Residential High-Rises without the usage of Air-Conditioning in Tropical Regions - A CASE STUDY OF THE MET IN BANGKOK

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Short Summary

Is it possible to entirely abolish energy-consuming air conditioning systems and simultaneously maintain a high living quality, a comfortable atmosphere and sufficient natural light in a high density living environment? To find answers to this question, the paper will use the completed case study “The MET” in Bangkok designed by WOHA Architects Singapore. The possibilities of abolishing a/c, will appear in building analyses, interviews with experts and conclusions from detected (measured) acoustic decibel, temperature and wind speed. The substantial questions are: Which existing knowledge and which architectural strategies must be combined and modified to create the optimal system in respect to building energy consumption and low carbon sustainability? What is their impact in terms of architectural design? How will these conditions influence the building typologies, floor plans and detailed openings in housing construction?
The paper will clarify the challenges in the design processes to realize those typologies, façade structures and windows details in tropical conditions.
This paper is part of the dissertation by this author and focuses as its central theme, how the design of a building and façade structures can affect good living quality and interior climate in tropical and subtropical regions without the use of a/c.

Keywords: Low Energy, Residential High Rises, Air-Conditioning, Living Comfort, Energy-Consumption, The MET WOHA Architects, Opening Requirements, Cross Ventilation, Floor Plan Configuration, Façade Structures, Building Typologies.

1. Introduction

This field survey investigates whether a pleasant living comfort with natural ventilation and without usage of air conditioning is possible. The hottest climatic period (April) was selected as research period, in order to determine the worst case or the most extreme and serious condition. There is air conditioning for each residential unit. However, one can assume that when utilizing the building concept the air conditioning might not be necessary. The appropriation of air conditioning meets the comfort requirements of the clients, the wealthy residents, and accounts for the standardization of air conditioning for every apartment in tropical regions. It is the purpose of this proposal to identify whether a comfortable living environment can actually be facilitated without the use of air conditioning.

2. Residential High Rise Project The MET

The MET is a pilot project, not because of its height amounting to 266 meters and thus constituting the tallest residential high rise in Thailand, but because it represents a completely new high rise type. The Singapore architects WOHA have developed a specific solution for a dense construction with natural ventilation in the tropics. “Most tropical high-rise housing in developing countries replicate cold-climate models, with sealed facades and total reliance on air-conditioning and mechani-

cal Ventilation. However, in the tropics light winds, year-round balmy weather, constant temperatures and high humidity make outdoor living desirable. In addition, the environmental conditions high-up in dense and populated Asian cities are preferable to those near the ground – there is more privacy, better views, lower humidity, stronger breezes, better security, less noise and less dust."[1] The project has won numerous awards and prizes. At last it was nominated in May 2013 for the Aga Khan Award for Architecture. The porous structure of the building enables the natural ventilation of the 370 residential units. The building consists of three residential towers, the interspaces are open and therefore, a good ventilation of the overall structure is possible (fig. 1). These basic structures are merely connected via bridges and walkways which facilitate the building with half-public communication zones and private recreational areas with green surfaces (fig. 3).
Moreover, the exposure is optimized. None of the rooms requires artificial lighting throughout the day. Only the kitchen in its closed version (e.g. floor type 29 in the middle part of the house) requires artificial exposure. However, the partitions are not supporting and can therefore be removed upon request.
Vertical cultivation and high-rise gardens provide additional conditioning of fresh air (fig. 2).

