Field investigations on the application of ACQ treated wood and use of metal fasteners and connectors in residential construction

Prepared for

Homeowner Protection Office
Suite 2270 – 1055 West Georgia,
Vancouver,
BC V6E 3P3

By

Dr. John N.R. Ruddick
Mychem Wood Protection Consultants Ltd.,
1365 Ottawa Ave.,
West Vancouver,
BC V7T 2H6

December 2006

This project was sponsored and funded by the Homeowner Protection Office in partnership with the Technical Advisory Committee of the Canadian Home Builders Association of BC.

Disclaimer

Executive Summary

A survey of buildings at four locations in the Lower Mainland region and additional samples of connectors and fasteners supplied by two builders from Vancouver Island and Lower Mainland were used to assess the problems of corrosion from metal fasteners and connectors in contact with alkaline copper treated wood.

It was concluded that even though connectors had been specified and used, conformed to the recognized requirement of G185 level of zinc galvanizing, in some cases red rust was visible. However, many connectors were free of visible corrosion on the surface and edges.

Based on the observation that in some cases the wood had no watermarking and the design was such that it would not be easily exposed to weather, it was concluded that some corrosion is likely occurring due to residual water and mobile copper in the treated wood at the time of use.

In other examples, the corrosion was observed only on samples exposed to weather, indicating that in these cases the combination of weather (rainfall) and residual mobile copper in the wood had produced the corrosion.

In some buildings, the corrosion was much more evident on lumber that had been incised to enhance the level of preservative treatment. This suggests that the corrosion hazard was elevated by the higher preservative loading found at the surface of incised treated lumber, compared to that on the surface of unincised lumber specified for out of ground contact use.

During the survey, it was noted that in many cases fasteners which were not galvanized had been used. Discussion with builders concluded that this resulted from confusion of fastener requirements during the introduction of the new alkaline copper treated wood.

It was recommended that a larger survey be carried out to confirm findings of this preliminary survey. Removal of fasteners is required to identify more accurately the degree of corrosion taking place. It should also examine the impact of the retention of the preservative and wood species on the corrosion of fasteners. Damage to zinc protective coatings during use of fasteners was also shown to be a problem and further research is needed to confirm the impact of this corrosion and how it may be prevented.

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Background

Since January 1, 2004, chromated copper arsenate (CCA) treated lumber has been phased out in residential use (although CCA-treated plywood and shingles or shakes are still permitted). Depending on the application and availability of local suppliers, treated wood in residential buildings is being replaced with Alkaline Copper Quaternary (ACQ) or Copper Azole (CA-B) treated lumber. The copper contents in these new preservatives are significantly greater, which increases the risk of galvanic corrosion. Literature and research that is currently available from Canadian Mortgage and Housing Corporation (CMHC), manufacturers and industry organizations recommend using connectors, fasteners and flashings that are compatible with ACQ or CA-B treated wood. Materials that have been suggested by manufacturers as being compatible with ACQ and CA-B pressure-treated wood include:

Fasteners	Stainless steel, hot-dipped galvanized (G185[1]) and polymer coated.
Connectors	Stainless steel and hot-dipped galvanized. Hot-dipped galvanized connectors must have a minimum coating of G185[1] (more than triple the G60 coating required for CCA treated lumber).
Flashings	Stainless steel, copper and flexible membranes.

Current literature on ACQ/CA-B pressure-treated wood also recommends that fasteners, connectors and flashings made of aluminum should not come into contact with ACQ/CA-B treated wood including railings and door thresholds. Hot-dipped galvanized anchor bolts and G185[1] strap anchors should be used for ACQ foundation sill plates. As well current literature indicates that stainless steel or hot-dipped galvanized fasteners and connectors should be used with ACQ/CA-B treated wood for deck and floor ledger boards, nailing strips, interior wall sill plates (including powder actuated fastener nails), and when fastening wall sheathing to ACQ treated sill plates.

Despite following these guidelines, one major builder in the Greater Vancouver area suspected accelerated corrosion on fasters used in conjunction with ACQ treated wood. A home warranty insurance provider in British Columbia also identified similar concerns.

In 2005, the Homeowner Protection Office (HPO) requested Dr. John N.R. Ruddick (UBC[2] and MWPC) to undertake field investigations at a sample of building sites in the Lower Mainland area to determine the nature and possible existence of problems associated with ACQ treated wood and metal components. This report is based on the examination of four residential complexes and two additional material samples supplied from other residential construction projects.

[1] G185 refers to the weight of zinc coating referenced in ASTM A 653/A 653M-05a and is 1.85 oz/ft^2 or 600 g/m^2 of zinc.

[2] Dept. of Wood Science, Faculty of Forestry, University of British Columbia

Project Objectives

1. Examine metal components that have been used in conjunction with various applications of ACQ treated wood in up to 6 new housing developments in the Lower Mainland area.
2. Determine whether the proper metal components were specified and used in conjunction with the ACQ treated wood applications being examined.
3. Assess whether or not there is an indication of premature corrosion of the metal components.

Methodology

Senior Technical Management at five companies were contacted to identify a property that had been built since January 2004, and which had included a decking built with one of the new alkaline copper based treated wood. After discussion with one of the five managers, it was clear that their building would not fit the stated scope of the project and so further discussion was not held. Each of the remaining four management groups was contacted to set up a site visit at the selected structure and to supply specifications for fasteners and connectors for the identified structure.

Due to the sensitive nature of the project, each site visit was made with the representative of the company present. No samples were collected although requests were made to each company to provide any material they may have removed during routine maintenance. The survey was then based on a visual evaluation of the types of fasteners and connectors used, with particular attention being given to the type of corrosion protection of the fasteners and connectors. A photographic record was made to illustrate the condition of the metal in contact with the treated wood. For confidentiality purposes, some pictures were edited to cover product identification marks.

During the site visit information was also collected about routine strategies that may impact on the process of material selection and use.

In addition to the on-site visit, two sources of metal bolts, fasteners and connectors were received and also examined for corrosion. These are also discussed in this report.

Terminology used in discussing corrosion of fasteners

Corrosion - Corrosion is a natural process during which a material interacts with its environment causing fundamental changes in its chemistry. The rate of corrosion and type of change depends on both the environment and the material. Additional information on corrosion processes and the materials and processes used to protect metals from corrosion are found in the Appendices 1 and 2.

White rust - This white coating which forms on zinc coated fasteners or connectors is an oxidation product formed by the corrosive effects on the zinc. The reaction produces white zinc oxide type chemicals that are more resistant to corrosion than the zinc itself. However, under severe corrosion environments, the zinc will eventually become depleted and corrosion of the underlying iron will commence.

Red rust - This red coating that forms on unprotected iron is the oxidation product formed by oxygen, water, and iron reacting together. The red rust is iron oxide (Fe_2O_3). The breakdown of the iron to form the oxide results in significant loss in strength of the fastener or connector. Although there are other more accurate methods of assessing corrosion during scientific testing of corrosion resistance of materials (see Appendix 2), the amount of red rust observed is considered a good indicator of the degree of corrosion.

