Study on Material and Mechanical Properties of Autoclave Aerated Concrete

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Abstract

Autoclaved aerated concrete is a versatile lightweight construction material and usually used as blocks. Compared with normal concrete (i.e., dense concrete) has a low density and excellent insulation properties. Due to the formation of air voids to produce cellular structure, hence low density is achieved. Aerated autoclave concrete block is produced by mixing of cement, fly ash, water, lime, and aluminum powder. AAC block is a replacement for conventional red clay bricks, which we normally use for our building construction. The preliminary studies were made on the materials used in the autoclave aerated concrete and then mix is proportioned. Further mechanical properties such as compressive strength, flexural strength test were made and results good.

Keywords: Aerated Autoclave Concrete, Aluminium Powder

1. Introduction

AAC stands for autoclaved aerated concrete. It was invented in early 1920’s by a Swedish architect named J A Eriksson. His purpose for designing AAC was to reduce consumption of timber and provide a cheaper and sustainable building solution. In addition global warming also has its own growth where construction industry remains the main reason behind the peak depletion of the soil. Rice in urbanization, deforestation, pollution etc...Are the factors that lead to natural extinction.

To overcome these problems, an innovative material developed –AAC blocks. AAC has a very flexible system. It is also as autoclaved cellular concrete (ACC). this innovation focuses on Eco friendliness and directs a path to sustainable development. It also satisfies the rule of 3R’s reducing, recycle and reuse.
AAC is manufactured by a process that involves slurry preparation, foaming /rising, cutting, and steam curing (autoclaving). The raw materials of the AAC block is fly ash, cement, aluminum powder, gypsum, lime, and water. AAC blocks offer superior performance and reduced project cost due to bigger size and light weight. Bigger size leads to faster laying at site. Reduced weight translates to reduced dead-weight on structure and higher thermal insulation.

AAC-blocks (Autoclave Aerated Concrete) a unique and excellent type of building material due to its super heat fire & sound resistance. AAC blocks light weight and offers ultimate workability, flexibility and durability.

**Manufacturing Process**

The autoclaved aerated concrete production process differs slightly between individual production plants but the principles are similar. Portland cement, lime, gypsum, aluminum powder is mixed to form slurry. The slurry is poured into the moulds as in the figure 1. Over a period of several hours, two processes occur simultaneously.

![Figure 1 Process of Manufacturing of AAC Blocks](image)

The cement hydrates normally to produce ettringite and calcium silicate hydrates and the mix gradually stiffens to form a “Green Cake”.

The green cake rises in the mould due to evolution of hydrogen gas formed the reaction between the fine aluminum particles and the alkaline liquid. The gas bubbles give the material its cellular structure. The complicating factor is that the temperature of the cake increases due to the exothermic reactions as the lime and the cement hydrate, so the reaction proceeds faster. When the cake has risen to the required height, the mould moves along a track to where the cake is cut to the required block size.
Depending on the actual production process, the cake mould may be demoulded entirely on to a trolley before cutting, or it may be cut in the mould after the sides are removed. The cake is cutting by passing through a series of cutting wires.

![Figure 2 Processes of Cutting Blocks](image)

At the cutting stage as shown in figure 2 the blocks are still green-only a few hours have passed since the mix was poured into the mould and they are soft and easily damaged. However if they are too soft, the cut blocks may either fall apart or stick together, if they are too hard.

The wires will not cut them. Then the blocks are loaded into the autoclave. Its take a couple of hours for the autoclave to reach maximum temperature and pressure,

This is held for perhaps 15 -21 hours. The blocks are removed from the autoclave and cooled. The block has achieved their full strength and is now packed ready for the transport.

2. Materials Used

Cement

Mostly India cement where used in manufacturing of autoclaved aerated concrete blocks. Cement is a binding material, used to binding the ingredients. the amount of cement is used for 3.024m3 mould is 440 kg – 450 kg. Initial and final setting time of the cement is checked. It ranges from 165 – 180 minutes.

Based on our requirements the usage of cement content is varied. If the compressive strength is getting low means, the particular amount of cement is added.

Sand
The sand which is used to increasing the strength of blocks. Before the sand is used for manufacturing it should be tested. In sand the silica content, moisture content and residue is to be checked.

The silica content should be below 98% and residue ranges from 98 – 100%. The wastages should not be more. Moisture content 0.06%. some cases the sand is not to be used.

**Fly Ash**

Fly ash is a byproduct from burning pulverized coal in electric power generating plants. Fly ash is the best known and one of the most commonly used pozzolans. The amount of fly ash is used in manufacturing of AAC blocks is 1150 – 1160 kg for 3.024 m³. The factor for waste slurry and pure slurry is 150 & 550 (for blocks), for lintels 200 & 700.

