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A Complete Solution To Concrete Roof For Arresting Heat Penetration In Warm and Humid Climate at Indian Context- A Case Study

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Abstract - Building sectors are the major energy consumers and it leaves 'carbon foot prints'. As the construction industry is moved from the zero energy materials (stone, soil, thatch/leaves and unprocessed timber) to modern materials (steel, concrete and cement) more energy is required to produce the modern building materials. In India, the concrete is the major construction material whose thermal conductivity is high. The roof is the most and for the longer period exposed component of building to the sun light and around 75% of heat is transmitted through roof. The use of low thermal conductivity materials as weathering course over the concrete roof will provide not only conformability but also save energy. In this context, various weathering courses which are suitable for warm and humid climate are selected and analyzed. A Case Study is considered in Puducherry, South India and Energyplus simulation software of United States is used to assess the energy required for District heating and cooling. A complete solution to roof for arresting the heat penetration is arrived as per Energy Conservation Building Code of India.

Keywords-Thermal conductivity, thermal resistance, roof insulation, extruded polystrurene..

I. INTRODUCTION

India is the second largest populated country in the world and has three biggest cities, namely Mumbai, Kolkata and Delhi, within the rank of 20 biggest cities in the world. It has 23 cities that has a population of above one million each. India has 120 crores population as per 2010 censes and power produced by various means is not sufficient to meet its energy needs [1]. By 2025, India's demand for energy will probably increase by a factor of 2.5. In India, the construction industries consume 33% of electricity and responsible for 30% of Green house gas emissions (GHG) [2]. The growing gap between the energy demand and supply emphasizes the need for a more stable, more environment-friendly alternative (ie) the proactive route is to design and construct energy efficient buildings to conserve the precious electricity. It is also reported that the GHG emission could be reduced up to 80% ; by comparable measures, like better insulation of different components of the building [3]. Realizing the important of energy conservation. India has come up with comprehensive guidelines in energy conservation in buildings in 2007 in the form of an Energy Conservation Building Code (ECBC) [4]. The above code defines the norms and standards for energy performance of buildings and their components based on five climate zones recognized in India and specified in the National Building Code of India (NBC-2005) [5]. One of the aspects that are dealt in ECBC is the guidelines on building envelope. Since the roof is exposed the most and for the longer period to the solar radiation 75% of the heat enters a building from the roof only. To reduce the heat penetration and thereby reduce electricity consumption various techniques have been adopted. A common practice followed in the developed countries is roof gardens. Various research works have been carried out worldwide to save energy with installation of roof gardens [6-14]. But the research work to find out suitable materials for insulation in warm and humid climate is in an infancy phase. In India, Lime brick bat coba(LBBC) is being used as weathering course over the concrete roof. The broken/damaged bricks have been used for preparing LBBC and that will absorb more water and lead to dampness and cause leakage in the weaker part of roof. Self weight of LBBC is also considerable which needs additional strength in the form of concrete and steel to support it. To overcome these difficulties this paper has provided various suggestion for roof insulation as per ECBC. The Energyplus, version 7.0 simulation software of Department of Energy, United States has also been used to analyze the case study.

II. ENERGY EFFICIENCY OF BUILDING ENVELOPE

2.1 ECBC Guidelines for buildings

The Govt. of India (GOI) has launched the Energy Conservation Building Code (ECBC) through the Ministry of Power in May 2007 based on United States Agency for International Development (USAID) of America. In India, five climate zones have been recognized according to NBC, namely. hot-dry; warm and humid; composite; temperate and cold, as per the weather conditions. ECBC covers the following aspects of buildings: 1) building envelopes; 2) mechanical systems and equipments including: heating, ventilation and air conditioning (HVAC); 3) service hot water heating; 4) interior and exterior lighting and 5) electrical power and motors.

