Impact Factor (SJIF): 3.632

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

Volume 3, Issue 2, February-2016

Determining the flow rates required and temperature of inlet cold stream to provide thermal comfort in badminton court of sama sports complex using CFD.

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Abstract — *It's believed that good facilities are fundamental to developing sporting opportunities for everyone, from the youngest beginner to the international class athlete. Badminton court situated in sama sports complex situated in Vadodara is taken for case study for this project work. Vadodara Municipal Corporation has completed sama indoor sports complex in September 2014. M.V. OMNI PROJECTS (INDIA), an Ahmedabad-based civil & engineering solutions provider, is the civil contractor for the project. The project is coming up cover an area of 33,000 Sq Mt, with an investment of Rs. 65 croresThe objective is to estimate the flow rates required in given sports complex by using CFD technique. Designing Ventilation system for flow rates such that to maintain velocity for given flow conditions below 0.1 m/s in playing domain so as to avoid air deflecting the shuttle and also achieving thermal comfort simultaneously are the main agendas for this project.*

Keywords*- Flowrates,Temperature,Thermal comfort,CFD*

"I.INTRODUCTION"

Vadodara Municipal Corporation has completed sama indoor sports complex in September 2014. M.V. OMNI PROJECTS (INDIA), an Ahmedabad-based civil & engineering solutions provider, is the civil contractor for the project. The project is coming up cover an area of 33,000 Sq Mt, with an investment of Rs. 65 crores.

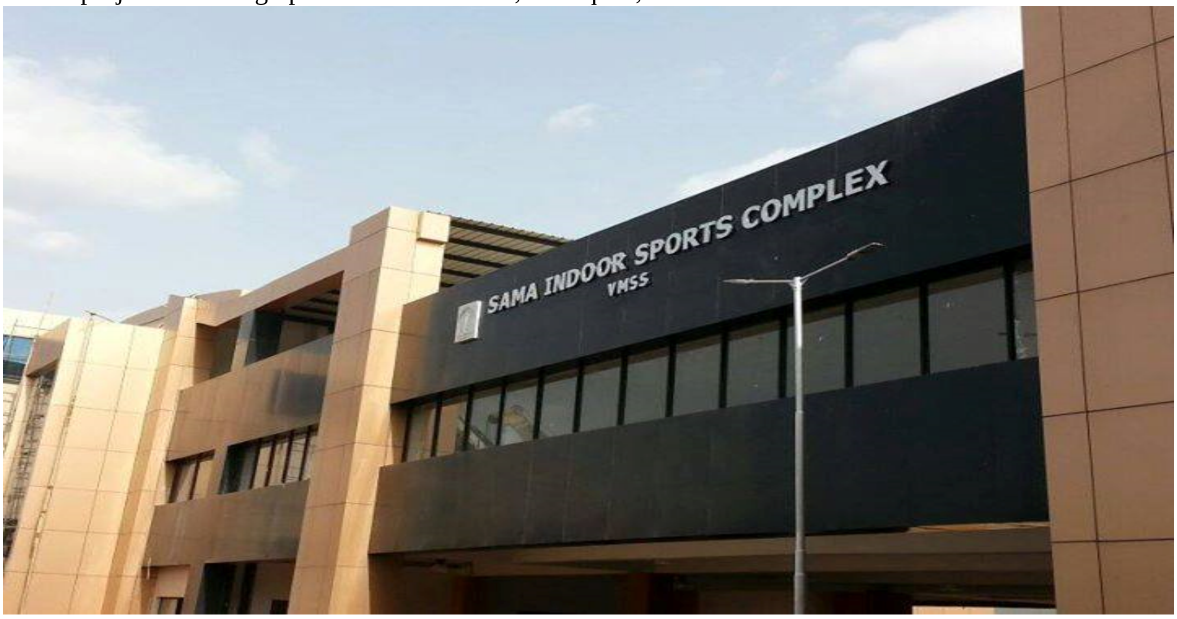

Figure 1 Showing Building of sama indoor sports Complex

It consists of Basketball Unit : 3 courts for basketball & volleyball, Media gallery, Dormitories for players with sitting arrangement. First floor of Basketball Unit : Table tennis courts (03 nos.) and Boxing Ring with sitting arrangement. Provision of Ramp for the Basketball Unit. Administration Building : Rooms for Billiards, Chess etc games, Offices for Staff, Conference Room & Cafeteria. Swimming Pool Unit : 8 Lane – 50mt. Racing pool & Diving Pool (05mt. deep.) – with sitting arrangement. Dormitories, Locker & Changing Rooms. Swimming Pool Unit – First Floor – Badminton Courts with synthetic surface (06 Courts) with sitting arrangement Gymnasium Building : Massage room, Warm–up room and offices for staff. Landscaping & Ample Space for parking.

Good design needs to be based on a sound understanding of such issues as the current trends and practices within individual sports, the wider leisure industry and the lessons to be learnt from previously built schemes. Good design needs to be embraced within the earliest vision statement for a particular project and enshrined in the initial briefing stage through to the final detailed specifications and operational arrangements.

Badminton has the most exacting visual requirements so that players are able to sight a fast moving shuttlecock: the lighting requirements are very specific; there should be no natural day light and the color of the walls must create a suitable background for sighting the shuttle. The hall should be warm with controlled ventilation and a resilient floor to prevent injuries. The basic considerations for badminton court design are as follows.

A Flooring

The preferred flooring for playing badminton is a sprung floor covered with a vinyl impact absorbent covering. This creates an area-elastic floor covered with a point-elastic top layer; and is referred to as a floor with combined-elastic properties.

B Wall colours

A background against which a fast moving shuttle can be seen easily is critically important for the successful playing of the game. The ideal badminton hall has four plain walls with no windows or roof lights. There should be no distracting attachments, particularly brightly coloured items. The surface texture, colour and reflectance value must be consistent and uninterrupted over the full height of the hall. In the case of a refurbishment where it is not practical to remove glazing, it must be covered by blinds or shutters to exclude natural light completely.

C Height of the playing domain:

The heights indicated above are the minimum clear heights over the critical volume of the court and below any obstructions such as beams, basketball backboards, cricket net rails and lights 6.1 m is the absolute minimum height for recreational badminton such as in a small scale college level hall. A clear height of 7.5 m will be accepted for premier level activities using existing facilities, but 9.0 m is preferred. A minimum of 12.0 m clear height is required for Badminton World Federation (BWF) level 1 tournaments; a minimum height of 9.0 m is required for other international events, but 12.0 m is preferred.

Table 1 Height requirement in a badminton court

Level of play category	**Minimum height requirement(m)**
International	9.0
Premier	9.0
Club	7.5
Community	6.7

D Lightning:

It is essential to consider lighting early in the design stage so that the lighting layout, lamp type and background colours can be co-ordinated with other aspects of the design. (ref. Sport England's forthcoming Design Guidance Note 'Artificial Sports Lighting'). The lighting design in a badminton hall must take into consideration the requirements for provision of:

• Effective illumination of the shuttlecock and court markings to aid players and to assist match officials in the execution of their duties

• Suitable and sufficient lighting for spectators.

The shuttle may also be hit very high and over some distance, which demands a degree of up lighting to pick up the shuttle in flight. Preferred lighting conditions are obtained when the luminaires are suspended from the ceiling, however, luminaires must not be directly positioned over the court. The game involves the players looking upwards to follow the flight of the shuttle and they must be able to do so without being troubled by glare or having their attention distracted by bright light sources.

E Heating and ventilation

Most sports hall heating and ventilation systems will be designed to deliver a temperature range of 20-25^{o}C. The most comfortable temperature for playing Badminton is around 22-24^{o}C. It is recommended as Per ASHRAE handbook of 2004 that no less than 1.5 air changes per hour be made. Any heating or ventilating system that moves the air can deflect the shuttlecock.

Therefore it is important that heating and ventilation systems are designed taking this into account. The location and protection of all air input and extraction grilles or openings must be carefully considered, particularly in relation to the flight path of the shuttlecock. It is better if ventilation systems are designed to operate around the perimeter of the hall, to limit air movement over the court. The air velocities within the playing area should not exceed 0.1 m/s (meters per second). An minimum of 1.5 air changes per hour is recommended by ASHRAE handbook of 2004.

Badminton court situated in sama sports complex situated in Vadodara is taken for case study for this project work. The objective is to estimate the flow rates required in given sports complex by using CFD technique. Designing Ventilation system for flow rates such that to maintain velocity for given flow conditions below 0.1 m/s in playing domain so as to avoid air deflecting the shuttle and also achieving thermal comfort simultaneously are the main agendas for this project.

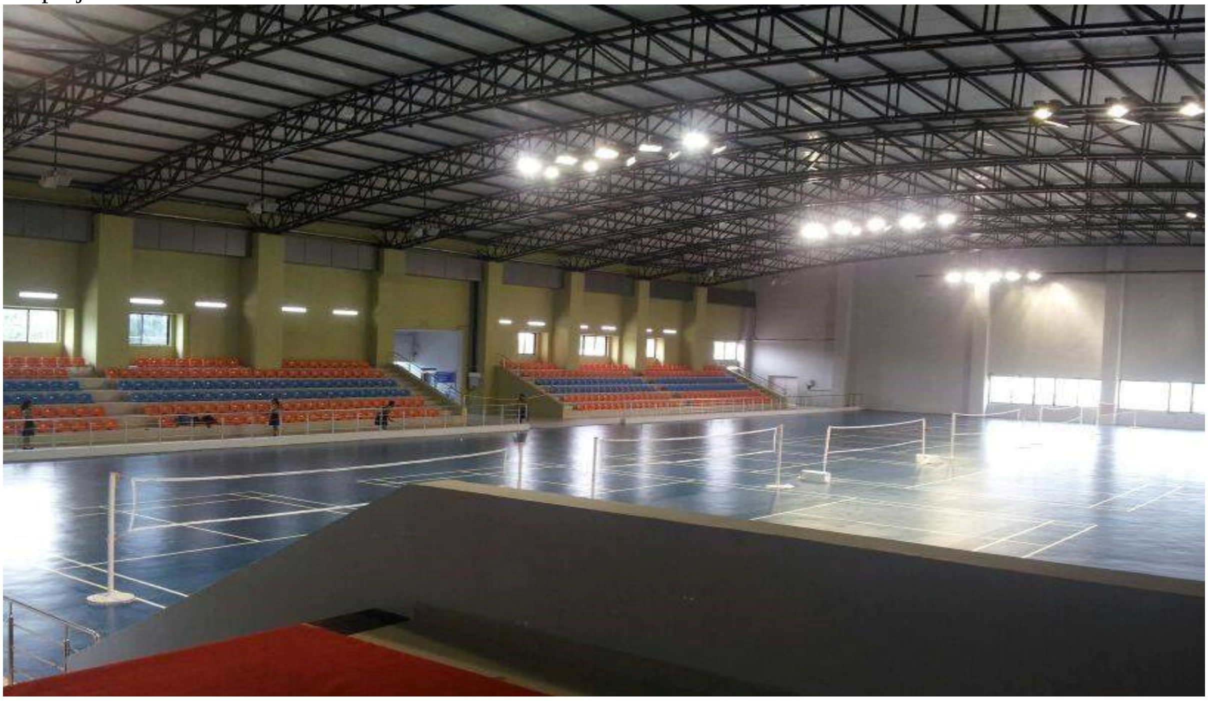

Fig 1.2 Showing badminton court of sama sports complex with 6 courts

"II.CFD"

Computational Fluid Dynamics (CFD) is the use of computer-based simulation to analyze systems involving fluid flow, heat transfer and associated phenomena such as chemical reaction. A numerical model is first constructed using a set of mathematical equations that describe the flow. These equations are then solved using a computer program in order to obtain the flow variables throughout the flow domain. Since the advent of the digital computer, CFD has received extensive attention and has been widely used to study various aspects of fluid dynamics. The development and application of CFD have undergone considerable growth, and as a result it has become a powerful tool in the design and analysis of engineering and other processes. In the early 1980s, computers became sufficiently powerful for general-purpose CFD software to become available. CFD deals with 4 basic steps modeling, meshing, solver and post processing.

