CRITICAL GAP IN RESEARCH ON ADAPTIVE THERMAL COMFORT OF CHILDREN IN PRIMARY SCHOOL BUILDINGS

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Abstract- 'Thermal Comfort' can be defined as the mental satisfaction of the inhabitants in their environment due to their thermal aura. There are many factors which affect human comfort while carrying out building design. The experiments are carried out based on the subjective evaluation of their thermal sensation and simultaneously recording the environmental parameters. The paper discusses about the various research that have been conducted to investigate the ranges of parameters causing adaptive thermal comfort. The paper mainly points out the research recently contributed towards the analysis of thermal comfort of children in various built set-up. Emphasis is made by the author on the missing gap and thereby the urgent necessity required to find the adaptive thermal comfort levels of children in primary school buildings. The conclusion is established by reviewing the missing gap in the International standards such as ISO 7730, ASHRAE 55, EN 15251.

Keywords- Adaptive thermal comfort, ASHARE 55, ISO 7730, Primary School Buildings.

I. INTRODUCTION

It is a proven fact that human metabolic system always tries to maintain the core temperature constant around 37^0 C. The thermal interaction of our body with the environment always works towards keeping this core temperature constant [1]. The important climatic elements involved in building design towards attaining human thermal comfort are solar radiation, long wave radiation to sky, air temperature, humidity, wind and precipitation. To list out a few primary factors that affect the thermal exchange of clothed body are metabolic rate, air temperature, mean radiant temperature, air motion, vapor pressure, clothing type and materials fit [2].

1.1. Adaptive Thermal Comfort

According to AHSRAE standard 55, thermal comfort is defined as the condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation [3]. The approach adopted by Fanger P. Ole in the year 1970 was to devise an index (Predicted Mean Vote PMV) that can be precisely calculated and then use this as a proxy for comfort. As stated in ANSI/ASHRAE Standard 55-2010, PMV is defined as an index that predicts the mean value of the votes of a large group of persons on the seven point thermal sensation scale. PPD (Predicted Percentage Dissatisfied) is then determined from PMV [3].

People who are accustomed to living in air conditioned spaces are quite likely to develop their living habit within modulated surroundings and in case the thermal condition happen to deviate from the normal range of comfort, it becomes critical for the occupants to bear. Meanwhile people who always live in naturally ventilated set-up, can easily withstand more variable range of indoor thermal conditions influenced by the regional variations of daily and seasonal climate. Thermal preferences of these people as well as their tolerance level are likely to range over a wide temperature setting than those given in the ASHRAE Standard 55 comfort zone. Therefore a proposal for a new adaptive comfort standards came up in the year 2001 [4].

II. RESEARCH ON ADAPTIVE THERMAL COMFORT

2.1. Global Scenario

Research on adaptive thermal comfort is never ending process with its earlier work founded by Fanger P.O. in Denmark in the year 1970. Later scientists like Parsons K. C., Fergus Nicol, Michael Humphreys, Susan Roaf, Richard De Dear etc. have contributed tremendously to this field. The experiments conducted by them were based on subjects within climate chambers in the beginning and then later on they conducted in actual field either naturally ventilated or air conditioned buildings such as offices, residential buildings, outdoor premises etc.

People are more sensitive to the sudden temperature changes within short span of a few hours [5]. Every region has got its own identity in terms of culture, climate and buildings. For this reason, according to Nicol F., et. al, teachers, researchers, students, architects, engineers and others should be encouraged to see the intricacies associated with the comfort situation of the place they dwell in [1].

2.2. Research Scenario in India

In India, it had been a blind practice to follow ASHRAE Standard 55 due to the fact that there have been no considerable amount of field work taken place in the country on this field of research [6]. Some studies initiated by Sharma and Ali in India in the year 1986 is remarkable since his invention of Tropical Summer Index. Later the research did not progress much.

Very recently scientists like Madhavi Indraganthi, Home B. Rijal etc. carried out extensive research in the country based on adults in various residential as well as commercial buildings in various tropical climates.

Jyothirmay Mathur et. al explains about the comfort ranges through experiments conducted in naturally ventilated residential and office buildings in composite climates in India [7]. Many research have taken place in cold regions of India too [8, 9]. Thermal comfort range of university students during winter season and summer season have been evaluated at Tezpur University in 2013 [10].

A recent study based on extensive survey done on occupants in naturally ventilated Indian offices were found to be showing a completely different figure unlike that given in the ASHRAE and EN Models. Therefore a study model called IMAC was derived in the year 2015 which is proved to hold good for Indian context [11].

