Journal of the Institute of Engineering
Volume 18, No. 1
ISSN: 1810-3383
Published: February 2025

Printed in Nepal

Comparative Analysis of the Effectiveness of AAC Block with Red Brick as Building Construction Material

Naresh K. Manandhar [a], Pradeep Pokhrel [a,b]

[a] *CEM, LIAST, Civil Engineering, Lumbini Buddhist University, Nepal*
[b] *Viswa Consult Pvt. Ltd., Kathmandu, Nepal*
Corresponding Author: [a]nareshmanandhar070@gmail.com

Received: 2024-04-08 Revised: 2024-08-03 Accepted: 2024-08-06

Abstract:
Red Bricks and AAC Block, both are being used as building construction materials in the building construction recently in Nepal. Red Bricks are being used from very old age but the AAC Block has been in the market for very few years only, so, there exists some doubts regarding its performance. For a technical person like engineers and project managers, there should be proper knowledge about the materials so that they can choose a better option for the construction with better performance in the future, in other words, the material shall be more effective than the other. The effectiveness of the material is determined based on their properties; the physical, mechanical, economic, and environmental aspects. The material shall be strong, durable, and economical. The laboratory tests of samples of Red Bricks and AAC Blocks, cost analysis, and review of literature, articles, and journals were done to analyze the effectiveness of the materials The results were checked for size, density, strength, water absorption, cost, and environmental impact. The result showed that AAC Blocks were properly sized with lower density, lower compressive strength, cheaper, faster, and environmentally friendly than red bricks but with higher water absorption capacity. The red brick sizes were non-uniform as well with liable to cause adverse human and environmental hazards. Overall, they both have their suitability on the construction, but due to the uniform sizes, light weight, availability with required compressive strength, and economic and eco-friendly aspects, AAC Block is a better option in use for construction. In the case of a load-bearing structure, the red brick is still suggested.

Keywords: Red Bricks, AAC Blocks, effectiveness, size, density, water absorption, compressive strength, economic, environment friendly.

1. Introduction

The human residence history starts from primitive society living in caves to present reinforced concrete structures and still new structural forms and technological innovations are taking the lead [1]. Over time, the building materials have been changed and developed due to various reasons like natural constraints, available local materials, climatic effects, disaster risks, and cultural diversities, giving new construction techniques and designs [2]. Various materials are available today that can be used for the same purpose in the buildings but their use varies based on the functionality requirement. The right materials choice shall be made by the engineers or designers to meet the product requirements like low weight, higher performance, and cost reduction [3]. The decision in the selection of building construction materials has significant consequences on economic, operational, and environmental aspects as these constitute 50-70 percent of total building construction projects [4].

The selection of material is based on its significance in structural, economic, operational, and environmental aspects. The basic requirements of the building materials are durability, strength, and economy. Various codes and standards are available that specify the physical and mechanical properties of each building material. The physical and mechanical properties of building materials like shape and size, density, water absorption, and compressive strength are mainly taken into account. The economic aspect, from purchase to installation, is another vital aspect. Furthermore, the safety and environmental aspects are also accounted for during the selection of building materials. For a country like Nepal, where there are low economic conditions but rapid urbanization, high-rise constructions but a high risk of earthquake, a more traditional approach in construction, and requirement of the strength of the material, the building material should be strong, and durable, economical, fast, earthquake resilient and environment friendly.

"Bricks are the masonry unit not exceeding 300mm in length, 150mm in width nor 100mm in height" [5]. The common building solid bricks are the burnt clay building bricks that are commonly used in building and civil engineering construction work in which frogs do not exceed 20 percent of this volume [5]. It is composed of clay, silt, and sand. Red clay Brick is one of the oldest and most durable construction materials which was a fundamental building material during the Mesopotamian, Egyptian, and Roman periods. Bricks were used extensively and upgraded during the Roman period. It was used in medieval and even in modern times. It has testified to its strength and durability over a long period. In addition to that, easy availability, cheap, easy handling, and easy manufacturing process, it gained popularity among people [6].

