

Effect of Balcony Space in Multi-residential House

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ABSTRACT

In these days, the balcony space is remodeled as a living space in Korea. The balcony space is a medium space where connects indoor and outdoor in multi-residential house and act as climate-filter space where can minimize indoor environment changes with the changes of outdoor climate. Expanding the balcony means that lose a buffer space and it causes a thermal discomfort such as cold draft in winter. And it also causes increasing of condensation at the surface of the wall and windows and the heating/cooling load.

In this study, indoor thermal environment properties with or without balcony were investigated through field measurement, and base on the results of field measurement, the thermal comfort, condensation rate and heating and cooling load were analyzed through numerical simulation (TRNSYS Simulation coupled with Window5 and Therm5). Finally, to settle the problems of balcony extension case, the alternative window systems were suggested in this study.

KEYWORDS: Balcony remodeling, Thermal Environment, Building load, Measurement, Simulation

1. INTRODUCTION

The balcony space has been used as a buffer space to alleviate the effect of outdoor climate on indoor environment. Especially, the balcony spaces fitted with windows for multi-story residential buildings in Korea, and play an important role in indoor thermal environment. However, the balcony space is remodeled as a living space in Korea recently. Against this trend, the Korea government authorities permit remodeling of balcony space from December 2005.

As an affirmative aspect, remodeling of balcony is expected to have a variety on uniformed existing multi-residential house design. However, as a negative side, removing balcony space causes a thermal discomfort such as cold draft and increases the heating and cooling load. Therefore, the designer and construction engineer should suggest the new types of exterior wall and window system considering heat loss and thermal discomfort in case of removing balcony space.

Although many studies were reported for the balcony remodeling, almost former studies were focused on quantitative aspects of balcony space (Yoon 1999).

In this study, the physical characteristics of balcony space were analyzed through field measurement and numerical simulation. The effect of balcony space on indoor thermal environment was analyzed by field measurement. Based on the field measurement, the characteristics of window system with or without balcony space were analyzed by Window5 and Therm5. These results were inputted as variables of TRNSYS (TRansient System Simulation Program) Simulation. Finally, the heating/ cooling load and condensation rate was calculated by TRNSYS simulation. These results

suggested in this study will be used as a guide to develop the new types of building skin such as exterior wall and window system.

2. ANALYSIS OF THERMAL CHARACTERISTICS BY FIELD MEASUREMENT

2.1. Outline of field measurement

1) Analysis model

The analyzed house is a multi residential house located at Seoul city in Korea. The analyzed houses are second(with balcony) and fifth floor(without balcony) of 12 floors respectively. No one was occupied in the analyzed house at that time.

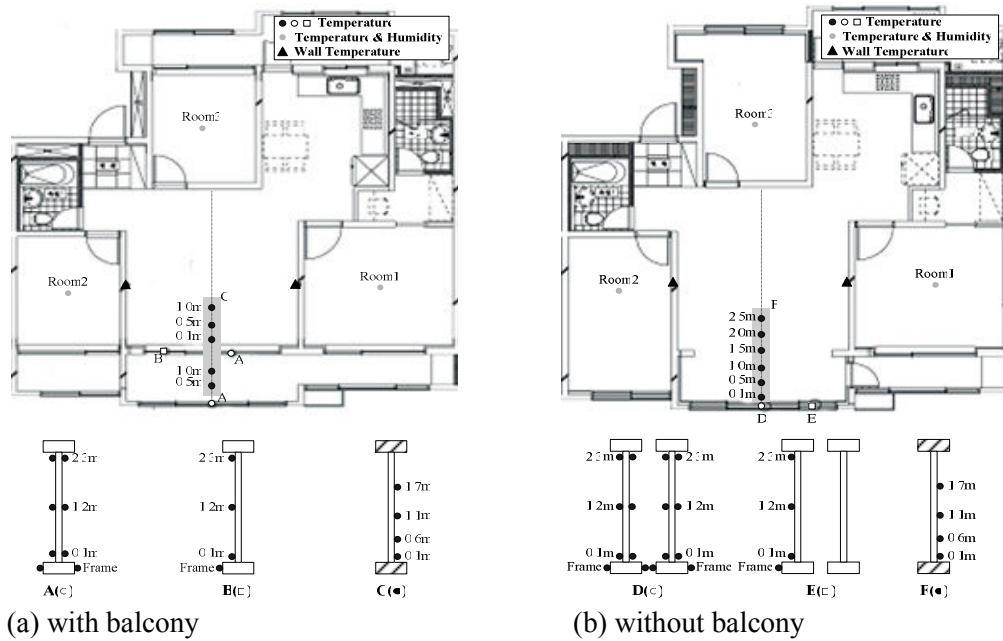


Figure 1. Analysis model house (with and without balcony)

