

Forschungsvorhaben: Quantifizierung der Resttragfähigkeit von Verbundglas

REST-VSG: Rechnerische und Experimentelle Studien zur Ermittlung der Resttragfähigkeit von VSG

English:

At present, neither DIN EN 14449 nor DIN EN 12600 provide a possibility to classify laminated safety glass (LSG) in terms of adhesion and residual load-bearing behavior. The aim of this research project was therefore to find proposals for a normative regulation. The test concept comprises four different tests: "Pummel" test and "Adhesive-Shear test" to characterize the adhesion, "Trough-Cracked-Bending (TCB)" test to characterize the residual load-bearing capacity under static influence, modified pendulum impact test, to characterize the residual load-bearing capacity under dynamic influence. The tests were first performed on laminated safety glass with polyvinyl butyral (PVB)-based interlayers and in a next step on laminated safety glass with interlayers of ionoplast (Sentry glass) and ethylene vinyl acetate (EVA). In the pummel test, both the performance and the evaluation were considered. To develop a uniform pummel scale, reference images from various film manufacturers were used. These were subjected to various automated image evaluation methods, whereby texture analysis using Gray-Level Co-Occurrence Matrices (GLCM) and subsequent consideration of the texture characteristics "contrast", "correlation" and "homogeneity" proved to be effective in creating a new pummel scale. Knowledge of the image scale (number of pixels/cm) is crucial for successful texture analysis. During the execution of the pummel test it was found that due to insufficient pummeling, too large fragments stuck to the film, which led to an underestimation of the pummel value in the automated evaluation procedure. It is therefore essential to ensure that the glass surface to be examined is completely pulverized. The storage temperatures must be adapted to the glass transition temperatures of the intermediate layers. In addition, it is recommended to limit the pummel tests to small samples with a glass thickness of maximum 3 mm. 1,100 mm x 360 mm laminated glass test samples were used for the TCB tests. A modified four-point bending test setup was designed as a test setup in which the laminated glass is pulled upwards to eliminate influences from its own weight. The maximum deflection as a function of time, the true stress and strain in the film and the size of the delaminated area were evaluated. The results were compared for the different input parameters: glass thickness, adhesion of the interlayer, crack initiation, load level and test temperature. However, due to large scattering of the test results on standard PVB, which makes reproducibility impossible, the TCB test can only be used to classify films in the higher stiffness range. The coincident crack must be examined. In addition to the TCB tests, residual load capacity tests under dynamic influence were carried out. A modified pendulum impact test according to DIN EN 12600 was designed as a test setup, in which the laminated glass was pre-damaged by a bore hole before "pendulum". The test showed a good reproducibility of the fracture patterns, which allows a differentiation of the foils with regard to the residual load bearing capacity. The results of the pummel, TCB and adhesive shear tests were checked for correlation. It was found that only a partial correlation between the pummel value and the size of the delaminated area after the TCB test exists. A correlation between the degree of adhesion and the residual load-bearing behaviour could not be established. This is partly due to the fact that both a high and a low degree of adhesion can have both positive and negative effects on specific parameters of the residual load-bearing behavior. The originally planned two-stage test concept was therefore replaced by a separate analysis of the residual load-bearing behavior and the adhesion.