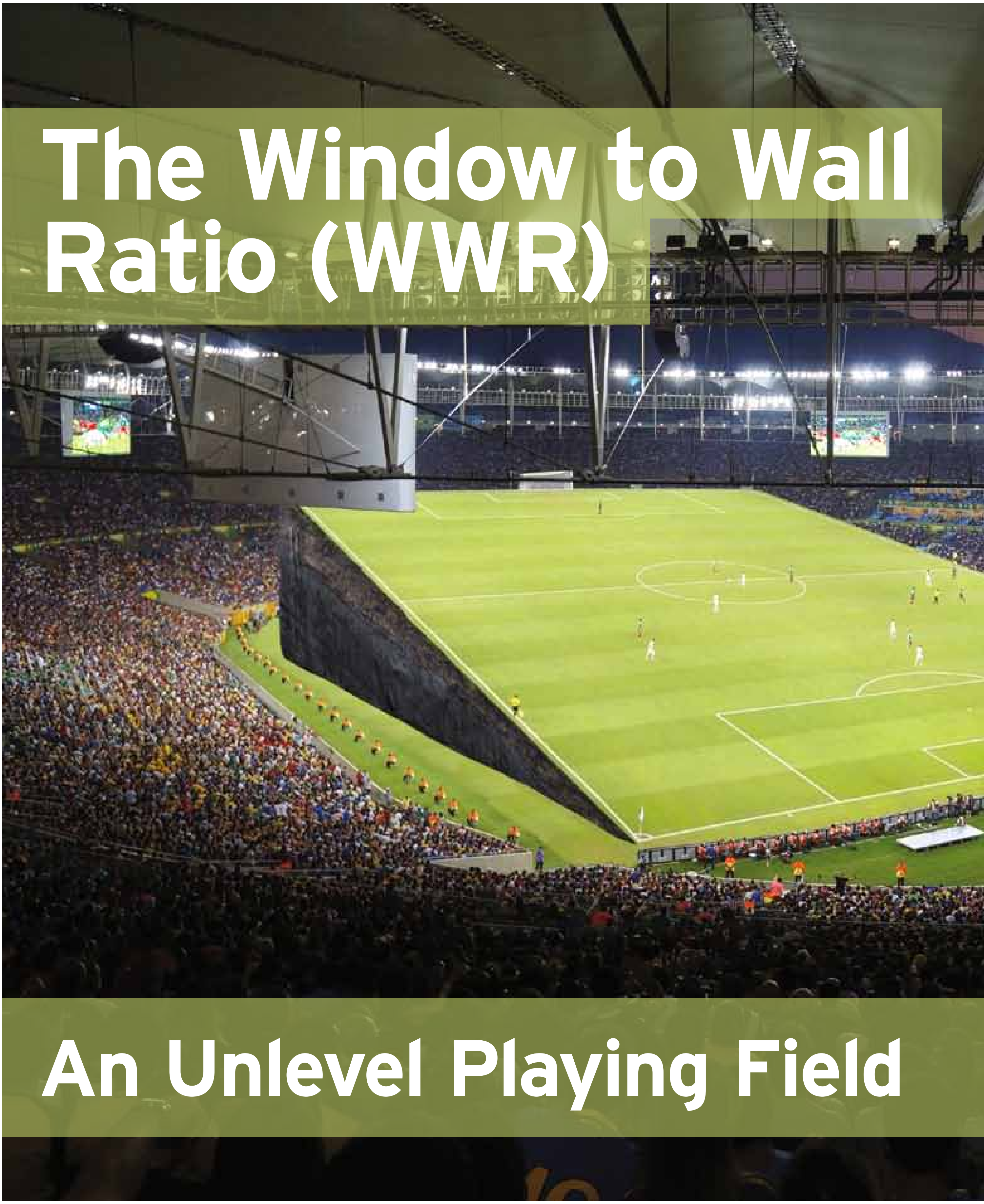
The Window to Wall Ratio (WWR)

An Unlevel Playing Field



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Global concerns about the energy efficiency of buildings is creating a 'challenge' against the extent to which light-transmitting glass is used in exterior building façades. This challenge is made by organisations wanting to reduce energy consumption by increasing the use of opaque, light-blocking materials of construction such as bricks, stonework, concrete, and metal panels.

The 'playing field' for this challenge is the Window to Wall Ratio (WWR), the percentage of an exterior building façade made of glass versus opaque materials of construction. The WWR represents a balance between light transmission and thermal performance (heat gain or loss) of a building façade. This balance is determined during building design by calculations specified by building codes.