**Aluminum Powder**

Aluminum powder is used at a rate of by volume. Aluminum power reacts with calcium hydroxide and water to form hydrogen. The hydrogen gas forms and doubles the volume of raw mix creating gas bubbles up to 3 mm (1/8 inch) in diameter. At the end of the foaming process, the hydrogen escape into the atmosphere and is replaced by air.

**Lime**

Lime powder required for the AAC production is obtained either by crushing limestone to fine powder. Mainly grey with specks of white or brown in color. The purpose of adding lime is to make a binding between materials. 90 – 100 kg of lime is used for 3.024 m³ mould, based on our requirements.

It is made up of calcium carbonate and has the chemical formula CaCO₃. Lime has high pH. Composed largely of calcite and aragonite, and water soluble, hard and durable.

Before the lime is used for manufacturing it should be tested, for checking it is having good property (or) bad one. In lime the calcium oxide (CAO) content & temperature should be checked. The temperature should be lies between 55 - 60°C. and calcium oxide content should be below 80%.

**Gypsum**

Gypsum is a very soft mineral composed of calcium sulfate dehydrate. It has the chemical formula of CaSO₄.2H₂O. Gypsum is almost PH neutral. It is colorless to white, may be yellow, blue. And it is translucent, very soft, and water-soluble. Nearly 20 kg of gypsum is used for 3.024 m³ mould.
Water

The amount of water to the amount of cement used is called water to cement ratio. These two ingredients are responsible for binding everything together. Only the RO water is used for manufacturing blocks. Nearly 100 - 120 kg of water is used for 3.024m³. Here the water is classified into three types.

i. RO water

ii. Feed water

iii. Boiler water

In water the level of PH, Total dissolved solids and PPM can be checked for each stages. According to the stages the level of PH, TDS & PPM is varied and kept as a constant level.

i. Ro Water

The PH of water used for manufacturing is 7 - 7.5. Total dissolved solid content should be with in 50 - 100. The PPM within 5-20.

ii. Feed Water

The PH of water used for manufacturing is 8 - 8.5. Total dissolved solid content should be with in 100 - 200.

iii Boiler Water

The PH of water used for manufacturing is 9 - 12. Total dissolved solid content should be within 350 - 5500. The PPM within 5-20.

Soap Oil & Sodium Dichromate

Which is used to slow rising and reducing damages during cutting the blocks. The amount of soap oil is used is 500 ml & sodium dichromate is 20 gm, these amount is only for 3.024m³ mould.

Advantage of AAC Blocks
One of the most important is its lower environmental impact. Improved thermal efficiency reduces the heating and cooling load in buildings. Porous structure allows for superior fire resistance. Workability allows accurate cutting, which minimizes the generation of solid waste during use. Resource efficiency gives it lower environmental impact in all phases of its cycle, from processing of raw material to the disposal of waste. Light weight saves cost & energy in transportation, labor expenses, and increases chances of survival during seismic activity. Larger size blocks leads to faster masonry work. Reduces the cost of project. Environmentally friendly: when used, it helps reduce at least 30% of environmental waste as opposed to going with traditional concrete. There is a decrease of 50% of greenhouse gas emissions.

When possible, using autoclaved aerated concrete is a better choice for the environment. Energy saver; it is excellent property that makes it an excellent insulator and that means the interior environment is easier to maintain. When it is used, there is usually not need for any supplementary insulation.

Great acoustics: when you think of concrete, you do not consider it to be excellent for acoustics, however autoclaved aerated concrete has excellent acoustic performance. It is able to be used as a very effective sound barrier. Great ventilation: this material very airy and allows for the diffusion of water. This will reduce within the building. ACC will absorb moisture and release humidity; this helps to prevent condensation and other problems that are related to mildew.

They are also produced in sizes that are easy to handle for quick construction. Since blocks and panels fit so well together, there is a reduced use of finishing materials such as mortar.

Long lasting the life of the material is extended because if is not affected by harsh climates or extreme changes in weather condition. It will not degrade under normal climate changes either Quick assembly since it is a light weight material and easy to work with, the assembly is much quicker and smoother.

**MATERIAL TEST**

**Table1: Test on Materials**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Materials</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cement</td>
<td>Initial and final setting time</td>
</tr>
<tr>
<td>2</td>
<td>Lime</td>
<td>Determination of Cao content &amp; temperature</td>
</tr>
<tr>
<td>3</td>
<td>Sand</td>
<td>Determination of silica content &amp; moisture</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>4</td>
<td>Water</td>
<td>Determination of PH, TDS</td>
</tr>
<tr>
<td>5</td>
<td>Fly ash</td>
<td>Residue check</td>
</tr>
<tr>
<td>6</td>
<td>gypsum</td>
<td>Residue check</td>
</tr>
</tbody>
</table>

**TEST ON CEMENT**

The test is conducted for determining the initial and final setting time of the cement.