Blocks are defined as masonry units exceeding the size of a brick in any dimension [5]. Autoclaved Cellular (Aerated) Concrete (AAC) Block is a concrete masonry unit that is produced by steam curing in an autoclave machine at a maximum ambient temperature generally between 170 and 215°C [7]. It is composed of cement, aggregate, lime, aluminum powder, additives/admixtures, and water.

AAC Block is a lightweight, load-bearing, high-insulating, durable building product with wide ranges of size and strength [8]. AAC Block has existed as a building material since the beginning of the 20th century. Swede Axel Eriksson discovered the modern AAC Block and its advantages in manufacturing like the rapid hardening of moist concrete foam by autoclaving and having shrinkage almost absent [9].

Both of these materials have a similar function, their use as infill materials, in building construction. This research intends to provide a comparative analysis of the physical and mechanical properties of these materials, their economic impact, and their environmental effects, thus helping the responsible person in the selection of the right material.

2. Previous Works

Various studies have been done regarding the Red Bricks and AAC Blocks, especially related to their physical and mechanical properties, cost expenses, and environmental impact caused by them. The results varied as per the research while the core comparison between the red Bricks and the AAC Blocks shows relatively similar results. The research carried out in Nepal found that the sizes of the red Bricks were mostly undersized [10, 11] as compared to the standard size specified on the NS and IS codes. The densities of the red Bricks were in the range of 1500-2000 kg/m3, which is a little lesser than the standard density in the lower end [10, 11]. The water absorption of red bricks was found up to 20% [11] and less than 12% [10] with impressive compressive strengths ranging from 7.8 to 22 MPa [11]. Similarly, for the AAC Blocks, the exact and uniform size were observed for the samples with the lower densities, 0.4 and 0.6 gm/cc, but higher water absorption of 193% and 114% and lower compressive strength of 1.88 and 2.76 MPa respectively for G2 and G4 grouped AAC Blocks in Turkey[12].

On the aspect of the environmental impact, researchers have found that there is an adverse impact of red Bricks on humans and the environment. Deterioration of air quality, climate change, human health effects, loss of vegetation and soil fertility, deterioration of animal life, and historical monuments. Atmospheric emission of greenhouse gases like CO, CO2, SO2, NOx, particulate matter, Black carbon, volatile organic compounds (VOC), tropospheric ozone (O3), and total organic compounds (TOC) that are generated during brick manufacturing causes serious damage to the health of living beings as well as metallic structures, mostly effects are observed on heritage sites and temples [13]. The emission of harmful chemicals is causing air pollution, fertile soil is exploited and human health is being affected where vision and pulmonary disorders were observed in female workers in Chennai [14]. Air pollution is found to be three times higher near the brick kiln, TSP and PM10 are increased in the air, than in other places which elevates the health cost of people by causing health problems like the gastrointestinal tract, skin-related diseases, respiratory complaints, and genitourinary problems [15]. The production of red bricks promotes global warming and climate change due to the emission of various greenhouse gases which has caused adverse worldwide environmental and health issues [16]. The manufacturing of a good brick consumes around 3 kg of fertile topsoil, which contains nutrients and organic matter that are required for crop growth. To manufacture a good quantity of bricks, a huge amount of topsoil is used resulting in the consumption of a large quantity of fertile cultivable land, and a decline rate of crop yield [17]. It was found that the manufacturing of one square foot carpet area of red brick requires 25.5 kg of topsoil, consumes 8 kg of coals, and emits 12 kg of carbon dioxide gas while the manufacture of the same quantity of AAC Block consumes only 1 kg of coal and emits 1.5 kg of carbon dioxide. Also, it was observed there is a 30 % savings in energy while using AAC Blocks than the red bricks [18].

The comparative evaluation between red bricks and AAC Blocks has been carried out in the past, where the AAC Blocks were found to be light-weighted, being one-third of that of red bricks [16, 19] to almost half of the red bricks [20, 21]. Similarly, the compressive strength of the brick was found to be almost similar [22, 16] or higher than that of AAC Block [19, 20]. The water absorption of the AAC Block was slightly higher than the red Bricks [20, 22, 16].

