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THE PERFORMANCE OF CURVED NON-FERROUS REINFORCEMENT FOR CONCRETE STRUCTURES

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Outline



- **Why bending reinforcement?**
- **Design of bent reinforcement**
- **Performance of bent FRP's**
- **Experimental program**
- **Experimental results**
- **Conclusions**

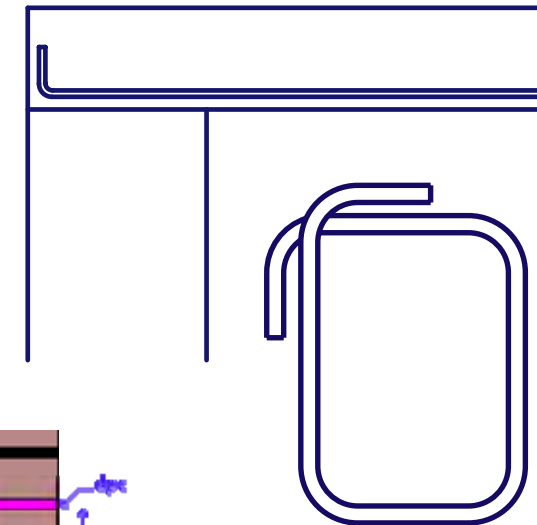


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Why bending reinforcement?

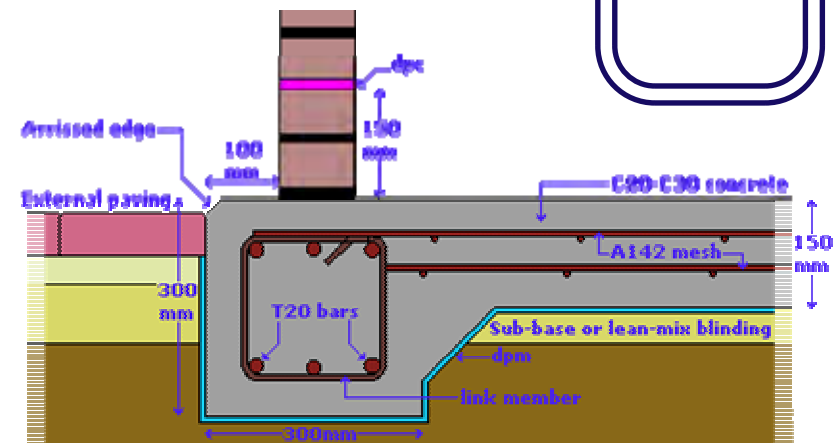


- End anchorages



- Element connection

- Shear reinforcement





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Types of curves (BS8666)



Shape code	Shape
00	
11	
12	
13	
15	
21	

25	
26	
31	
33	
41	
44	

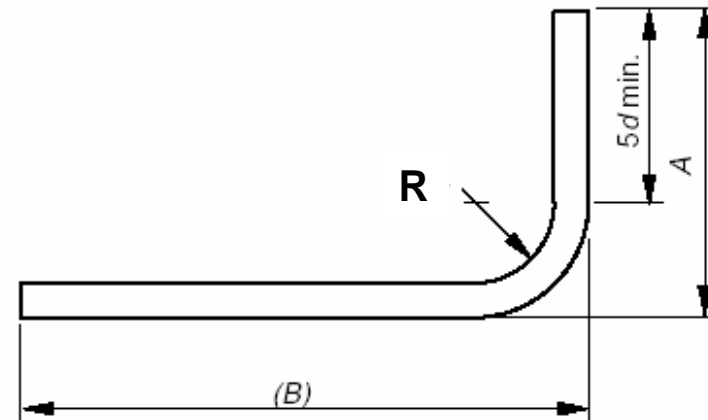
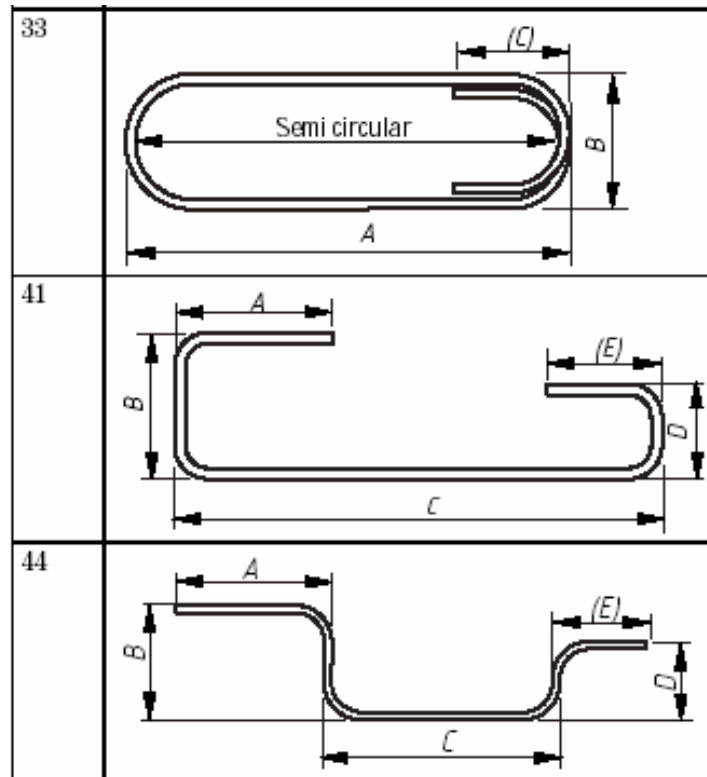
46	
51	
77	
77	
99	<p>All shapes where standard shapes cannot be used. No other shape code number, form of designation or abbreviation shall be used in scheduling. With the exception of rectangular links, 5 bends or more are undesirable and may be impractical within permitted tolerances but they shall be drawn out in full and coded 99.</p> <p>A dimensioned sketch shall be drawn over the dimension columns A to E. Every dimension shall be specified and the dimension that is to allow for permissible deviations shall be indicated in parenthesis, otherwise the fabricator is free to choose which dimension shall allow for the tolerance</p>

