A Critical Study to Assess the Hurdles in Adoption of Sustainable Walling Materials in Construction Industry

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Abstract: There is a considerable need for the alternative or eco-friendly walling materials. In the present study an attempt is made to explore the alternative to the conventional walling materials. New walling materials like Hollow concrete blocks, aerated autoclaved concrete (AAC) blocks, rapid wall panels etc. were studied. A structure questionaries'-based study was conducted to assess the hurdles for adoption of these materials. At present, CLC blocks, AAC blocks and Rapid wall Panels are generally preferred in the construction industry and the use of red clay brick is reduced. Around 60% of the respondents are willing to change their current walling material if got a chance. So, it can be concluded that these new walling materials can be explored as a sustainable walling material.

1. Background

Due to the rapid growth of urbanisation, development is also progressing at a fast pace while also facing the lack of energy source in the world. Increase in the housing demand ultimately results in demand of walling material. Environmental pollution from the conventional method and technologies has become harmful to mankind, animals and plant life health. So, there is a need of the use of modern technology materials that can satisfy the need as well as other selling points include low life cycle costs, energy efficiency, higher resistance to fire, high acoustic efficiency and conservation of natural resources. In future, the construction industry will depend on sustainable development with the use of sustainable walling materials which are of good quality and eco-friendly.

2. Review of Literature

Awana and Kumar [1] performed an investigation in density and compressive strength of cellular lightweight concrete (CLWC) blocks using fly ash bricks. Their research has found that the lightweight concrete has an appropriate strength for the industrialised building system to be a substitute construction material. Baker Gregory (2002) [2] has researched how the extended polystyrene isolated panel combustible core Complies in the case of exposure of high temperature to a radiant heat source. It tracked the behaviour of the isolated panel’s extended polystyrene heart. The author concluded in the first place that while the extended polystyrene core of specimens was ignited by higher flue temperatures, the combustion spread through the core was not seen. Chen et al. [3] investigated the static and dynamic mechanical characteristics of extended polystyrene (EPS). Static and dynamic compressive and tensile test results measure the EPS density of 13.5 kg/m³ and 28 kg/m³ at various strains. The authors acquired dynamic power, young module, and the ability to absorb energy from the two EPS foams at different stress rates. Any analytical associations are derived from
the test results. The data obtained above can be used to model EPS properties in numerical simulations of structural isolated panels with EPS moisture core subject to impacts and exposure loads. Mohammad Arif Kamal [4] studied various properties of Autoclaved Aerated Concrete (AAC) blocks and compared it with Cellular Lightweight Concrete (CLC) and clay blocks on the basis of insulation, strength, density, construction time, energy saving and durability. The author then quoted various advantages and disadvantages of AAC blocks and concluded that was used in different part of the world because of its relatively low consumption of readily available raw materials, durability and energy efficiency. Rohit Raj et al. [5] carried out an expanding Polystyrene sheet prospects analysis as Sustainable Construction Material in order to evaluate the various building methodologies and technologies used in the country to reduce cost, reduce Carbon emissions and to provide indoor comfort and less energy needs. There is a collection of different aspects of EPS in the reinforced concrete with a view to its potential development and construction in order to make it efficient in terms of resources. This contributes in a safe and economical structure for EPS embedded systems. Singh and Sharma [6] used waste material from thermal power plant. Geopolymer bricks, main ingredients of brick were totally replaced by the waste coming out from Thermal power plant, waste of burnt coal known fly ash, waste coming from metal casting industry foundry sand. The study was carried out on (230×110×75) mm size of geopolymer brick with 100% replacement cement in geopolymer concrete bricks using fly ash, waste foundry sand and mineral material. Somiah et al [7] investigated the causes of illegal siting of buildings in Asakae and suggests steps to curb them. They also suggested that the people should be given daily public education on land-use planning and the building regulations of Ghana. Rapid Wall Panel analysis as an effective building material was conducted by Suhas Tayade et al [8], they have discussed how the housing unit’s shortage in India by 90 million was needed in 2015 to grow sustainably. Structural conduct of the rapid wall plate was studied and complex then ordinary bricks were discovered. Finally, they have come to the conclusion that the fast wall panel is cost efficient, eco-friendly and provide rapid construction. Thorat et.al [9], based on analysis in these case studies, explored different aspects related to use of HCB. Hollow Concrete Bloocs (HCBs) were used for beam construction, walls and so on. The authors concluded that if properly engineered the HCBs then they are the prime material for today's buildings to achieve dimensional precision and high quality of finishing and cost competition with other materials.

