

Investigating Performance of Windscop Installed on Towers in Arid Regions with Using Computational Fluid Dynamics (Case Study: I&M Bank in Nairobi)

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ABSTRACT: The windscops are designed mainly to direct the wind and fresh air in the buildings. The windscops are able to gather the outside air and direct it into the building. If we want to make a windscops very effective, it shall be able to rotate on all directions. The windscops performance reaches to its top point when they are designed to direct the air for a big hall like an amusement park, etc. In this paper we paid more of our focus on performance analysis for a type of windscops which are installed on tower peaks. At first, we conducted analysis by means of GAMBIT software regarding the geometric model of windscops and the structure analysis, and then we continued to analyze them by means of FLUENT software regarding their pattern of flow. The results of such analyses were demonstrated as velocity on X&Y directions, and flow pattern.

Keywords: Windscops, Natural Ventilation, CFD, Renewable Energy, FLUENT

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INTRODUCTION

Undoubtedly, making use of airflow is of great importance in terms of creating a comfort and healthy environment for human's labor and life because it causes increase in physical and mental performance and decrease in consuming non-renewable fuels. The subject matter of this paper is conducting study on buildings ventilation. Nowadays by hearing the work "Ventilation", some modern mechanical systems comes to our mind and we are always busy eliminating the related issues on using such mechanical systems. Nowadays by getting smaller and smaller spaces for building constructions, one of our major problems is how to install such huge mechanical systems on the buildings, on the other part; high energy consuming seems to be one of their other issues which are always concerning about. However, the aforementioned mechanical systems for air ventilations fail to procure enough and smooth amount of fresh air for whole building, so that the architectures set hand together to think more about old architectural designs for procurement of fresh air by means of their combination with modern technologies. In the contemporary architecture, the changes arising from climatology changes are becoming more and more important for us. Architectural sustainability may mean modern future architectures by applying modern appropriate technologies. The architectural sustainability on the other part means that they shall be compatible to the buildings physical status and the whole situation of earth and its energy resources, so that we will be able to make a better use of them instead of their wasting or neglecting. The modern wind catcher plans and roof of building equipped

with natural ventilation architecture are design more aerodynamic than the traditional structures. It means that they own a circular shape and structure to increase the airflow. The natural ventilations deem to be a symbol in green designing. This kind of designing includes modern complicated technological architectures down to less modern ones. When airflow exists around a building or it comes from just one side and leaves there from the other side, it means natural ventilation. The windscops are design in order to be used for air direction towards a building. The windwards are able to collect wind and direct it in the building. A windscops is of top performance if it rotated to all directions. If a windscops is of fixed model and its head is not set with the airflow, so it does not have enough performance there or it may perform reversely, it means a wind trigger device. The windscops performance is highly important especially for large environments like an amusement park or wide open areas. It that situations the windward causes to direct the cool air to the downwards, then it mixes with the existing air and the result is fresh and cool air. The windscops are able to be installed on building with a bit distance from them in way that the fresh air shall then be procured by means of underground pipes, or we may install them on towers peak, so that the wind with high speed is trapped and it can direct it into the building.

The Building Compatible with Sustainable Architecture

In the rest of study we introduced some plans compatible with the environment taking into consideration of the role of wind in their architecture. The first plan was implemented in New Caledonia which is

named Renzo Piano. In this plan, the land slope and construction and plant windbreakers were applied for airflow controlling (Figure 1-A). The next plan was implemented in Buddhist Temple in a Holy Island located at Scotland which is named Andrew Wright. In this plan the building and area are constructed on a hill behind the airflow in a sun area of land (Figure 1-B).

