AN INTRODUCTION TO:

WOOD DESTROYING INSECTS

Their Identification, Biology, Prevention, and Control

BY HARRY B. MOORE, Ph.D.
PROFESSOR EMERITUS OF ENTOMOLOGY
NORTH CAROLINA STATE UNIVERSITY
RALEIGH, NORTH CAROLINA

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ECONOMIC IMPORTANCE OF WOOD-DESTROYING INSECTS

Though the question has often been raised, it is virtually impossible to arrive at a precise figure concerning the economic loss caused by the attack of wood-destroying insects. Much of the damage is scattered and never reported. In some cases it is not recognized as insect damage, and in other cases the cost of repair related to insect damage, as separated from that caused by other factors, is not broken down in budget figures.

Questionnaires which gather information from homeowners in one geographic location cannot be used to generate information for the country as a whole. The problems vary in intensity and type from one area to another. The same holds true when figures concerning the structural pest control industry are gathered from state regulatory agencies. Very few states maintain extensive records, and those that do are not necessarily representative of those that do not. Nevertheless, there is a great need for factually-based economic impact data.

The statement often quoted is that it costs the public approximately $500 million per year for the prevention and control of subterranean termites alone (Ebeling, 1968) and for replacement of damage they cause. Subterranean termites are the cause of the great majority of the losses from insect attack on structural timbers and other wood or cellulose-containing components in buildings. In the years since, a number of authors have come up with a wide range of figures. Mauldin (1986), after reviewing their data, concluded that the EPA estimate of over 750 million dollars for annual termite damage in the United States during 1981 is probably the best estimate available. Current figures could be considerably greater because of inflation alone.

Regardless of the lack of factually-based loss figures, it is obvious to most of those associated with the construction and maintenance of housing that insects do play a significant role in the deterioration of wood components in almost all parts of the country. This may well increase in light of much tighter restrictions by the Environmental Protection Agency on the use of insecticides and wood preservatives.

THE PLACE OF INSECTS IN THE ANIMAL KINGDOM

Most people associated with the construction and maintenance of houses are not particularly interested in insects, though they are often concerned with the results of insect activities. They may want to know how the damage is accomplished, how it may be recognized, what its significance is, and what steps may be taken to prevent it or to stop its progress if it has already started.

In order to discuss all of these factors intelligently, it is necessary to understand which organisms are responsible and to know something of their characteristics, habits and life histories. Through such knowledge we can understand where the weak spots in their life cycles exist and how to best employ control procedures against insect pests.

All living creatures belong to either the

Animal or Plant Kingdoms. Insects belong to the former. The Animal Kingdom is divided into large groups called phyla, which are in turn subdivided into classes, one of which is the class Insecta. Insects, along with spiders, ticks, centipedes, crabs and many other similar classes of animals, all belong to the phylum Arthropoda. All of the arthropods have segmented bodies, jointed legs and a hard shell for a skeleton.

THE CHARACTERISTICS OF INSECTS

The insects form the largest class in the Animal Kingdom. More than three fourths of all kinds of animals known to science are insects. Almost a million kinds have already been named, and several thousand more are discovered and classified each year. Fortunately, only a small percentage of the many kinds are of any economic concern to man. An even smaller number are wood destroyers.

What distinguishes insects from other animals which are similar—the arthropods? In the adult insect (Fig. 0-1) there are three characteristics that will do this:

1: *The body is divided into three major divisions: head, thorax and abdomen.*

2: *Three pairs of legs and, in most cases, two pairs of wings are present on the thorax.*

3: *There is one pair of antenna (feelers) on the head.*

There are so many different kinds (species) of insects, it is necessary to divide them into groups with similar characteristics so they can be more easily described and discussed. As with all other animals, the class Insecta is divided into orders, the orders into families,

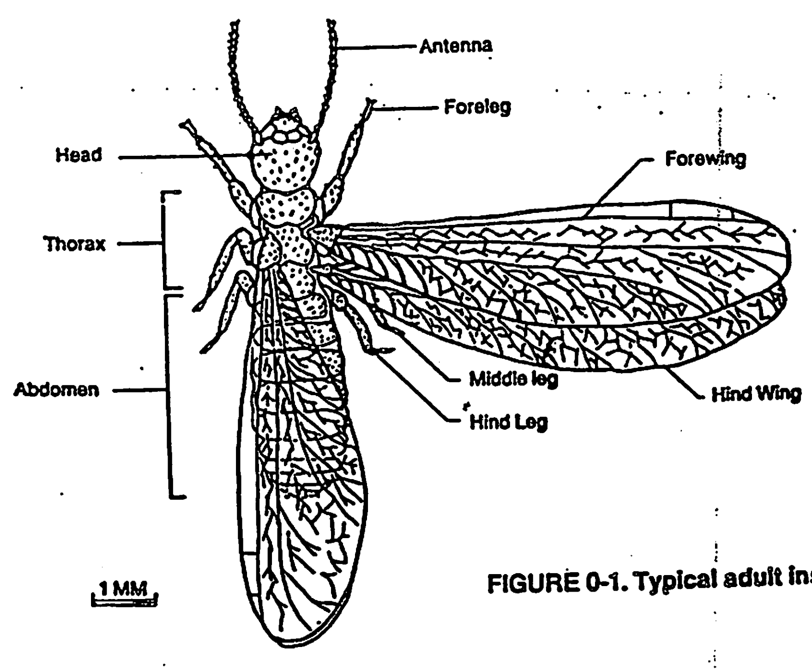

FIGURE 0-1. Typical adult insect.

the families into genera, and each genus into species. The details and principles of classification are beyond the scope of this manual, but the following example illustrates the point:

PHYLUM: Arthropoda (insects, mites, ticks, spiders, lobsters, etc.)

CLASS: Insecta (insects)

ORDER: Isoptera (termites)

FAMILY: Rhinotermitidae (subterranean termites)

GENUS: *Reticulitermes* (some subterranean termites)

SPECIES: *Reticulitermes flavipes* (the eastern subterranean termite)

Depending on the author, there are 30 or more orders of insects recognized. We are concerned with only three of them in this manual: the order Isoptera (termites), the order Hymenoptera (bees, ants and wasps), and the order Coleoptera (beetles). It will not be necessary to deal will all of the families or species of these orders. The order Coleoptera alone has more than 250,000 described species in the world and is represented in the United States by more than 100 families containing about 30,000 species. Of these, only a few families have representatives which damage or inhabit wood in buildings. The same is true for the other two orders.

THE GENERAL BIOLOGY AND DEVELOPMENT OF INSECTS

At different stages of their development, insects may look very different and may even have very different behavior. In order to understand why this is true, we must examine in a general way, the developmental biology of insects.

Most insects pass through a rather complete change in appearance after hatching from the egg. This change is called metamorphosis, and at least two types of metamorphosis are recognized.

1. Complete metamorphosis occurs when the insect passes through four stages in its development—egg, larva, pupa and adult (Fig. 0-2A). Members of the orders Coleoptera (beetles) and Hymenoptera (bees, ants and wasps) have this type of metamorphosis.

2. Incomplete metamorphosis (sometimes called gradual metamorphosis) occurs when the insect does not pass through all four stages, as, for example, the Isoptera (termites), which develop as egg, nymph and adult (Fig. 0-2B).[1]

The insect eggs considered in this manual are usually very tiny and not easily visible without magnification. They have many shapes and may be deposited singly or in groups by the female. They are placed in locations that enable the resulting larvae or nymphs to find food easily. In the case of termites, eggs are deposited within the workings of the termite colony. The beetles, bees and wasps with which we are concerned here place the eggs very carefully into or on the surface of wood. The ants, like the termites, place them inside the workings of the colony. The term "colony" will be discussed later.

The nymphs which hatch from the termite eggs look very much like the adults, except for being smaller and not having wings. Their color is much lighter than that of some adults. They increase in size very gradually through a series of molts (shedding of their external skeletons) and, as they become older and larger take on more characteristics of the adults. Thus, if they will become winged forms, they gradually develop on the surface of their bodies small wing buds, which become fully expanded wings when the adult stage is reached.

The larvae hatching from the eggs of beetles, bees, ants or wasps are referred to most frequently as grubs. Grubs look nothing like adults. Depending on the species involved, they may or may not have legs. They have no evidence of wings developing externally. They too increase gradually in size through a series of molts, but do not change in their other features. Finally, when the larval development is completed, they became pupae.

The pupal stage is one which is inactive as far as feeding is concerned, but otherwise is extremely active. Adult tissues are formed in

1. Some authors have described a more complex life cycle for termites, but this description will serve our purposes.

the pupal stage. The process is gradual, with the pupal form slowly disappearing and the adult form and color gradually becoming more pronounced as the pupal tissues are broken down and those of the adult established.

