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TECHNICAL REPORT

Subject	Load tests on juliette barrier panes
Client	C R Laurence
Report Number	JBC4858/01
Date	12 June 2020
Author	J. B. Colvin

1 INTRODUCTION

C R Laurence have developed a vertical rail fixing system for Juliette barrier panes. The system was tested with 3 glass thicknesses under the supervision of JCGC Limited. The tests were undertaken on 2nd December 2019 observed by John Colvin.

A brief curriculum vitae for John Colvin is given in Annex A.

2 APPARATUS

The test apparatus consisted of a strongback, on which was mounted two rigid posts, representing the structure at either end of the juliette barrier. Figure 1 shows the strongback with a juliette pane mounted.

Figure 1.

The loads for the tests were applied as a concentrated load of diameter 25 mm, by means of a manually operated hydraulic jack and monitored with a 50 kN load cell. Figure 2 shows the loading apparatus.

Figure 2.

Deflections were monitored by 6 load deflection transducers. These were mounted on a freestanding support frame, shown in figure 3.

Figure 3.

Figure 4A.

Figure 4B.

Three were positioned at the same level as the load applicator and three were positioned near the bottom edge. These are shown in figures 4A and 4B.

The upper deflection transducers were horizontally positioned in the centre of the test piece span (transducer 2) and at the quarter points (transducers 1 and 3). The lower transducers were positioned near the centre of the span; two were 100 mm above the lower edge of the pane (transducers 4 and 5) with one at the centre of the bottom edge (transducer 6).

3 TEST SAMPLES

The test samples consisted of laminated glass fitted into the vertical rails at each end. The test samples are shown schematically in figure 5.

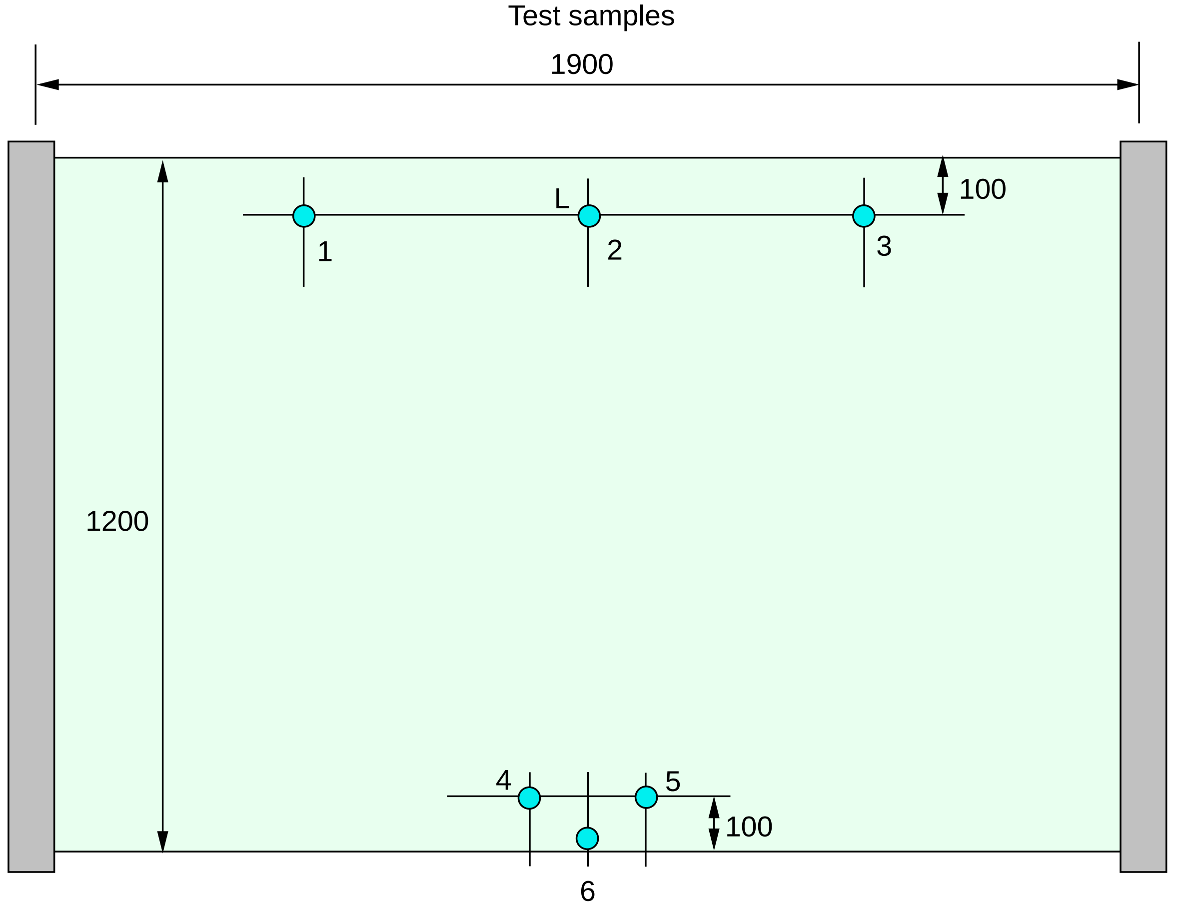


Figure 5.

Three types of glass were tested.

