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CORROSION OF METAL FASTENERS IN TIMBER

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A large number of New Zealand buildings rely on the stability of their metal-timber joints. It is therefore logical that we at Building Research Association (BRANZ) should want to develop an understanding of the hazards these joints may face in use. This interest is heightened by the increasingly widespread use (dating from initial emergence 10 to 20 years ago) of two particularly types of metal timber joint.

Bolts in treated timber posts, whether in "pole houses" where the structure hangs within a framework of poles, or in conventional house construction styles with the treated timber replacing concrete or masonry piles supporting the platform on which the house is built. These joints are important because of the likelihood of long periods of dampness of the timber.

Punched plate fasteners in prefabricated roof trusses and other components. There does not appear to be any report attributing a drastic problem to corrosion-induced failure of these joints, but they are a corrosion scientist's nightmare in theory, because of the very large exposed to buried area ratio, their relatively shallow penetration into the timer (compared, say, to nails), and the density of timber-metal contact per volume of timber.

There are two potential causes of failure of metal-timber joints. The first is because the metal has corroded sufficiently for the fastener to lose its strength. The second, degradation of the timber itself induced by reactions between the timber constituents and iron (or steel) corrosion products, is also very important. Such reactions cause the timber to lose its tensile strength and become spongy (Marion and Wissing, 1960a). This effect on the timber is sometimes called "nail-sickness", and was commonly found in the past around steel fasteners in wooden-hulled ships. If corrosion of the fastener occurs, it may be possible to replace it - though with nail plates this could prove rather difficult. This will not restore the integrity of the metal-timber joint, however, if nail-sickness has occurred. In such cases, it will inevitably be necessary to cut or drill out the affected timber. In some situations, such as a nail-plate joint in the middle of a span, this type of repair may well be impossible.

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BRANZ investigations of metal-timber interactions were begun in the early 1970s, and resulted in a paper (Whitney, 1977) to a Seminar on pole housing at the University of Canterbury in May 1977. This discussed the factors likely to affect corrosion rates of bolts in house poles, and proposed precautions which should be taken. The absolute minimum protection is hot-dip galvanising, because electroplated zinc is customarily as little as a tenth as thick as hot dipped galvanising and so does not have adequate durability. Though zinc corrosion products do not seem to participate in cellulose (timber) degradation reactions (thus appearing to give both the steel and the timber some protection), where the timber remains very wet (such as within 300mm of the ground or in places frequently wetted by rain or run-off water) the zinc can be lost from the bolt within a few years, so exposing the timber to the steel. For these conditions, additional protection was seen as desirable. Shrink-on plastic tubing over the galvanising was proposed as the best method, though liberal use of grease was suggested as a suitable alternative. Variations in supply of shrink-on tubing and the spread of powder-coating facilities have influenced BRANZ to now recommend use of powder coating of the hot-dipped galvanised bolts. This is discussed in our Building Information Bulletin 206 on pole house construction (Building Research Association of New Zealand, 1978). Our laboratory tests suggest that powder-coated bolts are much more tolerant of driving into tight holes without coating disruption than are bolts with shrink-fit tubing. Designers would not expect bolts to need to be driven; but site conditions sometimes result in this. Powder-coating is a factory-performed process with small factories well spread over NZ amenable to doing house lots, so that it also lessens the chance of mistakes in site application of protective coatings.

One of the factors which has an important effect on corrosion of metals embedded in timber is the treatment given to the timber to improve durability or fire resistance (Whitney, 1977). The development of timber preservative treatments has greatly extended the range of uses of timber, by enabling it to be used at moisture contents far above those at which untreated timber would be expected to decay.

