Hong Kong Residential Buildings with Reduction of the Utilisation of Air Conditioning

Ferdinand Oswald

Institute of Architecture Technology, Graz University of Technology
Rechbauerstr. 12/I, 8010 Graz, Austria; ferdinand.oswald@tugraz.at

Abstract

Over recent decades, residents of large tropical and subtropical cities living in modern buildings have been making increasing use of split-air conditioning systems. The utilisation and power consumption of these systems in humid and hot subtropical regions is colossal, the latter being a major disadvantage of air conditioners. It is assumed that air conditioning in the seven-million metropolis Hong Kong alone requires additional energy amounting to 6.8 GWh per year (Figure 1).

The problem definition outlined above raises a number of questions that will be clarified in the course of this paper. The main question in this paper is concerned with the possibility of employing architectural means to provide sufficient comfort in HK without having to use air conditioners. How can architects promote the potential of technologies and traditional concepts, or even initiate them? Hong Kong Housing Authority Residential Building will show up answers to these questions.

Figure 1. Residential Building with split air-conditioners, HKHA © Ferdinand Oswald

1. Introduction

The South Eastern Chinese coastal region with its 150 million inhabitants requires an energy quantity of 145 GWh per year to cool their apartments with air conditioners [1]. At the same time, these split-system air conditioners continue to heat up the urban environment with their warm exhaust air, discharging 40% of required cooling energy in the form of heat into the ambient air, thus also exacerbating negative effects of the urban heat island. According to statistical calculations, the worldwide urban population will almost double by 2050, increasing from 3.5 billion to 6.3 billion [2]. Subsequently, energy required for cooling will almost double by 2050 as well [3]. Given that the urban population cannot do without air conditioning, this forecasted growth is bound to pose a huge challenge to energy production and the carbon footprint. For future conurbations in sub-tropical regions, therefore, it will be of crucial importance to seek specific solutions for problems such as overburdened energy grids and local climate change. Reducing the use of split-system air conditioners is an urgent issue. It seems possible to increase comfort and reduce mechanical ventilation at the same time with the help of specifically natural ventilation systems for residential housing in tropical regions. Results from specific research projects [4] and scientific measurement furthermore produced evidence that specific natural cross ventilation can optimize human behaviour for periods of up to 85% of the year (e.g. Hong Kong) [5] (Figure 2).

1.1. Ngau Tau Kok Estate, Hong Kong

Upper Ngau Tau Kok Estate is one of Hong Kong Housing Authority’s few estate projects that was tailored to the specific location, and this Site Specific Project was to enable enhanced natural ventilation as compared to HKHA’s other high-rise estate projects. This paper investigates the extent to which Upper Ngau Tau Kok
Estate’s position in the urban context, its building typology and façade apertures influence natural ventilation of habitable space, and will look into possibilities of using thermal mass and assess the effects of solar irradiation as well (Figure 3).

2. Project description

Planned by Hong Kong Housing Authority as a novel residential high-rise typology at the turn of the millennium, Upper Ngau Tau Kok Estate complex was fully completed in 2009 in place of MARK V typology buildings that HKHA had developed in the 1960s. In 1989, HKHA had already begun to redevelop the area, demolishing the old high-rises and gradually replacing them with new ones. In 2009, finally, five of the old residential blocks had been replaced by six new ones consisting of 780 dwelling units. The new Upper Ngau Tau Kok Estate offered 4,584 new flats in all.
Since this new estate is higher than the old one, it not only offers more habitable space within the same area, but higher air speeds around the upper storeys of the now higher buildings allow for more effective natural ventilation. Moreover, the new Upper Ngau Tau Kok Estate has a larger range of dwelling typologies, with six different one to two room dwelling types in the residential blocks. One major difference to the previous housing typologies is that natural lighting and ventilation have been improved in the circulation areas and access corridors, which are arranged centrally between the dwellings in the respective wings. The photo shows a corridor in HKHA’s former MARK V residential block without any natural lighting and ventilation (Figure 4).

2.1. Climate

Hong Kong is situated at a latitude of 22.3°, just below the Tropic of Cancer (23.5°). The city receives regular sunshine from the north throughout the year with southern insolation varying strongly from season to season. In winter, there is more direct southern insolation than in summer. This is explained in more detail in the chapter “Reduction of solar heat gain”. Annual solar altitude and path in Hong Kong are as shown in the stereographic illustrations.

