Sustainable infrastructure-sustainable building design & construction

Sheela Eshwariah
Environment Protection Training and Research Institute

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Dr. M. Viswanadham [1] S.Eshwariah [2]

1. *Department of Civil Engineering, Jawaharlal Nehru Technological University, Hyderabad , India*
2. *A.P State Housing corporation Ltd, Hyderabad, India*

Abstract

Construction is a major consumer of natural resources, a potential polluter of environment and yet indispensable for socio-economic development. Sustainable Building design aims at durability, economy, reducing pollution and environmental degradation. The embodied energy content of different materials help in identifying alternative materials and methods of construction. It helps in how energy can be saved by selection of one building component or complete building system when the alternative systems can satisfy all the physical requirements- in terms of strength, stiffness and thermal performance of the building.

Building materials are responsible for about 20 percent of green house gasses emitted by the building during its life time. Green buildings shall use the products that are non-toxic, reassemble, renewable and/or recyclable wherever possible. Locally manufactured products are preferred so that the collective material environment of locality remain a constant and moreover the fuel for transport of material is saved.

Experimental study is made on unconditioned single room tenement houses constructed with burnt clay bricks, machine made sand cement blocks and the local stone masonries and different roofs of monolithic RCC, composite section of shabad stone+PCC and loose shabad stone on country wooden frame. The energy content of materials used was computed and the surface temperatures inside and outside were measured continuously for 48 hours with 2 hour interval to study their thermal behaviour. They were rated with their energy consumption and the final Thermal Performance Indexes. All the sections were found to be structurally safe but their energy consumption and their thermal performance is varied. It is found that the building sections made with locally available material found to be safe, durable, energy efficient and thermally comfortable compared to those with those of high energy materials like RCC.

Key words: sustainable construction, green buildings, thermal comfort, embodied energy, energy efficient construction, affordable housing construction

1 Introduction

Sustainable development is the development that meets the need of present without compromising the ability of future generations to meet their own needs. The goal of sustainable environment is to ensure that every one has secure living environment which promotes health and well being and provision of which deos not require an unsustainable level of resource use. Construction is indispensable for development but also a major consumer of natural resources and potential polluter of the environment. Sustainable management of construction resources and control of environmental degradation will require the increasing use of energy efficient and clean technologies, utilising renewable natural resources.

The building materials industry is also a major user of the world's non-renewable energy sources and minerals. The building construction industry, which is the primary infrastructure industry consumes 40% of materials entering the global economy and generates 40-50% of global output of GHG emissions and the agents of acid rain. Therefore there is concern about the impact of the resource use in buildings on the global environment. The energy not only includes the use of fuels in in production process, and in transporting them to the factory. It also includes the energy used to make and maintain the machinery used in production process.

The proportion of national energy consumption used in buildings is over 50 percent. While largest part of this energy relates to energy consumption of the buildings in use, the used in production of buildings is a significant and a growing element of this total energy use.

The term Green building refers to a structure and using process that is environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition. The material required for construction should also meet the requirements of strength, dimensional stability, and thermally efficient. Sustainable Building design should aim at durability, economy and reducing pollution and environmental degradation.

A building designer should have Professional judgement in the selection of material for building how to save energy in selection of a building assembly, building component or complete building system in terms of strength, stiffness and thermal performance. Strength is the measure of stress required to fracture the material. Stiffness is the rigidity of the material, the extent to which it resists deformation and dimensional stability is the ability of material to maintain its essential or original dimensions while being used for its intended purposes. Thermal performance is the capacity of building sections to provide resistance to changing climatic conditions.

Strength is the measure of stress required to fracture the material. Stiffness is the rigidity of the material, the extent to which it resists deformation and Thermal performance is the capacity of building sections to provide resistance to changing climatic conditions.

