THE PERFORMANCE OF CURVED FRP REINFORCEMENT FOR CONCRETE STRUCTURES

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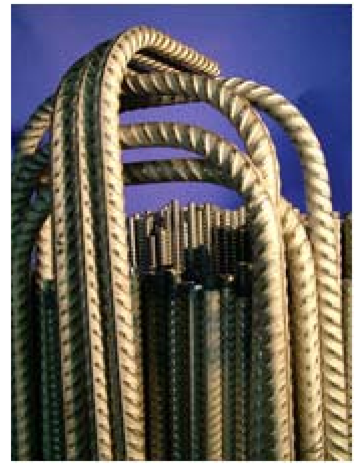
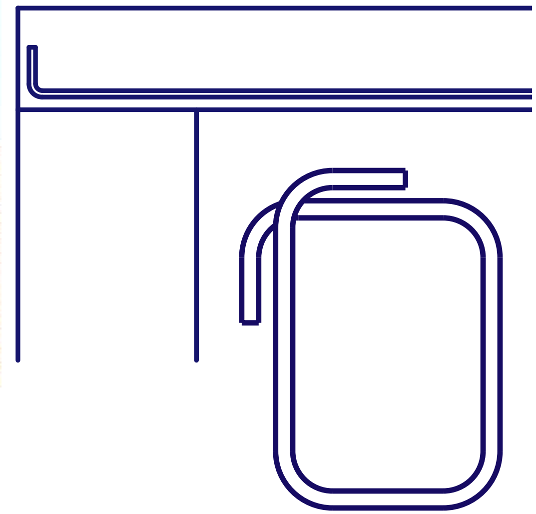
Outline

- Introduction
- Performance of bent FRP’s
- Experimental programme/results
- Conclusions

