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Human Thermal Comfort In Residential House Buildings Of Jimma Town, Southwest Ethiopia.

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Abstract: Indoor human thermal comfort is an important factor in indoor air quality assessment. Thermal comfort affects human health, work efficiency and overall wellbeing. Thermal discomfort in indoors lowers the emotional and physical health of the occupants. This paper targets to explore human thermal comfort in residential house buildings of Jimma town and state some possible mechanisms to improve the existing thermal discomfort in large number the houses. For the study, 303 structured questionnaires were distributed to the residential houses in thirteen places of the town based on predetermined criteria. The study reveals that human thermal discomfort in residential houses Jimma town are mainly from poor architectural design and improper use of heat generating appliances in indoors. The uses architectural design that suites the present climatic conditions and use of materials that facilitates ventilations will enhance the realization of the required human thermal comfort in residential houses of the study area.

Key words: Indoor environment, Jimma town, Physical parameters, Residential houses, Thermal comfort, Thermal Discomfort, ventilations.

1 INTRODUCTION

Human thermal comfort is one aspect of indoor environmental quality (IEQ) assessments. For the fact human spend most of their time in indoors, indoor thermal environment affects human lives at large[1]. Thermal comfort is the result of complex interactions between building, building systems and people and it. Thermal comfort plays a significant role in human performance at both mental and physical levels [2]. Failure of human beings to respond to the environment through thermo-regulatory mechanism causes thermal discomfort [3].Thermal discomfort experience by occupants of a built environment causes lower emotional health manifested as psychological distress, depression and anxiety as well as lower physical health manifested as heart disease, insomnia, headache, fatigue, boredom and poor arousal [4]. Buildings are designed and constructed to provide healthy and comfortable environments for humans working, living, learning, curing, and processing in it [5]. In meeting these basic requirements, the building should not cause harm to its occupants or the environment and must, for example, be structurally stable and safe [1].The use of natural and healthy materials, for residential house construction, contributes to the well-being of the occupants and to a feeling of connection with the bounty of the natural world. Uses of many fabricated construction materials for residence have significant environmental impacts from pollutant releases, habitat destruction, and depletion of natural resources during extraction and acquisition of raw materials, production and manufacturing processes, and transportation[6].

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This paper assesses about sources of human thermal discomfort in indoors of residential houses of Jimma town and recommend on the ways to improve it through natural means and through simple design dependent architectural works.

2. Description of the study area

Jimma town is one of the most important trade centers in the south western part of Ethiopia since its foundation 1837. It is at altitude of about 1740m from sea level with warm temperature rainy climate without distinct dry season and known by continuous change of climatic conditions in a day [7]. The town is situated at 7º 41' North Latitude and 36º 5' East Longitude [8].In 2015,the measured maximum temperature of 34.1^{o}C is registered in March and minimum value of 0.5^{o}C is recorded in February. Maximum rain fall of 67mm is registered in June as well expressed in table 1.

Table 1. Measured values of climatic variables of Jimma town in 2015[9].

Month	Temperature(^{0}C)		R. Hum. (%)		Wind Speed (m/s)		R. Fall (mm)
	Max	Min	Max	Min	Max	Min	Max
January	32.0	1.4	55	21	0.19	0.04	6.1
February	32.6	0.5	64	26	0.23	0.06	7.9
March	34.1	4.2	82	22	0.40	0.05	26.3
April	32.0	9.8	65	34	0.31	0.07	45.1
May	31.2	11.5	79	47	0.36	0.04	26.0
June	30.0	12.5	92	47	0.56	0.08	67.0
July	28.0	14.2	83	58	0.92	0.14	57.2
August	29.5	12.0	98	56	0.34	0.01	30.5
September	29.0	11.5	82	51	0.36	0.03	45.4
October	29.8	10.2	66	41	0.42	0.09	34.6
November	28.6	12.0	69	41	0.55	0.30	37.0
December	29.5	8.2	85	45	0.26	0.01	28.6

* *in all month the minimum rain fall is 0.0 mm.*

3. Methodology of the study

Field study method was utilized to collect data from thirteen sites of the town. In the study the first place of the town, business areas, and recent areas: Jiren, Merkato and Bishishe, Bachoo Bore and other areas respectively are included. Structured questionnaires are distributed to selected 303 residential houses, for 95% confidence level at confidence interval of 5.6 for 30,016 housing units in the town based on [10].

