Australian Journal of Basic and Applied Sciences, 9(2) February 2015, Pages: 232-240

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

Study of Thermal Distribution over the Roof and Walls in SUMMER

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ARTICLE INFO

Article history:
Received 25 October 2014
Received in revised form 26 November 2014
Accepted 29 December 2014
Available online 15 January 2015

Keywords:
Thermal performance, Thermal distribution, Thermal comfort, Upper part, Middle part, Lower part, Passive approach.

ABSTRACT

The thermal performance of a building in usage depends on design variables, material properties, weather data and a building's usage data. For a particular design, thermal performance of a building strongly depends on the major building elements, roof and wall. The solar radiations reaching the roof and wall heat them. The received thermal energy by the roof and walls is distributed over the surface area. Thermal distribution depends on the outdoor temperature. The roof and walls become the secondary sources of heat. The conducted and radiated thermal energy through roof and walls are transmitted to the inside of the building. The energy received by the indoor results in the indoor temperature. The indoor temperature of a building, leads to the conclusion of the comfort or the discomfort of the occupants. Whether the heat energy transmitted by the roof or wall are equally distributed or not is the inquiry of this study. In this study roof or wall surface is divided into three equal parts and they are named as Upper, Middle and Lower parts. Six experimental modules were constructed for this study and they were named as SID, DOD, PUD, OAS, OGS and RCC. The SID, DOD, PUD and RCC modules were built with same type of walls and with different types of roofing systems. The OAS and OGS modules are constructed with the same type of material for roof and walls. Thermal measurements of roof and walls were recorded for the summer season of 2014. These modules adopt passive approach. It is noticed that the three parts of roof and walls showed different temperatures. It was distinct in the case of SID, OAS and OGS roofs and walls, than the DOD and PUD modules. Regarding RCC module, different parts roof and the walls showed a very little variation. DOD and PUD module's roof and walls showed a uniform variation.

To Cite This Article: Mrs. M. Ponni and Dr. R. Baskar, Study of Thermal Distribution over the Roof and Walls in SUMMER. ***Aust. J. Basic & Appl. Sci.,*** *9(2): 232-240, 2015*

INTRODUCTION

Worldwide, 30-40% of all primary energy is used in buildings. The developed and developing countries use fossil fuels and the low income countries, dominantly use biomass. In different ways, both patterns of energy consumption are environmentally intensive, contributing to global warming. Without proper policy interventions and technological improvements, these patterns cannot be changed. On the global level, knowledge regarding the energy use of building stocks is lagging behind. The residential sector accounts for the major part of the energy consumed in buildings; in developing countries the share can be over 90%. On the other hand, the energy consumption in non-residential buildings is also significant.

The pattern of energy use in buildings is strongly related to the building type and the climate zone. Consumption of energy mostly occurs during the building's operational phase, for the purpose of heating, cooling and lighting. This urges the building experts to produce more energy-efficient buildings and to renovate the existing buildings. The diversity of buildings, their distinct uses pose a challenge for the recommendation of energy conservation measures. Specific solutions are required for each situation, such as for the construction of new buildings, renovation, for small family houses and for large commercial buildings. These strategies apply to buildings in both warm and cold climates. The energy consumption also depends on the behavior of individuals, such as gender, age and socio-demographic conditions. Awareness should be developed among the consumers.

Thermal performance and efficiency of buildings should be measured through climate responsive design. The use of site and climate for design with regard to thermal efficiency has further potential for reducing active energy, which is the operational energy of the building. The high interest for passive energy utilization for the provision of thermal comfort, opinions should be developed to assist for the saving of the energy through life cycle costing. This fundamentally involves the computation of the capital cost of the building and cost of

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operating the building over its life. The active energy cost often exceeds the capital costs of buildings. Climate conscious design requires a thorough understanding of the local climate; and the engagement of several strategies for the development of an agreeable micro-climate for the maximum indoor thermal comfort.

Whenever there is a temperature difference between the conditioned indoor space of a building and outdoor ambient, heat transfer takes place through the building structure (walls, roof, floor etc.). This is known as fabric heat gain or loss, depending upon whether heat transfer is to the building or from the building. The fabric heat transfer includes sensible heat transfer through all the structural elements of a building. Exact analysis of heat transfer is somehow tough. Anyway most of the heat transfer takes place through the roof of the building.