Once the adult forms appear, the amount of time that may elapse before they leave the wood and become active varies with the species. More details concerning activity will be included in the discussions of individual types of insects.

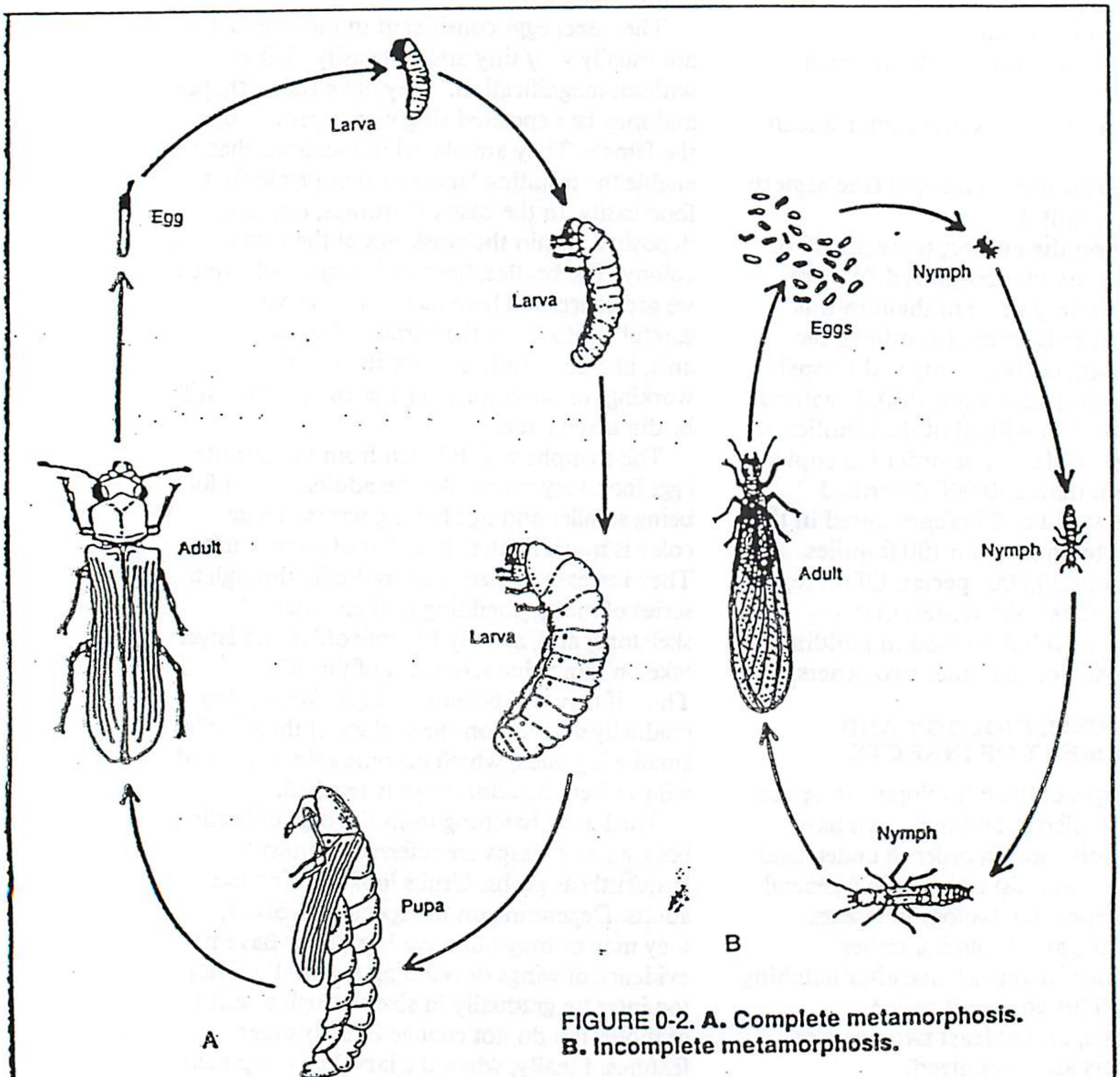

FIGURE 0-2. A. Complete metamorphosis. B. Incomplete metamorphosis.

DAMAGE TO WOOD BY INSECTS

Wood-boring insects may be grouped conveniently into those which damage: standing trees or newly felled logs; sawn timber and wood products during seasoning or storage; and wood in use. They may also be further grouped as to whether they attack hardwoods or softwoods or attack heartwood or sapwood. Certain insect species attack more than one of these groups.

The primary concern of this manual is the group of insects which attack seasoned wood in use. Attention will be given to some additional species which, though initiating attack in unseasoned wood, may survive and complete their development in wood which is air dry and in use. It is also necessary to be cognizant of some damage inflicted by insects in wood prior to its milling, seasoning and use.

Three things are necessary for insect attack—a source from which the infestation spreads, susceptible wood, and suitable conditions of temperature and humidity. Relatively little is known about some factors which make certain woods more attractive to insects than others, but insects are often quite selective. Fungal decay in wood often renders it more susceptible to infestation, but may also repel insects. Some insects can tolerate wide ranges of physical conditions; other cannot survive great fluctuations in temperature or humidity. Prevention of attack by insects is sometimes closely related to the proper handling of lumber during milling and storage.

Fungal decay and insect damage are sometimes confused. Both may be present in the same piece of wood. This manual will treat the damages inflicted by various types of insects in such a way that confusion between decay and insect damage should no longer be a problem.

Insect attack is generally characterized by tunnels or cavities (often containing wood powder or fecal pellets) within the wood. In many cases there are holes of various shapes and sizes on the surface. The wood powder (frass) may be pushed out through the holes, forming small piles beneath or on the surface of infested wood, indicating that adults have emerged recently or that live insects are working inside the wood. Sometimes, when attack is severe, the wood may be reduced to a hollow shell or to a powdery condition. In other cases, there may be very little external evidence of attack, and the interior condition of the wood can only be determined by probing with a sharp instrument or by striking or pounding the surface (sounding) to detect hollows by sound differences.

No part of the United States or U.S. territories is completely free from wood-destroying insects. The problem in Alaska is so small as not to warrant concern. The problems in tropical and semi-tropical areas are at the opposite end of the spectrum. The most important type of insect that attacks wood is the subterranean termite, found in all states except Alaska and in all U.S. territories. The subterranean termite causes the vast majority of the insect-caused damage to wood in use. There are various species of wood-inhabiting beetles, bees, ants and wasps that are general in their distribution, but the significance of their damage is well below that of subterranean termites. In tropical and in warmer and more humid temperate climates, drywood termites are a very significant problem; in some cases they cause over half of the recorded attacks on wood. Even where they are common, however, their damage is usually much less severe than that of subterranean termites.

Potential economic losses and the significance of the damage inflicted, as well as appropriate control measures, depend upon the type of pest involved. It is therefore essential to accurately identify the cause of the damage and to distinguish insect damage from other factors involved in the deterioration of wood. Failure to appreciate these points often results in needless waste of wood or in unnecessary treatments.

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CHAPTER 1

TERMITES: THEIR BIOLOGY AND IDENTIFICATION

INTRODUCTION

Termites, belonging to the order Isoptera, are small to medium-sized insects. They live in social groups (colonies) composed of individuals in different stages of development and of different forms and functional types (castes). Each colony is really a family, being composed entirely of descendents from one original pair of individuals. Both winged and wingless adult individuals occur in a colony. Some adults may have short wing buds. In winged adults, the four wings are very thin, have few veins, are transparent to translucent, and the front and hind pairs are equal in size and shape. The order name, Isoptera, means "equal wings," and refers to this common characteristic of termites. Termites have mouthparts developed for chewing. As indicated previously, they have a gradual, though somewhat complex, metamorphosis (change in form) during development.

Although termites are referred to as "white ants" in some parts of the world, they have only a superficial resemblance to ants, and are, in fact, much more closely related to cockroaches than any other type of insect. When winged termites and winged ants occur in similar places at similar times of the year, persons not thoroughly familiar with their differences sometimes confuse them. Winged termites can be distinguished from winged ants on the basis of several characteristics, some of which are illustrated in Fig. 1-1.

The termites with which we are concerned all feed on wood. Their role in nature is to act as scavengers and hasten the breakdown—and return to the soil as humus for plant growth—the tremendous amount of dead and fallen trees and other cellulose-containing material that is continuously accumulating in forests and elsewhere. Throughout much of the world, they are the insects most destructive to wood structures.

