ADAPTIVE COMFORT IN BUILDINGS LOCATED AT THE HOT DRY CONDITION OF DAMATURU - NIGERIA

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Abstract- Heat tolerance was measured in buildings located in hot dry area. The occupants of three buildings selected within the faculty of sciences, Yobe State University, Damaturu (Chemistry Laboratory, Physics Classroom and Lecture Hall B) were studied about their responses to peak values of thermal parameters for three consecutive days. The morning and evening measures were taken with (Thermometer, Anemometer and Hygrometer) where Thermal Comfort Questionnaire Survey was used in accessing the occupants. The results revealed that over eighty percent (80%) of the indoor users in each case were comfortable within higher values of thermal parameters. It was numerically recorded across the three buildings that when pMT was at (40 – 50) ºC while pRH and pV were constant, 86.3% of indoor users were comfortable within the indoor condition; but when pMT was at same value as above while pRH and pV set to outdoor condition, 77% of indoor users were comfortable within the indoor condition. The study concluded that heat tolerance in buildings increases in ratio of 1.12/1.0 with the decrease of outdoor air infiltration for users to become more comfortable indoor. School buildings should follow a reduced infiltration of outdoor poor thermal conditions in the area so that the required majorities (80) % were comfortable.

Keywords- Thermal Parameters, Heat Tolerance, Adaptive Comfort, Occupants, Thermal Discomfort, Hot Dry Condition.

I. INTRODUCTION

Heat tolerance or adaptation to changes in building indoor conditions enables occupants to control their feelings about the space/environment and maintain comfort over wider range of temperatures: from personal factors: dress code; consumption style; metabolic rate; etc, to building factors: open able windows; operable blinds; local fans; spatial variation; landscape; etc. Thus adaptive comfort builds on the principle that people experience differently and adapt to a variety of indoor conditions, depending on their clothing, their activity and general physical condition.

Research conducted over many years on large numbers of people by the American Society of Heating, Refrigeration, and Air Conditioning Engineers, ASHRAE, concluded that there is a range of combined temperatures and humidities that provides comfort to most people (80%). But that there is no one temperature and humidity condition at which everyone is comfortable. People are comfortable at a range of temperatures and humidities.

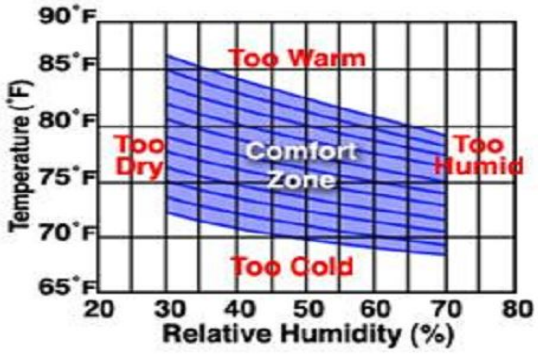


Fig. 1: - Comfort Zone Chart according to ASHRAE 55, 2010

Fig 1, Comfort Zone Chart shows "Indoor Air Temperature" on the vertical axis and "Relative Humidity on the horizontal axis. The shaded area is known as the "Comfort Zone". As the temperature rises in a hot, dry, desert-like environment, lower humidity levels are still within the comfort zone.

For the period of 6 - 8 months, hot dry condition generate undue indoor thermal discomfort to building occupants brought about by the climatic features accredited to the outdoor space. The case of buildings where outside air temperatures are below the inside temperatures has not been the problem in this area. The study area is believed to be the highest heat stricken zone in the country, above 40˚C (Community Portal of Nigeria, 2012). The objective of building design here is to achieve an acceptable thermal condition by regulating the outdoor thermal parameters prior transmitting the direct effect of the site on to the users: intense sunshine/glare; low humidity of the air; large diurnal temperatures; and blowing dust (The Ministry of New and Renewable Energy, MNRE, 2010).

Studies have shown that building occupants in the tropic environment have a higher heat tolerance and can adapt to the environment that they are used to (Hussein I., and Rahman M. H. A., 2009). Due to the past thermal sensation experienced by building occupants in any given condition, their thermal expectations and preferences also shifted up. This research tried to evaluate the extent to which the values of temperatures and humidities were tolerated or adapted by building indoor occupants when the outdoor air infiltration is controlled in the study area. The control media here is referred to windows or openings and therefore the documented results are not generalized.

