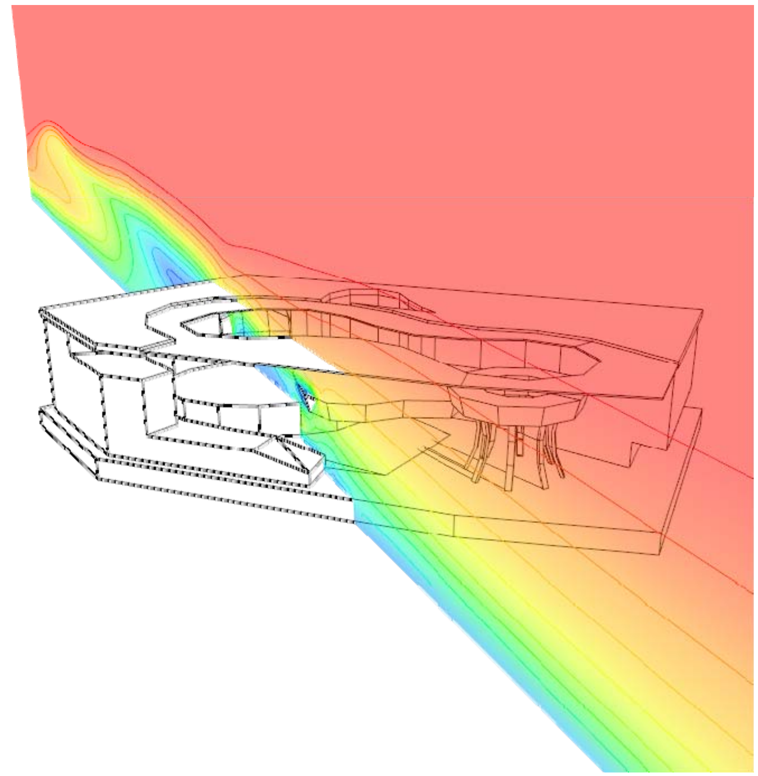
AIRFLOW SIMULATION REPORT

MIAMI SCIENCE MUSEUM

DoE Modeling Grant



PREPARED BY

COMPILED ON

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DECEMBER 20, 2008

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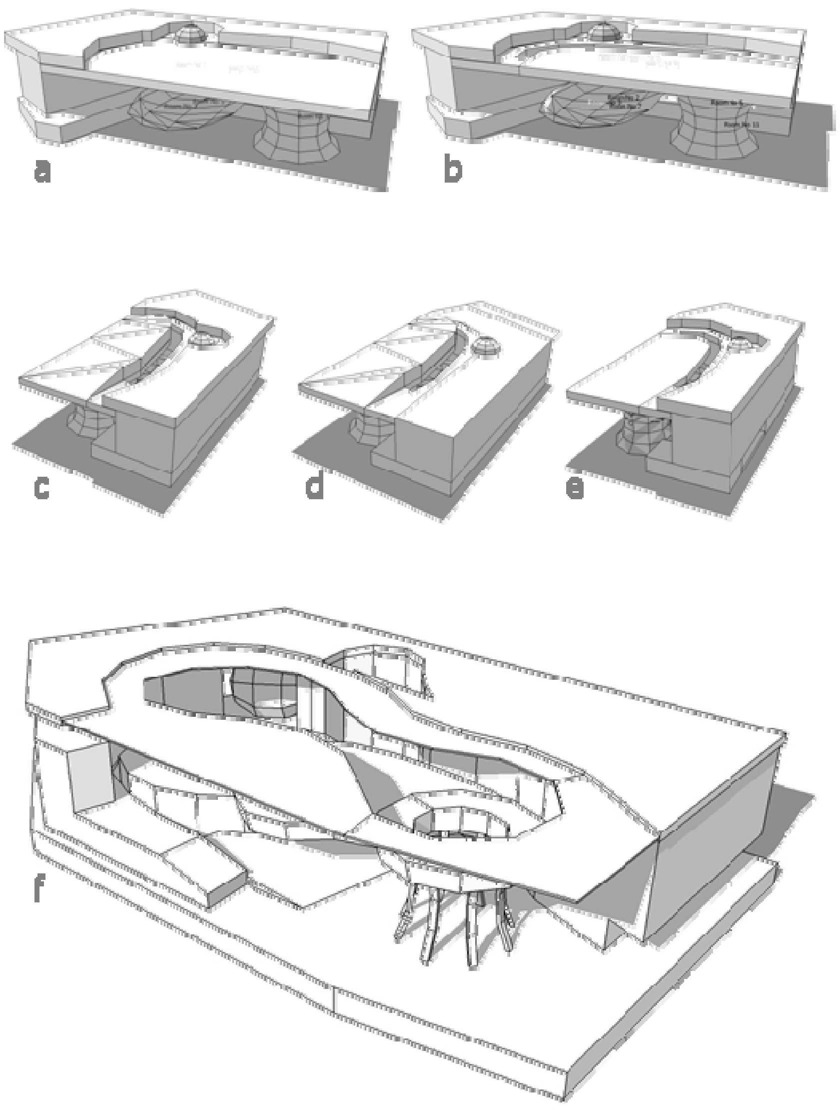