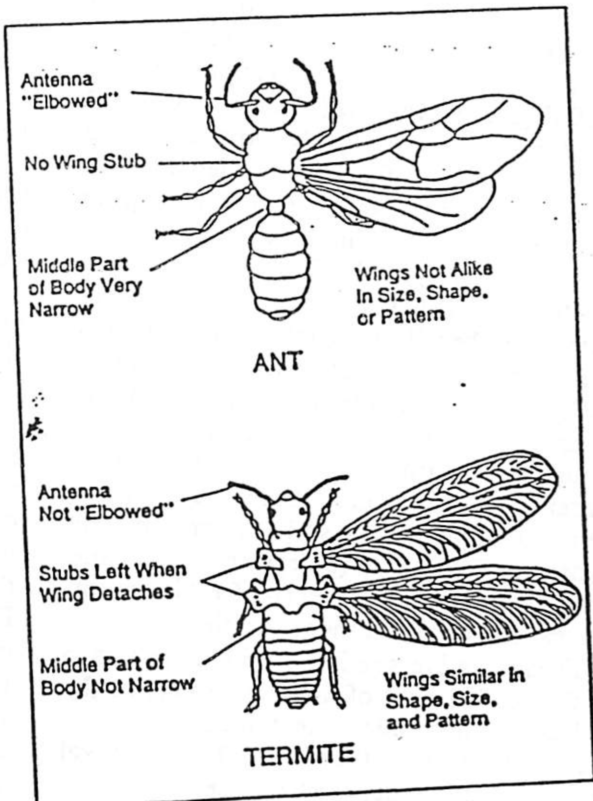

FIGURE 1-1. Winged termite and winged ant compared.

In the contiguous United States there are 43 species of termites, only 13 of which require significant attention as pests of structures. In Hawaii and the Pacific territories, there are two species of great economic significance, while in Puerto Rico one species does the vast majority of the damage in structures (personal communication, July 1975, Luis F. Martorell, Professor Emeritus, Entomology Department, University of Puerto Rico, Rio Piedras, Puerto Rico). In the U.S. Virgin Islands, there are two species of economic significance.

DISTRIBUTION

Termites occur in virtually every state of the United States except Alaska, and in all U.S. territories. They cause varying degrees of trouble, depending on the geographic location. The presence or abundance of termites in an area is controlled by their environmental requirements, such as temperature, humidity and soil moisture and type. Termites in general have extended their natural range to approximately the 50 degree Fahrenheit (10 degrees Celsius) annual mean isotherm north and south of the equator. Because of man-provided heat in structures, they may well extend their range to more northern areas. The situation in Wisconsin is probably typical of most areas where termites extended their range into colder climates. Esenther (1969) has pointed out that only "man-oriented" colonies have been found in Wisconsin, where the northern limit of the eastern subterranean termite coincides with an annual minimum isotherm of -22 degrees Fahrenheit (-30 degrees Celsius). They cease their activity above the soil at approximately 32 degrees Fahrenheit (0 degrees Celsius) and move downward 3 to 4 feet (1-1.5 m) in the soil to escape adverse weather conditions.

The most adverse effect of winter appears to be the confinement of the termites below the soil zone where adequate food supplies are found, which is near the surface. Their survival in cold climates depends on their ability to rebuild populations during the warm season (Esenther, 1969).

For convenience in describing prevention and control procedures, the destructive termites of this country and its territories have been grouped as the following types: dampwood, drywood, subterranean and tree-nesting. The characteristics of these types will be detailed later. Dampwood termites occur as pests in structures on the Pacific Coast, the desert Southwest and in southern Florida only. They are of relatively minor importance.

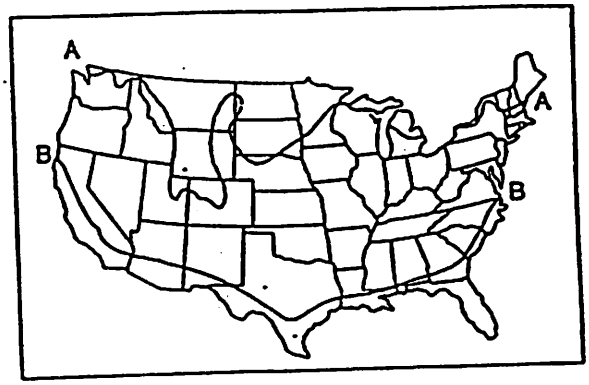

FIGURE 1-2: Subterranean termites are found in the areas below line A-A; drywood termites are found in the areas below line B-B.

The distribution of drywood and subterranean termites in the contiguous states is shown on the map in Fig. 1-2. Except in southern California and southern Florida, subterranean termites are the most common and destructive type where both types occur. Hawaii, the Pacific territories, Puerto Rico and the U.S. Virgin Islands also have both drywood and subterranean termites as problems. In Hawaii and the Pacific territories, subterranean termites are the most destructive type, with the exception of Midway Islands, where the drywood termites are equally important (letter dated 10 June 1976 from Thomas H. Lauret, Entomologist, Department of the Navy, Pacific Division, Naval Facilities Engineering Command, Makalapa, Hawaii). The subterranean termites are a relatively minor problem in Puerto Rico, but there is also occasional damage from tree-nesting termites (letter dated 18 May 1975 from Luis F. Martorell, Professor Emeritus, Department of Entomology, University of Puerto Rico, Rio Piedras, Puerto

Rico). Drywood termites are the major problem there. In the U.S. Virgin Islands, subterranean termites are slightly more important as pests than are drywoods. The Virgin Islands also have tree-nesting termites as very minor pests.

BIOLOGY AND HABITS OF TERMITES

CASTE SYSTEM

As mentioned earlier, termites exist in distinct forms called castes. There are three basic types of individuals: reproductives, soldiers and workers.

There are several kinds of reproductives. The most highly developed type is the primary reproductives, which are sometimes referred to as swarmers. They are typical insects, light tan to black in color, with four equal-sized wings, three pairs of legs, one pair of antennae, a pair of large eyes on the head, etc. (See Figs. 0-1 and 1-3A).

There are secondary (supplementary) reproductives (Fig. 1-3B) that are only slightly pigmented and have short wing buds. There is a third, rare type referred to as tertiary reproductives (Fig. 1-3C) which occur in some species. They are unpigmented and completely wingless. The primary reproductives (swarmers) are sexually mature males and females (kings and queens) that have the function of producing offspring to allow for growth and maintenance of a young colony population. The secondary reproductives are produced if the primary reproductives die, are cut off from a portion of the colony, or if the colony greatly increases in size. The secondary queens may produce even more eggs than the primary queens and thus cause a rapid population growth. The tertiary reproductives are also replacement forms and function to aid in maintaining colony strength.

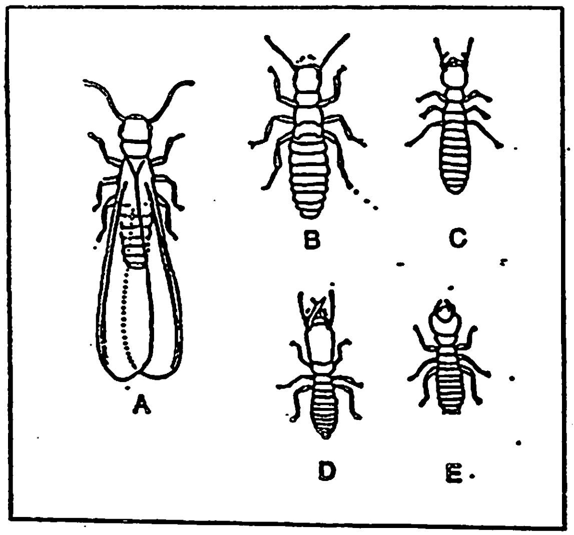

FIGURE 1-3: Primary (A) and supplementary (B&C) reproductives, soldiers (D), and worker (E) termites."

The soldiers are sterile (sexually immature) adult males and females. Most have enlarged heads, are only slightly pigmented except for the head, and have no wings. Most have very large jaws or mandibles (Fig. 1-3D). In some species there is another type of soldier called nasutes (Fig. 1-21), which have pear-shaped heads. Nasutes eject a sticky substance from the long tube located on the front of the head. The soldiers function to defend the colony from natural enemies, primarily ants. They block openings in the nest or workings of the colony with their heads. Those with large mandibles use them to destroy attackers. Those called nasutes entangle the foe with the sticky fluid which they exude.

Workers are sterile adults which are wingless and unpigmented (Fig. 1-3E). They make up the largest proportion of the colony's adult population. A true worker caste does not exist in most of the termite species of concern in this manual. Where there is no worker caste, the worker's function is taken over by nymphs or by pseudergates (false workers.) The pseudergates are size stable individuals functioning as workers but still capable of molting and becoming soldiers or reproductives. In most colonies, nymphs past the first two stages of growth function as workers. Workers, whether a true adult caste, pseudergates, or nymphs of soldiers and reproductives, have the responsibility for providing food for themselves, the reproductives, soldiers and very young nymphs. They also enlarge the workings (nest) of the colony and groom (clean) each other and the soldiers, reproductives, young nymphs and eggs. When the colony is under attack, they assist the soldiers in its defense.

