Effect of Replacement of Fine and Coarse Aggregate by Sawdust in Solid Concrete Blocks for Different Mix Proportions

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Abstract
The need for natural aggregates has intensified in the field of building and construction lately which, by default, is bringing about a tremendous diminution of resources, soaring of prices and simultaneously, the developing nations are perturbed about the management of the wood waste or sawdust .This paper propounds the salient features of an experimental study based on Timbercrete blocks produced by partial replacement of coarse and fine aggregates with sawdust. Various features like compressive strength, water absorption and density were studied at various replacement percentages. To assess the performance of timbercrete blocks at multiple replacement percentages and experimental study was conducted. Hence, blocks of dimensions 150mm×150mmx150mm were tested, for the aforementioned characteristics, at various replacement percentages of both coarse and fine agglomerates. As a maneuver, a concrete assortment of 1:2:4 was used where sawdust was utilized to replace 5%, 10%, 15%, 20% and 25% of the aggregates gradually. “Gunny bag curing” was administered as a method of choice for curing. After the experiment was carried out, the compressive strength for 5%, 10%, 15%, 20% and 25% blocks were recorded as 9.87N/mm², 8.48N/mm², 5.2N/mm², 3.78N/mm² and 2.66N/mm² respectively after 28 days.

Keywords: Timbercrete, Sawdust, Compressive Strength, Density, Water absorption, Gunny bag curing.

Introduction
India being one of the fastest developing countries of the world currently, due to its advancing industrialization and economy, is undergoing a colossal progression in urbanization. As a matter of fact, urbanization begets an epic rise in the population density which in turn engenders tonnes of contaminants being released into the natural environment each day and each second. This surge necessitates a crucial requisite of an efficient and economically reasonable housing which is eco-friendly at the same time. On account of this, the engineers and scholars have been striving to develop a better - rapid, cheaper, more effective and environmentally friendly materials and techniques to meet this indispensable demand. The conventional load bearing structures are supplanted by framed structures where the partition walls act as screens for privacy but not for load endurance excluding their self-weight. Hence, a low density, low strength material can be availed to minimize these dead loads. One such preference - timbercrete might be a breakthrough in this regard. A mud brick, which is presently utilised, uses fertile soil thus giving heavy self-weight and in addition, requires burning thus creating an ecological hazard. On the contrary, no tree has ever been cut down to produce timbercrete. The sawdust is procured from the saw mills where it’s a by-product in multiple shapes and sizes. This sawdust, otherwise dumped into the land or burnt deteriorating the environment, is better utilised, which is like harvesting gold from dust. The coarse and fine aggregates extracted from either stone crushing or from the rivers etc. This however reduces the self-cleaning potential of these rivers. Sawdust has a density of 400-600 kg/m³ and can be used to moderately replace these aggregates to produce the concrete blocks possessing low density, substantial strength at low cost. IS 2185 (Part 1) 2005 approves an average strength of 3.5N/mm² and 2.8N/mm² individual unit strength releases 1 tonne CO₂. Mixing of clinkers to supplementary materials called blending is considered as a very effective way to reduce CO₂ emission. It is estimated that the Rajasthan Marble Processing Enterprise produces 1800m³ (4500 tons) marble waste annually, which implies that using marble waste of The Rajasthan Marble processing enterprise as cement replacement material can indirectly reduce CO₂ emission to the atmosphere by 4500 tons annually. Recycling marble waste powder in substitution
of sand also indirectly can reduce environmental problems related to sand production. The design of concrete (M25) was done with locally available materials. Cement was replaced with replacement levels of cement (0%, 4%, 8%, 12%, 16%, and 20%). Four numbers of cubes of 150 X 150 X 150 and cylinder 150 mm diameters and 300 mm length were casted for each %age replacement.

Hence 72 cubes were casted for each compressive and split tensile strength. The compressive strength and split tensile strength of concrete of all mixes was determined at the ages of 7, 14 and 28 days of curing for the various replacement level of cement and addition of cement and addition of waste marble powder (0%, 5%, 10%, 15%) at the end of different curing periods.

**Advantages of sawdust**

Some of the advantages of sawdust concrete under certain conditions are its cheapness, light weight, nail-holding capacity, insulation value, and resistance to freezing, burning, and termites. Dry sawdust-concrete varies in weight from 40 pounds to 70 pounds per cubic foot. This advantage of light weight may be utilized best as a fill in ceilings or roofs where some insulation without excess weight is required in a solid material. The insulating value is similar to that of wood, varying considerably with the mixing proportions, weight, and moisture content. For average mixes its insulating value is ten or fifteen times as great as that of the usual mixes of concrete. Thus, for walls or floors of poultry houses or hog houses sawdust concrete may present a definite advantage. Its nail-holding capacity is somewhat inferior to that of wood but far better than that of plaster or masonry. Reports from various sources have indicated results from good to very poor.

