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The Interaction of the Structure and of the Physical Environment within the Building

L'interaction entre la structure d'un bâtiment et son environnement

Die gegenseitige Beeinflussung der Struktur und der Bauklimatik

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SUMMARY
In an age of more expensive energy, greater advantage could be taken of the environmental potential of the structure. Load-bearing walls can improve the thermal environment both in summer and in winter. Projecting floor slabs, and to a lesser extent projecting columns, can be used for sunshading, particularly in the subtropics. Concrete floor slabs attenuate airborne sound.

RESUME
La crise énergétique rend absolument essentielle une meilleure utilisation des possibilités virtuelles de l'environnement de la structure d'un bâtiment. Les murs porteurs amélioreraient les conditions thermiques en hiver aussi bien qu'en été. Les dalles de plancher et les colonnes en saillie protégeraient contre le soleil. Ceci s'appliquerait surtout aux pays tropicaux. Les dalles en béton atténueraient le bruit.

ZUSAMMENFASSUNG
In einem Zeitalter höherer Energiekosten könnte man mehr Gebrauch von dem bauphysikalischen Potential der Struktur machen. Lasttragende Wände können die Temperierung sowohl im Sommer als auch im Winter verbessern. Vorspringende Deckenplatten, und im geringeren Mass auch vorspringende Säulen, können zur Abschattung benutzt werden, besonders in den Subtropen. Beton-Deckenplatten dämpfen Luftlärm.

1. STRUCTURE AND ENVIRONMENT PRIOR TO THE 19th CENTURY

In the great buildings of the Middle Ages and the Renaissance the walls were load-bearing, and therefore part of the structure.

In summer, solid masonry buildings are pleasantly cool because of the thermal inertia of the masonry walls and roofs: the structure performs a secondary function by acting as a thermal store. In most parts of the world it is only necessary to reduce the temperature by a few degrees below the outside shade temperature to achieve pleasant conditions in summer, so that the thermal inertia is effective without artificial cooling.

Winter heating presents greater problems, because a much larger temperature change may be required for thermal comfort. The thermal inertia is equally helpful in reverse, but not sufficient in cool climates.

2. THE SKELETON FRAME, MODERN ARCHITECTURE, AND THE ENERGY CRISIS

In the late 19th century it became possible to design a skeleton frame to resist the loads acting on the building, and the load-bearing walls became unnecessary. At the same time the invention of the passenger lift increased the height of buildings. The simplistic methods for the design of load-bearing walls used in the late 19th century produced very thick walls, 1.83 m in the case of the 16-storey Monadnock Building erected in Chicago in 1891. Load-bearing walls were thereafter used mainly for low-rise buildings.

When the modern style of architecture came into existence, the scientific basis of environmental design received little attention. The technical emphasis was on the structure and the materials. Le Corbusier, Gropius and Mies van der Rohe were all interested in the lightness of the structure made possible by the skeleton frame, and the use of glass curtain walls to emphasize that lightness.

Energy was cheap and plentiful, and energy conservation was considered only insofar as it affected the overall cost, if it was considered at all. It is no coincidence that articles on Post-Modern Architecture started to appear shortly after the "energy crisis" of 1973.

3. THE STRUCTURAL ENGINEER AND THE INTERIOR ENVIRONMENT

Prior to the 19th century the architect designed both the structure and the interior environment of his buildings. Today these functions are divided between the architect, the structural engineer, and the mechanical/electrical engineer. It is not clear who is responsible for considering the environmental potential of the structure, and the establishment by the IABSE of the Task Group on Building Physics is therefore particularly welcome.

If we consider the life-cycle cost of the building, and allow for the steep increase in the cost of energy which seems highly probable, a return to load-bearing walls is appropriate for many building types.

Even if load-bearing walls cost more than a skeleton frame and curtain walls, this may be a worthwhile solution because of the energy saved. Moreover, modern methods for the design of load-bearing walls [1] which consider the contribution of the cross walls and the floors, produce much thinner walls for tall buildings than would have been possible in 1891. Twenty-storey buildings can today be erected with load-bearing walls 250 mm thick, which is only 14% of the thickness of the walls of the 16-storey Monadnock Building.

The structure can also be utilized for sunshading. A projection of the floor slab can provide completely effective sunshading in the subtropics at very small cost (Figure 1), if the building is suitably oriented and the extent of the projection precisely designed. Projecting columns can provide partial shading from the western sun.

