IMPACT: International Journal of Research in Humanities, Arts and Literature (IMPACT: IJRHAL)
ISSN (P): 2347-4564; ISSN (E): 2321-8878
Vol. 6, Issue 6, Jun 2018, 487-500

APPRAISAL OF EMBODIED AND THERMAL ENERGY OF VERNACULAR RURAL DWELLINGS – ANDHRA PRADESH, INDIA

Srikonda Ramesh

Department of Architecture, School of Planning and Architecture: Vijayawada, Andhra Pradesh, India

Received: 11 Jun 2018 **Accepted:** 15 Jun 2018 **Published:** 25 Jun 2018

ABSTRACT

This paper investigates native building materials used in a typical dwelling unit to understand the impact on the environment in terms of embodied and thermal energy. The dwelling unit designed and constructed using the local materials and local Artisans of Ravicherla, and estimated embodied the energy of 37.2% as compared to using conventional materials. Indoor air temperature found to be lower by 6-8 degrees lesser than the ambient air temperature during summer. It has been analyzed that the local materials consume only about 37.32% of energy (1.09 GJ / m^2*) as compared to a building with conventional materials which consumes about 2.92 GJ/ m*^{2}*. The indoor air temperature was found that the maximum temperature varies from 6 to 8*^{o}*C as compared to an ambient air temperature of 45*^{o}*C. The vernacular architectural practices provide an excellent solution to reduce the impact of buildings on ecology and environment with specific reference to Climate change.*

KEYWORDS: *Native Materials; Embodied Energy; Thermal Properties; Energy Conservation, Vernacular Dwelling*

INTRODUCTION

Buildings consume about 40% of Global energy production (Susanne *et al* 2014). Increase in Global population, changing lifestyle and increasing technology has influenced the energy consumption patterns of the buildings. Building materials consume a significant amount of energy during extraction of raw materials, processing, manufacturing, transportation, and installation at site. With an increase in global population and a shortage of housing, especially in developing nations, use of native materials in the construction of dwelling units proves to be an economical and sustainable solution by reducing the cost of construction, CO_2 emissions and energy demand, bringing down the total embodied energy of construction (Reddy, 2003). Extensive use of industrialized materials, especially in developing countries doesn't provide feasible solutions in view of diverse socio-economic and cultural backgrounds. Further, construction practices involving local building materials prove to encourage traditional skills and generate employment opportunities for indigenous people.

India is the second largest population in the world account for about 17.5% of Global Population. With the increase in population and being a developing country, India still has the majority of its population below the poverty line as per International standards. Urbanization has increased from 27.81% in 2001 to 31.16% in 2011 (India, 2011). This increase in urban population has resulted in developing slums and squatter settlements with deteriorated housing conditions. Buildings consume about 33% of total power consumption in India of which 8% and 25% are consumed by commercial and residential sector respectively (Saboor, 2014). With growing population is growing the demand for housing, and consumption of conventional materials for construction is further increasing the energy demand exerting more pressure on resources. This problem is not only in the urban areas but also exists in rural areas where the affordability of a decent housing condition is a distant dream. Traditional construction practices using local resources and materials are taught extensively in academics as energy efficient and eco-friendly practices (Ahmadreza, 2011). However, these traditional building construction practices are disappearing gradually as compared to the modern conventional construction practices with advancement in technology, new materials and new designs, which often do not consider the local climatic conditions and the various advantages offered by the native materials. Hence the building is designed and constructed with local practices of rural Andhra Pradesh with local materials and this paper is aimed at investigating the embodied energy and thermal properties to assess its workability and energy savings to repeat the same type of construction rural areas of Andhra Pradesh in particular in rural India in general. The construction activities occupy 38% of total energy consumption of the world (Anonymous 2007). Residential energy requirements vary from location to location, depending on climate, housing type, and affordable level (Mohsen *et al* 2001 and Lee et al , 2011) investigate the impact assessment of various building materials (concrete vs. steel) on the embodied energy of the building structure, and compare them with the Green Building Rating score attained under the material category for the same structure. There are a wide scope and potential for utilizing the industrial and mine solid wastes for the manufacture of building materials for promoting sustainable construction practices (Reddy, 2009). The use of the “alternative” building materials can reduce the initial production energy required for a reinforced concrete building by 30 - 40%, or the equivalent of 25 - 30 years of operational energy. The energy saved cumulatively over a 50 - year life cycle by this material substitution is on the order of 15 - 20%.(Huberman *et al* 2008).The load-bearing soil–cement block masonry and stabilized mud blocks filler slab have resulted in 62% reduction in embodied energy when compared to reinforced concrete framed structure building and 45% reduction when compared with burnt clay brick masonry and reinforced concrete solid slab building (Reddy *et al* 2008). The results of research conducted by praseeda *et al* 2015 revealed the significant difference in EE of materials whose production involves significant electrical energy expenditure relative to thermal energy use. Energy is one of the most important factors in economic growth and social development in all countries (Hassouneh, 2010 and BRE 2008). For this reason, as in the world, it is observed that the CO2 emissions concerning energy have increased in the last 20 years (Anonymous, 2003) The lesser the cost of the material gives the lesser energy intensively the same has been indicated by Choudary 2013 and Alter, 2013. The literature indicates that the load bearing construction is certainly a better alternative to RC framed construction for up to two storied structures in terms of embodied energy and environmental impacts (Kishore *et al* 2014). The housing sector plays a predominant role in energy consumption so the need to investigate appropriate less energy intensive materials projected by Cole *et al* 1993

