ACCELERATED FIELD SIMULATOR STUDIES

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ABSTRACT

Accelerated field simulator studies, whilst of longer duration than standard laboratory tests, can provide a greater range of biodeteriogens. Accelerated field simulator testing can generally yield results far quicker field testing, is far more secure and can be economically inspected with far greater frequency to yield measures of variation in performance. This paper provides a catalogue of studies that have been carried out in the accelerated field simulator at CSIRO, and the wide range of variables covered by such tests is highlighted.

INTRODUCTION

Standard laboratory testing, using small wooden blocks, can often give a rapid indication of preservative efficacy or natural durability. However, only a limited number of fungal species, and certainly only one species per test block, are normally included in such laboratory tests. Clearly the choice of appropriate test of fungi is difficult to make when considering a new preservative formulation. In practice, it is possible that one microbial species may be capable of detoxifying or modifying the chemical while another species may then destroy the substrate. Ideally, one would carry out a field test in the severest climate that the product under test would be used in. The field test may require as long as 25 years or more to produce final data.

In order to devise a much more rapid test than a field test while still providing a variety of (at least microbial) hazards, various attempts have been made around the world over the last 20 years, to "bring the field into the laboratory". Of course, it may be argued that access to a wet tropical field site can provide rapid results and therefore the need for the accelerated field simulator (AFS) would be reduced. However, such a tropical site must be secure against loss of tenure, theft and vandalism of specimens, loss through animals, floods, fire and damage by vehicles, cyclone, routine cleaning etc. Also, it must be

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economically inspected as frequently, if not more frequently, than every six months. These requirements almost necessitate such a tropical field test site being within the grounds of the research organisation itself. However, no wood research institution in Australia has ever been, or is currently, so well situated.

CSIRO first constructed a room for AFS testing in 1979, followed by a purpose built building (both at Highett) in 1981. Tanks from these facilities were transferred into the one, fully insulated, new building at Clayton in July 1992. Much research has already been performed, and will be described in some detail in this paper, illustrating the breadth of the work and thereby indicating the usefulness of the AFS in past, present and future research at the Division of Forest Products.

MATERIALS AND METHODS

Because their objectives vary greatly, a number of approaches have been taken, by different authors of this paper, in running their various trials. Basic to all of them is the AFS facility which is maintained at 28°C and 80-85% RH, in darkness. Containers range from small to large, the most numerous being stainless steel tanks of dimension 1.8 x 0.77 x 0.65 m. Some smaller tanks are used, as well as a large concrete drainage culvert capable of easily holding stubs of commercial sized poles. With the exception of some out of ground contact work (e.g. of decaying western red cedar weatherboards), all studies to date have been ground contact studies using soil from various sources (clay and sandy loams, plus, on one occasion, an artificial substrate). Some studies feature reconstructed soil profiles (i.e. litter layer and upper two horizons) transported from the field separately, with all tanks having screenings in the bottom for drainage. Watering is done from above and ranges from routine weekly to infrequently, to as required, based on moisture content readings of timber. Inspection intervals vary from as frequently as every 4 or 8 weeks, to every 6 months, or even yearly (in one case after a 5 year interval), depending on whether the requirement is for accurate determination of variability of performance or simply to differentiate the survivors from the others.

Advantages and disadvantages of this type of research have been presented and discussed before (Johnson *et al.*, 1982).

EXPERIMENTS AND RESULTS

For brevity, a description of experiments and results will adhere to the following format:

- *Reasons for carrying out the experiment*
- *Substrate and size*
- *Preservative (where applicable)*
- *Duration*
- *Findings*
- *Publications and/or reports*
- *Collaborators (if any).*

The experiments will be divided into three groups: preservative, natural durability and miscellaneous research.

Preservative research

1. Effects of concrete collars on efficacy of CCA
    - *Reasons for carrying out the experiment*: To see if concreted, CCA-treated poles were more susceptible to decay than those not concreted and to observe the effect of impervious barriers between the concrete and pole interface
    - *Substrate and size*: Radiata pine, pole stubs, commercial
    - *Preservative (where applicable)*: CCA at 20-40 kg dry salt m^{-3}
    - *Duration*: 5 years, completed
    - *Findings:* A CCA-tolerant brown rot fungus was found in the soil; both concreted and non-concreted stubs were readily decayed; presence of barrier between concrete and pole reduced decay; bandage with TCMTB prevented any decay; limited decay occurred if TCMTB added to concrete
    - *Publications and/or reports*: Reported to Joint Wood Preservation Committee (responsible to this conference) with journal publication in preparation
    - *Collaborators (if any):* None.

