Durable Disaster Relief Housing

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Source: http://forestnet.com/archives/June_06/spotlight.htm

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1 INTRODUCTION

Shelter needs after natural disasters come in three phases:

1. Immediate shelter: normally supplied by tarpaulins or light tents
2. Transition shelter: may be heavy-duty tents or more robust medium-term shelters.
3. Permanent buildings: Ultimately permanent shelters need to be constructed when the local economy recovers.

Immediate and transition shelters are typically supplied by aid agencies. Light wood frame is ideal for rapid provision of medium- to long-term shelter after natural disasters. However, there are challenges in certain climates for wood frame construction that must be addressed in order to sustainably and responsibly build them. For example, many of the regions which experience hurricanes, earthquakes and tsunamis also have severe decay and termite hazards including aggressive *Coptotermes* species and drywood termites. In extreme northern climates, high occupancy loads are common and when combined with the need for substantial thermal insulation to ensure comfortable indoor temperatures, can result in condensation and mould growth if wall and roof systems are not carefully designed.

The desire of aid organizations to maximize the number of shelters delivered tends to drive down the allowable cost dictating simplified designs with fewer moisture management features. It may also be difficult to control the quality of construction in some regions. Once built, “temporary” structures are commonly used for much longer than their design life. Occupier improvements over the longer term can potentially increase moisture and termite problems. All of these factors mean that the wood used needs to be durable.

One method of achieving more durable wood products is by treating the wood to prevent decay and insect/termite attack. However, commonly available preservative treated wood in Canada may not be suitable for use in other countries. Selection of the preservative and treatment process must take into account the regulations in both the exporting and receiving countries, including consideration of the potential for human contact with the preserved wood, where the product will be within the building design, the treatability of wood species, and the local decay and termite hazard. Simple design features, such as ensuring wood does not come into contact with the ground and is protected from rain, can reduce moisture and termite problems.

Building with concrete and steel does not eliminate termite problems. Termites will happily forage in a concrete or masonry block buildings looking for wood components, furniture, cupboards, and other cellulosic materials, such as the paper on drywall, cardboard boxes, books etc. Mud tubes running 10ft over concrete foundations to reach cellulosic building materials have been documented. Indeed, termites have caused major economic damage to cellulosic building materials even in concrete and steel high-rises in Florida and in southern China.

2 DURABILITY BY DESIGN

The degree of discretion allowed to the designer will be limited by cost considerations and by the need to adapt designs to local cultural and social needs. The ability to orient the house so that pitched roofs face the prevailing wind-driven rain may be constrained by existing infrastructure. Consequently, the 4Ds of durability by design, developed for residential construction in high-rainfall climates, are highly applicable to disaster relief housing.

- Deflection: Use pitched roofs, wide overhangs, and drip edges to deflect rain off the building. Avoid wood beams projecting beyond the roof line and cut back rafters at an angle so that the end grain faces downwards. Make allowances for wind-driven rain. Ensure runoff from roofs does not splash back onto walls.

- Drainage: Ensure any rain that does impact the building can run off rapidly. Keep the building shape simple. Avoid exposing wood end grains in general. Avoid water traps such as horizontal components at the bottom of vertical cladding. When plywood is used as exterior cladding, it should be oriented so that the outer veneer grain is vertical and flashing should be installed to provide a drip edge at the bottom so water does not work its way behind the wood sheathing. Slope surrounding soil away from the building.

- Drying: Ensure the design promotes drying after rain events by vapour diffusion and air flow. This is usually complicated by insulation requirements in cold climates and can be a lot easier in regions where insulation is less important.

- Durable materials: Materials are either durable naturally, or can be treated to become decay and pest resistant.

Moisture management systems should also be designed so that they will still work if the building is deconstructed and moved to a new location. Limited reliance should therefore be placed on caulking.

There are a number of key linkages between durability by design and durability by treatment. The structure should be designed to avoid wood components embedded in the ground, if at all possible (see below for preservative treatment recommendations for ground contact). As many of the components as possible should be fully protected from weather, including wind-driven rain, other than short periods during construction. This permits the use of penetrating preservative systems that do not work well when exposed to weather (see Durability by Treatment). Ideally the design should use lumber no larger than nominal 2 inches (2x4 to 2x12, for example) to aid in treatment of as high a percentage of the cross section as possible. Columns or beams can be built up as needed but built up beams should

not be exposed to the weather since the capillaries (capillary action that occurs between them can trap and hold water.

For typical residential house construction in termite zones, the 6Ss of termite management can provide long term performance. These are:

- Suppression of local termite colonies
- Site management to remove buried wood and stumps
- Soil barriers (chemical or physical) to keep termites away
- Slab and foundation detailing to prevent undetectable access
- Structural durability: see Durability by Treatment
- Surveillance and remediation

For disaster relief housing, it is typically impossible to ensure termites will be excluded through elimination of colonies, site cleaning to remove wood in ground, soil treatment, detailing of slabs, regular inspection and remedial treatment so structural durability becomes paramount. Nevertheless simple design features can reduce termite problems and optimise the performance of naturally durable or preservative treated wood.