**Disadvantages of sawdust**

In addition to the lower compressive with its chemical nature. For instance, strength, certain disadvantages are almost all of the softwoods tested by developed parents when sawdust is used for the stronger concrete than the harder aggregate. Sawdust-concrete of ordinary heavier woods. Red oak, Douglas fir, proportions will absorb water to a point and cotton. Wood developed zero compress of saturation where the weight absorbed strength with ordinary mixes. Only as much as 70 percent of the very low strength was developed when dry weight of the sample.

**Uses of sawdust in concrete**

The rising costs of building construction in developing countries have been a source of concern to government and private developers. This study investigated the use of sawdust as partial replacement for fine aggregates in concrete production. Sawdust was used to replace fine aggregates from 0% to 50% in steps of 10%. Concrete cubes measuring 150 x 150 x 150mm were cast and their compressive strengths evaluated at 7, 14, 21 and 28 days. Increase in percentage of sawdust in concrete cubes led to a corresponding reduction in compressive strength values. From the results, the optimum sawdust content was obtained at 10% and its corresponding compressive strength at 28 days is 7.41 N/mm² which falls within the characteristic strength of plain concrete (7 – 10 N/mm²). This concrete cannot be used for structural applications.

1. Sawdust is not a familiar material in the construction/building industry. This is either because it is not available in very large quantities as sand or gravel, or because their use for such has not been encouraged. For some time now, there have been calls for the use of local materials in the construction industries especially in developing countries to check costs of construction. Sawdust can be defined as loose particles or wood chippings obtained as by-products from sawing of timber into standard useable sizes.

2. Clean Sawdust with a reasonable amount of bark has proved to be satisfactory, since it does not introduce high content of organic material that may upset the reactions of hydration.

3. Wrote that sawdust is used mostly as a source of fuel for domestic cooking in most areas where they occur. He stated further that it is often dumped as waste products and that about 105 million tonnes of sawdust are generated annually in India alone.
4. Investigated the properties of coconut shells (CCS) and palm kernel shells (PKS) as coarse aggregates in concrete. His finding was that cost reductions of 30% and 42% were achieved for CCS and PKS concretes respectively relative to plain concrete.

5. Determined the compressive strength of concrete made with varying percentages of waste wood ash (WWA). They reported that compressive strength generally increased with age but decreased with the increase in the WWA content. Comparisons of the strength of WWA concrete with those of the control (plain) concrete of corresponding ages showed that the strength of WWA concrete was generally less than that of the plain concrete.

6. Studied the influence of wood ash (WA) on the slump of concrete. He used wood ash as Partial replacement of cement in varying percentages (0, 10, 20, 30, and 40%) in concrete Mixture proportion of 1:2:4. Test results showed that mixtures with greater wood ash content require greater water content to achieve reasonable workability.

Concrete is any product or mass made by the use of a cementing medium. It is a composite Material obtained by mixing together coarse aggregates (e.g. gravel, crushed stones), fine Aggregates (e.g. sharp sand), cement and water in suitable proportions. Sometimes additional Materials known as admixture are added to modify certain of its properties.

Cement
Cement is a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used on its own, but rather to bind sand and gravel (materials) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete.

Cements used in construction are usually inorganic; often lime or calcium silicate based, and can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to set in the presence of water (see hydraulic and non-hydraulic lime plaster).

Chemical composition
Portland cement consists essentially of compounds of lime (calcium oxide, CaO) mixed with silica (silicon dioxide, SiO2) and alumina (aluminium oxide, Al2O3). The lime is obtained from a calcareous (lime-containing) raw material, and the other oxides are derived from an argillaceous (clayey) material. Additional raw materials such as silica sand, iron oxide (Fe2O3), and bauxite—containing hydrated aluminium, Al(OH)3—may be used in smaller quantities to get the desired composition.

Fine aggregates
Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve. Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 5 mm.

The code to be referred to understand the specification for fine aggregates is: IS 383:1970.

The criteria to classify fine aggregates are:

- If they are Natural/ Man-made.
- According to their size.
- According to the IS specification.

Coarse aggregates
When the aggregate is sieved through 4.75mm sieve, the aggregate retained is called coarse aggregate. Gravel, cobble and boulders come under this category. The maximum size aggregate used may be dependent upon
some conditions. In general, 40mm size aggregate used for normal strengths and 20mm size is used for high strength concrete.

**Materials used**
- CEMENT
- SAWDUST
- FINE AGGREGATE
- COARSE AGGREGATE

**Tests performed**
- COMPRESSIVE STRENGTH TEST
- DRY DENSITY TEST
- WATER ABSORPTION TEST

**Literature review**

Sawdust is a by-product of cutting, grinding, drilling, sanding, or otherwise pulverizing wood with a saw or other tool; it is composed of fine particles of wood. It is also the by-product of certain animals, birds and insects which live in wood, such as the woodpecker and carpenter ant [16]. It can present a hazard in manufacturing industries, especially in terms of its flammability. Sawdust is the main component of particleboard. A major use of sawdust is for particleboard; coarse sawdust may be used for wood pulp.