Review of Literature:

Thermal performance of a building refers to the process of modelling the energy transfer between a building and its surroundings. India is in energy transition. The energy consumption in Indian residential buildings is the highest among all the Asia Pacific Partnership (APP) countries Bin and Evans .M (2008), and is increasing at a phenomenal rate. More than 30% of primary energy is consumed by non-industrial buildings, including houses, offices, schools, hospitals, and so on Anink D., Boonstra C., and Mak J.(1996). Energy consumed in the production of building materials is 20% of the world fuel consumption. It demands immediate action to develop energy efficient buildings. It is well known now that, uncomfortable buildings drive the users towards high energy solutions.

The total electrical energy consumed by Indian buildings is 33%. If the Energy Conservation code is enforced for the construction work, it will yield annual savings approximately 1.7 KWH. Estimates based on computer simulation models can use 40 – 60% less energy than conventional buildings. The efficiency of a building strongly depends on the selection of roof and wall and application of insulation and the orientation of the building. These are highly reasonable for the indoor temperature of a building. In other words the efficiency of a building is decided by the indoor ambient temperature of the building.

Roof is the element which directly receives the most of the solar radiation in different angles than the other elements of the building. Inadequate roof insulation results in heat transfer from the roof to indoor. Insulation can be applied between roof rafters or on the rafters. For concrete roofs, outer insulation over the concrete can be applied K.C.K. Vijaykumar, P.S.S. Srinivasan, S. Dhandapani (2007).

Indian concrete roofs, with 150mm of concrete and 75-100mm of weathering course transfers 50-70% of heat in to the occupant zone. High reflective coatings can reduce 20-70% heat transfer Tang, R. & Etzion, Y. (2004). The heat incoming into the occupant zone through roof is the main cause of discomfort Gut, P. & Ackernecht, D. (1993). The heat transferred into the occupant zone is true for single storey and top floor of the multi - storeyed buildings Langewiesche, W., (1950). Traditional architecture in hot climates has long recognised that the building colours can reduce cooling loads Givoni, B. (1976), Givoni, B. and Hoffman, M.E., (1968).

Common passive cooling systems have been classified into comfort ventilation, nocturnal ventilation cooling, radiant cooling, evaporative cooling, and using the earth as a cooling source Cavelius. R *et al* (2007). In the same way the most important techniques for passive cooling has been listed as Solar Shading, Insulation, Induced ventilation Techniques, radioactive cooling, evaporative cooling, earth coupling and desiccant cooling Kamal.M.A.,2012. The strategies of passive cooling fall in to three categories: 1) Heat prevention/reduction, 2) thermal moderation and 3) heat dissipation Geeth .N.B., Velraj.R., (2012).

The recent concept of energy efficient Green buildings attracted all the scientists and building architects to switch over from the present practice of mechanical cooling to ancient methods of passive cooling methods in an efficient modern way. It should be noted that a concept suitable for one place may not be suitable for another, if the climatic conditions are different Orosa J.A. (2012).

Even though the above methods are more suitable in reducing the heat gain to the Room, the cost incurred for the making such a roof should be considered. The initial cost associated for making the green roof is higher and it is difficult to maintain properly. It also requires stronger roof beam to support the various roof layers of the green roof. Also in the roof with roof coating, the detritions of roof coating over the time are a Major setback. The settlement of dust over the roof coating may completely spoil the performance of the roof coating K.C.K. Vijayakumar, P.S.S. Srinivasan, S.Dhandapani (2007).

Passive design approach makes use of natural energy in the environment which is available to the building through the use of the microclimate, the building form and fabric. Higher standards of living are being demanded today worldwide. A comfortable environment is where there is freedom from annoyance and distraction, so that working or pleasure tasks can be carried out unhindered physically or mentally. Air temperatures, humidity, air movement and air purity play a part while psycho sociological factors also have important roles to play Chand, L. (1976).

The attitudes of space users, the organization of indoor spaces, colour schemes and many other factors can all have influence on our mood and work output. Thus, there is interaction between all these factors, which complicate the comfort problem further. Such factors can be grouped under three headings: 1)Physical factors (sound, light, area-volume, radiation, air movement, temperature, inspired air, force field, relative humidity and atmospheric pressure), 2)Organism factors (age, diet and sex) and 3) Reciprocity factors (activity, clothing exposure and social level) Derek, J.C. and Brain, M. (1978).

