Role of building mass in functionality and strength: An Investigation on selected types of Kerala Residential Architecture

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Abstract: ***Residential Architecture and building technology of Kerala is passing through an important phase of design and construction methods with application of new technologies and new materials. Despite a number of cost-effective construction techniques and building materials developed through research, the residential sector has not seriously adopted or accepted these technologies in construction practice. The authors have initiated and conducted an investigation and comparative analysis of two different types of building construction methods in the residential sector of Kerala, adopting different construction technologies and materials. A comparative quantitative analysis of the materials consumption has been carried out for the major structural parts of the buildings, to understand the effectiveness of the technology in material utilization. The study and its findings reveal that with suitable appropriate technologies focusing on light weight construction methods for walls and roof construction, total materials for the building can be reduced without neglecting climatic responsiveness and design efficiency.***

Index Terms: Residential Architecture, Kerala, Building materials, Appropriate technology

I. INTRODUCTION

Natural resources are consumed by modifications of land, the manufacture of materials and systems, the construction process, energy requirements and waste products that result from operation, occupation and renewal [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]. While sustainable development is the need of the hour; we have to take lead in initiating activities that would minimize the exploitation of natural resources resulting in their effective utilization [3]. Optimization of the quantity of materials in the construction, to reduce the overall building mass, without compromising other requirements is an important aspect to achieve sustainability.

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 [4]. 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. [5-8]

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 [9].

Sustainable utilization of resources means using resources in such a way that future generations do not have to compromise with their existing needs. Different types of sustainable practices and Green rating systems have been developed by organizations, focused on different criteria for evaluation building systems. Material efficiency is one of the factors considered for the evaluation of rating systems. But most of the rating systems give more emphasis on energy efficiency, functional efficiency, and response to site and climate during evaluation. Optimization of the quantity of materials in the construction, to reduce the overall building mass, without compromising other 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 importance of sustainable approach 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 (10). Despite being blessed with immense natural resources, factors like population growth and urbanization demand a greater number of built structures and it puts more pressure on these resources of the State.

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.

As the most dominating proportion of the population of Kerala, the middle-income sectors of society are influenced by experimental construction technologies with depending factors of social acceptability, economic viability and environmental suitability. Material utilization of the residential structures for middle income sectors require a study and analysis to identify the over use of materials and the importance of appropriate construction technology for optimization of materials and valuable resources.

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. These residential structures have adopted various possibilities of construction technologies and 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 Ezhukone in Kollam district of Kerala, owned by Mr. Sudarsan. (Figure I). This residence was constructed in two floors in 2007, with a total floor area of 320 sq. m.

Walls of this residence constructed with a technology of rat trap bond system using high quality bricks with an exposed brick work finish. Roofs are designed with a flat and sloping combination, adopting filler slab technology using RCC and Mangalore tiles.

Figure I. Residence - A owned by Mr. Sudarsan

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. [11].

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 [11]

III. RESULTS AND OBSERVATIONS

A. Construction Technology and Materials

Table I: Construction Technology & Materials

Wall:		
Construction technology	**Residence A:** Rat trap bond brick work- 23 cm construction for inner and outer walls for ground and first floor level. Exposed brick work with cement mortar construction.	
	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:** First class wire cut bricks with dimensions of 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 slab with filler slab technology for flat and sloping roofs-12 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 construction with cement concrete 1:2:4 composition Mangalore tiles as filler material	
	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.)	37011	
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)	24.67	12.82
Cement (cu. m)	4.19	1.99
Roofs (including ceiling plastering)		
Coarse aggregate (cu. m)	34.6	5.76
Sand (cu. m)	24.98	4.1
Cement (cu. m)	9.8	1.63
Steel reinforcement (kg)	266	514
Mangalore tiles (as filler material) (nos.)	2883	

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 1 Sq.m area of the construction. 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)	0.0694	0.044
Sand (cu. m)	0.077	0.064
Cement (cu. m)	0.013	0.01

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.

