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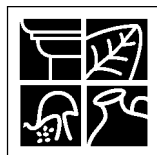
Conserving historic building fabric

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NEW “HERITAGE MATERIALS”

Reinforced concrete – use, deterioration and repair

Kevin Hunt



NSW
Heritage
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About the Speaker

Kevin Hunt is a structural engineer with Hyder Consulting where he leads their Diagnostics group, with particular emphasis on concrete and masonry building facades and waterproofing. Prior to joining Hyder he held a similar position with Arup Facade Engineering. Over the past decade, Kevin has undertaken inspections and condition assessments on many buildings around Australia and SE Asia. Earlier experience includes a period as a rural project manager in Papua New Guinea, and ten years in the construction field with Sydney Water.

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Reinforced concrete – use, deterioration and repair

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Concrete as a building material has been around for a very long time. In Yugoslavia, some has been identified which is thought to be over 7000 years old. It is present in the pyramids at Gizeh and the Romans used it in the Pantheon and in aqueducts in France, where it is still performing well. The earliest surviving Australian examples date from the 1860s and '70s.

Concrete today is an indispensable part of the fabric of modern society, used for everything from mundane road pavements and high rise building structures to the more exotic such as ferro-cement yacht hulls. Despite its long history of use, our understanding of the material has only really developed in very recent times, particularly with respect to its durability, and practices which were commonplace only twenty years ago would now be unthinkable.

Concrete comprises cement, aggregates (stone and sand of various grades) and water. It typically also contains additives to improve various characteristics such as workability, strength or resistance to chemical attack. It is nearly always reinforced with steel embedded within it, as it has high compressive strength but poor tensile strength.

While it has proved to be a very durable material, it is acknowledged to be susceptible to failure, most of which stems from this need to reinforce the concrete with steel bars or mesh. The same steel which enables a flat beam or slab to carry load, or controls cracking due to shrinkage, is capable of rupturing the concrete. This is the result of the four-fold expansion in volume which takes place when steel corrodes. There are also less common breakdowns which occur in concrete due to chemical incompatibility between cement and some specific types of aggregate. In cold climates there is the potential for breakdown by the freeze/thaw action of water near the concrete surface.

Corrosion requires air and water to take place, so the key to durability in concrete design is to have a mix which ensures that the reinforcement is always well protected from these elements. As long as the steel is cocooned in alkali-rich cement it is not at risk. Control of permeability of the concrete is fundamental to this, which in turn is dependent on the shrinkage which inevitably takes place as concrete dries out and hardens. The volume of cementitious products after they 'set' is less than their original volume when cast. This is compounded by the fact that more water is required to be added to a concrete mix to enable it to be handled in the wet condition than is required by the cement for the chemical process known as hydration. These volume changes result in pores, or worse, cracks, through which water and carbon dioxide can track to reach the steel.

Another key factor in the corrosion of reinforcing steel is the presence of chlorides. These may enter the structure later in life, for example in marine situations or where salt is spread on roads to melt ice. They may even be present in the mix itself: calcium chloride was used for many years as an additive to accelerate the hardening process and enable faster turnover of prefabricated elements in casting yards until the implications of this process were understood.

In existing structures, we are not easily able to change the nature of the concrete. As deterioration starts to occur, the emotively termed 'concrete cancer' steps have to be taken to arrest the decline and repair the damage. Fortunately, in most cases the onset of this deterioration is not necessarily a death warrant for the building, and repairs can be effected.

Before this is attempted, it is essential to have a full understanding of the cause and extent of the breakdown. It may already have reached, or be close to the point, where economical repair is not feasible. This decision may be affected by the nature of the building or structure. Economics may hopefully play little part in determining whether to retain or demolish a national icon.

Several tests are available to the engineer for diagnosing the condition of the concrete. The alkalinity of the concrete at the surface and at various depths down to the position of the reinforcement will give an indication of how much and how soon the reinforcement may be at risk. This is known as the depth of the carbonation front. The presence of chlorides can be determined, again at varying depths. The permeability of the concrete will give an indication of its susceptibility to absorption of air and water.

In many cases, the deterioration of the reinforcing steel is a localised problem, caused by an isolated air/water path or where reinforcement or fixings connected to the reinforcement are at or near the surface. In such cases the offending area can be cut out and repaired with a mortar patch. In this regard, significant advances have been made with the design of repair materials in very recent years. The key factor is to ensure that the steel is protected, and the weakest point is the interface between the new patch material and the original concrete. Shrinkage of the patching mortar must be avoided at all costs. Repair mortars now compensate for the natural tendency of the mortar to shrink, also containing latex products which give them some flexibility.

A secondary consideration in terms of durability, but understandably often foremost in the mind of the building owner, is the appearance of the patch material. Matching the colour, texture, sheen and other characteristics of the parent material is often reasonably straightforward, with a bit of trial and error, however there is a tendency for the new and old materials to weather at different rates, so that what looks good today may be a very prominent patch in 5 years' time.

There is a reluctance by some repair product manufacturers to adequately address the problem, with a very limited range of appearances available from their materials in Australia. There is a propensity for specifiers to recommend overcoating of the whole building, such as with a high-build acrylic paint in order to achieve a uniform appearance, which is also easily matched in future if further repairs become necessary. This may well be a blessing in disguise for some buildings, but for others the original appearance is their single most important feature, and it should not be discarded lightly. It also needs to be said that a building which is painted may mean a lifetime of higher maintenance costs. It will probably need repainting every ten years, perhaps less, to retain its smartness.

Manufacturers in the United States have been far more willing to put some effort into product development, particularly for appearance matching, and Australian manufacturers and distributors must be encouraged to do the same, particularly where the scale or prominence of the project can justify it.

Despite the advice to use an appearance-changing coating only as a last resort, these products have their place. Indeed, they may be essential as a means of preventing the absorption of moisture and air, in the latter case being classed as anti-carbonation coatings. In selecting a coating, one should have in mind what is intended to be achieved by that coating, if it is not simply a change of appearance. In particular it must be noted that some are waterproof but permeable to air. These will not necessarily arrest the advancement of the carbonation front. Others are not vapour-permeable, which can lead to blistering of the coating if there is moisture trapped behind it.

The first step in selection of repair techniques and products must always be a thorough investigation to understand the nature of the problem, otherwise a repair exercise may prove to be completely fruitless.

USEFUL REFERENCES:

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