COMMON CONFIGURATION OF LIGHT-WELL IN HIGH-RISE RESIDENTIAL BUILDINGS IN KUALA LUMPUR

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ABSTRACT

The rapid growth of urban population and increasing income in the Southeast Asia has resulted in the development of high-rise residential (HRR) buildings. The objective of this paper is to identify common configurations of HRR building regarding the vertical air passageways such as light-well and its connection with outdoor environment through horizontal air passageways such as void and corridors as well as windows. Therefore, this study surveyed high-rise residential buildings in Kuala Lumpur as a major city in Southeast Asia. Based on literature review the study addressed three main types of light-wells. Considering the light-well types and their possible connections to voids, corridors and windows, the common configurations of HRR buildings was derived, improved and tabulated. These common configurations and sub-configurations that can be derived from the main configuration, can be improved and optimized to develop more applicable system to induce natural ventilation in HRR buildings.

INTRODUCTION

Background:

The rapid growth of urban population and increasing income in the Southeast Asia has resulted in the development of high-rise buildings which are either used for housing or commercial purposes. The demand for high-rise buildings continues to increase into the future, for instance, in Singapore the number of high-rise buildings has increased by three times in the last six years, while in Bangkok and Kuala Lumpur (KL) the number has doubled within the same period ((Rimmer and Dick, 2009) and updated by www.emporis.com.). Most of these high-rise buildings are used for housing, particularly in Singapore due to high density (Yuen and Yeh, 2011). According to statistics obtained from National Property Information Center (NAPIC), the number of HRR and apartment buildings in KL increased to about 41% in last 10 years, and the number keeps growing annually (Ta, 2009). This is especially when Malaysian policy of housing in urban area (started from 1998) recommended HRR buildings for all income category groups. Government's vision in housing policy in KL seeks to achieve sustainability, adequate, comfortable, quality and affordable housing. Although until now KL achieved about 94 % of housing unites (NHP, 2012) required according to KL Structure Plan 2020, there are many questions that rises here. In other words, it is accepted that required quantities have been achieved within time frame. However, the main question is; have these housing units achieved the five criteria mentioned above?

Since the tropical climate in this zone is hot and humid with low wind speed, the residents of these high-rise buildings are dependent on mechanical systems to improve the indoor thermal environment which requires extra energy. Previous studies (Yeang, 1996, Ismail, 1996) emphasized that increasing demand for energy is as a result of not using bioclimatic design strategies in high rise buildings. In addition (Ismail, 2007) showed that the energy saving in high-rise building can be achieved based on bioclimatic design concept (i.e. building configuration and special features). Since the humidity is higher and the airflow speed is low in Malaysia, natural ventilation is one of the most important passive strategies used in traditional Malay house (Yuan, 1987). Therefore, in order to reduce the energy consumption it is recommended (e.g. (Yuen and Yeh, 2011, Givoni, 1998)) to use appropriate bioclimatic design strategies to induce natural ventilation into the building.

For the purpose of improving the indoor airflow passively, different strategies has been applied i.e., windows, balconies and appropriate shapes of the building. In addition, there are many special architectural features common in use in HRR buildings, i.e. light-well, recessed space (semi-enclosed), corridor and void which can be adopted as air passageways/ buffer zones to induce natural ventilation into the building. Nevertheless, these features have not received enough attention to optimize its effective performance in order to promoting natural ventilation. Light-well (deep courtyard) as vertical air passageway is commonly used in high rise building, especially in deeper-plan buildings, to admit daylight and to induce natural ventilation. This wide space appropriately connected with the outdoor environment will not only enhance the air flow through the light-well and cool down the building structure but also change the wind environment around the building (Givoni, 1998) especially at the pedestrian level.

Most of works of Ken Yeang, who pioneered in high-rise building bioclimatic design, was fundamentally based on cross ventilation strategy. The appropriate design, i.e. building configuration, orientation and windows, can be facilitated and maximized by the cross-ventilation in the units (Burnett et al., 2005). Moreover, in order to enhance natural ventilation in the building Yeang used some vertical enclosure (light-well) and semi-enclosed (recessed spaces) in the building. Comparative study (Ismail, 2007) between bioclimatic high-rise office building (Menara UMNO, by Yeang, 1996) and conventional high-rise building was conducted. The results showed that the energy consumption required for obtaining the thermal comfort and lighting is significantly reduced in UMNO building. Another study (Ismail, 1996) also revealed that the high-rise building with internal atria through opening at ground level and inverted double pitched roof wind scoops can facilitate and maximize cross-ventilation in a deep plan building. More recent study (Haw et al., 2012) been done in Malaysia shows that venture shaped roof wind-induced ventilation tower is able to generate extraction airflow rate of 10,000 m3/h at external velocity of 0.1 m/s.

Building configuration in HRR and air passageways strategies:

First, it is important to define and determine HRR building height. Most previous studies used the number of stories in the building to determine the height of the building. There is no uniform definition of high-rise apartment building. However, Goody et al (2010) identify three main types of rise housing namely; low-, mid- and high-rise in addition to super high-rise (skyscraper). The low-rise housing no more than four stories, mid-rise ranging from five up to fifteen stories, from sixteen to fifty as considered in their book as high-rise and over fifty is skyscraper.