Figure 1. Graphic Renderings of Different Studied Models

INTRODUCTION

As part of the design process for the Miami Science Museum, Syska Hennessy Group has developed a computational external airflow model. The intent of this model is to evaluate multiple options to inform the building form so that it responds to, and assists in, natural breeze flows through the site. All project modeling utilized the MicroFlo - Computational Fluid Dynamics (CFD) module within the Virtual Environment (VE) simulation tool published by Integrated Environmental Solutions (IES). To develop the model, a graphic representation of the building was created using three dimensional representative design models provided by Grimshaw.

The mathematical simulation of air flow involves the numerical solution of a set of coupled, non-linear, second-order, partial differential equations. MicroFlo uses the primitive variable approach, which requires the solution of the three velocity component momentum equations together with equations for pressure and temperature, these equations being known as conservation equations.

This analysis was completed as part of the DoE Modeling Grant to ensure desirable airflow rates and avoid stagnant warm air pockets around occupied outdoor areas. The multiple design options that were simulated, as listed below, are presented graphically on the left and discussed ahead.

a. Solid building form with large south facing undercroft without any openings for through-air-flow

b. Undercroft canopy with a “canyon” to enable breeze flow through the undercroft area

c. Aerodynamic canopy to create lower wind pressure above the canyon to further breeze velocities

d. Level building roof with the canopy height to reduce resistance to air flowing out of the canyon

e. Horizontal openings in the building form towards the plaza ground level to enable through-air-flow