Assessment of Embodied Energy of Building Materials Practiced in the Region

The unit comprises an area of 41.3 Sq. M. residence is measured and detailed quantities were drawn as specified in construction and total embodied energy of the unit is calculated Further, thermal conditions in a typical dwelling unit constructed using local materials was studied. The Variations between the ambient air temperature and the indoor air temperature was measured on typical summer and winter days for the selected residential unit. A field survey was carried out using Hotwire Anemometer and the observations of the studied and results were plotted for assessment.

Specification of building materials in construction plays a major role in determining the total energy consumption of the structure. Conventional materials like brick, RCC, glass, steel, and aluminum are energy intensive. A comparison of a few conventional and traditional materials that are available specified generally or predominantly practiced/used for various components of the building such as in roofing, masonry, flooring, and plastering in general, have been calculated and given in tables 1, 2, 3 & 4.

Table 1: Comparison of Embodied Energy for Various Roofing Options

S. No	Material	Energy in MJ/100m^2	% of Energy Equivalent to RCC
1	Conventional RCC	50338	100.0
2	Filler roof	46496	92.4
3	Reinforced Brick in	50214	99.8
4	Channel unit roof	37846	75.2
5	Cored Unit roof	42091	83.6
6	Jack arch roof	118860	236.1
7	Madras Terrace	77990	154.9
8	Palm tree frames and thatched topping	5021	10.0

It is observed from the above assessment that the Conventional RCC roof consumes about 503.38 MJ/ m^2 and is closely followed by filler roof slab and reinforced brick in the roof with 92.8% and 99.8% respectively as compared to RCC roof. However, traditional Jack arch roof and Madras Terrace roof are much more energy intensive, which consumes about 236.1% and 154.9% of energy respectively, as consumed by a conventional RCC roof. Whereas, native practices involving Indian Palm tree frames with thatched topping consume only about 10% (50.21 MJ/ m^2). Thatch roof needs skill labor for construction and if maintained well can last up to 20 years.

Table 2: Comparison of Embodied Energy for Various Masonry Options

S. No	Material	Energy in MJ/10 m^3	% of Energy Equivalent to Brick Work
1	Brick work in 1:4	29830	100.0
2	Fly ash bricks 1:6:9	23751	79.6
3	Traditional Bricks in 1:6	11336	38.0
4	Ashlars Masonry in 1:6	5249	17.6
5	Coarse Rubble stone in 1:6	6864	23.0
6	Burnt clay bricks 1:6	26175	87.7
7	Soil Cement blocks in 1:4	11179	37.5
8	Hollow Cement blocks in 1:4	11025	37.0
9	Rat Trap Bond in 1:4	23047	77.3

Table 3: Comparison of Embodied Energy for Various Flooring Options

S. No	Material	Energy in MJ/100 m^2	% of Energy Equivalent to Cement Tile Flooring
1	Cement concrete flooring	23318	80.2
2	Terrazo flooring	11320	38.9
3	CC flooring with burnt brick chips	16613	57.1
4	Red oxide flooring	14198	48.8
5	Precast local cement tile flooring	29081	100.0
6	Red sand stone flooring in cement mortar	7610	26.2
7	Local Napa stone flooring in cement lime	7532	25.9
8	Marble stone flooring	10901	37.5
9	Kota stone flooring	24281	83.5

Table 4: Comparison of Embodied Energy for Various Plastering Options

S. No	Material	Energy in MJ/100 m^2	% of Energy Equivalent to 1:3 Cement Plaster
1	12 mm plaster 1:3	5653	100.0
2	12mm plaster 1:4	4603	81.4
3	12mm plaster 1:5	4239	75.0
4	12mm plaster 1:6	3876	68.6
5	12 mm cement lime plaster1: 1:6	3518	62.2
6	12 mm cement lime plaster1:2:9	2910	51.5

Ashlar masonry (5249 MJ/10 $m^{3)}$ and coursed rubble masonry (6864 MJ/10 $m^{3)}$ done in cement mortar 1:6 consume 17.6% and 23.0% of the conventional brickwork executed in cement mortar (29830 MJ/10 $m^{3)}$ reducing the energy consumption in masonry considerably. Depending upon the geographical location and materials available in the region, stone masonry reduces the energy demand required for manufacturing the bricks. Soilcement blocks (11179 MJ/10 $m^{3)}$ and hollow cement blocks (11025 MJ/10 m^3) consuming 37% and 37.5% respectively which follows next only to the traditional stone masonry construction.