In Hong Kong, winters are mild with minimum temperatures dropping to 6.4°C and summers are hot with maximum temperatures climbing to 34.2°C. As explained in the previous chapter, Hong Kong’s climate is comparable to that of Guangzhou’s, since these cities are not far apart. The principal difference between both cities is that Hong Kong is located on the coast and Guangzhou lies further inland. Summer winds arrive mainly from the east, blowing from the sea over the mountain – at speeds of between 15 and 25 km/h. Hence, due to the flat sea, Hong Kong has more lively winds than Guangzhou (Figure 5).

2.2. Location

Upper Ngau Tau Kok Estate is located in Hong Kong’s Kwun Tong district in the urban area of Kowloon. With a population of 55,000/km², Kwun Tong is the most densely populated of Hong Kong’s eighteen urban districts. Kwun Tong is separated from the centre of Kowloon by a bay, where the old airport Kai Tak was once situated. Ever since the new airport was built outside Chek Lap Kok in 1998, HKHA has been revitalising the artificially filled Kai Tak peninsula as a housing development area. In Kwun Tong, Ngau Tau Kok is situated on a slope facing the bay. In the past, before the reclamation of land, the coastline was shaped like the horn of an ox – which is the literal translation of the
Figure 6. Site plan, Upper Ngau Tau Kok Estate, Hong Kong with living unit no. 3202 (red dot), © CADbasis-data from Hong Kong Housing Authority, reworked by Ferdinand Oswald, 2013

Figure 7. Wind analysis showing main wind from the east in summer in Upper Ngau Tau Kok: old MARK V building (left) and new Site Specific Project (right), © Hong Kong Housing Authority, 2009; reworked by Ferdinand Oswald, 2014

Figure 8. Wind analysis showing main wind from the east in summer (left), from southwest in summer (centre) and from north in winter (right), Upper Ngau Tau Kok Estate; wind analysis © Hong Kong Housing Authority, 2009; reworked by Ferdinand Oswald, 2014
Cantonese name Ngau Tau Kok. With a population of over 210,000, Ngau Tau Kok is one of the most densely populated quarters in the Kwun Tong district.

3. Natural ventilation

3.1. Positioning in the urban context

Upper Ngau Tau Kok’s position in the urban fabric is based firstly on the shape of the site; secondly, on the buildings’ orientation to the sea and configuration parallel to the mountain; and thirdly, on the wind’s main direction for optimisation of natural ventilation (Figure 6).

1. Due to the misshapen and irregular building site, the buildings were not able to be configured orthogonally, but were arranged slightly skewed toward each other instead. Both snake-shaped building arrangements are differently orientated, with the third residential tower twisted out of the building line.

2. Due to topographical circumstances, i.e. the length of the slope, the buildings are in a parallel position to the contour lines of the hill. This is advantageous for most of the dwellings facing the west, as they now have an open view to the sea and lagoon containing the Kai Tak peninsula.

3. In a wind analysis by Hong Kong Housing Authority, the old (left) and new (right) buildings of Upper Ngau Tau Kok are visible. This scenario shows the main wind coming from the east in summer as well as the wind corridor running from north to east between both snake-shaped high-rise complexes each consisting of three residential towers. This enables the main wind stream to pass freely through the building configuration. Both illustrations show how the buildings’ urban configuration optimises the wind flow. By contrast, the old MARK V buildings stood at right angles to the main wind stream so that not all parts of the buildings were naturally ventilated in an optimum way (Figure 7).

Hence, both structures are arranged with respect to prevailing easterly winds, forming a central corridor through which the wind flows, thus ventilating the free space on ground level and the other buildings very well. HKHA’s wind analysis continues with a detailed representation of natural cross ventilation of the buildings during prevailing easterly winds. In summer, the second most frequent wind comes from the southwest, with the ventilation principle working well from an almost opposite direction, too, as shown in a further wind graph compiled by HKHA.

