GEOANZ #2

Expertise
Geosynthetics
Engineered Construction Materials

Behavior of Bituminous Geomembrane Seams Exposed to Tensile Stress

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CANADA

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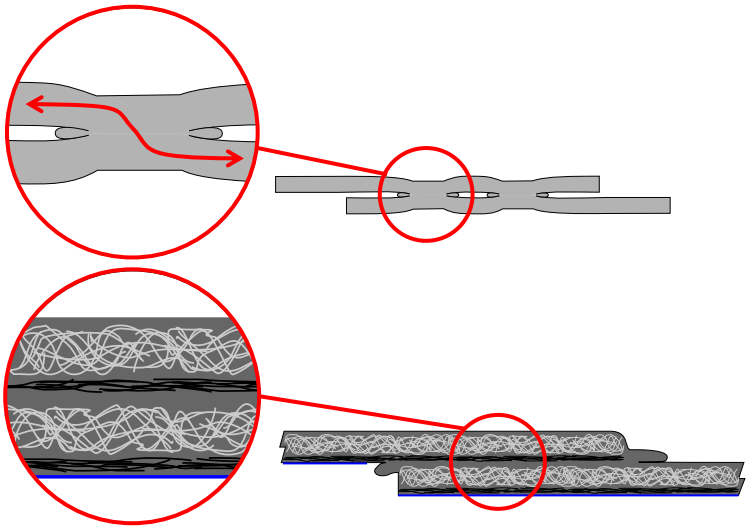
Difference between BGM Seams and other seams?

For thermoplastic geomembranes (monolithic PE, PVC) the seam creates a continuous material – down to the scale of the polymer.

For BGM, the seam binds the geomembrane sheets together to create a continuous (watertight) plane.



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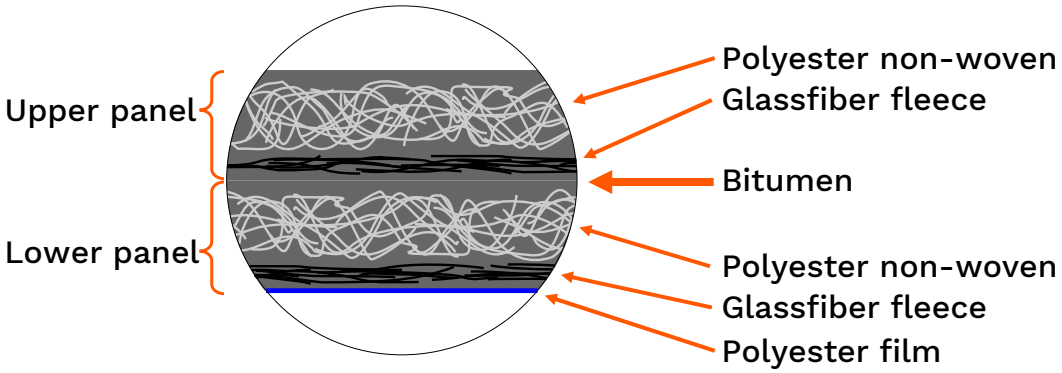
Seaming of a Bituminous Geomembrane