Housing is a multifaceted phenomenon which is expected to meet human requirements (functionality in use, safety, health, and comfort), economic requirements (economy of investment, construction and lifetime), cultural requirements (lifestyle, building traditions, business culture, aesthetics, architectural styles and trends, image), and ecological requirements (economy of raw materials, energy, environmental burdens and waste, also biodiversity). The EU Construction Products Directive 89/106/CE requires all structures to comply with six essential requirements: (1) mechanical resistance and stability; (2) safety in case of fire; (3) hygiene, health and the environment; (4) safety in use; (5) protection against noise and (6) energy economy and heat retention. All these aspects must be taken into account considering both building construction and modernization projects Sarja, A., Vesikari, E., (1996).

With all these information present work analyses six experimental modules to study the thermal distribution over the roof and walls.

Research Description:

Previous research efforts have investigated the thermal performance of various wall and roofing systems. In this study an attempt has been made to quantify the thermal distribution over different parts of roof and walls. All the modules have same floor, wall area and orientation. The size of the module is 3mx 3m x 3m. The galvanized sheets used in the modules have the same thickness of 0.21 mm. The walls have a thickness of 230 mm made up of brick. Two angles are used as purlins. The slope of the roof is maintained to be 2˚except RCC. Walls of the modules are white washed and the flooring is done with cement mortar. The modules are unconditioned and unventilated and unoccupied. A tri – divisional approach is applied, by splitting the area into three equal parts as shown in Fig.1. The space between each part is one meter. The three parts are named as Upper, Middle, and lower and further the temperatures are measured in the corresponding areas carefully for the summer period. The modules constructed for this study has been designated by three letter codes.

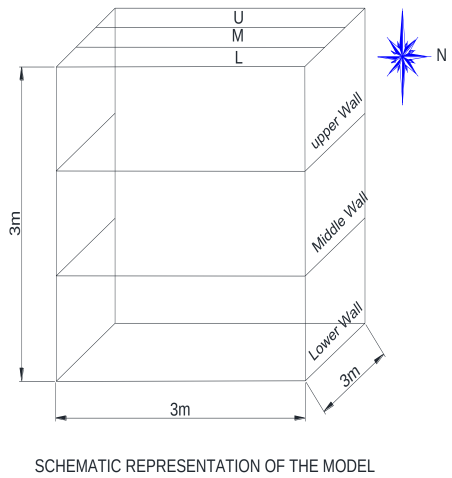

Fig. 1: Tri-Divisional Model.

Table 1: Construction data of the Research Modules.

Sl. No	Description	Dimension in m^2
1	Floor Area	9.29
2	Net Wall Area	35.26
3	Ceiling	11.16
4	Door	1.76
5	Overhang	1.82

First Module (SID):

First module is Single Decker (SID), in which Galvanized sheets are used as roof element, where the walls are made by bricks shown in Fig.2. When the solar radiation falls on the roof, the sheets are very easily heated even by early hours due to conduction and it continues for the whole day. During the peak hour the amount of heat transmitted into the building is massive.

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Second Module (DOD):

Second module roof is a newly designed roof. The design is carried out in four steps. In the first step, first roof is made using galvanized sheets. In the second step wooden reapers of size 3000 mm X 50 mm X 25 mm were arranged over the roof. The spacing between the reapers is 200 mm. In the third step, 50 mm packed mineral wool roll was spread. In the fourth step galvanized sheets were set over it as second roof. The two roofs are separated by 100 mm to 122 mm. Since light roofing system has two light roofs enclosing the wooden reaper and mineral wool, which is named as Double Decker (DOD) is shown in Fig.3. Hemi-cylindrical air ducts are formed between the galvanized sheets and the mineral wool bed. Likewise hemi-cylindrical air ducts of the same size are formed just below the wooden reapers and the lower side galvanized sheets. These ducts are useful in the process of air convection. The insulators wood and mineral wool avoids the heat transmission through the roof. This roof design adopts the passive design approach.

Third Module (PUD):

The roof of the third module is constructed with Polyurethane panels of length 3660 mm and breadth 1000 mm. Polyurethane panel is an industrial product is shown in Fig.4. The thickness of the panel is 35 mm and the thickness of the sheet sheets used by the industry is 0.35 mm. This module is named as Poly urethane Decker (PUD).

