



Basics of Concrete Repair and Structural Strengthening

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Why Does Concrete Need Repairing ?

- Corrosion of reinforcement
- Insufficient reinforcement
- Chemical damage
- Excessive loads
- Structural damage
- Fire damage
- Seismic damage
- Blast damage



Defects



Low cover steel reinforcement where carbonation or chlorides have reached the reinforcement altering its passive nature



Defects



Which can create de-lamination of sections which will ultimately fail.





The voice of the concrete repair and refurbishment industry

The Structural Concrete Alliance
brings together the expertise of:

BS EN 1504: A guide to concrete repair

- **BS EN 1504 is the new European and British Standard for the protection and repair of reinforced concrete.**
- **There are 10 PARTS to the standard covering TEST METHODS for material properties and SPECIFICATION for the KEY REPAIR MATERIALS, including coatings, mortars, bonding agents and injection materials.**
- **It also includes GENERAL PRINCIPLES for repair work and a standard for site application of products and systems.**

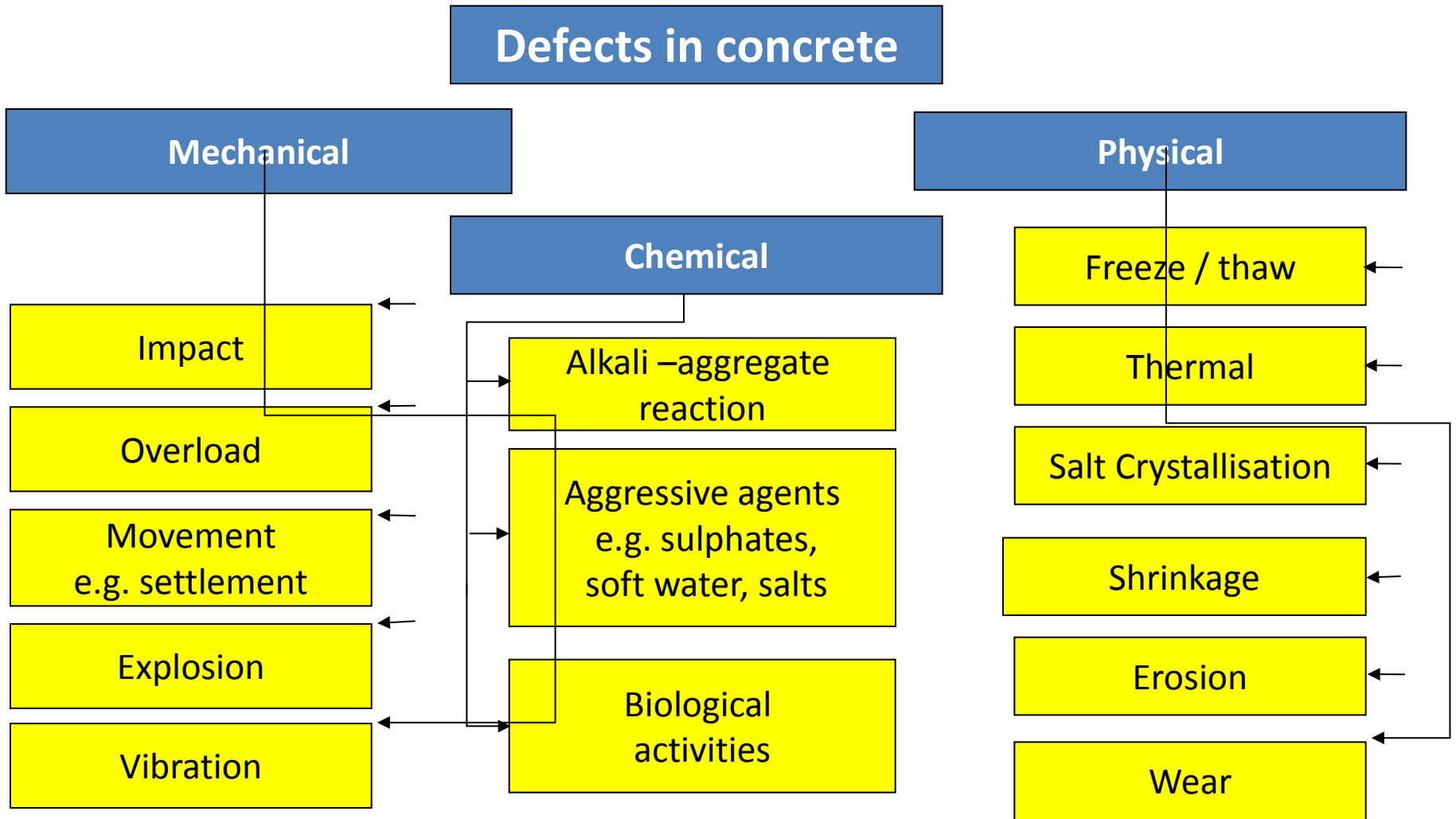
BS EN 1504

Parts	Title
Part 1	Definitions
Part 2	Surface protection systems for concrete
Part 3	Structural and non-structural repair
Part 4	Structural Bonding
Part 5	Concrete Injection
Part 6	Anchoring of reinforcing bars
Part 7	Reinforcement corrosion protection
Part 8	Quality control and evaluation of conformity
Part 9	General principles for the use of products and systems
Part 10	Site application of products and systems and quality control of the works

BS EN 1504 : A guide to concrete repair

- The standards apply across the 25 member states of the EU as well as Switzerland, Norway, and Iceland.
- The BS EN1504 series represents an opportunity to further improve concrete repair practice in the continent and present a challenge to the industry as it adapts to the new standards.
- The standards must now be used by Specifiers, particularly those operating under public procurement rules.

