Low-Cost Architecture and Associated Benefits: Thermal Comfort and Cost

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***Abstract* - Low cost architecture is viewed and assumed as inferior by a large section of society. Its benefits in terms of cost and thermal comfort are usually ignored. Low cost architecture involves optimising various factors such as resources, technology, materials and energy without compromising with the quality of the final product established according to certain benchmarks. Factors such as safety, durability and stability are kept in mind while designing a low cost building. This paper attempts to give a review of low cost architecture techniques being used and their associated benefits which include cost reduction and increase in thermal comfort. A building prototype made using low cost construction techniques has been compared with a benchmark building and then a detailed study has been done on its associated benefits: cost, heat gains, discomfort hours etc. The building is considered to be naturally ventilated. The results depicted that low-cost architecture is beneficial both in terms of cost and thermal comfort.**

***Index Terms* - low-cost architecture, construction techniques, energy consumption, thermal comfort, cost reduction.**

1.INTRODUCTION

Infrastructure is an essential and deciding factor for the growth of a country. Currently, India is one of the fastest developing country in the world. Therefore, it needs to have quality infrastructure keeping in mind the economy involved. Condition of existing infrastructure in most of the Indian cities is poor. Interventions are needed to provide quality infrastructure keeping in mind the money involved. Employing low cost construction techniques and materials can help us address this issue.

In India, construction cost is increasing around 50 percent over the average inflation levels. Every year there is an increase of 15%. This increase is primarily associated with increase in cost of material and labour (Suresh, 1996). Due to these factors construction is becoming unaffordable for lower income groups. Therefore, there is a need to adopt low cost construction materials and techniques which are affordable and energy efficient.

Researchers through case studies and experiments have established that we can save 26.11% of the cost using traditional walling methods and 22.68% of the cost using traditional roofing methods (Tam, 2011).

Due to land shortage, high rise structures have come into picture. They make extensive use of materials like steel and cement. These materials contribute to global warming and also they have high embodied energy (Srivastava & Kumar, 2018). So low cost architecture and its associated energy efficiency has become an issue of major concern. We need to look for sustainable low cost energy efficient technologies to be employed in construction.

Various institutions in India are working towards the same such as Building Materials and Technology Promotion Council (BMTPC) (Ministry of Housing and Urban Affairs, Government of India, 1990), Central Building Research Institute (CBRI) (CSIR - Central Building Research Institute, 2020) etc. They are majorly discussing and experimenting with usage and economics of such materials and techniques. They are working on creating provisions for the same in building codes, developing suitable technology and facilities for manufacturing (Srivastava & Kumar, 2018).

2. LOW COST ARCHITECTURE

Architecture which is affordable by a large section of the society particularly lower income groups can be referred to as low cost architecture. It depends on following parameters: income level of individual, size of the building, and affordability (Matsagar, 2015). Usage and choice of construction techniques and materials decides the affordability (Puri, Chakrabortty, & Majumda, 2015) (Matsagar, 2015). Some of the low cost building materials have been listed in figure 1.

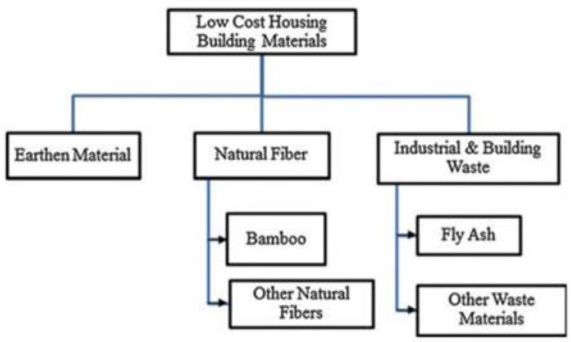


Figure 1 Low Cost Building Materials (Matsagar, 2015)

Low cost architecture involves optimising various factors such as resources, technology, materials and energy without compromising with the quality of the final product established according to certain benchmarks (Bhooshan, 2004).

The factors which assume top priority during cost reduction have been described in Figure 2.

