University of Ljubljana
Faculty of Mechanical Engineering

University of Ljubljana
Faculty of Mathematics and Physics

Experimental verification of glass panes deflections

Partners: **University of Ljubljana, Faculty of Mechanical Engineering**
Laboratory for Numerical Modelling and Simulation
Center for Experimental Mechanics
Laboratory for Sustainable Technologies in Buildings
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Slovenian National Building and Civil Engineering Institute
University of Ljubljana, Faculty of Mathematics and Physics

No. of ARRS project: L2-3172

ARRS project title: Development of technical guidelines for quadruple glazing

Assoc. Prof. Miroslav Halilovič
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1. Problem description

To verify the numerical model of glass insulating panels subjected to pressure and temperature changes, we must measure the displacements of a real-life panel and compare them with the simulated ones. We manufactured two types of panel samples to verify different constructions of the insulating panels. An asymmetric and a symmetric one as shown in Fig. 1.

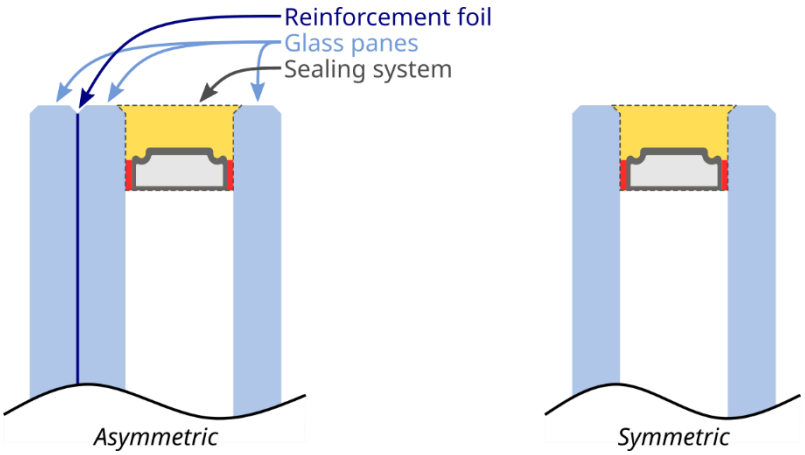

Figure 1: Assembly of the asymmetric and symmetric samples.

Additionally, each type of panel sample was manufactured in different panel configurations as summarized in Table 1. The dimensions of the panel samples range from 350×500 mm up to 2×2 m. The panel samples are constructed in three different panel assemblies: 12.12.2+18m+3, 12.12.2+16f+3 and 3+18m+3. The acronyms represent:

- *12.12.2* – glass pane assembled from two 12 mm glass panes laminated together with a reinforcement foil,
- *3* – 3 mm glass pane,
- *18m* – metal spacer 18 mm high,
- *16f* – foam spacer 16 mm high.

Table 1: Measured configurations of the glass insulation panels.

ID	Panel type	Panel assembly	Panel width (mm)	Panel height (mm)
A	asymmetric	*12.12.2+18m+3*	2000	2000
B	asymmetric	*12.12.2+18m+3*	1000	1000
C	asymmetric	*12.12.2+16f+3*	1000	1000
D	symmetric	*3+18m+3*	1000	1000
E	asymmetric	*12.12.2+18m+3*	350	500
F	asymmetric	*12.12.2+16f+3*	350	500
G	symmetric	*3+18m+3*	350	500

2. Measurement setup

To prepare the samples for measurements, we mount a special tube through the spacer (see Fig. 2) which enabled us to pressurize the panel chamber. For the pressurization we used a custom-made pressure control and measurement unit, shown in Fig. 2. The unit enabled us to precisely regulate and real-time measure the air pressure up to 250 mbar. The samples were supported in a special frame with wedge-type contact blocks. The location of the supports depended on the panel type as shown in Fig. 2. For the asymmetric panel, we fixed the thick and stiff laminated glass pane which exhibits almost no deflection. On the other hand, the symmetric panel was fixed in the middle to preserve a symmetric panel response.