4. Thermal comfort

Thermal comfort refers to the condition of mind that expresses satisfaction with the thermal environment and is evaluated by subjective evaluation [11]. Thermal comfort was defined by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) as that state of mind which expresses satisfaction with the thermal environment [12].Over the years, a large amount of empirical data has been obtained, in winter and summer, on how physical and personal parameters affects human thermal comfort in indoors [13]. Indoor environment is comfortable with the standard of air temperature ranging from 24^0C to 30^0C and set the upper limit of relative humidity to be in the humidity ratio of 0.12 with various values in summer and winter[14].

5. Results and Discussion

The distributed questionnaires contain objective questions that are summarized in tables and percentages. Table2. describes the response with regard to heat sources, ventilation system, type of kitchen, number of occupants, and ventilation systems. In table 3, descriptions were given for the materials out of which parts of the houses were constructed and energy sources in indoors were given.

Table 2: Responses of the questionnaires on general information about their homes

No.	Question item	Yes (%)	No (%)
1.	Connected to electric grid	72	28
2.	Have of heat generating devices in indoors	75	25
3.	Have operational air conditionnarie in indoors	0	100
4.	Use of electric Fan in indoors	1.3	98.7
4.	Have vegetation near the house for ventilations	53	47
6.	Have proper size of window for cross ventilation	32	68
7.	Have orientation that prevent direct fall of sun radiation to indoors	39	61
8.	Have proper roof insulation/ceilings	19	81
9.	Have door insulation	2	98
10.	Contains window insulations	28	72
11.	Constructed by professionals/engineers	11	89

Table 3: Construction materials used on buildings & others related cases in houses

1.Wall materials	Mud &wood Pole	Wood, Mud, & Bricks	Bricks	Others
%	85.4	3	5.3	6.3
2. Door Materials	Timber	Metals	Metal framed Glass	Metal+ Glass
%	83	8.2	6.7	3.1
3.Window Materials	Timber	Metals	Metal framed Glass	Metal+ Glass
%	86	4.3	5.6	4.1
4. Roofing	Corrugated iron sheet	Thatched	Concrete	Others
%	94.7	1.3	2	2
5. Floors	Concrete	Mud	Tiles	Others
%	28.7	57.9	10.1	3.4
6. Lighting devices	Incandescent Bulb	Bulb Energy Saver	Combination	Others
%	8.3	24.7	61	6
7. Energy for cooking foods	Charcoal/Fire wood	Kerosene	Electricity	Others
%	78.2	10.2	9	2
8. Age of house	< 5 years	5-9 years	10-14years	> 15 years
%	20.9	18.3	9.2	51.6
9. Attachments that generates heat	Mill house	Factory/simple industry	Kitchen	Others
%	3.7	8.3	58	30

From table 2 above, occupants in indoors sense thermal discomfort due to overheating coming from the use of heat generating devices, say use of electric/charcoal stoves for food cooking and other activities for survival. The problem of indoor thermal discomfort is aggravated from the absence of air conditionnarie and electric fan that are used for moderation of indoor thermal environmental condition. In almost all selected residential houses of Jimma town it is observed that, there are no door and wall insulations, but some 24% windows and 39 % of roofs/ceilings are insulated. Residents in the area do not equally understand the use of insulations at different parts of the houses;

- when wall of house is not properly insulated it causes asymmetric thermal radiation from different sides during heat gain or loss
- as house roof/ceilings do not have insulations, the rate of heat flow in to indoors through roof is high and magnify indoor thermal discomfort. Large numbers of the houses in the study (61%) have no proper ceiling in residential houses that contribute a larger share to consider thermally not comfortable.