The construction work with AAC Block is cheaper than the red bricks as the installation is fast and easy [16]. More savings are observed per unit rate due to less use of plaster and mortar during construction. The use of AAC Block reduces 25 percent of steel and 26.54 % of building cost [21]. The study done on residential and public buildings to evaluate cost-effectiveness showed that the minimum cost savings in residential buildings is 14.5% with 42% cost savings in material and 18% in steel. Similarly, in public buildings also, the cost savings were found to be 15% with 46% cost savings in materials. It was concluded that, overall, 20 percent of cost savings can be obtained by using AAC Block in place of red Bricks [23]. The time required for construction of the same area of walls with AAC Block is 3-4 times less than that with red Bricks resulting in 18% of cost savings [24]. There are also around 14-17 % fewer joints in AAC Block wall construction [16] which also supports less failure leading to safety[19]. The low density of AAC Block reduces the dead load of the building which is also a benefit of AAC Block that helps in reducing earthquake load in the building resulting in the safety of the building [16]. Also, the low weight of the building leads to design optimization, reducing sizes of frames, and reducing steel and concrete consumption- ultimately leading to cost optimization.

In this study, the Red Bricks and AAC Blocks samples were taken randomly from the market in Kathmandu district. The physical and mechanical properties of those materials were observed through the lab test reports, which were performed in a renowned testing laboratory in Kathmandu, strictly following the procedure stated in Nepal Standard codes as well as referencing the Indian standard codes. The civil norms for construction works and the district rate of Kathmandu district of the fiscal year 2079/80 were taken for a cost analysis to establish the economic aspect of those materials. The secondary data of previous articles and journals were referred to study the environmental impact of those materials.

3. Methodology

The primary data for this study were collected through the lab reports. The secondary data were observed through the rate analysis of civil work norms and district rates of Kathmandu for Fiscal year 2079/80, various codes specifying the products and their properties, and related journals, articles & previous studies on the AAC Block and red bricks. The Red Bricks and AAC Blocks samples were taken as stated in their respective NS codes. For a lot size of 2001-10000 numbers of red Bricks and lot of 10000 AAC Blocks, Table No. 4, NS-1:2035 and Cl. 10, NS 573-573: 2076 states the sample requirement for the test. For Red Bricks, 20 pcs were taken for a size check, 5 pcs for a Density check, 5 pcs for the Compressive Strength test and 5 pcs for the Water Absorption test. For AAC Blocks, 24 AAC blocks were taken at random, out of which 12 AAC Blocks were tested for compressive strength and 3 AAC blocks for Density, and the size of all AAC Blocks samples were checked. For water absorption, 3 AAC Blocks were taken.

3.1 Size

For checking the sizes, the length, width, and height of the full-size samples were taken. The size check was done for the tolerance limit as well. For red Bricks, the measurements were carried out as per NS 1:2035 (Fig2, 2A, 2B & 2C, Cl. Ka-3) and IS 1077: 1992 (Cl.6.2.1). For AAC Blocks, the measurements were done as per Fig.1, NS 573:2076 and Fig.1, IS 2185(part 3): 1984.

Figure 1: Checking sizes of Red Bricks

3.2 Density

For AAC Block, the dry density is calculated as stated in IS 6441(Part 1):1972 (Cl. 4.1.1, Cl. 4.1.2, and Cl. 5.1). For the red bricks, the same procedure was carried out for density calculation. Density is calculated as D= W/ V kg/m^3.

Figure 2: Weighing of samples for Density Calculation

3.3 Compressive Strength

The compressive strength test of Red brick is carried out as per IS 3495(Part1): 1992. The specimen is prepared and tested as per Cl. 4.1.2, Cl. 4.1.3, and Cl. 4.1.4 of IS 3495 (Part 1): 1992. For AAC Block, the specimen prepared as per Cl.2, Cl.2.1, Cl.2.2, and Cl.2.4 of IS 6441 (Part 5): 1972 and tested as per Cl. 4.2 and Cl.4.2.2 of IS 6441 (Part5): 1972.