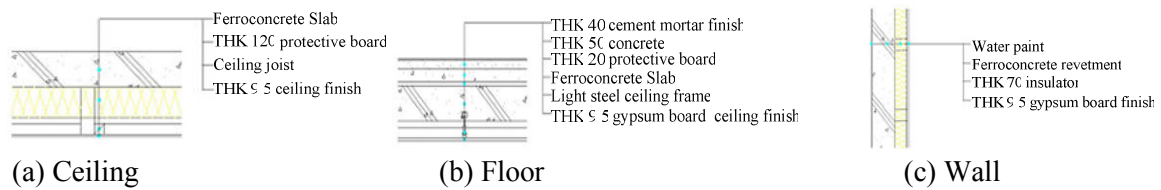


Figure 2. The layer of ceiling, floor, wall of the analysis house

Table 1. Measurement schedule and items

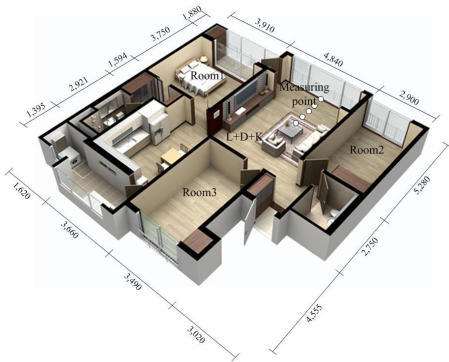
Day	Measurement items	Others
December 11	-	Equipment setting
December 12	- outdoor	-
December 13	Temperature / RH. Wind velocity	Ventilation quantity of a space with balcony
December 14	- indoor	-
December 15	Temperature distribution RH. Wind velocity	Ventilation quantity of a space without balcony
December 16	Globe temp.	-

2) Measurement details

The measurement was accomplished for six days (from 11th December 2006 to 16th December 2006). The target area of measurement was living room. From the measurement the temperature discrepancy between the balcony spaces was recorded. As a result, indoor thermal comfort was analyzed in a condition of with or without balcony space.

In all cases, the room temperature was set at 23 °C. The horizontal and vertical temperature was measured to analyze the effect of balcony space on thermal environment of indoor room.

Moreover, the indoor air flow, relative humidity, and globe temperature were measured to evaluate the indoor thermal comfort.



(a) Measurement place



(b) Measurement instrument

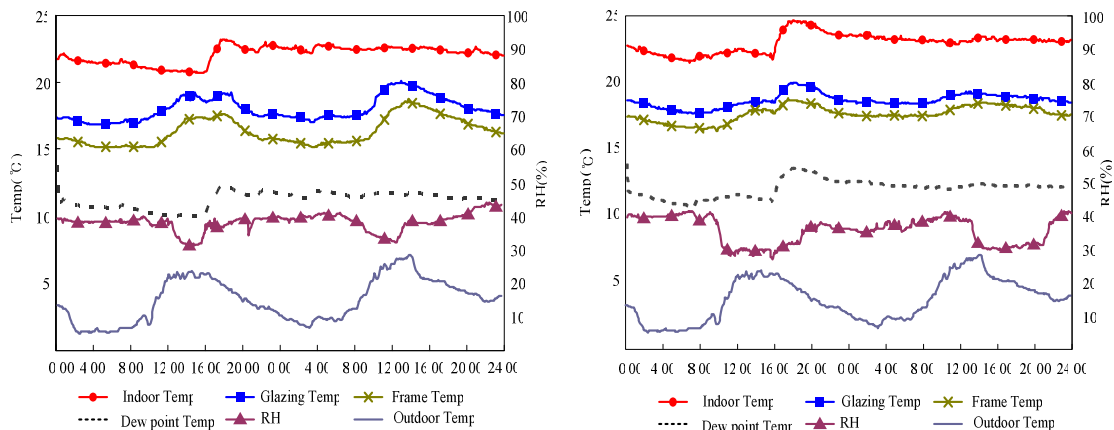
Figure 3. View of field measurement

2.2. Results of measurement

Figure 4 shows the indoor temperature, surface temperature, RH and dew-point temperature variation under with or without balcony in a same outdoor temperature and RH condition. Even though the outdoor temperature is same, the indoor and surface temperature is different between the two cases.