All termites in a colony are similar genetically. Any one of them, at the time of egg-hatching, is capable of becoming a member of any caste in the colony. The mechanisms which regulate the direction of development for each individual are quite complicated and beyond the scope of this book. The interested reader is directed to the extensive coverage of caste formation by Dr. E. Morton Miller (1969) and Dr. Ch. Noirot (1969).

COLONY DEVELOPMENT

SWARMING

A mature colony of termites will produce large numbers of winged kings and queens (swarmers or alates) each year. The possible number which can be produced will vary with the species and with the age and condition of the colony. When environmental conditions are proper and the winged forms are at the correct stage of development, the workers make openings to the outside, and the winged reproductives leave rapidly. They are then referred to as swarmers, and the vicinity around the emergence point may be filled with them for brief periods. In a given location, thousands of swarmers may emerge from numerous colonies simultaneously. This allows intermixing of individuals from many populations. The triggering mechanisms for swarming are so precise that different species of termites occurring in the same area tend to have their own seasons during the year when they swarm. There is some overlap of swarming seasons among species. The more specific details concerning the swarming seasons will be presented with the discussions of the different types of termites.

These swarms or flights occur for the purpose of dispersing the species over a larger area and thus insuring its survival. Among some bees and ants, which also swarm, the flights involve mating as well, but this is not the case with termites.

Termites are relatively weak fliers. They flutter close to the ground in most cases, and the direction and distance of the flights are strongly influenced by wind. Those that fly at dusk or at night are attracted to lights. The wings of most termites break off very easily, and swarmers often tumble to the ground after only a very short flight. Large numbers of cast-off wings commonly are found in the vicinity of a termite swarming site. Air currents can lift termites to high altitudes, and they sometimes are carried aloft to the tops of tall buildings.

This period when termites are leaving the nests, flying and seeking a mate and a new nesting site is extremely dangerous for them. They are preyed upon heavily by many kinds of birds, lizards and other animals as well as by spiders and their insect enemies, particularly ants. They are subject to drying out and to heat and cold. Many are trapped on the surface of water. A very small percentage survive long enough to start new colonies.

INITIATION OF NEW COLONIES

After the flight, be it long or short, the wings are shed, breaking off at a line of weakness near the base. The individuals are then potential kings and queens of new colonies. In many cases, the female assumes a "calling" position with her abdomen elevated at a right angle to the rest of the body. She releases from the underside of her abdomen a chemical messenger substance (pheromone) which attracts nearby males. Once a male encounters a calling female, she moves off. He follows close behind. The pair search for a suitable site for the establishment of a nest.

Wood-dwelling species (drywood and some dampwood types) enter wood directly, usually taking advantage of natural openings such as bark crevices, knotholes, nail holes, joints, etc. Earth-dwelling species and those that nest in soil and wood, the subterranean and the tree-nesting species, usually enter the soil under or near a piece of wood on the surface of the soil. However, pairs encountering suitable openings in any surface, such as wood, may be reasonably expected to penetrate the available surface. Their ultimate survival will then depend primarily upon the subsequent conditions of moisture and temperature extremes (Weesner, 1965). As soon as the pair have located a suitable site, they excavate with their jaws (mandibles) a small chamber large enough for the two of them and seal the entrance. Mating usually occurs within a few hours to weeks after the pair becomes established.

The single female cannot start a new colony. Establishment of a colony is dependent upon the survival of both sexes until they have become established in the nest site and have mated. The pair continue to live together for life, and they usually mate periodically. If one of the pair is lost, it is replaced by a supplementary reproductive.

The first eggs are laid within a week to several weeks after mating, depending on the nutrition available to the female. When the first eggs hatch, the new nymphs are cared for by the young pair. After two molts, the nymphs assume their role as workers and begin to feed and care for the original pair.

COLONY GROWTH

The development of the colony is very slow for several years. Eggs are not deposited continuously. After the first group of eggs has been laid, there is a period of several months before another group is laid. This process continues for several years. As the young queen matures, she lays a greater number of eggs, and her abdomen becomes enlarged from developing eggs (see Fig. 1-4). Eventually, a point is reached where the colony size stabilizes. That is, the queen has reached maximum egg production, and the loss of older individuals by death, or by swarming, or both, is approximately the same as the number of new individuals produced each year. As the colony becomes even older, there is a tendency for a greater proportion of swarmers to be produced each year.

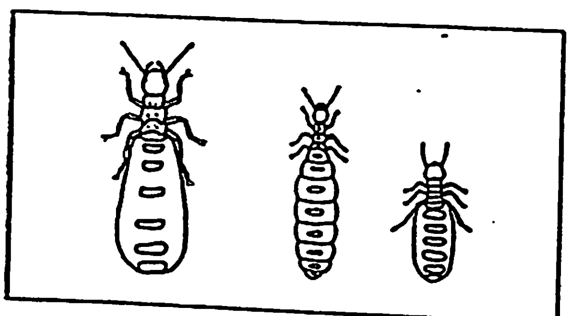

FIGURE 1-4. Primary and replacement queens enlarged from egg development.

The maximum population size reached by a termite colony will depend on several factors. Some species, particularly the drywood type, tend to have relatively small colonies, perhaps several thousand at most. Other types may reach populations of several hundred thousand. Among the dampwood and subterranean termites, if the primary reproductives are lost, they are replaced by a number of supplementary reproductives which have a high productivity of offspring. This results in extremely large populations.

COLONY SPLITTING

There are times, particularly among the subterranean termites, when groups of nymphs become relatively isolated from the main body of the colony because of the extent of the workings or because of some disturbance of the site. Sometimes they become isolated as a result of man's activities. When this happens, "subcolonies" may develop and exist independently or coalesce with the main body. This can happen because, among groups of nymphs (sometimes relatively small groups), there is the potential for certain individuals to develop into either soldiers or reproductives and thus create all of the castes of a normal colony.

EMERGENCE OF SWARMERS FROM A NEW COLONY

There is no clear indication as to how long it takes for most colonies to develop enough to start producing winged forms. Relatively small colonies of drywood termites produce swarmers, but subterraneans seem to require a much larger population for this to happen. Unless there is adequate food and conditions in the colony are favorable for its survival, no swarmers are produced. The older reproductive nymphs produced are consumed by the younger nymphs when colony conditions are not favorable. In most cases it requires a minimum of 3 to 4 years and as much as 8 to 10 years—for a colony of our native subterranean termites to become large enough and strong enough to start dispersal flights. When swarming occurs in a relatively new structure, it is because it was built over or near a strong colony that was not severely damaged during the construction process. Other species may not take so long, and some of the exceptions will be mentioned later.

COMMUNICATION IN THE COLONY

As might be expected in any social group, there is a need for termites to communicate with other individuals in their society. The most basic means of communication is through odor—chemical (pheromone) communication. In fact, each colony develops its own characteristic odor, and any intruder, be it a termite from another colony or a natural enemy, is instantly recognized as foreign when it enters the colony.

Termites respond to many kinds of stimuli which might affect the colony. One of the things that elicits immediate reaction is an air current, usually caused by a break in the surface of the termite workings. The source of the air current is actively sought and, when the source is determined, an alarm is given in the form of an odor (pheromone) trail laid down by the individual (usually a worker) which discovers the stimulus and moves away from it. This pheromone trail, in combination with tactile (touch) communication with other individuals encountered by bumping into them, serves to recruit additional colony members to the source of alarm. The recruited individuals add to the trail, thus intensifying the alarm.

The trail is eventually followed back to the source, and defense reactions occur. If intruders have entered the opening in the workings, the termites (both soldiers and workers) will attack by lunging forward and snapping with their mandibles. If they injure an intruder so that it can no longer move, the workers begin to deposit fecal matter to cover it or wall it off from the colony. Likewise, a hole to the exterior of the workings is immediately patched by this building reaction.

When a foraging termite worker finds a source of food, it recruits others to the source by the same trail-laying indicated above. The more foragers that find the food and return with it, the more intense the pheromone trail. If the source of food is depleted, the trail deteriorates in time and is abandoned.

Termite soldiers and workers of many species may be observed banging their heads rapidly on the surface of the workings when the colony is disturbed. The sound produced is sometimes audible to humans. The vibration of the surrounding surface is perceived by others in the colony, and they take up the banging reaction. This communication is through vibration of surfaces, not by airborne sound. Termites apparently cannot perceive sound waves transmitted in the air.

