Durability by Design
Load Carrying Silicone Bonding
Herz Jesu Church, Munich

Anneliese Hagl

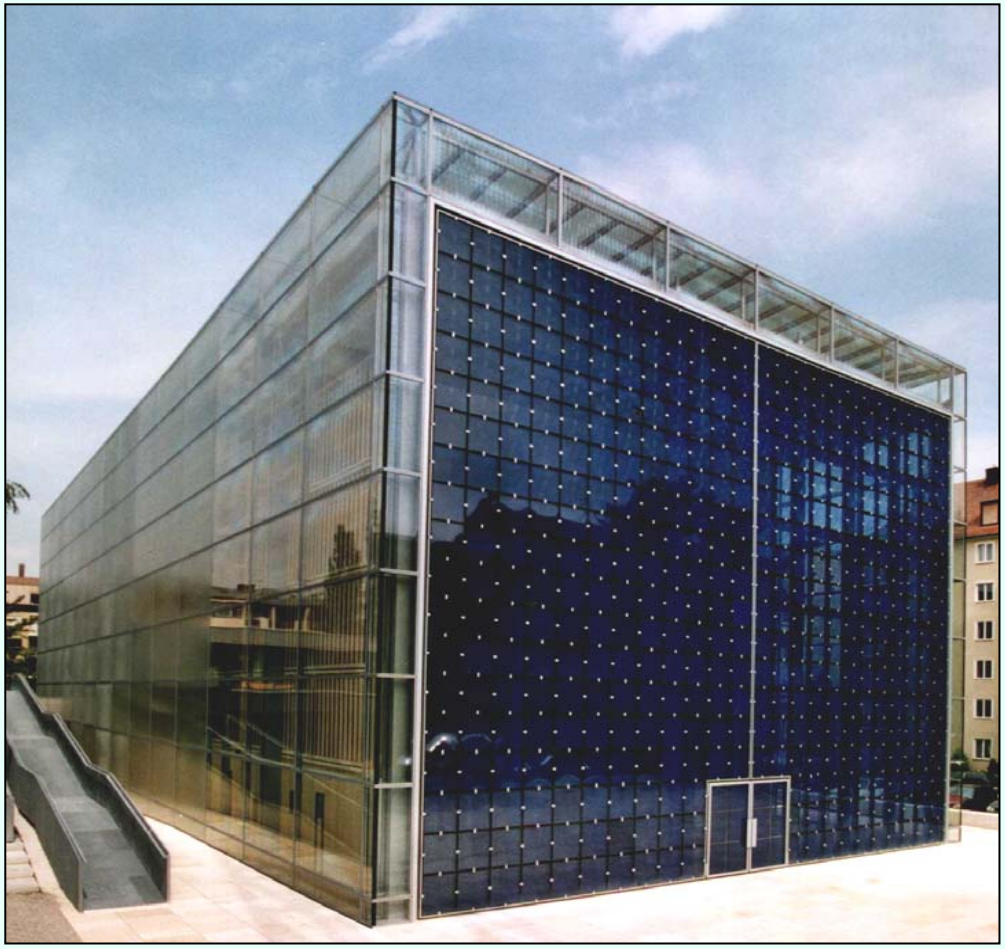
Contents of the Presentation

➔ **Design of the Façade of the Herz Jesu Church**

➔ **Bonding Technology for High Durability**

➔ **Experimental Tests for Material and Design**

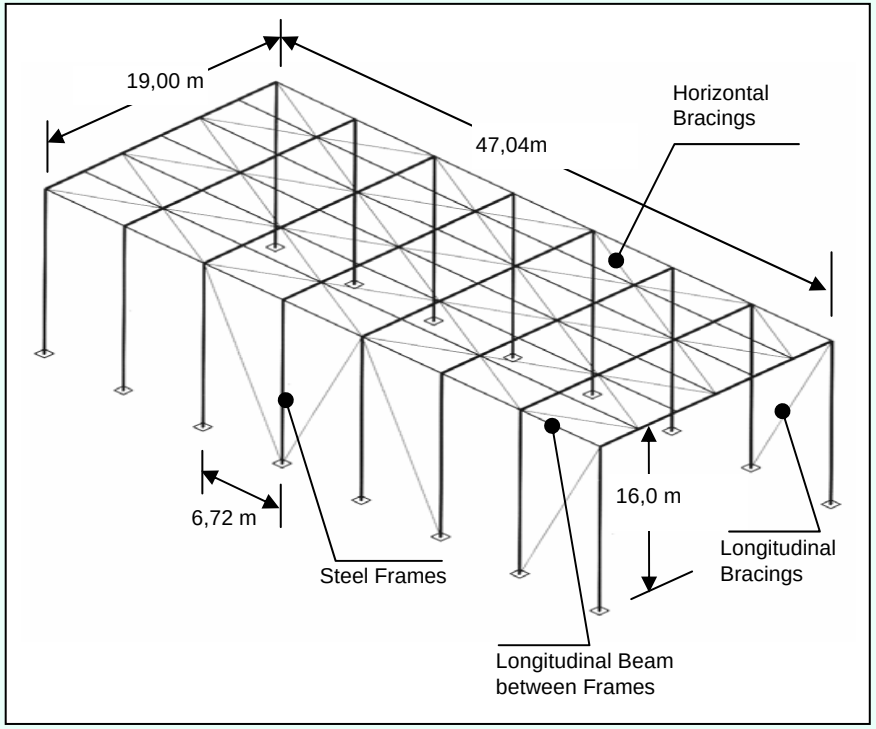
Herz Jesu Church, Munich



Architectural objective: Minimum of visible load carrying structures

- **Horizontal and vertical glass beams for support of the glass façade**
