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Enhancement of Thermal Comfort in Minimum Time for AMPHI Theater for Different Season with the Help of Transient Computational Fluent Dynamic Analysis using ANSYS Fluent

Shubham Shukla
M. Tech.
Truba Group Of Institutes college
Bhopal, India
sshukla1109@gmail.com

Rajeev Arya
Director
Truba Group Of Institutes college
Bhopal, India
aryarajeev25@yahoo.com

Nilesh Diwakar
HOD
Truba Group Of Institutes college
Bhopal, India
nilesh.diwakar@trubainstitute.ac.in

Abstract: **The main objective of the present work to enhance thermal comfort in minimum time for AMPHI Theater in different season such as summer and winter with the help of transient computational fluent dynamics analysis using ansys fluent. Four different 3D models have been created using ansys workbench design modular and simulated with same boundary conditions to find temperature distributions inside the AMPHI Theater for summer and winter season. Tetrahedral elements are used having triangular in shape with four nodes on each element. Air is used as working fluid, K-epsilon realizable design with enhanced wall treatment is used for turbulent flow inside the AMPHI Theater. Result show that the proposed design-4 of the AMPHI Theater having better thermal comfort with lest time to achieved the comfort temperature inside AMPHI Theater for both summer and winter season. This computational fluid dynamics analysis of AMPHI Theater can be used as pre-exanimation of future work in order to obtain better thermal comfort and also verify requirements for the installation of HVAC systems.**

Keyword: **ANSYS, HVAC system, Air condition, thermal comfort.**

I. Introduction

Thermal comfort is an essential factor that should be considered in building/office design process which can have a beneficial impact on the social and economic behavior aspects of people using these places. Comfortable climates can encourage the human for relaxation and can thus increase the commercial activity. Theoretical studies were mostly based on energy equations which are built in between human and environment and required very extensive mathematical work. Practical studies on the other hand were done by experimenting humans under various thermal environments, which were time consuming and could be misleading because of the personal opinions of people regarding to comfort.

A. *Air conditioning and its working principle*

Nowadays, the air conditioning system is widely used both in the home and in a commercial environment. Air cooling or air conditioning is the process of removing heat and humidity from the inside to improve occupant comfort. This process is often used to obtain a more comfortable indoor climate, typical of people.

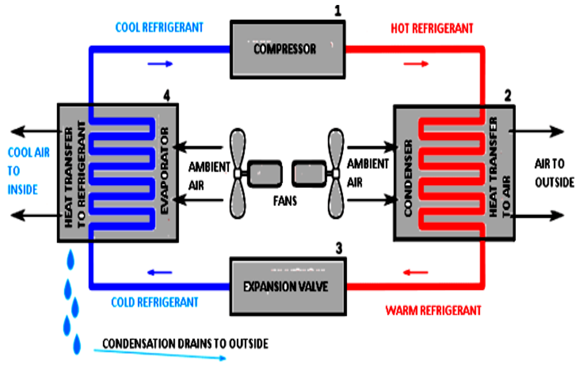

Fig. 1: working principle of air conditioning

II. Literature Review

Cătălin George Popovici [1] The aim of the study is to simulate the functionality of an HVAC system in different situations, both in summer and in winter, using the special ANSYS-Fluent software. A 2D construction model was created and the simulation of the internal conditions was the main elements of the study. The results are presented in the form of diagrams / graphs and spectra of parameters of interest. Simulating the functionality of the HVAC system with ANSYS-Fluent provides important results for the scenario examined. It can be determined with certainty that the recently implemented HVAC system is doing its job and providing adequate comfort conditions in the amphitheater during the two seasons.

Jéssica Kuntz Maykot at el. [2] This article is intended to examine the effects of gender on thermal comfort requirements in office buildings. The data comes from 83 field studies conducted in 2014 in three office buildings in Florianopolis, in southern Brazil. One of the buildings is fully air conditioned and the other two operate in mixed mode, i.e. H. Switches from air conditioning to natural ventilation.

Jindal A et al. [3] During the 2015/16 monsoon and the winter seasons, a field study was conducted to study the thermal environment and thermal comfort in naturally ventilated indoor classrooms (NV) of a composite state boarding school in the climatic zone of Ambala, India. A total of 640 responses were collected from 130 student's aged 10 to 18 in rural areas. An internal operating temperature of 27.1 ° C was recorded as a neutral temperature. It was discovered that the slope of the regression line, which is drawn between the sensation of heat and the internal operating temperature, is 0.056 / ° C, which differs significantly from previous similar studies in the bathrooms.

Földváry V at el. [4] The ASHRAE Global Thermal Comfort Database II project was launched in 2014 under the direction of the University of California at the Berkeley Center for the Built Environment and the University of Sydney Indoor Environmental Quality Laboratory (IEQ). The ASHRAE Global Thermal Comfort II database, now an online open source database, contains approximately 81,846 complete sets of objective observations on the indoor climate, along with subjective assessments of users of the exposed building.

III. Objective

There are following objective have been set for this work.

1. Study of air conditioning system for thermal comfort.
2. Prepare the different model of AMPHI Theater with different positions of inlet and outlet grills.
3. Perform the computational fluid dynamic analysis for all above models
4. Compare the various results such as temperature distribution and velocity distribution inside the AMPHI Theater and present the best model for better thermal comfort.

