CFD analysis of Thermal Comfort in AMPHI Theater

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Abstract: CFD analyses for an AMPHI Theater using ANSYS fluent were used to investigate the effects of better thermal comfort by moving inlet and outlet grills for both summer and winter seasons. The four 3D CDA designs for the AMPHI Theater were made using the Ansys workbench design module using approximate proportions. Seating in the AMPHI Theater is divided into 12 rows of 12 people each, with a total capacity of 100 people. The rows are stacked one on top of the other.

Keywords: Thermal Comfort, AMPHI, CFD.

I. INTRODUCTION

Having a pleasant environment can make people more likely to relax, which can lead to an uptick in business. Based on energy equations between humans and the environment, many of the theoretical studies required a great deal of math. When it came to functional research on the other hand, people were experimented on in various temperatures, which was a time-consuming process that could be misleading due to the differences in people's personal preferences.

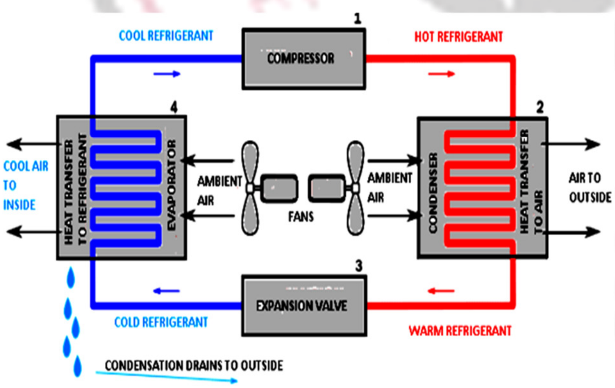

Figure 1 working principle of air conditioning

A humidity, ventilation, and temperature monitoring system in a building or vehicle that helps to maintain a cool environment in hot weather is defined as air conditioning. Air conditioners come in a variety of sizes and shapes, ranging from small units that can chill a single room to massive units mounted on the roofs of office blocks that can chill a whole house.

The air that must be cooled is continuously drawn into the cooling system via a suction duct, cooled using the cooling principle, and recirculated.

Sucking, cooling, and recirculating cooled air in an endless loop ensures that the interior remains at the ideal temperature for both comfort and industrial cooling. Compressor and fan motors receive 120 volts from the thermostat control when it's activated by the thermostat.

This hot liquid is then condensed back into a gas by means of the compressor, which serves as both a pump and a compressor for the gaseous refrigerant. As the liquid flows through the condenser coils, the heat is dissipated. Expansion of the liquid refrigerant occurs as soon as it passes between the condenser coils and the capillary tube. Front-facing evaporator coils can be found near the device's front.

Coolant penetrates these coils and swells into a gas, which chills them down. The compressor is attached to a suction line through which the gas passes through the coils. Once again, the cooling cycle is restarted by the compressor, which transforms the gas back into liquid form.

Air is drawn in through an intake and cooled by the evaporator logs before being returned to the room via the fan motor. One of its main functions is to cool the condensed coils by blowing outside air over them.

II. LITERATURE REVIEW

Vitor E.M. Cardoso at el. [1] Temporary areas, typically not fully internal, serve as distribution points where people wait to go or to be transported . A free bus station in a country with a mild temperature is the focus of this article's comparison of thermal comfort rating methodologies. In addition to field measures, 240 passengers were surveyed about their experiences on a hot-season train. The data gathered allowed us to evaluate the station's comfort levels using a variety of comfort models, including PMV-PPD, PMV, and the adaptive models specified by ASHRAE 55 and EN 15251. The results were compared to the subjective ISO 10551 scales of thermal preference (MTP) and thermal sensation (MTS). It's safe to say that the PMV-PPD and PMV models exaggerated the freshness perception. According to ASHRAE 55 and EN 15251, albeit more forgiving, the adaptive technique doesn't quite match the heat sensation of responders.

