Appropriate technologies for building mass reduction: A comparative Investigation of contemporary and light weight houses of Kerala

NIZAR S. A.[1] AND **DR. DILI A. S.**[2*]
[1]Associate Professor, Department of Architecture, TKM College of Engineering, Kollam-691005, India
[2*]Professor, Department of Architecture, TKM College of Engineering, Kollam-691005, India

Abstract: ***Construction technology in residential buildings sector of Kerala is passing through an important phase of experimentation with the application of new innovative technologies and building materials. Along with the traditional construction systems, there are number of cost effective and material efficient methods of construction techniques are prevailing in the state. The Authors have conducted an investigation and comparative analysis of two types of modern residences constructed with two different type of construction technologies. A comparative quantitative analysis of the results of the material consumption on the major structural parts of these buildings have been carried out to understand the effectiveness of the technology in material optimization. The study and its results reveal that with selection of appropriate technologies focusing on light weight construction methods for walls and roofs, total materials for the building construction can be reduced without compromising the space efficiency and the ability of the building's response to climate.***

Index Terms: Residential building, Kerala, Modern residences, Building materials, Appropriate technology

I. INTRODUCTION

Sustainability in construction relates not only to the extraction and production of raw materials, but also consideration in efficiency in terms of design execution of the structure [1]. Optimization of building materials can be defined as the process meant to achieve the best of available material, in order to make their use as effective as possible [1]. Utilization of large quantity of natural resources for meeting the fast-growing building activities and generation of waste has exerted unavoidable pressures on natural environment [2].

A building industry that depends on diminishing resources will ultimately become more costly as the resources will continue to be depleted, and would thus pose a negative impact [3]. The building industry in the future needs a decision system for selecting environmentally responsible building materials and construction technology [3]. Technology is the principle instrument that will facilitate more rational use of resources during the entire life cycle of a building; through the phases of construction, use and demolition [3].

A clear understanding of different design principles, methods and techniques of construction employed and materials used in traditional Architecture would be used in Contemporary Architecture by judiciously adopting them even while using suitable modern materials and modern technology. [4-7]

There is a great potential in the field of light weight building design, as the density optimization accompanied by intelligent integration allows the materials to be more easily maintained and recycled [8].

There are different type of Green rating systems for sustainable practices in the building sector, globally. The evaluation criteria for these rating systems have components from site selection and planning to building operation and maintenance. Though material efficiency is one of the component of the evaluation, it gets less importance compared to other aspects of evaluation. Optimization of the quantity of materials in the construction, to reduce the overall building mass, without compromising other necessary requirements is also an important aspect to achieve sustainability.

Different comparative studies have been conducted in the energy efficiency and cost-effective technologies in the residential sector in India and abroad. A comparative study of the different construction technologies and its related efficiency in optimization of resources and materials in the residential sector will give more insight in to the sustainable approaches in this sector.

A. Present Scenario of Residential buildings in Kerala

Kerala, located in the south west region of India having high population and residential density, compared to other states of India (9). Despite being blessed with immense natural resources, factors like population growth and urbanization demand a greater number of built structures in the residential category and it puts more pressure on these resources of the State.

As the dominating sector of the population in Kerala, the middle income groups are influenced by the experimental construction technologies, with depending factors of social status and acceptability and economic viability. Recently, supply of materials needed for the construction sector in the state failed to keep up with the demand. This has increased the cost of construction in various dimensions and began to badly influence the middle income group.

Many of the construction technologies in the residential sector of Kerala today resulted in large building mass, which consumes large quantity of materials. This demands a detailed study of the different aspects associated with overuse of materials, increasing the building mass and possibilities of proper optimization techniques and guidelines to control the use of materials according to its need.

II. METHODOLOGY

The authors have conducted a detailed comparative investigation and analysis of two different types of residences in Kerala, designed and constructed with two different types of technologies and materials. The investigation focuses on the suitability of the technologies in optimization of building materials in the construction. Being representative of the typical type of construction, these buildings show significant differences regarding the construction technology, structural characteristics and materials used. Therefore, by adequate comparison and evaluation of relevant characteristics of technology and materials, the resource utilization characteristics can be evolved.

After the Comparative study and analysis of the material consumption of the two selected residences, Results and Discussions will be carried out to evolve the research Conclusions of the investigation.

A. *Case Studies*

Selection of Buildings

Two Residential buildings, which have been selected for the study and analysis, which are located in the Kollam district of Kerala. These residences are designed for people belonging to middle income sector, considering their economic affordability. One of the selected residence designed and constructed in a contemporary residential style prevailing in this sector and the second one adopted a light weight innovative construction system in design and construction. As these residential structures have adopted different construction technologies and related materials, which are useful for the comparison on their appropriateness in a type of construction system, for the optimization of materials.

