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EXPERIMENTAL STUDY OF GREEN BUILDING MATERIALS AND CONVENTIONAL BUILDING MATERIALS IN ENERGY EFFICIENCY PERFORMANCE OF RESIDENTIAL BUILDING

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Abstract

The basic need of human beings is food, clothing and shelter civil engineering deals with the third need i.e. shelter directly. Building construction is one of the earliest activities associated since the beginning of the human civilization. As man has always needed shelter against natural weather conditions and extremities Man has transformed a lot in shelter right from caves to huts and from huts to R.C.C structures. Buildings consume a vast amount of energy, cost and CO_2 emission to the atmosphere during the life cycle stages of construction, use and demolition. Total life cycle energy use in a building consists of two components: embodied and operational energy. Embodied energy is expended in the processes of building material production, on-site delivery, construction, maintenance, renovation and final demolition. Operational energy is consumed in operating the buildings. In this paper the review is given about energy consumption,

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cost and CO_2 emission of the residential building. Energy required for various materials is calculated and energy efficient alternatives are suggested. Studies have revealed the suggestion of energy efficient alternatives materials and comparison of energy consumed by using each material. Current interpretations of embodied energy are quite unclear and vary greatly as change in site source of raw materials and embodied energy databases suffer from the problems of variation and incomparability.

Keywords— Embodied Energy, Life cycle, Joule, Operational, Filler Slab.

I.INTRODUCTION

The concept of sustainable buildings and use of environmentally friendly construction materials like stones, timber, thatch, mud etc have been practiced since ancient times. But the perception of people about strong and durable buildings have changed with the advent and lavish use of the present modern materials like steel, cement, aluminum, glass etc. A large amount of fuel energy gets consumed in producing such materials. These materials being industrial products further need to be transported to large distances before getting consumed in the buildings thus making them energy intensive. An estimate of the energy consumed in buildings using different permutations of materials and techniques will facilitate their appropriate selection and reduce the embodied energy consumption. Considerable amount of energy is spent in the manufacturing Processes and transportation of various building materials. Conservation of energy becomes important in the context of limiting of greenhouse gases emission into the atmosphere and reducing costs of materials. Non conventional or Green building thought in broader terms is a building which is planned, built, operated, maintained or reused with objectives to defend inhabitant health, improve employee efficiency, use wisely natural resources and reduce the environmental impact. Green construction or sustainable building which complements the building plan with concerns of economy, utility, durability and comfort. In other words, the green building procedure incorporates environmental considerations into every phase of the building structure. This process focuses on the design, construction, process and maintenance phases and takes into account the lot design and development effectiveness, energy and water effectiveness, resource efficiency, indoor environmental excellence, building-owner maintenance and the building‘s overall impact on the environment. A Green Building is one which utilizes less water, optimizes energy efficiency, conserves natural resources, generates less waste and provides healthier space for occupants as compared to conventional buildings.

II.PROBLEM STATEMENT

The environmental impact of a building depends on many factors, including energy (e.g. Embodied energy, energy used during the building operation, and energy used during Construction), materials, use of water and other resources. This research focuses on “Green” residential buildings, where special attention is paid to building energy Performance; in other words, the investigation focuses on low-energy residential Buildings, and particularly in the passive house standard, by taking care of cost, CO2 emission, Strength & durability ,reduction of wastes by utilizing for construction and water saving.

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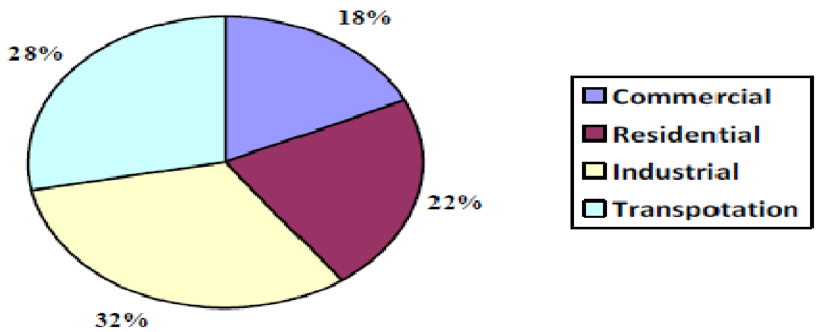
World Energy Consumption by Sectors - 2008