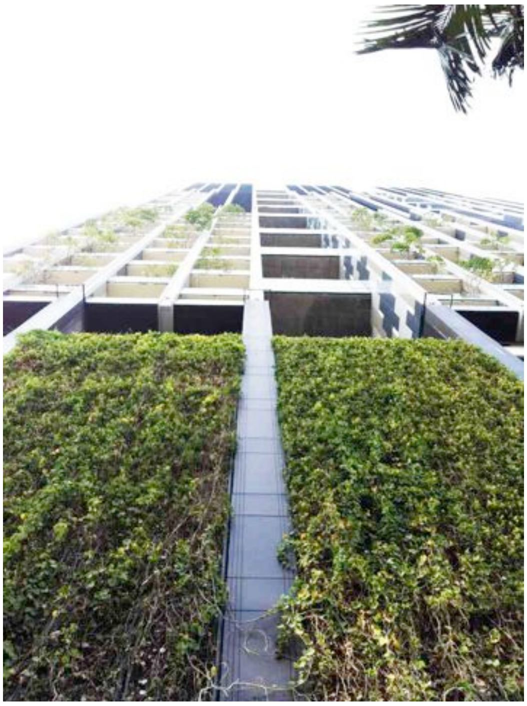
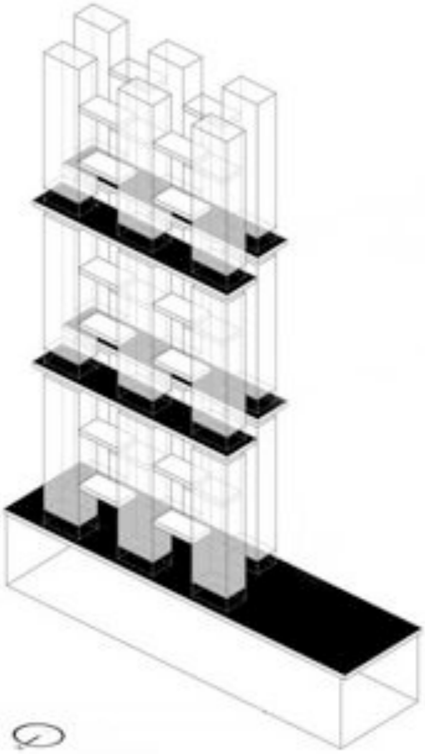


Fig. 1. Façade View the MET, Fig. 2. Vertical Cultivation the MET
© Ferdinand Oswald; Photo: Ferdinand Oswald

3.0 Climate Conditions Bangkok

The climate in Bangkok is warm and has a relatively high humidity. On principle, the climate can be distinguished according to three seasons. Summer, winter and the rains. The latter is triggered by the monsoon climate. The urban island-heat-effect causes a temperature increase and prevents excessive cooling during the night. Within these night hours the temperature in Bangkok therefore declines by 5 - 10 degrees Celsius. The prevailing climate urges people to use air conditioning throughout the whole year. The Bangkok residents actuate these aerations particularly during the summer months (March to July) (fig. 4)



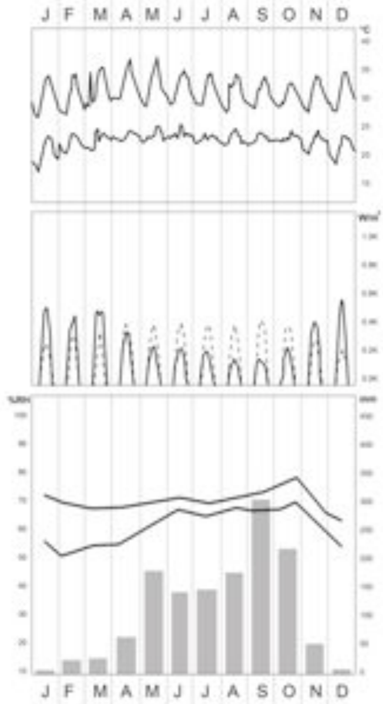
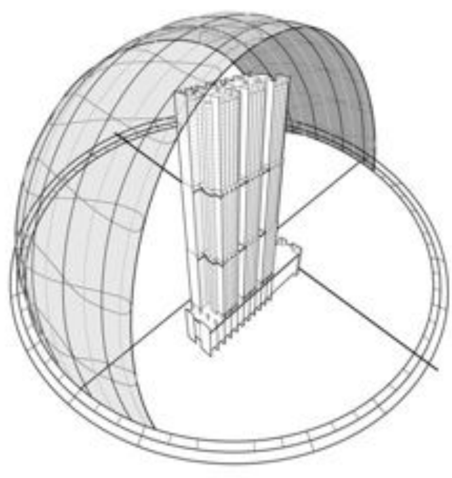


Fig. 3. Integration of Community Decks, Fig.4. Weather Bangkok © Dr. Nirmal Kishnani (1,2)

3.1 Wind direction and solar altitude

At this location the major wind direction is predominantly oriented from north. The building is transverse to this wind direction and can therefore ideally absorb the wind within its porous structure and openings (fig. 6).