Ceramic and vitrified flooring options with the advent of new flooring materials which are highly energy intensive are flooding the market in recent times, giving less scope for the use of local stone as an option for the same. Materials like marble and others are being transported across the country traveling around 1000 KMts before reaching the site. Whereas, local stone (75.32 MJ/ m^2) especially available in the Eastern Ghats region is hard and durable and consumes 25.9% of the total energy as compared tocement tile flooring (29081 MJ/ m^2). Apart from the above, other industrial materials like steel & aluminum are highly energy intensive. As compared to the energy involved in the production of these materials, the energy involved in transportation is negligible (Reddy, 2003). Aluminum, in spite of weighing lower than steel, consumes six times higher energy than steel. A traditional method of using timber for openings is reducing in modern context due to various reasons and specification of aluminum for doors and UPVC for windows is growing in recent times thus increasing the energy demand. Consumption of these materials need to be discouraged in view of reducing the energy demand. Glass though has lower embodied energy than steel, it increases the energy consumption in building due to overheating conditions in tropical countries like India.

THERMAL BEHAVIOUR OF NATIVE BUILDING MATERIALS

Thermal Conductivity (k) is one of the most important thermal properties of a building material, the reverse of which is known as Resistivity. The thermal conductivity is a physical property of a material and defines the ability of a substance to conduct heat. For building applications, it is generally considered to be constant (Ramesh and Kaushik, 2005).

Consider heat to be transferred from one side at temperature T_A to the other at temperature, T_B. Assuming steady state, *i.e.*, the heat transfer rate, q per unit area of the structure is the same through each layer,

$$q = Ah_a(T_A - T_o) = AK_1\frac{T_o - T_1}{L_1} = A\frac{T_1 - T_2}{L_2}K_2 = A\frac{T_2 - T_3}{L_3}K_3 = Ah_b(T_3 - T_B) \tag{1}$$

Where A is the surface area, $h\Delta T$ represent heat transfer by both convection and radiation, $\frac{K}{L}\Delta T$ represent heat transfer by conduction through various layers. L_1, L_2, and L_3 are the thickness of the layers of thermal conductivities,

K_1, K2 and K_3 respectively and the interface temperatures are $T_{o,}$ $T_{1,}$ T_2 and T_3. Thus

$$q = \frac{T_A - T_0}{R_a} = \frac{T_0 - T_1}{R_1} = \frac{T_1 - T_2}{R_2} = \frac{T_2 - T_3}{R_3} = \frac{T_3 - T_B}{R_b} \tag{2}$$

Where R's are thermal resistances as given by

$$R_a = \frac{1}{Ah_a}, R_1 = \frac{L_1}{AK_1}, R_2 = \frac{L_2}{AK_2}, R_3 = \frac{L_3}{AK_3}, R_b = \frac{1}{Ah_b} \tag{3}$$

Eliminating interface temperatures T_o, $T_{1,}$ T_2 and T_3 in the above equation, one obtains the total heat transfer rate through the composite layer as

$$Q = \frac{T_A - T_B}{R} \tag{4}$$

Where, $R=R_a+R_1+R_2+R_3+R_{b;}$ Hence, the total thermal resistance (R) in the path of heat flow from temperature T_A and T_B is the sum of several different thermal resistances.

Another important property of the material is the volumetric heat capacity $Q_{v,}$ which is equal to the quantity of heat required to raise the temperature per unit volume of the material by 1^0C, which is given by the product of specific heat and density of the material. Thermal diffusivity $\bar{v}$, is the ratio of the heat conducted by the material to the heat stored in it and is given in m^2/s. It determines the rate at which a non-uniform temperature distribution approaches equilibrium condition and is given by the ratio between thermal conductivity and product of density and specific heat of a material.

$$\bar{v} = k / \rho c \qquad \text{(Thermal diffusivity m}^2\text{/s)} \tag{5}$$

where k is the thermal conductivity, ρ is the density and c is the specific heat of the material.

Understanding time lag and decrement factor are important to determine the thermal behavior and heat storage capabilities of the material. Time lag and Decrement factor are determined by the property of the material and not on the climatic conditions (H.Asan, 2005). The phase lag or time lag is the time delay between the impact of the diurnal variation of the temperature and radiation on the external surface, and the resultant temperature variation on the internal surface.. The time lag for homogeneous materials subject to the temperature fluctuations with a 24 hours' period is given approximately by the formula:

$$\psi' = 1.38L\sqrt{\frac{1}{\bar{v}}} \tag{6}$$

where ψ' is the time lag (in seconds) L is the thickness(m) and ($\bar{v} = k / \rho c$) is the thermal diffusivity (m^2/s). Another important thermal property of a material is it U- value, where U is the Air to Air Transmittance and is given by

$$U = 1/R_a \tag{7}$$

And R_a, air to air resistance is the sum of the resistance offered by individual material and the surface resistance offered on the internal as well as the external surface.