World Energy Consumption by Sectors – 2011

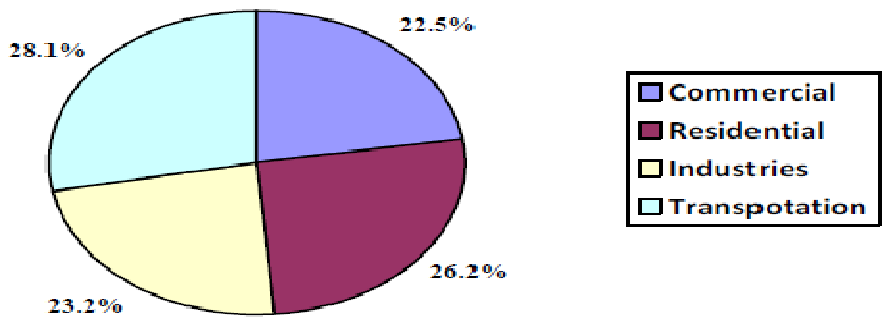


Fig 1. World Energy Consumption by Different Sectors

The energy consumption by different sectors is buildings, Transportation and Industries. The energy consumption by buildings for different years is shown in the figure; it clearly shows that the energy consumption by the buildings is more than that of the other sectors.

III. OBJECTIVES

The objective of the project is to develop buildings which utilize the natural resources to the minimal at the time of construction and operational stage. Non conventional buildings emphasize on the resource usage efficiency and also press upon the three R's - Reduce, Reuse and Recycle.

- Natural Resource Conservation, Energy Conservation, Materials Conservation & Water Conservation in construction of residential buildings.
- Cost reduction in the construction and use of residential buildings.
- Design for Human Adaptation

IV.METHODOLOGY

The total experimental approach involved in this work has been divided into four different phases. The details of the work in phase are narrated below.

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Phase-I:-

1) Study of available literature on above concept.
2) Identifying different methods of calculating embodied energy ad CO_2 emission.
3) Collecting the working drawing of residential building and preparing estimate.

Phase-II:-

1) Calculating Specific Energy and CO_2 emission of general materials.
2) Calculation of embodied energy and CO_2 emission of selected building components.

Phase-III:-

1) Identification of different energy efficient alternatives for selected building components.

Phase-IV:-

1) Analysis of different alternatives of selected building components with respect to cost, strength and embodied.
2) Laboratory tests on Conventional and non conventional Building materials.
3) Tests on Prism and Slab constructed with Conventional and Non conventional building materials.
4) Recommendation of the energy efficient materials.
5) Report writing.

MATERIALS

Conventional Building Materials

- Ordinary Portland cement
- Coarse aggregates
- River sand
- Burnt bricks
- Steel

Non-Conventional Building Materials

- Portland pozzolona cement
- M sand
- Stabilized mud blocks
- Recycled Mangalore Tiles

V. ENERGY CONSERVATION

Energy conservation refers to the efforts made to reduce the consumption of energy. There has been an enormous increase in the global demand for energy in recent years as a result of industrial development and population growth. Supply of energy, therefore, is far less than the actual demand. Consumption of energy in the civil engineering scenario comes into picture in a

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wide range as most of the materials and products constituting the construction materials require energy in one or many forms, from the time of extraction till it is used in the construction site.

Need of the hour is to answer the question why is energy to be conserved? Careful resource management is needed to ensure two major conditions, viz,

- Optimal utilization of available resources – to use locally available materials meeting the construction requirements and thus ensuring the energy consumed is low.
- To maintain a resource credit for the future generation - as most of the resource being used in civil construction practice is fast approaching extinction in terms of present growing rate.

Embodied Energy

Embodied Energy is the energy consumed by all the processes associated with the production of a product from the acquisition of natural resources to the product delivery. This includes the mining and manufacturing of materials and equipment, the transport of materials and the administrative functions. Typically, embodied energy is measured as a quantity of non-renewable energy per unit of building material, component or system.

