

# Performances of GFRP CIPP as Structural Liners

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INNOVATIONS FOR LIVING™

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# Major requirements for struct. pipe liners

- ➡ Stiffness and high  $P_{cr}$
- ➡ Bending / Tensile Strength
- ➡ Fast/easy installation
- ➡ Leak tightness
- ➡ Corrosion / Strain-Corrosion Resistance
- ➡ Environmental friendliness

# How can we get a high Stiffness ?

$$S_r = \frac{EI}{D^3} = \frac{E}{12} \times \left\{ \frac{t}{D} \right\}^3$$

Effect on : ↓↓	thickness	E-modulus
Thickn/Mat'l quantity	-	+
Weight	-	+
Easy handling	-	+
Energy/time to cure	-	+
Risks of undercure	-	+
Risks of cure shrinkages	-	+

# E-Modulus of Liners



EN 13566 Requirements :  $E_b^{sht} > 1500 \text{ MPa}$   
 $E_b^{lt} > 300 \text{ MPa}$  ( $\alpha > 20 \%$ )

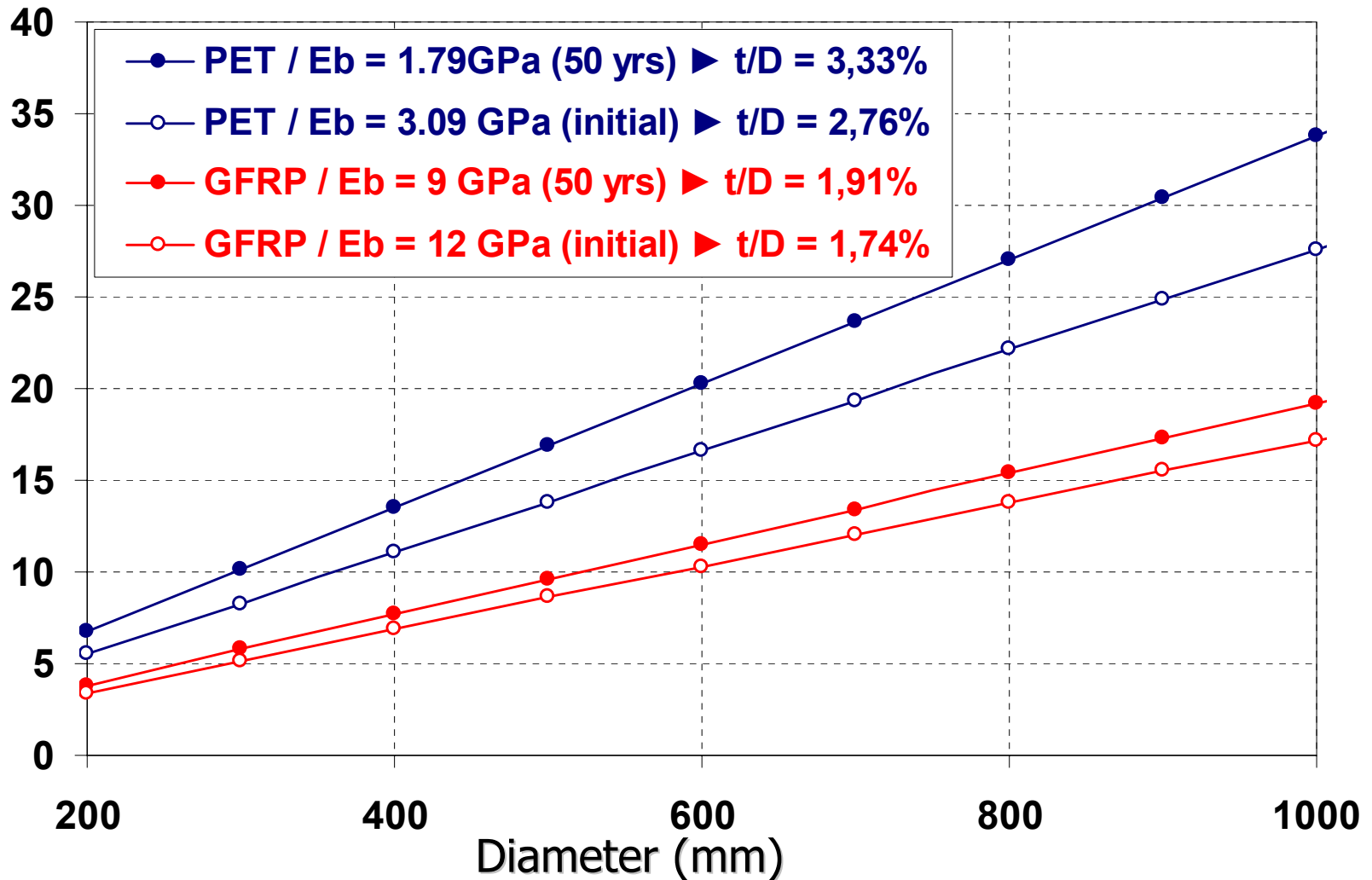
(ISO 14125)	GFRP			PET		
	Before aging	After 100 hrs. H <sub>2</sub> O 40°C	50 years	Before aging	After 100 hrs. H <sub>2</sub> O 40°C	50 years
<b>E-Modulus (Mpa)</b>	11891	12008	± 9000	3090 (*)	2662	1790 (*)
<b>50 y. Creep Factor</b>	-	-	$\alpha = \pm 60$ to 85%	-	-	$\alpha = 58\%$ (*)