Sawdust has a variety of other practical uses, including serving as mulch, as an alternative to clay cat litter, or as a fuel. Until the advent of refrigeration, it was often used in icehouses to keep ice frozen during the summer. It has been used in artistic displays, and as scatter [17]. It is also sometimes used to soak up liquid spills, allowing the spill to be easily collected or swept aside. As such, it was formerly common on barroom floors. It is used to make Cutter’s resin. Mixed with water and frozen, it forms pykrete, a slow-melting, much stronger form of ice. Sawdust is used in the manufacture of charcoal briquettes.

At sawmills, unless reprocessed into particleboard, burned in a sawdust burner or used to make heat for other milling operations, sawdust may collect in piles and add harmful leachates into local water systems, creating an environmental hazard. This has placed small sawyers and environmental agencies in a deadlock. Questions about the science behind the determination of sawdust being an environmental hazard remain for sawmill operators (though this is mainly with finer particles), who compare wood residuals to dead trees in a forest. Technical advisors have reviewed some of the environmental studies, but say most lack standardized methodology or evidence of a direct impact on wildlife. They don’t take into account large drainage areas so the amount of material that is getting into the water from the site in relation to the total drainage area is minuscule [18].

In experimental study on Partial Replacement of Fine Aggregates with Quarry dust and Sawdust”. It was found the effect of quarry dust and sawdust, by adding quarry dust of 0%,10%,20%,30% and 40%. And sawdust of 0%,5%,10%,15% and 20% with fine aggregate, a matured fine aggregate has prepared. [12]

Utilization of Sawdust in Cement mortar and Cement Concrete. In this study as the percentage sawdust increase the density is found to decrease. Wastage of sawdust is minimized and recycled for construction work. [13]

In Partial replacement of fine aggregate with Sawdust and Quarry dust. In this study the effect of quarry dust and sawdust, by adding 10%,15% and 20% with the fine aggregate, a matured fine aggregate has prepared. [14]

In the research of partial replacement of quarry dust and saw dust in fine aggregate was experimentally carried out to investigate properties of both sawdust and quarry dust when used as partial replacement in brick. [15]
Methodology
Based on the Indian Standard (IS: 10262-2009) & (IS: 456-2000), design mix for M15 grade of concrete has been prepared by partially replacing cement with four different percentages by weight of MDP (0%, 5%, 10%, 15%, 20%, 25%).

Tests to be Performed
1. COMPRESSIVE STRENGTH TEST
2. DRY DENSITY TEST
3. WATER ABSORPTION

3.1: Sieve Analysis
A sieve analysis is a practice or procedure used to determine the particle size distribution of coarse and fine aggregates. In this we use different sieves as standardized by IS code IS: 2386 (part 1) -1963 and then pass aggregates through them and thus collect different sized particles retained over different sieves.

Equipment and Apparatus
I. A set of IS sieves of sizes 80mm, 50mm, 40mm, 20mm, 16mm, 10mm, 4.75mm, 2.36, 1.18mm, 0.6mm, 0.3mm and 0.15mm.
II. Balance with an accuracy to measure 0.1% of the weight of the test sample.

Procedure
1) The test sample is dried to a constant weight at a temperature of 100+/- 5 degree Celsius and weighed.
2) The sample is sieved by using a set of IS sieves.
3) On completion of sieving the material on each sieve is weighed.
4) Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.
5) Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100.
6) Result of the sieve analysis is represented graphically on a semi log graph with particle size as abscissa (log scale) and the percentage smaller than the specified diameter as ordinate.

Sieve analysis result (coarse aggregate)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Sieve Opening (mm)</th>
<th>Mass of CA Retained on each sieve Wn (g)</th>
<th>Mass Retained on each sieve (Rn)</th>
<th>Cumulative % retained</th>
<th>%Finer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>284</td>
<td>284</td>
<td>5.68</td>
<td>94.32</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>702</td>
<td>986</td>
<td>19.72</td>
<td>80.28</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>1316</td>
<td>2302</td>
<td>46.04</td>
<td>53.96</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>2264</td>
<td>4566</td>
<td>91.32</td>
<td>8.68</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>5</th>
<th>4.75</th>
<th>434</th>
<th>5000</th>
<th>100</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>2.36</td>
<td>0</td>
<td>5000</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>1.18</td>
<td>0</td>
<td>5000</td>
<td>100</td>
<td>0</td>
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<tr>
<td>8</td>
<td>0.6</td>
<td>0</td>
<td>5000</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>0.3</td>
<td>0</td>
<td>5000</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0.15</td>
<td>0</td>
<td>5000</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

**Result**

Fineness modulus of coarse aggregate = sum (cumulative percent retained)/100

= 692.33 / 100

= **6.9**

Fineness modulus of 6.9 means the average size of particle of given coarse aggregate sample is in between 6 and 7 positions of sieves from downward of the table i.e.: in between sieve size of 10mm to 16mm.
Fig 3.1 (a) – Graph (Sieve Analysis)
Fig 3.1 (b) Coarse Aggregates
Fig 3.1 (c) Sawdust
3.2: Slump Test
Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction.