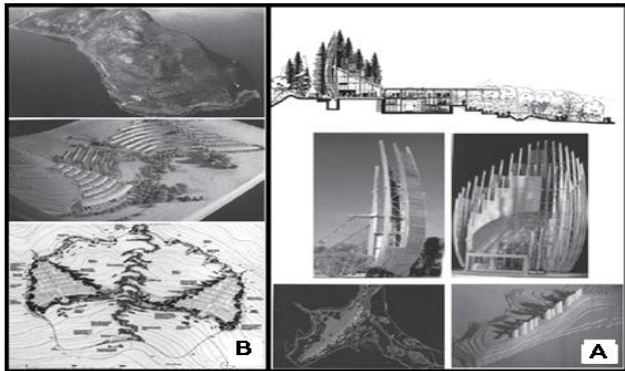


Figure 1.A. Gardening and whole building designing
B. Gardening designing and making use of sunk area of land for wind control

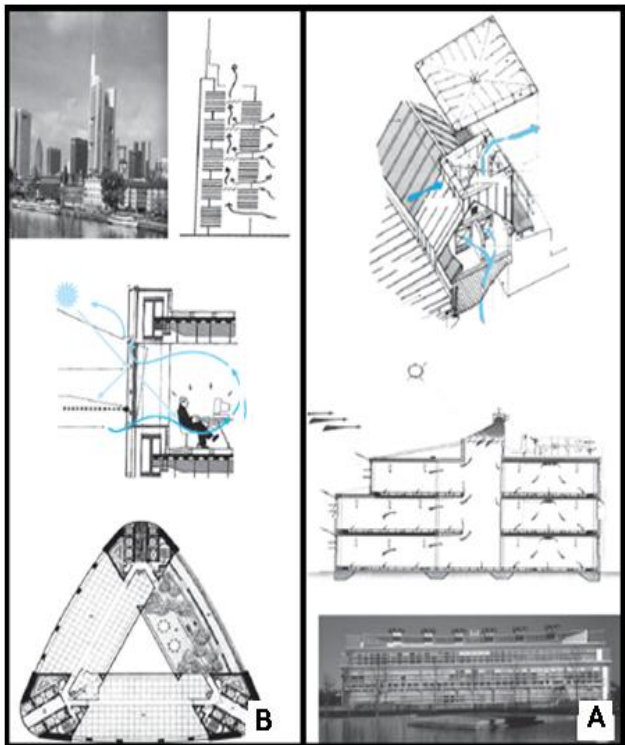


Figure 2.A. Making simultaneous use of appropriate plans and its applicable executive details, **B.** Open planning in combination with the nature.



Figure 3. St Mary Axe 30 Tower

In the Figure 2-A, the plan of RH Company is analyzed. In this plan, the pop-up doors and solar chimneys are applied for speed up the wind flow, and some especial canals are also applied for directing local cool air downwards and hot air outwards. The Commerzbank plan was applied in Frankfurt, Germany, which was designed by Norman Foster (Figure 2.B). The suspended gardens and open floors together with a central yard are applied there for making a direct connection with the nature and creating natural ventilation in the building. Another sample is St. Mary Axe 30, commonly known as Gherkin, located with a highly different architecture in London. This tower was completed in Dec. 2003 and opened in May 2004. This tower includes 40 floors with 180 m height. This tower was constructed by Britain Architect named Norman Foster. It is known that this tower is the first skyscraper which is compatible with the environment located at London. This tower's windows open automatically for the purpose of performing natural ventilation and it is predicted that this system reduces energy consumption in the rate of 40 percent (Figure 3).

RESEARCH METHODOLOGY

In order to analyze the fluids mechanics issues, there are three methods including: experimental, analytical and numerical. The development of numerical methods in recent decades in different sciences was extremely brilliant. Considering the high costs of numerical methods in eliminating geometrical issues, nowadays several scientists set their hand to solve issues through numerical analysis. We considered some stimulation methods in order to analyze the windscoops performance installed on tower peaks in I&M banks in Nairobi located at Kenya (Figure 4).

