Building Environmental and Sustainable Design Approach to Housing Developments

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1. INTRODUCTION

Sustainable development is of fundamental importance world-wide. In Hong Kong, the building industry is becoming the most important development and creates the greatest impact to the environment. A good building environmental design is to protect people and minimise its impact to the environment. From commercial to residential, lowrise to highrise, public to private buildings, inclusion of environmental consideration into a building design would always bring us a sense of integration of intelligence and consciousness into our environment. From the point of the dwellers, green features would not only mean a better and healthier living environment, showing harmony between human and the nature, but also serve as additional facilities that they can utilize at leisure time.

In February 2001, three departments of the Government of Hong Kong Special Administrative Region, Buildings, Lands and Planning, issued a Joint Practice Note, entitled Green and Innovative Buildings, outlining Government incentives for Green Buildings [1]. In new residential projects, green features such as balconies, communal sky gardens and podium gardens, sunshades and reflectors, wing walls and solar chimneys can now be excluded from calculations of the Gross Floor Area and/or Site Coverage. The incentives are part of the long term objectives by the Building Innovation Unit and the interdepartmental Working Group on Green and Innovative Buildings to implement reforms to enhance environmental performance of the built environment.

The function and performance of these green features implemented in the unique high-rise, high-density of urban context and hot and humid environment in Hong Kong need to be assessed critically. This paper investigates their potential benefits using advanced simulation tools and quantifies their performances in terms of health and comfort criteria.

2. GREEN BUILDING CONCEPTS

Under the Joint Practice Note No. 1, green features refer to balconies, communal sky gardens and podium gardens, sunshades and reflectors and wing wall. Utilization of natural resources and renewable energy is believed to be maximized, on incorporating these building features into the building design. The conceivable benefits will be the reduction of building energy consumption in air-conditioning and artificial lighting by using more natural resources. Air-conditioning is aimed at providing cooling to meet thermal comfort requirement. An alternative approach to achieve acceptable thermal conditions inside the building is to utilize natural ventilation. The idea of cross-ventilation within a building can efficiently reduce the indoor air temperature. A constant supply of fresh air can dilute pollutants, thus keeping a healthy habitat. The provisions of sunshades, reflectors and balconies can effectively reduce the solar heat gain inside the apartment so that the indoor air temperature, as well as the air-conditioning energy cost, can be reduced. On the other hand, these devices can still allow certain daylight penetration into the flat such that natural daylight can possibly reduce the reliance on artificial lighting.

3. BUILDING ENVIRONMENTAL ASSESSMENT

Objective assessment on the performance of building on incorporating these green features is crucial. Potential benefits achievable by the green features are site-specific and improvement in building performance can be quantified using appropriate building environmental assessment methodology and tools.

Microclimate, resulting from planning of buildings in terms of massing and height, local terrain, local wind climate data and the incorporation of building features, is a strong indicator to assess the design. Excessive airflow, not only affects the comfort of residents but also discourages them from using the communal facilities. Computational Fluid Dynamics (CFD) technique can be used for analysis on this concern. CFD is a computer-based simulating methodology for the finite volume solution of the fundamental equations of fluid flow [2,3]. Natural ventilation is another parameter of building performance that can be estimated at design stage. The functions of natural ventilation are to meet health requirement, to reduce room temperature and to provide for comfort ventilation. Minimum ventilation rate is required to safeguard the health requirement. In general, ventilation rate that ranges between 1 and 5 air changes is sufficient for the health requirement of residential building [4]. CFD analysis can estimate the potential ventilation rate generated from any design. Ventilation for cooling purposes is related to the thermal comfort inside the building. Another green feature such as wing walls has high potential for generating better ventilation and improving indoor thermal conditions. Dynamic thermal model (DTM) is a widely used tool for prediction of thermal conditions [5]. Annual electricity consumption can be greatly reduced if natural ventilation provision of a building is sufficient, and the demand of cooling load in air-conditioning can also be reduced.