Pilot study results conducted in the outdoor across the area by researchers provided some nominal values known as research assumptions. The building occupants (staff and students) in each case were used as research respondents and assumed to attain their comfort within the following indoor conditions at the time of survey:-

- (27 – 34) °C Indoor Air Temperature
- (25 - 40) % Indoor Air Relative Humidity
- (0.4 – 0.5) m/s Indoor Air Velocity
- Cloth Constant (universal/culture guided)
- Metabolic rate (Sedentary Activity)
- Age (18 – 40) years
- Gender (majority are male respondents)
- State of Health (Normal)
- Cultural expectation to clothing (uniform)
- Window sizes in all cases (1.2 x 1.2) m
- Walling Materials (230mm Hollow blocks)

II. DETAILS EXPERIMENTAL

2.1. Location of the study

The three buildings used for the purpose of this research were located at the Yobe State University - Faculty of Sciences, Damaturu – Nigeria as shown in Figure 2 below.



Fig. 2: - Locations of Chemistry Laboratory, Physics Classroom and Lecture Hall B

2.2. Materials and Procedures

The physical measurements (pM) about the three thermal comfort parameters: air temperature, (T), wind velocity, (V) and humidity (RH) were carried out in the morning session, coded (pMm) and afternoon session (pMa). The measuring equipments Fig 3, ANEMOMETER (Model AM-4812), Fig 4, HYGROMETER (wet and dry bulb) and Fig 5, THERMOMETER.



Fig. 3: - (Left) Digital Anemometer; Fig. 4: - (Middle) Hygrometer and Fig 5: - (right) Thermometer

The ANEMOMETER was used for measuring air velocity and has an accuracy of ± (2%+1d), 0.1 resolution as well as range of 0.4-30m/s. HYGROMETER was used for measuring relative humidity whereas the THERMOMETER was used for measuring air temperature. Indoor space was measured each case after calibrating the instruments to the referenced units for the purpose of reliability and accuracy of read-off values. The average values of the total points of measurements were recorded in the morning and afternoon sessions according to (pMm and pMa) respectively. Due to the distribution of the effects of thermal variables in the indoor space, six numbers of points were marked within comfort zone for measurement taking at the Chemistry Lab. and Classroom buildings. Eight numbers of points were marked within the occupied zone for measurement taking at the Lecture Hall building. All the readings were taken at a height of 1.0 m above floor level, which represents the height of an occupant at seated level. The maintenance section of the faculty of science building operates between 9am until 5pm. It takes about (30 to 40 minutes) to trek between the three measuring points. And therefore readings were taken from 10 am to 5pm daily. The samples were recorded at every 1 hour interval, alternately repeated for all three locations for a total period of 3 days.

2.3. Thermal Comfort Questionnaire Survey

Subjective Measurements (sM) in form of thermal comfort questionnaire survey: morning data, coded sMm and afternoon data, (sMa). The Faculty Building is occupied by a total of 582 occupants (539 students and 43 staff). The list of staff and students in the faculty building made up the sampling frame. In light of the time and financial constraints, a 17.2% sample size (n=100) represented the population size (N=582). However, taking into consideration the possibility of non-response, the study increased the sample size to 200 (20%). A systematic sampling strategy was used to randomly select the respondents from the sampling frame. The survey was conducted at the respective occupied spaces of the respondents (Lecture hall B, Chemistry Laboratory and Physics

Classroom). A total of 100 successful questionnaires were completed yielding a response rate of 50%.

The thermal comfort questionnaire survey was adopted and edited by the researcher for the purpose of this study from the following link: http://surveymonkey.com/s/VZWR6TM. It covered 4 sections. The subjective assessments basically treated for the research were respondents' vote (thermal comfort votes) in the occupied zone on the following:

i.) Thermal Preference Scale designed to assess how the perceived indoor thermal condition was preferred to change: 1(warmer), 0(no change), -1(cooler)

ii.) Assessment of relative humidity Scale assessed responses on how dry or wet the indoor condition was perceived: 1(air is wet), 0(air is just right), -1(air is dry)

iii.) Assessment of air movement Scale: 3 (much too still), -2 (too still), -1 (slightly still), 0(just right), 1 (slightly breezy), 2 (too breezy) and 3 (much too breezy).

The data collection followed the Morning (8-10am) and Afternoon (12-2pm) sessions. The plan for two-sessions and three-day activities were necessary to capture the different conditions and environmental changes at different hours of the day. Respondents' votes was based on the ASHRAE Standard (ANSI/ASHRAE) 55 – 2010 which specified an acceptable thermal environment to record 80% of occupants' vote as the central three categories (-1, 0, 1) of any subjective measurement.

