

Technical Suitability Assessment of Autoclaved Aerated Concrete Block as Alternative Building wall Construction Material; A Case of Nepal

Er. Deepak Khanal, Asso. Prof. Dr. Anjay Kumar Mishra*, Asst. Prof. Birat Ghimire

United Technical College Nepal, Bharatpur Metropolitan City-11, U-TEC Chowk, Chitwan, Nepal

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*Corresponding author: Dr. Anjay Kumar Mishra

Email: anjaymishra2000@gmail.com

Abstract

The increasing demand of construction is a challenge to be fulfilled in this regard different new construction materials are found to be utilized differently. One of the wall construction materials Autoclaved Aerated Concrete Block (AAC) is found to be used in Bharatpur Metropolitan of Nepal. The purpose of this research is to assess the technical suitability of Autoclaved Aerated Concrete Block as Alternative Building Construction Material for the construction of residential buildings and hotels. Laboratory test of the AAC blocks were done. Quality control chart and t-test were done for analysis. To test the physical properties, 5 samples of AAC block were observed for compressive strength, density and water absorption. The compressive strength of the AAC block was found to be 4.324 N/mm^2 even with a low density of 617.6 kg/m^3 when compared to a 3.402 N/mm^2 average compressive strength of brick of 1685.8 kg/m^3 density. However, the water absorption of the AAC block was found higher than that of the Clay brick.

Keywords: Compressive strength, water absorption, density.

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INTRODUCTION

Many companies have been established ever since these Autoclaved Aerated Concrete Block (AAC) blocks have been in use in the construction of the masonry wall of the commercial buildings. Marriott Hotel, Surya Nepal, Riddhi Siddhi Cements, Shaurya Cements, Narayani Steel, Gorkha Feed Industries, Palpa Cement, White House Engineering College, BKOI Builders, Paramount Construction, Chitwan CoE Nepal, Hotel Siraichuli are some of the big names which have used AAC blocks in their construction. Many companies have been established for the production such as Aero Lite, AAC Itta, Eco Blocks, AAC Lite and soon.

The increasing use of AAC blocks in construction field has resulted in the increase in the number of production industry in Nepal. The increased used in construction fields, mostly in the commercial buildings proves that the demand has also been in increasing trend since the onset of the use of the AAC block.

Both clay brick masonry and AAC block masonry and bricks have been found suitable to use in the present days. Also, several mortars are used in the

joints of blocks. Individual masonry elements are strong in compressive but weak in tension for AAC. Hence, the cracks are easily propagated on the surface of the masonry structure due to the low ductility. Thus, before using them as a building material, they must satisfy the minimum strength [1] as per the standard for their use in the wall.

AAC block has been recognized as suitable material for building construction. Thus, a need of the study of the suitability of AAC block has been felt.

RESEARCH OBJECTIVES

The objective of this research is to assess the technical suitability of Autoclaved Aerated Concrete Block as Alternative Building Construction Material in the Bharatpur Metropolitan city for the construction of residential buildings and hotels.

LITERATURE REVIEW

Urbanization and Construction in Nepal

Chitwan includes Bharatpur, Ratnanagar, Khairahani, and Rapati as the main urban area. The metropolitan city has an area about 554 km^2 and has a population of 199,867 according to CBS 2011. Today with rapid urbanization, high urban growth is annual

more population growth in Bharatpur. In order to cater the housing needs of increasing populations, multi-story building in the forms of collective and apartment housings is being developed. Building construction around a decade ago was completely a personal matter. There is tradition of construction houses through self-effort and utilizing conventional building materials and means. Considering these aspects, government has formulated national shelter policy 2012 with the vision of providing housing which is safe, adequate and as per living standards to all [2].

According to the World Bank reports, the groups of people with daily income less than US \$1.25 are considered as the low income groups or poor groups. The pace of urbanization has remained faster and is likely to remain so in the future. Nearly, 17.1% of Nepal's population resides in 58 designated urban areas according to the 2011 census. However, with the addition of 131 municipalities in 2014, 38.26% of Nepal's populations reside 191 designated urban areas. There have been fluctuations in inter-censal urban growth rate. Although the growth rate in the inter-censal decade was 3.43%, the average annual growth between 1981 and 2011 has remained at a high rate of 5.3%. Urban rural growth differential in 2011 is 2.4%. The level of urbanization is highest in the hill region 21.7% compared to the terai 15.1% and the mountain region 2.8% [3]. According to the CBS of 2001, there were 4,174,374 house/buildings or residential structures in total, out of which about 1.3 million houses in the rural area and about one hundred thousand in the urban area were temporary in nature, which means that about 33% of the total residential houses appear to have been constructed in a temporary manner. According to the standard of living survey of Nepal, 2003/04, the population living in the houses of their ownership was about 91.6% and those living on rent was 8.4% whereas, these number appeared to be 92.8% and 2.2% respectively in the year 1995/96. From the result of fiscal year 2009/10, these numbers appear to be 90% and 8% respectively. In the way, people living in a rented house has increased from 2% to 8% compared to the first standard of living survey, i.e. during the periods of 15 years [3].

Comparative Advantage of AAC Block

AAC blocks are manufactured using natural raw materials such as clay, slate, shale, fly ash and volcanic materials. The manufacturing process doesn't include any fire which thus doesn't produce air pollution in the surrounding. They are known for their improved thermal properties along with its non-combustible and fire resisting nature (up to 1600 °C).

The availability of AAC blocks in different customs sizes makes it economic for different sizes of walls. In addition to that, easy cutting, drilling, nailing, milling and grooving nature makes the block fulfills the individual requirement of the construction. Because of this, the reduction of operating cost of around 30% to 40% is observed in the AAC.

AAC blocks are 3-4 times lighter than the traditional bricks, which makes the construction work faster, easier and in turn makes use of less formworks and propping in construction. Additionally, the usage of these blocks reduces overall dead load of a building thereby allowing smaller cross-section of structural elements. Structurally in this construction, each wall and slab behave as a shear wall. These construction works are proven to be highly durable, low in maintenance and better colour [4].

