Green Building Handbook Vol 3

Super-Structure and Building Performance

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Introduction

The building envelope plays a significant role in the performance of a building, especially with regard to the green building components (heat loss, material use, maintenance, daylight ventilation). The building envelope can be divided into three sections, namely sub-structure, super-structure, and roof assembly (Emmitt & Gorse 2005). This chapter will focus on the super structure of the building envelope only.

Super structure

The super-structure consists predominantly of the load- and non-load-bearing walls - including all doors and windows – and suspended floor slabs.

Walls

A wall is a continuous, usually vertical structure that is thin relative to its length and height (Emmitt & Gorse, 2005). Apart from functioning as structural elements, external walls mediate the conditions between the external and internal environments. Thus, external walls are required to resist moisture penetration from the outside; wind and thermal gain and/or loss, depending on the season and the climatic conditions. The functional requirements of a "green" wall are:

Resistance to weather and ground moisture – the walls should resist the penetration of moisture from the ground (rising damp) and from any rain. A typical barrier for rising damp is a damp-proof course that should be laid continuously above the ground in walls whose foundations are in contact with the ground. A typical barrier for moisture penetration through the walls is to separate the outer skin of masonry from the inner skin of masonry by the creation of a cavity. The outer skin serves to act as a moisture barrier while the inner skin acts as a thermal store and is able to carry the loads of any upper floor and/or the roof. In contemporary applications in the UK and elsewhere the cavity is filled with an insulation material. A solid masonry wall will only resist moisture penetration by absorbing rainwater into the thickness of the masonry unit and its eventual evaporation to the outside air during dry periods. The extent of absorption is dependent on the permeability of the masonry unit and the mortar used, as well as the extent of exposure of the wall. In highly exposed areas a single masonry unit may not be able to absorb driving rain without transferring the moisture to the face of the inner skin. Rendering of the wall, i.e., applying a wet mix of cement and sand over the outer face of the masonry unit, will improve the units resistance to rain penetration.

Durability and freedom from maintenance – all walls should be durable for the expected life of the building and require little maintenance or repair other than to its external finish or colour.

Resistance to the passage of heat – the walls should provide resistance to transfer of heat where there is normally sufficient air temperature difference on the opposite sides of the wall. This transfer of heat takes place through conduction, convection and radiation. Conduction is the rate (unit time) at which heat (per unit area) is conducted through a material (unit thickness) per degree of temperature difference; the more dense a material, the lower is the rate of heat conduction. Convection is the transfer of heated air to cooler air or cooler surfaces. Radiation is the radiant energy from a body radiating equally in all directions and which is partly reflected and partly absorbed by another body and converted to heat (Emmitt & Gorse, 2005). Due to the complexity of the combined modes of heat transfer through the fabric of buildings it is convenient to use a coefficient of heat transmission as a comparative measure of transfer through the external fabric of a building. This coefficient is described as the U value, and takes account “the heat transferred by conduction through solid materials and gases, convection of air in cavities and across inside and outside surfaces, and radiation to and from surfaces” (Emmitt & Gorse, 2005:130). A high U value describes a high rate of transfer, while a low U value describes a low rate of transfer. Walls should provide adequate insulation against excessive loss or gain of heat, have adequate thermal storage capacity and the internal face of walls should be at a reasonable temperature as condensation is likely to form on cold internal surfaces. External walls should ideally resist heat transfer through to the inner wall, while the inner wall should act as a thermal store of any internal heat. Thus, the optimal location of insulation is between the two wall skins. As efforts are made to improve levels of thermal insulation, the problem of thermal bridging becomes of greater importance. Thermal bridging is caused by appreciably greater thermal conductivity through one part of a wall than the rest of the wall, especially where openings in walls occur. The greater the level of thermal insulation, the greater the effect of thermal bridging (Emmitt & Gorse, 2005). Areas where thermal bridging typically occurs is through single pane glazing, metal door and window frames, solid masonry sections (window and door heads and sills), cavity ties, etc. Because the resistance to the passage of heat of a cavity wall by itself is poor, an insulation material is required to be added to the wall. Most of these materials are not self-supporting, and, thus, common practice is to fill the cavity with the insulation material. To achieve a targeted U value of 0.35W/m^{2}K, the assumption is made that most of that value must be achieved by the insulation material; generally, an insulation material of 40mm thickness together with the two skins of the wall will yield the desired U value (Emmitt & Gorse, 2005). The most effective way of insulating a cavity wall is to fill the cavity with some insulating material that can be blown into the cavity through small holes drilled in the outer leaf of the wall (Emmitt & Gorse, 2005).