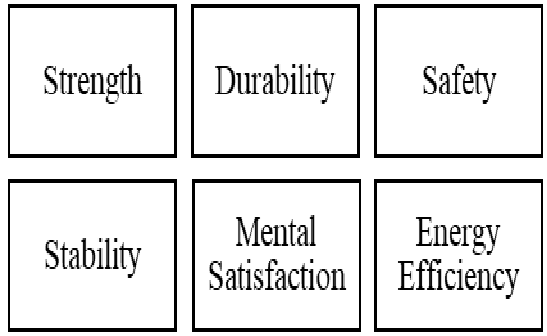


Figure 2 Cost Reduction Factors

2.1 Potential Low Cost Construction Techniques

Some of the potential low cost construction techniques for walling and roofing have been discussed in table 1.

Technique	Brief	Merits	Demerits	Reference
1. Rat Trap Bond Masonry  Figure 1 Rat Trap Bond	Bricks are placed vertically and cavities are created in between.	• Less number of bricks used around 20-35%. • Thermal comfort. • Less Dead Weight.	• Services need to be preplanned. • Maintenance issues. • Skilled masons required.	(Joshi, et al., 2017)
2. Filler Slab  Figure 2 Filler Slab	Nonfunctional concrete is replaced by some filler materials such as clay pots, clay bricks, coconut shells etc.	• Less dead weight. • Less usage of concrete, therefore economic. • 30% saving of concrete.	• Filler material may react with concrete compromising its strength.	(Chougule, Mota, & Patil, 2015)
3. Rapid Wall (GFRG: Glass Fibre Reinforced Gypsum) Technique	Made of residual powder from fertilizer industries. Panels are hollow and light weight and	• Water and fire resistant. • Earthquake Resistant. • Eco friendly. • Doesn't require curing time.	• Lightweight, therefore not wind resistant which imposes	(Bandgar & Kumthekar, 2016) (Tayade, Shinde, & Patil, 2015) (Reddy,

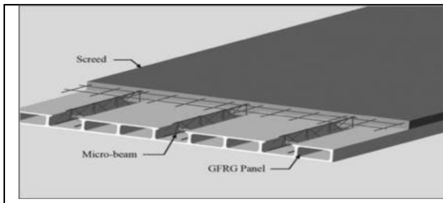
 Figure 3 GFRG Panel	are easy to assemble.	• Less Labour required. • 50% saving in construction cost.	limit on height of structure.	Wagh, & Deshmukh, 2017)
4. Plank and Joist Roof  Figure 4 Plank and Joist Roof	Precast RCC joists and precast cement concrete planks are used.	• 15-20% reduction in construction time due to precasting. • No shuttering • Better quality control due to prefabrication.	• Transportation cost of prefabricated modules.	(Building Materials & Technology Promotion Council)
5. Funicular Shell Roof  Figure 5 Funicular Shell Roof	Doubly curved shells are used. Made with materials having good compressive strength such as brick tiles, stones etc.	• Earthquake resistant. • Less usage of steel and cement.	• Skilled labour required.	(Building Materials & Technology Promotion Council)
6. Ferrocement Channel Roof  Figure 6 Ferrocement Channel Roof	Precast roofing channels made of ferrocement are used. Placed in form of segmental arch profile adjacent to each other. The valley formed between two adjacent arches acts as a T beam taking all the loads.	• Light weight roofing. • Reduction in construction time.	• Skilled labour required.	(Building Materials & Technology Promotion Council)
7. Partially Precast RCC Joist and Brick Panel Roofs/  Figure 7 Precast RCC Joist and Brick Panel	Precast joists are used. Brick panels are provided in between having reinforcement bars.	• Cost saved: 20-25%. • Due to precast elements, time is saved.	• Services need to be preplanned.	(SEP India, 2011)

Table 1 Potential Low Cost Construction Techniques

3.CASE STUDY

The case study discussed in following sections is of a school prototype developed for villages of Uttar Pradesh by Ar. Rajiv Kacker, Point Architects Private Limited, Lucknow. This project was winning entry for the competition held by UP Education for all. The case discussed is situated in Hardoi, Uttar Pradesh, India.

