Concrete Defects - Cause & Cure

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• What does a defect in concrete look like?
• What are the main causes of defects in concrete?
• How do you identify defects in concrete?
• What is the best way to procure concrete repair works?
• What are the principal methods of repair?

Concrete is a great material...

Concrete is a composite material composed of fine and coarse aggregate bonded together with a fluid cement that hardens over time.

- lasts forever - 5600 BC
- is the most widely manufactured human-made material (measured by tonnage)
- still the most widely used construction material

What is concrete & where does it come from?
• Structures constructed 25 - 35 years ago often suffer from poor quality construction
• Construction is well regulated now and quality of workmanship is generally good
• Most problems with concrete originate from bad workmanship & design issues

**Defects in concrete**

**Mechanical**
- Impact
- Overload
- Vibration
- Erosion
- Settling

**Chemical**
- Alkali-aggregate reaction
- Moisture
- Temperature
- Freezing / thawing
- Aggressive agents
  - e.g. sulphates, soft water, salts
- Erosion
- Wear

**Physical**
- Thermal
- Salt crystallisation
- Shrinkage
- Biological activities
- Freeze / thaw

• Buildings and structures need to be maintained
• Many of these assets start to fail due to the lack of simple planned maintenance
• This lack of maintenance can lead to costly repairs that could have been prevented
The main causes of defects in concrete

- Chloride attack (marine salts, de-icing salts)
- Carbonation (carbon dioxide)
- Poor construction (lack of cover to steel, poor quality concrete, poor compaction)
- Lack of maintenance (drainage outlets blocked)

The main cause of defective concrete is corrosion of the reinforcement caused by chloride (salt) attack

The main sources of chlorides in concrete are:
- Road salts
- Marine spray/wetting
- Accelerators
- Marine Aggregate

Carbonation of concrete is where carbon dioxide from the atmosphere permeates the concrete
- When the carbon dioxide and moisture reach the reinforcement, the alkaline passivating layer is destroyed and the steel corrodes
- This can lead to spalling of the surface
Typical defects in concrete

- Spalling caused by reinforcement corrosion
- Cracking due to shrinkage or overloading
- Frost damage at construction stage
- Alkali silica reaction (ASR)

When steel corrodes the volume increases significantly.
- Concrete is weak in tension
- This increase in volume can cause the face of the concrete to burst off (spall)
- When this happens on a building or a bridge soffit this can lead to serious damage, injury or loss of structural integrity
• Concrete has a tendency to crack (weak in tension)
• Cracking in concrete is normal but can be controlled with good design and good working practices
• Cracking can be caused by many things but the most common are shrinkage, settlement and overloading

• Some of the worst damage to concrete happens when it is being poured
• If concrete is subjected to low temperatures before it has cured, this can lead to severe irreparable damage
• If concrete gets frosted there is no way to repair it, it has to be replaced

• Alkali silica reaction (ASR) is not common in Scotland but where it does occur it has a dramatic effect on concrete
• There is no fix for this problem but it can be managed to reduce the rate of progression
Identification of defects in concrete

- Visual survey
- Hammer test
- Instrument survey (cover meter, ferroscan)
- Intrusive survey (break-outs)
- Site sampling and testing
- Laboratory testing of samples
- Creating a defects schedule

The first line of attack in understanding defects in concrete is a visual inspection by an experienced survey technician.

- This inspection can go a long way to getting a good understanding of the general condition of a structure or building and can identify many obvious defects.

BS EN 1504 is clear: there must be a survey and interpretation of results before embarking on a concrete repair project! This is the principal stage where contract risk can be controlled.

One of the key skills in determining the condition of concrete is the hammer test, also known as sounding.

- This test is used to identify where concrete has failed.
- In most cases, the failure is caused by corrosion of reinforcement which expands and the concrete spalls.
• There are a suite of instruments that can be used to help in the examination of concrete.
• These include:
  – Cover meter
  – Ferroscan
  – Half cell potential
  – Ground probing radar
  – Rebound/Schmidt hammer

• As good as instruments are, it is still essential to verify results by intrusive investigation.
• Investigation can be by core or breakout, both are usually carried out after reinforcement is located to ensure minimum damage is caused to the reinforcement.

• During the breakout process samples are gathered for further examination, these include:
  – Lump samples, Cores, Drill dust
  – All depth of cover and reinforcement condition are logged
  – On site tests are carried out to determine the depth of carbonation
  – Petrographic Analysis
Carbonation

- Values in bold type indicate where the carbonation front has encroached within 5mm of the shallowest reinforcement.

