# Demonstration and Test Structures for Urban-Wildland Interface: Wildfire and Wood-Destroying Insects

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## Abstract

Two small structures were built as an integral part of the program of the UC Forest Products Laboratory. The urban-wildland interface building exhibits common building materials and construction details. Materials were selected because of their common usage in California or because of their demonstrated fire, thermal, or moisture performance characteristics. A number of choices were related to fire test results on building subassemblies that were conducted with Federal Emergency Management Agency support from 1998 to 2002. Included are four cladding materials, three types of windows and glass, two types of roofing material, an attic area and a cathedral ceiling, and five vent types. The setting for the structure is a "fire safe garden" area that displays models of plant types and arrangements. The demonstration construction materials also include plywood and oriented strandboard sheathing; 2 by 4, 3 by 4, and 4 by 4 studs; flashing and seismic hold-downs. The "Villa termiti" serves as a test bed for detection and treatment for insects, particularly beetles and drywood termites. This building has easily removable wall coverings and other areas to permit the insertion of special termite-containing blocks. With the blocks in place, testing was done over a number of years to assess the viability of a number of local or "whole house" treatment methods, and the information has been since published. Unlike normal residential structures, it has been possible to determine the effectiveness of insect location and extent of treatment. The building has also served as a test-bed for assessing a wide range of acoustic emission detectors for insects.

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## Urban Wildland Interface Demonstration Structure

Federal Emergency Management Agency (FEMA) funding provided to the University of California Forest Products Laboratory (UCFPL) during 1998 to 2002 resulted in considerable research on the performance of common construction materials, and common landscaping vegetation, under simulated wildfire exposures. Research conducted under this grant also resulted in practical durability and performance information related to general design and detailing of structures, and the installation of materials. To aid in the dissemination of this information to the construction community and California residents, a demonstration structure was funded and designed by UCFPL.

The demonstration structure is a slab-on-grade foundation with a floor area of approximately 80 $ft.^2$. Construction materials were selected to demonstrate the major components and assemblies found in homes. With regard to wildfire issues, construction materials included roof coverings, cladding options, framing and glass types found in windows, and vents. Two different roof overhang widths were incorporated into the design, as well as boxed and open eave constructions. In order to better represent wildland to structure interface issues in this setting, defensible space was created by incorporating a patio and grass into the landscape design (Fig. 1). Native drought resistant plants were incorporated into the near-home vegetation plan.

## Roof

The roof shape consists of a traditional gable design with a 4-in-12 pitch. One-half of the roof was covered with "30-year" asphalt impregnated fiberglass strip (3-tab) shingles, and the other half was covered with western redcedar, fire retardant treated shakes ("heavies"). Type 30 roofing felt was used in the construction, and oriented strandboard (OSB) as used as the sheathing material.

The asphalt composition shingles consist of a base (felt) material, asphalt, and a surfacing material (granules). When glass fiber felt is used, a Class A rating is obtained for the roof covering, the highest fire resistance rating available. Use of cellulose fibers as the felt material would result in a Class C fire rating for the roof covering.

Fire-retardant treatments (FRT) for many wood-based construction materials have been available for a number of years. These typically are rated for interior or exterior use and can either be spray applied (typically in service) or applied using a pressure impregnation process in a treating facility. The shakes used in this structure were pressure treated using FTX fire-retardant chemical a propriety formulation manufactured and treated by Chemco Corporation, that provides a "stand alone" Class B fire rating. This product has been listed and approved for use by the California Office of the State Fire Marshal and has passed the 10-year natural weathering test required by that office. A Class A "assembly" rating can be achieved with this product if an additional fire barrier material is used between the FRT shakes and the sheathing. Approved fire barrier materials include a Type 72 capsheet material (also called roll roofing) and DensDeck® sheathing, a glass fiber faced gypsum product manufactured by Georgia Pacific Corporation. When used, the capsheet material is overlapped in sheet fashion, just like normal roofing felt. The DensDeck material comes in 4 by 8 sheets.

Even though the approved fire barrier materials have a Class A fire rating, research conducted at the UCFPL has shown that some assembly ratings were vulnerable when construction materials deviated from the assembly originally used to achieve the Class A assembly rating. The Type 72 capsheet material should be rated for exterior fire exposure. A fire-resistant tape for the panel joints, or alternative sheathing material, may be required to maintain the fire rating when DensDeck is used.

