Deterioration of reinforcement bar.

Core sampling.

Analysing concrete failures in-situ

***Joanne Booth** of **Lucideon** discusses the range of testing procedures available for concrete during its structural life.*

Concrete is created using raw and processed materials and is therefore a non-standard product due to the variation of its constituents. The materials are usually sampled from many different places and batched in different proportions with a variety of additives to improve air content and consistence and control setting times etc. As such, the quality and performance of concrete can vary.

To ensure concrete is capable of performing in the manner that it was designed to do, the product should be tested at different points during its life cycle, ie, when batched and poured, fully cured and in-situ. In-situ testing is normally used to understand the cause(s) and consequences of deficiencies. Failure analysis enables the most appropriate course of action to be taken to instigate repairs, decide on replacement or, where necessary, apportion responsibility.

There are a variety of European Standards under the EN 12390[1] series that deal with the sampling and testing of wet concrete and laboratory-cured concrete for physical properties, including compressive strength, density, flexural strength, water absorption, durability and chloride content. The prescribed tests highlight any problems during pouring and after initial curing.

The testing process becomes more complicated when concrete begins to show deficiencies during its working life. When investigating a potential problem, a visual inspection should always be conducted prior to deciding on sampling rates, sampling techniques and test requirements. An experienced consultant or test house can often understand the causes of a failure from visually examining the deficiency. Floor cracking is often due to poor design and incorrectly calculated joints, which can easily be identified through a visual assessment.

The flaking corrosion of an exposed reinforcing bar would indicate carbonation of the concrete, whereas a more penetrative localised corrosion of the reinforcement would indicate chloride attack. Small amounts of concrete can be sampled from areas of failure by using hand tools. The samples can be tested on-site to establish the depth of carbonation (as per BS EN 14630[2]) using the phenolphthalein indicator, which must be done on freshly exposed concrete or in the laboratory to detect the presence of chloride ions (BS 1881[3]).

There are a range of non-destructive techniques available, each of which has limitations. The position, size and depth of the reinforcing bars can be mapped using a cover meter; these can be used to check that the design is fit for purpose. The meters are simple to operate but can be unreliable if the correct parameters are not used and it is difficult to obtain clear readings, particularly if there is more than one layer of bar and it is placed at a depth greater than 200mm.

For floor slabs, a ground-penetrating radar (GPR) can be used to scan large areas; this will show the presence of voids, reinforcement and any cracking. As with cover meters, this tool is best used with some prior knowledge of the construction make-up and also requires an experienced operator to interpret the readings. Both techniques provide much more reliable results if small

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areas are opened up to verify bar diameters, centres and depth of cover in order to calibrate the equipment.

Half-cell potential can be used to map corrosion in reinforcing bars over larger areas. This does require breaking the surface of the concrete to expose areas of reinforcement; however, this is minimal. There is no British or European Standard available but there is an ASTM Standard[4], which provides guidance for classifying the measured potential in three categories: more than 90% chance, less than 10% chance or an uncertain chance of corrosion.

Inspection

When assessing large areas, a visual inspection is often carried out to determine the sites to be sampled, which will generally be chosen as the poorer-quality sections. A rebound hammer test[5] can be used to delineate any areas of poorer quality. Testing is usually conducted using a grid pattern over a nominally 3 × 3ft (0.9 × 0.9m) area and results can be estimated quickly and easily in-situ. The results are more accurate when the hammer is calibrated against cores sampled on-site and testing is carried out in the laboratory. This technique is ideal for large areas as each test can be performed in a relatively short period of time (ten to 15 minutes) without causing damage.

When concrete is degrading, the first characteristic to be investigated is the compressive strength[6]. Removing core samples from site is the most reliable method to understand concrete strength. Ideally, samples should not contain reinforcement and must be taken so that when the core is prepared for testing it has a diameter:height ratio of 1:1. The core should also be prepared correctly, ie, ground or capped at each end before testing. Material from the crushed core can be used to establish mix proportions, presence of sulfates and aggregate grading size.

Cores are not only for strength testing, they can also be thinly sectioned and used for petrographic analysis[7]. This is an excellent technique for forensic analysis and provides details on a number of parameters, including mix contents, presence of voids, chemical attack, air entrainment, analysis of cracks and alkali–silica reaction.

There are many more techniques available; these are the more common ones. It is worth noting that experienced technicians need to be used in order for the correct sampling and analysis route to be devised, to provide the most time- and cost-efficient outcome. ■

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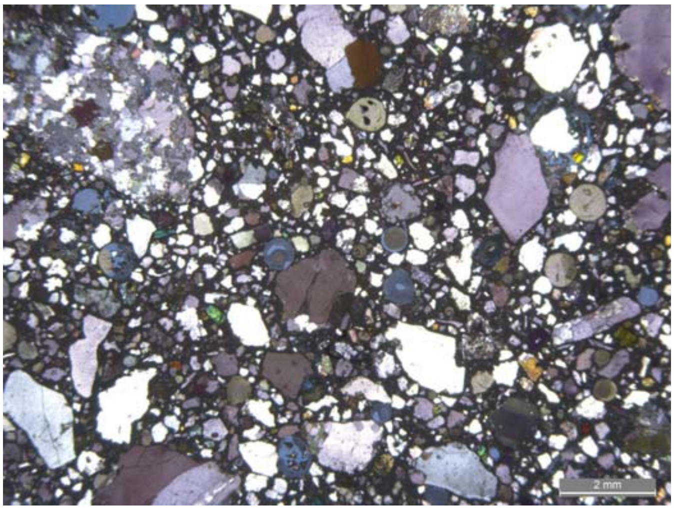

Concrete sample under petrographic analysis.