The static basic structure of the building is based upon a supporting construction, which is arranged in north-south direction. Thus, these protruding features function not only as essential architectural design elements but principally serve as shields for window openings, because the building was situated parallel to the course of the sun (east-west) (fig. 5).



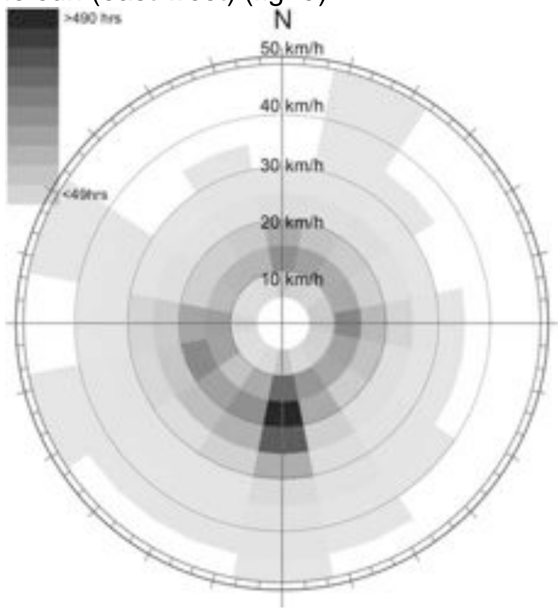


Fig. 5. Sun Course over the MET, Fig. 6. Wind Direction and Wind Speed © Nirmal Kishnani (3,4)

3.2 Wind currents

Wind currents exist in vertical and horizontal direction. The horizontal weather winds produce wind pressure and suction. They collide with vertical wind currents and their intensity is therefore mitigated. Thus, both wind currents provide for a variety of air movements and the wind can ideally infiltrate the apartments. The vertical wind currents originate from temperature and pressure differences and take place within the building structure and between the residential towers (fig. 7 and 8). This uplift that triggers various air circulations is utilized by swallows that can continuously be watched around the building. With their enclosed basic structures and flat building facade surfaces other high rise buildings cause undesired one-sided and strong air currents. These lead to extreme wind blows that are uncomfortable for pedestrians and that are also avoided by gliders at a greater height.

Fig. 7. and 8. Building Structure the MET ; © Ferdinand Oswald; Photo: Ferdinand Oswald

3.3 Wind speeds

Due to Bangkok's vicinity to the sea a sufficient wind strength within the city can be expected throughout the whole year (fig. 6). At increasing altitude the wind speed increases steadily. At the street level, the wind speed is almost zero. Measurements at the Sathorn Road displayed a wind speed of only 0.52 meters per second (m/s). This air flow cannot even be noticed as a slight breeze (wind strength 0-1)[2].
Nevertheless, 65 meters further, along the ground floor entrance area leading up to the MET, there is a very high air circulation of 6.13 m/s. The measurements on spot correspond to the wind strength 4, a moderate breeze (fig. 9). Even at the ground floor the building structure creates wind currents. This appoints to the efficiency upon which the building structure directs the wind downwards.