Fourth Module (OAS):

The fourth module is constructed by using trapezoidal Asbestos sheets for the roof and wall. In India asbestos products are available in the form of plain and trapezoidal sheets which are used without any hesitation. Though asbestos is banned by New eland, Australia, Turkey, Japan, Singapore, USA, and UK due to its disease making nature but it is used still in India, Indonesia, China, Russia and Brazil. Russia is the richest producer of asbestos about 50%. Asbestos is a set of six naturally occurring silicate minerals used commercially for their desirable physical properties. Like galvanized sheets, asbestos she*et al*so allows the solar radiation through the roof and walls and consequently enhances the temperature of the dwelling area to a painful level in the hot sunny days. Roof, wall and door of the module use this asbestos sheet. Hence this module is named as Overall Asbestos Sheet module (OAS).

Fifth Module (OGS):

The roof and wall of the fifth module OGS is constructed with Trapezoidal Galvanized sheets. Since the galvanized sheets are being used for roof and walls the module has been named as Overall Galvanized Sheet module (OGS). Galvanized sheet roofing is adopted by the industries, workshops, warehouses and is also followed by the Low economy Group community because of its light weight, easiness in construction and low cost. Being a conductor the sheets easily receives and permits solar radiation into the occupant zone through the roof and walls. The floor of the module also takes part to increase the indoor temperature of the module.

Sixth Module (RCC):

The sixth module is a RCC roof. A room of size 3m x 3m x 3m of a one storey building has been considered for this experiment. The roof consists of concrete, weathering course and Mangalore Tile is used over the weathering course.

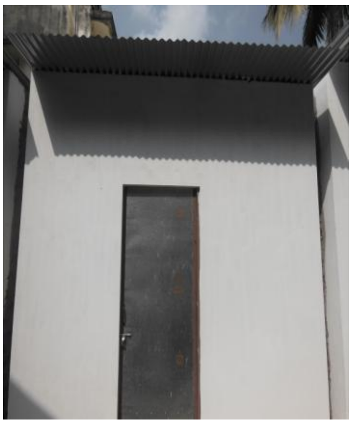

Fig. 2: SID

Fig. 3: DOD.

Fig. 4: PUD

Experimental Setup:

The experiments were carried out in Chidambaram, Tamil Nadu, 11˚24΄N latitude and longitude 79˚44΄E.The location is characterized by hot and humid weather. The modules, used in this study are exactly identical in terms of their geometry, area and climate conditions. All the modules are east oriented. SID, OGS and OAS are provided with single roof and DOD and PUD are provided with double roofs.

All the modules are fully instrumented. In six hours interval (6, 12, 18hr) the roof, wall and floor temperatures were measured by means of Infra-Red Thermometer. Roof, wall, floor and indoor and outdoor ambient temperature and relative humidity field data have been catalogued for summer months for six different roofing systems exposed to weathering on an indoor and outdoor test facility. The data are plotted for the time period from April to July 2014.

Results over the Monitoring Period:

The modules considered for this study are east oriented. The Upper part of the roof is in the west side and lower part is in the east side. The modules considered are low sloped about 2˚ except the RCC roof. From the sun rise to the noon the eastern side of the roof and wall is highly irradiated by solar radiation than the west side. Naturally the expectation is that the east side of roof should possess a high temperature than the west side. Hence this study has concentrated to measure and estimate the existence of temperature difference between the upper, middle and lower parts of the roof and walls. Though the measurements were taken for three different times of a day, the analysis is concentrated only for the noon mean temperature measurements of the summer season.

The three equated parts roof temperatures of the six experimental modules shown in Figure 5.

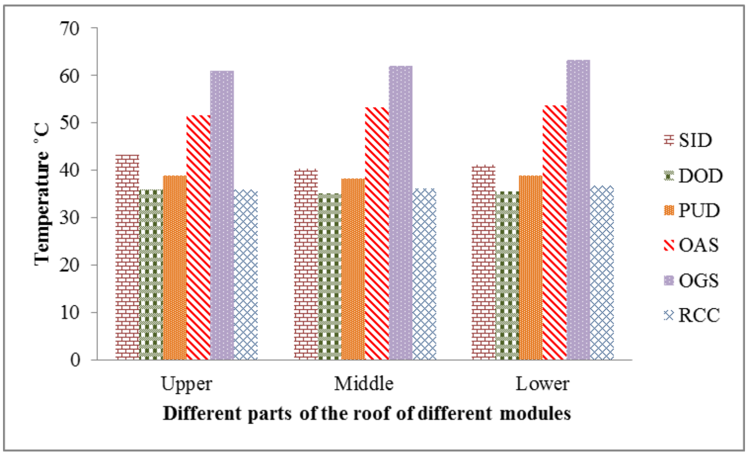

Fig. 5: Roof temperature in the noon.