Chloride

- Values less than 0.2% by value of the weight of the cement, the risk is negligible (bold type).
- Between 0.2 and 0.5% it is deemed low, or moderate (bold & underlined).
- Over 1% the risk is normally thought to be high (bold, italic & underlined).

Survey & Investigation

1/2 cell potential values formatted to the guidelines given in Concrete Society Technical Report.

- Values less negative than -200mV are in normal type, indicating a 5% risk that corrosion was occurring at the time of measurement.
- Values in the range -200mV to -350mV are in bold indicating a 50% risk that corrosion was occurring at the time of measurement.
- Values more negative than -350mV are in bold and underlined indicating a 95% risk that corrosion was occurring at the time of measurement.

Element | Half-Cell Potential (mv) | Least Negative | Most Negative | Note
--- | --- | --- | --- | ---
TA01 | +71 | -284 | | 
TA02 | +12 | -292 | | 
TA03 | +82 | -106 | | 
TA04 | +136 | -114 | | 
TA06 | +68 | -176 | | 
TA08 | +67 | -237 | | 
TA09 | +64 | -99 | | 
TA10 | +10 | -341 | | 

The best way to procure concrete repair works

- Making best use of survey information
- Using the defects schedule created during the survey
- Using the CRA Standard Method of Measurement for Concrete Repair
- Choosing a qualified contractor
- Reducing Contract risk
If a proper survey as required in BS EN 1504 has been carried out then you will have access the following information:

- A detailed report containing a condition survey of the elements of the structure or building that have been surveyed
- A schedule of defects that can be used to populate a bill of quantities
- Recommendations of what work is required to rectify defects (including an indication as to how long these repairs might be expected to last)

The Concrete Repair Association (CRA) provide a Standard Method of Measurement for Concrete Repair (SMM)

- This can be downloaded from their website in both excel and PDF (FoC)
- This document can be used in conjunction with the defects schedule to create a bill of quantities for the works

The Concrete Repair Association (CRA) hold a list of member companies on their website

- It is highly recommended that contractors for concrete repair projects are selected from this list of suitably qualified specialist companies
  - http://www.cra.org.uk
• Concrete repair contracts are often perceived as high risk
• Project budgets are regularly exceeded
• High probability of changes to quantities and methodology

SO -
• The more information you have about your structure or building the lower the commercial risk becomes
• Don’t leave it to the contractor to determine quantities, this will carry a massive risk premium
• Produce a comprehensive tender/contract document

Principal methods of repairing defects in concrete

• Break out and replace
• Cathodic protection (impressed current, galvanic and hybrid)
• Migrating corrosion inhibitors
• Protective coatings
• Carbon fibre strengthening

• The traditional method of repairing concrete is to break out the failed concrete and replace with new material
• This is probably the most invasive method of repair but has a good/reasonable success rate
• Cathodic Protection is regularly used to augment a concrete repair strategy
• Cathodic Protection can extend the life expectancy of a building or structure significantly
• Cathodic Protection can range from impressed current systems designed to last for decades to simple galvanic anodes added to a repair

• Migrating Corrosion Inhibitors (MCI) are a simple cost effective way of controlling corrosion where initial failure has not yet occurred
• MCI is spray applied to the structure and migrates through the covercrete to the reinforcement
• MCI forms a chemical barrier on the steel surface which protects the reinforcement
On completion of concrete repairs projects it can be beneficial to apply a protective coating over the repairs. This can give significant protection against carbonation and will also provide additional protection to low cover reinforcement. Protective coatings can improve the aesthetics of a completed project by giving an even uniform finish.

On occasion it can be necessary to increase the load carrying capacity of a concrete structure or floor. In the past this could involve many tonnes of secondary steelwork. In many cases this can now be achieved using carbon fibre plate or fabric. Concrete is a great, proven and versatile material. Concrete provides cost effective construction solutions. Like any other building or structure, ones constructed of concrete need to be monitored and maintained. If properly designed and placed concrete can last a long time (for-ever!) Make sure when using concrete as a building medium that it is placed correctly, and as designed.

Conclusions

- Concrete is a great, proven and versatile material
- Concrete provides cost effective construction solutions
- Like any other building or structure, ones constructed of concrete need to be monitored and maintained
- If properly designed and placed concrete can last a long time (for-ever!)
- Make sure when using concrete as a building medium that it is placed correctly, and as designed