Building Enclosure Fundamentals:

A concise introduction

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The building enclosure is defined as the physical component of a building that separates the interior from the exterior: it is an environmental separator. In practise the building enclosure must provide the “skin” to the building, i.e., not just separation but also the visible façade. Unlike the superstructure or the service systems of buildings, the enclosure is always seen and is therefore of critical importance to owners, the occupants, and the public. The appearance and operation of the enclosure have a major influence on the interior environment and on factors such as comfort, energy efficiency, durability, and occupant productivity and satisfaction.

Functions

In general the physical function of separation required of the building enclosure may be further grouped into three sub-categories as follows:

1. **Support** functions, i.e., to support, resist, transfer and otherwise accommodate all the structural forms of loading imposed by the interior and exterior environments, by the enclosure, and by the building itself. The enclosure or portions of it can be an integral part of the building superstructure, usually by design but sometimes not.

2. **Control** functions, i.e., to control, block, regulate and/or moderate all the loadings due to the separation of the interior and exterior environments. This largely means the flow of mass (air, moisture, etc.) and energy (heat, sound, fire, light, etc.).

3. **Finish** functions, i.e., to finish the surfaces at the interface of the enclosure with the interior and exterior environments. Each of the two interfaces must meet the relevant visual, aesthetic, wear and tear and other performance requirements.

A fourth building-related category of functions can also be imposed on the enclosure, namely:

4. **Distribution** functions, i.e., to distribute services or utilities such as power, communication, water in its various forms, gas, and conditioned air, to, from, and within the enclosure itself.

Almost all enclosures must satisfy support, control, finish and distribution functions. However, *only* the support and control functions must be provided over the entire surface of the enclosure: control and support functions must continue across every penetration, every interface, and every assembly. The lack of this required continuity is the cause of the vast majority of enclosure performance problems. The need for finish and distribution varies over the extent of the enclosure. It is rather unlikely to find an enclosure that requires a finish on the interior and exterior everywhere. It is even more unlikely to find a building that imposes the distribution function on the enclosure over its entire surface.

The **support function** is of primary importance. Without structural integrity, the remaining functions are useless. However, the industry has reached a high level of understanding and accomplishment in this area. Support systems have evolved from massive elements pierced at a few locations to efficient primary structural systems (such as steel or concrete frames) with lightweight framed infill and sheathing. The trend to lightweight enclosures is likely to continue as the demand for more resource-efficient buildings grows.

For physical performance, the most common required enclosure **control functions** include

- rain,
- air,
- heat,
- vapour,
- fire & smoke,
- sound,
- light (including view, solar heat, and daylight),
- insects,
- particulates,
- access

and many more. Like support, as these control functions are required everywhere, continuity of these control functions, especially at penetrations and connections, is critical to a successful enclosure. The most important control function with respect to durability is rain control followed by airflow control, thermal control, and vapour control. The level of fire and sound control required varies with code requirements and the owner's desires.

Unlike the control and support functions, which rely on continuity to achieve performance, the **finish function** is optional, and may not be needed in some areas.

For example, above suspended ceilings or in service or industrial spaces where the finish is often deemed unimportant. Exterior finish is often termed "cladding", but the term is imprecise, since cladding systems and materials often includes some control functions (such as UV control, solar control, impact resistance, etc.) while also delivering the finish function.

The **service distribution function**, a *building* function often imposed on the enclosure, largely services the adjacent interior spaces and only needs to be met where there is a service or utility to be distributed – large proportions of most enclosures do not need to fulfill this building function. The distribution function of the building however usually impacts the control-related functions. For example, service entrances penetrate the entire enclosure, and pipes, ducts and wires that run through insulated stud spaces can seriously reduce the performance of insulation installed here.

Confusion about the classification of the functional roles of enclosure components and materials is far too common, and this confusion can cause serious performance and durability problems. For example,

- vinyl wallpaper is often applied as a finish, but in fact fulfills the control-related function of vapour diffusion control and acts as a Class I vapour control layer. This unintentional control of diffusion can, and too often does, create serious mould problems in air-conditioned buildings.
- drywall is often seen as fulfilling a finish function, but in fact, the paint is more often the finish and the drywall often serves as a control layer for fire, sound, and air flow. If a designer or builder stops the drywall above a suspended ceiling because a finish function is not needed here, the required fire, sound, and airflow control will also be missing.
- a thick, self-adhered, bituminous membrane is often used to drain water and control airflow in high-performance assemblies. However, this membrane is also a very low permeance vapour control layer, and locating it on the outside of all or most of the insulation in a cold climate can lead to damaging cold weather condensation.

