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Seminar IV

Thermal Performance of Buildings

Comportement thermique des bâtiments

Wärmetechnisches Verhalten von Gebäuden

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SUMMARY
The thermal performance of buildings is one of the most important considerations both in the architectural as well as the structural design of buildings. The paper cites several examples of details and modifications which when properly designed can significantly increase the thermal performance of buildings and thereby reduce the heating and cooling energy demands of such structures. Among them are fenestration details, thermal bridges, heat storage, and solar heating and shading.

RESUME
Le comportement thermique des bâtiments est un des aspects les plus essentiels dans le projet architectural et structural de bâtiments. L'article donne plusieurs exemples de détails constructifs et de modifications qui, correctement réalisés, peuvent augmenter de façon significative le comportement thermique de bâtiments; les besoins en énergie de chauffage et de refroidissement de telles structures s'en trouvent ainsi réduits. Le rapport traite également des détails de fenêtres, de ponts thermiques, d'accumulation d'énergie, de chauffage par énergie solaire et d'écrans de protection solaire.

ZUSAMMENFASSUNG
Das wärmetechnische Verhalten von Gebäuden ist eines der wichtigsten Kriterien beim architektonischen sowie strukturellen Entwurf von Gebäuden. Es wird über mehrere Beispiele von konstruktiven Details und Änderungen berichtet, welche, wenn korrekt entworfen und ausgeführt, das wärmetechnische Verhalten von Gebäuden bedeutend verbessern. Damit werden die Energieansprüche für Heizung und Kühlung von Gebäuden reduziert. Es wird auch über Fensterdetails, thermische Brücken, Wärmespeicherung, Sonnenenergie und Sonnenschutz berichtet.

INTRODUCTION

The thermal performance of buildings is one of the most important considerations not only in architectural design of buildings (or system design of building services) but also in structural design. In the recent energy crisis, various measures for energy conservation have been included in architectural design to reduce the heating and cooling loads of buildings. Thermal insulation for windows, walls and roofs, air tightness of windows and proper shape of sun shades are considered to be the principal factors of an energy conserving design. On the other hand there are numerous features of thermal performance of buildings would affect structural design. The fact that most of the participants in IABSE meetings are structural engineers, makes such papers relating to thermal performance of building structures as a whole or building components welcome and called upon. This is because a sound approach to structural design with respect to thermal performance of buildings is important to stimulate structural engineers. Additional emphasis should be placed on the thermal performance of buildings in relation to air conditioning system design. The following are some examples of the themes considered interesting and informative for the Building Physics Session newly installed at IABSE Vancouver Conference.

1. EXPANSION AND CONTRACTION OF BUILDING STRUCTURES

The main frame of tall buildings may not suffer serious damage from thermal expansion and contraction, but it may cause a lot of problems where different materials meet in various parts of the building. Large, long structures usually require thermal expansion joints to accomodate possible expansion and contraction. Measures for absorbing thermal stresses within the structure are generally used, but the effects on minor parts such as bolts have not been clarified in terms of fatigue and other unexpected damage.

2. LOCAL THERMAL STRESS IN FENESTRATION

Breakage of glass panels sometimes occurs due to local thermal stress producing a hazard to people at large. The local thermal stresses are caused by non-uniform thermal pressures on different parts of glass panes. For example, the sunlit part of a glass pane will tend to expand more than the shaded part. This is likely to occur in heat absorbing glass on a very cold day. In order to avoid this, care must be taken in designing the joint details where a glass pane meets the framing to allow for expansion and contraction. Theoretical and experimental studies would enforce the practicability for safety in fenestration design.

3. THERMAL BRIDGES

Structural members often act as thermal bridges. This has not been of too much concern when people were not conscious of energy problems. However, in the age of energy conservation just as building insulation is regarded very important in every part of the exterior surface of a building, it is being recognized more strongly than before that uninsulated portions of structural members can give rise to considerable heat loss. It is obvious that such heat loss would impair the effect of heavy insulation in a wall, for example, despite the fact that the surface area occupied by the structural members is only a small portion of the total surface area of the wall. Uninsulated parts of structural members also allow condensation of water on their inside surfaces giving rise to unexpected damage. In particular, condensation on the surface of exterior walls within the plenum ceiling space is unrecognizable and likely to occur unless proper treatment was made.

4. HEAT STORAGE TANK

The space beneath the basement floor is often used as a heat storage tank or thermal reservoir. In large buildings basement girders are so large that the space between girders can be used to store large amounts of water. In order to shift the peak demand of electricity, cold energy can be stored in the tanks by operating refrigeration machines with off peak electricity at lower rates. The thermal performance of such heat storage tanks on a dynamic basis has been studied quite extensively in accordance with heating and cooling load variations in the room. It is interesting to control the operation of an air conditioning system by predicting the load pattern for the following day.

5. THERMAL MASS EFFECT OF BUILDING STRUCTURES

It is generally known that heavy structures tend to have more stable temperatures in the interior spaces than light weight constructions. Tall buildings are more likely to be constructed with steel frames and columus and light weight floor slabs, thus disploying a rather rapid thermal response. The room air temperature in such a building is apt to rise and fall quite quickly in accordance with heat supply and extraction. The heavy structure in massive buildings, on the other hand, responds slowly to thermal impact. Calculation of room air temperature variation taking account such thermal behaviour has been extensively made in recent years, as owners of buildings have become conscious of the annual energy requirements for heating and cooling. Optimum control strategies using computers have been investigated and realized in some of the advanced examples. Studies are required to explain the method of selection of a desirable thermal performance in terms of heat capacity of building structures for tall buildings. A structure with low mass but high thermal inertia might possibly be desirable.

6. SOLAR HEAT GAIN AND HEAT LOSS FROM WINDOWS

Windows must be designed so as to promote solar heat gain in winter and discourage it in summer as well as for daylight and ventilation. Windows can be considered as solar heat collectors in themselves if thermal storage devices are provided in the interior spaces. In colder countries, double or triple glazing is justified to reduce heat loss in winter. In warmer countries where the cooling season dominates, however, insulated windows often interfere with heat dissipation from inside to outside during the night, because a considerable amount of heat generated from lights, electrical appliances and occupants during the daytime is accumulated within the building structure unless other means of night purge ventilation are provided. Thermal balance between these two situations has not been clearly determined, as this must be quantitatively evaluated on an annual basis.

7. SOLAR SHADING DEVICES ON FENESTRATION

Solar shading devices provided on the outside of fenestration is often referred to as "brise-soleil" especially when they are designed to be an integral part of the main structure of a building. The thermal performance of intercepting direct solar radiation to reduce the cooling load has been analyzed and indicates a different optimum configuration for different localities. The sunlit members of shading devices might cause excessive thermal stresses due to repetition of temperature changes between day and night particularly in hot countries. The supporting structures are also very important as they are often installed along streets. Special care must be taken when the buildings are to be built in earthquake prone countries, lest they sould fall on the street.

8. SUMMARY

The topics discussed above are some of the examples of details effecting the thermal performance of buildings which might attract the interests of structural engineers as well as scientists of building physicists. There must also be many other interesting topics in this area to stimulate participation. Interaction between the different specialists are particularly important for enhancement of the quality of buildings and the IABSE Vancouver Conference is expected to provide a forum to open fruitful discussion for the future of building technology.

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