III. INTERNATIONAL STANDARDS ON THERMAL COMFORT

3.1. ANSI/ASHRAE 55

'American Society of Heating, Refrigerating and Air Conditioning Engineers' have produced standard known as ANSI/AHSRAE 55-2010, revised with latest amendments in 2013 which specifies 'thermal environments for human occupancy'. More precisely speaking, this standard specifies thermal environmental conditions acceptable for healthy adults for atmospheric pressure equivalent to altitudes up to 3000 m in indoor spaces designed for human occupancy for periods not less than 15 minutes [3]. It applies to indoor environments where the aim is to attain thermal comfort of indoor environments where moderate deviations from comfort occur [12]. In this standard PMV/PPD Model has been followed.

3.2. ISO 7730

International Organization for Standardization has set standard called ISO 7730 which specifies the Ergonomics of the Thermal Environment- Analytical Determination and Interpretation of Thermal Comfort using calculation of the PMV and PPD indices and Local Thermal Comfort Criteria. The purpose of this standard is to specify acceptable thermal environmental conditions for comfort by same PMV/PPD model [13]. The same organization has another standard, ISO 7726, Ergonomics of the Thermal Environment – Instruments for measuring Physical Quantities. For practical purposes, to achieve correct values, these specified instruments have to be used.

3.3. EN 15251

CEN (European Committee for Standardization) has set a standard on Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics called EN 15251: 2007. This was developed by Comite Europeen de Normalisation (CEN).

3.4 Standards Followed in India

National Building Code of India, NBC (BIS 2005) specifies two ranges of indoor design conditions, but it is done not according to the climate conditions of the country. Summer design conditions and winter design conditions specified in Part 8, Section 3, 4.4.3 closely resembles ASHRAE 1992. Whereas even ECBE (Energy Conservation Building Code) do not recommend any temperature/ humidity conditions at all [14].

A study on assessment of indoor air quality in secondary school have been carried out in Hyderabad city while the researcher recommends an urgent need of attention of our country on setting national standards, guidelines or regulations on the matter [15].

IV. ADAPTIVE THERMAL COMFORT OF CHILDREN

4.1. Introduction

University of Sydney's ASHRAE RP 884 project which is actually the base of world data base of thermal comfort field experiments commissioned in 1995 -97, presently contains more than 22,000 data [16]. It has been observed that most of these data are based on experiments on adults. Even though the thermal comfort study on children had originally started by M. Humphreys in the year 1973, in school classrooms, there are no remarkable progress made on them over the years.

Emphasis is given in many research papers that the comfort conditions of babies, children and pregnant women are varied since their metabolic rates and surface area ratios completely differ from normal adults [17]. According to Mishra Asit Kumar et. al, children have different levels of thermal sensation, metabolic rates, clothing restrictions and different sensitivities to temperature changes. It has been proved that children have wide variance in their response level and their activities differ considerably from that of adults on day to day basis [18].

To sum up, the surveys done so far on thermal comfort study with children as subjects are not many and therefore more and more studies have to be done for them [18].

4.2. Unique Survey Methods for Children

In the case of experiments with children as subjects, there are a lot of factors to be taken into account. Survey methods should be simple and manageable. These should have better usability and responsiveness from children. Managing uncertainty risks from

children's response is also crucial. The feedback taken from them should be observed with better benchmarking which has to be tallied with design intentions and through client review [19]. Mostly the survey tool is based on Building Use Studies Workplace Questionnaire which has been used worldwide [14].

As we all know, children are very sensitive group of subjects to deal with, especially to get questionnaire surveys answered correctly. So a very careful and intelligent structure of questionnaire need to be prepared by understanding the general psychology of children. Basically these need simplicity to obtain correct answers from the young minds. Most of the questions need cartoon illustrations along with verbal description. Normally this is done on a Likert Scale to obtain utmost clarity keeping in view that rating scale should be easily grasped and more appealing to make the children quickly respond and thereby gives a better result [20].

4.3. Available Research on Primary School Children

The study on thermal comfort of children of age group 7- 11 years in primary school actually took place way back in 1971 in England. According to the 262 records which were created give an assumption that the children's responses to temperature differed significantly among themselves, but has no much difference according to their gender [21].

Again in 1974, the study carried out by A.Auliciems during winter showed that cold discomfort caused major problem. This study took place in Queensland, Australia. The analysis of over 4000 assessments were then compared with the former study which took place in England. This study concludes that provision of optimum thermal conditions in schools should be major concern [22].

