The testing of concrete to evaluate condition and form

Simon Bladon of **CRL Surveys** deals with, and attempts to give some guidance on, the approach to surveying and testing hardened concrete to evaluate extents and causes of deterioration, as well as the form of uncoated 'as-cast' concrete.

TOP LEFT:
Close visual inspection and marking up.

TOP RIGHT:
Covermeter survey.

The testing of concrete is an extensive topic and a function that is not always completely understood by the people requiring the results. For the newcomer, or even some of the more senior people who only occasionally get involved, there are a potentially bewildering array of tests and equipment now available. Generally, methods of testing are presented as schedules or lists, with little advice concerning appropriate use, interpretation and more importantly when inappropriate.

Of utmost importance is that companies carrying out the in-situ testing of hardened concrete should be UKAS accredited for their site works and associated processing and reporting, as well as the laboratory doing the analysis and sample testing.

ASSESSMENTS OF DAMAGE AND DISTRESS

This involves what should be the simplest of procedures, ie, visual inspection and hammer testing (also termed a 'delamination survey').

Although 'simple', their importance cannot be underestimated, whether being used to monitor a structure, assess the significance, or severity of damage, or putting together a Schedule of Defects for a repair Bill of Quantities. Accurate nomenclature and measurement are vital.

These activities should always be undertaken by more senior personnel, trained and competent, who know where to look, know what they are looking at and with the skills to correctly interpret what they find.

Where practicable, a visual inspection should be augmented with hammer testing, with concrete surfaces subjected to light sounding using a 'lump hammer'. The hammer should be drawn over the surfaces and used lightly to tap the concrete in order to identify loose, hollow and delaminated/spalling areas.

TESTING AND SAMPLING PLAN

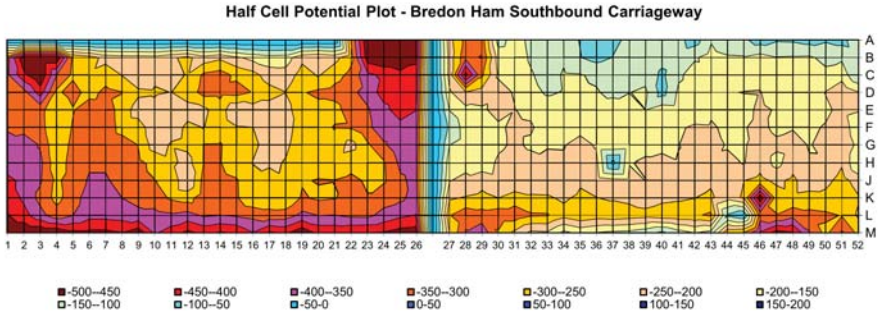
Areas selected for gathering data during visual inspection and hammer testing should always be spread equally, to be representative of the 'good', the 'bad' and the 'indifferent'.

ASSESSMENTS OF CONCRETE MATERIAL CONDITION

To assess the concrete material condition of a structure, or individual elements, measurements of cover to reinforcement, sampling for chloride analysis and in-situ testing for depths of carbonation should always be undertaken.

Generally, the covermeter used to determine the depth of the reinforcing does not need to be overly complicated and be able to produce images of reinforcement distribution and detailing. As long as it has been calibrated and its limitations, precision and accuracy are understood, it will be sufficient to determine the depths of cover for analysis purposes. It is important to measure directly and record the original 'as-cast' depths of cover at spalled locations, assess any repeating patterns, or locations of spalling and include those locations elsewhere on the structure in the sampling and testing plan.

Sampling of the concrete – again driven by the results of the visual inspection and hammer testing – will, for analysis purposes, invariably comprise drilled dust sampling, involving drilling into the concrete and collecting the resultant dust produced. Points to consider are the size of drill bit to be used. As most concrete will have a relatively large/coarse aggregate, say up to 25mm, the drill bit should be at least 25mm diameter and the holes drilled to depths greater than 25mm, or multiple holes drilled at each location. This ensures that the dust sampled is representative of the concrete, not just the aggregate, as



well as ensuring that sufficient dust is collected.

Analysis of the dust samples will, again, be driven by the visual inspection and the survey technician's interpretation but will invariably include chloride contents. Exposure conditions and other evidence may drive other analyses, eg, for the contents of cement, sulfate and or alkalis.