According to the heat loss from the exterior wall, the indoor temperature was dropped to 21.0 °C under the without balcony space, as result, the indoor temperature could not regulate with a set point.

Temperature difference with or without balcony space is about 2 °C. However the surface temperature is higher than dew-point temperature in both cases.



(a) With balcony

(b) Without balcony

Figure 4. Temperature and relative humidity distribution

3. NUMERICAL ANALYSIS

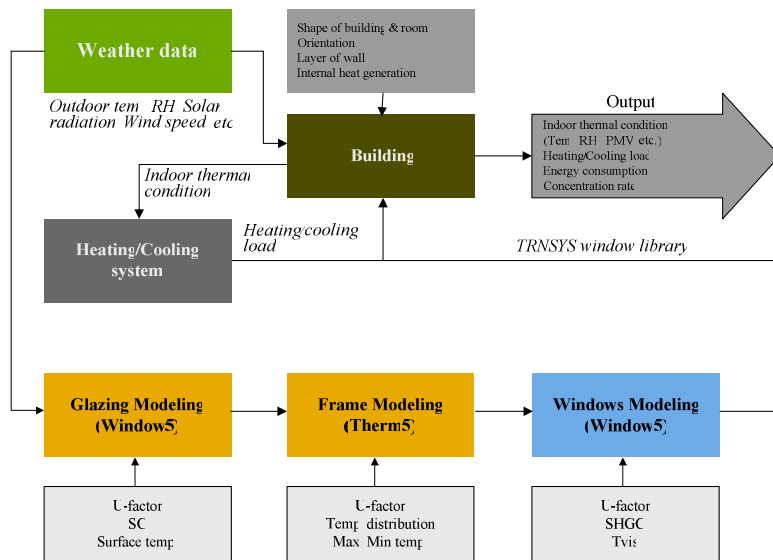


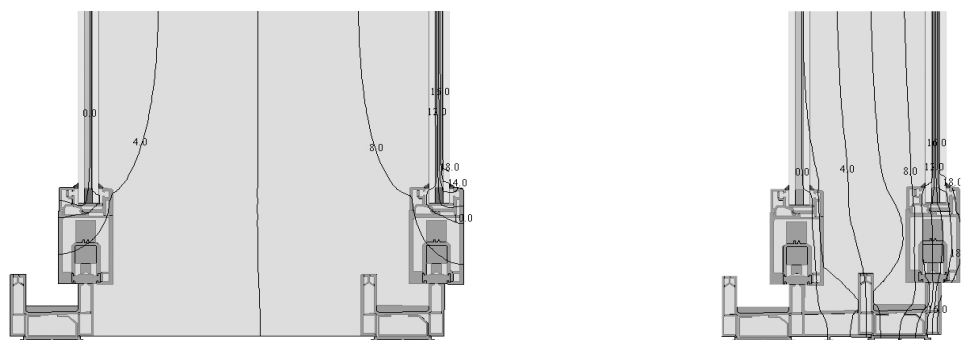
Figure 5. Schematic of integrated simulation tool

In order to compare the indoor environment such as indoor thermal condition, building heating/cooling load, and condensation rate of a space under with or without balcony, the integrated simulation method was suggested in this study. The integrated simulation method is based on the TRNSYS, and the windows installed in a measurement house were modeled through Window5 and Therm5. Window modeling is divided by three steps. First, glazing is modeled through Window5 and the next frame is modeled through Therm5. Finally, these are integrated through Window5. These results were added in TRNSYS window library and applied to building modeling for TRNSYS simulation. When windows were modeled, indoor temperature was set 20 °C and outdoor temperature was set 0 °C respectively by KS(Korean Industrial Standard). Figure 5 shows the information flow in the integrated simulation.