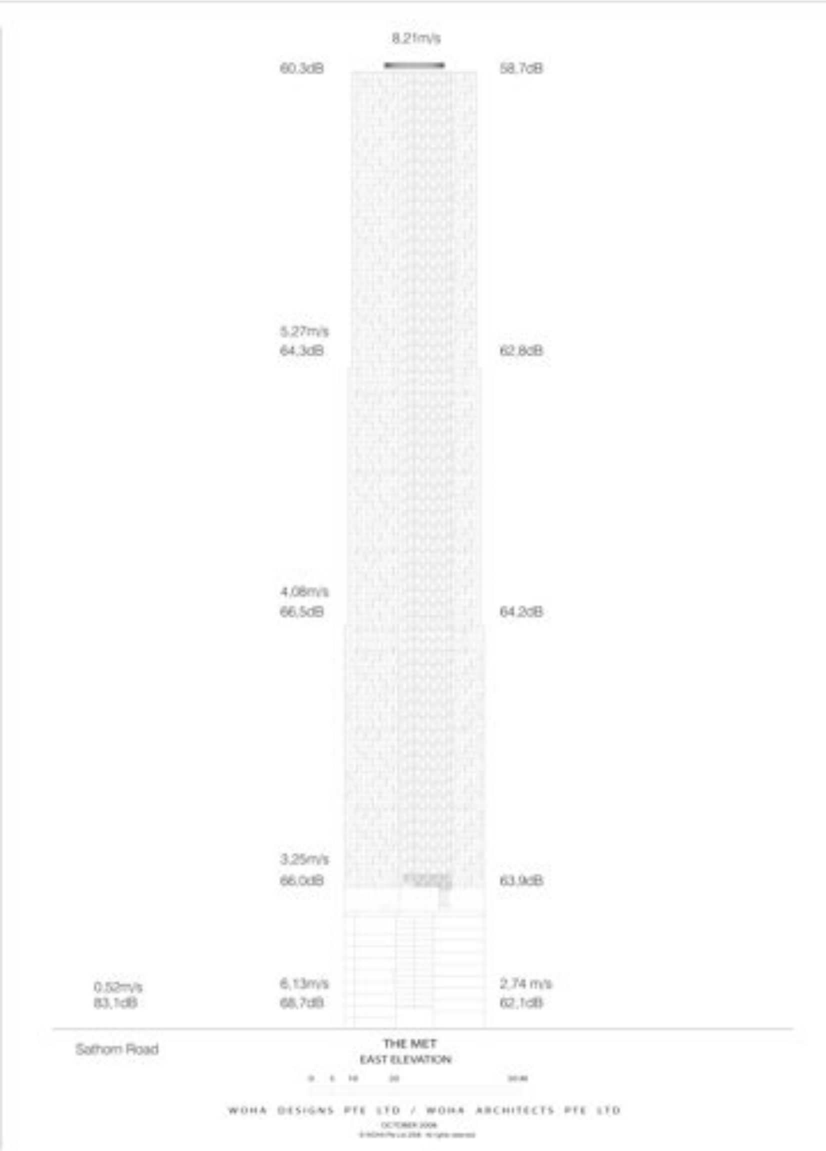


Fig.9. Results Wind Speed and Decibel; © Ferdinand Oswald, WOHA (5)

Due to the higher wind speed at increasing altitude there are less cultivations at higher storeys. In the upper third of the building there are hardly any balconies with trees and cultivations (fig. 10). The WOHA architects are widely experienced at transposing cultivations upon residential high rises. It is probable that the strong winds up to a height of 260 meters adversely affect the plants. In consideration of the strong wind strengths the stability of the trees must be ensured. Moreover, the evaporation at the surface of the leaves as implicit result of the wind presents a danger. Due to the lesser contact surface of the winds and the possible prevention from leave separation, small-leaved plant species are more suitable for an environment that is exposed to wind [3].
Nevertheless, the higher residential units (top third) are in particular demand. (Despite the higher costs of top-storey residential units in comparison to the lower two-thirds of the building, these vacant top-apartments are seldom. Status: April 2013.) They provide better views, facilitate a better ventilation (stronger wind speed) and a better air quality. The top wind speed has been measured at the roof top of the building. The wind speed accounts for 8.21 m/s and therefore corresponds to the wind strength 5 (Beaufort) that is identified as fresh breeze. The measured vertical wind current at the top storey reaches a similar wind strength. It is caused by the uplift and the channel-shaped interspaces of the residential towers reinforce this chimney effect.

Fig.10. Integration of Greening, © Dr. Nirmal Kishnani (6)

3.4 Impact of water areas on comfort

Water areas are located in the common areas and some of the apartments are allocated with private pools. The air as it is cooled off by water circulates within the building structure and can eventually flow into the residential units. In the entrance area the pleasant breeze, the shade, and the influence of the numerous bodies of water establish a comfortable place to linger. In this area air measurements accounted for a temperature of 32.3 degrees Celsius. Simultaneously, the temperature at Sathorn Road was 4.2 degrees Celsius higher (36.5 degrees Celsius) (fig.11).