(\*) Source : Trenchless Technology Center - Louisiana Tech. Univ.

# Required Liner Thickness To obtain a Liner Stiffness $S_r = 0.040$ (SN 5000)



Liner Thickness (mm)



# Effect of E-Modulus on Critical Buckling Pressure $P_{cr}$

$$P_{cr} = \frac{E}{(1-\nu^2)} \times \left(\frac{t}{D}\right)^{2.2} (*)$$

(\*) Glock's simplified equation  
 (source : L.K.Guice & J.Y.Li, « Buckling Models and Influencing Factors for Pipe Rehabilitation Design »)

Applicable to a rigidly encased thin ring under uniform ext. pressure

		E-mod (Gpa)	t/D for SN = 5000	$P_{cr}$ (Mpa)
<b>GFRP</b>	Initial	12	1,74%	<b>1,78</b>
	50 years	9	1,91%	<b>1,65</b>
<b>PET</b>	Initial	3,1	2,76%	<b>1,26</b>
	50 years	1,79	3,33%	<b>1,11</b>

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# Bending Strength of Liners



EN 13566 Requirements :  $\sigma_b > 25\text{MPa}$  and  $\varepsilon_b > 0.75\%$

(ISO 14125)	<b>GFRP</b>	
	Before aging	After 100 hrs H <sub>2</sub> O 40°C
<b>Bending Strength (Mpa)</b>	358	319
<b>Bending Strain (%)</b>	4,2	3,4



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# Fast/easy installat<sup>o</sup> with trenchless CIPP



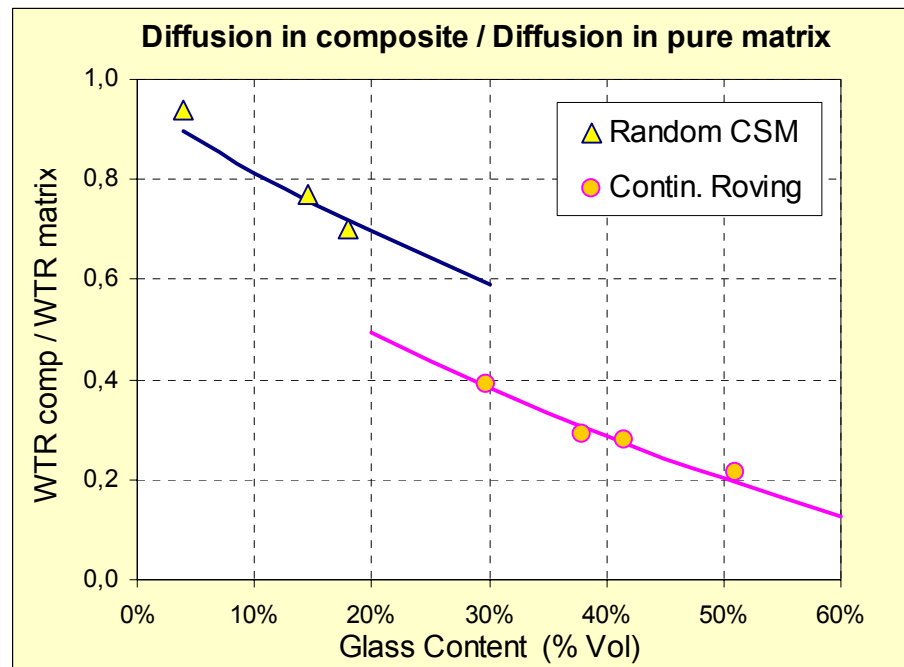
- Glass fibers → low thickn./stiffn. ratio → low wgt → easier handling
- Glass fibers → low thickness → fast /full cure ... with UV or heat
- Glass fibers translucency → full cure with UV light
- Often preimpregnated
- Fast installation : winch-in-place or inversion
- Reduced noise and traffic discomfort