Copper - Alkaline copper preservatives are manufactured from copper chemicals such as basic copper carbonate which are dissolved in amine solvents. While in the amine solvent the chemical remains dissolved since it forms a complex. When the preservative is forced into the wood under pressure it reacts with the wood. The acid nature of the wood causes the copper complex to break down during which the copper binds to the wood. Excess copper can remain soluble in the remaining amine solvent and can be leached from the wood causing green deposits of basic copper carbonate. When these are present on the wood they indicate the availability of mobile copper and hence a corrosive environment.

Because iron is above copper in the electrochemical series of standard electrochemical reactions, then iron will displace copper from solutions, causing it to precipitate onto the metal surface. So in some cases the deposition of copper can be detected, although in most cases the formation of the red iron oxide is most obvious where corrosion is significant.

Incising - When timber is pressure treated, two quality control parameters are used. They are the penetration of the preservative from the wood surface, and the amount of preservative in a specified assay zone. In some woods, such as spruce or pine heartwood, penetration is difficult to achieve. For that reason, incisions are made in the wood surface, to allow the solution to penetrate easily to the required depth. When timber is incised, it usually indicates that it has been treated for use in ground contact and that the species resists treatment. These conditions will result in higher surface loading of preservative than that found in easy to treat sapwood, treated for above ground uses.

Building Complex 1

This complex was comprised of a large number of residences surrounding a countryside setting. Each residence had a small deck at the rear of the unit. ACQ treated wood was used for the decks, the supporting timbers and stairs.

Inspection of the deck supporting structure quickly revealed two observations. The first was that a mixture of different quality of fasteners and connectors had been used. At the six decks inspected, most of the fasteners hammered directly into the ACQ treated wood appeared to be non-galvanized and were heavily red rusted. The fasteners used with hangers and straps appeared to be a mixture of un-galvanized and possibly some galvanized. Without removal of the fasteners it was not possible to confirm their type. Discussions with the technical manager indicated when the structure was being built, there was confusion about the type of fastener needed and that some common nails may have been used. The hangers were galvanized and they appeared from the labeling to meet the G185 standard. They commonly showed red rust on the edges. The technical manager informed the author that a hanger had been removed during routine maintenance and it had shown clear red rust formation on the inner surface. Inspection of the hangers on several decks showed red rust on the edges, some white rust and clear green copper deposits (Figures 1 to 9).

The second observation was that electroplated galvanized strapping had been used and showed severe red rust formation. This confirmed the unsuitability of electroplated galvanized material in contact with ACQ treated wood.

The stairs were made from ACQ treated wood and were fastened with proprietary galvanized brackets and bolts. Identification marking confirmed that the brackets conformed to the G185 requirement. Both the bolts and the bracket showed a very small amount of white rust on a few connections but no red rust was visible.

The decking support structure was built using incised ACQ pressure treated lumber. As would be expected from the use of a spaced board deck, wetting of the lumber while in service was observed.

From this complex it was concluded that some corrosion (both red and white rust) of the connectors was observed where it was in contact with the treated support lumber. Copper deposits accumulated on many of the hangers, confirmed that mobile copper was being precipitated onto the hanger. The level of corrosion would result from a combination of the initial interaction with the treated wood at the time of installation and the subsequent wetting of the wood in service.