- **Load carrying line type bonding using silicone adhesives instead of high number of point supports**

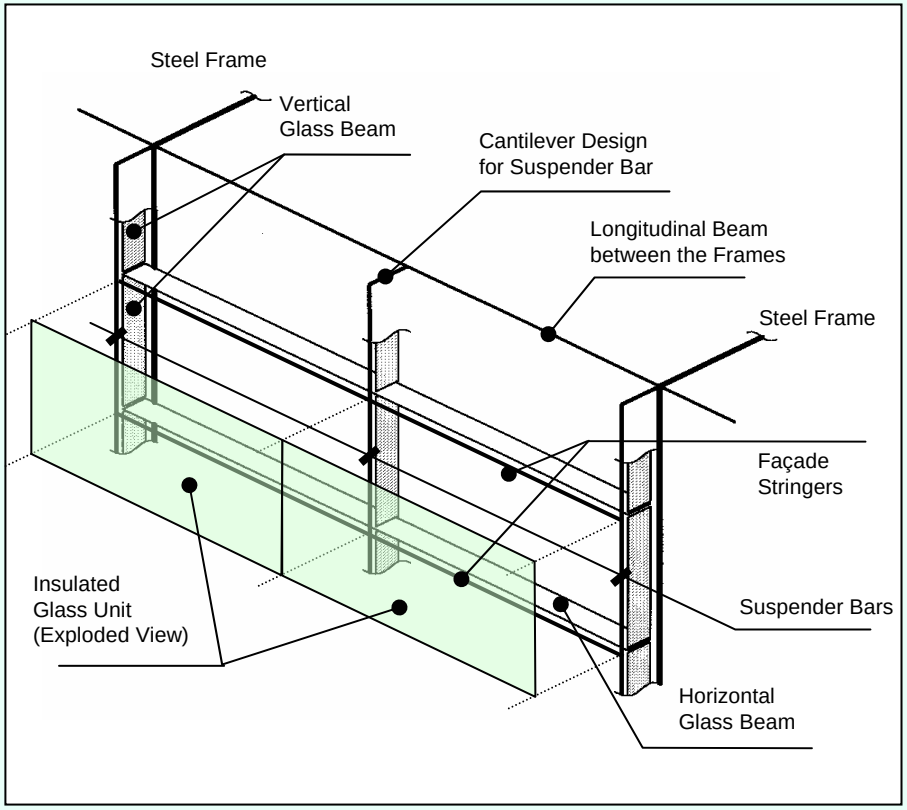
Structural System, Herz Jesu Church



- **Steel framework primarily based on eight stiff-in-bending steel frames**
- **Steel frames composed by two welded hollow sections for minimum sizes**
- **Steel frames shifted into the interior of the building for optical reasons**
- **Bracings on top and longitudinal sides for stiffening of the building**

