



BOND BEHAVIOUR OF FRP REINFORCING BARS IN CONCRETE BEAMS



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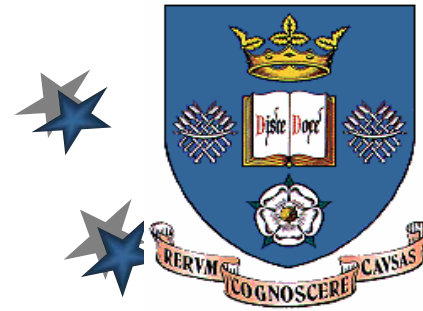
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Presented by:
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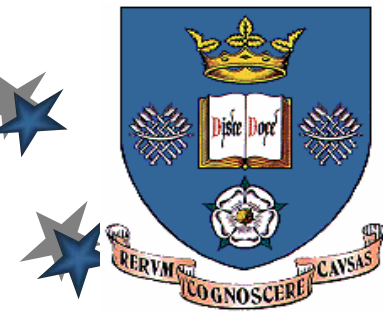
Outline



- **Description of FRP EUROCRETE bars**
- **Importance of bond investigation in FRP bars**
- **Experimental programme**
- **Test results**
- **General discussion**



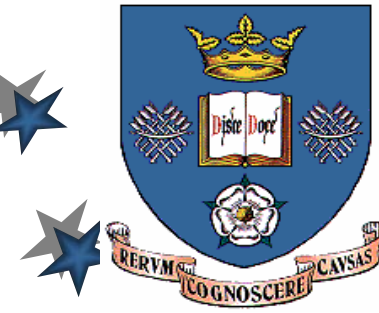
Properties of EUROCRETE bars used in beam tests



	GFRP bar d=13.5 mm	GFRP bar d=8.5 mm	CFRP bar d=8 mm
Young Modulus (MPa)	45000	115000	115000
Direct tensile strength (MPa)	>1000	>1000	>1500
Tensile strength under beam loading conditions (MPa)	700-750	900-950	1300-1380
Elongation at failure under beam loading conditions (%)	1.55-1.65	2.00-2.10	1.13-1.20



Importance of investigation of bond in FRP materials



Different properties than steel bars:

- Lower Young Modulus (Longitudinal, Lateral)
- Lower shear strength (in axial and transverse direction)
- Different texture of bar surface
- Much higher normal strength