The WWR playing field is 'unlevel' or unfair or uneven because it does not take into consideration a key factor that can detrimentally affect the light transmission/ thermal performance balance – building run-off. Rainfall washing over opaque materials of construction leaves residue that bonds firmly to glass and reduces light transmission. Light loss caused by building run-off can be estimated when a building is designed, but this approach is not currently considered.

The outcome of the WWR challenge will influence the scope and content of building codes, and could easily affect the future of many glass and glazing companies worldwide. Already the WWR challenge is causing the use of glass in external building façades to decline in some countries. This downward trend will continue if organisations promoting opaque materials of construction have their way.

Glass industry leaders are calling for ways of resisting the WWR challenge. This can be done, as described in this article, by highlighting basic flaws in the arguments supporting the challenge against glass. It can also be done by applying to building code regulators for more glass as a trade-off for losses in light transmission caused by rainwater run-off from opaque materials.

Alternatively, glass suppliers can apply surface protection to resist attack by building run-off and maintain the original light transmission. This is a much simpler and more cost-effective way of achieving a 'level' or fair playing field.

The WWR Challenge, Players and Referees

The 'challengers' on the WWR 'playing field' are organisations wanting to reduce the WWR by substituting opaque building materials for glass in building façades. Opaque materials are often considered as higher in energy efficiency compared with glass because they block light transmission, a source of radiant heat. These materials may require less energy for heating and air conditioning but this can be offset by higher costs for artificial lighting and associated cooling.

On the 'defending side' are supporters of glass, the only material of construction that allows direct transmittance of sunlight which is essential for many reasons. With sunlight, of course, comes heat from solar radiant energy. This heat can, however, be controlled in ways other than reducing the WWR such as the use of triple glazing, solar control coatings and shading.

Glass is used in building façades primarily for its light transmission, clarity and cleanability. It is also used for reasons of aesthetics, "sparkling" images and high perceived values.

'Referees' for the WWR challenge are the building codes of governments aiming to reduce energy consumption and carbon emissions by regulating the overall energy efficiency of buildings. These governmental referees are working on the basis of calculations that compare the energy efficiency of glass with other building materials when new.

Reasons for the Window to Wall (WWR) Challenge

Governmental authorities in countries all over the world are discussing strategies to improve the energy efficiency of buildings and revising building codes to reduce energy consumption. These revisions to building codes are based on the thermal performance (heat gain or loss) of building façades, including external glazing, which has led to debates about limits for the WWR.

As indicators of the importance of the WWR goals and determining ways of achieving them:

- On average, buildings use one-third of all energy consumed, according to research studies;
- Residential and commercial buildings account for nearly 40% of total energy use in the United States, according to the U.S. Department of Energy;
- In many countries, air conditioning can take up to 60% of the energy bill;
- Artificial lighting and its associated cooling costs constitute 30-40% of a commercial building's energy use, according to the handbook of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE);

Concerns about these and other energy requirements of buildings have led to the WWR challenge and proposals for using building codes to reduce the WWR in order to control solar heat gain, energy requirements for heating, air conditioning and lighting as well as carbon emissions.

Glass is currently being challenged based on a 'prescriptive' option under building codes. This option defines and specifies the WWR based on comparisons made by computer models and calculations that are simulated or theoretical – not based on actual field conditions.

Most countries offer another option - a trade-off using one material of a building with increased thermal performance to offset a second material with reduced performance. Architects and designers wanting to use more glass for its light transmission, clarity, cleanability, aesthetics and "sparkling" image should pursue this option.

The concerns about energy efficiency and other important factors have led to proposals by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) to reduce the WWR in buildings. Originally ASHRAE proposed a limit of 30% for the WWR, but this was challenged by the glass and glazing industries.

The latest ASHRAE proposals are to limit the WWR to 30% for buildings smaller than 25,000 ft^2 (2,336m^2) of gross conditioned floor area. For all other buildings they propose a limit of 40%.

In the United Arab Emirates (UAE), with its multitude of all-glass buildings, Dubai has set a limit of 60% for glazing in buildings to become effective in 2014. Abu Dhabi is said to be considering a limit of 30% but may include ways for designers to exceed this limit through shading or by increasing the amount of glass on the north sides of buildings. Also at stake in the WWR challenge is a range of other functions important for buildings, such as daylighting for the productivity and comfort of occupants. Daylighting is also important for managing the levels of artificial lighting and related costs inside a building.

The use of building codes to reduce the WWR is a comparatively easy option for governmental agencies. The WWR is based on calculations and the results are measurable, at least in theory, when a building is being designed. This does not mean, however, that reductions in the WWR provide the best or most cost-effective solutions.