In winter, average temperatures reach approximately 15°C. These low temperatures mean that no natural ventilation for cooling is necessary. On the contrary, residents close their windows in order to retain indoor warmth and to prevent it from being carried away. Winter winds usually arrive from the north (see third illustration). The buildings now stand tangentially to the direction of the wind so that it flows parallel to the building complex, thus reducing the force of cross ventilation within the complex. Their configuration is thus tailored to the requirements of all seasonal wind and weather conditions (Figure 8).

3.2. Building structure

The typology of the five identical high-rise blocks was specifically developed for Upper Ngau Tau Kok Estate. Five of the six residential towers have an identical design in order to keep costs low by cutting planning expenditure and using prefabricated building elements. Only the sixth tower differs from the others in shape. As regards its ideal position on the site, the building wings are placed slightly askew so that they do not stand fully in an orthogonal grid. All individual towers feature symmetrically mirrored and reproduced L-shaped wings in the centre, thus forming an S-shaped complex: each residential block therefore consists of two identical L-shaped wings. Each building wing houses an access and circulation area with three elevators and an emergency stairwell. In the centre of both wings – i.e. on the axis of reflection, there is a third stairwell. Each storey contains 20 dwelling units. Building heights of the six blocks range between 35 and 40 floors. The building in the focus of this study is block no. 4 with 40 floors. The ground floor, which is called first floor in Hong Kong, contains semi-public access areas. Therefore, this building has a total of 39 habitable floors with 780 dwellings that are all accessible via a central corridor (Figure 9).

3.3. Façade

Typical for HKHA’s residential high-rise typologies are the recesses in the façade that act as vertical ventilation shafts to air the bathrooms and, partly, also the kitchens. One special feature of Upper Ngau Tau Kok’s typology is that these recesses are continued right through to the corridors (access areas). In both central wing areas, this characteristic recess cuts through the entire depth of the floor plan, making Upper Ngau Tau Kok estate so unique.

Based on computer-assisted wind simulation, HKHA investigated the functionality of natural cross ventilation by ascertaining wind speeds around the building when corridors were open or closed. Both simulations show
Figure 9. Floor plan, residential block no. 4 of Upper Ngau Tau Kok Estate showing dwelling unit no. 3202 (in red) with axis of reflection, wind speed measuring points, wind direction, negative and positive pressure (+ or -) during 24 hour period on 24 and 25 August 2013 made by Ferdinand Oswald, © CAD basis data courtesy of Hong Kong Housing Authority, reworked by Ferdinand Oswald, 2013

Figure 10. Wind simulation: open corridors (left) and closed corridors (right) with main wind from the east in summer, Upper Ngau Tau Kok Estate, © wind simulation: Hong Kong Housing Authority, 2009, reworked by Ferdinand Oswald, 2013
areas in various shades of blue to grey representing low to high wind speeds respectively. Dark blue areas in the wind simulation figure on the right indicate lower wind speeds, while in the simulation figure on the left, light blue to light grey areas signify higher wind speeds. A closer look at the figures reveals that airflow is intensive through both open sides of the corridors (Figure 10).

In residential block no. 4, the Sheung Wing House, wind intensity was recorded as wind speed on the 32nd storey at 17 different façade openings as well as on the 41st storey, the roof storey, in hourly intervals in the course of a 24-hour period. The floor plan shows the measuring points, outward and inward wind flow as well as positive and negative pressure conditions (+ or -) during the period of measurement on 24th and 25th August 2013. At the time of measurement, prevailing winds blew solely from the east (see arrow "wind direction"). Interestingly, wind flow into the building on the western façade occurred from the opposite direction to oncoming winds from the east. A closer look at dwelling unit no. 2 (marked red in the floor plan), which is situated on the western side of the building, reveals that the wind flows into the openings from the opposite direction to the oncoming wind. This is caused by differences in air pressure, a fact that becomes evident when looking at the bigger picture – in this floor plan, positive pressure is represented by (+) and negative pressure by (-). Depending on the wind’s direction, this very high building creates various zones of pressure. As a rule, high pressure builds up on the windward side, and low pressure forms on the leeward side. However, on the western façade of the building under investigation, things were quite different. Although this façade is on the leeward side of the building, a zone of positive pressure builds up, forcing the air stream into the units. This has to do with the unit being a corner flat where the two outward sides of the building meet, thus promoting the formation of strong eddies. In this process, air is pressed around the edge of the building, which creates positive pressure. In addition, upward and downward air currents evolve, for instance, from air heating up and rising. Such factors can also lead to changing air pressure conditions at the façade of the building.