Experimental programme in the University of Sheffield



- **Pull-out Cube tests:**

4 phases, more than 130 specimens

- **Beam tests:**

4 phases, more than 37 beams -

9 of them designed to fail in bond

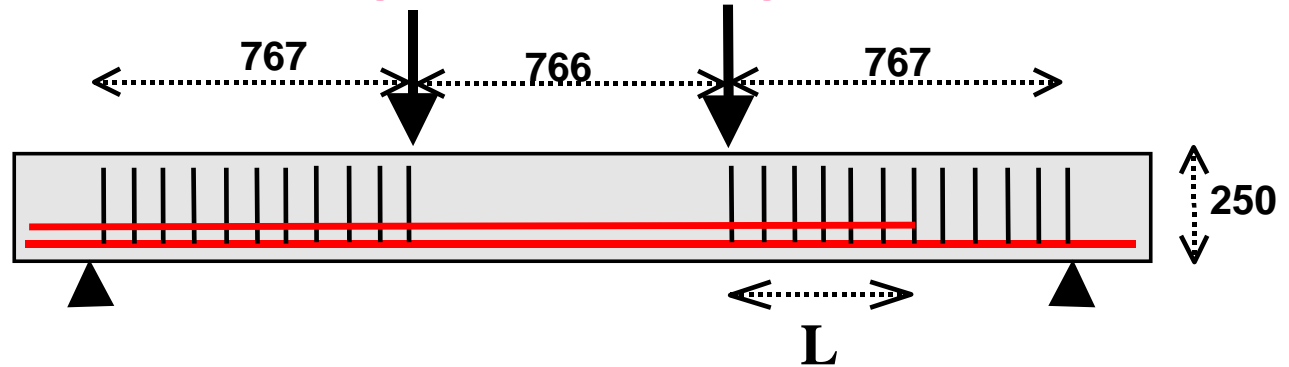


Test arrangement for beams designed to fail in bond

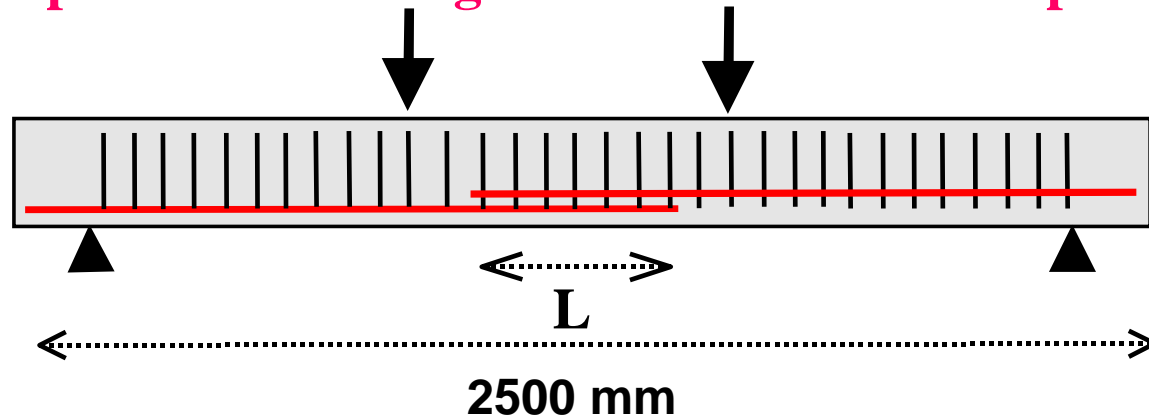
Parameters:

- Reinforcement arrangement
- Embedment length
- Diameter / cover ratio

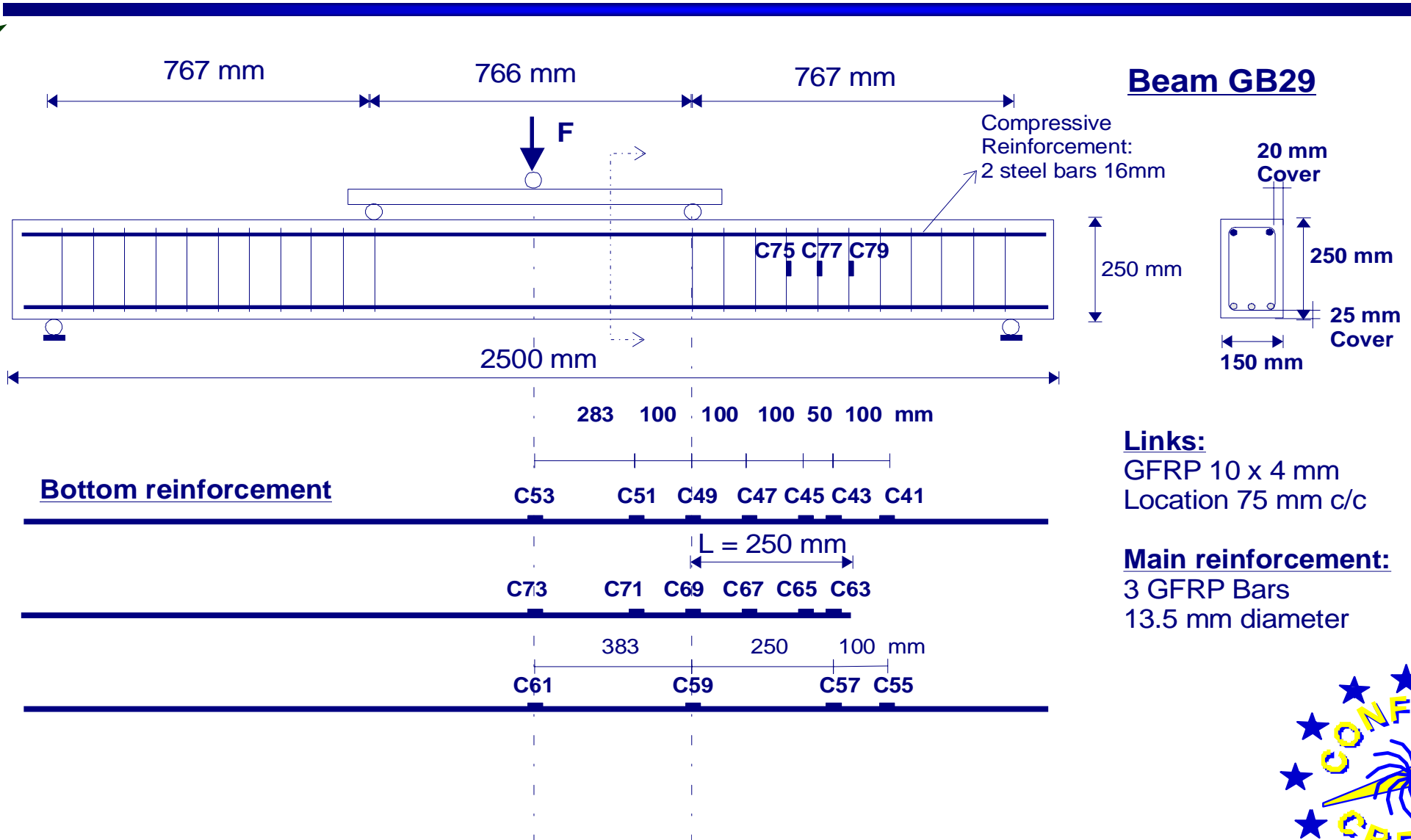
Single bar anchorage:



Spliced reinforcing bars between the load points:



Typical arrangement of strain gauges



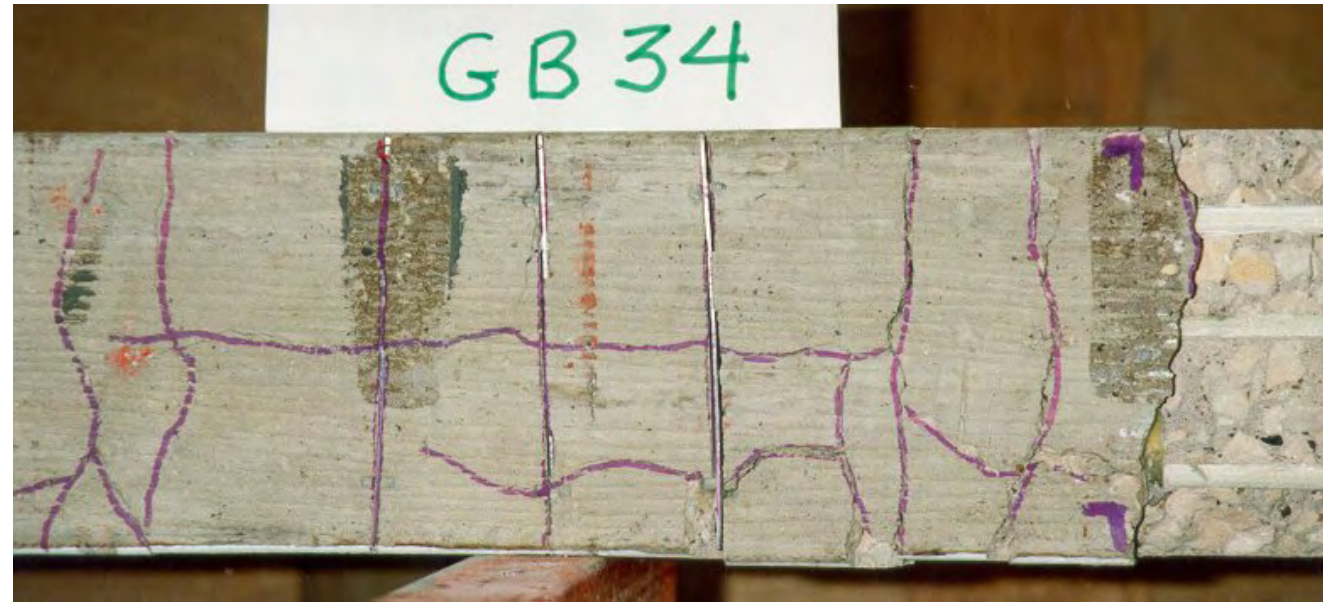
Beam GB29

Links:
GFRP 10 x 4 mm
Location 75 mm c/c

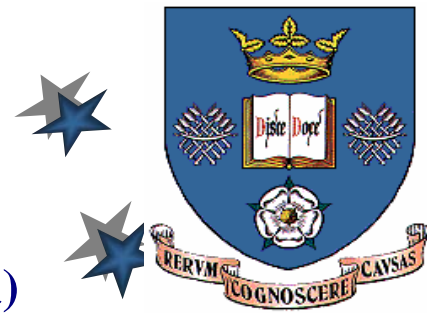
Main reinforcement:
3 GFRP Bars
13.5 mm diameter

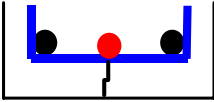
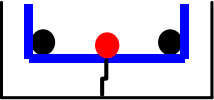
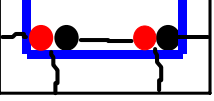
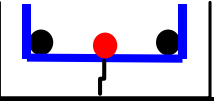
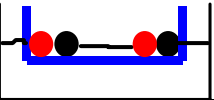
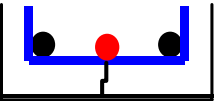
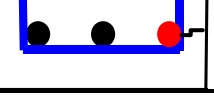
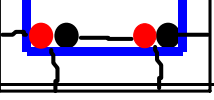
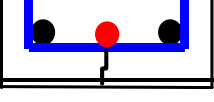


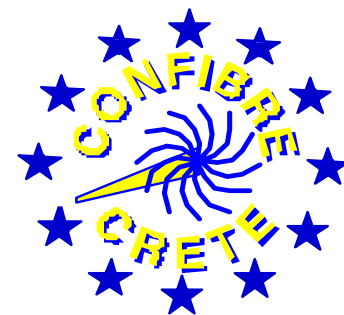
Failures in beams



Summary of test results



Beam	Bar diameter- Anchorage length	Type of failure	Maximum average bond strength (MPa)
GB29	d = 13.5 mm L = 250 mm		3.2
GB30	d = 13.5 mm L = 300 mm		2.7
GB31	d = 13.5 mm L = 300 mm		3.8
CB32	d = 8 mm L = 300 mm		4.6
CB33	d = 8 mm L = 300 mm		5.7
GB34	d = 8.5 mm L = 370 mm		3.2
GB35	d = 8.5 mm L = 300 mm		3.0
GB36	d = 8.5 mm L = 300 mm		4.1
CB37	d = 8 mm L = 580 mm		3.7