A good reference for establishing the optimal thermal performance of walls is the Code for Sustainable Homes as applied in the United Kingdom. The Code, launched in December 2006, is a new national standard for the sustainable design and construction of homes. The Code presents significant challenges for all types of construction, especially with regard to thermal performance. Central to meeting this challenge is the implementation of improved insulation and reduced air leakage. Significantly the performance required at each of the six levels of the Code can be met with building systems and materials currently available. However, ongoing improvements in the performance and cost of renewable technologies and products will be required if higher performance levels are required in future. It is important to note that there is no ‘one-size-fits-all’ solution: each building site, type and size has unique attributes and requires a bespoke solution tailor-made for each circumstance. Generally a U-value of between 0.2 and 0.28 W/m^{2}K for walls is deemed Best Practice, while the optimal value for all types of wall construction is currently around 0.15 – 0.17 W/m^{2}K, reflecting the best balance between overall CO_2 reduction and insulation costs (Concrete Centre 2008). A cavity width of 150 mm can provide a U-value of 0.15 Wm^{2}K which equates with *Passiv Haus* performance (Concrete Centre 2008). Specification One, one of the six specifications, has an external wall U-value of 0.28 W/m^{2}K, which is achievable with a cavity of 100 mm or less. The details for Specification One are shown below.

Table 1: Specification One

Element	**Value**
Wall	0.28 W/m^{2}K

Roof	0.11W/m^{2}K
Floor	0.18 W/m^{2}K
Openings	1.5 W/m^{2}K
Thermal bridging Y-value	0.04 W/m^{2}K
Air leakage	5m^3/(h.m^2) at 50 Pa

Specification Two is similar to Specification One, but the external walls have a lower U-value of 0.2 W/m2K and a wall cavity of around 120 mm to 140 mm (Concrete Centre 2008).

Specification Three is similar to Specification Two but with the addition of mechanical ventilation with heat recovery (MVHR).

Specification Four broadly reflects *Passiv Haus* standards in terms of air leakage and insulation. The details for Specification Four are shown below.

Table 2: Specification Four

Element	**Value**
Walls	0.15 W/m^{2}K
Roof	0.11 W/m^{2}K
Floor	0.15 W/m^{2}K
Openings	0.8 W/m^{2}K
Thermal bridging Y-value	0.04 W/m^{2}K
Air leakage (MVRC)	2m^3(h.m^2) at 50 Pa

The new draft South African building regulations dealing with energy efficiency in buildings, SANS 10400-XA:2010, recognises the fundamental role of the building envelope in improving energy efficiency in buildings. The draft regulation defines the building envelope as "elements of a building that separate a habitable room from the exterior of a building or a garage or a storage area." The draft regulations follow the example of the UK Code and set minimum W/m^{2}K values for walls according to the surface density of the construction chosen. Essentially construction with a surface density of greater than 180 kg/m^2 must have a minimum total R-value of 0.4, while construction with a surface density below this must have a minimum total R-value of 1.9 and 2.2 depending upon the climatic zone in which the building is to be erected.

SANS 204:2010 Edition 1 is the South African National Standard dealing with energy efficiency in buildings. SANS 204 specifies the design requirements for energy efficiency in walls, fenestration and roof assemblies. The wall values are similar to the draft building regulation, while fenestration values are calculated using a formula that takes into account the area of the glazing, the U-value of each glazing elements, energy constants, solar heat gain coefficient, and shading. The minimum total R-value for roof assemblies vary between 2,7 to 3,7 depending upon the climatic zone in which the building is to be erected.

Air leakage plays a significant role in reducing the thermal performance of the building envelope, particularly in a well insulated building. The units of measurement for air leakage are m3/(h.m^2) at 50 Pascals (Pa) where m^3 is the volume of air, h is per hour, and m^2 is per floor area at a fixed difference between internal and external pressure of 50 Pa (Concrete Centre 2008). To reduce air leakage the following areas require careful attention:

- Cracks, gaps and joints in the structure (including potential shrinkage, settlement or perpend joints in the brickwork)
- Joist penetrations of external walls (especially inner leafs of cavity walls)
- Service and duct penetrations (water, electrical, waste, HVAC)
- Areas of un-plastered masonry wall (intermediate floors, behind fittings, in celing voids)

SANS 204:2010 Edition 1 also sets maximum standards for air leakage: for openable glazing the maximum value is 2 L/s.m^2 with a pressure difference of 75 Pa, while for non-openable glazing the maximum value is 0,306 L/s.m^2.

