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Flexural Performance in Eco-Friendly Building Materials: The Role of Sawdust and Steel Fibre in Cement Composites

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ABSTRACT

The emergence of environmentally sustainable construction materials has become a central focus in modern construction methods, prompted by the necessity to reduce ecological footprints and promote sustainable progress. This study investigates the flexural strength of concrete beams with varying combinations of steel fibres and sawdust, considering two curing periods of 7 and 28 days. The results show that the incorporation of steel fibres generally enhanced flexural strength, with the highest strengths of 5.4 MPa and 5.8 MPa observed in beams containing 10% steel fibre. Conversely, excessive sawdust content (10%) led to a decline in flexural strength, emphasizing the detrimental effect of sawdust on concrete's mechanical properties. Notably, beams with 0.5% steel fibre and 5% sawdust exhibited enhanced flexural strength, even surpassing the control group, highlighting the reinforcing role of steel fibres. These results provide valuable insights into optimizing the composition of sustainable cement composites to achieve superior flexural strength, contributing to more resilient and eco-friendly construction materials.

Keywords: Flexural Strength, Concrete Beams, Steel Fibres, Sawdust, Sustainable Cement Composites

1. INTRODUCTION

The development of eco-friendly building materials has emerged as a pivotal theme in contemporary construction practices, driven by the imperative to minimize environmental impact and foster sustainable development. In this context, the integration of unconventional constituents such as sawdust and steel fibres into cement composites offers a promising avenue for achieving both structural resilience and ecological responsibility. This paper delves into the realm of flexural performance, a critical aspect of construction materials, to investigate the symbiotic influence of sawdust and steel fibres in cement composites.

Through systematic analysis and experimentation, this study aims to unravel the multifaceted dynamics governing the flexural strength of these eco-conscious building materials. By shedding light on the intricate interplay between sawdust, steel fibres, and cement, we endeavour to provide valuable insights into the fine-tuning of sustainable building materials, contributing to the evolution of a greener and more resilient construction industry.

According to Okedere *et al.* (2017) and Ogunbode *et al.* (2013), the sawmill industry generates a substantial amount of sawdust, which poses a significant solid waste management challenge. In response, open burning is the prevalent method for its disposal in Nigeria. However, Jacob *et al.* (2016) emphasize the associated environmental and health risks. Sawdust and wood process dust, highly flammable, can cause fires and explosions, especially when accumulated in large volumes. Disposing sawdust in water bodies can lead to flooding and property damage (FAO, 1991; Elijah & Elegbede, 2015). Shamsain (2002) reports studies in Nigeria indicating that occupational exposure to wood dust is linked to respiratory diseases, with workers exposed to wood dust showing increased respiratory symptoms, irritations, allergies, and sensitivity.

Hessel (2002) notes reduced lung function and respiratory health effects among wood dust-exposed workers. Komolafe *et al.* (2021) even associate wood dust exposure with cancer risk. As indicated by Ganiron (2013) and Ganiron and Ucol-Ganiron (2013), sawdust has been explored as a potential replacement for fine aggregate in concrete manufacturing. Sawdust concrete is formulated by blending sawdust, gravel, and a specific water content to enhance workability and facilitate cement hydration, contributing to improved bonding. This type of concrete is characterized by its lightweight properties, as well as its resistance to heat and fire.

According to Kovac (2004), Steel Fibre Reinforced Concrete (SFRC) emerges as the third significant structural material based on concrete, surpassing traditional reinforcement methods involving steel rods and stirrups, as well as steel mesh reinforcement in concrete, known as ferrocement. Holschemacher *et al.*, (2010) found that the fibres play a crucial role in attaining a designated load-bearing capacity following matrix fracture, with the extent of this contribution influenced by factors such as distribution, alignment, and embedded length. Waqas *et al.* (2014) stated that concrete, when reinforced with steel fibres, exhibits enhanced characteristics, including heightened ductility, increased durability, and enhanced structural strength. This approach reduces the demand for additional steel reinforcement and enhances resistance to impact and abrasion.

2. METHODOLOGY

For this investigation, sawdust was sourced from local sawmill facilities situated in the urban region of Ibadan. It was utilized as a partial replacement for fine aggregate, with substitutions of 5% and 10% during the batching process. The steel fibres used were obtained from recycled local steel binding wires collected from various construction sites within the same vicinity. These steel fibres were precision-cut to achieve a uniform length of 50mm. The primary cementitious material chosen for the study was Portland limestone cement (CEMII), characterized by a density of 1440 kg/m³ and a strength class of 42.5, making it well-suited for a variety of concrete mixtures. The fine aggregate was sourced locally, comprising sharp sand and stored in a dry, shaded area to prevent moisture absorption. The coarse aggregate consisted of granite with a maximum crushed size of 20 mm, meeting the specified concrete composition criteria. In preparation for blending with the concrete, the sawdust underwent an extensive drying process to eliminate moisture content.

Subsequently, a screening procedure was employed to ensure the removal of particles that were excessively large or small, thereby ensuring uniformity in the mixture.