Minimum number?



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Specification for bending



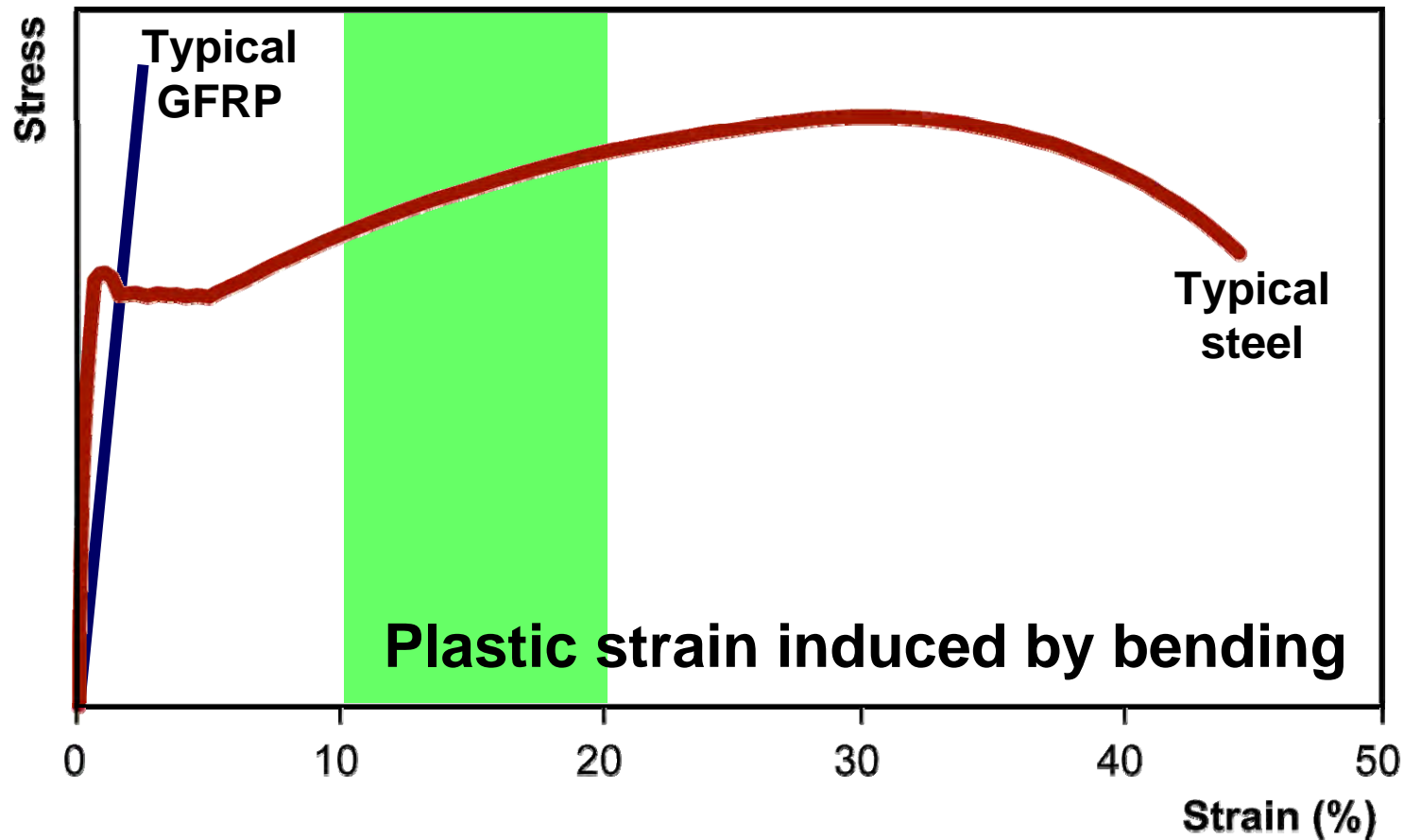
$$R \geq 2d$$

Standardised shapes (BS8666)