Introduction

- End anchorages

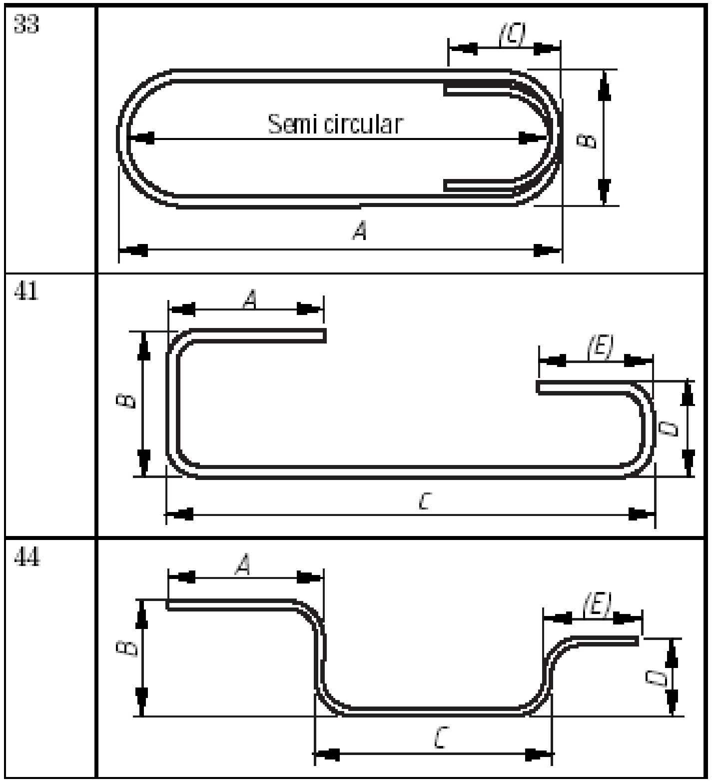


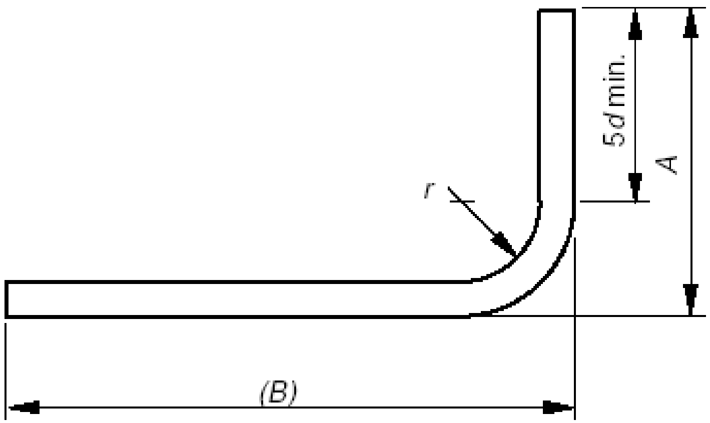


- Element connection

- Shear reinforcement

Introduction

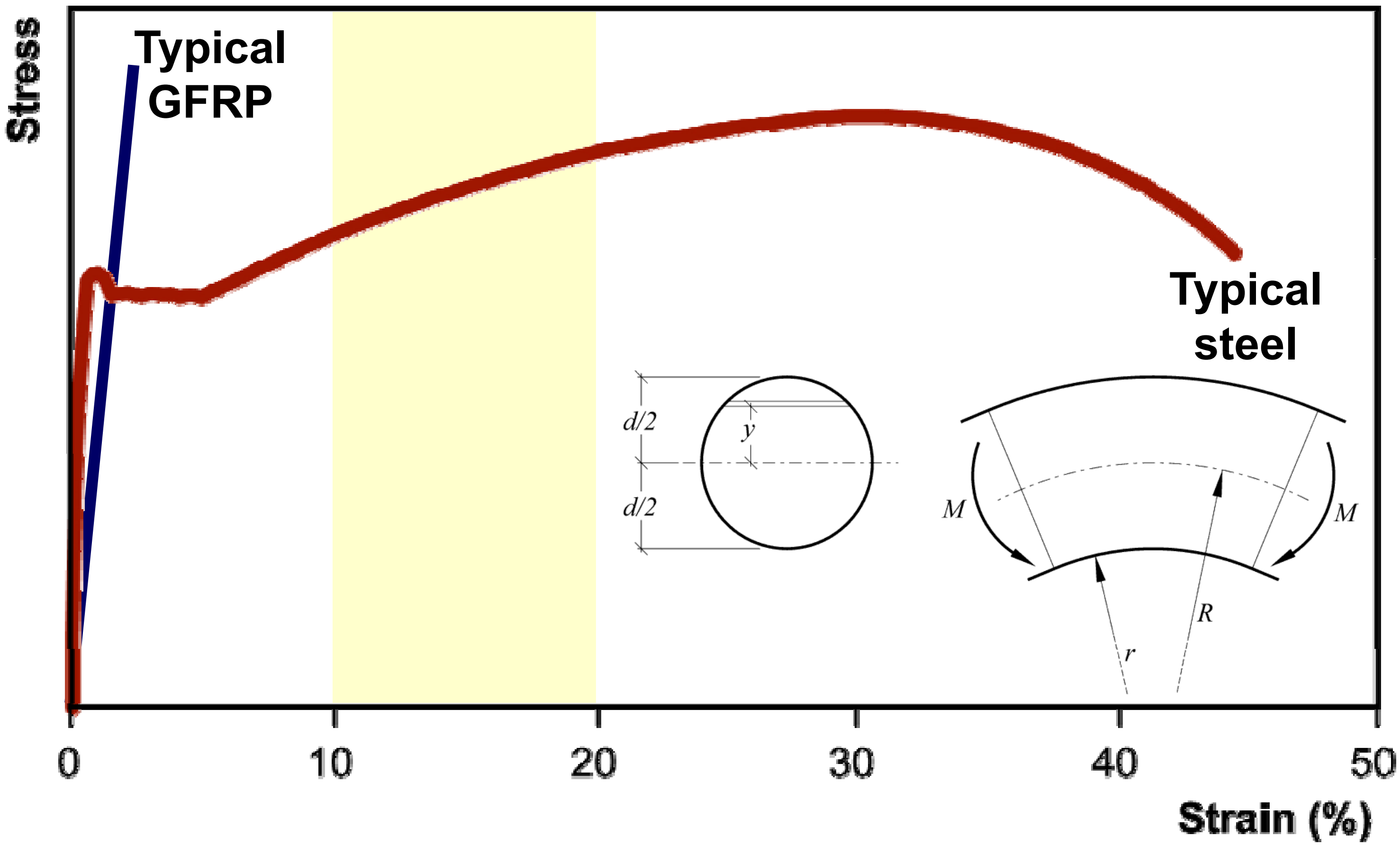




r ≥ 2

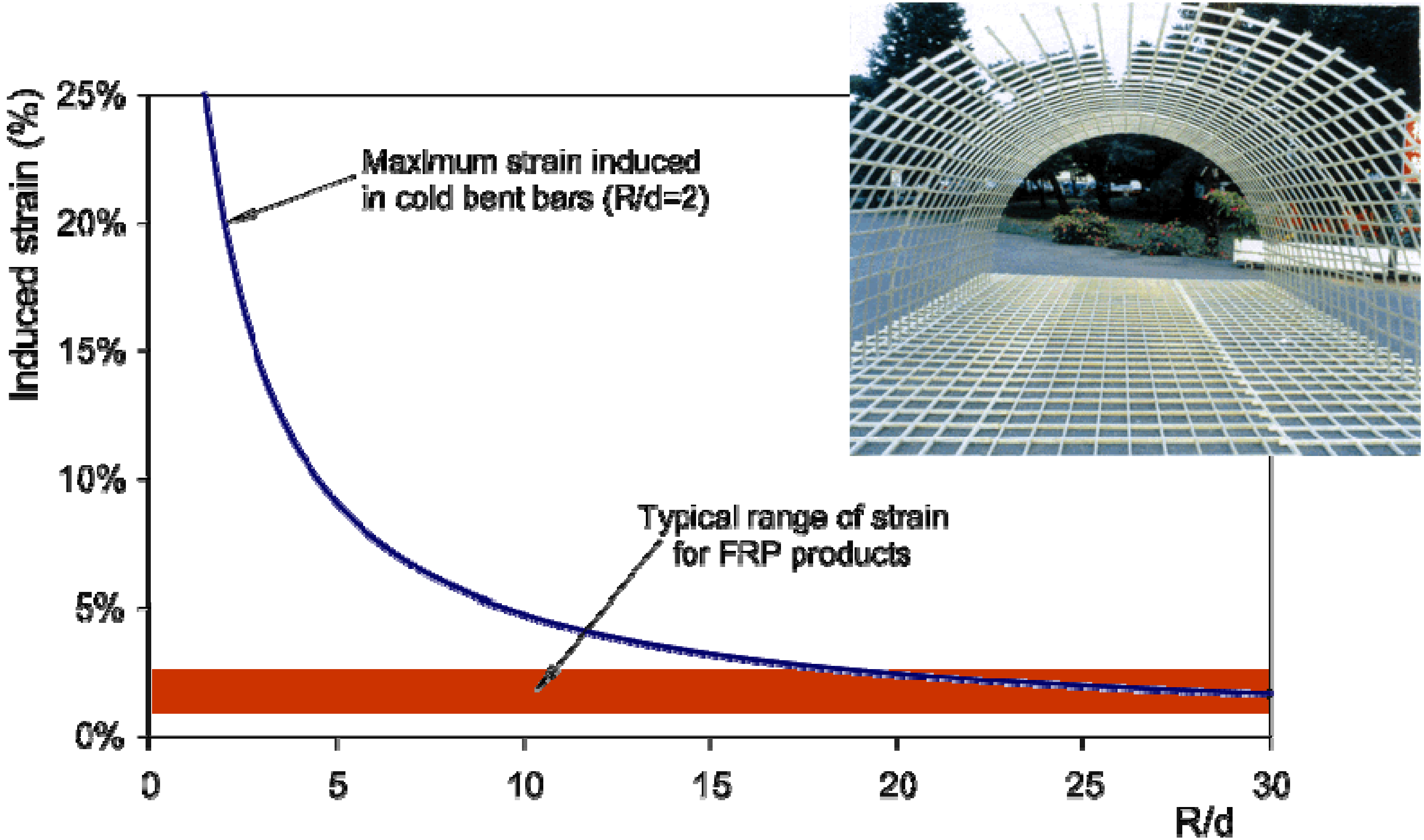
Standardised shapes (BS8666)