Roof temperature of the upper, Middle and lower parts of different modules is in Table 2.

Table 2: Roof temperature variation of the three parts (UML) of six modules.

Roof	Upper part	Middle part	Difference	Middle part	Lower part	Difference
SID	43.2	40.4	2.8	40.4	41.2	-0.8
DOD	36	35.2	0.8	35.2	35.6	-0.4
PUD	39	38.2	0.8	38.2	38.8	-0.6
OAS	51.6	53.2	-1.6	53.2	54.2	-1.0
OGS	61	62	-1	62	63.4	-1.4
RCC	36	36.2	-0.2	36.2	36.8	-0.6

The upper part of the roof keeps a higher temperature than that of the middle part in the case of SID, DOD, and PUD roof systems as shown in Fig.5. The temperature variation noticed from the table 2 is 2.8˚C in SID and it is 0.8˚C in the other two cases. In the case of OAS, OGS and RCC the middle part has a higher temperature than that of the lower part. The variation observed is 1.6˚C in OAS and 1˚C in OGS and 0.2˚C in RCC. And further the lower part has a higher temperature than that of the middle part in all the above cases. As a net result middle part of these roofs possesses a lower temperature than the other two parts. In the case of OAS, OGS and RCC the upper part is at a lower temperature than that of the middle and lower parts. The middle part of all the six roof systems possesses a lower temperature than that of the lower part and the variation ranges from 0.4 to 1.4˚C.

The temperature of three equated parts of the North wall of the experimental modules at noon is shown in Figure 6.

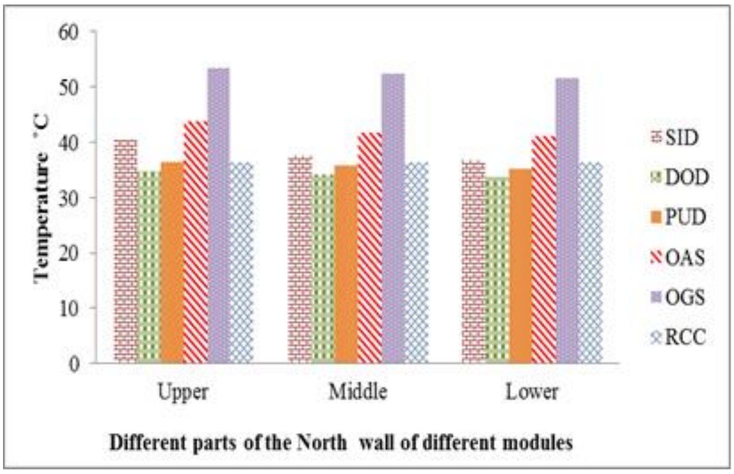

Fig. 6: Temperature of North wall in the noon.

Temperature of the upper, middle and lower parts of the north wall of all modules is shown in Table 3.

Table 3: Temperature variation on the three parts (UML) of the north wall of all modules.

North wall	Upper part	Middle part	Difference	Middle part	Lower part	Difference
SID	40.6	37.6	3	37.6	36.8	0.8
DOD	34.8	34.4	0.4	34.2	33.8	0.4
PUD	36.4	35.8	0.6	35.8	35.2	0.6
OAS	43.8	41.8	2	41.8	41.2	0.6
OGS	53.4	52.4	1	52.4	51.6	0.8
RCC	36.4	36.4	0	36.4	36.4	0

The upper part of north wall of every experimental module shows a high temperature than the other two parts as shown in Fig.6. The temperature decreases from upper to the middle and the lower part of the wall. The temperature variation from the upper to middle part is found in table 3, in the case of SID it is 3˚C, in the case of OAS it is 2˚C and OGS it is 1˚C and it is 0.6˚C in PUD and 0.4˚C in DOD and no variation in RCC. The variation from middle to lower is 0.8˚C in SID and OGS and is 0.6˚C in the case of PUD and OAS and in DOD it is 0.4˚C and no variation exists in the case of RCC. It is concluded that the highest influence of roof temperature over the north wall is shown on SID and the higher influence is shown on OAS and the high influence is on OGS.

The temperature of three parts of South wall of the experimental modules at noon is shown in Figure 7.