The antennae also are involved in communication. Their exact role is uncertain, but there must be physical contact through the antennae for some types of communication to occur. This antennal contact is involved in food exchange and grooming, which will be discussed later.

ENVIRONMENTAL REQUIREMENTS OF TERMITES

■ FOOD

All living organisms require nutrition. For the termites of concern here, nutrition usually is derived from wood and other cellulosic materials. In nature, they feed exclusively on wood, primarily digesting out the cellulose and passing most of the remaining components as waste. In man-invaded environments, termites attack many additional products and commodities. They still depend primarily on cellulose for their nutrition, but will damage many materials which they encounter but cannot digest. Damaged materials may include plastics, rubber, asphalt, metal, mortar and many others. Primarily, this damage occurs when the indigestible items are encountered during the foraging for food.

The more cellulose in a plant or plant product, the more attractive it is to termites. However, there are some tree species which produce heartwood that is repellent or even toxic to termites. These heartwoods usually will not be attacked until the repellents and/or toxins have been leached out by weathering.

Wood products like paper are favorite foods of termites because they are nearly pure cellulose, the other wood constituents having been removed in the manufacturing process. Also, cotton, burlap and other plant fibers are actively consumed by termites.

Strange as it may seem, the termites cannot themselves digest the cellulose which they consume. They are dependent upon large numbers of one-celled animals called protozoans that live in the termite's gut. These protozoans engulf the wood particles as they pass through the intestine and break down the cellulose into simpler compounds that the termites can absorb as food. This relationship is beneficial to both species, since the protozoans cause no harm and are provided with food and a protected environment by the termites.

The worker termites that consume the wood share their nourishment with other members of the colony. The very young nymphs, the soldiers and the reproductives also exchange food, particularly during grooming. This food is given up by the workers instinctively and not through charity. Dead or dying members of the colony also are consumed. At times, when soldiers, reproductive nymphs, and alates are too numerous for the good of the colony, they are killed and consumed by the workers.

Termites have the habit of grooming (cleaning) each other with their mouth parts. In the process of cleaning the surface of another individual's body, the worker picks up various secretions, fungus spores, wood particles and other attractive substances. Sometimes, if the grooming process is too vigorous, the thin integument (skin) of the individual being groomed is penetrated. The penetration triggers an immediate attack, and the unfortunate individual is consumed by the workers.

The exchange of food from the anus and the occasional consumption of other individuals in the colony is the means by which the cellulose-digesting protozoans are transferred from the older to the younger members of the colony.

Fungi also play a role in termite nutrition. Certain wood decay fungi are highly attractive to termites. Others are repellent or even toxic. In those cases where an attractive fungus has partially decayed wood, the wood is more easily digested by termites, and the fungus itself is said by some to provide a needed source of nitrogen in the termite diet. Ultimately, wood-destroying fungi exhaust the nutritive value of wood for termites, and extensive decay in wood is of no benefit to foraging termites. Conversely, when termites attack wood, they usually bring fungus spores on their bodies. When liquid water reaches the damaged wood, it is more easily trapped in the termite workings and evaporates more slowly than in simple surface wetting. This causes the fungal spores to germinate and fungus growth to continue for longer periods than it otherwise would.

■ MOISTURE

Moisture in specific amounts is vital to the survival of termites. In most instances, drywood termites can obtain enough water from the wood upon which they feed and from the very efficient use of water formed internally by the digestive process. They extract so much water from their fecal pellets that the pellets are dry and hard, like tiny seeds or grains of sand.

Dampwood species require more water than drywood termites and must live in wood that is constantly moist, usually in wood that is in contact with the soil. They too produce fecal pellets, though their pellets are not as dry as those of drywood termites.

Subterranean and tree-nesting species, primarily obtain their moisture from the soil. They maintain contact with the soil in order to survive unless there is a constant above-ground source of moisture. The type of soil has a very great effect on the ability of subterranean termites to flourish. Subterranean termites generally prefer rather sandy soil over a clay base. They can and do survive in many other types of soil.

■ PROTECTION

Termites have relatively little resistance to drying out. There are differences among the species, but all of them live in ways which protect them from desiccation. One of the ways is to live inside of wood or soil or both with little, if any, exposure to outside air. The termites tend to seal themselves into their workings by closing openings to the outside and by relying on finding sufficient moisture in their immediate environment.

They protect themselves from extremes of heat and cold by moving around inside the wood or soil in which they are nesting until they find the most suitable temperature. In cool climates, termites benefit from the heat energy provided by man in his structures, and they may remain active year around. In nature, they cease activity at low temperatures.

Since they are soft-bodied, termites are very susceptible to attack by their natural enemies if they venture outside of their closed workings. For this reason, they tend to wall off all possible access points for entry by ants and other enemies. When, for example, drywood termites make an opening in the surface of the wood in which they are feeding in order to discard fecal pellets, they reseal the hole with fecal pellets cemented together with body secretions. If they invade a second piece of wood in contact with one in which they have become established, they fill the gap between the two pieces with cemented fecal pellets. Dampwood termites tend to behave in a similar way, using soft fecal material and fecal pellets to seal all openings and gaps.

Subterranean termites often must forage far, sometimes above ground, from their initial workings to find food. They move underground through tunnels. Tree-nesting termites usually construct a nest well above ground on a tree or post. Whenever these termites leave the confines of the soil or the wood in which they are feeding, they construct shelter tubes in which to move from the soil to the wood or the above-ground nest.

When subterranean termites invade the wood of a structure that is separated from the soil by intervening concrete, masonry or other impervious material, they construct shelter tubes over the surface to the wood (Fig. 1-5). Periodically, they must return to the moist galleries in the soil

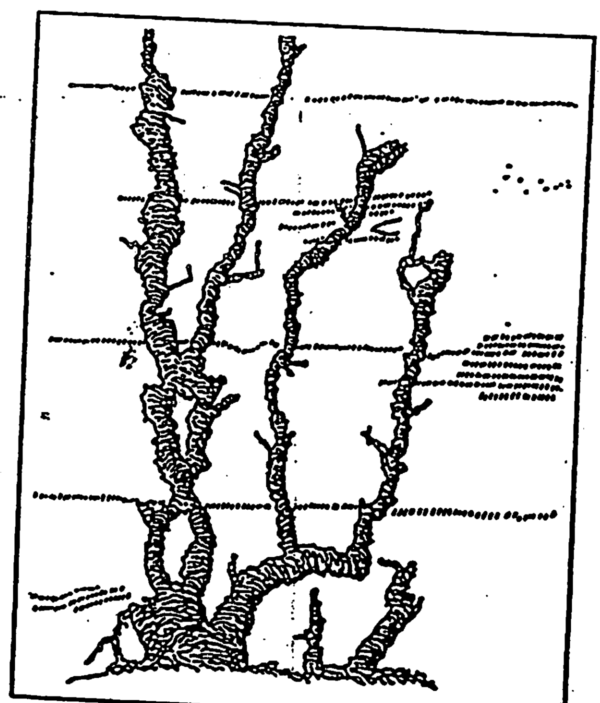

FIGURE 1-5. Termite shelter tubes on foundation wall.

to replenish the water lost from their bodies in the relatively dry air of their workings above ground. There are instances where there is an above-ground source of moisture from a plumbing or rain leak or from condensation on pipes, etc. This allows the termites to remain in the wood without ground contact.

Contrary to some published reports, the shelter tubes do not necessarily conduct moist air from the soil to the wood. Ebeling (1968) states that a humidity sensor, inserted into termite galleries in joists only 18 inches (45 cm) above ground and directly connected to the ground by shelter tubes, indicated a humidity that was identical with that of the air around the joists. The shelter tubes do provide some protection from air movement and, no doubt, do prevent some loss of moisture. The primary function of shelter tubes is probably protection of the termites from natural enemies. It is important to note here that in areas of low humidity there is a reduction in the construction of shelter tubes by subterranean termites, except in the case of desert species.

The tubes are constructed by worker termites from particles of soil or wood and bits of debris held together with fecal material just as mortar is used to hold together stones in a wall. The density of the shelter tube walls will vary with the ultimate use of the tube. When tubes are first constructed over impervious surfaces, they have walls that are so thin and loosely constructed as to be like a coarse filigree. If tubes are exploratory, they have branches and forks and usually rise only short distances on the surface. When a tube makes contact with wood above ground, it may become a working tube and is usually reinforced and the walls substantially thickened. Should large numbers of workers begin to feed in the wood, there may be numbers of tunnels constructed one on another to provide many routes for quick movement.

