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Comparative study of different building material to enhance thermal comfort

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ABSTRACT:

According to International Energy Agency it is reported that worldwide buildings consume almost 40% of energy. With growing population and improvement in living standards this energy consumption may further increase. Therefore it is important to design buildings with enhanced thermal comfort with minimum use of fossil fuel based energy. Providing thermal comfort without increasing the cost is primary requirement in building construction. Present work is a small step in this direction, presenting the study of traditional and modern building design and materials.

Present work reports the comparison of old traditional building (1960) and modern day building (2008)material . During the study observation have been taken for outside environment temperature, inside temperatures,humidity etc. Understanding heat transfer and temperature distribution through building material .

Comparative study of old Indian traditional materials such as limestone, cow dung, soil,soil pot and currently used material i.e. cement has been done. Study about these materials and climatic effect on these materials has been experimentally conducted through six cubicles constructed with size is 2 .9 feet by 2.9 feet by 2.5feet .Materials such as limestone, cement, cow-dung and soil pots were studied on the cubicles and it was found that limestone was able to give more cooling.

This study is useful from the point of view of better designing of new residential buildings and for improving the energy efficiency of the buildings. Further for future it is important to develop multilayer insulating walls which can enhance thermal comfort without increasing the size and cost of construction.

The fundamental purpose of buildings is to provide man with a comfortable working and living space, protected from the extremes of climate. In these days of fuel crisis it is important that such comforts be provided with as little expenditure of energy as possible. Traditional architecture with hundreds of years of experience behind it, has evolved appropriate building methods for each type of climate. In most cases such buildings create a very comfortable living environment without any mechanical cooling or heating. In

contrast with these, modern buildings provide a much lower degree of thermal comfort and many of these are not usable without mechanical cooling and heating. In India only a small percentage of population can afford the cost of air-conditioning, the majority lives in uncomfortable structures. The purpose of this paper is to suggest methods for ensuring thermal comfort in buildings by natural means. Many of the methods have been used in traditional buildings in India but there are some which are based on recent scientific research. Natural heating is not discussed here because the heating requirements in most parts of India are minimal.

Passive solar heating has been found to be popular in the U.S.A. and other countries because it can provide temperatures comparable to those provided by fuel based heating systems. In harsher climates solar heating reduces the need for conventional heating systems and thus saves large amount of energy. Natural cooling, on the other hand, can seldom provide the low temperatures that are possible with mechanical air-conditioning . In some cases it is necessary to supplement natural cooling with conventional air-conditioning.

The coolness of an old building on a hot summer afternoon never fails to impress the visitor and makes one wonder how the builders could creates comfortable buildings without the aid of modern scientific knowledge. Spurred on by the energy crisis, we are today accumulating a vast body of technical literature on "passive cooling systems" and yet our present-day buildings tend to be poor performers compared to the well tempered buildings. When architects talk of passive cooling, it is as if the maintenance of certain specified temperatures in a building is an end in itself. On the other hand, the indigenous builder could not care less if the building was cool or warm so long as people could be comfortable within or without the building.

And in this, the builder's task was simplified by the willingness of the building users to put up with minor inconveniences.

The indigenous buildings were either humble dwellings or monumental palaces and temples. In either case, devoted workers in adequate numbers were available to maintain the buildings. The task of the modern architect who designs not only residences but factories, offices, hotels, hospitals, commercial centers, educational institutions and places of entertainment, is a lot more complicated. Some of these new buildings have more exacting requirements than those of the older ones, while the use is strictly impersonal. However, the tools, materials and techniques available today are more than what the indigenous builders had access to. The theory of passive cooled or naturally cooled buildings is well-developed. Various techniques suggested for environmental control in modern buildings are:.

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INTRODUCTION

Building material is any material which is used for a construction purpose. Many naturally occurring substances, such as clay, sand, wood and rocks, even twigs and leaves have been used to construct buildings

Apart from naturally occurring materials, many man-made products are in use, some more and some less synthetic. The manufacture of building materials is an established industry in many countries and the use of these materials is typically segmented into specific specialty trades, such as carpentry, plumbing, roofing and insulation work. This reference deals with habitats and structures including homes

The use of traditional building materials and design is often found itself in a difficult situation, that is either being under the threat of perished under the force of modernization or being innovatively implemented to meet modern building standards and living conditions. Traditional building materials and design have gained renewed attention in the green building movement, thanks to the use of locally accessible resources that address local conditions in a cost effective way.