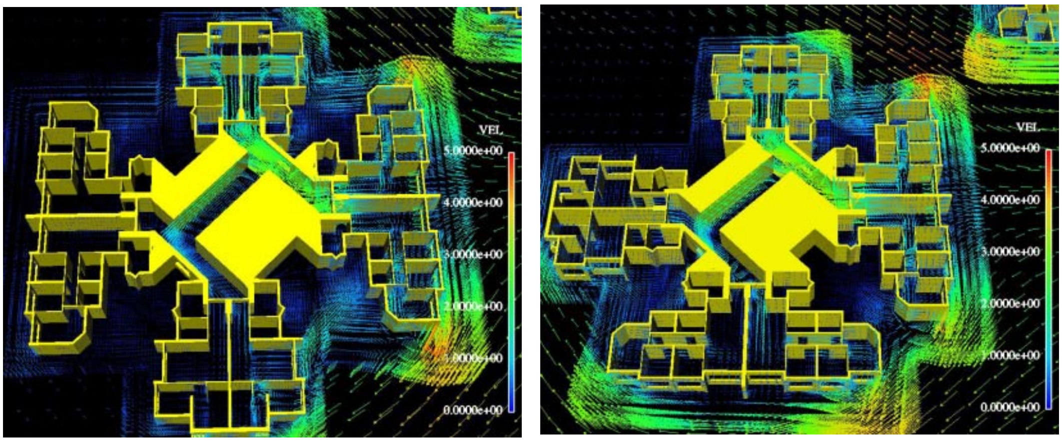


Figure 1. Assessment of natural ventilation inside flats by CFD

Natural lighting is also a crucial element in the assessment of building environment. Lighting performance associates with well-being and working performance of residents. Good natural daylight design, which can be quantified by Daylight Factor, can minimise the reliance of artificial lighting. The quality of natural daylight is also a criteria for building performance. Visual comfort, quantified by Glare Index, could determine the effectiveness of some of the green features such as the sunshade, reflectors and balcony. Natural daylight simulation using computer software such as Radiance can provide all the necessary information on these aspects [6].

4. RESULTS

4.1 BALCONY

Balcony makes use of the veranda concept for climatic purpose. It can be used to increase the depth of the façade to buffer interior space and to reduce the solar heat gain. Balcony also provides an opportunity for landscaping. The plantings can assist with the buffering process. It would catch the wind breeze to enhance natural ventilation.