Type A: 13.5 mm laminated glass comprising two plies of 6 mm toughened glass with a 1.52 mm interlayer of standard PVB

Type B: 17.5 mm laminated glass comprising two plies of 8 mm toughened glass with a 1.52 mm interlayer of standard PVB

Type C: 21.5 mm laminated glass comprising two plies of 10 mm toughened glass with a 1.52 mm interlayer of standard PVB

The vertical fixing rails consisted of two component parts, an angle section attached to the structure and a cover plate. Figure 6 shows the angle section bolt fixed to the rigid post. Figure 7 shows a pane in position and the cover plate.

The glass pane is seated on a setting block system built-into the foot of the angle (figure 8).

Figure 6.

Figure 7.

Figure 8.

The cover plate is bolted to the angle section. Figure 9 shows how the pane is fitted into the rail.

Figure 9.

4 TEST SEQUENCE

4.1 Loads

The vertical Juliette barrier support rails are intended for use on domestic premises. From BS 6180, the relevant barrier loads are:

- a line load of 0.74kN/m applied 1100 mm above finished floor level,
- a concentrated load of 0.5 kN, applied over a 25 mm diameter area, anywhere on the barrier up to 1100 mm above finished floor level, and
- a uniformly distributed load of 1.0 kN/m^2 applied over the area of the barrier below 1100 mm above finished floor level.

For the concentrated load, the most onerous location is in the centre of the span at 1100 mm above finished floor level.

The test rig is designed to apply a point load. It is relatively simple to test for the point load of 0.5 kN. However, it is possible to assess the effect of the line load by using equivalent concentrated loads, as described in Annex B.

In terms of generating the same deflection as a line load of 0.74 kN/m applied over the 1.9 metre span, the concentrated load equivalent to it is 0.879 kN.

In terms of generating the same stress as a line load of 0.74 kN/m applied over the 1.9 metre span, the concentrated load equivalent to it is 0.703 kN.

The sample was therefore tested at loads of 0.5 kN, 0.703 kN and 0.879 kN. An overload factor of 1.5 was additionally applied to the stress, i.e. a final load of 1.055 kN.

Each target load was held for 5 minutes, to allow for the effects of creep in the interlayer. At the end of the test the load was removed and the residual deflections (if any) monitored for a further 5 minutes.

After the initial test sequence was completed, the potential maximum span, which would be possible within the deflection constraints, was estimated. An equivalent test load applicable to the 1.9 metre span, W_{PLmax}, was generated using the process given in Annex B.

A second test was then undertaken using W_{PLmax} as a the first target load and 1.5x this as the second target load, each held for 5 minutes. At the end of the test the load was removed and the residual deflections monitored for a further 5 minutes.

4.2 Test conditions

The tests were undertaken in a warehouse. The temperature was 15 ^{o}C.

5 TEST RESULTS

5.1 Pane type A

Figure 10 shows the sample in place with the deflection transducers in position.

The results for the basic test sequence are shown graphically in figure 11.

Table 1 gives the load and deflection values at various stages.

Figure 10.

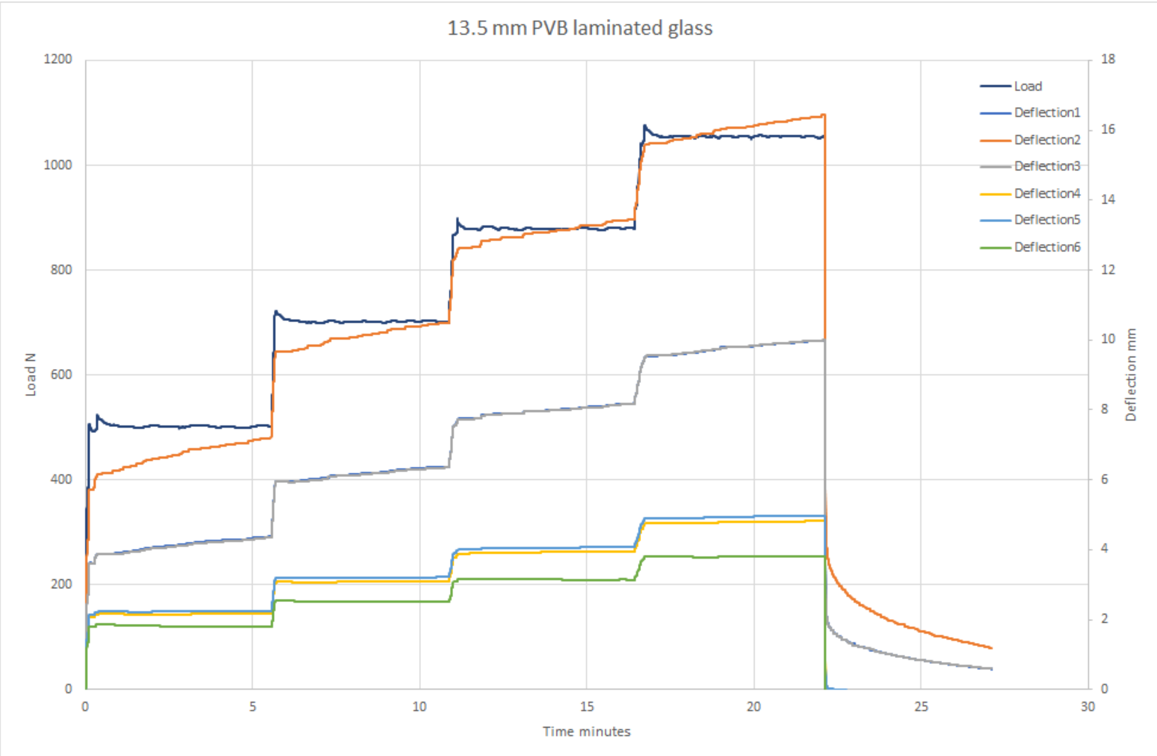


Figure 11.