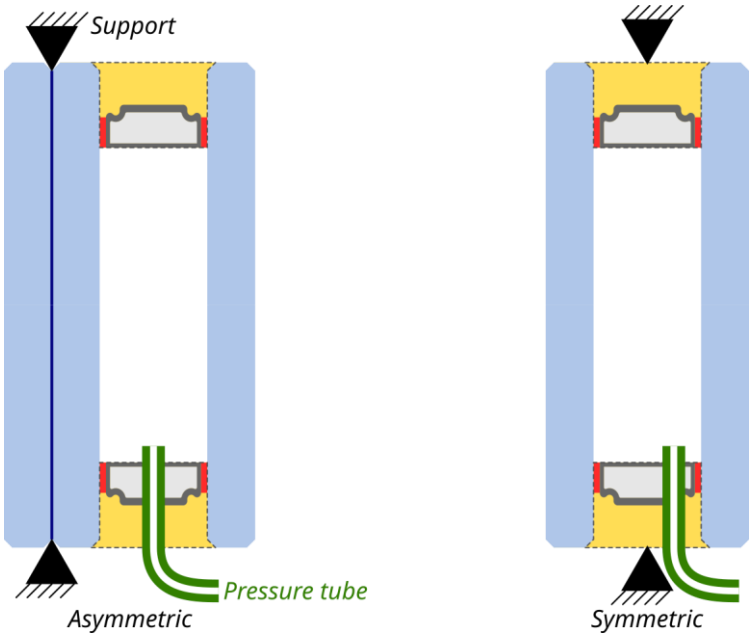

Figure 2: Support of asymmetric and symmetric samples.

Figure 3: Measurement setup – pressure control and measurement unit.

The measurement setup for measuring glass pane displacements is shown in Fig. 4 for the largest samples 2 x 2 m and in Fig. 5 for the smallest samples 350×500 mm. It is based on the Dantec Dynamics Q-400 measurement system which employs four 5 MPx digital cameras, which observe a spackle pattern (random dots) on the glass pane. Using the digital image correlation (DIC) procedure it can calculate the glass pane's displacements and shape from the acquired images of the speckle pattern. The pattern itself was printed on a self-adhesive PVC foil and then glued in the upper-left quadrant of the glass pane as shown in the Figures.

Figure 4: Measurement setup – measurement of displacements of the largest samples. Cameras are circled in red.

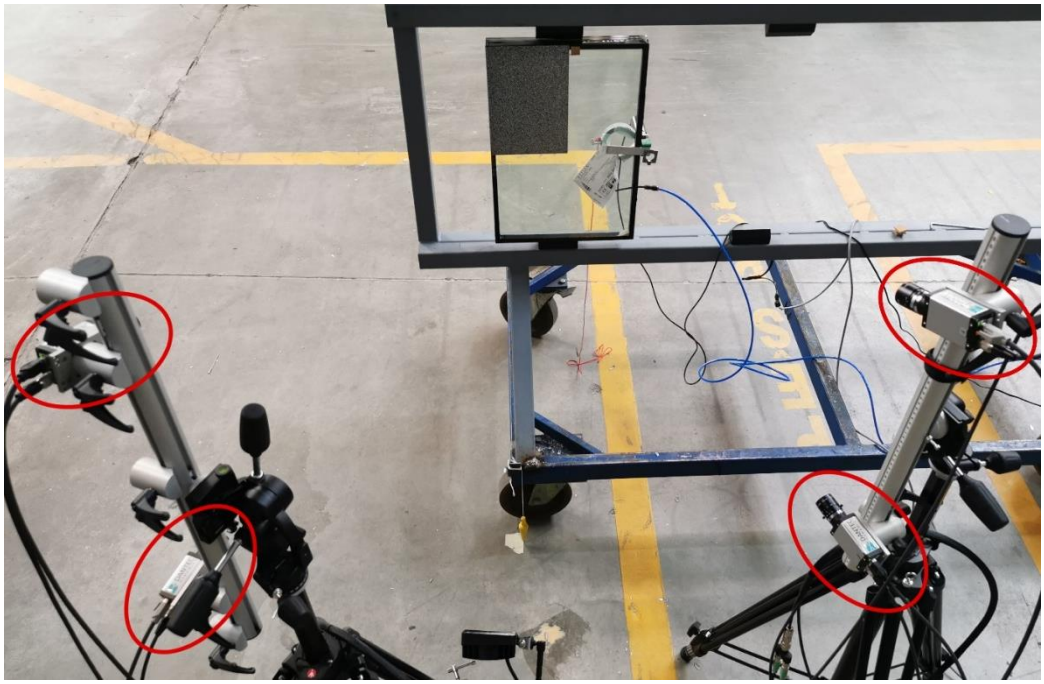

Figure 5: Measurement setup – measurement of displacements of the smallest samples. Cameras are circled in red.

