Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2016/01/jls.htm
2016 Vol. 6 (S1), pp. 125-132/Aini
Research Article

NUMERICAL INVESTIGATION OF ROOF TYPE EFFECT ON THE FLOW PATTERN ON THE STREET USING COMPUTATIONAL FLUID DYNAMIC

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ABSTRACT

Skyscrapers swerve strong winds and make them shift toward ground, so this situation makes a dangerous and undesired condition for passengers and they have to consume more energy for walking. In such a situation wind speed increases up to 15 m/s and cause unbalanced conditions for passengers. Also, when wind speed is high, we may observe accumulation of smokes produced by vehicles and other pollutions in passenger's section. We can cause air movement and natural ventilation in urban areas by suitable designing of buildings roof in a site. Also, type of roofs plays an important role in configuring suitable air movement and eventually natural ventilation. Proper arrangement of buildings together causes their suitable usage of wind and consequently natural ventilation. So, when we designing skyscrapers, it is important to consider wind flow and path lines around buildings. In this article, we've dealt with numerical investigation of effect of roof form on flow pattern in the street using computational fluid dynamic. In order to do this, we first did geometrical modeling, meshing and boundary conditions in GAMBIT software and the then model is solved using FLUENT software. Results of solving flow are showed in terms of speed vectors in directions X & Y and path lines.

Keywords: *Natural Ventilation, Type of Roof, Computational Fluid Dynamic*

INTRODUCTION

Energy consumption in buildings of Iran in comparison to European countries is 4 times more. Domestic and commercial sectors are the most important energy consuming sectors in the country. This sector continuously involves the most amount of energy-consumption. Energy consumption at domestic sector was equal to 2.15 million oil barrel at year 1967 which reached to 616 million barrel at year 1978. And, during this period it has had an average growth of annually 11/21%. This growth is limited due to revolution conditions at period of 1978-83 and has had an average annually growth of 10/04%. Energy consumption in residential sector was equal to 231.4 million barred at 1978 which has reached to 426.8 million barrel at 2006 which has had an average annual growth of 6/38%.

Therefore, about 45.8 % of energy is consumed in residential and commercial sectors at year 2006 (Bahadori Nejad and Dehghani, 2008).

As stated before, building sector is considered to be the most energy –consumer sector in the country. Considering building technologies in order to saving and optimizing energy– consumption as an effective role in this way. It's worth mentioning that high consumption of energy doesn't mean more comfort in the building.

Existing dissatisfactions relating to lack of comfort, relate to mechanical cooling and heating equipments. In building with air – conditioning plant involves more energy – consumption and more dissatisfaction than buildings without such plant.

So, in most cases we use buildings which despite several times amount of energy. Don't provide more comfort. Therefore, this question arises that what are effective factors in efficiency and optimization of energy consumption? Main factor are categorized in to 3 groups:

a) Designing – architecture of the building
b) Design of mechanical and electrical plant
c) Resident's behavior.

Conducted studies by Baker (1996) show that above – mentioned factors increase normal energy – consumption up to 10 times more. Design architecture of the building can increase energy – consumption 2/5times more than normal consumption. And if we add electrical and mechanical plants amount of consumption in causes two times equal to five times more than normal consumption. Residential share in this regard is residual of 10times, equal to 2.
With attention to role of architect as designer of the building in optimized consumption of energy and decreasing energy-loss, it's necessary to investigate amount of heat-exchange in different parts of the building.

Architecture and Energy Consumption Optimization in Building

We can strongly say that continent and effect of weather conditions on forming building are of limited architectural factors which haw derived human's attention at the beginning of making shelters and with pass of time and change of styles, movements and definitions of art and beauty and evolution of need and views and developing architectural spaces. Foundation of this requirement hasn't changed. Accordingly different step of continental designs are grouped in to 4 steps:
1) Society and transmittance of units.
2) Determination of totalities of the building.
3) Designation of plan and view.
4) Designation operational details of the building.
5th component i.e. totalities of skeletal structure of building means organizing general form and skeleton of a building and investigated factor in this regard are: determining direction of building establishment, form of building (ratio of external surface to useful volume), situation of building establishment proportional to floor, and from and slope of the roof. Among above factors, the way of establishment and form of the building can decrease energy-loss in two ways. First, direction of sunshine and second direction puff. In addition, Amin Najafi's studies (1987) show that in a conventional house with four sides open, amount of energy – loss in walls is 29%. Roof 26%, floor with open air 20%, openings and air holes11% (Bakhshandeh and Hamrangnejad, 2002). Considering loss of about 26% from roof, form of roofs is very effective in optimization of energy consumption especially in winter. Therefore, taking actions in order to enhance quality of the building in terms of thermal exchanges will lead to significant saving in consumption of energy in whole of the building.

