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Study of the energy performance of Korean apartment buildings with alternative balcony configurations

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Abstract

The purpose of this study is to evaluate the impact of the new regulations design changes on heating loads of apartment buildings and identify the construction configurations (e.g. glazing types, thermal properties, window area ratio, etc.) of the new designs that will ensure the energy performance is at least on the same level as those with a traditional balcony configuration.

Keywords

balcony, energy, configurations, study, alternative, buildings, apartment, korean, performance

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Study of the Energy Performance of Korean Apartment Buildings with Alternative Balcony Configurations

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1. Introduction

Korean residential apartments, as seen in Figure 1, typically have balcony areas at both the front and the back. Windows are installed internally separating the living area from the balcony; and externally separating the balcony from the outside. The balcony areas are not thermally conditioned, but function as a buffer zone to mitigate heating/cooling loads and environmental impacts such as external noise.

Figure 1. Typical Korean apartment.

Recent updates to the Korean building regulations are more flexible than those in the past in terms of allowing alternative building designs, such as new configurations of the previously compulsory balcony areas in new and existing apartments (e.g. various balcony depths, no internal windows, various glazing types for external windows systems, etc.). Since the new regulations came into force, house owners and housing construction companies prefer designs which maximize the living space and minimise the balcony areas in order to increase flexibility of space utilization. This tendency leads to a reduction in the thermal buffering which potentially impacts on the energy performance of apartment buildings. It is, therefore, important to ensure that the thermal performance is not degraded when these buffer balcony spaces are minimized/ removed to give expanded living areas.

The purpose of this study is to evaluate the impact of the new regulations design changes on heating loads of apartment buildings and identify the construction configurations (e.g. glazing types, thermal properties, window area ratio, etc.) of the new designs that will ensure the energy performance is at least on the same level as those with a traditional balcony configuration.

A parametric analysis has been carried out using the ESP-r simulation program. A reference model was defined representing a typical Korean apartment with conventional balcony spaces. The thermal performance of the various design configurations has been investigated by varying the following: thermal and optical properties of glazings, window-to-wall area ratio, width/depth ratio and apartment orientation.

2. Balcony in Korean apartments

Conventionally, balcony areas are used as service areas (e.g. wahing, drying clothes, storage etc) rather than living areas. Due to changes within the building regulations, house owners are allowed to expand the living areas by refurbishing and reducing the balcony areas. Figure 2 illustrates a plan views of a Korean apartment with a traditional balcony area (a) and a refurbished balcony area (b). It can be seen in Figure 2(b) that the internal walls and windows that used to be separating the living areas from the balcony areas have been either removed or relocated.

(a) original plan (b) refurbished plan
Figure 2. Apartment plan views with different balcony areas.

This refurbishment could lead to possible problems associated with a reduction in energy performance, reduced environmental conditions inducing condensation and thermal dis-comfort. There are, however, no specific design guidelines for 'appropriate configurations' of alternative balcony spaces (e.g. type of glazing, window-to-wall area ratio, etc.). A number of researchers have studied the effects of different balcony configuration in terms of thermal comfort [1], condensation [2][3], and energy performance[4][5][6]. Most of these previous studies focusing on the energy performance were based on calculations from dynamic building simulation programs where building models were made by treating balcony areas as an integral part of the thermal envelope of the main living area instead of modelling it as a separate zone with geometric dimensions. These approaches would not represent the true performance of the building as it would experience different solar radiation distributions and heat gains when compared to the actual results.
Depending on the dimensions of the balcony areas and the modelling approach adopted, the calculated solar radiation entering the living areas through the windows of the balconies are different. It is required to evaluate the energy performance of this type of designs by taking account of the thermal and optical properties of the glazing system; and at the same time, the geometric characteristics that would affect the solar distribution analysis on the inside building surfaces.

3. ESP-r modelling of typical apartments

3.1 Geometric model

The Geometric model used in the ESP-r simulations was configurde to represent the typical Korean apartment with balconies at both front and back, as shown in Figure 3. It is necessary to consider the number of spaces surrounding the living room to take account of the appropriate boundary conditions and perform a solar radiation distribution analysis for all the balcony and glazing dimensions.. The study focused on a middle floor living room space and two balcony spaces on the north and south façades.
Two type of shapes for the living room are selected for the reference model while maintaining the total floor area for both cases: 0.5 and 1.5 width/depth building ratios. For the reference case, the width of the living room is 4.5 m and the depth is 9.0 m (i.e. floor area of 40.5 m^2). A typical balcony depth for Korean buildings of 1.4 m is used for the balconies of the reference case. The glazing covers 80% of the external south façade of the balcony and 49% of the internal south façade. The north facing balconies were assumed to have glazing that covers 20% and 30% of the external and internal north façades respectively. A number of case models were created with various configurations including: alternative south balcony dimensions, glazing properties, orientations and glazing dimensions on the external south façade.