$$R_a = 1/f_o + R_b + 1/f_i \tag{8}$$

Where $1/f_o$ and $1/f_i$ are, the resistances offered on the external and internal surfaces respectively. While internal surface resistance for wall and roof are, constant and do not depend on orientation and exposure, external surface resistance is dependent upon the orientation of the surface and the exposure to direct solar radiation and external surface resistance for roof depends upon exposure conditions. In the current context of calculating thermal properties of native building materials, the south wall with normal exposure is considered as a general case for walls ($1/f_o$ = 0.076 m^2 deg C/ W) and roof with normal exposure is considered ($1/f_o$ = 0.044 m^2 Koenigsberger, 2012). Based on the above equations 1 to 8, various thermal properties like thermal diffusivity, U- value and time lag for wall and roof are calculated for different native building materials given in Table 5.

Table 5: Various Thermal Properties of Available Local Building Materials for roof topping and walls

Material (w/r)	Thermal Conductivity W/M Deg C	Density Kg/ m^3	Specific Heat J/Kg Deg C	Width (mts)		Thermal Diffusivity * 10^{-6} m^2/s	U- Value W/m^2DegC		Time Lag Hrs	
Laterite Stone (w)	1.83	2160	710	0.4	-	1.1933	2.39	-	8.4	-
Indian Palmyra Palm (w/r)	0.11	640	1210	0.15	0.075	0.1420	0.64	1.20	9.2	4.6
Bamboo (w/r)	0.159	721	126	0.1	0.1	1.7502	1.21	1.29	1.7	1.7
Thatch (r)	0.05	240	2050	-	0.02	0.1016	-	1.82	-	1.4
Mud (w)	0.518	1922	1382	0.2	-	0.1950	1.71	-	10.4	-
Straw (w/r)	0.07	240	1000	0.02	0.02	0.2917	2.06	2.30	0.9	0.9

AN EXPERIMENTAL CASE STUDY DESIGN AND CONSTRUCTION

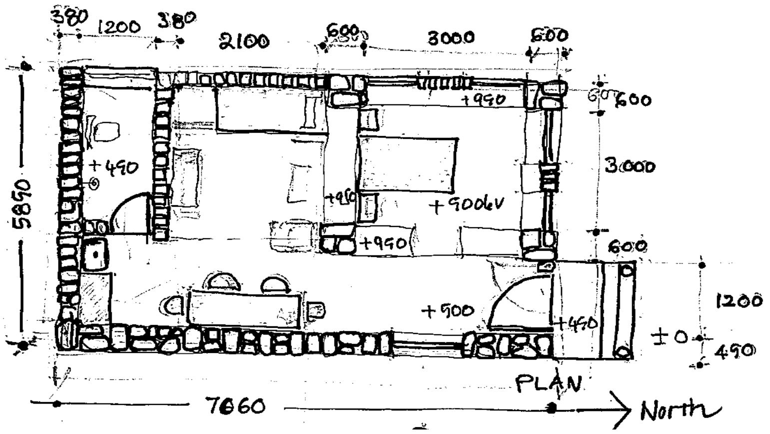

Figure 1: Rural Dwelling with a Multipurpose hall / 1 BHK with Local Material

A typical residence of 41 sqm of one-bed unit with kitchen cum dining space along with a toilet has been designed and constructed in Ravicherla, Andhra Pradesh as shown in Figure 1 and 2. It is a load bearing structure with native laterite stone with cement mortar 1:6, Indian palm for pitched roof frames and straw with thatch 0f 300mm thick roof covering are used to construct the residence by the Artisans with local skills. In addition, few conventional materials such as AAC blocks, pre-stressed steel frame for the circular window, U PVC Windows and Aluminum doors are also used in the building, keeping the certain current practices.

As shown in *Figure 3,* superstructure masonry *of* 380 mm - 600mm was built in laterite stone and cement mortar. Flooring is done using local Napa stone sourced within 50 km radius. Indian palm is used in preparing framework for the roof and as a vertical member to support the roof as shown in *Figure 4.*

This timber framework for the roof is covered with bundles of straw tied together and arranged in an alternating pattern to form a thick layer of roof cover. Main entrance 1200mm wide opens from 1500mm wide passageway and expenses as bedroom on one side and ends into a kitchen in the other end.