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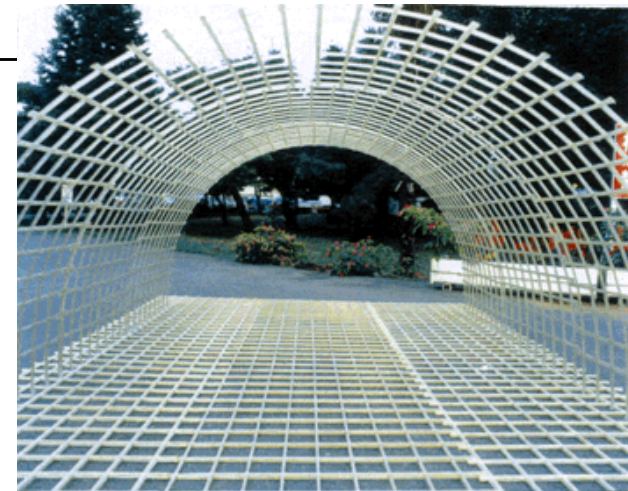
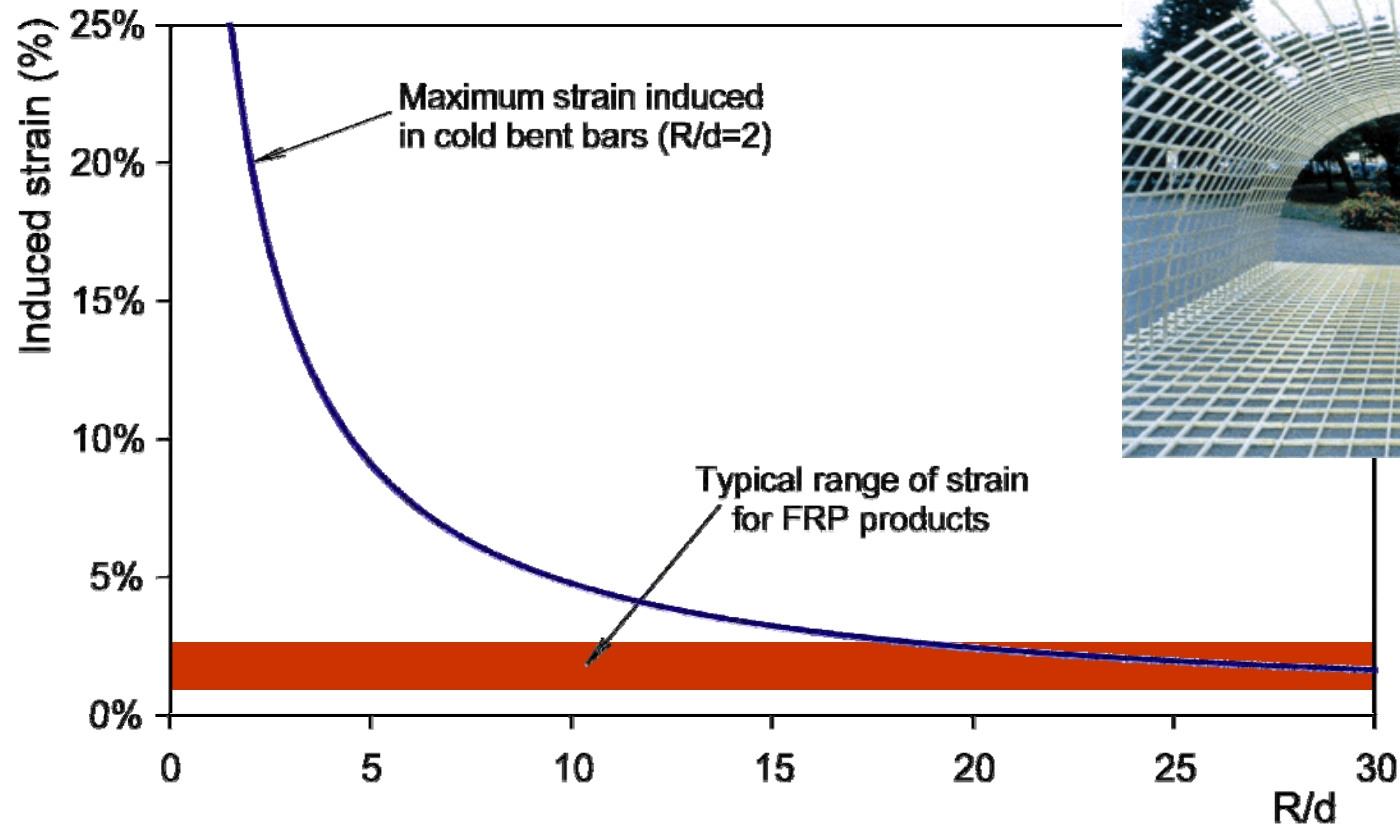
Specification for bending





