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Urban Ventilation as a Countermeasure for Heat Islands toward Quality and Sustainable City Planning in Hong Kong

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ABSTRACT

Countermeasures for urban heat islands (UHI) and measures to create sustainable urban living space are a complex and broad subject. The study reported here was one of the initiatives under the government of Hong Kong SAR that addressed the need for countermeasures for UHIs and creating sustainable urban living space, which have been widely demanded for environmental improvement. The thermal quality of the urban living environment in general (e.g., urban air ventilation, the UHI effect, urban greenery, and pedestrian environment) is a significant local issue that affects health and livability. The study formulated a number of countermeasures and recommendations regarding building permeability and separation, building site coverage, and greenery. Only the urban air ventilation recommendations of the study are reported in this paper. As of May 2009, these recommendations are being publicly consulted in Hong Kong. Upon completion of the consultation process, by the end of 2009, the government of Hong Kong will formulate policies and strategies to implement the recommendations.

Background

Sustainable urban living space is a complex and broad subject. In the policy address of the Hong Kong SAR government (2006), one of the priority issues was the quality of the environment. The policy states:

> Hong Kong deserves and can afford a better living environment today. … There exists a strong community consensus on the pressing need to take decisive measures to improve air quality and our environment generally…. What is important is to focus on the overall strategic direction, set targets for different stages, establish guiding principles and introduce specific policy initiatives for environmental protection…. Environmental protection is a long-term undertaking. First, we must adopt a forward-looking strategic approach by setting improvement goals for different stages.

As countermeasures for UHIs, the government is committed to "adopt the concept of greening of rooftops whenever practicable in the design of new buildings. We are studying the wider application of the concept with a view to encouraging more projects to adopt this approach."

According to the *First Annual Implementation Progress May 2006*, the Buildings Department (BD) of the Hong Kong SAR government commissioned a study for the purpose of promoting design features and developing design guidelines for countermeasures for UHIs. By the end of 2008, this study drew up recommendations for improvement. The study focused research on how new building designs can support quality urban living by, among many other things, mitigating the ill effects of UHIs.

Quality urban living space are created within a living and working environment that supports the sustainable development of the city. According to SUSDEV 21, "Sustainable Development in Hong Kong (Susdev21, 1997) requires, amongst many other concerns, reducing the environmental burden we put on our neighbours and helping to preserve common resources." (1999 Policy Address of HK Government). Quality urban living space can be achieved by the combined efforts of town planning and urban design, building design, transport planning supported by policies on energy, transportation, land administration, environmental protection, and so on. Town planning and urban design provide a framework for physical and spatial arrangement of built forms and their three-dimensional relationship with spaces and surrounding settings to achieve a high quality. Building design must have high quality, both within private space and beyond, and be integrated with public space, to explicate innovative ideas that are beneficial to the environment. Seeking ways to implement countermeasures for UHIs in general is a key concern.

Locally, the built environment can create attractive and comfortable urban living spaces and assist in providing a neighborhood context that fosters good health as well as good social relations. A “quality and sustainable building” improves urban climate (e.g., enhances air ventilation, mitigates the UHI effect, and decreases pollution runoff and exhaust emission); enhances the overall quality and comfort of surrounding public spaces and pedestrian areas; and provides a natural, green space and other physical amenities for the benefit and enjoyment of pedestrians and the neighborhood. Thus, the study focused on the local area and specifically on how new building design can support high-quality urban living spaces. The identified key generic urban living space concerns included the following:

1. Urban climate: Urban climate issues, with priority on enhancing air ventilation and mitigating the UHI effect
2. Pedestrian and public spaces: Quality of life and thermal comfort in surrounding public spaces and pedestrian areas
3. Urban greenery: Provision of more natural and green space for mitigating UHIs and for the benefit and enjoyment of pedestrians and the neighborhood

To address the above generic urban living space issues, one effective approach is to promote both urban planning and building design practice. The study focused on how new building design can support these generic concerns, despite recognizing that individual developments at the local level are mostly limited to offering interventions within their respective boundaries.

