Silicone Bonded Point Supports - Behaviour under Cyclic Loading

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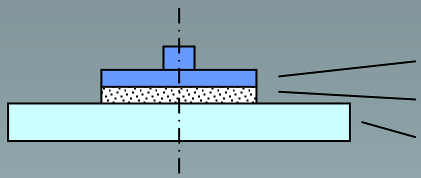
Why Bonded Point Supports?



In contrast to mechanical point supports, bonded point supports offer :

- No or low visibility from outside
- 'Soft' load introduction, beneficial for the glass unit
- No drilling of holes into glass in case of planar point supports

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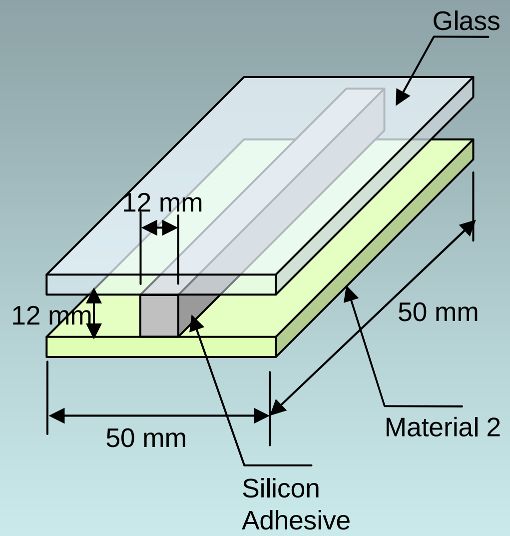
- **Failure Behavior of Silicone Bonded Point Supports**
- **Cyclic Test Campaign on Point Supports**
- **Conclusions**

Bonded Point Supports and ETAG 002

- Line-type bonding designs for structural glazing systems are covered by European guideline ETAG 002.
- ETAG 002 is limited to simple geometries - rectangular cross section and a two-sided joint design.
- For material approval a special H-type specimen is defined in ETAG 002 for determination of mechanical limits.
- The operating conditions of ETAG 002 does not require much knowledge about the adhesive material properties.
- Due to their geometry, the application of bonded point supports is obviously beyond the scope of ETAG 002.

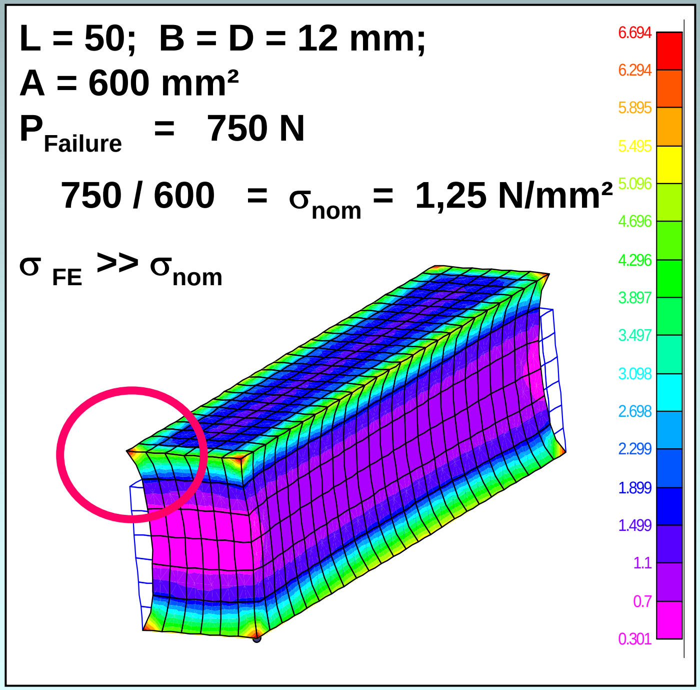


Therefore the much more complex failure mechanism of bonded point supports has to be taken into account asking for additional experimental investigations.

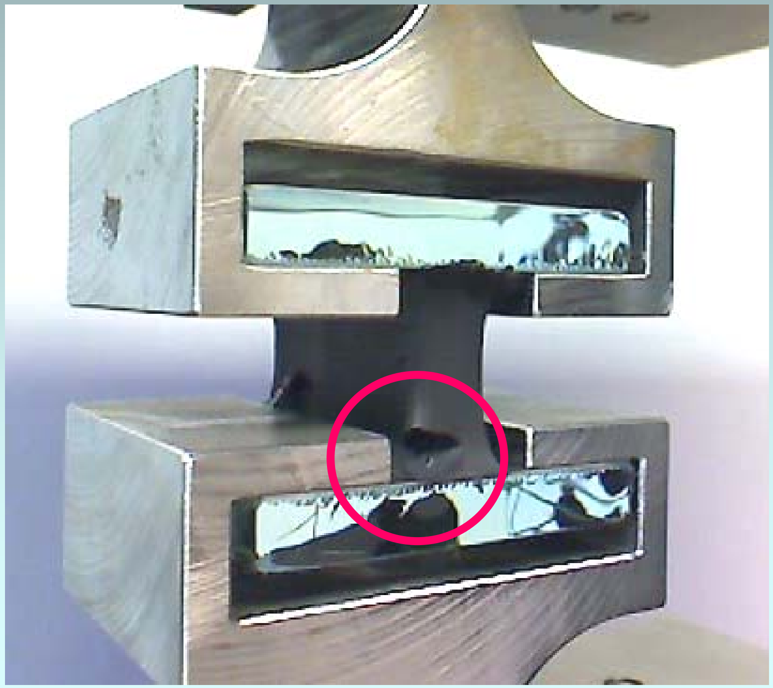
ETAG H-Specimen under Tension Loading

If Silicone is bonded to a significantly stiffer material, e. g. glass or aluminum plates, the lateral contraction is suppressed and the interface leads to complex 3D stress state and to a stiffer behavior in comparison to uniaxial tests.

The failure of the H-specimen according ETAG 002 is affected by stress peaks at the corners due to the stiff interfaces.