Many traditional building materials have benefited from innovative technologies in both manufacture and application.These developments have made several traditional building materials more financially feasible, environmental friendly and technically sound.

Types of Building Materials Used in Construction

1. Old traditional building material as limestone , mud ,soil, animal dung ,vessels
2. Modern building material

Natural Building Materials

Building materials can be generally categorized into two sources, natural and synthetic. Natural building materials are those that are unprocessed or minimally processed by industry, such as lumber or glass. Synthetic materials are made in industrial settings after much human manipulations, such as plastics and petroleum based paints. Both have their uses.

Mud, stone, and fibrous plants are the most basic building materials, aside from tents made of flexible materials such as cloth or skins. People all over the world have used these three materials together to create homes to suit their local weather conditions.

In general stone and/or bricks are used as basic structural components in these buildings, while mud is used to fill in the space between, acting as a type of concrete and insulation.

1.1 Mud and clay :

The amount of each material used leads to different styles of buildings. The deciding factor is usually connected with the quality of the soil being used. Larger amounts of clay usually mean using the cob/adobe style, while low clay soil is usually associated with sod building.

The other main ingredients include more or less sand/gravel and straw/grasses. Rammed earth is both an old and newer take on creating walls, once made by compacting clay soils between planks by hand, now forms and mechanical pneumatic compressors are used.

Soil and especially clay is good thermal mass; it is very good at keeping temperatures at a constant level. Homes built with earth tend to be naturally cool in the summer heat and warm in cold weather. Clay holds heat or cold, releasing it over a period of time like stone.

Earthen walls change temperature slowly, so artificially raising or lowering the temperature can use more resources than in say a wood built house, but the heat/coolness stays longer.

Peoples building with mostly dirt and clay, such as cob, sod, and adobe, resulted in homes that have been built for centuries in western and northern Europe as well as the rest of the world, and continue to be built, though on a smaller scale. Some of these buildings have remained habitable for hundreds of years.

1.2 Cement :

A cement is a binder, a substance used in construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used solely, but is used to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete.

Cements used in construction are usually inorganic, often lime or calcium silicate based, and can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to set in the presence of water (see hydraulic and non-hydraulic lime plaster).

Non-hydraulic cement will not set in wet conditions or underwater; rather, it sets as it dries and reacts with carbon dioxide in the air. It is resistant to attack by chemicals after setting.

Hydraulic cements (e.g., Portland cement) set and become adhesive due to a chemical reaction between the dry ingredients and water. The chemical reaction results in mineral hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. This allows setting in wet condition or underwater and further protects the hardened material from chemical attack. The chemical process for hydraulic cement found by ancient Romans used volcanic ash (pozzolana) with added lime (calcium oxide).

Cement bonded composites are an important class of building materials. These products are made of hydrated cement paste that binds wood or alike particles or fibers to make precast building components. Various fibrous materials including paper and fiberglass have been used as binders.

Wood and natural fibers are composed of various soluble organic compounds like carbohydrates, glycosides and phenolics. These compounds are known to retard cement setting. Therefore, before using a wood in making cement boned composites, its compatibility with cement is assessed.

Wood-cement compatibility is the ratio of a parameter related to the property of a wood-cement composite to that of a neat cement paste. The compatibility is often expressed as a percentage value. To determine wood-cement compatibility, methods based on different properties are used, such as, hydration characteristics, strength, interfacial bond and morphology.

1.3 Limestone:

Limestone is a sedimentary rock, composed mainly of skeletal fragments of marine organisms such as coral, forams and molluscs. Its major materials are the minerals calcite and aragonite, which are different crystal forms of calcium carbonate (CaCO3).

About 10% of sedimentary rocks are limestone . The solubility of limestone in water and weak acid solutions leads to karst landscapes, in which water erodes the limestone over thousands to millions of years. Most cave systems are through limestone bedrock.