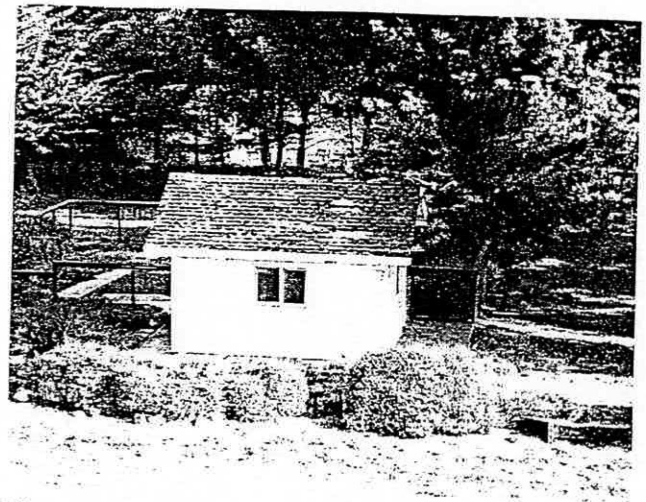

**Figure 1.** ~ *Demonstration structure showing stucco clad wall, asphalt comp roof covering, and landscaping vegetation. A through-roof vent on the roof surface is also visible.*

## Exterior Cladding

Four cladding materials were used on the structure, including hardboard, fiber-cement, vinyl, and three-coat stucco. With the exception of the stucco, all cladding materials consisted of horizontal lap siding products. The hardboard product was a nominal 16-inch-wide textured pattern with an approximate 15.5-inch exposure, three nails per bearing, and a shiplap joint. The fiber-cement siding was a nominal 6-inch-wide textured pattern with a 5-inch exposure and a plain bevel lap joint. Most of the fiber-cement siding was blind nailed (nailed only through the underlap), but a small area was face-nailed (nailed through both the under- and overlap portion of the lap joint.) The vinyl siding had a 10-inch exposure and was locked at the lap joints. Since the vinyl siding was used on an end-wall, a rake soffit panel was used.

The fire performance of selected cladding materials covered the spectrum. Traditional three-coat stucco has been reported to perform well under urban wildland interface (UWI) fire exposures. The performance of lap siding products varied and was dependent on the cladding material and the design of the lap joint. The lap joint is the most vulnerable feature in solid wood siding products (Fig. 2). Under simulated wildfire exposures, performance improved when interlocking joints were used, such as shiplap and tongue-and-groove joints. Plain bevel lap-joints did not perform well. For example, in testing conducted at the UCFPL, flame penetration occurred in just over 1 minute when plain bevel siding was used, and just over 21 minutes when a

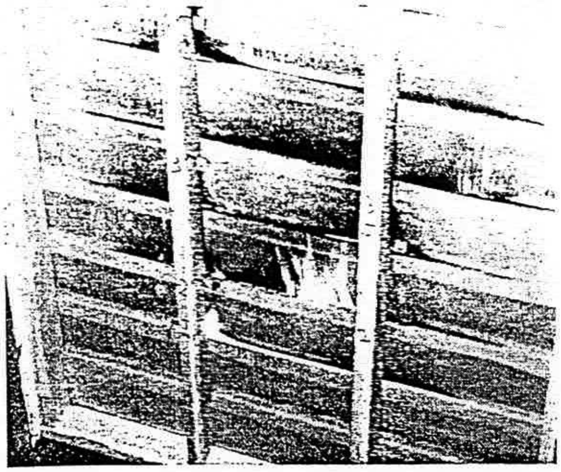

Figure 2. ~ *Fire test of a horizontal lap siding product, showing the vulnerability of the joint.*

shiplap pattern was used. In both cases a 150 kW flame impingement exposure was used. Fiber-cement plain bevel siding performed slightly better than the solid wood shiplap product, pointing to the benefit of a non-combustible product, particularly at the joint. It was interesting to note that a fire retardant treated (intumescent) solid wood product with a plain bevel lap joint was also tested and it performed as well as the shiplap and fiber-cement products. The composite wood siding products such as hardboard siding, did not perform well in the fire tests, even when integral lap joints were used. The fire exposure caused them to deform at the joints, resulting in flame penetration to the underside of the siding. Although vinyl cladding does not sustain combustion when the flame source is extinguished, it readily deforms and drops off the wall. In this situation, the fire performance quickly becomes solely dependent on any underlying materials that may be present.

