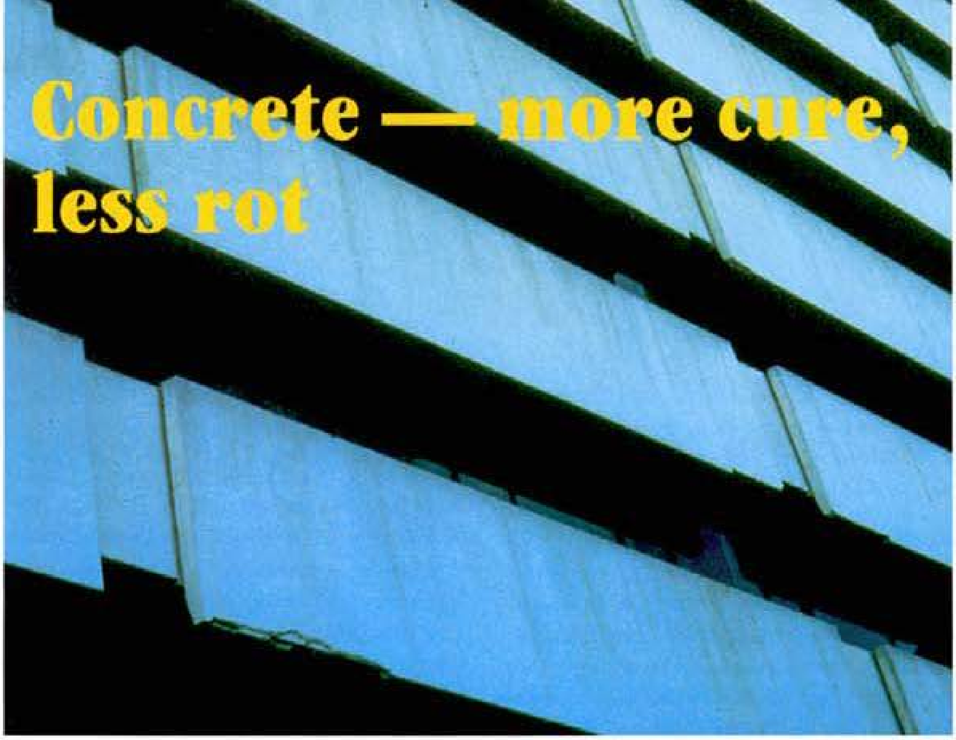
Concrete — more cure, less rot



Decay of the concrete facade of a building in Canberra. The overhangs have since been levelled off.

The symbols of contemporary urban life — skyscrapers and pavement — dominate modern cities. But we often forget that their main ingredient, concrete, has been around for a long time. In ancient Rome, all of the roads and many public buildings, such as the Pantheon, employed concrete in their construction.

After the fall of the Roman Empire, the development of concrete technology lapsed until the 18th and 19th centuries, when British engineers developed a mixture based on what is still known as Portland cement. Most of today's big buildings consist largely of concrete, yet many show signs of decay soon after construction.

Reinforcing steel rods help strengthen these concrete edifices so that they can support their massive loads. The outer layer of concrete between the exposed surface and the reinforcement is known as the 'cover'. Unfortunately, the steel under the cover often rusts, particularly in marine environments and polluted areas, resulting in flaking of the concrete.

Dr David Ho and Mr Don Beresford, both of the CSIRO Division of Building Research in Melbourne, put the cost of remedying corrosion problems in Australian city buildings at about $50 million a year in the late 1970s, and believe it is likely to reach $200 million a year by the turn of the century. For the denser concrete jungles of the United Kingdom, the cost associated with corrosion in the construction industry is already about $700 million annually, most of it due to corrosion of the steel reinforcement.

History provides us with an example of how durable reinforced concrete constructions can be. Mulberry Harbours, constructed in Normandy for the D-Day landings in 1943, are still in good condition after 40 or so years, even though in some places the concrete only covers the steel reinforcement to a depth of 25 mm.