Limestone has numerous uses: as a building material, an essential component of concrete (Portland cement), as aggregate for the base of roads, as white pigment or filler in products such as toothpaste or paints, as a chemical feedstock for the production of lime, as a soil conditioner, or as a popular decorative addition to rock gardens.

Various methods are used by researchers such as the measurement of hydration characteristics of a cement-aggregate mix; the comparison of the mechanical properties of cement-aggregate mixes and the visual assessment of microstructural properties of the wood-cement mixes.

It has been found that the hydration test by measuring the change in hydration temperature with time is the most convenient method. Recently, Karade et al. have reviewed these methods of compatibility assessment and suggested a method based on the 'maturity concept' i.e. taking in consideration both time and temperature of cement hydration reaction.

Design Details

Five cubicle with same size and used different materials constructed .Area and design of cubicle is 2.9 feet by 2.9 feet by 2.5 feet. In these cubic different material as limestone, cement, dung of animals , soil pots used as raw material. We record four month data temperature at different time period from January to April . in these cubicle wall size is four inch and plaster from inner and outer side is ½ inch so total thickness of wall is five inch.

3.2.1 limestone ,cement ,animal dung ,no material and soil vessel wastage

Figure 1 : Cubicle Limestone, Cement and Cow Dung

1. Height 2.5 feet
2.legth 2.9feet (2.8 feet and 1inch Plaster)
3. Width 2.9 feet (2.8 feet and 1inch Plaster)

Figure 2: Cubicle Design

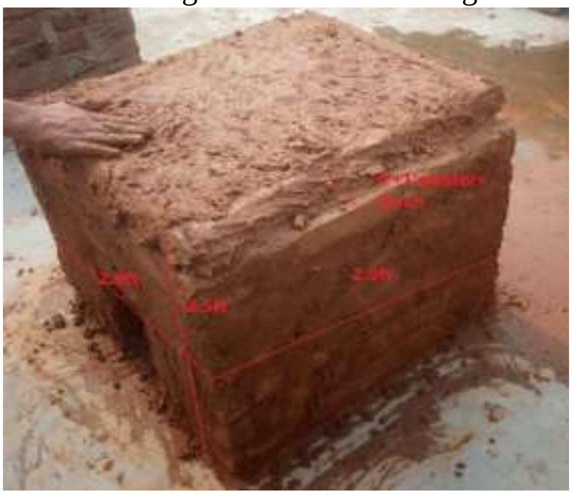


Figure 3 :Animal dung

Figure 4: soil pottery /vessels

Figure5: Cement

Figure 6 : Without Material

2.2 Inner Side Structure of Cubicle

1. Height 2feet and 5 inch roof
2. 4 inch wall size
3. ½ inch plaster on 1 wall so 1 inch plaster on both wall
4. 2.0feet length
5. 2.0 feet width

