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Utilization of Sawdust in Concrete Masonry Blocks: A Review

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ABSTRACT

SDC (Sawdust Concrete) was developed in 19th century. It has been well recognized due to its lightweight and cost-effectiveness. Presently, developed countries have created opportunities to use wood waste in the concrete construction to reduce the environmental burden. Although SDC has received little consideration as a lightweight masonry block in building works but it has been intensively investigated in many countries for decades. The aim of this review is to summarize the last five years (2012-2016) research work related to utilization of sawdust in concrete masonry. However, it is important to explore existing ideas and approaches developed by previous researchers as a reference and guidance for the future research. There are lots of opportunities to develop lightweight concrete especially throughutilizing sawdust as a fine aggregate replacement material in concrete. However, this review paper is focusing on utilization of sawdust, as to reduce environmental impacts poses by the waste products of furniture industry and a by-product of wood industry. As a conclusion, this review paper summaries the existing important ideas and useful information for the fellow researchers, as to enhance the utilization of sawdust to produce lightweight masonry units. It is recommended that considerable research is required on the sawdust cement blocks, which can deliver more confidence on their utilization as a green building construction material.

Key Words: Sawdust, Fine Aggregate, Concrete, Compressive Strength, Masonry Blocks.

1. INTRODUCTION

Due to rapid growth of industrialization, the industrial waste creates the environmental and economic problem associated to their disposal. During the recent years there has been increasing focus on the application of discarded items and by-products from numerous sources in building works. Along with the environment protection, numerous studies were conducted on recycling of waste products as construction resources. Utilization of such waste materials into the building works could be a feasible answer not only to the pollution problem, but also to the challenge to high cost of construction materials which are being faced by many developing countries. One of such important waste is the sawdust which is comparatively plentiful and economical.

Sawdust is waste produced by timber industries, obtained from cutting, sawing or grinding of timber in the form of particle Fig. 1. Sawdust incorporated in cement has been familiar as 'sawdust cement' [1]. However, the development of sawdust concrete is still under investigation.

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Some of researchers have focused utilization of sawdust with additive materials, chemicals, waste materials, light weight aggregate, sand replacement. However, this paper highlights the possible use of sawdust in masonry concrete blocks as a sand replacement adopted by former researchers from Nigeria, Ghana, Brazil, China, Iraq, Turkey, UK, India, Philippines, France and Malaysia. It is expected that this information can be useful for the new researchers to discover more on sawdust concrete.

2. PRETREATMENT OF SAWDUST

Although sawdust consists largely of cellulose, comprises soluble sugar, acids, resins, oils and waxes,and extra organic materials. These extractable substances affect the setting of cement, particularly in lean mixes. So, irregular deviations of properties in various kinds of sawdust, the only safe process is to conduct trial tests of available sawdust to observe whether it has desired strength can be produced. Pre-treatment of sawdust is, therefore, essential to ensure that extractable materials in the sawdust do not affect hardening process of the cement. Lime need to be added as 1/6-1/3 volume per volume of cement to the sawdust earlier to mixing [2,7].

3. REVIEW OF PREVIOUS RESEARCH

The summary of literature reviews of published articles since 2012-2016 has been presented in Tables 1-5. Tables 1-5 are showing previous research work carried out on SDC to develop the lightweight, cost effective, durable and environmental friendly material for the construction industry. It was observed that the utilization of SDC has a wide capability, use as a sand replacement in concrete which reduces the environmental pollution and creates solution to the sustainable construction material to build cost effective structures.

4. DISCUSSION ON PREVIOUS FINDINGS

Sawdust pre-treatment is, therefore, necessary to ensure that extractable materials in the sawdust do not affect the hardening process of the cement. Two methods of pretreatment has been discussed by Saeed [7]: boiling sawdust in lime added water and addition of waterproofing material diluted in kerosene to sawdust, the better results were found with second method. According to Paramasivam and Loke [2] the optimum socking time for 'Kempus' sawdust was found to be 60 minute earlier to mixing. However, lime is added 1/6-1/3 volume per volume of cement to the sawdust [2].