From a more practical point of view it is useful to divide the functions of the enclosure into various sub-categories to which we can assign actual products and sub-system assemblies. With respect to the control function, these are termed *control layers*.

The most important and commonly defined enclosure control function layers are, in approximate order of importance:

1. water/rain control layer (e.g., drainage plane & gap or waterproofing),
2. airflow control layer (e.g., an air barrier system),
3. thermal control layer (e.g., insulation, radiant barriers, etc.), and
4. vapour control layer (e.g., vapour retarder or vapour barrier as required).

Each control "layer" may be a single material, or a sub-assembly of materials that together provide the control desired. In many cases, two or more of the control functions are provided by a single material or layer (e.g., a membrane may provide water and air control, or spray foam insulation may provide vapor, air, and thermal control).

The "Perfect" Enclosure

Figure 1 shows an idealized enclosure with the four control layers labelled, along with cladding, support and interior finish function layers.

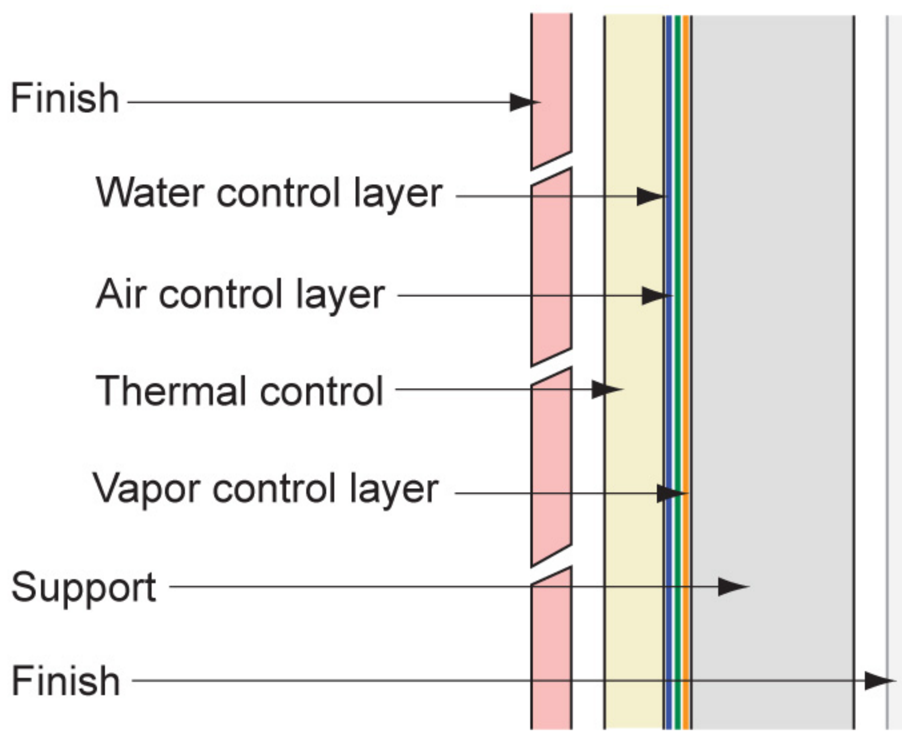

Figure 1: Idealized enclosure showing the four primary control layers

The water, air and vapor control layers are shown as thin lines to indicate that they can, in reality, be quite thin (e.g. less than $^1/_{16}$" or 1 mm) and still perform their functions very well.

The support and the thermal control layer are shown as thicker components, because in practise these layers need to be thicker (e.g., well over 1" or 25 mm) to perform their function. Depending on the span and to a lesser extent the magnitude of the loads (snow, wind, dead, etc.), the support structure will usually be in the range of 3" to 8" (75 to 200 mm) for walls with a span height of 8' to 20' (2.4 to 6 m). Depending on its material properties, the climate, and building design, the thermal control layer will usually be 2" to 10" thick (50-250 mm).

Figure 2 depicts the special, but common and practical, case of an assembly that collapses the water, air, and vapor control layers into a single physical material (such as a plastic or bituminous membrane), and provides an optional service distribution space and interior finish.