Thermal resistivity is the characteristic property of material which depends on density, porosity, moist content , fibre diameter, ,etc.,. The energy efficiency of different building materials in relation to performance is given by comparing the energy costs of obtaining one unit of some property the designer is interested in using a range of materials for use of structural materials, it is the stiffness of the material which is of greater importance. These costs are even higher than the range of structural costs, would be used because of other advantage of the durability they offer. Durability is defined as the service life of a material under given environmental conditions.

Increasing the efficiency of energy use in building- materials production is important for three reasons; its oblivious advantage of energy saving savings, making the durable building material made available at prices affordable by the poor and help in reducing the environmental degradation.

2. Energy and environment:

The scarcity and cost of durable building materials is considered as one of the main obstacle for better housing standards. As populations grow and become more urbanised, the soil and vegetable materials on which traditional rural building methods have depended are no longer cheaply or freely available and they are being replaced by processed or factory made materials. As a result the produced materials have become too expensive to the poor and likewise Large scale Industrially produced materials have become Energy intensive. Therefore designers and builders have to work on the choice of Building materials from the point of view of Total embodied energy. Production of these materials has added another problem of environmental pollution. Pollution arising from the production of building materials arises at three levels.

- At local level (under 1 km),caused by gasses produced in combustion of fuels, causing health risk to workers and local residents.
- At regional level (up to 100 km) pollution can cause climatic modification through thermal effects or persistence of particles in the atmosphere.

At Global level it is the emittence of greenhouse gasses causing Global warming and other gasses causing acid rains. The principal measure which can be taken to reduce energy pollution associated with building materials processes is to reduce their total primary energy consumption. Similarly reduction in greenhouse gases is also achieved by fuel substitution.

Table1. Contributions to green house warming by various gases

Gas	Contribution to warming (percentage)
Carbondioxide	50
Methene	19
CFCs	17
Tropospheric ozone	8
Nitrous oxide	4

Henderson and shorrock, 1990

Fuel	CO_2 emmisions,Kg/GJ	
Coal	91	92
Natural gas	50	55
Oil(petroleum)	69	84
Electricity		231

Henderson and Shorrock ,1990/

Figures for delivered energy include overheads of generation and distribution

Hence Energy conservation is an important issue in building design. It has become necessary to minimise the total energy consumed during buildings life time. The total energy consumed in building during its life time may be many times that consumed in its construction. In national and global budgets; the material industries of which building materials comprise a large portion are ,in general, energy-intensive , and have been shown to account for over 20 percent of world fuel consumption. In most cases the energy embodied in materials of which a house is made will be several times larger than annual consumption of energy in use, so there will be faster return on savings made in construction energy than on equivalent savings made in energy consumption.

Building designers have much control over the total amount of energy embodied in a building, through proper selection of materials than they have over the amount of energy consumed annually in use.

Building materials are responsible for about 20 percent of green house gasses emitted by the building during its life time. Green buildings shall use the products that are non-toxic, reassemble, renewable and/or recyclable wherever possible. Locally manufactured products are preferred so that the collective material environment of locality remain a constant and moreover the fuel for transport of material is saved.

2.1 Energy analysis:

Energy analysis is the evaluation of the total quantity of energy which has to be taken from primary energy sources in order to produce a given commodity or service. It includes not only the direct use of fuels in production process but also the amount of fuel used in obtaining the raw materials used in production process and transporting them to the factory. It should also include the energy used to make and maintain the machinery used in production process. The total quantity of energy calculated in this way is called the gross energy requirement of commodity and is expressed in the appropriate energy units.

Figure below illustrates the process of energy analysis, and shows that four levels of energy use can be distinguished.

