Environmental Performance of Adaptive Building Envelope Design: Urban housing in Seoul, Korea

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ABSTRACT

Since the first construction in 1962, apartment housing represented modernity and quickly became a ubiquitous urban housing typology in the midst of Korea’s rapid economic growth. Prominently influenced by the 1930s rational architecture from Europe, the housing site planning for Seoul systematically multiplied into a linear urban pattern of slab typologies. As the city stepped into the 21st century, the old slab typology—criticized for their lack of diversity and low density, adapted a new housing model from North American urban residential schemes—the mega glass tower. Energy consumption of the new tower typology has doubled from the linear slab model due to the increase in glazing ratio, the application of tinted green double glazing in replacement of clear double glazing, and the irregular orientation of the floor plans. This research analyzes the environmental performance of the new tower typology in comparison to the previous slab typology with the objective to improve the quality of future urban housing design and planning in Seoul.

INTRODUCTION

1930s rational architecture from Europe prominently influenced the housing site planning for Seoul, which systematically multiplied in a linear urban pattern. Consequently, typical urban housing layout in Seoul has the characteristics of expanding horizontally or orthogonally in clusters. These forms of clusters follow a linear, single orientation, slab configuration which conceptually provides a level of equality in housing that is in line with early ideas of modernity in the realm of architecture (Kang, 2004, p. 144-146). From a practical perspective, each unit could receive an equal amount of daylight, cross ventilation, and views outward within this system. This idea of equality, despite its formation of unity in the residential sector, simultaneously erased local identities of neighborhoods to the point where eventually every development appeared the same as the other throughout the entirety of the city.

Figure 1  1960s to 1990s Old slab typology apartment housing in Seoul, Korea.
Quite recently this linear apartment development strategy and residential culture have come under critical scrutiny. As the city stepped into the 21st century, the slab typology has been criticized for their lack of life quality, diversity, and dynamic urbanism. The old slab typology building can no longer provide the high density required by the city and create a healthy urban living environment. Developments from the 1960s to 70s remain in poor condition until the point of demolition (Kang, 2004, p. 143). As a reaction, from the demand for housing supply and its heavy reliance on the market, the scale of developments has increased to the mega glass tower. This residential tower typology of higher density is a model adapted from contemporary North American urban residential schemes. The tower simply as a typology has decreased the quality of residential living furthermore, in terms of creating a variety of housing clusters on a block and integrating with the urban built environment and community. Thus, a successful housing model does not exist yet in the city.

Figure 2  New tower typology highrise housing preconstruction sales in Seoul, Korea.

This research determines to analyze the environmental performance of the new tower typology with the objective to improve its quality in terms of architectural design and energy consumption through the building’s envelope. Further examination of the relationship between the building envelope and environmental impact of the urban layout provides insight for sustainable housing developments in Seoul.

BASE CASE STUDY: SLAB TYPOLOGY ENERGY PERFORMANCE

The typical slab housing typology constructed from 1960s to 1990s, were built to the height of 8-10 story as multifamily mid-rises with one or two vertical circulation cores servicing all the residents of the building. This typology allowed for each unit to have a double orientation towards north and south, guaranteeing a sufficient amount of daylight, cross ventilation, and solar gains.

Figure 3  Floor plan of the old housing type used in the base case study and diagrammatic depiction of the enclosed balcony.
An old slab typology flat of 136m² was studied as a base case. It was constructed in the early 1980s and had been planned for demolition in the near future by the developer into new residential buildings. When examining a typical floor plan from the slab typology, two important characteristics of the layout are the open kitchen to living room floorplan and the enclosed balcony spaces to the south and north exposures. The open plan layout is crucial for effective natural cross ventilation during the humid months of July and August. The distribution of internal gains from the kitchen is an insignificant amount according to the occupant, but still a diminutive contribution to the internal temperatures as an auxiliary source of heat.

The enclosed balcony spaces function as buffer zones that control heat loss during the winter and also have the purpose of solar protection in the summer season as overhangs or cantilevers. The balcony of the slab typology is typically a glazed area of 50% to the façade area, detailed with two sliding window apertures that open 50% horizontally. The exposed south vertical surface of this flat in the base case study also has a 50% glazing ratio to the façade. Clear double glazing is used on the apertures to the exterior as well as to the glazed interior sliding partitions that divide the balcony from the interior living room space. The advantages of controlling heat loss as a buffer space, and storing the captured solar gains to the flat is a key factor found in the floor plans of the old slab typology.