If exposure conditions dictate, drilled dust sampling can be done incrementally, ie, taking separate subsamples at different depths, to evaluate how deeply contaminated, and to what extent the chlorides, or other substances have penetrated into the concrete.

Testing for depths of carbonation can also be undertaken on the drilled holes. This is normally done by producing a freshly broken edge on the side of the drilled hole and spraying with a solution of phenolphthalein indicator. Do not just spray the drilled hole, as this may give erroneous results (note – phenolphthalein is highly flammable, but also acts as a pretty good laxative, so remember to wash your hands after use).

REINFORCEMENT CORROSION CONDITION

The potential for reinforcement corrosion will usually be assessed using the measurement of half-cell potential, with the rate of reinforcement corrosion assessed by the measurement of resistivity.

These days, half-cell potential is undertaken using silver–silver chloride electrodes, as older copper–copper sulfate electrodes are prone to contamination and need regular recharging with solution. However,

TOP LEFT:
Breaking drilled holes prior to cleaning and carbonation testing.

BOTTOM LEFT:
Carbonation testing (purple colour pH less than 10).

TOP RIGHT:
Half-cell potential measurement.

ABOVE:
Half-cell potential contour plot of an abutment (either side of a central joint).

ABOVE:
Rig set-up for core sample drilling.

values should always be recorded as copper–copper sulfate equivalent, if not directly being converted by the instrument used.

Care must be taken when selecting test areas. Measurements should not be taken from saturated concrete or very dry concrete. Results obtained from concrete structures or elements in or containing water, cladding panels and dry soffits, for example, need to be carefully considered and interpreted.

Generally, a four-probe, Wenner array instrument will be used for measurements of resistivity, as this piece of equipment allows surface measurements to be taken, as opposed to the two-probe instrument that requires holes to be drilled into the concrete.

The corrosion rate of the reinforcing can be measured using linear polarisation resistance (LPR), but by comparison with taking half-cell potential measurements, the equipment is relatively expensive and testing at each location can take several minutes. This makes it far more time consuming and therefore expensive when compared with half-cell potential and resistivity, and is generally only used when specific information is required.

It is always wise to select representative locations for exposure of the reinforcement, eg, selected 'hot' (anodic) and 'cold' (cathodic) areas, to evaluate the actual corrosion condition of the reinforcing.

ASSESSMENTS OF CUTTING OUT, DEFECTS TO REPAIRS

Reinforcement at representative existing spalled locations should be chased back to sound concrete in order to assess both the extent of corrosion in relation to the depth of carbonation and depth of chloride contamination at that location.

In addition, the relative dimensions and form of potential repairs, compared with the typical defects, should be assessed to provide some data for the subsequent preparation of a concrete repair Bill of Quantity.

In addition to the above, to assess the likely depth at which the reinforcement is at risk, it is advisable to expose and inspect the reinforcement within sound areas in some locations, at progressively greater depths of cover, for evidence of corrosion.

ASSESSMENTS OF REPAIRS

Previous repairs should be subjected to close scrutiny. Notes concerning the following should be made:

- are repairs associated with any structural features, eg, structural edges, joints, or other such features
- what are the relative colour/s difference – concrete vs repairs
- is the surface finish different – texture and aesthetics
- was the patch cured
- has the patch slumped, or is there any other plastic deformation
- is there any displacement, or misalignment
- is there any cracking and crazing, and/or staining
- has the patch delaminated.

Representative repairs should be broken out to assess the following:

- preparatory breaking out, feather edging and squaring-off
- reinforcement cleaning and priming
- concrete cleaning and priming
- repair material type
- repair depths and layering
- material hardness, compaction and voids.

INTRUSIVE STRUCTURAL INVESTIGATIONS

CONCRETE STRENGTH

In an ideal world, the crushing of representatively sited and correctly prepared, carefully treated core specimens would always be the way forward. However, where coring is not prudent or possible, the determination of rebound number, again in representative locations, with a calibrated hammer and complying with the details of the standard procedure can give a reasonable idea of possible strength.

REINFORCEMENT/PT DETAILING

This is where the high-tech equipment can come into its own, with imaging scanners, with or without radar, together with modern ultra-sonics assisting with the location and investigation of potentially sensitive details and conceivably reducing the need for extensive, damaging breaking out, which could possibly become potential vulnerable locations in the future. C