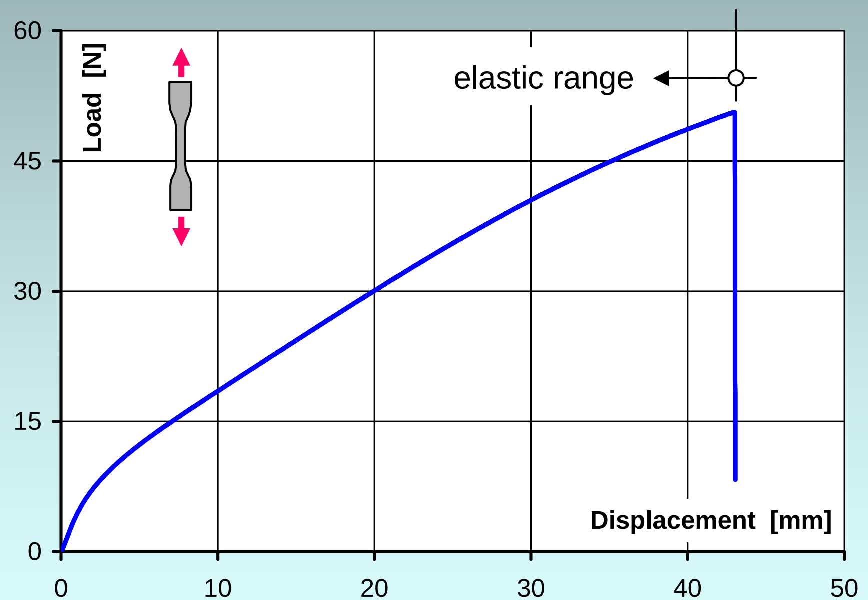
FE Analysis



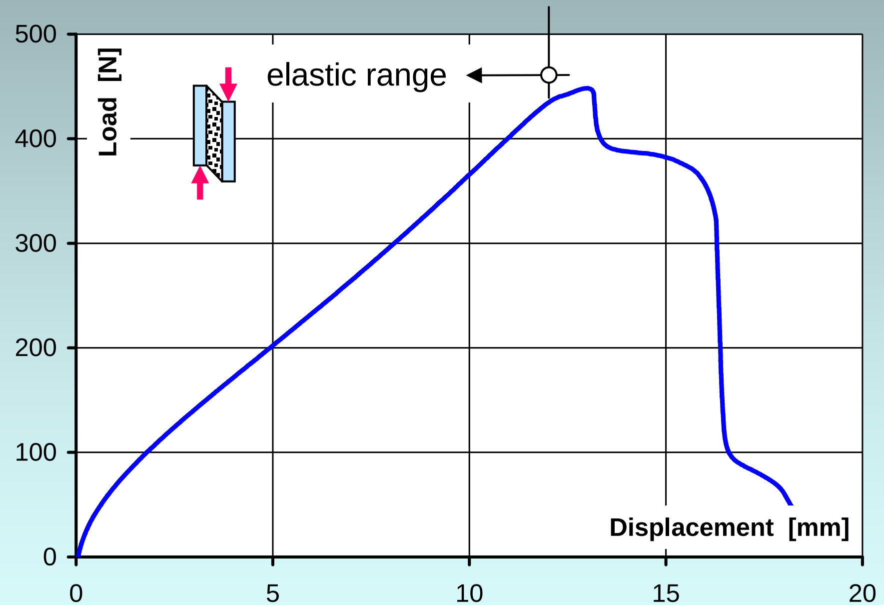
Test run

Silicone under Uniaxial Tension or Simple Shear

- In case of loading without suppression of lateral contraction, Silicone shows a much more soft behavior (e.g. for tension and for shear).
- The failure occurs suddenly after a large elastic range when the maximum load is reached.



Tension



Shear

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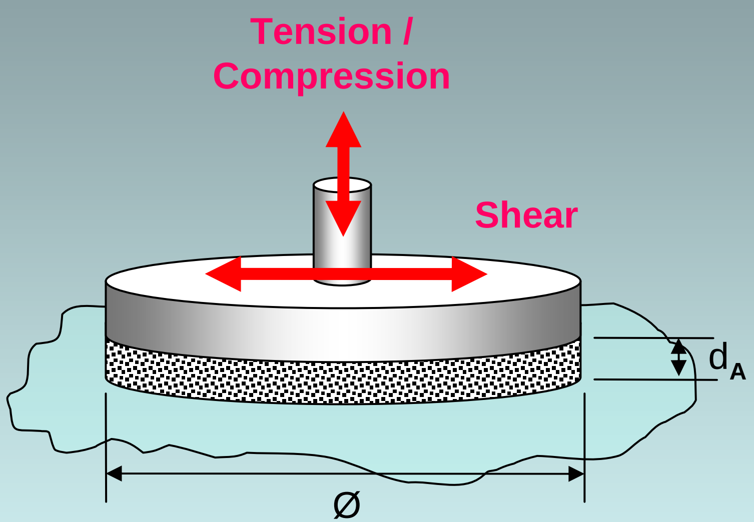
Planar Point Supports



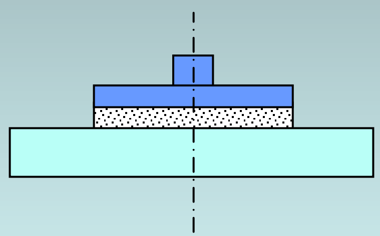
Typical loads are:

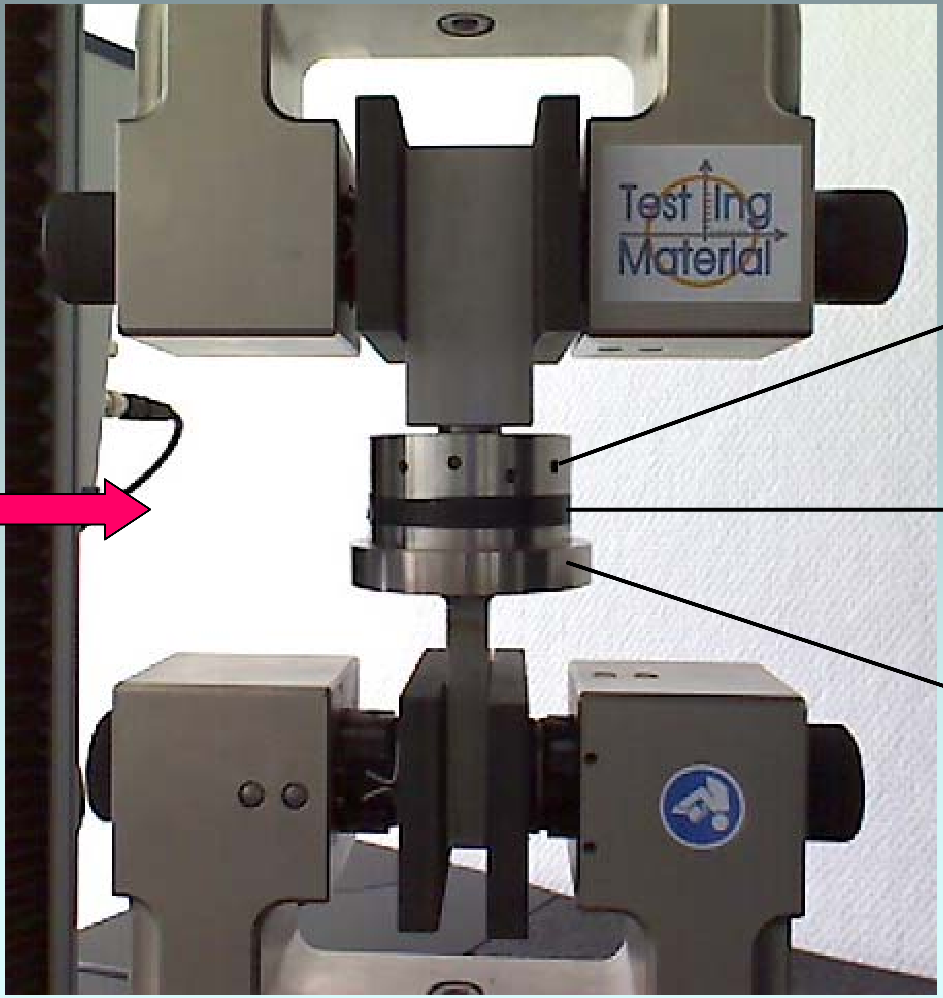
Shear	soft characteristic, typically beneficial for thermal loads
Tension	a higher effective stiffness can be observed due to suppression of lateral contraction

Tensile loads are on the one hand more critical for sizing and on the other hand more difficult to understand.

Therefore, research focus is given to tensile load cases and the special failure mechanism.