Figure 2. Cooling load and energy simulation of balcony design

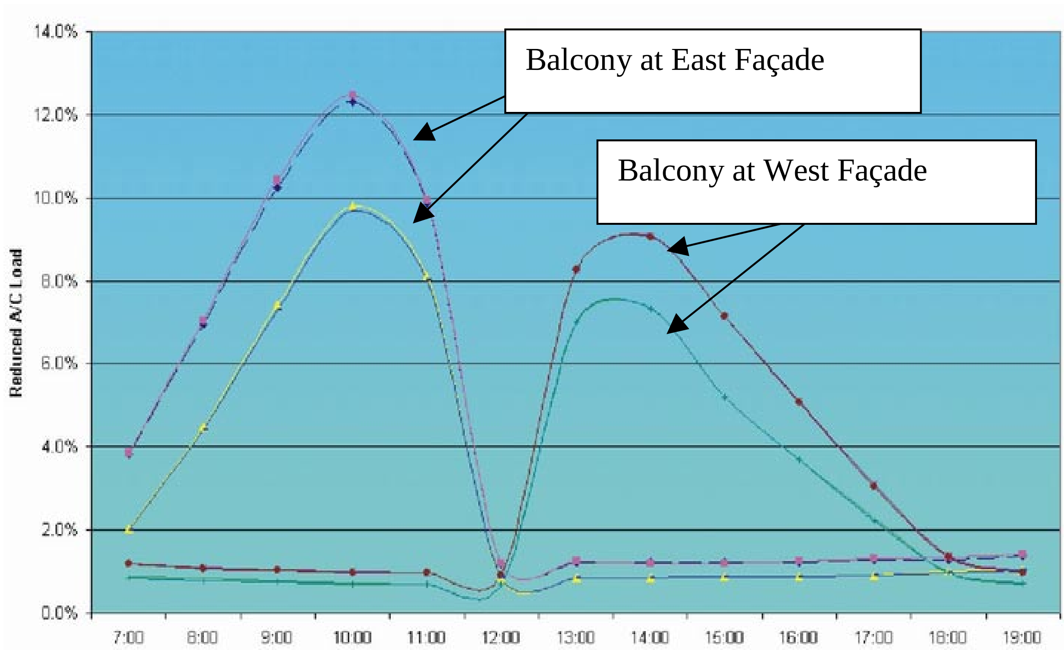


Figure 3. Potential reduction in air-conditioning load by balcony

There are two major benefits for the dwelling designed with balcony: better solar shading and enhancement of natural ventilation. Similar to the effect of sunshade, the slab of the balcony of the upper floor acts as a deep overhang to the window of underneath floor (Figure 2). This deep overhang permits a large glazing area for the space, which minimizes the direct solar heat gain while admitting more diffuse sunlight reflected from other surfaces of surrounding buildings.

By using the DTM and energy model of a typical housing unit of Hong Kong, the maximum reduction in cooling load could be as high as 12% with the provision of balcony for a specific housing design (Figure 3). The saving in air-conditioning energy varies with the orientation of the balcony. Average saving in air conditioning energy is about 6%.

4.2 COMMUNAL SKY GARDENS

In the high-rise and high-density built environment in Hong Kong, tall buildings are usually linked together or grouped and sheltered by one another. This creates a problem on building environmental. The linked tall buildings reduce the airflow around buildings induced by wind and usually create stagnant areas on the leeward side. For a dwelling with a single side openable window, the effectiveness of natural ventilation for the dwelling will be decreased if the window is facing the stagnant regions. Sky garden could improve wind permeability.

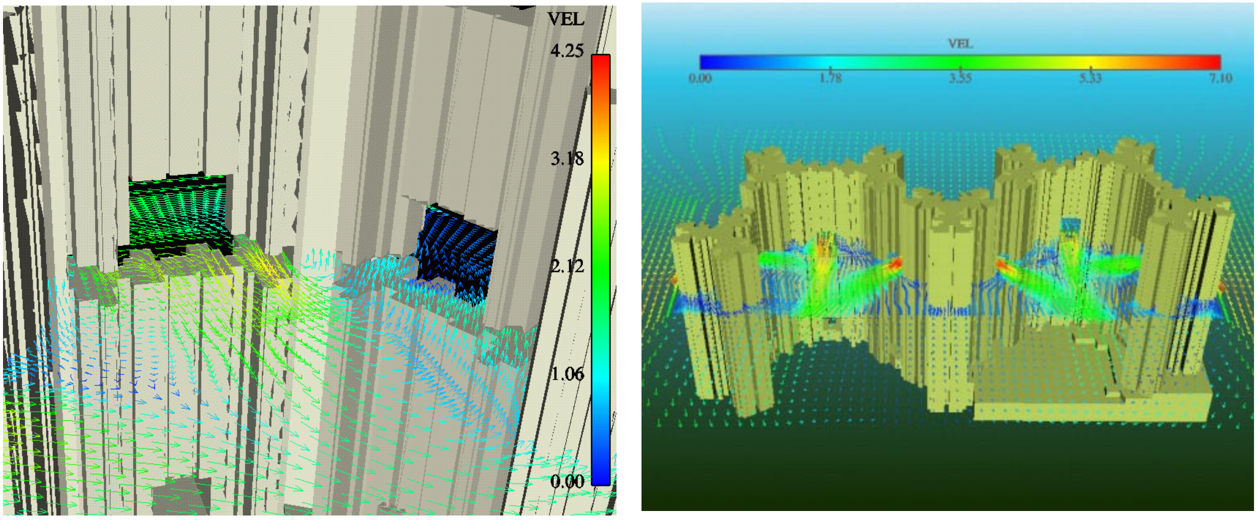


Figure 4. Air flow around sky garden at Shui Chuen O HOS Development (left) and Overview of wind distribution through sky garden openings (right)

	Mean Ventilation Coefficient of flats at leeward side	
	With Sky Garden	**Without Sky Garden**
Block 1	0.29	0.24
Block 2	0.36	0.22
Block 3	0.35	0.22
Block 5	0.34	0.21
Block 6	0.35	0.23
Block 7	0.27	0.25
% Increase of Mean Ventilation Coefficient	**+ 43.1%**	**-**