3.2 construction properties

Typical constructions that are currently used in new Korean residential buildings have been modelled in this study. The external walls of the living spaces are concrete insulated walls with a U value of 0.47 W/m^2K while the external walls of the balconies are un-insulated concrete with a U value of 2.9 W/m^{2}K and glazing properties as described in section 3.3 in this paper. For both the reference case, and typical Korean construction case, a clear glass double glazed unit with a U value of 3.3 W/m^{2}K is used for the living spaces and a similar unit is used for the exterior windows of the balcony spaces.

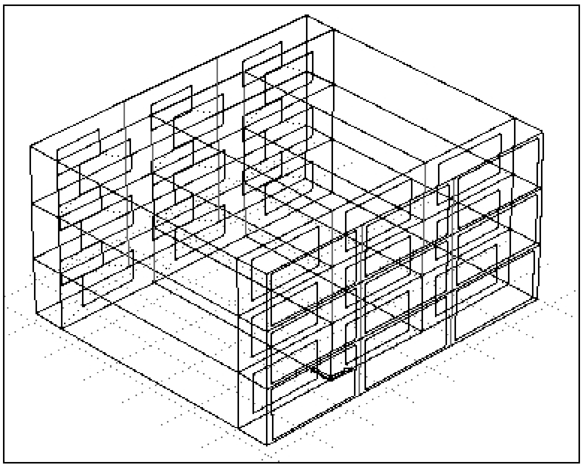


Figure 3: Reference building model used in the simulation

3.3 Weather data

The hourly climate data used in this study were based on the Korean Typical Reference Year data. A monthly overview of temperature and direct normal solar radiation is given in Table 1.

Table 1: Climate data

	Ambient Dry Bulb Temperature (°C)			Direct Normal (W/m^2)	
Month	Min.	Max.	Aver.	Max.	Aver.
Jan.	-14.0	8.0	-3.4	929.0	130.7
Feb.	-10.0	10.0	-0.6	701.0	142.0
Mar.	-4.0	18.0	6.2	877.0	155.8
Apr.	3.0	24.0	11.9	771.0	149.7
May	7.0	29.0	17.3	675.0	161.2
Jun.	13.0	32.0	21.5	762.0	140.6
Jul.	18.0	33.0	24.7	526.0	86.6
Aug.	15.0	33.0	25.0	633.0	115.3
Sep.	13.0	29.0	21.2	769.0	142.6
Oct.	3.0	28.0	14.6	848.0	163.2
Nov.	-5.0	18.0	6.9	783.0	111.4
Dec.	-10.0	11.0	-0.6	673.0	94.4

3.4 Glazing properties

A number of glazing types were used in this study with wide range of U values as well as solar transmittance. Table 2 describes the U values of glazing options while Figure 4 shows the solar transmittance profiles associated with the glazing options.

Table 2: U values for glazing options

Type of Glazing	U-value (W/m^{2}K)
Double clear, air filled	3.3
Double clear, argon filled	2.5
Double, low emissivity, air filled	2.5
Double, low emissivity, argon filled	1.5
Triple, low emissivity, argon filled	1.5
Triple, low emissivity, xenon filled	0.7

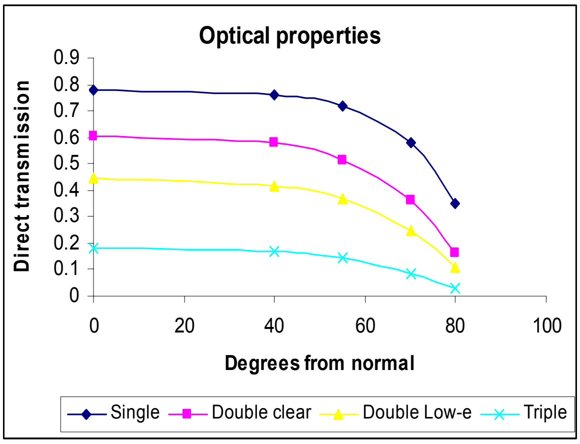


Figure 4: Solar transmittance for glazing.

3.5 Operation

An air infiltration leakage of 0.7 air changes per hour has been assumed for the whole day in the living spaces where heating and cooling set-points have been considered to follow the guidance of building regulations; and set at 21°C and 27 °C respectively. Internal heat gains (e.g. occupants and lights) have not been taken into account due to the low values associated with these..