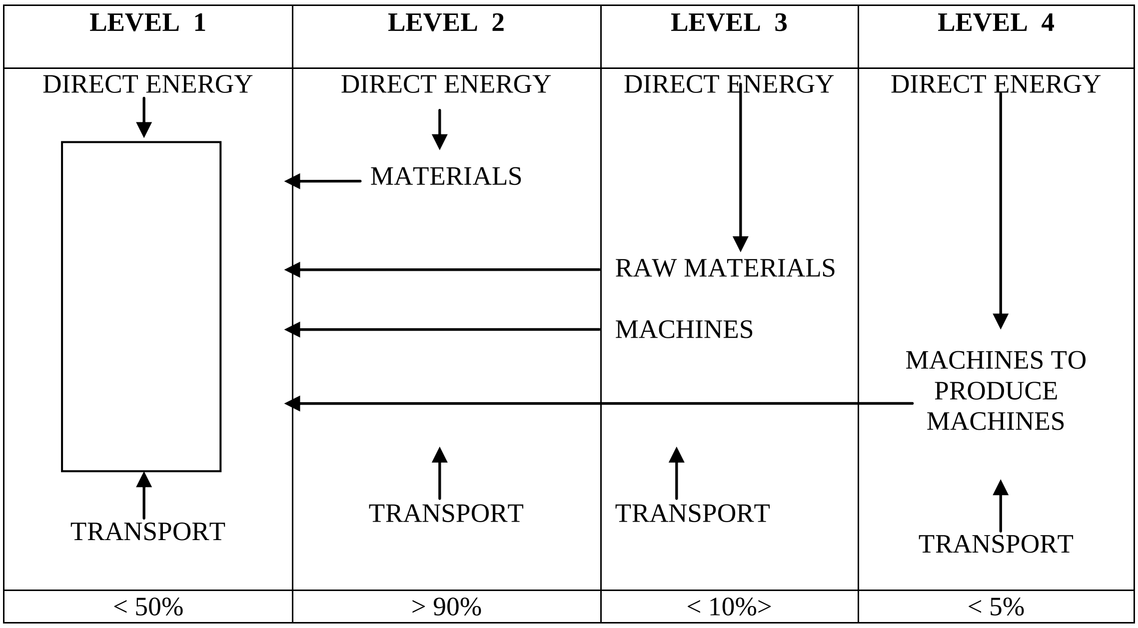

Figure: 2.1 Materials and Energy flows in building production

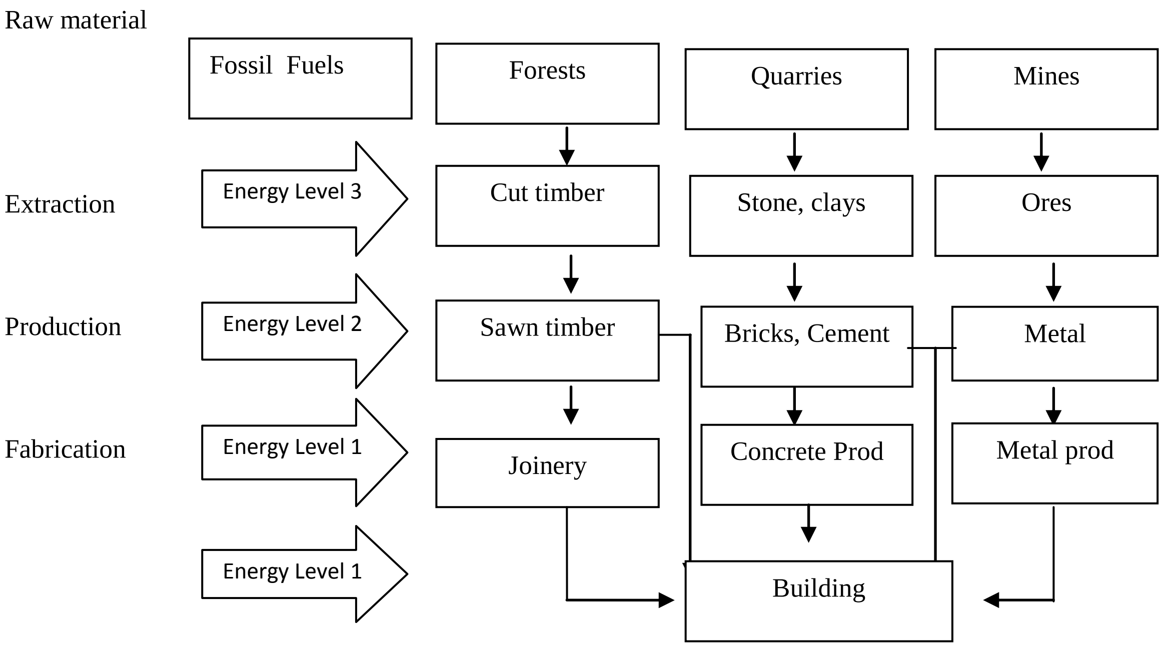

Figure: 2.2 The Sources of the energy used in building Materials manufacturer

- The first is the energy used in process itself.
- The second is the energy used in the production of the materials used in the process
- The third combines the energy used in the equipment and other inputs to the production process
- The fourth includes the machinery needed to make the machines and materials inputs.

It has been found that levels 3 and 4 are unlikely to contribute more than 10 percent at most to the gross energy requirement, so they can be generally ignored, in obtaining a first approximation.

However, it is important to note that a high portion of energy used in most buildings is used in production of small number of key materials, including concrete, mortor, plaster, bricks and timber.

2.2 Energy requirement for building materials manufacture:

On the basis of energy intensity, (the gross energy requirement to manufacture unit weight), building materials have been classified in to four categories; high,medium,and low-energy materials.

- Very high-energy materials are those with energy intensities above 50GJ/ton.
- High-energy materials are those with energy intensities between 50 and 5Gj/ton like, Aluminium,steel, plastics, glass and cement.
- Medium-energy materials are those with energy requirements between 0.5 and 5GJ/ton like, concrete,lime, plaster and building blocks based on cent or lime and fried-dry bricks and tiles and transported Timber.