The slump test is the simplest workability test for concrete, involves low cost and provides immediate results. Due to this fact, it has been widely used for workability tests since 1922. The slump is carried out as per procedures mentioned in ASTM C143 in the United States, IS: 1199 – 1959 in India and EN 12350-2 in Europe.

Fig 3.2- Slump Test Apparatus

Procedure
- Clean the internal surface of the mould and apply oil.
- Place the mould on a smooth horizontal non-porous base plate.
- Fill the mould with the prepared concrete mix in 4 approximately equal layers.
- Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers, the tamping should penetrate into the underlying layer.
- Remove the excess concrete and level the surface with a trowel.
- Clean away the mortar or water leaked out between the mould and the base plate.
- Raise the mould from the concrete immediately and slowly in a vertical direction.
- Clean away the mortar or water leaked out between the mould and the base plate.

3.3: Compressive Strength Test
Test for compressive strength is carried out either on a cube or cylinder. Various standard codes recommend concrete cylinder or concrete cube as the standard specimen for the test. American Society for Testing Materials ASTM C39/C39M provides Standard Test.
Fig 3.3 Compressive Strength Test Apparatus

Procedure
For cube testing two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used. This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of this specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on the whole area of specimen. These specimens are tested by a compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm² per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Procedure for Cube Test
1. Remove the specimen from water after specified curing time and wipe out excess water from the surface.
2. Take the dimension of the specimen to the nearest 0.2m.
3. Clean the bearing surface of the testing machine
4. Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
5. Align the specimen centrally on the base plate of the machine.
6. Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
7. Apply the load gradually without shock and continuously at the rate of 140 kg/cm²/minute till the specimen fails.
8. Record the maximum load and note any unusual features in the type of failure.
Trial Mix
1. CEMENT: Ordinary pozzolana cement (OPC) has been taken as per the proportions made.

2. FINE AGGREGATE: Here as per the proportions the fine aggregates are taken that pass through the 4.76 mm sieve.

3. COARSE AGGREGATE: Here both sizes of aggregate have been taken that were retained on respective sieve.

4. After that cement, water, fine aggregate and coarse aggregate were mixed thoroughly in the mixing machine by taking the quantity of material required for the 5 cubes of which average strength of compressive strength results is to be taken.

5. After mixing the materials thoroughly in the mixing machine concrete was taken out and slump test performed.

![Fig 4.1 Trial Mix Being Prepared to Be Cast into Moulds (Cubical) Slump Test](image)

This test is done to find out the workability of the concrete. It consists of a frustum mould and a tamping rod.

I. Frustum Mould

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Height</td>
<td>300mm</td>
</tr>
<tr>
<td>Base diameter</td>
<td>200mm</td>
</tr>
<tr>
<td>Top diameter</td>
<td>100mm</td>
</tr>
</tbody>
</table>

II. Tamping rod

<p>| | |</p>
<table>
<thead>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>16mm</td>
</tr>
<tr>
<td>Length</td>
<td>600mm</td>
</tr>
</tbody>
</table>

Frustum mould is filled with concrete mix in 3 layers equally. Each layer is tamped 25 times and the excess concrete is removed and the surface is levelled by a trowel. Now the mould is raised immediately and slowly
vertically upwards and the slump is measured as the difference between the height of the mould and that of concrete.

Slump value for mix design: **75mm**.

**Compressive Strength Test**
Concrete cube of size 150mm x 150mm x 150mm after 7 days of curing is taken out of water and allowed to dry for 1 hour and then it is placed in the testing machine by aligning centrally on the base plate of the machine. Now the load is applied and the result is being recorded for the first crack and the maximum load.

**RESULT OF COMRESSIVE STRENGTH TEST FOR TRIAL MIX AT 7 DAYS**

![Compressive strength machine](image-url)
Dry Density Test
The concrete density relies upon the aggregate and sawdust ratio. It was observed that with the increase in the percentage of sawdust, the density decreases. The change of density with the change in sawdust replacement percentage is depicted in the following table.

<table>
<thead>
<tr>
<th>S.NO</th>
<th>proportions</th>
<th>Compressive strength(N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cement</td>
<td>sand</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1.8</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**Table 4.1 (a)**

![Graph 4.1 (a)](https://example.com/graph41a.png)
Table 4.1 (b)

<table>
<thead>
<tr>
<th>S.NO</th>
<th>PROPORTION</th>
<th>DRY DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CEMENT</td>
<td>SAND</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
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<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Graph 4.1 (b)

Dry Density vs Replacement percentage

Water Absorption

Sawdust is very much prone to moisture and as a consequence, water absorption enhances with increase in the amount of sawdust. Each block was tested for water absorption on the 28th day of the experiment.
Table 4.1 (c)

<table>
<thead>
<tr>
<th>S.NO</th>
<th>PROPORTION</th>
<th>WATER ABSORPTION (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CEMENT</td>
<td>SAND</td>
</tr>
<tr>
<td>1</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>2</td>
<td>1.00</td>
<td>1.90</td>
</tr>
<tr>
<td>3</td>
<td>1.00</td>
<td>1.80</td>
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<tr>
<td>4</td>
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<td>1.70</td>
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<tr>
<td>5</td>
<td>1.00</td>
<td>1.60</td>
</tr>
<tr>
<td>6</td>
<td>1.00</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Calculations

1:2:4 (CEMENT SAND COARSE AGGREGATES RATIO)

\[
 \frac{1}{1+2+4} \times 1.57 = 0.2242 \\
0.2242 \times 1440 = 323 \text{ kg for 1m}^3 \\
323 \times 0.0033 = 1.0659 \text{ kg for 1 cube}
\]

Graph 4.1 (c)
= 1.1x7 kg of cement
= 7.7 + 5% (losses)
= 8.085 kg for 7 cubes.