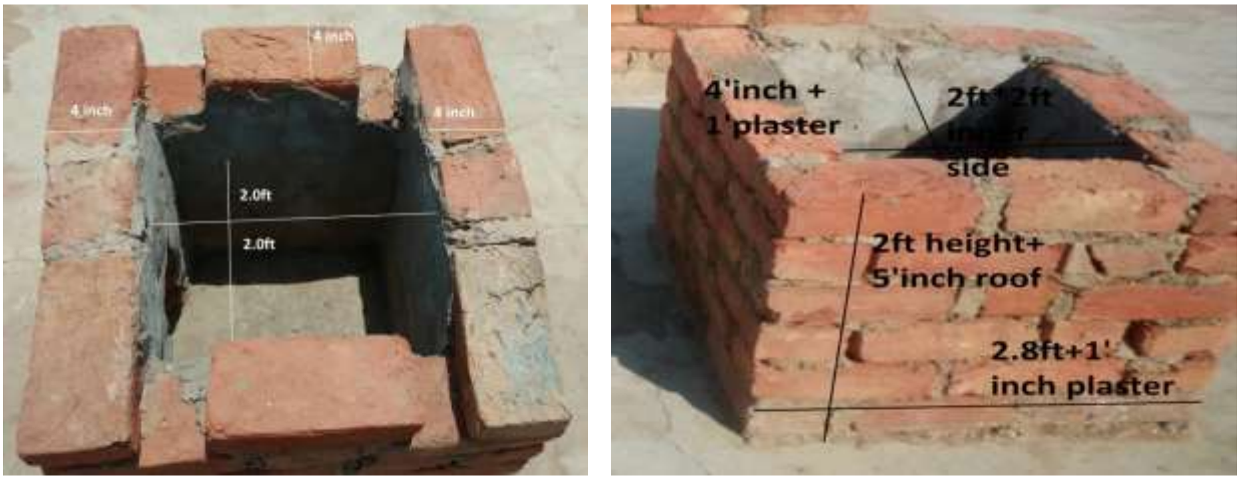


Figure 7: Design and measurement of cubicle

Experimental Method

Temperature measurement in today's industrial environment encompasses a wide variety of needs and applications. To meet this wide array of needs the process controls industry has developed a large number of sensors and devices to handle this demand. In this experiment you will have an opportunity to understand the concepts and uses of many of the common transducers, and actually run an experiment using a selection of these devices. Temperature is a very critical and widely measured variable for most mechanical engineers. Many processes must have either a monitored or controlled temperature. This can range from the simple monitoring of the water temperature of an engine or load device, or as complex as the temperature of a weld in a laser welding application. More difficult measurements such as the temperature of smoke stack gas from a power generating station or blast furnace or the exhaust gas of a rocket may be need to be monitored. Much more common are the temperatures of fluids in processes or process support applications, or the temperature of solid objects such as metal plates, bearings and shafts in a piece of machinery.

Temperature meter :Temperature cab be measured via a diverse array of sensors.

Figure 8 :Temperature meter with sensor

4.1 Experimental observation:

DATE	TIME	LIMESTONE	CEMENT	NO MATERIMAL	ANIMAL DUNG	POTTERY/ SOIL WASTAGE	OUTERSIDE TEMPERATURE
02.03.17	12.00PM	26.6	28.0	29.6	29.0	26.8	33.0
	01.00PM	27.5	29.0	30.5	30.0	31.0	33.5
	02.40PM	30.0	31.1	33.2	34.0	34.0	34.8
	04.00PM	29.0	29.9	32.7	31.2	30.2	33.0
04.03.17	8.00AM	23.6	21.5	19.8	22.0	22.1	20.2
	9.00AM	23.8	23.0	20.3	22.5	22.0	22.5
	10.30AM	22.7	23.8	24.3	24.0	24.8	26.3
	12.00AM	25.4	26.9	29.5	27.8	29.5	31.5
	1.00PM	27.3	28.9	31.2	31.8	30.6	32.4
	2.00PM	29.0	31.0	31.4	33.0	31.0	32.9
	4.30PM	29.5	31.3	30.8	31.4	31.1	31.8