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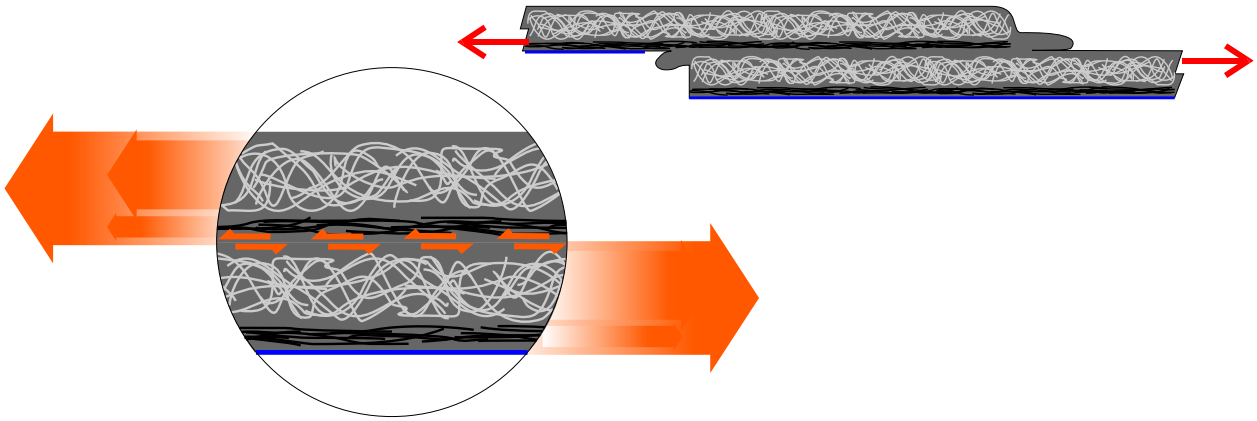
Mechanical Continuity of the Seam

When there is a tensile force across the seam, a shear stress develops on the interface between the two sheets



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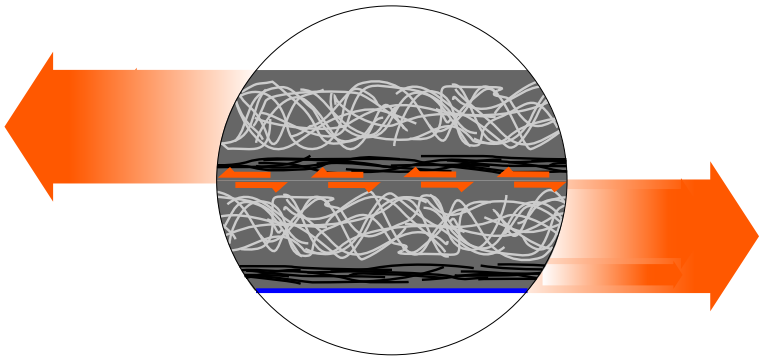
Mechanical Continuity of the Seam

The only material connecting the two sheets together is the bitumen.
Therefore, **the seam strength depends on the properties of the bitumen.**



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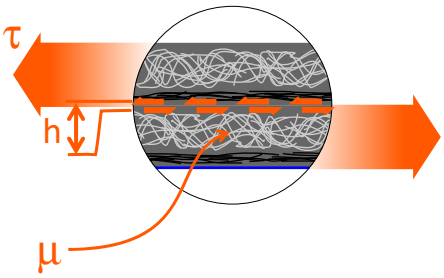
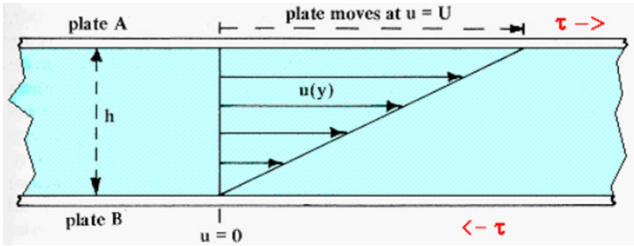
Mechanical Continuity of the Seam

Based on classical theory on viscosity, the equation $\tau = \mu\ (U/h)$ defines the viscosity 'μ', where:

- 'τ' is the stress
- 'μ' is the viscosity
- 'h' is the distance between planes
- 'U' is the strain rate