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Cold bending of FRP's



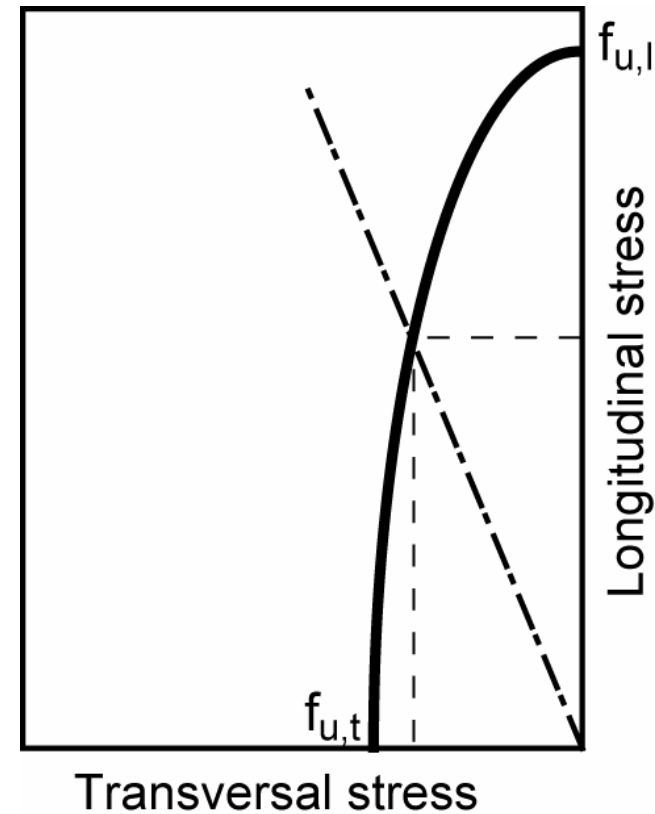
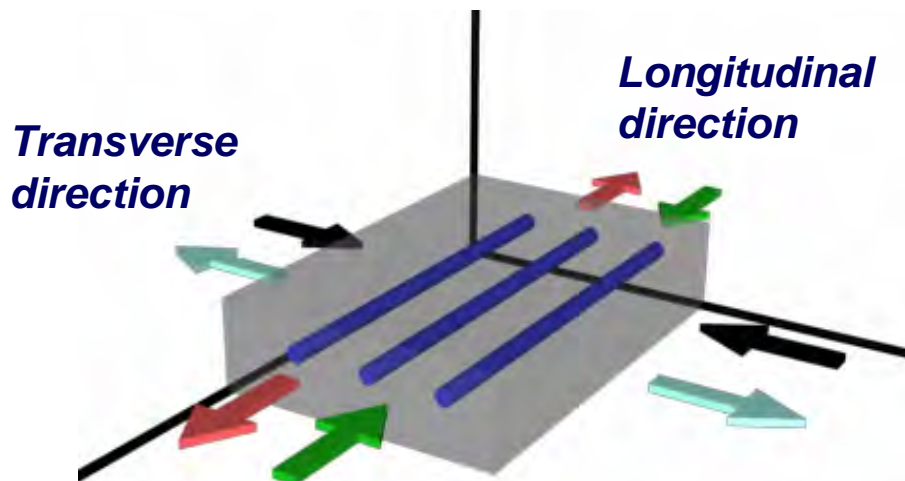