## Windows

The fire performance of windows depends on the types of frame material and glass. Research at the UCFPL showed that the glass is the more important factor when considering fire performance (**Fig. 3**), with double pane windows offering better performance over single pane, and tempered glass performing somewhat better than annealed. The demonstration structure used three different frame materials, including vinyl, vinyl clad wood, and aluminum. The aluminum window was a single-hung type and had single pane, annealed glass. Both the vinyl and vinyl clad wood used double pane, tempered glass. The vinyl window was a double-hung type (both the upper and lower sash can move), and the vinyl clad was a gliding window. A gliding window is similar to a sliding glass door in that it has two sashes, with one sash being able to move horizontally past the other. The size of the vinyl and aluminum windows was similar, both approximately 2 feet wide and 3 feet high. The vinyl clad sliding window was approximately 4 feet wide and 3 feet high.

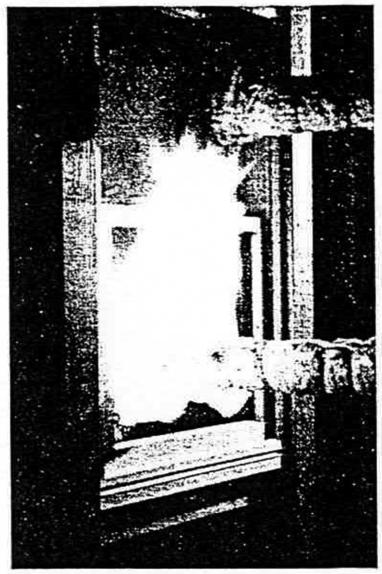

Figure 3. ~ *Glass breakage and flame penetration during the fire test of a window.*

## Venting

Results from research conducted at the UCFPL, and from post mortems conducted after the 2003 Southern California wildfires have shown that vents can provide entry points for flame and burning embers (7). Flame and ember entry can potentially cause loss of structures. Attic and crawlspace ventilation, obtained by incorporating multiple vents in the building, have also traditionally been required by building codes to serve as a moisture management tool. The demonstration structure included many examples of common roof and soffit vents to facilitate a discussion of the design, vulnerability, and function of vents. Since the structure was built on a concrete slab, crawlspace vents could not be used.

Roof vents included through-roof ("eye-brow") vents on both the shake and asphalt shingle roofs, and a ridge vent at the roof peak. A gable end vent was used just below the rake on the fiber-cement end of the structure, and soffit vents were incorporated into the eaves. Frieze-block vents were used on the side of the structure that was built with an open eave construction. These vents consisted of two 2-inch diameter holes drilled through each piece of blocking that were inserted into each roof rafter cavity (**Fig. 4**). One-quarter inch mesh screen was attached to the inside of blocking member. Strip vents were used on the boxed eave side of the building. Soffit materials used in the boxed in eaves in-

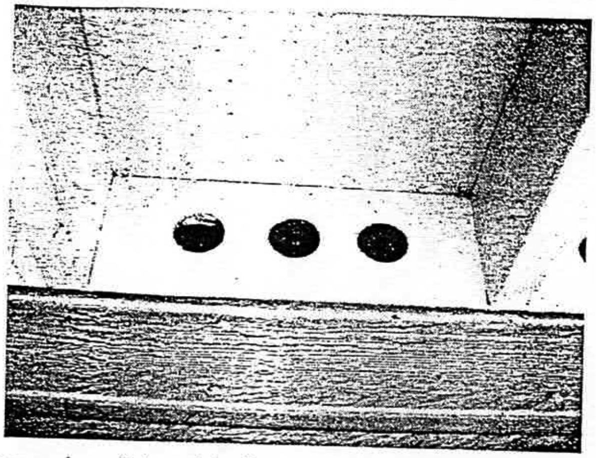

Figure 4. ~ *Frieze block vents cut into the blocking in an open eave.*

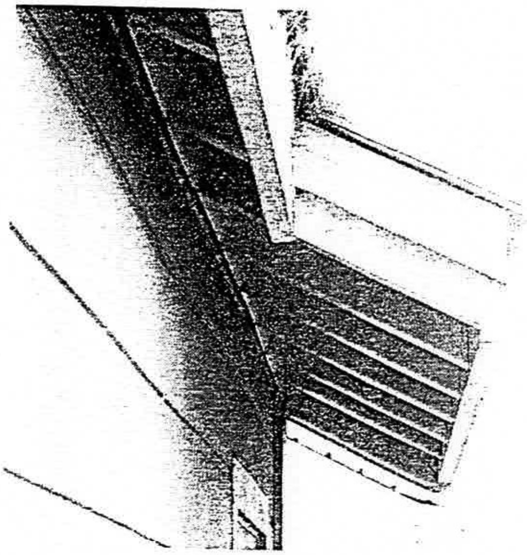

Figure 5. ~ *Six- and 18-inch overhangs were shown in conjunction with this open-eave construction.*