https://www.princeton.edu/~maelabs/hpt/mechanics/viscosity.htm

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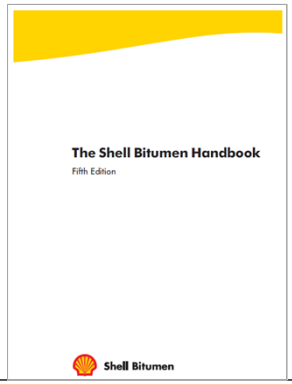
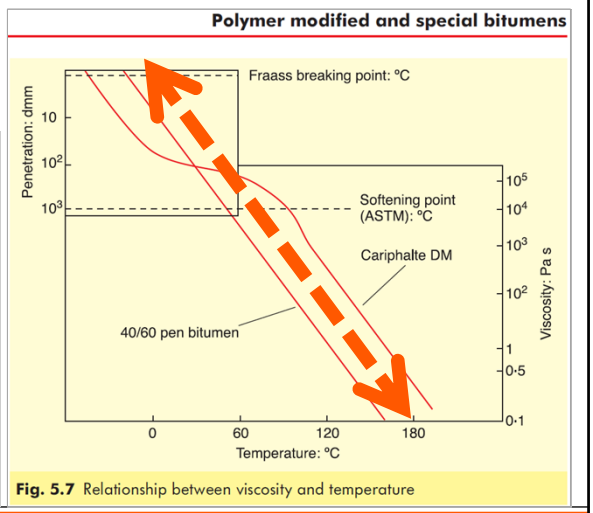
Viscosity of Bitumen?

From the Shell bitumen handbook:

- The relation between viscosity and temperature extends across the entire range of service temperature.
- The shape of this relation depends on the formulation of the bitumen.
- For 'simple' bitumen, the relation is linear in a semi-logarithmic scale.





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Experimental work

Goal:

1- confirm that the bituminous geomembrane seam performance indeed relies on the viscosity of the bitumen

2- Discuss the impact on the performance of a structure

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Experimental Work

A sample of bituminous geomembrane was recovered from a project.

Seams were performed using the edges of the roll, i.e., in machine direction.

Welding conditions were ideal:

- Dry, hard and smooth concrete substrate:
  - Control of the pressure;
  - Control of the width.
- Room temperature.
- No solar exposure.
- Experienced installer.

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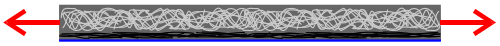
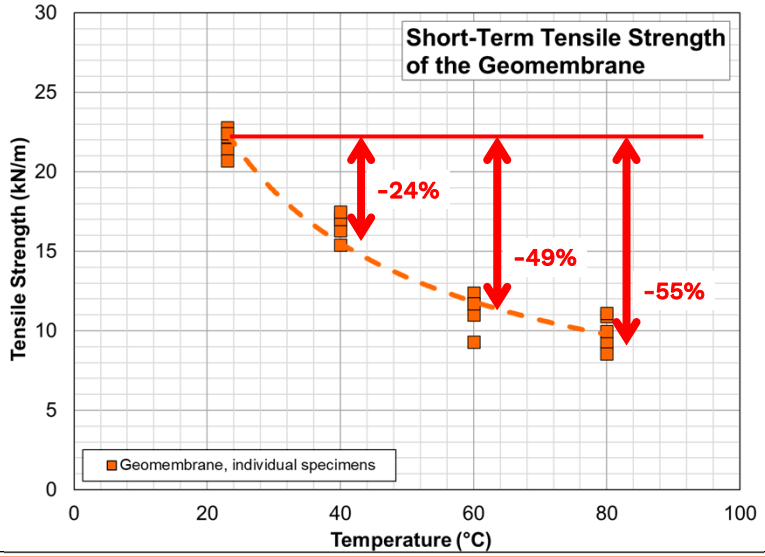
Results – Tensile Strength



Retained strength of the Sheet at service temp., vs the Sheet at 23°C:

- 76% at 40°C
- 51% at 60°C
- 45% at 80°C

These observations reflect typical properties of the polyester non-woven, which provides most of the tensile properties at break of the BGM.