**Consistency**

Consistency = weight of water sample/weight of cement x 100

\[
= \frac{123}{400} \times 100 = 30.75.
\]

**Water content for final setting time**

\[
= 0.85 \times \text{consistency} / \text{weight of cement} \times 100
\]

\[
= 0.85 \times 30.75 / 400 \times 100 = 105 \text{ ml}.
\]

![Figure 3 Setting Time Test for cement](image)

**Result**

Final setting time = Initial reading + time taken for ring needle fully immersed = 150 min + 30 min = 180 min.

**TEST ON SAND**

In this test determination of silica content and residue is checked.

**Result**

Initial weight \( w_1 \) = 5 gm
Final weight \( w_2 \) = 0.96 gm
Percentage of silica content = \( \frac{0.96}{0.05} = 19.4 \% \).
TEST ON LIME

Lime is used for as a binding material in a proportion of material.

![Image](image_url)

**Figure 4: Lime content**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Time In Minutes</th>
<th>Temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>32</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>39</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>45</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>61</td>
</tr>
</tbody>
</table>

**Table 2 Lime Test Report (Temperature)**

Determination of CAO content in Lime

Calcium oxide has the chemical formula CaO & also called quicklime. It is a white crystalline substance. It is generally produced from calcium carbonate or lime stone.

**Cao content** = 30.87 x 2.8 = 85.96 %

The percentage of Cao content should be below 80%.
Figure 5 Test on CAO content in Lime

Table 3 Sand Residues

<table>
<thead>
<tr>
<th>S.No</th>
<th>Sieve size(micron)</th>
<th>Retain(gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1400</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>600</td>
<td>0.56</td>
</tr>
<tr>
<td>3</td>
<td>217</td>
<td>46.63</td>
</tr>
<tr>
<td>4</td>
<td>pan</td>
<td>52.54</td>
</tr>
</tbody>
</table>

Figure 7: Weight of the Residue sand

Total = 0 + 0.56 + 46.63 + 52.54 = 99.74%

Result
The percentage of waste is 0.26%. hence it is economy & suitable for production.

SAND – MOISTURE
Result

Weight of sample W1 = 100gm
Weight of sand after dry W2 = 97gm
The percentage of moisture content in sand is 0.3%.

FLYASH

Result

Initial weight w1 = 100gm
Final weight w2 = 10gm
The percentage of waste is 10%.
The percentage of waste should be below 20%.
MATERIAL PROPORTION
The materials used for manufacturing of AAC blocks are fly ash, cement, lime, gypsum, aluminum, soap oil, sodium dichromate.

Factor
The factors to be considered for wastages and pure mix for aerated autoclaved concrete blocks.
1. Waste slurry - 150
2. Pure slurry - 550

CALCULATION OF WET & DRY WEIGHT OF FLY ASH

FLY ASH
According to the mixing of water with fly ash the weight of slurry is varied. For determining wet & dry weight the slurry is weighted i.e. the slurry is taken from mixing chamber in a jar. Then it is weighted.

Fly ash + water = 1.489kg
Factor = 550 (pure mix)

Wet weight
= 550 x 1.489/0.489
= 1675 kg.

Dry weight
= 1675/100 x % of fly ash
= 1675/100 x 66.45
= 1112.8 kg.

Percentage of fly ash taken from chart.
For liter weight 1.489 kg the percentage of fly ash is 66.45

WASTAGES

Wastages (after cutting) = 1.483kg
Factor = 150 (pure mix)
Wet weight
= 150 x 1.489/0.489
= 460 kg.
Dry weight

\[ \text{= } \frac{460}{100} \times \text{% of fly ash} \]
\[ \text{= } 320 \text{ kg.} \]

3. QUANTITY OF MATERIAL FOR 3.024m\(^3\)

<table>
<thead>
<tr>
<th>S.NO</th>
<th>MATERIALS</th>
<th>DRY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fly ash</td>
<td>1150 – 1160 kg</td>
</tr>
<tr>
<td>2</td>
<td>Wastages</td>
<td>310 - 320 kg</td>
</tr>
<tr>
<td>3</td>
<td>Cement</td>
<td>440 kg</td>
</tr>
<tr>
<td>4</td>
<td>Lime</td>
<td>90 kg</td>
</tr>
<tr>
<td>5</td>
<td>Gypsum</td>
<td>20 kg</td>
</tr>
<tr>
<td>6</td>
<td>Aluminum</td>
<td>1.20 kg</td>
</tr>
<tr>
<td>7</td>
<td>Soap oil</td>
<td>500 ml</td>
</tr>
<tr>
<td>8</td>
<td>Sodium dichromate</td>
<td>20 gm</td>
</tr>
</tbody>
</table>