Glass Façade Herz Jesu Church

Design Philosophy

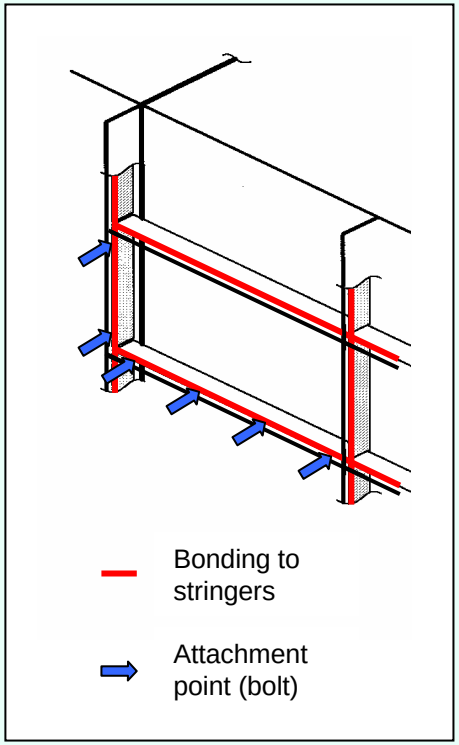


Hanging system for realization of slender frame elements

Main Components

- **Insolated glass units (width 3.35 m, max height 2.4 m)**
- **Horizontal glass beams (length 6.7m)**
- **Vertical glass beams (max length 2.4 m)**
- **Vertically arranged suspender bars (dead loads)**
- **Horizontally arranged façade stringers (wind loads)**

Load-bearing Connection of Glass Beams



- **Bonding of glass beams to steel stringers realized by silicone adhesive**
- **Steel stringers bolted to façade stringers and suspender bars**
- **Primary function of horizontal glass beams: Transfer of wind loads from façade to steel frames**
- **Primary function of vertical glass beams: Support of the horizontal glass beams**
- **Critical case for the bonding: peeling off by tension**
  - **Horizontal beam: peak suction load 1.6 kN**
  - **Vertical beam: maximum dead load 0.3 kN**

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Parameters affecting Joint Durability

(Kinloch, A. J. „Durability of Structural Adhesives“)

Environment	**Presence of moisture identified as most hostile environment, especially in combination with high temperature**
Adhesive type	**Chemical type of structural adhesives important for joint durability, depending on physical and chemical attack mechanisms**
Adherend, adherend surface pretreatment	**Application of primers helpful in producing durable joints by stabilizing surface layers e.g. oxides**
Applied stress	**Increased rate of strength loss by presence of externally applied or internal stress by lowering energy barrier unbroken/broken**
Joint design	**Emphasized durabilitiy effects by high stress distributions on interface between adhesive and adherend (interfacial failure typical after environmental attack)**

