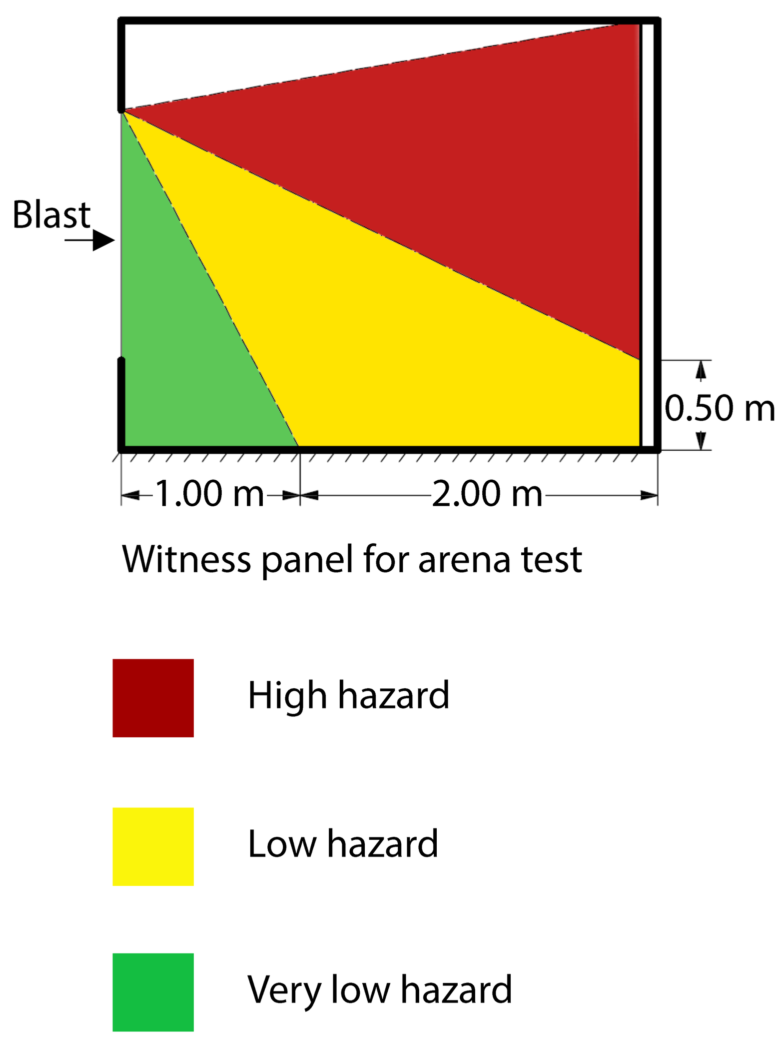
HCU HafenCity Universität Hamburg

# GLASS STRENGTH FOR HIGH STRAIN RATES

## MOTIVATION

*Facade of Brussels airport after the terror attack on 22.03.2016 [nzz.ch].*

Main target in building and facade design is to protect people inside the building and to reduce damages in the facade and main structure to minimize the risk of building collapse. Investigations of bomb blast attacks show that the large part of fatal casualities were caused by glass splinters of the broken windows acting as shrapnel. Therefore, the glazing system is an important issue within the design of blast enhanced facades. It is required that the glass panels remain in the facade frames during a bomb blast event and that hazard criteria are fulfilled if specified. E.g. ISO 16933 specifies hazard criteria for windows for arena tests.




*Hazard criteria for windows according to ISO 16933.*

## GLASS STRENGTH

Aim of the research project is to determine short time design values for glass surface strength of glass products used for windows and facades that are required for impact or blast loading. Beside other aspects load duration and tempering level influence the glass surface strength. Microscopic surface flaws can grow under permanent load, e.g. dead load until glass fracture occurs with delay. Therefore every glass code offers surface strength design values for untempered glass products depending on the load duration. The shorter the load duration, the higher the design surface strength. Usually long term (dead load), mid term (snow) and short term loading (wind) is distinguished. The German glass standard DIN 18008 considers the load duration by $k_{mod}$ factors, which are based on fracture mechanical model. For long term load duration the fracture mechanical model can be verified by long term tests.

Due to high complexity of such tests for short load duration, occuring during impact or bomb blast events, there is only limited test data available to confirm the theoretical fracture mechanical model. The available test data results from complex pendulum or shocktube tests, but this data is not sufficient for a solid statistical determination of characteristic fractile values (5 % fractile, 95 % quantile).

