THE SERRAGLAZE WINDOW - A REVOLUTION IN DAYLIGHTING

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ABSTRACT

SERRAGLAZE is a breakthrough daylighting system designed to be incorporated into the primary glazing of normal sidelit rooms to save energy and enhance comfort.

The paper describes the design, construction and optical properties of the plastic SERRAGLAZE panel, the key component of the system. This transmits the light needed to maintain a view through the window, but intercepts higher incidence light and redirects it to provide reduced near-window glare and increased deep-room illumination levels.

The SERRAGLAZE panel is shown to comprise two identical transparent high precision plastic mouldings, each having one flat surface and one containing microscopic grooves that intermesh with those of the other moulding. The intermeshed surfaces are physically and optically bonded together to form a composite panel containing a multitude of microscopic air pockets that act as near-perfect mirrors by the phenomenon of total internal reflection. These air pockets are entirely responsible for the optical properties of the material.

The paper then reviews how the plastic SERRAGLAZE panels are preferably incorporated into glazings and windows. Included in this review is a description of a new type of window design, known as the enhanced SERRAGLAZE window, which has been developed to maximise the daylighting benefits.

KEYWORDS

Daylighting, shading, glazing, energy-saving, comfort, sustainability.

BACKGROUND

SERRAGLAZE is one of a number of patented ‘SERRA’ (**S**tacked **E**lemental **R**efractor/**R**eflector **A**rray) branded products which have in common the presence of a generally prismatic micro-structure designed to support light refraction and/or reflection in order to achieve a desired function. SERRAGLAZE is the first SERRA product to be designed primarily for use within the architectural glazing industry.

DESIGN & CONSTRUCTION OF SERRAGLAZE

It is planned that there will eventually be a family of SERRAGLAZE products covering a range of optical characteristics. Also in the future, alternative methods of manufacture are expected to offer productivity and application enhancements. For the present, however, and for the purposes of this paper, SERRAGLAZE is a single product manufactured by a particular process. The product and the way it is produced are illustrated in Figure 1.

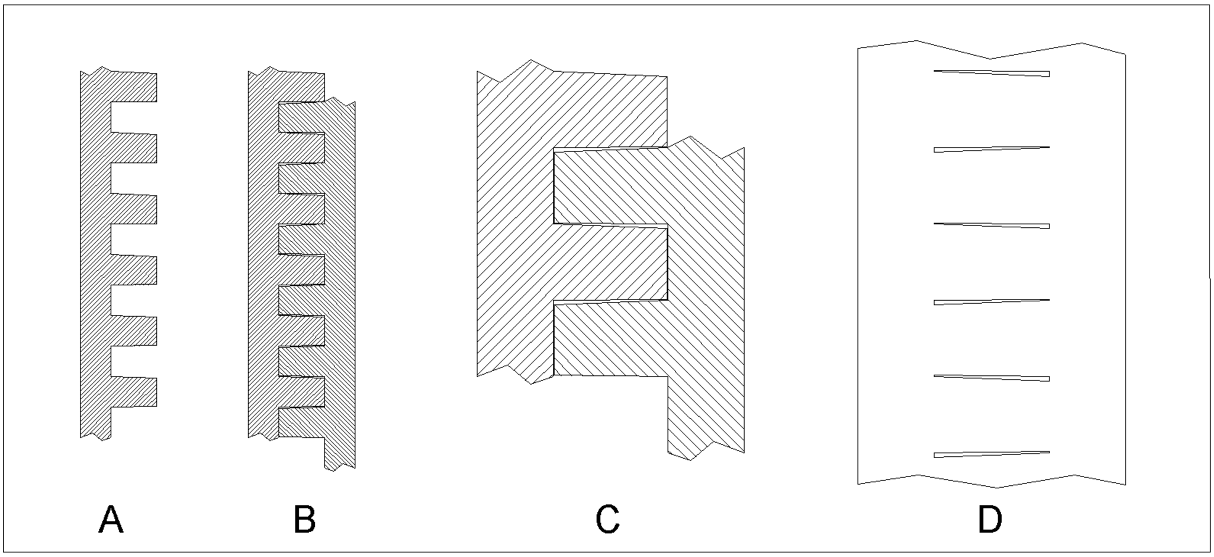

Figure 1: Design and construction of SERRAGLAZE

The sketch denoted A in the figure depicts a partial cross section of a sheet of thermoplastic material that extends perpendicular to the viewing direction. The approximately rectangular toothed prismatic structure shown is embossed into one surface of the sheet that has typical dimensions 300 x 300 x 0.5mm (prior to embossing). Tooth width is approximately 0.3mm, tooth spacing is very slightly more than tooth width and tooth depth is approximately 0.5mm. The flanks of a tooth are not perpendicular to the plane of the material but possess a small rake or draw angle that is different for each flank of the tooth.