Type of the Roof

Roof is a part of building that protect building continuously from atmospheric factors including rain, snow, heat, sunlight etc. form of roof: is different in various places of the word and this difference is because of existing materials and different weather conditions. Some kinds of common forms of roofs are shown in figure 2a. Root has a long history in architecture of the world and residential construct ions from ancient times confirm this fact (Figure 1).

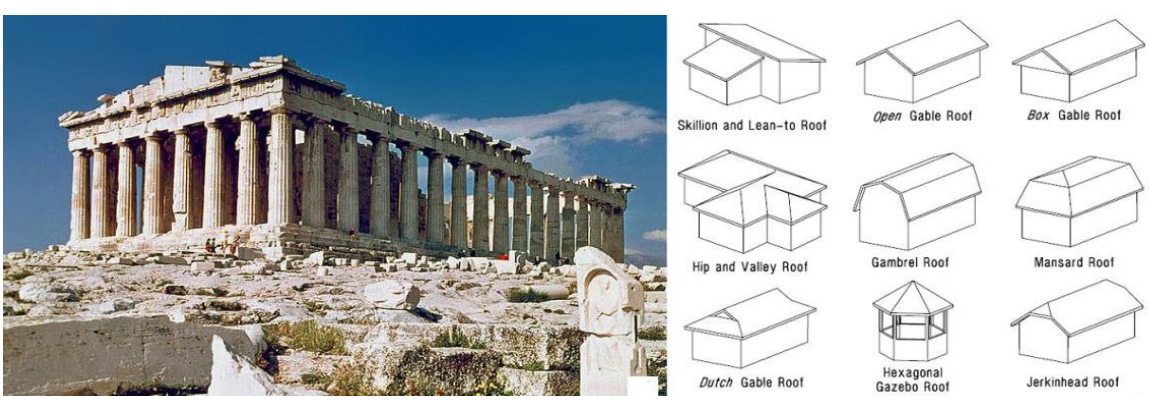

Figure 1: Different Type of Roof

In traditional architecture of Iran roof is also a part of life and it is used as yard in addition to existence of complex and beautiful volumes. In some cities like Nain around of the roofs were climbed with some boxes up to 1.5 m high and kind of yard were made which had been used for sleeping in summers. Furthermore, walls overcastting part of the roof at various times of a day has a secondary continental role. Such spaces were used in mosques too.
There's such a space above roof of the Sepahsalar mosque which is used as place for washing named chehel- shir. Another sample is Abbasian house in kashan which has a yard in the roof in which possibility of ventilation is provided by architects through subtile framings of regular mesh. Another application of roof in Iranian architecture is formation and wind ward on it as ventilator. (Figure 2-A). In fact windward is a sample of Iranian engineering masterwork (Hasan *et al.*, 2007). Another amazing kind of a roof can be observed in historical city Masooleh. In which yard of upper house is roof of bottom house (Figure2-B).