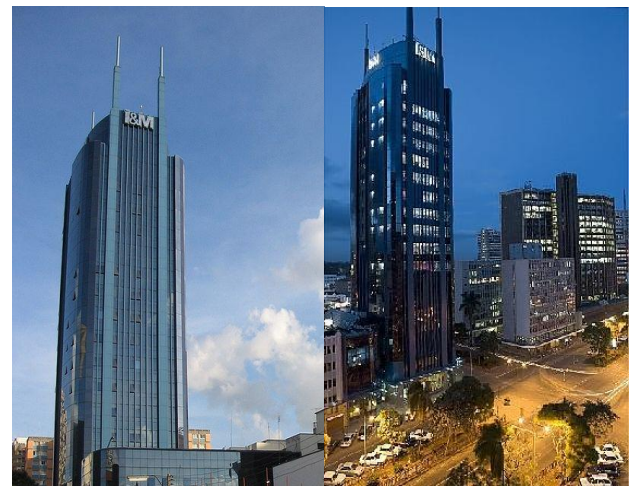


Figure 4. Front and back view of I&M Bank in Nairobi

In this plan, the airflow is entered from the higher and lower balances. Due to some pressure differentials between air entrance and exit flow, the entered air to the occupied area of the building are directed. The geometrical structure together with the existing maps is all created in GAMBIT software. (Figure 5)

As we see in figure 5, we made use of two conditions of speed entry for solving this flow. Then we transferred this geometry to the FLUENT software. The FLUENT Software is deemed as the best programming

software for modeling the fluids flow and heat transmission in complicated geometry. This software is based on limited capacity method which is a powerful method in computational fluids mechanics.

We determined k-ε as the turbulence model in this study. The model of k-ε is a common perfect but expensive model which is used for turbulence description. This is also used for describing the turbulence details by average flow and penetration flow, and also for creating and depreciation of the turbulence. Two transfer equations are solved in this model (minor differential equation of PDE), one for kinetic energy of turbulence K, and the other for the rate of kinetic energy depreciation, i.e. ε.

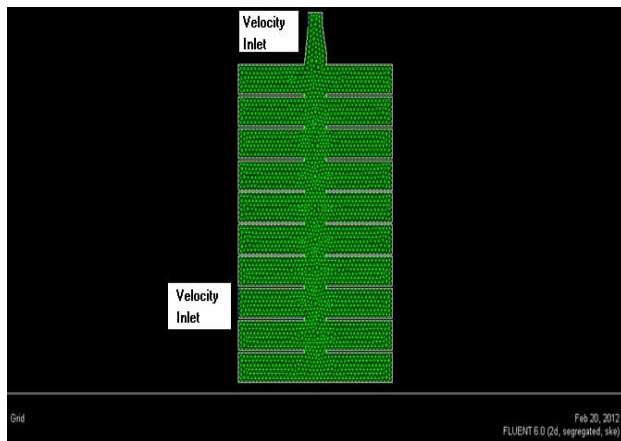


Figure 5. Geometrical, meshing and boundary conditions in the model.

The model k-ε standard, applies the transfer equations of 1 and 2, which are used for K and ε in the FLUENT software. (6)

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_i} \left[\left(\alpha + \frac{\alpha_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + G_k + G_b, \quad (1)$$

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_i}(\rho \varepsilon u_i) = \frac{\partial}{\partial x_i} \left[\left(\alpha + \frac{\alpha_t}{\sigma_k} \right) \frac{\partial \varepsilon}{\partial x_j} \right] + C_{1s} \frac{\varepsilon}{k} (G_k + C_{3s} G_b) - C_{2s} \rho \frac{\varepsilon^2}{k}$$

$$k = \frac{1}{2} (\overline{u'^2} + \overline{v'^2} + \overline{w'^2}) \quad (3)$$

K= Kinetic energy related to the turbulence, at= Turbulent viscosity, Gk= turbulent kinetic energy creation due to average speed gradient, Gb= turbulent kinetic energy creation due to buoyancy force (6). The equations include five settable fixes which amounts are equal to:

$$\sigma_k = 1.0 \quad C_x = 0.09 \quad C_{1\varepsilon} = 1.44 \quad C_{2\varepsilon} = 1.92 \quad \sigma_\varepsilon = 1.30$$

In order to analyze the performance manner of windscops installed on the supposed tower peaks, the wind is entered with the speed of 2m/s from the tower entrance and the wind with the speed of 7m/s are entered from the windward position.