Thermal bridging is another significant area where thermal performance can be negatively impacted on: the rate of heat loss for an individual thermal bridge is determined by its linear thermal transmittance in W/mK. When this value is determined it is multiplied by the length of the thermal bridge. An alternative and simpler method is to use a default heat loss coefficient known as the y-value (W/m^{2}K) to give an estimation of the overall heat loss in a building. The y-value is multiplied by the total area of exposed elements in the building (Concrete Centre 2008). Typically this default value is 0.15: however, for high performance walling a value of 0.08 can be used. New high performance design details currently under development promise to reduce this further to 0.04 (Concrete Centre 2008).

The effect of conventional wall ties in wall cavities of 100 mm or less is insignificant: however larger cavities generally require bigger wall ties where heat loss does become a factor.

SANS 204:2010 Edition 1 does not deal with thermal bridging at this stage.

Resistance to passage of sound – sound is transmitted as airborne sound and impact sound (Emmitt & Gorse, 2005:136). The most effective insulation against airborne sound is a dense barrier such as a solid wall that can absorb the energy of airborne sound waves. However, the denser the barrier the more readily it will transmit impact sound. Thus, to reduce impact sound an absorbent material is required. Generally measures adopted to reduce thermal losses or gains will work in favour of resisting the passage of sound.

Windows and doors

A window is an opening formed in a wall or roof to admit daylight through some transparent or translucent material. As the window is considered part of the wall its performance should be equal to that of the wall with regard to at least resistance to weather, durability and maintenance, fire safety, thermal performance, control of sound and security. For the purposes of this study, the following functional requirements of windows will be addressed.

Daylight factor – the prime function of a window is to admit adequate daylight for the efficient performance of daytime activities. The quantity and quality of light admitted depends on the size of the window or windows in relation to the area of the room lit, the depth inside the room to which useful light is required to penetrate and the type of material used (clear or obscure). The intensity of daylight varies significantly during the course of the day, the month and the season. Thus, in order to make a reasonable prediction of the level of daylight internally, a daylight factor is used where the factor is a ratio of the internal illumination to the illumination occurring simultaneously externally from an unobstructed sky, i.e., not obstructed by buildings or trees. The calculation is based on an overcast day as a minimum value. Generally, the daylight intensity, assuming a uniform overcast day at midday, will range between 10 000 and 25 000 lux, depending on geographic location. The lux value is divided by 50 to calculate a daylight factor. Using the guide provided by Emmitt & Gorse (2005:337) the daylight factor required for different rooms in a dwelling is 1 for bedrooms (50 lux), 1.5 for living rooms (75 lux), and 2 for kitchens (100 lux). In the calculation of daylight factors it is usual to determine the quantity of daylight falling on a horizontal working plane.

Daylight penetration – generally it is assumed that the depth of light penetration is equal to the height of the window head above floor level and a spreading out of light horizontally due to the reflection of light off window reveals and other surfaces. Thus, two windows of equal height in a wall will result in a greater spread of light than a single window of the same height, even though the depth of penetration will be the same. Windows in adjacent walls will give good penetration and reduce glare by lighting the area of wall surrounding the adjacent window. In the calculation of daylight factors it is usual to determine the quantity of daylight falling on a horizontal working plane 850mm above floor level to correspond with the height of working surfaces.

Quality of daylight – consideration must also be given to the quality of the light to avoid glare. Glare is defined as “a condition of vision in which there is discomfort or a reduction in the ability to see significant objects, or both, due to unsuitable distribution or range of luminance or to extreme contrasts in space or time” (Emmitt and Gorse 2005:342). Two distinct aspects of glare are defined, namely disability glare and discomfort glare. The former refers to glare that impairs the vision of objects without necessarily causing discomfort (such as a person standing against a highly lit background) while the latter refers to glare that actually causes discomfort, including eye strain.