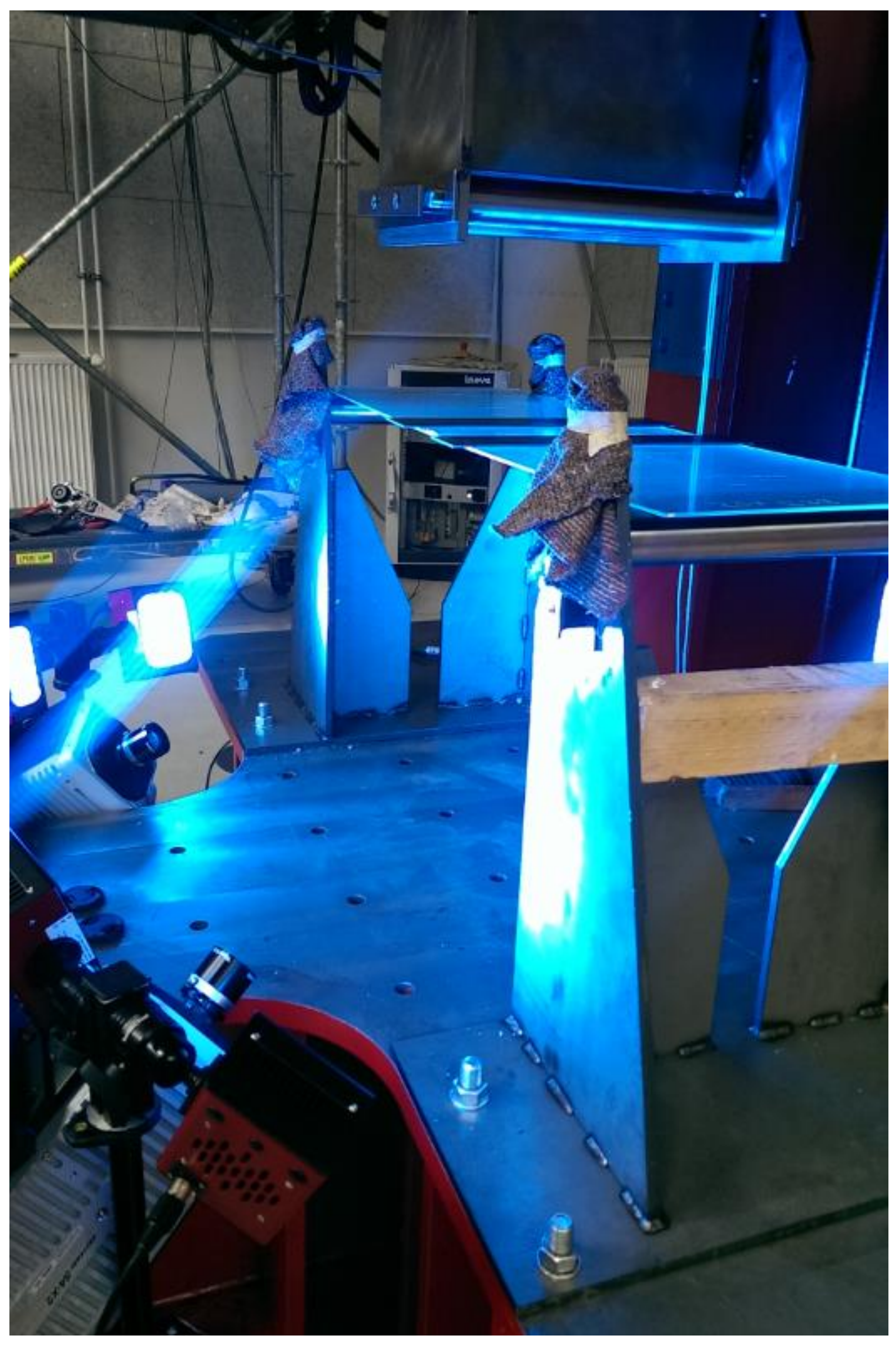
Therefore there is a lack in the verification of the theoretical fracture mechanical model, especially in terms of high strain rates.

## METHODS

200 glass specimen with the dimensions 1100 mm x 360 mm are tested by four point bending test. The tests are run with standardized strain rate (2,9E-05 $s^{-1}$) as well as with high strain rate (2,3E-02 $s^{-1}$) on the same testing machine in order to investigate strain rate behaviour of glass surface strength.

