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Examine Thermal Comfort Inside The Indoor Swimming Pool Through Various Configuration of Inlet and Outlet Vents

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Abstract

Research is now focused on numerically evaluating how occupational level affects pool temperature in a big competition pool. Ansys Fluent, a program for "Computational Fluid Dynamics" (CFD), was used to carry out the experiment. In this study five configuration of inlet and outlet are consider in the indoor swimming pool. The study only focus on achieve the thermal comfort in the spectator area and pool area without increasing and decreasing the volume temperature of indoor swimming pool. In case 2, changing the position of outlet there is minor changes in the volume temperature as compare to case 1. In case 3, case 4, and case 5 decreasing the temperature at spectator area of 10%, 11%, and 14% as compare to case 1 respectively.

Keywords: Spectator, Thermal comfort, Ventilation, Computational fluid dynamics, Indoor swimming pool, etc.

I. INTRODUCTION

A system that includes "ventilation", "heating", and "air conditioning" is often referred to as HVAC [1]. In the context of enterprise data centres, the inclusion of HVAC systems in the planning and management process is essential, as they are integral components alongside servers, storage, networking, security, and electricity [2]. These systems are responsible for regulating the ambient atmosphere of the data centre, encompassing factors such as humidity, temperature, air movement, and air filtration [3]. Almost all pieces of IT gear have certain temperature & humidity requirements. Product specifications and physical planning guidelines often detail these needs [4]. The safety, security, fire, and environmental issues of all of the equipment in the data center must be taken into consideration while designing HVAC system [5]. This is why proper forethought, installation, and upkeep of an HVAC system are essential [6]. In addition, emergency planning has to be included. A data center may, for instance, use HVAC redundancy, stockpile replacement parts, and store portable cooling units as backups [7].

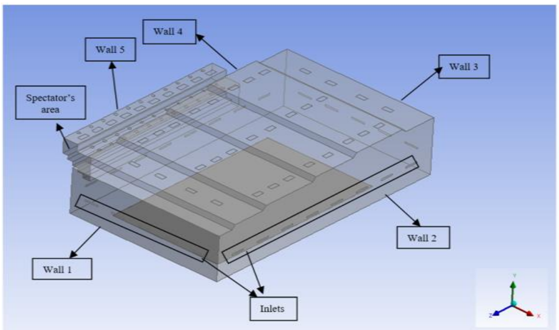
By maintaining a comfortable temperature and humidity level and filtering out harmful bacteria, the HVAC systems in hospitals play an essential role in patient care [8]. Due to these variables, particular consideration must be given in design of the hospital air conditioning systems to a number of criteria that are also relevant in other industries [9]. In a healthcare environment, air conditioning serves a multitude of purposes beyond basic comfort provision [10]. The optimal functioning of medical equipment utilised in hospitals and other healthcare facilities is contingent upon its sensitivity to temperature and humidity levels [11]. However, the design of such structures is made more complicated by the fact that hospitals must have rooms with quite distinct uses [12].

There are several forms of building ventilation, such as smoke ventilation, balanced ventilation, natural ventilation, and mechanical ventilation [13]. Buildings must have proper ventilation to prevent them from turning into gashouses of stagnant air [14]. Accumulation of carbon may result from inadequate air circulation. Bacteria in the building might also be increased [15]. This makes the environment unsafe for human habitation. In order to replace the stale air with fresh air, ventilation is an essential activity [16]. The use of a ventilator, or mechanical ventilation, to provide artificial breathing is known in medicine as aided or mechanical ventilation [17]. With the use of mechanical ventilation, air may be pushed into and out of the lungs, facilitating the exchange of gases such as carbon dioxide and oxygen [18]. To safeguard the airway from mechanical or neurological causes, to guarantee sufficient oxygenation, or to expel excess carbon dioxide from the lungs are only a few of the many reasons mechanical ventilation is used [19]. People who need ventilators are usually monitored in an intensive care unit, and a number of healthcare professionals are involved in their usage [20].

II. RESEARCH METHODOLOGY

A. Design

The layout of the swimming pool used for this investigation is shown in Figure 1. At present, the swimming pool occupies an area of 25 by 15 meters, and the surrounding area is 35 by 25 meters with a height of 8 meters. Totaling there are 24 and 26 supply air jets in the pool area. Both Five and four on wall 1 and wall 3, eight on wall 2 and wall 4, and two, three, and four air jets on wall 5 make up the area. The roof of the spectator area has 33 supply air jets. There are a total of 120 m^2 of stands for the viewers' area, distributed along four long rows. With an average seating surface of 1.2 square meters, the spectator area can accommodate 100 people. Wall 1 and wall 3 are symmetry in inlet as respect to shape of inlet and arrangement of the position. Wall 2 and wall 4 are symmetry in inlet as respect to shape and arrangement of position of inlets.



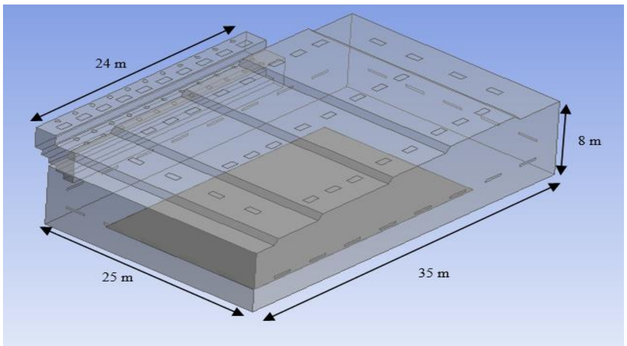


Figure 1 Domain and area of indoor swimming pools representation [21]

1. Design 1

In this design of indoor swimming pool, total 26 inlets are present in wall 1, 2, 3, & 4 and 33 inlets are present in ceiling of spectators area. There are two kind of shape use for the inlet. Shape of the inlet is rectangle and round, which is, attach in the walls and spectators area respectively. The dimensions of the rectangular entrance are 1.8 m in length and 0.2 m in breadth. The diameter of the round inlet are 0.4 m and difference between each round inlet are 2 m. Light and outlet having a same length and width of 1.2 m and 0.6 m respectively. Arrangement of the inlet, outlet and lights are illustrate in Figure 4 and Figure 5.