To meet the WWR challenge, glass and glazing companies should be aware of basic flaws in arguments supporting the challenge.

Basic Flaws in the WWR Challenge

The goal of improving the energy efficiency of buildings is not subject to question. Arguments in support of reductions in the WWR are problematic, however, because they do not take into consideration critical factors that can detrimentally affect the balance between light transmission and thermal performance (heat gain or loss) upon which the WWR is based.

Opaque materials of construction are often considered as higher in energy efficiency compared with glass simply because they block light transmission, a source of radiant heat. Blocking light transmission means, however, that opaque materials do not have important performance features that include daylighting with its benefits for building occupants such as improved comfort and productivity as well as reduced requirements for artificial lighting. Blocking light transmission also detrimentally affects the appearance, aesthetics and perceived value of a building.

Opaque materials have no light transmission and their thermal performance is unlikely to change, but the light transmission of glass can drop significantly with exposure to building run-off. In general, the more opaque materials used in a building façade the greater the loss in light transmission. This makes the WWR playing field even more unfair, because the building materials proposed as substitutes for glass are the reason that the WWR is out of balance.

The ultimate control of heat gain or loss is to block sunlight completely, but this could mean living in a concrete bunker – not a healthy option!

Achieving a balance between light transmission and thermal performance might be easy if the situation was static, but environmental conditions on the façade of a building are dynamic and ever changing.

In reality, the energy efficiency calculations used in building codes are virtually meaningless because they are based on three fundamental flaws:

- Computer software used for energy efficiency calculations produces simulated or theoretical values, instead of being based on actual field conditions;
- The calculations assume static conditions, but external building façades are subject to many variables that fluctuate with ever changing weather and other environmental conditions;
- A major variable overlooked or ignored is rainwater running off opaque building materials and leaving residues that bond firmly to glass reducing light transmission.

By reducing the light transmission of glass, the run-off from opaque building materials creates an unlevel playing field for the WWR challenge.

The Real Challenge – Balancing Light Transmission and Thermal Performance

If the top priority for building design was thermal performance/solar energy control, we might be living and working in concrete bunkers. If light transmission was the only criteria, we might reside in all glass buildings. Neither of these options is practical for obvious reasons, so the real challenge is to find a cost-effective and workable balance between light transmission and thermal performance of building façades.

Industries, trade associations and governmental agencies are spending much time, effort and money towards reaching consensus about the light transmission/thermal performance balance. This balance is a key factor in determining limits for the WWR. Whatever limit is set by a country, it is reasonably assumed that this represents an acceptable balance between light transmission and thermal performance.

Unfortunately this situation is not stable because the balance between light transmission and thermal performance upon which the WWR is based can change. The original energy efficiency of opaque materials is unlikely to change, but light transmission can easily drop if glass is unprotected against its enemies.

The enemies of glass can easily cause light transmission to drop because they are contained in rainwater run-off from opaque materials such as bricks, stonework, concrete and metal panels.

Why Building Run-off Makes an Unfair Playing Field for the WWR

Rainwater running off opaque materials such as bricks, stonework, concrete and metal panels contains three enemies of glass – moisture, alkalinity and dirt (MAD). These enemies can easily attack glass, staining and discolouring its surface. As a result, light transmission is reduced.

Like bare metal surfaces, unprotected glass is "raw" and chemically reactive. These and other properties of glass make its surface susceptible to degradation by MAD. Moisture and alkalinity attack the exposed surface - causing corrosion, etching and staining/discolouration. Dirt bonds

firmly and makes the surface difficult, if not impossible, to clean and keep clean.

Moisture and alkalinity, either individually or together, can etch or dissolve the surface of glass, making it appear dull and sometimes white in appearance. Moisture can be in its liquid form, such as rainfall, or as a vapour in high humidity areas. Alkalinity comes from hard tap water, sea water and construction materials such as cement dust and building run-off from bricks, stonework, concrete and metal panels.

Dirt can damage the surface of glass in some cases, but most harm is caused by harsh and aggressive cleaning methods. Although some dirt can be washed away easily with detergent and water, most dirt bonds firmly to the surface of glass, restricting sunlight and reducing the original levels of light transmission. There are two general categories of dirt:

- Organic dirt, which does not normally attack glass but can attach firmly to the surface and be difficult to remove. For exterior glass, this includes traffic film, bird droppings and tree sap. For interior glass, organic dirt includes finger marks and cooking oil vapours.

- Inorganic dirt bonds chemically to glass and is difficult, if not impossible, to remove using conventional cleaning methods. Inorganic dirt on exterior glass includes sea spray, industrial emissions, metal oxides from railways and construction materials such as cement dust and building run-off. For interior glass, an example is limescale from hard tap water.