Table 1. Sky garden performance

Figure 4 shows the results of CFD analysis of a housing development. The design of sky gardens on the linked buildings increases the building permeability to wind. Generally, sky gardens are located at the mid-level of the buildings as to reduce the stagnant areas on the leeward side. As the wind speed within that area increases, the performance of natural ventilation adjacent to those areas is improved. Table 1 summarises the mean ventilation coefficients generated by different blocks of the development. The ventilation coefficient, which is determined by the pressure profile for estimating the ventilation, increases by about 43% with the provision of sky garden.

In terms of ecology, sky gardens help to provide more greenery space to the built environment. The sky gardens are usually designed as landscape areas for public recreational purpose. However, caution should be taken for high wind speed at that building altitude. Some mitigation measures may be required to avoid excessive high pedestrian wind speed, causing discomfort, at the sky gardens using compact or porous windbreaks or windguards.

4.3 COMMUNAL PODIUM GARDENS

The provision of podium garden can have many advantages. Its existence not only enhances the amenity of building occupants in terms of daylight, outlook, view sharing, privacy in residential buildings, ventilation and wind mitigation, but also provides a landscape area for public recreational purposes.

Pedestrian wind discomfort is always a concern in podium garden since excessive local wind speed may occur. CFD can be used to predict the air speed distribution (Figure 5). Undesirable high wind speed would affect outdoor activities and causing inconvenience to the walking pedestriansand causing potential damages to the plantation in the gardens. Prediction from CFD would help to identify if there is any channel or funnelling effect associated with building geometry arrangement. Distribution of wind amplification factor, i.e. the ratio of local wind speed to the prevailing wind speed, is used in spotting the wind amplifying region.

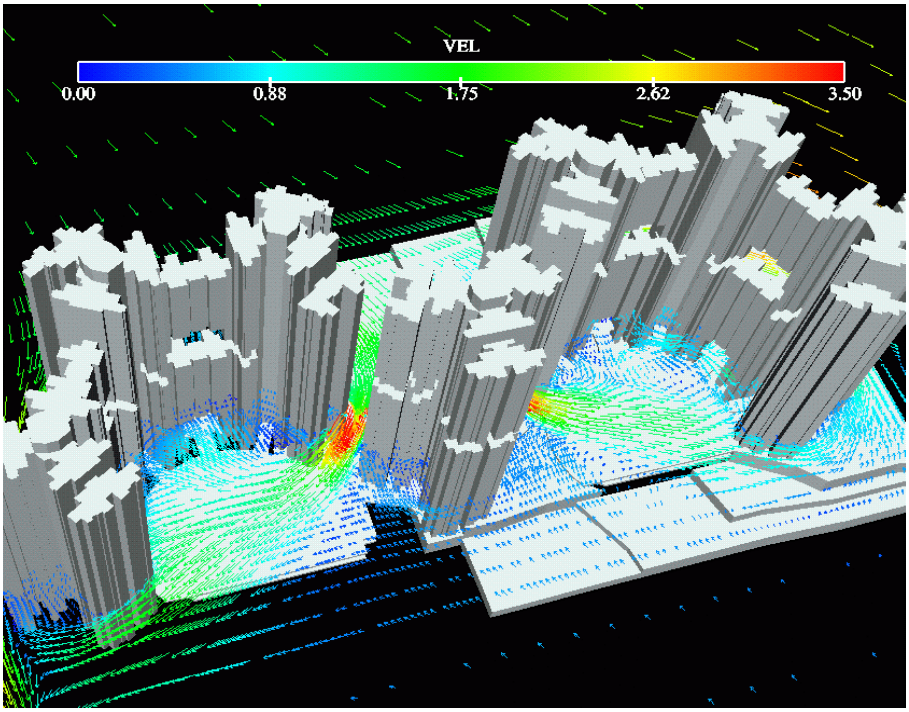


Figure 5. Microclimate at the podium of Shui Chuen O HOS development

As shown in Table 2, the microclimate analysis in a residential development has considered the winter and summer wind conditions. The results of CFD simulation have to be checked against the design criteria for pedestrian comfort.