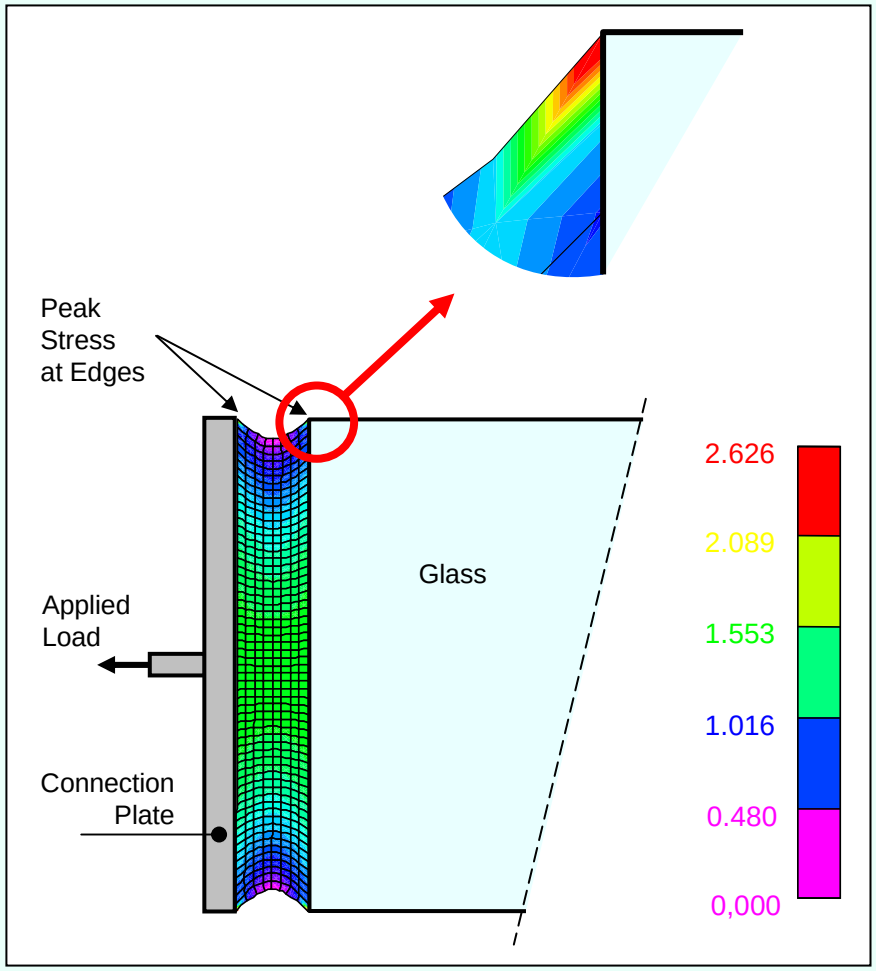
Analysis of Parameters for Glass Façade

Environment	**Arrangement of bonded structures inside glass façade favorable regarding humidity, temperature**
Adhesive type	**Selection of silicone adhesive dominated by structural glazing requirements**
Adherends	**Glass beams resulting from façade design, stainless steel channels for reduced corrosion**
Adherend surface pretreatment	**Purification of glass surfaces by a special cleaning agent, additional coating of channel surfaces with primer**
Moisture / Stress / Temperature	**Effects of moisture, stress and temperature mainly determined by bonding geometry,** ↳ **careful bonding design reqired**

Bonding Design Aspects for Increased Durability

The Question is...	The Solution is...
➢ How to diminish attack of moisture (e.g. cleaning agents) acting on the bonding	✓ Small surfaces for minimizing exposure of bonding to environment
➢ How to obtain a favorable stress distribution in the adhesive evoked by external loads	✓ Low loading of adhesive and interfacial regions exposed to environment
➢ How to consider changing temperatures leading to thermal stresses and other effects	✓ Low shear stiffness for low thermal loading

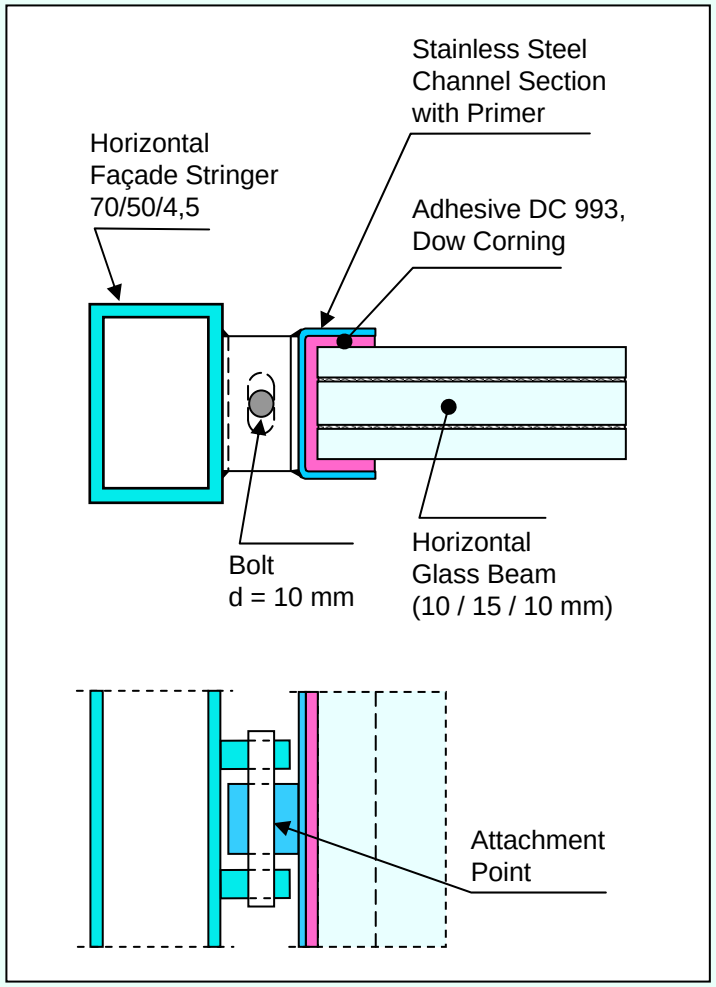
Conventional Structural Joint (Steel Band)