Similarly, we will calculate for 5%, 10%, 15%, 20%, 25%

**Casting**

Casting is a manufacturing process in which a liquid material is usually poured into a mould which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mould to complete the process. Casting materials are usually metals or various cold setting materials that are cured after mixing two or more components together. This is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods.

Compaction was done using an electrically vibrating machine. Moulds of 150mm×150mm×150mm were casted at the enlisted percentages: 5%, 10%, 15%, 20% and 25%. Later, remoulding was done after the next 24hrs and 7 cubes of each mix were casted.

![Fig 5.1 (a) Prepared Cubes](image-url)
Curing

Curing is an integral part of the process of working with concrete blocks. After the blocks are in place, it begins to dry as the moisture in it evaporates. The more slowly this process happens, the stronger the resulting block is. Curing methods help to slow down the drying of the blocks, resulting in a stronger bond and more durable structure.

Curing is thus the process in which the blocks are protected from loss of moisture and kept within a reasonable temperature range. After 24 hours the blocks and beams were removed from the moulds and kept for curing in buckets and plastic jars. The curing was done for a period of 7 days for prisms after which they were checked for flexure. Nine samples for each mix were made for compression testing out of which three were cured for 3 days, three for 7 days and three for 28 days after which testing was done. In this project curing was done by pounding the samples in water.
Fig 5.1 (d) VIBRATING MACHINE

5.1 (e) Vibrating Machine
Compressive strength machine

Fig 5.1 (f) Compressive Strength Machine
Fig 5.1 (g) Compressive Strength Machine
Weight Machine

Fig 5.1 (h) Weighing Machine
Results

To introduce the sawdust usage in timbercrete blocks, an experimental analysis was done. All the analysis and results so obtained have been presented graphically and in the form of tables. The table 1 and the quintessential nature of the graph shown in fig.1 shows that with increase in the percentage of sawdust used compressive strength reduces significantly. Therefore, the partition walls in case of framed structures can be constructed from the timbercrete blocks to minimize the dead load along with cost reduction. The average value for strength needed for the partition walls ranges from 3.2 to 5 and can be achieved appreciably by proper curing to the mix of 1: 1.7 (0.3): 3.4 (0.6) or 15% replacement.

On density analysis, it was observed that density reduces with enhance in the percentage of sawdust. The results are depicted in table 2. The density of timbercrete with the mix 1:2:4 and 15% replacement were found to be 2190.

The absorption of water is allowable up to some degree however, excess absorption culminates in leaching of rain water into the blocks, their shrinkage following drying and ultimately, cracking of the blocks.

With increase in the percentage of sawdust there is a remarkable increase in the water absorption too. It is however noted that it's only the percentage of sawdust resulting in the increase of water absorption. For 1:2:6 ratio with 15% replacement factor the water absorption is 3.77% which is permissible.

Timbercrete influences the cost factor also more like other characteristics. The costs can be brought down by about 15% - 20% figure if timbercrete supersedes the conventional blocks.

Key Features

- Sawdust cement can be looked upon as being intermediate a light weight concrete on the one hand and timber on the other .the properties of the set product can be made to vary chiefly by varying the proportion of cement to sawdust, although some additional variation can be obtained by altering the proportion of mixing water.
- The practical range of proportion of cement sawdust is from 1:1to about 1:3 by volume.
- Timbercrete is the only structural brick or block product on the market that traps carbon which would normally end up as greenhouse gases in our atmosphere.
- It has substantially lower embodied energy compared to clay fired bricks.
- It has a higher insulation value (R) in comparison with traditional solid masonry bricks blocks and panels.
- It has a workable thermal mass which is the ability to store thermal energy and release it slowly.
- It boasts unique and, in some situations, improved engineering qualities such as better resilience and improved breaking load resistance compared to unreinforced clay and concrete products (as tested).
- Lighter weight (up to 2.5 X lighter than concrete or clay).
- Unique workability, it can be nailed and screwed into just like timber, but retains all the advantages of conventional masonry.
- Higher fire resistance – at 190 mm thick, outperforming typical concrete blocks, clay, timber and steel construction. It has the highest possible fire rating exceeding FRL 240/240/240. This ground-breaking innovation is an Australian invention and proudly Australian owned. It has several international patents (PCT) and trademark protection granted in most of the world’s population.