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 (0.0694 cu. m), as the wall construction adopted exposed brickwork system with no 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 slightly higher quantity of cement (0.013 cu. m) and sand (0.077 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
Walls (including plastering)		
Coarse Aggregate (cub. m)	0.11	0.091
Sand (cu. m)	0.078	0.063
Cement (cu. m)	0.031	0.025
Steel Reinforcement (kg)	8.31	7.85

Comparative study and analysis of the consumption of materials for the roof work including beams, for 1 sq. M. area of the residence shows that, Residence A consumed maximum quantity of coarse aggregate (0.11 cu. m), cement (0.031 cu. m) and sand (0.078 cu. m) for the roof construction. This is due to the additional thickness of the roof to accommodate the filler material, and sloping profile of the roof system in half portion of the upper floor roof. 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 least amount of steel reinforcement (7.85 kg.), as the additional requirements of beams are minimum in this residence.

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 comparatively larger quantity of materials.

The differences in construction technology clearly influenced the quantity of brickwork and materials for both residences. Residence A used rat trap bond system for wall construction without any plastering on walls. Though this technology comparatively reduced the quantity of materials compared to conventional brick bond system for walls, limitation in reducing the wall thickness is a major disadvantage. Its structural stability and aesthetics aspects have different opinions also.

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. Though this residence used filler slab construction system for reducing quantity of materials, the sloping roof system with complications, in the upper level of the building, utilized additional materials and thus increased the total quantity per unit area.

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. So, it can be concluded that, with suitable appropriate technologies for walls and roof construction, total materials for the building can be reduced without affecting climatic responsiveness and design efficiency.

REFERENCES

1) Makeya. A. R & Nguluma. H. M; "Optimization of Building Materials and Design Towards Sustainable Building Construction in Urban Tanzania", C I B World Building Congress-2007 (CIB2007-070), 2007; 2086-91

2) A. K. Kasthurba, K. R. Reddy, and D. Venkat Reddy; "Sustainable Approaches for Utilizing Waste in Building construction: Two Case Studies in India", International Journal of Earth Sciences and Engineering, ISSN 0974-5904, Volume 07, No. 03, June 2014, PP 838-844.

3) A. M. S. Lakshmi, B. V. Subha; "Sustainable Building materials in Kerala- an Overview"; Proc. Of Int. National Conference on Advances in Civil Engineering, 2010; 2010 ACEE, DOI: 02ACE, 2010.01.11.

4) Sustainable Building Design Manual - Volume 2

5) A. S. Dili, M. A. Naseer. T. A. Zacharia Varghese; "Passive Methods of Kerala Traditional Architecture for a Comfortable Indoor Environment: A Comparative Investigation during Winter and Summer", Building and Environment 45 (2010), 1134-1143

6) A. S. Dili, M. A. Naseer. T. A. Zacharia Varghese, "Passive Methods of Kerala Traditional Architecture for a Comfortable Indoor Environment: Comparative Investigation during various periods of rainy season", Building and Environment 45 (2010), 2218-2230

7) A. S. Dili, M. A. Naseer. T. A. Zacharia Varghese, "Passive Environmental control systems of Kerala Vernacular Residential Architecture for comfortable indoor Environment: A Quantitative and Qualitative analysis", Energy and Building 42 (2010), 917-927.

8) A. S. Dili, M. A. Naseer. T. A. Zacharia Varghese; "Passive control systems for a comfortable indoor Environment: Comparative investigation of traditional and modern architecture of Kerala in Summer", Energy and Building 43 (2011), 653 - 664.

9) Forrest Meggers, Hansjurg Leibundgut, Sheila Kennedy, Menghao Qin, Mike Schlaich, Werner Sobek, Masonari Shukuya; "Reduce CO2 from Buildings with Technology to Zero Emissions: - Sustainable Cities and Society", Sustainable Cities and Society 2 (2012) 29-36 (ELSEVIER).

10) IS. SP: 2005. National Building Code of India, 2005, Bureau of Indian Standards, Newdelhi-2005.

11) A. S. Dili, "Simple and Cool - A House can be lightweight, Cool and Cost effective", Architecture, Time, Space and People, The official Magazine of the Council of Architecture, India. Vol-18, Issue 101, January 2018.