As a part of the house, absence of knowledge on the use of insulation aggravates the problem coming from improper house orientation which facilitates direct fall radiations in indoors. As it is observed the occupants responded as they have vegetation, 53%, to excrete fresh air to indoors for ventilations but it is not in proportion to the size of the houses around and they do not have the capacity to supply sufficient amount of fresh air in indoors with respect to types of houses, distance from the house and wind directions. Improper size of windows and lack of well oriented houses adds problems of thermal discomfort for the direct fall of suns radiation to interior part of the houses in addition to lack of thermal insulation of windows, doors and roofs to control asymmetric radiations and moderate the heat flow in indoors. Table 2 specifies 89% of sample residential houses are constructed without the consent of professionals in the field. All the design dependent architectural parameters could be assessed and implemented to construct thermally comfortable house indoors with respect to the existing climatic conditions in the area. Local and unqualified workers could construct residential houses with no as such attention for human indoor thermal comfort in them. As shown in table 3, 85.4% of the residential houses walls are from Mud and wood pole of large thermal lag across it. The use of combination of mud, wood and brick for wall is expanding at greater rate but it is at lower rate 3% and newly constructed residential houses walls are out of bricks and it is rated 5.3%. Some 6.3 % of the residential houses walls are from other materials that are listed above. Timber is widely used as door and window materials in most traditional houses since it rates near 85% in both. Use of metals for door and window rates 8.2% and 4.3% respectively and 6.7% of metal framed glass is used for doors and 5.6% for windows though they have higher thermal conductivity and generates thermal discomfort in indoors as compared wood and mud wall. The roofing materials for the study area are almost, 96.7%, from corrugated iron sheet of higher thermal conductivity to allow large amount of radiations during hot seasons and also trap heat to outside during cold seasons as most residential houses that have no proper insulation for their ceilings. The most painful thermal condition in indoors comes from the use of charcoal/ fire wood78.2% and kerosene 10.2% as energy sources generates two dimensional problems, one creating thermal discomfort in indoors and in other side environmental pollution during production and transportation for use. The lighting devices in indoors uses energy saver bulb, incandescent bulb, combinations and others; 8.3%, 24.7%, 61% and 6% respectively that adds indoor thermal discomfort for the materials heat generation during their operations. In addition to these factors, most residential houses in Jimma town were attached to various heat generating source; 3.7% Mill houses, factory or simple industry 8.3% and kitchen 58% that creates thermal discomfort in indoors.

6. Methods to improve indoor thermal environments in Jimma town

Warm temperature rainy climate without distinct dry season makes complex conditions to set constant thermal comfort at indoors. The climatic conditions in the area continuously changing as expected from worldwide consequences and the change is evident as observed a number of changes in a day. Most thermal discomfort in residential houses is from design dependent architectural parameters that could be handled by professionals in the field. Some observational points and related views are stated here under.

6.1 Reducing the effect of heat generating devices in indoors

Using heat generating devices will increase the thermal load in the interior space of the house building, and therefore house occupants' needs to reduce the use of such devices in indoors. Proper designs of kitchen for residential houses, most appropriate of detached type, are a means to reduce the load in indoors. The use of day light is important to reduce the cooling load and reduces the heat from lamps and when we need to use light from lamp Compact Fluorescent are best of all in giving light only in a space.

6.2 Ventilations in indoors

Nearby vegetation and tree are important sources of fresh are to indoor spaces of the houses. Jimma town seems a town with green plants but for separate residential houses the existing vegetation and trees are not sufficient to supply enough amount of fresh air to indoors that are used to set thermal comfort for the occupants. With this respect, the house orientation, wind direction, the openings and the free space in the court yard of the houses determines the use of vegetation and trees for the indoor ventilations. Shading in other respect is another important factor which protects direct falloff radiations to internal from external sources and facilitates indoor thermal comfort for occupants. For cross ventilations in indoors, the size and the orientation of windows play a significant role together with house orientations

6.3 Awareness creating about indoor thermal comfort

In modern society peoples spend most of their time in indoors and thermal comfort setup in indoors is the very essential aspect for human health, work efficiency and overall wellbeing. A person needs to be aware of the use and the way to set up for their indoors staring from the design to the final house erecting and then while achieving various activities in it. The society should know the need of professionals for setting thermally comfortable residential houses at all time; the stake holders in the area should work on the importance of thermal comfort by organizing seminars, workshops and trainings for best outcomes.

7. Conclusions

Thermal discomfort in indoors is mainly from low understanding about the concept as most of them can be managed easily to set human thermal comfort. Design dependent architectural parameters shares a greater part in setting indoor thermal comfort for humans and from the study residential houses of Jimma town are not comfortable and they need corrective tasks for the benefit of the occupants. The corrective measure includes, planting vegetation near the houses, having proper opening size for windows and doors, reducing the use of heat generating devices in indoors, detaching kitchen houses from residential houses, and use of energy sources that will not pollute in large the indoor environmental conditions, such as use of electric energy for cooking food and other purposes. The problems should not persist and all the new buildings should be designed and constructed by professional or engineers to incorporate all factors that are needed for human thermal comfort

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