Stiffness of AAC Block

The stiffness, k , of a body is a measure of the resistance offered by an elastic body to deformation. For an elastic body with a single degree of freedom (DOF), the AAC Block infilled RC frame showed a gradual decline in lateral stiffness from 215KN/mm to 1.5KN/mm [19].

Compressive Strength of AAC Block

Compressive strength may be defined as the measured maximum resistance of a concrete specimen to axial loading. An average compressive strength of 2.86 MPa has been completed on 650 kg/cum density AAC cubes following 28 days of the usual water-curing. A compressive energy of more than 20 MPa is obtainable with the addition of silica fumes, polypropylene fibers and steel mesh reinforcements, for special programs in which extra compressive energy is required. Since blocks crafted from AAC are 1/3 to 1/2 the weight of ordinary concrete blocks. For the cause of bearing, the self-load of the AAC block-wall, blocks of compressive power zero.21–0.31 MPa are used, in comparison to traditional blocks of 0.42-0.56 MPa [5].

The specimen size and shape, approach of pore-formation, path of loading, age, water content material, traits of substances used and technique of curing are reported to influence the strength of aerated concrete. Pore structure of the air pores and mechanical condition of pore shells have a marked influence on the comprehensive strength. Values of compressive strength for different densities are reported in table 2.1 [6].

Table-0.1: Property of AAC block with Respect to Density

Dry density (kg/m ³)	Compressive strength (MPa)	Static modulus of elasticity (kN/mm ²)	Thermal conductivity (W/m ⁰ C)
400	1.3-2.8	0.18-1.17	0.07-0.11
500	2.0-4.4	1.24-1.84	0.08-0.13
600	2.8-6.3	1.76-2.64	0.11-0.17

700	3.9-8.5	2.42-3.58	0.13-0.21
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Dry Density of AAC Block

The water cementitious materials ratio is associated with the quantity of aeration received and accordingly the density. For a given density, water-cement ratio increase with share of sand. For AAC with pozzolans, water-strong ratio seems to be greater vital than the water-cementitious ratio, regardless of the techniques of pore-formation [6].

As many bodily residences of aerated concrete rely on the density (three hundred-1800 kg/m³), it's far vital that its houses be certified with density. While specifying the density, the moisture condition i.e. Oven dry condition or at equilibrium with atmosphere) wishes to be indicated. The fabric as added from autoclaved may be 15-25% heavier than oven-dry substances. This cost can be high as 45% for extremely low density aerated concrete [6].

The density of AAC levels from 250 to 1,800 kg/m³, as compared to 2400-2600 kg/m³ for traditional concrete. Therefore, the load of a structure built with foam concrete could surely be decreased considerably, main to superb savings inside the use of reinforcement steel within the foundations and structural individuals. AAC blocks are best for the complete constructing structure and own high structural integrity. The product is light weight and easy paintings potential approach that it's far very brief to install on web page, thereby saving in metallic, cement, and mortar and plastering charges [5].

Water Absorption of AAC Block

Aerated concrete being porous, there's a strong interaction between water, water vapour and the porous device and there exists numerous moisture shipping mechanisms. In the dry nation, pores are empty and the water vapour diffusion dominates, at the same time as some pores are filled in better humidity regions. Capillary suction pre-dominates for an detail in contact with water. These mechanisms make it tough to predict the impacts of pore size distribution and water content on moisture migration [6].

Water Absorption of AAC Block

The water vapour transfer is explained in termed of water vapour permeability and moisture diffusion coefficient whereas capillary suction and water permeability characterize the water transfer. The moisture transport phenomena in porous materials, by absorbing and transmitting water by capillarity, has been defined by an easily measureable property called the sportively, which is based on unsaturated flow theory. It has been shown that the water transmission property is better explained by sportively than by permeability. The concept of capillary hygroscopicity also employs the same principle as sorption. These values give a fair indication of the fineness of the pores [6].

These properties are in particular important in concrete, as well as being important for sturdiness. It may be used to predict concrete sturdiness to face up to corrosion. Absorption capacity is a measure of the porosity of aggregates. It is likewise used as a correlation aspect in willpower of free moisture by oven-drying method. The absorption ability is decided by finding the load of floor-dry pattern after it's been soaked for twenty-four hr. And once more locating the burden after the pattern has been dried in an oven; the difference in weight, expressed as a percentage of the dry pattern weight, is the absorption ability [5].

Durability of AAC Block

AAC especially includes tobermorite, which is plenty greater solid than the goods fashioned in normally cured aerated concrete, and for this reason it is durable. However, aerated concrete has high porosity, permitting penetration by means of liquid and gases. This may result in the harm of the matrix. Freeze-thaw reactions are said to be significant as a long way as AAC is worried at saturation degree of 20-40%. At better tiers of saturation, the pattern will become brittles and cracks completely. Protective precautions using bitumen-based materials are necessary when sulphate attack is anticipated. Carbonation can lead to increase in density but it is not very serious unless the exposure to CO₂ is too serving [6].

Thermal Conductivity of AAC Block

The amount of pores and their distribution are also critical for thermal insulation. Finer the pores better the insulation. As the thermal conductivity is influenced by the moisture content in moisture by mass increase thermal conductivity by 42%, it should not be reported in oven dry condition. Based on the thermal performance requirements for buildings, as optimum materials design has been proposed by tada [6].

It is a measure of the material conductivity as tested in a laboratory procedure that measures the heat flow through building material under steady and constant climatic conditions. It is important to remember that these laboratory conditions do not reflect the normal climatic cycles. Based on the above definition, it is obvious that the lower the K value the higher the insulating value [5].

Fire Resistance of AAC Block

In practice, the hearth resistance of aerated concrete is extra than or as right as ordinary dense concrete and as a result their use does no longer involve any chance of unfolding of flames. An crucial motive for such behavior is that the materials is exceptionally homogeneous, unlike everyday concrete wherein the presence of coarse mixture results in differential prices of growth, cracking and disintegration. The top hearth resisting property of aerated concrete is where its closed

pore shape can pay wealthy dividends, as warmth switch thru radiation is an inverse characteristic of the number of air-stable interfaces traversed. This coupled with their low thermal conductivity and diffusivity offers an illustration that aerated concrete possesses better hearth resistance residences [6].

