THERMAL TRANSMITTANCE (U-VALUE CALCULATIONS) OF SUSTAINABLE BUILDING MATERIALS FOR WALLS

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***Abstract*: Mud, lime, wood, stone and others traditional materials are silent used in house constructions in many countries, especially in India. Thermal comfort level changes for different indoor and outdoor condition which can be measure. The thermal comfort level can be changed for indoor by putting thermal materials like insulation, but the out comfort level is not control by human. Indoor thermal conditions can be improved by the selection of building components, optimum orientation & proper selection of building material. This paper contains the values of the different materials to control & perform better for the thermal comfort and to meet with value of energy conservation building code (ECBC).**

***Keywords*: Thermal performance, Thermal transmittance, sustainable building materials, and ECBC.**

1. INTRODUCTION

Due to their inherent properties, different building materials respond differently to climatic conditions. The thermal properties of building components such as walls, ceiling and floors together determine the energy consumption patterns and comfort conditions in an enclosed space. Various building materials, such as factory produced extruded hollow brick, concrete blocks, sun dried mud-brick and aerated concrete blocks have been used for construction works.

2. THERMAL PERFORMANCE

Many parameters are considered when selecting material, including durability, cost, compressive strength, water vapour absorption and transmission, simplicity of application, and thermal conductivity, fire resistance. The factors that contact the choice of materials can be summarized as Follows:

-Thermal performance
-Thermal resistance
-Cost
-Environmental impact
-Availability

1.1 CLASSIFICATION AND PROPERTIES OF THERMAL EFFECTS ON MATERIALS

CLASSIFICATION OF MATERIAL:

1.1.1 Classification by type of substance
- On solid material
- On fluid

1.1.2 Classification by types of effect
- Chemical effect- reaction, decomposition
- Biological effects- sterilisation
- Physical effects- phase change, dimension change, heating
- Chemical effect are decomposition, reaction

1.1.3 Classification by temperature range effects
- Cryogenic effects- superconductivity
- Mid-temperature effects
- High-temperature effect- ionisation, dissociation

1.1.4 Classification by function of its study
- To know the effects - expansion, decomposition)
- To avoid the effects- food preservation) [1]

1.2 PROPERTIES OF MATERIAL

Material property may be classified according to the material (i.e. metal properties, polymer) or according to the application; in the concluding case, the standard category is:

Mechanical properties (mainly structural) are density, shear modulus, strength, elongation, hardness-damping, fracture, fatigue, young's modulus, rigidity-plasticity.

Thermal properties are thermal expansion coefficient and capacity, thermal conductivity, density.
Chemical properties are corrosion, environmental attack, oxidation, composition, erosion.
Optical properties are absorbance, reflectance, emissivity, fibre optics.
Acoustic properties are acoustic impedance, speed of noise and sound attenuation.
Thermal conductivity (k-value) is property denoting a materials inbuilt ability to conduct heat. It is an inherent material property and temperature dependant also. Units are W/m.k
Thermal transmittance (u-value) is property denote a resources ability to conduct heat. It is the reverse of thermal resistance (R-value), it is property denoting a materials resistance to heat. It is dependent on temperature and thickness of the material. Units are m2.k/W. Relationship between k, R- value & U-value are R-value= thickness of material (d)/ K, U-value= 1/R- value.[2]
Thermal mass is the ability of a material to absorb heat energy. The heat store capacity of building materials helps to achieve the thermal comfort conditions by providing a time stoppage to the flow of heat. High density materials, like steel, brick, concrete and stone have high thermal mass. Thermal mass is most suitable for climates with a diurnal variation of more than 10^{o} C.
Thermal insulation is the reduction of heat transfer through a material. Heat flow is a consequence of contact between objects of differing temperatures. Insulating material reduces the thermal conduction thus reducing unnecessary heat loss or gain. The insulating capability of a material is measured with thermal conductivity (k). Low thermal conductivity is equivalent to high insulating capability (R-value)[3]

2. SUSTAINABLE BUILDING MATERIAL

2.1 Sustainable building material: sustainable building material can be defined as material with largely act in terms of particular criteria. The criteria are commonly used:

- Low embodied energy
- Locally available material
- Environmental impact
- Thermal efficiency
- Recyclability of building materials
- Construction and demolition waste
- Waste and pollution generated during manufacturing process
- Use of renewable energy
- Operation & Maintenance costs

Traditional green building material: Lime, Mud, Wood, Stone

2.2 Contemporary Green building materials

Fly Ash Brick
Hollow Concrete Block
Perforated blocks
GFRG Glass fibre reinforce gypsum
Precast Ferro cement panels
Autoclave aerated concrete blocks