2.2 ECBC guidelines in building envelope

Building envelope refers to the exterior façade and it comprises of: walls, windows, roofs, skylights, doors and other openings. The design features of the envelope strongly affect the visual and thermal comfort of the occupants, as well as the energy consumption in buildings. In roofs, the U-factor (thermal conductance) for all assemblies or minimum R-value (thermal resistance) for all the five climate zones of India are prescribed for 24 hours use buildings and daytime use buildings is given in Table-1. The exterior roofs can meet the prescriptive requirements by (i) using insulation with the required R-Value; (ii) using a roof assembly that meets the maximum U-factor criterion for thermal performance as prescribed in ECBC. Various techniques to insulate different types of roofing systems can be adopted based on the manufacture's recommendations and as per ECBC guidelines.

III. THERMAL RESISTANCE OF BUILDING MATERIALS

The conductive heat transfer through the building envelope depends upon the conductivity of the building materials used. The thermal resistance (R) is proportional to the thickness of materials of construction and inversely proportional to its conductivity. The thermal resistance (R_T) is calculated by eqn. (1) as per ECBC.

$$R_T = -R_{si}+R_t+R_{sc} \text{……………eqn. (1)}$$

Where, R_1 is the thermal resistance of the components in the wall/roof; R_{si}–interior surface thermal resistance & R_{sc}-exterior thermal resistance. Materials with a greater number of fine, closed and air-filled pores are the best thermal resisting materials and the bulk density of these materials is usually below 7000 N/m^3 .The thermal resisting materials should be protected against the moisture since the co-efficient of heat conductivity of water is about 25 times higher than that of air. Good quality thermal resisting materials are: reasonable fire proof, does not absorb moisture, high resistance against the attack of insects and do not undergo deformation. Some of the standard thermal resisting material used in constructing industry in India are: rock, wool, slag wool, fiber board, flexible blankets, sawdust, wood shavings, cork board slabs, mineral wool slabs, aluminum foils, products of cement boards, chip boards, foam glass, gasket cork sheet and foam plastic etc. Now a days, the extruded polystyrene (XPS) and expanded polystyrene (EPS) is being used in well developed countries like US & EU as thermal resisting materials.

IV. TRADTIONAL METHOD OF INSULATION

In olden days, buildings were constructed with lot of open spaces, more windows and doors. Hence the air circulation was good and the word insulation was not coined. Today due to population explosion in India, cities and towns have grownup majestically. Due to rapid hike in price of land value, it is not affordable to the people who really want to buy sufficient land and construct houses with proper ventilation. The narrow constructions with inadequate ventilation due to minimal or no provision of open spaces, doors and windows results in hot air getting trapped within the structure. To make the building inner comfortable the occupants are switching over to tailor made solution of investing in air-conditioners without thinking the stopping of heat transfer from building components. The roof is the horizontal component of a building which is mostly affected by direct infrared sunrays and transfer more heat inside the building. In India many Architects, Engineers and Contractors are using traditional weathering course system which is a Lime Brick Bat Coba (LBBC) to minimize heat penetration. The Indian construction industry is using the rejected/damaged bricks during construction for weathering course. Brick is a clay product which absorbs water from the surrounding. Once the water starts entering, it acts as a reservoir of water. The stagnated water on the roof surface produces heavy strain and finds its way to the slab below and seeps through weak areas. Therefore, the LBBC is neither acting as an insulator nor a water proofing materials. The lack of availability of any better alternative for thermal insulation, the LBBC was used in earlier days. Today, polystyrene insulation panels are used as an alternative for thermal insulation in Middle Eastern countries. The awareness about the polystyrene insulation still is low not only among public but also among architects, building materials consultants and contractors in India.

V. MODERN METHOD OF INSULATION

A complete solution for roof insulation which comprises of the best rigid polystyrene foam with compatible water roofing materials and optional tiling works is achieved. Polystyrene consists of small size closed cells and outer foam skin of denser materials on both sides. While switching over to this new method, the cost of construction will approximately increase by 10%. But after insulation, it will reduce indoor temperature which inturn reduce the usage of air conditioners drastically and thereby approximately 35% on the electricity bills can be saved. The two important polystyrene material used for thermal insulation are: 1) Expanded polystyrene (EPS) and 2) Extruded polystyrene (XPS). The properties of polystyrene as on insulation material are: 1) polystyrene is a eco-friendly material as it is a 100% recyclable product; 2) it has homogeneous structure and high resistance to water and vapour diffusion; 3) the thermal conductivity is approximately 0.030 w/mk at 40^{o}C; 4) it has high compressive strength; 5) it remain dry in high relative humidity and ambient temperature; 6) it is stable and has excellent resistance to acids, basis cold bitumen and silicon oil; 7) it contains flame retardant materials.