Introduction

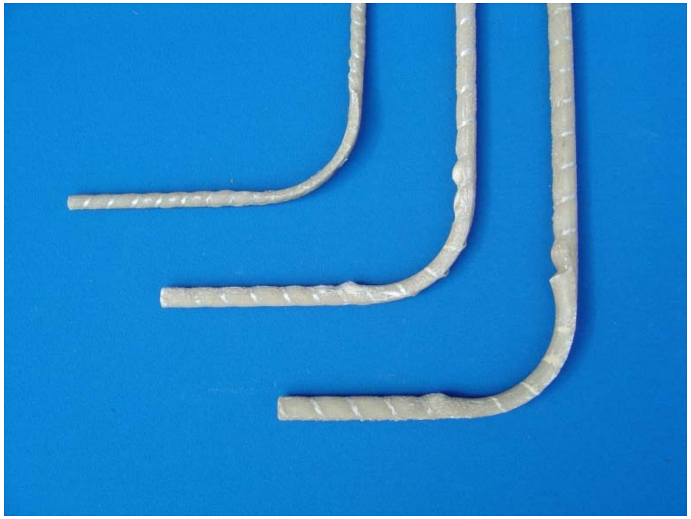


Plastic strain induced by bending

Introduction



Pre-bent FRP's

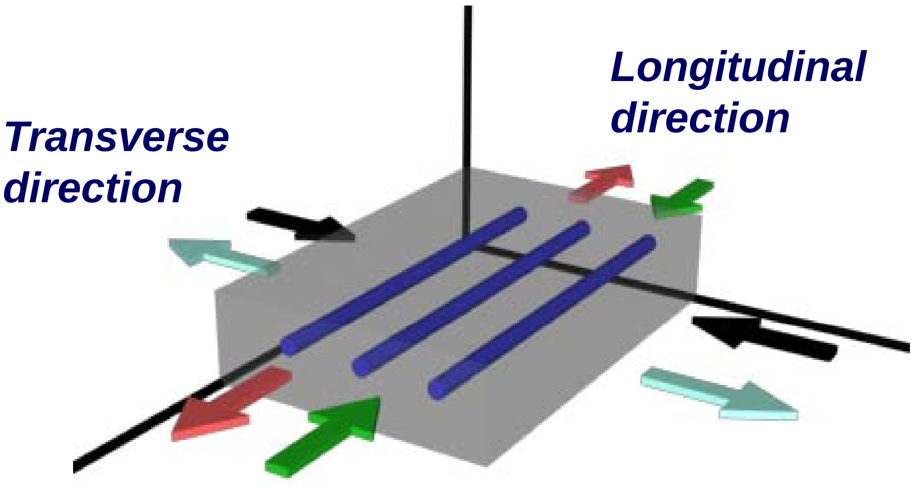


- **Thermosetting FRP's:**
  can only be pre-bent at the factory

- **Thermoplastic FRP's:**
  could offer a valid solution for on-site bending of reinforcement

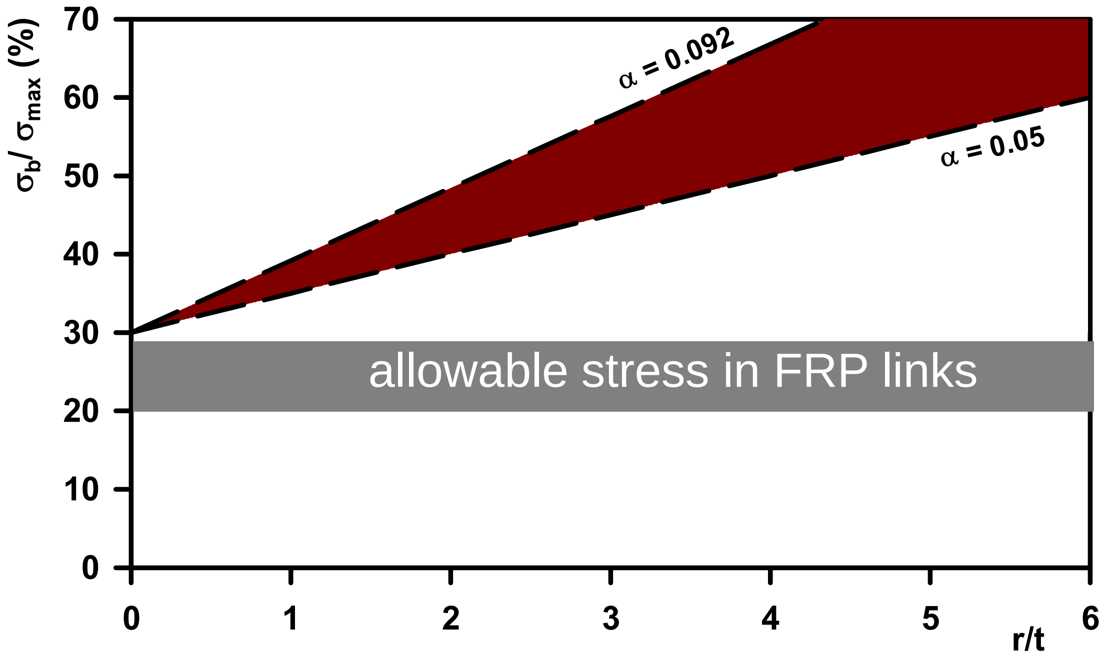
Performance of bent FRP's

The tensile strength of FRP bars can be largely reduced when subjected to a biaxial state of stress