(Common causes of defects; EN 1504 Part 9 Figure 1)



Specifying to BS EN 1504

Products and systems for the protection and repair of concrete structures

1 Assess the damage

- Examine the original design approach
- Survey the present condition
- Consider the environment
- History of the structure

2 Choose options

- Consider the intended use of the structure
- Design life of the structure
- Performance of systems
- Seek advise on the best options

Specifying to BS EN 1504

Products and systems for the protection and repair of concrete structures

3 Choose Repair Principal

Principle	BS EN 1504	Problem	BS 1504 reference
1	Protection against ingress	Concrete is a porous material and is exposed to aggressive chemicals or contaminated water.	PI
2	Moisture control	Excessive water penetration can cause damage to reinforced concrete.	MC
3	Concrete restoration	Restoring the original concrete after spalling and delamination.	CR
4	Structural strengthening	Increasing or restoring the structural load-bearing capacity after excessive loads or weakened structure.	SS
5	Increasing physical strength	Increasing physical resistance to impact damage, abrasion and wear and tear.	PR
6	Resistance to chemicals	Increasing resistance of concrete surface to chemical attack.	RC

7	Preserving or restoring passivity	Restoring the concrete to a highly alkaline condition to protect steel rebar.	RP
8	Increasing resistivity	Increasing the resistivity of the concrete to prevent rebar corrosion.	IR
9	Cathodic control	Preventing corrosion of rebar reinforcement	CC
10	Cathodic protection	Reducing or preventing the corrosion reinforcement.	CP
11	Control of anodic areas	Creating conditions for the steel rebar not to be subject to corrosion.	CA

4 Choose Correct Repair Methods

THIS IS WHERE THE ENGINEER HAS THE MOST IMPORTANT DECISIONS TO MAKE

Specifying to BS EN 1504

Products and systems for the protection and repair of
concrete structures

5 Choose materials

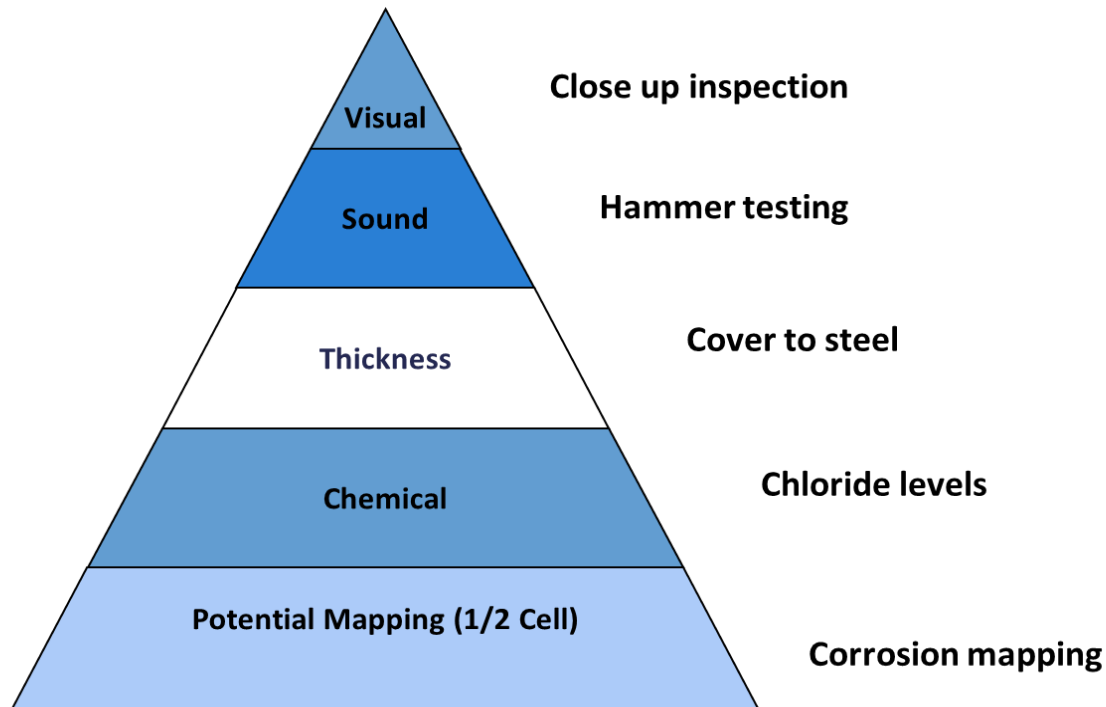
6 Choose correct specification

DIAGNOSING FAILURE

Condition surveys



Methods of monitoring for corrosion activity



Two main catalysts for corrosion

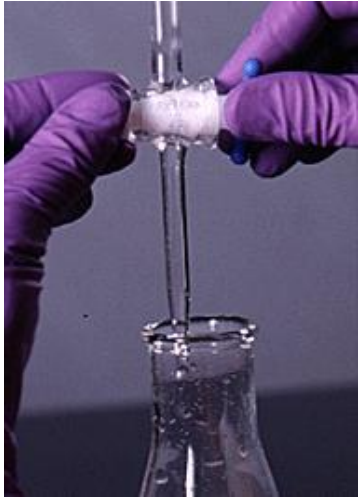
- Chloride ions (Cl⁻)

Chloride ions from salt (sodium chloride) break down the protective layer on the steel that was established by the alkalinity within the concrete.