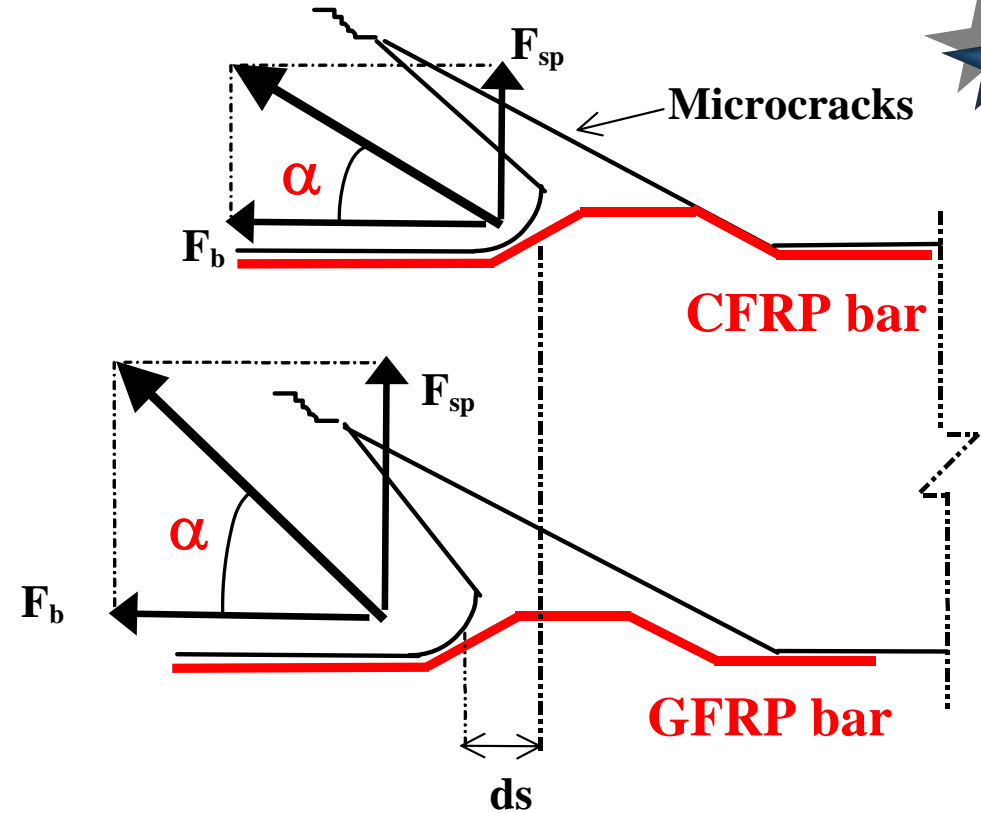


- **GFRP bars splitting bond strength around 70% of CFRP bars**

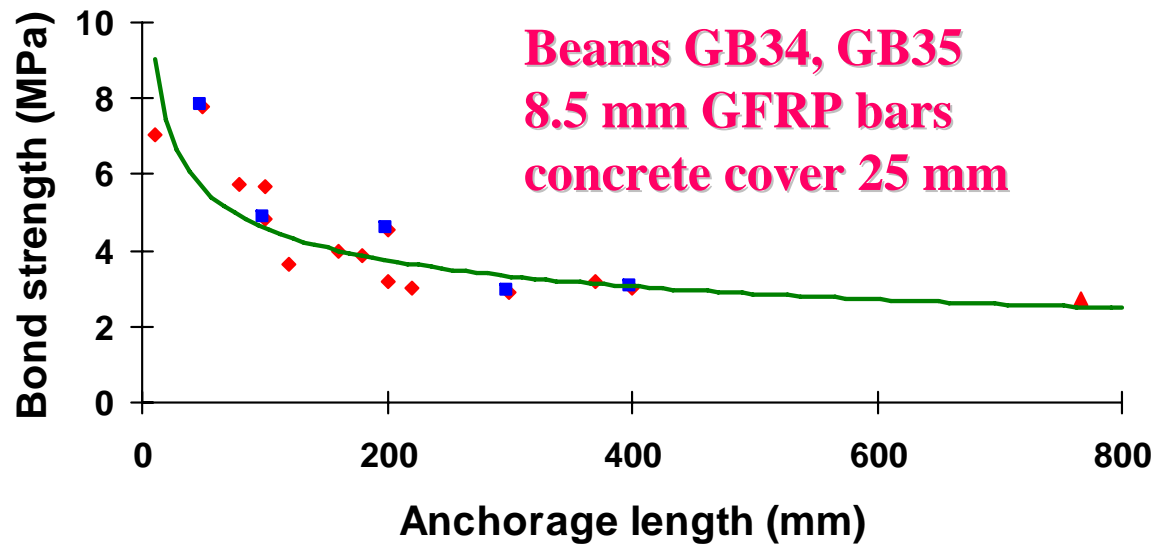
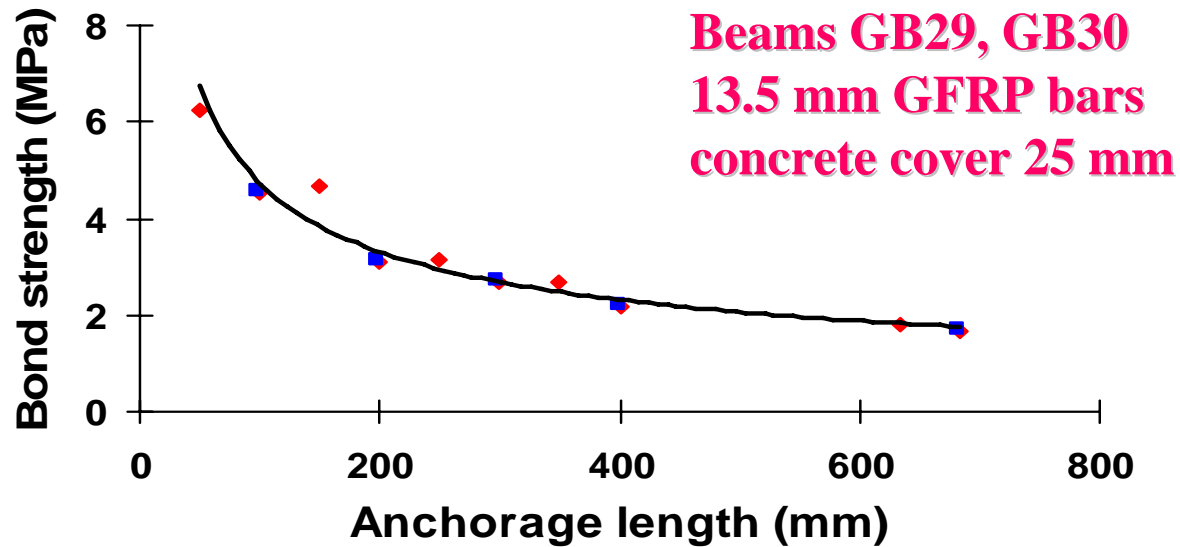
Possible Reason ?