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Performance of bent FRP's



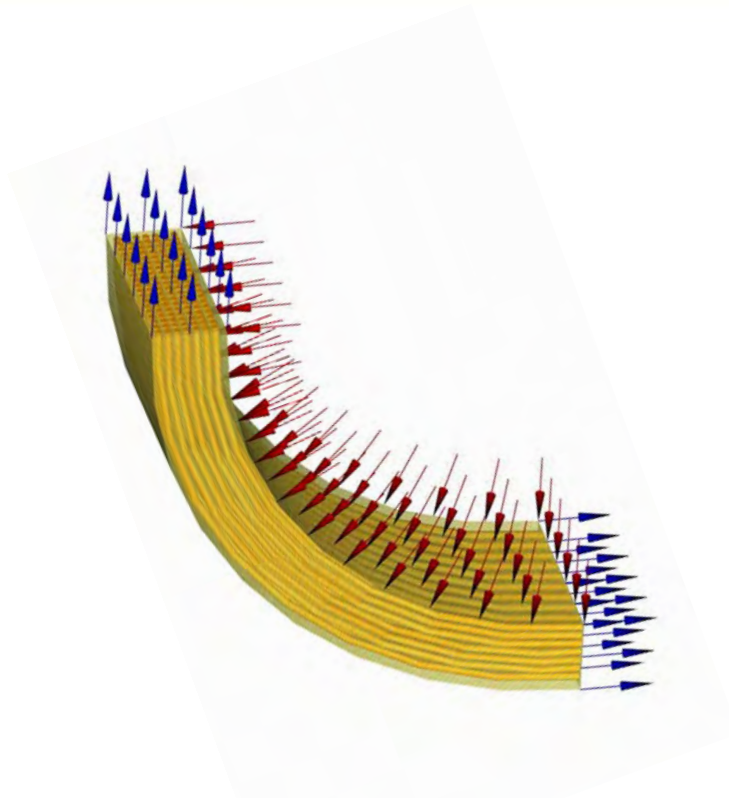
The tensile strength of FRP bars can be largely reduced when subjected to a biaxial state of stress





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Performance of bent FRP's



Premature failure at bent portion



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Performance of bent FRP's



Design equation (JSCE, 1997)



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

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



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Use of thermoplastic 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**



R/t ~ 1



R/t ~ 13

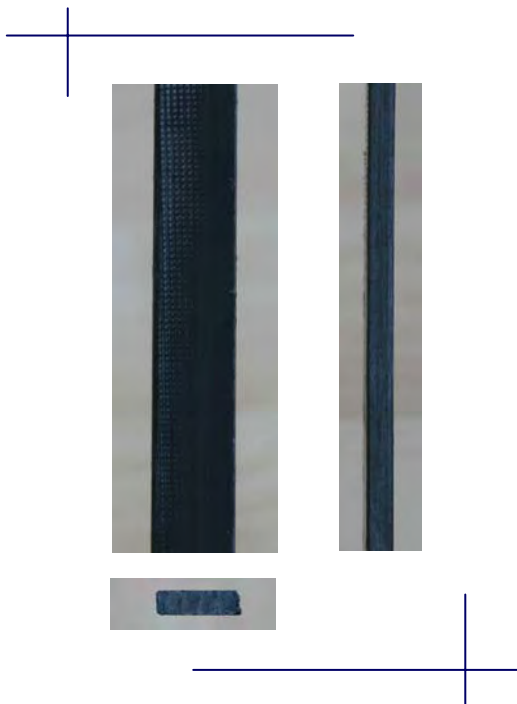


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Use of thermoplastic FRP's



GFRP thermoplastic strip (10x3mm)



Properties

Tensile strength (MPa)	720
Tensile modulus (GPa)	28
Ultimate strain (%)	1.9
Glass content (%v/v)	35
Density (g/cm ³)	1.48