- Carbonation

This is caused through atmospheric carbon dioxide, an acid gas, that permeates through the pores and reacts with the alkalinity

Testing for Chlorides



- Normally by titration
- Laboratory tests
- Quantabs



Investigation

Testing for Carbonation



- Phenolphthalein
- Fresh fractures

Other investigative techniques

- Pull-off testing
- Covermeter
- Core drilling and testing
- Schmidt hammer
- Half cell potential
- Radiography
- Thermal imaging



Patch Repairs Key Steps

- Concrete Preparation
- Repair Mortars
- Protective Coatings

Preparation

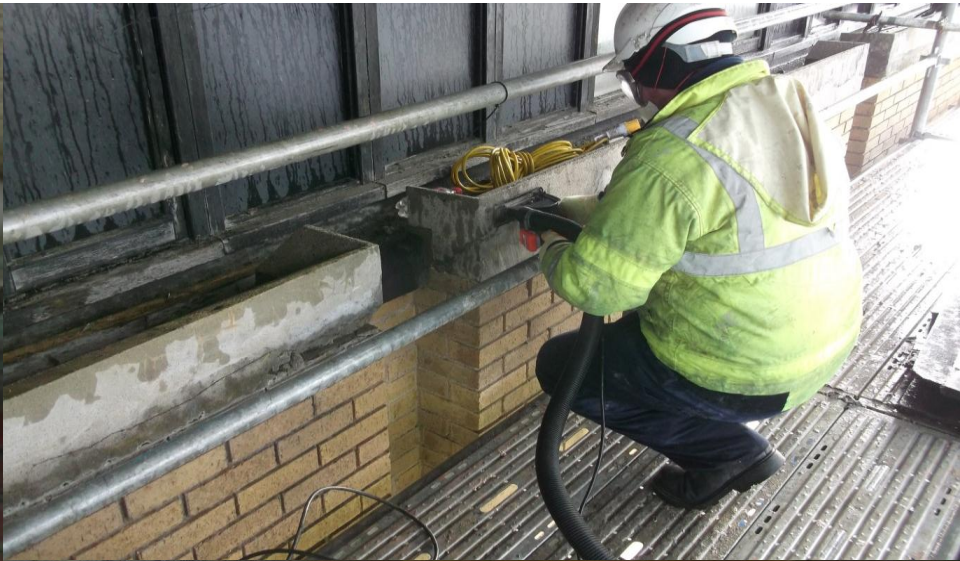
Concrete - Cleaning

Remove contamination, cement laitance, coating etc



- Low pressure water jetting
- High pressure water jetting
- Grit blasting
- Steam cleaning
- Needle gunning
- Scabbling
- Flame spalling

Methods of Removing defective concrete



Preparation

Steel – Preparation



- Remove contaminated concrete 50mm beyond visible corrosion
- Grit Blast to achieve first quality to BS 7079 : Part A1 (equivalent to Swedish Standard SA 2½ quality, dull grey metal, devoid of any corrosive products)
- Add additional reinforcement where required

Methods of Application



- Hand applied patching mortars
- Fluid micro concrete
- Spray applied concretes



Hand Applied Repairs

- Polymer Modified Mortars
- Repair depths to 10 - 75mm
- Typical size $<0.5\text{m}^2$ on vertical faces
- Typical size 400 x 400mm by 50mm deep on soffits
- Manual Placement
- Large numbers - small in size