Test Configuration for Tension



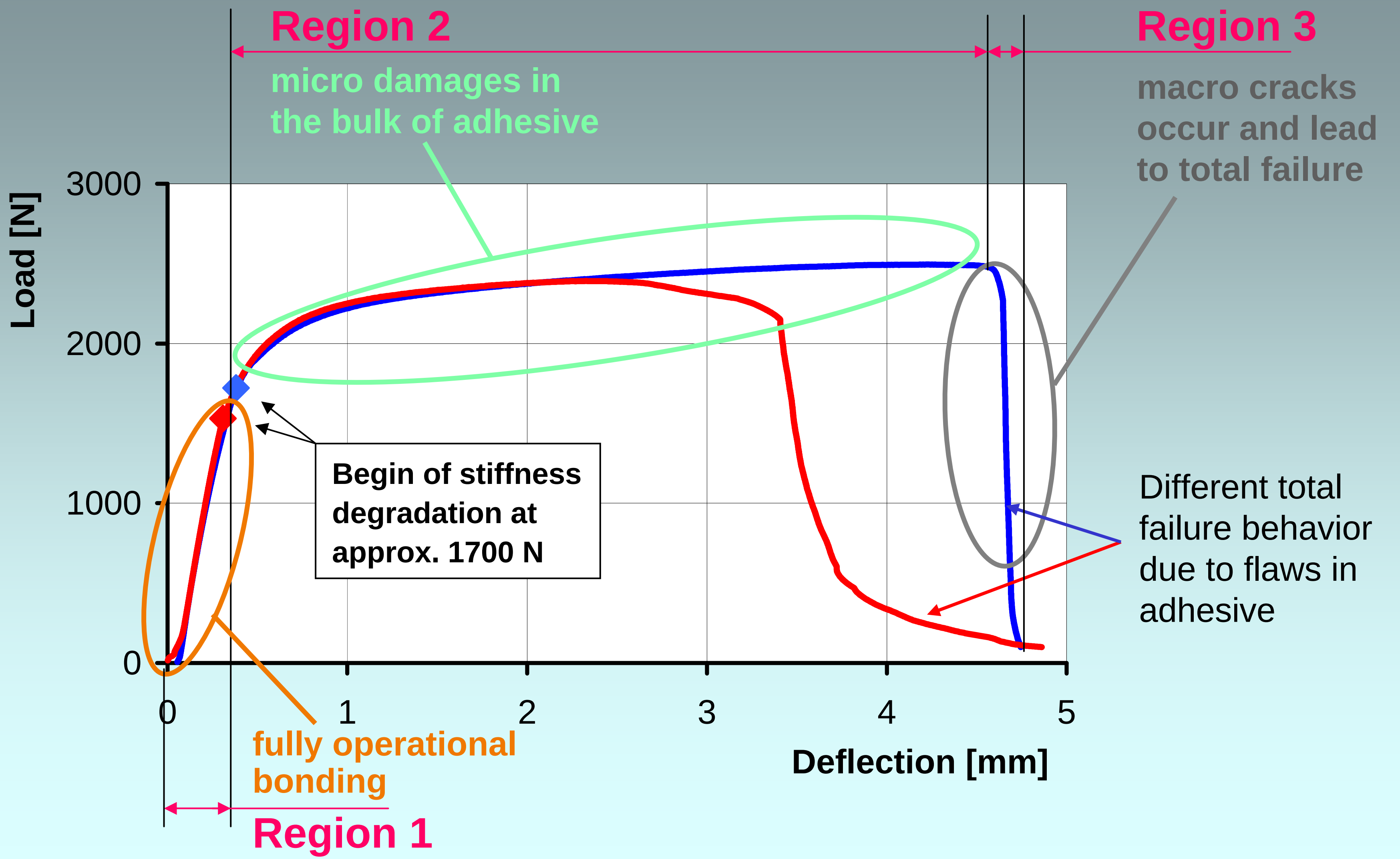


upper fitting
simulating support

Silicone adhesive
Ø 50mm (two
component DC993)