- Low-energy materials are those with energy requirements less than 0.5GJ/ton like aggregates for concrete and mortar, natural and artificial pozzolanas, soil and stabilised soil.

Table: 2.1 Comparative energy requirements of building materials

Material	Primary energy requirement GJ/ton
Very-high-energy	
Aluminium	200-250
Plastics	50-100
Copper	100+
Stainless steel	100+
High-energy	
Steel	30-60
Lead, zinc	25+
Glass	12-25
Cement	5-8
Plasterboard	8-10
Medium-energy	
Lime	3-5
Clay bricks and tiles	2-7
Gypsum plaster	1-4
Concrete	
In-situ	0.8-1.5
Blocks	0.8-3.5
Precast	1.5-8
Sand lime bricks	0.8-1.2
Timber	0.1-5
Low-energy	
Sand, aggregate	<0.5
Flyash,RHA,volcanic ash	<0.5
Soil	<0.5
Spence and Cook, 1984 and Lawson, 1991	

Building sand	15MJ/Ton
Broken stone	100 MJ/Ton
Crushed aggregate	220MJ/ton
Rai,India	

1MJ =238.9k cal or 1 Cal = 4. 184J

Fuel consumption of individual Brick kiln in Delhi vary from 100 to over 300kg of coal per 1000 bricks .i.e.,2600 t0 7800MJ/1000 bricks. Gandhi, india,1986

In addition to the difference in quantity of energy used, there are also significant differences in the quality of energy or fuel used. The High –energy materials commonly depend on high grade fuels such as electricity, oil and pulverised coal in their manufacturing processes which are costly and may also have to be imported. By contrast the medium-energy materials, particularly bricks, tiles and lime, can often use lower grade fuels such as fire wood, low-grade coal or oil, sawdust and crop-waste, which are more available. They can also often utilise solar energy for drying process. Most of low energy materials use little purchased energy, though they use significant amount of human or animal labour.