Figures for Complex 1

Figure 1 General view showing treated wood fence and decks

Figure 2 General view showing treated decks

Figure 3 Hanger with red rust and copper deposits

Figure 4 Hanger with red rust and copper deposits

Figure 5 Electroplated strapping showing red rust

Figure 6 Red rust on common fasteners

Figure 7 Corrosion of mild steel un-galvanized nails

Figure 8 Corrosion of mild steel un-galvanized nails

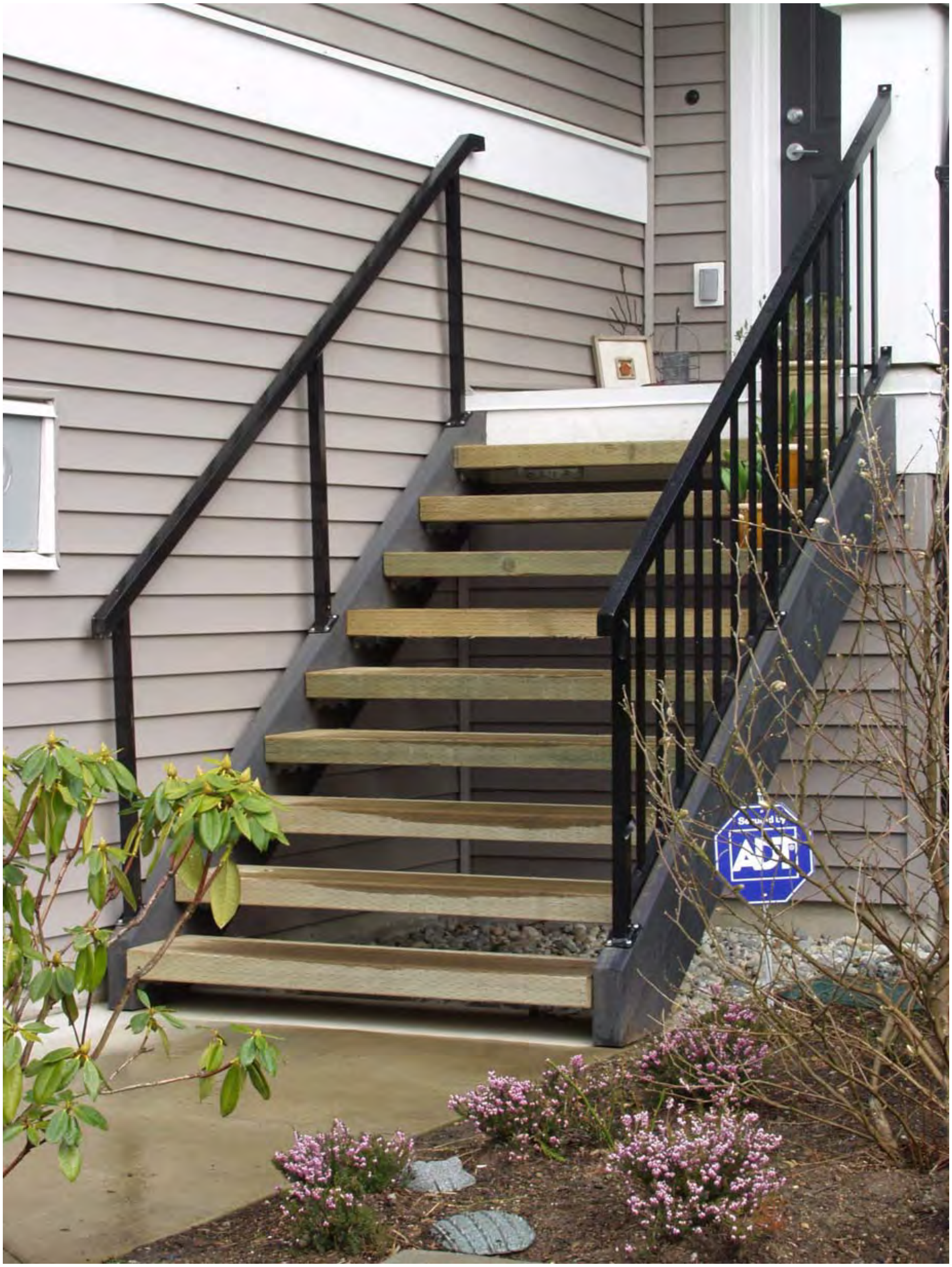

Figure 9 Stairs showing construction design

Building Complex 2

A single deck was examined in this complex. Again it was a spaced deck design. The owner had placed tubs with plants on the decks and wetting of the support structure below these locations was observed. The support structure was constructed from incised ACQ treated lumber. The first significant observation was that the hangers at the outer perimeter showed corrosion whereas those adjacent to the building did not (Figures 10 to 17). The hangers showed red rust on the edges and white rust on the surface. (It should be noted that connectors that are punched out of galvanized sheets will have reduced levels of protection on the edges.) Green deposits confirmed the precipitation of copper on the wood and hanger. Watermarking of the wood showed that wetting of the wood in service had significantly contributed to the observed corrosion. The movement of the green staining adjacent to the hangers confirmed the interaction of the ACQ copper with the zinc in the galvanizing.

The hangers were proprietary and the labeling suggested that they conformed to the required galvanizing of G 185. However, the heads of the nails used to toe-nail the deck frame together were severely corroded and appeared to be common (un-galvanized) nails.

From the observations at this second complex, there is clear evidence of red rust formation on both fasteners and connectors. The red rust formation was particularly prevalent on the edges of the hanger and the heads of the nails. It had begun however in some cases to show on the visible face of the hanger.

The obvious red rust or white rust on the heads of nails suggests that the corrosion may be occurring as a consequence of mechanical damage to the galvanizing during nailing. Again no hangers or fasteners were recovered during the inspection. The level of corrosion would result from a combination of the initial interaction with the treated wood at the time of installation and the subsequent wetting of the wood in service.

Figures for Complex 2

Figure 10 Copper deposits and red rust on lower edge of hanger

Figure 11 Copper deposits and red rust on edges of hanger and nails

Figure 12 White rust on proprietary hanger, the specifications of which meets the G185 requirement

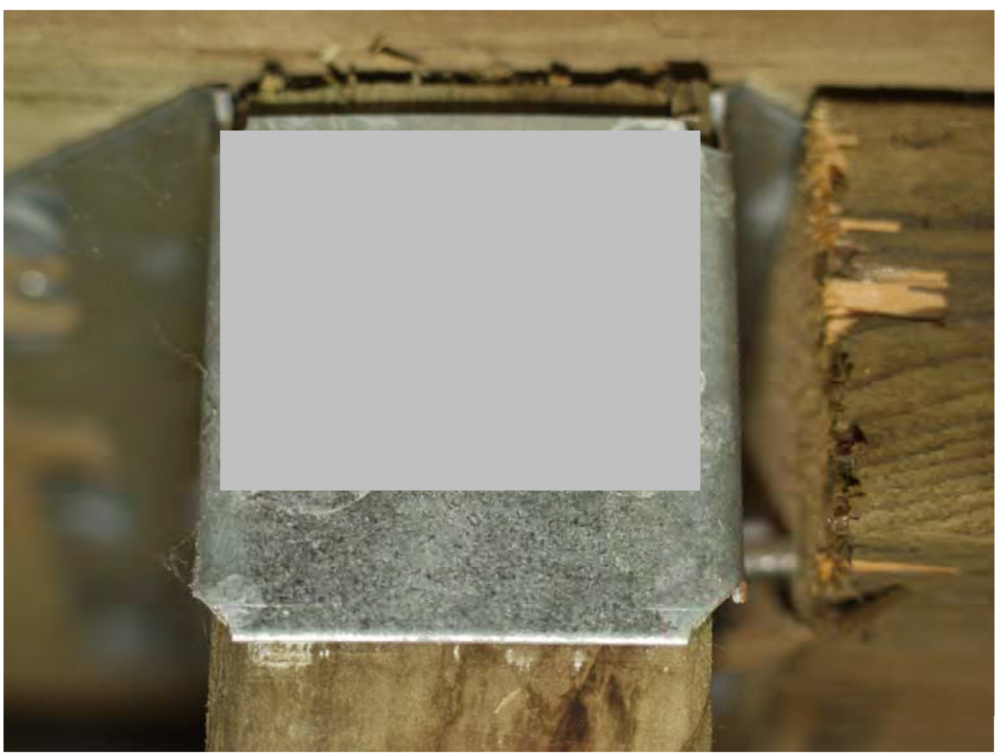

Figure 13 No corrosion on proprietary hanger, the specifications of which meets the G185 requirement on rear drip deck

Figure 14 Small amount of red rust on edge of proprietary hanger, (the specifications of which meets the G185 requirement) and lower galvanized nail head. Common nails on right have red rust.

Figure 15 White rust on proprietary hanger, (the specifications of which meets the G185 requirement) and nails

Figure 16 White rust on proprietary hanger, (the specifications of which meets the G185 requirement) and nails. Green copper deposit visible on lower hanger surface.

Figure 17 Small amount of red rust on the edge of proprietary hanger, (the specifications of which meets the G185 requirement)

Complex 3

Two decks were examined at Complex 3 (Figures 18 to 26). Both had been modified since the original construction. In the first deck the owner had been concerned over the splitting and cracking in the original timber stairs. He had therefore changed the design and used decking boards in their place. These originated from the neighbor's deck. Examination of the fasteners did not show corrosion. Unfortunately the complete under surface of the deck support structure had been painted making it impossible to assess the corrosion of the fasteners. In addition, extensive blocking had been added to the basic structure by the owner. The shoes for the posts were galvanized and showed no corrosion. They were the original connectors and posts. The hangers had also been replaced. They were not G 185 rated connectors. They had been fastened with screws. Nails into the blocking were showing signs of red rust.

A second deck at the adjacent property was also examined. Like the first it had been extensively modified since construction. The main change was the use of a solid plywood deck with a membrane, so that the structure below was not getting wet. Nevertheless the toe nailing of the ACQ treated deck support showed red rust and appeared to be un-galvanized. Original fasteners in the original stairs were heavily corroded. It was not possible to determine whether they were galvanized or not – but the heavy corrosion would suggest that they were not galvanized. The metal shoes for the post base location were galvanized and showed no corrosion. They were not the original connectors or posts. Toe-nailing of timbers at the top of the support posts had been done with un-galvanized nails which showed red rust.

In front of the properties, an incised ACQ treated timber had been used as a road island barrier. The bolts used on the barrier were slightly corroded, but the level of galvanizing could not be determined. The barrier was not part of the construction project.

Figures for Complex 3

Figure 18 General view of the underside of the deck showing the painted wood and the modified structure. Connectors are galvanized but appear generic electroplated and would not therefore conform to G 185. They are fastened with screws. Nails into the incised block to which he connector is attached show some red rust.