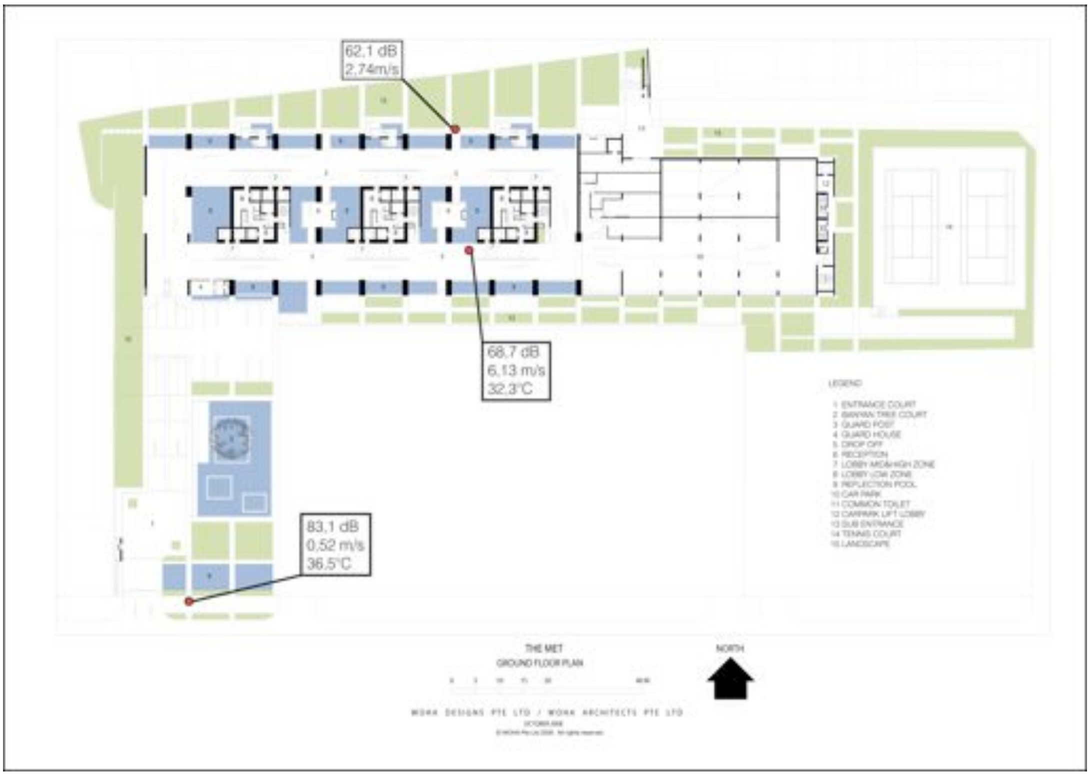


Fig.11. Ground floor the MET - Wind Speed, Decibel and Temperature
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4.0 NATURAL VENTILATION

Natural ventilation enables a renunciation of air conditioning. This requires a closer investigation of the following three levels of the building:

1. The porous structure of the building as it is already described above.
2. The floor plan configuration which must facilitate cross ventilation.
3. The openings must meet numerous requirements and comply with external influences.

These will be elaborated according to the following points:

4.1 Floor plans

The three residential towers each contain a core development with two residential units. One unit is oriented towards north, the second unit faces south; both are staggered in reverse order. This enables an air entrance from the rear of the residential units and a very efficient cross-ventilation (fig. 12). Numerous windows can be opened from north and south in order to provide thorough ventilation. However, the hallway between several rooms must be partially ventilated (dependant on the floor plan type). According to the standard floor plan of the middle units (storeys 29th to 46th) there are two bedrooms with integrated bathrooms that are located at the facade side. Cross ventilation of the bedrooms is only provided when the doors are open. This leads to privacy restrictions. The opening of the balcony door and the tilting-window in the bathroom allow for an one-sided ventilation. However, due to the absence of the cross ventilation its efficiency during the hot climate period is disputable (fig. 13). A solution to the problem in terms of this floor plan type is difficult. The room layout of the large bedroom in combination with the bathroom facilitates continuous cross ventilation. The cross ventilation can also be implemented in the living room and kitchen without any restrictions. If the small bedrooms were connected to both facade sides they would be conceptualized as through rooms without a hallway.