2.1 Cellular Lightweight Concrete Blocks

Figure 1 shows a Cellular Light Weight blocks (CLC, is a light weight concrete version which is manufactured in atmospheric conditions like regular concrete. CLC Blocks are cement materials formed by mixing cement slurry. In order to minimise environmental emissions and global warming CLC block can be used as an alternative to traditional bricks.

Figure 1. Cellular Lightweight Concrete Block

2.1.1 Advantages of Cellular Lightweight Concrete

- Optimum thermal insulation
- Substantial weight reduction (dead-load)
- Highly increased fire rating
• Maximum sound absorption (no echoes in empty rooms and halls).
• Fastest progress in construction

2.1.2 Disadvantage of Blocks
• The disadvantage of Block is not insulated for northern climates because the frame wall is not being insulated. Therefore, the cold air from the outside will transfer into the house.

2.2 Autoclaved Aerated Concrete (AAC) Blocks
The AAC is an environmentally friendly, certified green building material. AAC is pore-rich, non-destroying, reusable and recyclable as shown in Figure 2. Autoclaved aerated concrete is classified as an aircrete, light, load-bearing, high-intensity, durable body-product developed in a wide variety of dimensions and strengths. AAC offers fantastic opportunities to improve construction performance and simultaneously reduce building costs.

![Figure 2. Autoclaved Aerated Concrete (AAC) Blocks](image)

2.2.1 Density
• The AAC density for standard concrete is between 250 and 1800 kg/m3, compared with 2400 and 2,600 kg/m3.
• Therefore, there are definitely substantial savings for the use of reinforcement steel.

2.2.2 Compressive strength
• An average compressive strength of 2.86 MPa has been achieved on 650 kg/cum density AAC cubes following 28 days of the standard water-curing.
• A compressive strength of more than 20 MPa is obtainable with the addition of silica fumes, polypropylene fibres and steel mesh reinforcements, for special applications in which more compressive strength is required. Since blocks made from AAC are 1/3 to ½ the weight of normal concrete blocks.

2.3 Hollow concrete blocks
Another type of material is available in the market and is considered for the present study and shown in Figure 3. Hollow blocks are defined as those blocks which have core void area greater than 25% of gross area having one or more holes open at both sides.
2.3.1 Advantages

- Rapid Execution of Work: Hollow concrete block are of uniform and regular size and it has less weight.
- Increase in Floor Area: It is possible to construct thin walls using hollow blocks.
- Reduces Construction Cost: Hollow block helps in saving construction materials and therefore use of hollow block reduces construction cost. Better Insulation Properties: Hollow concrete block have good insulating properties against sound, heat and dampness.
- More Durable: Hollow concrete block masonry can safely withstand the atmospheric action and it requires no protective covering.

Table 1. Comparative Analysis of Clay Bricks, AAC blocks, CLC Blocks.

| Properties                  | Red Bricks                                                                 | CLC Blocks                                    | AAC Blocks                                    |
|-----------------------------|---------------------------------------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Dimensions                  | 190mm x 90mm x 90mm                                                      | 600mm x 200mm x 100-300mm                    | 600mm x 200mm x 100-300mm                    |
| Deviations in size          | 5 mm (+/-)                                                               | 3 mm (+/-)                                   | 1.5 mm (+/-)                                  |
| Compressive Strength        | 2.5 - 3.5 MPa                                                            | 2.0 – 2.5 MPa                                | 3.0 – 4.0 MPa                                 |
| Dry Density                 | 1950 kg/m³                                                               | 800 - 1000 kg/m³                             | 550 - 650 kg/m³                              |
| Fire Resistance             | 2 hours                                                                  | 2 hours                                      | Up to 6 hrs for 200 mm thickness              |
| Reduction of sound (DB)     | 50 for 230 mm thick wall                                                | 50 for 200 mm thick wall                     | 45 for 200 mm thick wall                      |
| Heat conductivity           | Approx. 0.81                                                             | Approx. 0.70                                 | Approx. 0.16 – 0.25                           |
| Mortar Consumption          | 0.1 per m³ with 1:6 / 1.35 bag of cement                                 | 0.025 per m³ with 1:6/ 0.5 Bag of cement     | 0.018 per m³ with 1:6/ 0.5 kg Bag of Cement   |
| Energy Saving               | No saving                                                                | Upto 20% reduction in energy                 | 32% approx. Air Condition Load for heating and cooling will be reduced |
| Cost Benefit Factor         | Not changes substantially                                               | Less than AAC blocks                         | Dead Load Reduce Structural Cost              |
| Carpet area                 | No considerable effect                                                   | No change                                    | About 2 - 3 %                                 |
| Specific Gravity            | 2.4                                                                      | 0.6 - 0.65                                   | 0.6 - 0.65                                   |

