濟州大學校 產業技術硏究所 論文集, 第9卷, 2號, pp.77-82, 1998. 12
Cheju National Univ. R.I.I.T. Jour., Vol.9, No.2 pp.77-82, 1998. 12

Thermal Analysis of Passive Solar Schoolroom Designs

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ABSTRACT

This paper studies thermal performances of three types of schoolroom configurations designed to maximize the use of solar energy. Each design contains certain distinctive characteristics in trapping and utilization of solar energy. To carry out the thermal analysis here numerical simulations as well as on-the-site measurements are peformed for a certain period of time (unsteady state). The results are then extended to predict the long term average thermal performance of each configuration during a typical wintry season. Suggestions are further made to improve its overall environmental conditions when designing a schoolroom with passive solar concepts.

Key words : Schoolroom, Solar energy, Thermal analysis, SERI-RES

Ⅰ. Introduction

The first schoolroom design(Type I) put much emphasis in maximizing direct gains through south-facing windows. It also shows the reenforcement of insulation of the old design prevailed before the oil crisis. The second design prepared later(Fig. 1) harnesses.

Both the concept of direct and indirect gains(Type II). Finally, the third design(Type III) under consideration(Fig. 2) concerns the indoor lighting effects, when applying the solar energy for space heating. Apart from the configurations of Type I and Type II, this design locates the hallway on the south side of the building so that it could be used as an attached sunspace for each schoolroom.

Ⅱ. The Schoolroom Design of Type I

In this design, the south-facing area is comprised of two sections. The upper half consists of two layers of operable windows for direct gains, while the lower half is characterized by a non-operable glazing followed by a black iron plate for quick absorption and emission of solar energy. As the sun's rays pass through the outer glazing and hit

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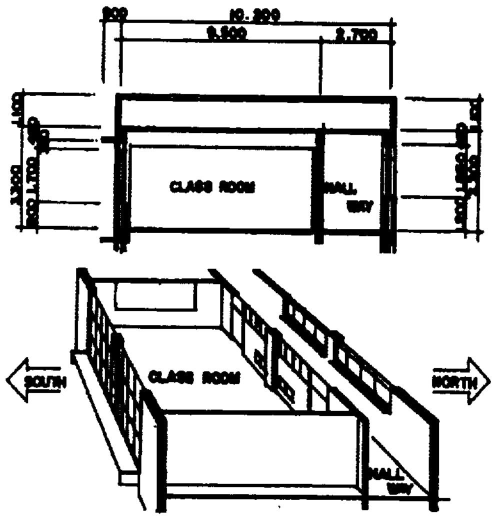

Fig. 1 Main section detail (above) and perspective (below) of the Type II schoolroom design

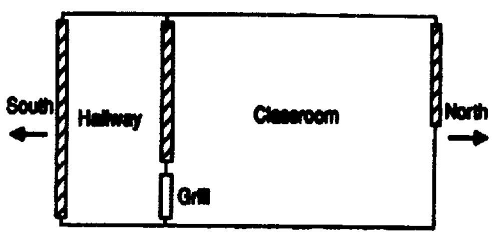

Fig. 2 Schematic diagram of the Type III schoolroom

the surface of black iron plate, this immediately raises its temperature and in turn heats the air trapped within the glazing and the iron plate. Thermosyphoning could be induced by opening the upper and lower vents which allows continuous flow of hot air into the classroom during heating periods (Fig. 3). In summer, overhang structures prevent the indoor temperature from Overheating and cross-ventilation is induced by opening the windows in the opposite (north) side of the schoolroom (Fig. 4). Passive cooling is attainable. This is also the case with the Type I and Type II designs for hot seasons. Fig. 5 gives the details of the floor plan of a typical schoolroom regardless of its Orientation and design characteristics.