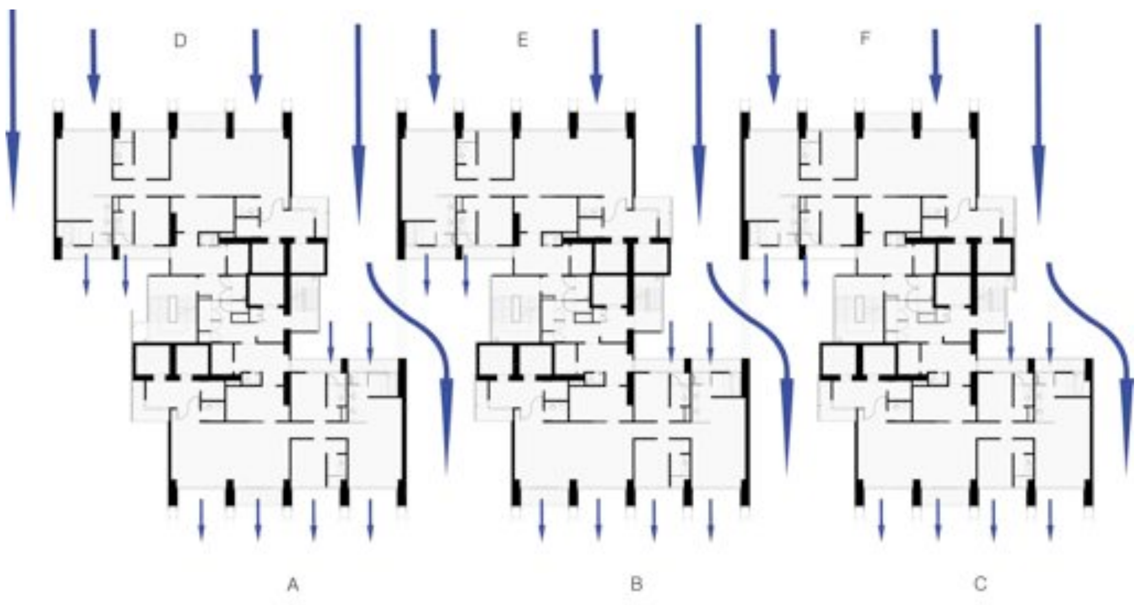

Fig.12. 29th Floor Plan the MET with Wind Circulation; © Ferdinand Oswald, WOHA (8)

4.2 Openings

Altogether there are 14 doors and window flaps that can be opened for the purpose of cross ventilation within one residential unit (Exemplified according to unit 29C, middle area, storeys 29-45 there are 9 window flaps, 4 doors to the canopied area, and one sliding door to the balcony). Although there are only 3 doors and 2 window flaps along the back facade side, there is sufficient air current throughout the residential units. Theoretically, there are 196 different ventilation combinations that result from these 14 openings (fig. 13).

Fig.13. 29th Unit C Floor Plan the MET with Openings Categorization
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Moreover, an air current in longitudinal direction can be actualised, for instance from the northern bedroom through the living room. The apartment entrance door was designed to be air-permeable and therefore allows for a continuous air current. It is made of vertical wooden staves and exhibits the necessary permeability for the air current to circulate onto the openings in the living room (fig. 14a). The window flaps can be folded out from beneath. This tilting mechanism anticipates the penetration of rain. In terms of the intense monsoon-rains in the rainy season this mechanism is an indispensable attribute for windows located at the outer facade. A suitable dosage of the air current via the ideal opening cross section is problematic. The loggia doors and window flaps allow only for a thorough opening or closing (fig. 14c). Merely the balcony sliding door enables a fine adjustment of the opening cross section. Thus, the air current volume and – intensity cannot be perfectly controlled. A needlessly high air change might be created. This excessive air speed triggers for instance a situation in which loose papers get blown away. One solution could be the development of window openings that allow for a decided control of the opening cross section. An example here could be the traditional wooden struts window of the old Tulous of the Fujian region in China (fig. 14 d and e). These can be regulated manually and with minimal movement of the element. However, the disadvantage here is that the shut-off struts no longer ensure light transmittance. Throughout the research project Structure and Facade, the IAT - Institute of Architecture Technology, Graz University of Technology is currently developing opening systems that meet these requirements. It is yet to be identified which cross sectional opening shape and size may represent the ideal opening for natural ventilation (fig. 15 c).In contrast to the overhead window flaps, the loggia doors have no locking function. Therefore, problems alluding to excessive draft are triggered. The loggia doors thunk shut with a loud bang. One way to solve this problem would be the appropriation of different adjustable opening angles in order to fix the doors.