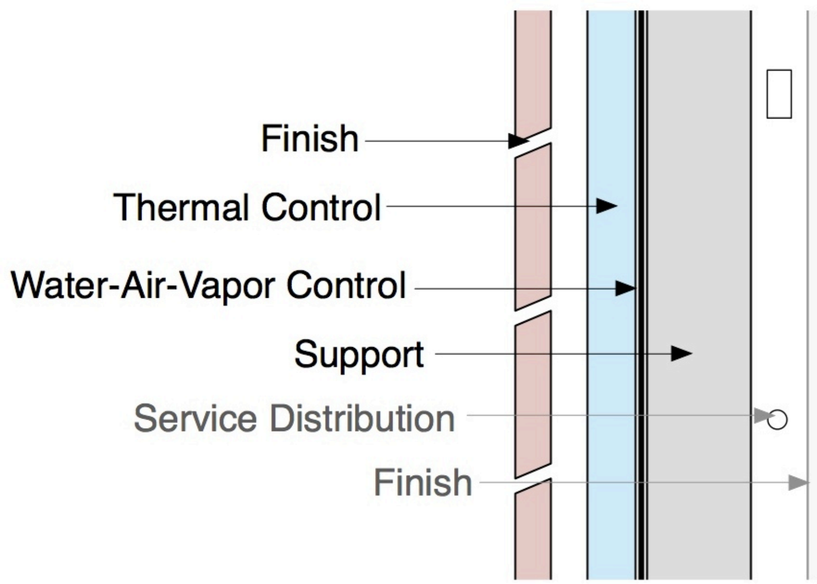

Figure 2: **Idealized enclosure with service distribution and finishes**

High-Performance Enclosures

The key to high performance is that the four control layers be provided and that they be as continuous and unbroken as possible across penetrations and transitions. The design and construction team must be able to identify which materials/sub-assemblies are providing each of the four control functions. Once the control layers in each enclosure component (e.g., window, roof, wall) are identified or specified, continuity analysis is conducted by drawing a line for each control layer around the entire enclosure through all penetrations and transitions. Any interruption in a line is a defect that must be rectified.

Figure 3 provides an example of a common type of building enclosure for commercial and institutional construction: a steel-framed primary superstructure, with light-gauge steel stud infill, and a brick veneer cladding. High-performance aspects include

- a continuous air-water-vapor control layer applied to the *exterior* of the primary structure and enclosure support (to ensure it is easy and practical to achieve continuity), and
- a continuous layer of thermal control on the exterior of the air-water control layer, uninterrupted by thermal bridges (especially the steel structure). The insulation within the framing is optional, and often not worth the risk of moisture problems for the small performance gain provided.