A final difference which is characteristic of these types of manufacture is that the high-energy materials tend to be manufactured in large production units, and therefore require more energy in distribution to the point of use than for medium or low energy materials. The energy cost of transporting building materials 100km by road is about 250MJ/ton. Thus the transport energy of delivery of bricks from a large scale brick works or block plant where the average delivery radius might exceed 100km would add 10 to 15 percent to the total energy cost of the delivered materials. Transport by rail or water are considerably cheaper in energy costs. Below table shows some typical figures for transport energy requirements, per ton per Km distance for different modes of Transport.

Table: 2.2 Energy requirements for different modes of Transportation

Mode	Energy intensity MJ/ton/Km(India)
Truck	2.85
Van	-
Rail	0.9
Water:	
Sea	0.09
Inland	0.9

from Rai,1986 (primary energy interest investment energy)

It may be noted that transport by truck is over three times more costly in energy terms than transport by train or river boat; transport by sea-freighter costs only 1/30th that by truck.

3.Thermal performance of building sections

The sensation of thermal comfort in indoor is closely related to the heat balance between the human body and the surrounding environment. Hence an affordable shelter that can keep one cool during summer and warm during winter is desired. To a greater extent by suitable manipulation of building materials, planning and designing it is possible to modify the effects of external climate to the desired indoor environment.

The function of the building elements/sections are to act as barrier between the desirable conditions inside and the extreme conditions outside.

The external surface temperature of building depends on the solar radiation and solar radiation and surface colour while the internal surface temperature of building section depends on thermo physical properties of building materials and thickness.

The indoor air temperature is strongly influenced by the heat storage capacity of the walls, roofs, floors and internal partitions.

When a structural element of a building is exposed to outdoor air temperature and direct solar radiation, the outer layer absorbs the heat. This raises the temperature of the first layer above that of out door air and adjacent layer below. As there exists the temperature differential between the out side air and the outer most layer, some heat energy is lost to the outside by convection and radiation and at the same time, as the subsequent layers of the element are at lower temperature, heat energy is conducted to adjacent layers below. At any instant, the amount of heat flowing either directions depends on the resistance to the heat flow within the wall.

A portion of heat received by layer is used in raising its temperature and remainder is conducted to the layers below. This process of absorbing and passing some heat energy to the next layer continues through the wall to the innermost layer and the inside surface heat is transferred by convection and radiation to the enclosure. Because each layer absorbs some heat before passing it on, the magnitude of heat released to the inside space would be released to the inside space would be reduced to considerable extent depending on the mass of the structural element. The interval between the outer layer absorbing the heat and inner layer transmitting to indoor is called the 'time lag'. This varies with the thermal capacity of structure and the sol-air temperature wave form.

Thermal transmittance, U-value is the heat transmittance through unit area of the given building divided by temperature difference between the air either side to the building unit in 'steady state' condition. Inverse of the U-value is the thermal resistance of section including the surface film resistance on either sides. The structural heat gain or loss of a building section depends on colour of the outside surface the heat storing capacity(Q) and their thermal resistance (R).

$R = L/K$ and

$Q = KA\,(Th-Tc)/L$

Where, L is the thickness of the section in m,

K is the thermal conductivity of material in W/mK,

A is the area in m^2,

Th is the temp of hot surface in K,

Tc is the temp of cold surface in K.

A light (less heavy) structure cools of much more quickly than a heavy structure, on the other hand if the roof is lighter it also transmits comparatively more heat and this may increase the indoor temperature during the day time. In tropical climate the problem gets more complicated by the large diurnal swings of temperature and high intensity of solar radiation. Under these conditions the commonly used steady state property namely 'U- value' alone can not form a satisfactory basis and the thermal storage affect of thickness of the building section can not be ignored.

Thermal damping,(D) is a characteristic dependent on the thermal resistance and the thermal capacity of the structure and is given as,

$D= (To - Ti)/To \times 100$

Where, To is outside surface temperature range (Tos max- Tos min)

Ti is inside surface temperature range (Tis max – Tis min)

Thermal performance index of a building element is given by

TPI = (T is- 30)x100/8

Where, Tis is the peak inside surface temperature.