3. Results

The DIC measurement system measured the displacements of approximately 14 000 points on the quarter of the glass pane surface. The measured displacement fields of all measured samples are shown in Figs. 7 – 13. The displacements for all samples are shown at maximum pressure (panel burst or the measurement was stopped by the operator), except for sample D (symmetric, 1×1 m). This sample greatly changed its shape around 15 mbar, mimicking a buckling behavior. The displacements are therefore shown at 10 mbar, where the displacements were still symmetric across the sample's diagonal. The center (maximum) displacement of the glass pane as a function of the pressure inside the panel chamber for sample A is shown in Fig. 6, where a strong nonlinear response is observed.

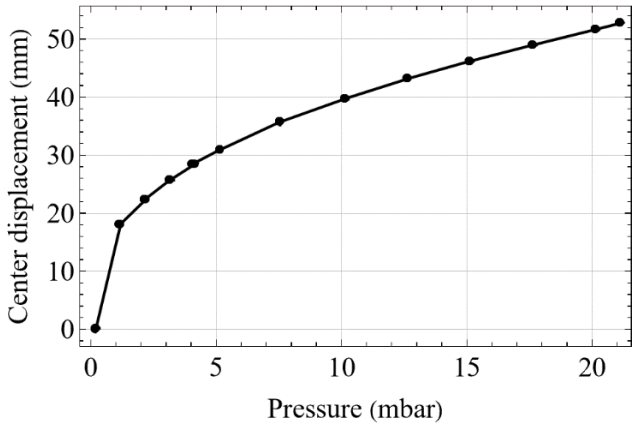

Figure 6: Center (maximum) displacement as a function of the pressure of sample A.

