Comparison of Fly Ash Based (AAC) Block and Clay Bricks for Structure and Strength Properties

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Abstract. Fly Ash, a waste product collected from precipitators of coal based thermal power plants can be utilized as a potential resource as construction material. Fly ash, being fine light weight silica particles can cause environmental pollution if not managed properly, and/or not utilized as construction material. Fly ash can be used along with cement, cementitious materials to develop bricks and blocks which possess good properties for civil engineering structures. This paper presents comparative analysis of clay bricks and fly ash based autoclaved aerated concrete (AAC) block properties, methodology, process and material required for preparing fly ash based AAC block as per Indian standard code provisions, inspection and quality control. The textures of the blocks with fly ash were very similar to that of clay bricks; the sample with the additive contains spherical fly ash particles. These fly ash particles led to reduction in the density of the blocks and a substantial improvement in their durability. Use of this additive could have practical implications as a means of recycling and for achieving cost savings in blocks production. The structural cost, cement mortar for plaster & masonry, breakage, construction speed, quality, fitting & chasing, carpet area, availability, energy saving, chemical composition of fly ash based AAC blocks compared with normal clay bricks that delivered good results. From the present study, it can be concluded that fly ash based AAC blocks can be used as an alternative to clay bricks because of their strength, uniformity and smooth surfaces and lower cost. The cost of fly ash-based blocks was found about 20-35 % lesser than the clay bricks.

Key Words: Fly ash, Autoclaved aerated concrete (AAC), Clay bricks, Cost reduction.

1. Introduction

In India coal based thermal power plants are major source of energy needed for the sustainable development of the country. Huge quantities of coal of varying qualities are burnt in different thermal power plants for energy production which gives huge quantities of residues in the form of fly ash. It is also known as flue ash having smaller silica particles along with elements and collected from the electrostatic precipitator of the thermal power plants. Currently about 320 MT (Million Tones) of fly ash is produced annually in India [1]. The fly ash production is expected to further increase up to 1000 MT/year. India has big reserves of coal and fossil fuel based energy sources are likely to be continuously exploited despite big thrust on renewable energies, being cheaper and readily available. Consequently huge quantities of various classes of fly ash are available currently and more so in future. The fly ash management is strongly warranted as it is potent environmental pollutant causing health hazards to human beings and live stocks, if the dumped fly ash stocks become air borne. Fly ash is a waste which can have serious environmental impacts if it is not managed and used properly. Fly ash can be best used with cement in concrete mix to reduce the amount of costly cement and it would
be further imperative to reduce the amount of natural resources like clay, by blending rice husk ash, metakaolin, micro silica to save natural clay resources [1]. Experiments have revealed that Class F fly ash having fine ash particles, lower calcium content and better pozzolanic properties can be effectively used in cement, fly ash mix with better working ability and strength of bricks, blocks. Thus, Fly ash can be effectively used in building materials and save energy, lower carbon emission and cost on production of cement as considerable quantity of cement can be replaced with fly ash.

Sweden was the first country to develop AAC i.e. autoclaved aerated concrete in the year 1924[2]. Since then, it was used predominantly as commonly used building material in Europe, Asia and as well as in other parts of the world. Its various physical properties including high load bearing capacity, lighter in weight, high insulating and durability is available in different sizes and strengths. It offers enormous opportunity in order to enhance quality of building and hence help in the cost reduction at construction sites [3].

These AAC blocks helps in reduction of building cost to a greater level by reducing wall load and thereafter helps in reduction in structure’s loading [4]. AAC finds its greater use in buildings as it reduces the overall construction cost and also results better in terms of efficiency. Since last few years, peoples are unaware of the amazing features of this constructional material. Lesser size of structured members, requirement of reduced size of bricks and reduced reinforcement along with some other factors like decrement in the width of plastering and requirement of less mortar makes it less costlier and cheaper material. Keeping in view, the comparative performance for efficiency, cost, durability and physical strength of AAC blocks and clay bricks, a study was planned to prepare blocks and clay bricks from fly ash obtained from coal based thermal power plant at Suratgarh using different proportions of fly ash, cement and other materials which would offer desirable properties of blocks and bricks from civil engineering and building materials point of view. This paper summarizes the structure and strengthening properties of these AAC blocks and cost factors are compared with clay based conventional blocks.