f. Updated building form incorporating lessons learnt from all prior analyses

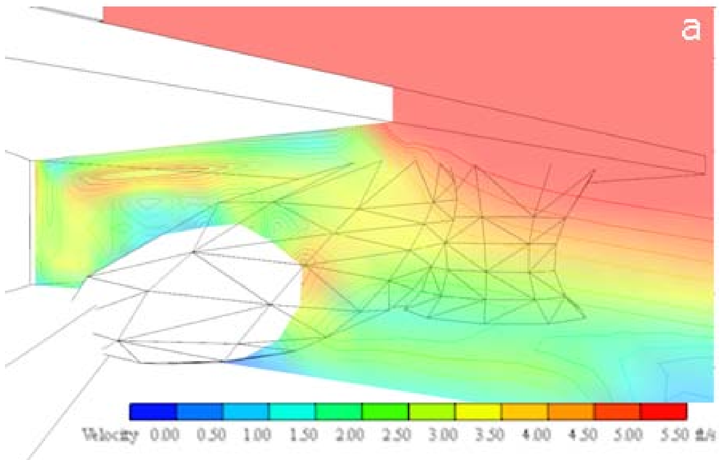

Figure 2. Undercroft Breeze Velocity Profile – Solid Building Form

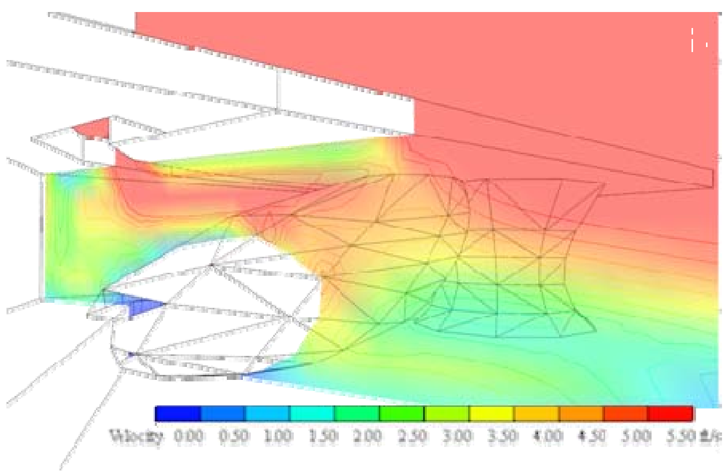

Figure 3. Undercroft Breeze Velocity Profile – Undercroft Canopy with Canyon

UNDERCROFT CANOPY CANYON

The building form is conceptualized as a solid building block on the north and west boundaries of the site, partially-enclosing a plaza towards the south-east, which takes a form of a high undercroft with an 80' high canopy. The predominant wind direction for the site is from south-east with an average wind velocity ranging from 10-15 ft/s. The plaza is accordingly sited so as to capture the breeze to the maximum.

Considering the impact on breeze flow in the undercroft area, it was understood early on in the design process that this building form needed appropriately sized and located through-openings in the solid blocks which would enable the breeze to cross-flow through and out of the plaza to achieve wind velocities optimum for outdoor thermal comfort.

These velocities were identified in the range of 3 to 6 ft/s, beyond which the breeze would either not be noticeable or too uncomfortable. The first analyses, without any openings, reinforced the assumptions and it was found that the wind would flows right over the undercroft canopy leaving a large pocket of positive pressure but almost still air below (Fig.2).

In an attempt to relieve this positive pressure in the undercroft, a "canyon" or a vertical through opening was proposed in the canopy above the undercroft. The updated simulations illustrated that although this canyon enabled a through-flow with significant velocities, this effect was only limited very close to the ceiling of the undercroft (Fig.3, 6). It was found that that canyon did not affect, to any appreciable extent, the still air conditions at the ground level (Fig.5).

A few iterations to the roof form were evaluated, attempting to maximize the pressure difference above and below the canyon and hence enable more through-airflow. These iterations are presented in the next section.

