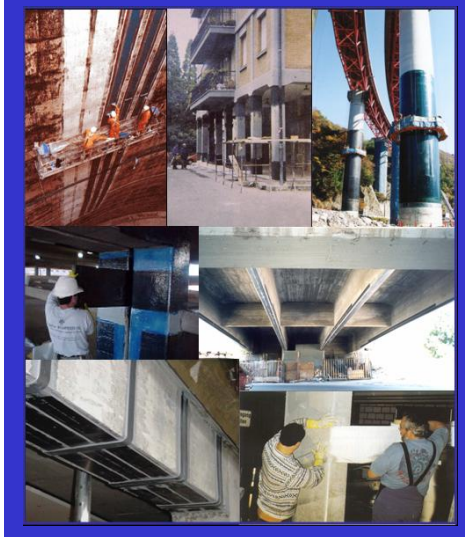
STRENGTHENING AND SEISMIC RETROFITTING OF STRUCTURES WITH COMPOSITE MATERIALS



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- INTRODUCTION
- MATERIALS AND TECHNIQUES, BASIS OF DESIGN
- STRENGTHENING OF RC STRUCTURES
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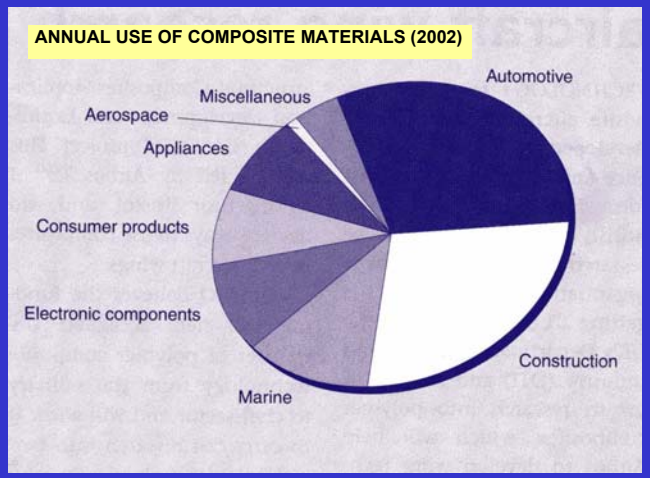
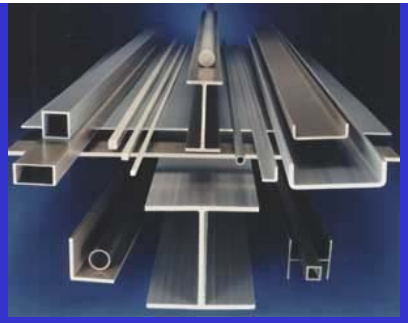
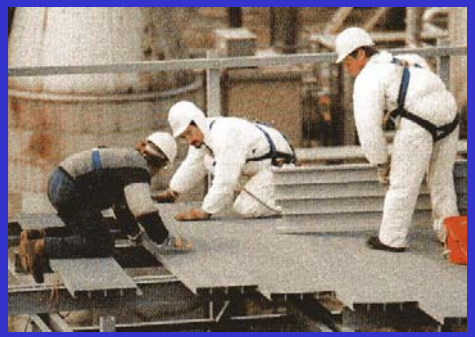
  - CONFINEMENT
  - DETAILING
- STRENGTHENING OF MASONRY
- STRENGTHENING OF TIMBER
- DURABILITY
- RECENT AND FUTURE DEVELOPMENTS
- SUMMARY AND CONCLUSIONS

INTRODUCTION



WORLDWIDE MARKET (2005): US$45 billion
21% → STRENGTHENING
300% GROWTH FROM 2005 – 2010 (SPI)





