

Two-fold sustainability – Adobe with sawdust as partial sand replacement

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Abstract. Adobe is a material that is economic, environment friendly, and provides better indoor air quality. The material required for the preparation of adobe include clay, sand, and sometimes straw or other organic materials. These materials do not require industrial processing or transportation, however, sand mining has been recently posing a threat to the environment. Therefore, to enhance the existing sustainability of adobe, sand can be partially or fully replaced by other waste materials. This approach will not only solve the problem of excessive sand mining, it will also address the issue of waste management. Sawdust is one such waste material that can be used to partially replace sand in Adobe. This paper presents the results of compressive and flexural test carried out on Adobe samples with partial sand replacement by sawdust. The results show that about 4% sand replacement by volume produces higher compressive strength, whereas the flexural strength reduces with the use of sawdust. However, since flexural strength is not a critical property for adobe, it is concluded that replacing sand with sawdust by about 4% of volume will be beneficial.

1. Introduction

When it comes to low-cost sustainable construction, adobe is an ideal material [1]. In the regions of the world where it remains dry during most of the year, the legacy of the use of this material goes as far back as 10,000 years [2-4]. Adobe structures have been found in South Asia, Africa, Europe, and Central Asia with the types of structures ranging from important religious buildings to ordinary houses [5-11]. As well as the historical use of adobe [12], it is estimated that a considerable proportion (about 30%) of the current world population lives in houses made of adobe [13]. In the present day, adobe structures can be found in Africa, Iran, Afghanistan, Yemen, Iraq, Syria, Spain, Germany, England, France, Portugal, Italy, Denmark, and Sweden [14].

Despite its economy and sustainability, adobe suffers from challenges such as weakened tensile strength, which results in faulty behaviour when subjected to adverse conditions, such as earthquake, for e.g. [15]. The interest of the scientific and engineering community to increase the mechanical properties of this material has increased over the past few years [16]. Some of the efforts at increasing the mechanical properties have been directed at including some kind of reinforcement, for example, wire mesh [17]. Other researchers have focused on addition of materials to reduce the brittle behaviour and cracking due to shrinkage [3]. The additional materials sometimes consist of processed and synthetic materials such as cement or plastic fibres; however, most of the time in order to maintain the sustainable



nature of this material, natural fibres such as kenaf or waste materials such as fuel ash have been used [6]. Saw dust is another such waste material that is produced out of woodwork. The conventional uses of sawdust produced at sawmills include preparation of feed for livestock or re-use for making plywood etc., and such other uses. However, most of the times, the disposal of excess sawdust poses a challenge. The timber industry plays a vital role in Malaysian economy [18] and large quantities of sawdust waste materials are produced as a result. The disposal of this material, such as in landfills, poses a great challenge [19]. Moreover, it has been reported that sand mining for use as aggregate in concrete is the cause of many environmental challenges such as degradation of rivers, rising sea levels, destruction of aquatic habitats, destruction of ecosystems and biodiversity, etc. [20].

To address the above mentioned challenges that arise from excessive sand mining and disposal of waste sawdust into landfills, it is a good idea to use sawdust as partial sand replacement during the production of concrete as well as adobe. If added to adobe, it is expected that sawdust will positively affect the mechanical properties of adobe by reducing the dry shrinkage and increasing the ductility of the material. Such a use can be referred to as two-fold sustainability as it is aimed at addressing the environmental issues of sand mining and sawdust disposal by adding it to an already sustainable and environment friendly material, adobe. Therefore, the present study is aimed at exploring the use of adobe as partial sand replacement during the preparation of adobe.

2. Methodology

In order to achieve the objectives set out for this study, a total of 36 specimens were tests, 18 out of which were cubes tested for compressive strength and the remaining 30 were prismatic specimens tested for flexural strength. The cubes were 150 mm × 150 mm × 150 mm in size, whereas the prismatic specimens were 150 mm × 150 mm × 500 mm. The materials used for the preparation of these specimens included clay, sand, and sawdust. The clay proportion consisted of 30%. The details of specimens along with mix proportions used are provided in Table 1.

Table 1. Details of specimens and mix proportions used.

S. No.	Detail of Specimen	Clay Proportion	Sand Proportion	Sawdust Proportion
1	3 cubic specimens named C0-1, C0-2, and C0-3; and 3 prismatic specimens named P0-1, P0-2, and P0-3	30%	70%	0%
2	3 cubic specimens named C1-1, C1-2, and C1-3; and 3 prismatic specimens named P1-1, P1-2, and P1-3	30%	60%	10%
3	3 cubic specimens named C2-1, C2-2, and C2-3; and 3 prismatic specimens named P2-1, P2-2, and P2-3	30%	50%	20%
4	3 cubic specimens named C3-1, C3-2, and C3-3; and 3 prismatic specimens named P3-1, P3-2, and P3-3	30% %	40%	30%
5	3 cubic specimens named C4-1, C4-2, and C4-3 and 3 prismatic specimens named P4-1, P4-2, and P4-3	30% %	30%	40%

The mixing procedure involved adding all the ingredients first to the concrete mixer followed by addition of water in small amounts until a malleable adobe mass was obtained. The adobe mix was then poured into moulds for the preparation of test specimens. The test set up for the compressive testing is shown in Figure 1, whereas the test set up for flexural testing is shown in Figure 2.