Climate Condition of Seoul

![Psychrometric chart defining the summer and winter comfort zones (Szokolay, 2007).](image)

The comfort band calculated from the equation, \( T_n = 17.8 + 0.31 \times T_o \), defines the summer comfort band range between 23 °C and 28 °C. The winter comfort band ranges from 17.5 °C to 20.5 °C. From the psychrometric chart, the red points plot the months of July and August. The relative humidity levels are high throughout the entire year but only falls outside the boundaries of comfort when the external temperature starts rising in the summer months of July and August. The yellow boundary defining the summer comfort zone shows that for the majority of July and August are outside comfort limitations. Consequently, cooling load consumption is also the highest during this period of discomfort due to this relative humidity level.

BASE CASE STUDY: TOWER TYPOLOGY ENERGY PERFORMANCE

Urban housing in Seoul has changed drastically since 2000 in terms of typology, construction, design and not absolutely for the better. The market demanded for housing with significantly higher density as the city became over populated. As a consequence, office-tower type urban residential models found common in North American cities (i.e. New York City, Los Angeles, and Chicago) were adapted...
into the residential sectors of Seoul. These towers satisfied the market’s new density demand and provided diversity in the design of the floor plans (in comparison to the simple slab floor plates), in its irregularity and asymmetry. Each unit found more variety in the layout of the interior spaces and orientation towards the city. But these deeper tower plans have appeared to create new problematic environmental issues. The new tower typology unit which is analyzed closely as a case study is a corner unit of 132m² exposed to both south east and south west. Most of the units within the towers have lost the benefits of natural cross ventilation and north-south orientation of the old slab model. Externally the tower typology has not been able to address its contribution to the urban fabric of the city in providing an improved open space. In fact, the quality of the open space is in greater threat of diminishing due to the height and higher obstruction angles created by these mega towers.

Urban living in a dense city such as Seoul is a constant fight for more space. Due to the desire for maximizing floor sq meters for liveable space, the previous enclosed balconies have been erased for maximum floor sq meter and consequently the envelope has become a 100% fully glazed façade. From the post occupancy evaluation with the family, most discomfort was expressed during the summer months for overheating, weak natural ventilation, and high bills for cooling. In the tower typology base case, poor operable aperture on the glass façade with a small area of merely 0.84m² which tilts outward with a maximum angle of 30°, is a hindrance to the performance of natural ventilation.

![Figure 5](image.png)

**Figure 5** Construction standard comparisons between base cases of the old slab typology and the new tower typology (Jang, 2002).

### Glazing Type and Thermal Performance

An essential difference between the two typologies is found in the envelope of the building. In terms of construction, the heavyweight construction of the old slab typology has transformed into lightweight construction in the new tower typology. The external wall of the slab typology had a typical U-value of 0.47W/m²K—concrete load bearing wall construction with insulation placed on the inner side
of the wall. In the old slab model, the envelope of the building had a 50% glazing ratio to the façade. This ratio increased nearly to 100% in the new towers. Clear double glazing with a standard U-value of 3.0W/m²K and solar transmittance g-value of 0.707 has been replaced with tinted (commonly green tint) double glazing with a solar transmittance g-value of 0.422. The tinted glass has become a conventional strategy by contractors for urban housing to accommodate the increased glazing area and reduce overheating. In the new tower typology base case, poor operable aperture on the glass façade with a small area of merely 0.84m² which tilts outward with a maximum angle of 30°, is also a hindrance to the performance of natural ventilation.

![Diagram of building layout]

Figure 6  TAS simulation results show that the new tower typology unit has multiplied in annual heating and cooling consumption by approximately 50% in comparison to the old slab model. Previous research data collected from various organizations such as, the Korean Solar Energy Society, Seoul National University of Technology, and Korea Institute of Energy Research Department showed thermostat temperatures set at 20°C for winter heating simulations and 25°C for summer cooling. Both units are 136m² and 132m² in floor area, similar in the layout of the interior spaces, and with the same occupancy.