	Wind Conditions	Wind Comfort Criteria	CFD Simulation
Winter	Wind direction: NE Wind Speed: 3.1 m/s	< 10 m/s (walking)	Estimated maximum local wind speed = 6.5 m/s
Summer	Wind direction: E Wind Speed:2.8 m/s	< 7.5 m/s (strolling or standing)	Estimated maximum local wind speed = 5.7 m/s

Table 2 Results of wind comfort analysis.

4.4 SUNSHADES AND REFLECTORS

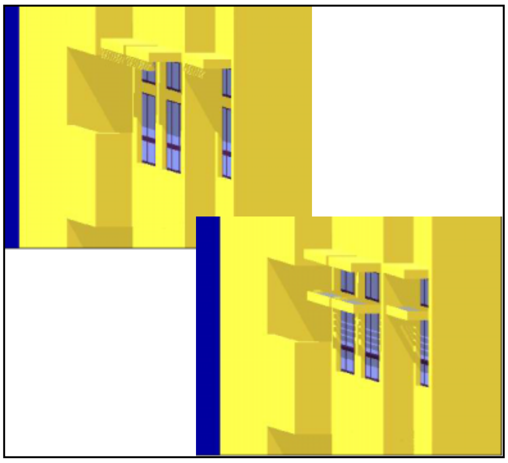


Figure 6. Sunshade (above) and sunshade with reflector (bottom)

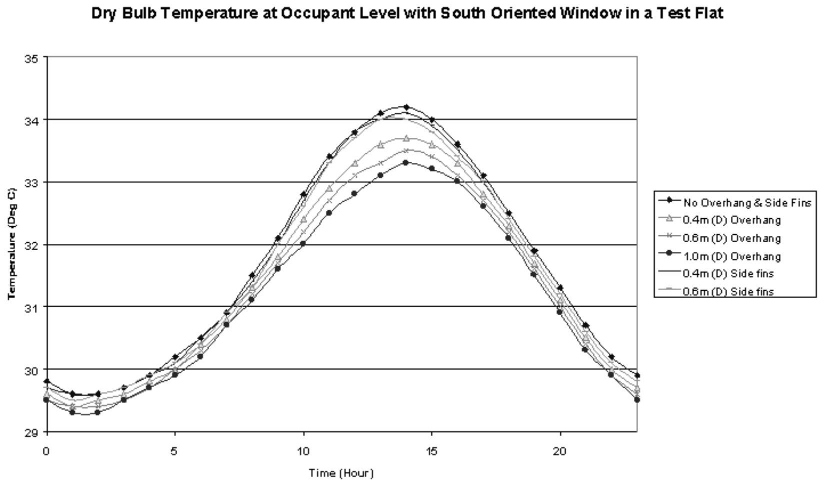


Figure 7. The effect of solar shading on the internal room temperature.

The function of sunshade is to control solar heat gain and to enhance daylight as to reduce the need for artificial lighting. Effective design of sunshades and reflector should block solar penetration but light enhancing systems (Figure 6). The shade can form a light-guiding device which reduces the excess illumination at the window and provides an even distribution across the room. This approach has high potential in Hong Kong where high angles of sun can be diffused by the light shelf and directed to the interior.

The assessment of solar heat gain reduction can be estimated by the DTM analysis. Figure 8 shows the effect of a sunshade in the form of an overhang with different depth, installed at the windows on the south façade.

The performance on natural daylight can be achieved by daylight analysis using computer software such as *Radiance* (Figure 8). The objective of having effective natural daylight and sunlight design is to avoid the direct sunlight component but maximize the daylight penetration.