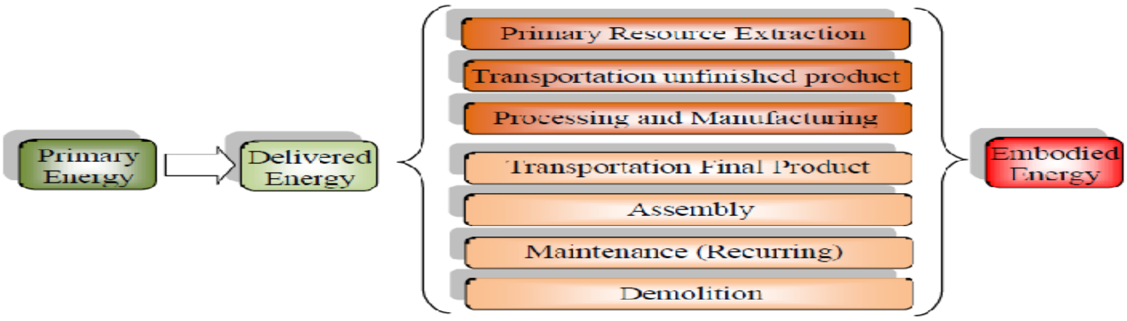

Fig: 2 Energy Detailing in Embodied Energy Estimation

Embodied Energy Calculation

There are number of tools that have been developed to help assess embodied energy. Process analysis, statistical analysis, input output analysis and hybrid analysis are among the major methods used for embodied energy computation. These methods possess different limitations and their level of accuracy varies. As a result their embodied energies differ and cannot be juxtaposed.

In the calculation of embodied energy of the building structure, there will always be uncertainty in:

- The amount of materials used,
- The embodied energy of the materials, and
- The source and content of the materials.

It is thus important to estimate the range of uncertainty of the input parameters such that the resulting uncertainty in the embodied energy of the building structure can be predicted and the most influential input parameters can be identified.

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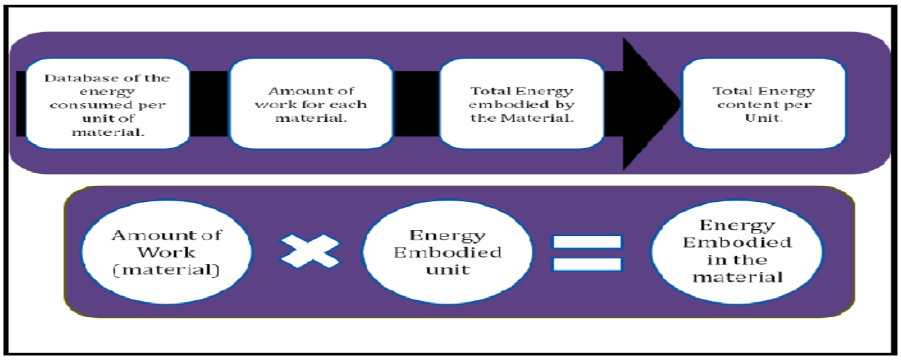

Fig: 3 Methodology for finding Embodied Energy

Table 1.Embodied Energy Coefficients of Building Materials as per AVEI

Sl. No.	Material	Unit	Energy
1	Burnt Brick	MJ/No	3.75
2	Solid Concrete Block	MJ/m^3	12.98
3	Hollow Concrete Block	MJ/m^3	8.00
4	River Sand	MJ/m^3	29.58
5	Steel	MJ/m^3	226368
6	Cement	MJ/kg	3.60
7	Stone (virgin rock)	MJ/m^3	104.00
8	Crushed Stone Aggregate	MJ/m^3	215.80

VI. CARBON DIOXIDE EMISSION CALCULATION

Carbon Dioxide Emission from the Construction industry is one of the major threats to the Sustainability of Environment; it can be reduced by using the non conventional building materials for the Construction