4. Simulation cases

The analysis focused initially on the possible alternative design options for the south facing balconies as it is the most common type of balcony orientation for Korean residential buildings. More than 200 building models were created and simulated using the ESP-r simulation program. It should be noted here that the base case represents a conventional balcony (i.e depth 1.4 m, using clear double glazing for both inside and outside facing windows). In detail, the following design options were modelled:

- The depth of the south balcony used in the reference case has been changed from 1.4 m to 0.7 m then with no balcony area. This was undertaken to examine the effects of change to the balcony's geometric dimensions on the heating load; and the associated solar radiation entering the building space.
- A combination of glazing systems as those described in section 3.4 were modelled for the inside and outside windows of the front (i.e. south for the reference case) balcony.
- All glazing types shown in Table 2 were used for all cases when assuming that the living area has been extended and the balcony totally removed (i.e. no buffer space).
- Glazing areas covering 80%, 65%, 50% and 35% of the external façade of the front facing balconies has been modelled. This was done for all cases where the balcony space has been removed. All combinations of glazing types have been modelled in all cases with different glazing sizes.
- South and North orientations were selected in order to investigate the effect that building orientation, and especially the calculated incident solar radiation on surfaces, may have the various configurations of balcony areas.

5. Results

5.1. The effect of balcony depth on heating load

As can be seen in Figure 5, in the case where design changes (e.g. balcony dimensions) have been applied to south oriented balconies, the heating loads for the cases where the balcony has been removed (i.e. no balcony) are lower (i.e. 37.5 kWh/m^{2}·annum for case 3, 32.5 kWh/m^{2} annum for case 4, 28.2 kWh/m^{2}·annum for case 5) than the base case (i.e. 45.6 kWh/m^{2}·annum for case 1). The opposite pattern can be noticed for cases where the same design changes are applied to north oriented balconies, In these cases the heating loads for the apartments where the balcony has been removed are higher (i.e. 71.9 kWh/m^{2}·annum for case 3) than the base case (i.e. 61.3 kWh/m^{2}·annum for case 1) and decrease as the thermal performance of glazing improves. Balcony depth has a different effect on the heating loads for the various balcony orientations. South-oriented balconies have disadvantages in terms of limiting the hight for south facades solar gains that could be potentially entering the main living area (i.e. there are shading effects associated with these cases). On the other hand, north facades receive significantly less solar radiation than the south facades and for north-oriented balconies the thermal characteristics of the constructions are more important (i.e. to limit heat losses through them) than the shading effect that balconies may have on the main living area. This has been confirmed from the simulation results of this study.

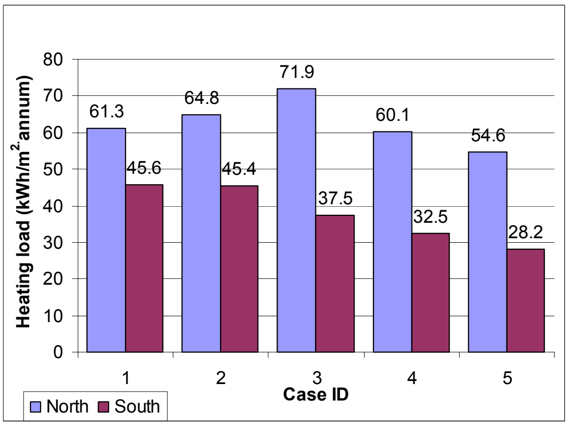


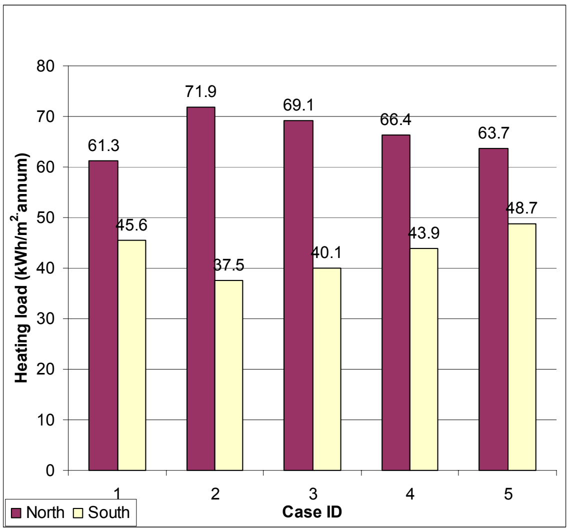
Figure 5: Comparison of heating loads according to balcony depths and glazing types (window-to-wall ratio: 80 %).

Table 3: Description of case ID in Figure 5.