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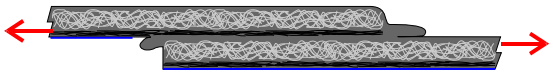
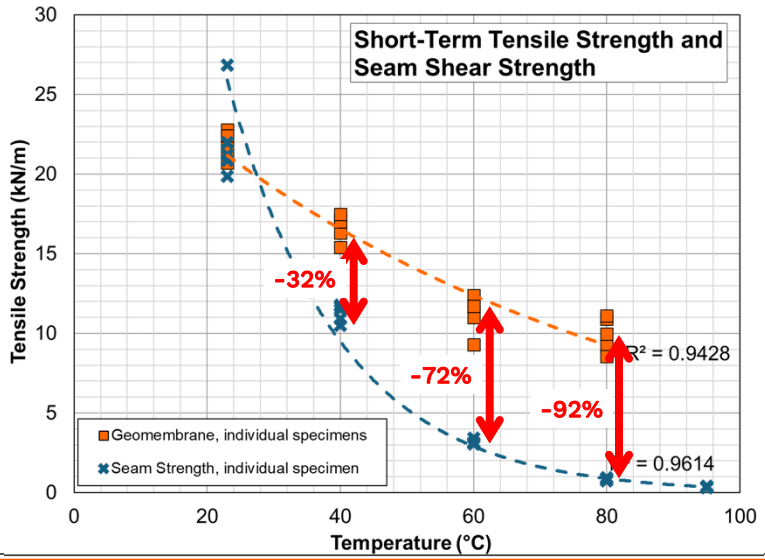
Results – Seam Shear Strength



Retained strength of:
the Seam at service temp.,
vs Sheet at service temp.:

- 68% at 40°C
- 28% at 60°C
- 8% at 80°C



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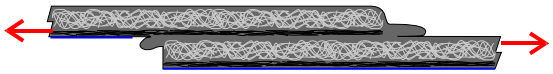
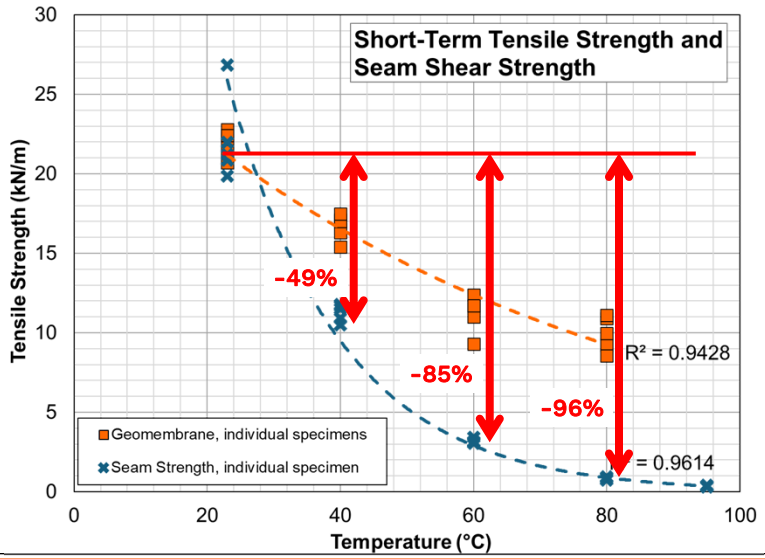
Results – Seam Shear Strength



Retained strength of:
the Seam at service temp.,
vs the Sheet at 23°C:

- 51% at 40°C
- 15% at 60°C
- 4% at 80°C

Clearly, the seam offers much less resistance than the sheet when exposed to a high temperature.



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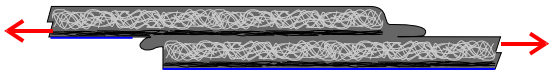
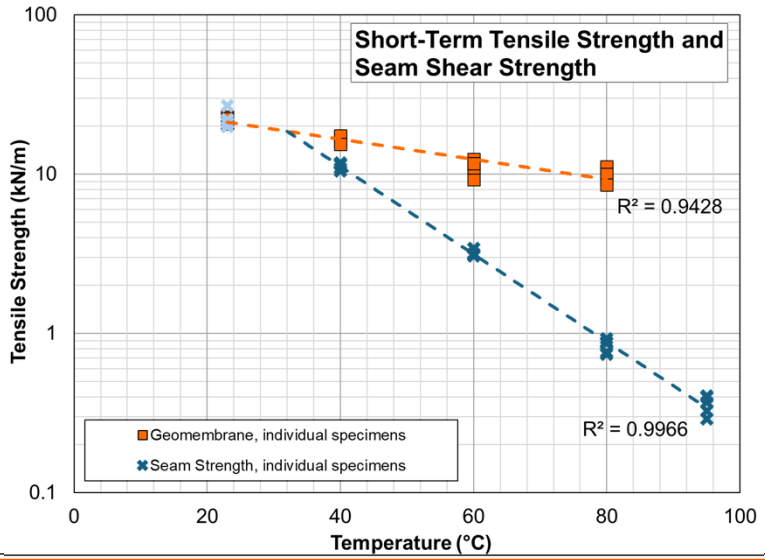
Results – Seam Shear Strength



