Issue 2021/2

Utilization of the economic potential of “cold-bent” glass by investigating its load-bearing behavior and load-bearing ca-pacity as mono-, laminated and insulating glazing as well as the constrained load on the steel substructure AiF No.: 20191N

Summary of the research project AiF No.: 20191N

When glass panes are cold-bent, they are forced into a substructure to approximate a curved shape. The design of these cold-bent panes is not yet regulated by standards at either national or European level. However, due to the increasing demand for efficient design of curved glass facades and the resulting transparency, the cold bending method is being used more and more frequently in prestige projects and impresses thanks to key features such as energy efficiency and the higher strength of the panes used, compared to traditional methods such as press bending.

There are no rules for dimensioning the panes. For each individual construction project, procedures for determining the stresses acting and calculating the resulting deformations must be established in complex approval procedures. There is no coherent design concept that can be incorporated into the existing standardization documents and that would replace these approvals. In addition to the actions to be determined, considerations regarding strength have not yet been specifically addressed for the method. After larger experimental studies on point-bearing discs, there was still a lack of knowledge regarding other common bearing types, such as line-bearing applications. An accurate representation of the stress and deformation quantities for these applications has not yet been achieved. Furthermore, the transfer of the cold bending principles applicable to monolithic panes to other glass products, such as laminated and insulating glass, which is essential for increasing the use of this method, has not been scientifically proven.

The aim of the research was therefore to first examine the behavior of monoglass during cold bending in previously uninves-tigated boundary conditions in order to subsequently derive design principles for the cold bending of glass panes. The most common storage method used in the construction industry is linear storage. In order to enable a comparison with point-supported glazing, a test bench was developed that allows the glass to be bent while maintaining the straightness of the edges. With this test bench, the entire process of cold bending and the resulting shape finding could be investigated. A wide range of tests was carried out, covering different glass types, glass thicknesses and dimensions. This made it possible to characterize the cold bending of glass panes using various relevant parameters. In the process, crucial insights were gained into the shape formation of the glass panes as a function of pre-improvement, force-deformation relationships and the stress state introduced by cold bending. These tests were subsequently reproduced by finite element calculations, which provided a deeper insight into the failure-inducing stresses and the processes inside the pane during cold bending. The findings from monolithic panes were subsequently transferred to other glass finishing products. First, laminated glass panes with different thicknesses and film types were investigated in order to derive the influence of the effective shear bond on the findings already obtained from monolithic glass. These experiments were also reproduced numerically and extended by a time-dependent component. By modeling the viscoelastic properties of the interlayers, it has become possible to make statements about the longterm behavior of cold-bent laminated glass. Relevant limit states of the composite effect known from structural glass construction could be assigned to the different sections of the cold bending. The influence of cold bending on the residual load-bearing capacity of the laminated glass was investigated as a function of the magnitude of the cold bending and, together with the fracture patterns obtained during the static tests, led to a recommendation for the type of glass to be used.

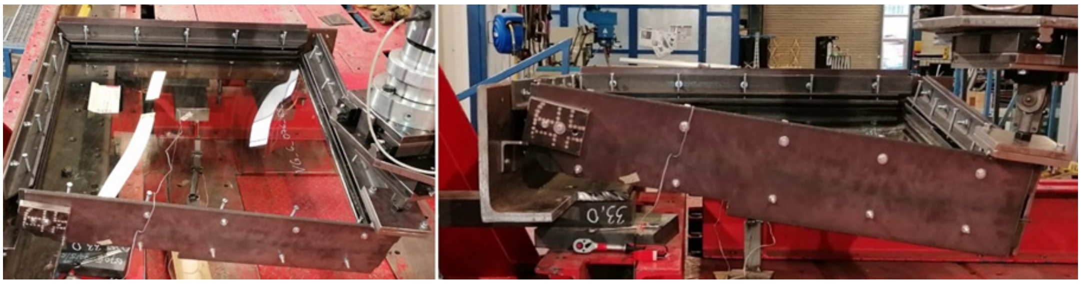

Image 1: Test bench for cold bending of square panes.

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Subsequently, insulating glass panes were also cold-bent. Specifically, the relative displacement of the two glass panes to each other was observed. The insulating glass panes examined had two different commercially available edge seal systems, which were also varied in their dimensions. Based on these investigations, the influence of the edge seal systems on the behavior of the panes during cold bending could be determined. Again, the behavior of the monolithic glasses could be transferred to the finishing products. Numerical simulations of the insulating glasses examined revealed that the relative displacement of the panes to each other influences the pressure acting in the space between the panes. This additional load case was previously unknown, but can play a decisive role in certain formats.

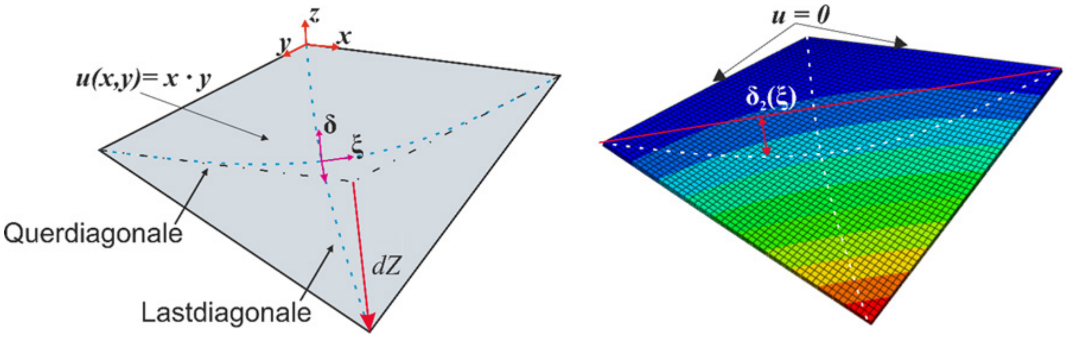

Image 1: Deformation figure and numerical approximation.

In summary, a design concept with proposals for limit state considerations according to the currently valid European standardization concept for the individual glass products was developed. This concept is supported by assistance for the precise numerical modeling of cold-bent applications. This created a basis for bringing the cold bending method into the standardization discourse and opening it up to a wider range of users through future regulations.

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