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# Leaktightness : effect of glass fibers

- High strength → high pressure resistance
- Lower water absorption and diffusion (= low permeability)



- Correct selection of fiber sizing/binder will further minimize water absorption and aging

# Leaktightness test



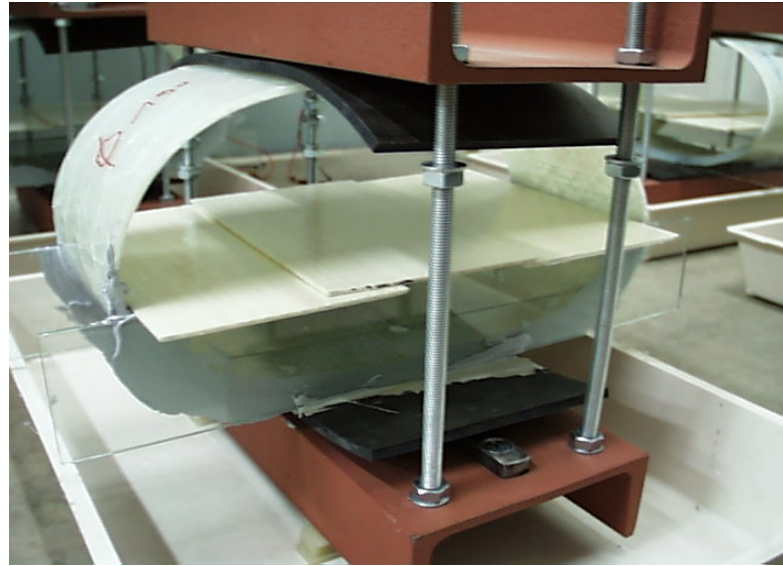
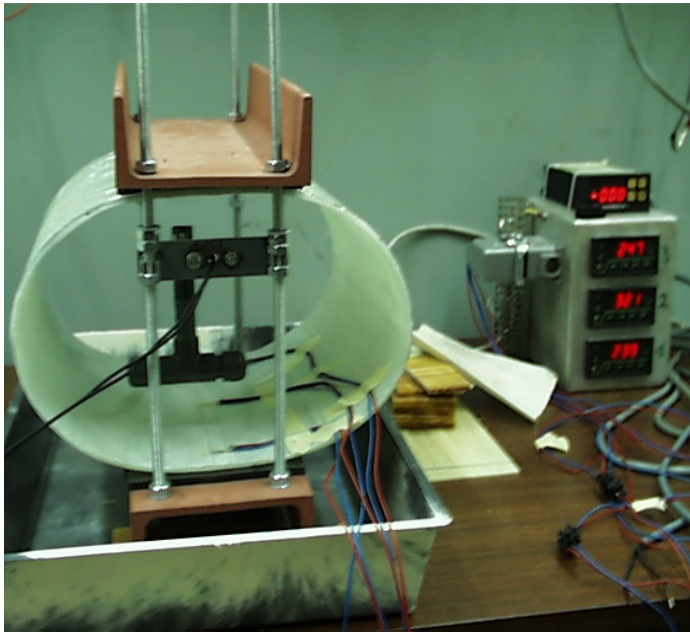
Source : IKT Gelsenkirchen - Germany

