Advances In Multidisciplinary & Scientific Research
A Multidisciplinary & Interdisciplinary Journal

Volume 9, No 3, 2023 Series

Evaluating the Workability of Sustainable Cement Composites with Sawdust and Steel Fibre: A Slump Test Analysis

Obakin O.A., Oladunmoye O.M., Ajayi S.A. & Taiwo J.B.
Department of Architecture,
University of Ibadan,
Nigeria.
E-mail : morenifunmi@gmail.com
Phone; +234 8033591023

ABSTRACT

Sawdust, a by-product of woodworking and timber processing, exhibits a substantial influence on reducing workability of cement composites, with its effect surpassing that of steel fibre. This comprehensive study evaluated the rate of workability and slump value reduction of sawdust and steel fibres on the workability of cement composites. It revealed that sawdust has a significant influence on workability, even surpassing the effect of steel fibres. The research demonstrated that the combined inclusion of both materials led to a substantial reduction in slump values across various trials, with reductions ranging from 0% to 55%. Notably, trials with higher sawdust content and lower steel fibre content experienced the most pronounced reductions. For instance, a 10% addition of sawdust resulted in a 22% reduction in slump value. These findings provide valuable insights into the optimization of cement composite mixtures for construction applications, underscoring the intricate interplay between steel fibres and sawdust in the modification of its workability.

Keywords: Sawdust, Steel fibres, Workability, Slump values, Cement Composites

Aims Research Journal Reference Format:
Obakin O.A., Oladunmoye O.M., Ajayi S.A. & Taiwo J.B. (2023): Evaluating the Workability of Sustainable Cement Composites with Sawdust and Steel Fibre: A Slump Test Analysis. Advances in Multidisciplinary and Scientific Research Journal Vol. 9. No. 3. Pp 66-72. . www.isteams.net/aimsjournal. dx.doi.org/10.22624/AIMS/V9N3P7

1. INTRODUCTION

In the realm of sustainable construction, the quest for materials and methodologies that align with modern building requirements while upholding environmental principles has gained paramount significance. This paper delves into a novel avenue of investigation within sustainable construction—specifically, the integration of sawdust and steel fibre into cement composites. This convergence of natural, renewable sawdust and the reinforcing attributes of steel fibre presents a compelling proposition with multifaceted implications for contemporary construction practices. The two primary objectives underpinning this research are as follows:

i. Waste Mitigation: Sawdust, frequently a by-product that remains underutilized within industrial contexts, holds the potential to significantly mitigate waste accumulation. Its incorporation into cement composites provides an eco-friendly outlet for this material while simultaneously addressing concerns surrounding waste disposal and environmental impact.

ii. Structural Enhancement: The introduction of steel fibre into the composite matrix serves to bolster mechanical properties, enhancing structural robustness. This reinforcement mechanism aims to ameliorate issues such as surface cracks and augment the overall durability of construction components, thereby contributing to the creation of longer-lasting, resilient structures.

Sawdust, comprised of fine wood particles from various sources, is considered an organic waste resulting from timber processing (Tyagher *et al*., 2011). Sawmills in Nigeria generate substantial amounts of sawdust, estimated at 5.2 million metric tons annually, with a significant concentration in the south-western region (Kehinde *et al*., 2009). Sawdust and other process dust in mills pose significant fire and explosion hazards due to their flammable nature, as highlighted by Jacob *et al.* (2016). When ignited, wood waste and dust can lead to fires, which may escalate to explosions in areas with a high concentration of dust. Moreover, workers exposed to wood dust are at risk of respiratory infections.

In Nigerian wood industries, the predominant practice for managing wood waste involves open burning, emitting pollutants like carbon monoxide, sulphur dioxide, nitrogen oxides, and ash into the atmosphere. This wood smoke not only increases the risk of lower respiratory infections but also interferes with the lung development of children. Additionally, certain chemicals in wood smoke, such as polycyclic aromatic hydrocarbons, are suspected carcinogens. Furthermore, the disposal of sawdust into water bodies can obstruct drainage systems and contribute to flooding during the rainy season, potentially resulting in loss of lives and property damage, as noted by Elijah & Elegbede (2015).

The development of admixtures and foreign materials in concrete has made significant strides, with the potential to substitute steel in certain applications, as noted by Balendran *et al*. (2002). Among these advancements, fibre reinforcement stands out as a key player, capable of fundamentally altering concrete properties. Numerous studies have investigated the impact of adding fibres on the mechanical performance of concrete, considering variations in concrete type and specimen size. Holschemacher *et al*. (2010) emphasized that fibres play a pivotal role in achieving specific load-bearing capabilities after matrix fracture, contingent on factors like allocation, orientation, and embedded length. Concrete reinforced with steel fibres, as highlighted by Waqas *et al*. (2014), exhibits improved qualities such as enhanced ductility, durability, and structural strength. It requires less steel reinforcement and boasts improved resistance to impacts and abrasion.