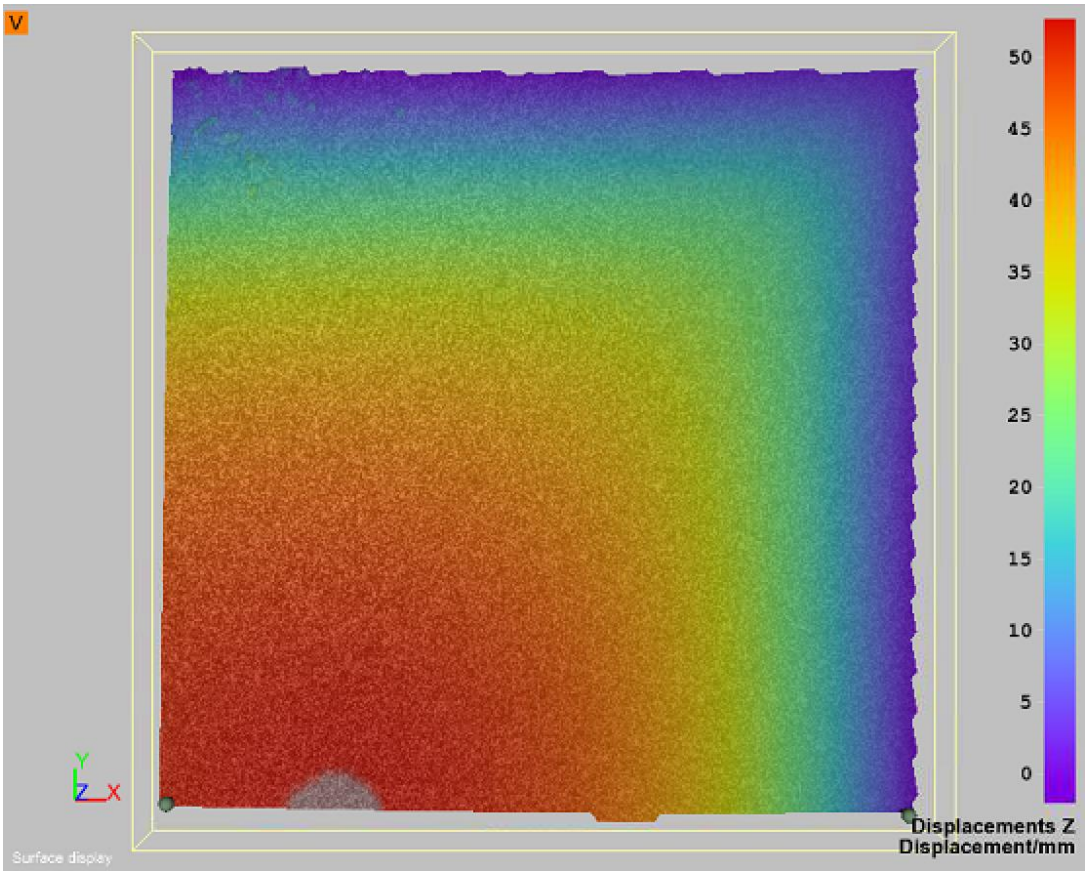

Figure 7: Displacement of sample A at 20 mbar pressure.

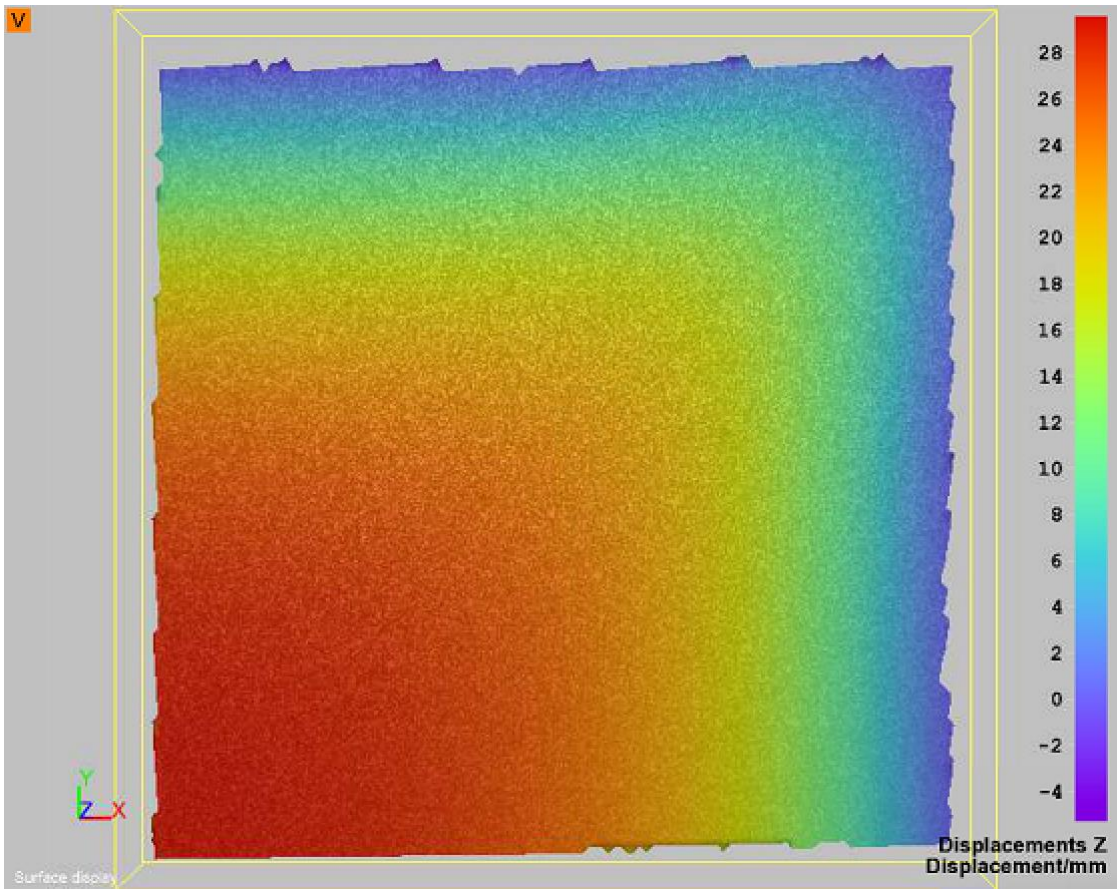

Figure 8: Displacement of sample B at 100 mbar pressure.