Quality Control Chart

Currently, Quality is highly focused in competitive environment. To ensure quality charts are found to be applied for avoiding quality failure. A quality control chart is a graphic that denotes how correctly the process is under control this method is used by *Sarbottam* Cement also to ensure quality of cement [7]. It was first developed by Walter Andrew

Shewart to produce the special and common causes of variation in the construction of various components while working for Bell Telephone Co. in 1924 in United States of America [8]. It has been standard methods in industrial engineering.

METHODOLOGY

The study area is Bharatpur Metropolitan City. The city is the emerging city of Nepal which has a lot of construction works going on. A total area of 554 sq. km is covered by the metropolitan with 29 wards [9]. The study is only limited to two wards of the city, Ward no. 10 & Ward no. 11.

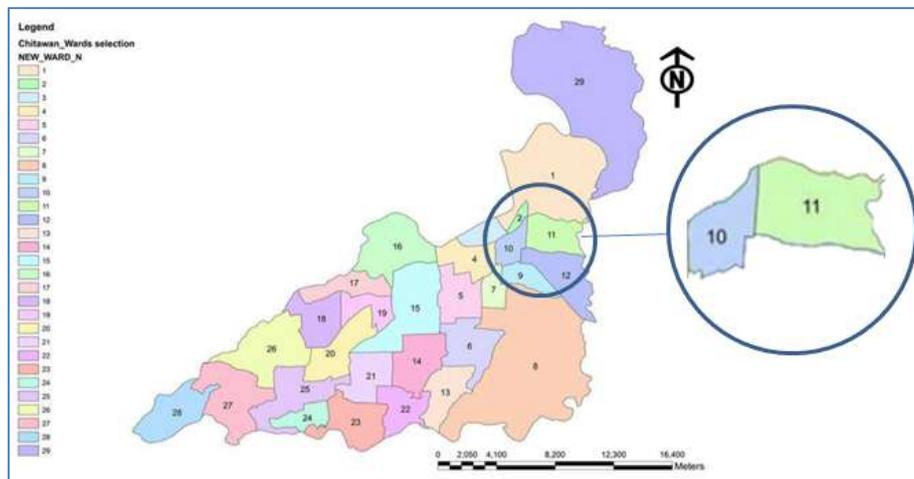


Fig-3.3: Map of Nepal [10]

Research Approach

Lab experiments for comparison of physical properties on the samples and statistical approaches for the standard assessment were done.

DATA COLLECTION

Primary Data

Primary data are the main data for the analysis and interpretation of result for this research work.

Experimental Research

For the study in AAC block and its comparison for the suitability, different laboratory tests and the verification of the strength, water absorption, density and its dimensions with the standards is necessary.

Hypothesis Testing

The hypothesis as shown is prepared for testing and a two tailed t-test is performed where null hypothesis and the alternative hypothesis prepared is as follow:

H₀: There is no significant difference in the mean experimental value of different properties from the standard mean.

H₁: There is significant difference in the mean experimental value of different properties from the standard mean.

A test for the significance of the mean of random samples for each property of the AAC block and clay brick separately were performed for n – 1 degree of freedom where nis the number of samples (n = 5). Here, 5 numbers of samples were taken and tested for the compressive strengths and dry densities. Sample means of AAC blocks and clay bricks were computed separately. A two tailed t-test was performed.

Dry Density

The dry density is defined as the mass of solids per unit volume mathematically,

$$\rho_d = \frac{M_s}{V} \dots \dots \dots Eq1$$

Where,

- ρ_d = Dry density
- M_s = Mass of solid
- V = Volume

5 samples each from five stakes were taken. All 25 samples were tested for dry density for AAC

Blocks as well as for clay bricks blocks and compared to its standard.

The standard for the densities of different materials is provided in the IS 875 part I. The dry density as per the IS 875 part 1, for autoclaved reinforced cellular wall slab (as per the standard) lies between 1000 kg/m³-550 kg/m³ whereas for the clay burnt bricks lies between 1600 to 1920 kg/m³. (Bureau of Indian Standard, 1987) whereas as per IS 2185 part 3, which divides the AAC blocks in 5 groups has recommended 5 ranges of density at oven dry condition between 450 to 1000 kg/m³. (As per IS 2185 part 3) [11].

Compressive Strength

The compressive strength as defined by the IS 516-1959, is the maximum applied compressive force divided by its cross-sectional area upon which the force is applied [12].

The compressive strength of AAC block was determined by axial compression tests of cubical specimens, according to the requirements set by the [12] IS 516(1959). It was crushed in compressive strength testing machine and its crushing strength and the crushing strength were noted for each sample. The compressive strength of AAC block is divided into 5 categories as Per IS 2185 part 3. As per the standard, the compressive strength of the block should lies between 1.5 N/mm² and 7 N/mm²[13]. Thus, for comparison, 5 samples from each 5 clay bricks stacks and AAC blocks stacks were tested and compared with the standards.

Weight

The weight of AAC block and clay bricks were measured in the lab by weighing it on the weighing machine and weight for individual sample was recorded.

Water absorption

IS 3495 Part 2 covers the part of test of water absorption by the brick where the immersion of the sample is made for 24 hours at 27° C [14] “Methods of Tests for Burnt Clay Building Bricks”. The water absorption limits for the brick samples are provided in the IS 1077 1922 which shall not be greater than 20% at any condition [15].

Water absorption test at 24 hours water immersion is not given in standard of AAC blocks IS-2185 part 3 (Autoclaved Cellular Aerated Concrete Block).However, for the comparison purpose, the water absorption value is taken from the published literature of Sherin *et al.* [16] where a value close to 48% is obtained as water absorption for AAC block.