Corrosion of metal fasteners in timber occurs only at timber moisture contents above a certain threshold. Various values for this threshold have been suggested. An indication of what are regarded as severe hazard levels may be obtained from the statement in the British Agrément Board Certificates for nail plates that the moisture content of the timber must not exceed 18% for any significant period and must not exceed 22% at any time. Part of BRANZ assessments of the hazards likely to face metal/timber joints is therefore assessment of

moisture contents of timber in houses. Previous studies (Whitney 1975, Orman 1955) have already reported data on this, and the most recent BRANZ work has concentrated on subfloor timber because this seemed a neglected area. Last winter, surveys were done on houses in Christchurch, Hamilton and Wellington. The full intricacies of the results are still being examined, but there seems a vague correlation, as would be expected, to moisture content of the ground under the house and the degree of ventilation. Most houses gave no cause for concern, but a few had moisture contents in excess of 19%. A report on these surveys will be produced, probably late this year.

A side effect of timber treatments is that they leave residues which can, in some instances, enhance corrosion rates of metals in the treated timber. BRANZ therefore decided to investigate electrochemical methods of measuring the instantaneous corrosion rates of metals embedded in treated timber. If successful, such a method would provide useful information, for instance on whether there is an initial fast corrosion which subsequently slows down. These attempts failed because of the high resistivity of timber when the moisture content of the timber is in the range generally found in buildings, and the different resistivity in different directions through the timber. To retain an immobilised medium while having uniform properties in all directions, experiments were devised using an agar gel loaded with the timber preservative chemical components, and these experiments have been successful. Though remote from a real timber situation (sufficiently so to make it impossible to talk about true rate of fastener corrosion) we now have a useful method of screening for corrosive effects of preservative chemicals on metal fasteners (Duncan, 1981). Thus, for example, copper-chromium-arsenic, or CCA, treatment is that most widely used in New Zealand where high durability is needed. BRANZ examined the effect of the copper and chromium residues, (singly and together) on corrosion rates of mild steel, stainless steel, galvanised steel, and brass fasteners. Stainless steel can be predicted from this to have a negligible corrosion rate in CCA-treated timber. The other metals all give measurable corrosion rates in these tests. The residue in greatest concentration is sodium sulphate, and this promotes corrosion. The chromium residues have an inhibiting effect on corrosion (though the inhibition is slight on mild steel) and the copper residues markedly promote corrosion.

Problems with gel characteristics have so far prevented application of this technique to borate treatments or to the more recently-developed alkyl ammonium compound preservatives, but alternative gelling agents now being investigated may allow such tests.

Building Research Establishment (BRE) in England have had test programmes running for the past eight years on nail plates, chiefly looking at their behaviour in timber in a controlled climate room (90% RH, 27°C) with periodical wetting. Various types of protection by coatings have been included in the tests. Little detail can be given on results because no reports have yet been published. BRANZ is unlikely to pursue studies in this field in view of the long lead that BRE has, and in view of their agreement to keep us informed of their progress.

There are techniques available, using AC impedance measurements, (Lorenz and Mansfield, 1981) which are able to filter out electrode reaction characteristics from the characteristics of the surrounding medium and this is very useful in dealing with high-resistivity media, such as timber. The expertise and equipment for this is specialised, and Chemistry Department at Victoria University seems the only laboratory in New Zealand able to help us in this field. BRANZ is discussing with them the prospect of investigating corrosion rates of fasteners in timber at moisture contents in the range 18 to 30% using these methods.

There seems a basic lack of information on the iron corrosion product reactions which weaken timber. BRANZ has therefore let a research contract to Professor Ferrier of Victoria University to investigate aspects of this. Previous studies in this field are few (Emery and Schroeder(1974), Marion and Wissing (1960b)) and they differ in their proposals of mechanisms to explain these reactions. If the initial work is successful it may be extended to study the effects of other metal ions (especially zinc and copper) in such reactions.

BRANZ is aware of the considerable advance in forestry practice, timber preservation methods, and design developments which seem destined to extend even further the uses of timber in building. The precautions discussed here - for example. protection methods for bolts in pole houses, and the need to keep timber moisture contents controlled - are not new concepts. It is hoped that restating them in this paper will help to keep them in the mind of designers, in view of the difficulty that can be experienced in remedial action, especially if timber degradation has occurred.

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