lower fitting
simulating glass

Test Results of Point Supports Ø = 50 mm, d_A = 4 mm



Movie of Test Run

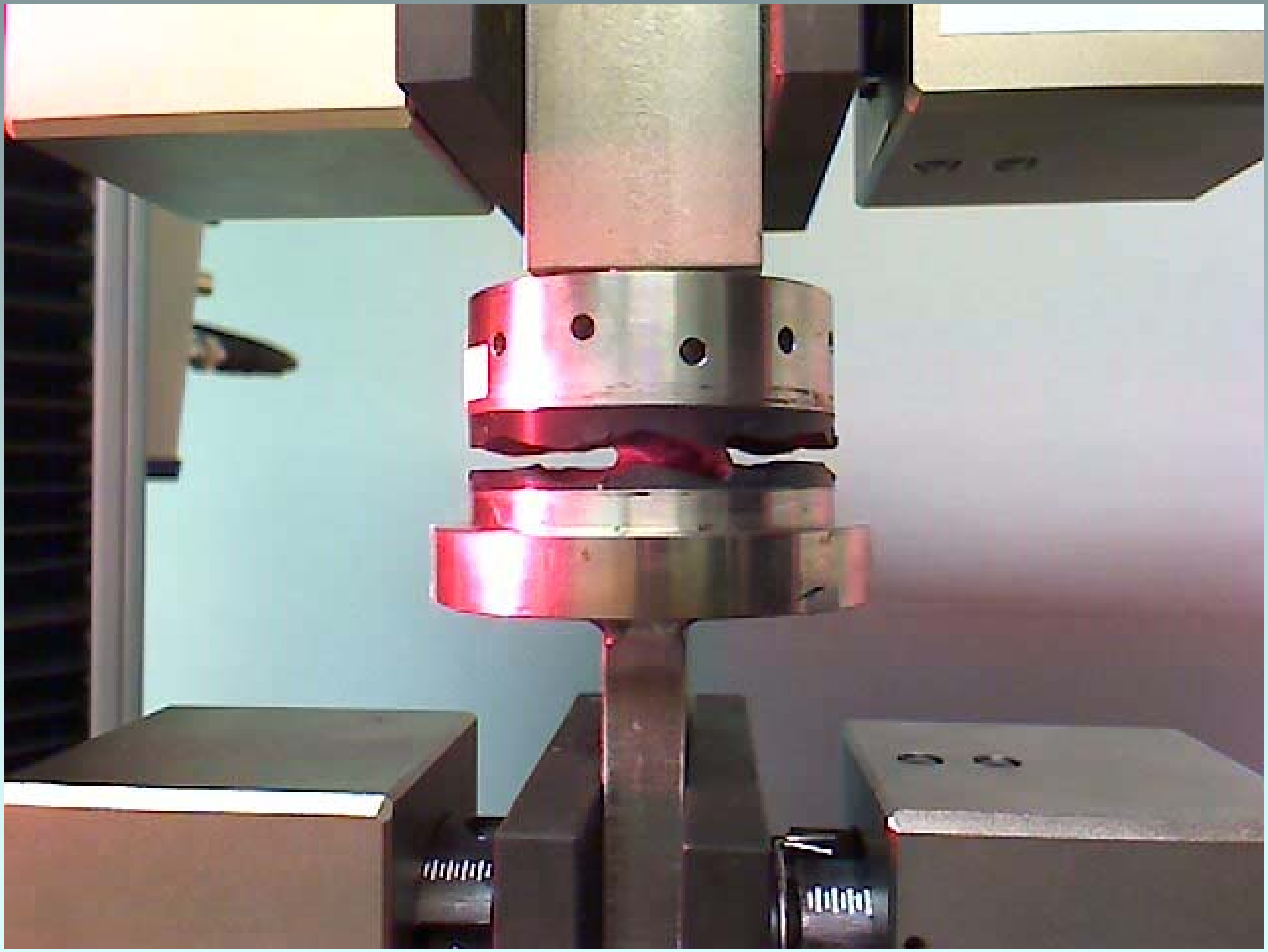
start

one step

255 s

real time

total failure



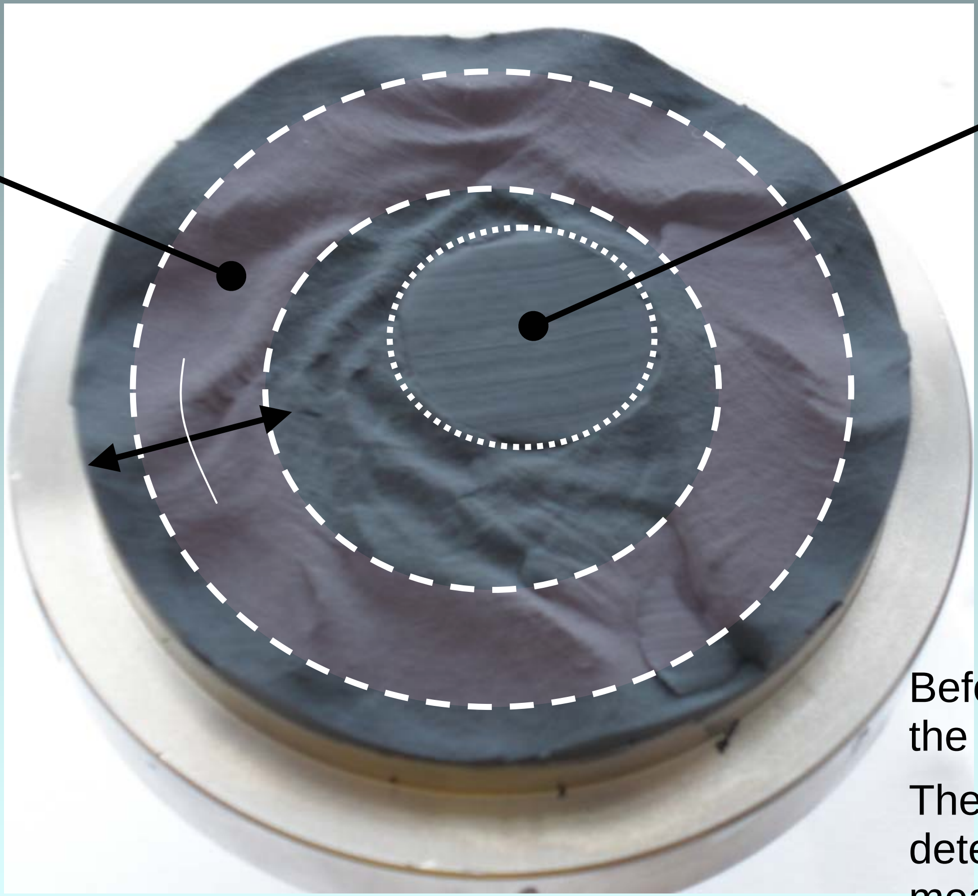
This is how the Failure occurs in Region 3 (Hypothesis)

Phase 1

Beginning of macro cracks at an inner circle

Phase 3

Finally the core fails



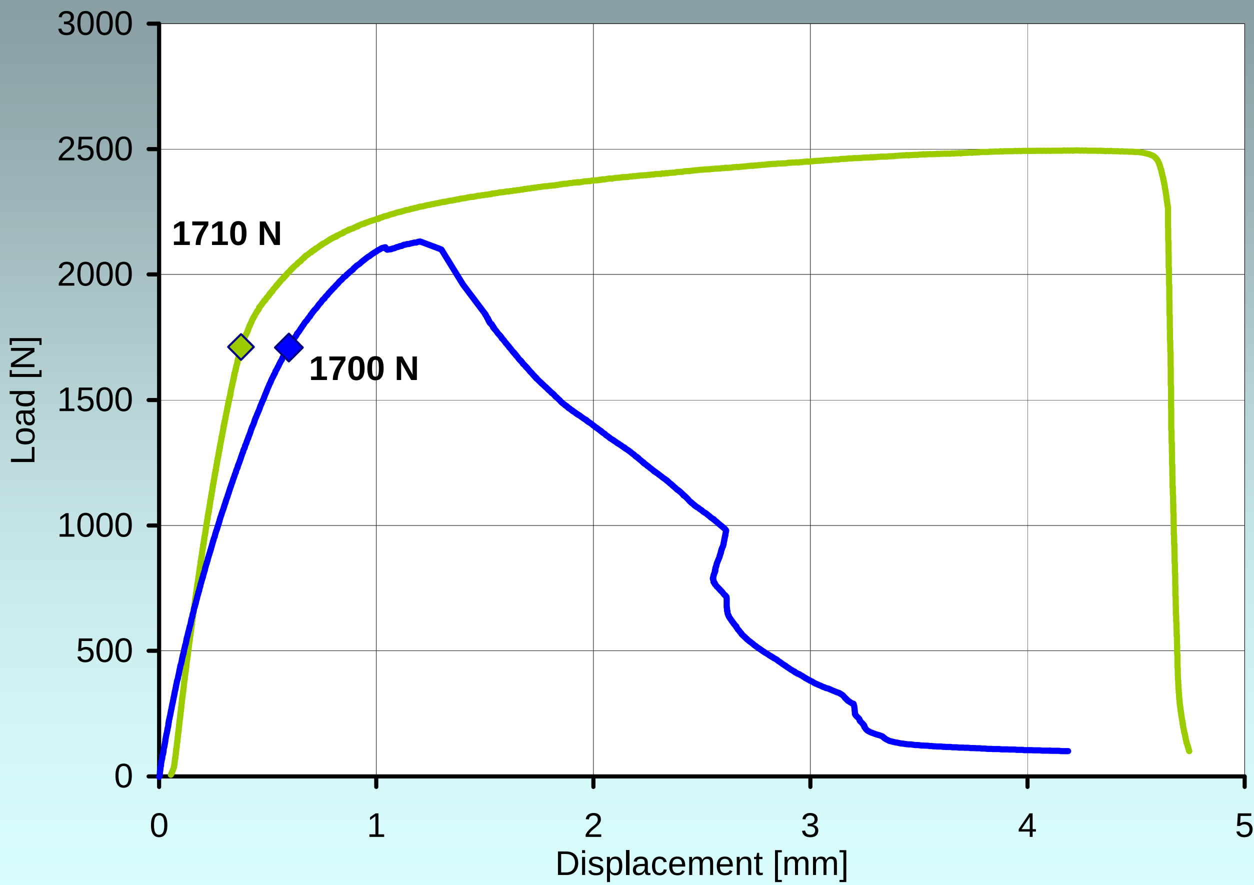
Phase 2

Crack-progress to inside and outside

Before the final failure occurs the specimen was cut up.

The failure mechanism was determined comparing the measurements synchronized with the video of the test run.