2.3 Agro waste building materials

Rick husk cement building particle board
Timber jute fibre polymer bonded panel
Baggase polymer bonded boards
Ground nut hull cement building board

2.4 Construction and demolition waste

Concrete Tiles, Excavated Material, Bricks, Glass, Plaster, Metal and Steel, Concrete Rubble, Fly Ash Lime Gypsum (FALG)[4]

2.4.1 FLY ASH

Types of fly ash are generally mixed with concrete:-
Class C - produced from burning lignite coals
High-calcium fly ash that contains less than 2% carbon contents
Class F – produce from anthracite coals
Low-calcium fly ash that contains less than 5% carbon contents

Utilization of fly ash in building materials

Ready-Mixed Fly Ash Concrete
Precast Fly Ash Concrete blocks
Clay Fly Ash Bricks

Lime Fly Ash Bricks
Lime Fly Ash Cellular Concrete
Fly Ash Sand Lime Bricks[5]

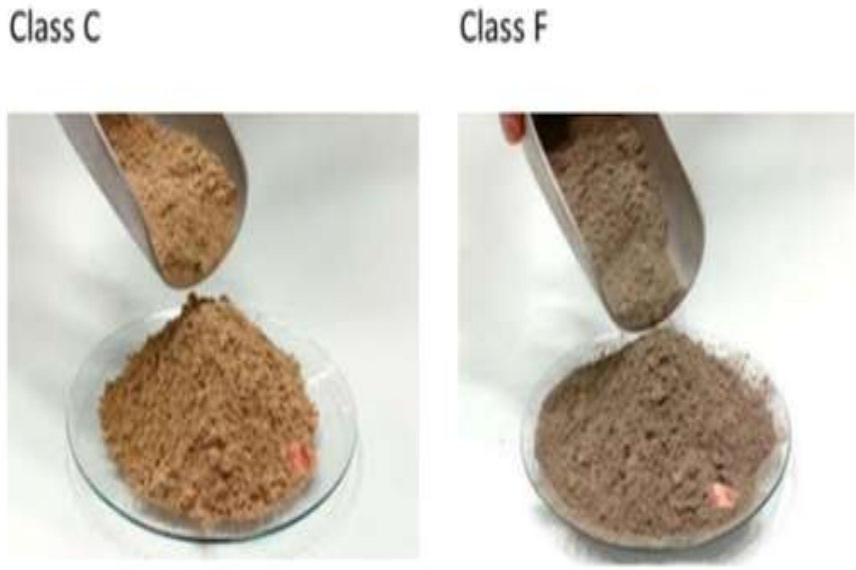


Figure 1: Types of Fly Ash (Class C&F)

CALCULATION:

Thermal resistance = The formula for calculate U value = 1 / (Rso + Rsi + R1 + R2 ...)[6]

Thermal conductivity = K value

Relationship between k, R- value & U-value:

R-value= thickness of material (d)/ K

Thermal transmittance (U-value) = 1/R- value.

K value of plaster = 0.721 (NBC 2016)
R value = 0.012/0.721=0.017
K value of fly ash =0.44 (NBC 2016)
R value of fly ash = .23/0.44=0.52
K value of plaster= 0.721 (NBC 2016)
U value= 1/0.017+0.44+0.721 = 1.799 W/m2.K