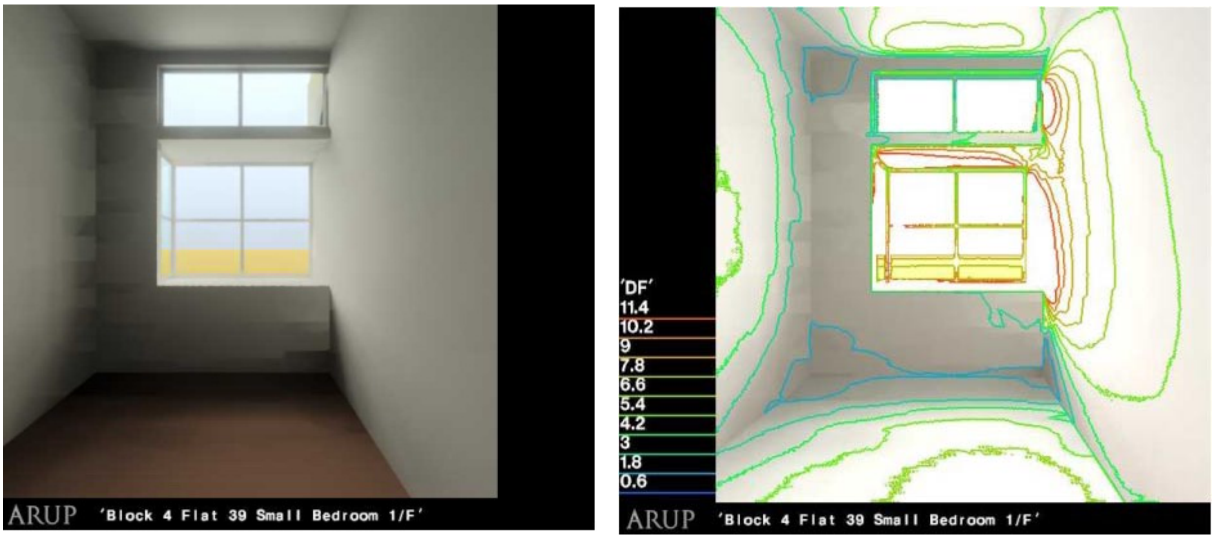


Figure 8. Sunlight (left) and daylight (right) simulation results of Shui Chuen O HOS Development

Performance Parameters	Without Sunshade	With Sunshade (500 mm Overhang)
Glare Index	43.7	32.8
Daylight Factor (DF)	3.2	3.0

Table 3. Results of sunlight and daylight analysis

Light reflector can distribute light evenly and reduce glare as shown in Table 3. It can reflect light off its top surface through the upper glazing to the ceiling, where it is then reflected deeper into the space. Sunshade and reflector may reduce the daylight performance due to their obstruction to the sky component. Their effect, however, is small as shown in the daylight factor determined.

4.5 WING WALL

Single-sided ventilation, normally adopted by the building design in Hong Kong, has poor ventilation because the indoor-outdoor pressure gradient across the opening is very small. Provision of vertical project to any two openings of a face, commonly termed as the wing wall, can generate a higher-pressure gradient across the openings. Experiments carried out by Givoni [7] has demonstrated that the ventilation generated can then be one order higher than that generated by one-side ventilation. As discussed by Givoni [7], the required projection of the wing wall is one-third the depth of the room and can be easily integrated into the architectural design.