IV. Methodology

Cinepolis Aashima Mall, Bawadiya Kalan is a chain of theatres in India that exhibit a myriad of movies around the year. It is a Mexican movie theater chain & plans to operate 500 screens in India with an investment of ₹ 1,500 crore and has signed deals with 12 developers in eight cities to set up 110 screens in the first phase. There are also plans to enter into deals with developers to create 200 more screens across India by 2010. Cinépolis has locations
in India at: Bhubaneswar, Jamshedpur, Newdelhi, Thane, Chandigarh, Amritsar, Pune, Bengalu, Patna, Ahmedaba d, Surat, Bhopal, Ludhiana, Mangaluru, Jaipur, Hyderab ad, Coimbatore, Hubballi, Vijayawada, Kolkata, Vadoda ra, Mumbai, Kochi, Guwahati, Muzaffarpur and Luckno w.

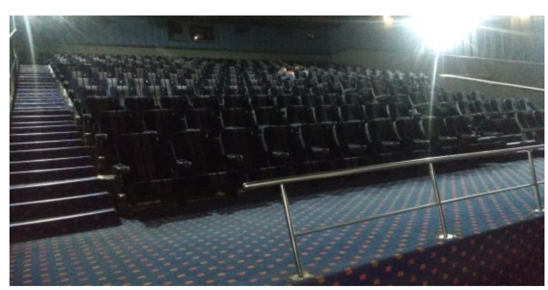

Fig. 2: Interior view of Cinepolis Aashima Mall Bhopal

A. Algorithm used for Computational fluid dynamics analysis

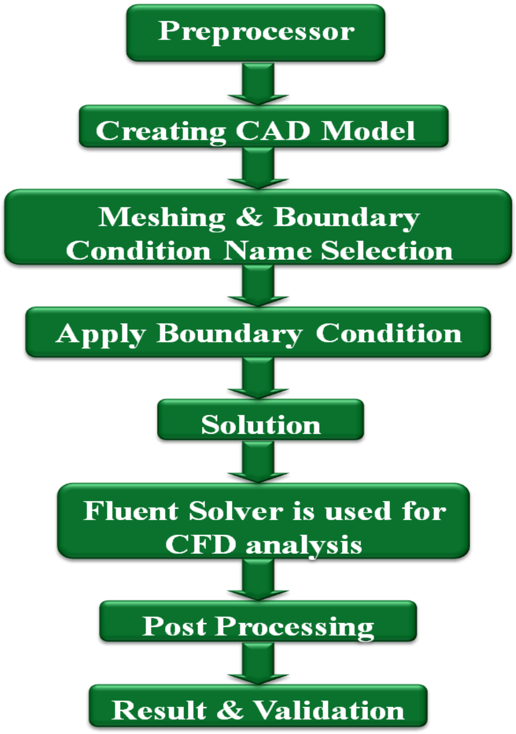

Fig. 3: Algorithm used for Computational fluid dynamics analysis

B. CAD geometry of AMPHI Theater design-1:

CDA design for AMPHI Theater of design -1 is created using Ansys workbench design modular with approximate dimension. The capacity of AMPHI Theater for 100 peoples distributed as 12 people on 8 rows, each row is placed on a higher step than previous one. There are total 4 inlet grilles of 0.6 m x 0.6 m placed at ceiling and 24 inlet grilles of 0.15 m x 0.5 m placed at risers and total 6 outlet grilles of 0.6 m x 0.6 m placed at ceiling as shown in figure No 4.

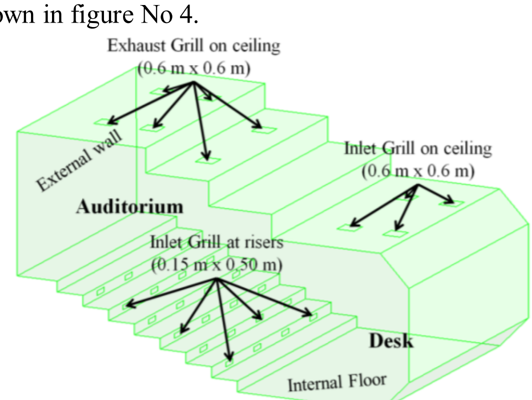

Fig. 4: CDA geometry of AMPHI Theater design -1

C. Meshing of AMPHI Theater design-1:

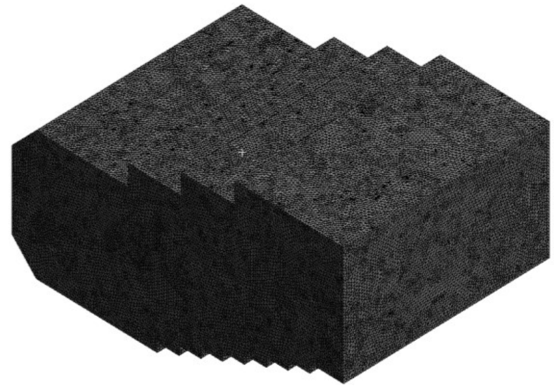

Fig. 5: Meshing of AMPHI Theater design -1

After completing the CDA design of AMPHI Theater is imported in ANSYS workbench for further computational fluid dynamics analysis where next step is meshing. Meshing is a critical operation in finite element analysis in this process CAD geometry is divided into large numbers of small pieces called mesh. The total no of nodes generated in the present work is 266852 and total No. of elements is 1444060.