"III.MODELING AND MESHING"

As discussed in CFD, which deals with 4 basic steps modeling, meshing, solver and post processing. This present section deals with modeling & meshing of the domain which includes ducts and extract grills.
The detailed plan view of auto-cad model is as shown in the figure below.

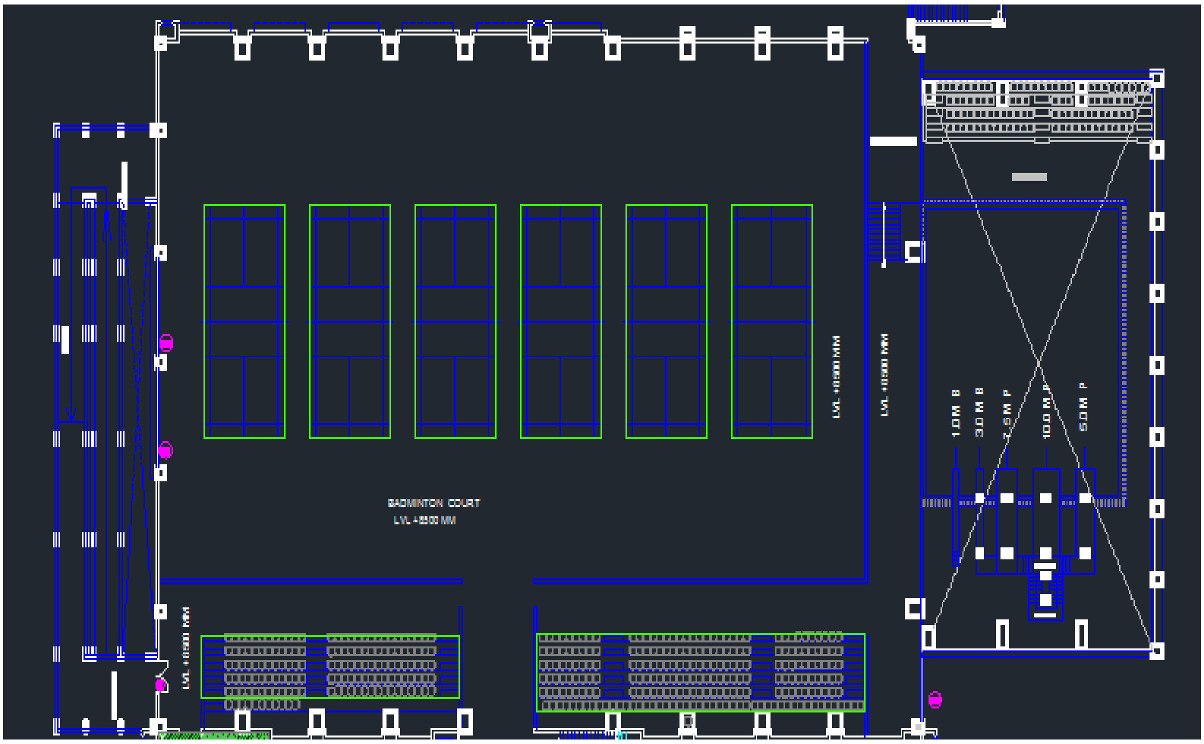

Figure 3.1 Sama badminton court plan view.

The badminton court consists of 6 ducts at the top with each duct having 16 grills or duct openings from which cooled , conditioned air is supplied. It also has 32 extract grills located around the perimeter at 1m height from the ground level as this the best location as observed from literature review earlier. The flow rates of supply and return ducts are decided by required number of Air changes desired in the domain. the minimum air changes required for indoor sports facility as per ASHRAE standards are 1.5.

A AIR CHANGES PER HOUR:

The volume of fresh air (make up air) required for proper ventilation is determined of the size and use of the space.

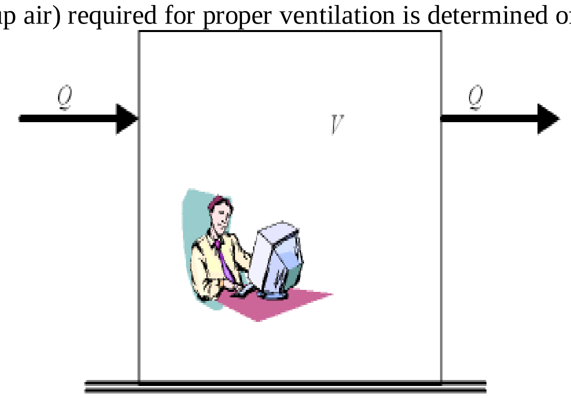

Figure 3.2 Air changes per hour.

The fresh air supply to a room can be calculated as

q = n V

where

q = fresh air supply (ft3/h, m3/h)

n = air change rate (h-1)

V = volume of room (ft3, m3)

Note that in many cases local regulations and codes will govern the ventilation requirements.

Initially 3 ACH were tried on trial and error basis. The idea is to check whether it is feasible to use this flow rate or not. The supply air temperature was maintained at 20^{o}c. the desired results would be air velocities below 0.1 m/s in playing domain with simultaneous thermal comfort.

2d Model was exported from Auto-cad and later extruded to 7.5m as per Elevation view from AutoCAD drawing and converted to 3d model. Then duct was modeled in Gambit software, it was also used as meshing tool. As the volume of domain is large mesh size was also large. Mesh size was 30,98,546 elements. The dimensions of model , supply duct openings and return grill opening are as shown in table-2

Table 2 dimensions of model

Sr. no	TYPE	MAGNITUDE
1	Length	58.7m
2	Width	40.25m
3	Height	7.5m
4	Volume	17590 m^3
5	Supply Duct opening	0.8mx0.8m
6	Return Duct opening	1mx0.2m

Models 2d and 3d views are shown in figures 3.3 & 3.4 respectively. Mesh is shown in figure 3.5

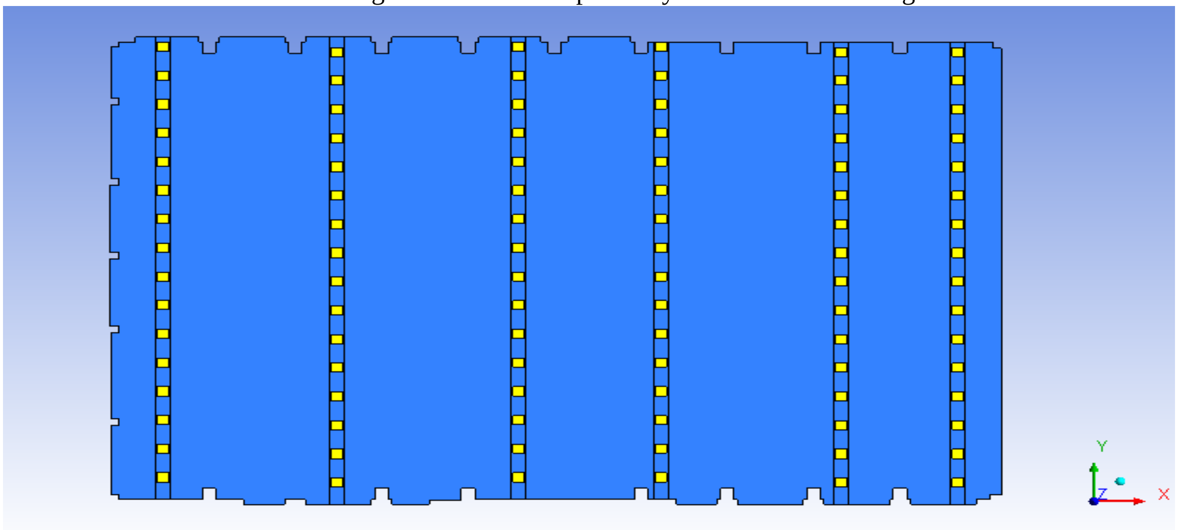

Figure 3.3: 2d top view of the sama badminton court

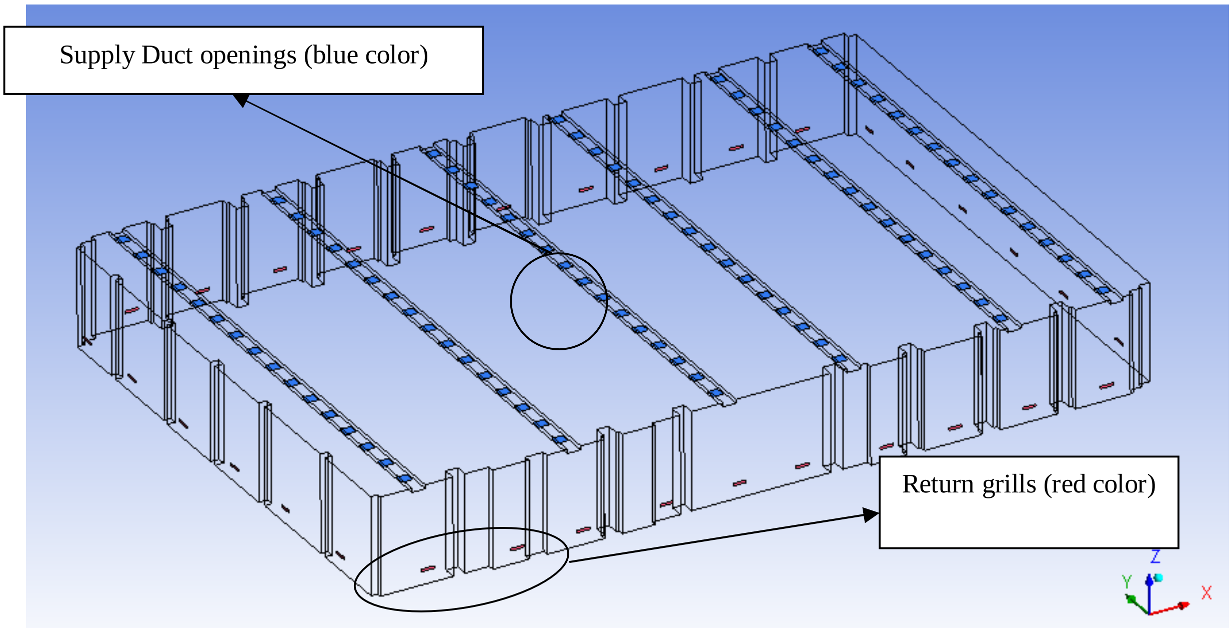

Figure 3.4: 3d view of the sama badminton court

There are total 96 supply openings from 6 ducts i.e. 16 openings in each duct. Return grills are total 32 in number. Total flow rates of supply ducts should match return grills flow rates.