Table 1. Loads and deflections for type A glass

Load N		Deflection mm after 5 minute dwell					
Target	Actual	1	2	3	4	5	6
500	502	4.4	7.2	4.3	2.2	2.3	1.8
703	702	6.4	10.5	6.3	3.1	3.2	2.5
879	880	8.2	13.4	8.2	4.0	4.1	3.1
1055	1056	10.0	16.4	10.0	4.8	5.0	3.8
0	0	0.6	1.2	0.6	-0.1	-0.1	-0.3

The maximum deflection at 0.879 kN load is 13.4 mm. For deflection limits, a maximum span would be 2.2 metres. The equivalent load for this (see Annex B) is 0.951 kN. The second test sequence was thus 0.951 kN followed by an overload of 1.427 kN, each held for 5 minutes, with the load taken off an residual deflections monitored for 5 minutes.

The results for the basic test sequence are shown graphically in figure 12.

Table 2 gives the load and deflection values at various stages.

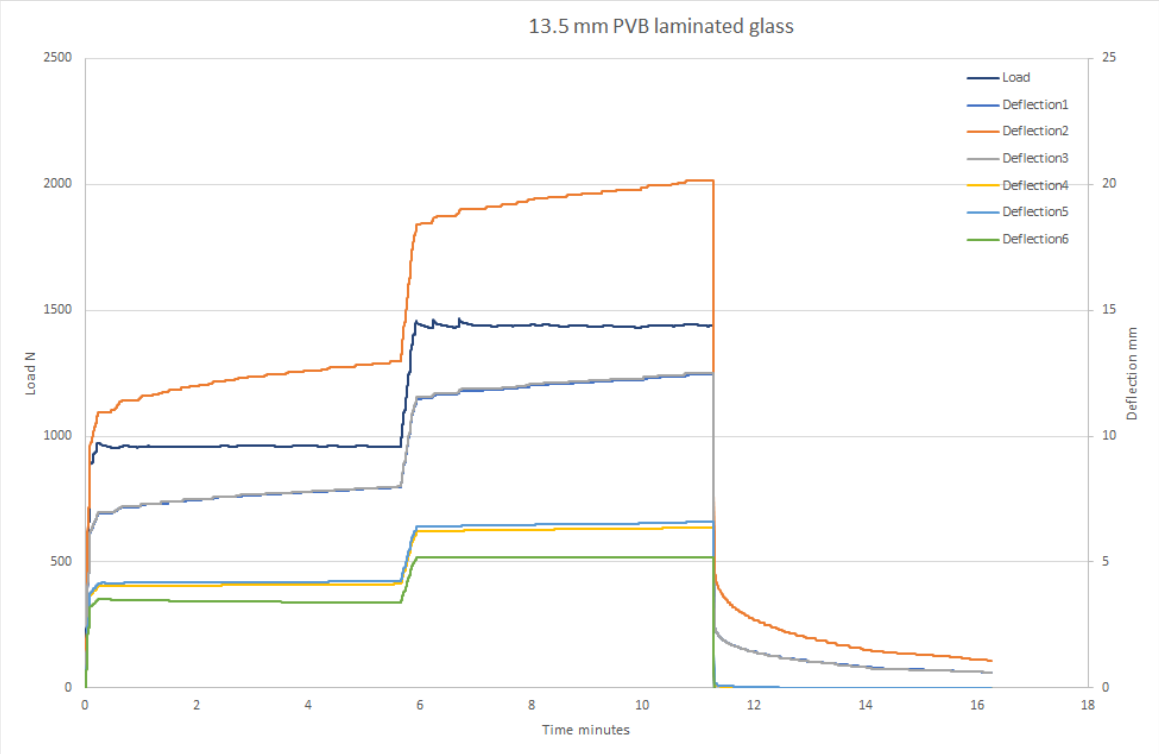


Figure 12.

Table 2. Loads and deflections for type A glass

Load N		Deflection mm after 5 minute dwell					
Target	Actual	1	2	3	4	5	6
951	960	7.9	12.9	7.9	4.1	4.2	3.4
1427	1443	12.4	20.2	12.5	6.4	6.6	5.2
0	0	0.6	1.1	0.6	0.0	0.0	-0.1

5.2 Pane type B

The results for the basic test sequence are shown graphically in figure 13.

Table 3 gives the load and deflection values at various stages.