VII. FILLER SLAB AS ENERGY EFFICIENT SLAB

Filler slab technology is a simple and a very innovative technology for a slab construction. The reason why, concrete and steel are used together to construct RCC slab is in their individual

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properties as separate building materials and their individual limitation. Concrete is good in taking compression and steel is good in tension. Thus RCC slab is a product which resists both compressions as well as tensile. Filler slab is a very cost effective roofing technology. It is not easy to remove, the concrete from the tension zone, hence concrete can be replace (partially); that part of concrete using light weight and low cost filler material. This method of construction is called filler slab. Filler slab technology is being used across India, but substantial amount of work on the successful promotion and mostly adopted in South India. These filler materials are so placed as not to compromise the structural strength, stability and durability, resulting in replacing unwanted and non-functional tension concrete, from below and thus resulting in economy of high energy material consumption and respective cost savings and decreased dead load of the slab and resulting in economy of high energy materials consumption and considerable cost saving and decreased dead load of the slab. An internal cavity can be provided between the filler material which adds an extra advantage; other than cost savings and energy savings; improved thermal comfort for the interiors. Also an added advantage of lower dead weight transferred to the supporting elements and finally onto the foundation to further adds up cost saving in design of these elements.

CASE STUDY BUILDING PLAN

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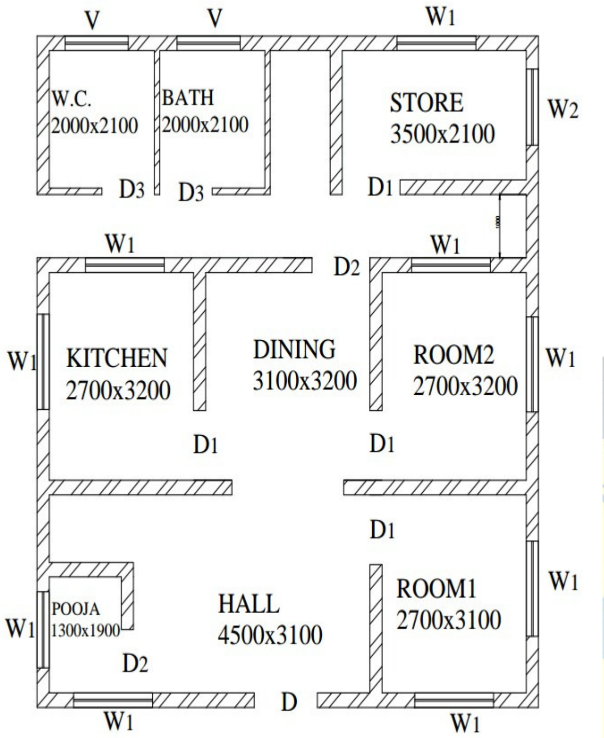

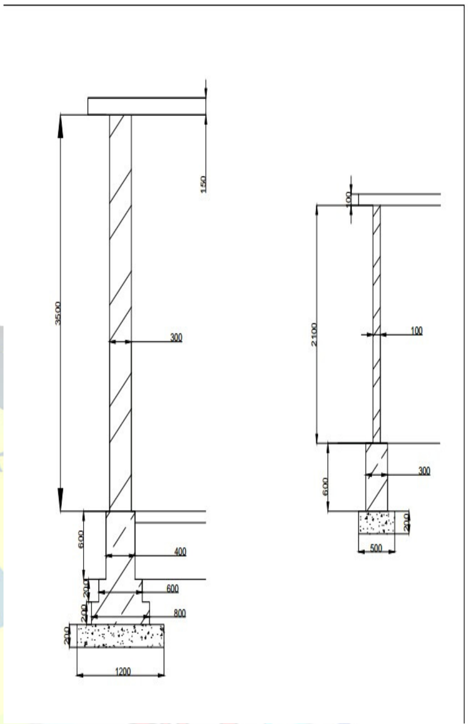

Features of the Building

The building is designed as load bearing masonry structure, constructed with Burnt Bricks as the basic building material. Plan of the building is shown above; Salient features of the building are,

- Total built up area – 1000 Sq.ft
- Regular and conventional type of foundation is adopted.
- Building is constructed without any column footing.