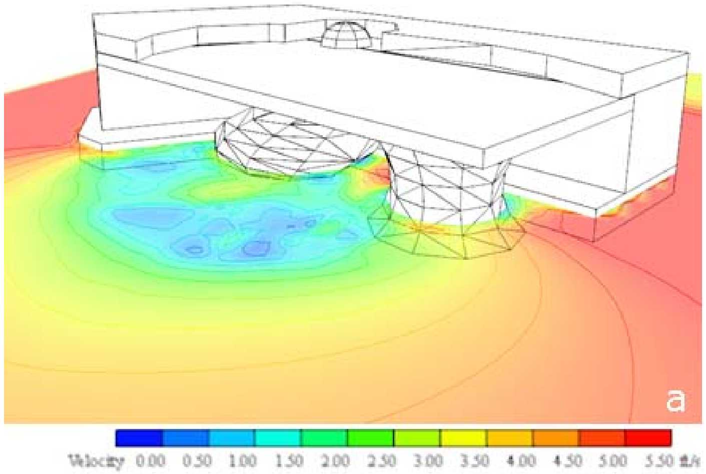

Figure 4. Plaza Level Breeze Velocities – Solid Building Form

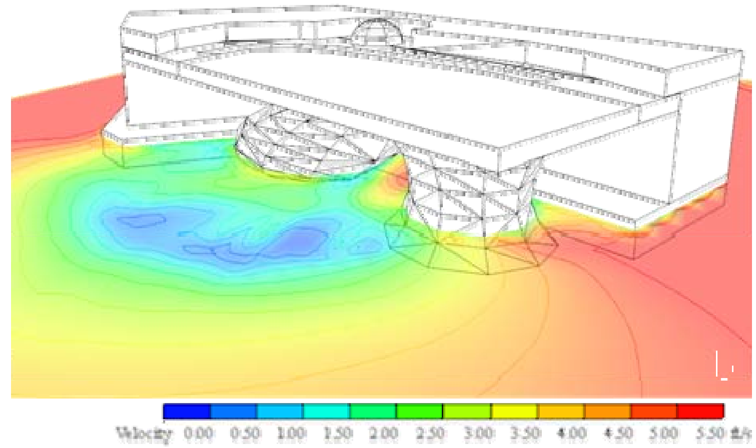

Figure 5. Plaza Level Breeze Velocities – Undercroft Canopy with Canyon

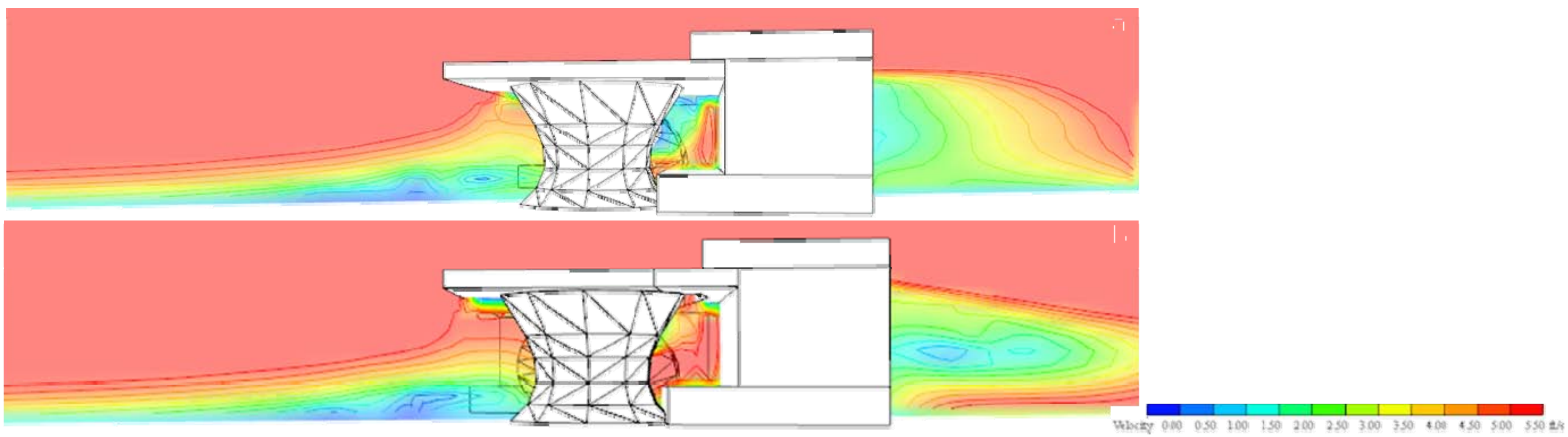

Figure 6. Building Impact on Wind Velocity Profile – without and with Canyon on Undercroft Canopy