	6.00PM	28.5	29.8	29.7	29.4	28.0	26.2
	7.30PM	27.0	27.4	28.1	26.2	23.5	20.1
	9.00PM	25.5	24.5	24.2	23.4	21.0	17.2
05.03.17	6.00AM	22.8	21.8	19.3	19.8	19.0	19.0
	8.30AM	20.8	20.0	20.2	20.8	22.7	23.1
08.03.17	9.15PM	27.4	28.8	29.1	28.9	28.6	22.1
	11.00PM	26.6	26.8	26.2	26.6	27.0	20.7
09.03.17	6.00AM	24.0	24.3	23.7	23.7	25.2	17.4
	8.45AM	24.0	25.1	25.0	25.4	25.3	26.0
	10.00AM	25.3	26.7	26.9	26.6	26.1	29.2
	12.00AM	29.4	30.3	30.9	31.7	31.2	36.6
	1.00PM	29.8	31.4	33.2	32.3	31.0	40.1
	2.10PM	28.9	30.5	31.7	33.9	32.2	37.9
	4.00PM	27.8	29.9	31.0	32.2	32.4	38.3
	6.00PM	28.3	30.1	30.0	30.3	28.9	28.2
	8.00PM	28.5	29.4	27.9	28.4	28.2	21.4
	9.30PM	27.2	27.8	26.6	25.7	26.3	20.5
10.0317(RAIN)		26.5	25.8	25.1	24.9	25.6	26
12.03.17	10.30AM	20.3	22.0	21.9	21.9	20.0	24.2
	11.30AM	23.5	24.7	24.0	24.4	23.2	29.8
	01.15PM	26.0	27.2	27.7	25.8	25.6	33.2
	02.42PM	24.6	27.7	28.2	27.9	24.5	31.4
	04.00PM	26.8	29.2	28.6	26.9	24.8	31.0
	06.00PM	25.8	28.6	26.3	26.1	25.6	21.5
	09.00PM	23.0	24.7	23.8	22.5	23.9	19.9
13.03.17	09.19AM	16.8	18.7	17.6	17.5	16.3	18.0
	10.30AM	18.7	22.2	21.6	20.9	20.4	22.8
	11.00AM	22.4	23.2	23.8	24.4	23.6	25.0
	12.00AM	22.6	23.4	26.8	25.0	23.8	26.9
	03.00PM	26.5	27.2	27.8	27.5	26.3	29.0
	05.30PM	25.5	28.2	27.8	27.9	26.0	28.0
	09.30PM	23.5	23.3	20.8	23.2	24.5	15.8
04.04.17	08.45AM	20.0	22.0	23.0	22.0	23.0	32.0
	10.00AM	25.0	26.0	27.0	25.0	26.0	35.0
	11.00AM	29.0	31.0	31.0	30.0	32.0	37.0
	12.40PM	35.0	36.0	36.0	35.0	35.5	40.0
	02.00PM	38.0	39.0	39.0	39.0	39.0	40.0
	03.30PM	40.0	42.0	42.0	40.0	41.0	42.0
	05.20PM	34.0	35.0	36.0	35.0	36.0	39.0
	06.30PM	28.0	29.0	30.0	30.0	29.0	37.0
	08.30PM	24.0	24.0	23.8	24.0	24.0	32.0
05.04.17	09.00AM	13.2	14.7	15.0	15.0	15.0	32.0
	12.00AM	32.3	33.5	34.0	33.7	34.0	38.0

	01.34PM	38.0	39.0	40.0	38.0	39.0	42.0
	02.50PM	40.5	41.0	42.0	41.8	42.0	42.5
	05.00PM	32.5	34.0	34.0	33.0	34.0	39.0
	06.45PM	29.0	30.0	30.2	30.0	30.0	37.0
06.04.17	09.02AM	16.0	17.0	18.0	17.0	17.5	33.0
	10.30AM	29.0	30.0	31.0	31.0	31.0	36.0
08.04.17	11.00AM	14.0	15.0	16.0	15.0	14.0	33.0
	01.00PM	32.0	33.5	35.0	34.0	34.0	36.0
	03.45PM	32.5	34.0	34.0	34.0	33.0	38.0
10.04.17	10.00AM	19..6	20.0	21.0	20.0	21.0	31.0
	09.00PM	17.0	18.0	17.0	17.0	17.0	25.0
11.04.17	09.00AM	18.5	20.0	21.0	20.5	21.0	33.0
	11.00AM	26.7	28.0	29.0	29.0	27.0	40.0
13.04.17	09.00AM	15.5	17.0	18.5	18.2	18.2	33.0
	12.00AM	40.0	41.0	42.5	42.5	42.5	43.0
	03.00PM	44.0	45.5	47.0	47.0	47.0	47.0
	06.00PM	27.0	28.3	29.2	29.0	29.1	35.0
	09.00PM	23.0	21.0	20.9	20.7	21.0	20.0
	12.00PM	18.0	16.5	16.0	16.5	16.0	16.0
16.04.17	08.00AM	16.0	16.0	14.0	14.5	14.5	21.0
	09.00AM	26.5	28.0	28.3	29.0	28.4	33.4
	12.00AM	38.0	39.5	40.0	40.0	40.0	42.0
	02.00PM	45.0	46.0	47.2	47.4	47.4	48.0
	03.00PM	45.5	46.3	47.5	47.5	47.4	48.0
	05.00PM	37.0	38.0	40.0	40.0	40.0	24.0
	08.00PM	27.0	28.0	28.0	38.0	38.0	38.3
20.04.17	11.00AM	34.0	35.2	38.0	38.0	38.0	38.3
	03.00PM	43.0	45.0	46.3	45.5	45.3	47.5