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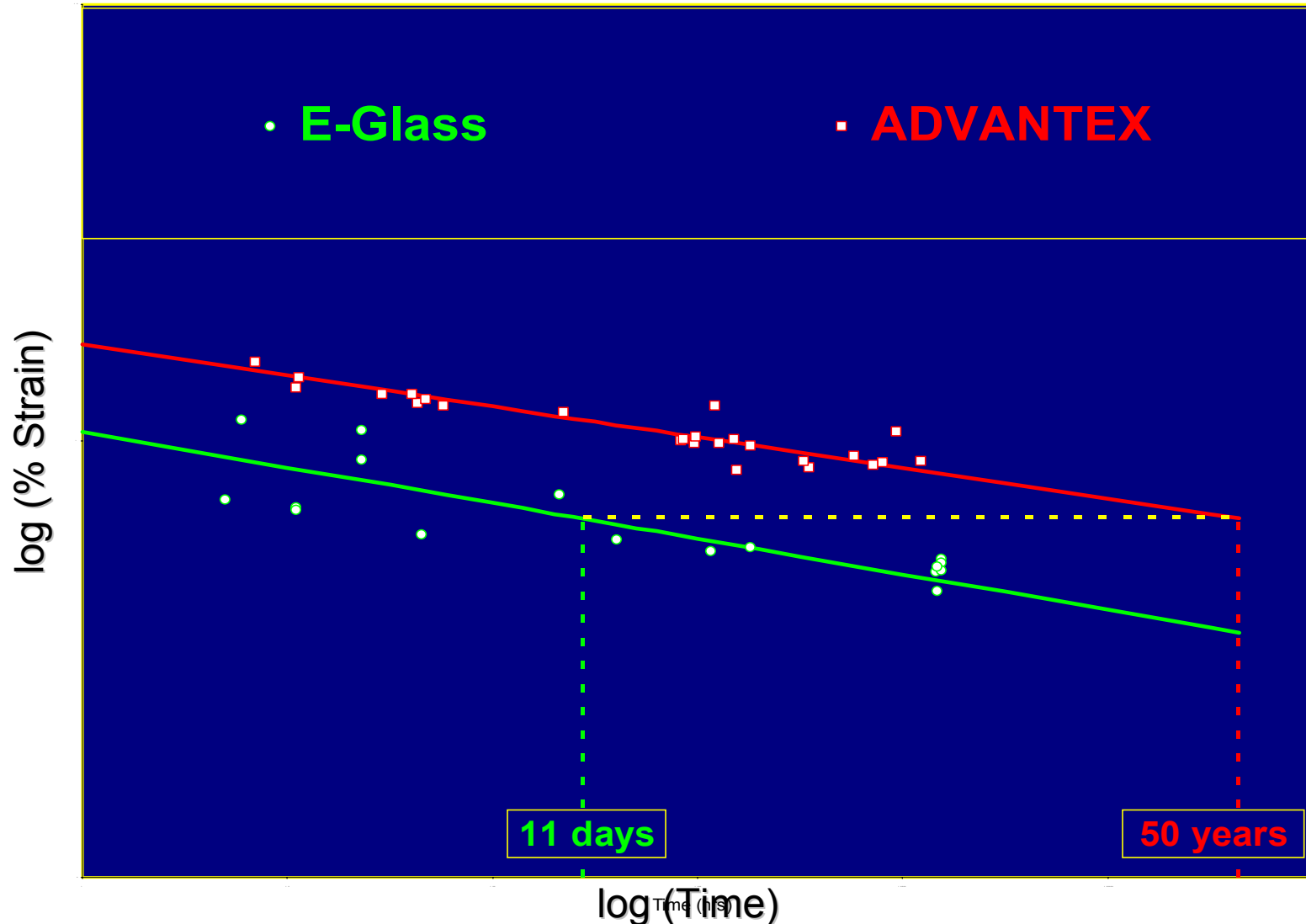
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# Strain-Corrosion of Pipe Rings in diluted $H_2SO_4$



# Strain-Corrosion of Pipe Rings in diluted $H_2SO_4$ (10%)





# What is **ADVANTEX**® glass ?



Advantex® glass = E-glass, boron-free  
= E-CR glass

It combines :

- electrical and mechanical properties of traditional E-glass
- corrosion resistance of E-CR glass

# Advantex<sup>®</sup> glass meets the following glass standards



Designation: D 578 – 00

**Standard Specification for  
Glass Fiber Strands<sup>1</sup>**

DEUTSCHE NORM

September 2001

	<b>Glas</b> Teil 1: Begriffe für Glasarten und Glasgruppen	<b>DIN</b> 1259-1
ICS 01.040.81; 81.040.01		Ersatz für DIN 1259-1:1986-09
Glass — Part 1: Terminology for glass types and groups		
Verre — Partie 1: Terminologie pour type de verre et groupe de verre		

