Building planning and design

CHAPTER 4

4.1 Introduction

This chapter covers shape and size, the 'body' and the 'skin' of the building and issues of internal organization. It provides a basis مفاصل for articulating the building on the site in order to provide an energy efficient and comfortable internal environment.

4.2 Form

The orientation of a building may be fixed but if choice is possible it should face south to take advantage of the Sun's energy (Chapter 5). Total volume, too, is likely to be prescribed and so, often, the first major design decisions are allocating volumes to various activities and developing the form of a building.

Form is governed by a number of functional considerations that are discussed below, and in more detail in the following chapters, and include:

- the use of the Sun's energy and daylight (Chapters 5 and 8)
- provision of views for occupants
- heat loss through the building envelope
- the need for ventilation (Chapter 9)
- acoustic attenuation if required.

In the recent past, the glass blocks of Mies Van der Rohe يلخص epitomized an architecture that shut out the natural environment and provided an acceptable internal environment through the use of considerable energy and معقد sophisticated services.

The Queens Building at De Montfort (Chapter 13) is the نقيض antithesis of this and articulates the building both on plan and in section to respond to the environment and make the best use of natural energy sources. The likelihood is that environmental considerations will allow for freer forms and, thus, a welcome architectural diversity; but before we can draw any conclusions about form we need to know more about how buildings work.

4.3 The building 'body'

An important consideration is how quickly a building responds to heat inputs (internal and external), and this is related to the thermal conductivity of its materials, the thermal mass (or heat capacity – both discussed above in Chapter 2), and, related to these, the admittances of the elements of the construction.

دخول

The admittance, *Y*, of a constructional element, put simply, is the amount of energy entering the surface of the element for each degree of temperature change just outside the surface and, as such, has the same units as the U-value ($W/m^2\,K$) (Appendix B). The admittance of a material depends on its thickness, conductivity, density, specific heat and the frequency at which heat is put into it. (In addition to the admittance, the response of building elements to energy cycles depends on the تنقیص decrement factor and the surface factor;[1] put simply, once again these factors are associated with time lags in energy flows, with the decrement factor representing the 'damping' effect of an element's response to an energy gain.) Considerably more technical explanations of these concepts are to be found in References 1, 2 and 3. Table 4.1 gives properties of some constructions.

As can be seen from the table, dense constructions have higher admittances, which is to say they absorb more energy for a given change in temperature. (One must be careful, however, because for multilayer slabs, the admittance is determined primarily by the surface layer; thus, a 300 mm slab with 25 mm of surface insulation will respond more as a lightweight than as a heavyweight material).[4]

If a building absorbs a great deal of heat and only experiences a small temperature rise it is said, in no very precise manner, to be thermally heavyweight. Such buildings tend to have high admittances and a great deal of thermal mass, usually in the form of exposed masonry. Lightweight buildings, on the other hand, may have thin-skinned walls, false ceilings with lightweight panels, metal partitions and so forth. The CIBSE[5] has tried to be more precise and has defined a heavyweight building as one whose ratio of admittance value to U-value is greater than 6; British Standard 8207,[6] on the other hand, uses a ratio of 10. The concept matters more than the number.

The particular importance of these issues is in providing comfortable conditions in the summer without the use of air conditioning. This is not simply a problem for office buildings – countless schoolchildren in the UK were educated in the 1960s and 1970s in lightweight, underinsulated, overglazed buildings that overheated in the summer, particularly on the top floor in westerly-facing classrooms in the late afternoon.

Table 4.1 Admittance and density of selected construction elements[7]

Item	Admittance ($W/m^2\,K$)	Density (kg/m^3)
1. 220 mm solid brickwork, unplastered	4.6	1700
2. 335 mm solid brickwork, unplastered	4.7	1700
3. 220 mm solid brickwork with 16 mm lightweight plaster	3.4	1700 for brickwork 600 for plaster
4. 200 mm solid cast concrete	5.4	2100
5. 75 mm lightweight concrete block with 15 mm dense plaster on both sides	1.2	600 for concrete 600 for plaster

Normally, the heat flow into a building from the outside is approximately cyclical. On a daily basis, the Sun rises, the air temperature increases and heat is transferred directly via windows and indirectly via the building structure. As the Sun sets the building starts to cool, and the following day the cycle continues. In the winter, the external gains are insufficient and so the heating system supplies heat each day during the period of occupancy. At night, the temperature is allowed to drop to conserve energy. Again, the following day the cycle continues.