D. Different boundaries of AMPHI Theater proposed design-1

Different boundaries of AMPHI Theater proposed design-1 on longitudinal section is shown in figure no. 6. There are total 4 inlet grilles of 0.6 m x 0.6 m placed at ceiling and 24 inlet grilles of 0.15 m x 0.5 m placed at risers and total 6 outlet grilles of 0.6 m x 0.6 m placed at ceiling.

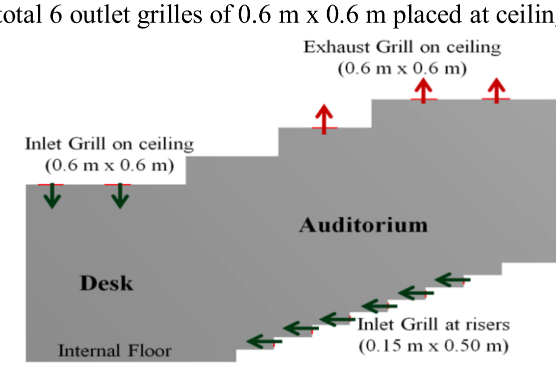

Fig. 6: Different boundaries of AMPHI Theater proposed design-1

E. CAD geometry of AMPHI Theater design-2:

CDA design for AMPHI Theater of design-2 is created using Ansys workbench design modular with approximate dimension. The capacity of AMPHI Theater for 100 peoples distributed as 12 people on 8 rows, each row is placed on a higher step than previous one. There are total 32 inlet grilles of 0.15 m x 0.5 m placed at risers, 2 inlet grilles of 0.6 m x 0.6 m placed at ceiling and total

6 outlet grilles of 0.6 m x 0.6 m placed at ceiling as shown in figure 7.

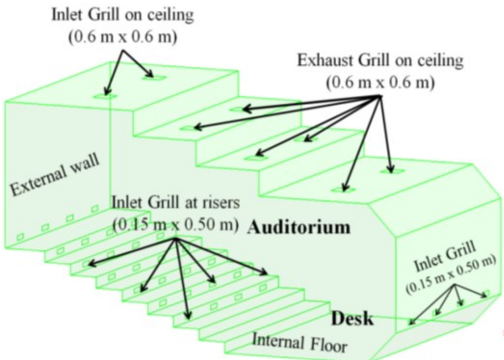

Fig. 7: CDA geometry of AMPHI Theater design-2

F. Meshing of AMPHI Theater design-2:

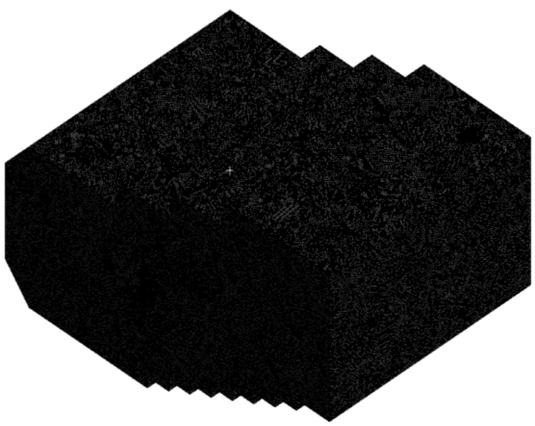

Fig. 8: Meshing of AMPHI Theater design-2

The size of elements set as 50 mm where number of nodes generated for this design total is 1508471 of Elements is 8399546. Types of elements used are tetrahedral which is a triangular in shape with four nodes on each element as shown in figure 8.

G. Different boundaries of AMPHI Theater for proposed design-2

Different boundaries of AMPHI Theater proposed design-2 on longitudinal section is shown in figure No 9. There are total 32 inlet grilles of 0.15 m x 0.5 m placed at risers, 2 inlet grilles of 0.6 m x 0.6 m placed at ceiling and total 8 outlet grilles of 0.6 m x 0.6 m placed at ceiling.

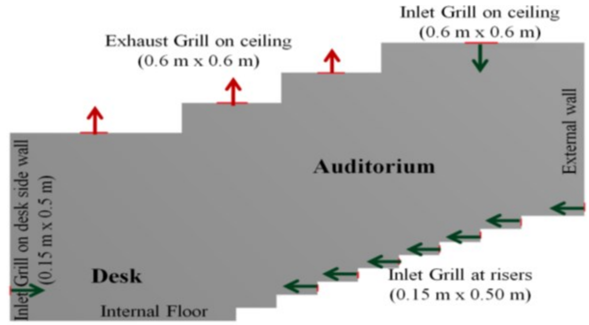

Fig. 9: Different boundaries of AMPHI Theater proposed design-2

H. CAD geometry of AMPHI Theater design-3:

CDA design for AMPHI Theater of design -3 is created using Ansys workbench design modular with approximate dimension.

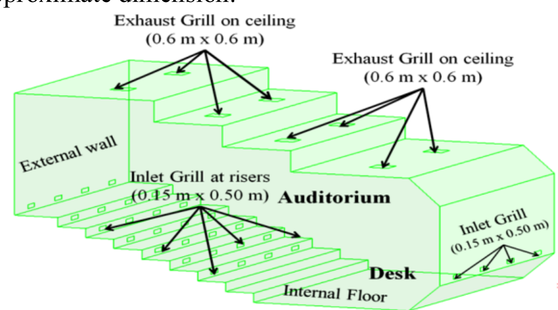

Fig. 10: CDA geometry of AMPHI Theater design -3

The capacity of AMPHI Theater for 100 peoples distributed as 12 people on 8 rows, each row is placed on a higher step than previous one. There are total 32 inlet grilles of 0.15 m x 0.5 m placed at risers and total 8 outlet grilles of 0.6 m x 0.6 m placed at ceiling as shown in figure No.10.