4.2 Specific Heat and Thermal Conductivity:

Material	Specific heat(KJ/Kg-K)	Thermal conductivity(W/m-K)
Bricks	0.88	0.811
Stone	0.84	1.83
Cement	0.84	0.721
Limestone	0.84	1.800
Cattle Manure /Cow Dung	0.68	1.992

4.3 Without plaster building R and U Factor :

L1 = 0.0 m; k1 = 1.721 W/m^2-K
L2 = 0.1016 m; k2 = 1.811 W/m^2-K
L3 = 0.0 m; k3 = 1.721 W/m^2-K
hi = 8.3 W/m2-K; ho = 22.7 W/m^2-K

$RT = 1/8.3 + 0.0/1.721 + 0.1016/1.811 + 0.0/1.721 + 1/22.7 = 0.22063$ w/m^2-k
$U = 1/RT = 4.5324$ W/m^2-k

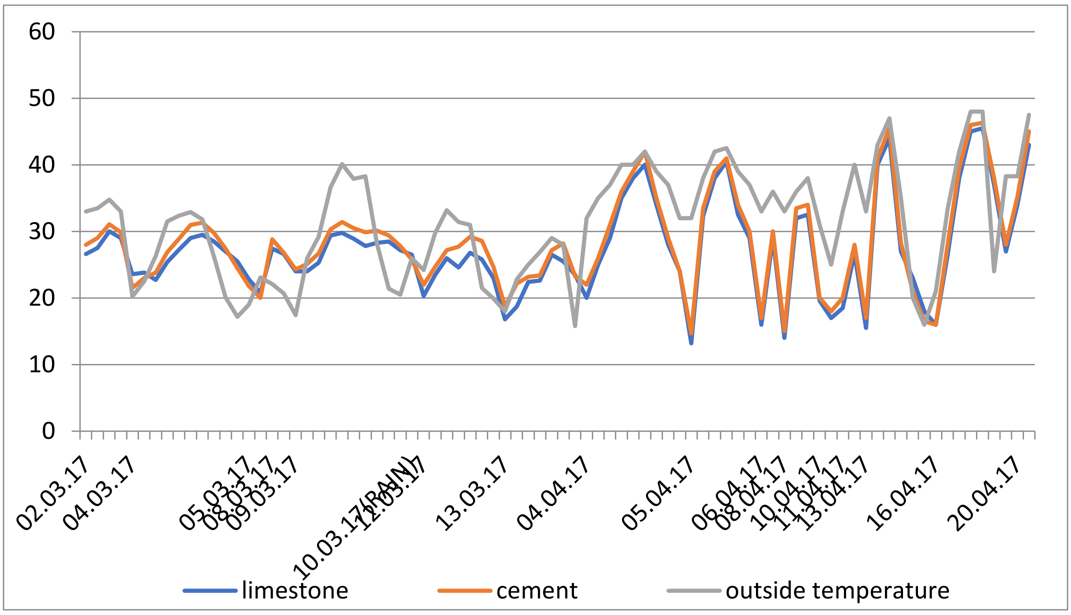
4.5With Cement material plaster cubicle:
L1 = 0.0127 m; k1 = 1.721 W/m^2-K
L2 = 0.1016 m; k2 = 1.811 W/m^2-K
L3 = 0.0127 m; k3 = 1.721 W/m^2-K
hi = 8.3 W/m2-K; ho = 22.7 W/m^2-K
$RT = 1/8.3 + 0.0127/1.721 + 0.1016/1.811 + 0.0127/1.721 + 1/22.7 = 0.2353$ w/m2-k
$U = 1/RT = 4.2498$ W/m^2-k

4.6With Limestone material plaster cubicle :
L1 = 0.0127 m; k1 = 1.800 W/m^2-K
L2 = 0.1016 m; k2 = 1.811 W/m^2-K
L3 = 0.0127 m; k3 = 1.800 W/m^2-K
hi = 8.3 W/m2-K; ho = 22.7 W/m^2-K
$RT = 1/8.3 + 0.0127/1.800 + 0.1016/1.811 + 0.0127/1.800 + 1/22.7 = 0.234$ w/m2-k
$U = 1/RT = 4.27$ W/m^2-k