2. Literature Review

The building construction materials have been evolving ever since the human being started constructing buildings for their settlements, industrial houses and other purposes. It all began with use of earth based mud blocks which were poor in strength with lots of moisture holding capacity and easy disintegration. These blocks were further stabilized by using materials like Portland cement, gypsum, lime etc. followed by cured magnesium oxides and now a days, the fly ash - cement based concrete mix [5]. The quality in terms of physical properties of the fly ash including fluidized fly ash and pulverized fly ash is determined by the fineness of its particles, the silica oxides, aluminium oxides, magnesium oxide contents which in turn determines the pozzolanic activity of fly ash cement mix, strength, shape and durability of bricks or blocks prepared from such construction materials mix [6]. Elavarasan et al. [7] reported a comparative analysis of earth blocks developed from natural soils obtained locally with that of earth blocks stabilized with cementitious materials like cement, fly ash, fine aggregate and fine aggregate. They observed that the earth blocks though less costly were weaker in strength and load bearing as compared to the earth blocks stabilized with the cementitious materials.

3. Materials and methods

3.1 Raw Materials Required

In the present study, AAC block so formed is a mixture of fine powdered fly ash combined with different proportions of aluminium, water, gypsum, cement and lime. Hardening is done by the process of steam curing in the autoclaves. Its unique physical properties make it suitable to use in several construction sites and buildings including hotels, schools, hospitals, industrial and commercial buildings, and ware houses and in several other forms. The volume of air is about 60% to 85% by volume is present in these AAC blocks.
3.2 Methodology
In present study, AAC block produced from mixture of calcined gypsum 5%, lime (mineral) 20%, cement 10%. For binding purposes, water 0.60% is used. The usage of the aluminium powder is at a rate of 0.08% by volume [8]. For aggregation purposes, the fly ash i.e. generated from thermal power plants which contains silica content (65%) is used as aggregates.

AAC blocks are produced by mixing the raw material in appropriate proportions in dosing and mixing unit. The materials filled in dosing units are thoroughly mixed and poured into the separate containers till the desired amount of material is pumped. Similarly gypsum, cement and lime powder are poured into separate containers. After achieving the appropriate proportions of all the ingredients, control system devices releases these ingredients into a mixing drum. After mixing the ingredients in the dosing and mixing unit, the slurry is poured into moulds to prepare blocks. Precautions should be taken to oil the moulds so that the slurry after solidification doesn’t stick to moulds. For dimensional accuracy of the blocks, the demoulding and cutting is performed. The blocks are then cured and lifted to transport it to the autoclave chamber for about twelve hours where hardening of the blocks is carried out. The hardened blocks are used for comparing the various properties.

In the hardening process by steam pressure, it attains at temperature of about 190 - 200° C and pressure from 8-12 bars, this sand (quartz) reacts with Ca(OH)2 in order to form (CaO-SiO2-H2O), which acts as the main binding phase of the cement-based materials. This hydrate provides AAC blocks unique properties as well as high strength [10]. The autoclaving process enables the material for instantaneous use at buildings and construction sites. As it is mentioned above that in AAC blocks, the 80% composition is because of the air, therefore the low density results in the low compression strength of these blocks. Experimentally, it can bear the loads upto a capacity of about 8 mega Pascal which is about half to the regular concrete’s compressive strength.

The properly dried AAC blocks were evaluated for parameters such as chemical composition, structural cost, cement mortar for plaster & masonry, carpet area, breakage, construction speed, quality, fitting & chasing, availability and energy saving.

4. Experimental Procedure
4.1 Compressive Strength Test:

4.1.1 Apparatus:
Compression testing machine, Vernier Caliper, Weighing Balance, Straight Edge, Drying Oven were used for conducting the experiments.

4.2 Specimen preparation
Specimens can be cut using rotating steel metal blades or using carborundum, and with the alike instruments. There will be no any reinforcing rods in the pieces. The whole area must be cut clean and plane. Strong care will be taken to ensure that the pressure surface of the cubes i.e., the contact surface of the test machine plates does not deviate from evenness more than 0.1 mm. The same accuracy will work on the joint surface if the cubes are made up of several pieces. The evenness will be viewed on all two diagonals using straight-edge. The deviation will be corrected using milling, dry grinding, grinding or any other process.

4.3 Grinding the Specimen
Carborundum or sandstone slab was used as a medium of grinding in order to achieve the plane grinding in cubes. Continuous flushing of water is done as the slab is kept horizontally. The operation of grinding involves the uniform as well as circular movements of test cube section. Intense care must be done to ensure even wearing of the test cube. Hard pressing of the cube with the slab must be performed to check even grinding. This process should be in continuation until the cube seems to be quite even, after thorough inspection by steel ruler. Fine results can be achieved by surpassing the ruler slowly on the surface of the cube. The process must be performed one by one to each diagonals.
of the cube. One must ensure that the cube must be clear from any dust or dirt particles before inspection, as a slim layer of dust may lead to irregularities in the surface. The grinding operation of the cubes must be performed one after the other series of the cubes. When the grinding of second batch initiates, the first batch cube must be dried out. This should be done in order to check the accuracy of the specimen. Any discrepancy in the evenness can be corrected using regrinding.