cluded a fiber-cement sheet material and a 0.75-inch-thick A-C plywood. A plastic strip vent was used with the fiber-cement soffit material. This strip vent was designed for use with the soffit material. A metal strip vent material was used with the plywood soffit material. Regarding flame impingement exposures, our research showed that the knots and core gaps in the inner plies are the vulnerable features in the plywood. Even though the fiber-cement material is noncombustible, this boxed-in eave would still be vulnerable to ember and flame impingement exposures because of the vent.

## Roof Overhang

Wide roof overhangs have been shown to reduce the amount of water-related damage that occurs in structures (3). It is also generally thought that wide overhangs make the structure more vulnerable to ember and flame impingement exposures. In order to provide a forum to discuss these points, the demonstration structure was designed to have two overhang widths. The boxed-in eave side of the structure has a consistent 18-inch overhang. The open-eave side of the structure was split so that one-half of the building length has an 18-inch overhang, and the remainder has a 6-inch overhang (**Fig. 5**).

## Other Features

The inside of the structure was left unfinished in order to show other construction materials and demonstrate selected construction practices. One-half of the structure exhibits an attic construction using manufactured trusses. The other half was built with a cathedral ceiling. The through-roof vent was only used in the attic portion of the structure.

A variety of wood products were used in the structure. The sill plate material was treated with one of the new non-arsenical preservatives, ammoniacal copper quat (ACQ). Use of this material facilitates discussion of the recent voluntary withdrawal of chromated copper arsenate (CCA), and some of the performance issues related to the copper-based non-arsenical preservatives, particularly relative to the performance of CCA. Both plywood and OSB sheathing was used throughout the structure. OSB was used as the roof sheathing and also on selected walls. Plywood was used at the eave edge in the open eave construction and on selected walls. Whereas Douglas-fir studs were used throughout for wall framing, 3 by 4 members were used at locations where panel-to-panel joints occurred to "eliminate" miss-nailing ("shiners") at these locations. Even though the contractor was told the rationale for using the 3 by 4 members, some shiners did occur. Use of 3 by 4's at panel joints is a good idea, but evidently not fool proof. Finally, holddowns were used so that seismic issues could be discussed.

## Villa Termiti

Structural insect pests have significant economic impact throughout the United States. Ranked in recent surveys, termites and ants dominate the pest control market for structures across the country (1, 2). Money spent for the control, prevention, and damage repairs due to structural pests exceed $5.65 billion per year (4). Among termites, species of greatest pest importance include West Indian powderpost termite (*Cryptotermes brevis* (Walker)), western drywood termite (*Incisitermes minor* (Hagen)), eastern subterranean termite (*Reticulitermes flavipes* (Kollar)), western subterranean termite (*Reticulitermes hesperus* Banks), and Formosan subterranean termite (*Coptotermes formosansus* Shiraki) (8, 20, 21). Although newer taxonomic techniques and exotic pest introductions has and will continue to increase the number of important termite pests 6, 21), the Argentine ant (*Linepithema humile*) is the dominant structural ant pest in North America (23). For reviews of important structural pests in the United States, see Su and Scheffrahn (20, 21), Lewis (8, 9), and Mallis (15).

For many decades, the management of structural insect pests was achieved primarily through the use of chemicals; drilling slabs for subsurface applications; surface applications to soil for subterranean termites and foraging ants, fumigants for drywood termites, as well as topical and subsurface injections to wood. However, the public is showing increased interest in non-chemical and least-toxic approaches to insect control (11). Least toxic includes active ingredients with benign effects to mammals and other non-target organisms and also includes the use of detection devices that better target pest infestations resulting in lesser amounts of toxic materials being applied. The list of non-chemical and least-toxic techniques presently marketed in the United States for structural pests currently includes excessive heat and cold, electrocution, microwaves, baits, biological control using parasites and pathogens, active ingredients specifically designed for pest species, and detection technologies for better targeting of pest infestations (5, 8, 21). For some termite species, many of the non-chemical methods are "spot or localized" (restricted to a single spot within a board or small group of boards (11, 17). Unfortunately, there has been limited published field research for most non-chemical and least-toxic management methods for structural pests. Finally, although non-chemical and least-toxic management methods are gaining in popularity, their local availability has been spotty or slow. Good reviews for chemical, non-chemical, and least-toxic methods for managing structural insect pests can be found in Lewis (7, 10), Lewis and Haverty (11, 12), Lewis et al. (13), Mallis (15), Potter (16), Scheffrahn and Su (17, 18), Scheffrahn et al. (19), and Su and Scheffrahn (20, 21).