A temperature of 8^0 C has been considered over abase temperature of 30^0C. It depends on the total heat gain through the building section.

For thermal comfort the building section should ensure lower internal surface temperature to minimise the radiant heat load to the occupants.

4.Strength, Energy and Thermal performance:

The embodied energy content of different materials help in identifying alternative materials and methods of construction. It is required to know how energy can be saved by selection of one building assembly, building component or complete building system rather than another when both alternative systems can satisfy all the simultaneous physical requirements- in terms of strength, stiffness, thermal performance and so on of the building.

Energy efficiency of different materials in relation to performance is given by comparing the energy costs of obtaining one unit of some property the designer is interested in using range of materials. For use as structural materials, it is the stiffness of material which is of greater importance, since this govern both the deflection of beams and slabs and the buckling of columns. Table below shows the energy requirements for one unit of stiffness of different materials.

Timber is the most energy efficient material for use in structures, being several times more efficient than steel or reinforced concrete. It also explains that use of aluminium for structural purposes is extremely expensive in terms of energy utilisation. Thus aluminium is preferred to other materials only for reasons like resistance to corrosion.

Materials used in external walls, claddings and insulation all need to be evaluated in terms of their thermal resistivity. The energy costs of different materials, per unit of thermal resistivity are shown in the table below

Table: 4.1 Energy requirement for one unit of stiffness of different materials (after Biggs)

Material	Elastic Modules (MN/m2)	Density (Kg/m3)	Energy (Kj/Kg)	Energy cost of one unit of E
Timber(sawn)	110 000	500	1 170	53
Mass concrete	14 000	2 400	720	124
Brick	30 000	1 800	2 800	167
Reinforced Concrete	2 700	24 000	8 300	738
Steel	210 000	7 800	43 000	1 598
aluminium	70 000	2 700	238 000	9 180

Table: 4.2 Energy requirement to obtain one unit of thermal resistivity of different materials (after Biggs)

Material	Resistivity,r (MK/W)	Bulk density (Kg/m3)	Energy (KJ/Kg)	Cost of one unit of resistivity (KJ)
Foamed polystyrene	29.4	25	120 000	74
Glass wool	23.8	145	150 000	91
Timber(soft wood)	7.7	500	1 170	110
Gypsum plaster	2.7	1 200	1 800	800
Light weight concrete	0.7	1 200	720	1 252
Mass concrete	0.48	2 400	720	3 600
Glass	0.95	2 500	15 000	3 947
Rigid PVC	6.2	1 350	116 000	25 270

The issue of choice of materials is much more complex . The trade-offs between energy costs of materials and energy savings has to be considered in the context of the life time energy costs of the buildings.

5.Experimental study:

A study has been made on three proto type single room tenement buildings of 225sft facing east with uniform roof height and window area constructed with different materials at village Pargi of Rangareddy district, 90km west of Hyderabad in the month of May.

Building 1. 200mm stone cement block masonary in cement and pointed with composite roof of 38mm stone slabs+ 63mm cement concrete.

Building 2. 230mm brick masonary in cement with 20mm cement plaster inside and 12 mm cement plaster out side with 115mm RCC roof.

Building 3. 460mm stone masonary in mud with 20mm mud plaster in side and 12mm cement plaster out side. Roofed with 25mm thick stone slabs placed loosely on sloped wooden rafters.

The energy content of the building sections studied above is also calculated excluding the human energy consumed during manufacture and in construction.