Only limited performance regarding durability and fracture expected due to

- **Peak loading of interfacial region between adhesive and adherend at edges**
- **Tension loaded surface exposed to environmental attacks**
- **Unstabile fracture mechanics behavior**

New Design Philosophy for Adhesive Joint

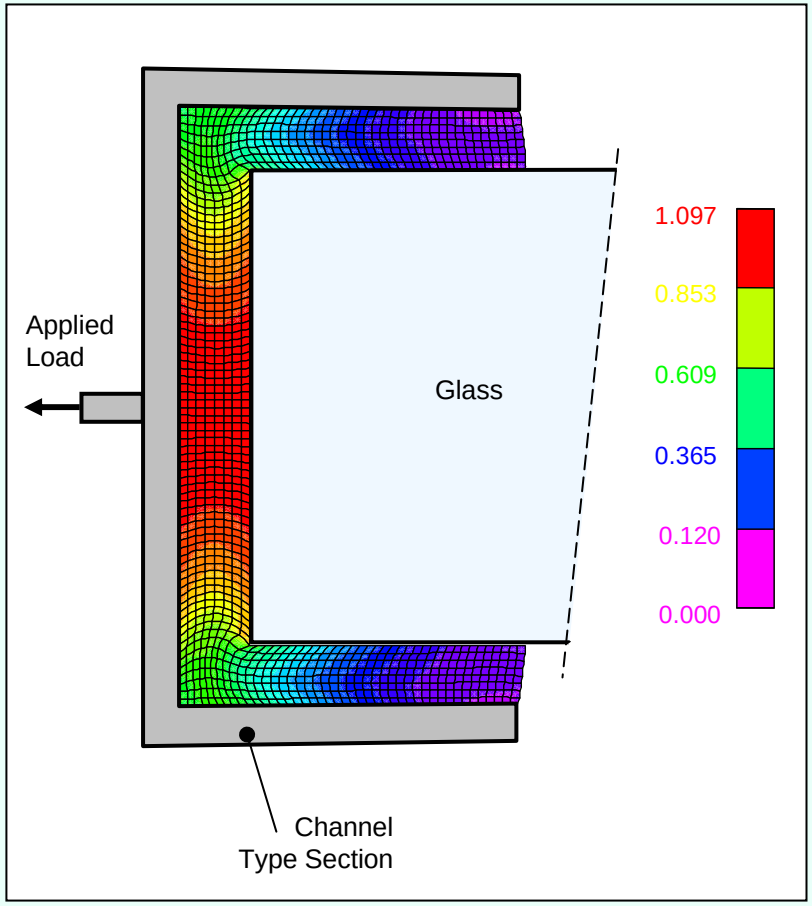


Idea:

Encapsulation of structural adhesive for protection against environment

- **Selection of channel type cross section**
- **Three sided bonding design**
  - **one front region**
  - **two side regions**