Representation in a semi-logarithmic scale generates quasi-perfect linear regressions (i.e., exponential model $y=a.e^{bx}$) when withdrawing the results at 23°C



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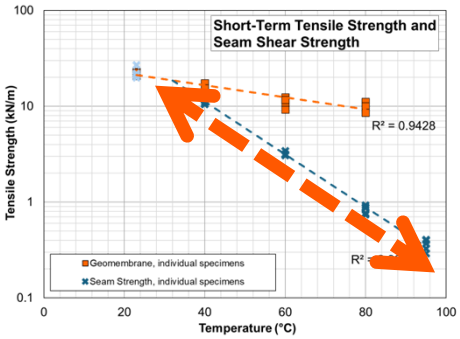
Results – Seam Shear Strength

The relation 'Seam Shear Strength' versus 'Temperature' is exponential.

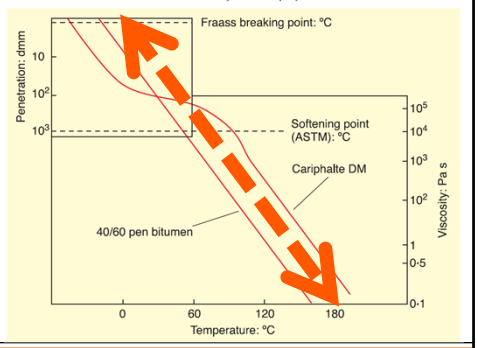
...as is the relation between 'Viscosity' and 'Temperature' of bitumen, per the "Shell Bitumen Handbook".



This observation supports that:

- Properties of the bitumen control the behavior of the seam
- The classical equation which defines viscosity $\tau = \mu\ (U/h)$ controls the shear resistance of the seam

  ... when the strain rate 'U' is imposed.



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In the field, a strain rate is rarely imposed, but a stress may prevail, e.g., consequence of a forced elongation.

Can a constant stress cause the failure of the bituminous geomembrane seam?

This can be answered by conducting tests where a constant load is applied on the seam, and observing its behavior – i.e., creep tests.

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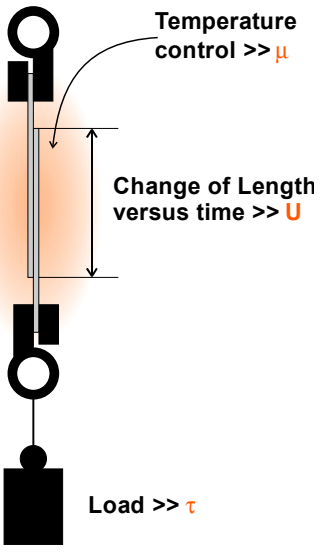
Creep Tests

The goal of these tests is to observe the behavior of the seam exposed to a constant tensile stress, which better reflects field conditions, to confirm that the equation for viscosity $U = h.\tau/\mu$ applies to bituminous geomembrane seams.