Hye-Jin Cho and Jae-Weon Jeong [2] The major goal of this study is to assess the thermal pleasure in an office complex that uses a drying system that uses 100 percent outside air, liquid cooling, and indirect and direct evaporative cooling (LD-IDECOAS). The TRNSYS 17 programme, which is incorporated into an EES (Engineering Equation Solver) tool, is used in this study to propose a method for assessing the thermal environment using a series of energy simulations. The supply air temperature (SA) is calculated using prior studies' suggestions for LD-IDECOAS seasonal operation modes. The room air temperatures are approximated based on the assumption that the relative humidity of the cabin air is sustained at the levels set by supplementary humidifying devices. Following that, given the indicated internal climatic conditions, the expected average marks (PMV) are calculated.

Rahul Simha and Andrei Claudiu Cosma [3] The use of thermal imaging cameras as a non-invasive tool for automatic modelling of human thermal comfort under temporary settings has been explored in this work. The researchers used data from 30 healthy people who worked in an office with a temperature of 21.11 degrees Fahrenheit. The temperatures were measured in degrees C and 27.78 degrees C. The temperature of the office, the relative humidity, the temperature of exposed skin, and the temperature of clothing were all measured automatically for around 27 minutes per individual, utilising remote sensors and avoiding direct contact with humans. Subject feedback was taken every minute during the experiment to determine thermal comfort levels. For this experiment, the clothing isolation and metabolic rate were kept roughly constant (0.54 and 1.1 met). Measurements of average skin warmth were taken at five sites, with the average values of 33.0 degrees Celsius, 34.5°C and 35.6°C corresponding to complaints of coldness, comfort and heat respectively. At 32.3°C, 33.8°C and 35.0°C, the average temperature of the clothes was also recorded in three separate positions. Thermal cameras with optical and thermal modes are found to be precise enough to regulate HVAC systems without requiring invasive testing.

Jaewan Joe at el. [4] There are novel approaches to establishing control that use several agents, as well as methods for identifying and controlling distributed models. Thermal zone is separated into subsystems for system identification, and each subsystem's number of criteria is evaluated separately before being combined into an inverse model for the full thermal zone using the dual decomposition procedure. Several MPCs are executed iteratively by sharing control input information until they converge using a distributed optimization technique influenced by the Jacobin multiplication inversion method (PJ-ADMM). The DMPC controller is used to improve the operation of an air-cooled chiller while giving separate operating temperature limitations for each radiant floor circuit, using a model based on data and weather forecasts. The radiation comfort distribution system with predictive control can deliver localised thermal conditions while saving significant energy. Construction operations throughout the cooling season resulted in a 27 percent reduction in electricity usage compared to the baseline control for the system and climate evaluated.

Lindsay T. Graham, Aleksandra Lipczynska, Stefano Schiavon, and Aleksandra Lipczynska [5] Researchers describe a field study in which they assess the impact of rising room temps and air motions on thermal comfort and productivity. This research was carried out in three different environments (one with a set point of 23 degrees Celsius, which is an usual set point in Singapore, and 2 with high ambient temperatures (up to 28 degrees Celsius)). The ceiling fans were shared among the detainees. The results demonstrate that at an ambient temperature of 26°C with the fans running, the most comfortable heat with the heat closest to the neutral condition is obtained. The rise in heat set point from 23 to 26°C resulted in a large gain in thermal compatibility (from 59 to 91 percent) and a 44 kWh/m^2 reduction in electricity for comfortable cooling.

III. METHODOLOGY

One of India's most well-known theatre chains, Cinepolis Aashima Mall, Bawadiya Kalan screens numerous films every month. In the first phase, it has struck arrangements with 12 developers in eight Indian cities to build 110 screens, with an investment of a total of 1500 crore. More than 200 new screens will be built in India by 2010 through agreements with developers.

Located in the Bawadiya Kalan district of Punjab, the Cinepolis Aashima Mall has a capacity of 300 people, and the building's breadth is 42 feet, height is 45 feet and length is 78 feet. The typical rate of cooling for this cinema is 30 minutes.