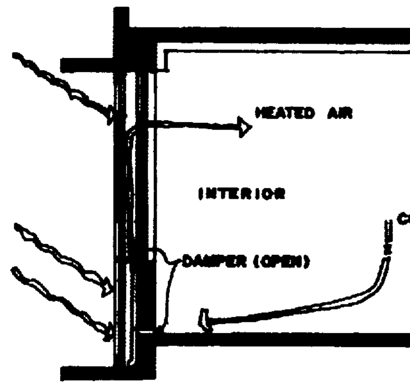

Fig 3. System operation of the Type II schoolroom design

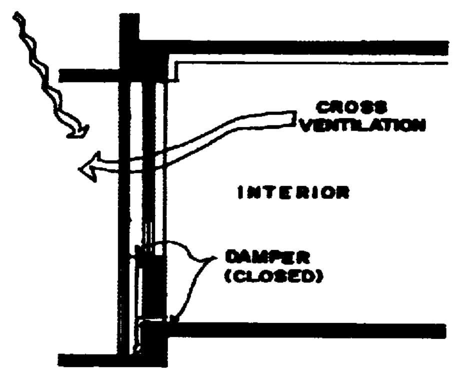

Fig. 4 System operation of the Type II schoolroom design

III. Numerical Analysis

In the present analysis, the standard version of SERI-RES has been used to predict the thermal behavior of a schoolroom unit under various climate conditions. The program is chosen since it provides

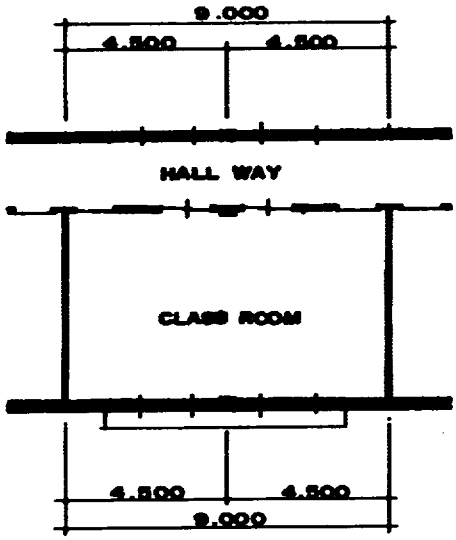

Fig. 5 Floor plan of the Type II schoolroom design

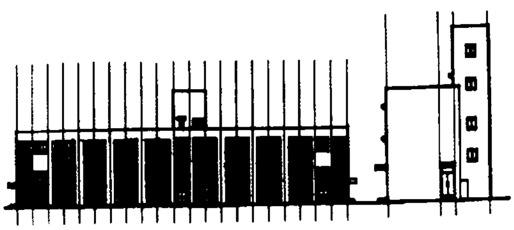

Fig. 6 A front(left) and left view(right) of a typical Type II passive solar school building design

various means to analyze passive solar structures without undue difficulties. Extensive treatment of the thermal effects of solar energy on buildings is possible. It is implemented with an interactive editor for creating building description files which eases the task of simulation.

In simulating any particular unit, the symmetry plane of the wall between :nits is assumed to be adiabatic. This assumption is strictly valid when the two adjoining units have the same temperatures as a function of time. Even when the adjoining units are not at the same temperature, such as when one unit is an end unit, the differences are small compared to inside-outside temperature differences. The interzonal air flow between the classroom and hallway is assumed to be 0.35 air changes per hour. This accounts for the occasional opening of the door during intermissions. Most of the heat flow between the zones is through the partition wall that separates the schoolroom and hallway. Internal gains due to the presence of students are calculated with 210 kJ/hr per each student. Each schoolroom is occupied with 50 students. Classes are held from 9 to 5.

Ⅳ. Measurements

Four different locations (Fig.7) are selected to make measurements for the verification of our analysis. At each location, the measurements are carried out simultaneously for the passive solar schoolroom design of Type I and that of Type II. These were located in the vicinity of each other.

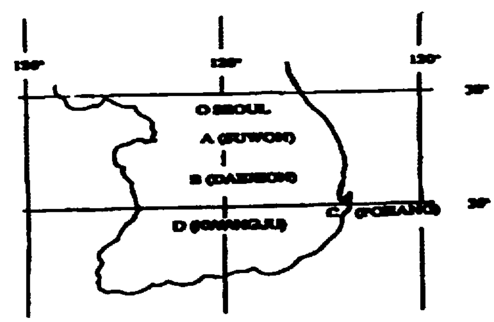

Fig. 7 The locations for the measurements: A(Suwon), B(Daejeon), C(Pohang), and D(Kwangju)

Measured quantities are the outdoor temperature, indoor temperature, solar radiation and wind speed. During the measurements(each for a period of a few days) all auxiliary heating units were shut down. Table a details each location.