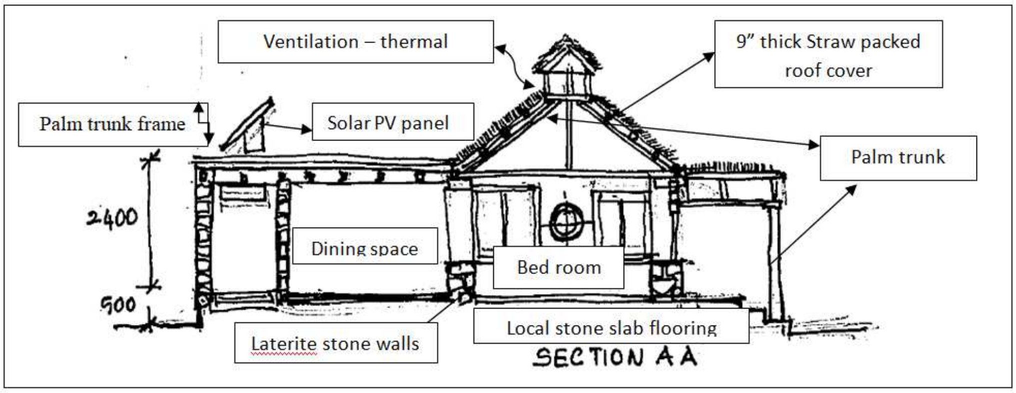

Figure 2: Cross Section of Rural Dwelling Unit Showing a Few Components

Figure 3: Southern Side View of the Rural Dwelling

Figure 4: Palm Trunk Roof Frames and Laterite Stone Wall

The kitchen includes a small kitchenette and dining space for four people. Attached to the dining is the toilet and with the entrance oriented along the north direction. Aluminum doors and U - PVC and steel windows are specified and fixed in the residence.

EMBODIED ENERGY

Embodied energy calculations can be split into – energy involved in the production of the materials and energy involved in the transportation of the material from production to site(Ramesh,2011, 2015; Reddy, 2003). However, in this paper, the only energy involved in the production of the materials is considered in calculating the total embodied energy. The total embodied energy of the studied unit is calculated, where most of the materials were sourced locally and within a radius of 50 Km. Actual quantities of various materials used in foundation, masonry, roof, and openings were drawn from detailed measurements of the studied unit and the embodied energy of each material is calculated. Integrating the energy values of all materials gave the total embodied energy of the studied unit as given in table 6.

Table 6: Embodied Energy of Various Materials as Specified in the Rural Dwelling (Figure 2)

S. No	Material (Units)	Quantity	Energy MJ/Unit	Total (MJ)
1	Stone (Cu.M)	27.015	686.8	18553.9
2	Cement (tonnes)	2.9	5850	16965.0
3	AAC Blocks (Kg)	907.5	3.6	3267.0
4	Local Napa stone Flooring (SqM)	41.3	75.37	3112.8
5	Pressed Steel Frame for circular window (Kg)	139	42	5838.0
6	UPVC Windows (SqM)	3.9	2069.4	8070.7
7	Sand Filling (CuM)	55.75	0	0.0
8	Aluminum Door (Sq M)	3.47	6000	20820.0
9	Thatch roof with timber (Indian Palm) frame and 400 micron Recycled PVC Sheet (SqM)	63	50.24	3165.1
Total Energy in MJ				**79792.5**

The energy involved in the transportation of materials to the site is not considered. The total energy 79.79 GJ is given for the total built-up area of the studied residence, which accounts to about 1.93 GJ/m^2. Major savings in terms of energy can be attributed mainly towards the local materials and techniques like course rubble masonry, Local Napa stone (local granite) flooring and thatch roof with Indian Palm trunk frames. However, the energy consumed could have been further reduced if the locally sourced timber was used for the openings. It is to be noted that the building consumed only about 37.32% of energy (1.09 GJ / m^2) as compared to a building with conventional materials which consumes about 2.92

GJ/ m^2 without considering the energy contented by the openings.

THERMAL CONDITIONS IN THE RESIDENCE

Vijayawada classified as Warm Humid Climate as per ECBC 2009 (Energy Conservation Building Code) has summer temperatures reaching 47^o C. With very high outdoor air temperature, it is important to maintain the indoor air temperatures below ambient air temperature inside the building to avoid overheating. To analyze the thermal performance of the native building materials when specified in construction, the indoor air temperature was measured on 21/5/2016 and 21/12/2016 and plotted on the graph against the ambient air temperature on the respective days in the studied residence at Ravicherla, Vijayawada. *Figure 5* explains the existing ambient air temperature and the Indoor air temperature measured for a 12-hour period with 3-hour interval on 21/5/2016, the hottest month in a year. *Figure 6* explains a similar condition between ambient air temperature and Indoor air temperature measured for 12-hour period with a 3-hour interval measured on 21/12/2016, winter month in a year.