The construction industry has shown growing interest in fibre-reinforced concrete due to its ability to enhance structural performance beyond that of plain concrete, as observed by Lie and Kodur (1996). By bridging cracks and providing post-cracking ductility, fibre reinforcement primarily aims to reduce cracking and modify the material's behaviour after matrix cracking, aligning with the work of Bentur and Mindess (2006) and Vajje (2013).

The aim of this study is to evaluate the workability of sustainable cement composites that incorporate sawdust and steel fibres through a comprehensive analysis using slump tests by providing valuable insights into the fine-tuning of cement composite mixtures for construction applications, emphasizing the role of sawdust and steel fibres in modifying workability, thereby contributing to more environmentally friendly and efficient construction practices.

2. METHODOLOGY

Materials Procurement

Sawdust: The sawdust utilized in this study was sourced from residual sawdust stockpiles located proximate to sawmill facilities within the urban area of Ibadan. Within the batching procedure, a partial substitution of fine aggregate was implemented, involving weight replacements of 5% and 10%. Steel Fibre: The steel fibres employed in this study constitute recycled material sourced from local steel binding wires. These steel binding wires were sourced from multiple construction sites within the urban area of Ibadan. Subsequently, they underwent precision cutting to achieve uniform lengths of 50mm. Cement: Portland limestone cement, specifically of type CEMII with a density of 1440 kg/m³ and a strength class of 42.5, was selected as the primary cementitious material for this study. This particular cement type is versatile and finds application in a wide array of products, including concrete mixes ranging from C8/10 to C35/45. Notably, it possesses attributes that effectively mitigate bleeding in freshly placed concrete and exhibits robust water retention capabilities.

Aggregates: For aggregate selection, sharp sand, sourced from a local deposit, was chosen as the fine aggregate for the research. To maintain the integrity of the sand, it was stored in a shaded environment, safeguarded from moisture to ensure the surface remained dry and suitable for use. As for the coarse aggregate employed in this investigation, granite was selected, with a maximum crushed size of 20 mm, aligning with the desired specifications for the study's concrete compositions.

Sample Preparation

a. Sawdust Treatment

The sawdust was dried thoroughly to remove excess moisture and ensure consistent mixing with the concrete. After drying, it was then screened to remove any oversized or undersized particles, ensuring uniformity in the mix.

(b)Mix Design

The empirical mix design methodology, based on the Design of Experiment (D.O.E) approach as detailed by Sharma (2020), served as the foundation for this project. The determination of ingredient quantities for the concrete mix in this study strictly adhered to the procedures elucidated by the aforementioned author. The resultant mix design parameters and the definitive mix proportions for the concrete are meticulously outlined in Table 1 and Table 2, respectively.

Table 1: Mix design parameters

Parameters	Concrete Grade	Free Water-Cement ratio	Cement Type	Cement Specific Gravity	Fine Aggregate	Fine Aggregate Specific Gravity	Coarse Aggregate Type	Maximum Coarse Aggregate Size	Coarse Aggregate Specific Gravity	Slump
Values	M30	0.5	CEMII 42.5 grade	3.61	Zone-II	2.61	Crushed	20mm	2.65	60-180

Table 2: Final material proportion and concrete design mixture

Materials	Cement	Fine Aggregate	Coarse Aggregate	Water
Quantity (Kg/m³)	410	728	1029.1	205

(c) Sample Casting:
A total of eighty-one concrete cubes measuring 150x150x150mm were manufactured, distributed into nine distinct groups designated as T1 to T9. Each group consisted of nine cubes.

i. T1, the initial category, served as the control group, comprising concrete cubes without any partial replacement of sawdust or the inclusion of steel fibres.
ii. Groups T2 and T3 involved partial replacements, with T2 having a 5% partial replacement of fine aggregate weight and T3 featuring a 10% partial replacement.
iii. Groups T4 and T7 exclusively incorporated steel fibres, with T4 having 0.5% steel fibres by weight of concrete and T7 featuring 1% steel fibres by weight of concrete.
iv. Groups T5, T6, T8, and T9 combined steel fibres and sawdust. T5 featured 0.5% steel fibres by weight of concrete and a 5% partial replacement of fine aggregate. T6 included 0.5% steel fibres by weight of concrete and a 10% partial replacement of fine aggregate. T8 combined 1% steel fibres by weight of concrete with a 5% partial replacement of fine aggregate. Lastly, T9 incorporated 1% steel fibres by weight of concrete and a 10% partial replacement of fine aggregate.

Within each mixture, the weights of cement, coarse aggregate, and water were held constant, maintaining a consistent water-cement ratio. However, the weights of fine aggregates were intentionally reduced by 5% and 10% as part of the partial replacement process with sawdust. Additionally, steel fibre materials were introduced at 0.5% and 1% of the concrete's weight. For thorough and uniform dispersion, the materials were subjected to mechanical mixing in a portable concrete mixer. To facilitate the casting process, molds were lubricated using oil. Furthermore, prior to casting, a slump test was performed for each mixture to assess its workability.

During the casting phase, a consistent compaction method was employed, layer by layer, to fill the molds with concrete. After a 24-hour curing period, the concrete cubes were demolded and subsequently placed in curing tanks. The cubes thereafter underwent curing for 7, 14, and 28 days.