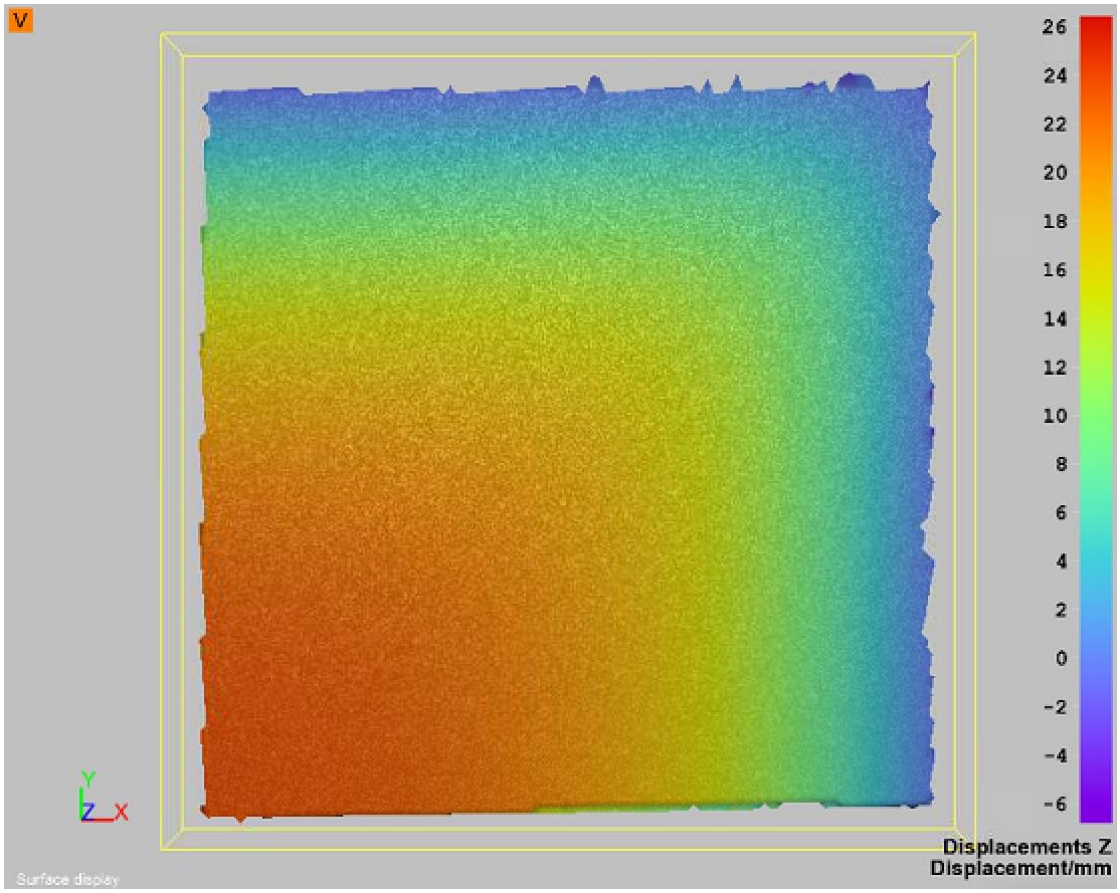

Figure 9: Displacement of sample C at 75 mbar pressure.