Premature failure at bent portion

Design equation (JSCE)



$$f_{fb} = \left(\alpha \frac{r_b}{d_b} + 0.3 \right) f_{fu} \leq f_{fu}$$

r_b is the radius of the bend in the bar
d_b is the nominal diameter of the FRP bar
f_{fu} is the design strength of a straight portion of the bar

Performance of bent FRP's

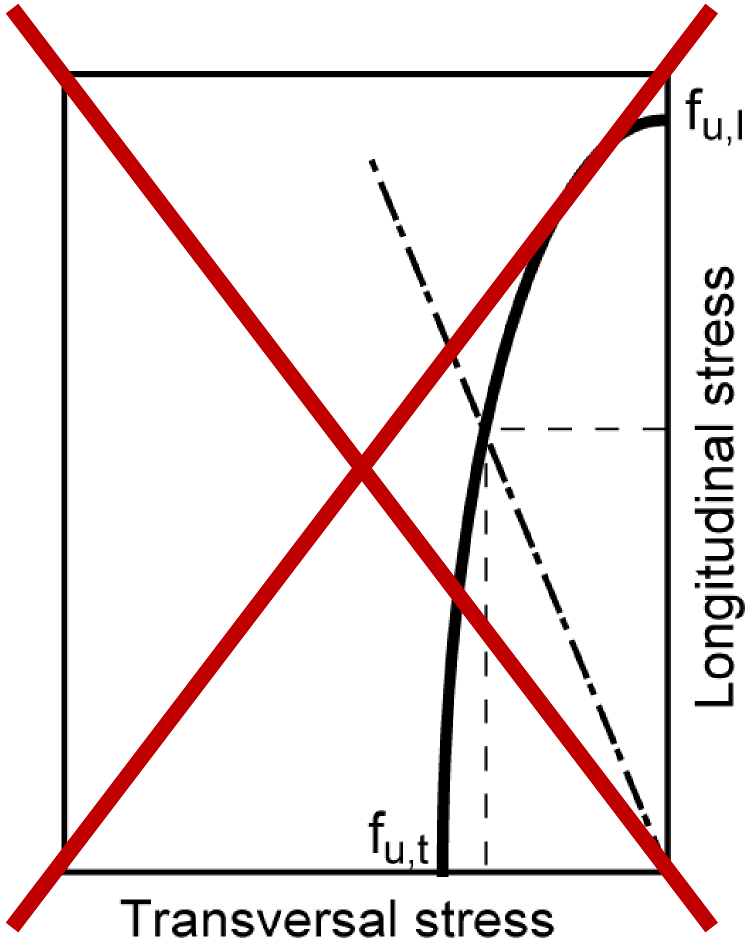
$$f_{fb} = \left(\alpha \frac{r_b}{d_b} + 0.3 \right) f_{fu} \leq f_{fu}$$

Bend geometry

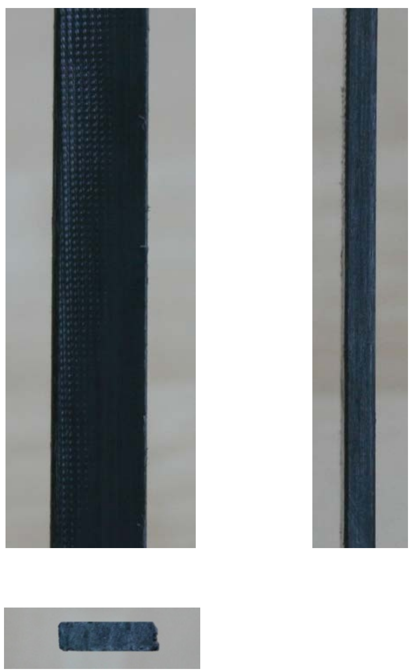
- r/t

~~Composite make-up~~

- ~~type of fibres~~
- ~~type of resin~~
- ~~volume fractions~~



GFRP thermoplastic strip (12x3mm)