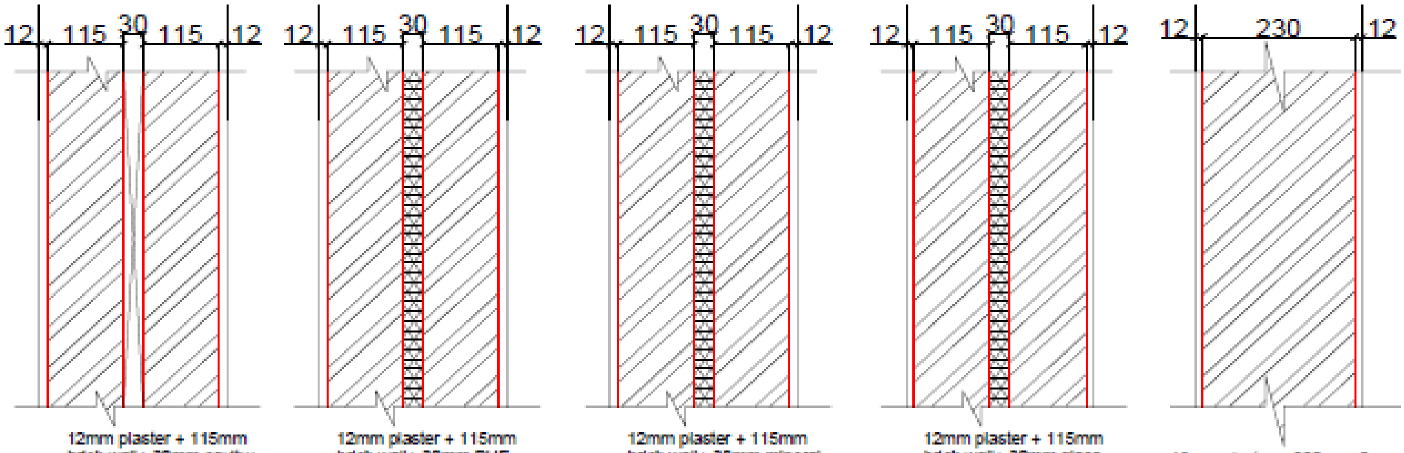
3. **CALCULATIONS: THERMAL TRANSMITTANCE U-VALUE**

Table 1: U VALUE FOR WALL MATERIALS

Wall materials	**Wall thickness(M)**	**R Value m2k/W**	**U Value W/m2K**	**Source**
Exterior Brick Wall 230 mm	0.254	0.31	**3.15**	NBC 2016
Cavity wall (30mm)	0.284	0.53	**1.88**	NBC 2016
Cavity with insulation (PUF 30mm)	0.284	1.74	**0.57**	SP41

Cavity with insulation (mineral wool 30mm)	0.284	1.31	**0.75**	NBC
Cavity with insulation (rock wool30mm)	0.284	1.01	**0.98**	NBC
Gypsum board cavity	0.074	0.41	**2.39**	ASHRAE
Gypsum with insulation PUF	0.074	2.44	**0.40**	ASHRAE, SP 41
Gypsum with insulation mineral wool	0.074	1.72	**0.57**	ASHRAE, SP 41
Gypsum with insulation rock wool	0.074	1.12	**0.88**	ASHRAE, SP 41
Fly Ash Brick Wall	0.254	0.55	**1.79**	NBC 2016
Hollow Concrete Block Wall	0.222	0.91	**1.09**	
AAC Block Wall[7]	0.1		**0.89**	NBC
Autoclaved Aerated Concrete Block Wall[8]	0.15		**0.59**	NBC
Autoclaved Aerated Concrete Block Wall	0.2		**0.445**	NBC
GFRG WALL panels	0.12	0.36	**2.77**	iit madras
FALG bricks	0.250		**0.594**	ASHRAE

[7] NBC 2016,Chapter 11
[8] NBC 2016,Chapter 11



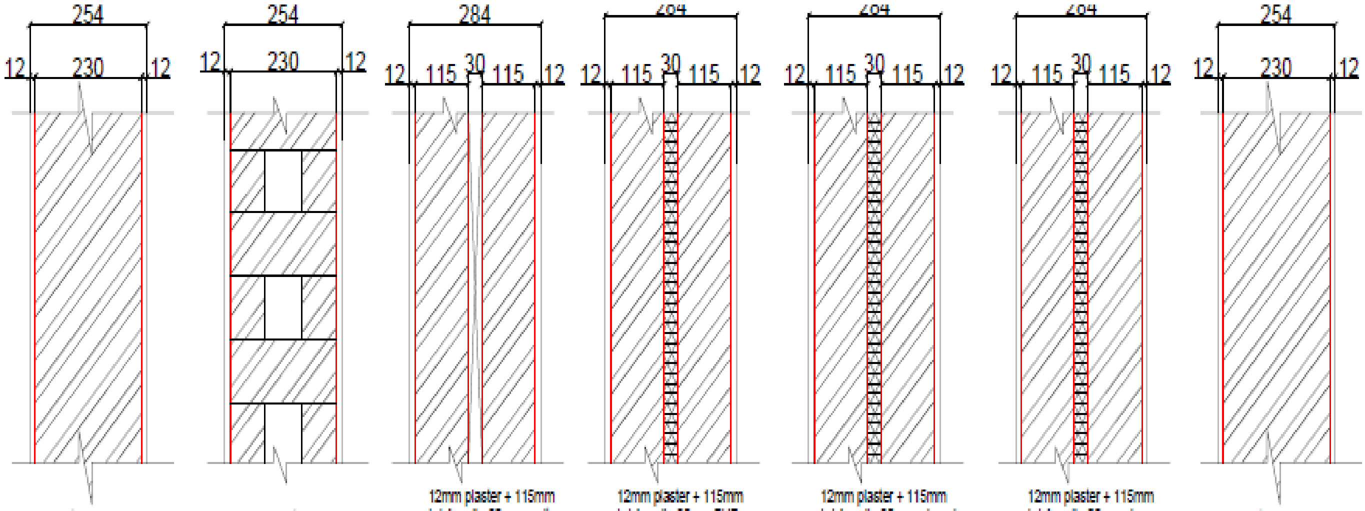
12mm plaster + 115mm brick wall+ 30mm cavity+ 115mm brick wall +12 mm plaster
R value = 0.531 m3.K/W