During wind speed test measurements at the openings of the façade, peak wind speeds of up to 3.1 m/s were recorded, while outdoor air speeds reached 1.7 m/s. To avoid interference caused by built structures, the outdoor air speed (measuring point 1*) was recorded in the free space between both building complexes on the ground floor. A wind speed of 1.7 m/s corresponds to wind force 2; wind speed of 3.1 m/s corresponds to wind force 3. But lower wind speeds, too, (0.8 m/s) would suffice to create sufficient wind flow for a comfortable indoor environment.

Wind speeds of between 1.5 and 2.2 m/s were recorded chiefly at the corridor openings (measuring points 7^ and 11^). Situated in the central area of the building structure, these openings are therefore very effective in providing natural cross ventilation. Notably, during the period of measurement, there was an interval of almost complete calm between 5 pm and 1 am with wind speeds of merely 0.0 to 0.5 m/s at many measuring points. High humidity (90%) and temperatures (29.2°C) can cause discomfort if there is no wind at all.

3.4. Floor plans

HKHA allowed us to test unit no. 3202 for a few days. Designated as number 02 on the 32nd floor, this tiny unit of the Upper Ngau Tau Kok Estate with a net dwelling area of 18.27m² is described as a “small flat” designed for one resident. It consists of one central room with an entrance door, and a kitchenette, both with windows facing west. There is a tiny bathroom containing a shower in the space between the kitchenette and a vertical ventilation shaft. A small vent in the bathroom’s eastward wall connects to this ventilation shaft, which faces south, as the floor plan of unit no. 3202 shows. (Figure 11).

![Figure 11. Floor plan, unit no. 3202 in Upper Ngau Tau Kok Estate, Hong Kong, China, showing cross ventilation and thermal mass during the day and at night, with measuring points of air and surface temperature measurements and wind speed measurements made by Ferdinand Oswald, CAD basis data © Hong Kong Housing Authority, reworked by Ferdinand Oswald, 2013](image_url)
These openings on both sides of the corridors not only promote cross ventilation at this particular point, but also produce a substantial wind stream throughout the entire building, which supports the cross ventilation of all dwelling units. At the same time, low pressure from the corridor virtually draws the air out of the flats. In that way, the units are cross-ventilated via the corridor. Residents of Upper Ngau Tau Kok Estate are very happy with the possibility of cross-ventilating their flats via the corridor, and do so by opening their entrance doors. Here, peak air speeds of up to 2.6 m/s were recorded at measuring points 14\textsuperscript{a} and 15\textsuperscript{a}. At the entrance door of the test unit no. 3202 (4\textsuperscript{a}), high air speeds of up to 2.9 m/s were measured. All three measurements were carried out at a similar time of the day while outdoor air speeds only reached 1.5 m/s (measuring point 1\textsuperscript{a}). To sum up: cross ventilation via unit entrances was found to be very effective, building up higher air speeds than outdoors. Cross ventilation works so well in this corridor via its relatively distant openings, because air pressure on the façade forces the air through these small openings.

Air speeds are higher at the unit entrances than at the windows in the façade. At both window apertures of the main room and kitchenette facing the west, air speeds only reached a maximum of 2.4 m/s. This is because the total cross-section area of both openings is larger than that of the entrance door, and the same amount of air entering the flat through these larger façade openings has to exit the flat through the smaller entrance door. Air pressure is therefore equal at this point and airflow picks up speed when it passes through the smaller opening. Furthermore, there is additional airflow from the bathroom window. This air current flows from the vertical ventilation shaft in the southeast into the bathroom window in the east, passing through the bathroom into the living room, where it exits the flat through the entrance door together with the main air stream. Both bathroom openings can be seen in the photo (Figure 12a) showing the vertical ventilation shafts.

3.5. Openings

Window openings

The window frames and openers are made of aluminium. This material is ideal in Hong Kong’s humid climate, as it is highly resistant to rust and corrosion. The photo shows (Figure 12b) façade openings of the units with differently glazed elements. In the centre of the largest opening, two large elements are openable to the outside. Above them, there are two smaller openers in the upper part of the window and below them, two fixed glazings in the parapet area. To the upper right of the large openings, there is an additional opening required for mounting and inspection work of the split-system air conditioning unit. If an air conditioning device were to block this opening, it would allow less air and light into the flat.