Once termites have established contact above ground and feeding progresses some distance from the initial shelter tunnel, they often will drop shelter tubes down from the wood toward the ground without support if they are in a protected area such as the crawl space under a house. Portions of these tubes break off numbers of times during construction before they are completed. A small pile of broken pieces usually will be found directly below a suspended tube. Those termites in the pieces which drop sometimes begin to build a tube up from the ground to meet the portion being built down from above. The upper portion of a tube is often lighter than the lower portion because it is constructed primarily of wood particles instead of soil.

Under certain conditions a fourth type of tube is constructed by subterranean termites. They are called swarming tubes, or swarming "castles" by some, because they are constructed as flight platforms for swarmers and they have many turret-like projections and flattened horizontal branches that vaguely resemble castle towers. They usually are constructed on the ground to a height 4 to 8 inches (10-20 cm), but sometimes are found projecting from heavily infested wood above ground. When swarmers are leaving the colony via these tubes or directly through a hole in wood or soil, the openings are heavily guarded by soldiers and workers.

SUBTERRANEAN TERMITES

MODE OF LIFE

The termites which usually have their workings associated to some degree with soil are referred to as subterranean termites. We have already discussed some of the habits and environmental requirements of this type. We need now to expand the discussion to include certain other characteristics that are distinctive about them and which will enable one to properly separate them from other types and make good decisions concerning their prevention and control.

DISTRIBUTION

As mentioned previously, subterranean termites are by far the most important insect pests of wood in buildings throughout the world. This is true for the United States and for most U.S. territories. Figure 1-6 shows the areas where subterranean termites are found and the relative hazard of infestation in the contiguous states. The high hazard designation would apply to the U.S. Virgin Islands, Puerto Rico, Hawaii, and the Pacific territories as well.

GENERAL CHARACTERISTICS

Most of the subterranean termites of economic significance in the contiguous states belong to the same genus *(Reticulitermes)* and are thus quite similar in appearance. The ones which occur in the U.S. Virgin Islands, Puerto Rico and in the southwestern desert areas of California and Arizona (genus *Heterotermes*) are similar enough to the *Reticulitermes* species that they may be recognized by the general descriptions of the insects, habits and damage which follow. Figures 1-3A, 1-3D and 1-3E have shown the characteristics of this group. The soldiers of all of the species are so similar as not to appear to be different unless examined by a specialist. The primary reproductives (swarmers or alates) vary in body color from coal black to pale yellow-brown. The wing colors do vary with species from nearly transparent pale gray to brownish or smoky gray when viewed against a white background. The wings have very few distinct veins in them except at the leading edge (Fig. 1-7A). There usually are two distinct longitudinal veins.

This characteristic will help separate subterranean swarmers from those of other types. The overall length of the swarmers varies from ⅓ to ½ inch (8-12 mm). The swarming season for most of the country is in the spring and early summer. In the desert Southwest and southern California, the swarms occur more commonly in the summer shortly after the first rains. Most of our native subterranean termite species swarm during daylight. The desert species swarm at night. It is not generally helpful to try to distinguish subterranean termites from other types on the basis of the time of year when they swarm. There is too much overlap between families and species for this to be valid in most areas.

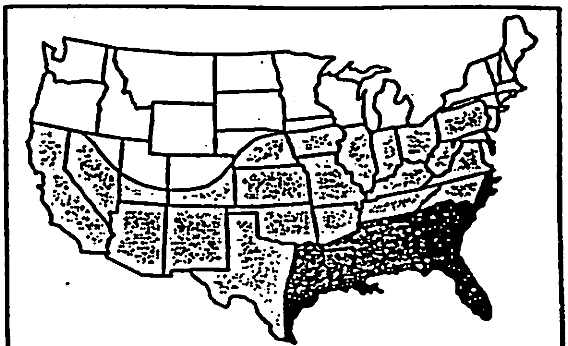

FIGURE 1-6. Geographic distribution of subterranean termite hazard regions. Modified from U.S.D.A.

A SPECIAL CASE

In Hawaii and the other Pacific islands particularly, and in a limited part of the contiguous states, there is another very distinct species that deserves particular attention. This is the Formosan subterranean termite. It has been spread from the Far East through shipboard infestations to all of the Pacific islands of concern in this manual and is the most destructive species of termite in Hawaii and Guam. It is also currently found in Alabama, Florida, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Texas. The species has

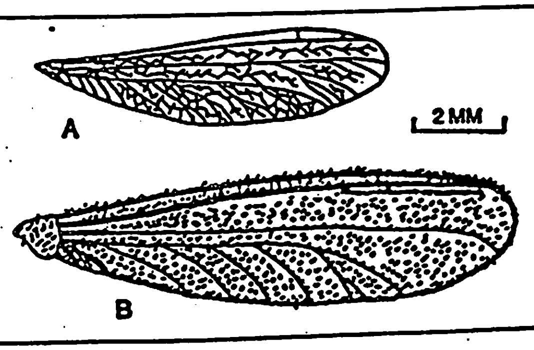

FIGURE 1-7. A. Reticulitermes wing. B. Coptotermes wing.

been reported in California. Beal (1967) believes that this species will eventually have the same distribution in latitude in the U.S. as it has in other areas of the world. This would not apply to arid regions. Particular watchfulness for this termite should be exerted along all Southern Coasts, the lower East and West Coasts, in the lower Mississippi Valley and in the Caribbean.

The Formosan subterranean termite is a much greater threat to structures than our native species. It is more vigorous and aggressive, as indicated by more rapid population development; more extensive tube and tunnel building; the rapidity with which new food sources are located and attacked; and the greater variety of materials attacked. According to laboratory tests by Su (1990), the Formosan species has a greater tolerance to the soil insecticides currently used to control subterranean termites than does one of our common native species.

The most obvious characteristics to distinguish Formosan subterranean termite swarmers from those of native species is by the larger size [up to 5/8 inch (15 mm) long] and the hairy wings (Fig. 1-7B). The Formosans also swarm between dusk and midnight rather than during midday. They are yellow-brown in color.

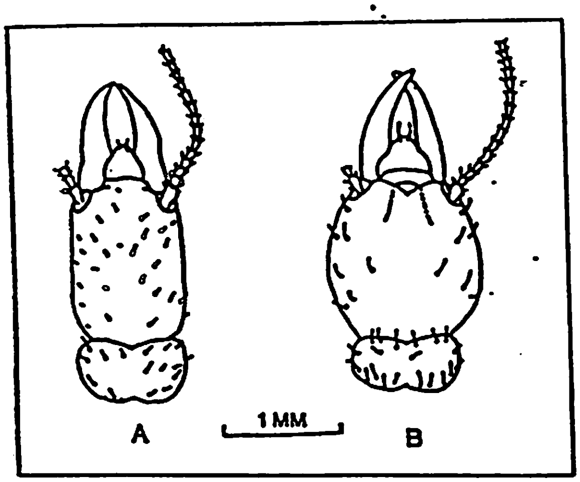

FIGURE 1-8. A. Head of native subterranean soldier. B. A Formosan subterranean soldier.

As shown in Fig. 1-8, the soldiers have oval-shaped heads with a conspicuously enlarged opening on the top as compared with the oblong and rectangular heads of the native soldiers. The Formosan soldiers also exude a whitish, sticky substance from the opening on the top of the head, a habit not shared by the native species. Also, soldiers are much more numerous in this species.

Formosans make nests of a rather hard material called carton, which resembles sponge. It is composed of chewed wood, soil, saliva and fecal material. The nests often are underground but sometimes fill cavities under fixtures or in walls of structures. The so-called nests of our native species are not so distinct, nor are they composed of material as durable as the carton.

■ SOURCES OF INFESTATION

When houses are built on land cleared of trees and brush, they are built in the midst of subterranean termite colonies in those geographic areas where the termites occur. With the constant search for food by the termite workers through underground tunnels, any cellulose source encountered will be attacked. On cleared land, the search may be desperate and the foraging constant.

The termites enter buildings through wood in direct contact with the soil, by building shelter tubes over or through foundation walls, piers, chimneys, etc., and by finding cracks or joints in concrete slab floors and building shelter tubes through them into wood above the crevices (Fig. 1-9). Any object making contact between the soil and the wood—trees, vines, weeds, plumbing, etc.— will serve as a support for shelter tubes.

It is also possible for termite swarmers to fly or be blown to a building site and then find a suitable spot to begin a colony. This, of course, would not usually create a damage problem for several years.

There is very little likelihood that subterranean termites will be incorporated into a structure through infested building materials. This may not be the case with other types, particularly drywood termites. When the infested wood is removed from contact with the moisture source that allowed the initial infestation to occur, the subterranean termites are not likely to survive long enough to re-establish soil contact after being placed in the structure.

■ SIGNS OF INFESTATION

The usual first sign of subterranean termite presence in a house, so far as the occupants are concerned, is the appearance of the swarmers. If the occupants are not present when the swarm occurs, they may find only large numbers of discarded termite wings, usually on a window sill. In the case of Formosan subterranean termites and our native southwestern species, the swarming occurs in the evening, and they are attracted to lights, thus increasing the likelihood of discovery.