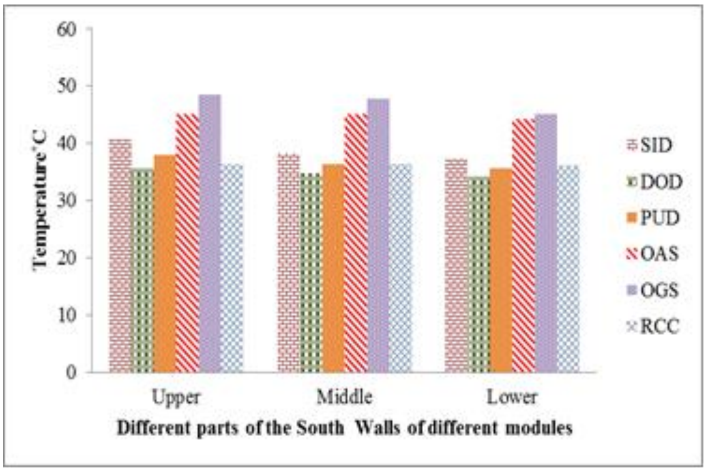

Fig. 7: Temperature of South wall in the noon.

Temperatures of the upper, middle and lower parts of the South walls of all modules are shown in Table 4.

Table 4: Temperature variation on the three parts (UML) of the South walls of all modules

South wall	Upper part	Middle part	Difference	Middle part	Lower part	Difference
SID	40.6	38.4	2.2	38.4	37.2	1.2
DOD	35.6	34.8	0.8	34.8	34.2	0.6
PUD	38	37.2	0.8	36.4	35.6	0.8
OAS	45.2	45.2	0	45.2	44.2	1
OGS	48.6	47.8	0.8	47.8	45.2	2.6
RCC	36.4	36.4	0	36.4	36.2	0.2

The upper part of south wall of every experimental module shows a high temperature than the other two parts as shown Fig.7. The temperature decreases from upper to the middle and the lower part of the wall. The temperature variation from the upper to middle part as shown in table 4, in the case of SID is 2.2˚C, in the case of DOD, PUD and OGS it is 0.8˚C and in OGS it is 1˚C and in the case of OAS and RCC no variation exist. It is concluded that the highest influence of roof temperature over the south wall is on SID and the higher influence is on DOD, PUD, and OGS. The temperature variation between the middle and lower parts in the case of OGS is 2.6˚C which shows a highest variation and in the case of SID it is 1.2˚C in PUD it is 0.8˚C and it is 0.6 ˚C in DOD and OAS it is 1˚C and in RCC it is 0.2˚C. The highest variation is found in the case of SID regarding the upper and middle part. So the influence of the SID roof is more on the south wall. The highest variation is shown by OGS between the middle and lower part.

The temperatures of the three parts of East walls of experimental modules at noon are shown in Figure 8.

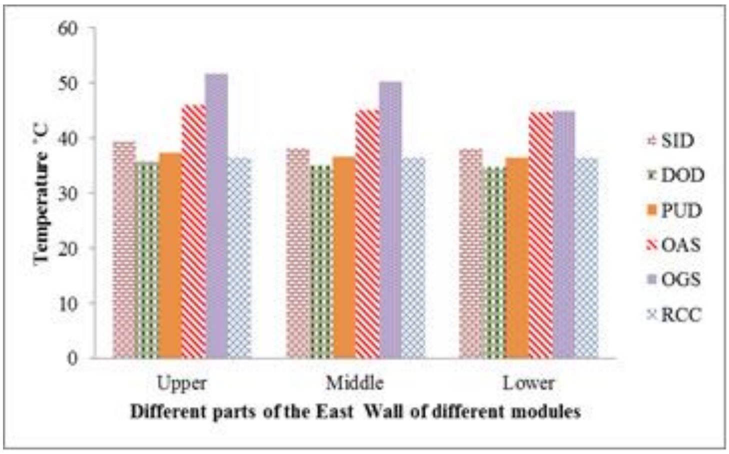

Fig. 8: Temperature of East wall in the noon.

Temperatures of the upper, middle and lower parts of the East walls of all modules are shown in Table 5.

Table 5: Temperature variation on the three parts (UML) of the East wall of all modules.