3.4 Water Absorption

A 24-hour Immersion Cold Water Test is carried out for the water absorption test of Red Brick as per Cl.4.1, IS 3495(Part2): 1992. Since there is no specific requirement for a water absorption test for the AAC Block in any codes, the same procedure is carried out for the AAC Block.

Figure 3: Compressive Strength Test in Compression Testing Machine (CTM)

Figure 4: Water Absorption Test

3.5 Cost Analysis

For cost analysis, the civil work norms for Red Brick masonry work and AAC Block Masonry work were taken. The rates of materials and manpower were taken from the Kathmandu District Rate of the fiscal year 2079/080. The rate analysis of masonry work using Red Bricks and AAC Blocks was done for different thicknesses of the wall, i.e., 4"/6"/8" for AAC Blocks and 4"/9" for Red Brick masonry.

3.6 Environment Friendly

For the environment-friendly aspect of Red Bricks and AAC Blocks, various journals and previously published research and articles were studied and a review was done based on those.

4. Results and Discussion

4.1 Physical and Mechanical Aspects

4.1.1 Size

The average size of Red Bricks samples was observed 223x103x53mm. which was smaller than the standard size of red Brick, i.e. 240x115x57mm. Every sample of red Bricks taken was found undersized and not within the tolerance limit. Whereas, the average size of AAC Block samples was observed 600x200x150mm as required. The uniformity in shape and size was observed with no tolerance limit issue. The volumetric comparision of the average sample size of red brick and AAC Block can be observed in Figure 5, where, the AAC Block was 15 times larger than the red Brick.

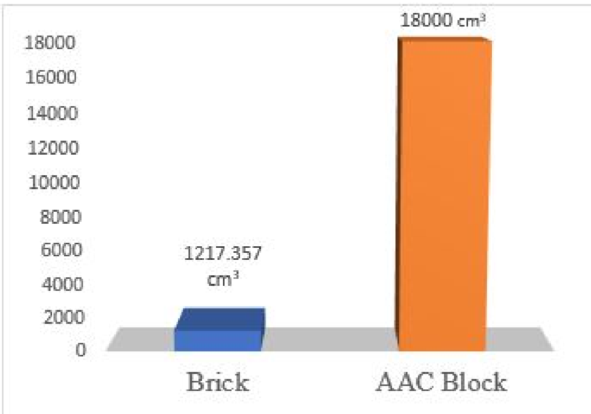

Figure 5: Average size(Volume) of samples taken of Red Brick and AAC Block (cm^3)

Due to this larger size, a larger area could be covered faster and the uniformity in Block size will make the work smooth and easier. Also, there will be fewer mortar joints, which would help in the reduction in mortar quantity. Ultimately, the work can be done fast and with ease with the AAC Block.

4.1.2 Density

The average density of red Brick was 1865.75 kg/m^3 and the average density of AAC Block was 602.80 kg/m^3. Both were within the specified range of 1600-1900 kg/m^3 and 550-650 kg/m^3 respectively. The density of an AAC Block is found to be 3 times lighter than that of Red Bricks. This certainly means that the AAC Block is much lighter than the red Brick. The use of AAC Blocks in place of red bricks will help in the reduction of dead weight on the structure. The lighter the structure, the lesser the vulnerability to the earthquake impact as the earthquake force is directly influenced by the mass of the structure.

4.1.3 Water Absorption

The limit for water absorption for red brick is 25 percent by weight. There is no provision for water

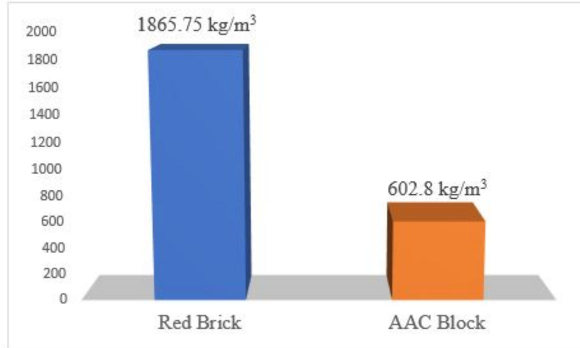

Figure 6: Average density of Red Bricks and AAC Blocks of samples taken (kg/m^3)

absorption for AAC Blocks, but due to its porous nature, it has the capacity of holding more water. The average water absorption percentage of Red Bricks samples was 16.07 percent by weight and the average water absorption percentage of AAC Block was 35.33 percent by weight. The water absorption capacity of AAC Block is 2 times more than that of red Brick. Though the water absorption is found to be high, with minor precautions, the water absorption issue of the AAC Block can be resolved by using plaster on the surface of the wall or using waterproofing chemicals. For the areas with less or no rainfall, no precautions need to be taken.