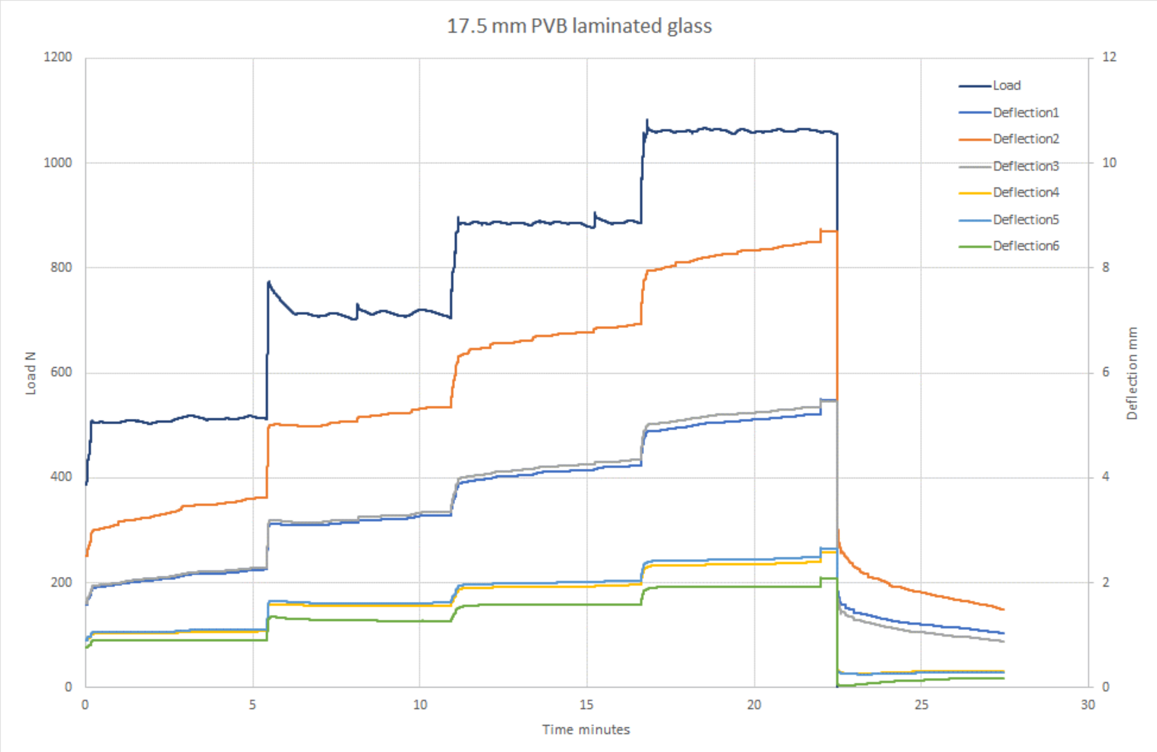


Figure 13.

Table 3. Loads and deflections for type B glass

Load N		Deflection mm after 5 minute dwell					
Target	Actual	1	2	3	4	5	6
500	514	2.2	3.6	2.3	1.1	1.1	0.9
703	715	3.3	5.3	3.4	1.6	1.6	1.3
879	888	4.2	6.9	4.3	2.0	2.0	1.6
1055	1063	5.2	8.5	5.4	2.4	2.5	1.9
0	0	1.0	1.5	0.9	0.3	0.3	0.2

The maximum deflection at 0.879 kN load is 6.9 mm. For deflection limits, a maximum span would be 2.6 metres. The equivalent load for this (see Annex B) is 1.325 kN. The second test sequence was thus 1.325 kN followed by an overload of 1.988 kN, each held for 5 minutes, with the load taken off an residual deflections monitored for 5 minutes.

The results for the basic test sequence are shown graphically in figure 14.

Table 4 gives the load and deflection values at various stages.