East wall	Upper part	Middle part	Difference	Middle part	Lower part	Difference
SID	39.4	38.4	1	38.4	38.2	0.2
DOD	35.8	35.2	0.6	35.2	34.8	0.4
PUD	37.4	36.8	0.6	36.8	36.6	0.2
OAS	46	45.2	0.8	45.2	44.8	0.4
OGS	51.8	50.4	1.4	50.4	45	5.4
RCC	36.6	36.6	0	36.6	36.6	0

The three equated parts of east walls of all the experimental modules show that the upper part has a high temperature than the lower part as shown in Fig.8. The temperature decreases from the upper part to the lower part in all the cases. The temperature variation between the upper and middle parts as shown in Table 5, in the case of SID is 1˚C, OGS is 1.4˚C and in the case of DOD and PUD is 0.6˚C and in PUD it is 0.8˚C In the case of RCC no variation is found. The temperature variation between the middle and lower part s of the OGS is 5.4 and in OAS and DOD is 0.4 and in SID and PUD is 0.2.

The temperatures of three parts of West walls of experimental modules at noon are shown in Figure.9.

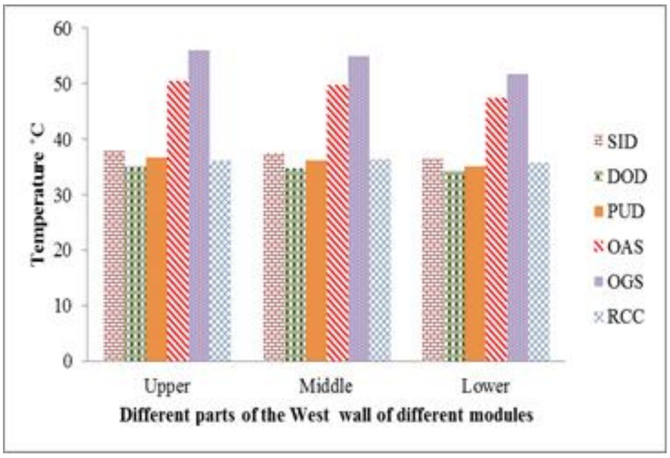

Fig. 9: Temperature of West wall in the noon.

Temperatures of the upper, middle and lower parts of the West walls of all modules are shown in Table 6.

Table 6: Temperature variations on the three parts (UML) of the West wall of all the modules.

West wall	Upper part ˚C	Middle part ˚C	Difference ˚C	Middle part ˚C	Lower part ˚C	Difference ˚C
SID	37.8	37.6	0.2	37.6	36.4	1.2
DOD	35.2	34.8	0.4	34.8	34.2	0.6
PUD	36.8	36.2	0.6	36.2	35.2	1
OAS	50.6	49.8	0.8	49.8	47.4	2.4
OGS	56	55	1	55	51.8	3.2
RCC	36.4	36.4	0	36.4	35.8	0.6

The three equated parts of west walls of all the experimental modules shows that the upper part has a high temperature than the middle and lower parts as shown in Fig.9. The temperature decreases from the upper part to the lower part in all the cases except RCC. The variation between the upper and middle parts as shown Table 6, in the case of OGS it is 1˚C and in OAS it is 0.8˚C and in PUD it is 0.6˚C and in DOD it is 0.4˚C and in SID it is 0.2˚C and in RCC no variation. The variation between the middle and lower parts in the case of OGS is 3.2˚C and in OAS is 2.4˚C and in PUD it is 1˚C and in DOD and RCC it is 0.6˚C.

Conclusion:

This study has investigated the temperature variations of different parts of roof and wall surfaces. It has been observed that 1) the temperature of the three parts of the roof were not uniform from the upper part to middle and to lower parts. 2) The middle parts of the roof systems of SID, DOD and PUD have a lower temperature than that of the other two parts 3) In the case of other three modules OAS, OGS and RCC the middle parts have a higher temperature than that of upper and lower parts 4) The lower parts of OAS,OGS and RCC have a higher temperature than that of the middle parts 5) The upper parts of north and south walls of the modules, were at higher temperatures than that of the other two sides of the walls.
6) The upper part of the east side wall has a higher temperature than that of the upper part of the west side wall. The careful temperature measurements of the north, south, east and west walls of the different modules shows that the upper parts of all the experimental modules ensure high temperature than that of the middle and lower part. 7) The roof temperatures of SID, OAS, OGS and RCC modules influence the walls to a larger level but the roof temperature of DOD and PUD modules influence the walls to a less extent.

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