2. Design 2

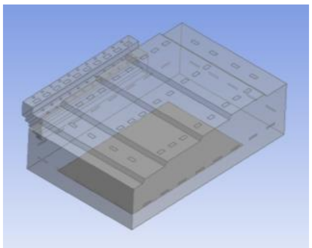
In this configuration of indoor swimming pool all parameter are same for dimension and position, which is use in design 1, except outlet position in ceiling of pools area. The position arrangement are illustrate in Figure 2. In this design of indoor swimming pool, total 26 inlets are present in wall 1, 2, 3, & 4 and 33 inlets are present in ceiling of spectators area. There are two kind of shape use for the inlet. Shape of the inlet is rectangle and round, which is, attach in the walls and spectators area respectively. The dimensions of the rectangular entrance are 1.8 m in length and 0.2 m in breadth. The diameter of the round inlet are 0.4 m and difference between each round inlet are 2 m. Light and outlet having a same length and width of 1.2 m and 0.6 m respectively. Arrangement of the inlet, outlet and lights are illustrate in Figure 4 and Figure 6.

3. Design 3

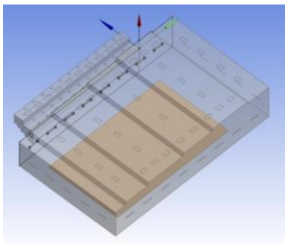
In this configuration of indoor swimming pool, remove 1 inlet from each wall 1, and 3 and attach to wall 5, which is located at spectators area show in Figure 2. In wall 5, length and width of the inlet is 1.8 m and 0.2 m and distance between them is 6.8m. The dimension of the inlet are same as use in design 1. The position arrangement of inlet, outlet and lights are illustrate in Figure 4 and Figure 7. The outlet are same as use in design 2,

4. Design 4

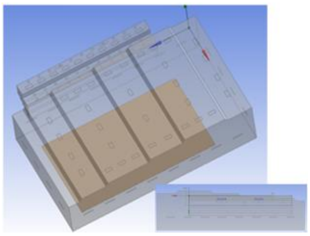
In this configuration of indoor swimming pool, remove 1 outlet from the ceiling of spectator area and attach to pool ceiling. Split 2 inlet into 3 inlet, which is present in the wall 5 in design 3and distance between each inlet is 5.1m, show in Figure 2. The length and width of the inlet of wall 5 are 1.2 m and 0.2 m respectively. All other dimension are same which is use in design 2. After the changes the position arrangement of inlet, outlet, and lights are illustrate in Figure 4 and Figure 8.



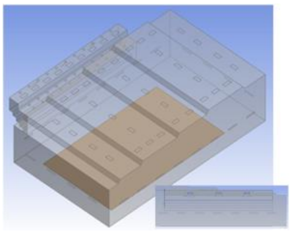
Design 1



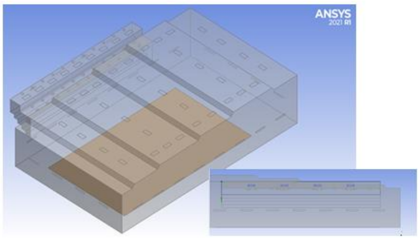
Design 2



Design 3



Design 4



Design 5

Figure 2 Various configuration of the indoor swimming pool

5. Design 5

In this configuration of indoor swimming pool, attach 1 more inlet in wall 5. The length and width of the inlet of wall 5 are 1 m and 0.2 m respectively, and distance between each inlet is 4m, show in Figure 2. All other dimension are same which is use in design 2. After the changes the position arrangement of inlet, outlet, and lights are illustrate in Figure 4 and Figure 9.

B. Mesh generation

In the process of mesh generation for an indoor swimming pool model using ANSYS Fluent, several steps were taken to ensure an efficient and accurate mesh. The main mesh elements used were tetrahedrons, chosen for their suitability in complex geometries. The element size for the main pool volume was set to 2.16 meters, providing a balance between computational accuracy and resource efficiency. For specific features like the inlet, outlet, and lighting fixtures, a finer mesh was employed using the face mesh method. This method allows for a more detailed representation of these critical areas, enhancing the accuracy of flow simulations near these features. The element size for these regions was set to 0.05 meters, ensuring that the mesh adequately captures the flow dynamics and boundary effects in these key zones. Figure 3 illustrate the mesh generation of indoor swimming pool model. For all the cases considered in this study number of element and nodes are in the range of 1,716,000 – 1,737,000 and 321,100-324,700 respectively. After the mesh generation do name selection of domain, which is, participate in the boundary condition. Figure 4-Figure 9 illustrate the domain name which participate in the boundary condition.