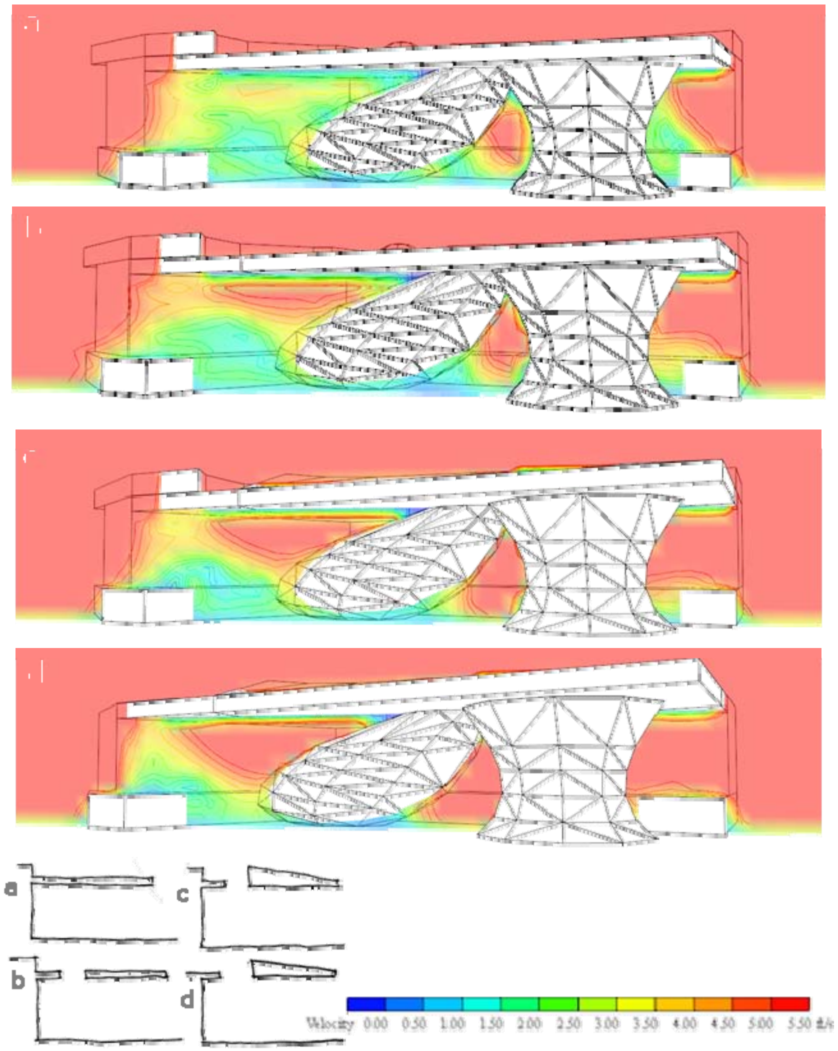

Figure 7. Undercroft Breeze Velocity Profile – Various Roof Form Options

ALTERNATE ROOF SURFACE PROFILES

Hypothetical Roof profiles were simulated to investigate the impact of surface geometry on creating significant pressure differential to enhance air-flow through the canyon. The different strategies that were considered:

- Increase airflow speeds above the canopy with a aerodynamic profile, hence reducing air pressure above the canopy and creating higher through-flow (option c)
- Reducing resistance to out-flowing air from the canyon by bringing the roof level down to match the top of canopy (option d)

It was found that each of the iterations had an impact on the height to which the air flow was impacted (Fig.7), but this relatively small opening, when compared to the volume of air in the undercroft, was not sufficient to instigate air flows that would affect the ground level 80’ below the canopy. However, when properly configured, a canyon of this scale could potentially help create comfortable breeze situations around terraces and outdoor circulation areas located at heights closer to the canopy.

It was believed that horizontal openings through the building blocks would be necessary in order to create air movement at the plaza ground level. An iteration with such opening near the ground was developed and is presented in the next section.

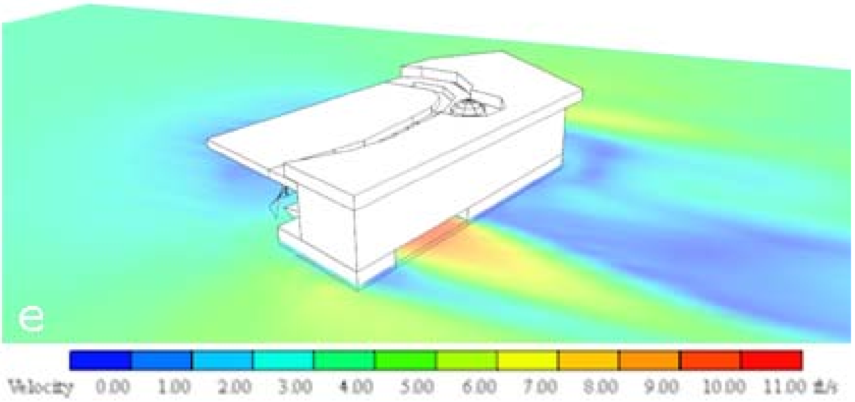

Figure 8. Impact of Horizontal Through-Flow Opening – Plan

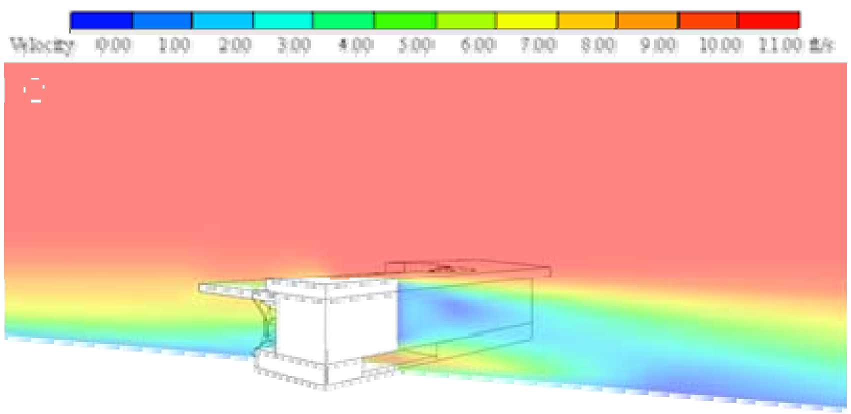

Figure 9. Impact of Horizontal Through-Flow Opening - Elevation

HORIZONTAL THROUGH-FLOW OPENING

To investigate the impact of horizontal openings, a cross-flow opening was modeled near the plaza ground level (Fig.8). The simulations presented that this link between the high-negative pressure of the leeward building side and the still-air undercroft did create air-flow through this opening. Interestingly, the wind speeds coming out of this opening were very high but were almost still at inlet (Fig.8, 9).