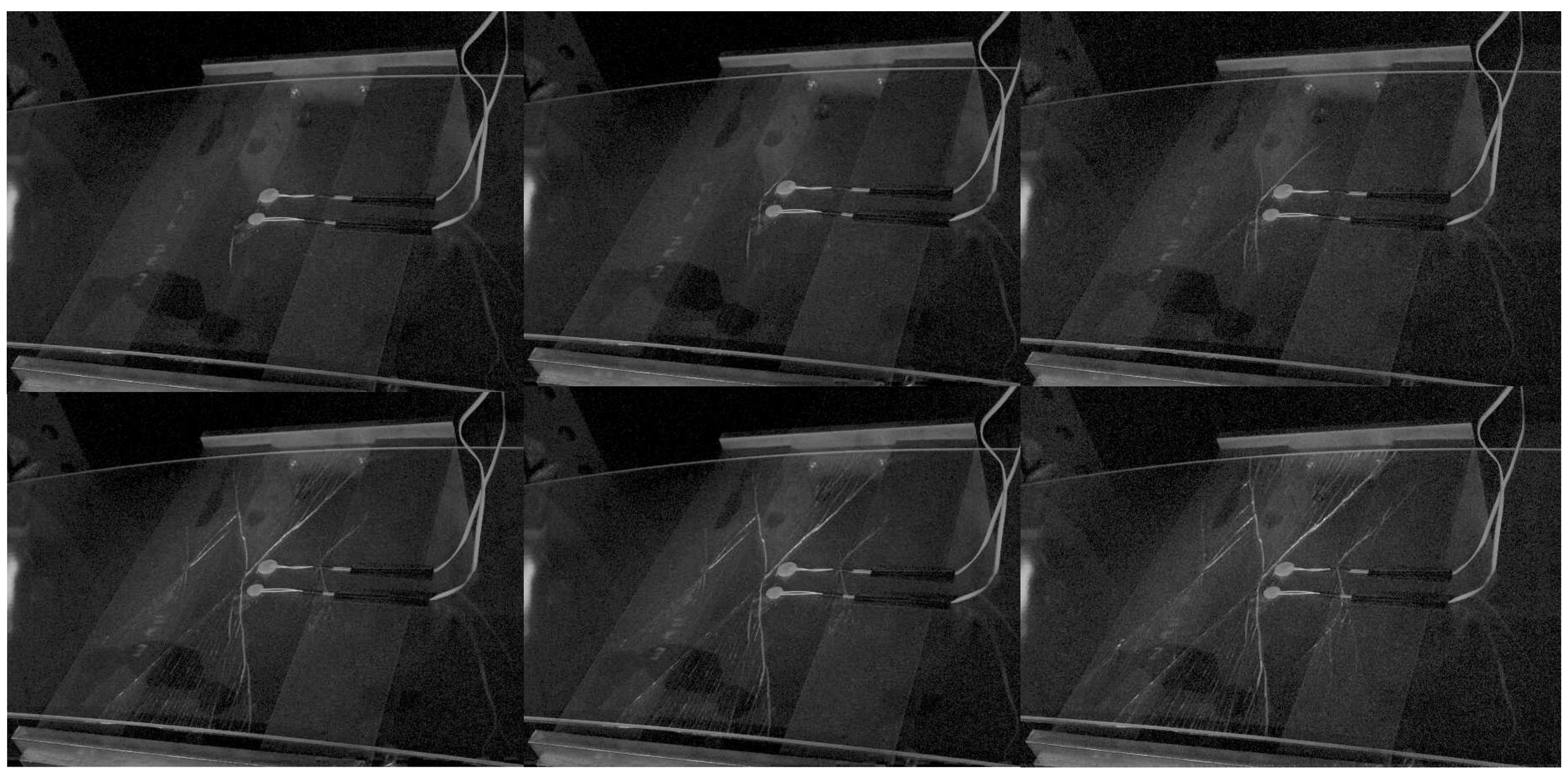
All common glass types in building sector; untempered glass (Float), heatstrengthened glass (HST), and fully tempered glass (FT) are subjected for testing.

In order to achieve a predamage of the glass surface comparable to long term site conditions and to reduce the variation of the test results, the glass specimen are treated with corundum. Another positive effect of such predamage treatment is, that the initial crack of the specimen is avoided to start from the edge.



*Four-point-bending-test setup in highspeed testing machine.*

The highspeed tests are performed up to surface stress rates of 2000 $Nmm^{-2}s^{-1}$, which are typical for impact or bomb blast events. The surface strains during testing are investigated by strain gauges and highspeed measurement amplifier. In addition highspeed cameras are used to monitor the location of initial crack.



*Untempered float glass specimen in breackage phase during highspeed test monitored with high speed camera in 30.000 fps mode.*


Project Manager: Dipl.-Ing. Matthias Förch
matthias.foerch@hcu-hamburg.de
Project Partner: Fachverband Konstruktiver Glasbau e.V.
Funding: Project Partner

Professorship: Prof. Dr.-Ing. Frank Wellershoff
Facade Systems and Building Envelopes
frank.wellershoff@hcu-hamburg.de
HafenCity University Hamburg
Überseeallee 16
20457 Hamburg