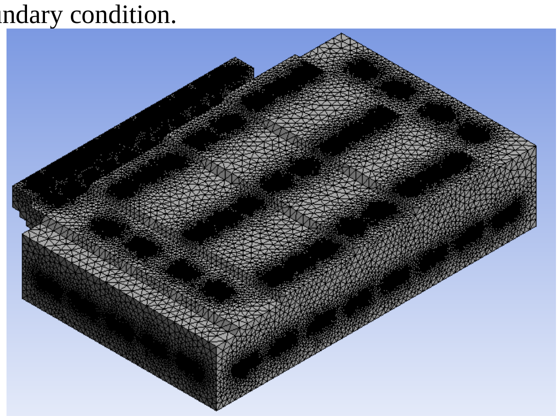


Figure 3 Meshed view of indoor swimming pool

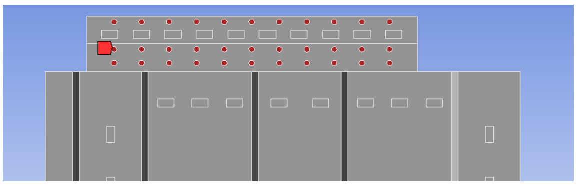


Figure 4 Inlet at spectator side in celling of all design consider

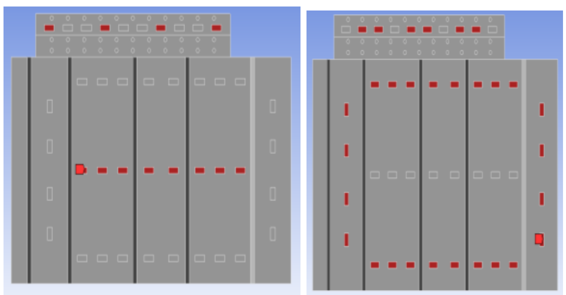


Figure 5 Outlet and light representation in Case 1

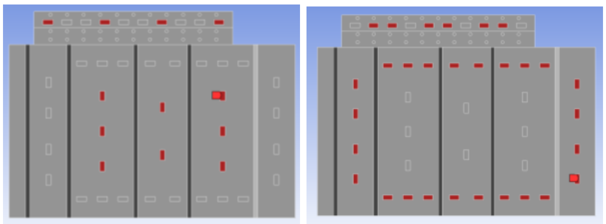


Figure 6 Outlet and light representation in Case 2

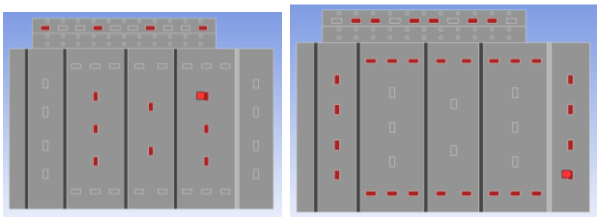


Figure 7 Outlet and light representation in Case 3

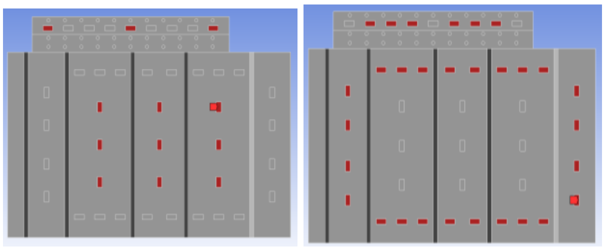


Figure 8 Outlet and light representation in Case 4

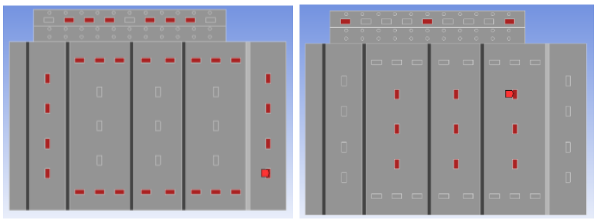


Figure 9 Outlet and light representation in Case 5

C. Boundary condition

The executable models used were k-epsilon (standard) turbulence and a pressure-based solver. For pressure-velocity coupling, the Coupled algorithm was chosen, the discretisation method was set to least square cell-based, and for pressure, momentum, and energy, the second-order upwind scheme was set. QUICK was set for the turbulent kinetic energy and turbulent dissipation rate. For solution control of pressure, momentum, density, turbulent kinetic energy, turbulent dissipation rate, and energy the value are 0.5, 0.7, 1, 0.75, 0.75, and 0.75 respectively. Air is directed towards the people in both the pool and the spectator sections at a 45-degree angle and maintained at a temperature of 16 degrees Celsius. In accordance with ASHRAE 62.1, the air change per hour (ACH) was determined to be 7. The predicted metabolic rate for each individual was close to 104 W [1 Met], which is the rate at which a person's energy expenditure is used while sitting. It was believed that the walls would maintain a constant temperature of 35 ºC and that the pool water would remain at a constant 29 ºC. For both the pool and the spectator portions, it was expected that the lighting units would output a heat flux of 2 W/m2 per unit. In Figure 10, see where the planes were placed that showed how each scenario in the present simulation turned out. Plane 1 and plane 2 are in XY plane with 23m, and 8 m distance. Plane 3, and plane 4 are in ZX plane with 2m, and 4.7 m distance. Plane 5, 6, 7, and 8 are on YZ plane with 1, 2, 9, and 16 m distance.

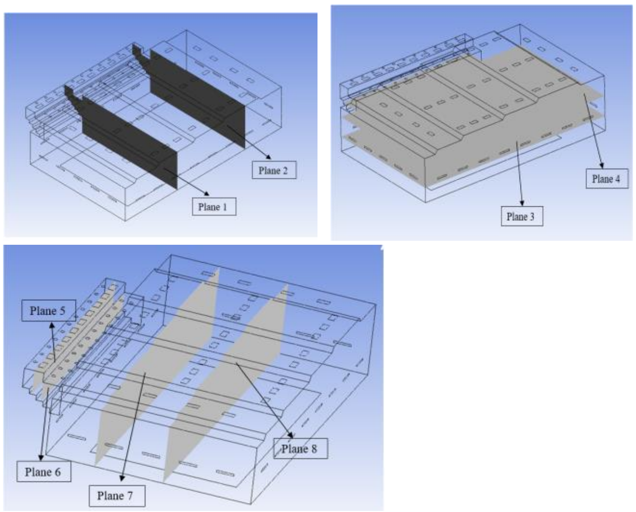


Figure 10 Planes representation in indoor swimming pool

D. Validation

For validate the current result a comparison was made between current result and result get from (Sobhi et al., 2022) [21] from CFD analysis for same configuration and boundary conditions. There were many numerical data to compare, so just picked average volume temperature. For validation of indoor swimming pool, turbulent flow (k - e Standard) model in ANSYS fluent were use.