Configuration concept in HRR building refers to the unit plan and the service core location as well as the link (corridor) between the units and services such as elevators and staircases. Small house design such as detached or even row houses is more varied than the design of multi-storied apartment buildings in terms of geometric configurations. Since the units in apartment building are sharing the service core in all floors, usually their design is based on specific criteria. In general, the objective of the design criteria to reduce the cost of construction (e.g., decrease the number of the elevators) and safety of the building (e.g., providing appropriate location and numbers of fire escape stairs). In the case of HRR building above factors and some environmental conditions are more critical issues. The most importantly the wind load influences on the shape of HRR tower and its orientation. The high elevation of the HRR buildings may also have effect on the surrounding environment such as shadow casting and pedestrian airflow. All of these design factors should be taken into account in the early stage HRR building designs. These factors are constraints faced by designers will be taken care of as it will be forcing them to produce similar design ideas and thus similar configurations. Although technology and engineering have further improve, most of the high-rise buildings constructed today remain fundamentally similar in terms of their configuration (Yeang, 1996). This design similarity prompted many researchers to derive the common configurations of HRR building.

Boutet, (1987) identified five basic configurations commonly used in apartment housing. These five configurations are square, rectangular, "U" shape, "L" shape and "T" shape. He studied the effect of configuration on the airflow environment around each layout of apartment housing. Givoni (1998) categorized the internal layout of multi-storeyed apartment buildings according to climatic performance aspects. There are two main types and under each type it is also categorized into further two sub types. The first main type is building with long corridors providing access to the units along them and this was further categorized as doubled-loaded corridors or single-loaded corridors. The second main type is the buildings with lobby of staircases and elevators which can be with two unit or more than two units. Givoni (1998) suggested that single-loaded corridors configuration in the first type and two unit configuration in the second type are better in terms of cross ventilation as they expose more than one side to the wind direction.

Goody et al. (2010) used external and internal layouts to differ between three different HRR building configurations namely; slab, tower and skip-stop plans. The slab building configuration is based on arranging the units along a common corridor that leads to elevator core; usually it is located in the center of the building, and ended by two fire escape stairs, usually found closer to the end of both sides of the corridor. The tower building configuration is based on arranging limited number of units around central elevator core and this type usually produced units more exterior exposures than those in slab configuration. The last type suggested by Goody et al is skip-stop plans which located a corridor only on every second or third floor. This configuration afforded each unit to include more than one floor and also allow at least one floor in each unit to external exposure of wind on either side of the building.

Ismail (1996) selected 14 high-rise building in Malaysia in order to identify a common configuration and to derive some special architectural features used to induce natural ventilation in high-rise buildings. These design features are deep recesses, atrium, wind scoop and ground floor void. He found such special strategies creating a reasonable thermal buffer zone that plays a good role for reducing direct exposure to outdoor environmental conditions. Similarly Ken Yeang (Yeang, 1996, Yeang et al., 1994) identify three different thermal buffer zones based on core position in high-rise building namely; central core, double core and single-sided core. Ken Yeang (1994) also introduced large buffer zones (sky court (or light-well), atria and recessed balcony) even in the central or peripheral parts of the high-rise buildings. This buffer zone (or as is referred in this paper as air passageway) can play a good role in terms of inducing natural ventilation.

Spaian (2003) based on literature review grouped all architectural design features from the view point of affecting natural ventilation. His study addressed four main categories and each one included different design features. These four groups are building forms and configurations, building details, internal layout and special architectural features. The first group included the type of buildings referred to Givoni as discussed above, building projection related to shadow devices which affect airflow in the building and building external layout shape referred to (Boutet, 1987), as also discussed earlier. For the purpose of the current study only the first and last group will be discussed and for more information of the other two groups refer to (Sapian, 2003). Based on literature review (Ismail, 1996, Yeang, 1996), Spaian (2003) also addressed his last groups as having six special architectural features namely, location of service core, atria, open central corridors, open ground floor (void), external wind scope and wind-wing wall. These features also can be considered as air passageways as air can flow through them from outdoor to indoor spaces.

Finally, Givoni (1998) also defined some air passageways from bioclimatic design aspects such as internal courtyards and attached enclosed open spaces. He categorized the spaces according to their relationship to the built part of the building namely, attached open spaces outside the walls' lines, semi-enclosed space surrounded by rooms on two or three sides and internal courtyard surrounded on all sides by rooms. This categorization is applicable either in terrace house or multi-storey apartment.

As discussed above studies used various aspects, i.e., bioclimatic design aspects and service core to address configurations of HRR buildings and their special features. However, there is no special study that addresses the configurations of HRR buildings from the special features or air passageway spaces point of view. Some air passageways are introducing natural ventilation into the heart of the HRR building such as solar chimney and light-well. If they are design in appropriate manner then the wind-induced may play an important role in terms of obtaining thermal comfort and thus saving the energy use in the building. This depends greatly on detailed treatment in design stage of air passageways (Givoni, 1998). A detail analysis of the physical configuration of HRR buildings of above literature reviews were elaborated in following section under discussion.