Hand Applied Repairs

Pre-dampen the substrate

Apply primer to steel
& concrete



Application of Mortar

Pack by hand



Finish flush



Cure



Application of Levelling Coat



Trowel applied



Sponge finish

Large Scale Repairs



Flowing Concrete
Sprayed Concrete

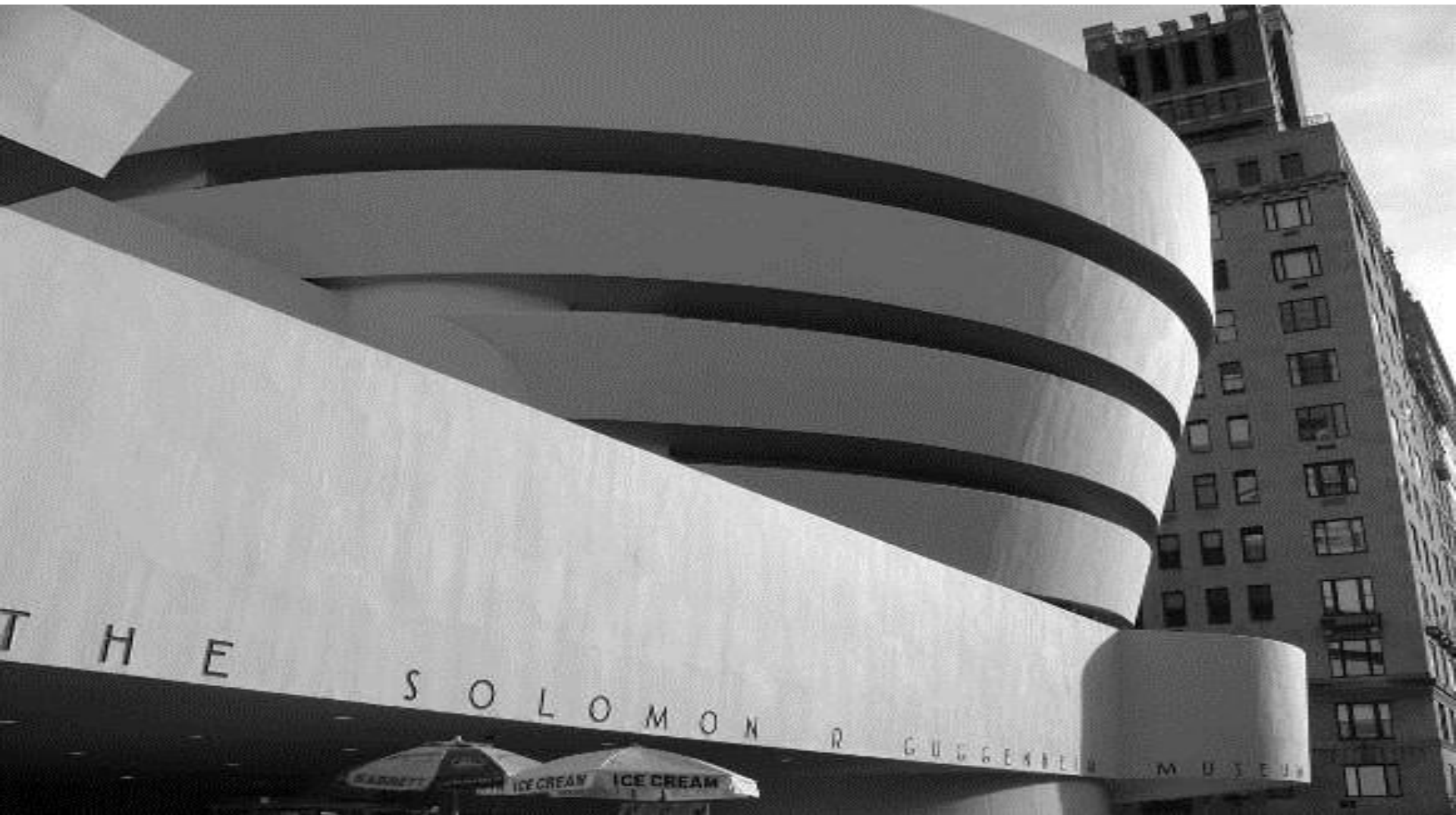


Flowing Concretes

- Rapid hardening Portland cement
- Pourable and pumpable
- Low exotherm
- High strength $>60\text{N/mm}^2$
- Aggregate grading $<10\text{mm}$
- Shrinkage compensated



Protective Coatings



Ensuring correct specification

- BS EN 1504 provides a framework to follow during concrete repair process
- It is a compulsory industry standard
- Products are classified according to BS EN 1504 Parts 2-7
- Part 10 details requirements for site application and quality control

FRP Composite Systems



Commercial Applications

- Military
- Aerospace
- Recreation
- Automotive
- Marine

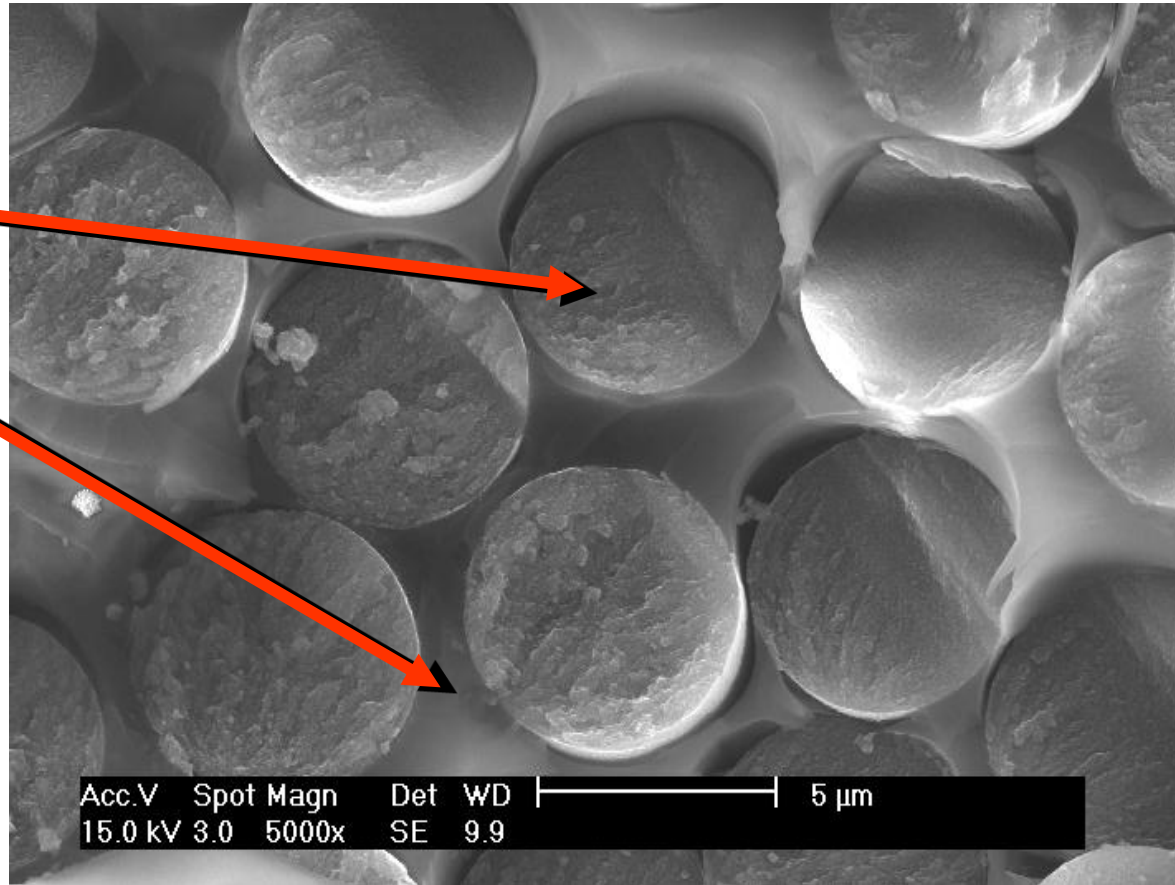


KNOWLEDGE TRANSFER

What do composite materials consist of ?