**INTERNATIONAL STANDARD**

**ISO 2078:1993(E)**

**Textile glass — Yarns — Designation**

# Single Filament Tensile Properties

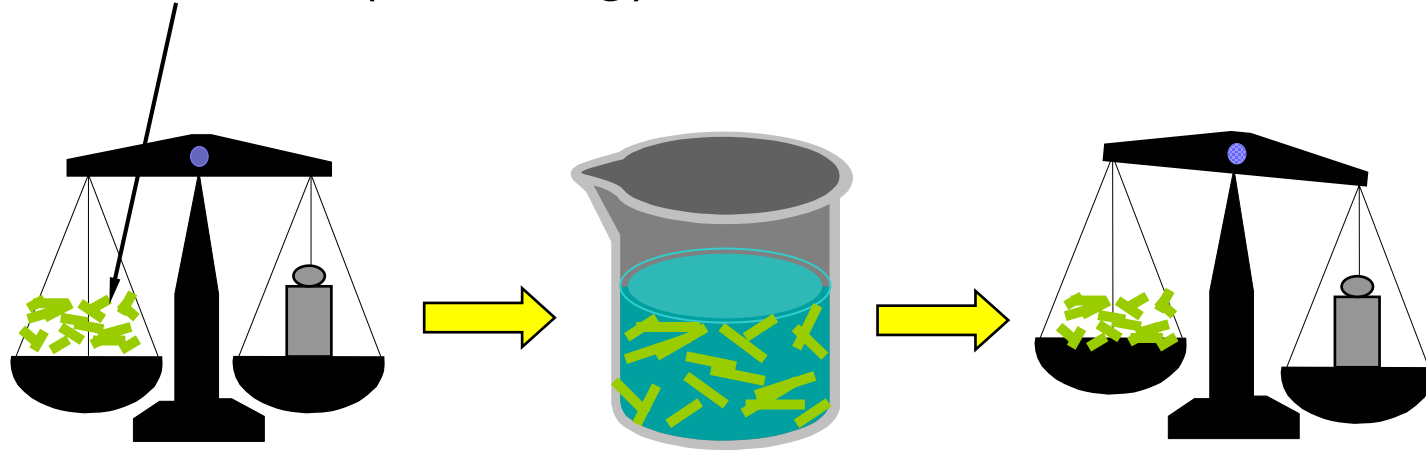


Test Method : ASTM D2101

	Advantex® glass	Traditional E-glass
Tensile Strength (MPa)	3100 - 3800	3100 - 3800
Tensile Strain (%)	4,2 - 4,6	4,2 - 4,5
Young's Modulus (GPa)	74 - 75	72 - 73

# Glass Weight Loss Tests

Glass fibers (no sizing)