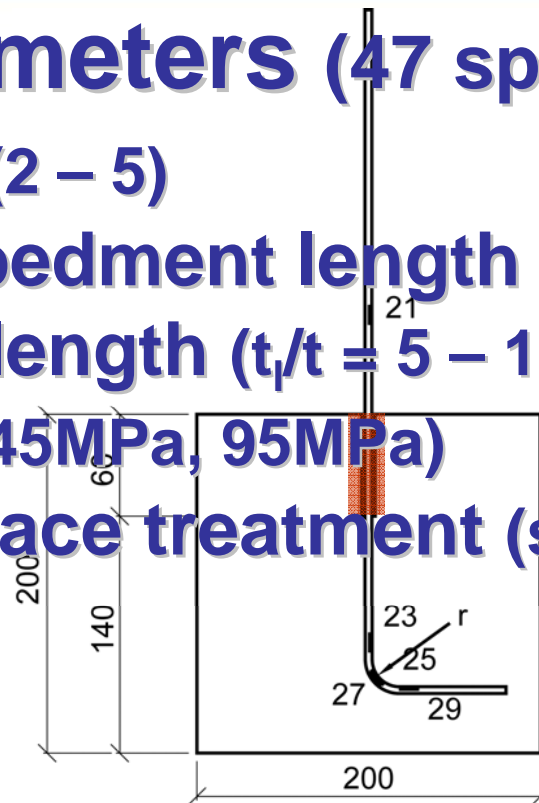
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Experimental program

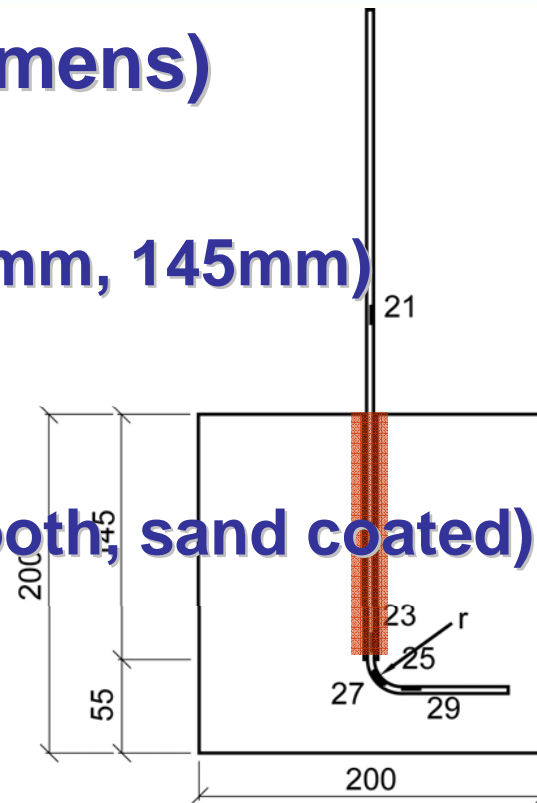


Parameters (47 specimens)