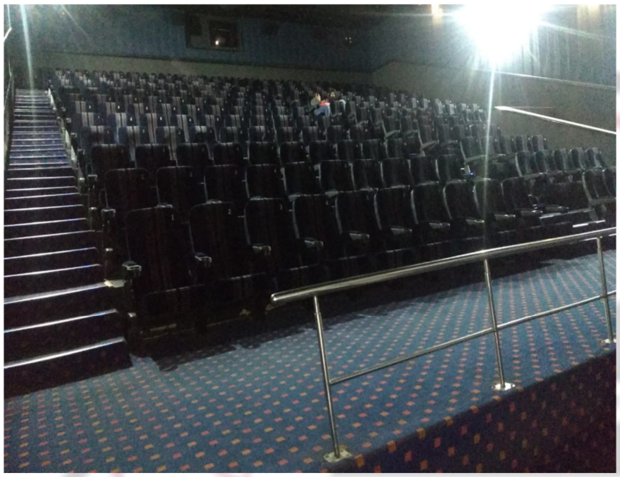

Figure 2 Interior view of Cinepolis Aashima Mall Bhopal

In accordance with CR 1752, ISO 7730 specifies three acceptable grades for general thermal comfort and local thermal discomfort parameters, while ANSI/ASHRAE Standard 55 proposes a similar methodology. The table establishes the distinct thermal satisfaction targets: category C for 70% acceptability. B for 80% acceptance and A for 90% acceptability and These factors serve as a gauge of how well the interior environment is controlled in relation to a specific set point.

Ansys workbench design module with approximate dimensions was used to develop the CAD design for AMPHI Theater of Design -1. The AMPHI Theater has a seating capacity of 100 people, which is divided into 12 rows of 12 people each. Each row is placed on a higher step than the one before it. There are 4 0.6 m × 0.6 m inlet grilles on the ceiling, 24 0.15 m x 0.5 m inlet grilles on the risers, and 6 0.6 m x 0.6 m outlet grilles on the ceiling.

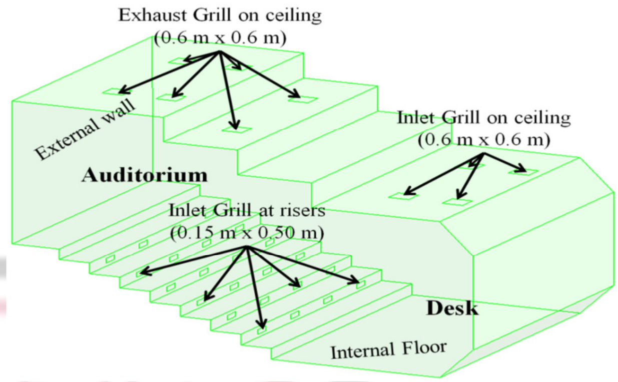

Figure 3 CAD geometry of AMPHI Theater design -1

Ansys workbench design modular with approximate dimension is used to generate CDA design for AMPHI Theater of design-2. The AMPHI Theater has a seating capacity of 100 people, which is divided into 12 rows of 12 people each. Each row is placed on a higher step than the one before it. At the risers, there are 32 input grilles measuring 0.15 m x 0.5 m, two intake grilles measuring 0.6 m x 0.6 m, and six exit grilles measuring 0.6 m x 0.6 m.

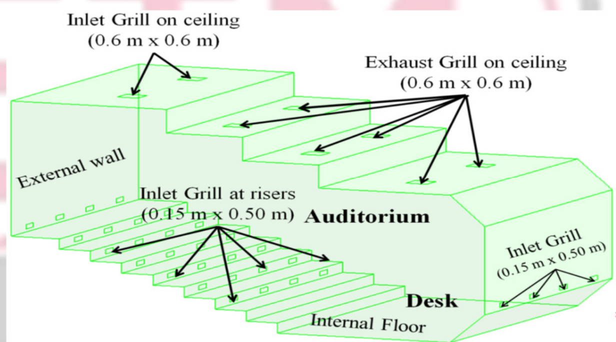

Figure 4 CAD geometry of AMPHI Theater design-2

Ansys workbench design modular with approximate dimensions was used to produce CDA design for AMPHI Theater of Design -3. The AMPHI Theater has a seating capacity of 100 people, which is divided into 12 rows of 12 people each. Each row is placed on a higher step than the one before it. At the risers, there are 32 input grilles measuring 0.15 m x 0.5 m and eight output grilles measuring 0.6 m x 0.6 m.