The building inspector would only by pure chance encounter swarmers outside the termite workings. His most likely evidence would be the shelter tubes constructed by the termites over foundation walls, in crevices between structural members, on infested wood, etc.

Wood that is visibly damaged also might be encountered. Externally, except for the presence of shelter tubes or soil in cracks and crevices, the only evidence might be dark areas or blisterlike areas on flooring, trim or framing members. These areas are easily crushed with a knife or screwdriver. In cases of extreme damage, there might be evidence that a board has partially collapsed at bearing points or has cracked and sagged between points of support. Internal damage in wood can sometimes be detected by probing the surface with a sharp instrument or by pounding the surface with a hard object such as a hammer or the handle of a screwdriver to detect sound differences that indicate hollow spaces.

■ CHARACTERISTICS OF DAMAGED WOOD

When damaged wood is broken open, the characteristics are such that activity of subterranean termites can be diagnosed, even if they are not currently present.

The damage occurs first in the soft spring growth (early wood) of infested members (Fig. 1-10). They tend to feed in structural wood until only the harder grain and a thin outer shell remain. In more completely damaged areas there may be spongelike masses of pale colored carton in the larger galleries. There may be considerable quantities of soil mixed with chewed wood in some cavities. The amount of carton produced by Formosan subterranean termites is much greater than that in other, native species. Formosans also commonly place carton outside of the damaged wood in wall cavities, etc.

The most generally distinctive characteristic of subterranean termite-damaged wood is the appearance of the gallery walls and the inner surface of the shelter tubes, which have a pale, spotted appearance like dried oatmeal. This appearance is produced by the plastering of soft fecal material on surfaces. There are no fecal pellets in the galleries of subterranean termites.

An obvious sign of infestation is the presence of live termites when shelter tubes or damaged wood are broken open. At certain times of the year, swarmers may be found in galleries. Most of the time, however, only soldiers, nymphs (workers) and pseudergates are seen when probing occurs. On rare occasions,

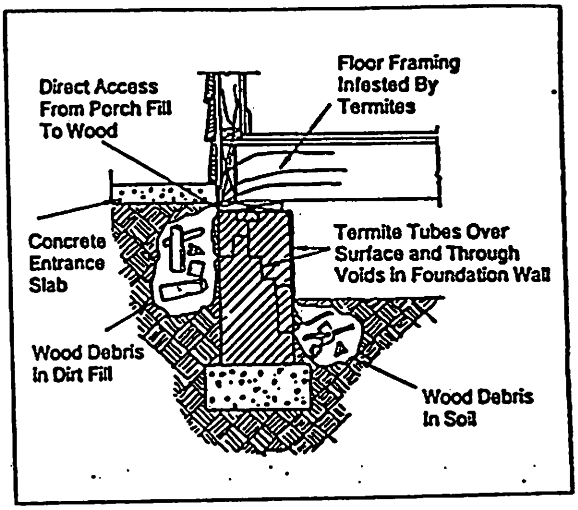

FIGURE 1-9. Cross-section of house showing points of termite entry.

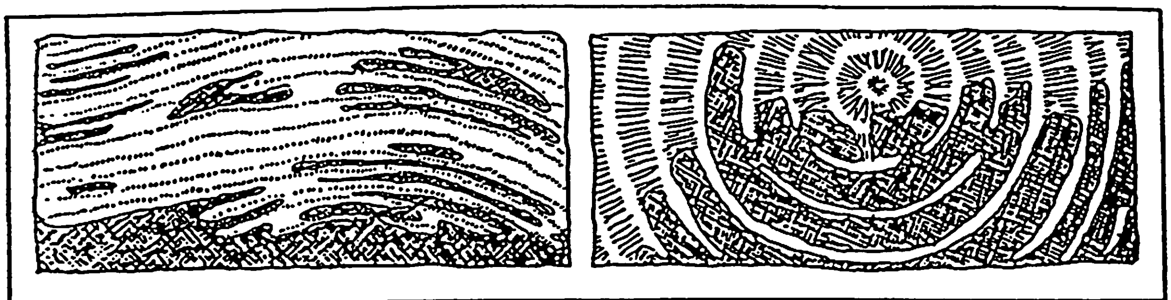

FIGURE 1-10. Cross-section of wood damaged by subterranean termites.

the functioning reproductives will be found in infested wood. The areas where they are active may have slightly larger galleries than other areas; otherwise there is no distinctive "nest." This is true in both soil and wood. To find primary reproductives in wood is extremely rare; replacement reproductives are more commonly found.

POTENTIAL FOR DESTRUCTION

The amount of damage that an infestation of subterranean termites might inflict on a structure depends on many factors. The number and size of the attacking colonies and the quality of the environmental conditions (including the wood) for the species involved are the most important considerations. These two factors are so interdependent that it is difficult to separate them. One of our native subterranean termites has an average colony size of 240,000 (Howard et al. 1982), while the Formosan subterranean termite colony will contain well over a million to several million individuals (Su and Scheffrahn 1988).

Some termite species, particularly the Formosan subterranean termite, are more aggressive as well as having large colonies, and will, given an equal amount of time, do more damage than other species. All other things being equal, if there is a good supply of soil moisture; if the humidity in the crawl space and subslab areas is high; and if the wood is in reasonably close proximity to the soil, subterranean termites may in time extend the damage to wood in a structure. Damage usually starts with the mudsill in houses built over a crawl space and with the sole plates of houses built on concrete slabs. Given enough time, subterraneans will extend the damage into the wooden floor members, the interior trim and furnishings, and into the walls to the roof timbers.

Except with Formosans, heavy damage by subterranean termites is not likely to occur within the first 8 or 10 years of a house's life. If treatment is undertaken when the first evidence of infestation occurs, very little serious structural damage is ever likely to occur. Houses should be carefully inspected at least once a year in all regions where subterranean termites occur. This will allow detection before damage is a problem.

Should evidence of termites be found, there is no cause for extreme alarm or undue haste. If Formosan subterranean termites are involved, control within a few months is recommended. If the problem is with native species, treatment within 6 months is recommended. The map in Figure 1-6, which shows the intensity of subterranean termite infestation, is a good gauge for determining the potential for damage in general. Long seasons of warm weather and plentiful supplies of water make conditions ideal for subterranean termite attack in the densely stippled areas. The same applies to all tropical areas outside the contiguous states.

DRYWOOD TERMITES

MODE OF LIFE

Drywood termites live entirely in wood that is moderately to extremely dry. They require no contact with the soil or with any other source of moisture.

SOURCES OF INFESTATION IN BUILDINGS

There are many ways in which drywood termites can start infestations in houses. The several species native to the Pacific Coast and the Southeast often live in dead limbs of trees, in utility poles, fence posts or firewood and fly as swarmers to nearby structures. They also can invade new houses from older buildings in nearby areas. In southern California and Arizona, southern Florida, the Pacific area and the Caribbean area, it is not uncommon for new houses to be infested by drywood termites within the first 5 years of their existence.

Ebeling (1975) says that, in southern California, homes in new residential tracts tend to become infested by drywood termites sooner and in greater numbers than by subterranean termites. In the Caribbean area, one species native to the West Indies may invade houses from outdoor infestations, but usually must rely on being transported to the site by man when infestation occurs in other areas, since their dispersal flights (swarms) rarely extend more than 100 yards.

Swarmers generally enter houses through attic vents or shingle roofs, but, particularly in hot, dry locations where there are crawl spaces, they often are found in the substructure where they have entered via foundation vents (Fig. 1-11). They also can enter exposed wood on the exterior or interior by finding cracks and crevices in or between boards or trim, particularly window sills and frames. They wedge themselves into the narrow space to get a purchase (mechanical aid) on the wood so they can more easily begin tunneling.

Drywood termite colonies usually consist of a few to ten thousand individuals at most, so they can occupy relatively small wooden articles. They readily establish colonies in furniture, dimension lumber, sash-and-door items, wood pulp or fiber insulation boards, plywood, paper, cloth and other products containing cellulose. They are easily introduced into buildings with such infested articles.