Table: 5.1 Energy content of building sections under study

Sl. No.	Section/Building type	Material	Material qty required	Basic Energy content/unit	Transportation Energy/unit	Total energy	Energy /sqm of plan area MJ
	WALLING						
1	200mm cement stone block masonary	Blocks	800	21		16800	
		Cement	12 bags	400	42*	5304	
		Sand	8cum	30	140#	1360	
					Total	**23464**	**1117**
2	230mm brick masonary with both sides cement plaster	Bricks	6500	4000/1000	336^	28184	
		Cement	17 bags	400	42	7514	
		Sand	10 cum	30	140	1700	
					Total	**37398**	**1780**
3	430mm stone masonary with out side cement plaster	stone	6 cum	100	140	1440	
		Cement	9 bags	400	42	3978	
		sand	6cum	30	140	1440	
					Total	**6438**	**307**

Table: 5.2 Indoor and Outdoor surface temperatures of Roofing sections under study

1	**ROOFING**						
	roof of 38mm stone slabs+ 63mm cement concrete.	Cement	9	400	42	3978	
		Stone	1cum	100	140	240	
		Metal	1cum	220	140	360	
		Sand	0.5	30	140	85	
					Total	**4663**	**222**
2	Roofing with 115mm RCC	Steel	150kg	30	2.24	4836	
		Cement	15	400	42	6630	
		sand	1	30	140	170	
					Total	**11636**	**554**
3	Roofed with 25mm thick stone slabs placed loosely on sloped wooden rafters	stone	0.91	150	280	390	
		wood	0.8MT	1000	280	1024	
					Total	**1414**	**67**

*2.8MJ/MT/km for 300 km= 840MJ/MT or 42MJ/bag
#2.8MJ/ton/Km for 50 km = 140MJ
^2.4cum/1000bricks and 2.8MJ/km for 50km = 336MJ
$ 2.8M/MT for 800km = 2.24MJ/kg of steel

The thermal behaviour of the same building sections were studied for continuous 48 hours in the summer month of May to understand their thermal performance. Measurements were taken in the middle of the roof and west side wall.

Table: 5.3 Indoor and Outdoor surface temperatures of walling of buildings under study

Time	Sh.Stone+PCC		4"RCC		Loose Sh.Stone	
	Inside	**outside**	**Inside**	**Outside**	**Inside**	**Outside**
10.00	36.2	40.4	32.8	37.0	35.1	45.4
12.00	43.0	46.4	37.2	44.0	0.0	0.0
14.00	46.2	48.4	43.0	49.4	**43.8**	**51.4**
16.00	44.6	43.4	**45.2**	42.6	41.2	45.0
18.00	38.6	37.0	42.3	37.6	38.5	38.2
20.00	36.0	34.6	37.5	33.8	34.7	33.0
22.00	34.0	32.2	34.1	31.0	0.0	0.0
0.00	32.4	30.4	34.6	29.6	31.6	29.7
2.00	31.0	29.2	31.0	28.4	29.7	27.0
4.00	29.8	28.0	29.8	**27.5**	0.0	0.0
6.00	**29.2**	30.0	29.2	29.8	28.8	**26.5**
8.00	31.0	33.0	30.2	32.0	30.6	34.0
10.00	36.2	40.4	32.8	37.0	33.2	41.4
12.00	43.0	46.4	37.2	44.0	37.7	48.6
14.00	45.0	**48.4**	42.6	**50.0**	41.8	51.2
16.00	**46.6**	46.4	44.4	42.5	42.4	47.3
18.00	43.2	40.5	42.5	38.4	38.7	39.4
21.00	39.0	36.8	38.0	33.0	36.0	33.0
23.00	36.0	33.8	34.6	30.3	31.2	29.2
2.00	32.8	30.2	32.4	28.4	30.4	28.4
5.00	29.8	**27.9**	**29.7**	30.2	**28.6**	27.6
8.00	31.4	**33.3**	30.4	33.2	31.3	36.5

Table: 5.4 Indoor and Outdoor surface temperatures of roofing of buildings under study