Figure 19 Post support showing absence of corrosion

Figure 20. Red rust on nails fastening deck joist to rim joist. Blocking is used in this design so no hangers are required

Figure 21. Red rust on common mild steel nails fastening deck joist to rim joist.

Figure 22. Red rust on common mild steel nails fastening stairs.

Figure 23. Red rust on un-galvanized screw.

Figure 24. Shoes for posts showed no corrosion.

Figure 25. Red rust on un-galvanized nails.

Figure 26. Corrosion on bolts on barrier fencing made from ACQ treated wood

Complex 4

The fourth complex was comprised of two groups of residential buildings each with its own decks (Figures 27 to 55). Approximately 12 deck structures were visually examined. The lumber was mostly unincised ACQ treated dimensional lumber (2 x 8 or 2 x 10). Incised lumber had been used for the blocking. Again, blocking had been used on these structures so no connectors were present. The focus therefore is on the fastener condition. There was a wide range of condition of the fasteners. Some bolts and washers in contact with incised ACQ treated lumber were corroded with white rust being present, but also some small amount of red rust. Some fasteners had small amounts of white or red rust on their heads and also deposits of copper salts from the adjacent wood. This was noted earlier and may be related to the mechanical damage to the zinc coating during the installation of the nail. However, in many other examples there were no signs of corrosion. There were also in the same piece, both un-galvanized and galvanized fasteners. The heads of the galvanized fasteners were often in good condition. (No fasteners were recovered so their total condition was not determined.) Since all the decks were of the same design and presumable the same materials, it suggests another factor may be influencing their condition.

The post bases were located with metal post base connectors. They were of two different materials. One was a proprietary hot dipped galvanized connector while the second was a generic powder coated material. Both showed no corrosion.

In the second group attention was focused on the stairs and the connectors and fasteners. The fasteners were clearly galvanized and conformed to G185. The ACQ treated timber showed no watermarking. This is consistent with the design of the steps, their location close to the building wall and the location of the connector. The general condition of the connectors (based on the exposed faces) was very good with no signs of corrosion on the faces. However, in all cases the edge of the connector showed small amounts of red rust. (As noted earlier, where connectors are punched out of pre-galvanized sheets of metal, the edges will have a low level of protection and may therefore exhibit some red rust which may not reflect the condition of the inner surface.) The fact that the timber had not been wetted in service suggests that the corrosion resulted from the initial reaction between the wet lumber and the fastener, immediately following construction. This raises the question of the degree of fixation in the lumber being used at the time of construction and the role this may play on the corrosion. In addition, the lumber used was incised. Incising is required when the ACQ penetration must be enhanced to meet the Canadian Standard and the natural permeability of the wood is insufficient. The combination of incising and a less permeable wood being treated will result in increased ACQ preservative loading near to the wood surface. It is generally recognized that without a complexing co-biocide, the ion exchange capacity of wood is limited. If this limit is exceeded then it will be present as mobile copper compounds and these would lead to increased corrosion potential.

Finally, some additional decks in this second group of buildings were examined. As before the spaced deck allowed water to wet the structure below. There again appeared to be both galvanized and un-galvanized fasteners in use. The galvanized fasteners both in the decking boards and the support seemed to be largely free of corrosion. However, the un-galvanized fasteners had extensive red rust on their heads. Attention was again focused on the post bases and the condition of the post base connectors and the fasteners. The base connectors were free of any corrosion products. The fasteners had red rust easily visible on their heads. Careful examination of the exposed shank of the nail between the connector and the post revealed it was clearly galvanized and there were signs of red rust on the shank too. Clearly the galvanizing had been damaged sufficiently during the nailing process to cause loss of the zinc coating leading to corrosion of the underlying mild steel.

Figures for Complex 4

Figure 27. White rust on galvanized bolt

Figure 28. White rust on galvanized bolt and washer contacting incised ACQ treated wood

Figure 29. White rust on galvanized bolt

Figure 30. Bolt, washer and nails all free from corrosion

Figure 31. Red rust on common mild steel nails

Figure 32. Galvanized connector and nails for post base showing no corrosion

Figure 33. Galvanized nails in unincised ACQ deck joist show no corrosion except for small amount of red rust on the head of the lowest one. Probable cause is damage during nailing.

Figure 34. Galvanized nails in unincised ACQ deck joist show corrosion (red rust) on the heads most probably due to loss of zinc coating during nailing.

Figure 35. Galvanized and possible common nails in unincised ACQ deck joist show corrosion (red rust) on the heads. Note lack of water marking on lumber.

Figure 36. Galvanized bolt, washer and nails in unincised ACQ deck joist show no corrosion

Figure 37. Galvanized bolt, washer and nails in unincised ACQ deck joist show no corrosion

Figure 38. Design of decking showing blocking. No hangers were used in this design.

Figure 39. Galvanized fasteners showing red rust on their heads due to loss of zinc during nailing

Figure 40. Galvanized fasteners showing red rust on their heads due to loss of zinc during nailing in incised ACQ lumber

Figure 41. Design of stairs showing untreated oriented strand lumber separating plastic tread from ACQ lumber

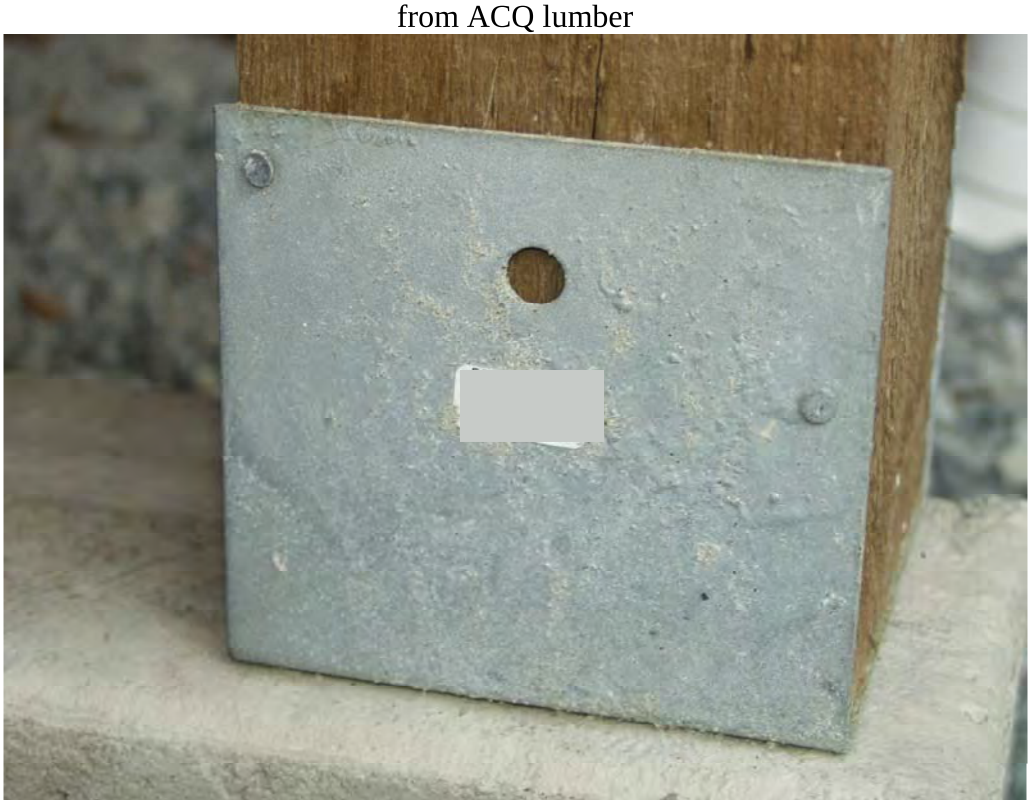

Figure 42. Galvanized post base connector and fasteners showing no corrosion

Figure 43. Galvanized connectors showing red rust on the edge. Note lack of watermarking of timber

Figure 44. Galvanized connectors showing red rust on the edge. Note lack of watermarking of timber

Figure 45 Galvanized connectors showing red rust on the edge. Note lack of watermarking of timber

Figure 46. Galvanized connectors showing red rust on the edge. Note lack of copper deposits on wood and lack of corrosion on face.