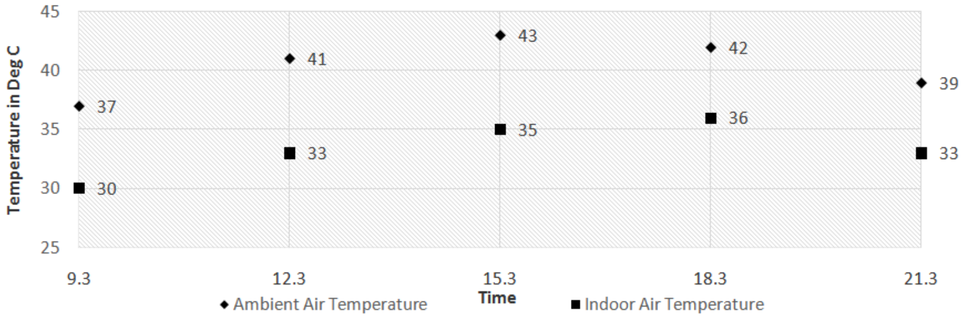

Figure 5: Variation between the Ambient Air Temperature and Indoor Air Temperature 21/5/2016

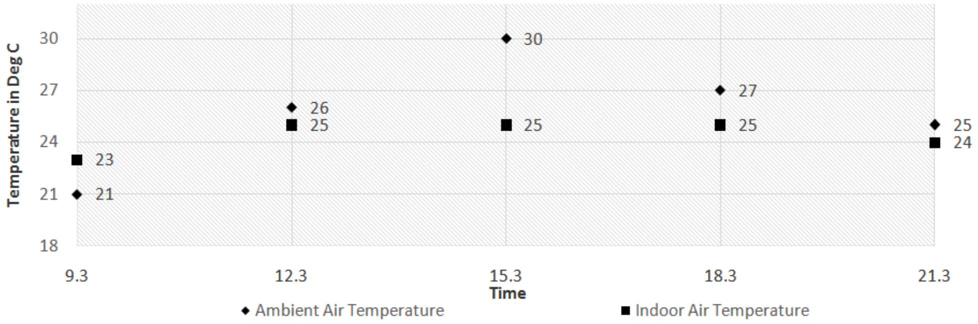

Figure 6: Variation between the Ambient Air Temperature and Indoor Air Temperature 21/12/2016

RESULTS AND DISCUSSIONS

Specification of building materials for various components of the building is a very important consideration to achieve sustainability and without causing any adverse impact to the environment. Consumption of energy for manufacturing the building materials leads to CO_2 emissions and resource depletion (Debnath, 1995). Investigations found that Ferro cement roof and Mangalore tiles roof consume about 21.6% and 31.1% less energy respectively as compared to an RCC roof. Furthermore, traditional roofing technique adapted using native materials like thatch roof with Indian palm framework (50.24 MJ/ m^2) consumes less than 10% of energy as compared to RCC roof (730 MJ/ m^2). It was found that soil- cement block building (1.64 GJ/ m^2) has consumed only 55% of energy when compared to conventional brickwork building (2.9 GJ/ m^2) and the studied building consumed only about 37.32% of energy (1.09 GJ / m^2) with a significant reduction in the total embodied energy. Analysing the thermal properties of materials from table 5 when plotted in graphs below (fig*ure 7, 8 & 9),* explains that the thermal behavior of materials can be altered with varying thickness when specified in construction. Building materials do behave differently with varying thickness but display similar thermal properties when the thickness is below 0.05M (H.Asan, 2005).

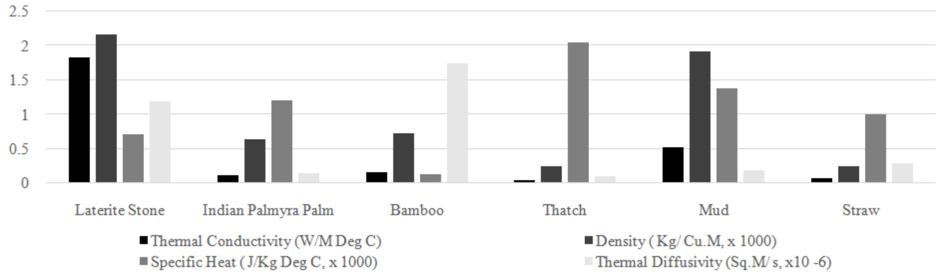

Figure 7: Thermal Conductivity, Density, Specific heat and Thermal Diffusivity of the Vernacular Materials

Thermal diffusivity of a material depends upon its thermal and physical properties including thermal conductivity, specific heat, and density of the material. As given in *figure 7,* it is observed that bamboo possesses highest thermal diffusivity despite having low thermal conductivity due to very low specific heat whereas Thatch has the lowest thermal diffusivity because of high specific heat, density, and low thermal conductivity values. Both materials put together for wall and roof provide maximum comfort conditions.