Key Issues

- The environmental benefits of using timber are not straightforward; although it is a natural product, a large amount of energy is used to dry and process it.
- Compressive strength, density and dynamic elastic modulus of mortar reinforced with wood sawdust wastes (WSW) has to be investigated.
- Using sawdust content larger than 1%, produces mortars with an excessive loss of compressive strength, especially for 3% of WSW.
• According to SEM results, a good adhesion was originated for 0.5 and 1% of WSW and for all WSW percentages used a positive effect on the post-cracking behaviour.

• The problem with concrete arises in the manufacture of cement and its environmental burden associated with high production of carbon dioxide (CO2) which is released to the atmosphere but also due to the diminishing of non-renewable sources was found.

• In addition, concrete density is a major concern in terms of weight and transport of materials. This is the reason for the increasing building construction with lightweight concrete which usually offer advantages such as economical reduction and more environmentally friendly composites.

• Sawdust waste incineration fly ash (SWIFA) has been employed to produce cement pastes and concrete mortar

• An important issue regarding this type of composite is the concern of using wood by-products in a cement matrix because of its high moisture absorption. Moreover, the low compatibility between the fibres and the cement is also taken into account. In this study, the pre-soaked water treatment of the WSW was effective to produce workable cement mixtures.

Saw Dust Quality

In many developing and developed countries, timber industry produces a significant quantity of sawdust as a by-product of the timber processing. Although a limited quantity of it is used as fuel in some countries, most of the sawdust generated is wasted. With the limited availability of dumping sites and landfills, sawdust disposal has become a serious problem facing the timber industry. Past studies have shown that sawdust being a lightweight material, can be used as aggregate in concrete mixes to produce lightweight concrete. As early as in 1940, investigation on the properties of sawdust concrete was reported (Beaver 1940). The physical and mechanical properties of sawdust concrete are not only depending on the amount of sawdust used but also on the chemical and physical characteristics of the sawdust. Due to the high-water absorption characteristics of sawdust, the sawdust concrete showed poor mechanical properties when used in significant quantities. The type of wood from the sawdust is produced is an important parameter, since different wood types have different amounts of extractable sugar. Mixes containing oak wood particles have failed to harden 24 hours after mixing (Ramadan 1988). The lime and calcium chloride are used in the mixes to minimize the influence of the retardation effect by the wood particles. Tests have shown that using the current manufacturing methods and equipment it is economically possible to use sawdust in manufacturing lightweight concrete block units that could be used in load-bearing applications with a reduction in material cost of about 35 to 40% (Murray et al. 1988; Rashwan et al. 1992). These block units have fire, shrinkage and sound transmission characteristics similar to standard lightweight units. Tests conducted on walls built using sawdust block units as the backing wythe in a typical masonry cavity walls constructed with traditional masonry units (Rashwan et al. 1993). The results showed that, although the sawdust blocks had lower mortar-to-unit bond strength, the walls in which they were used exhibited higher flexural strengths than conventional cavity walls. This paper reports and discusses the results of an experimental investigation into the effects of the mix compositions on the properties of sawdust concrete. The purpose of this study is to develop a suitable mix composition for sawdust concrete using a locally available sawdust for the purpose of producing load-bearing lightweight concrete masonry units.

General purpose cement (Type GP) conforming to AS 3971 was used as the binder in the concrete mixes. Commercially available, low-calcium fly ash from NSW, consisting of silica, alumina and lime between 58 and 63%, 24 and 29% and 0.5 and 2.5%, was incorporated in the concrete mixes. In addition, the commercially available hydrated lime was used in the mixes. Coarse river sand was used as fine aggregate. Radiata Pine sawdust was obtained from a timber manufacturing factory at St. Mary’s in Western Sydney region. All sawdust collected was swept up off the floor and air-dried prior to use. The mean density of the sawdust was 1250 kg/m³. The accelerating admixture used was calcium chloride of Type I (flake form) with a minimum calcium chloride concentration of 78%.
Application of Sawdust Blocks

- Density of sawdust varies from 650 kg/m³ to 1650 kg/m³. If this is used partially in manufacturing the mortar blocks as a replacement to sand can reduce the density to considerable extent.
- Compressive strength of blocks is a measure of their resistance to load application when placed in the crushing machine. I.S./B.S recommends 3.45 N/mm² mean strength of 2.59 N/mm² lowest individual strength
- S.T. Tyagher, (2011) used saw dust ash to partially replace cement in the production of sandcrete hollow blocks.
- According to Adebakin I. H. (2012) The percentage replacement of sand should not be 10 % to achieve better results in production of sandcrete blocks
- L.O. Ettu, (2013) investigated the variation of strength of OPC – RHA- SDA cement composites with mix proportion and found that for all percentage replacement of OPC with RHA-SDA at 28 and 50 days of curing at a given water cement ratio, the compressive strength increased with leanness of mix up to some level of leanness after which the strength reduced
- Density depends upon the sand and sawdust ratio. It is observed that density decreases with increase in percentage saw dust in sandcrete blocks.
- The variation of density for varying percentages of saw dust replacement is presented in Table 2 and partial replacement of sand with sawdust has a significant effect on the density of mortar. For zero percentage replacement density remains constant for different percentages of cement, sand, however for more % of sawdust replacement density reduces significantly.