Figure 47. Galvanized fasteners on decking – no corrosion visible

Figure 48. Corrosion (red rust) on mild steel fasteners in contact with incised ACQ treated wood.

Figure 49. Galvanized fasteners showing no corrosion

Figure 50. Corrosion (red rust) on the head of common (mild steel) fasteners in contact with unincised ACQ treated lumber

Figure 51. Galvanized post base connector showing no corrosion. Galvanized fastener heads show red rust due to loss of zing during nailing

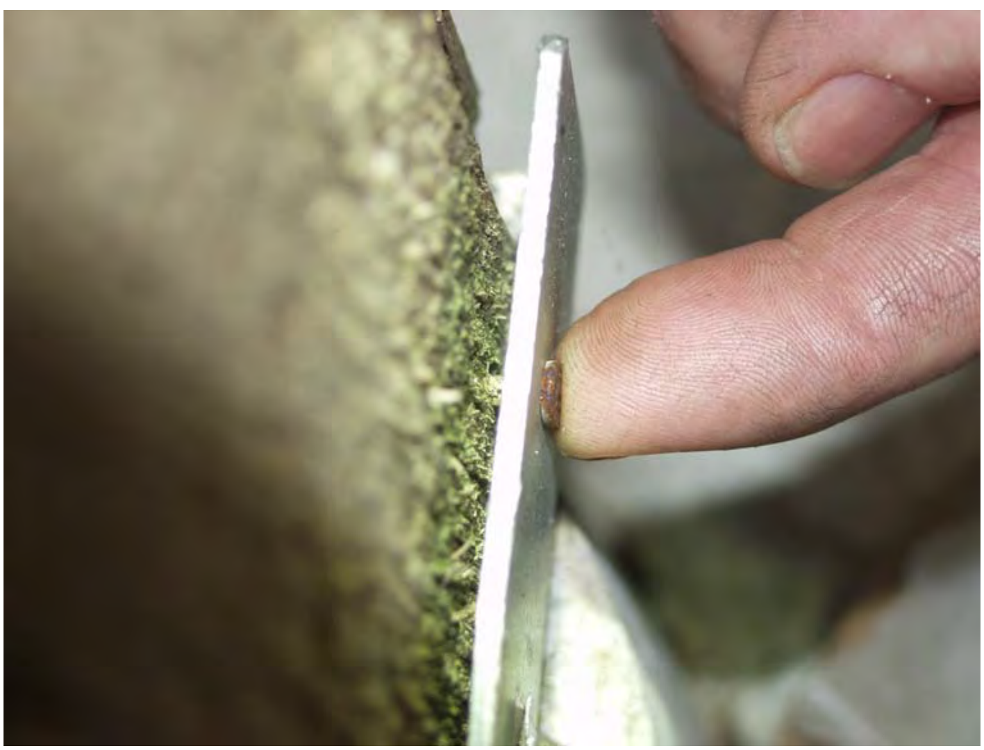

Figure 52. Galvanized fastener show white and red rust due to loss of zing during nailing

Figure 53. Galvanized post base connector showing no corrosion. Galvanized fastener heads show red rust due to loss of zing during nailing

Figure 54. Galvanized fastener show white and red rust due to loss of zing during nailing

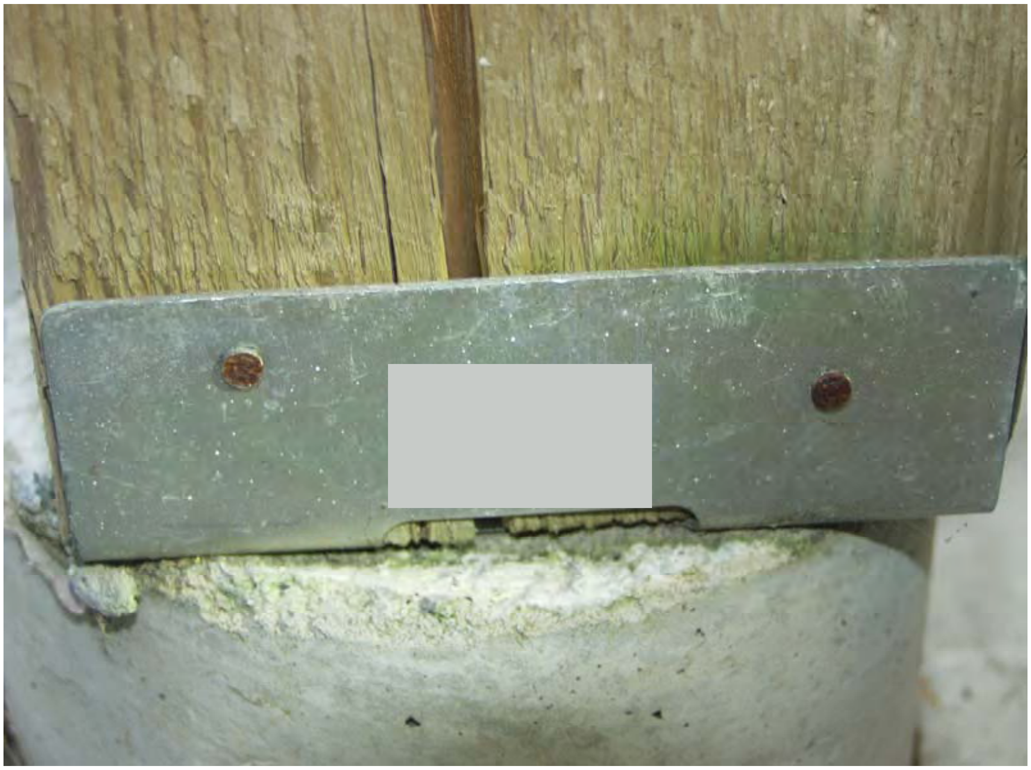

Figure 55. Galvanized post base connector showing no corrosion. Galvanized fastener heads show red rust due to loss of zing during nailing

Additional Sample 1

In 2006, a bracket and several epoxy coated screws were provided by a builder in Vancouver Island. According to the builder the package for the screws had indicated that they were suitable for use with ACQ treated wood. He also indicated that they had been in a structure for 6 months (Figures 56 and 57). The screws show heavy red rust on their shank. The heads were free of corrosion. Clearly the corrosion resistance is not sufficient for this use. The bracket was made from aluminum and so was heavily corroded. It is well known that aluminum materials should not be used in contact with copper containing materials.