Case ID	Details
1	Base Case (1.4m depth)
2	Alternative balcony size (0.7m depth)
3	No Balcony - Double clear, U=3.3 W/m^{2}K
4	No Balcony - Double Low-e, U=2.5 W/m^{2}K
5	No Balcony - Double Low-e, U=1.5 W/m^{2}K

5.2 The effect of window-to-wall ratio

To identify the effect of window-to-wall ratio variations on the energy performance of apartments where the balcony has been removed, a number of cases were compared for different window-to-wall ratios while containing identical glazing properties (i.e. double glazing). Figure 6 shows the heating loads for these cases and includes results for buildings where the design changes have been made at north and south balcony orientations. As discussed previously, north-oriented façades are mainly associated with the thermal characteristics of the constructions (i.e. U values). The heating loads for the cases where the balcony has been removed from these north facades (case 2, case 3, case 4, and case 5) are higher than the base case and are related to the amount of wall insulation and therefore the changes on window-to-wall ratio. In contrast with this, south-oriented façades are strongly affected by the amount of incident solar radiation as well as the thermal characteristics of glazing and wall construction. (i.e. U values) and for this reason the results from the simulations on heating loads seem to increase as the window-to-wall ratio on these facades decreases. Thermal and optical glazing properties are a significant determinant for the energy performance of apartments with south-oriented balconies. A more detailed analysis for the effect of glazing properties on heating loads is given in the following section.



F igure 6: Comparison of heating loads according to window-to-wall ratios of no balcony options.

Table 4: Description of case ID in Figure 6.

Case ID	Details
1	Base case (balcony & 80% outside window/wall ratio)
2	No balcony - 80% window/wall ratio
3	No balcony - 65% window/wall ratio
4	No balcony - 50% window/wall ratio
5	No balcony - 35% window/wall ratio

5.3 The effect of glazing types and room shapes on heating load.

The various glazing options that are described in Table 5 were assessed for their impact on the building's energy performance. This was done for a number of south-facing balcony configurations. Figure 7 shows the results when comparing heating loads for the reference case with conventional balcony and cases where the balcony has been removed from the south façade. From the cases where the balcony has been removed, the use of clear double glazing (i.e. Case 4) leads to better energy performance than the triple low-emissivity glazing options (i.e. Case 2. and Case 3) despite the fact that the U values of the triple glazing windows are lower. This is because the triple glazing windows have lower solar transmittance values and limit the solar radiation entering the room. It is concluded that the balance between the thermal characteristics and the optical properties of the glazing should be carefully considered for the cases presented in this paper.

The shape of the room will also effect the thermal loads and a number of different results can be produced depending on the combination of design changes that are applied e.g window-to-wall ratio, optical and thermal properties. These are also shown in Figure 7. It can be confirmed for the cases with conventional balconies (i.e. case 1), high width/depth ratio rooms have higher heating demand than the low width/depth ratio rooms due to the fact that they have larger external facing surface areas (assuming width is the south façade dimension). This is especially true for the facades with low amounts of glazing (e.g. 35% window-to-wall ratio).

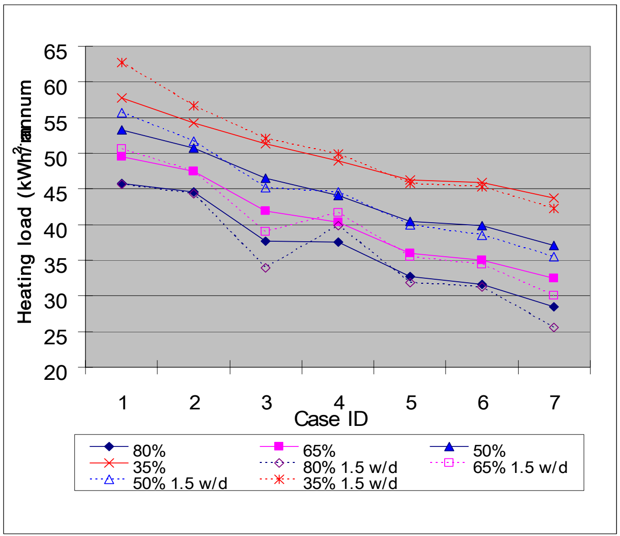


Figure 7: Comparison of heating loads according to glazing types and width/depth ratios (orientation: South)

Table 5: Description of case ID in Figure 7.

Case ID	Details	U (W/m^{2}K)	Transmittance
1	Base Case	3.3	0.61
2	No balcony – Triple Lowe	1.5	0.18
3	No balcony – Triple Lowe	0.7	0.18
4	No balcony - Double clear	3.3	0.61
5	No balcony - Double Low-e	2.5	0.45
6	No balcony, Double clear	2.5	0.61
7	No balcony, Double Low-e	1.5	0.45

7. Conclusions

In this study, a number of balcony configurations with various design options were assessed in order to investigate their impact on heating load. The results indicate that the design elements affecting the solar radiation entering the building (e.g. balcony depth, window-to-wall ratio, glazing optical properties, etc.) have a significant impact on the heating loads. A detailed solar distribution analysis needs to be adopted to assess the energy performance of Korea apartments with glazed balconies.

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