All of these windows, except for the ones in the parapet area, are openable and equipped with a fastening mechanism that locks the openers in the desired position (Figure 13). In that way, residents are able to operate their windows to suit their own needs according to weather conditions such as wind force, air temperatures and humidity. Once the window is locked into position, it remains in that position even when winds are strong. Figure 14 shows unit 02’s different windows (to the outside left), which are very well suited to this location and excellently operable as regards natural ventilation and controllability of airflow.

---

**Figure 12a. Vertical ventilation shaft with bathroom openings and exterior pipe system for water supply and removal at Upper Ngau Tau Kok Estate (Photo © Ferdinand Oswald, 2013)**

**Figure 12b. Window in the living room of unit 3202 at Upper Ngau Tau Kok Estate (Photo © Ferdinand Oswald, 2013).**
Instead of being hinged on the outer window frame, the window openers are connected to a point about 10 cm further inwards. Subsequently, when the window is open, there is a gap between the frame and the opener. Residents use this gap to clean the outer panes without having to lean out of the window. Thus, this convenient window construction also prevents falls.

Since this type of window is not hinged on the outer frame, it is divided into several smaller openings. Apart from cross ventilation, this sequence of openings could also be used for unidirectional ventilation. Low pressure forms on the leeward side of overhanging vertical window openings or elements, causing air to flow out in the wind shadow (negative pressure) of such an opening. This principle is shown schematically in the graphic (Figure 15). Whether or not unidirectional ventilation attenuates the effect of cross ventilation remains to be investigated. Parapet height is 1.10 m according to Hong Kong Building Regulations. However, windows are equipped with an additional safety guard to prevent smaller children from reaching said barrier with the help of a chair, table or similar object. That is why the safety guard is designed to cover the whole length of the window.

Door openings

Effective cross ventilation occurs via the entrance doors of the flats. This, in turn, leads to problems concerning privacy or intrusion when the door is open. However, an excellent solution to this problem has been found. Each entrance has two doors: an ordinary wind-proof, opaque wooden door leaf that is closed when leaving the flat; the second door is a wooden lattice sliding door that can be slid shut. This door lets air into the room while keeping intruders out. It only allows people to peer through the wooden latticework from the outside. Some residents block out unwanted views by attaching a curtain to the door that does not hamper the effectiveness of cross ventilation (Figure 16).
4. Thermal mass

In order to ascertain whether exposed thermal mass is utilisable for cooling during the hottest season in Hong Kong, a test series in the residential high-rise complex Upper Ngau Tau Kok was carried out. For this purpose, the bathroom of unit no. 3202 seemed most suitable, since that room is located at the outer edge of the building where the wall faces south, thus providing hypothetically ideal conditions for cooling with thermal mass. Surface temperatures of this southern façade were measured to test and monitor effects of thermal mass as a possible cooling agent. During the measurement period for thermal mass evaluation, the bathroom door and window element remained open towards the vertical ventilation shaft to allow cooler night air to carry away the stored heat from the exterior wall (Figure 17).

Indoor and surface temperatures of the bathroom wall recorded in the chart “Surface temperatures south façade – bathroom inside” [6] yielded the following results: daytime temperatures inside the bathroom were lower than the temperatures outside. Cool night air stored in the outer wall was passed on to the inside with a time lag. The reason for this is that the massive wall facing south only receives a low level of direct solar incidence in summer – a fact that has already been elucidated in this chapter in the chart showing direct solar incidence in Hong Kong. Another reason why the thicker loadbearing exterior wall is suitable for cooling is that its thickness is ideal for temperature transfer: a 30 cm thick wall effects a phase shift of approx. 24 hours.

Hence, the temperature curves of outdoor temperatures and surface temperatures of the interior wall run conversely and time-lagged. The indoor temperature of the bathroom benefit from this process: temperature peaks are buffered thus providing a comfortable temperature that lies somewhere between both extremes. Characteristics of this temperature curve are clearly shown in the chart (Figure 18).