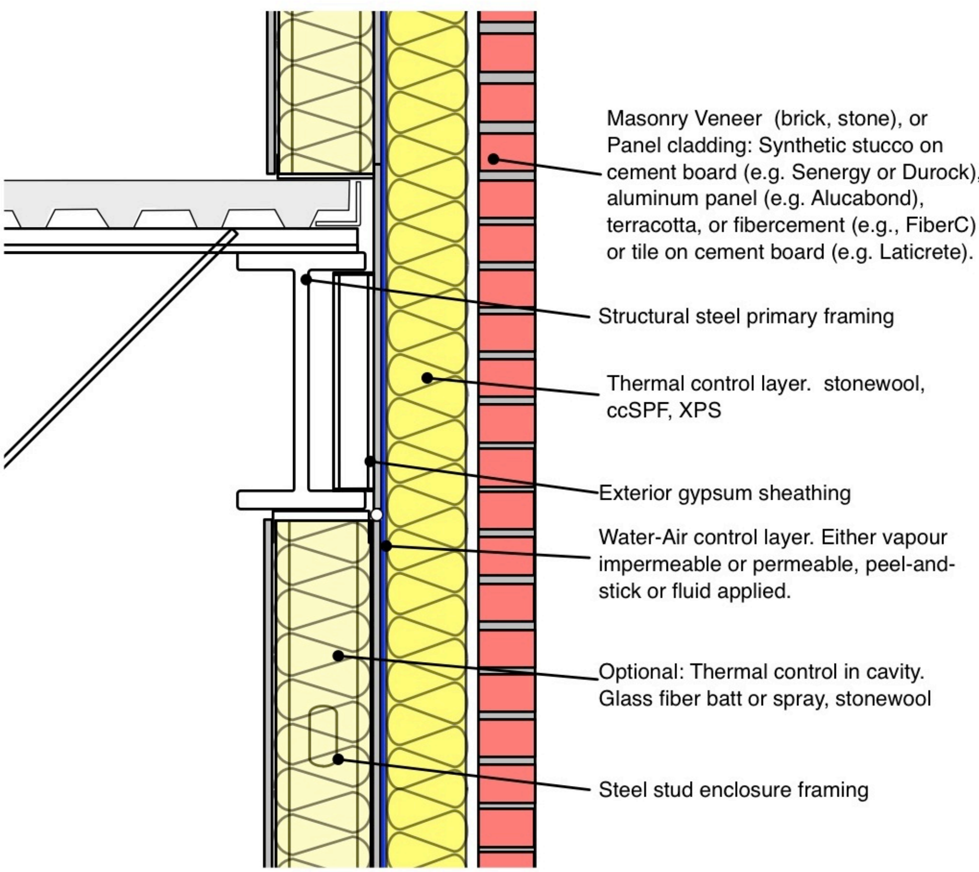

Figure 3: Steel-Framed, steel-stud infill enclosure with brick cladding

Different claddings, insulations, and control layer material choices are minor relative to the robust technical and practical advantages of the layering. Of course, different solutions will appear different, e.g., wood framing is less concerned with thermal bridging, and concrete masonry infill will always locate all of its thermal control on the exterior.

Historic and Alternate Construction

Although control layers are commonly defined and even labeled as such in modern enclosure designs, they are often more difficult to identify in existing and historic buildings. Older buildings used masonry as the primary water control layers (i.e., the storage or mass approach to rain control) as well as the support function (Figure 4). Air flow control was often a layer of interior plaster or exterior stucco, although sufficiently thick and impermeable masonry could fulfill that role.

A masonry wall retrofit for improved thermal control often uses spray foam as both a thermal control layer and air control, and requires a new interior finish / fire control layer in the form of gypsum board on steel studs (Figure 5). Alternatively, a higher performance lower-moisture-risk retrofit that changes the exterior appearance could use EIFS on the exterior, and empty steel studs on the interior (Figure 6). Labeling the control layers acts as a design quality control tool, as well as a means of effective communication in construction documentation.