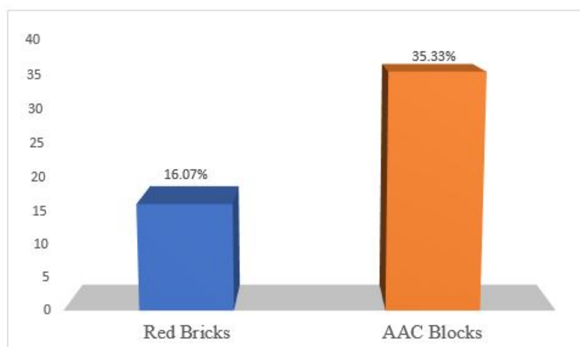

Figure 7: Average Water Absorption of Red Brick and AAC Block samples taken (% by weight)

4.1.4 Compressive Strength

The average compressive strength of Red Bricks was 6.40 MPa and the average compressive strength of AAC Block samples was 4.16 MPa. Comparing the strength of the AAC Block and Red bricks, the red brick has higher compressive strength than the AAC Block. The higher compressive strength of red brick is suitable for the load-bearing structures while the AAC Block, in

Nepal, is limited for use in non-load-bearing structures only. However, the AAC Block has strength more than the minimum required strength stated in the standard for AAC Block NS-573-2076 (min. 3MPa) and NBC 205:2012 (min. 3.5MPa).

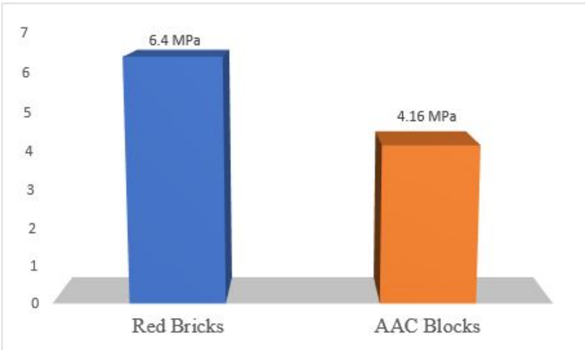

Figure 8: Average Compressive Strength of Red Brick and AAC Block samples (MPa)

4.2 Economic Aspect

After the cost analysis using civil work norms for Red Bricks and AAC Blocks, and the Kathmandu District Rates, the average cost for construction of the same masonry unit using AAC Blocks is 12 percent economical than by using Red Bricks.

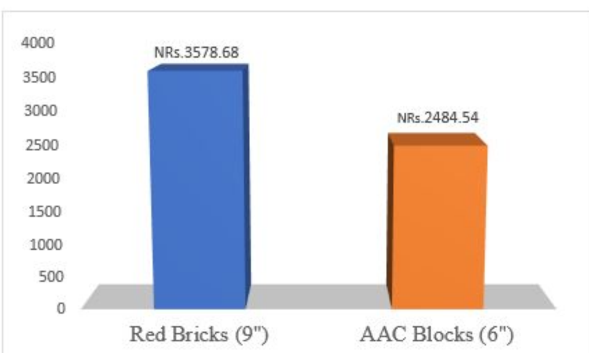

Figure 9: Cost Comparison per square meter construction of Red Brick and AAC Block (in NRs.)