Difference in Young's Modulus \Rightarrow

Difference in angle α



Method of working for the calculation of necessary anchorage lengths

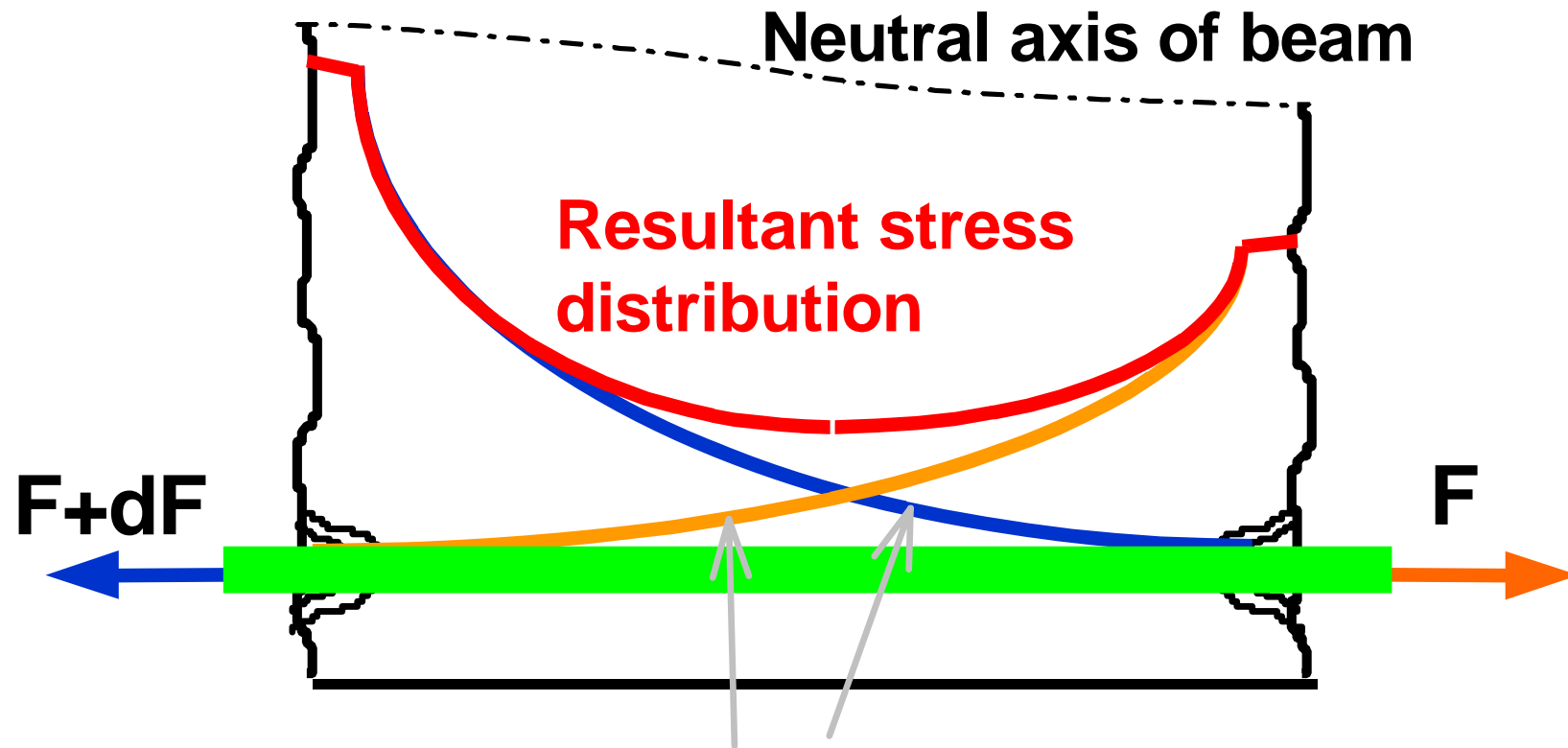


Advantages - Limitations of the method

Use of limited data  Predictions of