12mm plaster + 115mm brick wall+ 30mm PUF insulation + 115mm brick wall +12 mm plaster
R value =1.744 m2.K/W

12mm plaster + 115mm brick wall+ 30mm mineral wool insulation + 115mm brick wall +12 mm plaster
R value =1.31 m2.K/W

12mm plaster + 115mm brick wall+ 30mm glass wool insulation + 115mm brick wall +12 mm plaster
R value =0.014 m2.K/W

12mm plaster + 230 mm fly ash brick wall +12 mm plaster
R value =0.556 m2.K/W
U value =1.79 W/m2.K



12mm plaster + 230 mm brick wall +12 mm plaster
R value =0.316 m2.K/W
U value =3.156 W/m2.K

12mm plaster + brick wall in rat trap bond +12 mm plaster
R value =
U value =

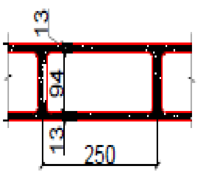
12mm plaster + 115mm brick wall+ 30mm cavity+ 115mm brick wall +12 mm plaster
R value = 0.531 m3.K/W
U value = 1.88 W/m2.K

12mm plaster + 115mm brick wall+ 30mm PUF insulation + 115mm brick wall +12 mm plaster
R value =1.744 m2.K/W
U value = 0.572W/m2.K

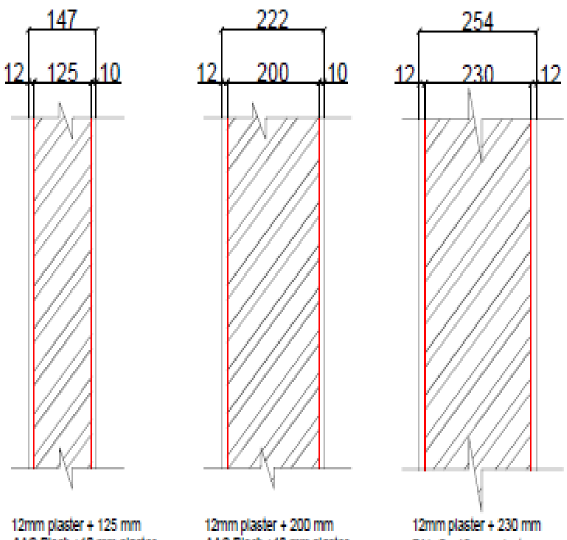
12mm plaster + 115mm brick wall+ 30mm mineral wool insulation + 115mm brick wall +12 mm plaster
R value =1.31 m2.K/W
U value = 0.759W/m2.K

12mm plaster + 115mm brick wall+ 30mm glass wool insulation + 115mm brick wall +12 mm plaster
R value =0.014 m2.K/W
U value = 0.985W/m2.K

12mm plaster + 230 mm fly ash brick wall +12 mm plaster
R value =0.556 m2.K/W
U value =1.79 W/m2.K



GRFG PANELS
R value=0.36 m2.K/W
U value=2.77 W/m2.K



12mm plaster + 125 mm AAC Block +10 mm plaster
R value =1.435 m2.K/W
U value =0.69 W/m2.K

12mm plaster + 200 mm AAC Block +10 mm plaster
R value =2.27 m2.K/W
U value =3.156 W/m2.K