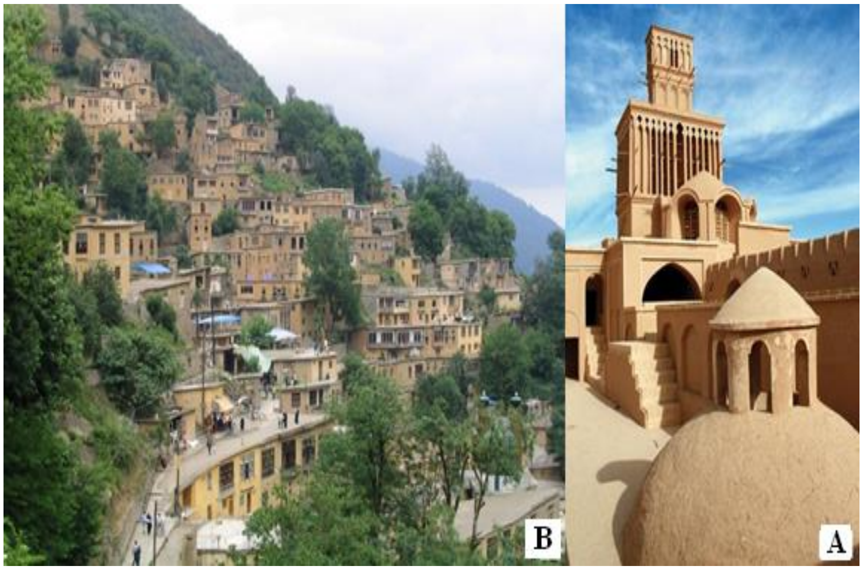

Figure 2: A) Picture of Iranian Wind Catcher B) View of Masuleh

In order to determine form of the roof cold Heat, humidity and rainfall conditions should be investigated separately. In regions that cold weather is considered as a critical factor and snowfall is high. Since snow acts like a suitable thermal insulator and prevents energy loss in the internal space of the building. It's necessary for the roof to be made in such a way that when snowfall, snow remain on it and not to slide down. So, slope of the roof should be gentle in order to cold wind easily passes on it.
In regions that hot weather is a critical factor; domical roof is preferred because it has many good properties. Finally in regions with high humidity and rain- fall hip roofs are preferred in order to direct water flow downward and provide possibility easy passing of rainsquall.

Flow Pattern around the Building

Flow pattern of air is windward around the building as shown in figure 4. Height of two- third of floor is called stay point above from which airflow is upward and passes from roof of the building. Below point air flow goes downward and makes vortexes in front of the building and finally passes from around the building we will observe more separation of flow and reattachments in leeward sides (Figure-3).
When passing from angles of the building including vertical and lateral angles, air flow accelerates. Buildings stand side by side and exterior form of buildings lead to formation of turbulent flaws and complex aerodynamic problems which make analyzing construction difficult (World Energy Council, 2008).

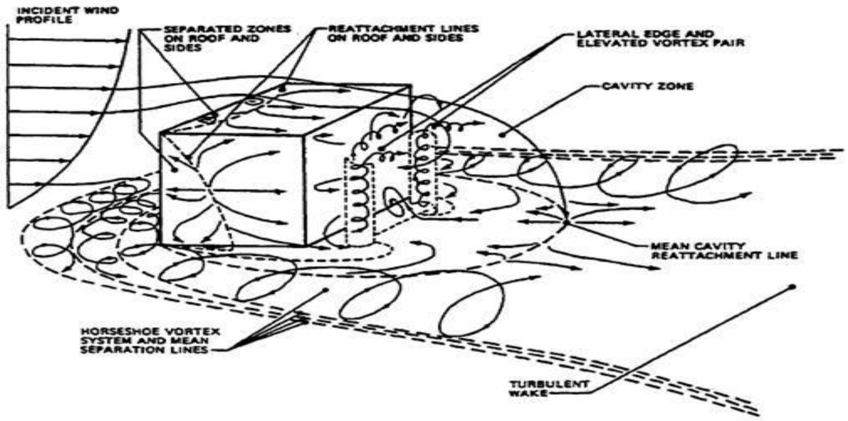

Figure 3: Flow Pattern around Building with Sharp Edge (World Energy Council, 2008)

Effect of Wind in Building

When wind meets construction turbulent flows will be made which is an important phenomenon. These flows even at an ideal mode which construction is symmetrical are not symmetric.

Turbulent flows are made completely random. Analyzing turbulent flows via theoretical relations is very hard (World Energy Council, 2008).

Skyscrapers swerve strong winds and change their direction toward the ground which leads to providing an undesirable and dangerous situation for passers and they have to consume more energy for walking. Increasing wind speed up to 15 m/s leads to unbalanced conditions for passers. Also when wind speed is very high we may observe accumulation smoke of vehicles and other pollutions in passenger, s section (Figure-4). Therefore, when designing skyscrapers, it, necessary to consider wind flow and flow pattern around the building.