3.1 Prototype Plan

The prototype plan has been illustrated in figure 10.

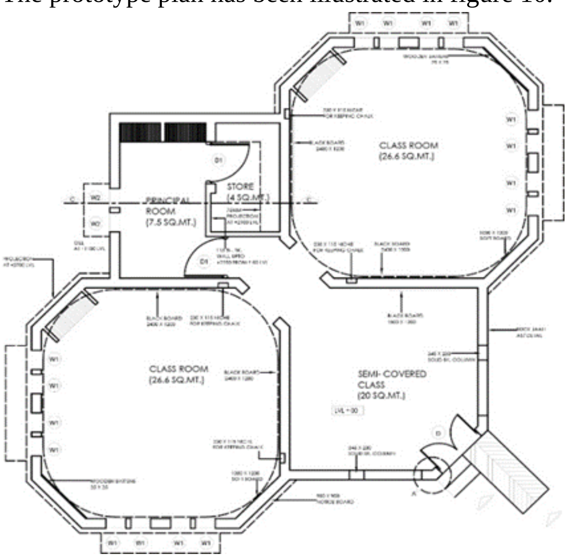


Figure 10 Prototype Plan

The prototype has been provided with following spaces: 2 covered classrooms, 1 semi covered class room, 1 principal room and 1 store room.

Figure 11 Building View

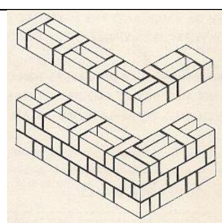
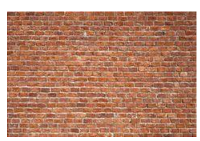
3.2 Building Specification and Construction Techniques

For our cost benefit analysis, we are considering two cases:

Case 1: Actual Building

Case 2: Benchmark Building

The specifications and techniques employed in both the buildings have been discussed in table 2. The rates have been taken from CPWD's DAR (CPWD, 2019).

Element	Case 1: Actual Building	Case 1 Cost (in Rupees)	Case 2: Benchmark Building	Case 2 Cost (in Rupees)	Cost % Difference ((Case2- Case1)/Case 2)/100
1. Wall	 Figure 8 Rat Trap Bond Wall	175304/-	 Figure 9 Brick Wall	270635/-	35.225%
2. Roof	 Figure 10 Filler Slab	65902/-	 Figure 11 RCC Slab	66278/-	0.567%
	 Figure 12 Corbelled Roof	143829/-		138121/-	(-) 4.13%

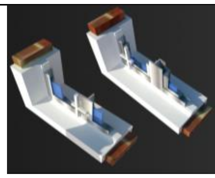
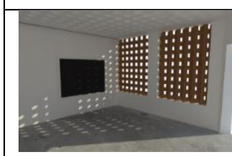
3. Door	 Figure 13 Flush Door Detail	9040/-	 Figure 14 Panel Door	10725/-	15.7%
4. Window	 Figure 15 Metal Window Detail	28070/-	 Figure 16 Timber Windows	47374/-	40.74%
	 Figure 17 Brick Jaali	7058/-		45167/-	84.37%

Table 2 Case 1 vs Case 2 Specifications

3.3 Simulation

Yearly energy simulations have been performed. Design Builder software has been used to perform the simulations.

