Requirements for exterior walls

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Requirements for Exterior Walls

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Designs for exterior walls for buildings have seldom been developed in a systematic, rational way. They have evolved slowly, keeping pace with gradual changes in social and economic patterns and environmental requirements. Today, with a dynamic architecture and many new materials, components and construction techniques available, a large number of new designs are possible. Unfortunately, some are being adopted without adequate consideration, and evaluation by the slow trial by use methods of the past is no longer adequate.

Although trial by use must always be the ultimate test, the cost of full-scale experiments is usually so great that considerable study and effort is justified in order to ensure that the design will perform satisfactorily. It must be recognized also that the conditions for such full-scale, long-time trials in use may not be those for which the information is later required. This is particularly true in Canada today where important changes such as humidification in winter are being introduced. It is now possible with the aid of building science to recognize the pertinent factors affecting the performance of walls and to analyse wall designs systematically as to probable performance in respect of their varied requirements. With this capability one may begin to discriminate between various designs for particular uses, and, even more important, to provide a basis for the development of improved designs.

Functions of a Wall

It is important, at the outset, to recognize that the over-all function of an exterior wall, in conjunction with floors and roofs, is to provide a barrier between indoor and outdoor environments, so that the indoor environment can be adjusted and maintained within acceptable limits. The requirements for a wall must, therefore, relate to its ability to remain in place and to be durable for a required length of time, while providing the necessary barrier or filter to wind, rain, solar radiation, heat, noise, fire, particulate matter, insects, animals and even humans. It may be required to transmit light (windows), while imposing a barrier to other factors; must not itself be a hazard to life or property; must contribute suitably to the form and aesthetics of the building generally; and finally must satisfy a number of lesser requirements such as colour, texture and porosity. All of this must be achieved as far as possible at an acceptable cost, including both initial and maintenance costs.

A complete list of all possible requirements could be a very long one. Fortunately it is seldom necessary to consider all of them in any given case. Further, many may be omitted from direct consideration as they will usually be satisfied automatically when others are met.

Principal Requirements of a Wall

1. Control heat flow;
2. Control air flow;
3. Control water vapour flow;
4. Control rain penetration;
5. Control light, solar and other radiation;
6. Control noise;
7. Control fire;
8. Provide strength and rigidity;
9. Be durable;
10. Be aesthetically pleasing;
11. Be economical.

Any such list is a compromise of sequence and coverage and has, inevitably, strong interrelationships between items so that it is necessary always to consider several of these requirements simultaneously.

Exterior Wall as a Barrier

Items 1 to 7 of the requirements listed relate to the service required of a wall as a selective separator between indoor and outdoor environments. An actual or potential flow of matter or energy is involved. The greater the differences between the inside and outside environments, the greater is the stress or duty imposed on the wall.

Thus, the elements of the wall must be selected so that in the first instance they impart the necessary resistance to keep heat, moisture, air and other flows within acceptable limits. The way they are arranged, however, is also important; this will determine the variations in conditions throughout the wall. These provide the environment in which the various parts of the wall must continue to function, and are seldom linearly graded from, outside to inside. Interactions between the various factors involved may produce conditions within the wall that require special attention. Some understanding of the phenomena involved is therefore necessary so that they can be judged quantitatively and wall designs evaluated.

Over-all Requirements

Items 8 to 11 may be regarded as general or over-all requirements that must be satisfied at the same time as the wall fulfils its basic function as a separator. They may apply to individual elements of the wall as well as to the wall itself, and even to the complete building, of which the wall is only a part.

Durability is an overriding consideration. Taken broadly it can be measured in terms of the time until some loss of function occurs that renders the service provided unacceptable. It is not a fundamental property of a material; it depends on the degrading effects of the service and the environment to which it is exposed. It is more appropriate to refer to service, life, as this properly implies the effects of the particular conditions of service.

The environment at any plane in the wall may be determined by the arrangement and selection of the materials used. The designer may, therefore, by judicious arrangement greatly ease the requirements for the various elements and thus broaden his choice. The real importance of durability is reflected in the cost of maintaining all the required functions of the wall over the required service life.

The requirement for *economy* is almost always present. The number of buildings that can be designed without regard for cost are so few that they need not be considered in this discussion. Both initial and operating costs, then, become an important but complex overall consideration in most designs. The designer may often be required, as part of the design problem, to vary the proportion of anticipated initial to operating costs to suit the economies of a particular venture. Initial costs may be reduced by selecting lower quality components at the expense of increased maintenance or reduced service life, or compromises may be adopted in other directions. Insulation may be reduced at the expense of heating cost or a simpler wall or window arrangement, with some sacrifice in function, may be adopted.

Aesthetic quality can also become a major factor in cost, although this is not always so. Form, colour, texture and pattern can usually be varied over a wide range without affecting other requirements. But insistence upon a particular aesthetic feature or quality may make it difficult to satisfy the service requirements or may force unsatisfactory solutions.

Aesthetic considerations frequently become involved in other ways. For example, inadequacies in design may allow cracks to develop so that water-staining occurs, surfaces spall or finishes degrade. Thus the aesthetic qualities of a building will be more readily maintained when the basic requirements have been satisfied.