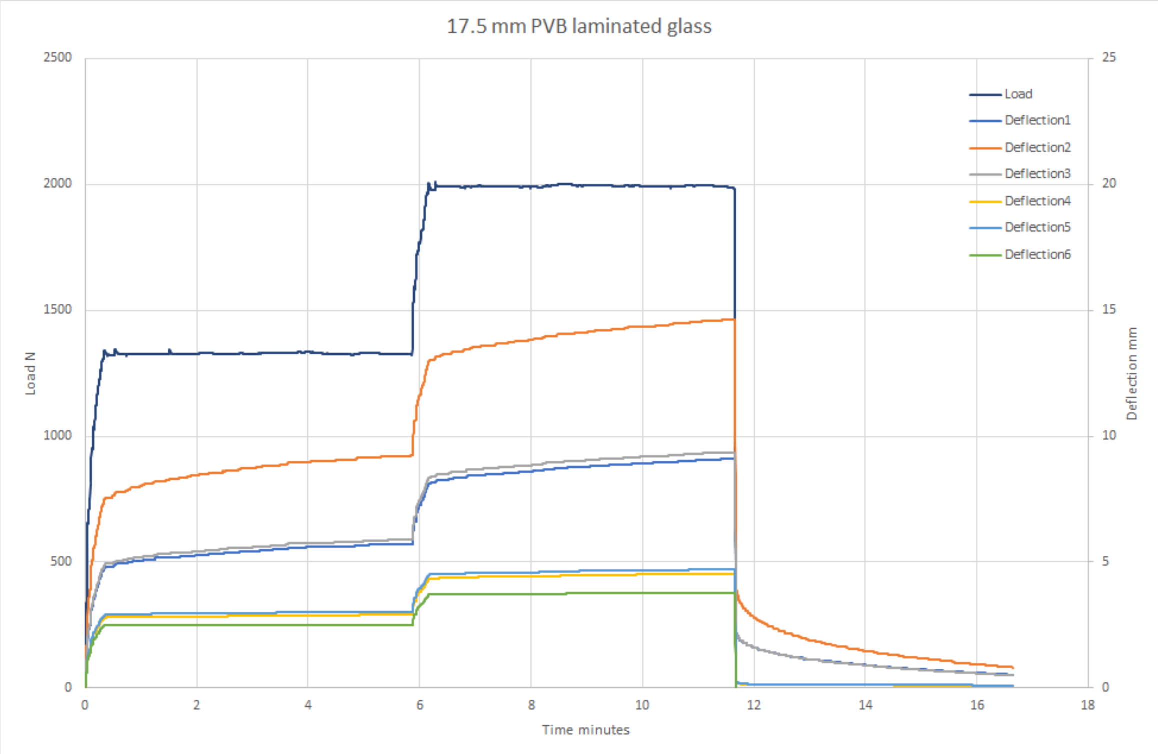


Figure 14.

Table 4. Loads and deflections for type B glass

Load N		Deflection mm after 5 minute dwell					
Target	Actual	1	2	3	4	5	6
1325	1328	5.7	9.2	5.9	2.9	3.0	2.5
1988	1995	9.1	14.6	9.3	4.5	4.7	3.8
0	0	0.5	0.8	0.5	0.1	0.1	0.0

5.3 Pane type C

The results for the basic test sequence are shown graphically in figure 15.

Table 5 gives the load and deflection values at various stages.

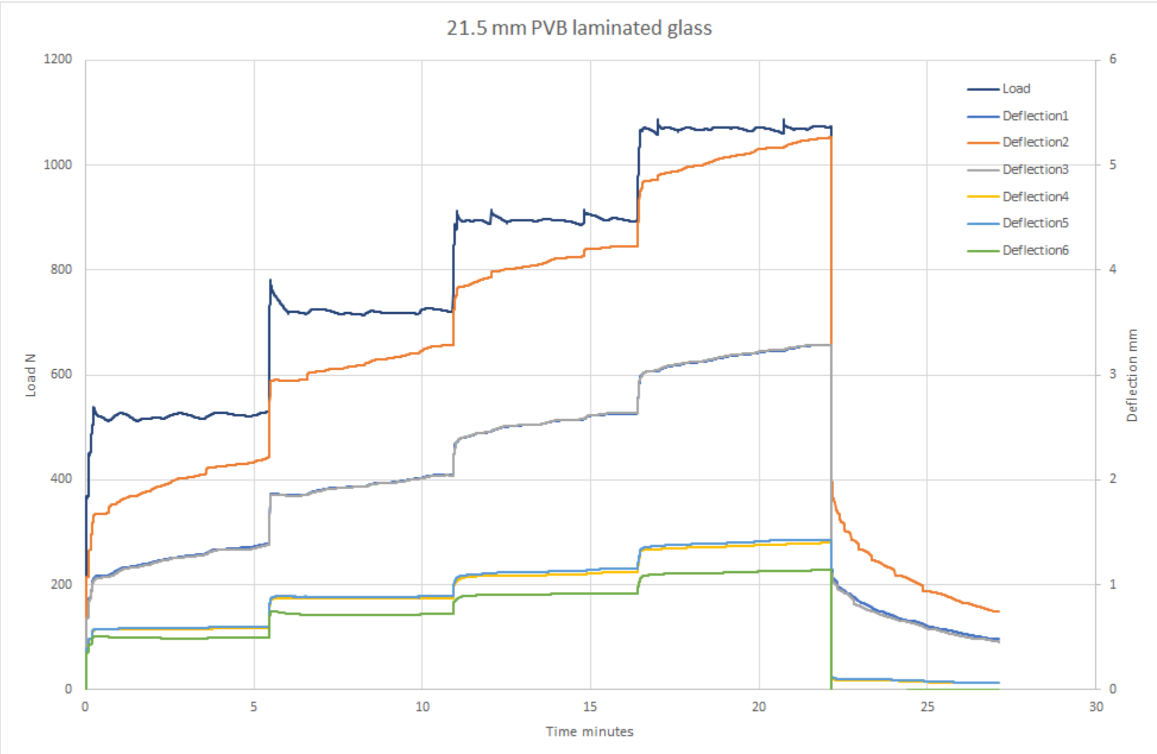


Figure 15.

Table 5. Loads and deflections for type C glass

Load N		Deflection mm after 5 minute dwell					
Target	Actual	1	2	3	4	5	6
500	527	1.4	2.2	1.4	0.6	0.6	0.5
703	725	2.1	3.3	2.0	0.9	0.9	0.7
879	896	2.6	4.2	2.6	1.1	1.2	0.9
1055	1063	3.3	5.2	3.3	1.4	1.4	1.1
0	0	0.5	0.7	0.5	0.1	0.1	0.0

The maximum deflection at 0.879 kN load is 4.2 mm. For deflection limits, a maximum span would be 2.9 metres. The equivalent load for this (see Annex B) is 1.64 kN. The second test sequence was thus 1.64 kN followed by an overload of 2.46 kN, each held for 5 minutes, with the load taken off an residual deflections monitored for 5 minutes.