12mm plaster + 230 mm FAL G +12 mm plaster
U value =0.53 W/m2.K

S.No.	Component	Total Th	Construction																	
			Layer 1		Layer 2		Layer 3		Layer 4		Layer 5							R Value	U ValueW	
			Thickness	Material	Thicknes	Material	Thickne	Material	Thicknes	Material		Material	R VALU	R VALU	R VALU	R-	R			
1.1	Wall												L-1	L2	L3	L4	L5			
1.1.1	Exterior Brick																			
	Wall 230 mm	0.254	0.012	Plaster	0.23	Brick	0.012	Plaster					0.0166	0.2836	0.0166			0.31689	3.155693	NBC 2016
1.1.2	Cavity Wall																			
		0.284	0.012	Plaster	0.115	Brick	0.03	Cavity	0.115	Brick	0.012	Plaster	0.0166	0.1418	0.2143	0.1418	0.01664	0.53117	1.882625	NBC 2016
1.1.3	Cavity wall with																			
	Insulation	0.284	0.012	Plaster	0.115	Brick	0.03	PUF	0.115	Brick	0.012	Plaster	0.0166	0.1418	1.4286	0.1418	0.01664	1.74546	0.572915	SP41
		0.284	0.012	Plaster	0.115	Brick	0.03	Mineral Woo	0.115	Brick	0.012	Plaster	0.0166	0.1418	1	0.1418	0.01664	1.31689	0.759366	NBC
		0.284	0.012	Plaster	0.115	Brick	0.03	Rock Wool	0.115	Brick	0.012	Plaster	0.0166	0.1418	0.6977	0.1418	0.01664	1.01456	0.985647	NBC
1.1.4	Internal Brick																			
	Wall 115 mm	0.139	0.012	Plaster	0.115	Brick	0.012	Plaster												
1.1.5	Gypsum																			
	Partition	0.074	0.012	Gyp Board	0.05	Cavity	0.012	Gyp Board					0.03	0.3571	0.03			0.41714	2.39726	
		0.074	0.012	Gyp Board	0.05	PUF	0.012	Gyp Board					0.03	2.381	0.03			2.44095	0.409676	
		0.074	0.012	Gyp Board	0.05	Mineral W	0.012	Gyp Board					0.03	1.6667	0.03			1.72667	0.579151	
		0.074	0.012	Gyp Board	0.05	Rock Woo	0.012	Gyp Board					0.03	1.0638	0.03			1.12383	0.889814	
1.1.6	Cement																			
	Stabilized Brick																			
	Wall																			
1.1.7	Fly Ash Brick																			
	Wall	0.254	0.012	Plaster	0.23	Brick	0.012	Plaster					0.0166	0.5227	0.0166			0.55601	1.798515	NBC 2016
1.1.8	Hollow Concrete																			
	Block Wall	0.222	0.012	Plaster	0.2	Conc. Bloc	0.01						0.0166	1.0638	0.0139			0.91379	1.094343	
1.1.9	Autoclaved																			
	Aerated	0.1	_	_	_	_	_	_	_	_	_	_	1.1236					0.89		NBC
	Concrete Block	0.15	_	_	_	_	_	_	_	_	_	_	1.6854					0.59333		NBC
	Wall	0.2	_	_	_	_	_	_	_	_	_	_	2.2472					0.445		NBC
		0.147	0.012	Plaster	0.125	AAC Block	0.01	Plaster	_	_	_	_	0.0166	1.4045	0.0139			1.43501	0.69686	nbc
		0.222	0.012	Plaster	0.2	AAC Block	0.01	Plaster	_	_	_	_	0.0166	2.2472	0.0139			2.2777	0.439039	nbc
1.1.10	perforated																			
	blocks																			
	GFRG WALL panels	0.12																0.36	2.777778	iit madras
1.1.11	sismo building technology (bmptc)	0.192	0.012	plaster	0.04	eps	0.09	cellular conc	0.04	eps	0.01	plaster	0.0166	1.0526	0.4787	1.0526	0.01387	2.6145	0.382482	nbc
1.1.12	LGSFG (Light wt. steel frame gauge)		0.02	light wt co	0.089	light wt. c	0.02	conc.panel												
1.1.13	FALG bricks	0.25	0.01	Plaster	0.23	FALG brick	0.01	plaster					FLY ASH=						0.594	ASHRAE

CONCLUSION

The aim of this research is to evaluate the thermal transmittance of sustainable building materials. Thermal transmittance (u value) of the burned brick wall (230mm) is 3.15 W/m2k, not much very good as compare to u values given in ECBC 2017 but it can be improve with using the insulating material such as mineral wool, rock wool etc. Fly Ash, Autoclaved Aerated Concrete, Glass Fibre Reinforce Gypsum, Fly Ash Lime Gypsum comes under the criteria for sustainable building material as their u values meet close to the ECBC 2017, they can be made from construction and demolish waste and industrial waste.

REFERENCES

[1] M. F. Ashby and K. Johnson, Materials and Design, Butterworth Publication, 2002.
[2] Manual of Tropical Housing and Building: climate design, by OH koenigsberger.
[3] USEPA- united states environmental protection agencysustainable-management-construction-and-demolition-materials.
[4] Source: IJER Additive to Cement –A Pozzolanic Material-Fly Ash, 27-28 Feb. 2016.
[5] Energy Conservation Building Code 2007.