5.1 Expanded polystyrene (EPS)

Expanded polystyrene (EPS) is a rigid, tough and closed-cell foam. It is usually white and made up of pre-expanded polystyrene breads. Rigid panels of size 2 feet x 8 feet or 4 feet x 8 feet which are known as bead-board are available in markets. The thermal conductivity values vary depending on the density of the EPS board. This value is 0.038 w/mk at 15 kg/m^3 and 0.032 w/mk at 40 kg/m^3. Adding of fillers like graphites, aluminum and carbon etc is reducing the thermal conductivity as low as 0.029.

5.2 Extruded polystyrene (XPS)

Extruded polystyrene foam consists of closed cells, offers improved surface roughness and higher stiffness and reduced thermal conductivity. The thermal conductivity varies between 0.029 and 0.039 w/mk depending on density of XPS. Water vapour diffusion resistance of XPS is around 80-250 and so it is suitable for wet environment than EPS. The XPS is about as strong as aluminum, but much more flexible and much lighter than aluminum. The advantage of XPS insulation are: 1) it increases the thermal resistance by 60-70%; 2) it absorbs water less than 1% by volume; 3) it has high compressive strength; 4) resistance to chemicals, pests and rodents; 5) easy installation; 6) fire retardant; 7) zero maintenance; 8) density is very less compared to traditional weathering course.

5.3 Application of polystyrene for insulation

It reduced strain on the structure due to thermal shocks and thereby increase the roof life. In toto, the XPS and EPS insulation adds value to buildings. For thermal comfort, the insulation is provided on: 1) exterior wall; 2) interior wall; 3)roof; 4) cavity wall. In exterior wall insulation, XPS and EPS are not affected by weather. Prolonged exposure to ultra violet radiation in sunlight may cause the surface to become pale and dusty which have no significant effect on insulation value. It is most efficient way of insulating building without interrupting structure elements. It is fixed behind the wall finish with adhesive or mechanical fasteners. Interior thermal insulation is used where existing building require insulation or building with special exterior finishes in which exterior insulation is not possible and building with intermittent air conditioning. It is fixed either with adhesive or by mechanical fasteners. In roof insulation, screed to slope, water proofing membrane, XPS, separation layer and ground layer are laid one above the other over the roof deck. Cavity wall insulation is an advantage where an external brick of any type and finish is required.

VI. CASE STUDY

In this study a proposed building of size 6.73x3.23m is considered and oriented such that the longer face (6.73m) is placed parallel to east-west direction. This building is located in Puducherry, South India which experiences a warm and humid climate.

6.1 Location of Puducherry

Puducherry is a mega town standing third in urbanization next to Delhi and Chandigarh in India. The total population of the town is 5 lakhs. It is located along the Bay of Bengal on one side and the remaining three sides are enclosed by flate ground of Tamilnadu state. It has the geographic Co-ordinates of 11 56’24’’N latitude, 79 49’48’E longitude. Puduchrrry is characterized by long warm summer and medium raining winter, a typical warm and humid climate. Beautiful beach with white town planned by French ruler and warm humid climate with long sunshine round the year attracts the tourist worldwide. The summer months from April to September are characterized by warm with occasional rain due to south west mansoon and average maximum daytime temperature of 37^{o}C (May) or higher. On the other hand the winter months from November to March is mild with total rainfall by North East mansoon and the maximum average precipitation of 416mm (or higher) occurs in the month of November. The average maximum temperatures during the winter vary between 31.60 ^{o}C and 33.60 ^{o}C.