Physical properties are the basic characteristics of wood and it is behavior to external influences other than applied forces. This includes grain and texture, density, moisture content, dimensional stability, thermal behavior etc. Awareness of physical properties is thus important, because they can significantly influence the performance and strength of the material used in the structural applications: higher the amount of sawdust lower is the workability [3,5,13,17].

FINE SAWDUST PARTICLES COARSE SAWDUST PARTICLES

FIG. 1. TYPICAL SAWDUST PARTICLES

TABLE 1. SUMMARY OF PERVIOUS RESEARCH WORK CARRIED OUT IN YEAR 2012

Reference	Country	Replacement of Material & Mix Design Procedure	Block Properties	Research Findings
Adebakin andAdeyemi [3]	Nigeria	0, 10, 20, 30 and 40% by volume of sand in 1:8 mix. Used water curing for 7, 14, 21 and 28days	Hallow (150mm x 450mm)	Compressive strength was found 4.26 to 1.80 N/mm2 for 0 to 40% sand replacement. 10% reduction in weight were observed at 10% sawdust replacement and about 3% reduction in production cost.
Akinwonmi [4]	Ghana	0, 20, 40, 65, 80 and 100%by weight of sand in 1:2 mix. Used water curing for 7, 14 and 28days	Solid (100x100x100 mm)	The optimum replacement of sand with sawdust was found to be 20 % and Flexural strength were observed 15.9 N/mm2 at 28day.
Moreira et. al. [5]	Brazil	5% by weight of sand in 1:2.5:2.5, 1:3.5:3.5, 1:4:4 and 1:5:5 concrete mixes. Used water curing for 7 and 28days	Hallow (size not mentioned)	Trial tests for the mass unit proportion, the different proportions of fine and coarse aggregates were taken (20/80, 25/75, 30/70, 35/65, 50/50 and 60/40) and good results were found on 50/50 proportion. 1:4:4proportion was found economical and 6.45 MPa compressive strength was observed at 28day.

TABLE 2. SUMMARY OF PERVIOUS RESEARCH WORK CARRIED OUT IN YEAR 2013

Reference	Country	Replacement of Material & Mix Design Procedure	Block Properties	Research Findings
Cheng et. al. [6]	China	0, 3, 5, 7 and 10% by weight of sand. Used water curing for 7 and 28days	Solid Blocks (100x100x100 mm)	The optimum replacement of sand with sawdust was found to be 5 %. There is a great tendency towards decreases the thermal conductivity and increases the heat preservation and insulation property in sawdust concrete.
Saeed [7]	Iraq	0, 5, 10, 15, 20, 25, 30 and 35% by weight of cement in 1:1 mix. Used water curing for 28days	Solid cubes (100x100x100 mm) and Prisms (100x100x500mm)	Bond between pretreated sawdust and cement paste is increased due to washing out harmful extractives in sawdust which inhabits setting and hardening of surrounding cement paste. Thus properties of SDC were highly being improved using pretreated sawdust. The compressive and Flexural strength were found increasing up to 50% for sawdust. Water absorption and thermal conductivity were highly be reduced.
Turgut and Gumuscu [8]	Turkey	0,10, 20 and 30% by volume of cement and ratio cement to lime powder waste as 1:5, 1:6 and 1:7	Solid Brick (For compressive 105x90x75mm) (For Flexural 105x225x75mm) (For unit weight 105x90x75mm)	Found 38.9% reduction in the thermal conductivity at 30% wood sawdust waste replacement with lime powder waste and found decreases in the modulus of elasticity at 10, 20 and 30% wood sawdust waste replacement 3.2, 27 and 46.6% as compared with normal mix.
Aigbomian and Fan [9]	UK	Sawdust (Cedar, Pine, Oak and Beech) with lime	Solid Blocks (100x100x100 mm)	The average compressive strength was observed for hardwood (Beech and Oak) sawdust as 3.75 and 2.07 MPa respectively, for softwood (Pine and Cedar) sawdust 1.3 and 0.15 MPa respectively and for mixed wood 0.20 MPa. Wood Crete made through mixed sawdust highlighted 18% reduction in density as compared to wood Crete made through hardwood and 0.08% increase in density compared to wood Crete made from softwood.