Today, in addition to wind tunnel which is commonly used for simulation of construction, CFD also has become a powerful tool for predicting flow pattern around constructions. considering above – mentioned problems which confirm sensitiveness of sky scraper against wind pressure scholars decided to investigate effects of this natural phenomenon on constructions[5].

Lipmow by publishing a paper for the first time at 1952 pointed to effects of turbulent wind flaws around ground surface. He also gave some models for investigating and showing these effects. These models later were recognized by Velazi and Kuhen at 1961 by completing and amending down port, s method. Fluctuations of pressure on the wind ward surface depend on performance of the lee nard building.

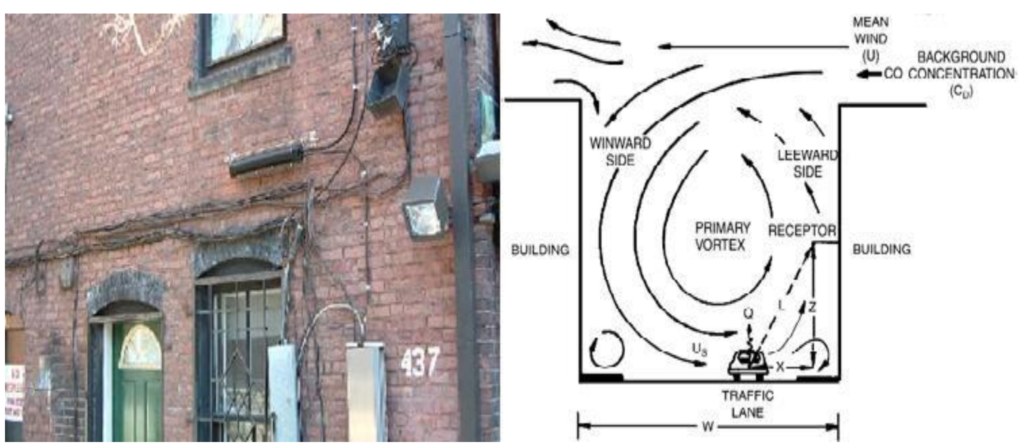

Figure 4: Dispersion of Pollutants around Building

Numerical Modeling

There are three method solving problems related to Fluids dynamics including: empirical methods, analytical methods and numerical methods. During recent decades, Progress of numerical methods has been significant in various sciences. With attention to high expense of empirical methods and weakness of analytical methods in solving engineering problems, today most of researchers tend to use numerical methods. In order to achieve effect of from of the roof on flow pattern in street two different modes are considered, in mode 1 flat roof is windflaw and hip roof lee nard and in mode 2 hip roof is windward and flat roof leeward.

Then geometry of building was mode using existing maps in Gambit software (Figures 5, 6). As we observe in figures 5, 6. We, we used two requirements of speed input and pressure output for solving the problem. Then this geometry Fluent software. Fluent software is peak of programming art for modeling fluid flow and heat transfer in complex geometries. This soft ware is based on limited volume method which is a very powerful and suitable method in computational fluid dynamics methods [6].