Table 1 shows a comparative analysis of the properties of the materials and its site suitability, adoptability and buildability. This will help the stakeholders to analyse the criteria for selection of a material.
2.4 Rapid Wall Panel

2.4.1 Physical and material properties:
Fastwall panels are the largest lightweight load bearing panels in the world. The panels are constructed from a length of 12 m, 3 m and 124 mm. The modular cavities of each panel are 48 cavities 230 x 94 mm x 3 m. One panel weighs 1440 kg or 40 kg/m². This density is 1.14g/cm³; the weight of comparable concrete/brick masonry only amounts to 10-12 percent. The physical and material properties of panels are as follows:

![Rapid wall Panel](image)

**Figure 4. Rapid wall Panel**

- Weight- lightweight 40 Kg/m²
- Axial load capacity 160 kN/m
- Compressive strength 73.2 Kg/cm²
- Unit Shear strength 50.90 kN/m
- Flexural strength 21.25 kg/cm²
- Tensile Strength 35 kN/ m
- Ductility 4
- Fire resistance 4 hr rating withstood 700-1000 °C
- Thermal Resistance R 0.36 K/W
- “U” Value 2.85 W/m²K

2.5 Geopolymer blocks

![Geopolymer Brick](image)

**Figure 5. Geopolymer Brick**

The term Geopolymer came from the reaction taking place between the alkaline liquid and the pozzolonic materials such as fly ash, GGBFS etc. The reaction is a very fast poly condensation reaction and this process is known as polymerization process.
2.6 Expanded Polystyrene (EPS)

Monomers (EPS) expansion by polymerization process known as expanded polystyrene (EPS) from 0.5 to 1.5 mm diameter to 40 to 50 times their initial size. Expanded polystyrene (EPS) as the most common polymer foam is commonly used as a centre of insulation for structural isolation panels. EPS is a rigid and tough, recyclable cell-closure material used for a wide range of applications including impact prevention packaging, safety helmet, structural crash toughness, road embankments, insulation-filled concrete frameworks, and lightweight EPS spumed concrete. EPS is used for building material filling the road embankment.

3. Objective of the Study
This paper aims to seek the different factors of modern walling materials which are not used up to their full potential.

- To study modern walling material.
- To determine the current acceptability of modern walling materials using a questionnaire survey.
- To analyse the result obtained from questionnaire survey and our suggestions according to the study for this thesis.

4. Research Methodologies

4.1 Questionnaire The questionnaire is divided into two parts. First part includes details to get the information of respondents and its organisation. Second part includes the questionnaire to know about the awareness of the selected modern walling materials, important characteristic factors, factors which prevent use of the modern walling materials and current walling materials being used. In second part, seven questions were formed this questionnaire is based on Likert’s scale of five ordinal scales from 1 to 5 (the least important – the most important).

4.2 Likert’s Scale
A psychometric response scale used for participant expectations or compliance with a statement or series of statements in questionnaires. Likert scales are a non-compare technique of scaling and are of a unidimensional type (only measure one feature). The respondent is asked by ordinal statement to
show their degree of consent to a particular statement. Most commonly seen as a 5-point scale ranging from “Strongly Disagree” on one end and “Strongly Agree” on other with “Neither Agree or Disagree” in the middle. Likert Scale used: 1 - Strongly Disagree / Least Important 2 - Disagree / Little Importance 3 - Neutral / Neither Important 4 - Agree / Important 5 - Strongly Agree / Most Important

4.3 Relative Importance Index

A questionnaire survey was conducted and primary data was collected with the aid of questionnaire. The methodology used in this study will help to rank the variables and so relative importance index was used to analyse the data. In our survey, many variables were identified which will influence the adoption of modern walling materials, based on a five-point scale where: 1- the least important to 5- the most important. Each variable will be transformed to relative importance index (RII) as follows:

\[
RII = \frac{\sum W}{A \times N}
\]

Where, \( W \) is the weights given to each variable by the respondents (ranging 1 to 5).

\( A \) is the highest weight (i.e. 5 in this case).

\( N \) is the total number of respondents. Therefore, all the scores obtained for adoption of modern walling materials were converted to relative importance indices to determine the relative ranking of the variables.