Testing Procedures
Slump Test: To assess the workability of freshly mixed concrete, a slump test was carried out on-site after each concrete mix. This test utilized specific equipment, including a slump cone, flat metal base, and tamping rod, each with precise specifications.

4. RESULTS AND DISCUSSION

The results of the slump tests are summarized in Table 3 and Figure 1, along with the slump percentage reduction.

Table 3: Concrete workability with different percentages of Steel Fibre and Sawdust

	T1	T2	T3	T4	T5	T6	T7	T8	T9
Steel Fibre (%)	0	0	0	0.5	0.5	0.5	1	1	1
Sawdust (%)	0	5	10	0	5	10	0	5	10
Slump (mm)	87	79	68	72	63	56	59	47	39
Reduction (%)	0	9	22	17	28	36	32	46	55

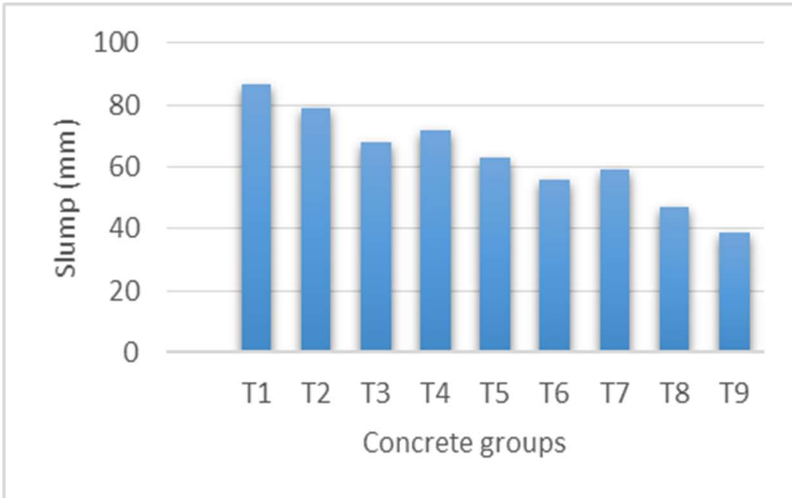

Figure 1: Slump Test Results

The results illustrate a consistent trend: as the proportion of sawdust and steel fibre increased, the slump values decreased. This decline in slump values can be attributed to the water-absorbing properties of both sawdust and steel fibre, which reduce the available water for cement hydration and aggregate binding. The impact of sawdust on slump values was more pronounced than that of steel fibre, as evident from individual test findings. For instance, T1 had a slump value of 87 mm, while T3, with no steel fibre and 10% sawdust, had a slump value of only 68 mm. Similarly, T4 had a slump value of 72 mm with 0.5% steel fibre but no sawdust, while T5 had a slump value of just 63 mm with 0.5% steel fibre and 5% sawdust.

The combination of steel fibre and sawdust also significantly affected the slump values. For example, T1 had a slump value of 87 mm, whereas T6, with 0.5% steel fibre and 10% sawdust, only had a slump value of 56 mm, representing a 35% reduction. Similarly, T7 had a slump value of 59 mm with 1% steel fibre but no sawdust, while T9 had a slump value of only 39 mm with 1% steel fibre and 10% sawdust, reflecting a 34% decrease. Notably, the addition of sawdust had a more substantial impact on slump values than the addition of steel fibre, as indicated by the % reduction column in the table. For instance, adding 5% sawdust to T1 reduced the slump value of T2 by 9%, while adding 0.5% steel fibre to T1 only reduced the slump value by 17%.

Similarly, adding 10% sawdust to T1 reduced the slump value of T3 by 22%, while adding 1% steel fibre to T1 reduced the slump value of T7 by 32%. The significant reduction in slump observed with increasing sawdust content at a constant water-cement ratio aligns with previous findings indicating that the workability of concrete decreases when sand is partially replaced by sawdust (Olugbenga *et al*., 2014). Furthermore, the trend of decreasing slump values with the addition of more steel fibres (Tauseef *et al.,* 2021) is consistent with the observed trend when comparing T4 and T7.

Additionally, it's worth noting that the combined addition of steel fibres and sawdust further reduced the slump values in each run, with a more noticeable percentage drop in runs with higher sawdust percentages and lower steel fibre percentages. For instance, the slump was reduced by 28% in T5 and by 46% in T8 compared to T1, respectively.

4. CONCLUSION

The study conducted slump tests to evaluate the workability of cement composites incorporating sawdust and steel fibres, revealing a consistent trend wherein increasing proportions of these materials led to a substantial decrease in slump values. This decline in workability can be attributed to the water-absorbing properties of both sawdust and steel fibres, reducing available water for cement hydration and aggregate binding. Notably, sawdust exhibited a more pronounced impact on slump values than steel fibres. When combined, these materials further reduced slump values, with the extent of reduction being more noticeable in composites with higher sawdust content and lower steel fibre content. These findings contribute to a better understanding of how to optimize concrete mixtures for construction, particularly in sustainable and environmentally friendly contexts, by balancing the intricate interplay between sawdust and steel fibres to achieve the desired workability without compromising overall structural performance.

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