In order to optimize the performance of these air passageways in terms of inducing the airflow into the building, the current study categorizes different spaces of air passageway under main groups according to the manner of using by occupants. Thus, there are three groups of air passageways namely;

1- Occupied (e.g. courtyard, atrium, solar space and void)
2- Temporarily occupied (e.g. case stair, corridor, void)
3- Unoccupied (e.g. solar chimney, light-well, double skin façade, wind scope tower).

Cheng (2011) considered that the recessed cavity is like light-well in the high-rise buildings and by referring to Givoni's categorization of the three air passageway spaces in multi-storeyed buildings as stated above. Similarly this paper categorized the light-well under three sub-division based on their location with the layout of the building. These three light-well types are as follows (Table 1);

1. Internal light-well: A deep courtyard that is surrounded on all sides by rooms spaces.
2. Attached light-well: A light-well is attached at the perimeter of the building. Therefore one or two side of the light-well is enclosed by perimeter wall or a corridor.
3. Semi-enclosed light-well: A recessed cavity that is surrounded by rooms on two or three sides but open on at least one side. The benefits from the semi-enclosed is that it provides more than one side openings.

The main objective of the current study is to derive the common configurations of HRR buildings in KL as a case study representing the tropical Asian cities based on the combination of the three types of light well (as vertical air passageways) with void and the corridor (as horizontal air passageways). This will help to obtain basic configurations of the HRR building from vertical air passageways aspects. Thus it will facilitate the study of airflow characteristics in three different vertical air passageways connected to outdoor through the horizontal voids or corridors and by themselves as in case semi-enclosed.

METHODOLOGY

To identify a common configuration of HRR building combined to vertical air passageway spaces for the purpose of optimizing natural ventilation, three different methods were used in this study. First set of information were gathered based on several basic configurations suggested in literature review. These were discussed in earlier sections. Secondly is the data collected using aerial images and digital maps of case study area and the third is set of data collected through a survey. Digital maps of three main cities; Kuala Lumpur, Johor Bahru and Penang were used to identify the areas with more HRR buildings to carry out the field survey.

A field survey was conducted to collect physical data on the selected HRR buildings. The survey in KL was conducted in five areas located around KLCC, and they are approximately located less than 10 km from KLCC (Fig. 1). Total of 25 buildings were surveyed within Ampang, Bangsar, Cheras, Wangsa Maju and Idaman-Ibukota areas in Kuala Lumpur City Center. Table 2 shows general information and status of each building. This table shows that out of 25 buildings that were visited in the five areas in KL only 11 cases were fully surveyed. Fig. 3 shows the external main façade and detailed snapshot of the light-wells for 12 HRR buildings as most of them fully surveyed.

A check list was developed based on objectives of the study and criterion derived from literature (e.g., (Sapian, 2003, Kleiven, 2003)). The following criterion was included in the check list;

- Must include at least one type of light-well and it has either rectangular or square plan.
- Name of the HRR building, its detailed address, number of floors and opening year.
- The light-well existence and its connection with a void and corridor.
- Layout drawing of the building (if there is no drawing provided measurements were taken on the site in relation to existing light-wells and their connection with void or corridor)
- Capture places such as the light-well, void, corridors, connection point and main external façade of the building in images.

Collected information were processed and tabulated in excel and reproduced the sketches by arranging them under categorization depend on the type of the light-well and connections with the void and corridor.

Since the light-well configuration has many variables thus deriving common configuration is difficult. Therefore, variables that may affect the airflow were only taking into account in achieving the purpose of the current paper. Some parameters can be fixed according to the survey results and literature review configurations, e.g. the area of the light-well and its height, respectively. Other parameters such as width of the block assumed to be appropriate for minimum common depth of the unit and the height of floor fixed at 3m. Since the types of the light-well and their connection to outdoor through horizontal are the main objectives of this paper, the possible common configurations regarding the connection between vertical and horizontal air passageways in HRR buildings were derived.

RESULTS AND DESCUATION

Common building configurations (theoretically):

From the literature review the paper derived 24 different configurations of theoretically possible configurations of HRR building as shown in Table 3. As shown in the table three major elements configure the HRR buildings namely; service core, corridor and fire escape stairs. These elements must be located in an appropriate manner among themselves on one hand and the main entrance of the building and the units' entrance on the other hand. The table presented five different layout; tower with services core at center, corridor (or liner), "L", "T" and "U" shapes as theoretically suggested in literature review (by (Givoni, 1998, Goody et al., 2010, Boutet, 1987)).

These five categories were combined with the three different types of light-wells suggested (by (Givoni, 1998)) as bioclimatic architectural features and one without a light-well option. Since the current study tried to cover the most possible configurations under these categories, it used large number of light-wells locations. In addition it used only simple and basic geometries (square and rectangle). As shown in the table, also, the configurations in attached light-well group has two options either attached to external wall of the building or attached to corridor internally, so these two options were elaborated in the same model to clarify this idea.