The mix design for this study adhered to an empirical approach as delineated by Sharma (2020), following the principles of the Design of Experiment (D.O.E). The quantities of ingredients in each concrete mixture were meticulously determined in accordance with Sharma's methodology. A total of fifty-four concrete beams, each possessing dimensions of 100x100x400mm, were meticulously fabricated and systematically categorized into nine distinct groups, denoted as CC1 to CC9. Furthermore, the weight proportions of the constituent materials for each concrete beam mixture can be found in Table 1.

Table 1: Weight proportions for 6 beams per mix

	CC1	**CC2**	**CC3**	**CC4**	**CC5**	**CC6**	**CC7**	**CC8**	**CC9**
Steel Fiber (%)	0	0	0	0.5	0.5	0.5	1	1	1
Sawdust (%)	0	5	10	0	5	10	0	5	10
Cement (kg)	10.66	10.66	10.66	10.66	10.66	10.66	10.66	10.66	10.66
Fine Aggregate (kg)	18.93	17.98	17.04	18.93	17.98	17.04	18..93	17.98	17.04
Coarse Aggregate (kg)	26.76	26.76	26.76	26.76	26.76	26.76	26.76	26.76	26.76
Water-cement Ratio	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33
Steel Fiber (kg)	0	0	0	1.02	1.02	1.02	2.04	2.04	2.04
Sawdust (kg)	0	0.95	1.89	0	0.95	1.89	0	0.95	1.89

In each concrete mixture, the proportions of cement, coarse aggregate, and water remained consistent, along with a constant water-cement ratio. The experimentation involved the modification of fine aggregate quantities by reducing them by 5% and 10% through partial substitution with sawdust. Furthermore, steel fibre materials were introduced in amounts equivalent to 0.5% and 1% of the overall concrete mass. To ensure even distribution, the constituent materials were rigorously mixed using a portable concrete mixer. During the casting process, a meticulous layer-wise compaction method was employed. Following a 24-hour curing period, the concrete beams were de-moulded and subsequently placed in curing tanks. The beams underwent curing for durations of both 7 and 28 days.

This procedure was followed by the flexural strength testing of the beams which was carried out with the aid of a flexure testing machine. The concrete beam testing procedure was conducted at two curing intervals: 7 and 28 days. Each testing day involved the evaluation of twenty-seven beams, with three beams selected from each of the designated categories (CC1 through CC9). The initial step involved marking each beam at a distance of 75cm from both of its ends, establishing these marks as the anchoring points. Subsequently, the midpoint between these marked ends, equating to 125cm, was identified, serving as the reference point for loading alignment. The beam was then positioned to ensure the central point corresponded with the loading point. The force application block was brought into contact with the beam, and a continuous load was applied at a consistent rate until the beam reached failure. Plate 3.10 displays the concrete beam within the flexural testing apparatus before load introduction, while Plates 1 and 2 illustrates the beam's deformation subsequent to the application of the flexural load.

Plate 1: Prior to load application

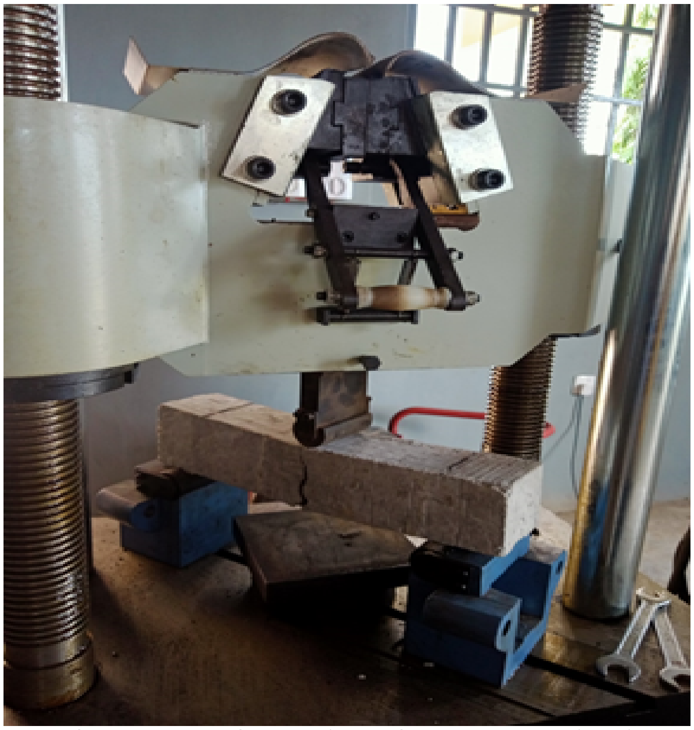

Plate 2: Beam Deformation after load application

3. RESULTS AND DISCUSSION

Flexural Strength

The flexural strength test involved examining fifty-four concrete beams after 7 and 28 days of curing, with twenty-seven beam samples evaluated on each test day. Table 2 and Figure 1 presents the outcomes of the flexural strength tests conducted on concrete beams that featured varying proportions of steel fibres and sawdust and underwent curing for 7 and 28 days.