The results for the basic test sequence are shown graphically in figure 16.

Table 6 gives the load and deflection values at various stages.

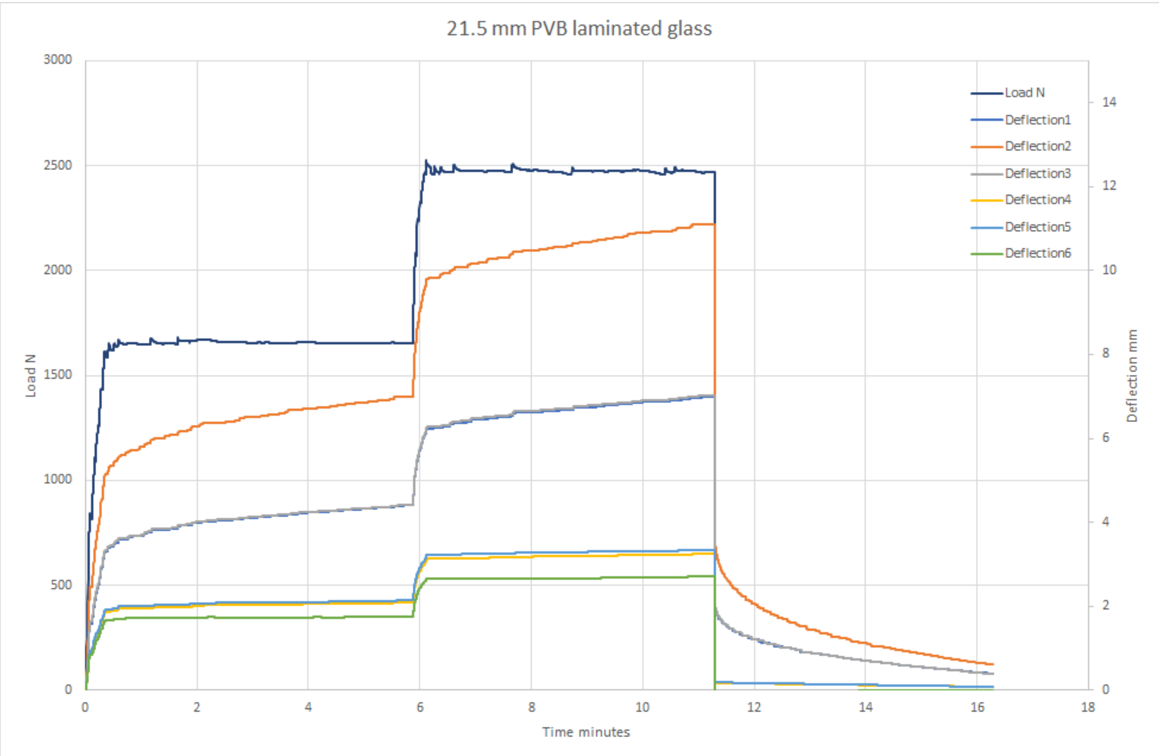


Figure 16.

Table 6. Loads and deflections for type C glass

Load N		Deflection mm after 5 minute dwell					
Target	Actual	1	2	3	4	5	6
1640	1657	4.4	6.9	4.4	2.1	2.1	1.7
2460	2472	7.0	11.1	7.0	3.3	3.4	2.7
0	0	0.4	0.6	0.4	0.1	0.1	0.0

5.4 Comments on the test results

The test samples performed satisfactorily. Despite the relatively low test temperature, all the samples showed some creep at constant load. The relaxation occurring after loads were removed indicates that this creep is reversible.

Figure 17 shows a plot of deflection against load for all three glass types. These plots are compared with theoretical deflections based on there being no creep in the interlayer.