Environmentally Friendly

Timbercrete is very environmentally friendly all the way from its raw ingredients through to its everyday use. Its main ingredient is recycled timber waste (cellulose). It has significantly lower embodied energy, and acts as a carbon trap. On top of all this, its improved insulation qualities mean. Timbercrete homes are more energy efficient throughout the year. Carbon Trap. Timbercrete’s main ingredient is cellulose, such as sawdust. This is often used for producing fertilizers, floor cover in horse stables, or is simply discarded or burnt. All of these uses have a negative impact on our environment, because as the product breaks down, it releases carbon dioxide gas into the atmosphere. This is referred to as “greenhouse gases”. When used for Timbercrete however, this vicious cycle is stopped because Timbercrete acts as a carbon trap, when the cellulose waste is preserved within a concrete tomb and never breaks down. Lower Embodied Energy Due To:

No Kiln Firing– Timbercrete does not need to use artificial or man-made drying processes. Conventional clay bricks require firing for strength and durability. This process consumes a large amount of energy and the toxic by-product is a poisonous cocktail of sulphuric, carbon monoxide and carbon dioxide gases.

Energy use during manufacturing- To manufacture 1m² of wall area, Timbercrete uses far less equipment and energy than other traditional brick and block making systems in its production process.

Energy to attain raw materials- Wherever practically possible Timbercrete Utilizes locally sourced raw materials.

Density and Matrix - Timbercrete’s dry density can be altered to suit specific requirements, ranging from 900 kg/m³ to 1500 kg/m³. Standard or typical Timbercrete is approximately 1.1 kg/L³. Its density is similar to water, followed by hardwood timber.

Airborne sound transmission loss- 100 mm to 110 mm thick Concrete and clay masonry performs well at preventing airborne sound transmission with an Rw rating of approximately 44 and 49 respectively, with 100mm (low density).
Timbercrete—being slightly less with a Rw rating of 41. While still to be tested, one can reasonably assume that a slightly higher density Timbercrete will result in a higher Rw rating. However, 100mm Aerated concrete blocks perform less than all the above-mentioned products at Rw rating of 38.

Durability Timbercrete is designed to last for generations. Independent tests prove that a Timbercrete block that is 190 mm wide has the highest possible fire resistance rating for building materials in Australia. It is impervious to termites and rot, and even bullet-proof! The colour will not fade and the bricks, blocks, panels and pavers will not wear away when exposed to extreme weather conditions. It even has superior bracing values (both in and out of plane) for those in earthquake prone or cyclonic areas.

Sound absorption

Timbercrete outperforms higher density clay and concrete bricks with a “weighted sound absorption coefficient” of 0.20 and a noise reduction coefficient (NRC) of 0.15 whereas typical clay and concrete products have an approximate NRC of 0.04. Timbercrete provides better resistance to airborne sound transmission then aerated concrete while providing less deflecting sound than higher density clay and concrete. In summary Timbercrete performs well at preventing sound transmission while having a sound absorbent quality which in effect helps to reduce echo or the “noisy room” phenomena.

Load-bearing Capacity

Timbercrete has a good load-bearing capacity. The formula can be altered slightly to achieve specific engineering requirements. Load-bearing typically ranges from 5 MPa through to 15 MPA or potentially greater if necessary. At 5 MPa a single standard 400 long X 200 mm thick

Timbercrete as bullet proof material

Timbercrete (tested in the US) was subjected to ballistic tests using a range of calibres projectiles. Tests showed that Timbercrete blocks absorbed the projectiles instead of shattering like concrete blocks. To date no bullet has ever been able to penetrate through a 200mm Timbercrete brick. Astonishingly even a 50 calibres Armor piercing bullet only penetrated 50 mm into Timbercrete.

Lifespan

Timbercrete longevity is the same as any other concrete product such as, ‘Hollow Core Concrete Blocks’. The expected life span is therefore hundreds of years. Also, like other concrete products, sealing or rendering increases its longevity.

Procurement of Sawdust

Sawdust or wood dust is a by-product or waste product of woodworking operations such as sawing, milling, planning, routing, drilling and sanding. It is composed of fine particles of wood. These operations can be performed by woodworking machinery, portable power tools or by use of hand tools. Wood dust is also the by-product of certain animals, birds and insects which live in wood, such as the woodpecker. In some manufacturing industries it can be a significant fire hazard and source of occupation carpenter dust exposure. Sawdust is the main component of particleboard. Wood dust is a form of particulate matter, or particulates. Research on wood dust health hazards comes within the field of occupational health science, and study of wood dust control comes within the field of indoor air quality engineering.