2. Yellow stringybark preservation
    - *Reasons for carrying out the experiment*: To evaluate the performance of yellow stringybark as a pole timber
    - *Substrate and size*: Stakes 20 x 20 x 150 mm
    - *Preservative (where applicable)*: CCA at five retentions to 40 kg m^{-3} in sapwood, untreated sapwood, untreated heartwood
    - *Duration*: 4 years, planned for a total of 5 to 10 years
    - *Findings*: No decay at retentions of 20 kg m^{-3} and above; untreated sapwood has failed; untreated heartwood has moderate decay
    - *Publications and/or reports*: Four Divisional Reports
    - *Collaborators (if any)*: SECWA.

3. PEC additives
    - *Reasons for carrying out the experiment*: Demands from certain unions for lower creosote content in Pigment Emulsified Creosote (PEC) led to test of biocide additives
    - *Substrate and size*: Sapwood stakes 20 x 20 x 150 mm cut from hardwood poles

- *Preservative (where applicable)* PEC, PEC plus TCMTB, Boracol 40, copper ethanolamine nonanoate (CEN), Quatramine 80, arsenic trioxide, troysan polyphase or CCA, vs HTC (High-temperature creosote), toluene and water controls
- *Duration*: 8 years, completed
- *Findings*: PEC and PEC + additives perform well at high (120 kg PEC m^{-3}) and moderate (60 kg PEC m^{-3}) retentions; severe decay at 30 kg PEC m^{-3}. Considering PEC treatments have creosote content equivalent to 65% HTC, PEC has more than held its own against HTC
- *Publications and/or reports*: Greaves *et al.*, 1985 (for 3, 6, 12 month results)
- *Collaborators (if any)*: Koppers, SECV.

4. Weathered HTC versus PEC
- *Reasons for carrying out the experiment*: To determine comparative efficacy of weathered HTC and PEC formulations
- *Substrate and size*: Quadrants from commercial poles, non-durable ash-type eucalypts or durable "regal" species
- *Preservative (where applicable)*: PEC and HTC, each treated at 60°C and 90°C, then 100 hours in weatherometer
- *Duration*: 9 years, completed
- *Findings*: When creosote retentions are similar, PEC performs as well as HTC
- *Publications and/or reports*: Divisional report in preparation
- *Collaborators (if any)*: Koppers, SECV.

5. Chlorothalonil
- *Reasons for carrying out the experiment*: To determine the efficacy of chlorothalonil as a wood preservative
- *Substrate and size*: Radiata pine and mountain ash sapwoods 25 x 25 x 150 mm
- *Preservative (where applicable)*: Chlorothalonil in oil vs CCA (Tanalith C)
- *Duration*: 4 years of at least 5 years
- *Findings*: Oil controls performing well and chlorothalonil performing better than CCA at all equivalent retentions; better in pine than in eucalypt
- *Publications and/or reports*: Laks and Woods, 1992
- *Collaborators (if any)*: ISK Biotech Corporation.

6. Cell wall penetrating formulations
- *Reasons for carrying out the experiment*: To determine the efficacy of copper-based formulations that swell wood cell wall (for better penetration)
- *Substrate and size*: Radiata pine and messmate sapwoods 20 x 20 x 130 mm
- *Preservative (where applicable)*: Tanalith C, CEN and various commercial water-based or organic solvent formulations of acypetac-copper
- *Duration*: 5½ years, completed
- *Findings*: Although Tanalith C was best, two ammoniacal formulations and CEN performed well, while organic solvent acypetac-copper formulation performed poorly
- *Publications and/or reports*: Cookson and Greaves, 1991
- *Collaborators (if any)*: Cuprinol, UK.

7. Diffusing remedial preservatives
   - *Reasons for carrying out the experiment*: Assess diffusing commercial formulations for remedial treatment
   - *Substrate and size*: Messmate natural rounds, 40-50 mm x 500 mm
   - *Preservative (where applicable)*: B_2O_3, B_2O_3 + CuO, $Na_2B_8O_{13}$ + CuO, each as fused solid rods
   - *Duration*: 20 months, completed
   - *Findings*: Boron diffused and protected wood against decay fungi introduced by predecayed dowels (with specimens in vermiculite rather than soil) whereas copper did not diffuse
   - *Publications and/or reports*: Greaves *et al.*, 1982
   - *Collaborators (if any)*: None.