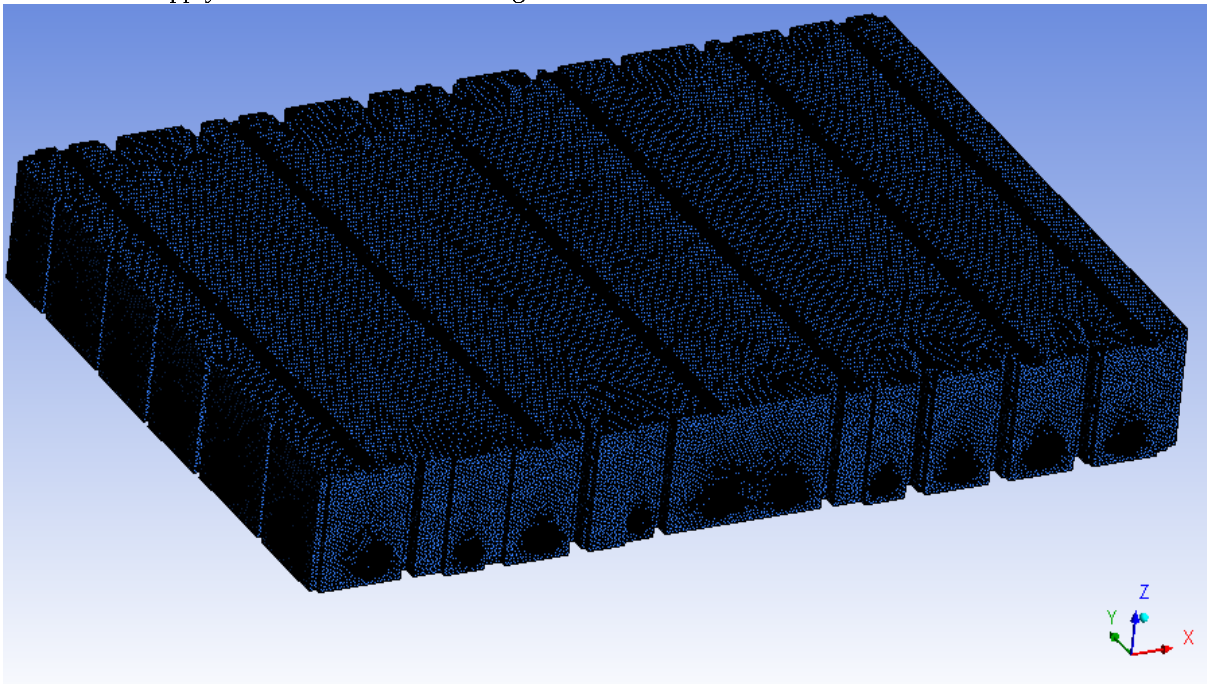

Figure 3.5: Mesh view for the sama badminton court

"IV. RESULT AND ANALYSIS"

Now set up boundary conditions and then use it in solver as input. The solver used for this Project is Fluent.

The boundary conditions include giving velocity input from the duct openings and temperature of supply cold air. Return openings are kept at normal room temperature and negative velocity inlet as the boundary condition.

After setting up these boundary conditions for turbulence in domain k-€ method was used. Solver was initialized and results were calculated for residuals of e-04 were considered for continuity, momentum and energy equations. After achieving this residuals simulation is said to be reach a steady state, even higher residuals of order e-05, e-06 can be considered but it will cost higher computational time and it has been observed residuals of order e-04 are giving satisfactory results.

For initial case we have considered 3 Air changes per hour (ACH). Total volume of domain is 17,597 m^3, total supply flow rate has been estimated according to this assumption of 3 ACH.

ACH= (Total Flow rate in M3/H) ÷ (Total Volume in M3).

So for 3 ACH Flow rate is been found to be 52800 Cubic metres per hour (CMH). So velocities of each supply and return grill openings can be found by dividing with their corresponding areas. For supply velocity it is 96 openings and for return fans it is 32 openings. Temperatures of supply air kept cold but return air is taken from room temperature which doesn't need any cooling mechanism. For ease of calculation heat generated from spectators, players and lightning system is been neglected which would rise the temperature of whole domain by 2-3oc depending upon the time of exposure.

According to ASHRAE thermal comfort is defined as state of mind which expresses satisfaction with the surroundings. In India a temperature range of 22-25oc is found to be satisfactory condition. The Agenda remains to achieve such low temperatures without having higher velocities in playing domain which in turn will deflect the shuttle in the badminton court.The boundary conditions and their magnitudes are as shown in table-3.

Table 3 Boundary Condition and magnitude

Sr.no	Boundary condition	Magnitude
1	Supply Air velocity from duct	0.239m/s
2	Supply Air temperature	20^{o}c
3	Return Air velocity from Extract grills	-2.292m/s

To analyse the flow patterns of velocities, their magnitudes and temperature levels in the domain at different locations few planes along z-axis (height), few planes along x & y axis were also considered. Total of 4 planes in z axis at a height of 1m, 1.5m, 3m, 4m were considered from floor level as zero reference. Two planes were considered in x- direction at

20m and 45m along the length axis which is approximately 58.7m long. Two planes were considered in y- direction at 12m and 30m along the width axis which is approximately 40.25m long. Total Height of domain is 7.5m.The planes considered are as shown in figure 5.1.

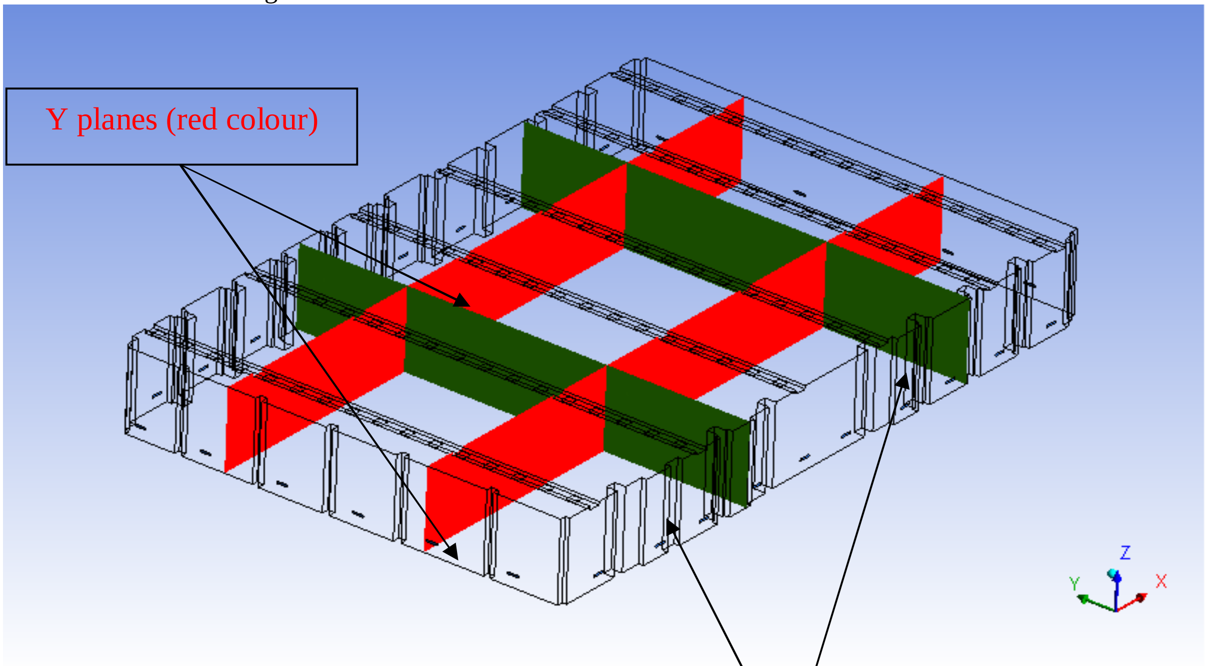

Figure5.1: 3d view of the x-y planes considered for analysis in the badminton court

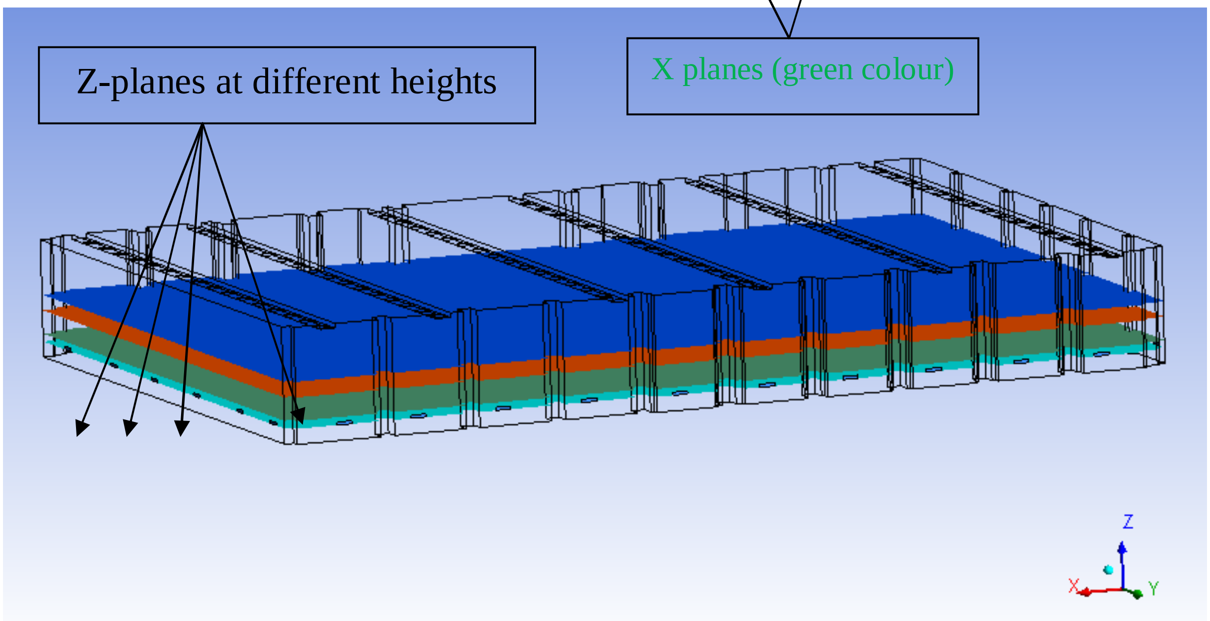

Figure5.2: 3d view of the Z- planes considered for analysis in the badminton court

For thermal comfort temperature levels of around 22°c-24°c is found to be acceptable and velocities ranging below 0.1 m/s are required to be achieved along with the temperatures. Z-planes up to a level of 4m in which players shuttle generally moves for most part of the game and beyond that height velocities level and air flow patterns are not of much significance. After setting up boundary conditions simulation was initialized in fluent assuming temperature of whole domain to be at 27°c initially for case-1 implying normal conditions & 37°c initially for case-2 implying summer conditions.