On detailed particle tracking analyses (Fig.10-13) It was clearly evident that the building surfaces on three sides along with the positive wind pressure created a trap of still air in the undercroft. All incoming wind particles, tracked at heights close to the ground, we diverted around this air-pocket and did not establish any through-flow. In other words, the canyon and the horizontal openings even when combined were too small to relieve the volume of air built-up in the undercroft.

The updated building form was developed with significantly larger openings – both horizontal and vertical and the results are presented in the following section.

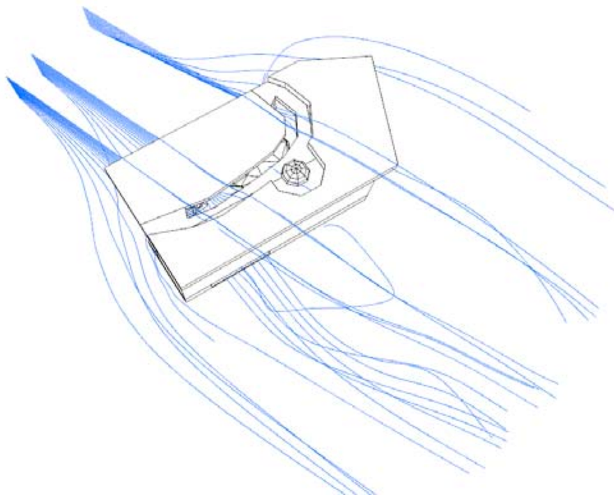

Figure 10. Building Impact on Wind Flow – Top View

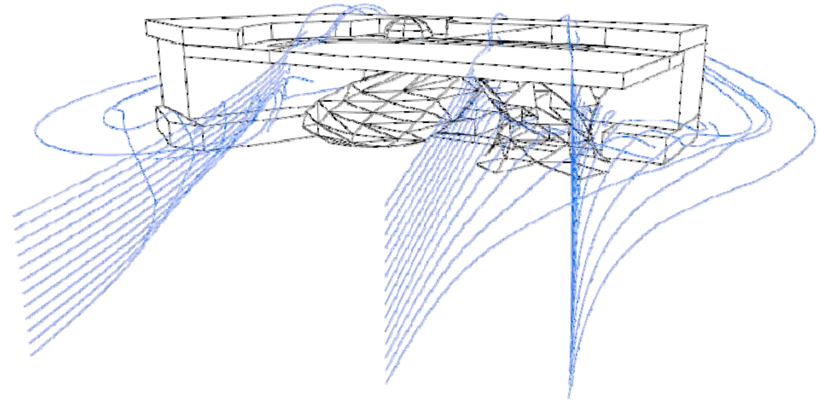

Figure 11. Building Impact on Wind Flow – Front View

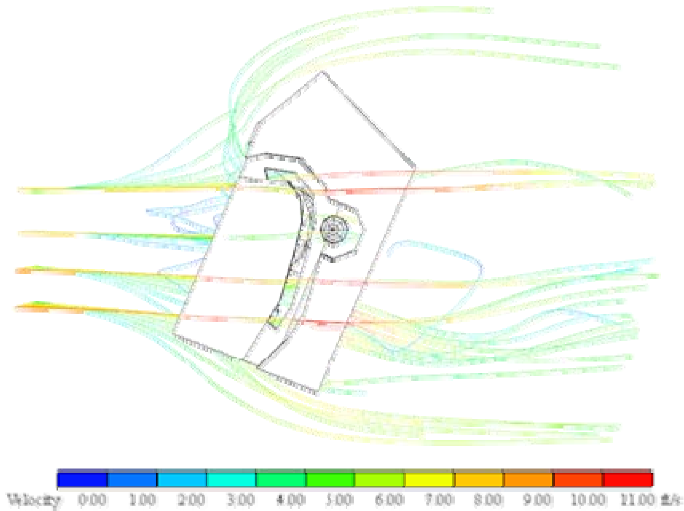

Figure 12. Building Impact on Wind Flow – Plan View from Top

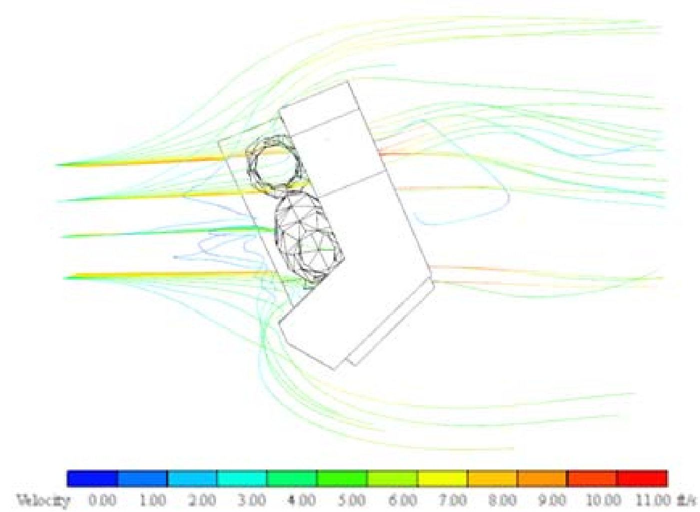

Figure 13. Building Impact on Wind Flow – Plan View from Bottom

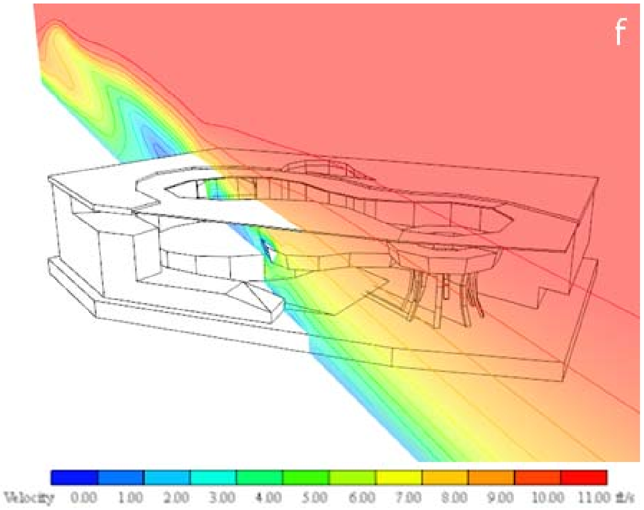