8. Decay in CCA-treated vineyard posts
   - *Reasons for carrying out the experiment*: Determine cause of premature failure of CCA-treated vineyard posts
   - *Substrate and size*: Radiata pine rounds
   - *Preservative (where applicable)*: Tanalith C and fire retardant CCA formulation (3S), individual rounds placed in large plastic tubes containing soil with or without additives of fertiliser, gypsum etc. as practiced in vineyards
   - *Duration*: 5 years, completed
   - *Findings*: Failures were rapid, due to a tolerant brown rot fungus, and confined to fire retardant formulation. The 3S formulation had a moisture content always higher than the Tanalith C-treated posts throughout this test
   - *Publications and/or reports*: Report in preparation
   - *Collaborators (if any)*: None.

9. Beehive treatments
   - *Reasons for carrying out the experiment*: To find preservatives for beehives that do not need overpainting, and are suitable for use in contact with food
   - *Substrate and size*: Radiata pine, mainly sapwood, 30 x 20 x 200 mm
   - *Preservative (where applicable)*: Dipped for 10 or 20 min. in benzalkonium chloride (Quatramine 80) or copper naphthenate (each at 4 concentrations)
   - *Duration*: 12 months
   - *Findings*: Wax dip prior to a single coat of paint was considered the most practical do-it-yourself treatment
   - *Publications and/or reports*: Robinson and French, 1984,1988
   - *Collaborators (if any)*: None.

10. Low temperature creosote treatments of sapwood and heartwood
   - *Reasons for carrying out the experiment*: Determine relative performance of radiata pine sapwood and heartwood treated with creosote
   - *Substrate and size*: Specimens 50 x 50 mm cross-section, originally treated as being all sapwood, top 100 mm removed from tops of specimens after 10 years field exposure, split radially to produce 50 x 25 x 100 mm stakes (one for exposure, one for retention analysis)
   - *Preservative (where applicable)*: K55 Creosote originally averaging 175-210 kg m^{-3}
   - *Duration*: 184 weeks (i.e. until all heartwood failed), completed
   - *Findings*: Most of sapwood still serviceable
   - *Publications and/or reports*: No report, may be used for calibration to remainder of specimens now in field for 24 years (Mulgrave/Rowville sites)
   - *Collaborators (if any)*: None.

11. Pretreatment of hardwood

- *Reasons for carrying out the experiment*: To obtain better protection of hardwoods by pretreatment with $Na_2S_2O_5$ before treating with CCA or chromium compounds.
- *Substrate and size*: Spotted gum sapwood 20 x 20 x 150 mm
- *Preservative (where applicable)*: Pretreat $Na_2S_2O_5$ followed by CCA, various chromium compounds, plus various controls, prior to leaching
- *Duration*: 5 years, completed
- *Findings*: CCA performance improved slightly by the pretreatment; chromium compounds whether the hardwood was pretreated or not performed poorly, being attacked mainly by brown rot fungi
- *Publications and or reports*: Not yet prepared for publication
- *Collaborators (if any)*: None.

12. Novel formulations

- *Reasons for carrying out the experiment*: Testing of novel formulations and some agricultural formulations already tried overseas as wood preservatives, to see if they have potential in hardwoods
- *Substrate and size*: Mountain ash sapwood, 20 x 20 x 150 mm
- *Preservative (where applicable)*: 16 fungicides each at 3 retentions, leached 5 years, ongoing
- *Findings*: 6 treatments continue to perform well
- *Publications and/or reports*: No reports yet prepared
- *Collaborators (if any)*: None.

Natural Durability Research

13. Natural durability of selected timber species

- *Reasons for carrying out the experiment*: To determine the relative durability of 36 timbers, to determine variability both within and between different trees of the same timber species
- *Substrate and size*: Specimens 20 x 20 x 100 mm, obtained from 50 x 50 x 100 mm tops removed from stakes exposed in field (Walpeup, Victoria) for 10 years; some fresh cut non-durable controls
- *Preservative (where applicable)*: CCA control offcuts, 12 kg m^{-3}
- *Duration*: 5 years, completed
- *Findings*: Variation between trees of same species greater than variation within a tree, median specimen lives obtained for all species and treatments except three (raspberry jam, brigalow and 12 kg m^{-3} CCA radiata sapwood control), Q3 obtained for all but a further two
- *Publications and/or reports*: Thornton *et al.*, 1981, plus journal paper in preparation
- *Collaborators (if any)*: None.