Case Study I: Residence A

The first selected residential building for the study was at Kunnikkode in Kollam district of Kerala, owned by Mr. Riyas. (Figure I). This residence was constructed in two floors in 2018, with a total floor area of 278 sq. m.

Walls of this residence constructed in a conventional English bond brickwork and plastered on both surfaces. Roofs have adopted flat roof RCC construction for the entire area of the residence, providing an exposed flat terrace on top.

Figure I. Residence - A owned by Mr. Riyas

Case Study II: Residence B

The second selected residential building was at Paravur, in Kollam district owned by Mr. Biju Nettara (Figure II). This residence also constructed in two floors in 2015, with a total area of 200 sq. m. [10].

Walls of this residence constructed with hollow concrete blocks of varying thicknesses of 15 cm and 10 cm for ground floor and first floor respectively, and plastered on both sides. Ground floor roof of this residence adopted RCC conventional flat slab, while the upper floor roof is designed in a sloping pattern covering with algae resistant shingles, with wide overhangs. Framework of the roof is designed with G.I tubular truss and a false ceiling constructed below this level using gypsum board.

Figure II. Residence - B owned by Mr. Biju Nettara [10]

B. *Method of Study*

The selection of construction techniques and materials for walls and roofs of a building, which have the highest share in the cost of construction is crucial. So this investigation concentrated on the evaluation of the construction technologies adopted and the materials used for the construction of walls and roofs. Quantification and comparative analysis of the materials used by each residence for a unit area of the construction will give a clear inference on the suitability of the type of technology used for the construction.

III. RESULTS AND OBSERVATIONS

A. Construction Technology and Materials

Authors have conducted studies on the construction technology [Table I] used and detailed quantity calculation of the different type of materials used [Table II] for the construction of walls and roof of the two buildings and comparative tables have been evolved. These results demonstrated the quantity of each material consumed by two residences in each part of the construction.

Table I: Construction Technology & Materials

Wall:	
Construction technology	**Residence A:** Conventional 23 cm brick work in English bond for inner and outer walls and cement mortar plastering
	Residence B: Hollow concrete Brickwork for inner and outer walls with cement mortar plastering 15cm thick walls-Ground floor 10cm thick walls –First floor
Materials	**Residence A:** Ordinary wire cut bricks of dimensions 22.9 x 11.4 x 7.5 cm and Cement sand mortar 1:6 composition.
	Residence B: 15cm x 20cm x 30 cm and 10cm x 20xm x 40cm hollow concrete blocks Cement mortar 1:6 composition
Roof:	
Construction technology	**Residence A:** RCC Flat slab -10 cm thick
	Residence B: Ground Floor- RCC flat slab – 10 cm thick First Floor- 4mm thick algae resistant shingles on top of cement board and steel framework
Materials	**Residence A:** RCC slab with 1:2:4 cement concrete composition.
	Residence B: RCC slab with 1:2:4 cement concrete proportion for the ground floor roofing. 4 mm thick shingles, cement board, steel frame work and gypsum board for false ceiling for first floor roofing.

B. Quantity of Materials

Table II: Final Quantity of materials consumed by each Residence for the construction of Walls and Roof

Particulars	Residence A	Residence B
Walls (including plastering)		
Bricks (23 x 11.5 x7.5 cm) (nos.)	44944	
Hollow concrete blocks (15 x 20 x 30 cm) (nos.)		1878
Hollow concrete blocks (10 x 20 x 40 cm) (nos.)		922
Sand (cu. m)	51.12	12.82
Cement (cu. m)	8.17	1.99
Roofs (including ceiling plastering)		
Coarse aggregate (cu. m)	28.17	5.76
Sand (cu. m)	19.96	4.1
Cement (cu. m)	7.92	1.63
Steel reinforcement (kg)	2513	514

IV. ANALYSIS AND DISCUSSION

Based on the results and calculations of the materials consumed by each residence for the construction of walls and roof, comparative tables have been prepared to show the quantity of each material, consumed by Residences for 1s. q.m area of the construction [Table III and IV]. This will give a clear indication of the material consumption of each residence for a unit area of construction.

Table III: Quantity of materials consumed by each Residence for the construction of Walls for 1 sq.m area of the Residence.

Particulars	Residence A	Residence B
Walls (including plastering)		
Bricks work (cub.m)	0.413	0.103
Cement Sand Mortar (cub. m)	0.145	0.044
Sand (cu. m)	0.188	0.064
Cement (cu. m)	0.03	0.01

A. Comparison of Analysis 1- Walls

Comparative analysis of the quantity of Brickwork needed for 1 sq. m. area of the residence, shows that Residence B consumed least quantity of brickwork (0.103 cu. m) with hollow concrete block system, and with application of light weight construction with 15 cm and 10 cm thick walls for the lower and upper floors respectively. Residence A consumed large quantity of materials for the construction of walls for 1 sq. m construction (0.413 cub.m), as conventional brick work.