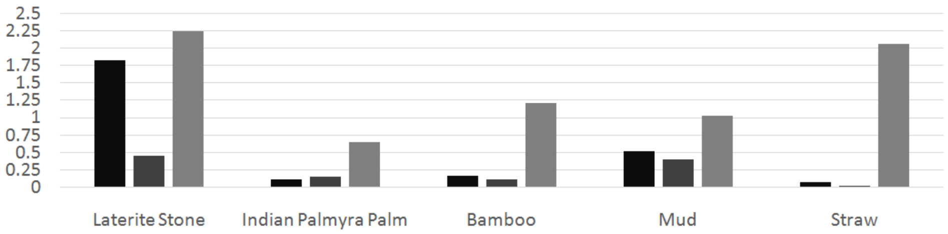

Figure 8: Thermal Conductivity, Thickness of the Material and Resultant U- Value of the Vernacular Materials

Materials studied can be categorized into two groups in terms of U-values – ‘materials with high thermal conductivity and high U- values’ and ‘materials with lower thermal conductivity and considerably higher U- values’. From *figure 8* it is understood that U- values of a material can be altered with varying thickness. With the change in thickness of the material specified in construction, U- values tend to change; a thickness of the material directly influences the resistance offered to the heat flow and consequently the resultant U-value.

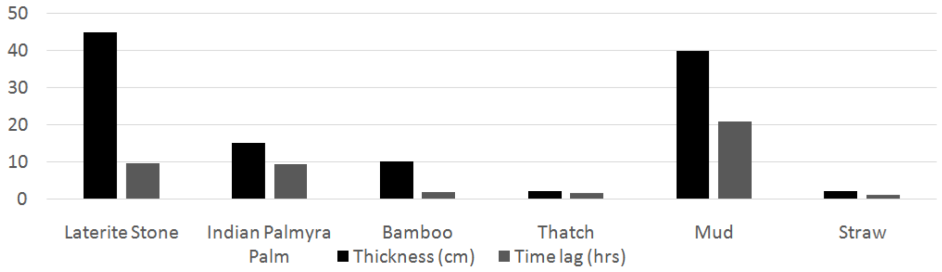

Figure 9: Thickness of Material used in Construction and Resultant time Lag of the Vernacular materials

The time lag of a material though is dependent on the thermal diffusivity values; thickness of the material specified in construction determines the actual time lag. As shown in *figure 9* materials like thatch and straw with a small thickness of 0.02m possess similar time lag. Time lag increases with increase in thickness of the material with which they are specified in construction. Laterite stone and mud wall exhibit higher time lag as the thickness increases in building components from 0.2m - 0.45m in both the cases.

Analyzing the data from *figure 5 & figure 6* indicates that in the month of May, the indoor air temperature was found to be lower by 6-8 degrees than ambient air temperature with the indoor air temperature touching its maximum at around 1800 hrs (6.00P.M.). For the recorded data in the month of December, it was found that indoor air temperature was almost constant with slight variation during daytime.

Though the variation in the thermal properties of the materials is high in nature, native materials such as laterite stone, mud and palm when used for walls; palm, thatch and straw when used for roofs, has shown adequate results to encourage the traditional practices using native materials in this region, with due consideration to energy consumption and further reducing the impact on environment.

CONCLUSIONS

A country with over 1.25 billion people, India, has most of its population living in rural areas which have rich natural resources and by-products from agricultural produce. These native materials with appropriate techniques if deployed for construction of a dwelling unit could considerably reduce the energy consumption and thus the impact on the environment. The inferences of this paper give a broad understanding of the traditional construction with native building materials in terms of its embodied energy and thermal behavior.

- Native building materials show a considerable impact on energy consumption, by reducing the total energy required for the construction from 2.9 to 1.09 $GJ.m^2$. Native varieties of stone can substitute brick masonry reducing the energy consumption to about 17.6 – 23.0%. Discouraging specification of aluminum and steel for openings will help further reduce the energy consumption. Traditional roof with palm trunk frame and thatch topping is the most energy-efficient option consuming only about 10% energy required by a conventional RCC roof. If maintained well, this can last up to 60 years with minimum maintenance. However, it can be limited only to the ground floor and vertical expansion is not possible.
- In addition, analysis of thermal properties of the native building materials in the scattered Eastern Ghats region of India that include Laterite stone, Indian Palmyra Palm, Bamboo, Thatch, Mud, and Straw indicate that the energy consumption required in buildings to maintain desirable thermal conditions could further be reduced. These materials exhibit higher time lag and lower U- values, and when specified with considerable thickness and helps in maintaining lower indoor air temperatures (less by 6-8 degrees) as compared to the ambient air temperature during summer and stable indoor conditions during winter.

Only six materials have been considered in this study while the opportunity of using the local materials for construction is immense whose thermos physical properties can be further analyzed to understand their respective embodied energy and thermal behavior in buildings. Though the results pertain to typical house typology in Ravicherla, Vijayawada from the Eastern Ghats, many other locations having similar conditions can explore the possibilities of reducing the embodied energy of the building using materials indigenous to the place, with due consideration to energy conservation and climate change.