Impact of Obstruction by Urban Layout and Energy

An important issue to deal with is the urban planning of the new tower typology. What environment or context should the tower be in? A repetitive distribution motivated by careless market driven developments will lead to the identical banality created by the old slab typology. Urban planners and city authorities must have a higher awareness to prohibit monotonous, simply cost-saving development. The sheer height of the new typology creates a greater challenge in terms of integrating with the urban fabric at the ground level. Environmentally, the longer overshadowing of neighbour buildings and the open outdoor spaces must be taken cautiously into consideration during the early urban planning stages.
Figure 7 Aerial photo depicting the urban layout of the old slab vs. the new tower typology. The typical urban canyon of the old slab typology in Seoul was a 1 to 1 ratio of height to width.

Figure 8 The thermal performance of a 1m² clear double glass glazed area for the two urban canyon ratios—1 to 1 and 3 to 1 ratio, maintains a parallel pattern to each other for the entire 12 months.
Three mid floor levels are studied to understand impact of obstruction angles. The balance in kWh/m²day calculates the difference between amount of solar gain and amount of heat loss over the area of a 1m² glazed vertical surface. At the 3 to 1 ratio urban canyon, the percentage reduction of annual incident solar radiation is already less than half of the available amount falling on the south vertical surface of a 1 to 1 ratio canyon. Corresponding to the different percentage reduction in the annual incident solar radiation, the thermal performance of glazing also shows a similar 50% to 60% difference between the two urban canyons. To take a specific example, in Figure 8, the 5th level floor which has a positive balance of solar gain than heat loss until the month of December in the 1 to 1 ratio canyon; at the 3 to 1 ratio canyon it shows for almost half of the year, there is greater heat loss than solar gain through the glazed area.

![Thermal Performance of Different Glazing Types]

Figure 9 The chart studies the thermal performance of different types of glass. Four types are studied: clear double glazing (U-value: 3.0 W/m²/K, solar transmittance g-value: 0.707), double glazing with low-e (U-value: 1.8 W/m²/K, solar transmittance g-value: 0.616), triple glazing (U-value: 1.2 W/m²/K, solar transmittance g-value: 0.64), and green tinted double glazing (U-value: 2.94 W/m²/K, solar transmittance g-value: 0.422).

The conclusion from this study is that, the three glazing types: clear double glazing, double glazing with low-e, and triple glazing, because of it proximity in solar transmittance g-values, perform similarly in the summer climate of Seoul. But for the cold winter months of November through February, the balance between solar gain and heat loss starts to vary according to their different U-values. In terms of thermal
performance for the lowest level floors at the ground, double glazing with low-e appears as a sufficient application for glazing choice to minimize heat loss.

The green tinted double glazing which has been applied to new urban housing construction in Seoul as a substitute or response to higher glazing ratios in the façade performs the worst in the winter season. Due to its lower solar transmittance g-value, the summer performance is stronger than the other options but it is at the cost of an extremely poor winter performance.

CONCLUSION

With an informed building envelope that responds to the climate in Seoul, the performance of the new tower typology is significantly improved. In terms of general strategies for energy saving for the new tower residential typology in Seoul, the most effective measures were found first in replacing the green tinted double glazing (0.422 g-value solar transmittance) with double glazing with low-e. Though the annual cooling consumption increases by 41% with the higher solar transmittance (0.707 g-value) of the double glazing with low-e, the more problematic energy consumption is in heating and this increased cooling amount is reduced again with the application of external shading. The second general strategy is to improve the U-value of the external walls from the standard of 0.47 Wm²/K to 0.28 Wm²/K. The improvement in the U-value of the external wall improves heating consumption by 11%. In addition the application of insulated night shutters and external shading devices to the façade of the new residential tower typology is crucial as an architectural solution in response to the demand for higher glazing ratios. Night shutters with 20mm of insulation with a 0.026 conductivity, can save 30% of heating consumption. The same device which is used as an external shading device can reduce 55.2% of cooling consumption. External shading devices dissipate any absorbed solar energy to the outside air and therefore play a key element for passive cooling. Internal blinds were the least effective in terms of solar control in comparison to external blinds.

To push energy savings to extremely lower values, selective use of the enclosed balcony is necessary in the interior. The final strategy can theoretically achieve values as low as 12.5 kWh/m² for annual heating consumption and 8.1 kWh/m² for annual cooling consumption.

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REFERENCES