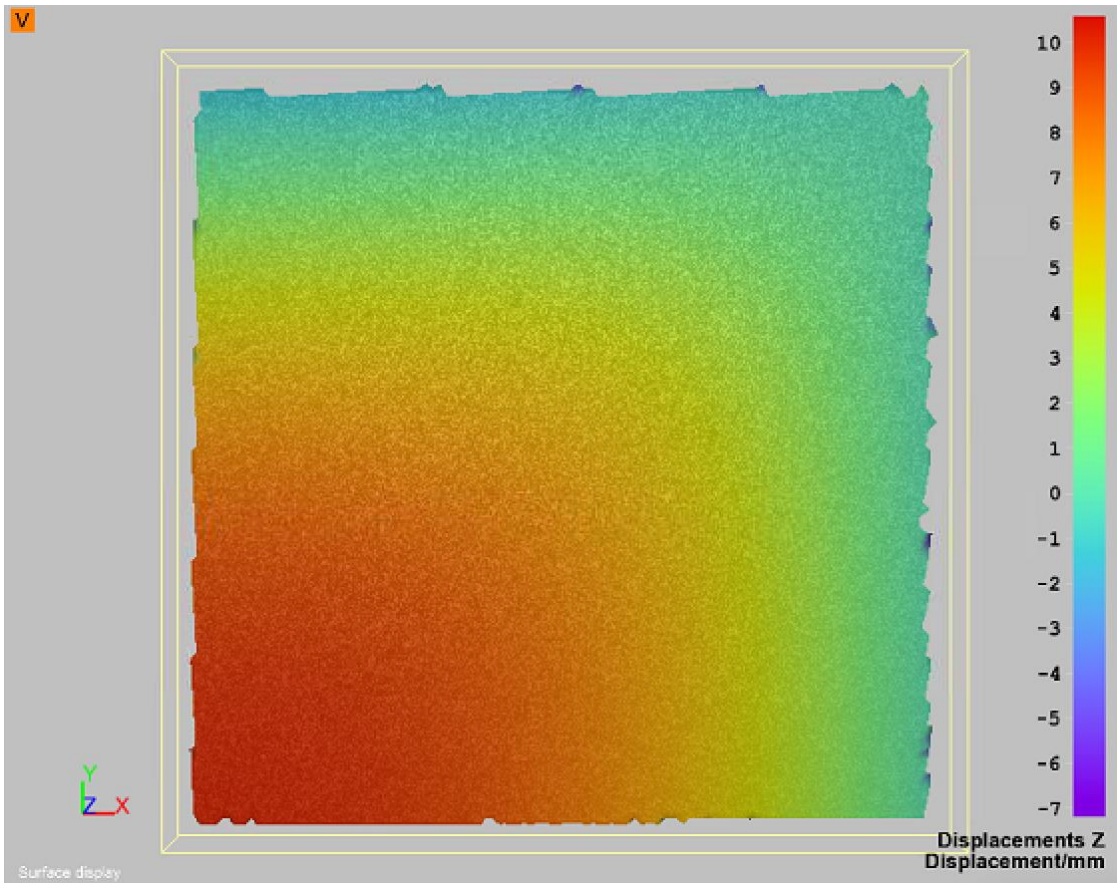

Figure 10: Displacement of sample D at 10 mbar pressure.