➤ **Fibres**

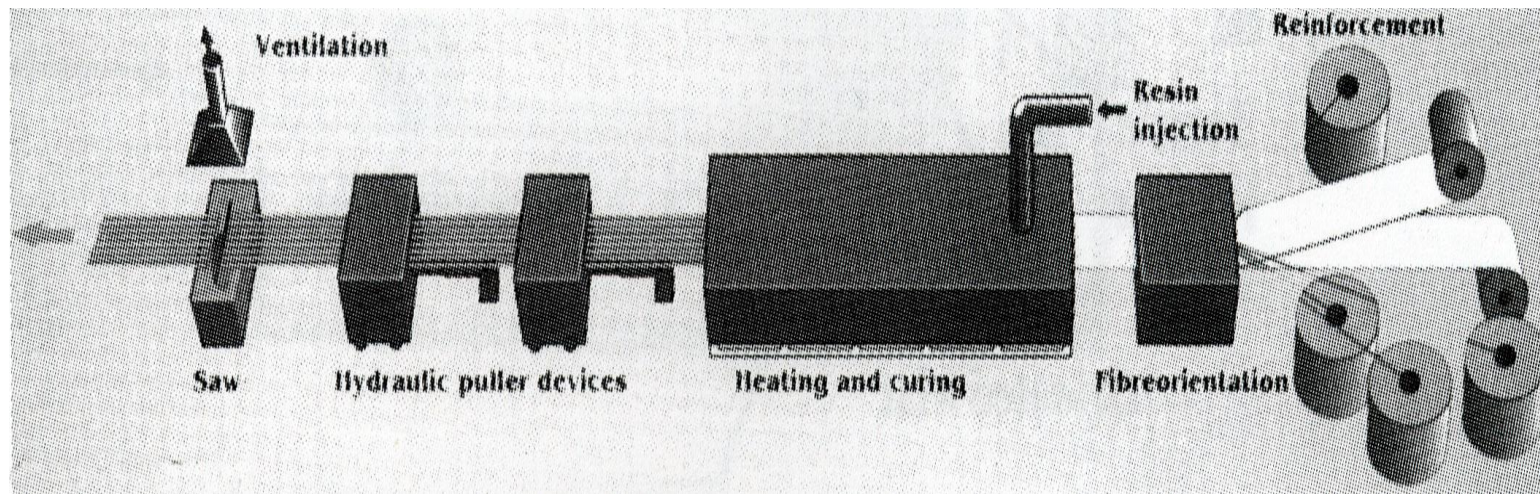
➤ **Matrix**



Pultrusion Process

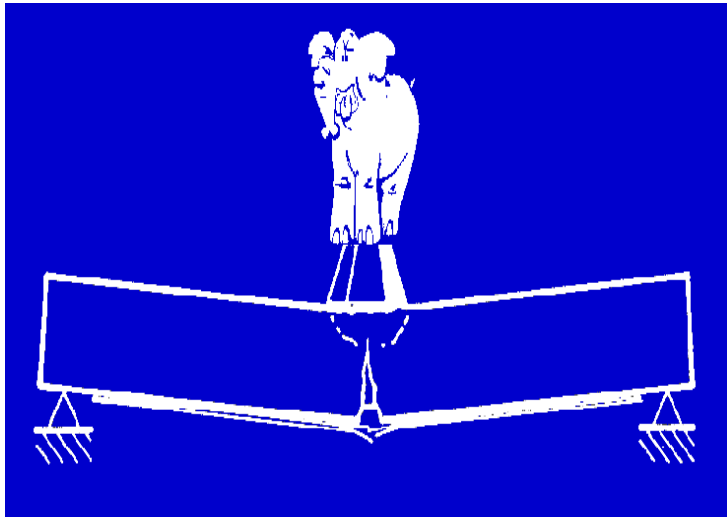
Composite elements manufactured through a warm extrusion process in which they are impregnated with epoxy resin while subjected to a tensile stress (Pultrusion)

Less flexible than fabrics they are applicable only on specific types of repair work



Principal Applications

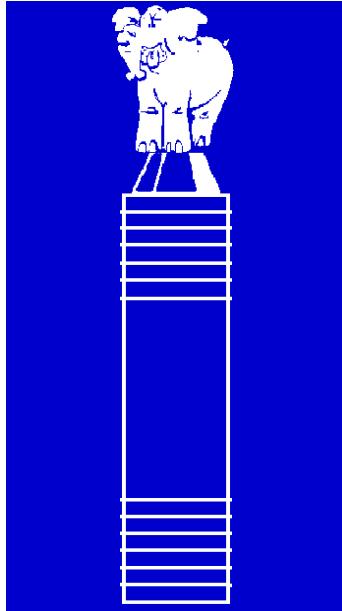
- Slabs



Flexural strengthening

Principal Applications

- Columns

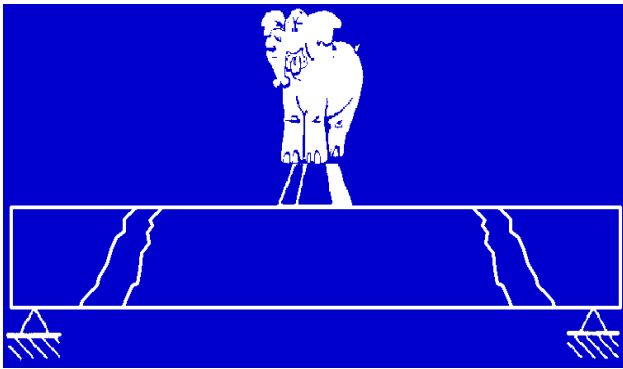


Confinement of axial loads



Principal Applications

- Columns/beam junction



Shear
strengthening;
increased ductility



Designing with FRP



- Qualify substrate
- Requirements:
- Concrete: 20N/mm² minimum
- Tensile bond test:
- 1 Nmm² minimum
- Failure within host concrete
- Steel- 15Nmm² minimum



FRP Adhesives

Epoxy Adhesives

- Primer
- Epoxy paste or leveling coat
- Adhesive Saturant, wet lay-up system.
- Adhesive Saturant, dry lay-up system.