The last of the requirements to be discussed, *strength and rigidity*, is a functional requirement that has important inter-relationships with other requirements. There is a further complication with walls because they may interact with the structural frame to contribute to its strength and rigidity. This inter-relationship may vary widely at the designer's choice, from curtain walls supported on the frame to designs in which walls contribute racking strength and rigidity or assist in carrying vertical loads. The extent of this inter-dependence must be considered in the structural design of both frame and wall.

There are, in addition, loads arising from wind that must be borne by the exterior wall and its parts; these must be transferred, together with the dead load of the wall, through suitable structural connections with the structural frame. This kind of structural analysis and design has been well established for many years and need not be discussed further. There is, however, one kind of loading arising out of dimensional changes in materials that deserves far more attention, particularly in the design of exterior walls and building frames, than it has yet received.

Dimensional Changes and Induced Loading

The strains and deformations in building elements from stresses produced by loading are well recognized and are regularly dealt with in structural design. But other small dimensional changes take place in materials due to causes other than loading. These may give rise to deformations, loads and stresses that are not always adequately taken into account. Creep, a deformation with time under load, and thermal expansion and contraction are usually considered in the analysis of the structural frame, but they may be neglected in the design of the wall itself. Dimensional changes may also result from changes in moisture content in certain materials and from aging and degrading effects produced by environment.

When these expansions or contractions are not restrained, the element merely changes dimension. This in itself may often be a problem. For example, a temperature differential of 100 deg. in steel or concrete gives rise to dimensional changes of about 0.06 per cent. When these are restrained by adjacent material or by an adjoining element, strains and corresponding stresses can develop. A strain of only 0.01 per cent is required to fail normal plain concrete in tension. A dimensional change of this magnitude can be produced by a temperature change of about 20 deg. Normal concrete blocks will shrink as much as 0.04 per cent when dried from a saturated state. Cracking, crazing or buckling of exposed surfaces or of surface coatings often occur as a result of temperature or moisture changes that promote either shrinkage or expansion.

Once cracks have developed, severe wetting of the wall will usually follow. This results not only from direct penetration of rain but also from the condensation of water vapour carried in air leaking outward through the cracks.

Obviously this whole subject of dimensional changes in materials and the induced loads and failures that can result merits more extended treatment. There is some discussion of the subject in **CBD 30** and this will be extended in future Digests. It has been introduced here because of its obvious relationship with other requirements. Dimensional stability, although a highly desirable characteristic of all materials, elements and components, and having particular implications in exterior wall design, bas not been listed as a requirement. It is implicit in the requirements for strength and durability and in the barrier requirements, because these influence temperature, moisture and other conditions that may produce dimensional changes. Discussion of it has served to emphasize further the inter-relationships and the inter-dependence of the various requirements that have been set out. It has also demonstrated the importance of a knowledge of the dimensional stability characteristics of elements and components as well as of materials in any rational approach to wall design.

Environmental Considerations

Determination of the outdoor environment and establishment of that desired indoors is an essential first step in exterior wall design. Only when these factors are known is it possible to assess the over-all performance requirements of the wall acting as a separator. Inevitably, at this stage, some aspects of the building services become involved. Through them certain features of the indoor environment are adjusted to the desired levels. The daylighting characteristics of the transparent portions of the wall must be considered in relation to lighting; and heating and cooling requirements are related to the nature of the wall as a barrier to solar radiation, heat, moisture and air during both winter and summer. Other barrier requirements such as those related to dust and smoke may have implications also for the services required. One consideration, that of the relative humidity to be carried indoors, is of such potential importance as a factor in indoor environment and the design of exterior walls for cold weather conditions that it merits special attention.

The nature of relative humidity, its effects upon building occupancy, and some of its implications in the operation of buildings have been discussed in **CBD 1**. Further developments, particularly the added precautions that must be taken to avoid difficulties, are outlined in **CBD 42**. Relative humidity, either indoors or outdoors, poses a problem mainly when it represents, at the particular temperature at which it is measured, a dew-point above the temperature on the cold side. During the summer, air-conditioned buildings and cold storage buildings may have special problems. Fortunately, the maximum outside dew-point in Canada is only likely to exceed the indoor temperature for short periods during the summer in buildings cooled for normal occupancy. Usually, the most perplexing situations occur in winter when the dew-point temperature indoors greatly exceeds that outdoors. In these cases special provisions may have to be made in the barrier characteristics of the wall or window for the control of heat, moisture, air and water vapour. Specifically, substantial relative humidities indoors with low temperatures outdoors introduce the possibility of wetting on the surface as well as within the wall (see **CBD 30**).

Once the indoor and outdoor environmental conditions and their various requirements have been established, the planning of a suitable wall may proceed. Estimates should be made of temperature and moisture conditions throughout the wall and any adjoining parts of the building frame for both winter and summer conditions. These thermal and moisture gradients should then be examined to determine the effect of the environment at any plane in the wall on the materials selected for its construction.

Conclusion

The differences in the properties of inside and outside atmospheres to be separated by a wall dictate the requirements of that wall. In combination with the properties of the materials to be used, these differences determine the environments within which each element must perform. The service life of a material is determined by the properties of the material and the conditions of the environment to which it is subjected.

Durable walls can be achieved by judicious selection of materials to suit the environment, by modification of the environment to suit the materials available, or by a combination of both. Such manipulation, however, requires an understanding of the pertinent properties of materials and the phenomena that operate within walls.