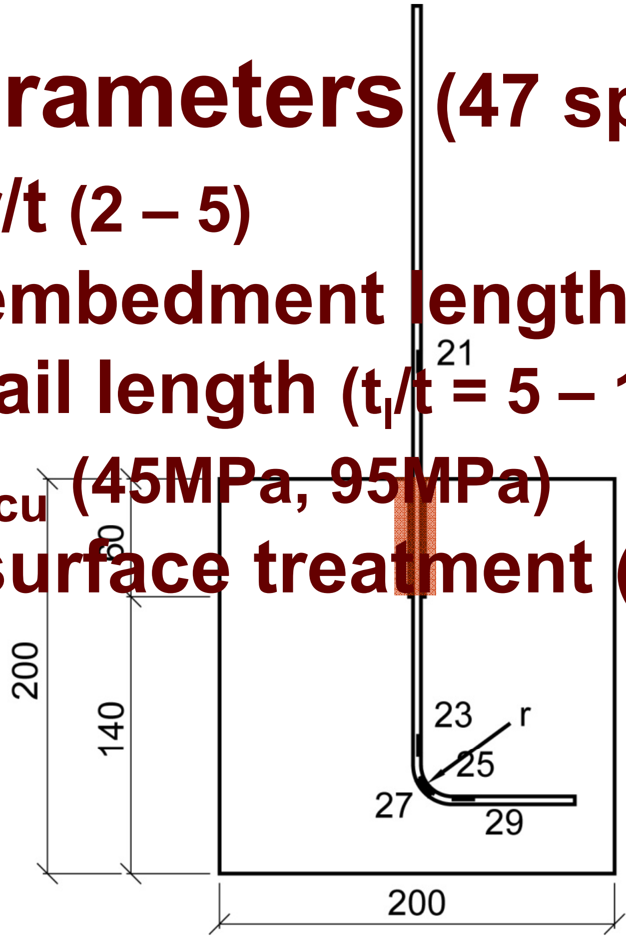


Properties	
Tensile strength (MPa)	720
Tensile modulus (GPa)	28
Ultimate strain (%)	1.9
Glass content (%v/v)	35
Density (g/cm3)	1.48

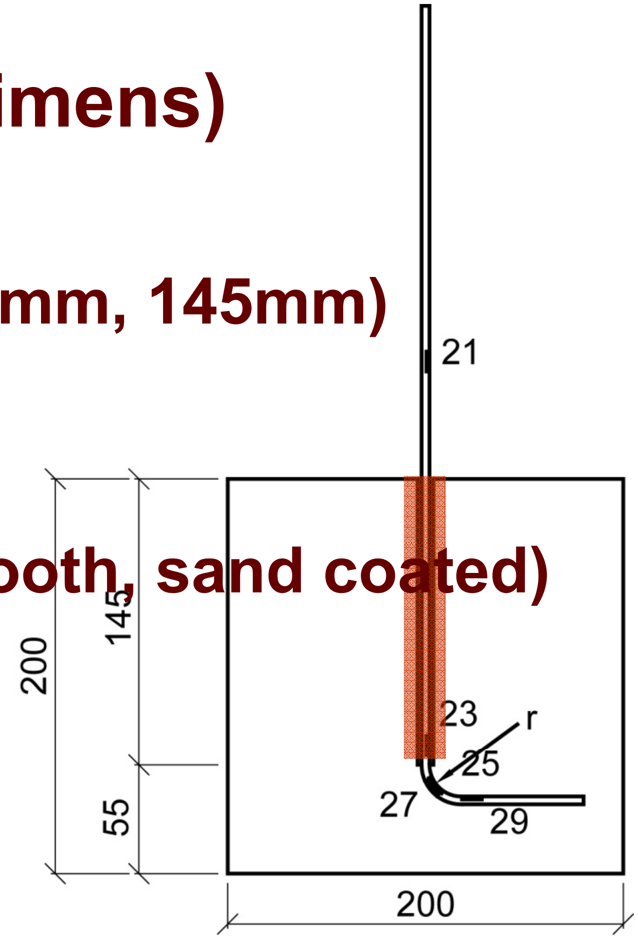
Experimental programme

Parameters (47 specimens)

- r/t (2 – 5)
- embedment length (60mm, 145mm)
- tail length (t_l/t = 5 – 15)
- f_{cu} (45MPa, 95MPa)
- surface treatment (smooth, sand coated)