Two waste products, dust and chips, form at the working surface during woodworking operations such as sawing, milling and sanding. These operations both shatter lignified wood cells and break out whole cells and groups of cells. Shattering of wood cells creates dust, while breaking out of whole groups of wood cells creates chips. The more cell-shattering that occurs, the finer the dust particles that are produced. For example, sawing and milling are mixed cell shattering and chip forming processes, whereas sanding is almost exclusively cell shattering.
Sawdust is a by-product of cutting, grinding, drilling, sanding, or otherwise pulverizing wood with a saw or other tool; it is composed of fine particles of wood. Certain animals, birds and insects which live in wood, such as the carpenter ant are also responsible for producing the saw dust. Sawdust has a variety of other practical uses, including serving as mulch, as an alternative to clay cat litter, or as a fuel. Until the advent of refrigeration, it was often used in ice houses to keep ice frozen during the summer. It has been used in artistic displays, and as scatter. It is also sometimes used to soak up liquid spills, allowing the spill to be easily collected or swept aside. As such, it was formerly common on barroom floors. Mixed with water and frozen, it forms pyrite, a slow-melting, much stronger form of ice. Sawdust can be used as an alternative substitute for fine aggregate in concrete production. Before using the saw dust, it should be washed and cleaned. because a large amount of barks is present which can affect setting time and heat of hydration of cement. Concrete obtained from sawdust is a mixture of sawdust, gravel with a certain percentage of water to enter the workability and full hydration of the cement which provide great bonding of the concrete.

**Chemical Characteristics of Sawdust**

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Constituents</th>
<th>Percentage (by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>SiO₂</td>
<td>87</td>
</tr>
<tr>
<td>2.</td>
<td>Al₂O₃</td>
<td>2.5</td>
</tr>
<tr>
<td>3.</td>
<td>Fe₂O₃</td>
<td>2.0</td>
</tr>
<tr>
<td>4.</td>
<td>MgO</td>
<td>0.24</td>
</tr>
<tr>
<td>5.</td>
<td>CaO</td>
<td>3.50</td>
</tr>
<tr>
<td>6.</td>
<td>Loss on ignition (LOI)</td>
<td>4.76</td>
</tr>
</tbody>
</table>

**PHYSICAL CHARACTERISTICS OF SAWDUST**

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Optimum moisture content (%) (OMC)</td>
<td>19.80</td>
</tr>
<tr>
<td>2.</td>
<td>Maximum dry density (g/cc) (MDD)</td>
<td>1.40</td>
</tr>
<tr>
<td>3.</td>
<td>Specific gravity (G)</td>
<td>2.15</td>
</tr>
<tr>
<td>4.</td>
<td>Cohesion C (KN/m²)</td>
<td>7</td>
</tr>
<tr>
<td>5.</td>
<td>Angle of internal friction</td>
<td>30⁰</td>
</tr>
<tr>
<td>6.</td>
<td>Un-soaked CBR (%)</td>
<td>5.2</td>
</tr>
<tr>
<td>7.</td>
<td>Soaked CBR (%)</td>
<td>2.95</td>
</tr>
<tr>
<td>8.</td>
<td>Free swell index</td>
<td>80</td>
</tr>
<tr>
<td>9.</td>
<td>Soil classification</td>
<td>ML</td>
</tr>
</tbody>
</table>
Characteristics of Sawdust Blocks
1. Fineness modulus of sawdust: 3.7
2. Fineness modulus of sand: 2.4
3. Moisture content of coarse aggregate: nil
4. Moisture content of fine aggregate: 0.5 %
5. Specific gravity of sand: 2.67
6. Specific gravity of coarse aggregate: 2.71
7. Fineness modulus of coarse aggregate: 6.9
8. Specific gravity of cement: 3.15

Conclusion
The utmost aim of the study was to focus on the role of sawdust in the timbercrete blocks.
1. Compressive strength of the blocks is the kingpin for the construction purposes which are to be kept in mind. The strength of the blocks of mix 1:2:4 and 15% replacement were 5.2 which is both efficient and economical enough to be used in the partition walls of framed structures.
2. Density of the blocks is inversely proportional to the sawdust percentage. A mix of 1:2:6 with 15% replacement is found appreciable for both compressive strength and density factors.
3. Water absorption tendency potential with increase in the percentage of sawdust. Excess water absorption causes decrease in the strength. However, the water absorption can be maintained within a permissible perimeter.
4. Gunny bag curing was opted over Complete submerge curing attributed to the fact that sawdust causes more voids in the blocks hence rejecting cement.
5. Furthermore research and study are required on the subjects of fire proof and thermal resistance properties, quality of sawdust and their effects on the compressive strength, bending strength, hardness, and shear strength. The realm of the study can further be widened to encompass the hollow concrete blocks and other blocks.

Future Scope
Usage of sawdust in concrete has a very wide scope because of its durability and lightweight. The ultimate aim of the sawdust concrete is to recycle the waste material from the saw mill. Utilizing concrete ingredients in the state of partial replacement. Saw dust concrete is a very versatile material for construction, which offers a range of technical, economic and environment-enhancing and preserving advantages and is destined to become a dominant material for construction in the new millennium. With the increasing high building construction, the construction weight becomes important and this problem can be solved using lightweight concrete. On the other hand, lightweight concrete is its low density, allowing construction on ground with only moderate bearing capacity, the need for less reinforcement.

References
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