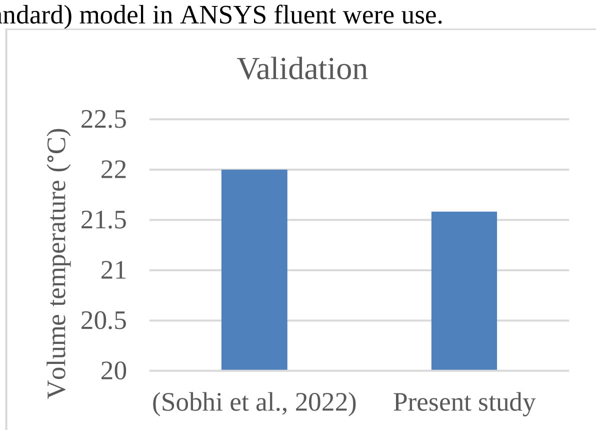


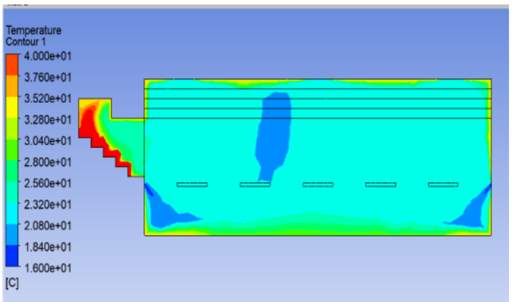
Figure 11 Validation result

The boundary condition is mention in upper section, which is use for simulate the model. Figure 11 illustrate the comparison of average volume temperature of both simulated model. The graph show that the difference between both results is about 1.9%, which is generally acceptable.

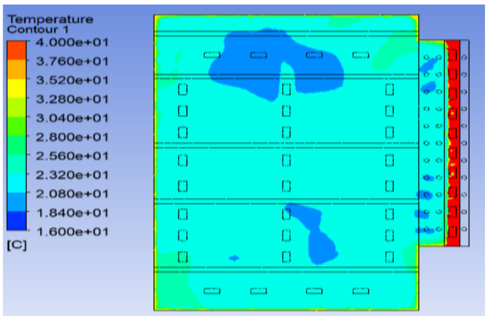
III. RESULT AND DISCUSSION

A. Temperature contour

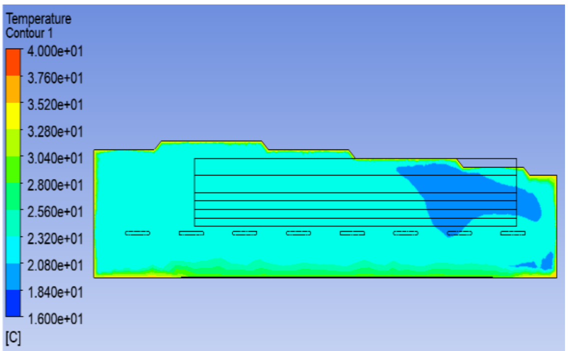
Temperature contour of indoor swimming pool are show in the form of various plane. Location of plane are mention in upper section. The color legends are show the equivalent temperature in that area. In the case 1, plane 1, & 2 having a high temperature in the spectator area, which is equal and greater then 40 °C. In the pool plane 1 & 2 both represent the green color which means in that area the temperature vary from 25 to 30 °C. in the case 2, due to change in the outlet position in ceiling of pool area the temperature are reduce inside the indoor area. In the case 3, remove 1 inlet from each wall 1, & wall 3 attach in wall 5 reduce in the temperature of spectator area. Which is illustrate in plane 5, & plane 6. In the case 4, splitting the inlet, which is located in wall 5, into 3 parts and removing the outlet from the ceiling of spectator attach in ceiling of pool area. Due to this arrangement inlet, cover more area in the spectators area. Temperature contour in plane 5, & 6 illustrate reduction in temperature in spectator area. In the case 5, removing the outlet from the ceiling of spectator attach in ceiling of pool area and attach 1 more inlet in wall 5. Due to this reduce the temperature in inside.