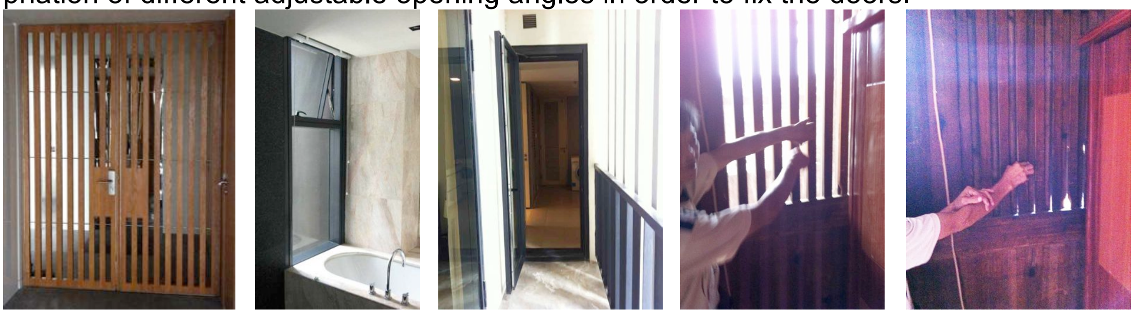

Fig.14. a) Porous Unit Entrance Door the MET, b) Top Hung Window the MET, c) Loggia Door the MET, d) Opened Sliding Window, Tulou China, e) Closed Sliding Window, Tulou China;
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4.3 Noise exposure road traffic

The noise exposure caused by road traffic at one of the most frequented roads in Bangkok accounts for 66.6 decibels (dB) at the middle part of the building and is therefore relatively high. The attempt of closing the window in order to create comfort did not improve the situation in terms of noise exposure. The windows are provided with single glazing and do therefore not contribute to soundproofing. Furthermore, the decentrally assembled cooling units are directly attached to the window. Even when the windows are shut the actuated air conditioning creates tremendous noise within the residential unit.
Noise measurements at the southern facade averting the street displayed only a slight noise reduction. This is justified by the fact that the adjacent building situated further south reflects the traffic noise back to the MET.
On average the noise exposure is only 2 dB lower than on the facade facing the street. At increased building altitude the noise exposure declines. On top of the building the decibels are least, at the middle part of the building they are very high. The higher acoustic measurements at the middle part of the building are justified by the fact that the adjacent building on the opposite side reflects the sound back (fig. 9).
The Hong Kong Housing Authority has used the so-called Noise Reducing Window (fig. 15 a). The window is constructed using two glass plates behind each other. Thus, the wind must pursue a labyrinth-like way and the acoustic waves cannot penetrate the interior of the room. Moreover, the perforated acoustic absorber is attached to the window reveals in order to transmit the noise. ."[4]
When taking into account the diversion of the wind flow the question is raised whether there is still sufficient wind speed inside the apartments. The wind pressure must reach a specific strength in order to facilitate efficient cross ventilation. A further development and investigation of this issue is perfectly reasonable, because the noise exposure of road traffic within Asian cities is usually very high. Unfortunately, it is likely that Bangkok's road traffic might increase within the next years, as the Thai government has started subsidizing the registrations for cars. Thus, it can be assumed that the noise exposure caused by vehicles in road traffic is on the rise.

