td><td>64.50</td><td>2571.43</td><td>11.47</td></tr>
<tr><td>21</td><td>0.31</td><td>62.00</td><td>2571.43</td><td>11.02</td></tr>
<tr><td>28</td><td>0.17</td><td>34.00</td><td>2476.19</td><td>6.04</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">AYIN-TIMBER + STEEL</td></tr>
<tr><td rowspan="4">7c.</td><td>AGE (days)</td><td>DEFLECTION (mm)</td><td>LOAD (KN)</td><td>DENSITY (Kg/m3)</td><td>FLEXURE (N/mm2)</td></tr>
<tr><td>3</td><td>0.31</td><td>62.00</td><td>2664.13</td><td>11.02</td></tr>
<tr><td>7</td><td>0.35</td><td>69.50</td><td>2603.17</td><td>12.36</td></tr>
<tr><td>14</td><td>0.35</td><td>70.00</td><td>2603.17</td><td>12.44</td></tr>
</table>

	21	0.37	74.00	2587.30	13.16
	28	0.37	74.00	2492.06	13.16
AYIN-TIMBER + AYIN-TIMBER					
7d.	**AGE (days)**	**DEFLECTION (mm)**	**LOAD (KN)**	**DENSITY (Kg/m3)**	**FLEXURE (N/mm2)**
	3	0.19	37.00	2901.59	6.58
	7	0.17	34.50	2730.16	6.13
	14	0.18	36.00	2317.46	6.40
	21	0.23	46.00	2444.44	8.18
	28	0.19	37.50	2253.97	6.67

A-2; Table of Reliability on Flexural Test

STEEL + STEEL	Steel + Steel				Steel + Steel				Steel + Steel				Steel + Steel		
	Length	Safety Index	Prob. Of Failure		Eff. Depth	Safety Index	Prob. Of Failure		Live Load	Safety Index	Prob. Of Failure		Dead Load	Safety Index	Prob. Of Failure
	2	1.089	0.138		0.15	1.891	0.0293		1	1.551	0.0605		1	1.149	0.125
	3	1.394	0.0816		0.2	1.841	0.0328		5	1.693	0.0452		3	1.171	0.121
	4	1.181	0.119		0.25	1.459	0.0723		10	1.693	0.0453		9	1.055	0.146
	5	1.773	0.0381		0.3	0.934	0.175		15	1.676	0.0468		12	1.663	0.0481
	6	1.776	0.0379		0.35	1.108	0.134		20	1.455	0.0729		18	1.325	0.0926
	8	1.038	0.15		0.4	1.602	0.0545								
	10	1.944	0.026												
STEEL + AYIN	Steel + Ayin				Steel + Ayin				Steel + Ayin				Steel +Ayin		
	Length	Safety Index	Prob. Of Failure		Eff. Depth	Safety Index	Prob. Of Failure		Live Load	Safety Index	Prob. Of Failure		Dead Load	Safety Index	Prob. Of Failure
	2				0.15	1.947	0.0258		1	1.808	0.0353		1	1.631	0.0514
	3	1.661	0.0483		0.2	1.9	0.0297		5	1.705	0.0441		3	1.095	0.137
	4	1.661	0.0483		0.25	1.799	0.0364		10	1.753	0.0398		9	1.521	0.0792
	5	1.121	0.131		0.3	1.622	0.0342		15	1.239	0.108		12	1.635	0.051
	6	1.719	0.0428		0.35	1.818	0.0343		20	0.533	0.297		18	1.627	0.0519
	8	1.596	0.0552		0.4	1.932	0.0277								
	10	1.98	0.0238												

AYIN + STELL	Ayin + Steel				Ayin + Steel				Ayin + Steel				Ayin + Steel		
	Length	Safety Index	Prob. Of Failure		Eff. Depth	Safety Index	Prob. Of Failure		Live Load	Safety Index	Prob. Of Failure		Dead Load	Safety Index	Prob. Of Failure
	2	1.216	0.112		0.15	1.22	0.111		1	1.723	0.0425		1	1.636	0.0509
	3	0.838	0.201		0.2	1.822	0.0342		5	1.59	0.056		3	1.661	0.0483
	4	0.89	0.187		0.25	1.775	0.0379		10	1.357	0.0874		9	1.558	0.0596
	5	0.936	0.175		0.3	1.696	0.0363		15	1.624	0.0522		12	1.408	0.0796
	6	0.763	0.223		0.35	1.746	0.0414		20	0.395	0.346		18	1.632	0.0514
	8	1.53	0.063		0.4	0.673	0.252								
	10	1.837	0.0331												
AYIN + AYIN	Ayin + Ayin				Ayin + Ayin				Ayin + Ayin				Ayin + Ayin		
	Length	Safety Index	Prob. Of Failure		Eff. Depth	Safety Index	Prob. Of Failure		Live Load	Safety Index	Prob. Of Failure		Dead Load	Safety Index	Prob. Of Failure
	2	1.387	0.0673		0.15	1.928	0.0269		1	1.566	0.0587		1	1.824	0.0341
	3	1.527	0.0634		0.2	1.898	0.0288		5	1.618	0.0528		3	1.719	0.0429
	4	1.107	0.134		0.25	1.714	0.61		10	1.682	0.0463		9	1.24	0.107
	5	1.477	0.0698		0.3	1.636	0.41		15	1.742	0.0408		12	1.719	0.0428
	6	1.168	0.121		0.35	1.771	0.0383		20	1.564	0.0589		18	0.895	0.185
	8	1.563	0.0618		0.4	1.753	0.0398								
	10	1.957	0.0252												