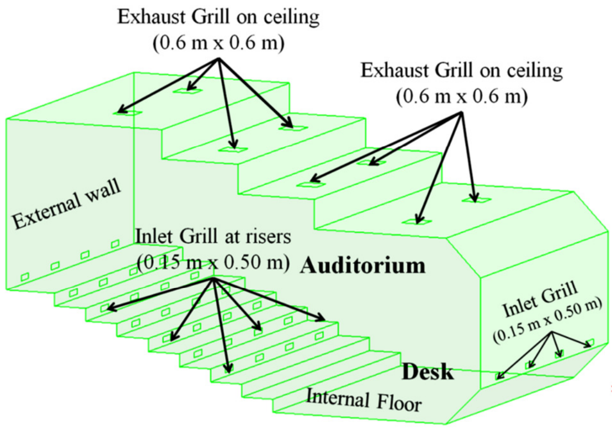

Figure 5 CAD geometry of AMPHI Theater design -3

Ansys workbench design modular with approximate dimensions was used to produce CDA design for AMPHI Theater of design-4. The AMPHI Theater has a seating capacity of 100 people, which is divided into 12 rows of 12 people each. Each row is placed on a higher step than the one before it. There are four 0.6 m × 0.6 m intake grilles on the ceilings and 28 0.15 m x 0.5 m inlet grilles on the risers, as well as six 0.6 m x 0.6 m exit grilles on the ceiling.

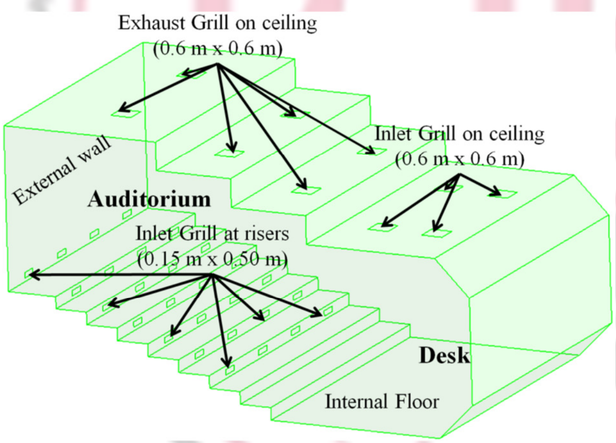

Figure 6 CAD geometry of AMPHI Theater design-4

With the help of transient computational fluent dynamics analysis utilising ansys fluent, the major goal of this work is to improve thermal comfort for AMPHI theatre in the shortest time possible in different seasons such as summer and winter.