- 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

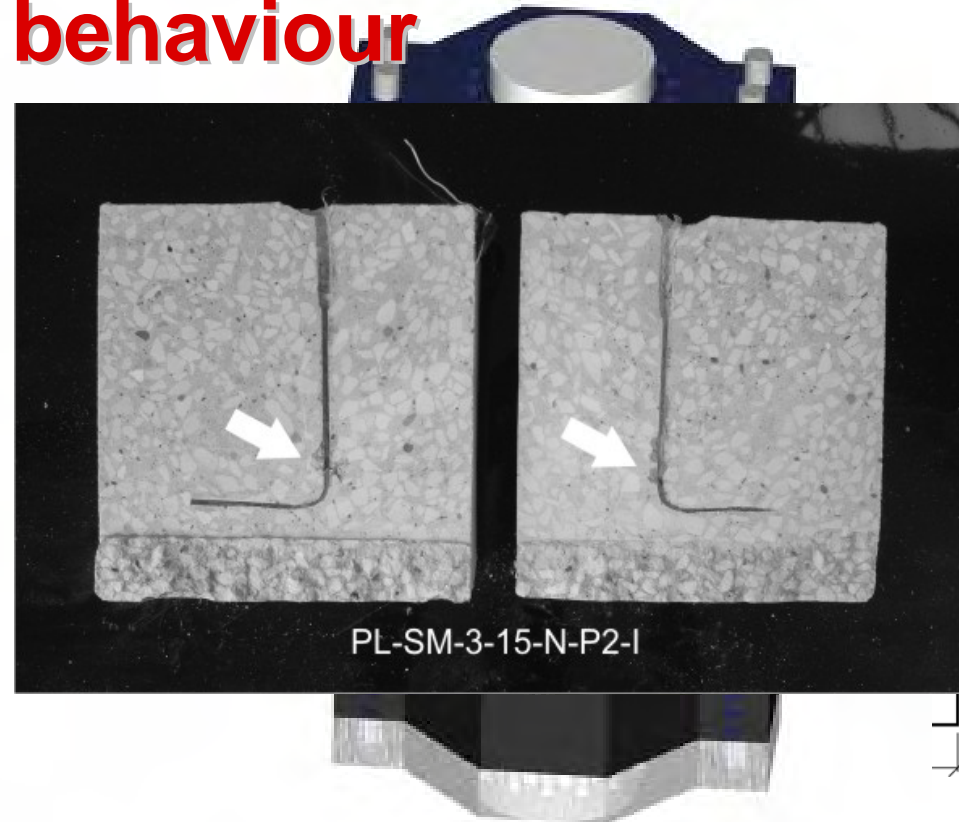


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Experimental results



Failure behaviour

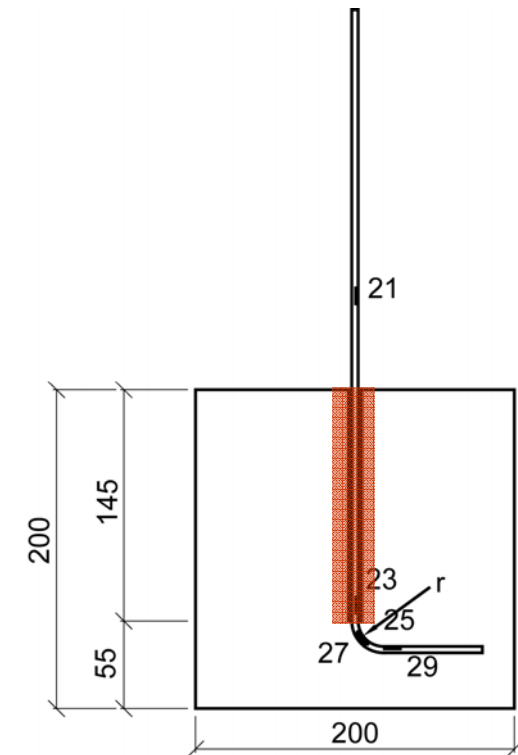
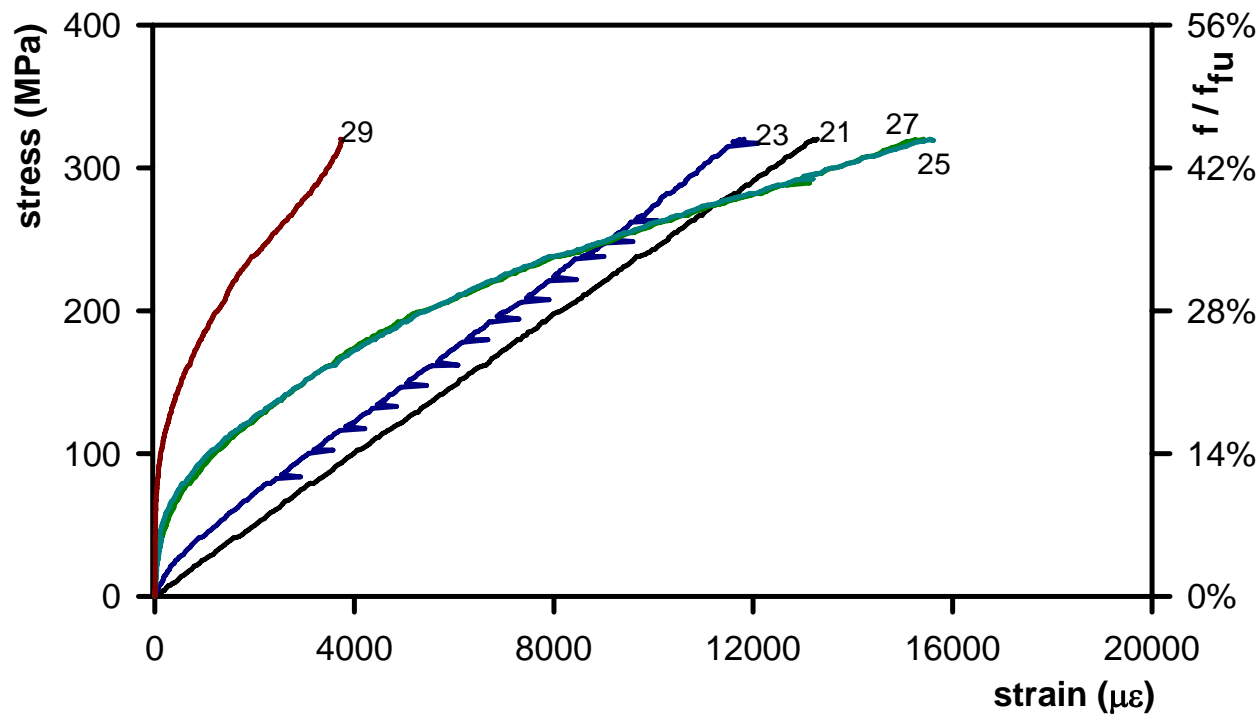