Light-well types categorization in KL:

Table 4 shows the scheme of the building configuration plan for each case of the 11 buildings. They are categorized according to the type of their light-well. Although each plan differs from the other, they can be considered within the configurations proposed based on literature review. The analysis emphasized that the common type is the attached light-wells and followed by semi-enclosed light-wells. It is noted in the table many cases have more than one type of light-well and therefore categorized under different groups. For instance, Panyai Panorama building has attached and semi-enclosed light-wells so it inserted under both groups. It is significantly noted that all buildings that have semi-enclosed light-wells also have attached light-wells. However, the internal light-well configuration is not common among these surveyed buildings.

Types of connection for the light-wells to outdoor through void and corridors in KL:

Table 5 shows the connection between vertical and horizontal air passageways of the 11 buildings. This is in order to show the most common connection type between all light-well types and outdoor environment through horizontal air passageways (void and corridor) and windows.

Based on literature review and survey results, this paper suggested and developed the parameters as matrix shown in Table 5. The analysis identifies 15 possible types of connections between the light-wells and horizontal air passageways which are void, corridor and their sub-types as well as windows through wall.

According to the survey results the study emphasized 6 different types of connections between all light-well types as vertical air passageway and void or corridor as horizontal air passageways. Table 5 shows that the most common connection is through corridors in all floors and followed by voids in the bottom floors such as elevated ground floor for car park. However, the highest building in this survey has void in the middle connected as in case Seri Maya building.

As shown in the table most common connection is attached light-wells and connected with corridors in all floors. Nevertheless, there are two sub-types of corridors namely; direct connection and indirect connection. Most cases have direct connection to outdoor through corridors that are open on one side of the light-well to outdoor and cross the width of the corridor. One case only categorized as indirect connection. This type of connection refers to receive the airflow from outdoor through two means which are windows and then through elongated axis of the corridor. Therefore, the direct connection is more effective as it induces the cross ventilation.

Internal light-well usually came without any horizontal inlet (such as corridor or void), instead they only depend on the indoor space which connected through the wall windows. Only two cases (Sri Wangsaaria and Axis Residency) out of 11 are without inlet. The semi-enclosed light-wells are also common especially in deeper plans and usually came with attached light-wells in the same building as shown in the table.

It should be mentioned here that other configurations of the light-wells are created by the enclosure of several blocks. In other words, as light-wells were investigated it was found in one building also that there are light-well configured by surrounding of more than one building or blocks. Although they have the same configuration concept but they differ in many perspectives such as the size, so this type is out of the scope of this paper.

Although the internal light-well in the case of Axis Residency and Sri Wangasria, were attached to the corridor, there is no opening or connection with the corridor. Therefore these two cases were not aligned as attached light-well typology.

Common configurations of HRR buildings:

In this section the study will derive the possible connections between vertical and horizontal air passageways/buffer zones in HRR buildings. This depends on all previous steps and processes as well as using the possible parameters in courtyard building as suggested in early study done by Ettouney et al. (1974) (Fig.2). Table 6 shows the common configurations of HRR buildings. Similarly KL HRR building categorization, also, there are 15 possible configurations based on the connection between the light-wells and void, corridor and windows. Some of the categorisations included more than one configuration in order to illustrate the other possible positions of the light-wells connection through windows. As noted in Table 6, none of the cases have the connection between the semi-enclosed light-well and indirect corridor connection as it is impossible to find in real case. Since these configurations were derived and developed from literature review and specific real cases, it is possible to derive other configurations under each category or group. However, these common configurations represent the majority of HRR building that include air passageways as bioclimatic design strategies.

CONCLUSION

According to the literature review the study developed and categorized the building, air passageways (special architectural features) and light-well types in HRR buildings. Based on these categorizations and the three systematic methods used in this study, and considering the light-well types and their possible connections with void, corridor and window, the common configurations of HRR buildings derived, improved and tabulated. According to the light-wells categorization considered in this study the attached light-wells especially internal attached with corridor is the most common type in HRR buildings in KL. Since the number of surveyed buildings were limited in this study, further study needed to include a large number of HRR building with the three types of the light-well. This paper considered only the light-well in one building, so the study needed to extend to light-wells configured by blocks or more than one building which are the primary parts that make up building groups.