## Test Bed

To simulate field conditions, a woodframe structure (named Villa Termiti) was built specifically as a test bed for efficacy trails involving detection devices, non-chemical and least-toxic management methods for drywood termites, as well as exterior soil sprays for foraging ants. The test bed has three levels (attic, drywall living space, and crawl space) and considerable useable space (20 by 20 ft. or 400 ft.$^2$) (Fig. 6). Construction materials included Pacific Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. menziesii) for stud walls, headers, and rafters, and foundation-grade redwood (*Sequoia sempervirens* (D. Don) Endl.) was used for mudsill plates. The exterior of the test bed consists of stucco walls and a shingled roof. Walls were built with 2- by 6-inch studs on 12-inch centers and allowed for easy installation of test boards of varying sizes (**Fig. 7**). No pressure-treated or otherwise chemically treated wood was used in this building. To better reflect the different building styles used in northern versus southern California (wood exteriors on raised foundations vs. stucco exteriors on slabs), a combination foundation were included in the design. An additional construction feature included wood panels with a door and two windows, the entire assembly being detachable for each exterior wall (**Fig. 7**). There are no interior walls, insulation, or fire blocking; however, the building does have electrical wiring and a nonfunctional wastewater plas-

Figure 6. ~ *The woodframe structure (Villa Termiti) built specifically as a test bed for efficacy trials involving detection devices, non-chemical and least-toxic management methods.*

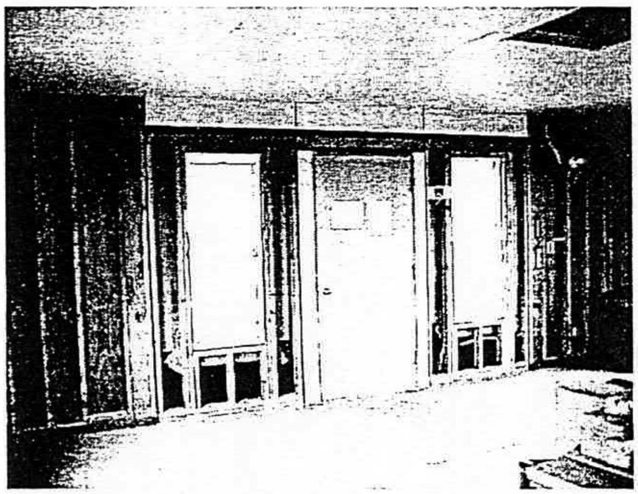

Figure 7. ~ *Interior walls were built with 2- by 6-inch studs, using 12-inch on-center spacing, allowing for easy installation of the test boards.*

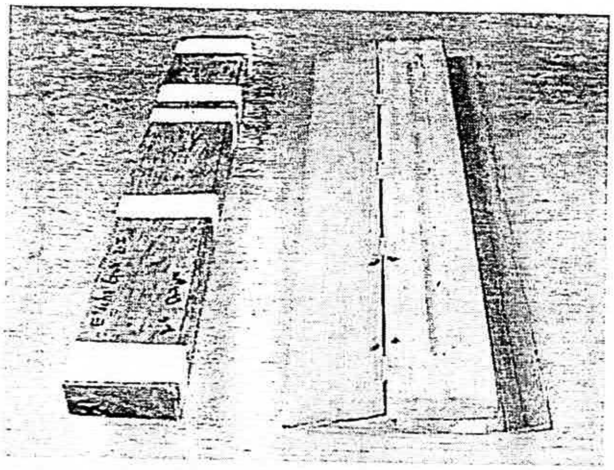

Figure 8. ~ *Sample test boards used in the efficacy trials involving drywood termite treatment methods, were 1 by 4s, 2 by 4s, and 4 by 6s. Test board contained three routed galleries of varying depth (one of which is shown on the right). Once galleries were filled with allotted number of termites, the boards were assembled and taped together (left).*

Figure 9. ~ *Artificially infested boards containing termites were randomized and installed in the test bed in exposed locations and behind drywall using drywall screws.*

tic (ABS) pipe. This symmetry of design allowed for testing unbiased by construction or aspect, and it enabled internal replication using an entire wall of wall voids. The structure is located at the University of California Richmond Field Station, Richmond, California.