Figure 56. Corrosion of aluminum bracket and decking screws after 6 months service in ACQ decking

Figure 57. Corrosion of green and brown epoxy coated decking screws

Additional Samples 2

The second set of samples was recovered by a builder in the Lower Mainland from a rear drip deck of a structure after 11 months in use. The first of the hangers (#1) had been installed on a building ledger and so had no direct exposure to weather. The nails and hanger were in good condition with no corrosion visible (Figure 58). The nails too retained a good coating of zinc with no sign of white rust.

Figure 58. Galvanized hanger the specifications of which meet the G 185 requirement removed from deck protected from weather.

The second and third samples were removed from the rim joist of the deck where they had been exposed to the weather (Figures 59 to 63). In this case extensive corrosion has taken place on the inner surface in contact with the ACQ treated wood. Some red rust is visible on the edge of the hanger and also on the inner surface. The nails have in some cases lost almost all the zinc galvanic coating. A green deposit of copper chemical is seen on the surface of the hanger. Casing nails used in ACQ stair treads show some white rust but no advanced corrosion. A galvanized lag bolt shows small red rust spots on the screw thread but almost no corrosion of the head or washer.

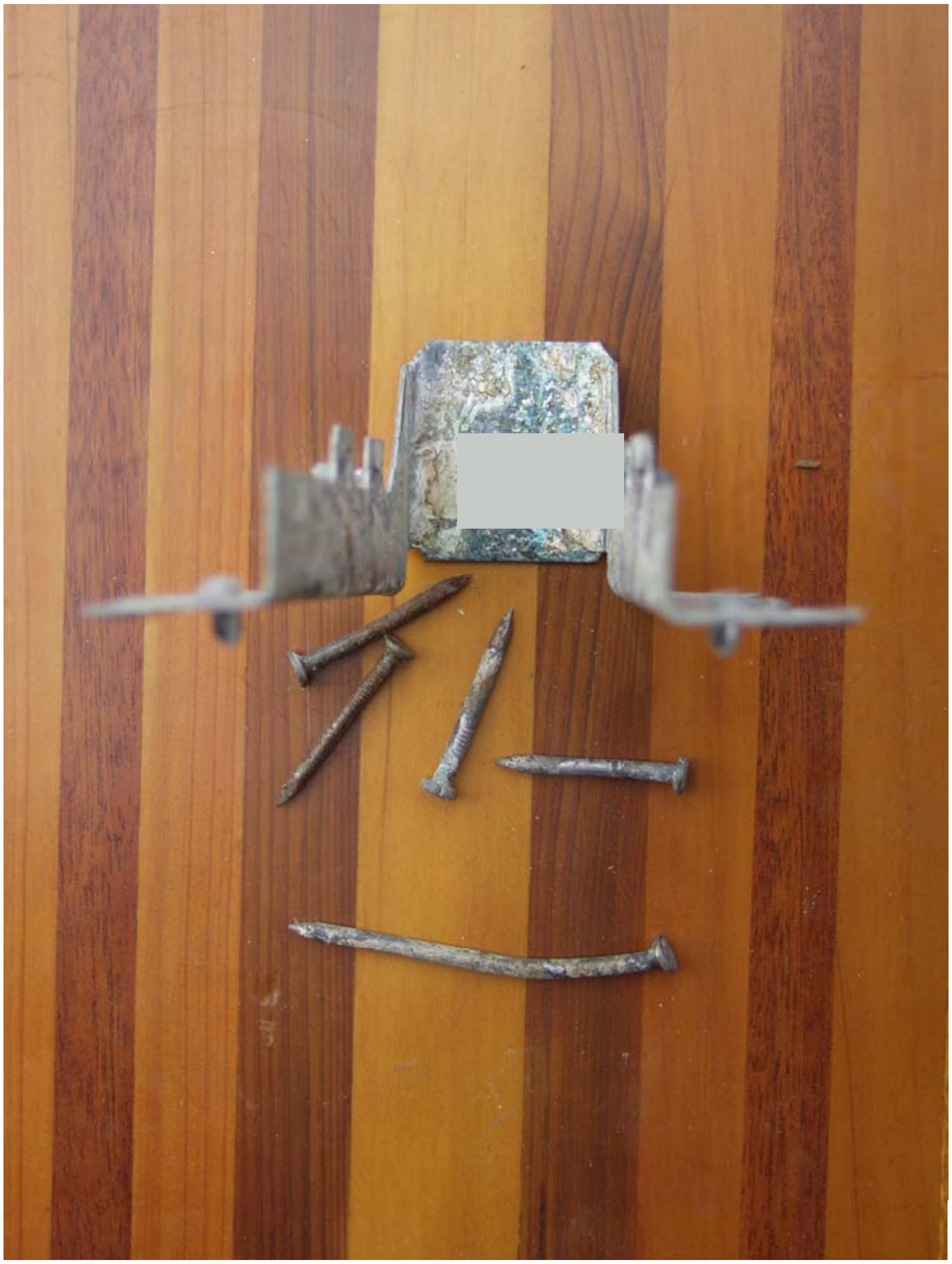

Figure 59. Corrosion of hot dipped galvanized hanger proprietary hanger, (the specifications of which meets the G185 requirement) and fasteners after 11 months exposure.

Figure 60. Corrosion of hot dipped galvanized hanger proprietary hanger, (the specifications of which meets the G185 requirement) and fasteners after 11 months exposure.

Figure 61. Corrosion of proprietary hot dipped galvanized hanger, (the specifications of which meets the G185 requirement) after 11 months exposure in contact with ACQ treated wood.

Figure 62. Galvanized casing nails removed from ACQ stair tread

Figure 63. Galvanized lag bolt removed from deck bracket into ACQ rim joist.

Conclusions

From the survey of fasteners and connectors examined in this research it may be concluded that:

- Some of the corrosion problems reported resulted from the use of mild steel fasteners containing no zinc coating.
- When no exposure to weather occurred, hangers coated with zinc to meet the G185 galvanizing requirement generally showed no corrosion.
- In other cases even with no exposure to weather, some connectors coated with zinc to meet the G185 galvanizing requirement showed red-rust on the edges and inner faces of some galvanized fasteners. This suggested that the corrosion likely resulted from residual moisture and mobile copper in the wood at the time of use. It should be noted that where connectors are punched out of pre-galvanized sheets, the edge protection will be limited and some corrosion may occur which will not necessarily reflect the condition of the surface of the connector in contact with the treated wood.
- Based on the above observation, incomplete fixation of the preservative will cause enhanced corrosion. Therefore it is important that completion of the fixation chemistry takes place before treated wood is used for construction. This could explain why in some cases similar exposures produced different corrosion results for identical connectors.
- In several cases, severe corrosion (based on the short exposure time of less than 2 years) was observed on hangers coated with zinc to meet the G185 requirement (based on manufacturer's information) and exposed to wetting but out of ground contact.
- In decks where the hangers were exposed to weather, corrosion appeared to be more common.
- Green copper deposits were often observed associated with corrosion of the fasteners and/or the connectors.
- Corrosion of fasteners and hangers in contact with incised ACQ treated wood, appeared to be more severe than that in contact with unincised ACQ treated wood in the same or similar structures.
- The worst corrosion on hangers occurred on the face of the hanger which is in direct contact with the ACQ treated wood. This may make the accurate assessment of corrosion more difficult unless some hangers are removed for evaluation.
- Epoxy coated decking screws which had no zinc coating beneath, were susceptible to corrosion during use. Presumably in the samples examined the coating had become damaged during installation.
- Aluminum connectors or flashing can not be used in direct contact with ACQ treated wood.