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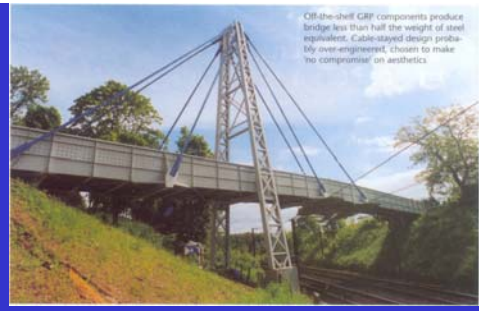

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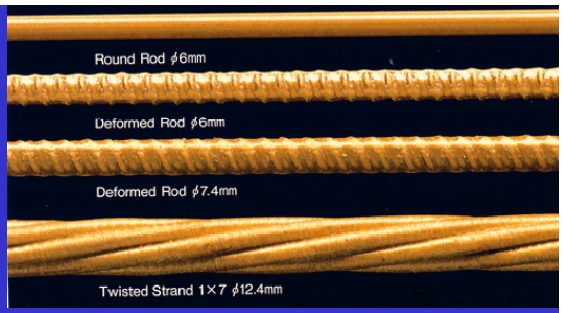

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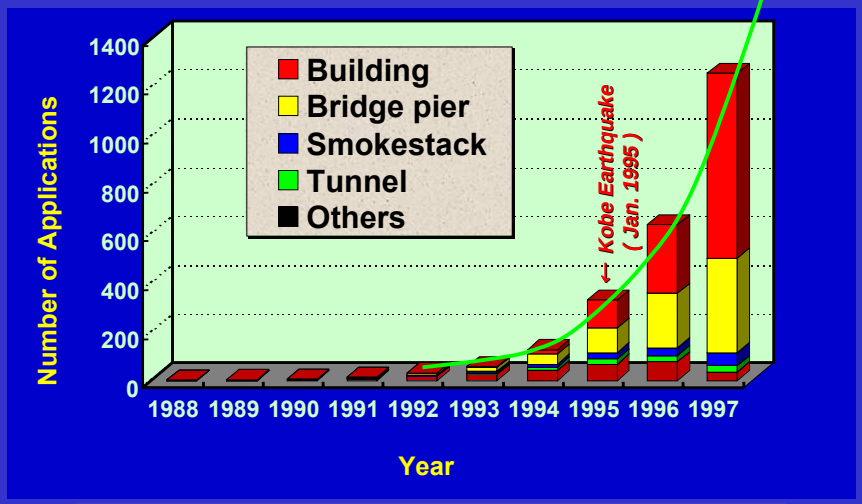
JAPAN

BUILDING RESEARCH INSTITUTE



CHINA : 1000 m^2 in 1998 , 600,000 m^2 in 2003 !!

GREECE : >1000 applications in the past ~5 years

TRADITIONAL TECHNIQUES - BEAMS

STEEL PLATING

TRADITIONAL TECHNIQUES - COLUMNS

SHOTCRETE JACKET

STEEL PLATES

STEEL JACKETING

ADDITION OF SHEAR WALLS

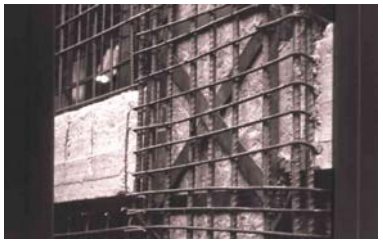
TRADITIONAL TECHNIQUES - SHEAR WALLS

STEEL PLATES

SHOTCRETE JACKET

TRADITIONAL TECHNIQUES - JOINTS

STEEL PLATES

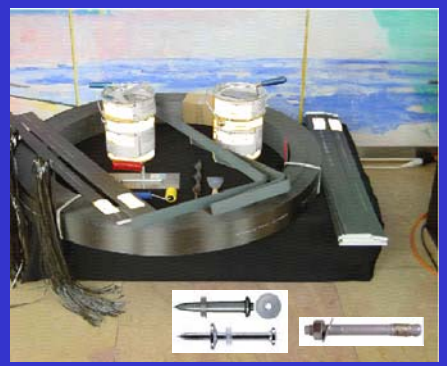


STEEL PLATES &
SHOTCRETE JACKETING

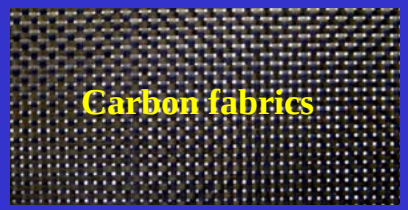
MATERIALS AND TECHNIQUES,
BASIS OF DESIGN