RESULTS OBTAINED for case-1:

Results obtained after the iteration are shown in figures as follow.

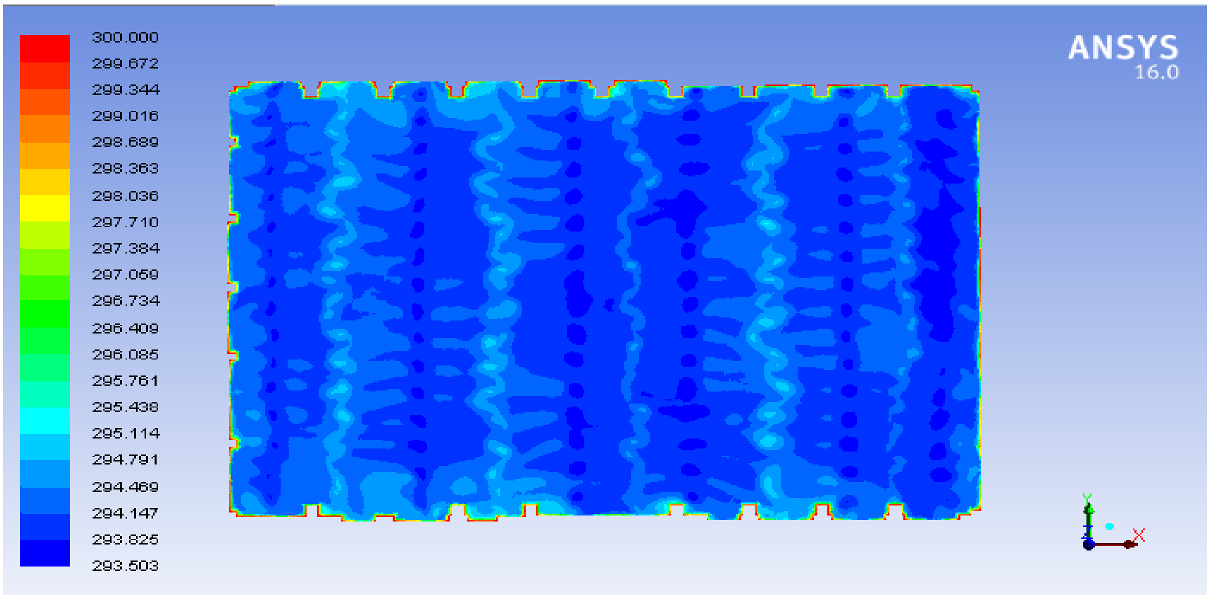

Figure5.3: Temperature contours at z-1m from the ground level.

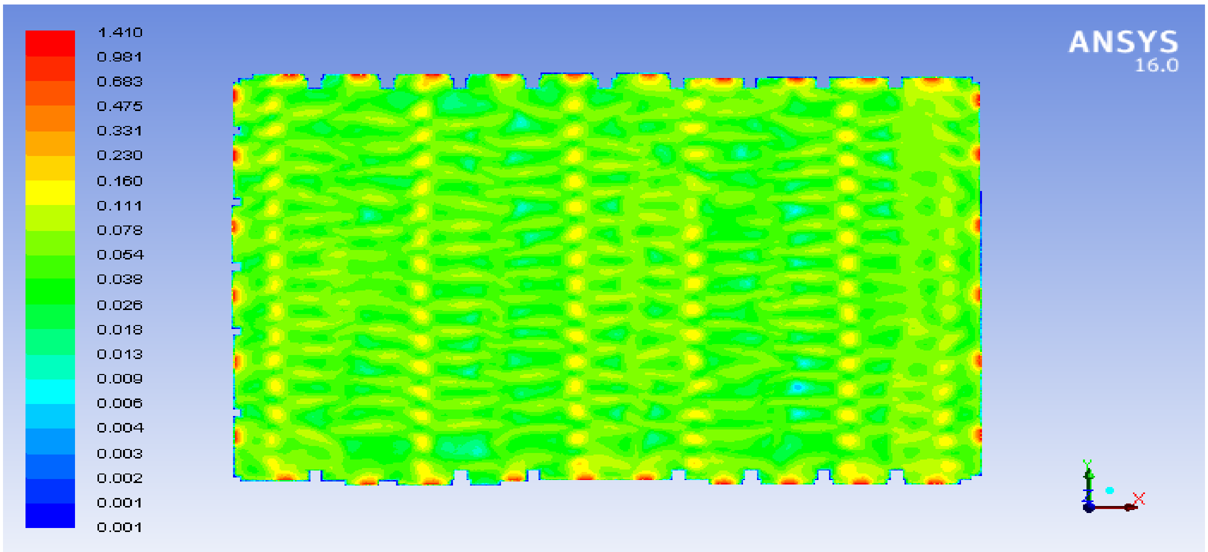

Figure5.4: velocity contours at z-1m from the ground level.

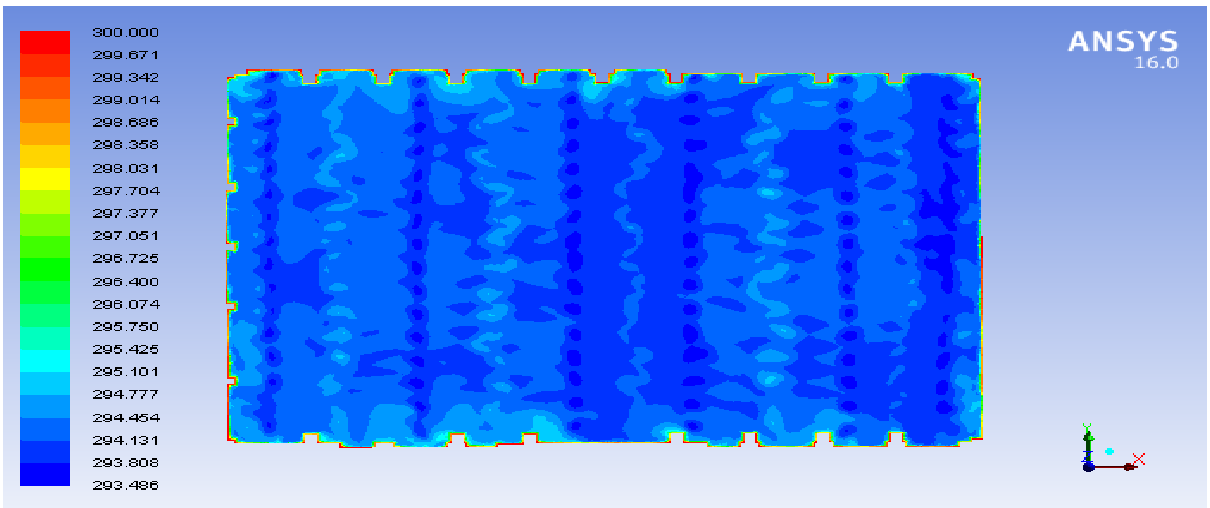

Figure5.5: Temperature contours at z-1.5m from the ground level.

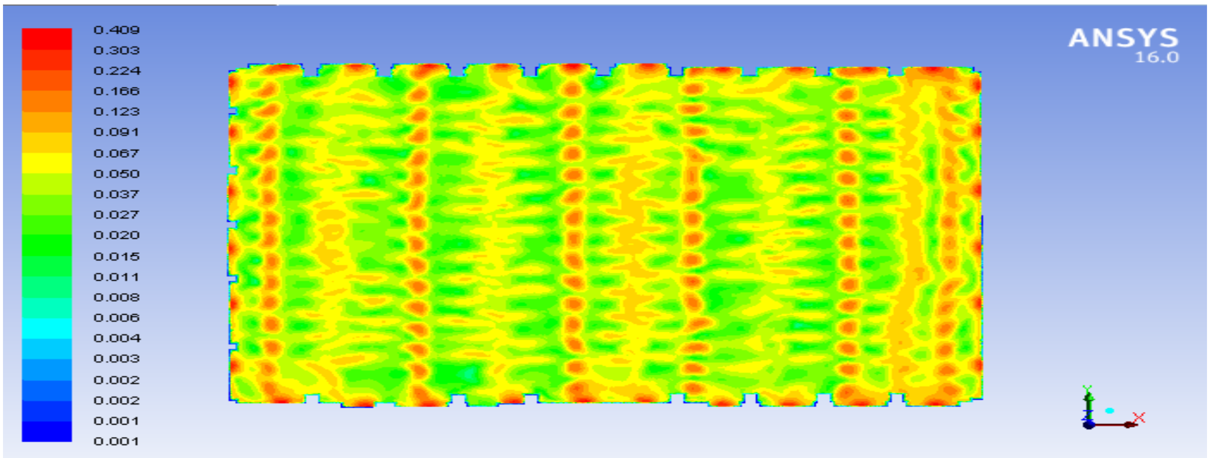

Figure5.6: velocity contours at z-1.5m from the ground level.

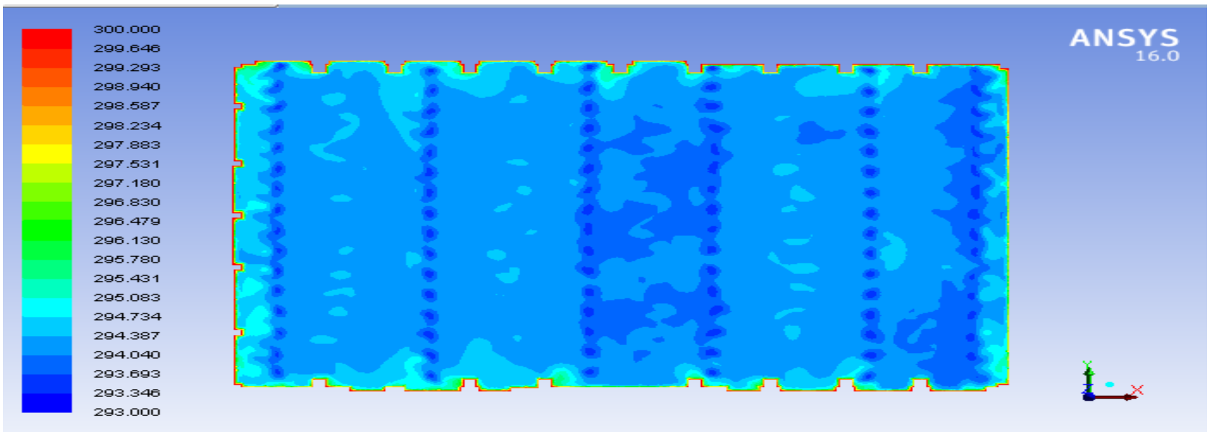

Figure5.7: Temperature contours at z-3m from the ground level.