I. Meshing of AMPHI Theater design-3:

The size of elements set as 50 mm where number of nodes generated for this design total is 1508471 and total no. of Elements is 8399546. Types of elements used are tetrahedral which is a triangular in shape with four nodes on each element as shown in figure 11.

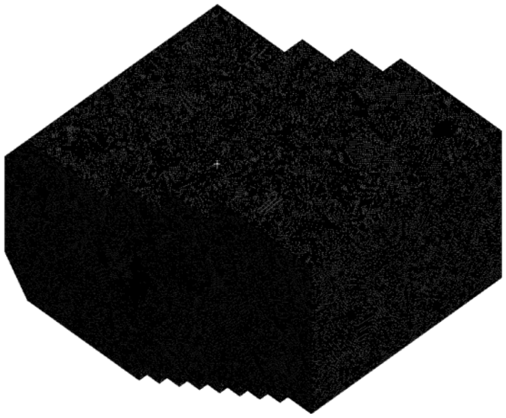

Fig. 11: Meshing of AMPHI Theater design -3

J. Different boundaries of AMPHI Theater for proposed design-3

Different boundaries of AMPHI Theater proposed design-3 on longitudinal section is shown in figure 12. There are total 32 inlet grilles of 0.15 m x 0.5 m placed at risers and total 8 outlet grilles of 0.6 m x 0.6 m placed at ceiling.

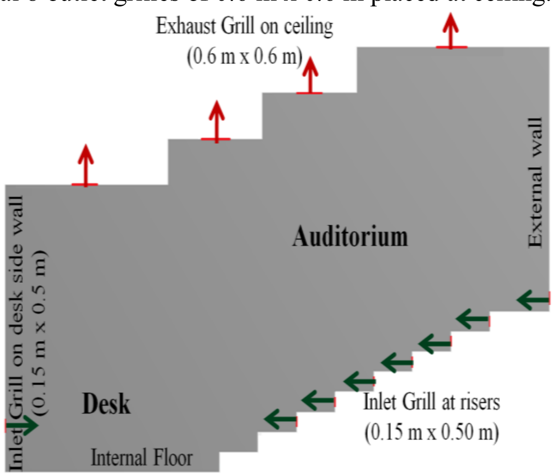

Fig. 12: Different boundaries of AMPHI Theater proposed design-3

K. CAD geometry of AMPHI Theater design-4:

CDA design for AMPHI Theater of design-4 is created using Ansys work bench design modular with approximate dimension. The capacity of AMPHI Theater for 100 peoples distributed as 12 people on 8 rows, each row is placed on a higher step than previous one. There are total 4 inlet grilles of 0.6 m x 0.6 m placed at ceiling and 28 inlet grilles of 0.15 m x 0.5 m placed at risers and total 6 outlet grilles of 0.6 m x 0.6 m placed at ceiling as shown in figure 13.

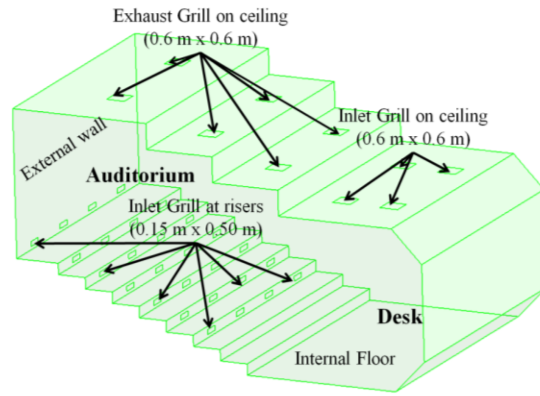

Fig. 13: CDA geometry of AMPHI Theater design-4

L. Meshing of AMPHI Theater design-4:

After completing the CDA design-4 of AMPHI Theater is imported in ANSYS workbench for further computational fluid dynamics analysis where next step is meshing.

Fig. 14: Meshing of AMPHI Theater design-4

The size of elements set as 50 mm where number of nodes generated for this design total is 1507855 and total no. of Elements is 8396249. Types of elements used are tetrahedral which is a triangular in shape with four nodes on each element as shown in figure 14.

M. Different boundaries of AMPHI Theater for proposed design-4

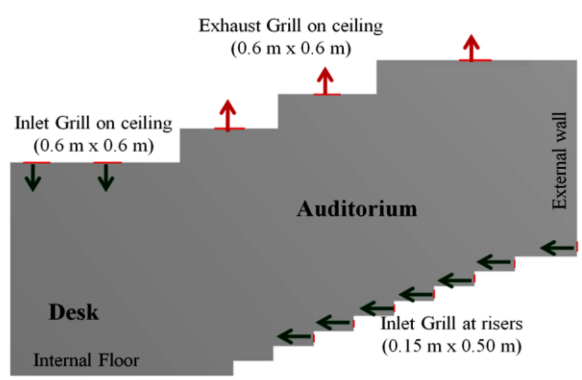

Fig. 15: Different boundaries of AMPHI Theater proposed design-4

Different boundaries of AMPHI Theater proposed design-4 on longitudinal section is shown in figure 15. There are total 4 inlet grilles of 0.6 m x 0.6 m placed at ceiling and 28 inlet grilles of 0.15 m x 0.5 m placed at risers and total 6 outlet grilles of 0.6 m x 0.6 m placed at ceiling.