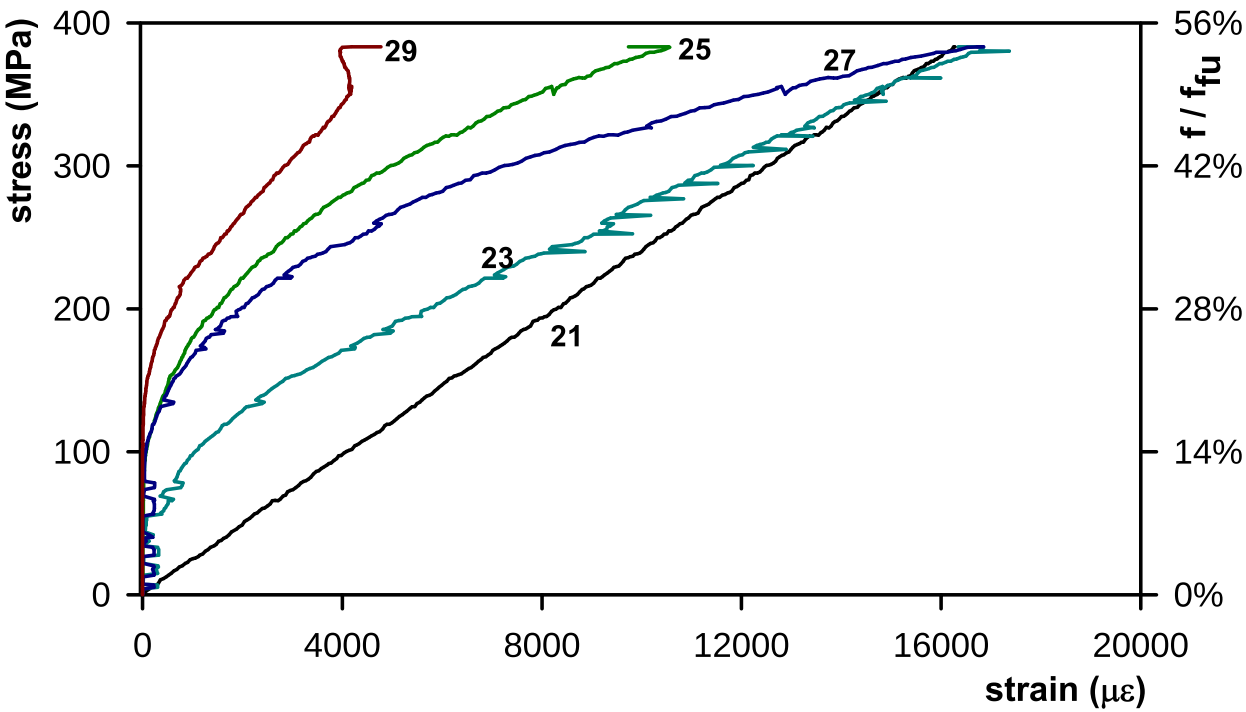


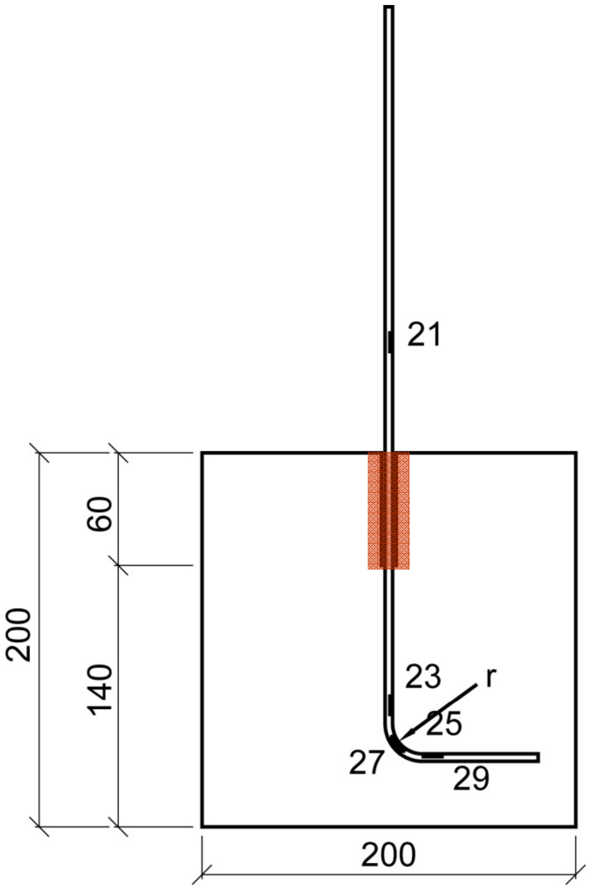
Type 2



Type 3

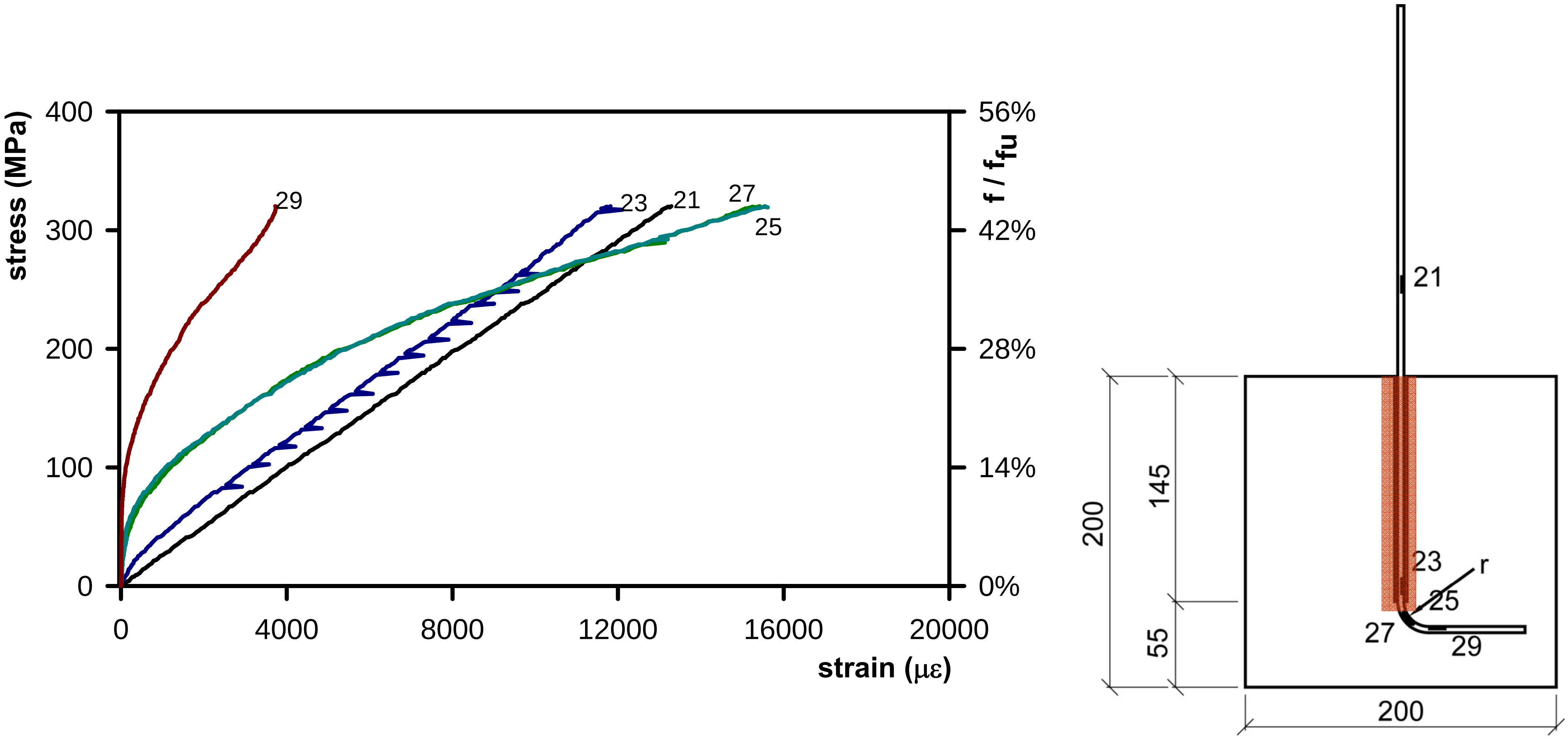
Experimental results





Strain distribution in specimens Type 2