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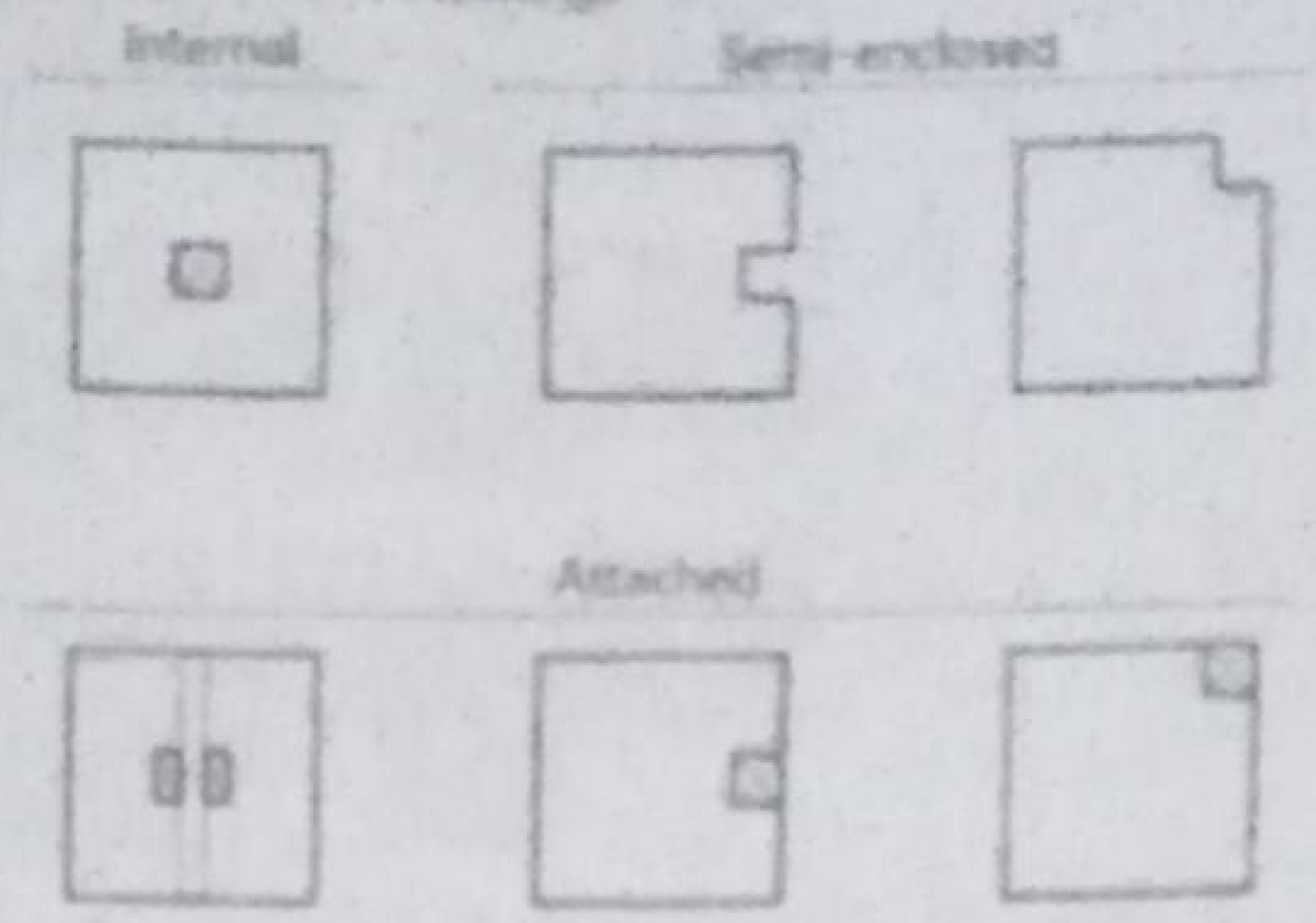
Figure 1: The five areas selected to survey of HRR building within KLCC

Table 1 Possible types of the light-well based on literature review and developed according to their position in HRR buildings



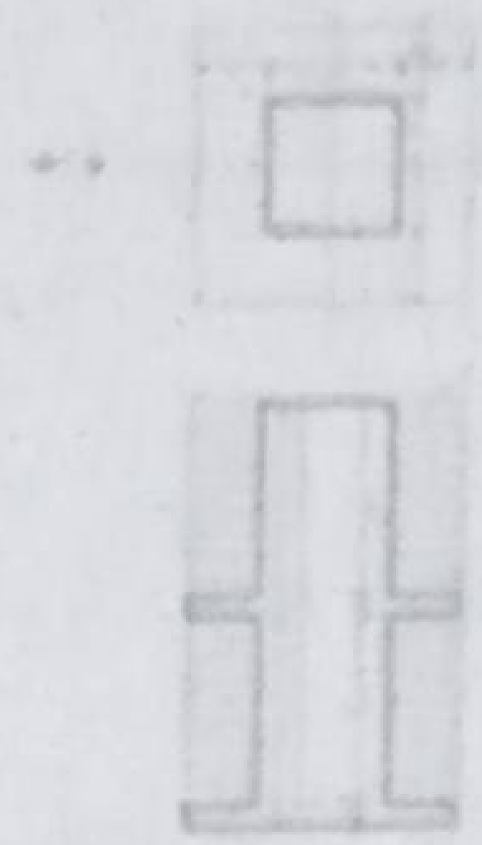


Figure 2 Possible physical configurations in plan and section of HRR building with internal light-well and voids developed by using Etzourny et al. (1974) model.