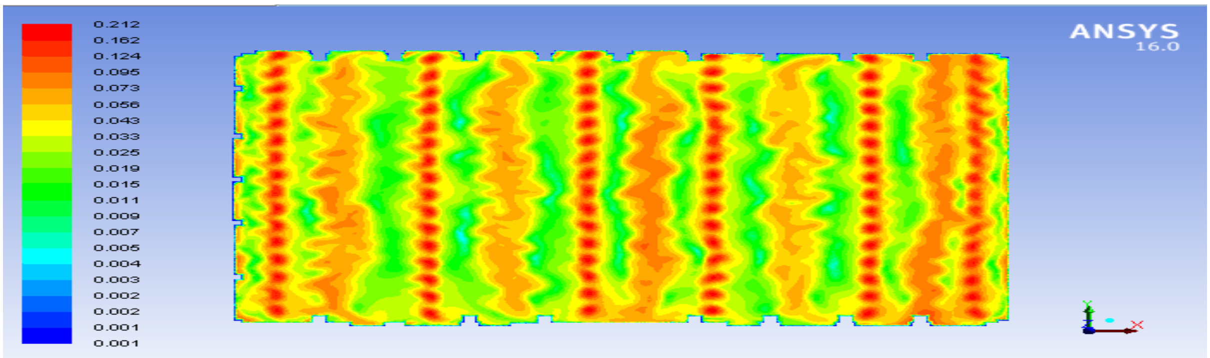

Figure5.8: velocity contours at z-3m from the ground level.

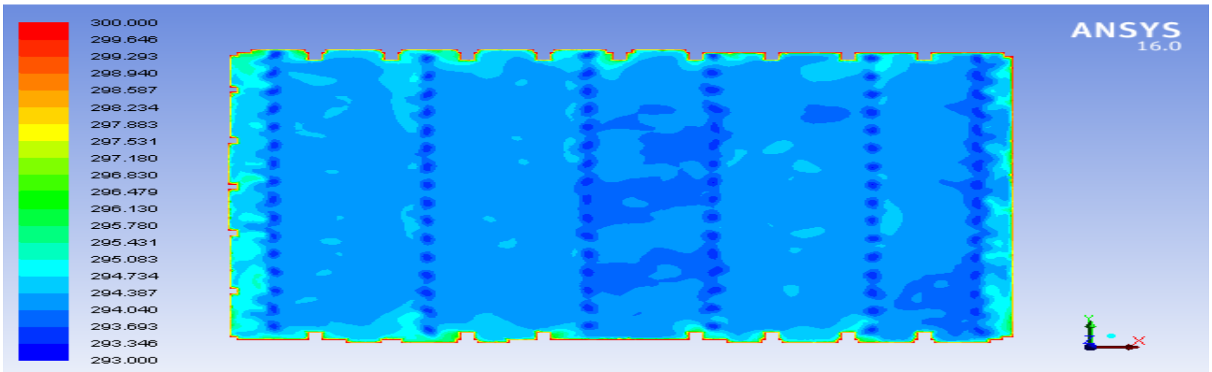

Figure5.9: Temperature contours at z-4m from the ground level.

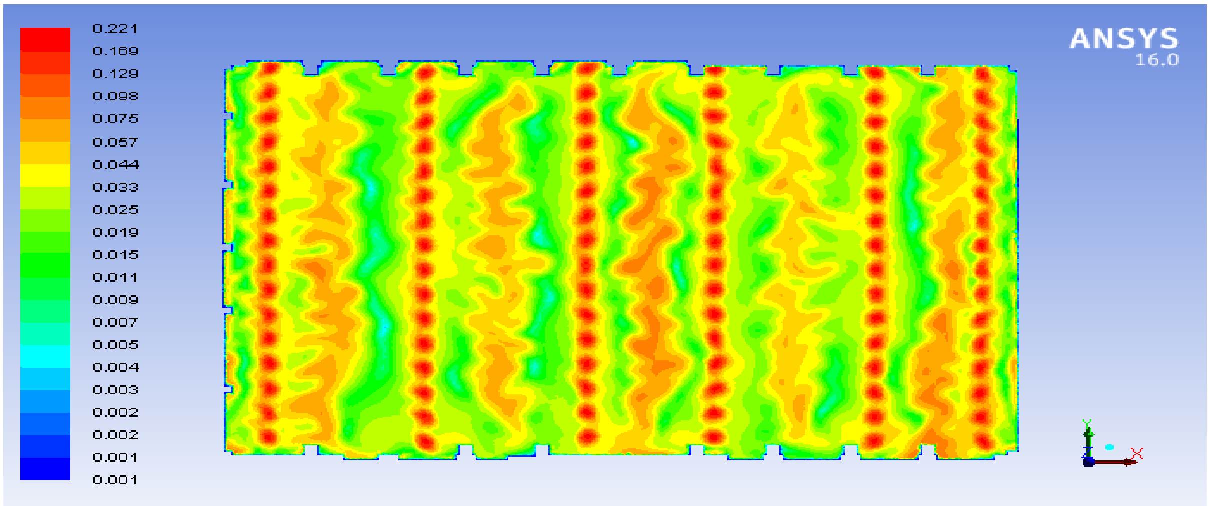

Figure5.8: velocity contours at z-4m from the ground level.

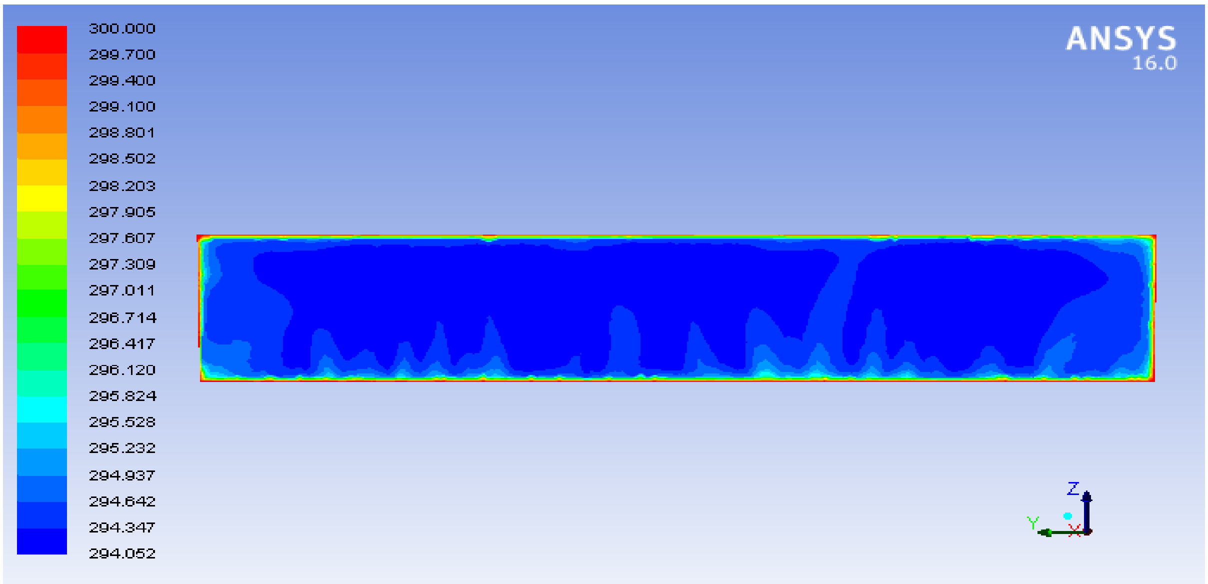

Figure5.9: Temperature contours at x-20m along length axis.

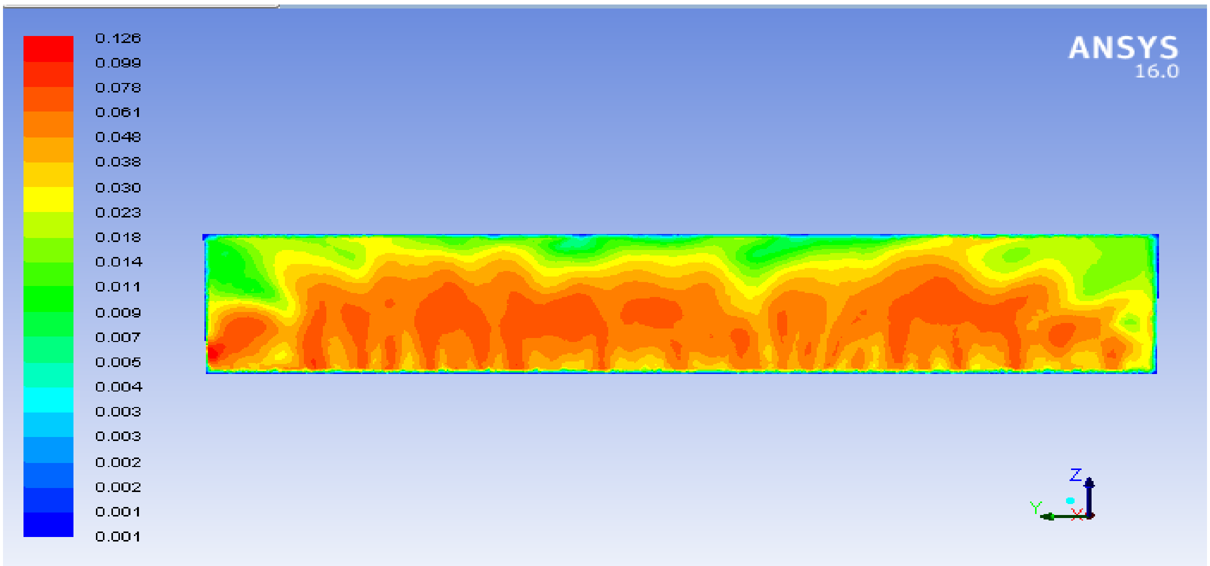

Figure5.10: Velocity contours at x-20m along length axis.