REFERENCES

1. *Ahmadreza Foruzanmehr, M. V., 2011. Vernacular Architecture: Questions of Comfort and Practicability. Building Research and Information , pp. 274-285.*
2. *Attar, S. G. A., 2013. Alternative walling system for Low Cost Housing by Using Bamboo. International Journal of Innovative Technology and Exploring Engineering, pp. 277-281.*
3. *Anonymous, Lighting the Way: Toward a Sustainable Energy Future, Inter Academy Council, 2007, http : // www .interacademycouncil.net/ File.aspx?id = 24548.*
4. *Anonymous, Turkey: Environmental Issues, Energy Information Administration,2003, http://www.eia.doe.gov/emeu/cabs/turkenv.html.*
5. *B.V.Venkatrama Reddy, K. J., 2003. Embodoed Energy of common and alternative building materials and technologies. Energy and Buildings, Volume 35, pp. 129-137.*
6. *BRE group, 2008, "Green Guide to Specification", http://www.bre.co.uk/ greenguide/, accessed May 10, 2010*
7. *Cole, R. J., 1993 'Embodied Energy and Residential Building Construction', Proceedings: Innovative Housing '93, Volume 1: Technology Innovations, pp. 49-59.*
8. *Choudary, S., 2013. Prospects of Low cost Housing in India. Geo Materials, pp. 60-65.*
9. *Debnath, A. S. S. a. S. Y., 1995. Comparative assessment of energy requirements for different types of residential buildings in India. Energy and Buildings, Volume 23, pp. 141-146.*
10. *H.Asan, 2005. Numerical Computation of time lags and decrement factors of different building materials. Building and Environment, pp. 615-620.*
11. *Hassouneh K, Al-Shboul A, Salaymeh A, Influence of windows on the energy balance of apartment buildings in Amman, Energy Conversion and Management, 51(8), (2010), 1583–1591,DOI: 10.1016/j.enconman.2009.08.037.*
12. *Huberman N, Pearlmutter AD, Life-cycle energy analysis of building materials in the Negev desert, Energy and Buildings, 40(5), (2008), 837-848, DOI 10.1016/ j.enbuild .2007 .06. 002*
13. *India, C., 2011. Census 2011. [Online] Available at: http: // www. censusindia.gov.in / 2011 census / PCA / PCA _ Highlights/pca_highlights_file/India/Chapter-1.pdf;[Accessed Jan 2017].*
14. *Kishore. K. N and Chouhan. J. S, (2014), "Embodied energy assessment and comparisons for a residential building using conventional and alternative materials in Indian context", J. Inst. Eng. India Ser. A, Vol. 95(2), pp. 117-127*

15. *Koenigsberger,O H., T. G. I. A. M. S. V. S., 2012. Manual of Tropical Housing and Building Climatic Design. s.l.:Universities Press 9India) Private Ltd.*
16. *Lee B, Trcka M, Hensen JLM, Embodied energy of building materials and green building rating systems — a case study for industrial halls, Sustainable Cities and Society, 1(2), (2011), 67-71, DOI 10.1016 /j.scs. 2011. 02. 002.*
17. *Mohsen MS, Akash BA, Some prospects of energy savings in buildings Amman, Energy Conversion and Management, 42(11), (2001), 1307–1315, DOI 10.1016/S0196-8904(00) 00140-0.*
18. *Praseeda, K L, Venkatarama Reddy, B V., and Mani, Monto,(2015) 'Embodied energy assessment of building materials in India using process and input–output analysis', Energy and Buildings 86:677-686, January 2015, DOI: 10.1016/j.enbuild.2014.10.042*
19. *Ramesh, S., Kaushik,S K , 2005. Energy Conservation Studies in Buildings. New Delhi, PCRA.*
20. *Ramesh,S, Kunapareddy, K., June 2015. Ecological Integrity and Environmental Protection for Vijayawada Region- Sctered Eastern Ghats. International Journal of Sustainable Built Environment, pp. 109-116.*
21. *[21] Ramesh, S, 'Appraisal of Vernacular Building Materials and Alternative Technologies for Roofing and Terracing Options of Embodied Energy in Buildings' 2011 2nd International Conference on Advances in Energy Engineering, (ICAEE 2011) December 27-28, 2011, Bangkok, Thailand, Energy Procedia 00 (2011) 000–000, Available online at www.sciencedirect.com, Energy Procedia, www.elsevier.com/locate/procedia.*
22. *Reddy BVV, Sustainable materials for low carbon buildings, International Journal of Low-Carbon Technologies, 4(3), (2009), 175-181, DOI 10.1093/ijlct/ctp025.*
23. *Reddy, B V V., Jagadish, K S., 'Embodied energy of common and alternative building materials and technologies', Energy and Buildings, 35(2), (2008), 129-137, DOI DOI 10.1016/S0378-7788(01) 00141-4.*
24. *Saboor S, A.B.T.P., 2014. Analytical Computation of Thermal Response Characteristics of Homogeneous and Composite Walls of Building and Insulating Materials Used In India. Ahmedabad, s.n.*
25. *Susanne Bodach, W. L. J. H., October 2014. Climate responsive building design strategies of vernacular architecture in Nepal. Energy and Buildings, pp. 227-242.*