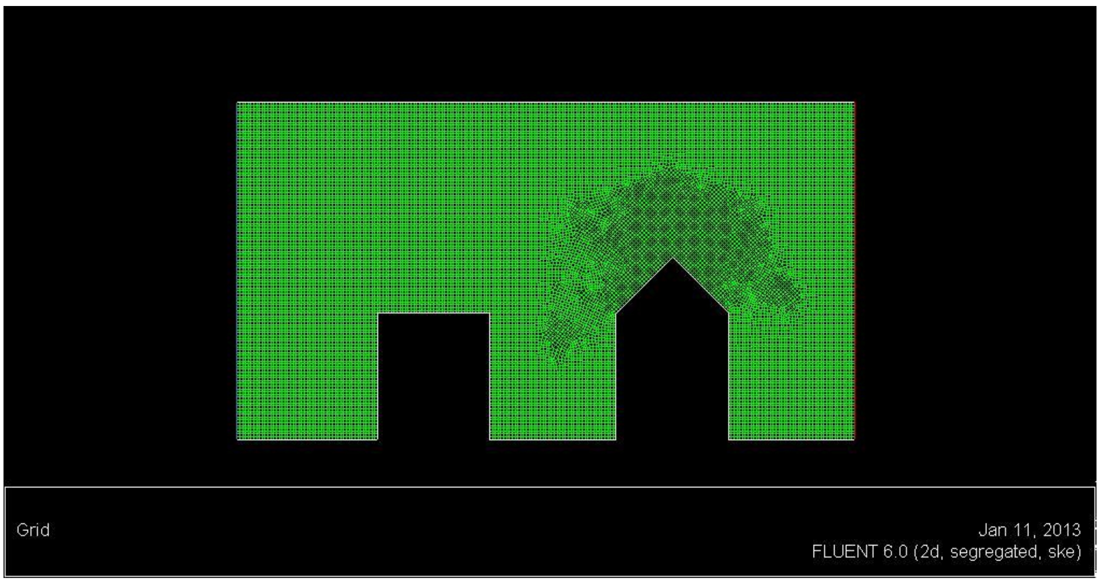

Figure 5: Geometric, Meshing and Boundary Condition in Model (Mode 1)

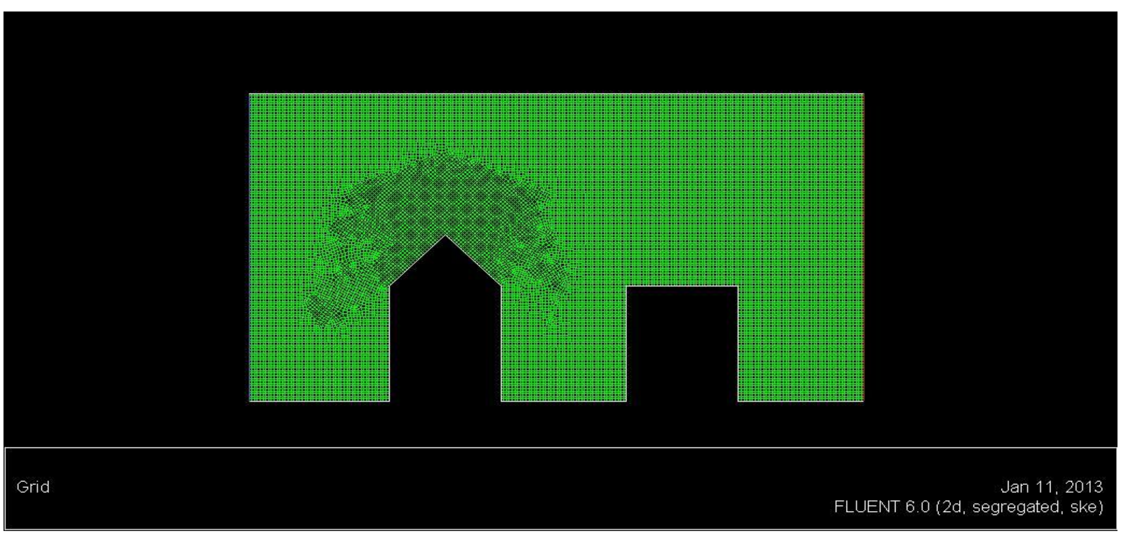

Figure 6: Geometric, Meshing and Boundary Condition in Model (Mode 2)

In this research k-ε is selected as model of turbulence. k-ε model is a quiet complete and general but very expensive model which is used for describing turbulence and is useful for expressing transferring of

properties of turbulence by mean flow and penetration and also for producing and depreciation of turbulence. In this model two transfer equations (Partial Differential Equation. PDE) are solved.
In order to study effect of roof from on flow pattern in the street, it, s assumed that a wind is blowing with reality speed (velocity) of v=5 m/s. In this situation with solving flow. Obtained results are shown in Figures 7 to 12.