4.6 SOLAR CHIMNEY

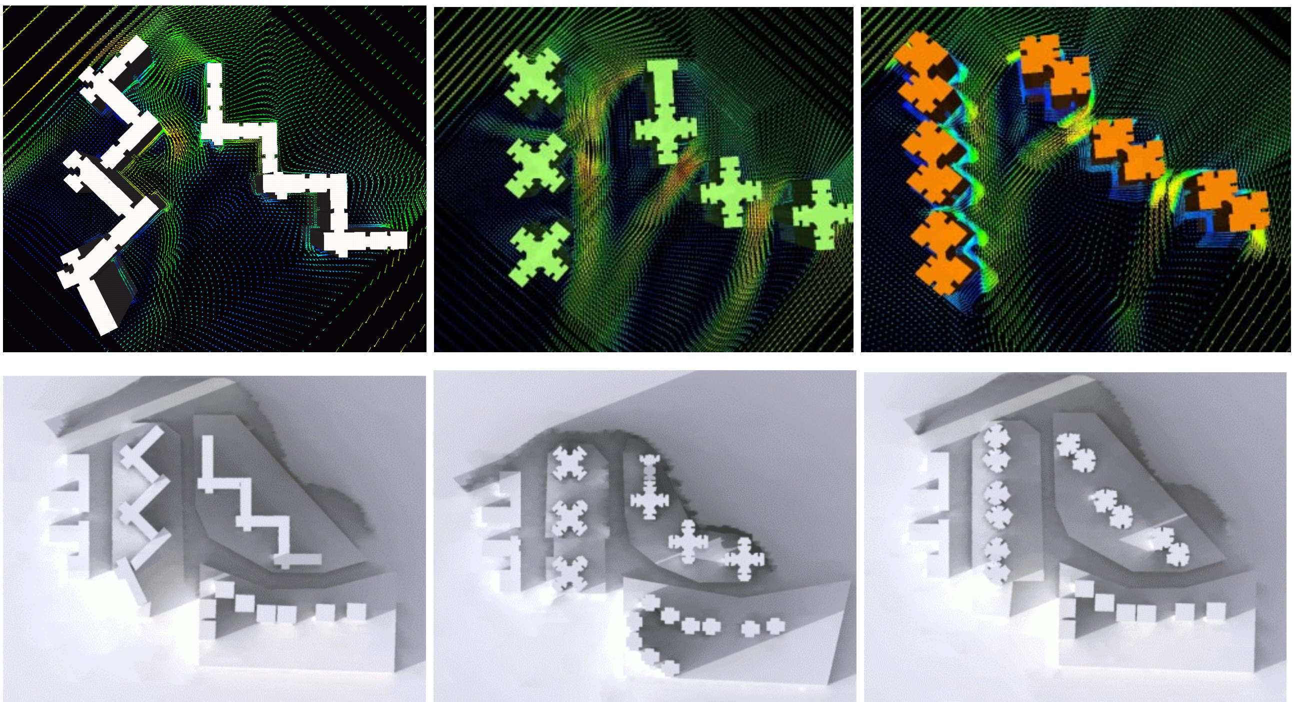
Anther effective method to accommodate the issue of single-sided ventilation is the adoption of solar chimney. Chimney, providing air-extract route for the building, is an effective design for cross ventilation. With the aid of the solar heating action, the buoyancy effect that drives the air movement could be enhanced. Limited by the existing building design practice, solar chimney is not common in Hong Kong. Its effectiveness on high-rise building is anticipated and is worthy to be explored by the building practitioners.

4.7 OTHER BUILDING PARAMETERS

Considerations of factors controlling natural ventilation and daylighting performance not just include the above-mentioned feature but also the massing of buildings and their geometrical factors, which are the building planning parameters. They are the orientation of buildings and openings with respect to the wind direction, building height and separation, building height arrangement and built form.

Orientation of buildings affects ventilation and daylighting performances in two major ways. Orientating the opening, say sky garden opening, to the prevailing wind direction would yield a better ventilation performance. As the west is supposed to be the direction receiving the highest solar heat gain into a flat, especially in the afternoon, avoidance of facing the main façade to the west helps to reduce the indoor air temperature and provides a visually comfortable environment.

Different combinations of building height and their separation will have different effects on the provision of natural ventilation and daylighting, and a general conclusion of their variation is always unable since it is site-specific. CFD prediction can be conducted in the evaluation at the planning and design stage of the development. Sufficient space between buildings and large openings between connecting blocks increases the average ventilation performance of the building. In addition, the amount of daylight received into a flat, particularly at the low-level, is affected by the height of nearby building blocks. The ratio of the building height to the separation between them, ie. blockage aspect ratio, can also be used as an indicator of the performance. Different built form will generate different building performance under different site environmental conditions (Figure 9).



(a) (b) (c)

Figure 9. Air flow diagrams (top) and daylight simulation (bottom) for different built form options (a), (b) & (c).

5. CONCLUSION

Several green features initiated by the Joint Practice Note No. 1 have been assessed using advanced simulation techniques such as Computational Fluid Dynamics, Dynamic Thermal

Model and Lighting Simulation Program for several housing developments in Hong Kong. The objectives are to improve the living environment and reduce energy consumption by making use of the natural resources – natural lighting and ventilation. This paper has demonstrated the performance of these green features in improving the built environment. Also, some building parameters are stated which would also affect the building environmental performance.

6. REFERENCES

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