Test Results on Point Supports Ø = 50 mm, d_A = 4 mm / 7 mm



Test specimens show:

- a similar failure load
- a softer behavior with increasing of adhesive thickness

The point of loss of stiffness indicates the limit of loading of a bonding geometry.

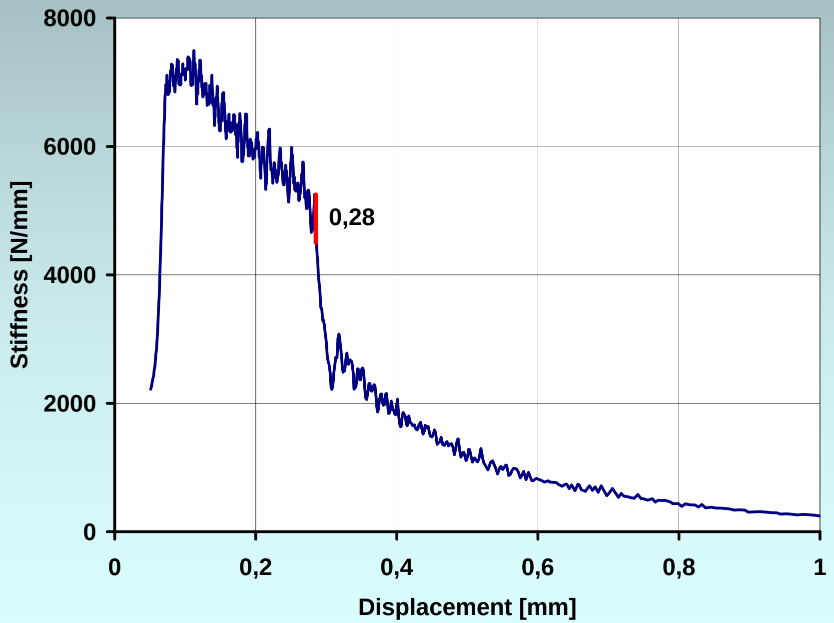
This phenomena is also observed by other geometries, e.g. U-type bonding.

Stiffness Degradation for Different Adhesive Thickness

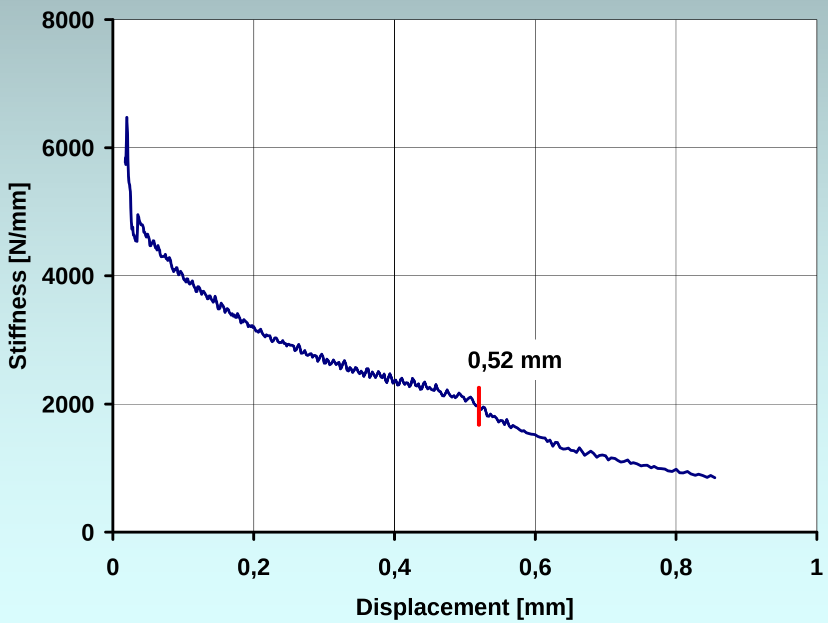
The ultimate load is about the same level at the point of loss of stiffness!

The point of loss of stiffness is predicted as the beginning of damage inside of the adhesive.

The stress level which is corresponding to this point is set to:
"Limit stress level for serviceability" or "estimated break"



Adhesive thickness 4 mm



Adhesive thickness 7 mm

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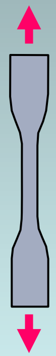
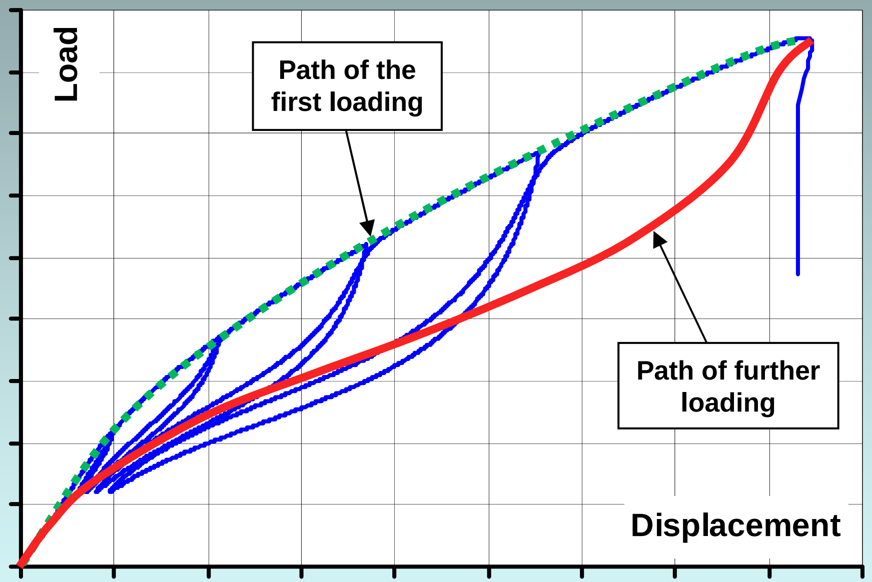
The Mullins Effect and Cyclic Loading



