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.
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

<table>
<thead>
<tr>
<th>Parts</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1</td>
<td>Definitions</td>
</tr>
<tr>
<td>Part 2</td>
<td>Surface protection systems for concrete</td>
</tr>
<tr>
<td>Part 3</td>
<td>Structural and non-structural repair</td>
</tr>
<tr>
<td>Part 4</td>
<td>Structural Bonding</td>
</tr>
<tr>
<td>Part 5</td>
<td>Concrete Injection</td>
</tr>
<tr>
<td>Part 6</td>
<td>Anchoring of reinforcing bars</td>
</tr>
<tr>
<td>Part 7</td>
<td>Reinforcement corrosion protection</td>
</tr>
<tr>
<td>Part 8</td>
<td>Quality control and evaluation of conformity</td>
</tr>
<tr>
<td>Part 9</td>
<td>General principles for the use of products and systems</td>
</tr>
<tr>
<td>Part 10</td>
<td>Site application of products and systems and quality control of the works</td>
</tr>
</tbody>
</table>
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.
Defects in concrete

Mechanical
- Impact
- Overload
- Movement e.g. settlement
- Explosion
- Vibration

Chemical
- Alkali –aggregate reaction
- Aggressive agents e.g. sulphates, soft water, salts
- Biological activities

Physical
- Freeze / thaw
- Thermal
- Salt Crystallisation
- Shrinkage
- Erosion
- Wear

(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 advice on the best options
Specifying to BS EN 1504
Products and systems for the protection and repair of concrete structures

3 Choose Repair Principal

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

4 Choose Correct Repair Methods

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

7 Preserving or restoring passivity

8 Increasing resistivity

9 Cathodic control

10 Cathodic protection

11 Control of anodic areas

Restoring the concrete to a highly alkaline condition to protect steel rebar.

Increasing the resistivity of the concrete to prevent rebar corrosion.

Preventing corrosion of rebar reinforcement.

Reducing or preventing the corrosion reinforcement.

Creating conditions for the steel rebar not to be subject to corrosion.
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

- Visual
- Sound
- Thickness
- Chemical
- Potential Mapping (1/2 Cell)

Close up inspection
Hammer testing
Cover to steel
Chloride levels
Corrosion mapping
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

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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 <0.5m$^2$ 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 >60N/mm²
- Aggregate grading <10mm
- 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

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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
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
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

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Seismic Strengthening

- Vaults
Earthquake Wall Paper
Flexural Strengthening
Shear strengthening
New floor opening
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