- Corrosion was often associated with the use of incised ACQ treated lumber. This may suggest that the higher surface retentions in such lumber will produce much worse corrosion than in unincised treated lumber.

- Based on the observations in the survey, damage to the fastener head during hammering can remove zinc leaving the head susceptible to corrosion.

- Electroplated strapping was found to severely corrode when in contact with treated wood.

Recommendations

1. These field investigations were carried out on a limited number of samples. Based on the survey, it is stressed that for alkaline copper treated wood, fasteners and connectors must be selected from manufacturers, who through their products literature confirm that they are consistent with G185 galvanizing. The alkaline copper treated wood is corrosive to mild steel fasteners.

2. Fastener manufacturers should be made aware that in a decking structure many of the timber components will be treated to higher preservative loadings than those specified for deck surface boards. Consequently, in testing of products for corrosion resistance, data generated on deck surface boards may not accurately reflect the corrosion hazard of the lumber used to construct decks.

3. Manufacturers of connectors and fasteners should review databases for higher preservative retentions found in incised lumber and lumber for use under more severe, or critical conditions (e.g. preserved wood foundations) to ensure appropriate recommendations are available for builders.

4. Because of the nature of the assessment in this survey, it was not possible to recover materials to determine their exact condition. In addition, the condition of the ACQ treated timber at the time of the construction was not known. It is therefore recommended that a more extensive study be undertaken in which fasteners and connectors are recovered from structures of a known age.

5. In addition, supplemental studies should be done under controlled conditions to investigate the influence of the condition of the ACQ treated wood at the time of use on the corrosion of G185 fasteners and connectors. These conditions should be:

- the fixation process is completed before the timber is used but the wood is wet
- the fixation process is completed before the timber is used but the wood is dry
- the fixation process is incomplete before the timber is used but the wood is wet

5. The problems of corrosion often were associated with the use of incised ACQ treated wood. Incising is used to enhance the penetration of the ACQ into difficult to treat wood. This could result in higher than usual surface retentions of ACQ, and more mobile copper at the surface of the treated wood, resulting in greater corrosion. The relative corrosion of commercial incised and unincised lumber should be assessed.

6. The impact of gun and manual nailing on damage to protective coatings needs to be assessed.

7. A much greater survey is needed of epoxy coated decking screws to determine the need for a combination of galvanizing and epoxy coating. Clearly the decking screws examined here had corroded extensively in less than 6 months. However, the ACQ treated wood was not assessed. Newer nails and decking screws which combine a zinc galvanic coating with an organic polymeric (e.g. epoxy etc.) coating should be assessed for their performance.

Acknowledgements

The assistance of several builders in locating structures and sharing their experiences is gratefully acknowledged. The author is therefore pleased to acknowledge the support of the Companies who provided assistance.

Appendix 1

Corrosion processes

Corrosion

Corrosion is a natural process during which a material interacts with its environment causing fundamental changes in its chemistry. The rate of corrosion and type of change depends on both the environment and the material. For example, a hard tap water with a relatively high calcium bicarbonate content, cause less corrosion than a soft river water, since the deposits of calcium carbonate formed by hard water provide protection against corrosion. Most chemical reactions speed up with increasing temperature. For this reason hot water is generally more corrosive than cold water. In addition, corrosion of metals in contact with water will increase with temperature, because of the higher diffusion rate of oxygen at higher temperatures (up to about 80 °C). Corrosion can be divided into five major categories based on the appearance of the corrosion damage. The five major differing types, is presented in the table below.

Type of corrosion

Type	Characteristic
Uniform corrosion	All area of the metal corroded at the same rate
Localized corrosion	Certain areas of the metal surface corrode at higher rates than others
Pitting corrosion	Highly localized attack at specific areas resulting in small pit
Erosion corrosion	Localized attack or fracture due to the synergistic action of a mechanical factor and corrosion
Dezincification	One component of an alloy is selectively removed from an alloy

Corrosion mechanism
Corrosion in metals is caused by a flow of electricity from one metal to another metal or a recipient of some metal or from one part of the surface of one piece of metal to another part of the same metal when conditions permit the flow of electricity. Corrosion phenomena can be divided into the basic reaction mechanisms of: electrochemical, chemical, and physical mechanisms. Corrosion of metals in moist environment is electrochemical in nature involving two or more electrochemical reactions taking place on the metal surface. The electrochemical process requires anodic and cathodic materials in electrical contact and an ionic conduction path through an electrolyte (usually water) through which the electrons can flow between the anodic and cathodic areas. The rate of this flow corresponds to the rates of the oxidation and reduction reaction that occur at the surface.

By combining with oxygen the iron is oxidized to form red iron oxide (Fe_2O_3). In addition, copper is a more noble metal than iron. So when copper ions are present in solution they can electrochemically react with iron ions causing them to be oxidized while the copper is reduced and precipitated.

Anodic reaction: $Fe \longrightarrow Fe^{2+} + 2e^-$ (e = electron)

$Fe^{2+} \longrightarrow Fe^{3+} + e^-$

Cathodic reaction O_2 (gas) $+ 2H_2O + 4e^- \longrightarrow 4OH^-$

$4Fe^{2+}(aq) + H_2O + O_2(g) \longrightarrow 2Fe_2O_3.xH_2O(s) + 8H^+(aq)$
Red rust

$Cu^{++} + 2e- \longrightarrow Cu$ (precipitate)

The end result is iron dissolves and forms red iron oxide while the copper is precipitated from solution. This explains why alkaline copper preservatives, which contain more copper (50 % expressed on an oxide basis) than CCA (18 % expressed on an oxide basis) have potential to be more corrosive. The degree of corrosiveness depends however on the amount of mobile copper. Therefore, provided most of the copper is bound to the wood or complexed with other components in the formulation, the amount of corrosion can be limited.

