Investigating concrete's durability

Concrete buildings poured in recent years appear to start crumbling earlier than their predecessors.

A survey of North Sydney buildings — done in 1979 by Ms S. Guirguis of the Cement and Concrete Association of Australia — revealed this trend. It showed that 69% of the buildings less than 15 years old had noticeable durability problems. More surprisingly, buildings less than 5 years old had an even greater potential in this regard.

The commonest problem is rusting of the steel reinforcement within the concrete. Since the corrosion product occupies more than twice the volume that the steel did, the interior expands and causes pieces of concrete to break off from the surface. Not only does this disfigure the building, it's a safety hazard to people near high-rise buildings, and ultimately it can create a structural weakness.

At the time of the survey the annual cost of repairs, Australia-wide, was estimated to be $50 million; by 1990 the figure was predicted to rise to $200 million.

In normal circumstances, concrete provides steel with a protective coating — a 'passivating' film — which is maintained by the alkalinity of the cement (a pH of at least 12). Over time, this alkalinity can be diminished by carbon dioxide from the air penetrating the concrete.

Any change in concrete formulation that reduces long-term alkalinity is therefore suspected of impairing concrete's durability. There are, according to Mr Don Beresford of the CSIRO Division of Building Research, quite a number of suspect components.

One such ingredient is calcium chloride, sometimes added to the concrete to speed setting. However, chloride ions can form hydrochloric acid and

Crumbling concrete on a modern high-rise building. What's the cause?

destroy the protective film on the reinforcement. Sea spray can also provide this potentially corrosive ion.

In another change, today's formulae often contain less Portland cement to reach the same specified strength. Improved technology in manufacturing cement and proportioning concrete mixtures has brought this about. Use of less cement may lead to smaller reserves of alkalinity, and earlier and more rapid rusting.

It is common for from 15 to 30% of cement to be replaced with fly ash from coal-burning power stations. As well as reducing costs, fly-ash concrete can be pumped more easily, and can achieve higher strength levels than its unblended counterpart. However, tests show that reduced long-term resistance to carbon dioxide may ensue.

Other additives, including water-reducing agents, find their way into modern concrete, and these may alter the material's porosity and permeability. Environmental factors such as increased air-pollution levels may also be having an effect. There are many reasons why concrete may be decaying earlier.

Mr Beresford and his colleagues are investigating some of the more likely ones in a research program sponsored by the Cement and Concrete Association.

They are making test blocks of concrete and subjecting these to accelerated carbonation tests. Using a chamber with a carbon dioxide level more than 100 times greater than normal (4% by volume), they can simulate 9 years of outside exposure in 8 weeks.

Although the tests will continue for some years, some preliminary results can be presented.

The depth to which carbon dioxide penetrated into each sample was revealed by breaking open the sample and applying a pH indicator, phenol-phthalein. After 8 weeks in the test chamber, carbon dioxide had penetrated 29 mm into the fly-ash concrete, compared with 18 mm in plain concrete. This test implies that fly-ash concrete is less durable.

However, extended water curing greatly reduced the carbonation depth. Also, tests on water movement through the samples, measured by changes in weight of the samples at various stages of wetting and drying, showed that the fly-ash concrete absorbed less water. This reinforces the view that fly-ash tends to improve the watertightness of concrete, and water is one of the elements necessary for rusting.

As Mr Beresford sees things at the moment, although fly ash may cause concrete to carbonate earlier, the rate of corrosion may be slower. Many more factors that affect durability need to be investigated. Other research at the Division is directed towards establishing the best repair procedures for affected buildings.

From the various studies, a suitable building code and a standard for durable concrete should result.

'The Effects of Fly Ash and Water-reducing Agents on the Durability of Concrete.' D.W.S. Ho and R.K. Lewis. (CSIRO: Highett 1981.)