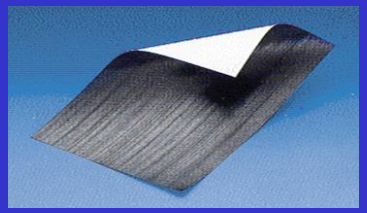
Basic strengthening materials

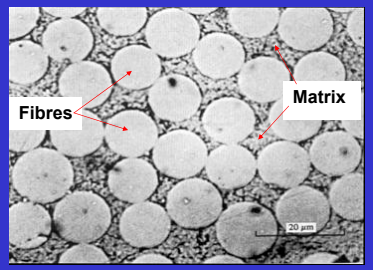
- CFRP laminates
- L-shaped CFRP laminates
- Unidirectional fabrics
- Multidirectional fabrics
- Two-part epoxy resins
- Mechanical fasteners

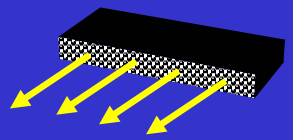


Fabrics









$E_f = E_{fib}V_{fib}+E_mV_m \sim E_{fib}V_{fib}$

$f_f \sim f_{fib}V_{fib}$

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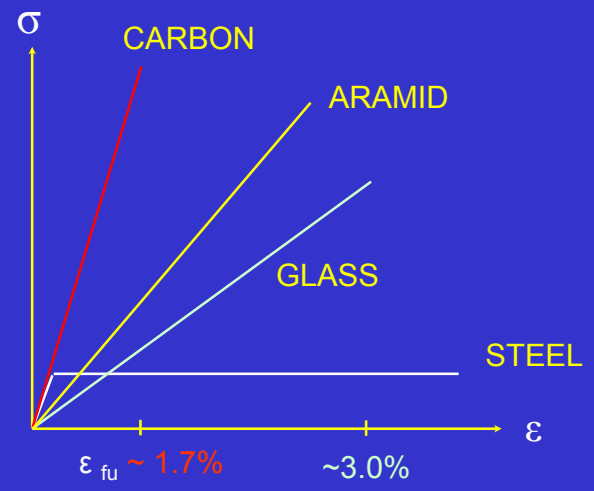

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Beam flexural strengthening with strips

Beam shear strengthening with fabrics

Slab flexural strengthening

BASIC TECHNIQUE

Column wrapping with fabrics

Fabric impregnation with resin

Resin-impregnated fabrics

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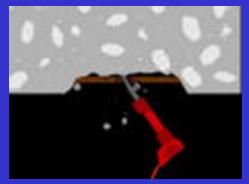
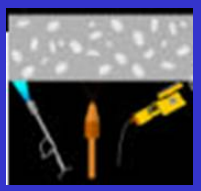
BE CAREFUL DURING EXECUTION !!



Removal of loose concrete



Smooth and clean surfaces

Repair

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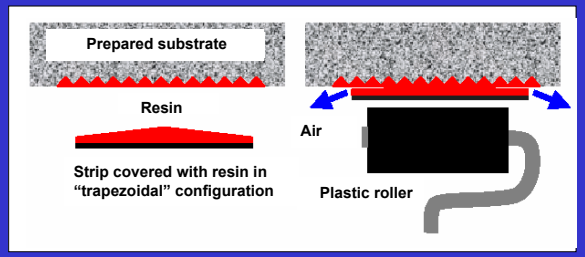
Application of strips