4.3 Environment Friendly Aspect

Upon the study of the environmental impact of Red Bricks and AAC Blocks, red Bricks are found to be adversely affecting the environment than the AAC Blocks. The table 1 shows the environmental impact of Red bricks and AAC Blocks:

Table 1: Comparison of Environmental Impact of Red Bricks and AAC Blocks

Comparison	Red Bricks	AAC Blocks
Raw Material	Utilizes the topsoil-suitable for cultivation	Utilizes inorganic components like cement, Aluminum, Sand, etc
Manufacturing Process	Burning of coal, wood	Steam Circulation
Emission of Gases	Emission of greenhouse Gases	No or very little amount of CO_2 Gases
Environmental Impact	Less Fertile land, Declined crop-yield rate, Global Warming, Climate Change	No soil, and water pollution, less air pollution
Human Health Impact	Eyes, Lungs, Skin, Respiratory, gastrointestinal, and genitourinary-related diseases	No such effect was recorded.

5. Conclusions and Recommendations

5.1 Conclusions

The following conclusions were made out of the results obtained:

i) The sizes of the AAC Blocks were found uniform while the sizes of Red Bricks were mostly undersized. The average size of the AAC Block was found to be 15 times larger than the average size of Red brick. Large area coverage in less time can be obtained using AAC Block and due to fewer joints, the quantity of mortar will be used less. This will save time, labor cost, and material costs.

ii) The average density of AAC Block was found to be one-third of the average density of Red Brick. The AAC Block can be considered a lightweight building construction material. Reduction in the dead weight of building- design optimization- also earthquake-resilient building construction.

iii) The water absorption of AAC Block is higher compared to that of Red Bricks due to its porous nature. The AAC Block can hold more water and may affect it in the long term, but this issue can be resolved by taking minor precautions like coating it with cement plaster or waterproofing chemicals.

iv) The Compressive Strength of the Red Brick is higher than that of the AAC Block. The Red Bricks falls on class 60 while the AAC Block also possesses the strength over the minimum requirement stated in the NS code (min 3 MPa).

v) The cost of one square meter of masonry wall construction with AAC Block is cheaper than that with Red Brick by 1.5 times which makes it economical to work with.

vi) The overall impact from raw material consumption, manufacturing processes, and production, the AAC Block is found environment friendly while the Red Brick is impacted by global warming, climate changes, air pollution, adverse human health effects, production loss, and good quality soil loss

5.2 Recommendations

i) The AAC Block has proven to be more effective than the red Bricks regarding Physical, mechanical, economic, and environmental aspects. Though with some solvable issues, the AAC Block can be used in residential, commercial, high-rise, or industrial buildings.

ii) With a minor flaw- water absorption, which can be eradicated easily at a low cost, the AAC Block is observed to be effective in its size, density, strength, cost, and environment friendliness. The time-saving, cost optimization, earthquake resiliency, and environment-friendly aspects of AAC Block are the great factors in choosing AAC Block over Red Bricks.

iii) Though the construction practice in Nepal is framed-structured nowadays, where AAC Block and Red Bricks both can be used as infill material, for the sole load-bearing construction purpose, red Brick is suggested. However, there is a technical limitation in the construction.

Acknowledgments

The author would like to express my sincere thanks and appreciation to the supervisor, Dr. Pradeep Pokhrel, for his invaluable advice, guidance, and encouragement throughout the period of this research. Also, the author is very much thankful to VISWA Consult for support in conducting the various laboratory tests of the materials for this research.

References

[1] J. Wu, H. Wei, and L. Peng, "Research on the evolution of building technology based on regional revitalization," *Buildings*, vol. 9, no. 7, p. 165, 2019.

[2] M. Vatan, "Evolution of construction systems: Cultural effects on traditional structures and their reflection on modern building construction," in *Cultural influences on architecture*. IGI Global, 2017, pp. 35–57.

[3] M. Babanli, F. Prima, P. Vermaut, L. Demchenko, A. Titenko, S. Huseynov, R. Hajiyev, and V. Huseynov, "Material selection methods: A review," in *13th International Conference on Theory and Application of Fuzzy Systems and Soft ComputingICAFS-2018 13*. Springer, 2019, pp. 929–936.

[4] S. Mattar and P. Manning, "Research in building materials," *Architectural Science Review*, vol. 18, no. 1, pp. 2–9, 1975.

[5] *IS 2248-1992 Glossary of terms relating to clay products for Buildings*, Std.