The thermal mass of the building evens out the variations. In the summer, by delaying the transfer of heat into a building, the time the peak temperature is reached can be altered. By using high-admittance elements the building fabric can store more of the heat that reaches the internal and external surfaces, thus reducing the peak temperatures. This 'balancing' effect can apply both during the day and at night, because if cool night air is brought into contact with high-admittance surfaces their temperatures will drop, i.e. there will be cool thermal storage. The next day, when warmer day-time air flows over the same elements, they will be cooled thus improving comfort conditions for the occupants. This technique is used both at RMC (Chapter 11) and De Montfort (Chapter 13).

Architecturally, the key requirement is to incorporate high-admittance materials in the building and expose them in an appropriate manner. This means that false ceilings, raised floors and plastered walls will need to be kept to a minimum. Appearance will obviously be an important consideration as walls and soffits (and services) are bared. However, there are a number of solutions – from brickwork walls with coloured bands to make them more attractive, to high-admittance ceiling linings such as cement-bonded chipboard. It may also be possible to exploit more complex approaches such as taking the incoming air supply over a concrete floor slab. Greater floor-to-ceiling heights will also, of course, provide more thermal mass for a given floor area. In some cases one element may be made to perform several functions. At De Montfort the heavy masonry stacks ventilate, provide thermal mass and help support the roof.

Heavyweight buildings have an important role to play where air-conditioning might otherwise be needed. However, study of a number of buildings has shown that:

- if loads are low, there is a limit to the need for thermal mass, and
- there can be a limit to its usefulness.[8,9]

To make efficient use of mass, one must be able to ventilate at night to lower the temperature, otherwise the heat absorbed tends to accumulate and discomfort results. This has practical implications: if night-time ventilation is under automatic control, the system should not be too complex; if under manual control, it needs to be foolproof, both in maintaining security and in preventing the entry of rain.

If loadings are low and air movement is good, comfort can be achieved with lightweight buildings. If a building is always in use – for example, sheltered housing schemes – heavyweight buildings are often appropriate, but if occupancy is intermittent a lightweight building can have a positive advantage. For example, in winter, the heat stored in a heavyweight building during the day may be released at night when there is no need for it. The process is somewhat similar to an electric storage heater that supplies heat during the day when needed, but cannot stop releasing heat after people have left. The significance of this, however, depends on the building; and as insulation standards increase and buildings become better sealed, there is a decrease in the amount of heat wasted by a building when all the occupants have left.

Unfortunately, there are no definite rules; each building needs to be examined on its own merits, and we shall return briefly to these considerations later in this chapter.

4.4 The building 'skin'

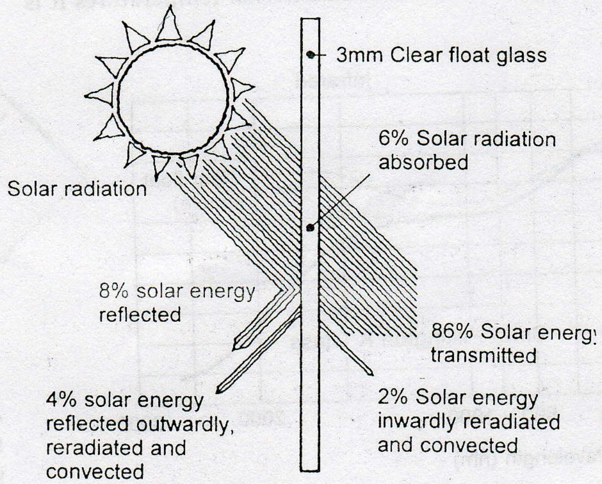
Development of the building envelope, or 'skin', is likely to be rapid in the next decade or so. Technological innovation ابداع in glass will allow window systems to respond to environmental conditions in ways not previously commercially viable for buildings. Sun-glasses which react to different light conditions are but a hint of the potential of glass.