Types of fibres

Carbon

- Elastic modulus of fibre 230 ÷ 440 GPa
- Tensile strength 2400 ÷ 5700 MPa
- Elongation at breakage 0.3 ÷ 1.8 %

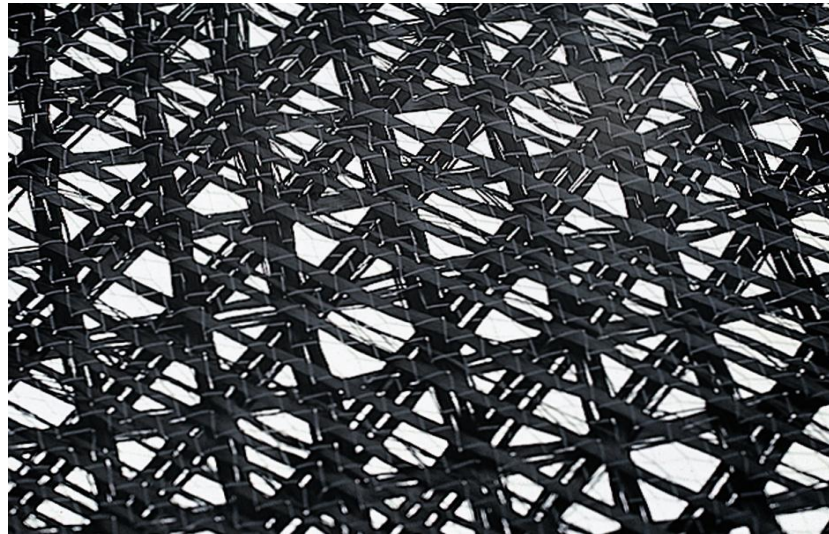
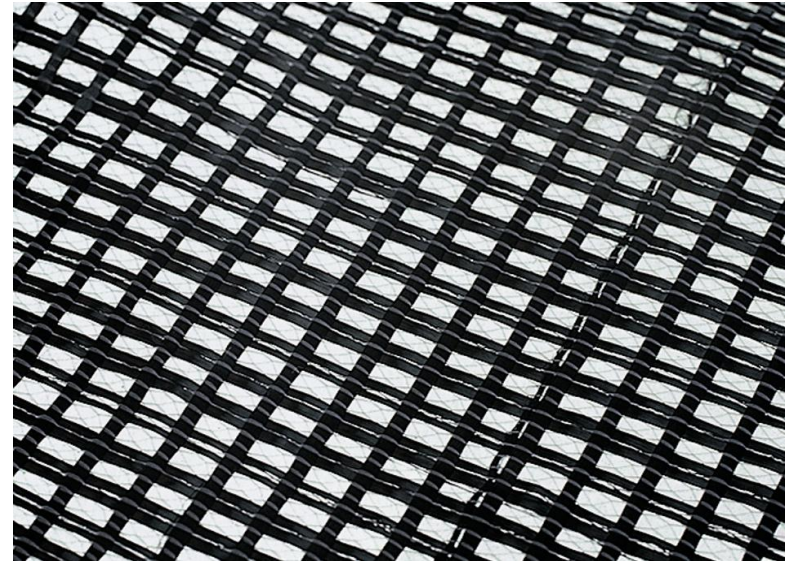
Glass

- Elastic modulus of fibre 72 ÷ 87 GPa
- Tensile strength 3300 ÷ 4500 MPa
- Elongation at breakage 4.8 ÷ 5.0 %

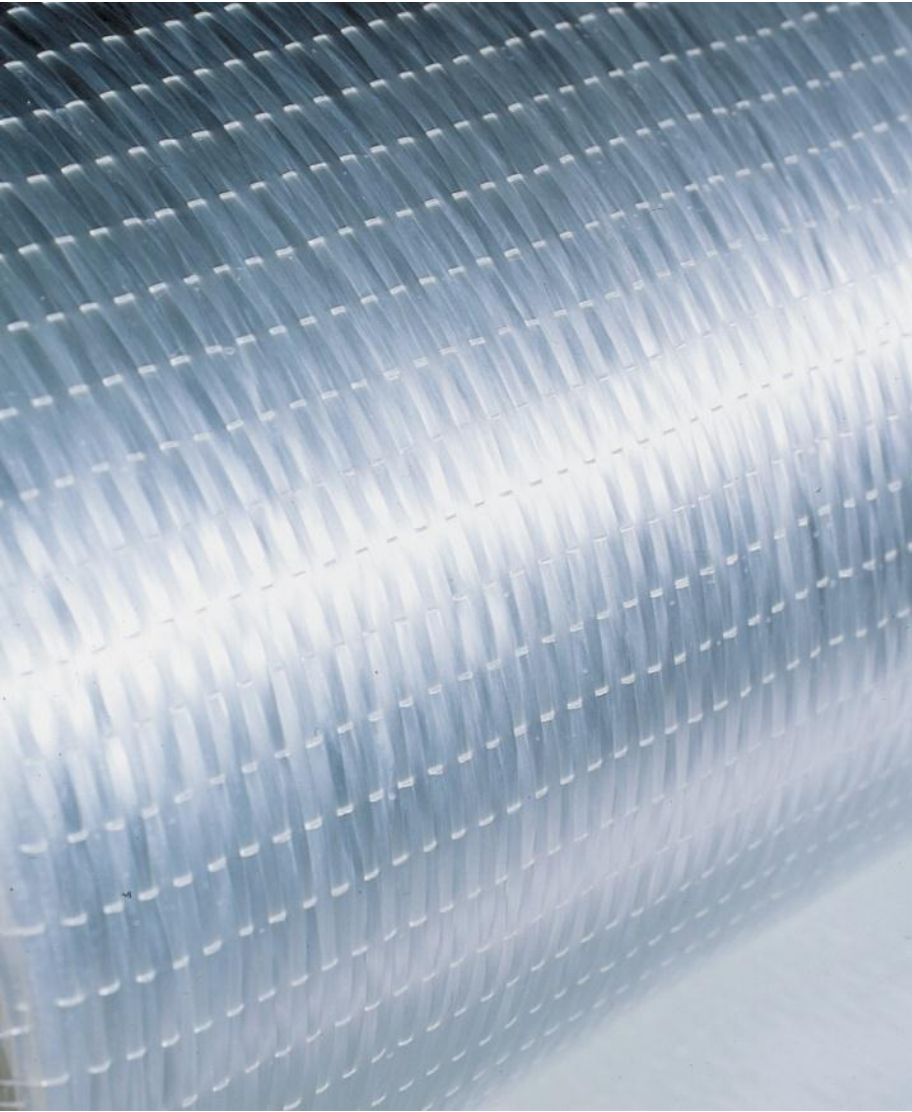
Basalt

- Elastic modulus of fibre 85 ÷ 98 GPa
- Tensile strength 3200 ÷ 4840 MPa
- Elongation at break 1.9 ÷ 3.2 %

FRP Fabrics



FRP Fabrics cont.