bond strength of longer bars

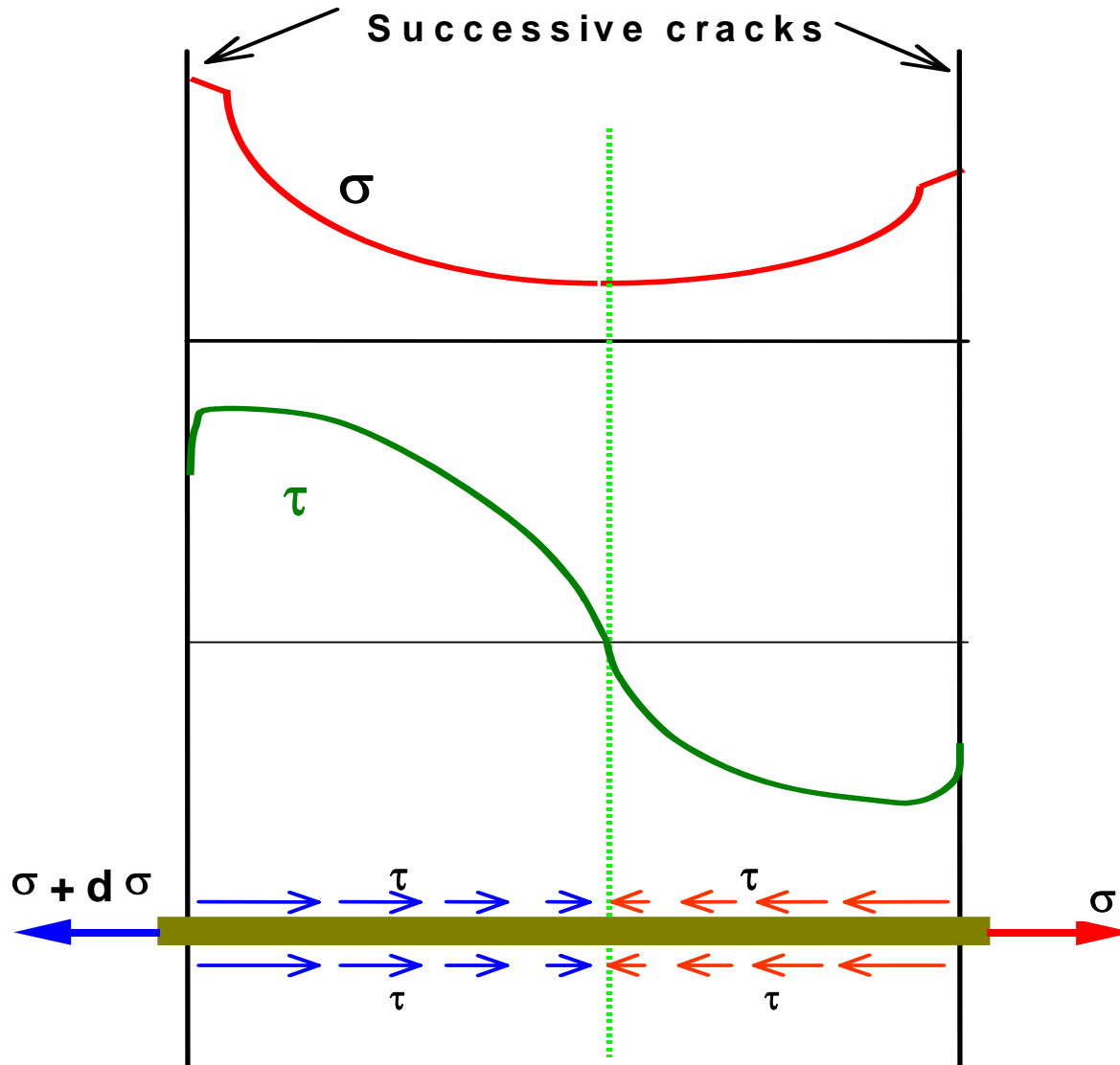
- Relies on specific experimental arrangement
- The influence of **concrete strength, concrete cover, transverse reinforcement - pressure** need to be incorporated