4.4 Conditioning
Before testing, the specimens must be habituated in moisture ratio varying from 10 (±2) % by weight. Calculations must be done on temperature of 105 °C and at dry weight. Drying must be done at a temperature lower than the 50°C. The specimens should be kept at room temperature after drying process is over and testing of specimen initiates.

4.5 Compression Load Testing
Compression of the cubes occurs by placing them in the compression machine. The load is being applied perpendicularly from the slices direction which results in the formation of thickness of cubes. In order to produce the one-piece cubes, load’s direction must be in perpendicular to mass rise while production takes place. Loading of the specimens must be done at 0.4 to 2.1 kgf/cm such that failure of the cubes occurs within the time span of half minute.

5. Calculations
In order to evaluate the compressive strength, following formulae was used.

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\text{Compressive Strength in (N/mm}^2\) = \frac{\text{Max load at failure in N}}{\text{Average area of bed face in mm}^2}
\]

Also the conventional clay bricks obtained from local markets were evaluated as controlled treatment.

6. Results
6.1 Results for Compressive Strength
The AAC blocks produced in the size (180 x 230 x 125 mm) were subjected to analysis of compressive strength [10]. The length and width is taken according to the size of compression testing machine plate that is 180 x 230 mm. Blocks were prepared with different bed surface. Also, different loads (175-165 kN) were imposed on test specimens which give different compressive strengths ranging from 4.22 to 4.12 respectively. The salient results are presented in Table 1. Table 2 shows the technical specifications of fly ash based AAC blocks and clay bricks. Furthermore, a comparison of different aspects of AAC blocks and clay bricks has been depicted in Table 3.

Table 1. Observation Table

| Sample | Dimension of Fly ash (AAC) blocks | Bed Surface area (average) in mm² | Failure point maximum load in KN | Strength (Compressive) in N/mm² |
|--------|----------------------------------|----------------------------------|---------------------------------|-------------------------------|
| A      | 180 230 125                      | 41400                            | 175                             | 4.22                          |
| B      | 180 230 125                      | 41200                            | 170                             | 4.15                          |
| C      | 180 230 125                      | 41200                            | 165                             | 4.12                          |
| Average|                                 |                                  |                                 | 4.18                          |
Table 2. Specification (Technical): Clay Bricks & AAC blocks

| Specifications          | Clay Bricks | AAC Block |
|-------------------------|-------------|-----------|
| Size (in mm)            | 240×80×120  | 650×180×(80 to 400) |
| Drying Shrinkage        | -           | 0.038%    |
| Fire Resistance (in Hours) | 2.5        | 3 to 6.5  |
| Sound Reduction Index (in Decibels) | 60 (in case of 250 thick walls) | 50 (in case of 220 thick walls) |
| Thermal conductivity “K” | 0.80        | 0.15-0.17 |
| Normal Dry Density (in kg/m³) | 1850      | 560 - 660 |
| Compressive Strength (in N/mm²) | 2.4 to 3.4 | 3.2 to 4.4 |
| Size Tolerance (in mm)  | ±4 to 14    | ±1.4      |

Table 3. Various Aspects of Clay Bricks and AAC blocks

| Aspects                  | Clay Bricks                  | AAC Blocks                  |
|--------------------------|------------------------------|-----------------------------|
| Cost (Structural)        | Nil                          | 15% savings in case of steel |
| Composition (Chemical)   | Farm Soil including sulphates, nitrates etc | Fly Ash 65-70 % |
| Energy Economics         | No economics                 | Nearly 25 % drop in heavy loads |
| Accessibility            | Deficiency in monsoon        | Available in all seasons    |
| Area (Carpet)            | Relatively Less              | More                        |
| Fitting                  | Every Type is possible       | Every Type is possible      |
| Quality                  | Varies in normal cases       | Consistent and Uniform Also |
| Speed of construction work | Relatively slow              | Faster because of large size, lighter in weight, Can be cut in to any dimension |
| Breakage                 | Nearly 8 to 14%              | ≤ 4%                        |
| Cement Used in Plaster & Masonry | Requires more due to irregular surface | Less because of even surface |

7. Conclusion
The fly ash based (AAC) blocks are valuable material for construction industry obtained from hitherto known as waste material from coal based thermal power plants. The average compressive strength of these fly ash based (AAC) blocks is 4.18 N/mm². Results reveals that even at higher compressive load could have been applied to validate the compressive strength which would enable use of fly ash based AAC blocks in high rise buildings or bridges with considerably extra load. The fly ash based (AAC) blocks have better civil engineering properties compare to the clay bricks and are also cost effective. The use for production of AAC blocks can provide effective solutions to manage this potential resource for sustainable development and to avoid its negative environmental impacts [12] . More innovations are needed to make fly ash bricks which have more desirable physico-chemical properties valuable for construction industry.
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