N. Boundary conditions:

Boundary conditions are assigned to create a virtual environment of the real life working of the system. The boundary conditions at different location of the AMPHI Theater are explained below.

1. Define the solver settings as pressure based transient and enable gravity option in y direction with the value of -9.81 m/s^2.
2. Working fluid set as air with density 1.22 kg/m3, Specific Heat 1006.43 J/kg K, Thermal conductivity 0.24 W/m^2-K
3. Set viscose design as K-epsilon realizable design with enhanced wall treatment
4. To determine the temperature distribution need to on energy equation.
5. Air temperature of 18 °C in summer and 20 °C in winter used for the CFD simulation.
6. For the outlet boundary condition the gauge pressure needs to be set as zero.
7. Under Discretization, select standard for Pressure, and second order for Momentum and Energy equation.
8. The Fluent solver is used for CFD analysis.

V. Results

The main objective of the present work to investigate the effects of better thermal comfort of AMPHI Theater by changing positions of inlet and outlet grills which is exposed in the same thermal conditions. Computational fluid dynamics analysis have been performed for AMPHI Theater using ANSYS fluent to investigate the effects of better thermal comfort by changing of inlet and outlet position. Four different 3D models have been created using ansys workbench design modular and simulated with same boundary conditions to find temperature distributions inside the AMPHI Theater for summer and winter season. Working fluid set as air with density 1.22 kg/m^3, Specific Heat 1006.43 J/kg K, Thermal conductivity 0.24 W/m^2-K. K-epsilon realizable model with enhanced wall treatment is used for turbulent flow inside the AMPHI Theater. For all four designs of AMPHI Theater following results with graphical representation and tabulated data have been explained.