Strain and bond stress distribution between cracks

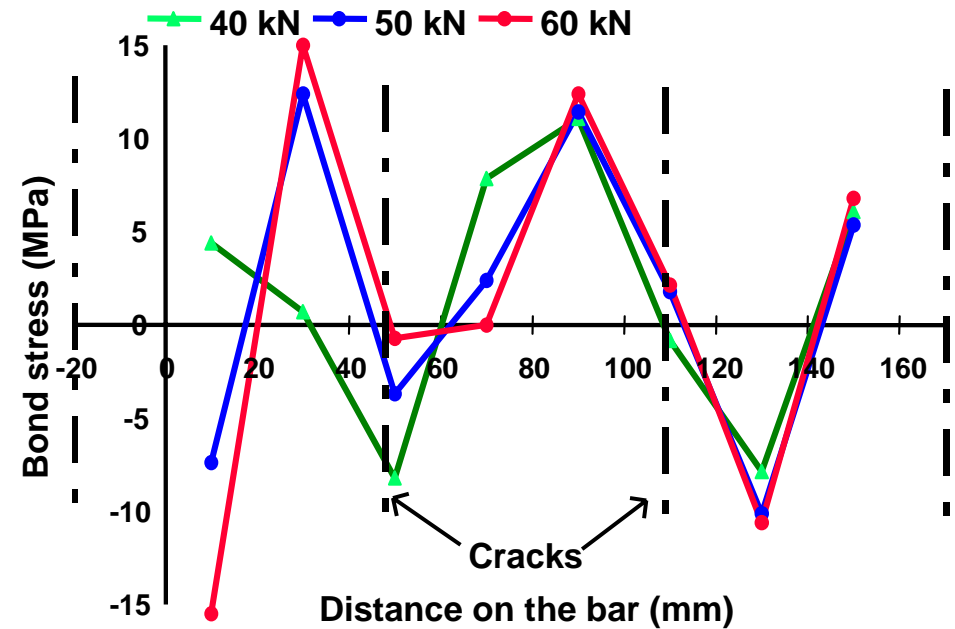
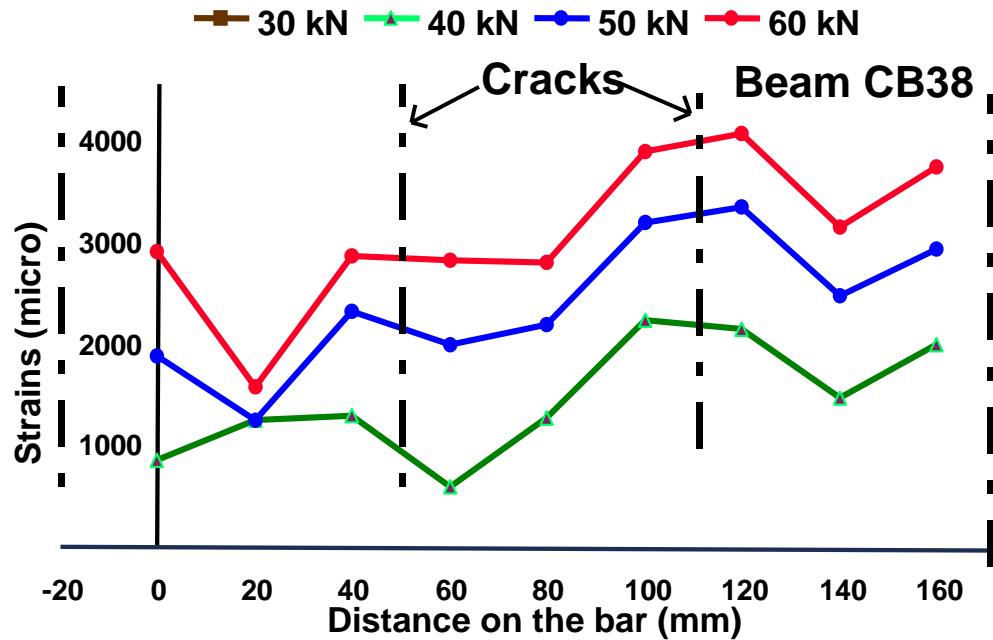