TABLE 3. SUMMARY OF PERVIOUS RESEARCH WORK CARRIED OUT IN YEAR 2014

Reference	Country	Replacement of Material & Mix Design Procedure	Block Properties	Research Findings
Boob [10]	India	0, 5, 10, 15 and 20% by weight sand in 1:4, 1:6 and 1:8 mixes. Used two method of curing sprinkler and gunny bag curing for 7, 14 and 28days	Solid Blocks (100x100x100 mm)	With gunny bag curing method for 1:6 ratio by 15% sawdust replacement gives strength of 4.5 N/mm2, density is 2000 kg/m3, which is reasonable and economical to be used for the partition walls in frame structure. Two methods (sprinkler and gunny bag covered) of curing were adopted to evaluate the effect of curing and the result of gunny bag covered method was observed the best results.
Kumar et. al. [11]	India	0, 10, 15 and 20% by weight of sand in 1:1.5:3concrete mix.(7 and 14days)	Solid Blocks (100x100x100 mm)	With 0, 10, 15 and 20% replacement of fine aggregate with sawdust gives the compressive strength values as 20.59, 18.15, 18.30 and 2050 N/mm2 respectively at 28 day of curing.
Tomas and Ganiron [12]	Philippines	0 and 100% by weight of sand in 1:2:4concrete mix. Used water curing for 7, 14 and 28days	Solid Blocks (100x100x100 mm)	The compressive strength at 28day was found 3122 psi which is lower than NMC (4258psi), about 10% reduction in weight and 44% cost saving for the same volume of sand.
Oyedepo et. al. [13]	Nigeria	0, 25, 50, 75 and 100% by weight of sand 1:2:4 concrete mix. Used water curing for 7, 14, 21 and 28days	Solid Blocks (100x100x100 mm)	Workability of concrete was observed to be decreasing as the percentage sawdust increases in the mix. The slump values 40, 9, 5, 6, and 15mm were obtained at 0, 25, 50, 75 and 100% replacement of sand by sawdust respectively. When the sand is replaced by sawdust at 0, 25, 50, 75and 100% results for compressive strength at 28day were obtained as 14.44, 13.00, 12.33, 11.11 and 10.57 N/mm2 respectively.

TABLE 4. SUMMARY OF PERVIOUS RESEARCH WORK CARRIED OUT IN YEAR 2015

Reference	Country	Replacement of Material & Mix Design Procedure	Block Properties	Research Findings
Ambiga [14]	India	0, 10, 20 and 30% by weight of sand in1:1.5:3 concrete mix. Used water curing for 7, 14, 21 and 28days	Solid Blocks (100x100x100 mm)	When the sand is replaced by sawdust at 0, 10, 20,and 30% results for compressive strength at 28day were obtained as 20.80, 16.30, 4.80 and 0.57 N/mm2 respectively. At 10% replacement of sand with sawdust gives about 10% reduction in weight and 3% reduction in production cost.
Xing et. al. [15]	France	0, 30, 40, 50 and 60%.Used water curing for 7 and 28days	Solid Blocks (100x100x100 mm)	The apparent density of Poplar sawdust178 kg/m3 and Saturated and surface-dried density 390 kg/m3.
handana, and Mynuddin [16]	India	0, 5, 10, 15 and 20% by weight in concrete mix 1:1.44:3.16 adopted water curing for 7 and 28days	Solid Blocks (100x100x100 mm) and Cylinders Ø100mmx200mm)	When the sand is replaced by sawdust at 0, 5, 10, 15 and 20% the average results for compressive strength at 28day were obtained as 27.78, 25.24, 21.42, 16.44and 10.58 N/mm2 respectively and the tensile strength was observed as 3.18, 3.11, 2.55,1.77 and 1.36 N/mm2. The concrete with 10%sawdust was proved to be optimum and cost effective.