Resin application | Bonding of strip | Rolling | Removal of excess resin

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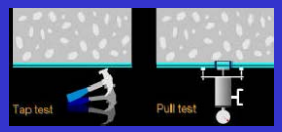
Application of fabrics



Fibers should be straight, not loose

Careful impregnation with resin. Rolling, air removal



Bond check

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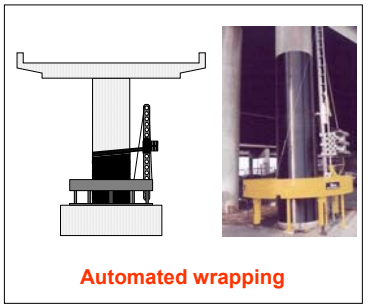
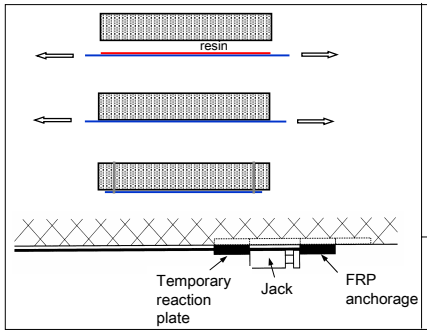
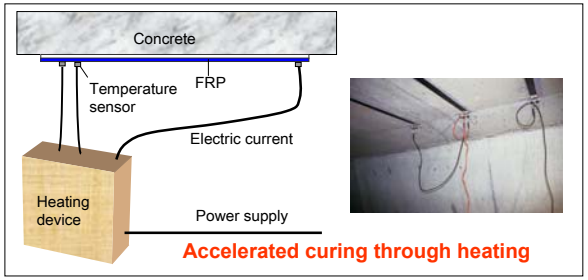


Automated wrapping



Prestressing



Accelerated curing through heating

SPECIAL TECHNIQUES - A

FRP inside slits (NSM)

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SPECIAL TECHNIQUES - B

Special prefabricated elements




Mechanically fastened laminates (e.g. anchor bolts, powder actuated nails)