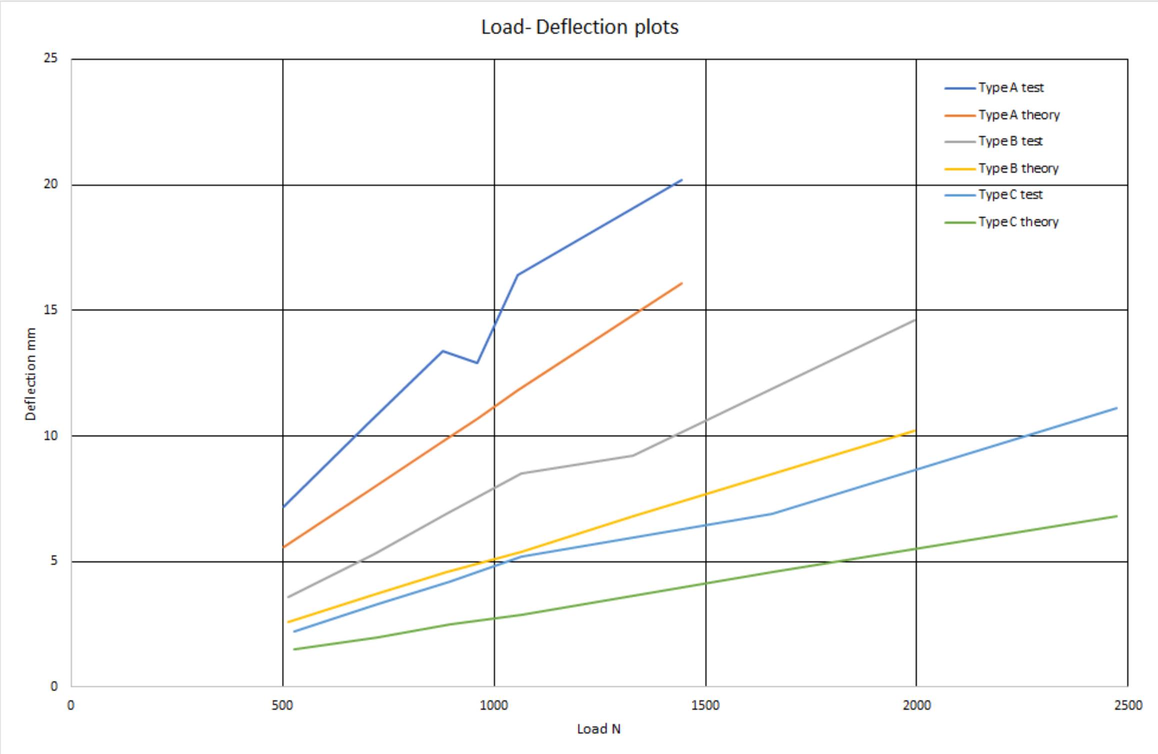


Figure 16.

For all cases, the actual deflection is significantly greater than the theoretical deflection, despite the relatively low test temperature, which would tend to stiffen up the interlayer.

For the purpose of estimating deflections in service, which may occur at much higher temperatures, the effective thickness of the glass should be considered to be much less than the actual thickness. A value of effective thickness which is currently used, for normal grade PVB, is 0.8x the sum of the glass thicknesses. It is recommended that this effective thickness is used to estimate potential deflections.

6 LIMITING SIZES

BS 6180 recommends that barriers without a handrail should be able to resist the barrier loads when broken. This is usually interpreted as meaning with one glass ply of the laminated glass broken.

For an 1100 mm high pane the maximum spans based on a single ply of toughened glass, with an allowable stress of 59 N/mm^2, are:
Type A, based on one ply of 6 mm glass, maximum span 1620 mm.
Type B, based on one ply of 8 mm glass, maximum span 2150 mm.
Type C, based on one ply of 10 mm glass, maximum span 2720 mm.

BS 6180 also recommends a maximum deflection of 25 mm at any point of the barrier.

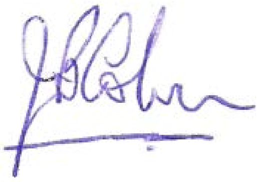
For an 1100 mm high pane the maximum spans, based on an intact pane with an effective thickness as indicated with a deflection limit of 25 mm, are:
Type A, based on 9.6 mm effective glass thickness, maximum span 1770 mm.
Type B, based on 12.8 mm effective glass thickness, maximum span 2200 mm.
Type C, based on 16 mm effective glass thickness, maximum span 2600 mm.

The maximum span is the lesser of the two above.

Juliette barriers are generally used externally, so they will also need to be able to resist the wind loads. Table 7 gives the Juliette barrier pane span limits based on the domestic external barrier loads and the maximum wind loads the panes can be expected to resist.

Table 7. Span limits and maximum wind loads for Juliette panes fixed using the vertical Juliette barrier support rails

Laminated glass type with normal grade PVB	Maximum span mm	Maximum wind load kN/m^2
13.5 mm (2 x 6 mm)	1620	1.43
17.5 mm (2 x 8 mm)	2150	1.45
21.5 mm (2 x 10 mm)	2600	1.60



John Colvin 12 June 2020

ANNEX A

Brief curriculum vitae for John Colvin

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Last updated December 2016

CURRICULUM VITAE

Name: John Bernard Colvin **Date of Birth**: 10/4/1948

Qualifications: B.A./M.A. (Maths) Cantab. (1969/1973)
Diploma of the Institute of Marketing (1983)

1969-1978 Pilkington Flat Glass Ltd., Technical Sales Laboratory. Senior technologist assessing the strength of glass, producing basic information for the mechanical design of glass. Developed mechanical design criteria for the use of glass subsequently incorporated into British Standards and developed the design methods for Pilkington Suspended Assemblies. Undertook the early (patented) experimental work leading to the development of the Pilkington PLANAR™ system.

1978-1986 Fibreglass (Pilkington) Reinforcements Ltd. Design engineer giving advice on the performance, properties, design and use of glass reinforced composites. During this period appeared in court as an expert witness for a Glass Reinforced Cement manufacturer in a successful claim against a leading UK engineering consultancy.

1986-1994 Pilkington Glass Consultants - Technical Services Manager. Ran the Technical Services Department, Technical Services Laboratory and Environmental Laboratory offering advice and test facilities for the performance, properties, design and use of glass in architecture and furniture. Further developed this activity to provide a commercial consultancy where the advice did not relate directly to Pilkington sales or product support. Represented Pilkington Glass Ltd. (through the Flat Glass Manufacturers Association) on British Standards committees concerned with glass properties, performance, design and use. Represented the British Standards Institute as the leading UK expert on European Standards committees concerned with glass strength and security glazing.