4.4 Air pollution

"The motor vehicle traffic is one of the main causes of air pollution. Particularly in urban areas, the exhaust gases cause serious adverse effects on people and the environment."[5] However, air pollution caused by road traffic at the MET does not present a problem. Although the building is located at one of the most frequented thorough fares of Bangkok, the air quality is very good.
This is justified according to the following, "In the 90s Bangkok grew so fast that the air quality dropped to a miserable level. The government has enacted emission regulations, ensured the widespread introduction of unleaded petrol, and issued a regulation that allowed cars with catalytic converters only. In addition, simple but effective measures were carried out, for example, paved roads in order to stir less dust. The air quality in Bangkok is now better than American standards stipulate."[6]
The Thai government subsidizes gas-powered cars. "Although today conventionally powered vehicles emit fewer pollutants than a few years ago, the emission of exhaust gas components such as benzene and soot particles continues to present significant environmental impacts. Especially the pollutant emissions of diesel engines earn much criticism."[7] Thus, gas-powered vehicles are less harmful to the air than gasoline-powered vehicles. Unfortunately, the production of gas-powered cars will now be abolished in Thailand. In terms of the air pollution problem in other Asian cities the appropriation of air filters should be considered. However, the use of such air filters would possibly diminish the air current to a degree that might be no longer sufficient. At the same time an exposure through window openings should be facilitated. A material specification that meets the requirements of translucency, weathering, and air cleaning should be deployed (fig. 15 b).

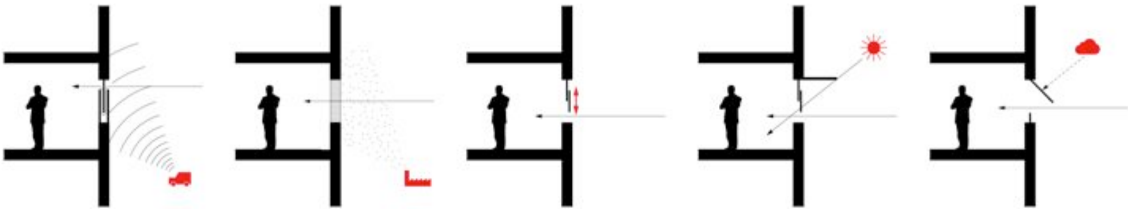

Fig.15. Requirements for Openings : a) Traffic Noise Load – Noise Reduction Window b) Air-Pollution Filter Window, c) Dimension of Window Width, d) Sunscreen, e) Rain Shield
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5 CONCLUSION

Due to the existent floor plan structure natural ventilation and the simultaneous renunciation of electronic air conditioning is enabled within the residential units of the MET. The measurements and the evaluation demonstrates that, even within Bangkok's hot season, natural ventilation and air currents do allow for a pleasant living comfort. The problematizing standards of the openings (fig. 15) can be added up to within one window. However, this requires openings that meet all these needs simultaneously.
The requirements of noise, air filtering, opening cross-section, as well as sun and rain protection must therefore be equally achieved upon this single opening.
Upon enquiring [8] the employees of the MET about the use of air conditioning, the survey led to the following results:
The experience of the staff revealed that most residents of the MET actually renounce the use of air conditioning. This thesis is based on the numbers taken from power consumption measurements within the individual units. The investigations of Dr. Nirmal Kishnani [9] confirm these numbers. "45% of the residents say, that they have low to moderate dependence and reliance on air-conditioning." The idea of returning to the passive natural air conditioning is currently difficult to implement among tropical cities. The electricity prices are low, facilitating a relatively affordable operation of the refrigeration systems. Air conditionings are easy to get and easy to install. Mostly these are assembled already in advance by the client or operator of the building, since this adds up to the expectations of the patronage.
Mistakenly, the air conditioning seems to present the only assumable answer to the external factors of heat, humidity, noise, and air pollution. The air conditioning is a deeply-rooted standard that meets the need of comfort in a self-evident and simple manner. Surprisingly, the floor plan conceptualizations and openings of older residential properties in Bangkok contain functioning cross ventilations without air conditioning. The invention of the decentralised air conditioning has changed the types of housing in the last 50 years thoroughly. We need to focus on and prove the assumption that the adaptation and reinterpretation of traditional housing typologies for new residential buildings aspires to a realization of the living comfort in a sustainable way. The MET proposal has become a pioneer project in its own right, representing architectural innovation in tropical regions.

Graphics

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