Figure 14. Undercroft Breeze Velocity Profile – Updated Building Form

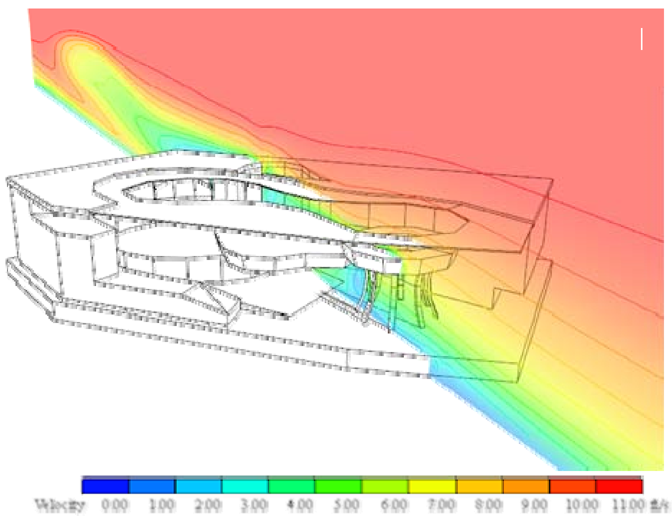

Figure 15. Undercroft Breeze Velocity Profile – Updated Building Form

UPDATED BUILDING FORM

The latest building design departs from the original schemes in that

- The outdoor plaza is significantly reduced in area and is at an elevated level
- Most outdoor occupied spaces are sited on higher floors closer to the canopy
- The canopy itself is significantly open as against the narrow canyon which was a part of earlier iterations
- There are two substantially large through openings – one around the planetarium on the north-west corner of the building and another vertical atrium in the north block.

The simulation results demonstrate that almost all outdoor areas meant to be occupied in the undercroft and on the plaza level have wind velocities in the desirable range of 3 to 6 ft/sec (Fig.14, 15) shown in greens on the left. Also, the occupied areas around the planetarium, which might depend on passive conditioning for certain parts of the year, have sufficient wind velocities (Fig. 16, 17) flowing through them to qualify as breeze.