EXPERIMENTAL TESTS

COMPRESSION TEST

Out of many test applied to the AAC blocks, this is the utmost important which gives an idea about all the characteristics of blocks and also concrete. By this single test one judge that whether block has been done properly or not Compressive strength is the capacity of a material or structure to withstand axial loads tending to reduce size. When the limit of compressive strength is reached, brittle materials are crushed. Concrete can be made to have high compressive strength. The size of the cube is 150 x 150 x 150 mm. shown in figure 6.1 The failure load of compressive strength of cube is calculated by using the formula

\[ \text{Compressive strength} = \frac{\text{Load}}{\text{Area}} \text{ N/mm}^2 \]
Table 5 Compressive strength of AAC blocks

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Size Specimen(mm)</th>
<th>Compressive strength(N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>150 x 150</td>
<td>3.66</td>
</tr>
<tr>
<td>2</td>
<td>150 x 150</td>
<td>3.73</td>
</tr>
<tr>
<td>3</td>
<td>150 x 150</td>
<td>4</td>
</tr>
</tbody>
</table>

CASTING OF SPECIMEN

To carry out pullout test reinforcement bars are to be casted inside 150 mm x 150 mm x 150 mm cube filled with reacon mixture. The rod is fixed at the center of the mould. Then the raw material is poured in the mould, for fixing the rod in their position some arrangement had been taken out.
Figure 11: Casting of Specimen for Pullout Test

PRE-CURING OF SPECIMEN FOR PULL OUT TEST
After the filling of raw materials into the mould, it has to be cooled in room temperature, about 3 hours.

Figure 12: Pre-Curing of Specimen for Pull out Test

Figure13: Cube after Treating Autoclave in 12 Hours

PULLOUT TEST
As per IS 11309-1985 ,this standard lays down the method for conducting anchor pull – out test and the evaluation of bond strength between reinforcement and grout concrete. The size of bars can be used are 8mm, 12mm, and 16mm.

4.3.4 TEST RESULTS

<table>
<thead>
<tr>
<th>S.No</th>
<th>Size Of Bars</th>
<th>Pull Out Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8mm</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.5</td>
</tr>
</tbody>
</table>
Table 5 Pull Out Test with 12mm Dia of Bar

<table>
<thead>
<tr>
<th>S.No</th>
<th>Size Of Bars</th>
<th>Pull Out Load (KN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>12mm</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.0</td>
</tr>
<tr>
<td></td>
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<td>5.5</td>
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<td>6.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.0</td>
</tr>
<tr>
<td>average</td>
<td></td>
<td>5.857</td>
</tr>
</tbody>
</table>

Table 6 Pull Out Test with 16mm Dia of Bar

<table>
<thead>
<tr>
<th>S.No</th>
<th>Size Of Bars</th>
<th>Pull Out Load (KN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>16mm</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.5</td>
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<td>5.0</td>
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<tr>
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<td></td>
<td>8.5</td>
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<tr>
<td></td>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.0</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>6.572</td>
</tr>
</tbody>
</table>

**FLEXURAL TEST**

Flexure tests are generally used to determine the flexural modulus or flexural Strength of a material. The material is laid horizontally over two points of contact and then force is applied to the top of the material through either one or two points of contact until the sample fails. The maximum recorded force is the flexural strength of that sample.
Table 7 Flexural Strength test

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Size of Specimen (mm)</th>
<th>Max Load (kN)</th>
<th>Flexural Strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100x100x200</td>
<td>1.49</td>
<td>0.28</td>
</tr>
<tr>
<td>2</td>
<td>100x100x200</td>
<td>1.54</td>
<td>0.308</td>
</tr>
<tr>
<td>3</td>
<td>100x100x200</td>
<td>1.58</td>
<td>0.316</td>
</tr>
</tbody>
</table>

Formula

$$\text{Flexural strength} = \frac{pl}{bd^2} = \frac{1.58 \times 10^3 \times 200}{((100) \times (100)^2)} = 0.316 \text{ N/mm}^2.$$ 

Conclusion

Aerated light weight concrete is unlike conventional concrete in some mix materials and properties. Aerated lightweight concrete does not contain coarse aggregate, and it is possess many beneficial such as low density, enhanced in thermal and sound insulation, reduced dead load in the could result several advantages in decrease structural elements and reduce the transferred load to the foundations and bearing capacity. Aerated lightweight concrete is consider economy in materials and consumption of by-product and wastes materials such as fly ash. In this study the material properties and mechanical properties of AAC blocks were investigated.

Acknowledgement

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