Through the first stakeholder consultation exercise, held in early August 2006, the key generic urban living space issues relating to new building design were identified and prioritized. The findings reinforced the outcome of the First Sustainable Development Strategy for Hong Kong (2005). The priority placed on urban climate and greenery was also shared by cities, including Tokyo and Singapore, as revealed in the overseas review of the study, while the undesirable pedestrian environment and public space issue was a particularly difficult problem in Hong Kong, given its extremely high density in the metropolitan area. (Tokyo 2005; BD 2005; Singapore Green 2003). Three key priority urban problems in Hong Kong are listed below for further investigation:

1. Undesirable air ventilation and UHI effect
2. Undesirable pedestrian environment and public space (especially in the metropolitan area)
3. Lack of greenery

Although these three issues were considered the top priorities in Hong Kong, air ventilation and related urban climate represented the top concern and pedestrian environment and public space followed closely as the next greatest concerns. The study focused on the building sector objectives that are intended to support higher quality and sustainable city goals. The corresponding building sector objectives are proposed as follows:

1. Promote building designs that facilitates better air ventilation
2. Promote building designs that mitigate the UHI effect
3. Promote building designs that enhance the pedestrian environment and public space
4. Promote building designs that provide more greenery

Due to the limited space available for this paper, only countermeasure 1, the urban air ventilation recommendations of the study, are reported in the following sections of this paper.

A Countermeasure for UHIs: Better Air Ventilation

Through the recent consultancy study, as commissioned by the Planning Department (2003–2005), the feasibility of establishing an air-ventilation assessment system in Hong Kong was assessed (Ng 2004, 2009). Based on a local and international expert review, the performance-based indicator of wind-velocity ratio” (VR) was introduced to scientifically quantify the impact of built developments on their surroundings. It is now known as the Air Ventilation Assessment (AVA).

The feasibility study identified that in the context of Hong Kong, emphasis should be placed on the street and pedestrian level, which represents the focus of public concern with respect to the quality of urban air and public space. In the typical street canyons of Hong Kong, air pollutants tend to be trapped in the bottom 15 m. For narrow and deep street canyons (H:W > 2:1), the pollutant dispersion is difficult at the pedestrian, or bottom, level. For public health and comfort, it is therefore necessary to (1) improve the permeability of the urban fabric and (2) increase the air volume, especially at the pedestrian level, to minimize any stagnant zones.

Regarding performance benchmarks, further extensive consultancy is needed to collect local data for analysis and recommendations. This benchmark development belongs to the second stage of the air-ventilation study, as commissioned under a separate consultancy by the Planning Department. The follow-up study, entitled Urban Climatic Map and Standards for Wind Environment: Feasibility Study, is to be carried out from July 2006 to mid 2009.

At this interim stage, the expert opinion, based on the preliminary results of a parametric study using computational fluid dynamic (CFD) modeling, is that 20% to 30% permeability is considered a reasonable scientific baseline (see Appendix F for more details). The range of 20% to 25% permeability is similar to the openness of the existing urban grids in districts such as Mongkok, where the older buildings typically are only 60 m high. Given the subtropical climate and urban density of Hong Kong, higher permeability, especially at the pedestrian level, should be promoted. In essence, the more wind, the better the urban living environment.

For recommended good practices, according to the feasibility study for establishing an air-ventilation assessment system in Hong Kong, the expert opinion about the prevalent high-rise developments (commonly > 20 storeys) was:

> Where practicable, adequately wide gaps should be provided between building blocks to maximize the air permeability of the development and minimize its impact on wind capturing potential of adjacent developments. As a rule of thumb, the gap between two building blocks should be ideally equivalent to 50% of the combined width of the two blocks. The gaps for enhancing air permeability are preferably provided with the largest permeable area perpendicular to the prevailing wind.

The equivalent permeability was 33%. The two-year Feasibility Study of Establishment of Air Ventilation Assessment System developed certain design features with specific reference to the high-density urban context in Hong Kong. At the individual building level, the relevant key design principles can be summarized as follows:

(a) Permeability along the major breezeway (depending on prevailing wind direction and sea breezes) is the priority.
(b) Permeability at the pedestrian or lower level is of greater significance than at the higher building level.
(c) Greater air volume is needed at the pedestrian or lower level, especially if narrow streets with traffic form deep street canyons where air pollutants and heat become trapped.
(d) Permeability at the higher building level is needed to safeguard air ventilation in the local environment.

The basic concern is to minimize any adverse wall effects at both the lower and upper levels, with particular attention to the prevailing wind direction and waterfront conditions. Where street canyons are unavoidable, especially in the metropolitan area, greater air volume should be promoted at the lower level.

A street canyon is a canyon (a deep narrow valley) formed in a street between tall buildings. The important geometrical feature of a street canyon, its aspect ratio (H/W), is the major parameter influencing air ventilation between the buildings, where H and W are the height of the buildings and the width of the street, respectively. For canyons with an aspect ratio higher than 2, the air flow above the buildings will not easily reach the pedestrian level, where the buildings are tightly packed to form a narrow street, especially when the flow is perpendicular to the axis of the canyon.