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ANO LIOSIA

CANOE - SLALOM

HOTEL HRA

MENIDI

VOULA

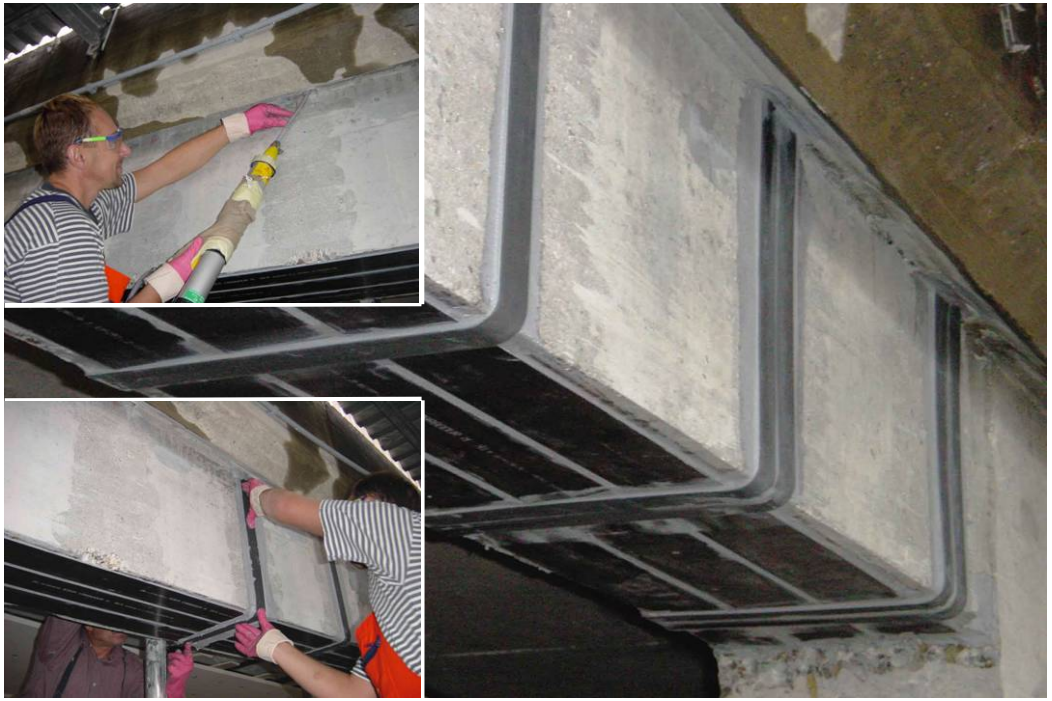
X.A.N.Θ. BUILDING – THESSALONIKI

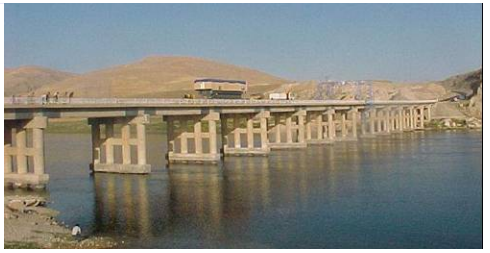

10

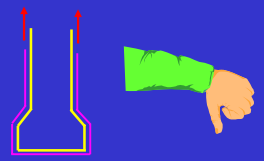

11


12


roth Gerüste
OTTO ZWICK!
Bauunternehmung
MÜNCHEN







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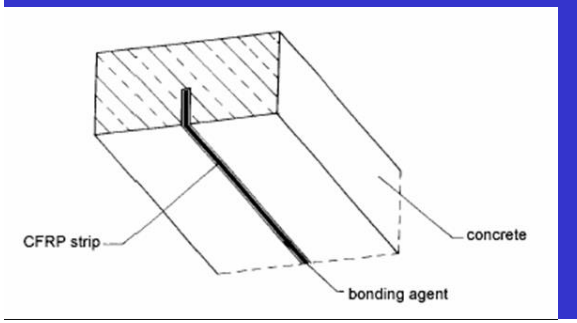