Dimensions Measurement

Standard provides a varied dimensions of the blocks 400 – 600 mm (length), 200 to 300 mm (height) and 100 – 250 mm of (width) as per IS 2385 part III [11] whereas NBC 119 400 mm (length), 200mm (width) 100, 150 and 200 mm (Height) whereas the same block could have length of 200 mm (half brick)[13].

Each masonry unit of clay brick as per National Building Code 109, the standard recommended dimensions of a clay brick is 240 (length), 115 (width) and 57 (height)[17].

Thus suitability of the AAC blocks is performed in the study after the measurements and data collection on the basis of compressive strength, dry density and water absorption test performed for 25 samples.

DATA ANALYSIS

All the experimental data were analyzed with Quality control chart which proved whether the production was under control or not.

Quality Control Chart

The quality control charts have been prepared for primary data (density and compressive strength) and is explained for the variation observed during the test. The value of the constants is given in Appendix 6[3].

$$Upper\ Control\ Limit = \bar{X} + A_2 \bar{R} \dots \dots \dots Eq2$$

$$Control\ Limit = \bar{X} \dots \dots \dots Eq3$$

$$Lower\ Control\ Limit = \bar{X} - A_2 \bar{R} \dots \dots \dots Eq4$$

Here in the equation Eq. 12, Eq. 13 and Eq. 14 gives the control limits for the data.

Where,

\bar{X} =Mean of Experimental Research

$A_2 = 0.57$ For 5 numbers of sample (Average considered) (Sengoz, 2018)

\bar{R} =Mean of Range

For Range which is the difference in the maximum and the minimum of the value in the samples, the ranges upper control limits and lower control limits could be expressed in as:

$$Upper\ Control\ Limit = D_4 \bar{R} \dots \dots \dots Eq5$$

$$Control\ Limit = \bar{R} \dots \dots \dots Eq6$$

$$Lower\ Control\ Limit = D_3 \bar{R} \dots \dots \dots Eq7$$

Where,

$D_4 = 2.11$ For 5 numbers of samples (Average considered)

$D_3 = 0$, Thus, Lower Control Limit is always zero[3].

Eq. 15, 16 and 17 gives the control limits for the range of data.

The research can be summarized as research matrix.

Table-0.2: Research Matrix

Objective	Variables	Collection Methods	Analysis Methods	Expected Outcomes
To access the technical suitability of AAC Block for building Masonry.	Dry density, Compressive strength, Weight, Water Absorption, Variation of size, Fire resistance	Lab work	Descriptive statistic, Quality control chart	Theoretical verification, Comparison of standard

Data Analysis and Presentation of Data

The suitability of AAC Block was accessed on the basis of dry density, Compressive strength, Weight of AAC block, Water absorption, Variation of size and Fire resistance properties.

The table 4.1 shows the mean value of measured Compressive strength, the Density and Water Absorption of the Clay Brick and AAC. The findings in detail are explained in the discussion section of each test.

Table-0.3: Mean Value of Measured AAC block and Clay brick properties

Test	Types of Brick	Mean Values	Standard Value
Dry Density	Clay Brick	1658.8 Kg/m ³	1600 – 1920 kg/m ³ (IS 875)
	AAC Block	617.6 Kg/m ³	450 -1000 kg/m ³ (IS 2185 part 3)
Compressive Strength	Clay Brick	3.402 N/mm ²	3.5 – 35 N/mm ² (IS 1077, 1992)
	AAC Block	4.324 N/mm ²	1.5 - 7 N/mm ² (IS 2185 part 3)
Water Absorption	Clay Brick	22% by volume	Max 20% (IS 1077, 1992)
	AAC Block	48% by volume	Not provided in the standard

Technical Suitability on the Basis of Dry Density AAC Block

Dry density of AAC Block was measured on the basis of 5 samples from 5 different production unit or stacks of AAC Blocks and the result obtained are in

the Table 4.2. The sample means and ranges observed after data analysis are shown in table 4.2. The dry density of the blocks varies from 602 kg/m³ to 637 kg/m³ with a mean of 617.6 kg/m³. The sample density measurement ranges varied from 4 to 40 kg/m³.

Table-0.4: Observed Dry Density for 5 Samples of AAC Blocks

SN	Mean Density (kg/m ³)	UCL Density	LCL Density	Range Observed	UCL Range	LCL Range
1	625	627.17	608.02	4	35.532	0
2	637			8		
3	608			20		
4	616			40		
5	602			12		
Mean	617.6			16.8		

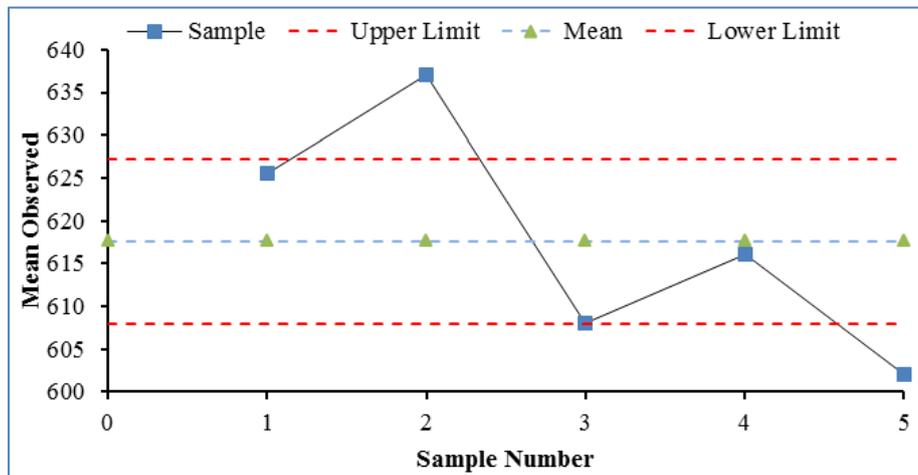


Fig.0.2: Mean Value Charts for Dry Density of AAC Block

The calculation of the control limits is shown in the Appendix 1 where the mean is 617.6 kg/m³ and the control limits are (627.17, 608.02) kg/m³ for the density of AAC block which can be seen in Figure 4.1. The manufacturing process is not under control as per statistical analysis. Only three sample means lay within

the control limits of mean density for AAC block which shows that the production process is not under control when considered with respect to the density. It infers that mass of the materials prepared for different batches is not consistent which are being used in the blocks.