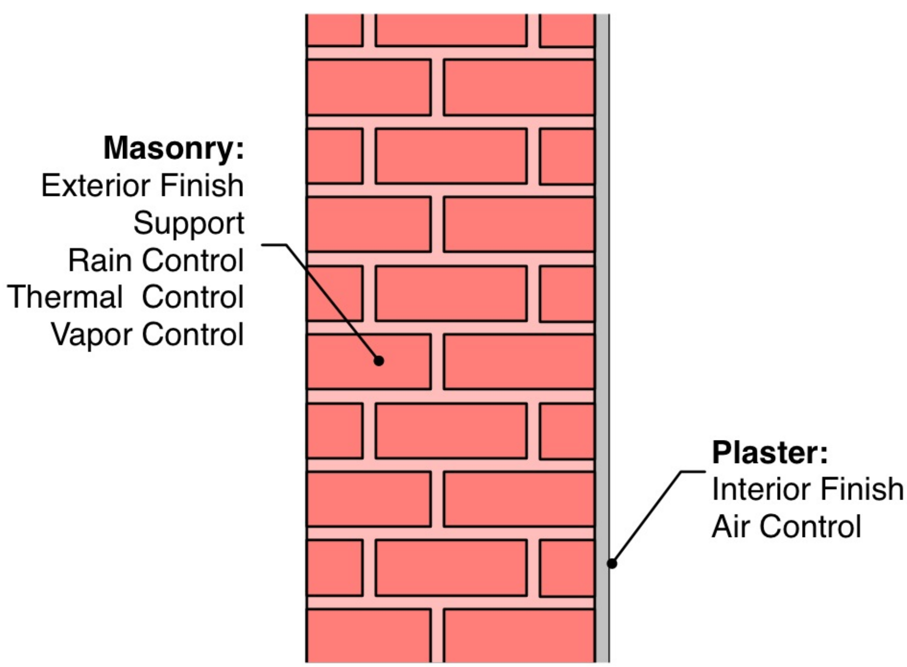

Figure 4: Historic solid masonry wall showing control layers

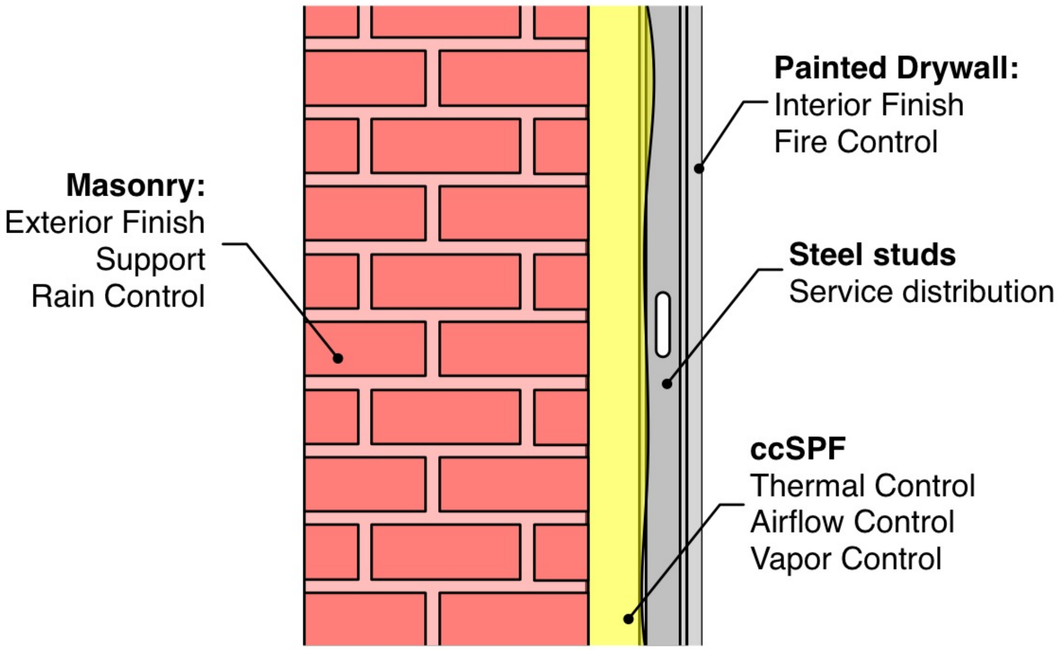

Figure 5: Interior retrofit of solid masonry wall showing control layers

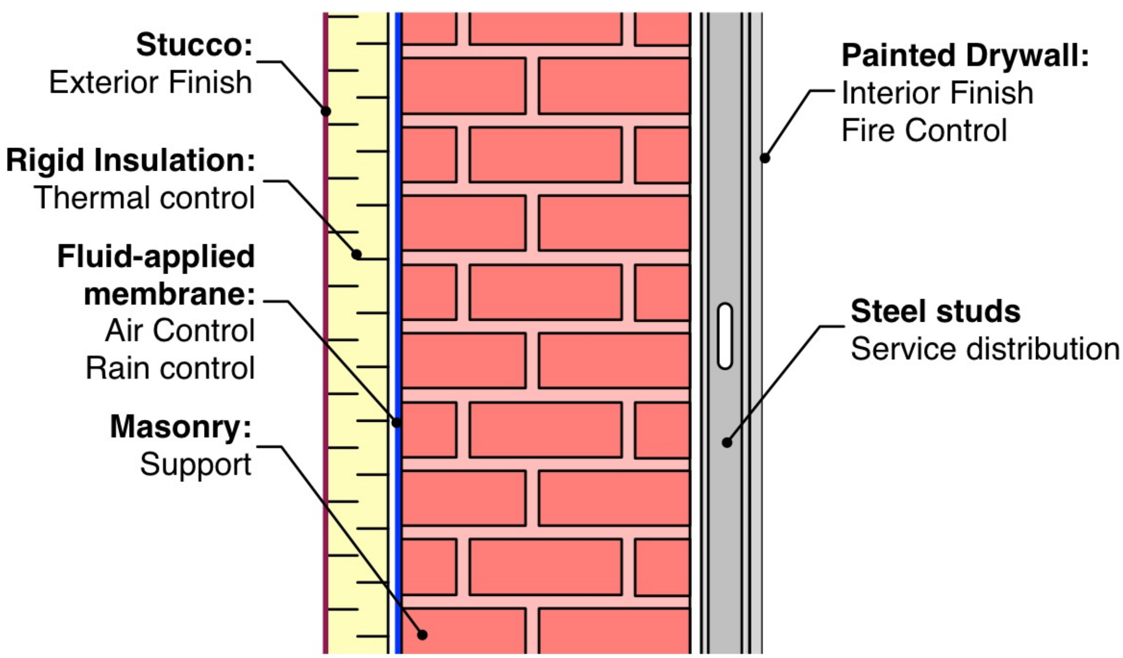

Figure 6: Exterior retrofit of solid masonry wall showing control layers