The density of sawdust largely depends on the species of wood. Due to hydrophilic nature, the density of sawdust generally varies from 650-1650 kg/m^3. The density of sawdust concrete also varies depending upon the type and amount of sawdust used in mix. Using 'Kempas' wood, the dry density of sawdust concrete has been found to be 1490, 930 and 850 kg/m^3 for the mixes with cement to sand ratios of 1:1, 1:2 and 1:3 respectively [2]. However, the density of concrete containing sawdust from rubber tree exhibited 1450, 1280 and 1065 kg/m^3 respectively for the same mix proportions [17]. It can be seen that for higher amount of sawdust, the water absorption increased significantly [10,20].

It is in general agreement that higher the amount, lower the strength development. Like mechanical properties, the compressive strength of concrete is greatly influenced by the type of sawdust in the mix. This has been reflected in the research findings of Paramasivam and Loke, [2] and Awal et. al. [17]. Paramasivam and Loke investigated the concrete containing 'Kempus' tree, where 28 day

TABLE 5. SUMMARY OF PERVIOUS RESEARCH WORK CARRIED OUT IN YEAR 2016

Reference	Country	Replacement of Material & Mix Design Procedure	Block Properties	Research Findings
Awal et. al. [17]	Malaysia	1:1, 1:2 and 1:3 cement to sawdust by volume	Solid Blocks (100x100x100 mm)	Slump were observed 40mm, 15mm and 5mm for mix proportions of 1:1,1:2 and 1:3 respectively and density of SDC at 28days were found, for the mix of 1:1, 1:2 and 1:3 are 1450, 1280 and 1065 kg/m3 respectively. Compressive strength at 28 day were observed as 18.65, 17.20 and 12.80 N/mm^2 for 1:1, 1:2 and 1:3 respectively. The tensile strength at 28 day were observed as 2.05, 1.95 and 1.30 N/mm^2 for 1:1, 1:2 and 1:3 respectively. The flexural strength at the age of 28 day were observed as 2.75, 2.20 and 1.90 N/mm^2 for 1:1, 1:2 and 1:3 respectively. The elastic modulus of 17100, 16400 and 11950 N/mm^2 were obtained for the mixes of 1:1, 1:2 and 1:3 respectively.
Garcez et. al. [18]	Brazil	0, 25, 50, 75 and 100% by volume of sand in concrete mix. 1:2:1.2	Solid cylinders (Ø 50mmx100mm and Ø100mmx200mm)	Sand is replaced by sawdust at 0, 25, 50, 75 and 100% the compressive strength at the age of 28 day was observed as 17.84, 14.00, 9.16, 7.52 and 4.11 N/mm^2 respectively and the tensile strength were observed as 2.28, 1.74, 1.25, 1.22 and 0.79 N/mm2.
Zakaria [19]	Malaysia	0, 10, 20, 30, 40, 50, 60 and 70% by volume of sand in mix proportion of 1:2.25 for the water curing period of 7 and 28days	Solid Blocks (100x100x100 mm)	Sawdust treating with 2% sodium hydroxide has been shown to produce good results. Silica fume used as admixture at 3% by cement weight and Super plasticizer at 1.5% for all mixes to maintain workability. When sand is replaced by sawdust at 0, 25, 50, 75 and 100% the compressive strength at the age of 28 day were observed as 44.5, 49.34, 43.64, 39.82, 31.21, 30.62,26.85 and 26.10 N/mm^2 respectively and the ultrasonic pulse velocity was observed as 4265, 4057, 3985, 3932, 3652, 3503, 3365 and 3235 m/s. It was detected that sawdust can be used as partial replacement of sand from 0-30% contributes to reduction ofwood waste without affecting concrete strength.

compressive strength of 1:3, 1:2 and 1:1 mix of cement to sawdust were found to be 5.0, 8.7, 29.8 MPa respectively. Incorporating rubber sawdust, the compressive strength of sawdust concrete at the 28 day were found to be 18.65, 17.20 and 12.8 MPa respectively for the same mix proportions. Fig. 2 demonstrates a liner connection between the compressive strength and ultrasonic pulse velocity of SDC at 28 day.