14. Natural durability

- *Reasons for carrying out the experiment*: To determine the relative durability of more than 70 timber spp.
- *Substrate and size*: Specimens 20 x 20 x 100 mm, again obtained from 50 x 50 x 100 mm tops removed from stakes in field (Mulgrave, Victoria) for 13 years; fresh cut specimens (as in 13)

- *Preservative (where applicable)*: CCA control offcuts, 12 kg m^{-3}
- *Duration*: 5 years for decay only, 2½ years exposure of both predecayed and non-predecayed specimens to termites
- *Findings*: Complete range of decay failures (brown rot, white rot, soft rot) occurring at either groundline, base or top of specimen; termite attack extremely rapid, reliable and reproducible; all completed
- *Publications and/or reports*: Johnson *et al.*, 1983 and accompanying Divisional Video, Johnson *et al.*, 1988, further journal publication planned
- *Collaborators (if any)*: None.

15. A comparison of the durability of old growth and regrowth timbers
    - *Reasons for carrying out the experiment*: A comparison of heartwood durability of timbers from different resources, i.e. regrowth or plantation against old growth
    - *Substrate and size*: Range of commercial timbers, 20 x 20 x 100 mm outer heartwood
    - *Preservative (where applicable)*: Some preservative (CCA), controls
    - *Duration*: 3½ years, ongoing
    - *Findings*: See Paper 2/21 (Johnson *et al.*, 1993) at this Conference
    - *Publications and/or reports*: 4 Divisional reports, paper 2/21 this Conference
    - *Collaborators (if any)*: Department of CALM, WA.

16. Comparison of Malas and Hopea for PNG poles
    - *Reasons for carrying out the experiment*: Assist PNG in choice of pole timbers
    - *Substrate and size*: Malas and hopea; outer heart, inner heart, and sapwood; 20 x 20 x 100 mm
    - *Preservative (where applicable)*: No preservatives
    - *Duration*: 4 years, completed
    - *Findings*: Large variation between and within trees of each species; malas more durable than hopea; malas sapwood has considerable durability
    - *Publications and/or reports*: 7 Divisional reports, may be published with or without data on penetration and resultant CCA loadings obtained using same trees
    - *Collaborators (if any)*: PNG ELCOM.

Miscellaneous Research

17. Decay resistance of composite sheet products
    - *Reasons for carrying out the experiment*: Compare decay resistance of cellulose fibre reinforced cement with the previously used asbestos fibre reinforced cement
    - *Substrate and size*: Small sheets, three-quarters buried in soil with added decay fungi and litter
    - *Preservative (where applicable)*: No preservative
    - *Duration*: 1, 5 and 10 year harvests, completed
    - *Findings*: Variation in both moisture content and (due to carbonisation) mass gain between the two products; returned to collaborator for strength and carbon content determinations compared to unexposed controls
    - *Publications and/or reports*: 3 Divisional reports
    - *Collaborators (if any)*: James Hardie.

18. Methane emission from termites
    - *Reasons for carrying out the experiment*: To estimate the amount of methane produced by termites in a *Coptotermes lacteus* mound.
    - *Substrate and size*: As for study number 14.
    - *Preservative (where applicable)*: No preservatives.
    - *Duration*: several days, completed.
    - *Findings*: Average methane flux was 0.7 mg per kg of termites per hour.
    - *Publications and/or reports*: Fraser *et al.*, 1986.
    - *Collaborators (if any)*: None.

19. Position of termite attack
    - *Reasons for carrying out the experiment*: To determine the effect of position of untreated hardwood specimens in the tank on attack by termites.
    - *Substrate and size*: Mountain ash sapwood, 20 x 20 x 100 mm.
    - *Preservative (where applicable)*: None.
    - *Duration*: 2 months, completed.
    - *Findings*: Specimens placed in rows at the end of the tank were attacked to a greater extent ($p<1\%$) than those in the middle of the tank.
    - *Publications and/or reports*: None.
    - *Collaborators (if any)*: None.