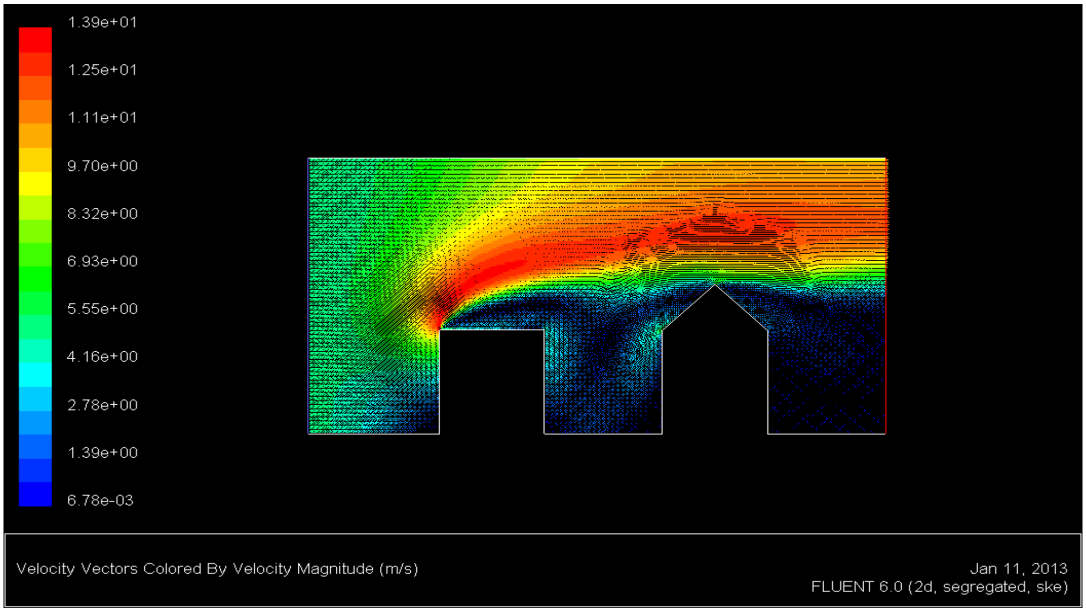

Figure 7: Velocity Vectors (Mode 1)

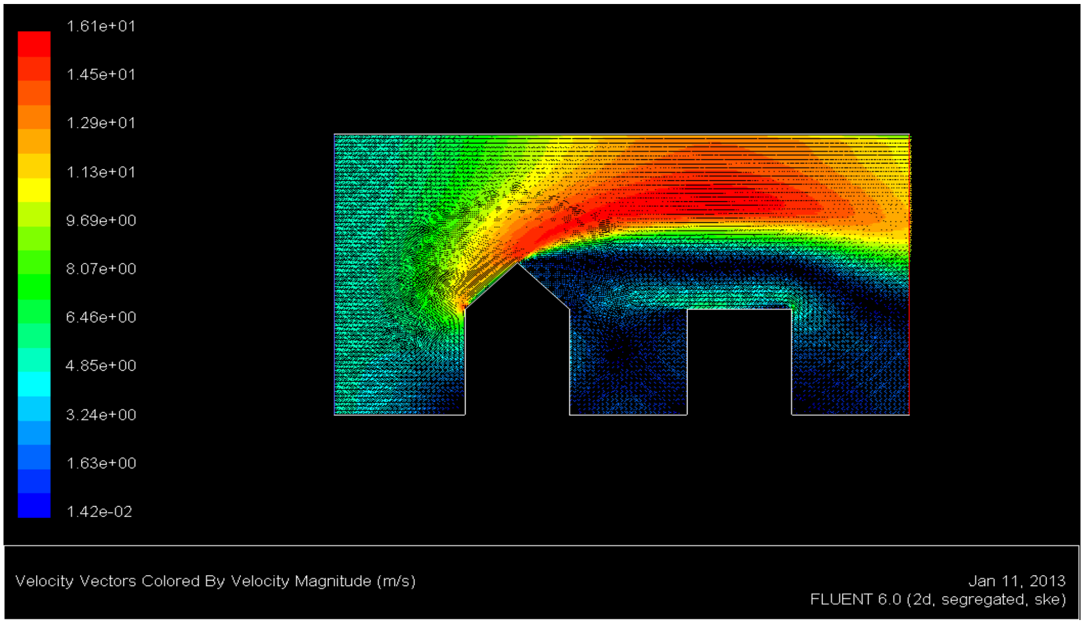

Figure 8: Velocity Vectors (Mode 2)