## Placement of Artificially Infested Sample Boards in the Test Bed

For efficacy trails involving drywood termite treatment methods, sample test boards were constructed to contain live termites (Fig. 8). The dimensional sizes of boards used were 1 by 4s, 2 by 4s, and 4 by 6s. Each board contained three routed galleries of varying depth (Fig. 8). Twenty-five live drywood termites (workers only) were inserted into each gallery, total per board 75. Artificially infested boards containing termites were randomized and installed in the test bed in exposed locations and behind drywall using drywall screws (Fig. 9) (11). Depending on the control method tested, 36 to 48 artificially infested boards were installed in the test bed.

## Placement of Naturally Infested Boards

The criteria used for selecting naturally infested boards for the study were acoustical emission readings greater than 10 counts per minute in at least one monitored position within the board (11). Corresponding acoustic emission readings for stratified levels were approximately 10, 30, and >40 counts per minute as registered by a handheld acoustic emission detector (Wood-destroying Insect Detector®, DowAgroSciences, Indianapolis, IN). When possible, an equal number of boards within each stratum were installed in the three areas of

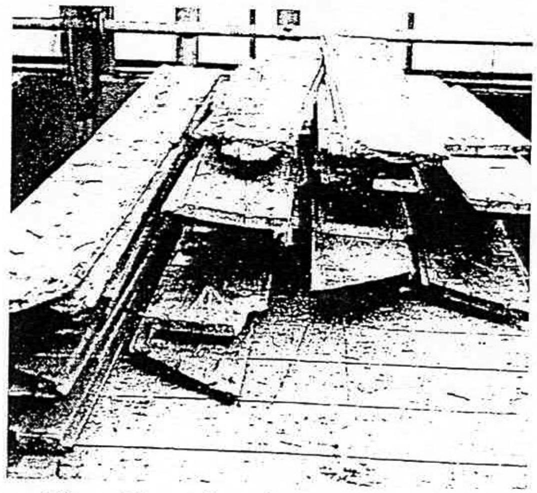

Figure 10. ~ *Naturally infested boards with measurable termite activity (>10 acoustical counts per min.) were used for each test.*

the test bed. All test boards were randomly selected and test positions randomly assigned among boards. In total, nine naturally infested boards with measurable termite activity (>10 acoustical counts/min.) were used for each test (Fig. 10).

## Drywood Termite Efficacy Studies

For drywood termite control efficacy studies, both artificially and naturally infested boards were treated with one of following treatments: fumigant (sulfuryl fluoride or methyl bromide containing 10% carbon dioxide), three different dosages (57.3 kg/m$^3$, 122.7 kg/m$^3$, 381.8 kg/m$^3$) of liquid nitrogen; heat; microwave; or electrocution (for descriptions of details for each management methods see (11)). Efficacy was highest (96% to 100%) for fumigants, heat, and liquid nitrogen (two highest dosages only); while intermediate and lowest efficacy values (44% to 95%) were for low dosage (57.3 kg/m$^3$) of liquid nitrogen, microwaves, and electrocution (11).

Additional studies conducted in the test bed included evaluation of detection devices, subterranean termite (*Reticulitermes* spp.) lab foraging study, and exterior surface soil spray for controlling Argentine ants (*Linepithema humile* (Mayr). For the detection study, an acoustic emission device was shown to be at least 80 percent effective in correctly identifying natural infested boards containing active drywood termite infestations (14). Based on a lab bioassay performed in the test bed, subterranean termites (*Reticulitermes* spp.) were not found to be attracted to treatments containing partially decayed wood (22). For the Argentine ant exterior spray study a new chemical active ingredient (Chlorfenapyr, BASF Corporation) was found to keep foraging ants from entering structures, including the test bed, for up to 8 weeks (23).

## Future Studies

A grant proposal to be submitted to a California state agency is being prepared that will investigate the use of infrared and x-ray for improving termite inspections. Additional research objectives include using acoustic emission devices to monitor drywood termite foraging and feeding activity to determine if these activities are seasonal in occurrence. Both studies will be conducted, in part, in the test bed.

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