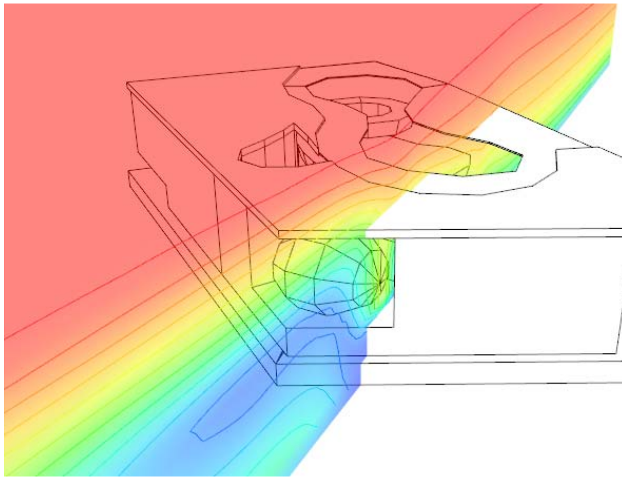

Figure 16. Horizontal Through-Flow Openings – Updated Building Form

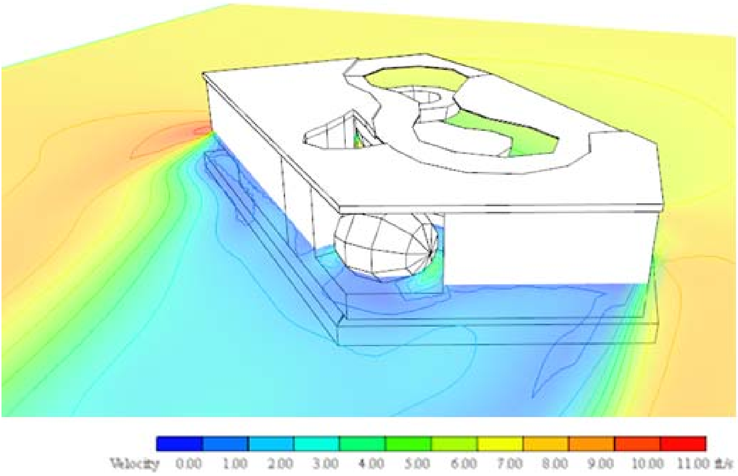

Figure 17. . Horizontal Through-Flow Openings – Updated Building Form

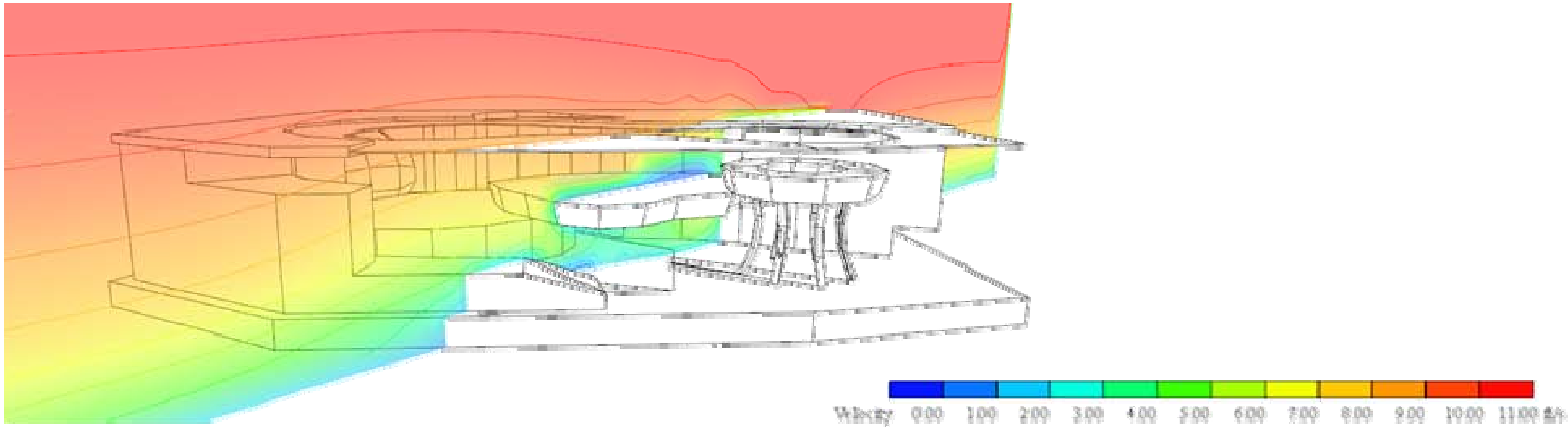

Figure 18. Undercroft Breeze Velocity Profile – Updated Building Form