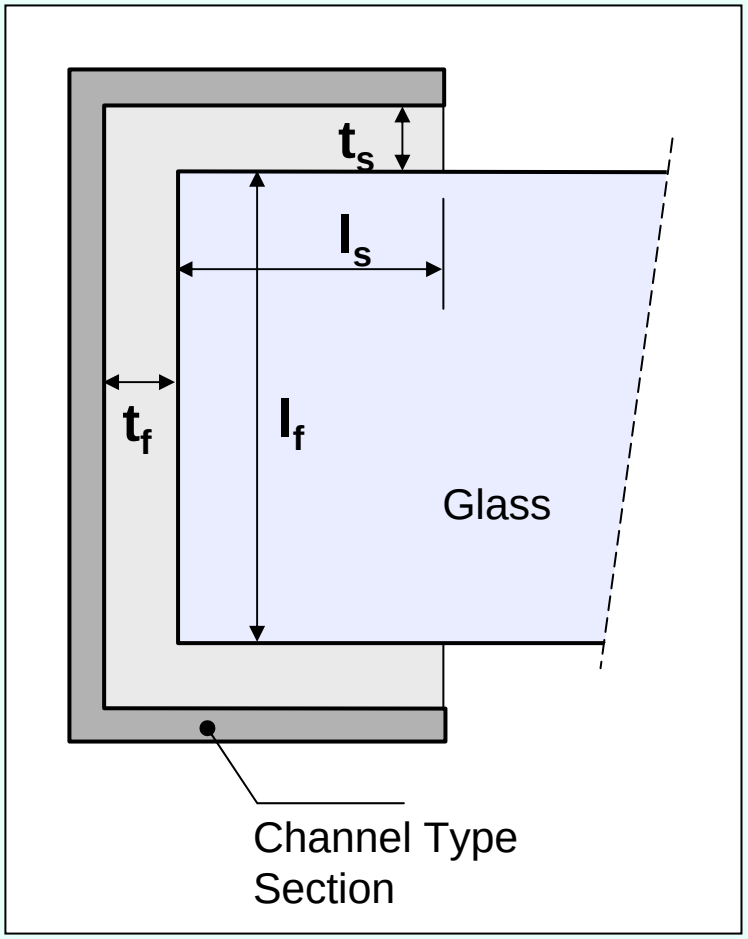
New Joint Design



Characteristics:

- **Encapsulation of highly loaded front region of the silicone adhesive**
- **Nearly unloaded adhesive surfaces exposed to the environment at the end of the side regions**
- **Second load path by shear of side regions in case of failure of front region**

Joint Geometry Parameters



l_f **defined by glass beam thickness**

t_s, t_f **minimum thickness requirement**

l_s **selected by design considerations**

Increasing l_s

+ reduction of diffusion of agressive environmental media

+ shear strength of side regions

- material consumption

- visibility

The Transparency

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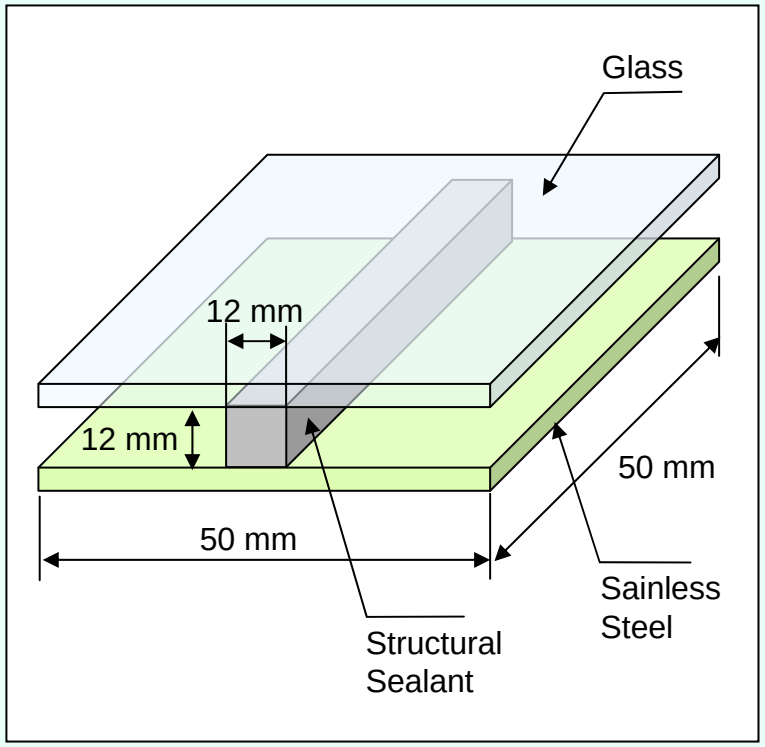
Certification Tests for Material Combination