RESEARCH FINDINGS

The results are according to what we demonstrated in the figures 6 to 8. In table 1, you can see the minimum and maximum speed levels in X & Y directions, and also the amount of speed.

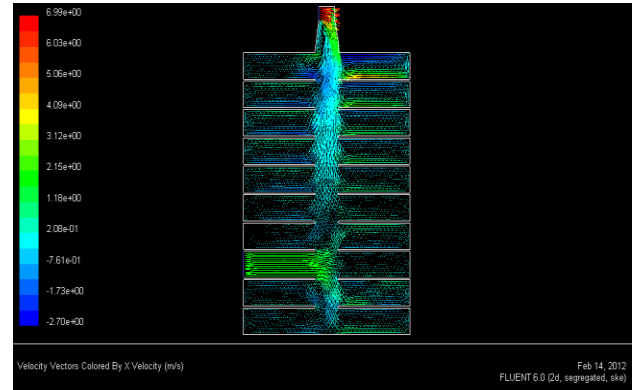


Figure 6. Velocity vectors colored by X-direction Velocity

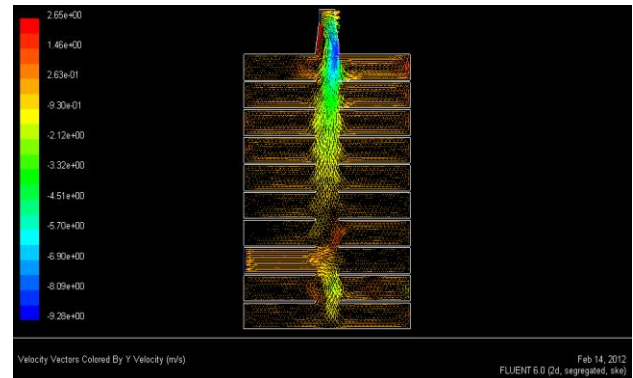


Figure 7. Velocity vectors colored by Y-direction Velocity

Table 1. Amounts of maximum and minimum speed rates in the model

	Velocity magnitude	Velocity in X direction	Velocity in Y direction
Minimum	0.002983	-2.700282	-9.282343
Maximum	9.477179	6.994643	2.649661

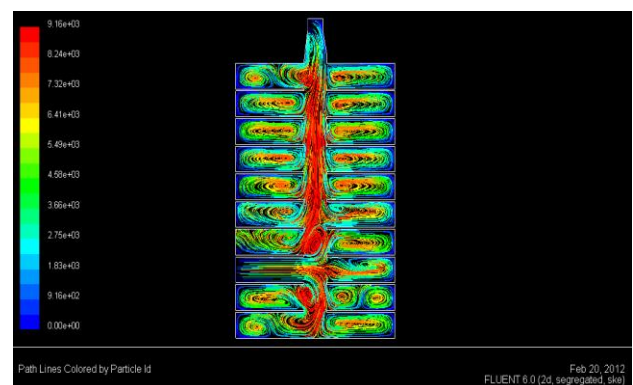


Figure 8. Demonstration of flow pattern in model

CONCLUSION

According to the reported results and shapes in this research we can conclude that the most velocity vectors are in the direction of +X, and are created in the sections where we have more horizontal flows, and its maximum was happened in the entrance of windscop and speed entry in the lower section of the tower (Figure 6). The most velocity vectors in the direction of -X, was happened at the floor of left sided rooms of the tower (Figure 6). The most velocity vectors in the direction of -

Y was happened in the output of wind trigger and the most velocity vectors in the direction of +Y was happened in the rooms walls (Figure 7). The speed in X & Y directions arising from wind flows with the speeds of $V=2\text{m/s}$ and $V=5\text{m/s}$, reached accordingly to 9.477179, 6.994643, and -9.282343. (Table 1). Also according to the reported velocity model in the structure (figure 8) we can conclude the appropriate performance of this system in order for great ventilation of internal spaces of towers. According to the reported shapes and results we can conclude that the FLUENT software has a nice capacity and capability in modeling the airflow in the windscop systems and we can obtain the flow parameters in a suitable manner by applying this powerful software.

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