So what's happened to concrete since 1943? Dr Ho believes the answer lies in changes in workmanship, inadequate on-site curing, and alterations in constituents over the last 40 years, including a decrease in the proportion of Portland cement used.

Modern concretes are strong, but strength does not necessarily mean durability.

Water sorptivity test

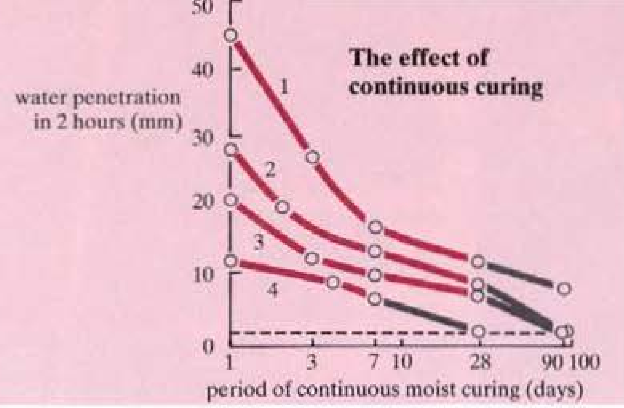
Concrete is traditionally made up of a mixture of cement, aggregates (sand or gravel), and water. The water makes the concrete workable, but too much weakens the hardened product by increasing its porosity. Builders 'cure' the concrete for several days by preventing water evaporating from the concrete. This enables the cement hydration process to continue and the concrete to harden and strengthen — reducing the size of its pores.

Over the last two decades, the industry has introduced the use of chemical and mineral admixtures, which can reduce the amount of water needed for workability, thus increasing the strength of concrete. Chemical water-reducing agents are now routinely included in all concrete production, and mineral admixtures are also used in most large Australian cities. For the industry, the main advantage is the cost-saving because, with these additives, the builder can reach a specified strength using less Portland cement in the mixture.

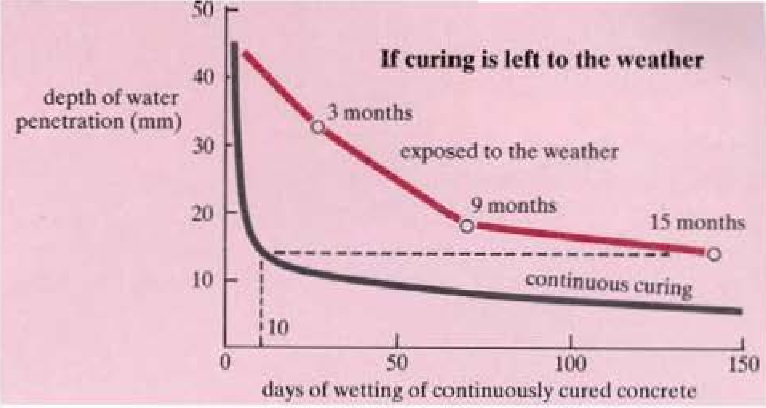
The building industry has a standard test for concrete known as the 28-day strength. This is the crushing or compressive strength attained by a sample cylinder of a particular type of concrete after 28 days of curing in a standard water bath or 'fog-room'.

Engineers have used 28-day strength as a measure of the quality of concrete. However, on-site curing is often limited to a week or less, so the 28-day figure does not provide a reliable index of the concrete's actual quality — particularly that of the 'cover' portion protecting the steel rein-

Repairing a reinforced concrete building.



Water penetration measurements showed that sorptivity fell to, effectively, zero (dotted line) after 90 days for all of these plain concretes except the lowest strength one (number 1). The strongest (number 4) reached zero sorptivity at about 28 days.



Ten days of continuous moist curing reduced the sorptivity of this low-strength concrete to a level not reached by another sample until 15 months after it was exposed to the weather following only 1 day's curing.

forcement. Thus it provides few clues to the concrete's likely durability.