a. Plane 2

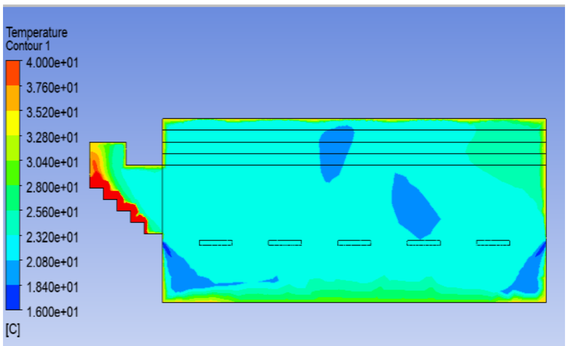


b. Plane 4

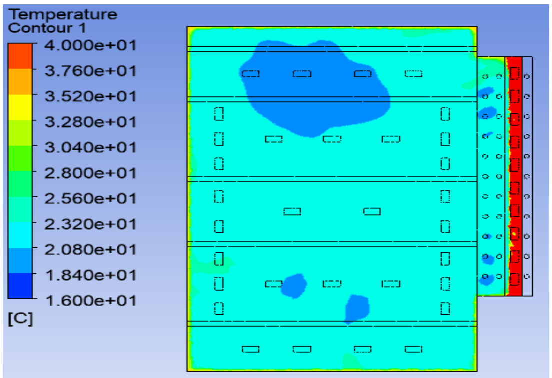


c. Plane 8

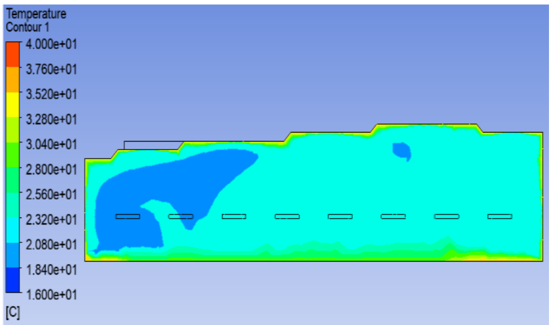
Figure 12 Temperature contour of case 1



a. Plane 2

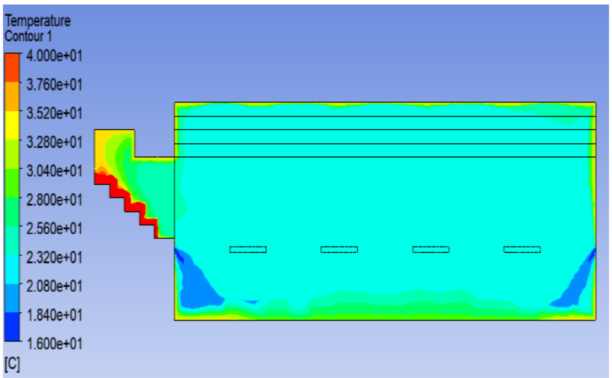


b. Plane 4

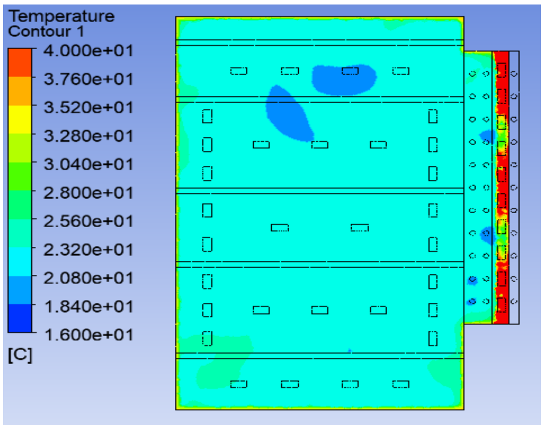


c. *Plane 8*

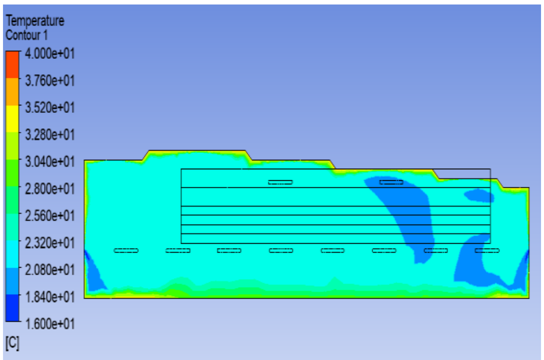
Figure 13 Temperature contour of case 2



a. Plane 2

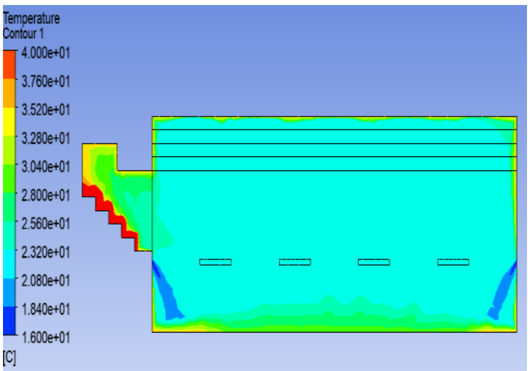


b. Plane 4

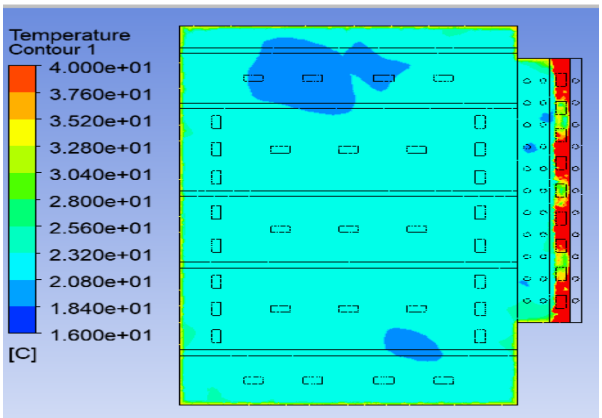


c. Plane 8

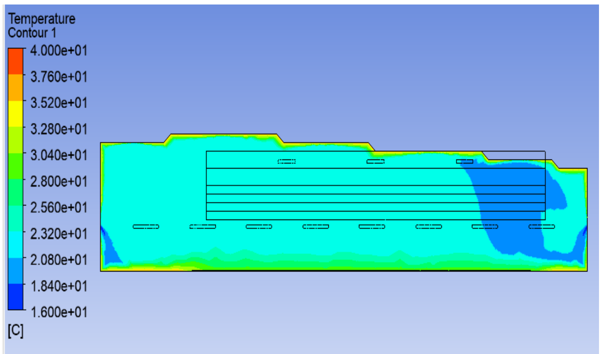
Figure 14 Temperature contour of case 3



a. Plane 2

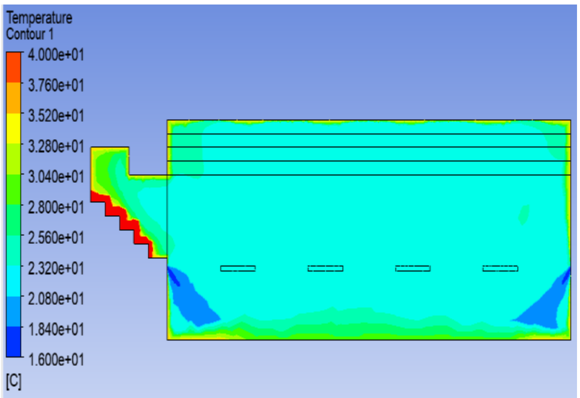


b. Plane 4

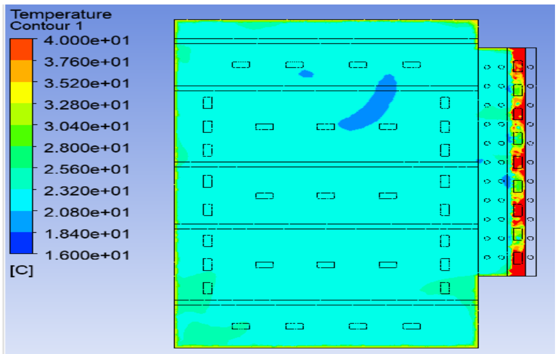


c. Plane 8

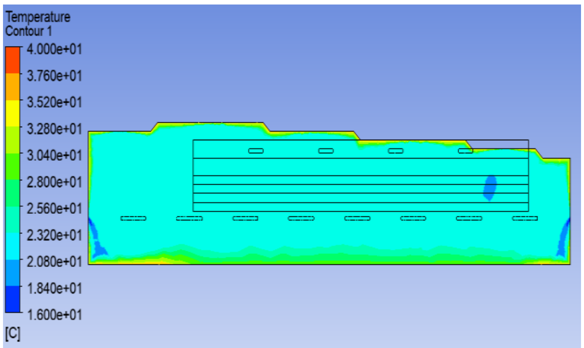
Figure 15 Temperature contour of case 4



a. Plane 2



b. Plane 4



c. Plane 8

Figure 16 Temperature contour of case 4

Table 1 Values of velocity components at each supply air jet.