The research on thermal comfort of primary school children then remained stagnant for many years. In the year 2001, a study conducted in schools at Netherlands on children of age 9-11 years in non-air conditioned classrooms shows that children adapt to clothing of value 0.9 clo during winter season and 0.3 clo in summer [23].

Marzita Puteh et.al conducted a study in the year 2012 on school buildings to observe whether students felt comfortable with their classrooms. Their study emphasizes that the effectiveness of teaching can be improved in quality by maintaining the thermal comfort in classrooms [24].

A study was conducted by Ruey-Lung Hwang et.al in 2012 in Primary and Secondary school buildings at Taiwan. The experiments were conducted in naturally ventilated class rooms. The adaptive comfort model of children and teenagers developed in this study provided a mechanism for the assessment of thermal comfort in naturally ventilated classrooms in Primary and Secondary schools. The quantitative analysis of thermal comfort under the influences of climatic conditions illustrated how the level of thermal comfort in naturally ventilated classroom changed as a function of Average Window Solar Gain [25].

In the year 2012, a survey on school children of age 7-11 years was conducted by Despiona Teli et.al in Hampshire, England. The applicability of the adaptive comfort model was investigated by comparing the comfort temperature equation derived from the survey with the equation used in the EN 15251. The results suggest that the children are more sensitive to higher temperatures than adults with the comfort temperatures being about 4^0C and 2^0C lower than PMV and the EN 15251 adaptive comfort predictions respectively [26].

Another study conducted by the same scientists in the year 2014 was on light weight junior school buildings. The study reported that current thermal comfort standards were not appropriate for the assessment of their thermal environment. Also they found that children are more sensitive to higher temperature than adults. Emphasis is given by the research about the urgent need of progress required in the study of thermal comfort on children [27].

Maureen Trebilcock et. al carried out a field study on thermal comfort in primary schools in Chile. Study was conducted in both summer and winter on 9- 10 year old children. They found a deviation of 3^0 C to 4^0C in their results from the comfort temperature found out using Humphrey's formula [28].

Another study was conducted on Italian school buildings in the year 2014. It was found that children reacted actively to discomfort, suggesting that they should be allowed to interact with their environment [29].

A study conducted in naturally ventilated primary schools in Athens, Greece in 2015 showed that girls are more sensitive to health effects than boys [30].

4.4. Necessity for Standards of Children

Current Comfort Standards such as ISO 7730 – 2005 and EN 15251 determine design values for operative temperatures in school classrooms based on the heat balance and the adaptive thermal comfort model respectively. These are based on comfort studies carried out in climatic controlled chambers or offices, university classrooms and such, where the subjects are seldom children. Despiona Teli et. al emphasize that more information is needed on children's thermal comfort, over a wide range of conditions [16].

Annexure A, Table A5 of ISO 7730 explains the design criteria for spaces in various types of buildings

in terms of operative temperature, maximum mean air velocity, based on PPD, PMV and PD. In this table various types of buildings/spaces have been mentioned. Out of them classrooms have the same criteria as that of Single Office, Landscape Office, Conference Room, Auditorium, Cafeteria/Rest Room etc. [13]. Again the design criteria for kindergarten is given separate, in this context, the author finds that there is a gap for children of age group 7 and above.

ANSI/AHSRAE Standard 55-2010 specifies that the body of available data does not contain significant information regarding the comfort requirements of children, the disabled or the infirm. It also states that it is acceptable to apply the information in the standard to these types of occupants if it is applied judiciously to group of occupants, such as those found in class room situations [3]. Here the author finds this idea absurd in the case of small children.

Students are a major constituents of India's population, which is second largest on the globe, thus justifying the need of research initiative in school sector where children are the primary users [31].

CONCLUSIONS

Thermal comfort studies on children have not been carried out extensively so far. Scholarly articles show that there are numerous sicknesses caused in children by the extremes of climatic conditions as well as seasonal changes. Standards on indoor thermal environment such as ISO 7730, ASHRAE 55, EN 15251 etc., when examined it can be found that the comfort parameters for young children have not been specified at all. It is concluded that the research on this field especially in primary school buildings has to be initiated across the world in different climatic conditions. Invention of more survey tools in case of young children need to be arrived at, to get the exact values from them.

ACKNOWLEDGMENTS

I am deeply indebted to Manipal University for all the support and motivation in quality research.

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