20. Monitoring soil biology
    - *Reasons for carrying out the experiment*: To determine the changes over time in the number of soil bacteria, fungi and Actinomycetes. Soil moisture content and pH recorded at isolation times.
    - *Substrate and size*: None.
    - *Preservative (where applicable)*: None.
    - *Duration*: 84 days.
    - *Findings*: No reduction in the number of propagules of bacteria or fungi were noted.
    - *Publications and/or reports*: None.
    - *Collaborators (if any)*: None.

21. Biodegradation of Stramit Space Board
    - *Reasons for carrying out the experiment*: To accelerate the biodegradation of this panel product by addition of nitrogen and inoculum.
    - *Substrate and size*: Segment of panel, 50 x 100 x 100 mm.
    - *Preservative (where applicable)*: None.
    - *Duration*: 12 weeks, completed.
    - *Findings*: The specimen in contact with the soil was more readily attached. Neither chicken manure nor fungal inoculum enhanced degradation.
    - *Publications and/or reports*: Divisional report.
    - *Collaborators (if any)*: Stramit Industries.

22. Other studies

    In addition: Decaying specimens are kept active for teaching/display purposes; litter from field test sites is AFS-predecayed until ready for transfer to soil surface of ongoing tests; brown-rotting CCA treated posts are kept active so that soil will contain such fungi; assessments of microbial propagules in soil at start of tests; non-durable species are predecayed for use as attractant baits in field, and as baits for use in buildings to detect subterranean termites (with or without subsequent insecticide addition); biodegradable plastic products have been

exposed in one soil type; attempts are being made to reproduce the actual succession of decay types influencing natural durability in the field; means of selecting likely tolerant organisms for new preservatives can be studied. Finally calibration tests of natural durability, AFS to field, have just been completed (against decay and termites) in the field using AFS-sized specimens (20 x 20 x 100 mm) that were matched with the fresh cut non-durable controls used in studies 13, 14 and 15. The latter field exposure was inspected more frequently than a normal field test (i.e. three times per year) and the last specimen became unserviceable after just under eight years.

Summary of AFS testing

Our work has shown that durability of a wide range of timber species and efficacy of preservatives (water-borne, oil-borne or solvent-borne) can be determined in the AFS. Specimens with cross-sections ranging from 20 x 20 mm (sawn) to commercial pole rounds have been successfully used. New preservatives are compared, against well known comparative control timbers/preservatives. While all tests are carried out at 28°C and around 85% RH, various soils (often with amendments from rotting specimens, decaying litter, etc.) have been used as well as artificial media. For some overseas institutions, their fungal cellar or soil-bed methodology (often using smaller test chambers, shallow soils and with resultant soil-drainage difficulties) apparently become almost exclusively a soft rot facility. However, AFS testing in CSIRO has provided the full range of decay hazards because the conditions are suited to the activity of brown rot and white rot decay (as evidenced not only by rot type, but also by fruit-body production, on both specimens and litter that occurs frequently in the course of some of our studies), as well as soft rot attack. Additionally, natural durability determinations have included the provision of a complete active termite colony over a 2½ year period.

Research to calibrate the AFS against some field sites has been underway for some time. One approach is to expose AFS-size specimens in both the field and the AFS, and inspect them frequently for decay or termite attack. Also, for two series of natural durability tests (against decay and termites), the AFS specimens were prepared from sound tops removed from the stakes after 10 to 13 years in the ongoing field tests. Deterioration in the stake tops in the AFS after 2½ years (termites) and 5 years (decay) was much more severe than in the field test specimens exposed in ground for around 25 years, even at the tropical and subtropical sites. Calibration will be attempted when biodeterioration of specimens the field test is somewhat further advanced, and publication considered at that time.

Although this paper only deals in general with advantages and disadvantages of AFS testing, it is clear that its economy and suitability for frequent inspection yields data that can be more extensive than that obtainable from field sites. The altered timber resource, or new preservatives, can be evaluated directly and precisely against known controls to give comparative results.

Publications: Complete list including Forest Products Conference (FPRC), International Research Group on Wood Preservation (IRG), as well as journal papers.

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Johnson, G.C., Thornton, J.D. and Nguyen, N-K. (1993). An accelerated field simulator study of the natural durability of heartwood from mature and regrowth trees. Proceedings 24th FPRC. Topic 2/21, 9 pp.

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