Table 1 Locations for measurements

Location	Latitude , ^{o}N	Longitude , ^{o}E
A(Suwon)	37.2	127.1
B(Daejeon)	36.3	127.4
C(Pohang)	36.0	129.3
D(Kwangju)	35.1	126.9

V. Results and Discussion

Figs. 8 through 11 show the indoor temperature variations of schoolrooms for the locations A(Suwon), B(Daejeon), C(Pohang), and D(Kwangju). As demonstrated in these figures, schoolrooms built according to the Type II design model perform better thermally over those of the Type I model. This manifests the significance of the thermo-circulation air flow into the interior during the hours of bright sunshine adopted in the Type II model. Figs. 8 and 9 also compare the predicted values with the measured ones where some minor discrepancies exist in the afternoon hours. However, the overall similarity of the profiles between these two values ensures the validity of the present numerical model. Fig. 12 shows the temperature differences between the upper and lower vents provided for thermo-circulation air flow in the Type

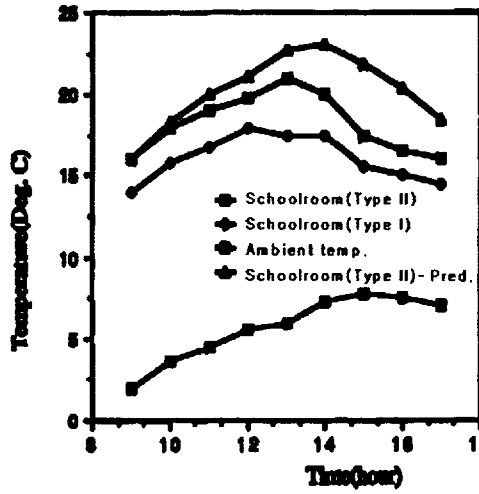

Fig. 9 Temperature variations for location B(Daejeon)

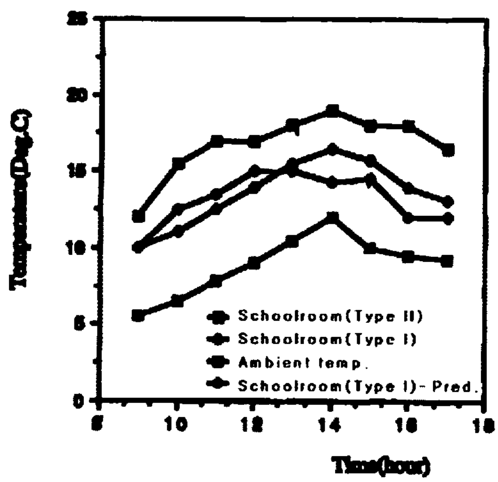

Fig. 8 Temperature variations for location A(Suwon)

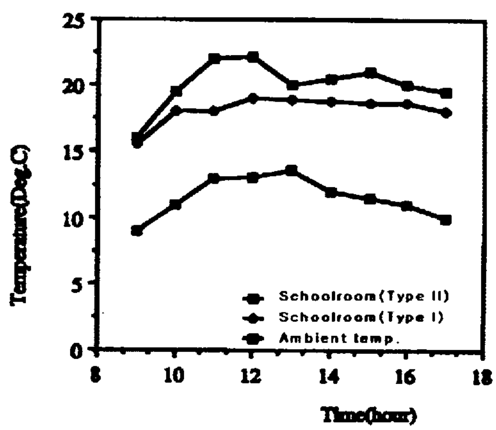

Fig. 10 Temperature variations for location B(Pohang)

II model. The difference in temperature becomes larger in the afternoon hours when solar radiation intensifies.