Table 2 Basic information of the buildings surveyed in KL and their status

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

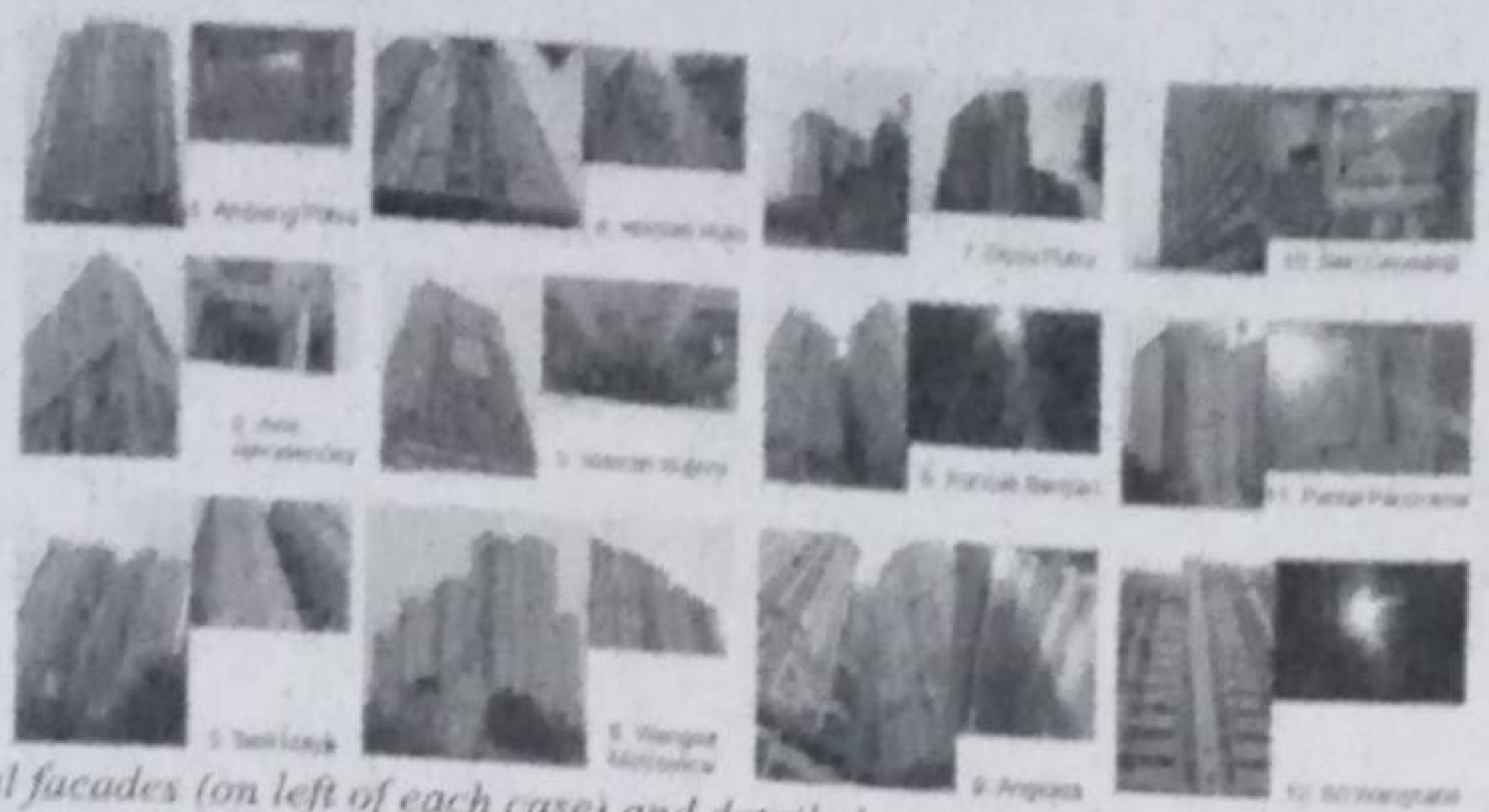


Figure 3 External facades (on left of each case) and detailed snapshots for light-wells (on right) for surveyed buildings in KL.

Table 3 Common possible configurations of HRR buildings derived theoretically from literature review and developed according to the light-well types (plans).