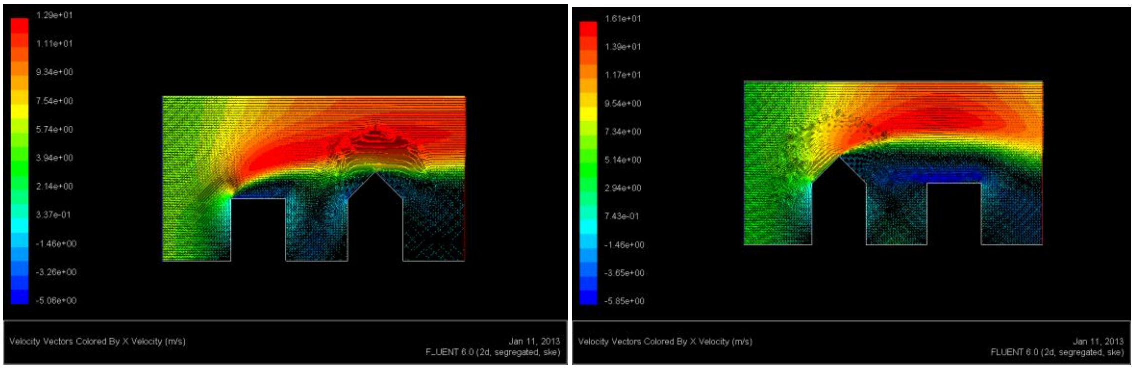

Figure 9: Velocity Vectors in x Direction

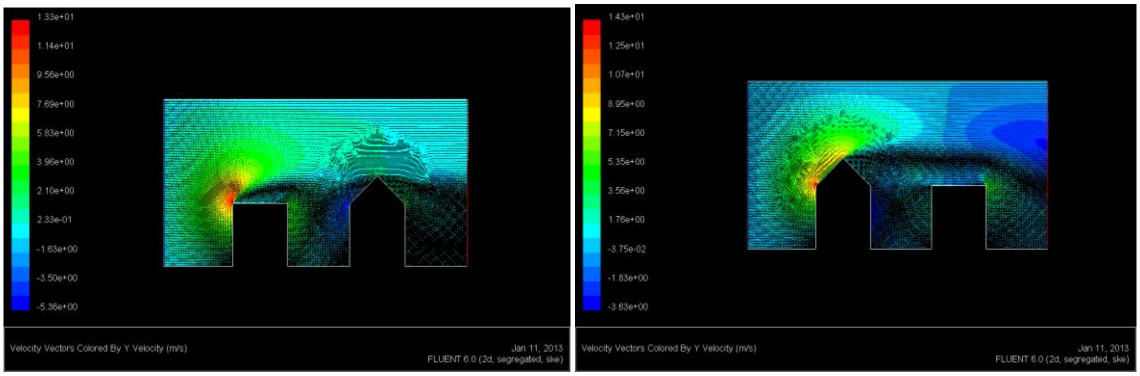

Figure 10: Velocity Vectors in Y Direction

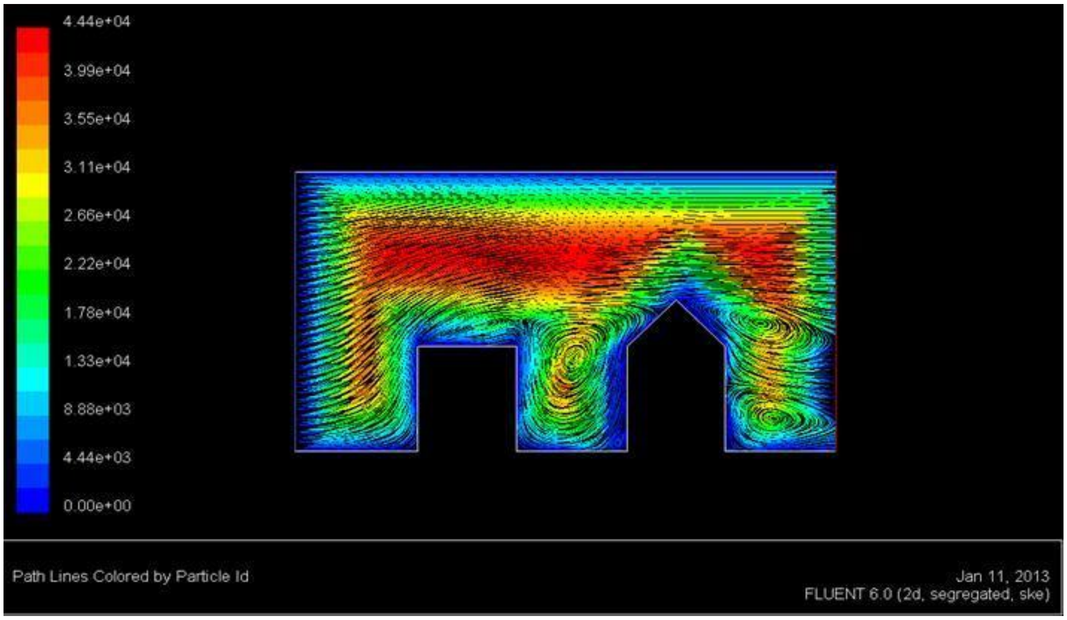

Figure 11: Flow Pattern around Building (Mode 1)

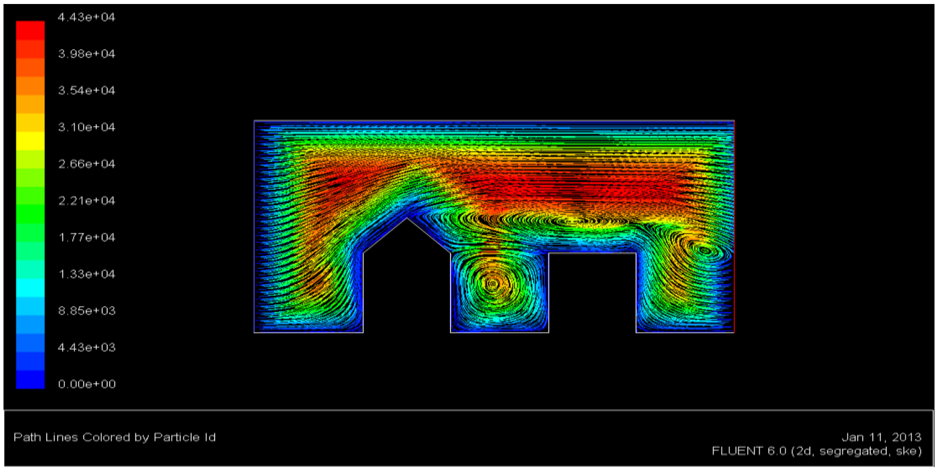

Figure 12: Flow Pattern around Building (Mode 2)

Conclusion

With attention to obtained results and figures in this research we can conclude that the most velocity vectors occurred above the building (Figures 7 and 8).

Maximum value of velocity also occurred in mode 2 (Figure 8) maximum velocity along direction x occurred in parts in which there are more horizontal path lines and the most of occurred on roof (Figure-9) minimum velocity vectors along direction x also occurred around the building (Figure-9). Highest values of velocity vectors along direction Y occurred at tip of the first wind ward building (Figure-10) and maximum value of velocity along direction Y occurred in mode 2 (Figure-10).

Also, considering obtained path lines (Figures 11 and 12) we can figure out that path lines at the street strongly depend on from and shape of buildings of two sides of the street.

It should be noted that vortex is made only at mode 1 which is clock wise (Figure 11). But two vortexes are made at distance between buildings in mode 2 which upper vortex is clockwise and bottom vortex is counter-clockwise (Figure-12). So, we conclude that direction of made Vortexes among buildings strongly depends on of the roofs. With attention to obtained values and figures we conclude that fluent soft ware has a very high capability w modeling paths around buildings and parameters related to path lines could be obtained by this soft ware desirably.

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