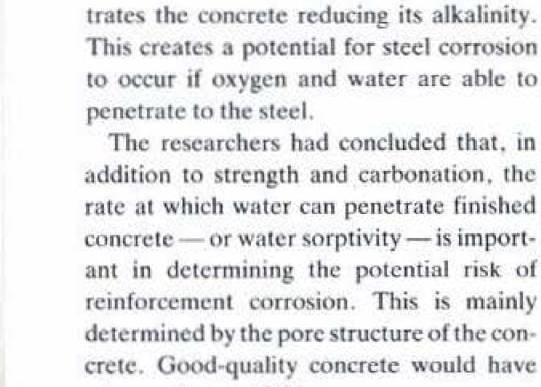
Dr Ho and his colleagues at the Division of Building Research have recently focused their efforts on how different curing practices affect concrete durability and the corrosion of embedded steel.

Their earlier work had shown that, given limited curing, concretes made from different constituents but having the same 28-day strength did not carbonate at the same rate. Carbonation is the process whereby carbon dioxide from the air outside penetrates the concrete reducing its alkalinity. This creates a potential for steel corrosion to occur if oxygen and water are able to penetrate to the steel.

The researchers had concluded that, in addition to strength and carbonation, the rate at which water can penetrate finished concrete — or water sorptivity — is important in determining the potential risk of reinforcement corrosion. This is mainly determined by the pore structure of the concrete. Good-quality concrete would have a low water sorptivity.

With Mr Russell Lewis, also of the Division, Dr Ho developed a method of measuring the extent to which water penetrates the layer of concrete covering the reinforcement. The two researchers then demonstrated the use of the method by assessing the relative water sorptivity of different concretes, both with and without admixtures, after various periods of wetting and drying.

A reinforced concrete staircase.



Rain simulator

A wind-driven rain simulator sprayed the surface of the concrete samples with water under various atmospheric pressures. The scientists calculated the water sorptivity by splitting the specimens at various times and gauging the depth of water penetration. They also developed a non-destructive test using measurements of electrical resistance between pairs of copper pins.

Unfortunately, the reinforcing steel often rusts.

One of their most important findings was that the water sorptivity of concrete — and hence its potential durability — can be dramatically affected by the initial curing period. Particularly for low-strength concretes, the degree of water penetration decreased markedly after 7 days of continuous moist curing.

When the initial curing period was extended to 90 days, all of the stronger concretes reached a state of zero sorptivity — a sign that most of the pores had closed. Some high-strength concrete can reach zero sorptivity within 28 days of curing.

As most concretes used in above-ground structures are moist-cured for less than a week, any further closing up of the pores has to rely on water from rainfall, or periods of high humidity.

The CSIRO team set up an experiment on the Division's site to gauge the effects of natural curing. They found that it took 15 months of exposure to improve the quality of concrete — initially cured for 1 day — to a stage reached in the laboratory after only 10 days of continuous moist curing. Although rainfall during the site test had been adequate, wetting of the concrete was intermittent, and this seemed to be the main factor slowing down the curing process relative to continuous moistening in the laboratory.

Further, the duration of rain, rather than the amount, is what counts in natural curing. For example, a 4-hour drizzling rain would be better than a 2-hour heavy downpour. Also important are the temperature and direction of rain.

As for the effects of additives, Dr Ho and Mr Lewis found that water-reducing agents appeared to reduce the water sorptivity of concretes. However, this needs to be verified by further measurements. What is certain is that each admixture has its own characteristics — affecting carbonation and sorptivity — and reacts differently with different cements.

The test procedure has already been applied in Perth, where engineers have measured carbonation and sorptivity on samples taken from a building where problems of steel corrosion have occurred.

With further experiments, the Division of Building Research hopes to identify more fully the factors that influence the durability of concrete. At the moment, the standard specifications for concrete are under revision. Dr Ho's continuing work on durability will eventually sort out which concrete mixes are the most durable, thus ensuring that some of the 'rot' will be taken out of urban blight.

Mary Lou Considine

More about the topic

Concrete quality as measured by water sorptivity. D.W.S. Ho and R.K. Lewis. *Civil Engineering Transactions of the Institution of Engineers, Australia*, 1984, **26**, 305–12.

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Investigating concrete's durability. *Ecos* No. 35, 1983, 30–1.