CFRP Plates



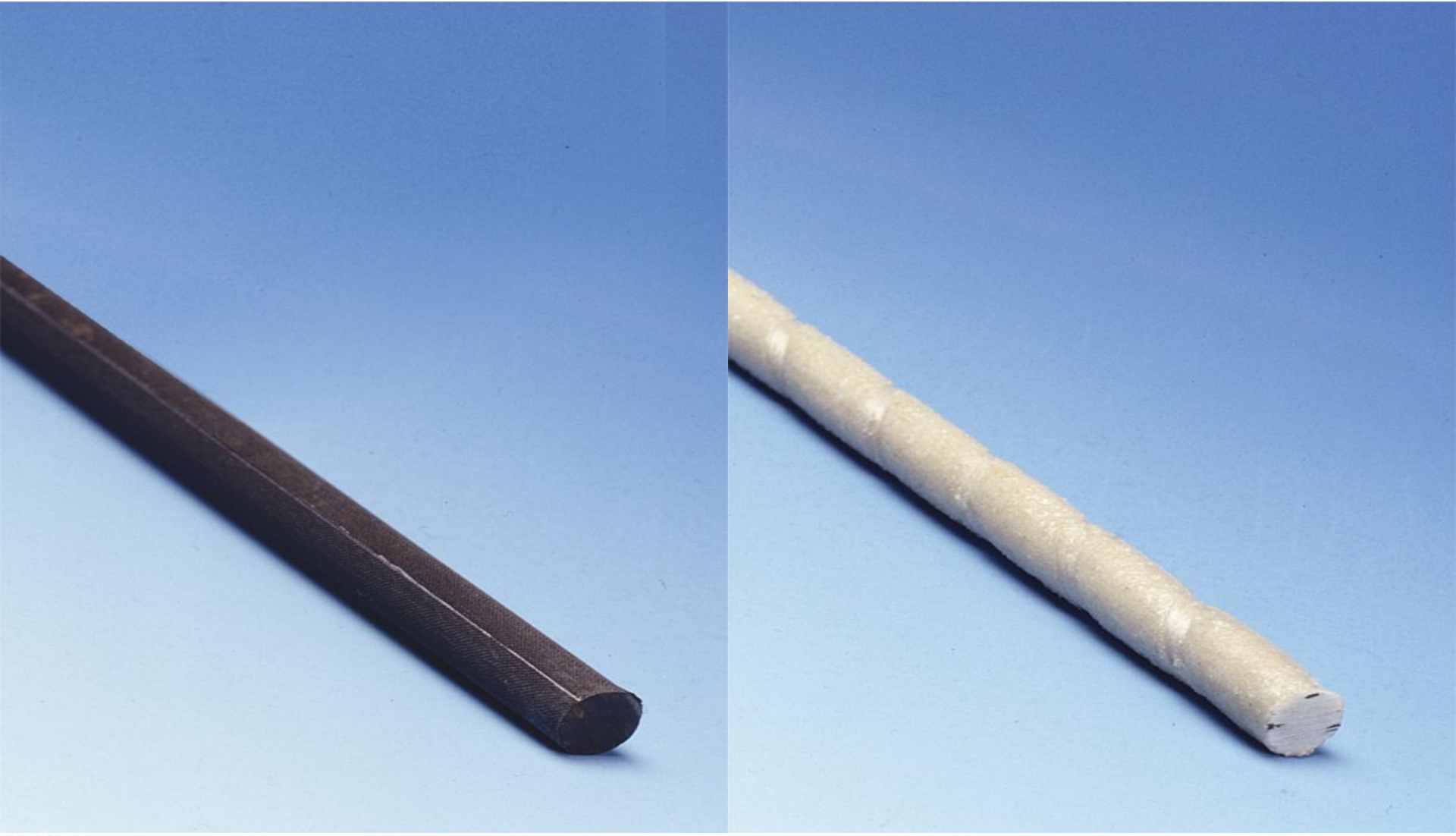
CFRP Plates

Advantages

- Ideal for flexural reinforcement
- Easy of installation
- Limited area of surface prep required
- Non-invasive, inconspicuous repairs
- Controlled quality on site
- Excellent, long-term track record



CFRP Rods









The voice of the concrete repair and refurbishment industry

The Structural Concrete Alliance
brings together the expertise of:

C & G FRP Rods

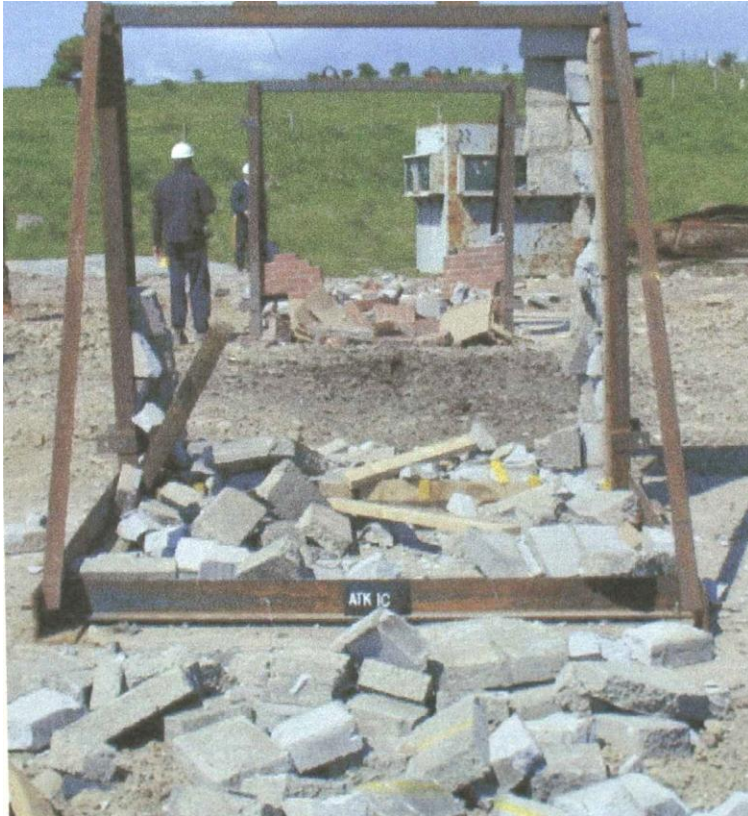
- Near surface-mounted carbon fibre rods