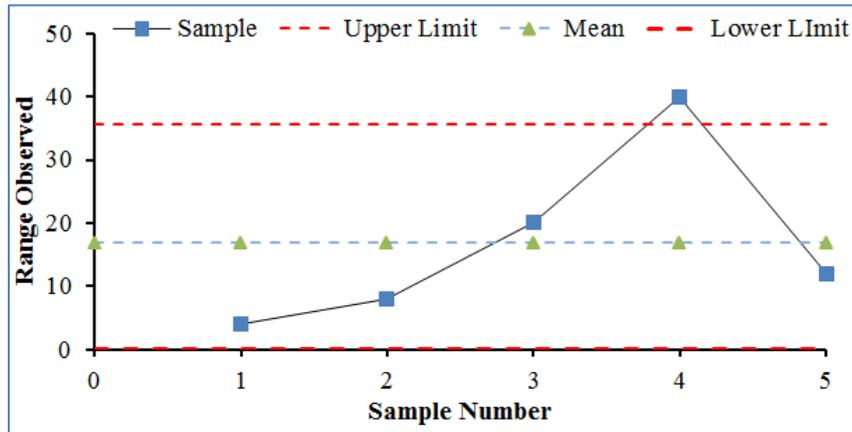


Fig-0.3: Range Value Charts of Dry Density of AAC Block

Mean for the range of density mean is 16.8 kg/m³ and the control limits are (35.532, 0) kg/m³ for AAC blocks as shown in Figure 4.2. Only one sample lies out of the range control limits for density of AAC block. It indicates that production unit of sample 4 requires attention for fact finding and correction.

The dry density of AAC Blocks were measured in lab and mean density was found to be 617.6 kg/m³. This is very comparable with the result of Rathi & Khandve, where the dry density of AAC Blocks observed were between 551-600 kg/m³ [5]. As per IS 2185 part 3, AAC dry density lies in between 450 to 1000 kg/m³ [11]. The observed mean density of AAC block lies between the specified limits of density of standard and the paper.

Statistical Analysis (t-test)

A t- test was performed to see if there is significant difference between many AAC block with standard. Since, AAC block varies in density as per its production, AAC blocks are divided into number of groups and as per the density, the AAC block collected

lies on category with density between 551 to 650 kg/m³ [11]. Thus, populations mean of 600.5 kg/m³ (taken as average of the value) is considered as standard mean value.

$$H_0: \bar{X}_{density} = \mu = 600.5 \text{ kg/m}^3$$

$$H_1: \bar{X}_{density} \neq \mu \neq 600.5 \text{ kg/m}^3$$

Here,

From the two tailed t-test, it was found that t-stat = 2.757 whereas for v = 4, t_{0.05} at 5% level of significance is 2.776. Since, t-stat < t_{0.05} for two tailed test, null hypothesis is accepted and hence, there is no significant difference between standard mean values obtained during experiment. The calculation is provided in Appendix 7.

Clay Bricks

Dry density of clay brick were measured from the 5 samples each from 5 stakes (5 x 5) and the mean results are shown in the table 4.3.

Table-0.5: Observed Mean Density for 5 Samples of Bricks

SN	Mean Density (kg/m ³)	UCL Density	LCL Density	Range Observed	UCL Range	LCL Range
1	1703	1696.28	1675.31	20	38.916	0
2	1695			40		
3	1687			12		
4	1705			16		
5	1689			4		
Mean	1685.8			18.4		

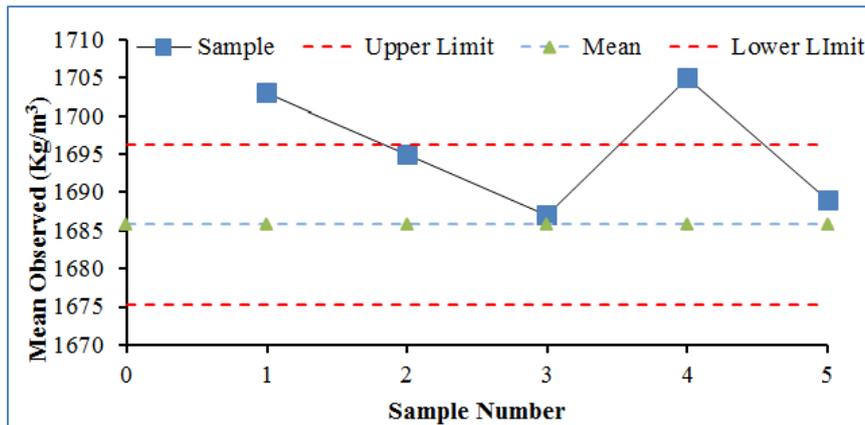


Fig-0.4: Mean Value Charts for Dry Density of Clay Brick

The calculation of the control limits is shown where the mean is 1685.8 kg/m^3 and the control limits is $(1696.28, 1675.31) \text{ kg/m}^3$ for the density of the clay brick. Clay bricks also didn't show uniform characteristics and doesn't fall within the control limits

as shown in the Figure 4.3. Hence, the production process of clay brick is also not under control with respect to the density. The result has to be verified using the range control chart which can be seen in the figure 4.4.