5. Data Analysis and Interpretation

Nature of your organisation of respondents. Through this we have done categorisation of various types of respondents based on their nature of respective organisation. This has helped us to know the view of different types of people of different sectors in the construction industry. The results have been presented in the following Table 2.

| Type       | Responses |
|------------|-----------|
| Client     | 18        |
| Contractor | 14        |
| Consultant | 13        |
| Institutions | 10    |
| Students   | 2         |

a) Do you feel there should be alternative to red clay brick (Where: 1- Strongly Disagree; 5- Strongly Agree)

The results of the question are represented in the following Table 3. From the result it is clear that respondents are willing to have an alternative to red clay bricks.

| Rating | No. of respondents | Percentage (%) |
|--------|--------------------|----------------|
| 1      | 2                  | 3.51           |
| 2      | 2                  | 3.51           |
| 3      | 11                 | 19.30          |
| 4      | 23                 | 40.35          |
| 5      | 19                 | 33.33          |
| RII    | 0.7929             |

b) Are you aware of the products? This aim of the question was to identify the awareness of the modern walling materials which we have selected. This helped us to know whether the modern walling materials are known by the respondents. The results are given in below Table 4.
Table 4. Awareness of different materials

| Material                                      | Count | Percentage |
|----------------------------------------------|-------|------------|
| Cellular light weight concrete (CLC) blocks   | 39    | 68.42      |
| Autoclaved aerated concrete (AAC) blocks      | 50    | 87.72      |
| Hollow blocks                                 | 54    | 94.74      |
| Geopolymer bricks                            | 31    | 54.39      |
| Rapid walls panels                           | 45    | 78.95      |
| Expanded Polystyrene (EPS) material [Thermocol Type] | 20    | 35.09      |

Table 5. Rating of various Properties

| Property/ Rating                          | 1 | 2 | 3 | 4 | 5 | Score | Priority | RII | Std. Dev. |
|-------------------------------------------|---|---|---|---|---|-------|----------|-----|-----------|
| High Strength                             | 6 | 4 | 17| 6 | 24| 209   | 12      | 0.733| 8.71      |
| Energy Efficiency                         | 3 | 2 | 21| 11| 20| 214   | 10      | 0.751| 9.02      |
| Quick Installation                        | 2 | 3 | 8 | 16| 28| 236   | 1       | 0.828| 10.81     |
| Light weight                              | 3 | 2 | 13| 19| 20| 222   | 6       | 0.779| 8.56      |
| Eco Friendly                              | 3 | 2 | 12| 14| 26| 229   | 5       | 0.804| 9.74      |
| Aesthetic Value                           | 3 | 7 | 18| 12| 17| 204   | 13      | 0.716| 6.43      |
| Fire Resistance                           | 1 | 5 | 17| 11| 23| 221   | 7       | 0.775| 8.88      |
| Sound Absorption                          | 2 | 3 | 20| 12| 20| 216   | 9       | 0.758| 8.76      |
| Termite Resistance                        | 1 | 4 | 22| 9 | 21| 216   | 9       | 0.758| 9.66      |
| Weather Resistance                        | 1 | 4 | 11| 16| 25| 231   | 4       | 0.811| 9.61      |
| Thermal Conductivity                      | 5 | 6 | 17| 13| 16| 200   | 14      | 0.702| 5.59      |
| Cost Effective                            | 3 | 1 | 14| 10| 29| 232   | 3       | 0.814| 11.15     |
| Reduced waiting time for material testing & approval | 2 | 5 | 18| 14| 18| 212   | 11      | 0.744| 7.47      |
| Improved waste Management and Environmental Performance | 4 | 3 | 15| 13| 22| 217   | 8       | 0.761| 7.96      |
| Increased Site Productivity                | 2 | 3 | 12| 11| 29| 233   | 2       | 0.818| 10.83     |

c) Rate the following characteristics which you would prefer in modern walling materials. (i.e. 1 – the least important, 5 – the most important)

This question was intended to find the desirable characteristics which are most preferred in the walling material. This was done by finding the importance of each characteristic by the respondents. Values of 1 to 5 were given to each characteristic (1 – the least important, 5- the most important). An option for specifying other characteristics and rating them accordingly were given to the respondents, in order to understand more desirable characteristics by respondents. Relative Importance Index method was adopted and the results are shown in the following Table 5.