All the above mentioned measures to keep wood dry will reduce its attractiveness to termites. Any local reduction in termite food or colony sites that can be achieved will be beneficial. Supporting wood components on solid concrete block piles, with more than 150mm of exposed concrete (separated by a membrane), is an ideal way to eliminate wood-soil contact, prevent wicking of water up to the wood, and ensure any termite tubing that does occur is noticeable and can be dealt with. Hollow concrete blocks can be havens for termites, so much so that they are used for our accelerated termite tests. Capping or filling them with concrete solves that problem. Similarly brick masonry can create channels through which termites will access the building unobserved, if not built with great attention to detail.

A durable damp-proof membrane between concrete and wood provides additional protection against dampness associated with soil level rise. Lifting the building off the ground in this way can also reduce the future impact of flooding. As an incidental benefit, chickens foraging under the structure can be an excellent biological control for termites. Any wooden steps up to the house should be supported above the ground on solid concrete blocks.

If a concrete floor slab is used, all efforts should be made to prevent development of any crack wider than 1mm and the edge should be exposed to a height of 150mm.

All metal fasteners and connections for wood preserved with copper-based wood preservatives must be stainless steel, heavy-duty hot-dipped galvanized steel, or fasteners recommended by the manufacturer for use with these preservatives. Avoid using thinly galvanized steel or aluminum in direct contact with preserved wood.

3 DURABILITY BY TREATMENT

Structural durability means using termite resistant wood species such as yellow cedar or pressure treating non-durable species. Most commercial preservative treatments are designed to protect against decay and termites. This includes Alkaline copper quat (ACQ), copper azole (CA), micronized copper azole (MCA), sodium borate (SBX) and insecticides in a buffered amine-oxide carrier, the last two for interior uses only. Thermal treatment is not effective against termites.

Wood requires deep preservative penetration to prevent termites tunnelling through the penetrated zone (probably accepting casualties as they go) to hollow out the middle. Canadian residential preservative treatment standards and European standards for preservative treatment are designed to protect against very low decay and termite hazards and may not last sufficiently long in regions with severe decay or termite hazards. American Wood Protection Association (AWPA) standards are designed to protect against Formosan subterranean termites (*Coptotermes*) which are recognized as some of the most aggressive in the world. Treatments effective against these termites should work against the *Coptotermes* present in areas like the Phillippines, Indonesia, the Caribbean, etc. Compliance with standards should be determined through independent quality assurance inspection.

Most Canadian species are difficult to reliably treat to meet AWPA standards using conventional pressure treatment processes because they are primarily composed of impermeable heartwood. Red pine sapwood is the most treatable (but 4 x 4s contain too much heartwood), Pacific Silver fir is the next best, then Western hemlock. Black spruce and red spruce are the most difficult. Jack pine, Lodgepole pine, white spruce, balsam fir, subalpine fir and Eastern hemlock are intermediate. The treatability of SPF depends on the species mix.

Interior components should be treated with SBX or insecticides in a buffered amine-oxide carrier (yet to be registered in Canada). These treatments are the best bets for achieving deep preservative penetration in Canadian lumber. Both of these treatments move deep into the wood without incising and without pressure, though SBX requires initial pressure treatment to get the required chemical loading and both benefit from an initial pressure treatment to shorten process times. Neither is suitable for exterior components without protection by, at minimum, a well-maintained 3-coat paint finish. FPInnovations has developed processes for treating SPF lumber with borate and insecticides in a buffered amine-oxide carrier. Both still require careful sourcing of material (SPF rapidly dried to low target MC cannot be treated).

Exterior components should be pressure treated with ACQ, CA or MCA which do require incising to meet standards. Chromated copper arsenate (CCA) treated permanent wood foundation (PWF) material should be used for ground contact where permitted (e.g. not Indonesia).

Plywood and PSL can be successfully treated with ACQ or CA and exposed to the weather. OSB can be treated during manufacture with Zinc Borate but this should not be exposed outdoors (except as overlaid siding product). LVL, I-joists and other engineered wood products can be problematic to treat, but there are options.

Prefabrication of disaster-relief housing can make it simpler to optimize decay and termite resistance by cutting all material to size prior to treatment and treating all wood components. Cuts/holes in lumber after treatment will expose untreated wood so they must be minimized. Treat any end cuts that do have to be made on site with borate/glycol for SBX, or with copper naphthenate for CA, ACQ or MCA-treated wood.

Wood treated with all of the above preservatives can be painted, but it is best to check the compatibility of the coating and the preservative in advance. Borates can affect the resins used in some coatings. The copper from freshly ACQ- and CA-treated wood can bleed through coatings. Preserved wood should be allowed to fully dry before coating. It is suggested to paint exterior wood the same mid-brown colour that wood treated with copper-based preservatives weathers to when exposed to the sun.

FPInnovations has field test data on Canadian preserved wood products demonstrating excellent performance against decay and termites in tropical and subtropical regions when treated to meet AWPA and CSA industrial standards. Experience with the Britco houses delivered to Indonesia (ACQ-treated hem-fir exposed lumber and plywood with SBX-treated SPF framing) suggests careful selection of wood, treatment and design can provide a durable Canadian disaster relief housing solution.

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4 ACKNOWLEDGEMENTS:

The author would like to extend his appreciation to Robert Jonkman of the Canadian Wood Council and Louis Poliquin of CECOBOIS for reviewing this document. The funding for this work was provided by Natural Resources Canada (Canadian Forest Service).