Corresponding to the above design principles, the list of building design features, applicable to both domestic and non-domestic buildings, potentially includes the following. They can be categorized into two aspects: pedestrian zone (ground to 15 m) and lower zone (e.g., 15–60 m). The proposed 60 m datum is roughly equivalent to the height of a typical 20-storey building built in the past few decades in the urban area of Hong Kong. The intention is to safeguard reasonable wind availability for the majority of existing buildings in the city.

Pedestrian Zone

- Building setback: Reduced site coverage at ground level on the facing streets and major pedestrian ways
- Split podium: Instead of a single podium with full coverage across the site, creating permeability for the breezeway so sea breezes can pass through the site
- Stepped podium: Reduced site coverage at the podium level above ground level for facing streets and major pedestrian ways
- Void deck: Provision of openings at the ground and pedestrian level for cross ventilation to clean the street directly

Upper and Lower Zones

- Building setback: Setback from streets, especially for widening the breezeway
- Gap or separation between towers: Instead of a substantial wall effect, facilitate the prevailing wind so sea breezes can pass through
- Varied or stepped building profile: Mix towers of different heights, according to the principle that height decreases in the direction from which the prevailing wind comes
- Sky gardens or refuge floors: Provide openings at the upper levels for cross ventilation
- Podium roof gardens under towers: Open above a safe parapet for cross ventilation and loftier podium roof gardens through a raised tower design

Because air ventilation is regarded as the top priority in Hong Kong, there appears to be wide public support for the government to step up the relevant measures, as appropriate. Owing to the fact that the local performance benchmark is under scientific investigation by the Planning Department through the follow-up AVA consultancy study until 2009, an interim recommendation is to adopt the indicator of building permeability to guide building design to achieve reasonable air ventilation. The preliminary guidelines are discussed in the next sections.

Design Guideline for Long Buildings

The building permeability requirement will be applicable to all new development sites equal to or larger than 2 ha. For individual new development sites smaller than 2 ha, the requirement is applicable wherever there is any "continuous projected facade length" longer than 60 m. Continuous projected facade length is defined as the total projected length of the facade of a building or buildings if any separation in between is less than 15 m. Table 1 shows the requirements in relation to building height and site area, taking into account considerations of wind science and practicality (i.e., design constraints) in smaller sites.

In addition to the definition of continuous projected facade length (Lp), the building permeability requirement is based on consideration of both building height (related to air ventilation) and site area (related to design flexibility and practicality concerns, especially in smaller sites). For smaller sites (e.g., < 2 ha.), a minimum building permeability (e.g., P ≥ 20%) is required regardless of building height. The proposed threshold for Lp in this kind of smaller site is based on local practicality considerations and relevant overseas references in ,light of Hong Kong's predominantly high-rise context. In Hong Kong, the length of a street block in an older urban area is approximately 60 m, and the typical frontage of a high-rise residential tower is about 35 to 50m. Therefore, the recommended 60 m threshold for accountable Lp in smaller sites less than 2 ha can address the situation (e.g., if such tower are closely packed together to form a wall-like effect).

For larger sites (e.g.,≥ 2 ha.), regardless of Lp, a medium building permeability (e.g., P ≥25%) is required when H ≤ 60m, while a higher building permeability (e.g., P ≥ 33.3%) is required when H > 60m. The application also follows the four design principles outlined below.

Design Principle 1: Building Separation (S)

The required building permeability will first be provided in the form of building separation (S), the accountable width of which is proportional to the length of the adjoining facades, in accordance with the stipulated building permeability criteria and in no case smaller than 15 m (Figures 1 and 2). Taking into account the immediate context, the 1/2 S criteria can be applied to the facade ends, with separation distance measured from the adjoining boundary line or the centerline of the adjoining street. The building permeability provides air paths through the development site to the neighboring areas.