6.2 Result and discussion

The different types of thermal insulation materials which are suitable for warm and humid climatic condition were selected and its thermal properties like thermal conductivity density, mass per sq.m were measured. The thermal resistances of various layer were calculated. The Energy-plus simulation software was used to calculate the heating and cooling energy required to make the building thermally comfortable and the results are listed in Table-2. A comparative study and cost analysis are made between the traditional method which is being used in most of the buildings in India and new method with XPS & EPS materials which is being used in US & EU and listed in Tables-3&4. From the above analysis the following results are arrived: 1) XPS and EPS provides better insulation than Lime bricks bat coba which results 13% energy saving; 2) The cost of new method of insulation is 10% higher than the traditional method. But life time running cost of the building is reduced and the 10% hike in construction can be earned within 5 years due to less use of electricity; 3) It is also observed that 66% of energy can be saved to use XPS for weathering course as compare to concrete roof without any weathering course; 4) The self weight of the XPS & EPS insulation materials is negligible compare to LBBC which reduces the additional strength required to withstand the weathering course in roof; 5) The new method also adds value to the building. The thickness of XPS was also increased as 0.15, 0.3, 0.45 m and tested the performance by Energy-plus. It is observed that the adding of XPS will not yield significant energy saving in buildings. For warm and humid climate, building with 24 hours usage it is suggested that the layer of insulation is listed in Table-5 is hold good for energy efficiency in buildings.

Table 5. Energy efficient insulation layers

Layer No	Name of the layers laid from outer to inner of building	Thickness of layer in meter
1	Polymer based paints-acrylic water based paint	0.005
2	Clay tiles	0.015
3	Weathering course cement mortar	0.020
4	Extruded polystyrene (XPS)	0.102
5	Felt membrane	0.00954
6	Screed with cement mortar	0.040
7	Concrete slab	0.130
8	Inner plastering with cement mortar	0.012
Total thickness of concrete roof with heat insulation layer		**0.33354**

VII. CONCLUSIONS

The horizontal component of the envelope namely roof is the most and for longer exposed component to the sun which transfer more than 75% of heat to the building and thereby increase the electricity consumption. To reduce the heat penetration through it, a traditional method of insulation which contains Lime brick bat coba is being used in India. Since bricks absorb more water and makes the roof as pool, various alternate insulation materials were identified and tested their U-factor as per ECBC. Finally it is concluded that XPS of thickenss 102 mm with the following layer of insulation is sufficient to make the roof as green roof in warm and humid climate for 24 hours usage building as per ECBC guidelines of India: polymer based paints-acrylic water based paint, clay tiles, weathering course cement mortar, felt membrane, screed with cement mortar, concrete slab, inner plastering with cement mortar of thickness 0.005, 0.015, 0.02,0.00954,0.04,0.13,0.012 metres respectively.

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Table 1. Roof Assembly U-Factor and Insulation R-Value requirement (Source: ECBC, India)

Climate Zone	24-Hour used buildings (Hospitals, Hotels, Call Centers etc.,)		Daytime used buildings/other Building Types	
	Maximum U-factor of the overall assembly (W /m^2 K)	Minimum R-value of insulation alone (m^2 K / W)	Maximum U-factor of the overall assembly (W/m^2 K)	Minimum R-value of insulation alone (m^2 K / W)
Composite	U-0.261	R-3.5	U-0.409	R-2.1
Hot and Dry	U-0.261	R-3.5	U-0.409	R-2.1
Warm and Humid	U-0.261	R-3.5	U-0.409	R-2.1
Moderate	U-0.409	R-2.1	U-0.409	R-2.1
Cold	U-0.261	R-3.5	U-0.409	R-2.1

Table 2. Comparison of U Factor and Energy Required for District Heating and Cooling for various Weathering Course Materials used in Indian Context

