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Reinhard Wollner
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Dear Reinhard

NSW Railways – polishing of graffiti scratches on toughened glass surfaces

We refer to your email correspondence dated 31 October 2011 requesting our opinion concerning the effect of polishing on toughened glass surfaces, including the typical depth of graffiti "tagging" scratches in relation to the compression layer of toughened glass. As requested, please find following our opinion concerning this matter.

Toughened glass is produced using a thermal process of heating and quenching to induce a pre-stressed condition in which the surface zones are in compression and the central zone between the surface compressive zones is in tension. Glass standards generally specify a minimum surface compression stress of 69 MPa for toughened glass. The exact shape of the distribution of stress through the thickness of toughened glass depends upon the shape of the panel, the temperature range over which cooling takes place and the rate of cooling. However, this distribution is approximately parabolic as shown in figure 1.

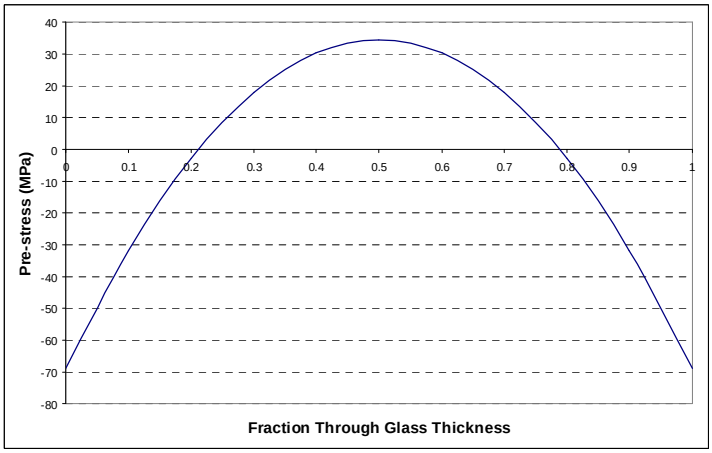

Figure 1 Typical parabolic stress distribution of toughened glass having a surface compression stress of 69 MPa.

For the parabolic distribution of stress through the thickness, the depth of the compression layers is of the order of 0.2 times the glass thickness (see Figure 1). Thus, for 6 mm glass thickness the depth of the surface compression layers is 1.27 mm.

In general, the nominal tensile breaking stress increases by the amount of compressive "pre-stress" developed by the heat treatment. When the glass is not subjected to a load, then breakage would generally not occur unless the surface scratch or damage is deeper than the surface compression layer. When the glass is subjected

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to a bending load then the tensile stress due to the bending is subtracted from the surface compression stress, which in turn results in a reduction in the depth of the surface compression layer. Therefore, if there is a deep scratch or surface chip, the anticipated safety factor for the design strength of the toughened glass can be reduced when the glass is subjected to a bending stress, due to the flaw then possibly penetrating into the higher tensile stress zone beneath the reduced surface compression layer depth. The typical reduction in the surface compression layer can be seen in the following example.

In this example it is assumed that a railway carriage has a window of size 1500 mm high x 1800 mm wide. Our calculations have shown that when this window is subjected to a pressure generated from an air speed of 150 km per hour then the maximum bending stress in the window glass (assuming it is 6 mm toughened glass) would be 14.09 MPa. This bending stress varies through the thickness of the glass linearly as shown in Figure 2. When this bending stress variation is superimposed on the toughening pre-stress then the resulting variation of stress through the thickness is as shown in the red broken line in Figure 2.

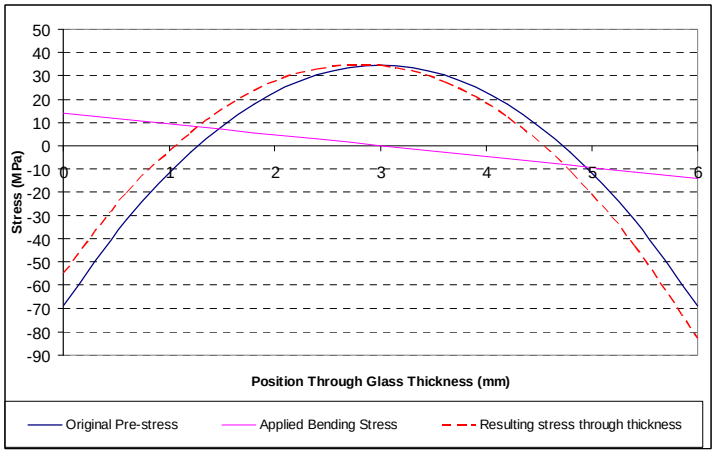

Figure 2 Stress distribution through 6 mm toughened glass having a 14.09 MPa maximum bending stress superimposed on the distribution for a surface compression pre-stress of 69 MPa.

From Figure 2 it can be seen that for this example, when the bending stress is superimposed on the toughening pre-stress, then the surface compressive zone is reduced to 1.05 mm deep one surface and increased to 1.46 mm deep on the other surface. Therefore, a scratch of depth up to 1 mm would still be within the surface compression layer.

However, based on my past observations of graffiti scratches, it is my opinion on the typical depth of graffiti "tagging" scratches would only be of the order of 0.2 mm, which is significantly lower than the depth of the minimum surface compressive zone in the above example. Therefore, such graffiti scratches would not necessarily result in glass breakage unless the glass were subjected to much higher stress than the bending stress used in the above example.

The effect of polishing on toughened glass surfaces to remove scratches would be to reduce the effective depth of the scratch. Furthermore, although the glass is slightly thinner in the area where the scratch is removed, the surface compression layers would be altered slightly in the process as the glass remains in equilibrium and therefore the compressive layer thickness is not reduced as much as the thickness of glass that is removed in the polishing process. Since the typical depth of scratches is much lower relative to the compression layer of toughened glass, then it is our opinion that scratches can be successfully removed.

Based on our previous experience we have found that the polishing process used by Glass Polish was able to remove deep scratches without producing very noticeable distortion in the treated area of the panel. Furthermore, unless very high thermal stresses are produced in the polishing process in removing some very deep scratches, we would not expect breakage to occur in the process. Therefore, it is our opinion that the method used by Glass Polish could be successfully used for removal of typical graffiti scratches on carriage windows in the NSW Railways.

Thank you for allowing us to assist you with our specialist consultancy advice and opinion. If you have any queries or require additional information in regard to the above please don't hesitate to contact Ignatius Calderone by email or on telephone number 0409 136 353 or 9561 1781.

Yours sincerely

Dr Ignatius Calderone
Director, Calderone and Associates Pty Ltd.