1994-1998 Pilkington Glass Consultants - Consultancy Services Manager. Ran the Consultancy Services offering advice on the performance, properties, design and use of glass in architecture and furniture and also the commercial consultancy service on glass and glazing. Responsible for the technical content of all Pilkington UK literature, including the 'Glass Book' released in 1995. Represented Pilkington Glass Ltd. (through the Flat Glass Manufacturers Association) on many British Standards committees concerned with glass properties, performance, design and use. Represented the British Standards Institute as the leading UK expert on European Standards committees and ISO committees concerned with basic glass, toughened glass, mirrors, glass strength (acting Chairman CEN/TC129/WG8), fire resistance, safety and security.

1998-2005 Technical Manager / Technical Director – Hansen Glass Processing. In charge of a small section and responsible for quality control, technical support, health & safety and training.

1998-date John Colvin Glass Consultant and **JCGC Limited**. Clients include Pilkington; Flat Glass for Europe (used to be GEPVP - a trade organisation which includes Pilkington, St. Gobain, Glaverbel and Luxguard); CAB (Confederation for Aluminium in Building); Arup Materials Consulting. During this period acted as an expert witness on Glass Reinforced Cement on behalf of Pilkington in their successful defence against litigation in France. Co-opted member of British Standards committees concerned with glass properties, performance, design and use. Represents the British Standards Institute as the leading UK expert on European Standards committees and ISO committees concerned with glass strength and security.

Standardisation Committee Involvement.
ISO/TC160/SC2/WG1 Glass Strength (ex-convenor);
ISO/TC160/SC2/WG7 Security Glass;
CEN/TC129/WG1 Basic Glass;
CEN/TC129/WG2 Toughened Glass;
CEN/TC129/WG5 Mirrors;
CEN/TC129/WG8 Glass Strength (convenor);
CEN/TC129/WG11 Fire Resistant Glass;
CEN/TC129/WG13 Safety Glass;
CEN/TC129/WG14 Bullet and Explosion Resistant Glass;
CEN/TC129/WG15 Anti-bandit Glass;
BSI B520 Glass in Building (covers all ISO, CEN and BSI glass standards);
BSI B520/4 (covers BS 6262, BS 6206, BS EN 1288, BS EN 12603, prEN 13474, BS EN 410, BS EN 673, BS EN 674, BS EN 675, BS EN 1098, BS EN 12898, prEN ISO 14438, BS EN 12758, BS EN 357, prEN 12488, prEN ISO 14439, BS EN 12600);
Chairman of BSI B520/5 (covers BS 5516).

Other activities
"Glass in Building"; edited Button & Pye - Wrote the chapters on glass strength, safety, security and load resistance.
"Structural use of glass in buildings"; ISE publication - Major contributor to the technical sections on glass strength and load resistance.
"Steel supported glazing systems"; SCI publication - Contributed the technical sections on glass strength.
"ICE manual of construction materials"; ICE publication - Wrote chapters 66, 67, 68, 70 and 71 in Section 9 "Glass".

ANNEX B

Equivalent concentrated loads

For a concentrated load applied, the deflection developed in a beam supported at each end is given by

$$y_W = \frac{1}{48}\frac{W_P L^3}{EI}$$

and the stress developed in the beam is given by

$$\sigma_W = \frac{1}{4}\frac{W_P L}{Z}$$

For a uniform line load applied, the deflection developed in a beam supported at each end is given by

$$y_w = \frac{5}{384}\frac{wL^4}{EI} = \frac{5}{384}\frac{W_L L^3}{EI}$$

and the stress developed in the beam is given by

$$\sigma_w = 0.125\frac{wL^2}{Z} = 0.125\frac{W_L L}{Z}$$

Basic equivalence concentrated loads to represent line loads

In terms of deflection, if $y_W = y_w$, then

$$\frac{1}{48}\frac{W_P L^3}{EI} = \frac{5}{384}\frac{W_L L^3}{EI}, \text{ i.e. } W_P = \frac{5}{8}W_L = \frac{5}{8}wL .$$

For a 0.74 kN/m line load over a 1.9 m span, in terms of deflection, the equivalent concentrated load is

$$W_P = \frac{5}{8}\times 0.74\times 1.9 = 0.879 \text{ kN}.$$

In terms of stress, if $\sigma_W = \sigma_w$, then

$$\frac{1}{4}\frac{W_P L}{Z} = \frac{1}{8}\frac{W_L L}{Z}, \text{ i.e. } W_P = 0.5W_L = 0.5wL .$$

For a 0.74 kN/m line load over a 1.9 m span, in terms of deflection, the equivalent concentrated load is

$$W_P = 0.5\times 0.74\times 1.9 = 0.703 \text{ kN}.$$

Equivalences of length

The most onerous load case for wider panes is the deflection generated by the line load. If the maximum recorded deflection is less than 25 mm, then the maximum span possible for the Juliette barrier can be estimated from:

$$L_{\max} = L\sqrt[4]{\frac{25}{y_w}}$$

The total line load for this span of pane would then be $W_{L\max} = 0.74 L_{\max}$. This would create a bending moment of

$$M_{L\max} = \frac{W_{L\max} L_{L\max}}{8}$$

The same bending moment can be achieved on the test span, L_T, by applying a concentrated load of

$$W_{PL\max} = \frac{4M_{L\max}}{L_{\max}} = \frac{W_{L\max}}{2}$$