Experimental results

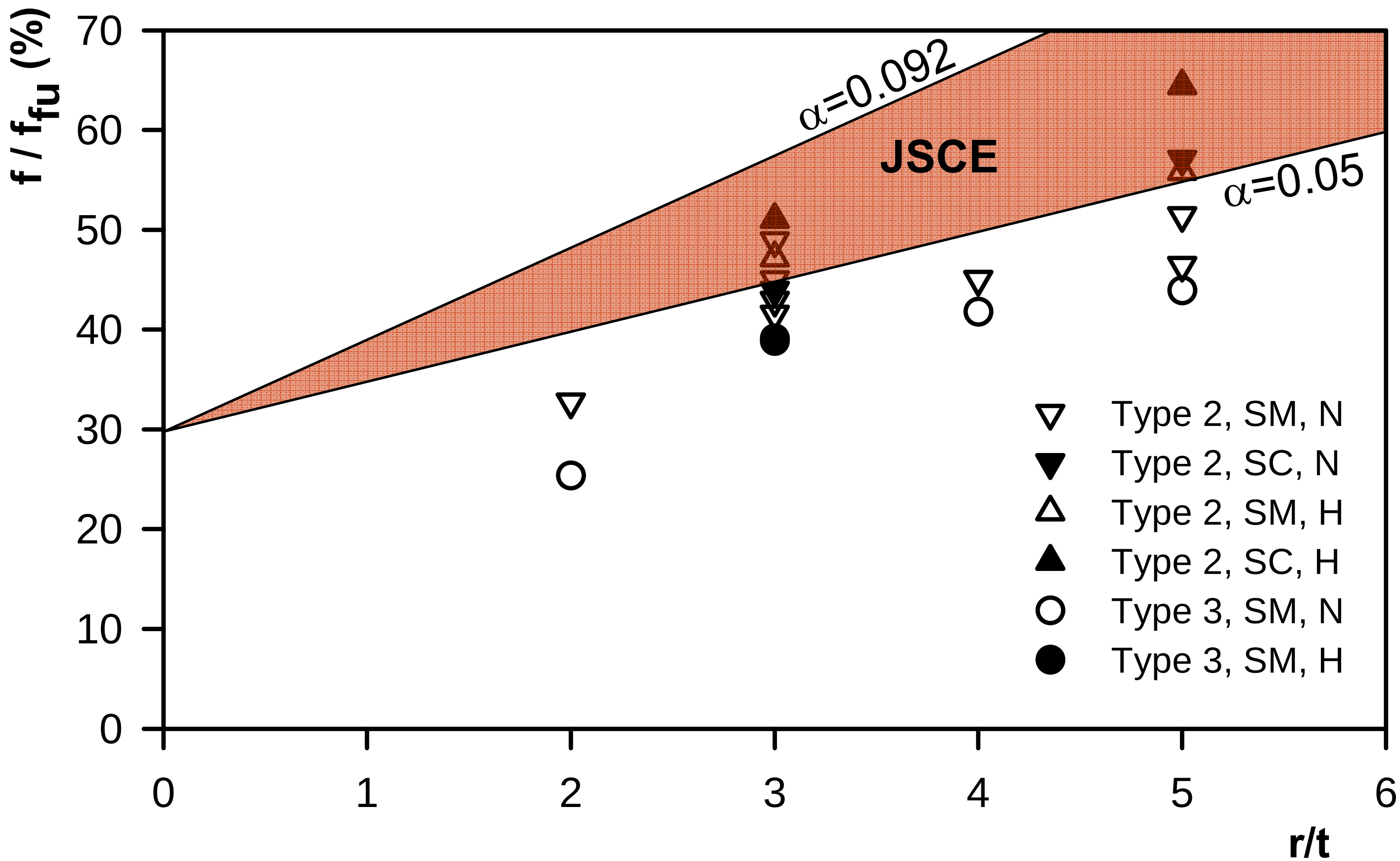


Strain distribution in specimens Type 3

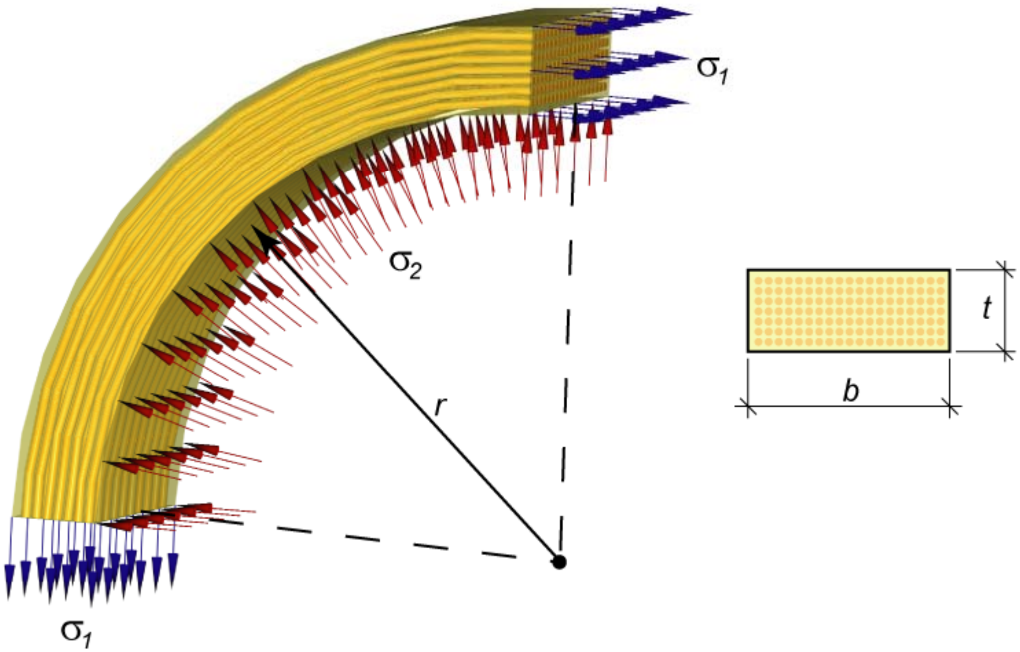
The University Of Sheffield.