Figure 1. Compressive strength test setup. **Figure 2.** Flexural strength test setup.

3. Compressive Strength Test Results

The results of the compressive strength test have been summarized in Table 2 and illustrated in Figure 3. It can be seen that while the average compressive strength for the three specimens with no sawdust is 2.1 MPa, it increases when sand is partially replaced by sawdust. For sawdust comprising 10% of the total mix, the average compressive strength increases to 2.19 MPa. This keeps on increasing to 2.43 MPa for 20% of the mix comprising of sawdust. However, when the proportion of sawdust is increased beyond 20%, the compressive strength starts decreasing. It drops back to an average value of 2.19 MPa for 30% and 2.05 MPa for 40%, which is even less than when no sawdust was used at all. Therefore, it can be concluded that the addition of sawdust increases the compressive strength of adobe with the optimum proportion of sawdust being around 20% when 30% clay is used. A look at the standard deviation values indicates that all the results are closely grouped together, which adds to the reliability of these results.

Table 2. Results of the compressive strength test

Sawdust Proportion	Specimen	Compressive Strength (MPa)	Average (MPa)	Standard Deviation
Nil	C0-1	2.16	2.1	0.06
	C0-2	2.09		
	C0-3	2.05		
10%	C1-1	2.24	2.19	0.04
	C1-2	2.18		
	C1-3	2.16		
20%	C2-1	2.47	2.43	0.11
	C2-2	2.31		
	C2-3	2.51		
30%	C3-1	2.17	2.19	0.02
	C3-2	2.2		
	C3-3	2.21		
40%	C4-1	2.14	2.05	0.08
	C4-2	1.98		

	C4-3	2.03		
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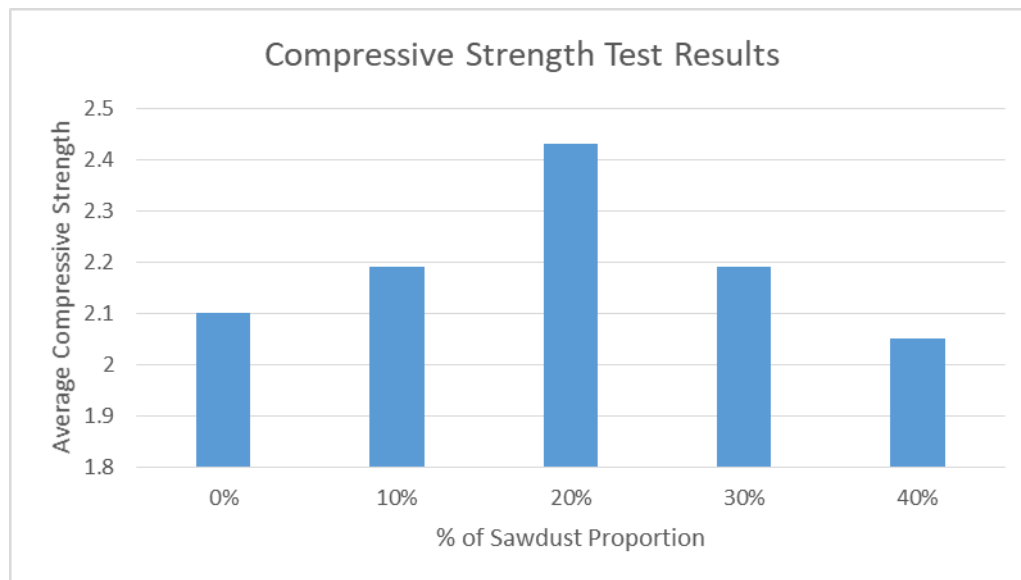


Figure 3. Average compressive strength for various % of sawdust proportions.