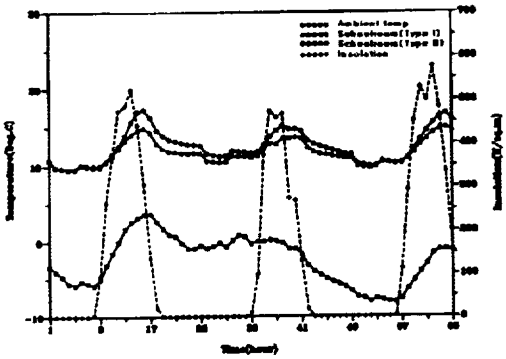

Fig. 11 Temperature variations of the upper and lower vents(Kwangju)

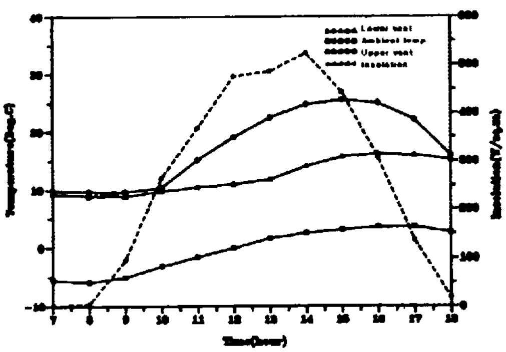

Fig. 12 Temperature variations of the upper and lower vents(Kwangju)

Fig. 13 is a result of the SERI-RES run which com[pares the thermal performance of the schoolroom configurations of the Type I, Type II and Type III model simultaneously under the same weather condition. The weather data are extracted from the Seoul TMY where it shows almost the same pattern of diurnal variation as shown here for a period of 5 days. The result is the output of the fifth day with the same initial condition. Again, the Type II schoolroom design of Type II dominates over others in its thermal performance. It is noteworthy that the Type III configuration could perform better thermally over the Type I model which is yet to be verified by in-situ measurements.

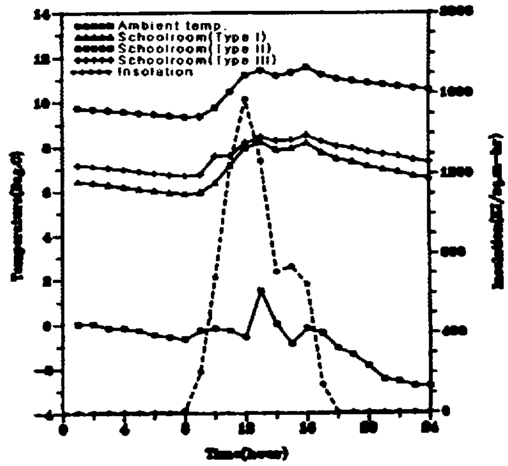

Fig. 13 Temperature variations of the Type I, Type II, and Type III schoolroom configurations under the same weather conditions

For the long term prediction of its thermal performance of a schoolroom, a typical weather data for the location of interest is used. These weather data are the accumulated results of several years and have been prepared in the TMY format suitable for the SERI-RES simulation. The runs are made for 5 months of heating period, from January to March and from November to December. Preliminary results are introduced here in terms of the solar heating fraction(SHF), which measures the solar dependency in heating a building.

The SHF value of the Type II model ranges from 78.8% to 100% when classes are in session and the desired indoor temperature is set at 18°C. This result has been verified for the schoolrooms located in B, C, and D, where only two or three occasions of auxiliary heating are recorded. The SHF values for the Type I schoolroom configuration show a range of 67.3% - 98.1%, which are very close to that of the Type III model. In December, the difference in SHF value between the Type I and Type II amounts to 21.4% in location C: 96.1% and 74.7% for the Type II and Type I design, respectively.

Despite its domineering thermal performance, there were a few negative feedbacks in operating the passive solar schoolroom configuration(Type II model) studied in the present analysis. First, it seems to be a nuisant daily routine for many students to open and close the vents every day. Second, there were some problems with bugs, since the gap between the non-operable glazing and the iron plate has become an attractive habitat. Third, the interior illuminances from the south facingwindows are not uniform, which are improved in the Type III model using the hallway as an attached sunspace.

Ⅵ. Conclusion

In the present study, three types of schoolroom configurations are examined for their thermal performance during heating seasons when classes are in session. It appears that the passive solar schoolroom design of Type II is more energy efficient than the other two alternatives(Type I, Type III). Under the same weather conditions in winter with average sunshine, it shows an extra indoor temperature rise of, at least, 2-3℃ higher compared to the other cases. The case of attached sunspace(Type III model) also gives a promising outlook for the future as the indoor illuminance becomes more of a crucial issue in public education facilities. However, this needs further study to verify its feasibility and to improve its thermal performance.

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