Table 2: Estimation of Quantities for the whole Building

Materials	Conventional Building Materials		Non Conventional Materials	
	Type of materials	Estimated Quantity	Type of materials	Estimated Quantity

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Cement	OPC 43	150 bags	PPC	90 bags
Fine aggregate	River Sand	9.545 Cum	M Sand	5.727 Cum
Coarse aggregate	Natural Crushed Aggregates	14.77 Cum	Natural Crushed Coarse Aggregates	8.56 Cum
Brick	Burnt Bricks	41650 No's	Stabilized Mud Blocks	3330 No's
Reinforcing Material	TMT bars	710 Kg	TMT bars	425 Kg
Filler Material	-		Mangalore tiles & Coconut shells	650 No's

Laboratory Test Results of Conventional & Non Conventional Building Materials

Table: 3 Test Results of CEMENT

SL. NO	Tests	Material	Results	Material	Results
1	Specific gravity	OPC 43	2.95	PPC	2.80
2	Fineness cement		6 %		8 %
3	Compressive strength		50 N/mm^2		53 N/mm^2
4	Initial setting time		65 min		145mn
5	Normal Consistency		32 %		34 %

Table: 4 Test Results of FINE AGGREGTES

SL. NO	Tests	Material	Results	Material	Results
1	Bulk density	River Sand	1.64 gm /cc	M sand	1.73 gm /cc
3	Specific gravity		2.62		2.22
4	Bulking of sand		39.76 %		42.5 %
5	Fineness modulus		3.23 %		4.20 %

Table: 5 Test Results of MASONRY MATERIALS

SL. NO	Tests	Material	Results	Material	Results

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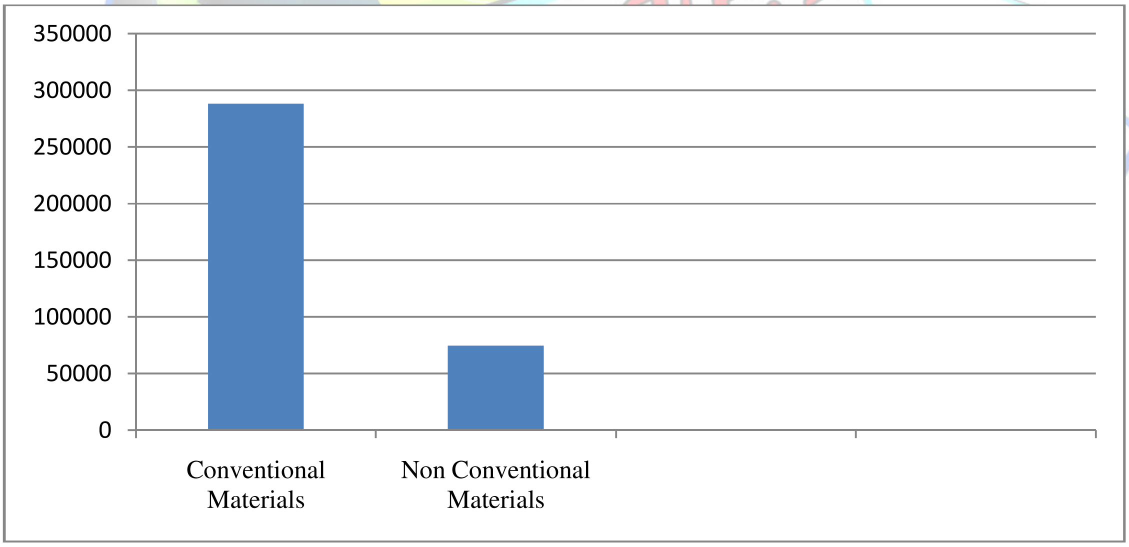
1	Water absorption	Burnt Bricks	12.02 %	Stabilized Mud Blocks	6.2 %
3	Compressive strength		3.86 N/mm^2		6.5 N/mm^2