The precise dimensions and angles are such that, when the sheet is meshed with an identical sheet turned through 180° about the 'vertical' (ie. keeping 'top' to 'top') as shown at B and enlarged at C, thin triangular shaped voids are created on each side of the tooth. These voids have a mean thickness of about 0.01mm, less than a quarter the thickness of a human hair.

The extremely precise manufacturing method employed to produce the embossed sheets is known as micro-replication. It is a proprietary process of Reflexite Corporation of Avon, CT, USA, details of which are held confidential by that company. However, the basic steps of the process are in the public domain. A master tool, produced by diamond machining, is replicated using proprietary plating processes and one of these replicas is used as the tool for producing the embossed sheets in a special type of compression moulding process.

After the sheets are embossed the crests of the teeth are coated with an ultra-thin layer of a UV curing adhesive prior to assembly, lamination and curing. The coating process, which was developed specially for the purpose, applies just sufficient adhesive (a thickness of few microns) to ensure that a complete physical and optical bond is achieved but not so much that excess fluid is squeezed into the voids. The process was adapted from the anilox process found in the printing industry, in which a ceramic roller is etched by a laser to create a multitude of tiny pockets. The pockets are filled with a precise amount of fluid by a chamber and doctor blade system and the fluid in the pockets is then transferred to the workpiece by rolling contact. The volume and spacing of the pockets determines how much fluid is transferred to the workpiece.

OPTICAL CHARACTERISTICS OF SERRAGLAZE

It may be shown that, if Ø is the angle a tooth flank makes with a perpendicular to the plane of the SERRAGLAZE material, total internal reflection (TIR) takes place for all light that can possibly strike the flank from the tooth side if the refractive index of the SERRAGLAZE material is greater than Cosec (45-Ø/2). For SERRAGLAZE, for which the maximum value of Ø is 2.5°, the threshold value of refractive index according to this inequality is 1.45. Since the refractive index of SERRAGLAZE is about 1.47, all the flanks of all the teeth support TIR and act as 'perfect' mirrors (since TIR is a significantly more efficient form of reflection than that performed by a normal 'silvered' surface). Since the mirrors are substantially transverse to the plane of the material, light that is reflected by them continues its way through the material. These reflection properties make SERRAGLAZE a very efficient light transmitter. However, although SERRAGLAZE neither absorbs nor rejects a significant amount of incident light, it is not completely loss-free because around 4% of incident light strikes the end faces of the voids and subsequently undergoes complex and unpredictable processes, due to the unknown form of the adhesive 'meniscus' in these regions. The effect of these processes is to generate a small amount of haze in the product.

The general behaviour of SERRAGLAZE is that of a beamsplitter, the split ratio of which varies with incidence angle, as illustrated in Figure 2.