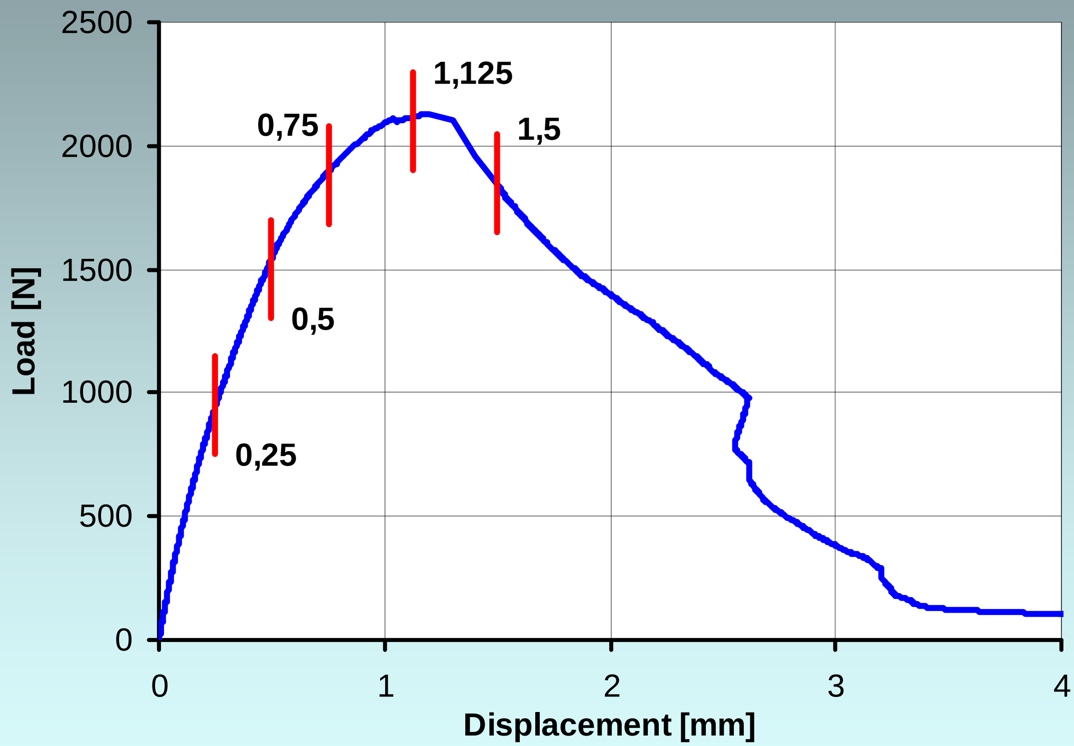


Silicone can endure a high deformation level under uniaxial tension load.

When preloaded we obtain by further loading a higher “softness”.

Nevertheless the fracture behavior is independent of a preloading for this kind of specimen.

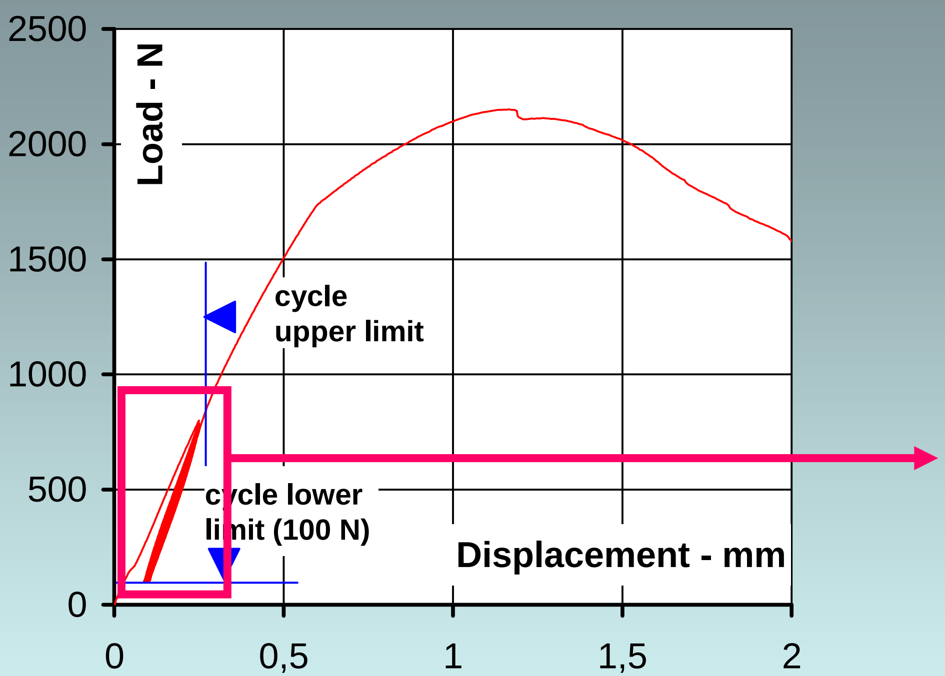
Cyclic Tests on Point Supports d_A = 7 mm

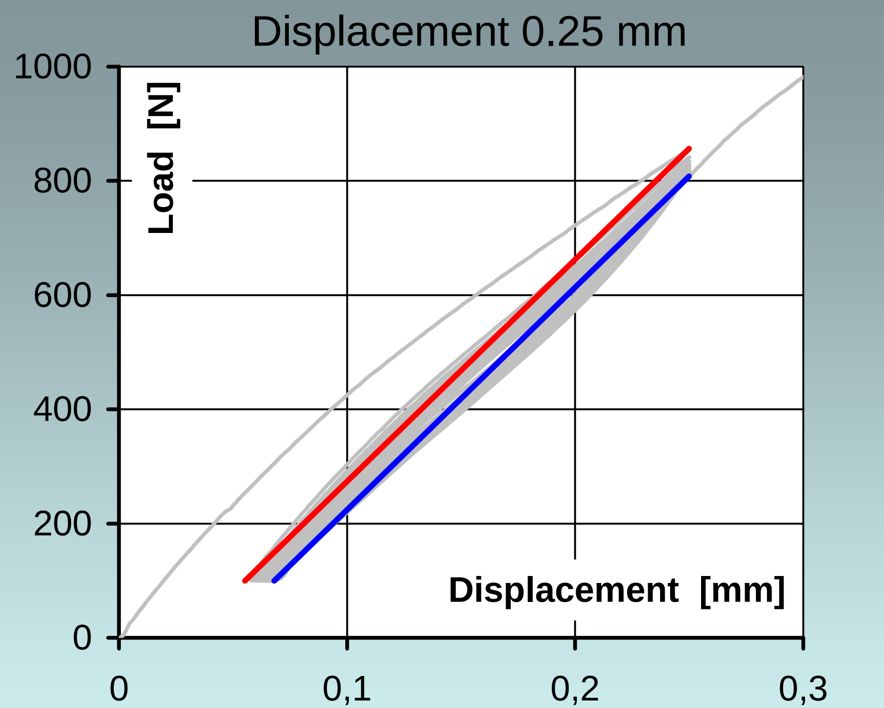


To verify the thesis of the beginning failure, cyclic tests were defined.

These cyclic tests has been carried out with 100 cycles and different displacement levels.

Cyclic Loading – Test Setup and Results for Low Amplitude





The upper limit of cyclic tests was set to the predefined displacements.

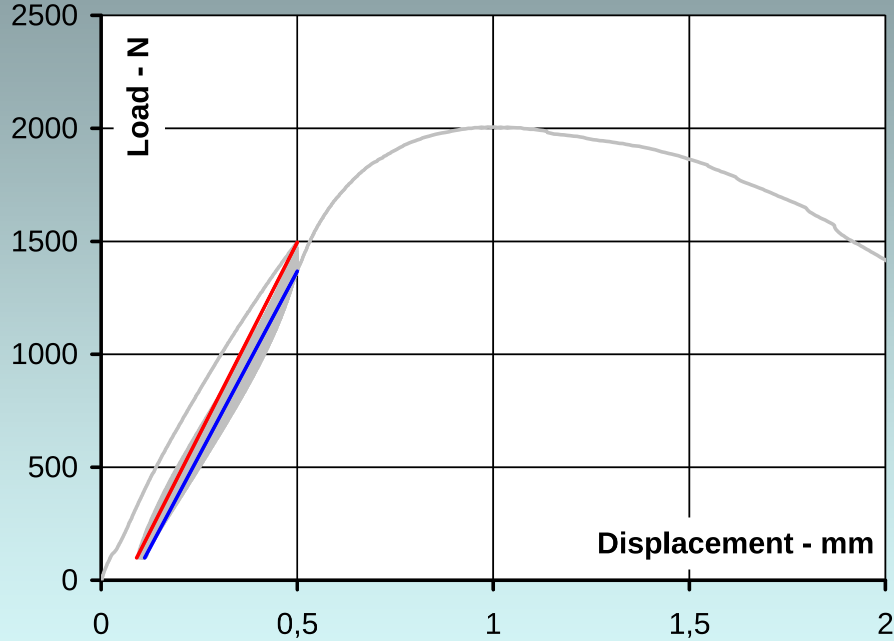
The lower limit was set to a limit load of 100 N - in order to avoid backlash in the test setup.