5. Psychrometric chart

5.1. Solar heat gains in winter

The area of passive solar heat gains is marked in red to the left of the comfort zone. Here, it is again shown separately outside the chart, together with the comfort zone. Measurements obtained at Upper Ngau Tau Kok housing estate were taken in the summer only, thus no winter data is available. However, the simulation in the psychrometric chart suggests that solar heat gains could also be utilised at this location in winter. A certain number of points (days) during the colder months
Figure 17. Comparison of different roof superstructures and temperatures inside during the day and night, chart simulation program PasCal (v.1.0), source: C. Tantasavasdi, T. Chenvidyakarn, M. Pichaisak, Integrative Passive Design for Climate Change: A New Approach for Tropical House Design in the 21st Century; Faculty of Architecture and Planning, Thammasat University, Thailand; Department of Architecture, University of Cambridge, UK, published in BUILT, 1 (1), 2011, p. 14

Figure 18. Surface temperatures of southern façade inside and air temperatures outside and inside the bathroom of unit no. 3202 of Upper Ngau Tau Kok Estate, Hong Kong, China, measured from 24 August 2013, 4 p.m., to 25 August, 7 p.m.; 1: temperature outside; 3: air temperature bathroom interior, 7: façade surface temperature inside, © Ferdinand Oswald, 2013
plotted in the area of passive solar heat gains proves that. In particular, heat gains could be utilised in the west, east and south. However, it needs to be noted that this would not save any energy, since residential housing in Hong Kong is not equipped with appliances for indoor room heating. Having said that, it could nevertheless contribute to enhancing indoor comfort in the colder season.

5.2. Thermal mass

According to the simulation programme in the psychrometric chart, both heating and cooling by means of thermal mass seem possible in Hong Kong. The effectiveness of cooling with thermal mass during the hot season is shown by the number of days within the blue line’s left hand area. This simulation suggests that thermal mass could be utilised for cooling for a substantial period of time, as confirmed by measurement results obtained in summer at Upper Ngau Tau Kok.

Opposingly, the dark red area indicates that there is no possibility of using exposed mass and night-purge ventilation for enhancing comfort because no points (days) are plotted in that area for Hong Kong.

This does not correspond to the results obtained on the spot. As explained in detail earlier, night-purge ventilation further optimizes the principle of thermal mass combined with additional night-purge ventilation in the way that the massive wall dissipates stored daytime heat that is then carried away by night ventilation. This is probably not expressed in the chart because day and night temperature differences obtained from official weather data are too small, and therefore night temperatures are not low enough to remove the heat from the thermal mass. According to Hong Kong meteorological office, the highest temperature on the day of measurement (24th August) was 31.1°C and the lowest was 27.3°C. That is a day/night difference of only 3.8°C. In the same measurement period, however, a maximum temperature of 30.8°C and a minimum temperature of 26.2°C was recorded at the spot, i.e. a greater day/night temperature difference of 4.3°C. At any rate, this difference would be large enough to cool indoor temperatures down to 27°C.

5.3. Natural ventilation

According to the simulation, natural ventilation is the most effective method of improving comfort levels in Hong Kong, as shown by the number of days (points) plotted within the pink-framed area representing natural ventilation. This area lies above and to the right of the comfort zone. In mid-summer, this cooling technique could improve comfort on almost all days. Measurements taken at Upper Ngau Tau Kok housing estate in August, i.e. the hottest season, suggest that this cooling technique would work very effectively.

5.4. Evaporative cooling

No measures relating to evaporative cooling were found at Hong Kong’s Upper Ngau Tau Kok. According to the psychrometric chart, there is no possibility whatsoever to enhance comfort by means of evaporative cooling in Hong Kong, as clearly shown by the two areas of direct (purple) and indirect (turquoise) evaporative cooling, situated in the simulation beneath, to the right and particularly above the comfort zone. Evaporative cooling does not work in Hong Kong because humidity is high during most of the year and saturated air cannot absorb any further moisture (Figure 19).

6. Potential for improvement

Conclusion

Measurements taken at the location show that natural ventilation works well at Upper Ngau Tau Kok Estate. Electrical power required for air conditioning systems could therefore be saved. Nevertheless, there is room for improvement at Hong Kong Housing Authority’s Upper Ngau Tau Kok Estate.