III. RESULTS AND DISCUSSION

3.1. Average of Thermal Parameter Values and Comfort Votes within Buildings (Controlled Openings)

Table 3.1: Indoor Thermal Comfort Survey.

Average values of pM and Sm as recorded	Day 1		Day 2		Day 3	
	M	a	m	a	m	a
pMT (℃)	27	42	32	45	19	41
pMRH (%)	19	22	21	24	23	27
pMV (m/s)	0.4	0.4	0.4	0.4	0.4	0.4
Votes	57	86	46	87	55	86

Source: Researcher's Analysis, 2014

Table 3.1, Shows how values of physical measurements (pM) and subjective measurements (sM) are recorded when the openings were controlled during the survey for the three buildings.

3.2. Average of Thermal Parameter Values and Comfort Votes within Building (Windows wide opened)

Table 3.2: Semi Outdoor Thermal Comfort Survey.

Thermal Parameters and Comfort Votes	Day 1		Day 2		Day 3	
	m	a	m	A	M	a
pMT (℃)	27	42	32	45	19	41
pMRH (%)	19	22	21	24	22	26
pMV (m/s)	0.6	0.5	0.4	0.4	0.4	0.4
Votes (%)	44	76	38	78	47	77

Source: Researcher's Analysis, 2014

Table 3.1 Shows how values of physical measurements (pM) and subjective measurements (sM) are recorded when the windows were opened during the survey for the three buildings.

The research emphasis was the occupants' thermal sensation (sMT) as their comfort votes or responses to the peak values of temperature (pMT): See above for the results of the subjective measurements through questionnaires corresponding to the physical measurements with instruments. For this reason, results of afternoon sessions were analysed since it gave the peak values of temperature.

It now follows from Table 3.1 and 3.2 above that heat tolerance as comfort votes among the occupants within the three buildings differed with the decrease/increase of outdoor air infiltration:

i. In Day 1 at the Chemistry Laboratory: when pMTa was recorded as 42˚C; the corresponding comfort votes, sMTa, at that condition was 86% of indoor occupants. But when the infiltration of outdoor air was increased at the same condition, the comfort votes drop to 76%.

ii. In Day 2 at the Physics Classroom: when pMTa was recorded as 45˚C; the corresponding comfort votes, sMTa, at that condition was 87% of indoor occupants. But when the infiltration of outdoor air was increased at the same condition, the comfort votes drop to 78%.

iii. In Day 3 at the Lecture Hall B: when pMTa was recorded as 41˚C; the corresponding comfort votes, sMTa, at that condition was 86% of indoor occupants. But when the infiltration of outdoor air was increased at the same condition, the comfort votes drop to 77%.

3.3. Indoor Thermal Conditions and Hot-Dry Air

The relationship between building's indoor and the hot-dry air is that the larger the openings the greater the exposure of indoor spaces to the outdoor air. It

can be seen that the influence of openings was proportional to the intensity of indoor thermal state.

CONCLUSIONS

Thermal control in building design was achieved by thermal massive materials, landscapes, etc, rarely by correct fenestration/openings in hot dry areas. To resuscitate this among designers, the influence of controlled openings on the intensity of indoor air temperature leading to the rise/drop in an adaptive comfort values for building occupants in the study area was studied and major conclusions are as follows:

1. Higher values of temperature (40 – 45) °C are evidently acceptable to the occupants of buildings located in the hot dry condition of Damaturu, Nigeria.
2. The measured values of thermal parameter indicated that the building occupants were abnormally comfortable to the hot dry condition due to their repeated exposure at the same condition – adaptation.
3. Their responses to the indoor thermal sate changed with a sudden rise/drop in the amount of incoming hot dry air through the openings. From the comfort votes, the ratio 1.12/1.0 or 86.3% to that of 77% means that the increase of outdoor air infiltration caused decrease to the number of indoor occupants whose comfort zones were attained.
4. The study was conducted in academic environment therefore schools should follow a reduced infiltration of outdoor poor thermal conditions so that the required majorities (80) % were comfortable for an effective teaching – learning process.

RECOMMENDATIONS

The research provides platform on which new buildings will demonstrate an outstanding level of quality in relation to the existing ones within the study area:

- Buildings could be designed with operable openings so that the hot dry condition is controlled by the occupants to their comforts.
- Walling material for buildings in the area could be hollow blocks since thermal regulation was similarly achieved within the selected buildings.

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