Strain distribution in spec



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Experimental results



Strain distribution in specimens Type 3

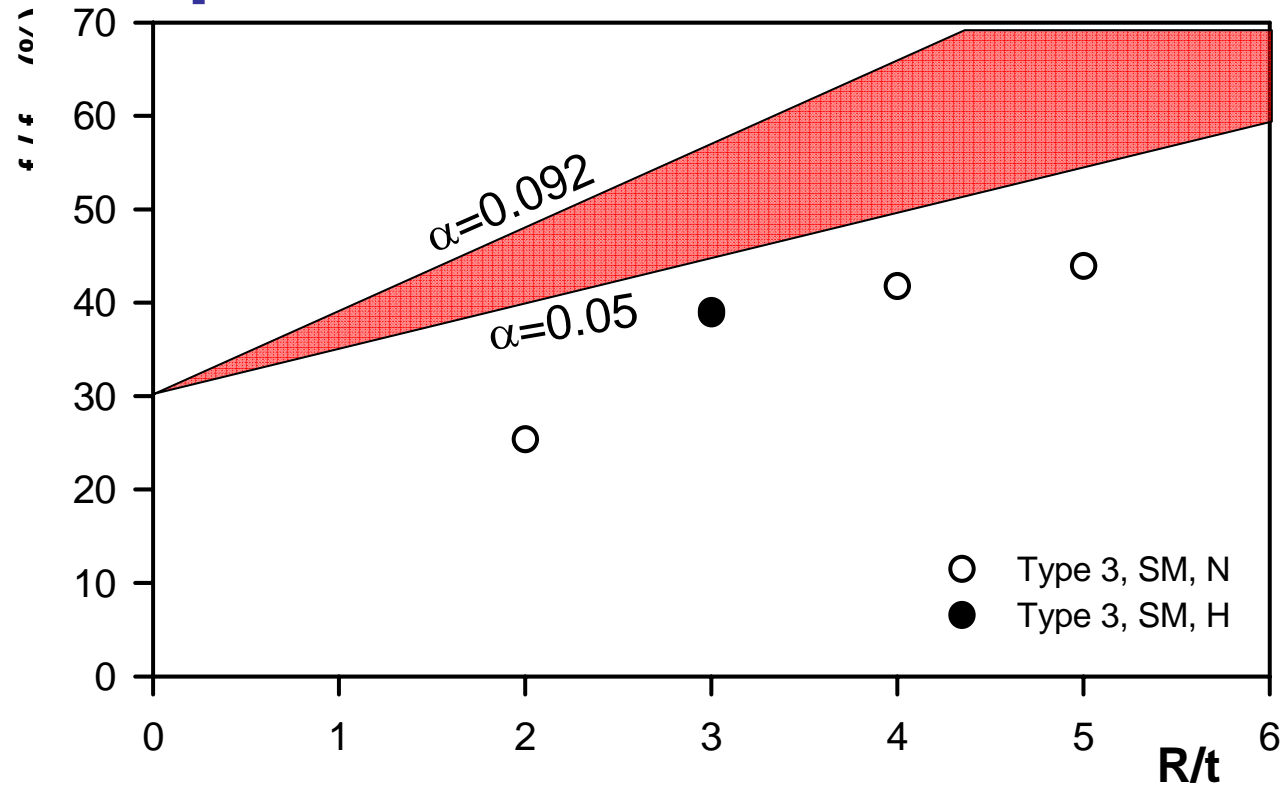


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Performance of bent FRP's



Unbonded specimens (Type 3) Experimental results vs. JSCE





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Final Remarks



- **Thermoplastics could offer a valid solution for on-site bending**
- **The capacity of the bent portion is not only a function of its geometry**
- **Values of $R/t > 4$ guarantee the development of 40% of the ultimate strength**
- **Need for a rational design method**