Building envelopes obviously need to be durable متين, economical, aesthetically جمالي pleasing, صامد للجو weathertight, structurally sound and secure. Psychologically, views out are very important. Environmentally, the questions that need to be addressed are: how they respond to solar radiation (both for the Sun's heat and light), how ventilation is made possible, how heat loss is minimized and how noise is controlled. The envelope will, to a large extent, determine how the internal environment is affected by the external one.

Solar radiation

Figure 2.4 shows the spectral distribution of solar radiation, to which the components of the envelope react in different ways. If we first consider the opaque مصمت elements, the amount of radiation absorbed at the surface depends in part on the colour of the surface. Lighter colours, of course, absorb less and reflect more of the incident radiation (Table 2.2).

Turning to translucent 100/ نصف شفاف materials each one has a different characteristic. Figure 4.1



4.1 Energy exchange at a window of 3 mm float glass.[10]

shows the energy exchange for plain 3 mm float glass. The percentage of solar radiation transmitted by a window varies with wavelength, as shown in Figure 4.2.

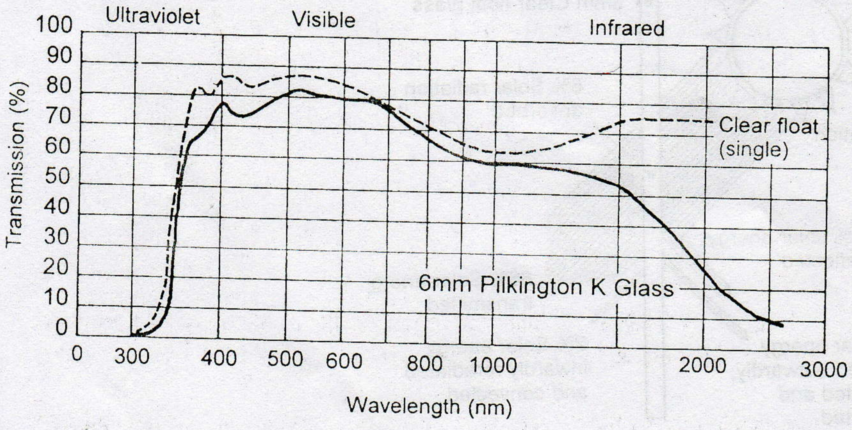
Figure 4.2 shows that glass filters the Sun's radiation much as the atmosphere does, absorbing some of the UV and infrared and letting through much of the visible light. A glasshouse will let in a great deal of solar radiation but will not transmit much of the far infrared produced by the room, much as clouds block the Earth's outgoing radiation. (See Figure 2.3 for an approximate spectrum of room radiation. Figure 4.2 does not continue far enough to the right to show the reduced transmission of clear float glass at longer wavelengths.)

The amount of radiation that enters and exits a room can be controlled to a certain extent by altering the components of the glass, by using several layers of glazing, by applying special coatings and filling the spaces between the panes with various gases, or by evacuating them; an example of the altered transmission characteristics is seen in the graph in Figure 4.2.

The heat loss from any building element is related to its U-value (Appendix B). U-values for different glazing types along with transmission and acoustic characteristics are shown in Table 4.2. (Note that this is for glazing alone; a more precise analysis would be needed to take the frame into account.)

The table shows that there is some loss of light and solar radiant heat as the U-value improves. However, in most applications this is not a significant disadvantage compared with the benefits obtained. It also shows that direct solar transmittance is not the same as direct light transmittance, and this suggests possibilities for glass development. In the summer, for example, an ideal glass would transmit light (to reduce the need for artificial lighting) but no other part of the solar spectrum (to keep the space cooler). In the winter both light and heat are likely to be advantageous. Similarly, in the winter a very low U-value saves energy. If, in the summer, the internal temperature is above the external – as often occurs in lightweight, non-air-conditioned buildings – a high U-value would help get rid of the heat. Glasses whose characteristics can be altered have enormous potential.

Energy loss through a window depends particularly on internal and external temperatures and is independent of orientation. Energy gain, on the other hand, obviously depends on direction because of the Sun. Appendix A gives a selection of solar data. When solar radiation data is used with internal and external temperatures it is



4.2 Spectral transmission curves for glass.[11]