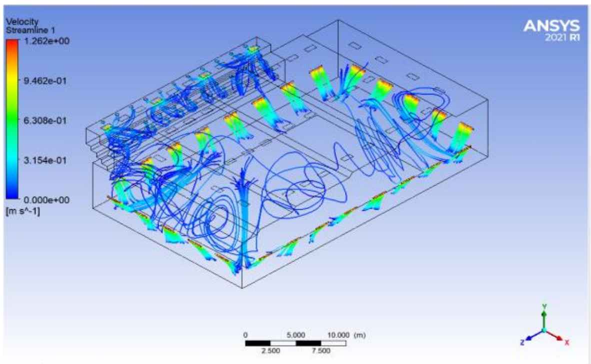
Type of supply air jet	X – velocity (m/s)	Y – velocity (m/s)	Z – velocity (m/s)
Spectators area (ceiling)	0.14	-0.14	-
Spectators area (Wall 5)	0.85	-0.85	-
Wall 1	-	-0.85	-0.85
Wall 2	-0.85	-0.85	-
Wall 3	-	-0.85	0.85
Wall 4	0.85	-0.85	-

Table 2 Case notation

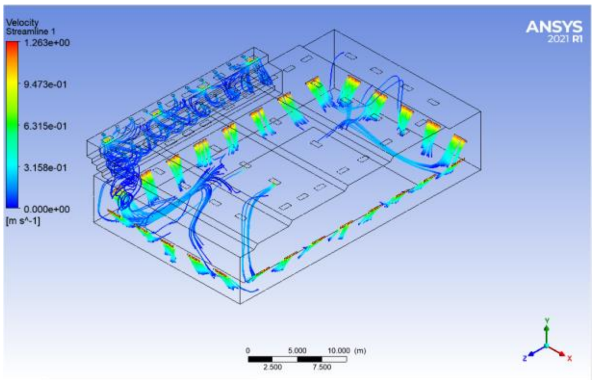
Cases name	Design
Case 1	Design 1
Case 2	Design 2
Case 3	Design 3
Case 4	Design 4
Case 5	Design 5

B. Velocity streamline

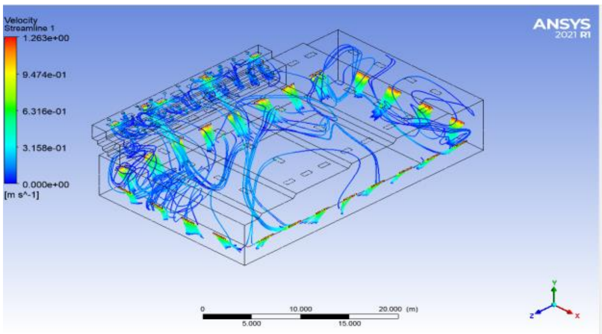
In this section, illustrate the velocity flow behavior inside the swimming space. In case 1, and case 2, velocity streamline show that the velocity flow at 45° towards the occupant in both pool area and spectator area. Temperature of the spectator area is more than thermal comfort due to this remove inlet from wall 1 & 3 and attach in wall 5. Due to that, find the reduction in temperature at the spectator area. In the case 4, splitting the inlet in 3 parts, which is located in the wall 5. Due to this air cover the more area at spectator's area, which is show in the figure below. In the case 5, air cover more area and stable equilibrium condition attach 1 more inlet in the wall 5. Flow direction and behavior of air illustrate in figure below. In the initially when air enter velocity at maximum and after some time when air cover some distance velocity get slow.



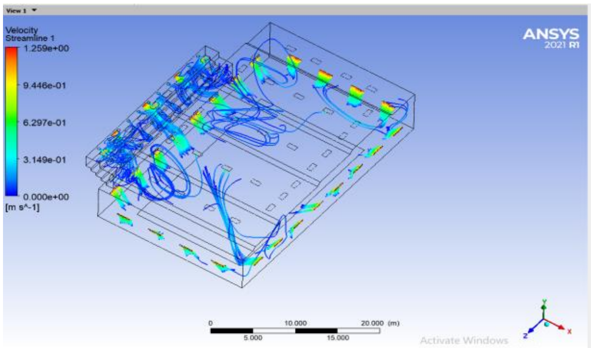
a. Case 1



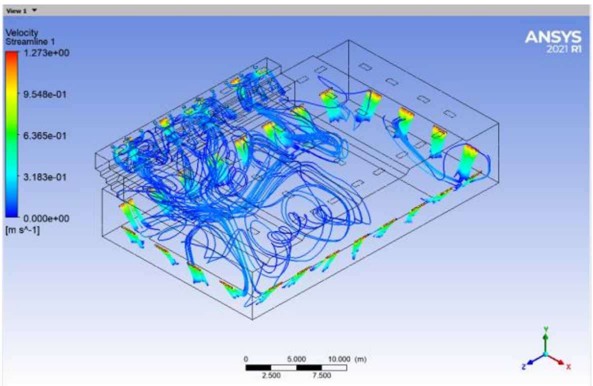
b. Case 2



c. Case 3



d. Case 4



e. Case 5

Figure 17 Velocity streamline representation of all cases

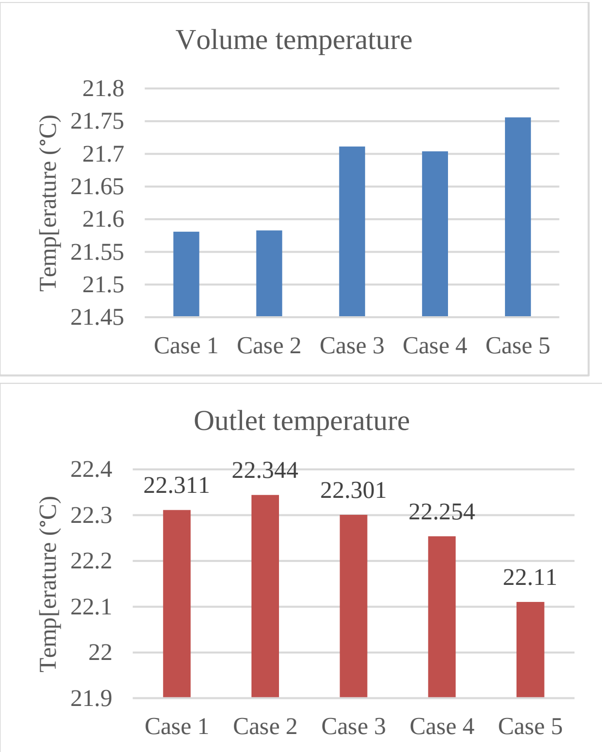


Figure 18 Average Temperature inside the swimming pool and Average Outlet temperature