The Consequences of Failing to Protect Glass Against MAD

There is a growing awareness by architects and within the flat glass industry of the need for durable, "non-stick", easy-clean glass surface protection. It is increasingly recognised that ordinary, unprotected glass is a high maintenance material of construction that needs protection against attack by MAD. It must be reiterated that, if unprotected, glass can easily lose its original visibility, clarity and cleanability. Architectural glass exposed to MAD results in costly call-backs, replacements, project completion delays, increased use of cleaning materials and higher energy consumption.

As a consequence of attack by MAD, the original light transmission of glass can easily drop, with negative effects on visibility and daylighting as well as the productivity and well-being of building occupants. Lower light transmission means higher energy costs for artificial lighting as natural daylighting is reduced. As a related consequence, glass can easily lose its original bright and "sparkling" appearance, making a building look dull and lifeless with lower perceived value.

As a further consequence, the loss in cleanability caused by MAD is attracting more and more attention as 'green' building design becomes increasingly important. Glass attacked by MAD is not 'green' because it requires regular but often ineffective washing with higher energy requirements, and it generates substantial amounts of climate-changing emissions of carbon dioxide (CO_2) and other greenhouse gases.

The Net Effect

Reduced light transmission is the net effect of unprotected glass exposed to building run-off and MAD. This is significant because, for glass, the WWR is based primarily on light transmission. Reductions in light transmission can occur quickly in some cases but normally occur gradually over time. By the time this effect is noticeable to the naked eye, 5% to 10% light transmission can easily be lost. With prolonged exposure, the effect can be reductions in light transmission of 50% or more.

As stated above in the paragraph 'Basic Flaws in the WWR Challenge', the WWR is based on calculations when materials of construction, both glass and opaque materials, are new. The insulation values of opaque materials such as bricks, stonework, concrete and metal panels are constant, and unlikely to change over time. The light transmission of glass, however, will drop with exposure to MAD. Also, as stated in the same paragraph, calculations for the WWR are based on static conditions when, in fact, they are variable. The calculations do not take into consideration the reductions in light transmission after months or years of exposure to MAD.

Flaws in arguments for reducing the WWR are significant and make an 'unlevel playing field'.

Conclusions

The balance between light transmission and thermal performance (heat gain or loss) is important in deciding any limits to be placed on WWR through building codes. Finding ways of achieving the most cost-effective and workable balance should be the overall goal.

Since the original energy efficiency of opaque materials is unlikely to change and the light transmission of glass can easily drop as a result of attacks by MAD, the focus should be on maintaining the original levels of light transmission.

The solution for achieving and maintaining a balance between light transmission and thermal performance lies somewhere between an all-glass building and a concrete bunker. Architectural glass plays a major role in the health, quality of life and productivity of building occupants. Glass connects people with the outside world, and it provides natural light and solar heat – making daylighting a central theme in the design of high performance buildings.

It is ironic that the opaque materials of construction proposed as substitutes for glass are the ones creating an 'unlevel playing field' for the WWR. This situation is a result of pressures to limit the WWR through building codes.

In general, the WWR playing field becomes more unfair as the use of opaque materials increases. This is because of residues of rainwater run-off from these materials which bond firmly to glass and reduce its light transmission.

To achieve a 'level playing field', building code 'referees' should either:

a) increase the WWR to allow more glass in a building façade as a trade-off for reduced light transmission caused by building run-off from opaque materials of construction or

b) maintain the original light transmission/ energy efficiency balance by protecting glass against the detrimental effects of building run-off.

The latter option is a more practical, cost-effective and fair way of achieving a balance between light transmission and solar energy control and, therefore, a better way of achieving a 'level playing field'.

Today there is no reason to overlook or ignore the need for protection against the enemies of glass. Technology exists for maintaining the original light transmission, clarity and cleanability of glass. Ritec International Limited pioneered durable glass surface protection starting in 1982 and has developed the only complete system for glass renovation, "non-stick", easy-clean surface protection and maintenance.

The Ritec ClearShield System™ converts, either in factory or on-site, ordinary glass into a "non-stick", easy-clean surface with average reductions of 50% in the frequency of cleaning and related energy requirements. This innovative System is guaranteed to maintain the original light transmission of glass, making a 'level playing field' for the WWR.

Ritec International Limited is developer and manufacturer of the 'ClearShield System' for glass renovation, protection and maintenance.

Ritec's website is www.ritec.co.uk. If you have any comments or questions about this article, please contact Stephen Byers at slb@ritec.co.uk.