Structure of façade

This typology has potential for cooling with thermal mass, provided day/night temperature differences are large enough and a reduction of solar heat gains in massive façade elements is given. Danger of overheating façades from the north is relatively small, and it is therefore not necessary to shade façade areas. Low solar intensity is shown in the above figure representing direct solar incidence from the north in blue.

The southern side of the façade is destined for the use of thermal mass, as direct solar radiation is weaker in summer and stronger in the cooler winter months (see above chart showing direct solar radiation from the south in green). Here, external factors of solar irradiation could be utilised ideally for enhancing indoor comfort: in the hot summer months, massive façade elements do not heat up as much due to weaker direct insolation, enabling the wall to store night cool that can be passed on to cool the interior space behind. Measurements to ascertain the effectivity of thermal mass + night purge cooling in Ngau Kau Kok were carried out in the hottest month of the year, in August, results of which are shown in the charts mentioned before. In the cooler winter months, the interior could benefit from the solar heat gains stored in the façade wall. Although in HKHA’s housing estates no energy is spent...
Figure 19. Psychrometric chart showing the comfort zone and passive cooling and heating technique of Hong Kong, as well as the area of passive solar heating (above left), area of thermal mass effects (above centre), area of exposed mass and night-purge ventilation (above right), area of natural ventilation (below left), area of direct evaporative cooling (below centre) and area of indirect evaporative cooling (below left).

© Ferdinand Oswald, Weather Tool 2013, © Autodesk, Inc. 2010
on heating appliances, indoor comfort could still be improved by utilising solar heat gains.

Problematic in this respect is the direct and continual intensive insolation from east and west throughout the year, and western and eastern facades of Ngau Tau Kok as well as many other residential buildings in Hong Kong are in dire need of improvement. Direct insolation from east and west is coloured orange in the above chart. These particular facades should not be shaded in the cooler winter months to enable them to absorb the heat, while, on the other hand, requiring protection from solar overheating in the hot summer months. Hence, a smart façade system is needed that would respond to various different seasonal requirements, for instance, a flexible protective system that would automatically open or close depending on solar intensity.

The University of Cambridge’s study “Comparison of different roof superstructures” [6] presented above could be applied in cases where solar heat gain reduction is desirable, e.g. for vertical façade areas. Superstructures that included an air space for rear ventilation behind the lightweight shading element performed much better than the other solutions in reducing solar heat gains. However, such superstructures or curtain façade systems need to be secured safely and are therefore quite elaborate and costly. Standards relating to façade elements and their ability to withstand forces such as wind pressure and suction are much higher in Hong Kong than in Europe, which is not surprising, since higher wind speeds and resulting hurricanes are a matter of course in Hong Kong. Naturally, costs will increase for appropriate façade systems such as for an ornamental Agrafe profile.

Openings

Façade openings require protection against solar heat gains because there is no massive wall that could buffer heat transmission. Residents can operate sunshading mechanisms on the inside of the windows on an individual basis. However, interior shading is not as effective as exterior shading, since absorption of insolation takes place in the interior, thus also releasing heat inside the room. An investigation into the “effectivity of various solar protection systems” was presented in the chapter “Solar heat gains”, discussing different shading options for window openings. However, whether or not a certain system is realised will depend on the cost. HKHA’s building projects do not include expenditure for high-quality shading systems, but if they did, they would certainly be required to comply with the same safety standards as for curtain façade systems due to the threat of high wind speeds and hurricanes.

Natural cross ventilation works well at Upper Ngau Tau Kok Estate. Considering the Site Specific Project Upper Ngau Tau Kok presented here, it is evident that the integration of an architectural concept for a construction method specifically suited to this location is urgently necessary. Meanwhile, HKHA have realised how important and effective natural ventilation is for residential housing and are now integrating natural cross ventilation in their new projects. The closed sliding gateset with timber entrance door open can work for a better thermal comfort of the inhabitants in a very good effectiveness if the corridor outside is not a fire protected one and in the same time keep the intimacy (privacy)+safety for them. However, the question as to which strategies HKHA could employ to modify their existing residential high-rises still needs to be answered. [7].

References

[7] Parts of the text above is published at: Oswald, F., Reduce A/C - Reducing the utilisation of air conditioning in high-rise buildings in subtropical and tropical climate regions, 2015, Graz, Austria.