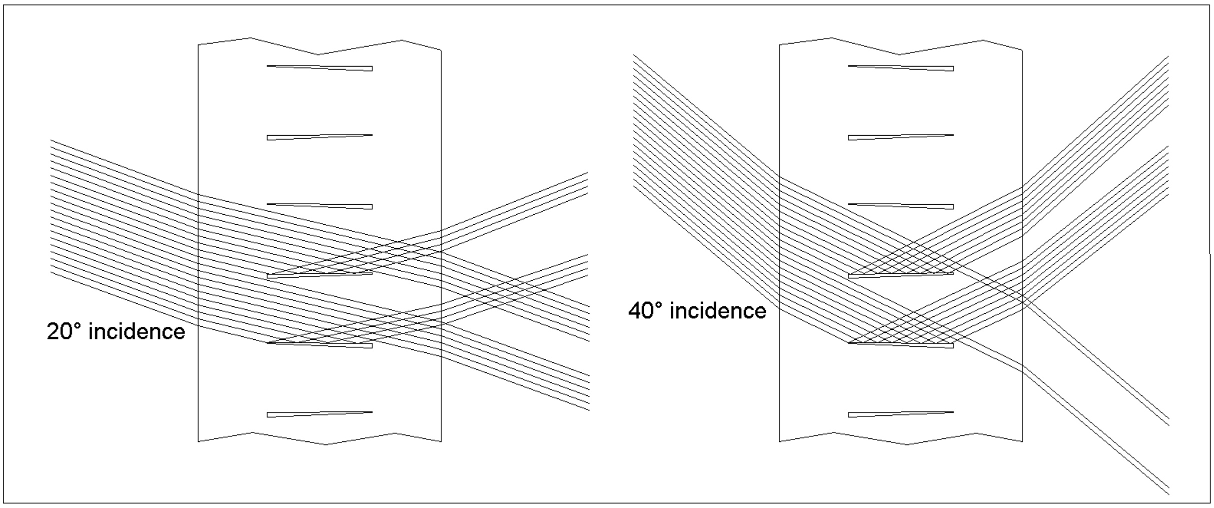

Figure 2: Raytraces of SERRAGLAZE illustrating behaviour as variable ratio beamsplitter

At higher incidence angles than those shown in the figure the ratio of redirected light to unredirected light becomes larger until, at an incidence angle of around 55°, virtually all the light is redirected and none is transmitted unredirected. At greater incidence angles than this a small proportion of the light undergoes reflections at both flanks of a tooth while at still greater incidence angles an even smaller proportion is totally internally reflected at the 'exit' face and fails to emerge from the device. These more complex behaviour patterns are relatively unimportant in most window applications because only a small proportion of the total incident light arrives at high incidence angles.

The ability of SERRAGLAZE to prevent high incidence sky light from passing directly down to the floor, where the occupants of a room are located, makes it very beneficial as a glare reducing medium and sunshade. In this latter respect, SERRAGLAZE also offers a very important bonus for the occupants of the room, because it treats solar IR radiation in much the same way as it treats visible light, thereby acting as a brise-soleil and shading the occupants from the direct heat of the sun as well as from its light. (Of course, SERRAGLAZE does not prevent the heat from entering the building, so the ventilation and/or air conditioning systems still have to cope with it, but at least the occupants feel the benefit.)

It should be noted that the precise optical properties of SERRAGLAZE are different according to which way up the material is oriented, although there is no difference in properties side-to-side. The chart shown in Figure 3 summarises the approximate behaviour of SERRAGLAZE (in either vertical orientation). The redirected light is the key to its function; this is the light that is removed from the occupants near the window and which re-appears towards the back of the room after using the (white) ceiling as a 'repeater station'.