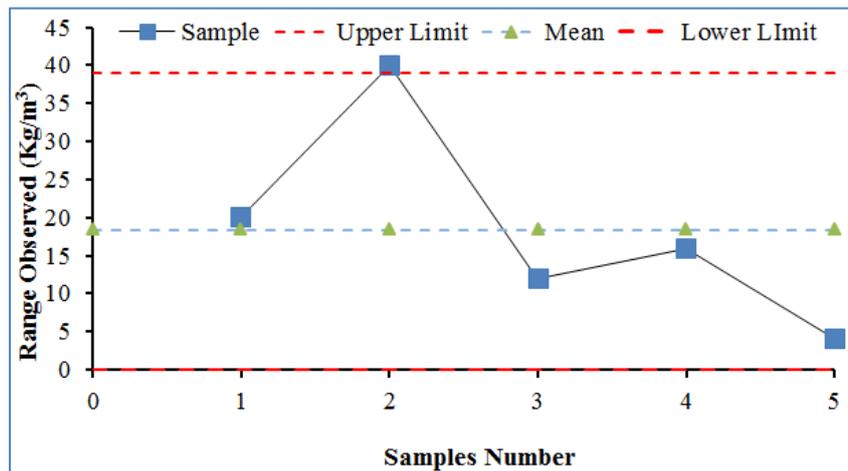


Fig-0.5: Range Value Charts of Dry Density of Clay Brick

Statistical analysis shows that mean of the range of density is 18.4 kg/m^3 and the quality control limits are $(38.916, 0) \text{ kg/m}^3$ for experimented clay brick samples. The range sample mean and the control limits, a control chart of range, are shown in figure 4.4. Out of five samples one sample, number 2 exceeds the range control limits for the density measured for clay bricks. Other samples mean are within the accepted limit or range.

The dry density of clay bricks measured in lab was found to be 1685.8 kg/m^3 . The dry density of clay brick of 1920 kg/m^3 was observed in the study of Rathi & Khandve [5]. Whereas, IS 875 part 1 suggests dry density of clay brick between 1600 to 1920 kg/m^3 [18]. Thus, the value obtained for the density of clay brick lies between the standard values. However, the production is not under control with respect to the density.

STATISTICAL ANALYSIS (T-TEST)

A t- test is performed for the density test performed in Clay Brick with the standard, since the number of sample is less than 30.

As per IS 875, dead load part of the standard suggests the density of clay brick between 1600 to 1920 kg/m^3 . Thus, a population mean of $\mu_0 1760 \text{ kg/m}^3$ (taken as average of the value) is considered and tested for the significance

$$H_0: \bar{X}_{\text{density}} = \mu = 1760 \text{ kg/m}^3$$

$$H_1: \bar{X}_{\text{density}} \neq \mu$$

$$\neq 1760 \text{ kg/m}^3$$

Here,

From the two tailed t-test, it was found that the t-stat = -17.778 whereas for $v = 4$, t at 5% level of significance is 2.776 . Since, t-stat $> t_{0.05}$ for two tailed test, alternative hypothesis is accepted and hence, the sample mean doesn't represent the population with

population mean 1760kg/m^3 . The calculation is provided in Appendix 7.

Both the densities of AAC and Clay bricks obtained from the test samples were compared to the standard as shown in table 4.9 suggest that the densities of clay found significantly lower than standard whereas the densities of AAC were found within the range. During the hypothesis testing, it was found that the AAC block satisfied the population mean of the given standard (IS 2385 part 3) whereas, the samples of clay brick failed to satisfy standard (an average of 1600 and 1920) for density. Though, it is towards the lower end, so it can be inferred that the quality is not perfectly in control.

Thus, the dry density of brick is 3 times that of AAC block which means AAC should be given more

preference in comparison to that of clay bricksto reduce dead load of the structure. The manufacturing process for both AAC block and red clay brick are not under control as per result obtained from the data with respect to the density.

Technical Suitability on the Basis of Compressive Strength AAC Block

Compressive Strength of AAC Block was tested on 25 numbers of sampleson Universal Testing Machine by taking 5 samples each from 5 stakes of AAC Blocks. Table 4.4 shows the mean of the 5 samples collected from 5 stakes in the construction sites. The mean range of compressive strength varies from 3.98 N/mm^2 to 5.45 N/mm^2 whereas computed range of measured samples varies from 0.08 N/mm^2 to 0.3 N/mm^2 .

Table-0.6: Observed Compressive Strength for 5 Samples of AAC Blocks

SN	Mean Comp. Strength (N/mm ²)	UCL Comp. Strength	LCL Comp. Strength	Range Observed	UCL Range	LCL Range
1	5.45	4.4038	4.2442	0.04	0.2961	0
2	4.12			0.08		
3	4.02			0.2		
4	4.052			0.3		
5	3.98			0.08		
Mean	4.324			0.14		

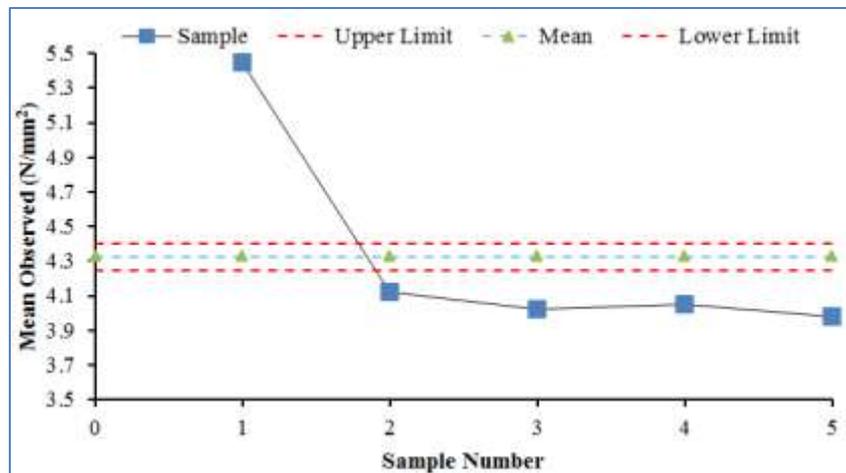


Fig-0.6: Mean Value Charts for Compressive Strength of AAC Block

The calculation of the control limits is shown in the Appendix 2. The mean compressive strength was found to be 4.324 N/mm^2 and the control limits are $(4.4038, 4.2442)\text{ N/mm}^2$ whereas that for the range of the compressive strength. The sample data are plotted and shown in the Figure 4.5. From table 4.4 of mean compressive strength and from Figure 4.5, the range chart reveals that the compressive strength is higher than the group it lies in of the compressive strength provided by the standard IS 2385 part 3 (4 N/mm^2). Therefore, the AAC blocks were found stronger in compressive strength. However, the control chart shows

that all values lie out of control limit, so the manufacturing process seems not in control with respect to the compressive strength.