Subsequently, it was perceived that the compressive strength of the concrete increased with increasing time of curing period. Obviously lower quantity of sawdust in the mix produced better results. Types of curing and length of curing period plays a vital role in the growth of concrete strength. Water curing has so far been widely practiced for curing of hydrated cemented concrete. Because of the very organic nature, concrete made with sawdust needs some modifications. It has been shown [10] that air curing at laboratory conditions produced better results as compared to the curing in immersed conditions. Similar behavior was observed in tension, flexure and modulus of elasticity of sawdust concrete [4,10,17-18].

The tensile strength of SDC, were investigated though split cylinder test according to ASTM C496/C496M at 7, 14 and 28 day, and the findings were presented in Fig. 3. It was observed as like the compressive strength, tensile strength also reduced with the growth in the quantity of sawdust [17].

The connection between the compressive and tensile strength has been shown in Fig. 4. It was observed that compressive is relational to the tensile strength. Though, the value of the correlation reduces with the increase in sawdust amount.

All these research findings have, however, been limited to short-term study only. Along with strength investigation of masonry units of particular type, it is also important to study the strength behavior of the masonry wall [21].

Apart from the application in masonry units, the application of sawdust in developing lightweight concrete seems to be a distinctive solution not only to the environmental issue but also to the economic and green construction [22]. However, no experimental data are yet available on the structural performance of masonry wall using sawdust brick or blocks.

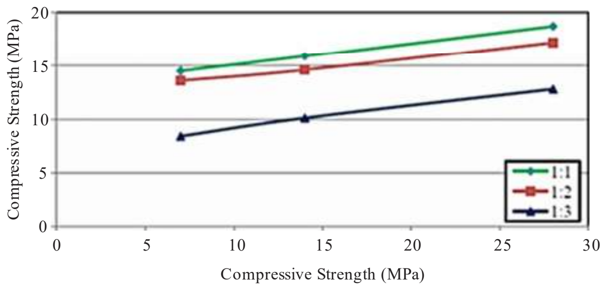

FIG. 2.COMPRESSIVE STRENGTH OF SDC

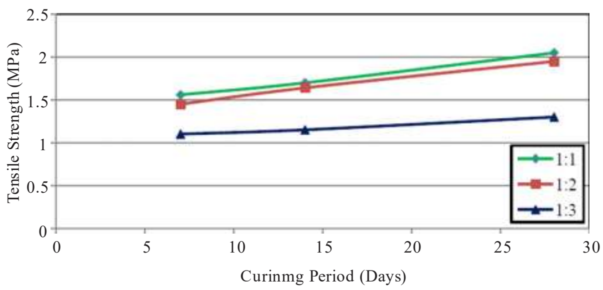

FIG. 3. SPLIT TENSILE STRENGTH OF SDC

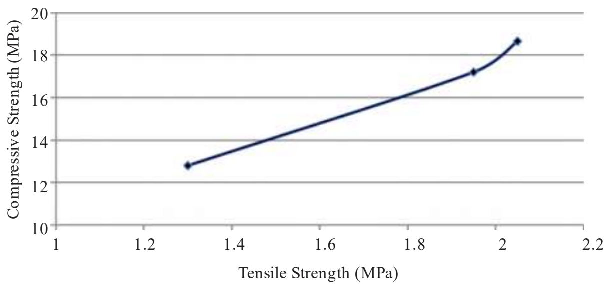

FIG. 4. COMPRESSIVE AND TENSILE STRENGTH RELASHIONSHIP FORSDC

5. CONCLUSION

Based on the literature review of last five-year research studies from eleven countries on the sawdust utilization in the concrete, it was observed that the compressive strength and weight of concrete decreases as the percentage of sawdust increases and water-cement ratio increases as the percentage of sawdust increases in the mix. Earlier research, suggested that sawdust concrete shows some promise for use in building construction. Hence, it can be utilized as lightweight masonry unit in buildings as a partition wall etc.

6. FUTURE RECOMMENDATION

To evaluate the in-depth strength performances including aspects of durability have been putting forward recommendation for future research in direction to discover well indulgent of sawdust as a green building material.

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