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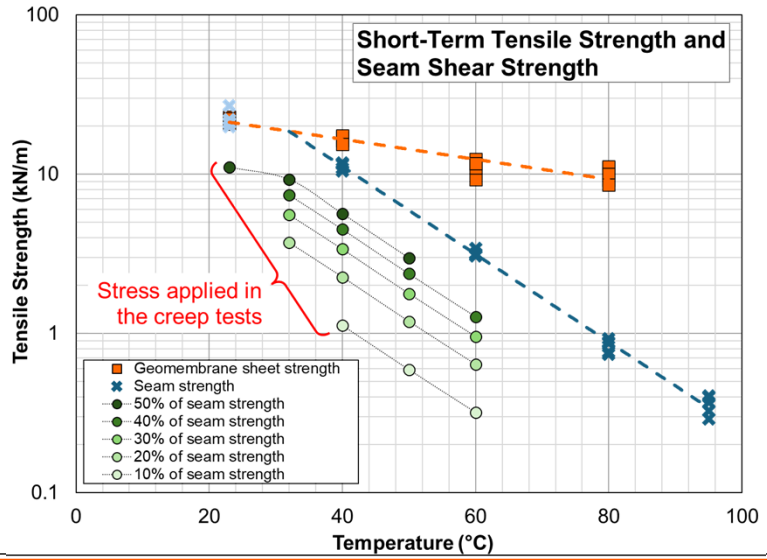
Creep Tests

Test parameters:

- Temperature: 23, 32, 40, 50, 60°C
- Applied load: 10 to 50% of the seam strength at the test temperature



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Results – Creep Tests

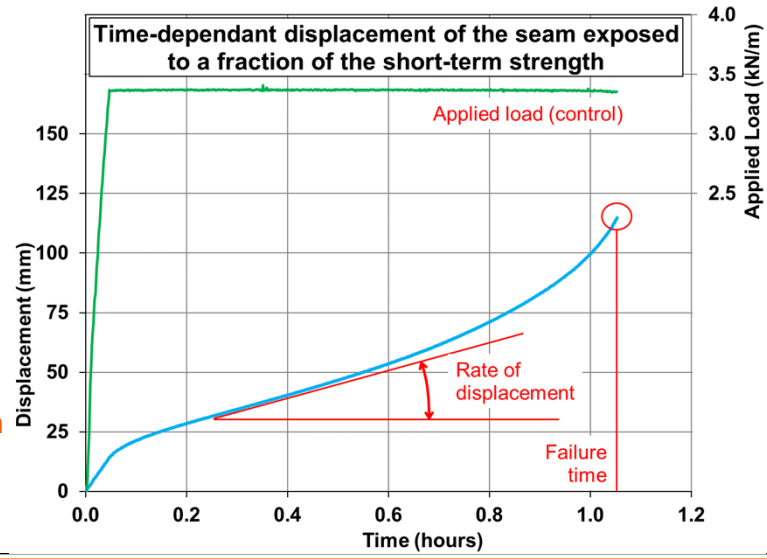
Example of test result, where

- Test temperature: 40°C
- Applied force = 30%
  - $F_{23°C\ (sheet)}$ = 21.9 kN/m
  - $F_{40°C\ (sheet)}$ = 16.7 kN/m
  - $F_{40°C\ (seam)}$ = 11.3 kN/m

>> $F_{(40°C,\ 30\%)}$ = 3.37 kN/m

Result of the test:

- Displacement rate: 58 mm/h
- Failure time: 1.05 h



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Results – Creep Tests

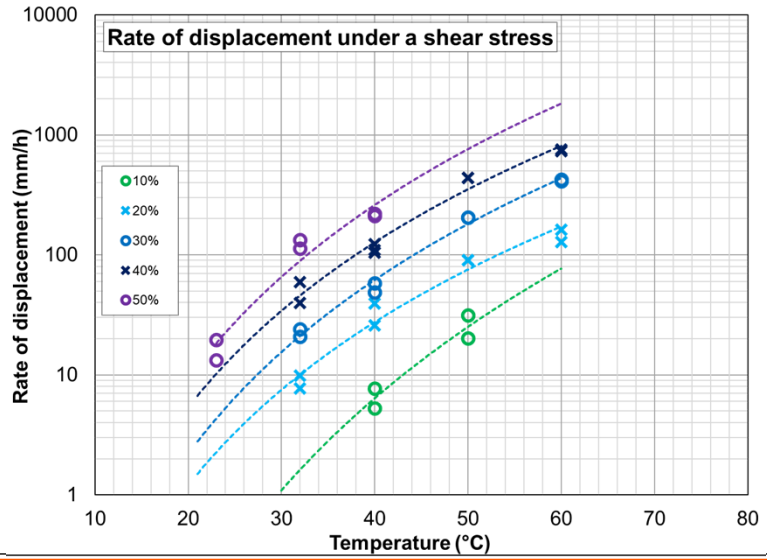
The rate of displacement depends on:

- The temperature
- The applied stress

Which confirms the viscous behavior of the seam in the range of temperature.

i.e., the equation $U = h.\tau/\mu$ appears to control the behavior of the seam, down to 23°C.