[6] F. M. Fernandes, P. B. Lourenço, and F. Castro, "Ancient clay bricks: manufacture and properties," in *Materials, technologies and practice in historic heritage structures*. Springer, 2010, pp. 29–48.

[7] *IS 2185-1984 (Part3): Autoclaved Cellular (Aerated) Concrete Blocks*, Std.

[8] R. Janani and K. Pradeep Kumar, "ijamtes.org," https://ijamtes.org/gallery/620-dec.pdf, 2018.

[9] W. V. Boggelen, https://www.arataumodular.com/app/wp-content/uploads/2022/08/History-Of-Autoclaved-Aerated-Concrete-The-\Short-Story-Of-a-Long-Lasting-Building-Material.pdf, 2014.

[10] S. K. Subedi, "Study of characteristics of bricks produced in kathmandu, nepal," *American Journal of Civil Engineering*, vol. 8, no. 3, pp. 64–76, 2020.

[11] S. Shrestha, "A case study of brick properties manufacture in bhaktapur," 2019.

[12] S. Andolsun, "A study on material properties of autoclaved aerated concrete (aac) and its complementary wall elements: their compatibility in comtemporary and historical wall sections," Master's thesis, Middle East Technical University, 2006.

[13] T. E. Aniyikaiye, J. N. Edokpayi, J. O. Odiyo, and S. J. Piketh, "Traditional brick making, environmental and socio-economic impacts: A case study of vhembe district, south africa," *Sustainability*, vol. 13, no. 19, p. 10659, 2021.

[14] P. Misra, R. Imasu, S. Hayashida, A. A. Arbain, R. Avtar, and W. Takeuchi, "Mapping brick kilns to support environmental impact studies around delhi using sentinel-2," *ISPRS International Journal of Geo-Information*, vol. 9, no. 9, p. 544, 2020.

[15] U. M. Manandhar and S. B. Dangol, "Study on evaluating energy conservation potential of brick production in saarc countries," *Kathmandu,*

Nepal: Min Energy Initiatives, Nepal and SAARC Energy Center, Islamabad, 2013.
[16] A. Thakur, A. K. Tiwary *et al.*, “A comparative study on conventional clay bricks and autoclaved aerated concrete blocks,” in *IOP Conference Series: Earth and Environmental Science*, vol. 889, no. 1. IOP Publishing, 2021, p. 012061.
[17] M. Hossain, A. Zahid, M. Arifunnahar, and M. Siddique, “Effect of brick kiln on arable land degradation, environmental pollution and consequences on livelihood of bangladesh,” *Journal of Science, Technology and Environment Informatics*, vol. 6, no. 02, pp. 474–488, 2019.
[18] P. Khandve and S. Rathi, “Aac block- a new eco-friendly material for construction,” vol. 2, pp. 410–414, 05 2015.
[19] P. Gautam and N. Saxena, “Comparison of autoclaved aerated concrete blocks with red bricks,” *International Journal of Engineering Research & Technology (IJERT)*, vol. 2, no. 10, pp. 2278–0181, 2013.
[20] M. Ima and I. Duwadi, “Comparative study on autoclaved aerated concrete block and conventional burnt clay brick,” 09 2019.
[21] A. A. Khan, M. Pradesh, and S. Shrivastava, “A review on cost analysis of building construction by using autoclaved aerated concrete block (aac), fly ash brick and clay brick as masonry component,” 2018.
[22] E. D. Khanal, A. P. D. A. K. Mishra, B. Ghimire *et al.*, “Technical suitability assessment of autoclaved aerated concrete block as alternative building wall construction material; a case of nepal,” *Saudi Journal of Civil Engineering*, vol. 4, no. 5, pp. 55–67, 2020.
[23] O. Rathi and P. Khandve, “Cost effectiveness of using aac blocks for building construction in residential building and public buildings,” *International Journal of Research in Engineering and Technology*, vol. 5, no. 05, pp. 517–520, 2016.
[24] A. K. Mishra and P. Aithal, “Socio-economic suitability of aac block in nepal,” *Solid State Technology*, vol. 64, no. 2, pp. 575–595, 2021.