Rank wise preference of characteristics of walling materials is shown in Table 6 below.
Table 6. Ranking Priority wise

| Rank | Property                                      |
|------|-----------------------------------------------|
| 1    | Quick Installation                            |
| 2    | Increased Site Productivity                   |
| 3    | Cost Effective                                |
| 4    | Weather Resistance                            |
| 5    | Eco Friendly                                  |
| 6    | Light weight                                  |
| 7    | Fire Resistance                               |
| 8    | Improved waste Management and Environmental Performance |
| 9    | Sound Absorption                              |
| 10   | Termite Resistance                            |
| 11   | Energy Efficiency                             |
| 12   | Reduced waiting time for material testing & approval |
| 13   | High Strength                                 |
| 14   | Aesthetic Value                               |
| 15   | Thermal Conductivity                          |

Factors that impose limitations on use of Modern Non-conventional walling materials. (i.e. 1 – the least important, 5 – the most important) This was done by finding the importance of each factor by the respondents. Values of 1 to 5 were given to each factor (1 – the least important, 5- the most important). Relative Importance Index method was adopted and the results are given in the following Table 7. From this we opine that, less capacity building in manufacturing is a hindrance in selection of materials.

Table 7. Rating of disadvantages

| Disadvantages                                      | 1 | 2 | 3 | 4 | 5 | Score | Priority | RII  | Std Dev |
|---------------------------------------------------|---|---|---|---|---|-------|---------|------|---------|
| Lack of codes/Standards available                 | 4 | 4 | 20| 13| 16| 204   | 3       | 0.7158| 7.19722 |
| Early Design Freeze, due to long lead time for manufacturing | 5 | 9 | 23| 9 | 11| 183   | 6       | 0.6421| 6.84105 |
| Inflexible/ not suitable for late design changes  | 3 | 8 | 15| 17| 14| 202   | 4       | 0.7088| 5.77062 |
| Inadequate co-ordination: Procurement, supply chain, site management | 6 | 8 | 15| 16| 12| 191   | 5       | 0.6702| 4.3359  |
| Lack of experience: Manufacturers, Clients, Contractors. | 3 | 9 | 10| 12| 23| 214   | 1       | 0.7509| 7.30068 |
| Low confidence level/ Distrust                    | 4 | 8 | 12| 16| 17| 205   | 2       | 0.7193| 5.45894 |


Ranking of factors that impose limitation of walling materials is shown in Table 8 below.

**Table 8. Ranking of factors**

| Rank | Factor                                                                 |
|------|------------------------------------------------------------------------|
| 1    | Lack of experience: Manufacturers, Clients, Contractors.                |
| 2    | Low confidence level/ Distrust                                         |
| 3    | Lack of codes/Standards available                                      |
| 4    | Inflexible/ not suitable for late design changes                        |
| 5    | Inadequate co-ordination: Procurement, supply chain, site management   |
| 6    | Early Design Freeze, due to long lead time for manufacturing           |

What type of walling material do you generally prefer? [Currently Use]
In this question we have tried to find out the different walling materials that are being preferred in the construction industry at present are presented in Table 9.

**Table 9. Walling material preference by respondents**

| Walling Material                                                                 | Count | Count Percentage |
|---------------------------------------------------------------------------------|-------|-----------------|
| a) Cellular light weight concrete (CLC) blocks                                   | 23    | 19.01           |
| b) Autoclaved aerated concrete (AAC) blocks                                       | 40    | 33.06           |
| c) Hollow blocks                                                                 | 20    | 16.53           |
| d) Geopolymer bricks                                                            | 5     | 4.13            |
| e) Rapid walls panels                                                           | 23    | 19.01           |
| f) Expanded Polystyrene (EPS) material [Thermopolis Type]                        | 4     | 3.31            |
| Other-As per my project work based on wall panels made of e-waste and corn con replaced partially to courses aggregates. | 1     | 0.83            |
| Clay brick                                                                       | 3     | 2.48            |
| Red brick                                                                        | 1     | 0.83            |
| High density resin panel                                                         | 1     | 0.83            |

6. Conclusion
The aim of this study was to find out different factors of modern walling materials which are hindering their adoption in construction industry and rank them in order by using Relative Importance Index (RII). The conclusion from the present study is as listed below:

- As RII is 0.7926 and more than 70% of respondents from Table 3, agrees for an alternative. So we can clearly say that there is need for an alternative to red clay brick.
- Around 90% of the respondents are aware of AAC blocks, hollow blocks and rapid wall panel. Around 65% of respondents are aware of cellular clay brick and Geopolymer brick. Around 35% of respondents know EPS material.
- The desired property which we get from respondents are:
  - Quick installation
  - Increased Site Productivity
  - Cost effectiveness
  - Weather Resistance
  - Eco friendly
- The Limitations of these walling materials are:
  - Lack of experience: Manufacturers, contractors, clients.
  - Low confidence level / Distrust
Lack of codes / Standard available

- At present, CLC blocks, AAC blocks and Rapid wall Panels are generally preferred in the construction industry and the use of red clay brick is reduced.
- Around 60% of the respondents are willing to change their current walling material if got a chance.

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