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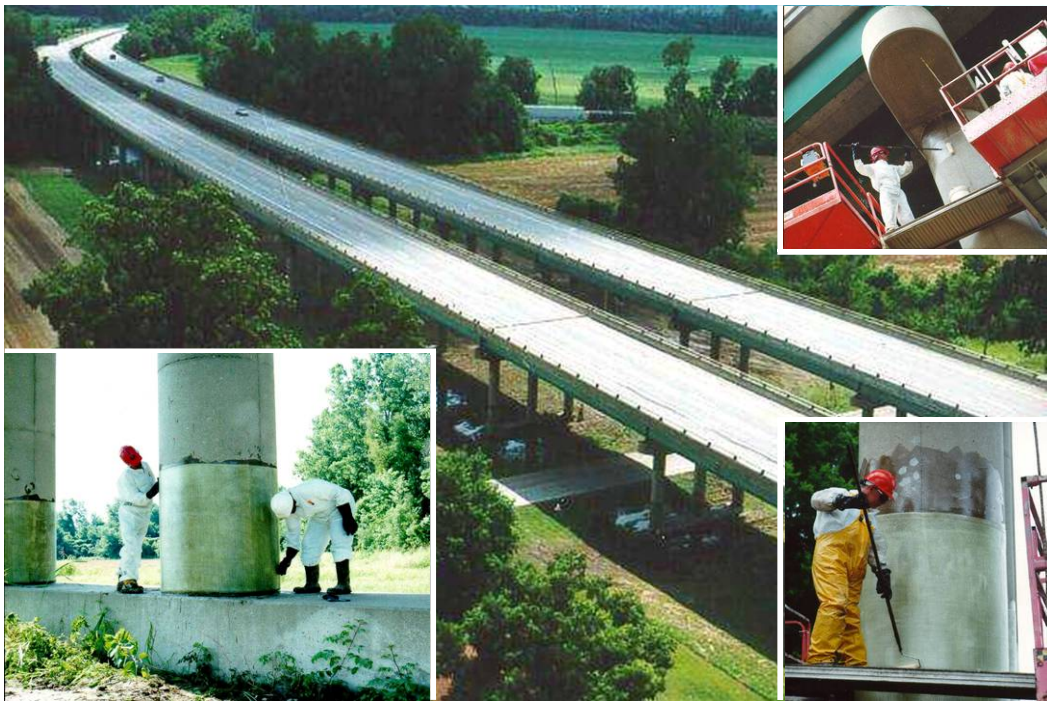
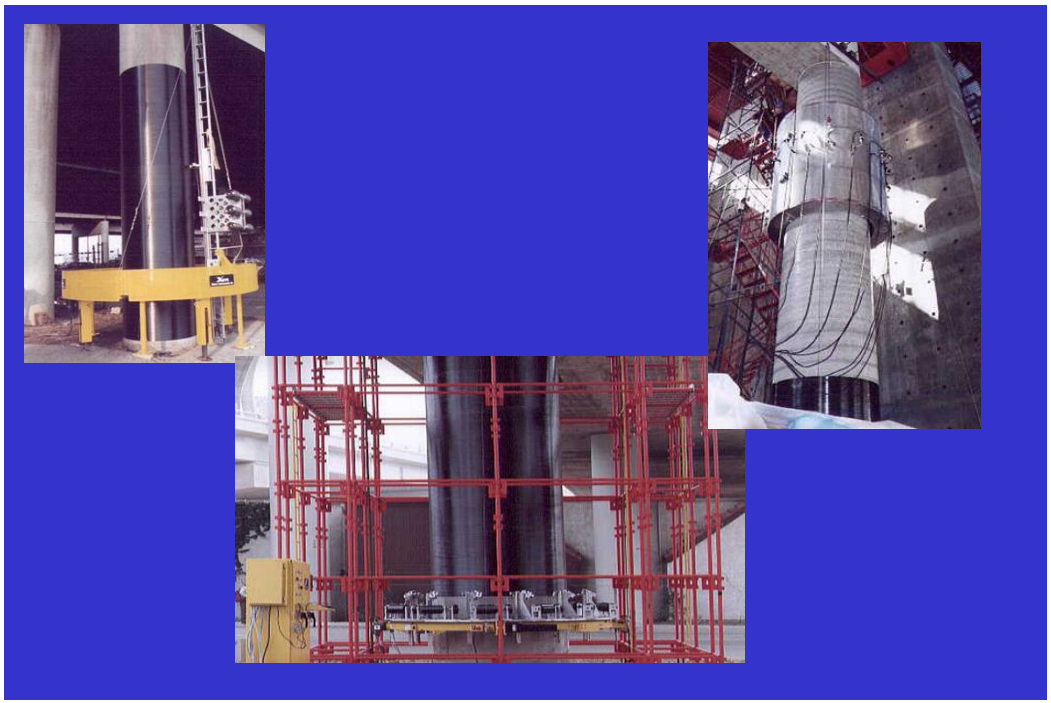
OCT 21 2002
OCT 21 2002

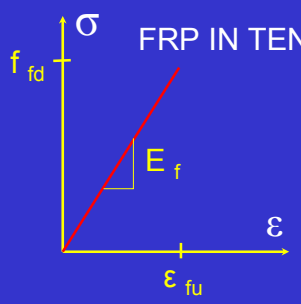




- Low weight
- Corrosion resistant
- Availability of long elements
- Easy and fast to apply, low disruption of occupancy
- High strength
- No change of cross section dimensions
- Jacketing without increasing stiffness

- High materials cost (not total !)
- Lack of ductility (but plenty of deformability !)
- Need for fire protection
- Lack of education