As per Sherin and Saurabh,compressive strength of AAC Blocks lies between $3\text{-}4\text{ N/mm}^2$ [16]. However, IS 2185 part 3 requires the AAC block to bear strength between $1.5\text{ to }7\text{ N/mm}^2$. Thus, an observed compressive strength of 4.324 N/mm^2 doesn't vary with respect to that of standard and other literatures which validate the test result.

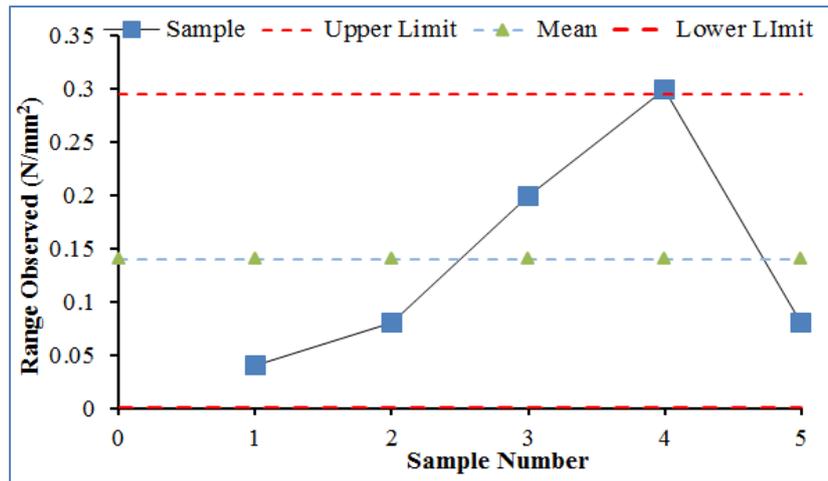


Fig-0.7: Range Value Charts for Compressive Strength of AAC Block

The mean of the range of the compressive strengths mean is 0.14 N/mm² and the control limits lies between (0.2961, 0) N/mm². For the range, only one sample lies outside of the control limit. It reveals that the unit produced sample number 4 stacks must be supervised and controlled for future production.

Statistical Analysis (t-test)

A t- test is performed for the compressive strength test performed in AAC block with the standard, since the number of sample is less than 30.

As per IS 2385 Part 3, compressive strength suggested for the same group of AAC block is 4 N/mm². Hence, a population mean of 4 N/mm² is taken for the test of significance.

$$H_0 : \bar{X}_{\text{compressive strength}} = \mu = 4 \text{ N/mm}^2$$

$$H_1 : \bar{X}_{\text{compressive strength}} \neq \mu \neq 4 \text{ N/mm}^2$$

From the two tailed t-test, it was found that the t-test carried at 5% level of significance showed that the t-stat = 1.149 where as for v = 4, t_{0.05} at 5% level of significance is 2.776 is observed. Since, t-stat < t_{0.05} for two tailed t-test, null hypothesis is accepted and hence, the sample mean represent the population with population mean of 4 N/mm² for AAC block. The calculations are shown in Appendix 8.

Clay Brick

Compressive strength was measured for collected samples of clay bricks in Universal testing machine. 5 samples of clay bricks were taken from the five different stakes of bricks (5 x 5) and its mean compressive strengths are shown in the Table 4.5. The mean range of compressive strength of clay brick varies from 3.1 to 3.59 N/mm² with mean of 3.402 N/mm² whereas, the range of measured compressive strength of clay brick samples lie between 0.04 to 0.2 N/mm² with range mean of 0.176 N/mm².

Table-0.7: Observed Compressive Strength for 5 Samples of Clay Bricks

SN	Mean Density (N/mm ²)	UCL Comp. Strength	LCL Comp. Strength	Range Observed	UCL Range	LCL Range
1	3.56	3.5	3.3	0.04	0.37224	0
2	3.1			0.4		
3	3.28			0.08		
4	3.48			0.16		
5	3.59			0.2		
Mean	3.402			0.176		

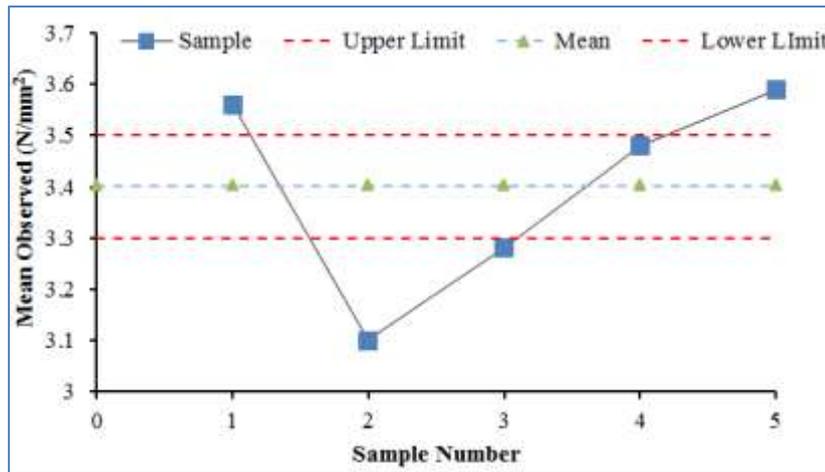


Fig-0.8: Mean Charts for Compressive Strength of Clay Brick

The calculation of the control limits is shown in the Appendix 2 the mean values were found as 3.402 N/mm² and the control limits are (3.5, 3.3) N/mm². The sample data are plotted and shown in the Figure 4.7 for the mean compressive strength. The manufacturing process is not under control as per the control chart Figure 4.7. Only 1 sample of mean compressive strength lies under the control limits out of 5 samples.