Table 1. Building height and permeability

Building Height (H)	Building Permeability (P)	
	For site < 2 ha.AND with any continuous projected facade length >= 60m	For site <=2 ha.
<= 60m	1/5 or 20%	1/4 or 25%
> 60m	1/5 or 20%	1/3 or 25%

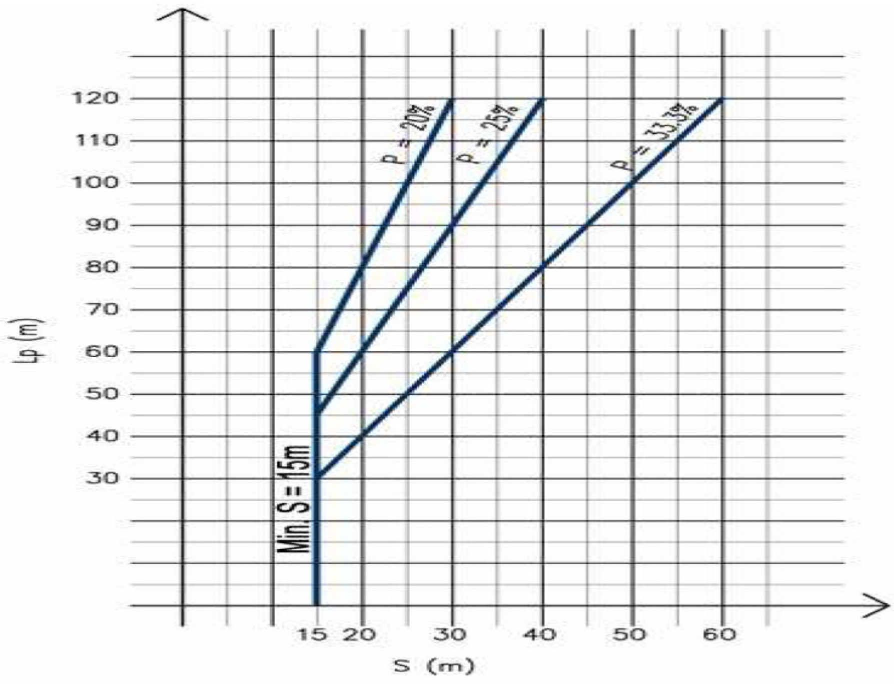
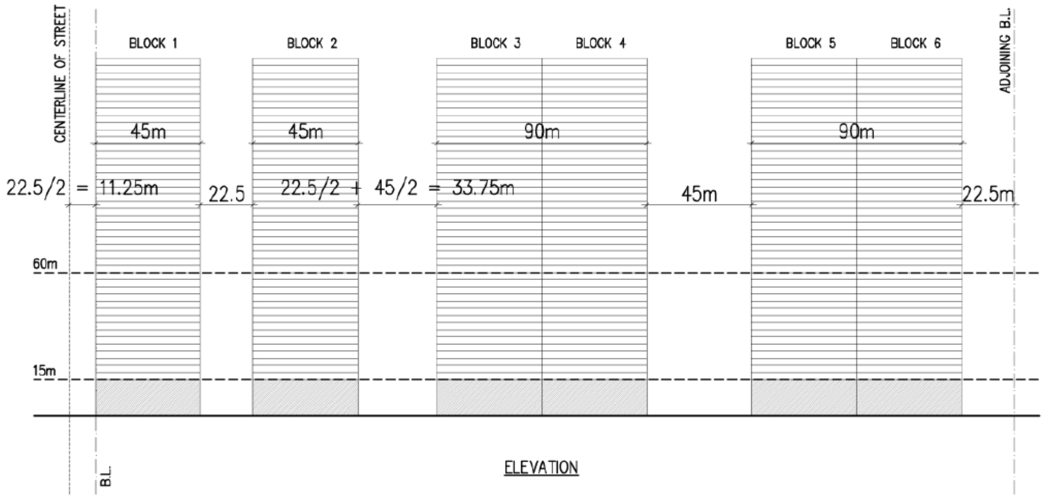


Figure 1. Building separation (S) requirement for different continuous projected facade length (Lp) at different building permeability (P).



$$\text{Total } S = 11.25 + 22.5 + 33.75 + 45 + 22.5 = 135\text{m}$$

$$P = \frac{S}{S + Lp} = \frac{135}{135+270} = 33.3\%$$

Figure 2. Example of building separation (S) calculation: H > 60m and site > 2 ha [i.e., building permeability (P) ≥ 33.3%].

Design Principle 2: Maximum Permissible Length of Lp

While the permissible length of individual facade (L) is governed by the design principle 1 in relation to the width of building separation (S), another contextual consideration relates to the maximum permissible Lp to the size of street canyons, if any, faced by the concerned facade. Lp shall not be larger than 5 times the mean width of the adjoining street canyons (Figure 3).