3.1. Windows analysis

1) Outline of the Window5, Therm5

The physical properties of window system installed in field measurement housing plane were analyzed through Window5 and Therm5. In case of the balcony existence condition, outdoor window glazing is made up 3 layers (6mm(glass)+6mm(air)+6mm(glass)), and inner window glazing also 3 layer (5mm(glass)+6mm(air)+5mm(glass)). In case of the balcony without condition, window system is



(a) with balcony space (b) without balcony space
Figure 6. Thermal properties of the analyzed window system

composed of two windows, one is made up 3 layers(5mm(glass)+6mm(air)+5mm(air)) and the other is the same. When analyzing the newly modeled window system, the frame and balcony space or air space also modeled to compare the total thermal performance of window system.

2) Simulation result

Table 2 and Figure 6 show the thermal performance of the analyzed window system. In case of the balcony existence condition, U-factor of outdoor glazing was 3.34W/m² K(18mm) and inner side was 3.37 W/m² K(16mm), and the frame was resulted in 2.09 W/m² K. In case of the balcony without condition, U-factor of total glazing was 1.739 W/m² K and the frame was 0.89 W/m² K. As shown in Table 2, the total U-factor of balcony existence condition was re-calculated by including the thermal resistance of balcony space.

Table 2. U-factor of balcony space and window of a space without balcony

	Balcony space	Window of a space without balcony space
Size	6/6/6/1330/5/6/5 (mm)	5/6/5/89/5/6/5 (mm)
Glazing U-factor	1.23 W/m ² K	1.74 W/m ² K
Frame U-factor	0.85 W/m ² K	0.89 W/m ² K

3.2. Building load simulation

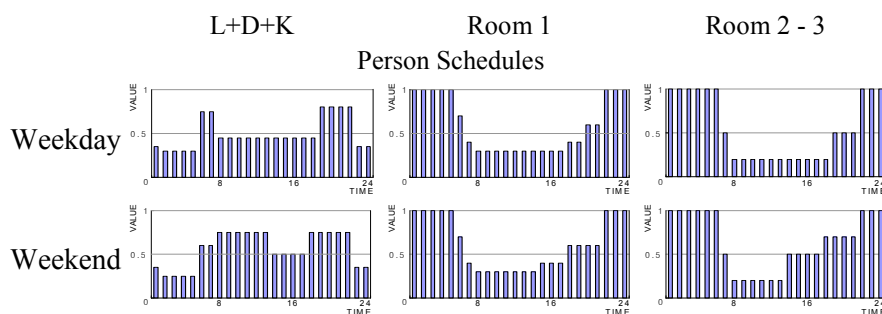
To analyze the building load and condensation rate for the alternatives of exterior wall construction, the TRNSYS simulation was performed.

1) Outline of the TRNSYS simulation

Analyzed building model is same as the field measurement housing plane. Indoor and outdoor wall constructions are also same as the measured building. In this paper the thermal difference and heating/cooling load were analyzed under the balcony with or without conditions. Table 3 and Figure 7 show the simulation conditions.

Table 3. Conditions for TRNSYS simulation

Weather data	Standard weather data (The society of air-conditioning and refrigerating engineers of Korea)	
Location	Middle floor, adjacent house neighborhood	
Heating set point	22 °C , 40%	
Cooling set point	26 °C , 60%	
Heat gain	Person (Seated at rest)	Sensible heat: 60 W, Latent heat: 40 W
	Lighting	Room: 10W/m ² , Living room: 13W/m ²
	Equipment	Room: 20W/m ² , Living room: 23W/m ²
Ventilation	0.7 ACH	