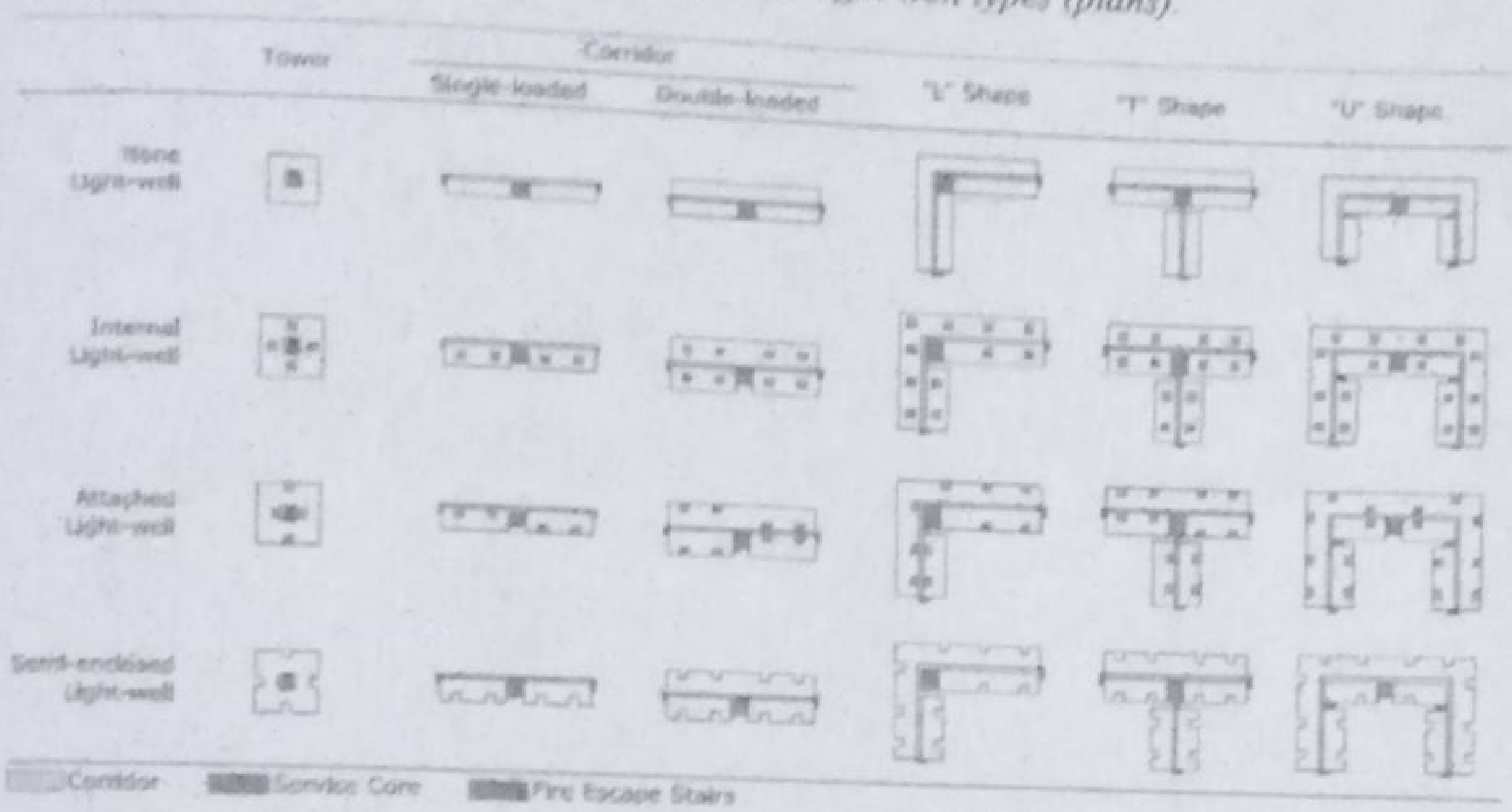


Table 4 Common configuration of HRR in relation to light-well type in selected case studies in KL (plans only.)