Design Principle 3: Design Alternative to Building Separation

Although building separation (S) is considered the most direct and effective means for air ventilation in the high-rise context of Hong Kong, design flexibility can be allowed to slightly vary the stipulated building separation area (e.g.,, up to one-third of the stipulated minimum area), provided the permeability area is offset within the adjoining façade zones defined by both vertical and horizontal zoning. The facade zones are vertically divided into three levels, given the consideration of the prevalent form of the urban context and environmental condition in Hong Kong (Table 2).

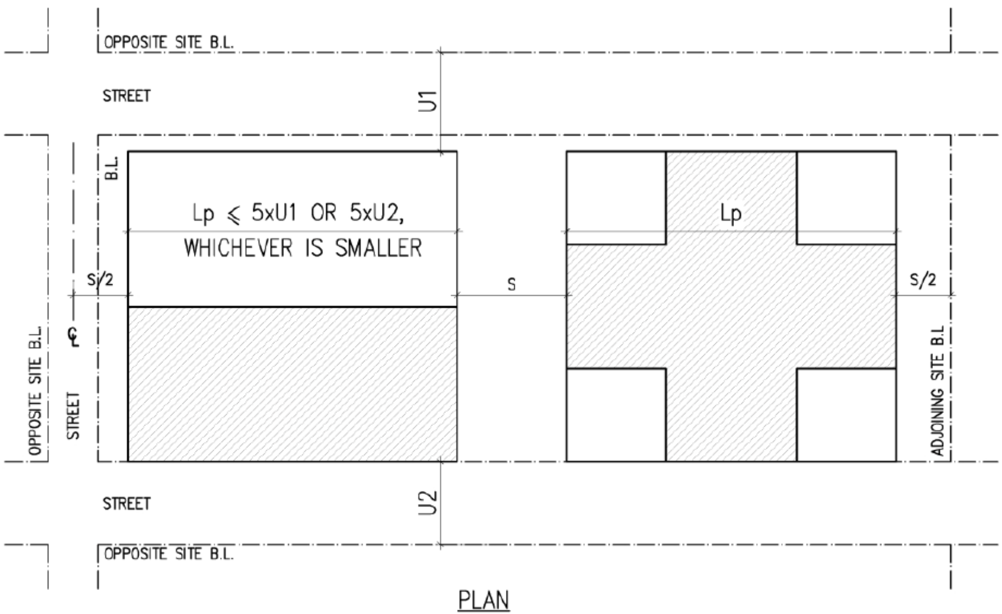


Figure 3. Relationship between overall continuous facade length (Lp) and the size of the adjoining street canyon (U).

Table 2. Vertical zones and design features for air ventilation

Vertical zone	Height range	Design features #
Pedestrian	10–15 m	Void deck, building setback, podium garden with cross ventilation design
Lower	15–60 m	Podium garden with cross ventilation design, Building setback, sky garden, refuge floor, varied building profile
Upper	Above 60 m	Building setback, sky garden, refuge floor, varied building profile

The permeability areas of the design should be determined by their respective open area for effective cross ventilation. Reduction factor may have to be further considered for very small openings. As a preliminary indicator, 3 m clear height and width can be considered the minimum dimension of an individual open area. Permeable railing design or similar can be reasonably accepted as long as such a provision does not materially affect the ventilation performance of the opening.

Horizontally, the facade zone is divided by the centerline of the facade surfaces in between the respective building separations. Typical means to offset the permeability area of building separation include the options in Figure 4.

Design Principle 4: Performance-Based Design Alternative

Because the performance-based method for AVA systems was developed under the feasibility study of the Planning Department, any special design (e.g., split podium design) cannot be done for a mass transit station or depot, large sports facility, or civic center, and must take the alternative approach, as long as an equivalent or better performance is achievable for air ventilation through wind tunnel modeling or CFD testing.

For development sites where most pedestrians are at an elevated level rather than at ground level, it can be demonstrated on a case-by-case basis that the building portion below the pedestrian level will not cause any material problems to sensitive users with respect to air ventilation. As such, the building separation requirement may be favorably exempted by the relevant authority for the concerned building mass at a lower level (Figure 5).

Some local developments at large sites have a potential wall effect problem with respect to air ventilation that should be separately reviewed to assess the implications. In a case with site constraints (e.g., development at a very small site where it is hard to accommodate the necessary functional areas at the G/F and podium levels if a setback is required), the approval authority should have the discretion to accept a reduced requirement to suit that case. Exemptions can be considered based on the individual merits of each case. Special circumstances (e.g., the physical location, immediate environs, and conservation of a heritage site) as well as particular functional requirements may render compliance impracticable or impose unjustifiable hardship.