4.7 With Cattle Manure/cow dung material plaster cubicle:
L1 = 0.0127 m; k1 = 1.992 W/m2-K
L2 = 0.1016 m; k2 = 1.811 W/m2-K
L3 = 0.0127 m; k3 = 1.992 W/m^2-K
hi = 8.3 W/m2-K; ho = 22.7 W/m^2-K
$RT = 1/8.3 + 0.0127/1.992 + 0.1016/1.811 + 0.0127/1.992 + 1/22.7 = 0.23338$ W/m^2-k
$U = 1/RT = 4.28486$ W/m^2-k

Results and Discussion

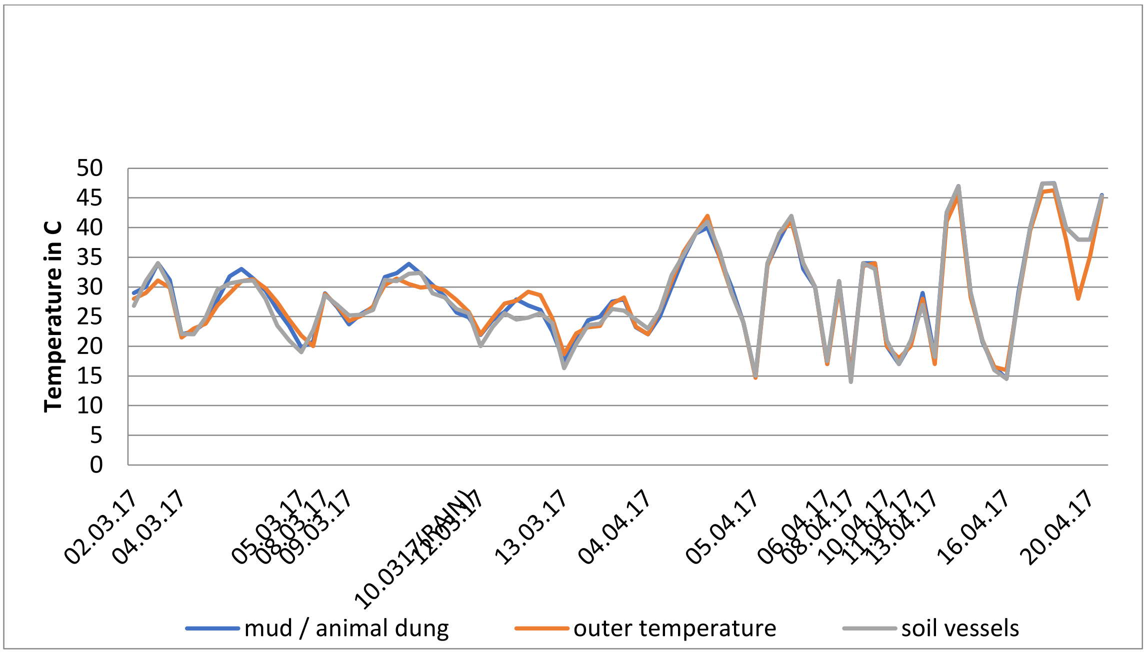
Cement and Limestone:



Graph 1 :

Comparative Graph lime stone, Cement and Outer Temp.
In first graph we compare limestone and cement cubicle temperature with outer temperature.There in march and April cement limestone temperature have batter performance compare to cement and other materials. Variation in limestone with respect to time are in minimum numbers.in march period variation between limestone and cement are lesser because of low temperature in day time but when summer started then difference between both material decrease near by 1 to 1.5 C . limestone performance is good comparative to cement , mud and potteries wastage. In winter season limestone's temperature is high/maximum comparative to other material but in summer minimum or low comparative other traditional and modern materials . maximum building in Old Rajasthan made from limestone .
Due to small size of cubicle effect of outer temperaure is maximim on cubicle temperaure . mud / animal dung and made from soil vessel building temperature is noramlly comman but result of these building material comparative to limestone aren't good.