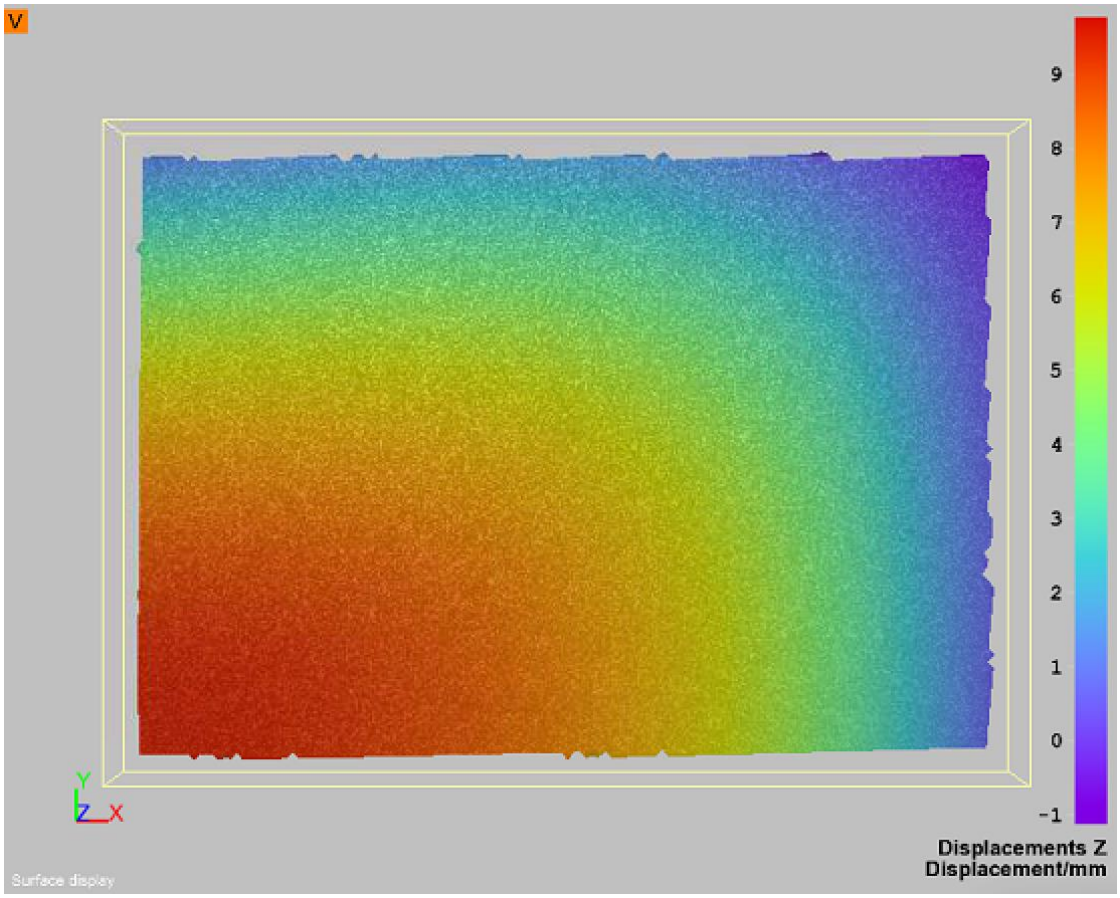

Figure 11: Displacement of sample E at 250 mbar pressure.

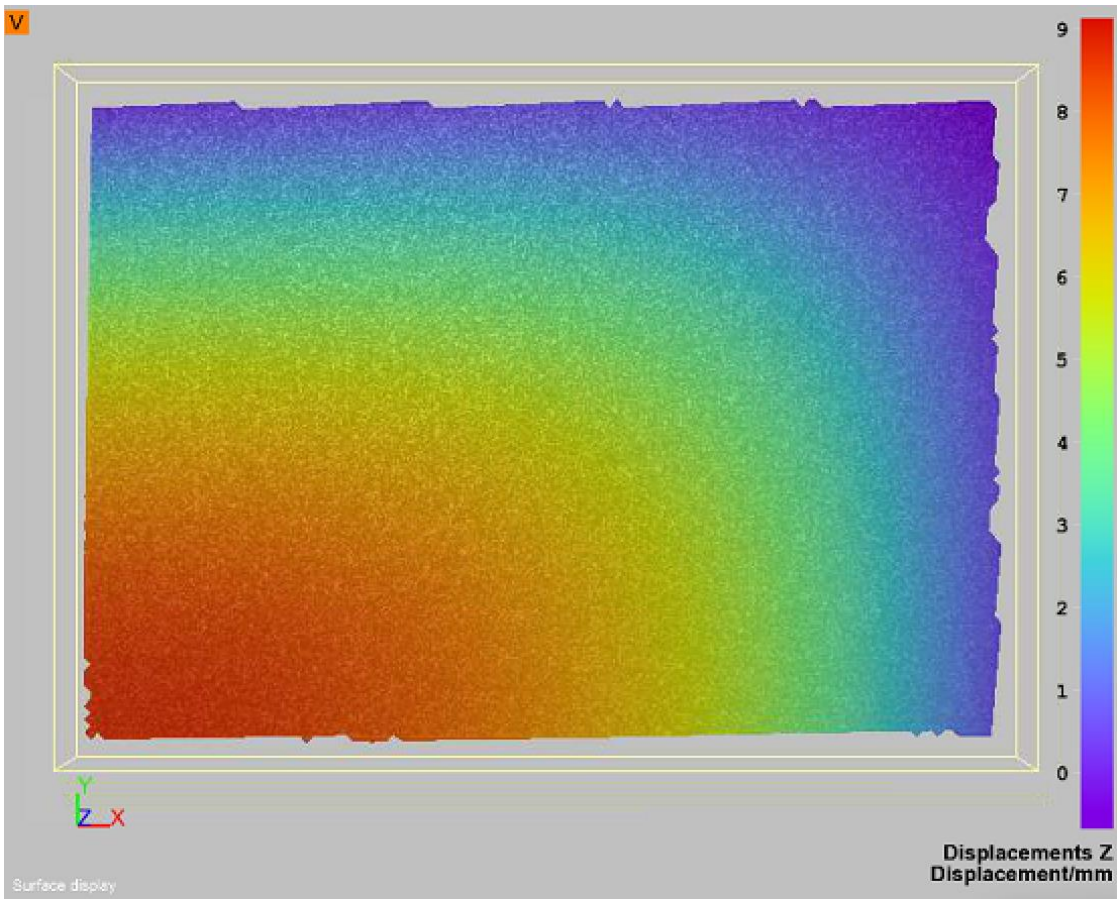

Figure 12: Displacement of sample F at 250 mbar pressure.