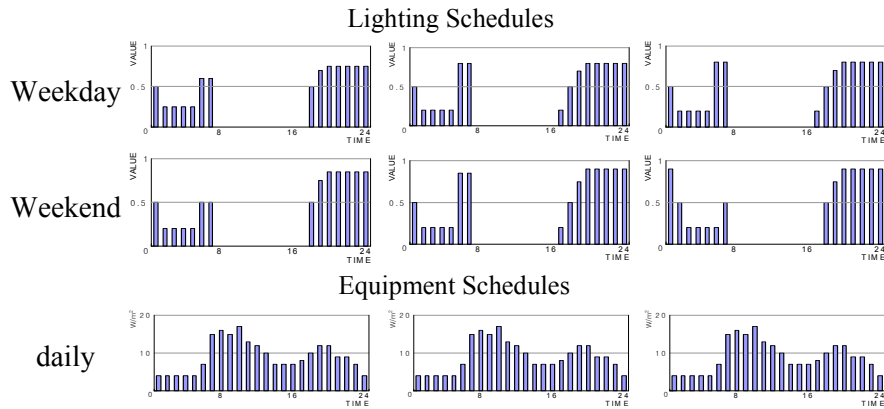


Figure 7. Schedules for TRNSYS simulation

2) Validation for simulation modeling

For the purpose of analytical validation for simulation modeling, the temperature prediction results were compared with the measurement results. From the comparison between simulation and measurement results, the simulation modeling in TRNSYS was modified to minimize the difference between the two, as results the solar radiation effect was adjusted mainly. Figure 8 shows the temperature fluctuation results with measurement and simulation at living room in case of balcony existence condition. As shown in Figure 8, simulation results are little different with the measurement results in daytime. This difference is caused by the theoretical supposition of simulation that the solar radiation is emitted constantly. However, in the case of actual measurement, the solar radiation is varied with the shading effect of the surrounding buildings. Moreover, this difference is not high so much considering the measurement and analysis error, and the variation pattern between simulation and measurement is similar. As results the simulation modeling which accomplished in this study were regarded as appropriate.

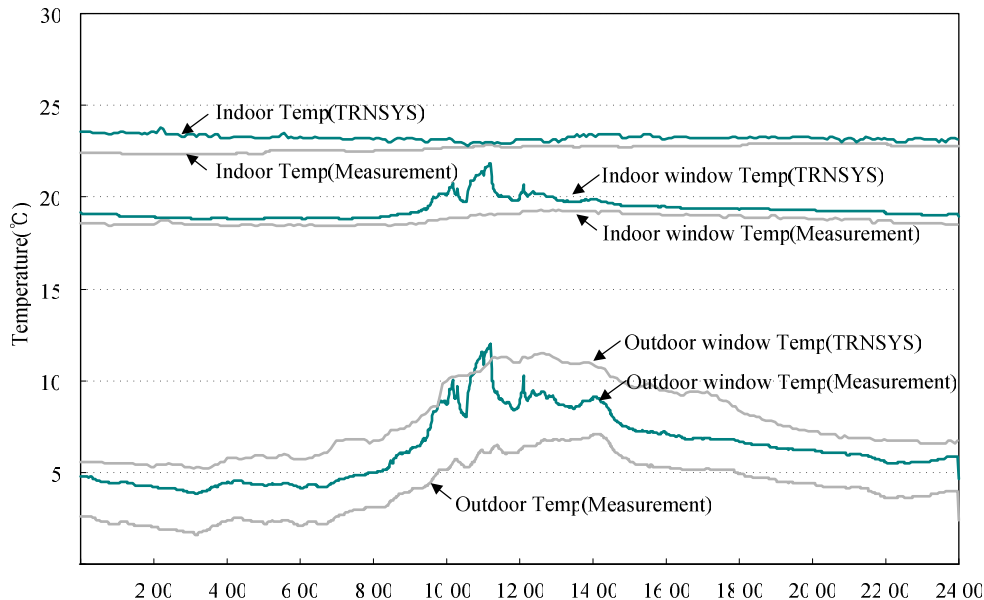


Figure 8. Comparison between simulation results and field measurement results

3) Simulation result

(1) Heating and cooling load analysis

Figure 9 shows the heating and cooling load of the analyzed house during one year. The heating load

of the without balcony space increased about 53% compare with the balcony existence condition. Cooling load increased remarkably with the removal of balcony space because the balcony was played role as shading device for the solar radiation. The cooling load of the without balcony space was increased about 54% than that of the balcony existence condition.