MATERIAL MODELS



$f_{fd} = f_{fk} / \gamma_f$

Effective design strength
$f_{fde} = \eta_e f_{fd}$

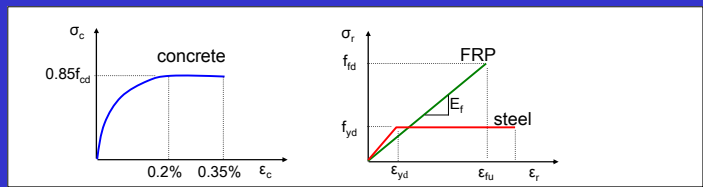
Material Safety Factor γ_f

Fibers	A	B
Carbon	1.20	1.35
Aramid	1.25	1.45
Glass	1.30	1.50

A : Rigid strips - normal conditions, fabrics, high quality control.

B : Fabrics – normal conditions, any material under difficult circumstances

Debonding: $\gamma_f = \gamma_{fd} = 1.5$



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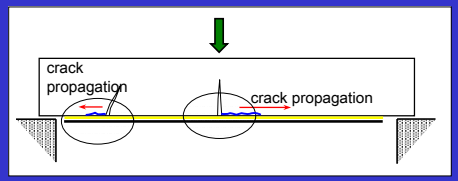
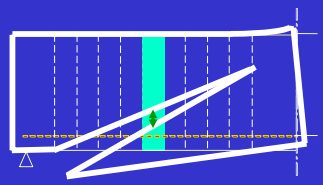
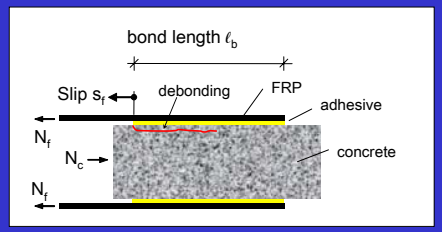
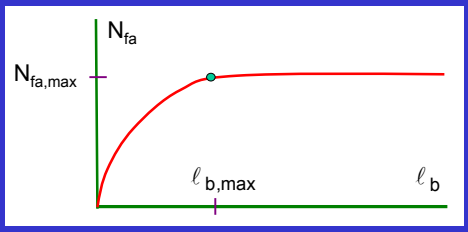
FRP – CONCRETE BOND









$$\ell_b \geq \ell_{b,max} \qquad N_{fa} = N_{fa,max} = b_f \sqrt{0.6 k_b E_f f_{ctm} t_f}$$

$$\ell_b < \ell_{b,max} \qquad N_{fa} = N_{fa,max} \frac{\ell_b}{\ell_{b,max}} \left(2 - \frac{\ell_b}{\ell_{b,max}}\right)$$

$$\ell_{b,max} = 0.6 \sqrt{\frac{E_f t_f}{\sqrt{f_{ctm} k_b}}}$$

$$k_b = \sqrt{\frac{1.5\left(2 - b_f/b\right)}{1 + b_f/100}} \geq 1$$

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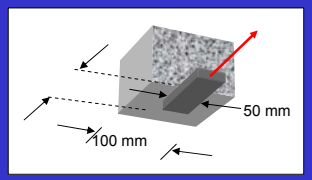
Example : calculation of debonding force



GIVEN:

$E_f = 180$ GPa $\quad t_f = 1.2$ mm

$f_{fd} = 3000$ MPa $\quad f_{ctm} = 1.9$ MPa

$$\ell_{b,max} = 0.6\sqrt{(180000 \times 1.2)/\sqrt{1.22 \times 1.9}} = 226 \text{ mm}$$

$$N_{fa,max} = 50\sqrt{0.6 \times 1.22 \times 180000 \times 1.9 \times 1.2} = 27.405 \text{ N} \approx \boxed{27.4 \text{ kN}}$$

Force corresponding to FRP fracture: 3000x50x1.2 = **180 kN**

Better to : maximize width & minimize thickness !!

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