(Institut for Windows Technology – ift, Rosenheim, Germany)

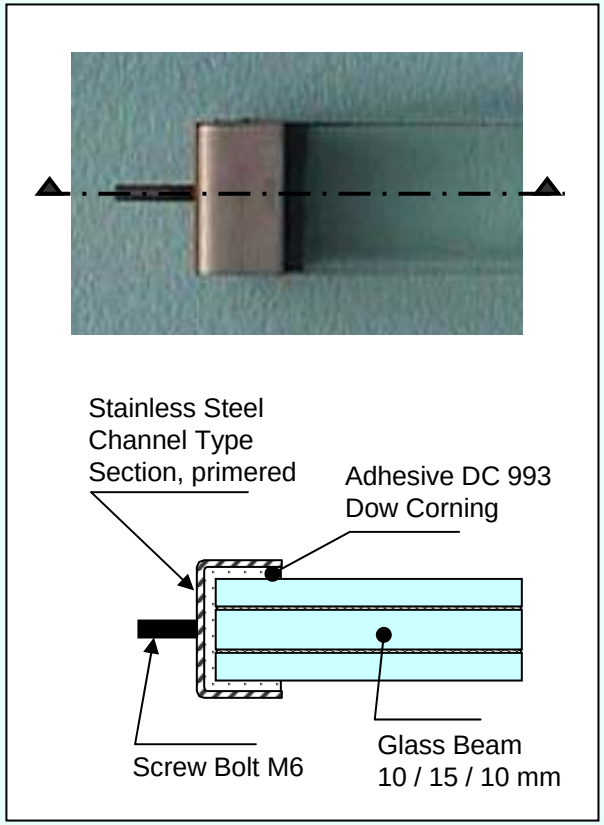


- **Samples according to guideline ETAG 02**
- **Samples tested for tension and shear strength, – 20°C to + 80°C**
- **Artificially aged or conditioned samples tested for tension strength**
  - **UV radiation plus immersion in hot water**
  - **Humidity and sodium chloride (NaCl) athmosphere**
  - **Humidity and sulphur dioxide (SO_2) athmosphere**
  - **Façade cleaning products**

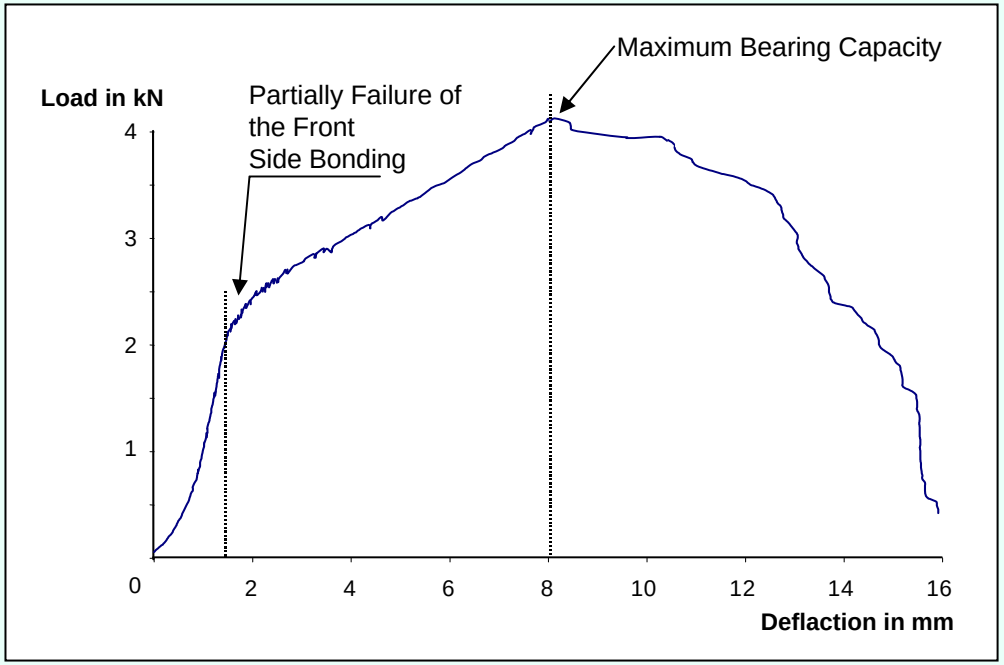
Test results: No significant decrease of mechanical strength