C. Temperature comparison

Case 1, having average volume temperature and outlet temperature of 21.581 °C and 22.311 °C respectively. In case 2, by change the location of oulet of ceiling of pool area, there is no chnages in the volume temperature and outlet temeprature. In case 3, remove inlet from wall 1 & wall 3, attach to the wall 5, due to that volume temeprature is increase and minor reduction in outlet temperature as compare to case 1 and case 2. In case 3, reduction in area of spectator as compare to case 1, & 2. In case 4, remove outlet from ceiling of spectator and attach to ceiling of pool area, due to that chnages there is reduction in volume temperature and outlet temperature as compare to case 3. Temperature of spectator area is same as in case 3. In case 5, increases the inlet in wall 5, due to that chnages increases volume temperature and decreases the outlet temperature as compare to case 4. Temperature decreases in the area of spectator as compare to remaining all cases.

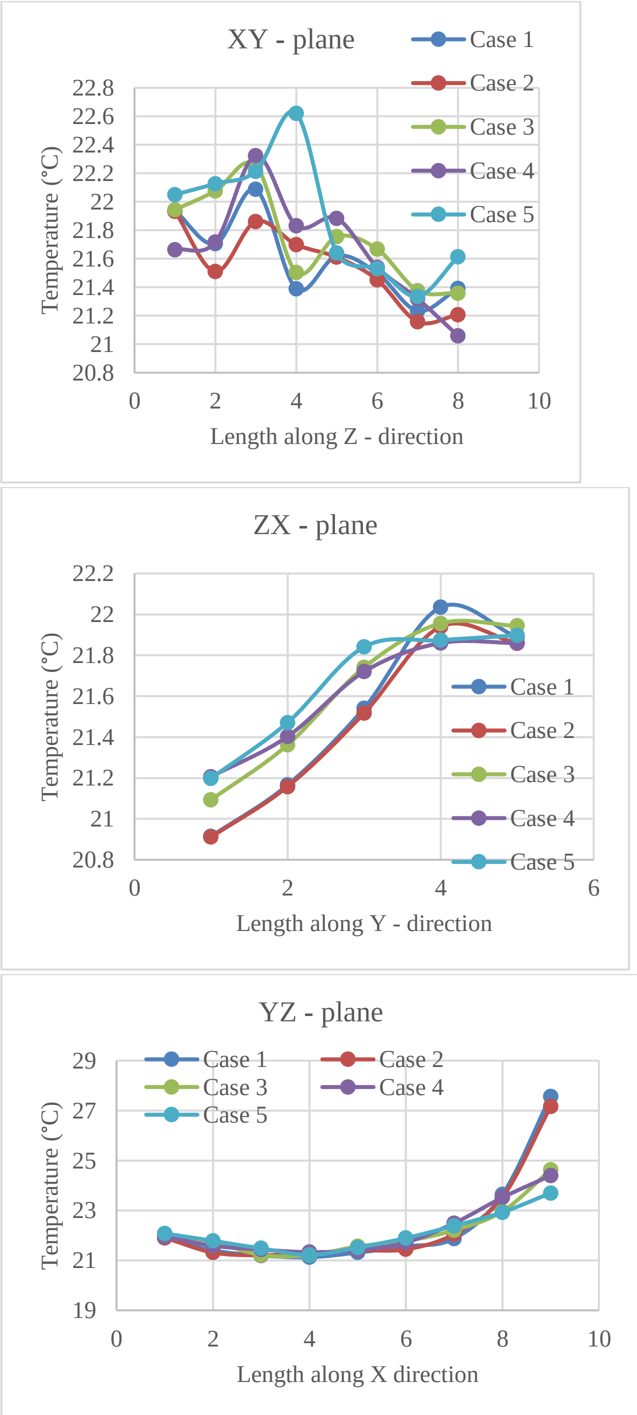


Figure 19 Average temperature in XY, ZX, and YZ plane

IV. CONCLUSION

The purpose of this research is to conduct a numerical analysis of the effect of indoor pool temperature on spectator thermal comfort. "Computational fluid dynamics" using ANSYS-Fluent was used for this investigation, with five different configurations of inlet and outlet setup. When it came to creating the perfect thermal environment for the spectators, the present simulation showed that the quantity and placement of the inlets were critical, particularly for large crowds. "Air conditioning" jets should be positioned as near to the chairs as feasible in order to battle the heat that is produced in this area. In order to prevent hot areas caused by airflow dead patches, this kind of study was carried out in the pool hall. Following findings are mention below:

- In the case 2, Change in the position of outlet in the ceiling of pool area, there is minor change in the average temperature of outlet and inside swimming area as compare to case 1.
- Removing the inlet from wall 1 & 3, and attach to wall 5, increases the temperature of inside swimming pool area. But decreases the temperature at spectator area as compare to case 1, and case 2.
- In case 3, and case 4, there is minor changes in the temperature of spectator area.
- In the case 4, due to change in outlet position and split inlet into 3 part which is located in wall 5, resultant

V. REFERENCES

[1] L. Morales Escobar, J. Aguilar, A. Garces-Jimenez, J. A. Gutierrez De Mesa, and J. M. Gomez-Pulido, “Advanced fuzzy-logic-based context-driven control for HVAC management systems in buildings,” *IEEE Access*, vol. 8, pp. 16111–16126, 2020, doi: 10.1109/ACCESS.2020.2966545.