Table: 6 Embodied Energy Calculation

Conventional Materials	Quantity	EE in MJ	Total EE in MJ	Non Conventional Materials	Quantity	EE in MJ	Total EE in MJ
OPC 43	150 bags	27000	288082	PPC	90 bags	7560	74581
River Sand	9.545 Cum	283		M Sand	5.727 Cum	2978	
CA	14.77 Cum	222530		CA	8.56 Cum	35117	
Burnt Bricks	41650 No's	8449		Stabilized Mud Blocks	3330 No's	3381	
TMT bars	710 Kg	29820		TMT bars	425 Kg	11970	
Filler Material	150 bags			Mangalore tiles & Coconut shells	650 No's	13575	



X axis – Types of Materials
Y axis - Embodied Energy Values

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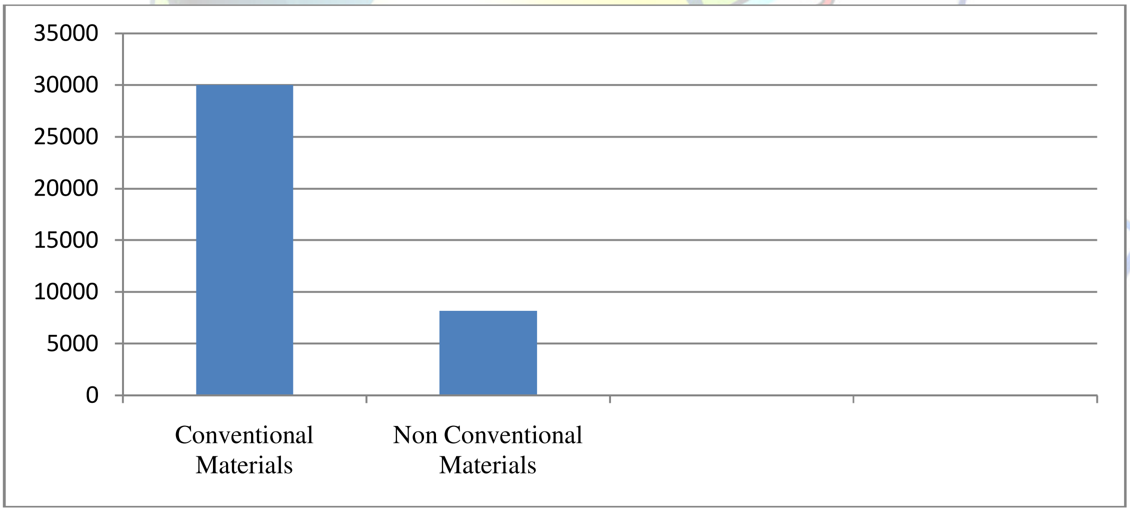
Table: 7 Carbon Dioxide Emission calculations

Conventional Materials	**Quantity**	**CO_2 in Kg**	**Total CO_2 in Kg**	**Non Conventional Materials**	**Quantity**	**CO_2 in Kg**	**Total CO_2 in Kg**
OPC 43	150 bags	4950	29995	PPC	90 bags	1722	8158
River Sand	9.545 Cum	27.67		M Sand	5.727 Cum	158.83	
CA	14.77 Cum	21265		CA	8.56 Cum	3442	
Burnt Bricks	41650 No's	828		Stabilized Mud Blocks	3330 No's	332	
TMT bars	710 Kg	2923		TMT bars	425 Kg	1173	
Filler Material				Mangalore tiles & Coconut shells	650 No's	1330	