Rate of displacement



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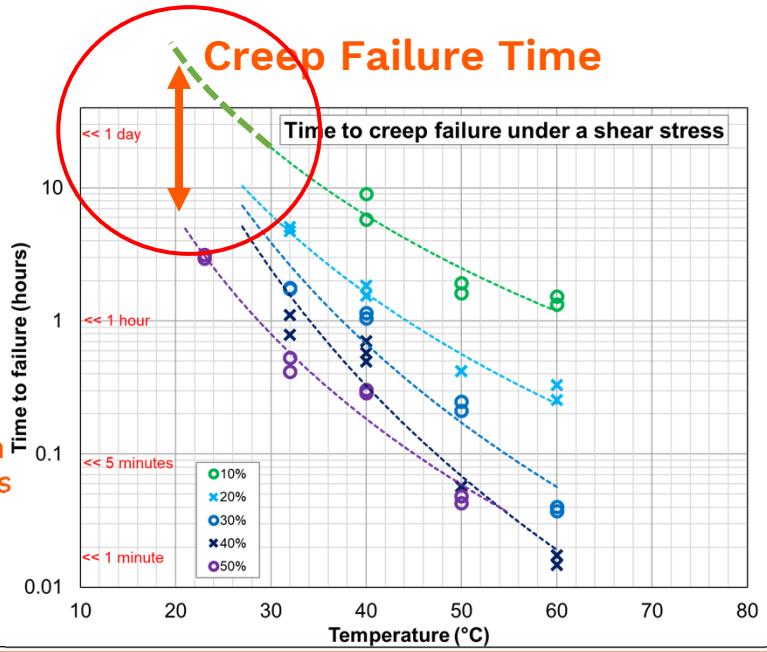
Results – Creep Tests

A failure was observed for every test.

Failure times are short.

Using the trends observed, it is possible to project that the seam exposed to as little as 10% of its short-term strength is likely to fail after a few days at room temperature.

Creep Failure Time



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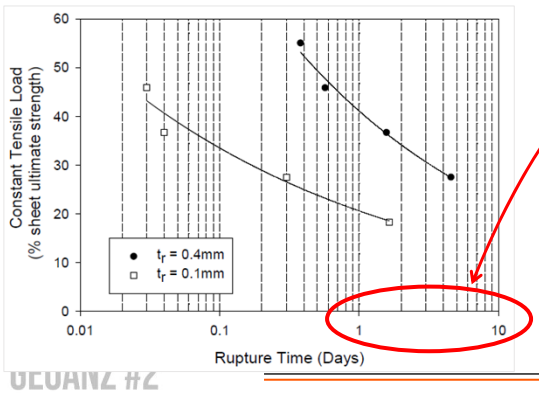
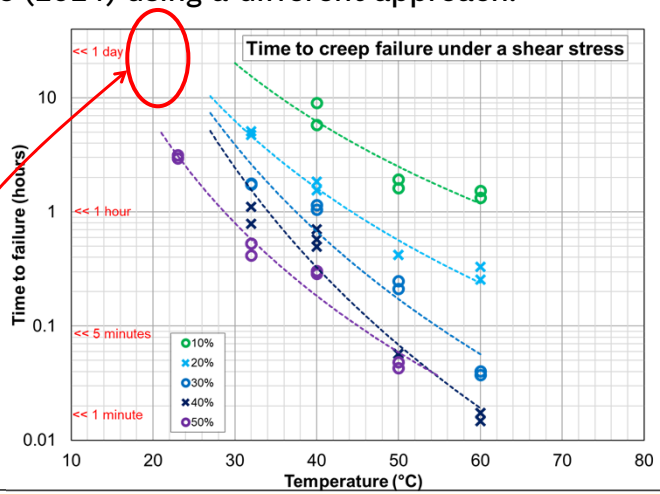
Results – Creep Tests

A projected failure time of a few days at room temperature is consistent with the observations made by Francey and Rowe (2024) using a different approach.