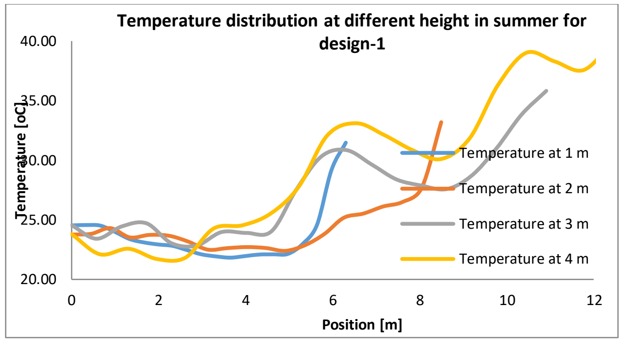

Fig. 16: Temperature distribution at different height in summer for design-1

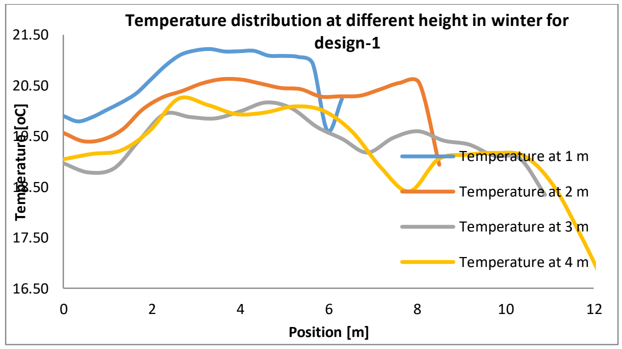

Fig. 17: Temperature distribution at different height in winter for design-1

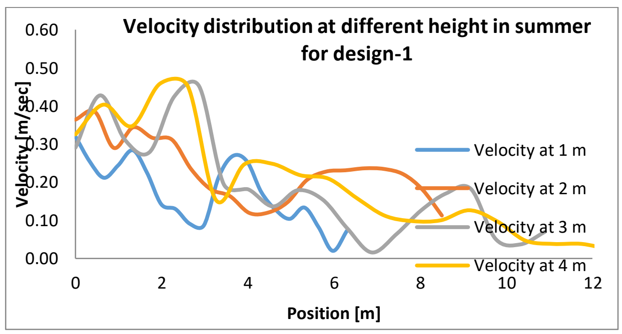

Fig. 18: Velocity distribution at different height in summer for design-1

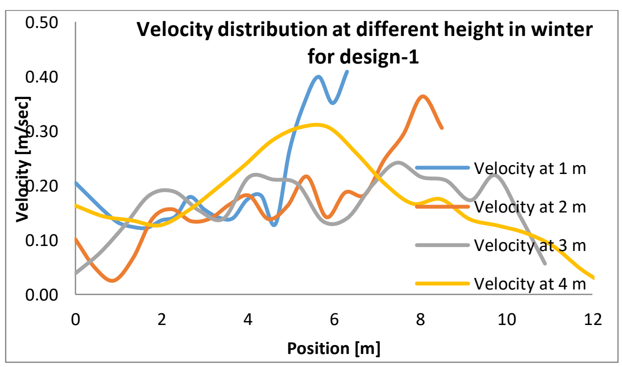

Fig. 19: Velocity distribution at different height in winter for design-1

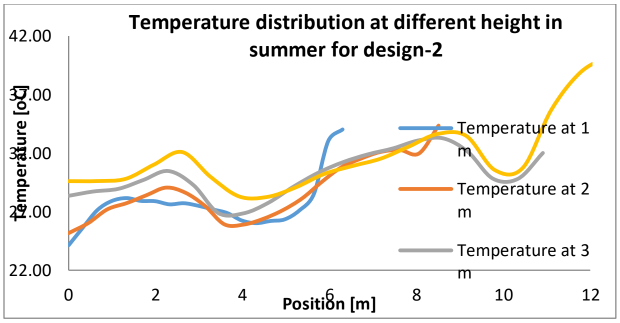

Fig. 20: Temperature distribution at different height in summer for design-2

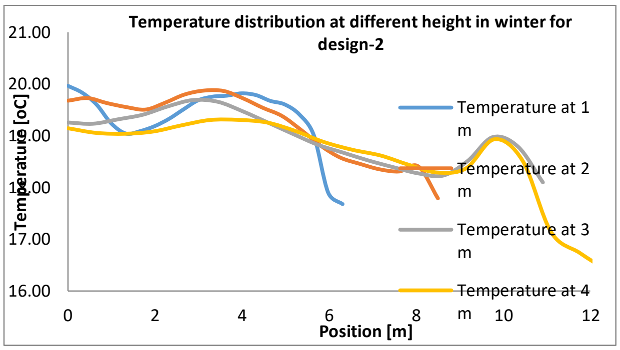

Fig. 21: Temperature distribution at different height in winter for design-2

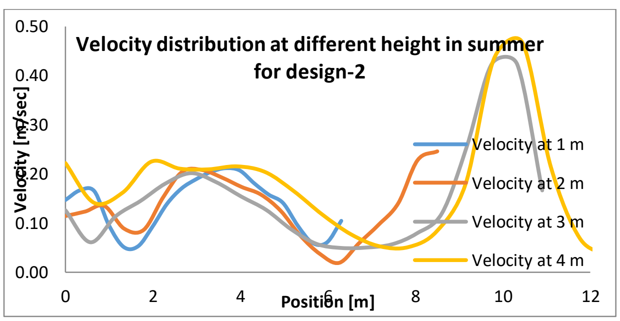

Fig. 22: Velocity distribution at different height in summer for design-2

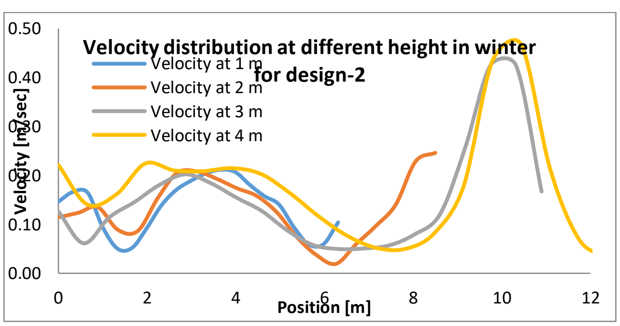

Fig. 23: Velocity distribution at different height in winter for design-2

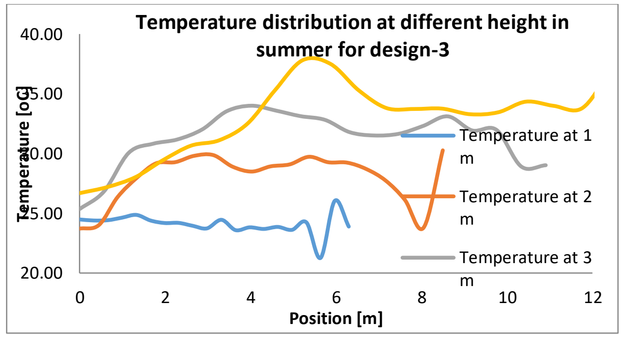

Fig. 24: Temperature distribution at different height in summer for design-3