Time	**SC Block**		**9" Brick**		**Stone in mud**	
	Inside	**outside**	**Inside**	**outside**	**Inside**	**outside**
14.00	36.2	**43.0**	32.4	43.4	33.6	**43.0**
16.00	32.2	39.5	33.8	44.0	**33.9**	37.4
18.00	37.0	37.8	35.4	38.0	34.0	35.0
20.00	36.6	34.5	35.2	36.2	33.8	33.6
22.00	36.0	32.4	34.8	32.8	33.2	31.4
0.00	34.9	31.0	33.0	30.1	32.8	29.6
2.00	33.6	29.8	0.0	0.0	0.0	0.0
4.00	32.6	28.8	0.0	0.0	32.4	28.8
6.00	32.0	**28.5**	29.6	**26.3**	32.2	29.2
8.00	31.6	32.0	**29.0**	37.4	32.0	31.8
10.00	32.6	37.6	29.7	32.7	32.5	37.4
12.00	33.8	40.6	31.3	37.3	33.0	41.8
14.00	35.1	43.0	0.0	0.0	33.4	42.8
16.00	37.2	41.2	32.9	**44.7**	33.8	40.4
18.00	**37.2**	35.6	**35.7**	38.1	34.0	34.6
21.00	36.2	33.4	34.4	32.6	33.6	31.6
23.00	35.2	31.8	0.0	0.0	33.0	29.4
2.00	33.3	29.6	30.9	27.3	32.4	**28.6**
5.00	32.8	29.1	30.0	26.3	31.9	28.8
8.00	**31.3**	32.0	29.4	30.6	**31.8**	33.2

The thermal behaviour of the building sections are compared with the the final Thermal damping,D and Thermal performance index,

TPI is the indicator finally contributed to the indoor comfort, keeping surface colour, orientation, openings in a common environment.

Table: 5.5 Thermal behaviour of different walling under study

	SC block masonary	230mm Brick masonary	430 Stone Masonary
tis max	37.2	35.7	33.9
tis min	31.3	29	31.8
Ti	6.9	6.7	2.1
tos max	43	44.7	43
tos min	28.5	26.3	28.6
To	14.5	18.4	14.4
D	62.41	63.58	85.41
TPI	**90**	**71.25**	**48.75**
Energy/sq m of plan area in MJ	**1170**	**2507**	**386**

Table: 5.6 Thermal behaviour of different Roofing under study

	Stone lab+concrete	RCC	Loose Shabad stone
tis max	46.6	45.2	43.8
tis min	29.2	29.7	28.6
Ti	17.4	15.5	15.2
tos max	48.4	50	51.4
tos min	27.9	27.5	26.5
To	20.5	22.5	24.9
D	5.74	31.11	38.96
TPI	**207.5**	**190**	**172.5**
Energy/sq m of plan area in MJ	**240**	**561**	**67**

Lower the TPI, better the Thermal performance of the section.

Table 1 of SP41 (S&T)-1987, Handbook on Functional requirements of Buildings Part-II recommends minimum Thermal Performance Standards for walls and roofs for characteristic climatic zones in India and table 6 categorises the un conditioned buildings:

TPI < 75 is rated as Good
>75 and <125 is rated as Fair

>125 and<175 is rated as Poor

> 175 and <225 is rated as very Poor

> 225 are Extremely poor.

All the walls were verified for safe stress and the buckling and found safe.

All the roofs were tested for bending and deflection and found safe.

6. Conclusions:

It is seen that that the buildings constructed with locally available materials not only consumed low energy but also performed well in terms of strength, durability and comfort.

Sections using cement and steel not only consumed more energy but also performed poorly for thermal comfort.

Burnt clay bricks though locally available, consumed more energy compared to stone and sand cement blocks due to high consumption of coal.

Extensive study must be done on the use of all locally available for strength and thermal comfort for the given Climatic conditions for their strength and thermal behaviour for use as construction material for energy conservation and overall Sustainability. These materials can also include the other renewable, reused or reduced materials or by-products of agricultural and industrial produces in that area.

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