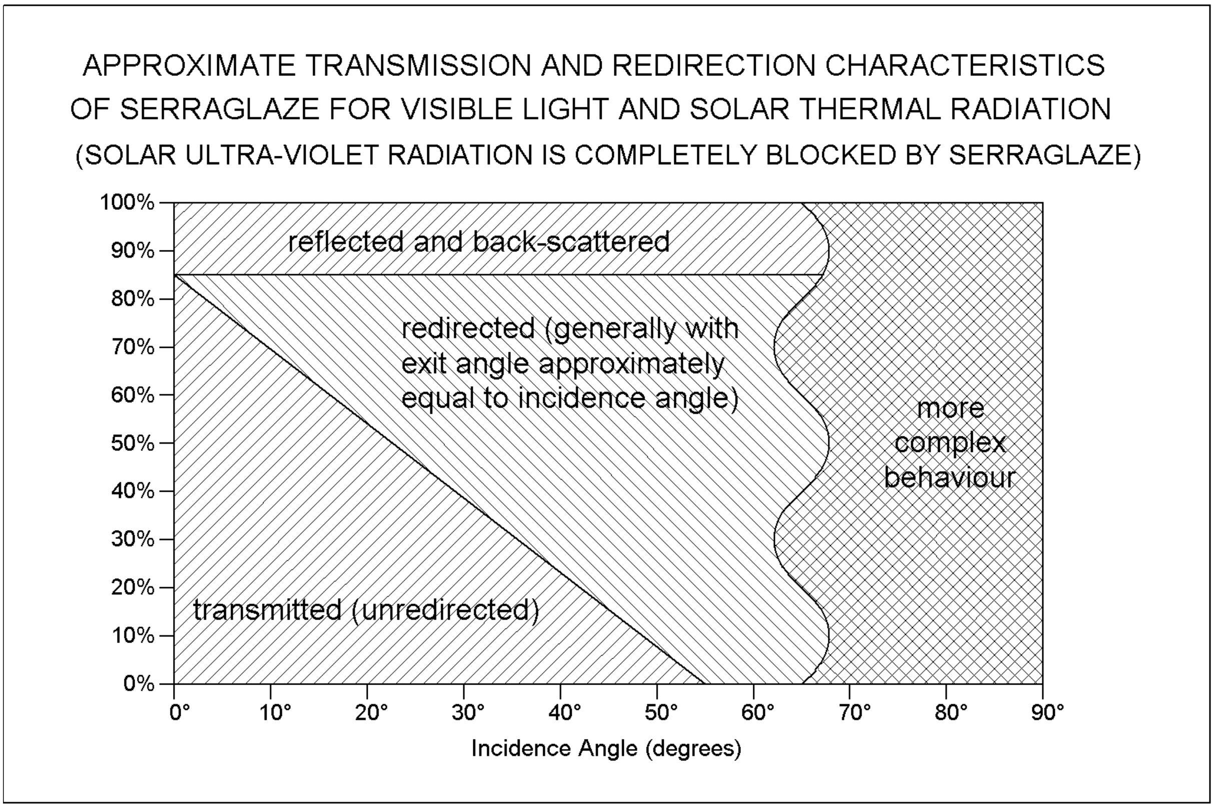

Figure 3: Approximate solar radiation properties of SERRAGLAZE

The ratio of tooth width to depth determines the slope of the diagonal line in the figure and other slope values are planned as part of the SERRAGLAZE family. It is also possible to change the slope of the diagonal (but only to reduce it, and in a less precise way) by changing the thickness of the adhesive layer when bonding the two sheets together. This works by displacing some of the adhesive into the void space during laminating, before curing, thereby effectively reducing the length of the tooth flank and hence the length of the mirror.

The chart of Figure 3 is useful for gaining a qualitative idea of the effect of installing SERRAGLAZE, but accurate quantitative calculations require a more rigorous treatment. Greenup et al (2000) developed an algorithm for the RADIANCE lighting simulation package (Ward (1994)) to simulate a daylighting component having similar optical behaviour to that of SERRAGLAZE and this algorithm may be adapted for SERRAGLAZE. (The input variables A1 and A2 of the algorithm should be set to 0.66 and 1.49, respectively, for SERRAGLAZE.) For simulations in the GENELUX environment, IES files for a number of outdoor environments have been developed and these are available from the author on request.

SERRAGLAZE WINDOWS

The preferred method for packaging SERRAGLAZE in a window is to combine it with the laminating adhesive in a sealed-edge laminated pane. This provides the necessary protection of the plastic SERRAGLAZE material against damage, dust and moisture and avoids the need to create any new industry infrastructures for handling and installing SERRAGLAZE.

A laminated SERRAGLAZE pane is normally manufactured by assembling a rectilinear mosaic of SERRAGLAZE panels between layers of laminating adhesive that are in turn sandwiched between sheets of float glass. The whole assembly is then encapsulated in a vacuum bag and cured in an autoclave in the normal way. However, due to the relatively low softening temperature of the PMMA material normally used to produce SERRAGLAZE, a lower temperature laminating adhesive and autoclave process than normal must be adopted. Both PU and EVA based adhesives have been successfully used.

Packaged thus, SERRAGLAZE may generally be specified in any pane of a multi-pane window. SERRAGLAZE does not occupy a surface, so glazing enhancements such as solar control and low-e coatings may be specified independently of (and their performance is not in general significantly affected by) the presence of SERRAGLAZE. It should be mentioned that SERRAGLAZE is also compatible with windows fitted with venetian blinds, as most of the redirected light generally passes between the blind lamellae (except when the blinds are set to exclude very low sun).

PERFORMANCE OF SERRAGLAZE

As already mentioned, SERRAGLAZE both reduces daylight levels near the window and increase them towards the back of the room. This combination of properties renders the room significantly more uniformly illuminated, thereby encouraging the pupils of the occupants' eyes to open wider and further reducing the need for artificial lighting beyond that due to the increased deep-room illuminance alone.

Figure 4 is presented in order to illustrate typical performance levels of SERRAGLAZE in a normal side-lit room. These calculations were performed using a simple spreadsheet-based daylighting program developed in-house to enable the relative merits of different SERRAGLAZE designs to be evaluated.

For these simulations an intermediate sky was selected with the sun at about 45° elevation behind light cloud (as indicated by the sky luminance radius vectors incident on the window). The room is 7m deep and 3m high with a full width window from 1m to 2.8m above floor level and ceiling reflectivity of 0.7 lambertian and 0.1 specular. The dotted line indicates the workplane daylight curve for conventional glazing while the solid curve shows it for the SERRAGLAZE installation. The data points give the SERRAGLAZE values as a percentage of conventional glazing illuminance for the five workstations shown and the max/min illumination ratio is recorded for the same five workstations.