"Factors affecting the tensile strength of bituminous geomembrane seams",
Geosynthetic International, May 2024





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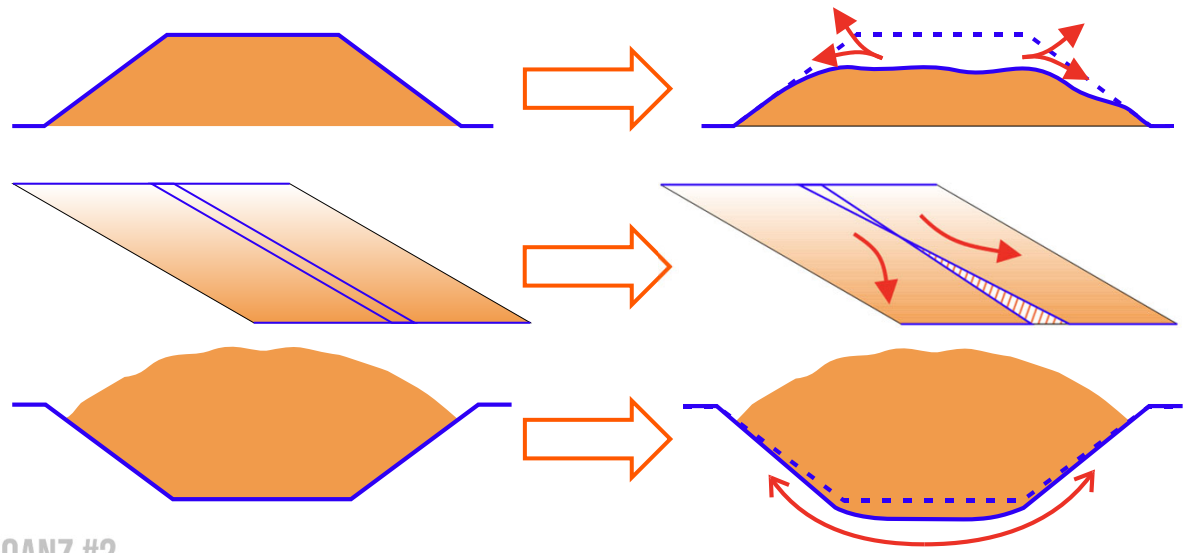
Example of field situation generating stress in geomembrane seams



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Conclusions (Bituminous Geomembrane Seams)
1- Predictable Behavior

- The Short-Term Seam Strength of Bituminous Geomembranes is highly sensitive to temperature.
- The bituminous geomembrane seam exhibits a viscous behavior in the range of temperature tested.
- Consequently, if a seam is exposed to a constant stress in this range of temperature, the time to failure will depend on the temperature and on the stress. But the failure will always come.

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Conclusions (Bituminous Geomembrane Seams)
2- Impact on the Design of Containment Structures

- The Reliability of the Seams depends on the risk of developing stress.
- More specifically:
  - Bituminous membranes have a long history of success when used on buildings, where the substrate is NOT prone to experience significant movements, i.e., where in-plane stress is unlikely to develop.
  - However, if the substrate is likely to settle, in-plane strain, hence in-plane stress, are likely to develop. We have demonstrated here that this scenario could be challenging for bituminous geomembrane seams, which could affect the reliability of the containment structure.

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Conclusions (Bituminous Geomembrane Seams)
3- Terminology

- Due to their viscous behavior, which fundamentally differs from the seams of other types of geomembranes, the terminology 'sealing' would be better-suited than 'welding' to qualify the seams of bituminous geomembrane.

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