Stress distributions inside the
concrete due to pullout actions

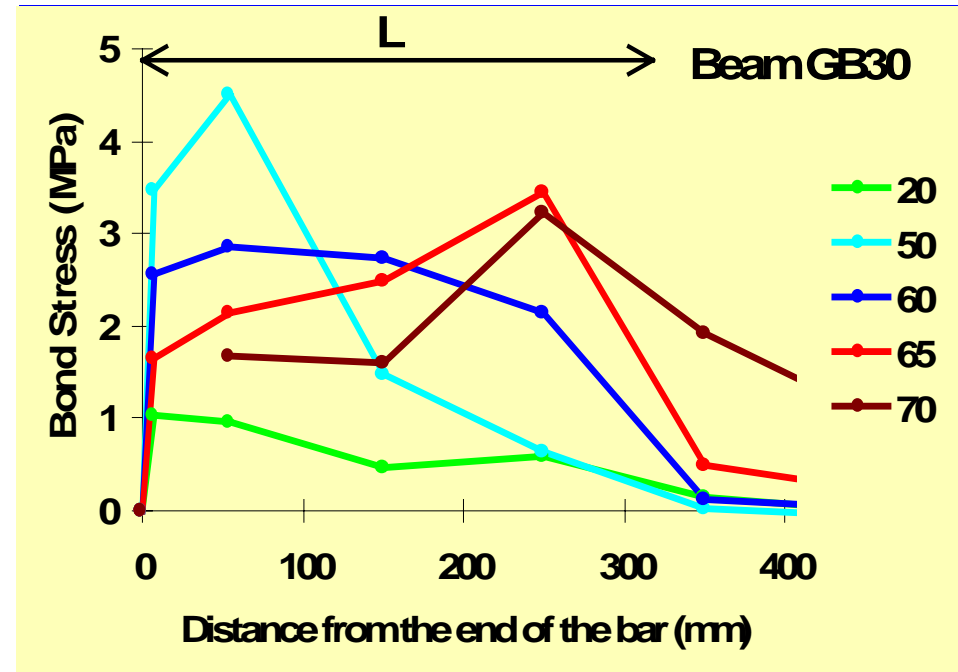
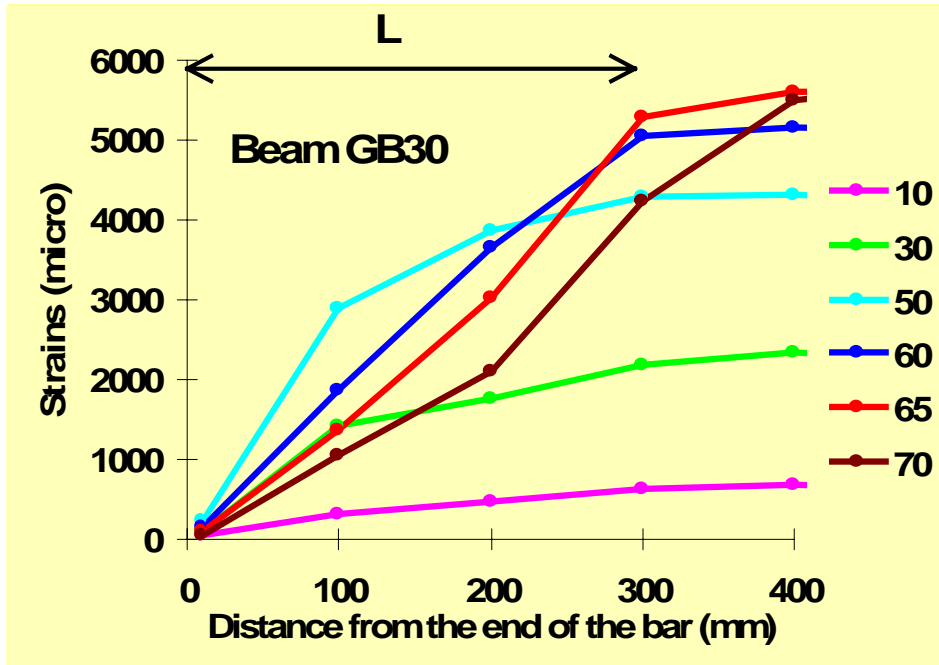
Strain and bond stress distribution between cracks



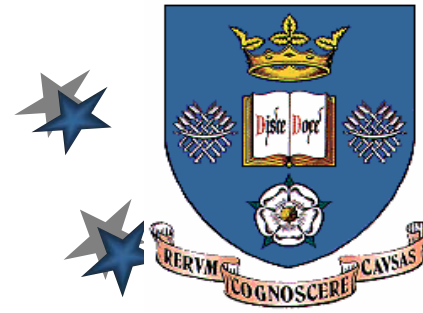
Strains, bond stresses distribution between cracks (experimental evidence)



Strain and bond stress distribution over a short embedment length in the flexural zone



Spliced bars



- Spliced bars developed **similar or even greater bond stresses** to the single bar anchorages (CFRP and GFRP)
- Transverse reinforcement in the constant moment area **did not contribute to the bond splitting resistance** of spliced bars



Concrete cover and transverse reinforcement



- Concrete cover may not be necessary for environmental protection of FRP bars, but it is **absolutely necessary** for the structural integrity of bond
- Transverse reinforcement resists splitting **only when is stressed** (e.g. in the shear span). Otherwise, it is activated **after** the formation of splitting cracks



Future considerations

- More emphasis on the **splitting behaviour of FRP bars** (single anchorages, splices)
Experimental and Analytical work needed
- Need for arrangement introducing a standard **test** for examining the **splitting bond behaviour** of reinforcing bars