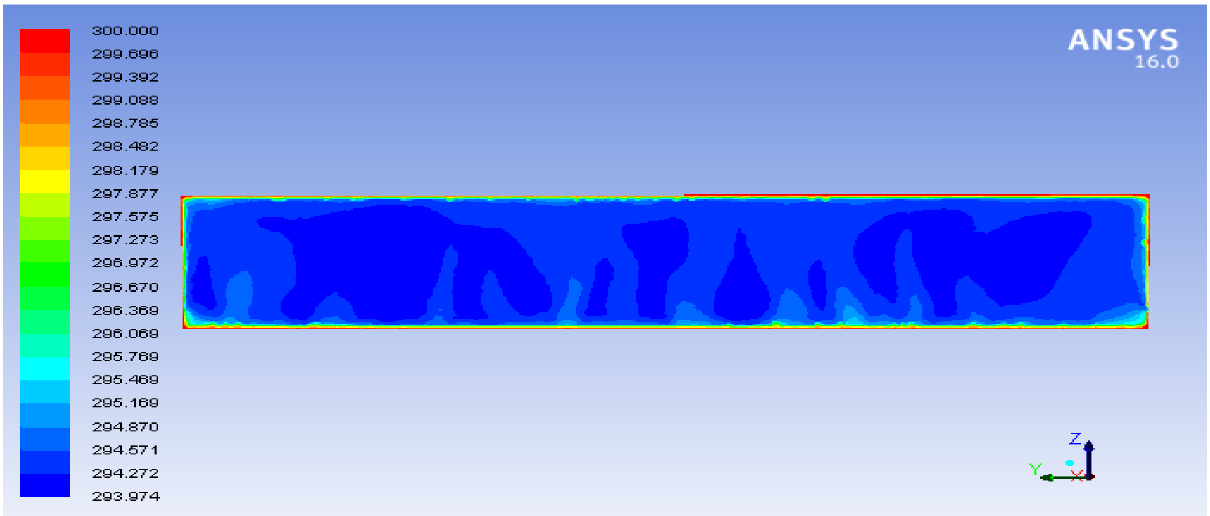

Figure5.11: Temperature contours at x-45m along length axis.

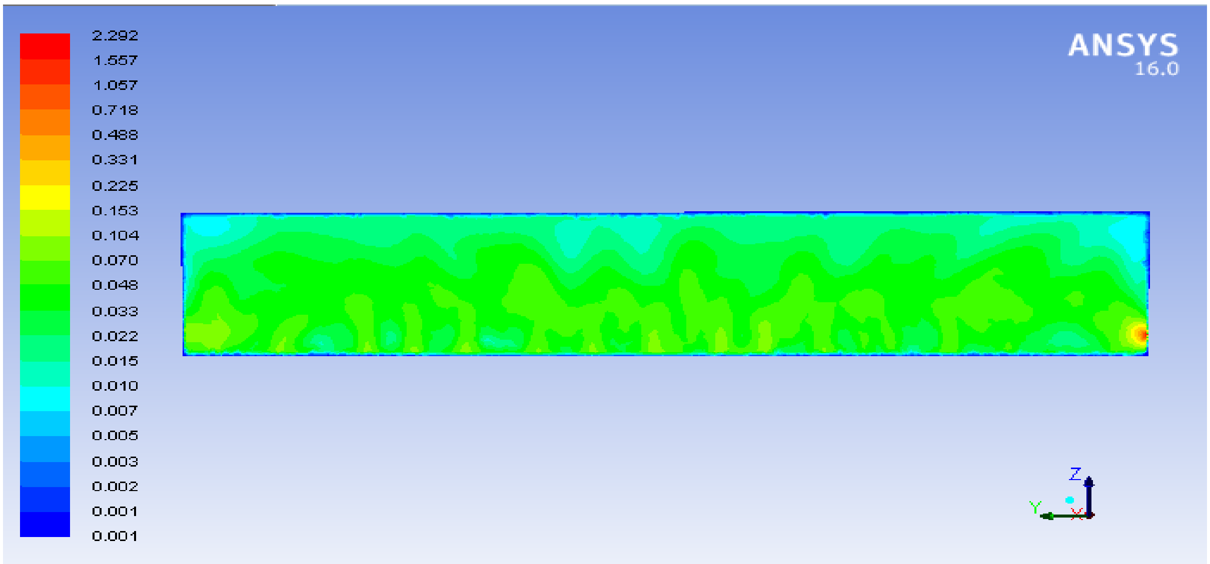

Figure5.12: Velocity contours at x-45m along length axis.

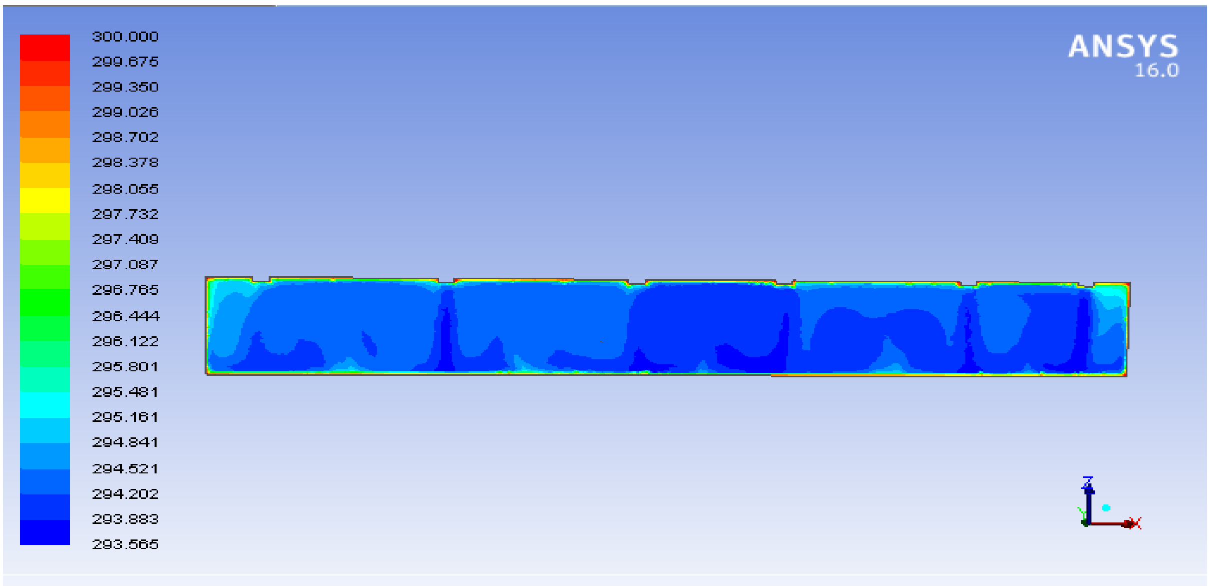

Figure5.13: Temperature contours at Y-12m along width axis.

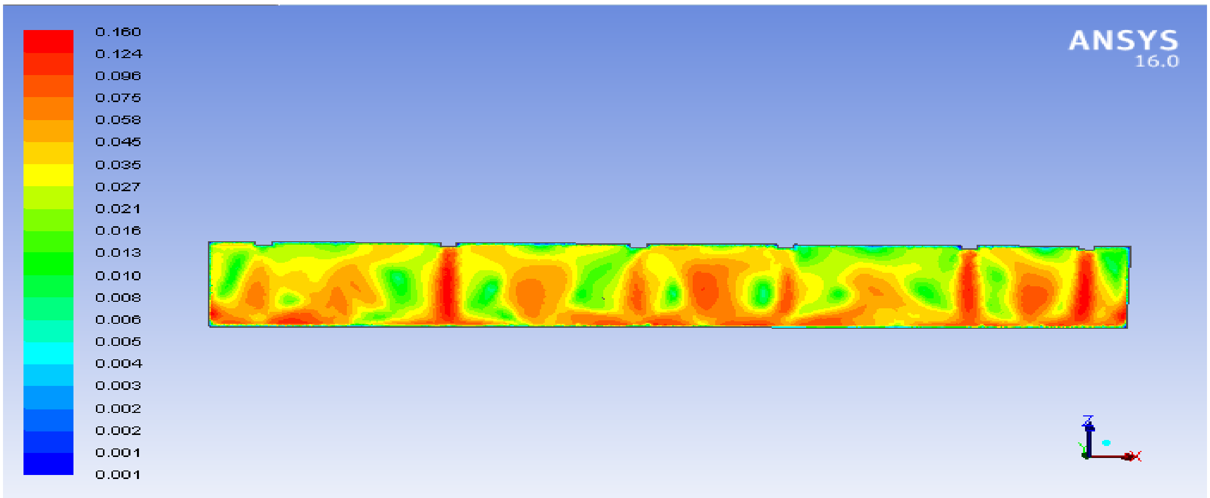

Figure5.14: Velocity contours at Y-12m along width axis.

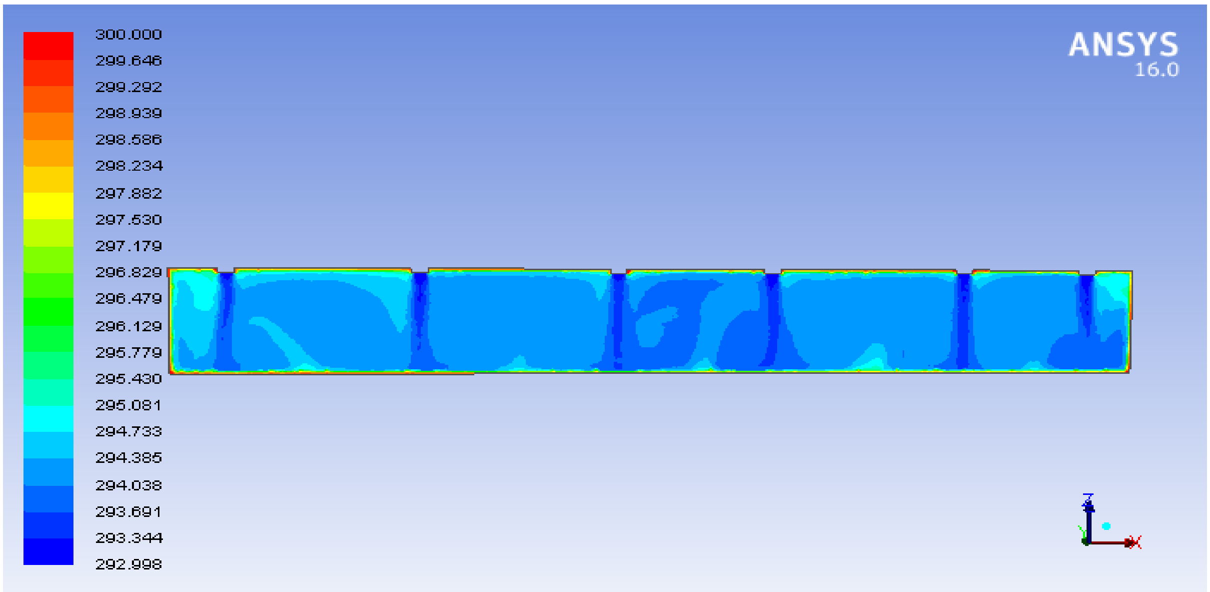

Figure5.15: Temperature contours at Y-30m along width axis.