Behavior of New Joint Design under Tension Loads

(ift, Rosenheim)



Specimen extracted from horizontal glass beam

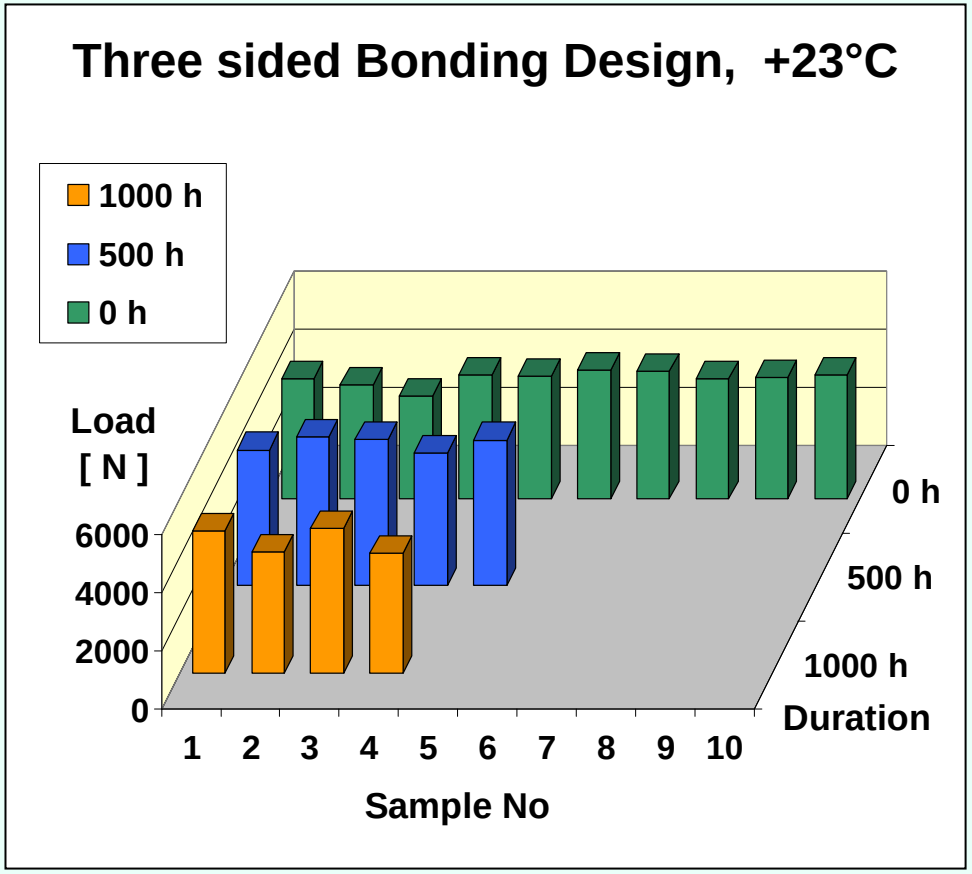


Load versus deflection plot showing regions of different behavior

Tension Strength Tests of New Joint Design

(ift, Rosenheim)

- **Investigated temperature range - 20°C to + 80°C**
- **Additional tests after continuous loading of 500 h and 1000 h (F_{cont} = 6 F_{Design})**
- **Behavior under environmental attacks assumed to be better than ETAG sample (corresponde to one sided bonding with exposed peak stress areas)**



Conclusions

- **Functionality of load carrying bonding of glass façade, Herz Jesu Church highlighted**
- **Joint design parameters affecting durability reviewed and discussed**
- **Innovative three sided joint design compared with conventional design solution**
  - **Encapsulation of regions of high stresses**
  - **Low loading of interfacial regions exposed to surface**
  - **Establishment of redundant load path**
- **Selection of joint material combination and design experimentally verified**

Due to the high potential of the presented joint design, a working group „Bonding“ was established for fundamental research in various types of structural adhesive joints (glass ⇔ metal).

Questions ?