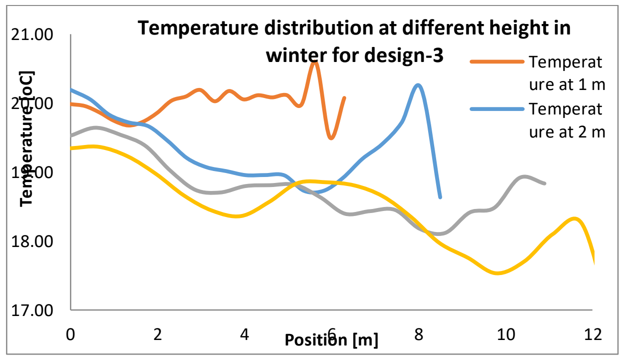

Fig. 25: Temperature distribution at different height in winter for design-3

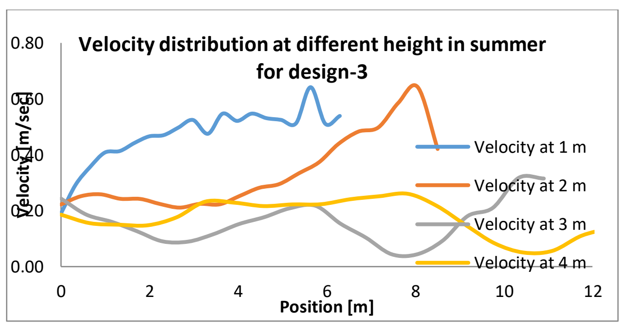

Fig. 26: Velocity distribution at different height in summer for design-3

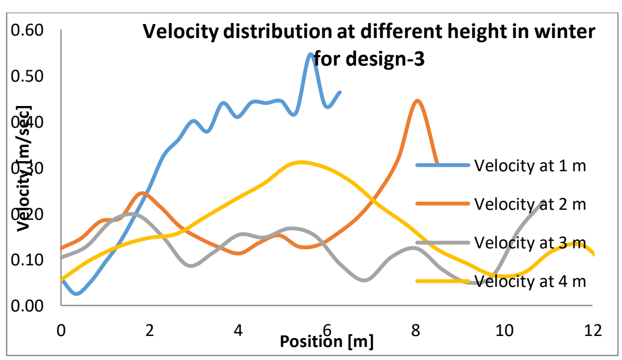

Fig. 27: Velocity distribution at different height in winter for design-3

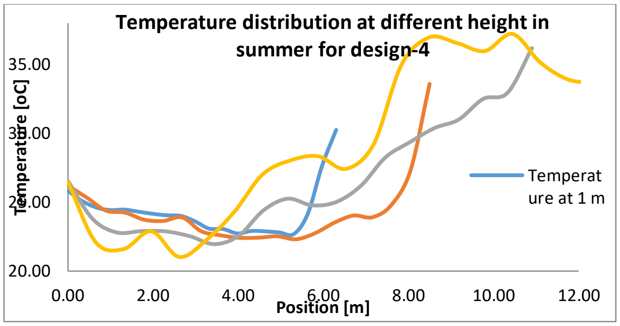

Fig. 28: Temperature distribution at different height in summer for design-4

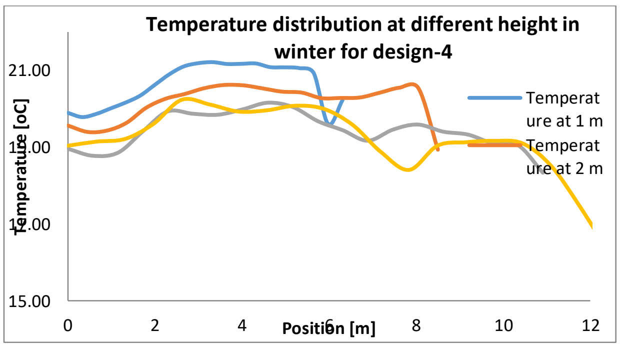

Fig. 29: Temperature distribution at different height in winter for design-4

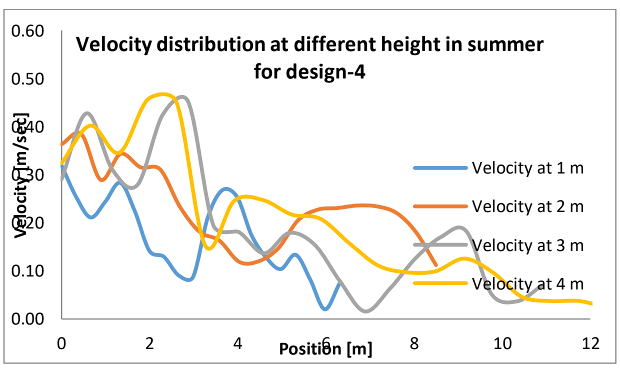

Fig. 30: Velocity distribution at different height in summer for design-4

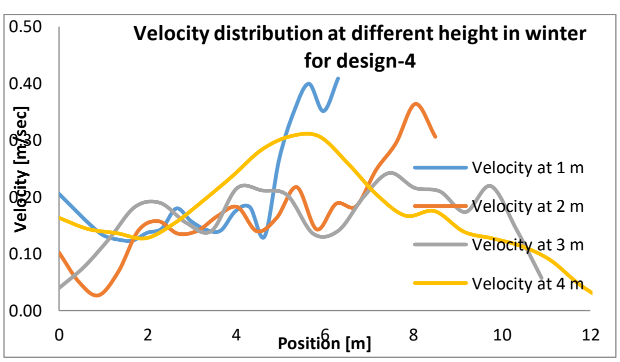

Fig. 31: Velocity distribution at different height in winter for design-4

Time taken to achieved the comfort temperature in AMPHI Theater

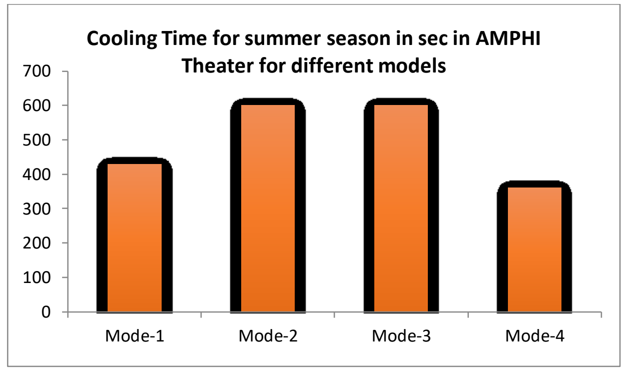

Fig. 32: Cooling Time for summer season in sec in AMPHI Theater for different models