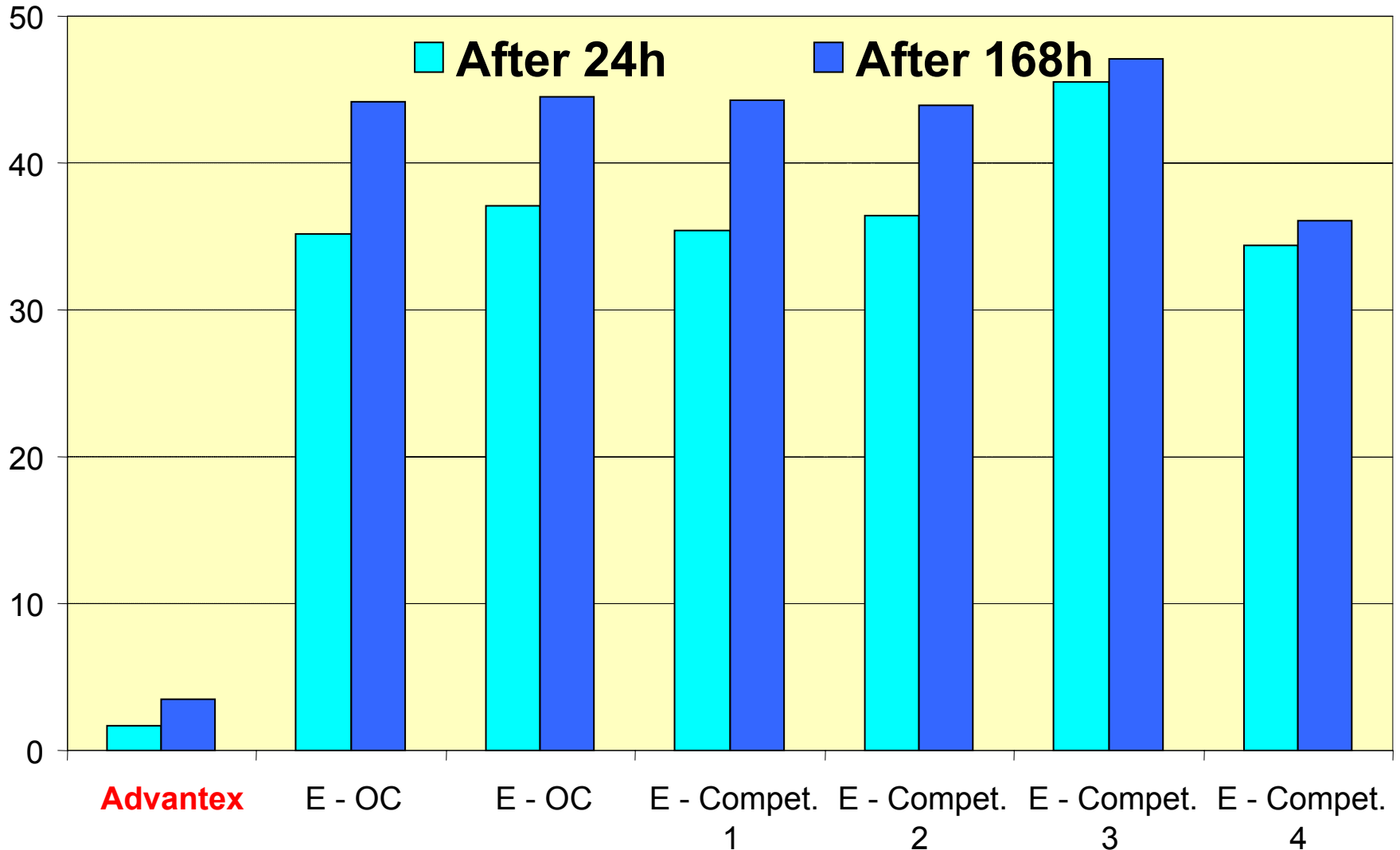


Weigh

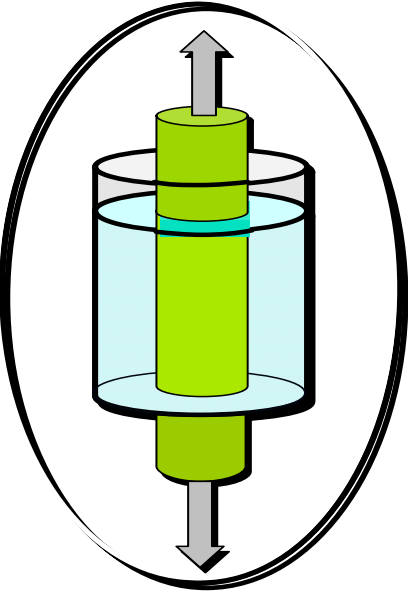