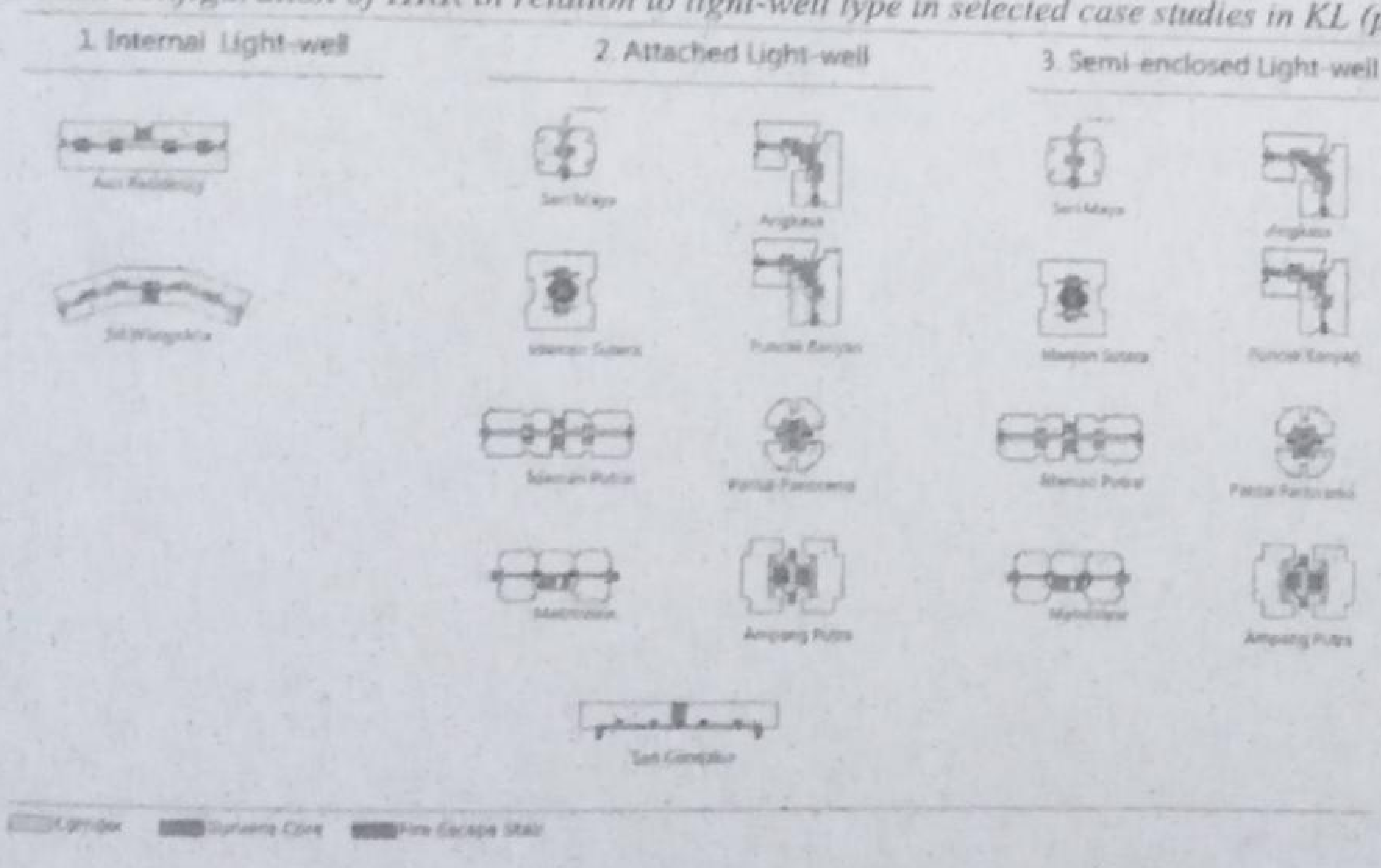


Table 5 Common configuration of HRR in some areas in KL regarding air passageways connections (plans & sections)

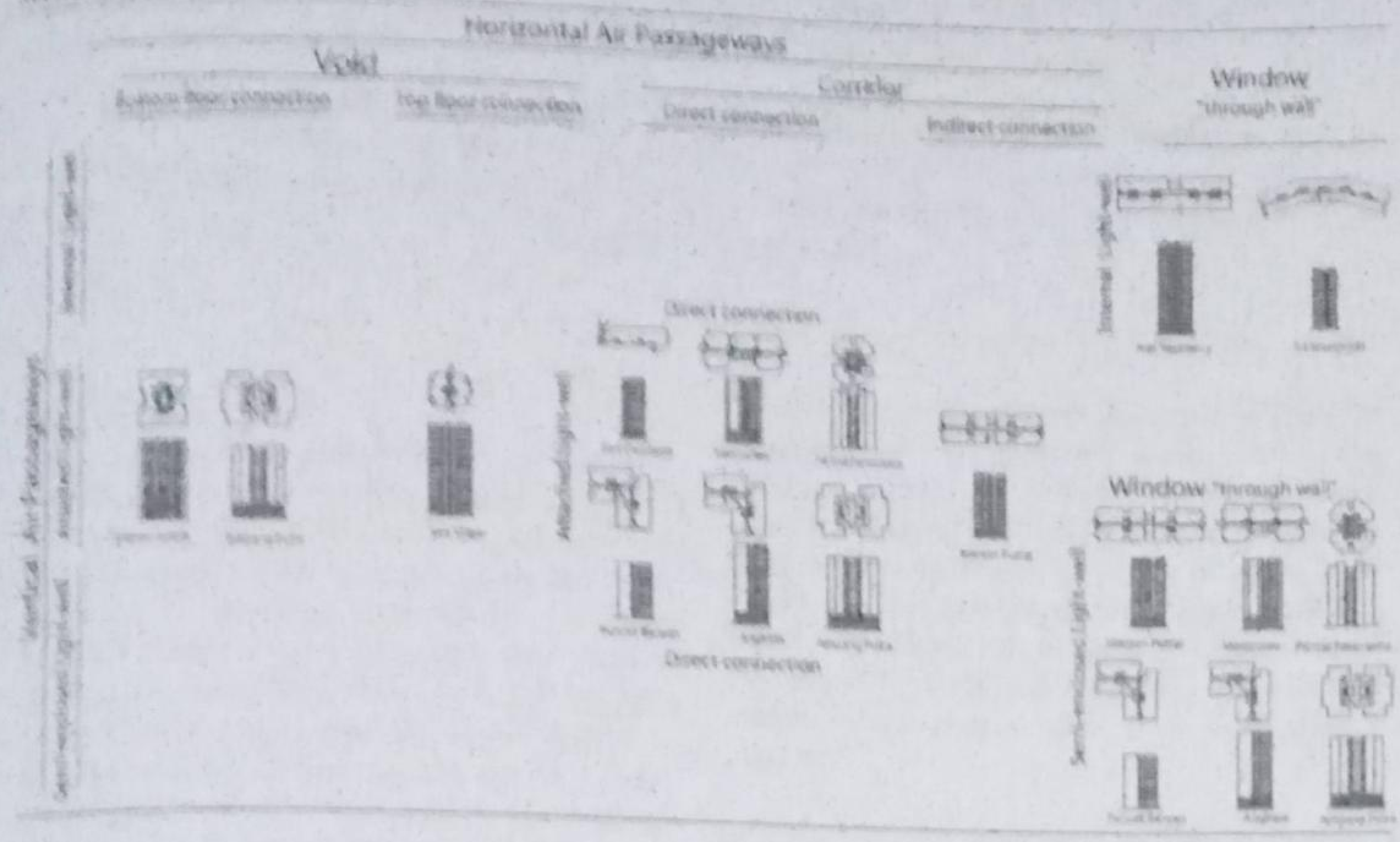


Table 6 Common possible configurations of HRR buildings regarding air passageways connection (plans & sections).