The degradation under cyclic loading can be classified in comparing of lines trough the lower an the upper reversal point of the first an the last cycle – the **upper** and **lower** fence lines.

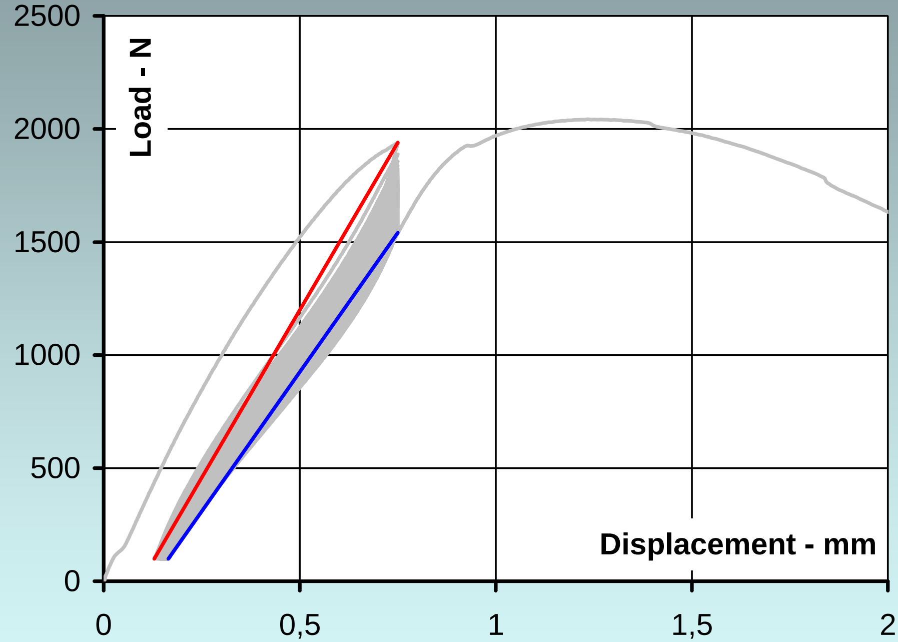
For a displacement of 0.25 mm we observe the fence lines as nearly parallel.

Degradation under Cyclic Loading – 0,5mm / 0,75mm

Displacement 0.50 mm

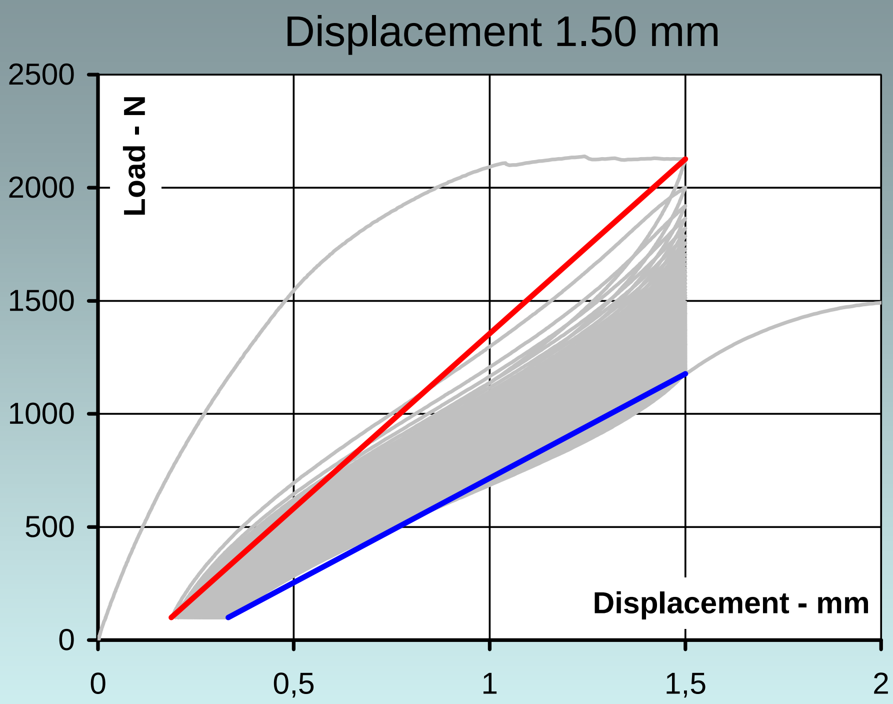


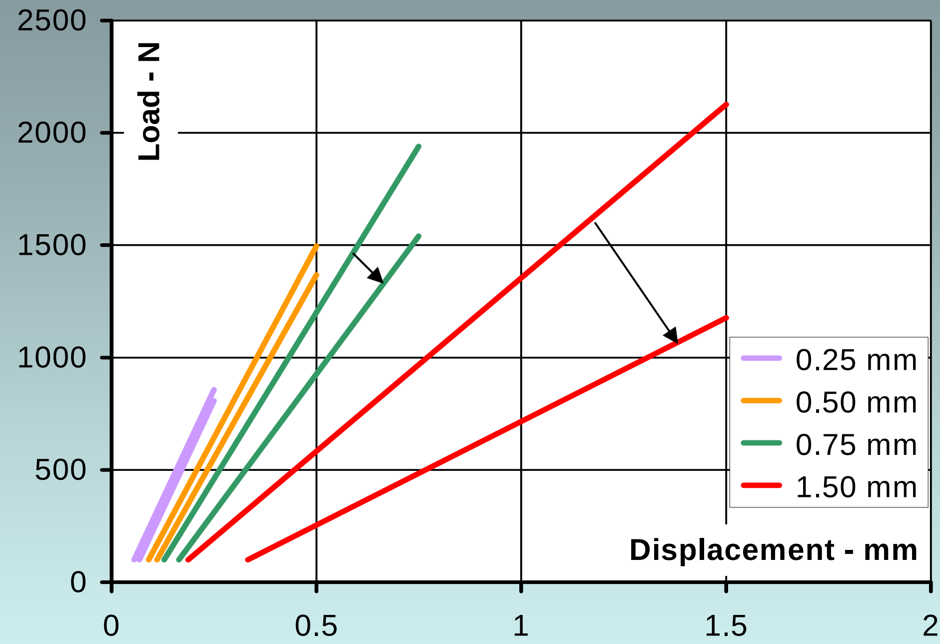
Displacement 0.75 mm



By increasing the displacement level a decreasing of the gradient for the lower fence line can be observed.