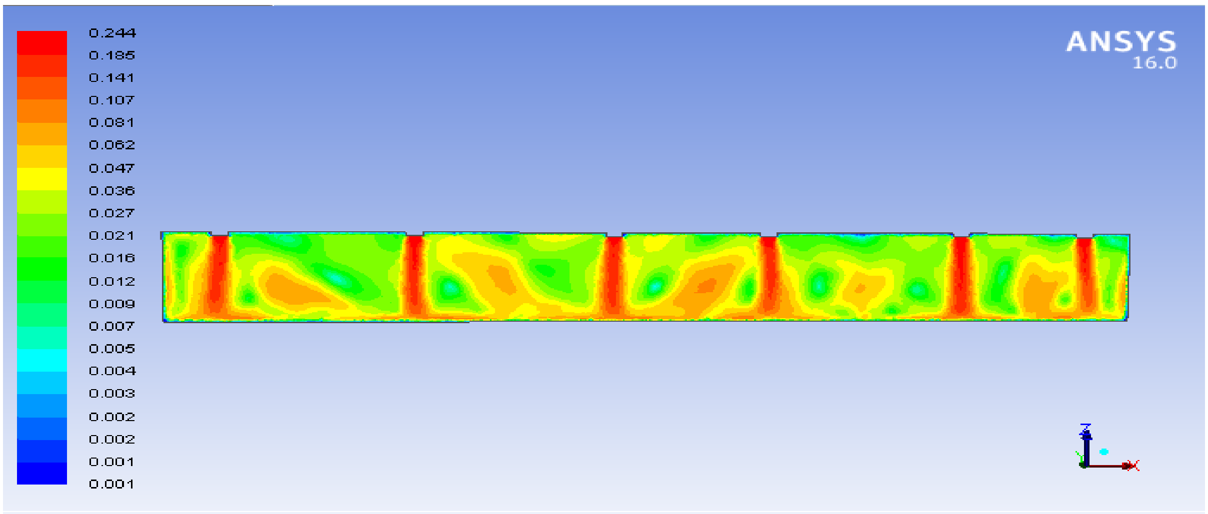

Figure5.16: Velocity contours at Y-30m along width axis.

RESULTS OBTAINED for case-2

Results obtained with 37^{o}c as initial temperature after the iteration are shown in figures ahead.

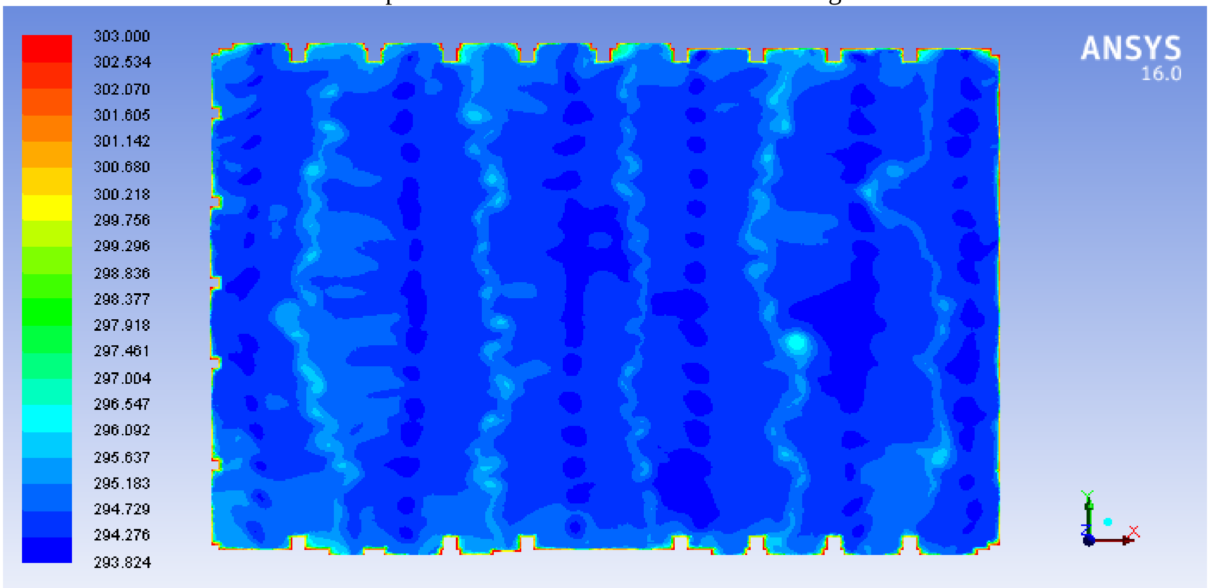

Figure5.17: Temperature contours at z-1m from the ground level.

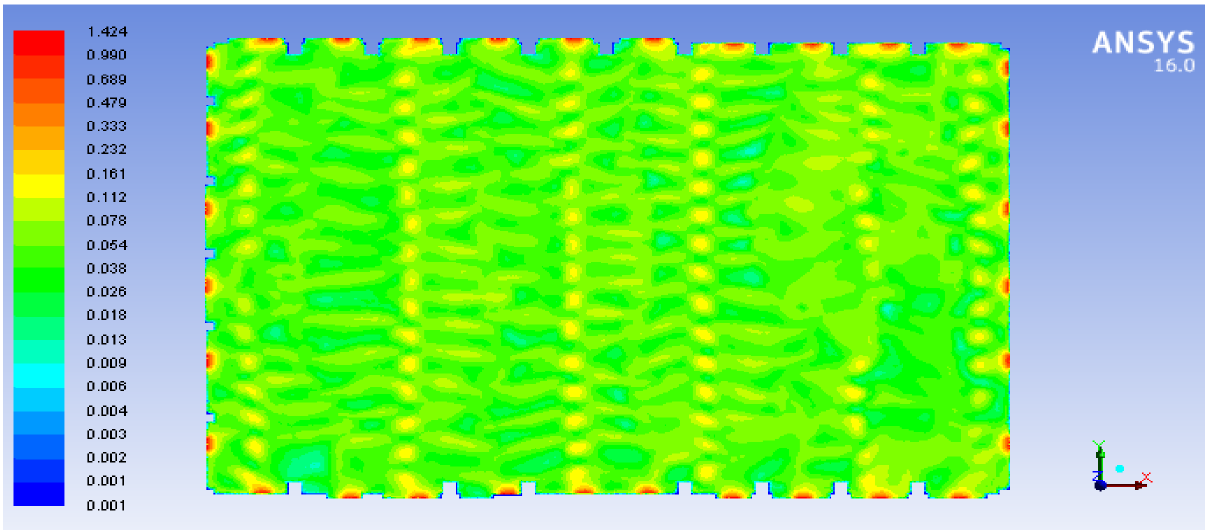

Figure5.18: velocity contours at z-1m from the ground level.

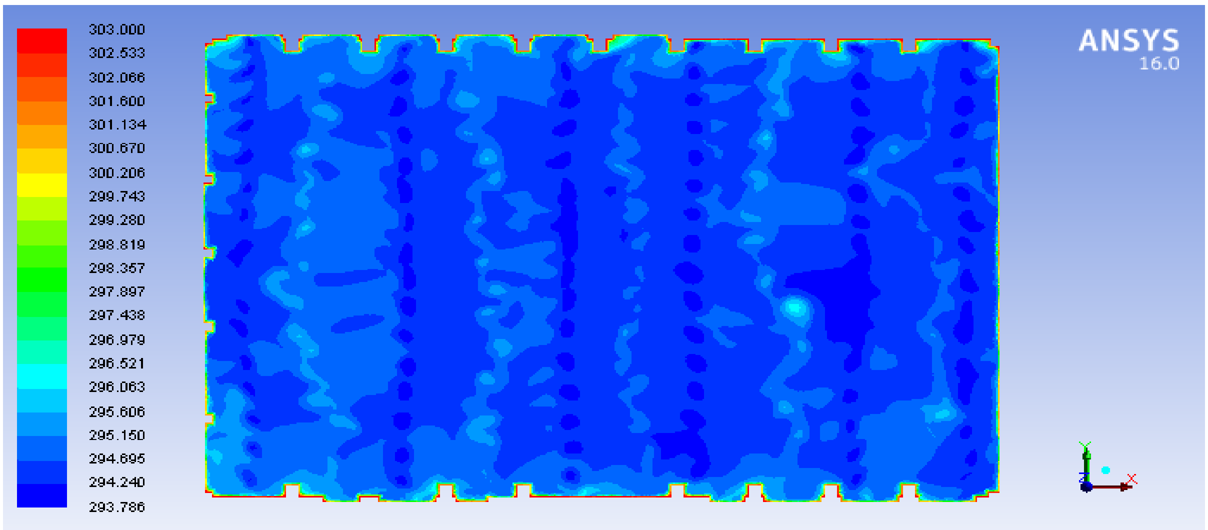

Figure5.19: Temperature contours at z-1.5m from the ground level.

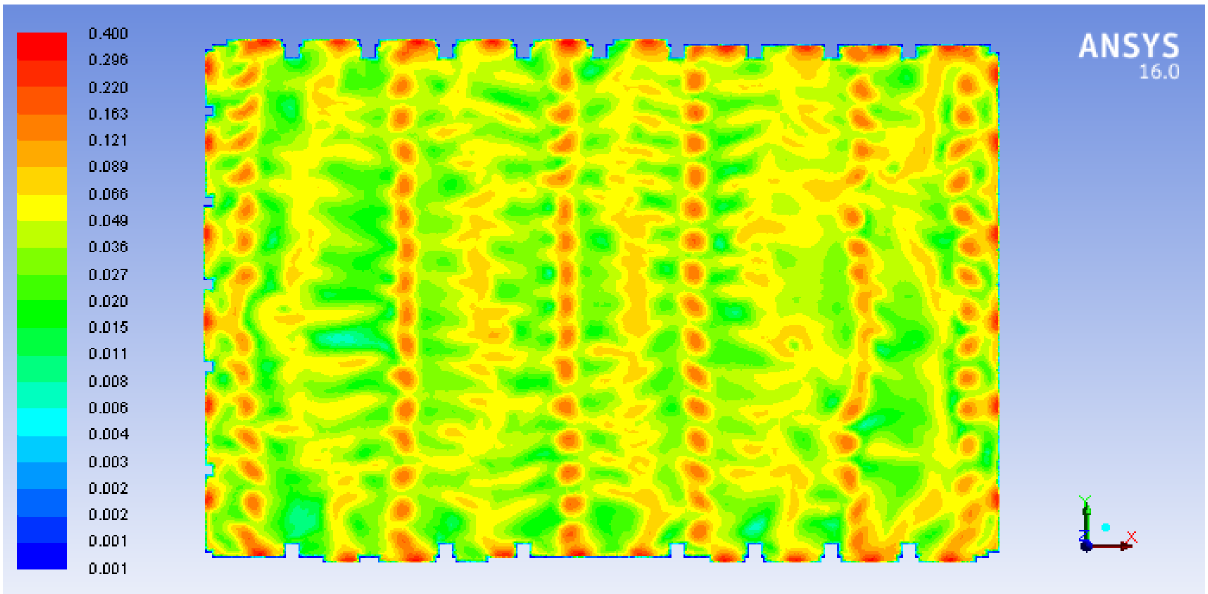

Figure5.20: velocity contours at z-1.5m from the ground level.