In regard to narrow street canyons, signboards of a large size can further block the air flow near the pedestrian zone. Vertical signboards are preferable from the perspective of air ventilation. A separate study is required to better understand the implications for city planning.

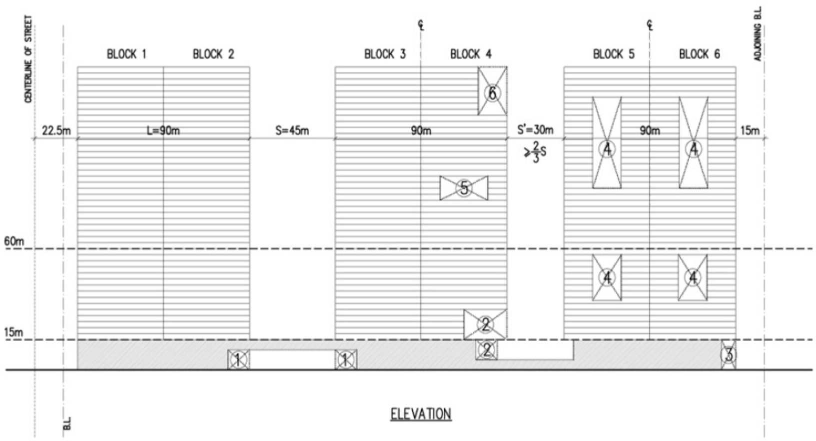


Figure 4. Typical alt ... uilding setback, (4)

Fig. 5.9 Typical alternative means to offset building permeability (P):

1. Void deck
2. Podium garden
3. Building setback
4. Sky garden
5. Refuge floor
6. Varied building profile

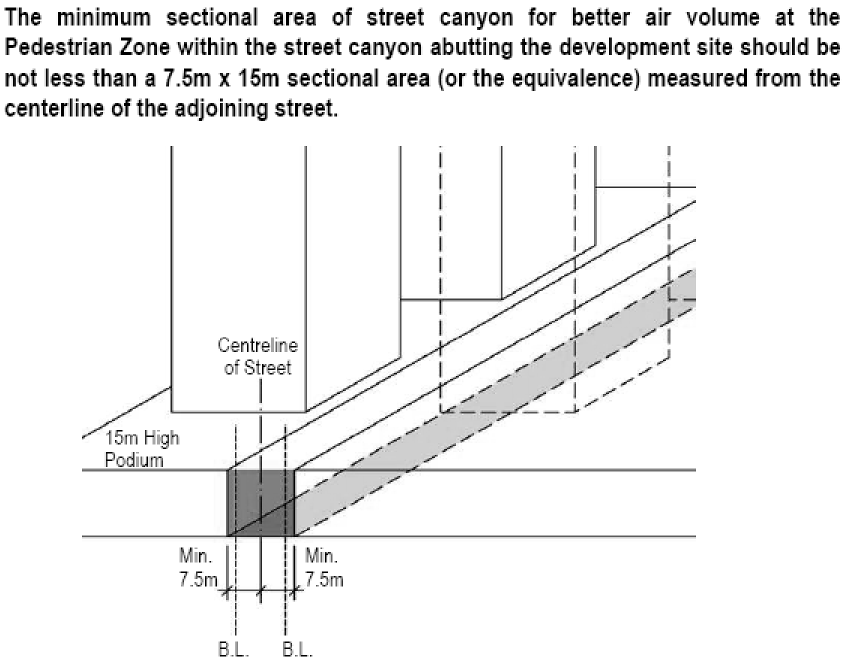


Figure 5. Design guideline for sites in urban areas facing narrow streets forming deep street canyons with H/W >2.

Note:

The above requirement is based on the following two assumptions:

1. A similar building setback at the pedestrian zone will be provided on both sides of a narrow street over time, so an effective air volume is achieved in a cross-sectional area of 15 m x 15 m at the bottom of deep street canyons, as the baseline to improve air ventilation.
2. This 15 m x 15 m sectional area of street is applicable to the typical urban context in Hong Kong; the podium is 15 m high and the towers are located above, with gaps in between.

Implementation

As of May 2009, the recommendations for countermeasures for UHIs are being publicly consulted in Hong Kong. Upon the completion of the consultation process by the end of 2009, the government of Hong Kong will formulate policies and strategies to implement the recommendations.

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