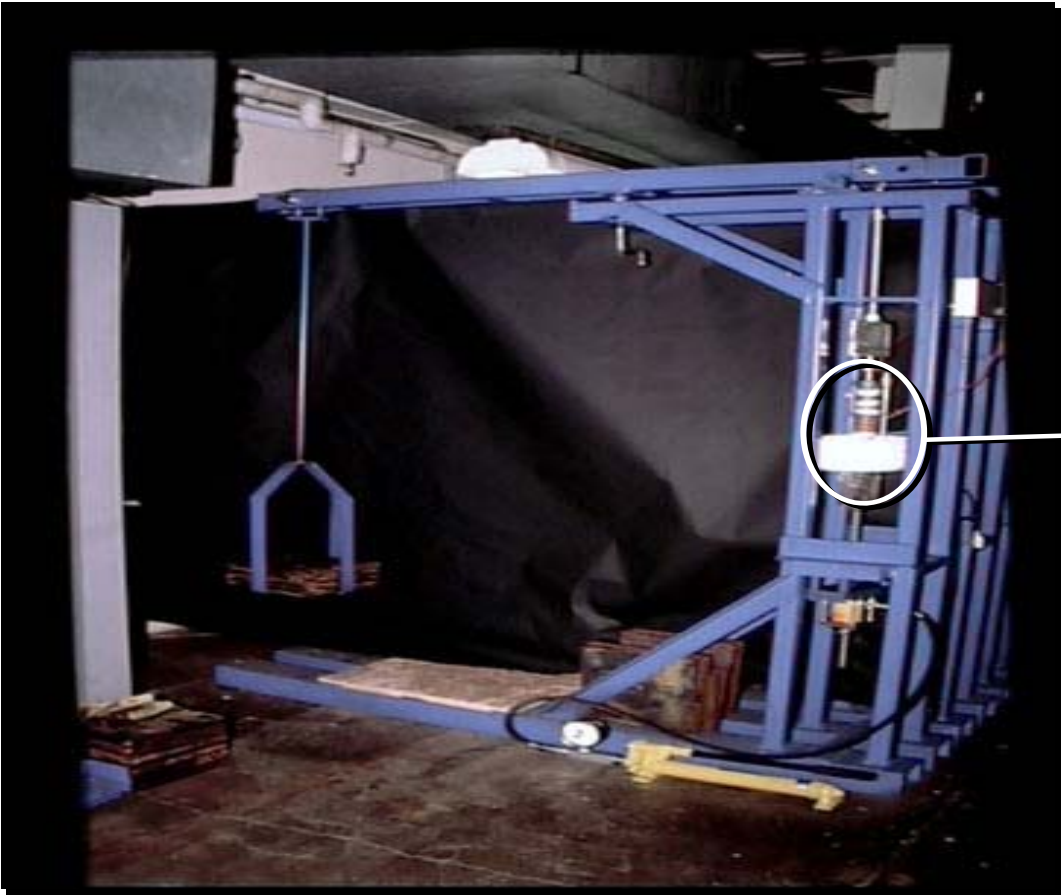
Immersion  
for 24 - 168 hrs  
96°C