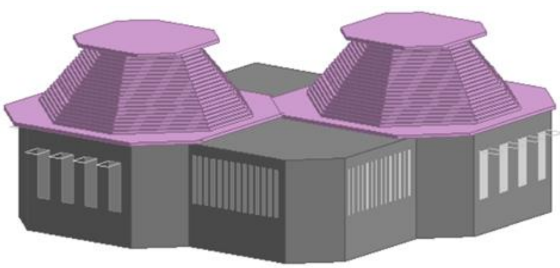


Figure 22 Case 1: Actual Building

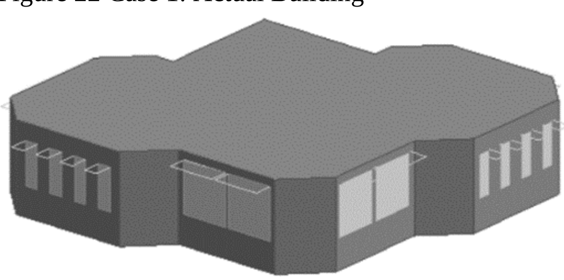


Figure 23 Case 2: Benchmark Building

3.3.1 Discomfort Hours

Discomfort hours have been calculated on yearly basis. Actual building has 5.07% less discomfort hours when compared to actual building.

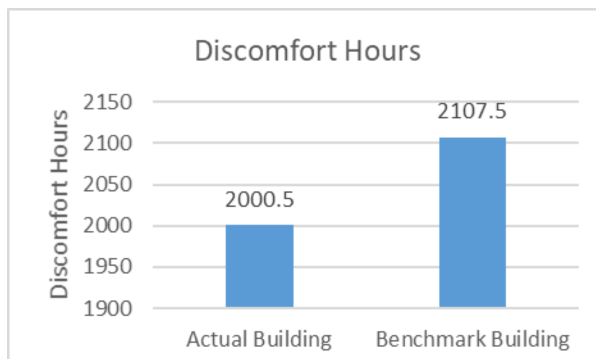


Figure 24 Discomfort Hours

3.3.2 Sensible Heat Gain

Heat gain in actual building is 25.43% less than benchmark building.

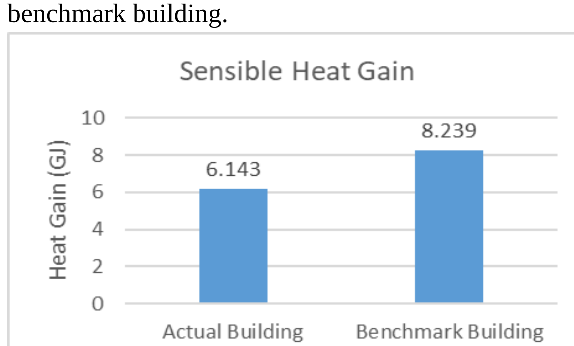


Figure 25 Sensible Heat Gain

3.4 Construction Cost

The construction cost breakup of each element and total construction cost has been discussed in table

Element	Actual Building (in Rupees)	Benchmark Building (in Rupees)
1. Wall	175304/-	270635/-
2. Roof	209731/-	204399/-
3. Door	9040/-	10725/-
4. Window	35128/-	92541/-
Total (in Rupees)	429203/-	578300/-

Table 3 Construction Cost

There is a difference of 25.78% between construction cost of actual building and benchmark building. Actual building is much cheaper comparatively.

3.5 Result

The results of the entire study have been discussed in table 4. The cost for all the building elements considered has been analysed.

	Benefit in terms of cost	Benefits in terms of thermal comfort
1. Wall	35.225% cost saved	-
2. Roof	2.60 % cost extra	-
3. Door	15.71% cost saved	-
4. Window	25.78% cost saved	-
5. Discomfort Hours	-	5.07% reduction in discomfort hours
6. Sensible Heat Gain	-	25.43% reduction in sensible heat gain

Table 4 Result

4.CONCLUSION

The study concludes that low cost architecture is beneficial both in terms of cost and thermal comfort. There is a total saving of 25.78% in cost by employing low cost construction techniques. Furthermore, there is a reduction of 5.34% in discomfort hours and 34.12% in sensible heat gain. Focus should be laid on optimising the design of each element so as to get associated benefits. Low cost architecture is very essential in a country like India as it can provide us with good infrastructure at reduced cost both in terms of construction and energy consumption. The case we discussed was for a naturally ventilated building. Similar studies can be done for conditioned buildings and the benefits in terms of energy consumption due to HVAC can be studied in detail.

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