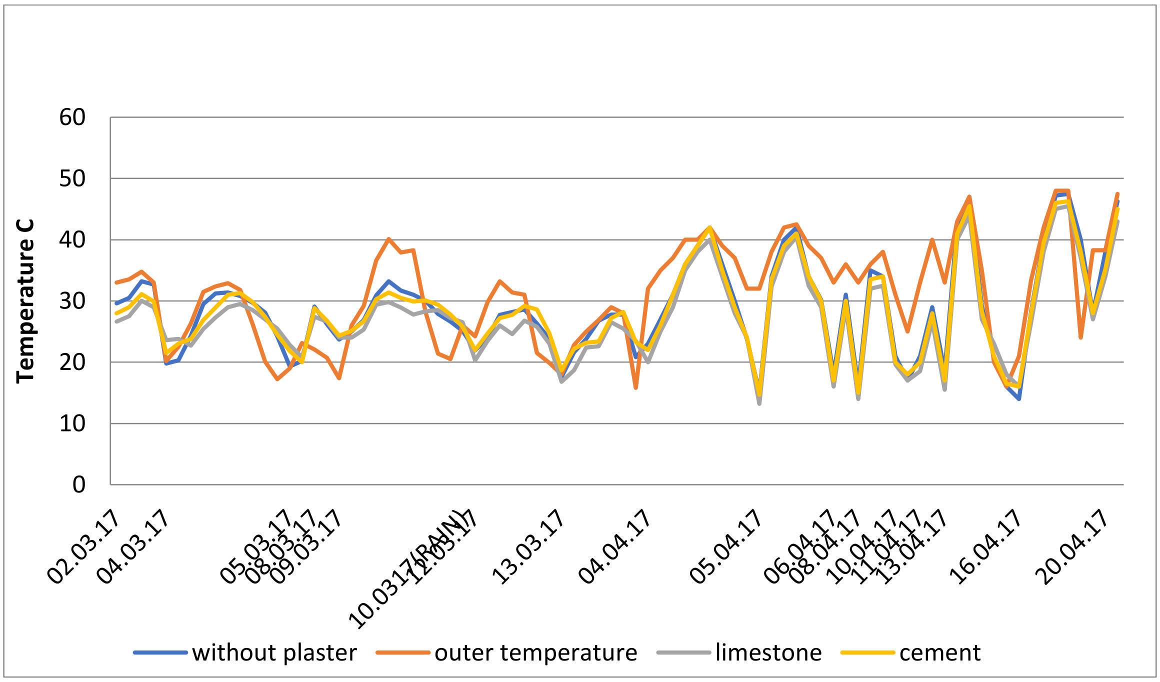
Cow Dung , Soil pots and Outer Temperature Comparative Graph:



Graph 2 : Cow Dung , Soil pots and Outer Temperature

Comparison of limestone, limestone, cement, without plaster cubicle with outer tempetarure :

In Recorded Data results from limestone ,cement and without plaster cubicle we find that limestone temperature is down near by 1 to 2 ^{0}C in summer and in winter it's performance is good from another materials. In summer ,temperature of limestone in day time is high .



Graph 3: Comparison of limestone, limestone, cement, withoutplaster cubicle with outer temp.

6.1 :Conclusions

The present study is based on evaluation of thermal comfort parameters for traditional and modern building materials.

Comparative study of old Indian traditional materials such as limestone, cow dung, soil,soil pot and currently used material i.e. cement has also been done in the present study. Experimental study about these materials and climatic effect on these materials has been conducted through six cubicles constructed with size is 2 .9 feet by 2.9 feet by 2.5 feet.Materials such as limestone, cement, cow-dung and soil pots were studied on the cubicles and it was found that limestone was able to give more cooling in summers.

6.2: Scope for Future Work

This study revealed the importance of wall thickness, wall height, orientation, ventilation and different materials for achieving thermal comfort in buildings in Rajasthan. Further studies are required for development of multilayer insulating walls and roofs with low cost solutions which can help reduce the heat flow and improve thermal comfort. Climate of Rajasthan is hot and dry for most of the months of the year and winters are quite cold for two to three months. Thus, buildings should be designed keeping in mind the climatic conditions of this area so that minimum energy is required for maintaining thermal comfort in the buildings.

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