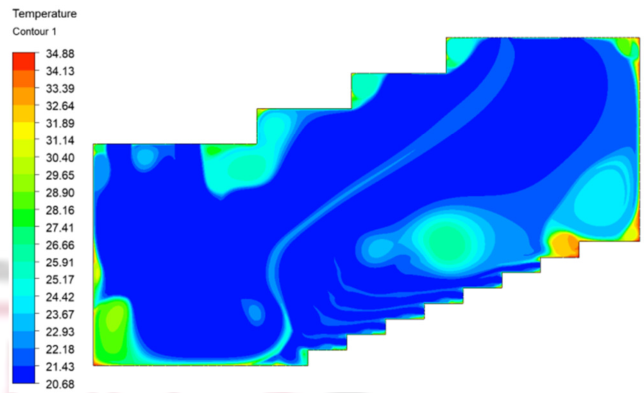

Figure 7: Temperature contour diagram

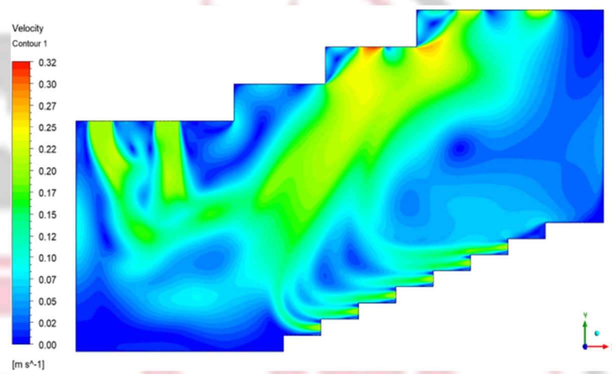

Figure 8: Velocity contour diagram

IV. RESULT AND DISCUSSION

The major goal of this study is to see how changing the placements of the inlet and outlet grills, which are exposed to the same thermal conditions, affects the AMPHI Theater's thermal comfort. ANSYS fluent was used to do a computational fluid dynamics analysis for the AMPHI Theater to evaluate the impact of modifying the inlet and outlet position on thermal comfort. To investigate temperature distributions inside the AMPHI Theater during the summer and winter seasons, four alternative 3D models were generated using ansys workbench design module and simulated with the identical boundary conditions. For turbulent flow inside the AMPHI Theater, a K-epsilon realisable model with enhanced wall treatment is used. The working fluid is air with a density of 1.22 kg/m^3, a specific heat of 1006.43 J/kg K, and a thermal conductivity of 0.24 W/m^2-K.