CFRP Anchoring systems



Protection of People



Blast testing of
unreinforced wall

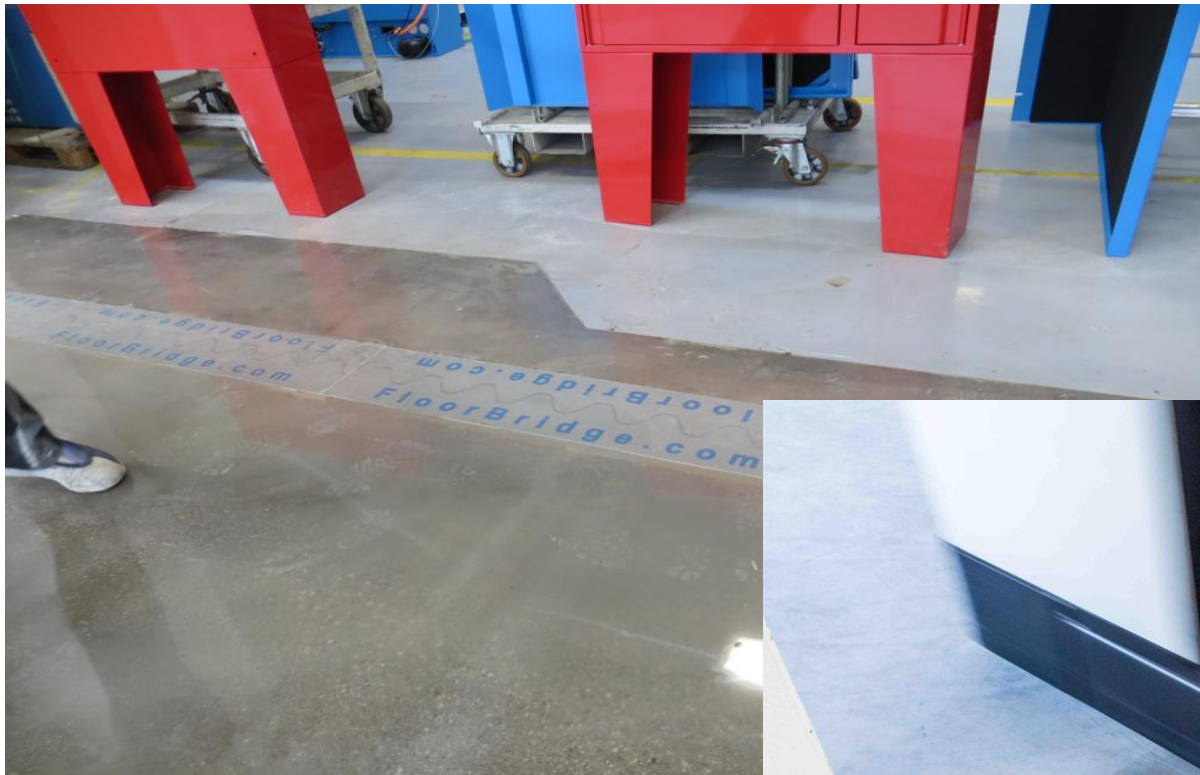


Composite reinforced
masonry wall

Blast to floor slab



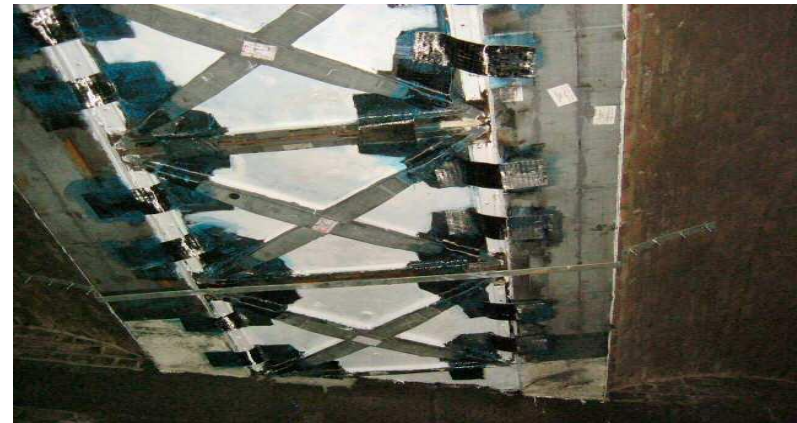
Composite Floor Joint Solutions



Hammersmith Road Bridge

Before

After



Seismic Strengthening

- Vaults



Seismic Strengthening

Earthquake Wall Paper



Flexural Strengthening



Shear strengthening



New floor opening



Confinement



Key benefits of Composites

- Lower weight
- Fast and lower cost installation
- Reduced life cycle maintenance costs
- Minimal business interruption
- Increased refurbishment opportunities
 - To extend existing asset life

Summary

- ✓ Composites are viable means of strengthening existing structures
- ✓ Proven performance since 1950's
- ✓ High strength-to-weight ratio
- ✓ Easy of installation
- ✓ Versatile
- ✓ Minimal limitations
- ✓ Wide array of fabric geometries to meet specific project needs
- ✓ Design guideline (TR55) to assist engineers



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