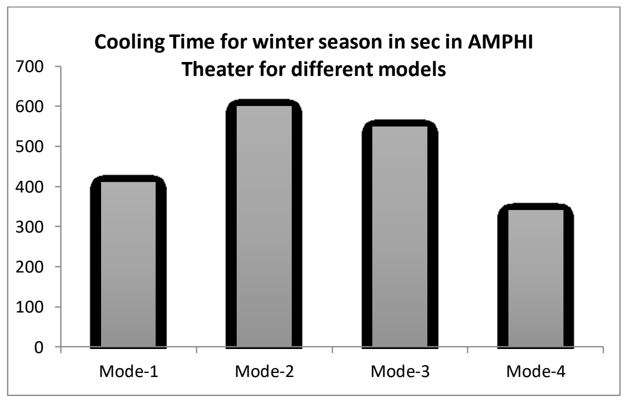

Fig. 33: Cooling Time for winter season in sec in AMPHI Theater for different models

After doing result analysis of all designs of AMPHI Theaters it can be summaries that to attained comfort temperature inside the AMPHI Theater, the minimum cooling time of 360 sec is observed as shown in figure 5.17 for proposed design-4 and the minimum time to attained thermal comfort during winter season is 340 sec is observed as shown in figure 5.17 also for proposed design-4.

VI. CONCLUSION

In the present work computational fluid dynamics analyses have been performed for an AMPHI Theater using ANSYS fluent to investigate the effects of better thermal comfort by changing positions of inlet and outlet grills for summer and winter season. For that four 3D CDA design of AMPHI Theater is designed using the Ansys workbench design modular with approximate dimension. The capacity of AMPHI Theater for 100 peoples distributed as 12 people on 8 rows, each row is placed on a higher step than previous one. For design-1 total four inlet grilles of 0.6 m x 0.6 m placed at ceiling and 24 inlet grilles of 0.15 m x 0.5 m placed at risers and total six outlet grilles of 0.6 m x 0.6 m placed at ceiling. For design-2 total 32 inlet grilles of 0.15 m x 0.5 m placed at risers, 2 inlet grilles of 0.6 m x 0.6 m placed at ceiling and total six outlet grilles of 0.6 m x 0.6 m placed at ceiling. For design-3 there are total 32 inlet grilles of 0.15 m x 0.5 m placed at risers and total eight outlet grilles of 0.6 m x 0.6 m placed at ceiling and for design-4 total four inlet grilles of 0.6 m x 0.6 m placed at ceiling and 28 inlet grilles of 0.15 m x 0.5 m placed at risers and total six outlet grilles of 0.6 m x 0.6 m placed at ceiling. Types of elements used are tetrahedral which is a triangular in shape with four nodes on each element. Working fluid set as air with density 1.22 kg/m^3, Specific Heat 1006.43 J/kg K, Thermal conductivity 0.24 W/m^2-K. K-epsilon realizable design with enhanced wall treatment is used for turbulent flow inside the AMPHI Theater. There are following conclusive points drawn from this work.

- After performing computational fluid dynamic transient analyses with absolute velocity formulation using pressure based solver for design-1. The temperature distributions inside the AMPHI Theater have been analyzed with interval of 10 sec, it has been observed that during the summer season variation in temperature is larger (21.82 ºC to 39.79 ºC at different height from floor) due to thermal gradient and during winter season temperature variation is small. Velocity profiles are almost similar for both summer and winter seasons (0.02 m/sec to 0.46 m/sec) due to same strategy of ventilation used. The total cooling time for summer and winter seasons are 410 sec & 430 sec respectively.
- After performing computational fluid dynamic transient analyses with absolute velocity formulation using pressure based solver for design-2. The temperature distributions inside the AMPHI Theater have been analyzed with interval of 10 sec, it has been observed that during the summer season variation in temperature is larger (24.14 ºC to 40.32 ºC at different height from floor) due to thermal gradient and during winter season temperature variation is small. Velocity profiles are almost similar for both summer and winter seasons (0.05 m/sec to 0.47 m/sec) due to same strategy of ventilation used. The total cooling time for summer and winter seasons is 600 sec.
- After performing computational fluid dynamic transient analyses with absolute velocity formulation using pressure based solver for design-3. The temperature distributions inside the AMPHI Theater have been analyzed with interval of 10 sec, it has been observed that during the summer season variation in temperature is larger (21.28 ºC to 37.83 ºC at different height from floor) due to thermal gradient and during winter season temperature variation is small. Velocity profiles are almost similar for both summer and winter seasons (0.04 m/sec to 0.64 m/sec) due to same strategy of ventilation used. The total cooling time for summer and winter seasons are 600 sec & 550 sec respectively.
- After performing computational fluid dynamic transient analyses with absolute velocity formulation using pressure based solver for design-4. The temperature distributions inside the AMPHI Theater have been analyzed with interval of 10 sec, it has been observed that during the summer season variation in temperature is larger (21.04 ºC to 37.22 ºC at 4 m height from floor) due to thermal gradient and during winter season temperature variation is small. Velocity profiles are almost similar for both summer and winter seasons (0.03 m/sec to 0.46 m/sec) due to same strategy of ventilation used. The total cooling time for summer and winter seasons are 360 sec & 340 sec respectively.

It have been observe from the above conclusion that the proposed design-4 of the AMPHI Theater having better thermal comfort with lest time to achieved the comfort temperature inside AMPHI Theater for both summer and winter season. This computational fluid dynamics analysis of AMPHI Theater can be used as pre-exanimation of future work in order to obtain better thermal comfort and also verify requirements for the installation of HVAC systems.

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.