Maximum dry bulb temperature: 40.27°C Maintained comfort temperature: 27°C

Case No.	Name of the layers used for weathering course	Thickness mts	Thermal conductivity (k) w/m.k	Density Kg/m^3	Mass in Kg Per sq.m	Total thermal Resistance m^2 k/w	U value w/m^2 k	Energy plus simulation	
								District Heating J	District Cooling J
1	Outside surface resistance					0.044	3.156	1.331 x 10^8	5.4899x 10^8
	Outer plastering	0.012	0.72	1860	22.32	0.017			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Inside surface resistance					0.167			
		0.154			**3.56.64**	**0.3169**			
2	Outside surface resistance					0.044	0.727	1.0513 x 10^8	3.27x 10^8
	Clay tiles	0.015	0.157	1900	28.5	0.0955			
	Weathering course mortar	0.02	0.93	1900	38	0.022			
	Lime brick bat coba	0.15	0.157	1900	285	0.955			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Inside surface resistance					0.167			
		0.327			**685.82**	**1.3755**			
3	Outside surface resistance					0.044	0.62	1.04 x 10^8	3.123x 10^8
	Polymer based paints-Acrylic water based paints	0.005	0.021	50	0.25	0.238			
	Clay tiles	0.015	0.157	1900	28.5	0.095			
	Weathering course mortar	0.02	0.93	1900	38	0.022			
	Lime brick bat coba	0.15	0.157	1900	285	0.955			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Inside surface					0.167			

	resistance								
		0.332			**686.07**	**1.613**			
4	Outside surface resistance					0.044	0.653	1.0148 x 10^8	3.14x 10^8
	Asphalt shingles	0.0032	0.03	1121.29	3.59	0.107			
	Clay tiles	0.015	0.157	1900	28.5	0.095			
	Weathering course mortar	0.02	0.93	1900	38	0.022			
	Lime brick bat coba	0.15	0.157	1900	285	0.955			
	Felt membrane	0.00954	0.1903	1121.29	10.698	0.0501			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Inside surface resistance					0.163			
		0.33974			**700.108**	**1.5281**			
5	Outside surface resistance					0.044	1.427	1.161 x 10^8	3.64x 10^8
	Polymer based paints-Acrylic water based paints	0.005	0.021	50	0.25	0.238			
	Clay tiles	0.015	0.157	1900	28.5	0.095			
	Weathering course mortar	0.02	0.93	1900	38	0.022			
	Screed	0.04	0.93	1900	76	0.043			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Inside surface resistance					0.167			
		0.222			**477.07**	**0.701**			
6	Outside surface resistance					0.044	0.4918	1.016 x 10^8	3.088x 10^8
	Clay tiles	0.015	0.157	1900	28.5	0.095			
	Weathering course mortar	0.02	0.93	1900	38	0.022			
	Extruded polystyrene (XPS)	0.05	0.033	29	1.45	1.52			
	Felt	0.00954	0.1903	1121.29	10.698	0.0501			
	Screed	0.04	0.93	1900	76	0.043			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Inside surface resistance					0.167			
		0.27654			**488.97**	**2.0331**			
7	Outside surface resistance					0.044	0.44	1.0102 x 10^8	3.013x 10^8
	Polymer based paints-Acrylic water based paints	0.005	0.021	50	0.25	0.238			
	Clay tiles	0.015	0.157	1900	28.5	0.095			
	Weathering course	0.02	0.93	1900	38	0.022			

	mortar								
	Extruded polystyrene (XPS)	0.05	0.033	29	1.45	1.52			
	Felt	0.00954	0.1903	1121.29	10.698	0.0501			
	Screed	0.04	0.93	1900	76	0.043			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Inside surface resistance					0.167			
		0.28154			**489.22**	**2.2711**			
	Outside surface resistance					0.044			
	Polymer based paints-Acrylic water based paints	0.005	0.021	50	0.25	0.238			
	Clay tiles	0.015	0.157	1900	28.5	0.095			
	Weathering course mortar	0.02	0.93	1900	38	0.022			
8	Extruded polystyrene (XPS)	0.102	0.033	29	2.958	3.0906	0.260	0.9813×10^8	2.899×10^8
	Felt	0.00954	0.1903	1121.29	10.698	0.0501			
	Screed	0.04	0.93	1900	76	0.043			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Inside surface resistance					0.167			
		0.33354			**490.726**	**3.8417**			
	Outside surface resistance					0.044			
	Polymer based paints-Acrylic water based paints	0.005	0.012	50	0.25	0.238			
	Clay tiles	0.015	0.157	1900	28.5	0.095			
	Weathering course mortar	0.02	0.93	1900	38	0.022			
9	Extruded polystyrene (XPS)	0.15	0.033	29	4.35	4.546	0.189	0.971×10^8	2.852×10^8
	Felt	0.00954	0.1903	1121.29	10.698	0.0501			
	Screed	0.04	0.93	1900	76	0.043			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Inside surface resistance					0.167			
		0.38154			**492.118**	**5.2971**			
	Outside surface resistance					0.044			
10	Polymer based paints-Acrylic water based paints	0.05	0.012	50	0.25	0.238	0.102	0.956×10^8	2.797×10^8
	Clay tiles	0.015	0.157	1900	28.5	0.095			