Performance of bent FRP's

The Concrete Centre



A Macromechanical approach



- **Force equilibrium**

$$\sigma_2 = \sigma_1 \frac{t}{r}$$

- **Failure criterion**

$$\frac{\sigma_1^2}{\sigma_{1,\max}^2} - \frac{\sigma_1 \sigma_2}{\sigma_{1,\max}^2} + \frac{\sigma_1^2}{\sigma_{2,\max}^2} = 1$$

A Macromechanical approach

- **Predictive model**

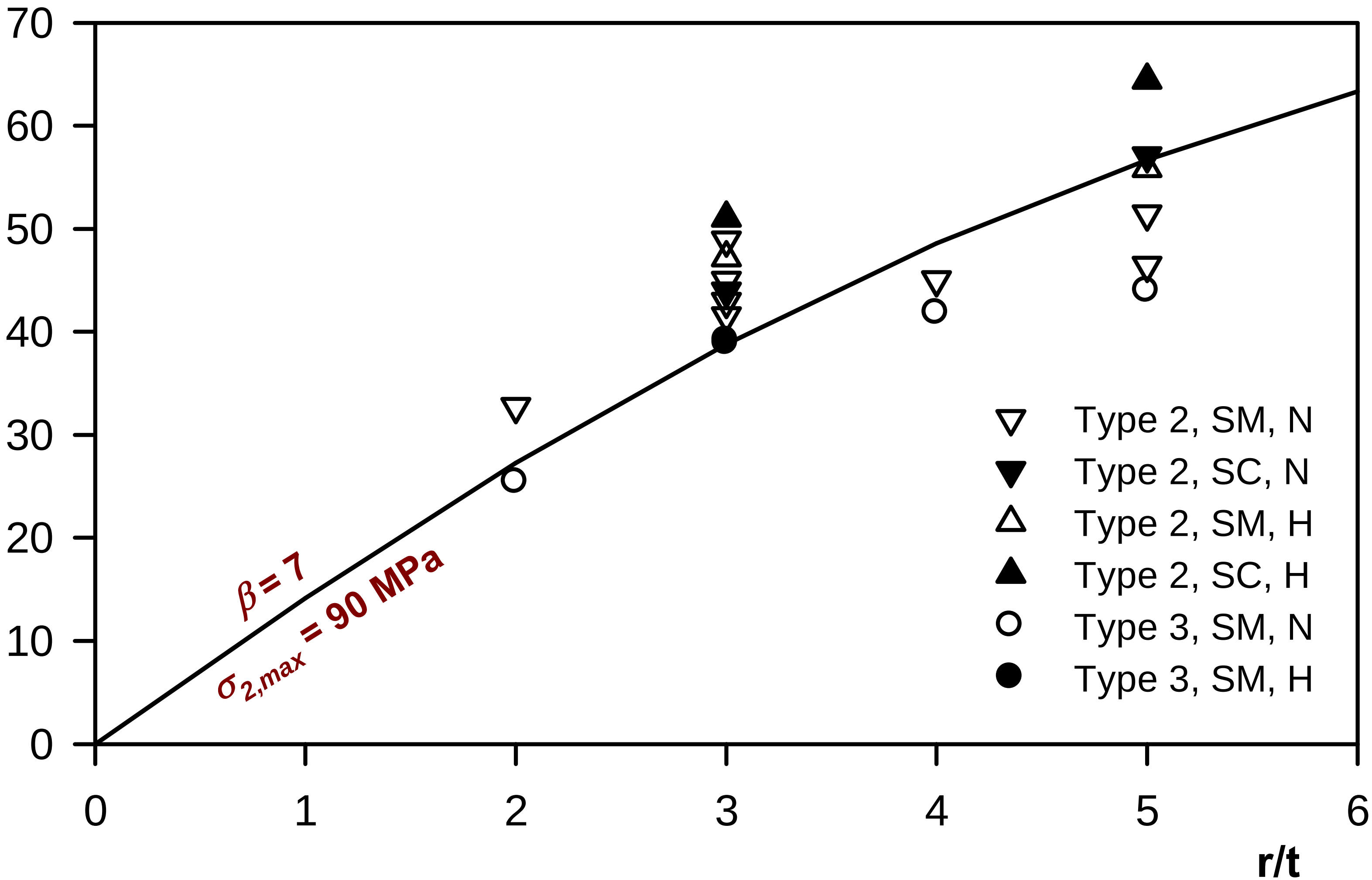
$$\frac{\sigma_1}{\sigma_{1,\max}} = \frac{1}{\sqrt{1+\left(\frac{h}{R}\right)+\left(\frac{h}{R}\right)^2 \cdot \beta^2}}$$

- **Material testing**
- **Micromechanics**

$$\sigma_{2,\max} = \frac{1}{k_\sigma}\left(f_{mc}+\sigma_{rm}\right)$$

$$\beta = \frac{\sigma_{1,\max}}{\sigma_{2,\max}}$$

A Macromechanical approach



Final Remarks

- The capacity of the bent portion is not only a function of its geometry
- Values of r/t > 3-4 guarantee the development of 40% of the ultimate strength
- The macromechanical based model adequately captures strength degradation of bent bars