The compressive strength of clay bricks, as per Sherin and Saurabh, lies between 2.5-3 N/mm² (Sherin & Saurabh, 2018). Whereas, IS 1077, suggests the compressive strength of very large range on various category in between 3.5 N/mm² and 35 N/mm² with 3.5 N/mm² as the lowest strength. Thus, obtained mean of 3.402 N/mm² is comparable to this range provided by literature and hence the experimented result for brick compressive strength reveals that the bricks are manufactured with proper ingredients and process.

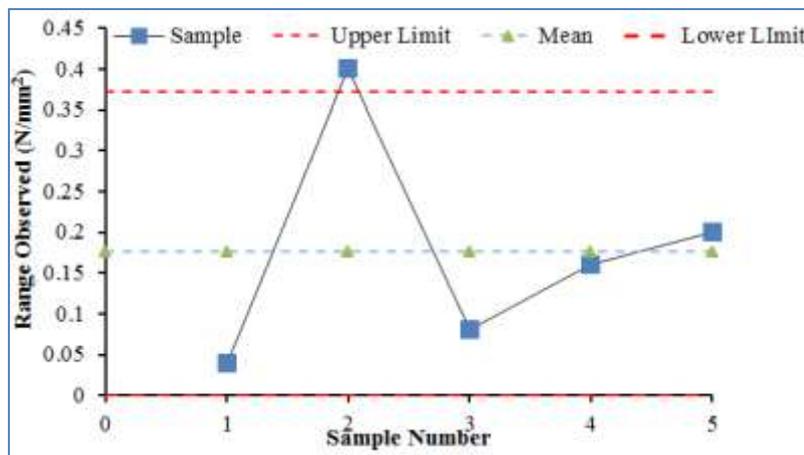


Fig-0.9: Range Charts for Compressive Strength of Clay Brick

The mean range of the compressive strength samples mean is 0.176 N/mm² and the control limits for the experimental samples range lies between (0.37224, 0) N/mm² for red clay bricks. The range control chart is produced and shown in Figure 4.8. Out of 5 samples one sample, sample number 2, doesn't lie within the range of the control limits. Thus, sample number 2 ranges need to update or immediate attention to bring the unit under control.

As per IS 1077, compressive strength suggested for a group of clay brick is 3.5 N/mm², the lowest among the other groups which seems closest to the samples collected. Hence, a population mean of 3.5 N/mm² is taken for the test of significance.

$$H_0: \bar{X}_{\text{compressive strength}} = \mu = 3.5 \text{ N/mm}^2$$

$$H_1: \bar{X}_{\text{compressive strength}} \neq \mu \neq 3.5 \text{ N/mm}^2$$

Here,

From the two tailed t-test, it was found that the t-test carried out at 5% level of significance showed that t-stat = -1.055 whereas for $v = 4$, t at 5% level of significance is 2.776. Since, $|t\text{-stat}| < t_{0.05}$ for two tailed

Statistical Analysis (t-test)

A t- test is performed for the compressive strength test performed in Clay brick with the standard, since the number of sample is less than 30.

test, null hypothesis is accepted and hence, the sample mean represent the population with population mean of 3.5 N/mm^2 for Clay brick. The calculation is provided in Appendix 8.

Thus, both compressive strength of samples of clay brick and AAC block belongs to the population of low strength clay brick and 4 N/mm^2 group of AAC block respectively. Despite having lower density than that of clay brick, AAC concrete block bears a higher compressive strength of 4.324 N/mm^2 compared to that of 3.402 N/mm^2 of clay brick. A material lighter in weight and simultaneously exerting lower dead load to the structure along with the higher compressive strength shows that AAC could be better alternative of brick. Thus, the analysis shows that AAC block could be better alternative because AAC are light and stronger in compressive strength.

Technical Suitability on the Basis of Water Absorption

Water absorption experiment was carried out for AAC Block by dipping the AAC Block on the water tank for the 24 hours. The blocks were weighted after curing from the water tank and percentage increase in weight was found 48%.

Water absorption was carried out for clay bricks dipping the clay bricks in the water tank for the 24 hours, the bricks were weighed after removing from the water tank and percentage increase in weight was found 22%.

According to [16] the water absorption capacity of AAC Block and clay bricks are very high 45% by weight and high 20% by weight respectively [16]. The water absorption of AAC is higher than that of Clay brick, higher absorption of water may increase dead weight. If exposed directly to rain water or any other source of water, water absorption capacity of AAC block was found to be twice that of Clay brick. However, the volume of AAC block is three times the volume of the clay brick.

Technical Suitability on the Basis of Fire Resistance

Fire resistance capacity of AAC Block is about 7 hours and the fire resistance capacity of clay bricks is about 2 hours [16]. This also proves the superiority of the AAC blocks over Clay bricks in terms of fire resistance.

CONCLUSIONS

Lower dry density (one third of clay brick) and higher compressive strength, supports AAC Block to be used as alternative masonry wall construction materials; however higher percentage of water absorption per unit weight is no hindrance in adopting AAC though relatively it is not discouraging. Statically Quality control that is mean chart and range chart supports the conclusions. Hypothesis conforms the results suitably

with help of t statistics. The comparison of AAC with brick work makes it technically more suitable in response to that of Brick for wall construction. AAC Block should be promoted as alternative masonry building construction materials to reduce dead weight, increase relative strength and economic benefits. Knowledge and awareness is required for increasing the use of AAC Block in construction. AAC Block being adopted and manufactured in Nepal, in Nepal it slowly is being effectively used in construction of building. Therefore many areas can be identified for further studies some of those are as follows:

To assess the comparative strength and weakness of AAC Block in comparison to all other materials. To analyze the acceptance and cost benefit of AAC Block at selected sites of construction in the study area.

Study on different part of construction in which AAC Block that can reduce dead load in compare to conventional brick masonry wall. More elaborated study of AAC Block for its durability and strength in buildings. Developing AAC Block to meet regional specific needs/demands for buildings.

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