Analysis of the usage of Cement sand mortar for 1 sq.m area of each residence shows that Residence B consumed least quantity of mortar (0.044 cu. m) due to reduced wall thickness. Residence A consumed higher quantity of mortar (0.145 cu. m), as the wall construction adopted ordinary brickwork with plastering.

Comparative analysis of consumption of cement and sand for the wall construction including plastering for 1 sq.m. area of each residence shows that, Residence B consumed least quantity of cement (0.01 cu. m) and sand (0.064 cu. m) and Residence A consumed higher quantity of cement (0.03 cu. m) and sand (0.188 cu. m) than Residence B.

Table IV: Final Quantity of materials consumed by each Residence for the construction of Roof for 1 sq. m area of the Residence

Particulars	**Residence A**	**Residence B**
Roof (including plastering)		
Coarse Aggregate (cub. m)	0.1	0.091
Sand (cu. m)	0.07	0.063
Cement (cu. m)	0.029	0.025
Steel Reinforcement (kg)	9.23	7.85

B. Comparison of Analysis- 2- Roof

Comparative study and analysis of the consumption of materials for the roof work including roof slabs and beams, for 1 sq. m. area of the residence shows that, Residence A consumed maximum quantity of coarse aggregate (0.1 cu. m), cement (0.029 cu. m) and sand (0.07 cu. m) for the roof construction. Residence B consumed least quantity of coarse aggregate (0.091 cu. m), cement (0.025 cu. m) and sand (0.063 cu. m) with minimum slab thickness and less usage of beams, with the design and construction technology.

Comparative analysis of the consumption of steel reinforcement for the roofs and beams for unit area of the residences, reveals that, Residence B consumed less amount of steel reinforcement (7.85 kg.), as the additional requirements of beams are minimum in this residence.

A qualitative study of the upper roof construction of the two residences reveals that, Residence A consumed large quantity of materials for the RCC roofing system, and its exposed flat roof absorbed large amount of heat energy, and affected the temperature level of internal spaces negatively. Residence B adopted a light weight sloping roof system with steel framed structures covered with mangalore tiles and shingles. Comparative analysis shows that, Residence A requires additional mechanical systems to control the temperature to make the residence comfortable during the summer seasons of Kerala. Meanwhile Residence B adopted sloping roofs with wide overhangs, for protection from rain, and false ceiling to control the indoor comfort levels, found to be an ideal solution for the different climatic seasons of Kerala.

V. CONCLUSIONS

Comparative analysis of quantity of materials consumed by each Residence for the brickwork of walls shows that, Residence B utilized minimum quantity, while Residence A consumed more than three times of materials consumed by Residence B for the construction of walls.

It is obvious that differences in construction technology clearly influenced the quantity of brickwork and materials for both residences.

Residence B adopted an innovative light weight construction system, with minimum thickness for the walls using hollow concrete blocks and plastered finish. As this technology consumed minimum quantity of brickwork, its usage of all materials is minimum, and thus reduced the overall building mass. It also gives a finished aesthetic looks to the building without compromising its structural stability.

Comparative analysis of the materials consumed by two residences for the roof construction shows that, they adopted different technologies for the constructions, which influenced the quantity of materials. Residence A consumed maximum quantity of RCC work with coarse aggregate, cement and sand with steel for the construction of roof, considering the materials for 1 sq.m area of the residence.

Residence B consumed minimum amount of coarse aggregate, cement and sand for the roof system, considering materials for 1 sq.m area of the residence. This is because of minimum usage of additional beams as a structural element, with compact design solutions and optimum room design.

A detailed comparative analysis of materials consumed by each residence for the construction of walls and roofs based on materials for 1 sq. m area of residence, revealed the following final conclusions. Residence B consumed minimum quantity of materials for the walls and roof, with light weight construction systems, and compact design solutions with optimization of area according to functions. Technological difference in the roof construction of the upper floors of the two buildings, reveals that Residence B is a more climatically responsive design solution for the prevailing climate of Kerala.

So, it can be concluded that, with suitable appropriate technologies for walls and roof construction, total materials for the building can be reduced without compromising the space efficiency and the ability of the building's response to climate.

It could also be concluded that it is very important to create awareness on the beneficiaries on the benefits of the construction technologies and the selection of materials, which is very much suitable for the Kerala climate and needs and at the same time optimize the use of resources.

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