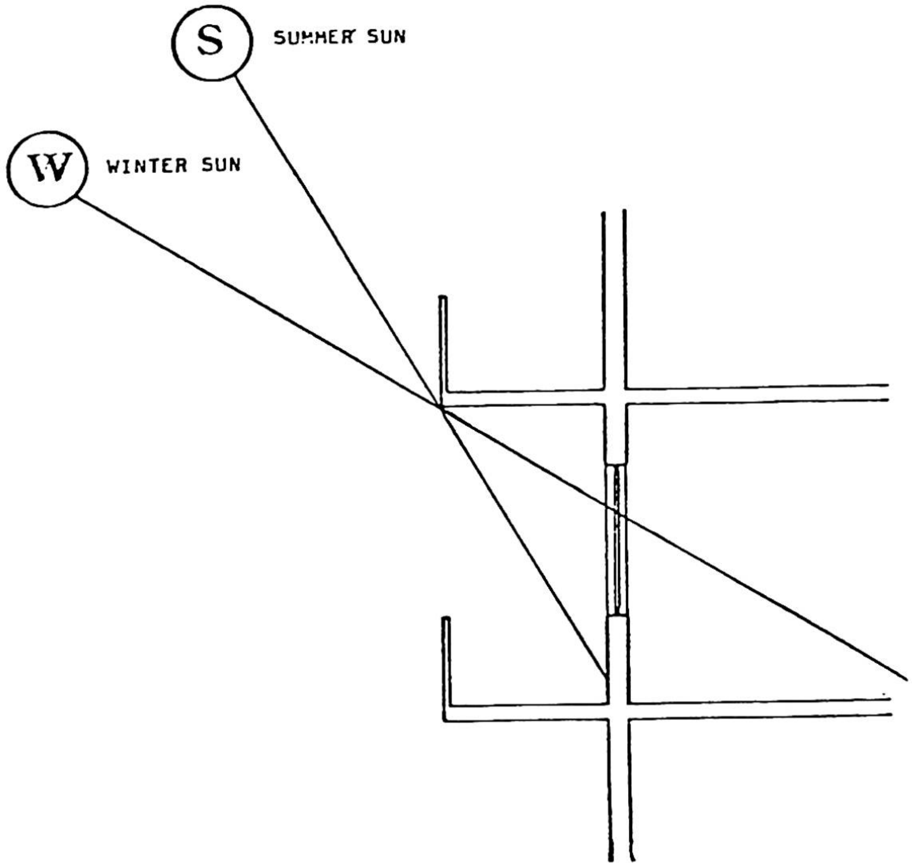

Figure 1

Buildings in or near the subtropics, whose principal facades can be oriented approximately north and south, are suitable for a simple and direct utilization of solar energy. The floor slab is designed to project beyond the southern (northern in the southern hemisphere) facade by a distance which depends on the latitude of the orientation. This allows the sun to shine through the window in winter (W), but excludes it in summer (S).

Sunlight can be wholly excluded for about two months in the year, and fully admitted for about two months during the coldest part of winter. Sunlight penetration can be designed to commence at noon on one equinox, and terminate at noon on the other. An ordinary large window thus acts as an effective and cheap solar collector.

The solar heating can be enhanced by the thermal inertia of the reinforced concrete floor, provided that a hard floor surface is acceptable, such as concrete, tiles or terrazzo. The solar heat is then stored in the concrete slab, and emitted gradually after sunset. The thermal inertia is reduced if wall-to-wall carpet is used which insulates the concrete slab.

As with all solar heating systems, it is necessary to have an alternative heat source for night time and for days when the sun is not shining.

The projection of the floor slab to form a narrow balcony generally *reduced* the maximum bending moment in a continuous reinforced concrete slab.

The ideal sunshading device does its job without interfering with natural ventilation, and without blocking natural light or the view which is one of the attractions of many high-rise buildings. Projecting floor slabs and columns meet these criteria.

In many multi-storey buildings designed in the 1950's and 1960's it has been necessary to keep the blinds almost permanently drawn in summer because too much solar heat would otherwise have been admitted. As the rooms are too dark with the blinds drawn, the electric lights are in use even on a bright sunny day. Artificial lighting produces a great deal of heat, which has to be removed by the air conditioning plant. Evidently the structure could be used to reduce the size of the air conditioning plant.

A concrete floor slab can also be used for sound attenuation. Concrete is an excellent insulator against airborne sound, and the acoustic environment of some apartment buildings could have been improved at a small cost by using a thicker reinforced concrete floor slab, possibly in conjunction with slightly larger spans. The flat plate structure, which uses thicker slabs because it deletes the beams, thus has particular merit for apartment buildings.

REFERENCE

[1] Design of Masonry Structures. Chapter 13, Volume CB, Monograph on Planning and Design of Tall Buildings. American Society for Civil Engineers, New York, 1978.