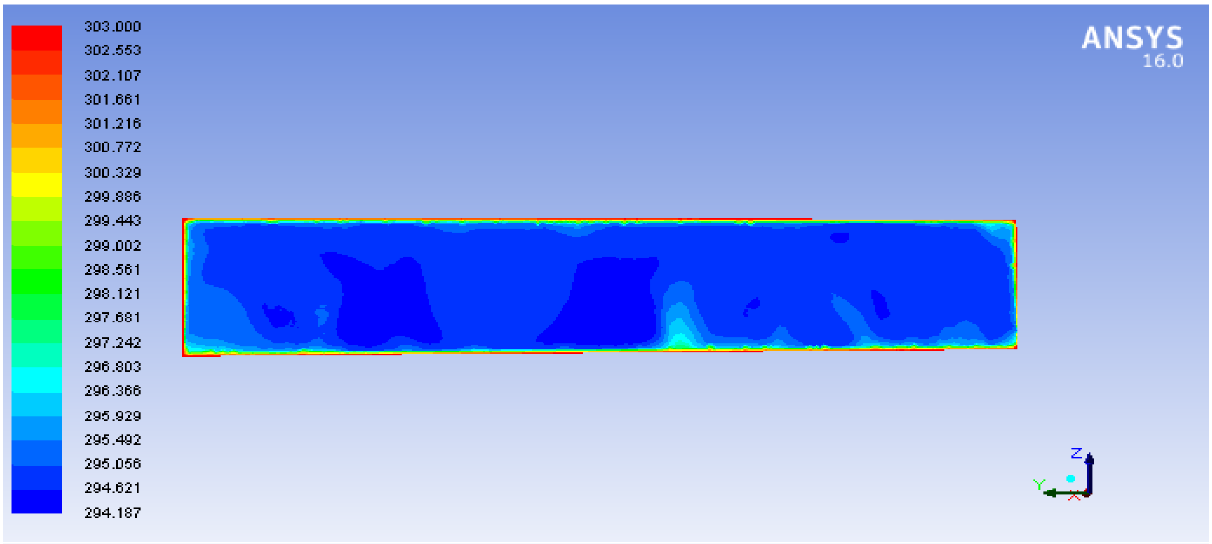

Figure5.21: Temperature contours at x-45m along length axis.

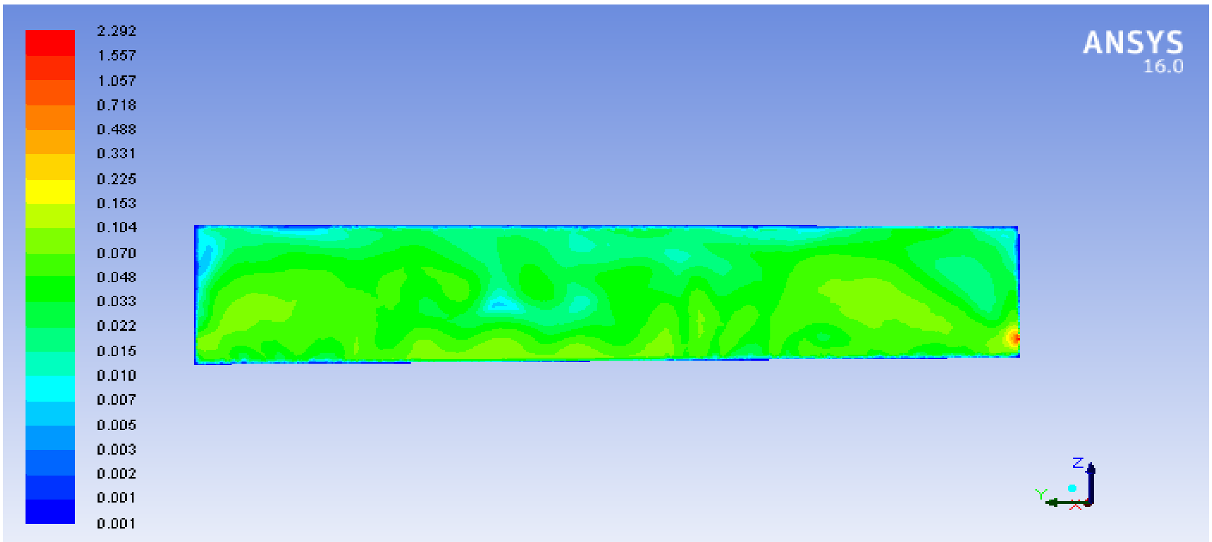

Figure5.22: Velocity contours at x-45m along length axis.

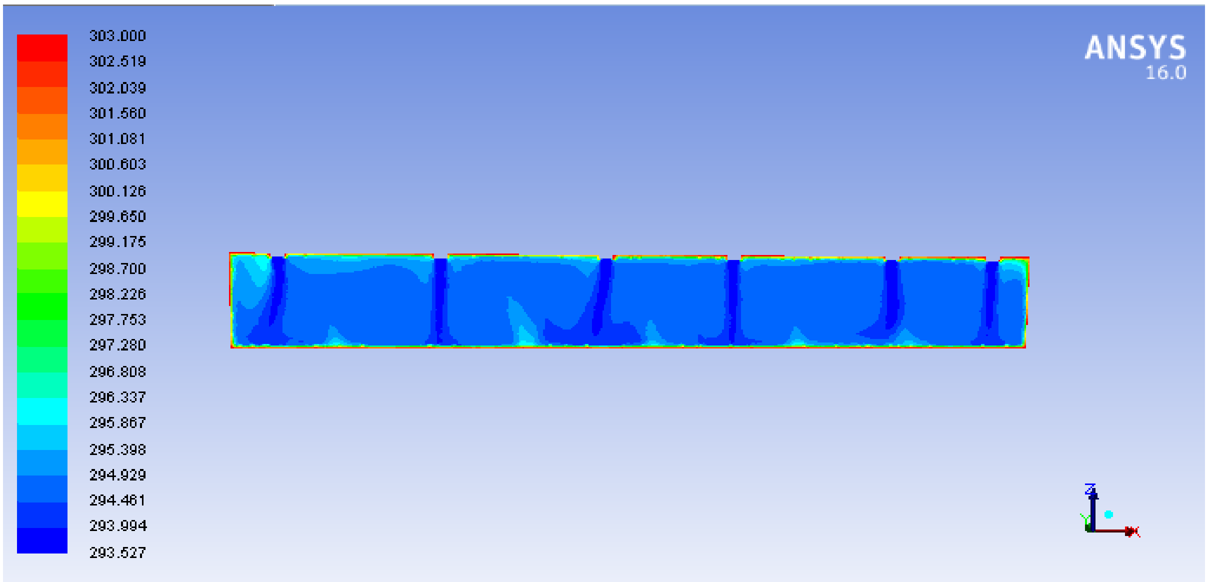

Figure5.23: Temperature contours at Y-30m along width axis.

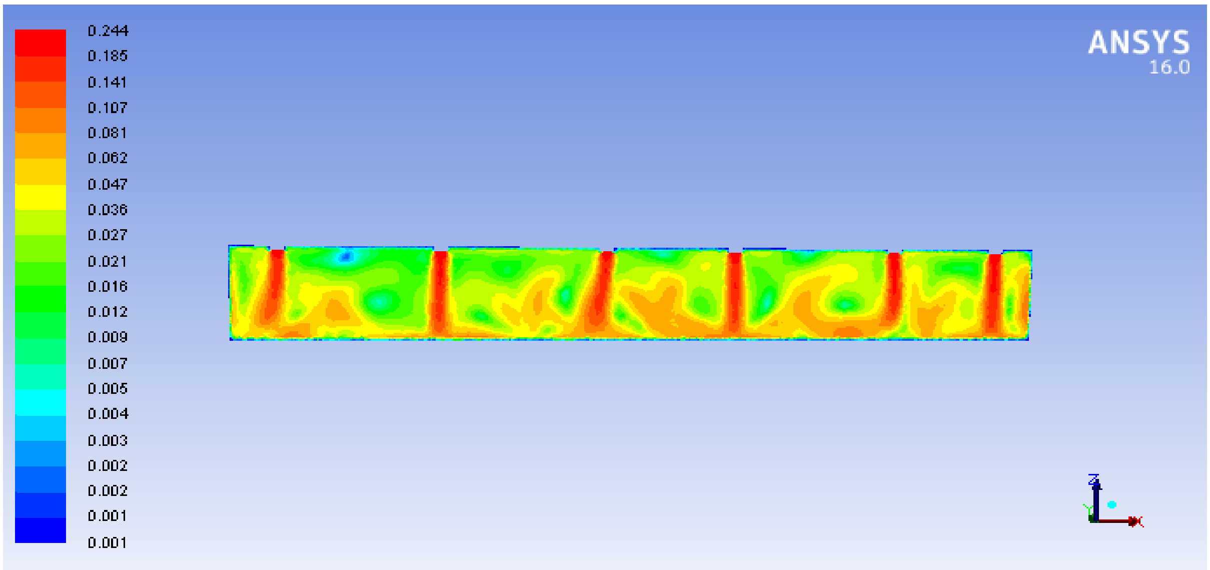

Figure5.24: Velocity contours at Y-30m along width axis.

"VCONCLUSIONS"

1. The average temperature levels at z-1m are 23°c for case-1 i.e. normal condition and 24°c for summer conditions which is well within the acceptable limits; the maximum velocities in playing domain are in a range of 0.15-0.16 m/s which is above acceptable limits for playing condition.

Note: Radiation heat transfer from walls and heat generation from human beings have been neglected which will increase the temperature by1.2°c more which is still acceptable comfort range for a maximum temperature of 26-27°c in summer being maintained inside.

2. The average temperature levels at z-1.5m are 22.7°c for case1 & 23.5 for case2, which is well within the acceptable limits; the maximum velocities in playing domain are in a range of 0.16-0.18 m/s which is above acceptable limits for playing condition.

Note: As it has been observed velocity pattern similar in both cases other results for case-2 have not been shown explicitly. temperature range is 1-1.5°c higher in case-2.

3. The average temperature levels at z-3m are 22.3°c which is well within the acceptable limits; the maximum velocities in playing domain are in a range of 0.17-0.20 m/s which is above acceptable limits for playing condition.
4. The average temperature levels at z-4m are 21.9°c which is well within the acceptable limits; the maximum velocities in playing domain are in a range of 0.19-0.22 m/s which is above acceptable limits for playing condition.

5. From results of x-y planes it has been observed velocities are higher directly above the supply openings when compared to other regions. Although high velocities of above 2m/s are found these are near wall velocities due to return grills which doesn't affect playing domain.
6. Finally it can be concluded that overall average temperature levels gives satisfactory results for thermal comfortbut the velocities above 0.1m/s in many regions are areas of concern for the given domain.
7. Measures have to be taken to decrease these velocities and bring them down to below 0.1m/s so as to avoid any deflection of shuttle.
8. One way to do that is increase number of openings, 2nd way to increase size of opening, 3rd method is to decrease the flow rates.
9. As changing number of ducts, size of ducts is not possible in this scenario decreasing the flow rates will be taken as preventive measure to bring down velocities.

ASHRAE limits the change of flow rates as 1.5 ACH is minimum number of air changes prescribed for any indoor sports stadium. Decreasing flow rates may also lead to rise in temperature which might cause to stray away from thermal comfort zone.

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