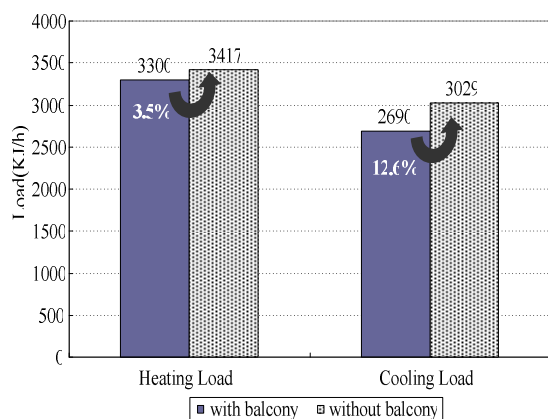


Figure 9. An annual heating and cooling load

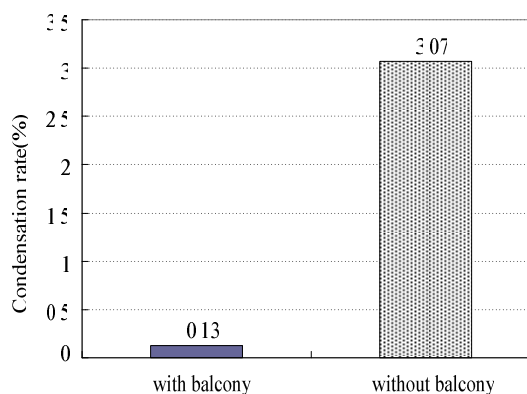


Figure 10. Condensation rate for inside surface of window

(2) Comparison of condensation rate

Figure 10 shows the concentration rate for inside surface of window in winter. The concentration rate is depending on the thermal conductivity of glazing system. The condensation rate is a frequency of condensation occurrence on window surface during heating period (15 day November ~ 15 day April). The frequency of condensation for the balcony existence condition was 0.13% (total 11 hours). While, in case of balcony non-existence condition, the condensation rate is increased by 3.07%.

(3) PMV

PMV of a space with and without balcony were calculated through TRNSYS. PMV was calculated during 24hours on January 15 which shows the lowest outdoor temperature. In case of a space with balcony, as seen from the results of Figure 11, PMV value of the balcony non-existence condition is lower than that of balcony existence condition about -1 in same floor heating condition. This means that the inhabitant in balcony non-existence condition may be feels more cool than people who live in balcony existence condition.

Table 4. Conditions for PMV calculation

Clothing[CLO]	1.0
Activity[MET]	1.0
Air velocity[m/s]	0.1
Relative humidity[%]	The calculated value through TRNSYS
MRT[°C]	
Temperature[°C]	

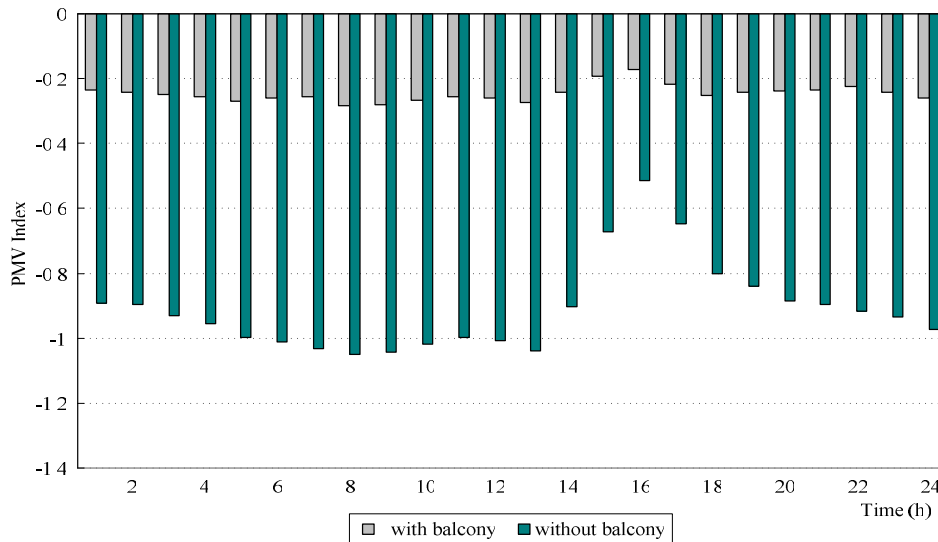


Figure 11. PMV comparison of with and without balcony space

4. CONCLUSIONS

The aim of this study was to evaluate the performance of balcony space in terms of thermal environment and energy consumption compared to balcony without condition. For this purpose, both field measurement and computer simulation were used. From the results of both measurement and simulation, it was conformed that the balcony space has many advantages either in a thermal comfort side or energy saving side. Moreover the integrated simulation method suggested in this study will be used for evaluating the physical properties of new types of window system.

ACKNOWLEDGEMENTS

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