Table 2: Flexural strength test results

	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9
Steel Fibre (%)	0	0	0	0.5	0.5	0.5	1	1	1
Sawdust (%)	0	5	10	0	5	10	0	5	10
Compressive Strength at 7 days (MPa)	3.5	3.4	3.3	5.0	4.7	4.0	5.4	4.9	4.4
Compressive Strength at 28 days (MPa)	3.8	3.6	3.5	5.3	4.9	4.3	5.8	5.2	4.7

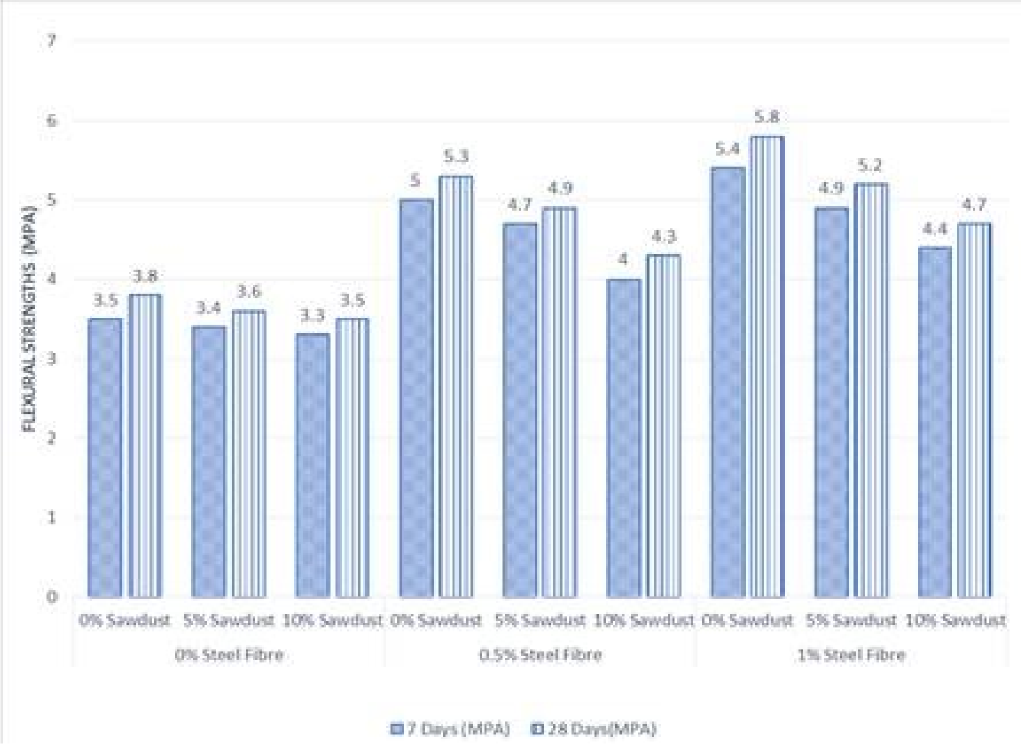

Fig 1: Summary of the flexural strength test results

The flexural strength assessment was conducted on a set of fifty-four concrete beams, encompassing two distinct curing periods of 7 and 28 days. Each testing day involved the evaluation of twenty-seven beam samples. Figure 1 illustrates the outcomes of the flexural strength tests carried out on these concrete beams, which incorporated varying combinations of steel fibres and sawdust, in conjunction with the two specified curing durations. The data also reveals a general augmentation in flexural strength with the addition of steel fibres, as indicated by higher readings for concrete beams containing steel fibres compared to those composed solely of sawdust. The highest flexural strengths, recorded at 7 and 28 days, were 5.4 MPa and 5.8 MPa, respectively, in the group of beams exclusively comprising 10% steel fibre.

Conversely, the 10% sawdust group exhibited reduced flexural strength, registering values of 3.3 MPa at 7 days and 3.5 MPa at 28 days, illustrating the detrimental impact of excessive sawdust content on concrete's flexural strength. This decline aligns with the observations of Savie (2010), highlighting a consistent trend of decreasing flexural strength with an increasing proportion of sawdust. Notably, when comparing the groups featuring 0.5% steel fibre and 5% sawdust, the presence of steel fibres resulted in a significant enhancement in flexural strength, even surpassing the control group. Although this increase was not as remarkable as in the groups containing only 0.5% steel fibre without sawdust, which exhibited flexural strengths of 5MPa and 5.3MPa, it distinctly underscores the reinforcing effect of steel fibres on concrete's flexural strength.

5. CONCLUSION

The observed pattern of sawdust's influence on concrete, as evident in the compressive strength data, mirrors the findings in the flexural strength results. Sawdust consistently exerts a weakening effect on strength, while the introduction of steel fibres serves to enhance flexural strength. It's noteworthy that the adverse impact of sawdust can be mitigated by a dual approach, involving a reduced percentage of fine aggregate substitution with sawdust and a concurrent increase in the proportion of steel fibre incorporation. This combination strategy effectively counters the deleterious effects of sawdust, ultimately leading to improved flexural strength in the concrete specimens.

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