X axis – Types of Materials
Y axis – Carbon Dioxide Emission Values

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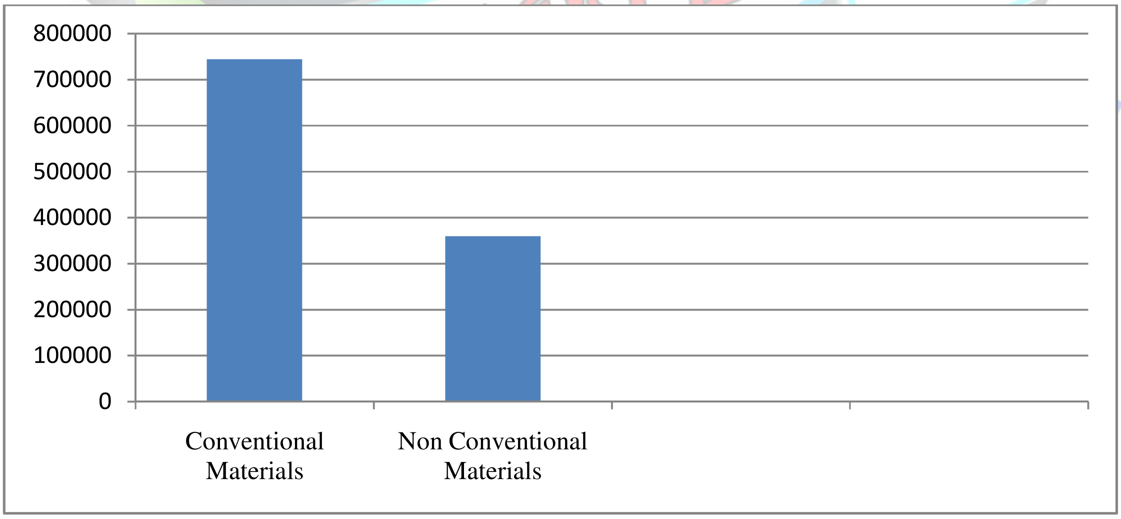
Table: 8 Cost Estimation

Conventional Materials	**Quantity**	**Cost in Rupees**	**Total Cost in Rupees**	**Non Conventional Materials**	**Quantity**	**Cost in Rupees**	**Total Cost in Rupees**
OPC 43	150 bags	60000	744270	PPC	90 bags	22800	360000
River Sand	9.545 Cum	12800		M Sand	5.727 Cum	7636	
CA	14.77 Cum	14770		CA	8.56 Cum	292075	
Burnt Bricks	41650 No’s	62475		Stabilized Mud Blocks	3330 No’s	5910	
TMT bars	710 Kg	31950		TMT bars	425 Kg	12825	
Filler Material	150 bags			Mangalore tiles & Coconut shells	650 No’s	13000	



X axis – Types of Materials
Y axis – Cost

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VIII. LOAD TEST ON CONVENTIONAL SLAB & FILLER SLAB

The slabs of dimension 10*4 feet were casted using RCC and Filler Materials such as recycled Mangalore tiles separately. After a curing period of 28 days load test on slab was conducted. 12 numbers of 50 kg and 10 numbers of 40 kg sand bags were prepared for the load test. 3 numbers of dial gauges were set at center of the span and at the 2 edges near the supports to check the deflection. The sand bags were then symmetrically placed in layers so as to create a UDL and the deflection behavior was checked using the dial gauges. The dial gauges are set as shown in the below figures. One dial gauge was placed exactly at the center of the span and the other 2 were placed at 1 foot distances from either supports.

Table 9. Load test Results of Conventional slab and Filler Slab.

SL.NO	Slab Type	Trial 1, Dial Gauge reading in mm			Trial 2, Dial Gauge reading in mm		
		Left Support	Centre of Span	Right Support	Left Support	Centre of Span	Right Support
1	Filler Slab	0.30	0.70	0.30	0.25	0.70	0.42
2	Conventional Slab	6.00	15.00	6.00	6.00	14.00	6.30

IX. Conclusion

- The Energy consumption for Brunt brick masonry is 4.17 times more than Stabilized Mud Block masonry. The embodied energy of the brunt bricks is more than the Stabilized Mud blocks and consumption of mortar is reduced in case of Stabilized Mud block masonry. The Embodied energy consumption can be reduced up to 75% with Stabilized Mud blocks.
- CO_2 Emission is reduced up to 65% by Constructing Stabilized Mud Block Masonry.
- 50 % of cost can be reduced by using Non conventional Building materials for the Construction of Residential buildings.
- Filler Slab is More energy efficient, economical and stable compared to Conventional Slab, 35 % of cost can be reduced by using filler slab technology, 30% of the Embodied energy

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can be reduced and 25 % of carbon dioxide emission can be reduced by adopting filler slab technology.

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