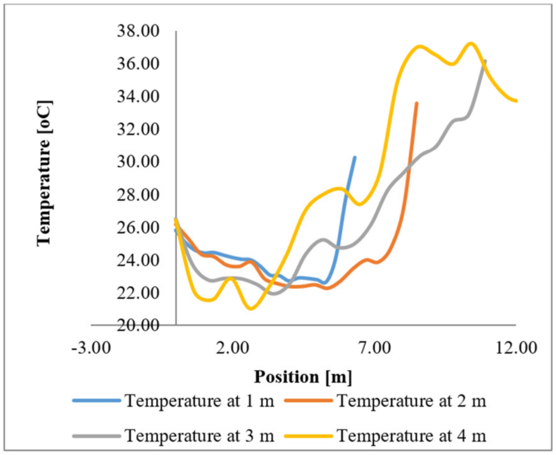

Figure 9: Temperature distribution at different height in summer

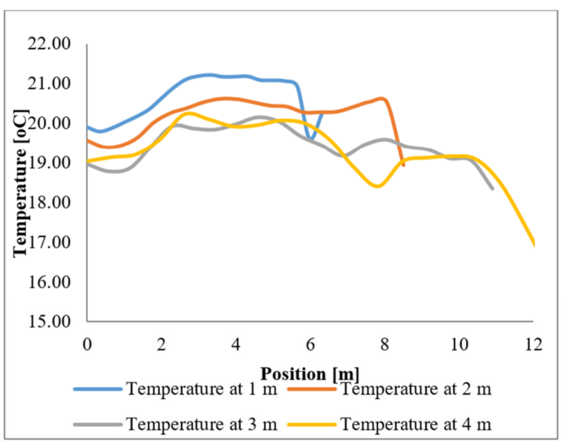

Figure 10: Temperature distribution at different height in winter

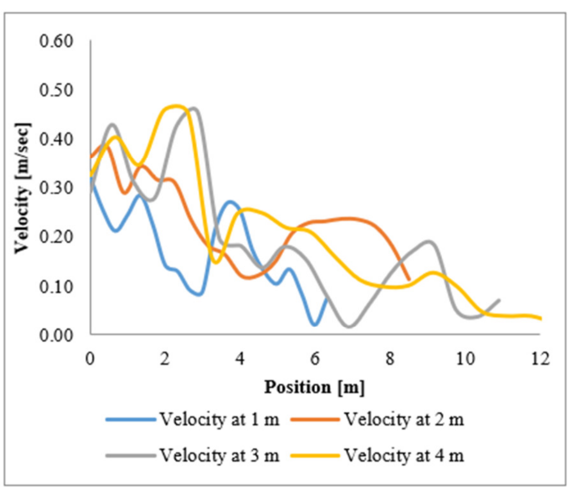

Figure 11: Velocity distribution at different height in summer

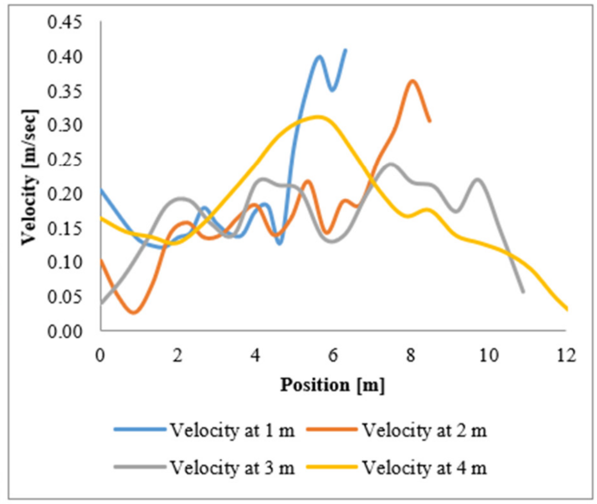

Figure 12: Velocity distribution at different height in winter

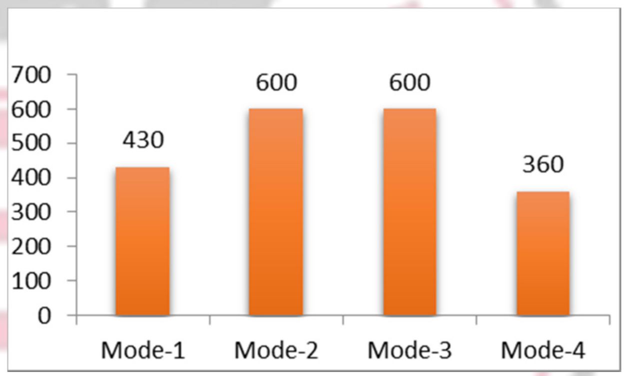

Figure 13: Cooling Time for summer season in sec in AMPHI Theater for different models

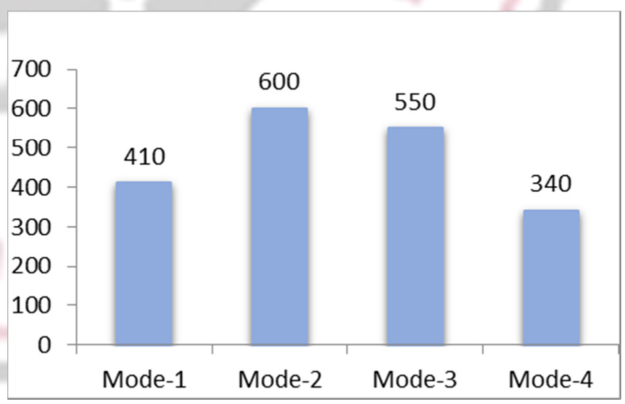

Figure 14: Cooling Time for winter season in sec in AMPHI Theater for different models

V. CONCLUSION

The impacts of enhanced thermal comfort by modifying the placements of inlet and outlet grills for summer and winter seasons were investigated in this paper utilizing computational fluid dynamics calculations for an AMPHI Theater using ANSYS fluent. For this, the AMPHI Theater's four 3D CDA designs were created using the Ansys workbench design module using estimated dimensions. The AMPHI Theater has a seating capacity of 100 people, which is divided into 12 rows with each row being higher than the one before it. The overall number of outlet and inlet grilles for design-1 is four at the ceiling, 24 at the riser, and six at the ceiling, with the total number of inlet and outlet grilles being 0.6 m × 0.6 m. In design-2, two inlet grilles of 0.6 m x 0.6 m placed at ceiling, six total outlet grilles of 0.6 m x 0.6 m placed at ceiling and there are 32 intake grilles of 0.15 m x 0.5 m put at risers. In the case of design 3, there are a total of 32 inlet grilles measuring 0.15 metres by 0.50 metres that are installed on the risers, and a total of eight outlet grilles measuring 0.60 metres by 0.60 metres that are installed on the ceiling; in the case of design 4, there are a total of four inlet grilles measuring 0.60 metres by 0.60 metres that are installed on the ceiling, as well as 28 inlet grilles measuring 0.15 metres by 0.50 metres that are installed Tetrahedral elements are those that have four nodes on a triangle form. Tetrahedral elements are those that have four nodes on each side and are triangular in shape. For turbulent flow inside the AMPHI Theater, a K-epsilon realisable design with increased wall treatment is employed with a working fluid of 1.22 kg/m^3, Specific Heat 1006.43 J/kg K, and Thermal conductivity 0.24 W/m^2-K.