The upper pair of charts, calculated for an unobstructed sky, indicates an approximately 5:1 improvement in illuminance uniformity when SERRAGLAZE is used in place of conventional glazing. The left chart is for SERRAGLAZE fitted as a direct replacement for conventional glazing while the right chart is for an 'enhanced performance' SERRAGLAZE window in which the frame is designed to take advantage of the ability of SERRAGLAZE to 'grab' light from the upper part of the sky vault and bring it into the room. Such a frame effectively increases the size of the window aperture (as evidenced by the fact that the area under the daylight curve is increased) but only for the SERRAGLAZE case. (For conventional glazing the amount of light entering the room is determined solely by the size of the hole in the wall.) The lower part of the enhanced SERRAGLAZE window, which does not contribute significantly to improved daylighting, is fitted with conventional glazing.

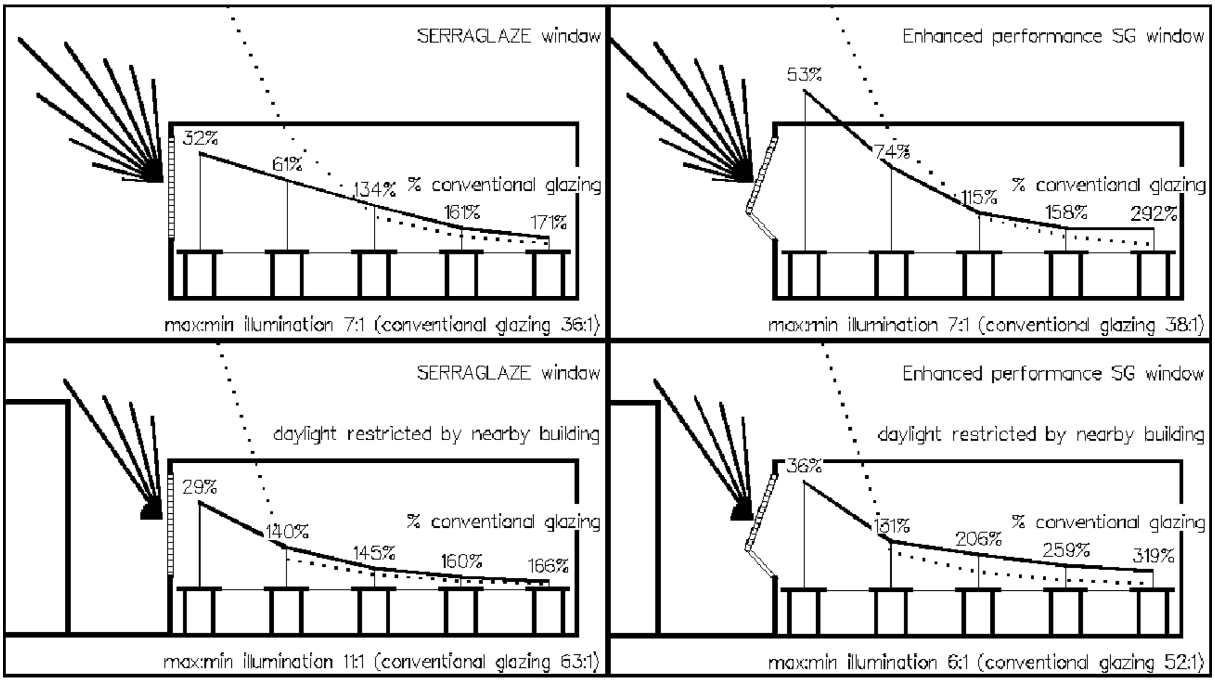

Figure 4: Typical daylighting and glare reduction performance of SERRAGLAZE

The lower pair of charts in Figure 4 shows the same results for a sky obstructed by a nearby building. For this type of outdoor environment the ability of the enhanced SERRAGLAZE window to bring more light into the room and to distribute it favourably (ie. to improve luminance uniformity) makes it the window design of choice, as the data clearly illustrates.

CONCLUSIONS

SERRAGLAZE offers architects, window designers and glazing specifiers new opportunities to simultaneously protect near-window room occupants from glare and solar thermal radiation, increase deep-room illumination and improve the uniformity of daylight throughout the room by simply specifying a modified glazing system that is compatible with current window and curtain walling design and installation practice.

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