	Weathering course mortar	0.02	0.93	1900	38	0.022			
	Extruded polystyrene (XPS)	0.3	0.033	29	8.7	9.091			
	Felt	0.00954	0.1903	1121.29	10.698	0.0501			
	Screed	0.04	0.93	1900	76	0.043			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Inside surface resistance					0.167			
		0.57654			**496.47**	**9.8421**			
11	Outside surface resistance					0.044	0.0695	0.951 x 10^8	2.777x 10^8
	Polymer based paints-Acrylic water based paints	0.005	0.012	50	0.25	0.238			
	Clay tiles	0.015	0.157	1900	28.5	0.095			
	Weathering course mortar	0.02	0.93	1900	38	0.022			
	Extruded polystyrene (XPS)	0.45	0.033	29	13.05	13.636			
	Felt	0.00954	0.1903	1121.29	10.698	0.0501			
	Screed	0.04	0.93	1900	76	0.043			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Inside surface resistance					0.167			
		0.72654			**500.818**	**14.3871**			
12	Outside surface resistance					0.044	0.053	0.9413 x 10^8	2.742x 10^8
	Polymer based paints-Acrylic water based paints	0.05	0.012	50	0.25	0.238			
	Clay tiles	0.015	0.157	1900	28.5	0.095			
	Weathering course mortar	0.02	0.93	1900	38	0.022			
	Extruded polystyrene (XPS)	0.3	0.033	29	8.7	0.091			
	Felt	0.00954	0.1903	1121.29	10.698	0.0501			
	Screed	0.04	0.93	1900	76	0.043			
	Concrete slab	0.13	1.73	2400	312	0.075			
	Inner plastering	0.012	0.72	1860	22.32	0.017			
	Extruded polystyrene (XPS)	0.3	0.033	29	8.7	9.091			
	Inside surface resistance					0.167			
		0.87654			**505.168**	**18.9331**			

Table 3. Comparison of Traditional and Modern Methods for Heat Insulation

Case No. as per Table .2	Method	Thickness mts	Mass in kg Per sq.m	Total Thermal Resistance m^2.k/w	U Factor	Energy required to keep the temperature at 27^{o}C, [cooling for one day in peak summer and heating for one day in peak winter] in Joules	
						Heating	Cooling
2	Traditional Method	0.327	685.82	1.3755	0.727	1.0513x10^8	3.27x10^8
8	Modern Method	0.33354	490.726	3.8417	0.26	0.9813x10^8	2.899x10^8
Difference		(-)0.00654	195.094	2.4662	0.467	0.07x10^8	0.377x10^8

Percentage of energy saving: 13%

Table 4. Comparison of Cost between Traditional and Modern Methods

Layer No.	Name of the Layer	Traditional Method [Cost per sq.m. in Rupees]	Layer No.	Name of the Layer	Modern Method [Cost per sq.m. in Rupees]
1	Clay Tiles	550	1	Polymer based paints	10
2	Weathering course mortar	390	2	Clay Tiles	550
3	Lime brick bat coba	500	3	Weathering course mortar	390
4	Concrete slab	2500	4	Extruded Polystyrene (XPS)	650
5	Inner plastering	640	5	Felt	100
			6	Screed	200
			7	Concrete slab	2500
			8	Inner plastering	640
	Total cost	4580		Total cost	5040

Percentage of hike: 10.04%