Weigh again

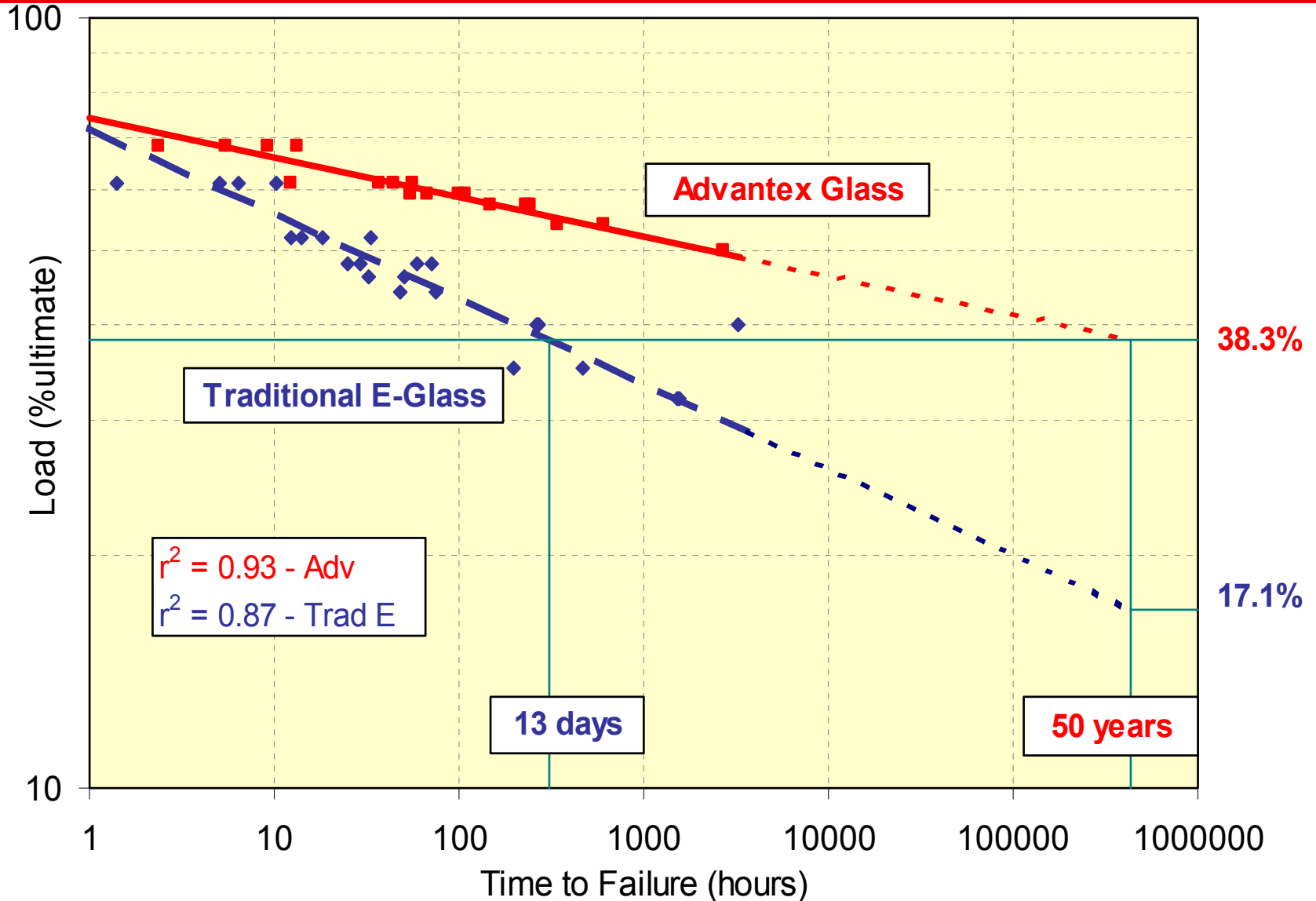
# Glass Weight Loss (%) in 10% HCl



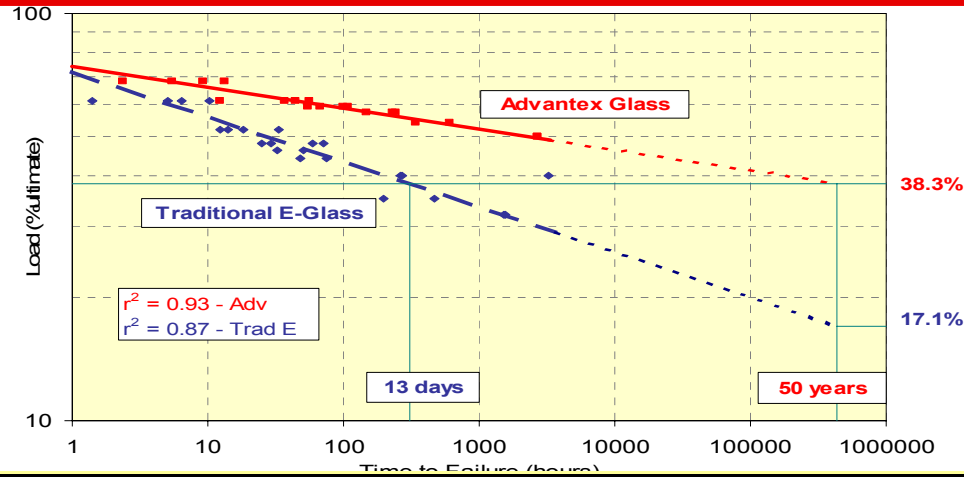
# Tensile Stress Corrosion to Rupture of Composite Rods



# Tensile Stress Corrosion to Rupture of Composite Rods in Tap Water



# Summary : Difference in Time to Failure at Same Stress Level



Life time at same stress level	Advantex® glass	Traditional E-glass
Salt Water	50 yrs	3 mo.
Tap Water	50 yrs	13 days
Deionized Water	50 yrs	5 days
Cement Extract	50 yrs	1 yr
pH 1 Acids	50 yrs	4 days



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# Environmental friendliness

## ... from beginning to end of chain



Advantex® glass / new technology → improved environment :

- Advantex® glass : boron-free, no added fluorine.
- Particulate reduction : ca. 85%
- Fluoride reduction : 50 to 90%
- NOx reduction :  $\geq 80\%$
- Advantex® glass fibers are non-respirable

# CONCLUSIONS (1)

## Glass Fibers provide :



- ▶ Stiffness / Stability for Structural Repairs
- ▶ Bending Strength
- ▶ Tensile Strength for Pressure Pipes
- ▶ Dimensional Stability (low shrink - low therm.exp.)
- ▶ Low Thickness (lower cure energy)
- ▶ Relatively low Weight

# CONCLUSIONS (2)

## Advantex<sup>®</sup> glass provides



- ▶ Environmental friendliness
- ▶ Experience and standardization (DIN, ASTM, ...)
- ▶ Long term durability (acid, water, alkali)
  - higher retention factors in all environments
- ▶ Worldwide availability in all forms  
(including various fabrics for pipe liners)

Thank you

Questions ?