It is now possible to appreciate several aspects to the use of metal in contact with treated wood. The first point is that it is important that the fixation chemistry of the alkaline copper preservative in treated wood must be complete before the treated timber is used. This will minimize the amount of mobile copper. In addition, since the ion exchange capacity of wood is limited, as the amount of preservative is increased for higher decay hazard uses, (for example ground contact uses, or critical structures such as utility poles) then the potential for corrosion will increase. The second factor impacting on the corrosion is the amount of water present at the wood – metal interface. That is why the application of water repellant coatings, paint etc. can significantly reduce the corrosion of metal fasteners in a vulnerable area – at the surface of the wood used above ground. The third strategy of reducing or preventing the corrosion is to prevent the copper ions and water from contacting the iron. This can be achieved by inserting a barrier between the two. This is the principle of barrier coatings. The final strategy is to use a sacrificial coating that will react with the water to form an insoluble solid which will coat the surface of the iron. This is the widely used method of galvanizing where the sacrificial coating is zinc, and during the reaction with water insoluble zinc oxidation products are formed. This is the “white rust” that appears on galvanized fasteners and shows the zinc is reacting as expected in the corrosive environment.

Appendix 2

Materials and processes for protecting metal fasteners

Material for fastener manufacturing

The material used to manufacture nails may be carbon steel, stainless steel, aluminum, or copper. All of these materials, (including the metals and their alloys) are susceptible to corrosion. Although no single material is suitable for all applications, usually there are a variety of materials that will perform satisfactorily in a given environment. In strongly corrosive environments stainless steel is most often specified.

Stainless steels are a family of iron-based alloys containing about 10.5% chromium or more, plus other alloying elements such as carbon (0.08%), nickel (8-12%), manganese (2%), phosphorus (0.045%), sulfur (0.03%), selenium (1%)(AZoM™.com 2005). Grade 304 stainless steel is the most widely used. Chromium is the element that provides the stainless steel with its "stainless" property. It forms a chromium-rich oxide surface film which resists corrosion by many acids and bases.

Carbon steel is the most widely used material, and accounts for over 64 million tons, or approximately 88%, of annual steel production in United States, because of their weldability, and low cost. However, carbon steel usually requires some form of corrosion protection when it used in highly humid or industrial environments and with treated wood. Steel is classified by the basis of carbon content.

Classification of carbon steel

Type	Carbon content
Mild steel	Less than 0.30%
Medium-carbon steel	Between 0.30 and 0.60%
High-carbon steel	More than 0.60%

Coatings for corrosion protection

Various nail coatings are applied to enhance the corrosion resistance of carbon steels since in some end-uses (e.g. preservative treated wood) can promote the corrosion. Some of commonly used coatings in residential wood construction are described below:

- Organic and Inorganic barrier coatings
- Metallic coatings (anodic and cathodic)
- Combination coatings (metallic with barrier top coats)

Organic and Inorganic barrier coatings

The primary function of organic and inorganic barrier coatings in corrosion protection is to isolate the metal from the corrosive environment. These coatings are generally applied by spraying or dipping the nails in solution and then removing the nails which are allowed to cure. The most common of these coatings contain various proportions of metal flakes (usually zinc and aluminum) dispersed in a resin. The coatings only protect the nail by isolating steel from contact with corrosive agents but do not provide sacrificial protection. Barrier coatings work only when not damaged and in the case of nails, the ductility of barrier coatings and adhesion to the metal is critical, as the coatings are susceptible to chipping and flaking during handing and hammering into wood. Organic coatings including paint, lacquer, plastic, oil and wax, afford protection by providing a physical barrier between the metal and the environment. Organic coatings are used in layer thickness of 0.05 to several millimeters, though most are in the range 0.07 to 0.20 millimeters. Like organic coatings, inorganic coatings are used to provide a mechanical barrier between the metal and environmental oxygen and water. Inorganic coatings include enamels, glass linings, and conversion coatings and are hard and shiny. However, organic and inorganic coatings are vulnerable to imperfections in the coating such as scratches where corrosion can initiate and spread to adjacent surface.

Metallic coatings (anodic and cathodic)

The metallic coatings are one of oldest methods of protection against corrosion. A corrosion resistant metal coating is applied over a less resistance metal, to improve the corrosion resistance of the less resistant metal. The coating method varies widely. The metallic coatings can be divided into two groups based on the corrosion protection chemistry. These are anodic to steel coatings (sacrificial coatings) and cathodic to steel coatings. Anodic to steel coatings (such as zinc) provide a barrier between the steel and external elements. If the coating becomes damaged, sacrificial protection starts and any exposed steel will not corrode if a sufficient quality of zinc is near the damaged area. Hot dip galvanized nails are the well known example of this type of coating. Nickel is a common example of cathodic to steel coating. When undamaged, it provides a barrier to the underlying steel with the excellent corrosion resistance of nickel in many environments. However, if the coating becomes damaged for example mechanically during application, the corrosion potential of the underlying steel will be assisted by the presence of the nickel.

Combination coatings (metallic with barrier top coats)

These fasteners combine hot dip galvanized or electro-galvanized coatings with organic topcoats. The hot dip galvanized or electro-galvanized coating layers provide sacrificial protection of the steel substrate while the topcoat creates a durable barrier.

Methods or applying coatings

Hot dip galvanizing

Hot dip galvanized (zinc) coating is the most well known example of anodic to steel coating (sacrificial) and the most common type of corrosion resistance coating used in North America. The method involves a pretreatment prior to immersion in a molten zinc bath at about 450 °C, resulting in the formation of a Fe-Zn alloy layer bonding the coating to the substrate. The coating works as a barrier metal coating that provides a thick barrier between the underlying steel and in wet applications. However, under severe conditions of moisture, hot dip galvanized (zinc) coating will not provide the iron fastener with long term protection against the electro-chemical corrosion process. Zinc can be applied as a coating by a number of process and thickness (Table). The effective life for protection by zinc coatings is directly dependent on the coating thickness. The standard coating thickness requirement is 600 g/m^2 (1.85 oz/ft^2), 3.3 mils (85 µm). The coating is generally uniform on all surfaces. Edges, corners and threads have coatings at least as thick, or thicker, than on flat surfaces providing excellent protection at these critical points. Hot dip galvanized coated nails are the only carbon steel fasteners recognized by building codes for treated wood applications.

Typical zinc coating process and thickness

Method	Process	Coating thickness ( )
Electro galvanizing	Electrolysis	0.5- 12
Mechanical galvanizing	Peening (cold welding)	2.5-145
Hot dip galvanizing	Hot dip	50-115

1 micrometer = 3.937×10^{-5} in.

Mechanical galvanizing
In mechanical galvanizing the steel is cleaned and loaded into a tumbler containing non-metallic impact beads and zinc powder. As the tumbler is spun, the zinc powder mechanically adheres to the parts. Different coatings thickness can be achieved by changing the ratio of zinc powder to nails. Coating thickness requirements contained in the ASTM Specification B 695 range from 0.2 to 4.3 mils (5.50 to 110 µm). Adhesion between the zinc and the steel is relatively low and the coating has less abrasion resistance than hot-dip galvanized zinc coatings since it does not bond with the steel. Mechanically galvanize nails can be used for outdoor applications but there is a high chance of zinc flaking.

Electro-galvanizing
Electroplated galvanizing coatings are applied to steel by electrochemical. Electro-galvanizing coating typically provides a very thin layer of zinc on the surface of the nail which has a small amount of corrosion protection, and serves mainly as a cosmetic appearance enhancement. Due to the extremely thin zinc coating, painting or other top-coating is recommended to improve the service life.