4. Flexural Strength Test Results

The results of the flexural strength test have been summarized in Table 3 and illustrated in Figure 4. It can be seen that while the standard remains low indicating close grouping of the results, the flexural strength actually reduces when sawdust is added to adobe mixture. The average flexural strength when no sawdust was used is 0.51 MPa, which reduces to 0.45 MPa with 10% of mix proportion comprising of sawdust. The flexural strength keeps reducing as the proportion of sawdust is increased to 20%, 30%, and 40% with the values of 0.42 MPa, 0.39 MPa, and 0.34 MPa, respectively. Although this reduction in the flexural strength of adobe with the addition of sawdust suggests that it may be optimal not to use sawdust as partial sand replacement. However, it should be noted that the flexural strength of adobe is very low to start with. The flexural strength of 0.51 MPa without any sawdust is also negligible and it is not possible to design any flexural structural members using adobe only. Adobe structures usually consist of load bearing walls that are primarily loaded in compression. The small openings such as door and windows are usually supported by the help of other materials such as wooden boards etc. Therefore, the negative effects of sawdust on the flexural strength of adobe can be discounted as insignificant.

Table 3. Results of the compressive strength test

Sawdust Proportion	Specimen	Compressive Strength (MPa)	Average (MPa)	Standard Deviation
Nil	P0-1	0.51	0.51	0.01
	P0-2	0.5		
	P0-3	0.52		
10%	P1-1	0.44	0.45	0.01
	P1-2	0.44		
	P1-3	0.46		
20%	P2-1	0.41	0.42	0.02
	P2-2	0.42		
	P2-3	0.44		
30%	P3-1	0.35	0.39	0.03
	P3-2	0.42		
	P3-3	0.39		
40%	P4-1	0.3	0.34	0.06

	P4-2	0.33		
	P4-3	0.41		

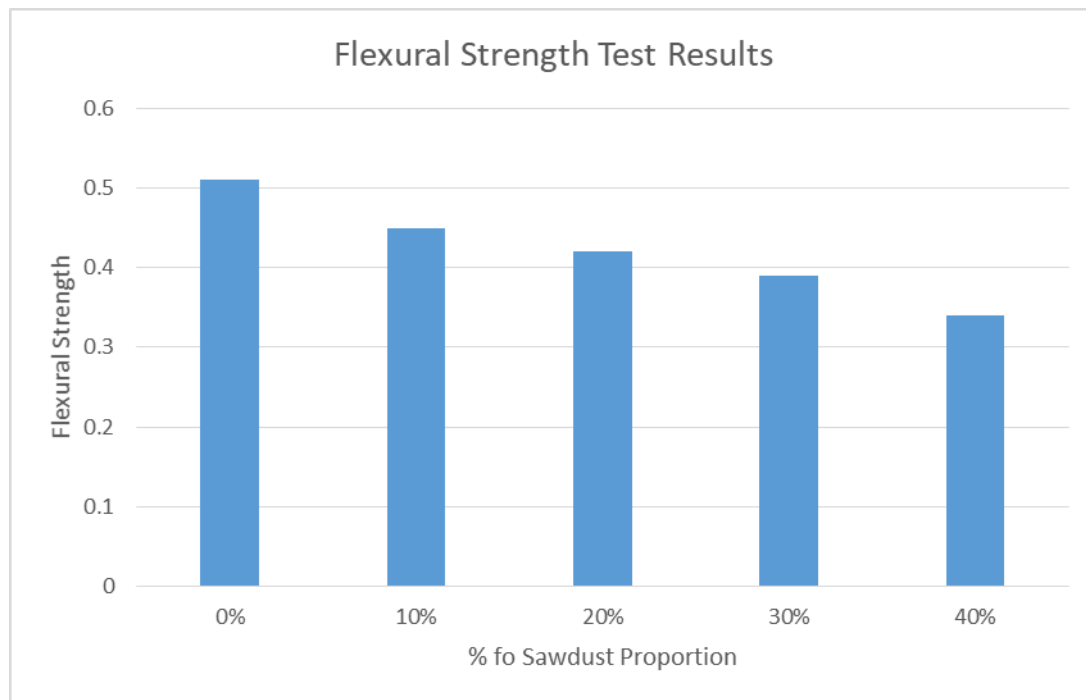


Figure 4. Average compressive strength for various % of sawdust proportions.

5. Conclusion and Recommendations

The results of the compressive strength and flexural strength tests have been presented when sawdust was used as partial sand replacement in adobe. The proportions of sawdust were varied from 0% to 40% at 10% intervals. From the results obtained, the following 2 conclusions can be drawn:

- Addition of sawdust increases the compressive strength of adobe. The ideal proportion of sawdust lies at 20%, which adds about 15% to the compressive strength.
- The addition of sawdust reduces the flexural strength of adobe, however, because of the fact that flexural strength is not a critical parameter for adobe, this effect is detrimental to the use of sawdust as partial sand replacement.

It is worth noting here that the clay proportion used for all the specimens in this study was fixed at 30%. It would be interesting to explore how the addition of sawdust influences both the compressive and flexural strength with varying proportion of clay in the mixture. Furthermore, it is noted that the generalizability of these results may be limited by the number of specimens used in the present study. However, these results may be treated as a starting point in order to set a direction for the future research in this field.

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