Load Degradation under Cyclic Loading



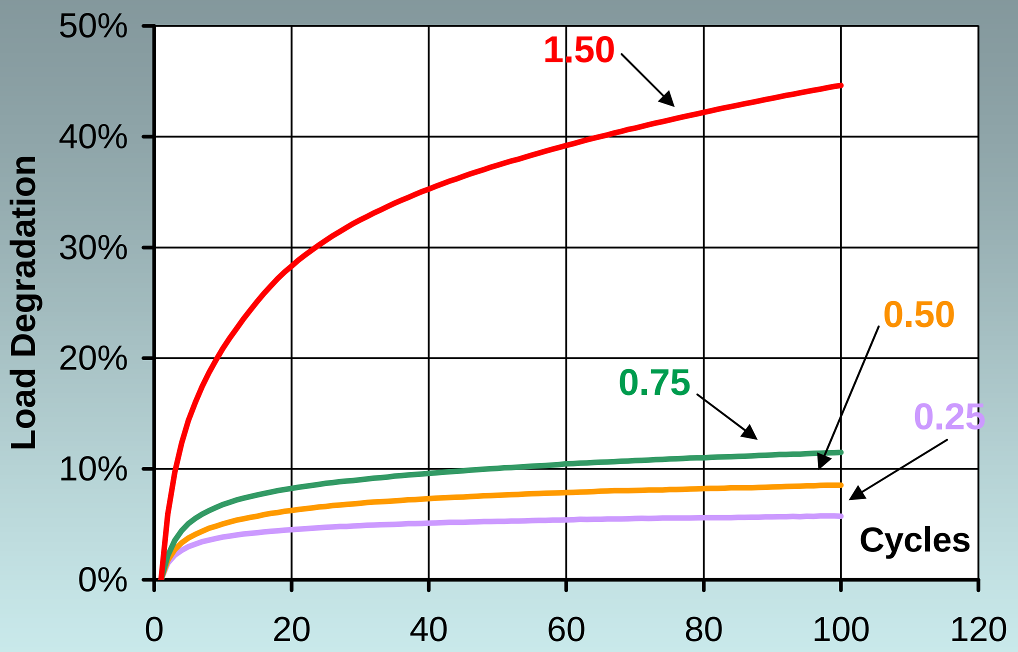


For the displacement level of 1.5 mm we observe a significant degradation of the gradient for the lower fence line (compared to the upper fence line).

The reduction of the slopes depends on the load level amplitude.

The higher the load level, the higher the decrease of the slopes.

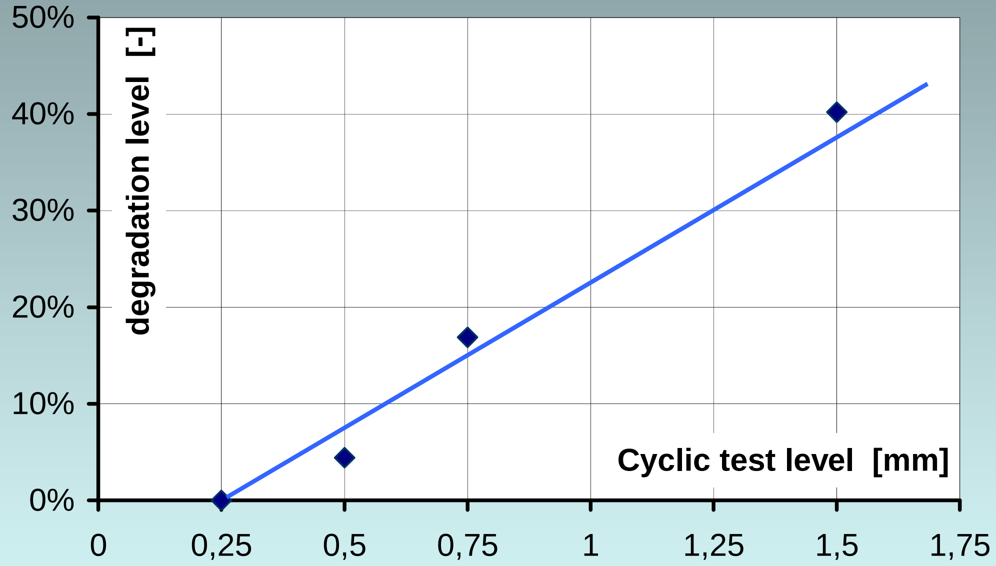
Load Degradation under Cyclic Loading



The load degradation increases with the numbers of cycles.

For a high displacement load level the failure can be detected by a significant degradation of the curve (1.5 mm).

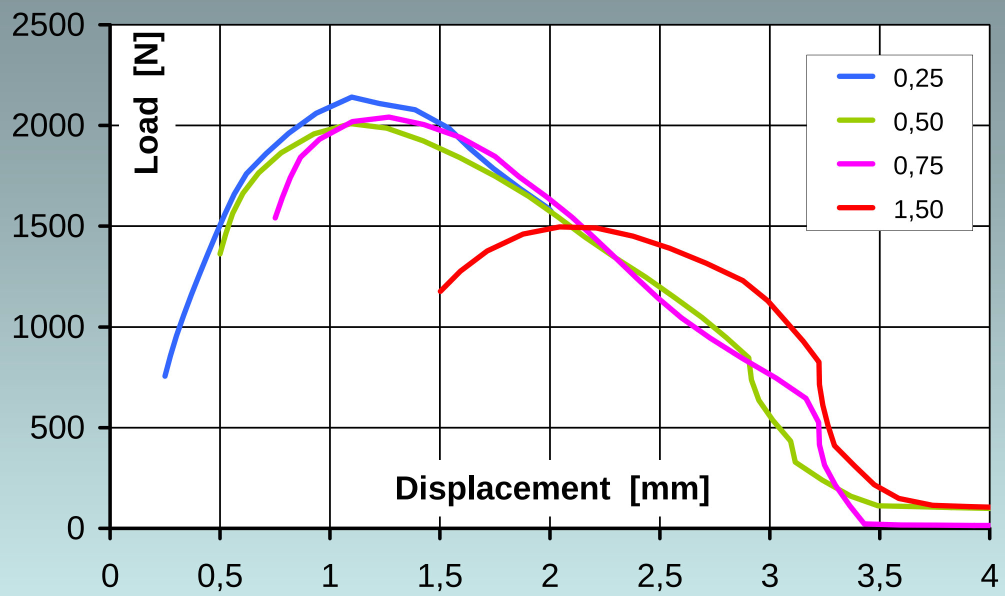
Degradation Level under Cyclic Loading



The degradation level describes the ratio of the slopes of upper and lower fence lines after 100 cycles.

The increase of the load amplitude leads to a increased degradation level.

Final Tension Tests after Cyclic Loading



For higher amplitudes the maximum load bearing capacity is significantly reduced.

The cycle loading leads to significant material damage beyond the Mullins effect. Please note that the Mullins effect should not impact ultimate load levels.

Contents

Conclusions - 1

- The tensile and cyclic test campaign has been performed for specimens with a diameter of 50 mm.
- The number of cycles was set to 100 and the upper displacement levels were set to 0.25 mm up to 1.5 mm.
- Two major aspects have been focused on:
  - first the change of behavior during the cycles
  - second the post-cycle behavior
- As expected the degradation of the material depends on the amplitudes of cycles.
- The slopes of the fence lines decrease with increasing cycle amplitudes.
- For small amplitudes an asymptotic behavior is obviously obtained.
- For large amplitudes additional tests with a significantly higher number of cycles are recommended for final statements.

Conclusions - 2

- The results are complemented by the investigation of the load bearing capabilities after the cycles. High amplitude cycles significantly reduce the material performance.
- The recommendation to use only the region of high stiffness – identified during tensile tests of bonded point supports – seems to be confirmed by these experimental results.
- Outlook: For further confirmation of the results, additional tests with bonded point supports are planned for different bonding thickness.

Thank you!

Dow Corning for performing the bonding of all needed specimens and the extensive support

The End

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