[2] N. C. Seong, J. H. Kim, and W. Choi, “Optimal control strategy for variable air volume air-conditioning systems using genetic algorithms,” *Sustain.*, vol. 11, no. 18, pp. 1–12, 2019, doi: 10.3390/su11185122.

[3] X. Yang, Z. Chen, H. Cai, and L. Ma, “A framework for assessment of the influence of China’s urban underground space developments on the urban microclimate,” *Sustain.*, vol. 6, no. 12, pp. 8536–8566, 2014, doi: 10.3390/su6128536.

[4] T. ANDROSICS and B. BARANYAI, “Optimized room arrangement and building shaping of an industrial and office facility,” *Pollack Period.*, vol. 15, no. 2, pp. 199–210, 2020, doi: 10.1556/606.2020.15.2.18.

[5] T. Lipinski, D. Ahmad, N. Serey, and H. Jouhara, “Review of ventilation strategies to reduce the risk of disease transmission in high occupancy buildings,” *Int. J. Thermofluids*, vol. 7–8, p. 100045, 2020, doi: 10.1016/j.ijft.2020.100045.

[6] D. Aviv *et al.*, “A fresh (air) look at ventilation for COVID-19: Estimating the global energy savings potential of coupling natural ventilation with novel radiant cooling strategies,” *Appl. Energy*, vol. 292, no. October 2020, p. 116848, 2021, doi: 10.1016/j.apenergy.2021.116848.

[7] J. Wang, J. Huang, Z. Feng, S. J. Cao, and F. Haghighat, “Occupant-density-detection based energy efficient ventilation system: Prevention of infection transmission,” *Energy Build.*, vol. 240, p. 110883, 2021, doi: 10.1016/j.enbuild.2021.110883.

[8] P. Ciuman and B. Lipska, “Experimental validation of the numerical model of air, heat and moisture flow in an indoor swimming pool,” *Build. Environ.*, vol. 145, no. April, pp. 1–13, 2018, doi: 10.1016/j.buildenv.2018.09.009.

[9] J. L. F. Blázquez, I. R. Maestre, F. J. G. Gallero, and P. Á. Gómez, “A new practical CFD-based methodology to calculate the evaporation rate in indoor swimming pools,” *Energy Build.*, vol. 149, pp. 133–141, 2017, doi: 10.1016/j.enbuild.2017.05.023.

[10] P. Ciuman and J. Kaczmarczyk, “Processes in the School Swimming Pool,” 2021.

[11] M. Lebon, H. Fellouah, N. Galanis, A. Limane, and N. Guerfala, “Numerical analysis and field measurements of the airflow patterns and thermal comfort in an indoor swimming pool: a case study,” *Energy Effic.*, vol. 10, no. 3, pp. 527–548, 2017, doi: 10.1007/s12053-016-9469-0.

[12] A. Limane, H. Fellouah, and N. Galanis, “Simulation of airflow with heat and mass transfer in an indoor swimming pool by OpenFOAM,” *Int. J. Heat Mass Transf.*, vol. 109, pp. 862–878, 2017, doi: 10.1016/j.ijheatmasstransfer.2017.02.030.

[13] A. Limane, H. Fellouah, and N. Galanis, “Three-dimensional OpenFOAM simulation to evaluate the thermal comfort of occupants, indoor air quality and heat losses inside an indoor swimming pool,” *Energy Build.*, vol. 167, pp. 49–68, 2018, doi: 10.1016/j.enbuild.2018.02.037.

[14] P. M. Sivaram, A. B. Mande, M. Premalatha, and A. Arunagiri, “Investigation on a building-integrated passive solar energy technology for air ventilation, clean water and power,” *Energy Convers. Manag.*, vol.

211, no. January, p. 112739, 2020, doi: 10.1016/j.enconman.2020.112739.

[15] H. Aulia, R. Budi, T. Faiz Dhiahaqi, and A. C. Ramadhani, “HVAC System Functionality with 3 Parameters such as Geometry Design,Duct Positions, and Cooling Time on Room Temperature Class III InpatientRoom at Bitung Hospital Based on Computational Fluid DynamicsSimulation,” no. January, 2023, [Online]. Available: https://www.researchgate.net/publication/367347494

[16] Y. D. Torres *et al.*, “Heating ventilation and air-conditioned configurations for hotelsan approach review for the design and exploitation,” *Energy Reports*, vol. 6, no. April, pp. 487–497, 2020, doi: 10.1016/j.egyr.2020.09.026.

[17] T. Korpela *et al.*, “Waste heat recovery potential in residential apartment buildings in Finland’s Kymenlaakso region by using mechanical exhaust air ventilation and heat pumps,” *Int. J. Thermofluids*, vol. 13, no. November, p. 100127, 2022, doi: 10.1016/j.ijft.2021.100127.

[18] S. O. D. Niaki, M. Pourfallah, and A. Z. Ghadi, “Feasibility and investigation of residential HVAC system with combined ground source heat pump and solar thermal collectors in different climates of Iran,” *Int. J. Thermofluids*, vol. 20, no. July, p. 100427, 2023, doi: 10.1016/j.ijft.2023.100427.

[19] T. Tsoutsos, S. Tournaki, C. A. De Santos, and R. Vercellotti, “Nearly zero energy buildings application in mediterranean hotels,” *Energy Procedia*, vol. 42, pp. 230–238, 2013, doi: 10.1016/j.egypro.2013.11.023.

[20] C. Becchio, S. P. Corgnati, M. Vio, G. Crespi, L. Prendin, and M. Magagnini, “HVAC solutions for energy retrofitted hotel in Mediterranean area,” *Energy Procedia*, vol. 133, pp. 145–157, 2017, doi: 10.1016/j.egypro.2017.09.380.

[21] M. Sobhi, M. A. Fayad, A. M. Al Jubori, and T. Badawy, “Impact of spectators attendance on thermal ambience and water evaporation rate in an expansive competitive indoor swimming pool,” *Case Stud. Therm. Eng.*, vol. 38, p. 102359, 2022, doi: 10.1016/j.csite.2022.102359.