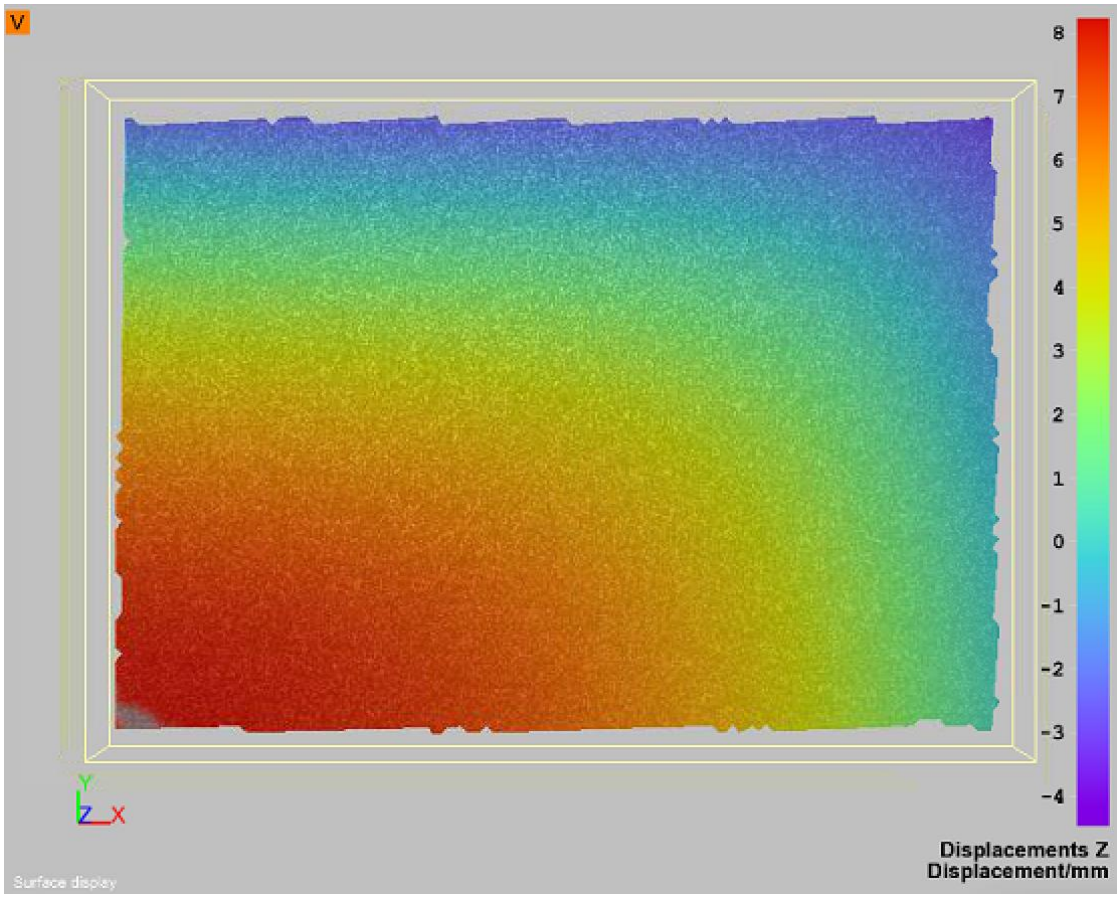

Figure 13: Displacement of the sample G at 250 mbar pressure.

4. Summary

We measured the displacement fields of glass panes while being subjected to the increased pressure inside the panel chamber. The panels were manufactured in 7 different configurations as summarized in Table 1. All samples were measured using a DIC measurement setup, resulting in full-field measured displacements. For each sample, we measured over 10 000 points on the quarter of the specimen. The measured displacement fields for all samples are shown in Figures 7 – 13 and will be further used for comparison with numerical model results.