REFERENCES

[1] Cătălin George Popovici "HVAC system functionality simulation using ANSYS-Fluent" Sustainable Solutions for Energy and Environment, Bucharest, Romania, Energy Procedia vol. 112 (2017) page from 360 – 365.

[2] Jéssica Kuntz Maykot at el. "Assessment of gender on requirements for thermal comfort in office buildings located in the Brazilian humid subtropical climate" Contents available at Science Direct Energy and Buildings 158 (2018) 1170–1183.

[3] Jindal A "Thermal comfort study in naturally ventilated school classrooms in composite climate of India", Building and Environment Accepted Date: 26 May 2018.

[4] Földváry V at el. "Development of the ASHRAE Global Thermal Comfort Database II", Building and Environment Accepted Date: 12 June 2018, doi: 10.1016/j.buildenv.2018.06.022.

[5] M.T.H. Derks at el. "Understanding thermal comfort perception of nurses in a hospital ward work environment" Building and Environment 140 (2018) 119–127.

[6] Ricardo Forgiarini Rupp, Richard de Dear & Enedir Ghisi "Field study of mixed-mode office buildings in Southern Brazil using anadaptive thermal comfort framework "Energy and Buildings 158 (2018) 1475–1486.

[7] Shilei Lu, Bo Pang, Yunfang Qi & Kun Fang "Field study of thermal comfort in non-air-conditioned buildings in a tropical island climate" Applied Ergonomics 66 (2018) 89e97

[8] Elena Barbadilla Martat el. "Assessment of thermal comfort and energy savings in a Þeld study on adaptive comfort with application for mixed mode of offices, Energy & Buildings Accepted date: 16 February 2018.

[9] Vitor E.M. Cardoso at el. "A discussion about thermal comfort evaluation in a bus terminal, Energy & Buildings, Accepted date: 5 March 2018.

[10] Hye-Jin Cho & Jae-Weon Jeong "Evaluation of thermal comfort in an office building served by a liquid desiccant-assisted evaporative cooling air-conditioning system", Energy & Buildings Accepted date: 6 May 2018.

[11] Andrei Claudiu Cosma & Rahul Simha "Thermal comfort modeling in transient conditions using real-time local body temperature extraction with a thermographic camera, Building and Environment 143 (2018) 36–47.

[12] Jaewan Joe at el. "A distributed approach to model-predictive control of radiant comfort delivery systems in office spaces with localized thermal environments, Energy & Buildings, Accepted date: 29 June 2018.

[13] Aleksandra Lipczynska, Stefano Schiavon & Lindsay T. Graham "Thermal comfort and self-reported productivity in an office with ceiling fans in the tropics" Building and Environment 135 (2018) 202–212.

[14] Luo M, Wang Z, Brager G, Cao B & Zhu Y " Indoor climate experience, migration, and thermal comfort expectation in buildings", Building and Environment, Accepted Date: 20 May 2018.

[15] Pazhoohesh M & Zhang C "A satisfaction-range approach for achieving thermal comfort level in a shared office", Building and Environment, Accepted Date: 4 June 2018.

[16] Rupp RF, Kim J & de Dear R. Ghisi E "Associations of occupant demographics, thermal history and obesity variables with their thermal comfort in air-conditioned and mixed-mode ventilation office buildings", Building and Environment, Accepted Date: 28 February 2018.

[17] Sally Shahzad at el. "Advanced Personal Comfort System (APCS) for the workplace: A review and case study", Energy & Buildings, Accepted date: 8 February 2018.

[18] Sun C, Zhang R, Sharples S, Han Y & Zhang H "A longitudinal study of summertime occupant behaviour and thermal comfort in office buildings in northern China", Building and Environment Accepted Date: 4 July 2018.

[19] Samar Thapa, Ajay Kr.Bansal, Goutam Kr.Panda, "Thermal Comfort in naturally ventilated office buildings in cold and cloudy climate of Darjeeling, India – An adaptive approach", Energy and Buildings, Accepted date: 13-12-2017.

[20] Wang Z at el. "Individual difference in thermal comfort: A literature review", Building and Environment Accepted Date: 27 April 2018.