Sunlight – the ultra-violet radiation in sunlight causes a breakdown of colours by oxidative bleaching. Thus, some form of windows blinds are required to reduce this effect. Typically this can be either internal and/or external shutters and blinds, or internal curtains. Fixed projections above windows will also control sunlight; if designed correctly they can reduce summer glare and sunlight while admitting winter sunlight. The term ‘radiation’ refers to the transfer of heat from one body to another; typically radiant energy from the sun passes through a window and reaches the floor where some of it is reflected and absorbed by the walls while some is absorbed into the floor. The amount of solar radiant energy is affected by the size and orientation of the windows and the type of glazing used. Geometric sun-path diagrams are used to calculate the extent of solar radiant energy penetration at any time of the day. With this information, interventions may be designed to reduce the negative impacts while allowing for the positive impacts.

Strength and stability – a window should be strong enough to resist the likely forces imposed on it by wind (negative and positive) when closed and be able to be secured sufficiently when open. The wind pressure on a window will be affected by the height of the window as well as the extent to which the window is protected or not. Wind charts are used to determine the wind speed for a particular location and a correction factor is used dependent on the height and the extent of exposure. Cognisance must be taken of the likely increase in wind speeds in some parts of the country as a result of climate change. However, even if windows are properly closed, a degree of air infiltration through the openings in the window frame occurs; this is referred to as air tightness. Air leakage can also occur at other junctions in the building, such as around frames or beams. Air leakage in buildings that are artificially heated and/or cooled will result in a loss of heat/cold and adversely affect the energy efficiency of the system. Air leakage or infiltration can be reduced through careful design and manufacture of the window assembly as well as careful installation. The extent to which air tightness is achieved is a contentious one. Achieving total air tightness can cause deterioration in the indoor air quality, especially if windows are not opened for a prolonged period due to adverse weather conditions or the property is unoccupied. Currently the challenge is to achieve a balance between air tightness and breathability.

Ventilation – a prime function of windows is to provide ventilation through the facilitation of an exchange of air between inside and outside. The number (rate) of air changes required will depend on the nature of the activities in the room and the number of occupants. The number of air changes is stipulated either in air changes per hour or litres per second when artificial ventilation is used. The rate of the exchange of air will also depend on variations between inside and outside pressure and heat, and the size and position of other openings in the room such as doors. For complete air change, circulation of air is necessary between the window (primary ventilation source) and one or more openings distant from the window.

Resistance to the passage of heat – a window will affect thermal comfort by the manner in which it allows the transmission of heat and through the penetration of radiant heat. Glass offers poor resistance to the passage of heat and radiation. Thus, the U value for a single glazed window of 6mm thick glass is 5.4W/m^{2}K, while that for a double glazed unit having two 6mm thick sheets of glass spaced 12mm apart is 2.8W/m^{2}K. The energy efficiency regulations in the UK require U values for windows and doors not to exceed 2.2W/m^{2}K, provided that the total area of the window is not greater than 25 per cent of the wall area. This requires the use of either double or triple glazing, although some single glazing systems are now available with a U value of 1.20W/m²K.

Thermal bridging – results when an area of the external building fabric has a higher transmission than another part of the external fabric resulting in lowered energy efficiency and in ‘cold spots’ where condensation may form. Thermal bridging at window openings generally occur at the frame, particularly metal frames; window and door jambs, lintels and sills; and the edge of double or triple glazing units. To resist thermal bridging thermal breaks are inserted that typically consist of some form of insulation.

Resistance to the passage of sound – the audible frequencies of sound are from about 20Hz (hertz) to 15 000 or 20 000Hz. The unit of measurement used to ascribing values to sound levels is the decibel (dB). Generally the desired dB range for buildings is between 30 to 60dB(A), where A is the weighting given to decibels. The transmission of sound through materials depends mainly on their mass – the more dense and heavier the material, the more effective it is in reducing sound. Glass is a poor insulator of sound, so the thickness of the glass needs to be increased to reduce sound transmission. Double glazing offers very little added value unless the gap between the glass sheets is increased to 100 or 300mm. The location of the window frame relative to the window reveal will also reduce the transmission of sound, with the deeper the recess the better the reduction.

Materials and durability – the materials typically used for window frames are timber, metals and plastic. The durability of these materials will depend on the quality of the material, the quality of the finish (varnish, paint), the detailing of the window head and reveal to protect it from exposure, and the extent of maintenance required and provided.

Conclusion

In any green building design, primary focus should go into maximising the performance of the external building envelope to minimise the influence of external climatic conditions on the indoor environmental conditions. Doing this will substantially reduce the extent of external intervention (lighting, heating, mechanical cooling and ventilation) required for the building to perform at normal human comfort levels.

References

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