DISTRIBUTION

There are several native house-inhabiting species which occur in the contiguous states. One important species, the western drywood termite, is found in the West, particularly in the coastal counties from scattered Washington localities to southern California. The greatest concentration occurs in the southwestern coastal counties of California. This species extends into eastern and southern Utah. There is a species that occurs in the southeastern states,

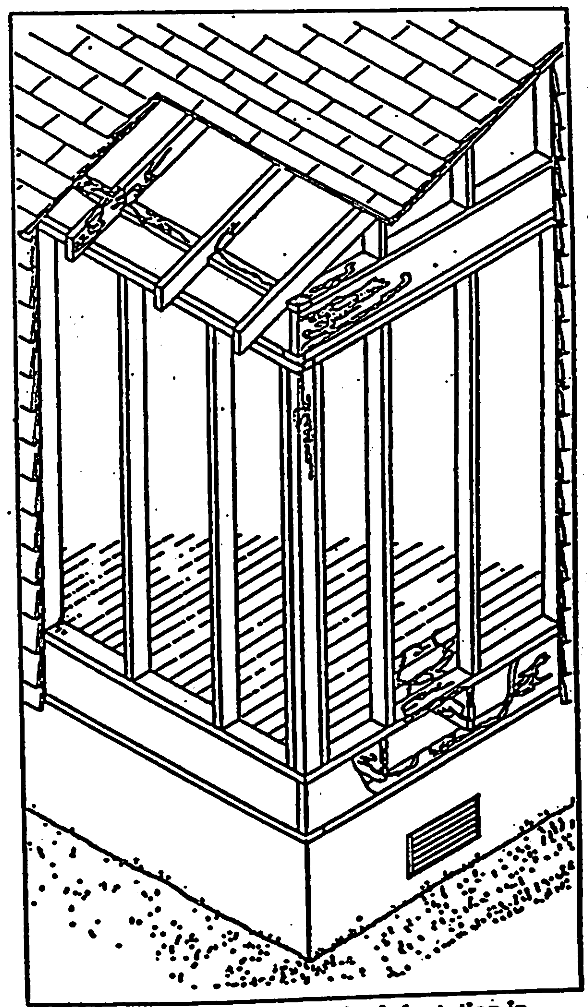

FIGURE 1-11. Drywood termite infestation in house attic and substructure.

particularly in southern Florida.

Minor economic populations are found in coastal areas from South Carolina to Texas. The really significant problems with these termites, other than those found in southern California and Arizona, exist primarily along the Gulf Coast, in Florida within 50 miles of the coast, and in the entire southern half of that state. Figure 1-2 shows the areas where drywood termites occur. Those infestations found along the Virginia and North Carolina coasts are very rarely of any economic significance.

There is one species, native to the West Indies, that is so widespread and so economically important that it requires special consideration. It has been called by several common names, such as powderpost termite, West Indian drywood termite, furniture termite etc. For the sake of convenience, this manual refers to this species as the powderpost termite. It has been introduced into tropical and semi-tropical areas around the world. The powderpost termite is the most important species of drywood termite in Puerto Rico, the U.S. Virgin Islands, the Pacific territories and in Hawaii. It has become well established in Florida and Louisiana on the mainland.

It is found in natural, outdoor infestations only in the Caribbean area. In addition, it, as well as the western species, has been transported in furniture and other wooden articles to many states scattered across the country. In some cases the powderpost termite has survived, multiplied and invaded the houses in which the infested articles are located. All such scattered infestations should be eradicated when discovered, even though powderpost termites are not likely to become established outside of the infested buildings.

All of this is to say that drywood termites are a constant source of damage to wood in houses in some specific areas. They can be found in small indoor infestations in almost any area of the country where they have been transported in infested articles.

GENERAL CHARACTERISTICS

All of the drywood termites belong to the same family (Kalotermitidae) and are quite similar in appearance. They are slightly larger than most subterranean termites and, in most cases, the swarmers are lighter in color. The most distinctive feature of the swarmers is the wing veins. There are several distinct longitudinal veins with many cross-veins in the front edge of the wing (Fig. 1-12). In this respect they resemble the Pacific Coast dampwood termites, but the drywood termites are much smaller.

You will recall that the subterranean termite wing basically has only two prominent longitudinal veins at the front edge (Fig. 1-7A). The wing colors vary from almost clear to rather smoky black. The swarmers are in most cases a light, yellow-brown color and swarm at night. The West Coast species and one Southeastern species are dark brown to black in color and swarm during the day. The swarmers vary in size from ½ to ⅝ inch (9-15 mm) in total length.

The fall is the primary swarming season on the West Coast. In the California and Arizona desert area, drywood termites swarm during the summer. In the Caribbean area, drywood swarmers appear primarily in the spring. In the Southeast, there are different species that swarm at any season except winter. In the Pacific area, there are swarms in spring and early summer and in late summer and early fall.

The soldiers of drywood termites (Fig. 1-13A) are generally typical of the large-headed, large-jawed type found in the subterraneans. The soldier of the powderpost termite is so distinctive, however, that it should be noted. It is the caste that most conspicuously distinguishes this species from all others. The head (Fig. 1-13B) is mostly black, almost as

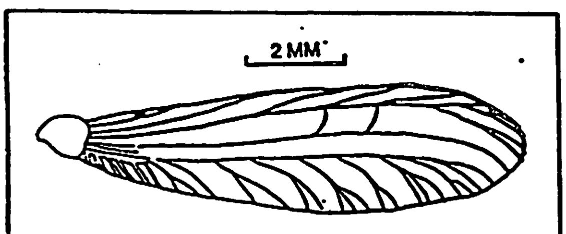

FIGURE 1-12. Drywood termite wing.

broad as long, is high, and is distinctly concave and rough in front. The mandibles (jaws) are not enlarged. The soldier in this species functions only to physically block openings in galleries and workings with its head.

SIGNS OF INFESTATION

The first evidence of drywood termite infestations is usually piles of fecal pellets. They vary in color from light gray to very dark brown, depending on the wood being consumed. The pellets are hard, elongate, less than 1/25 inch (1 mm) in length, with rounded ends and six flattened or concavely depressed sides. There are longitudinal ridges at the angles between the six surfaces (Fig. 1-14). The shape results from the pressure exerted on the fecal material in the rectum of the termite, where the water is extracted and conserved.

These pellets are eliminated from the galleries in the wood through round "kick holes 1/16 in (1.6 mm) or less in diameter." They tend to accumulate on surfaces or in spider webs located below the kick holes. The more concentrated the pile, the closer the source of pellets to the pile. If the pellets fall several feet, they are spread out and form very indistinct piles.

Swarming of the reproductives also indicates infestation. Discarded wings are more likely to be discovered by a building inspector than are the swarmers. Unless termites themselves are seen emerging or are congregated in one area, finding the wings might be misleading. This is because the swarmers, which emerge at night, are attracted to lights and could actually be from infestations outside the structure. As with other termites, the wings fall off very readily and tend to accumulate in the vicinity of swarmers.

Other than the pellets, there is very little external evidence of drywood termite attack in wood. The kick holes are closed with a secretion and pellets as soon as their use is completed. Probing with a sharp instrument or pounding the surface may reveal hidden damage, because drywood termites tend to work just under the surface of the wood, leaving a very thin veneer-like layer.

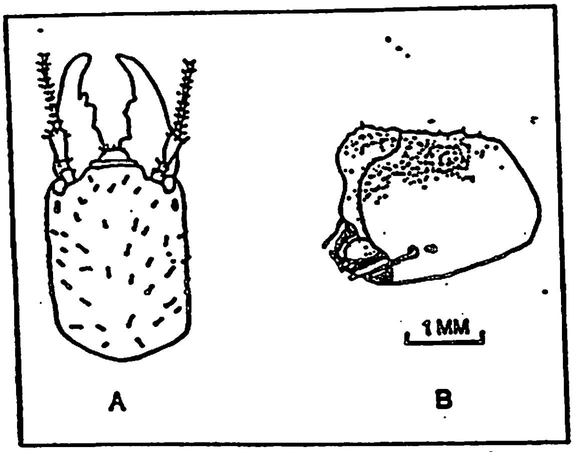

Figure 1-13. A. Heads of western drywood termite. B. Powderpost termite soldiers.

DAMAGE CHARACTERISTICS

The interior of wood damaged by drywood termites has broad pockets or chambers which are connected by tunnels that cut across the grain without regard for early wood and late wood (Fig. 1-15). The galleries are perfectly smooth and have no surface deposits such as those found in subterranean termite workings. There usually are some fecal pellets stored in unused portions of the galleries. These areas are often closed off by partitions made of fecal pellets stuck together with a secretion.

POTENTIAL FOR DESTRUCTION

Because the drywood termite's individual colonies are small, consisting of a few thousand individuals at most, damage to buildings per colony is less rapid and less severe than with subterranean termites. However, in-building swarming and reinfestation often causes proliferation of colonies and can result in extensive infestations over a period of time. Colonies

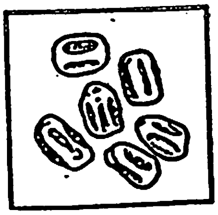
Figure 1-14. Drywood termite pellets.

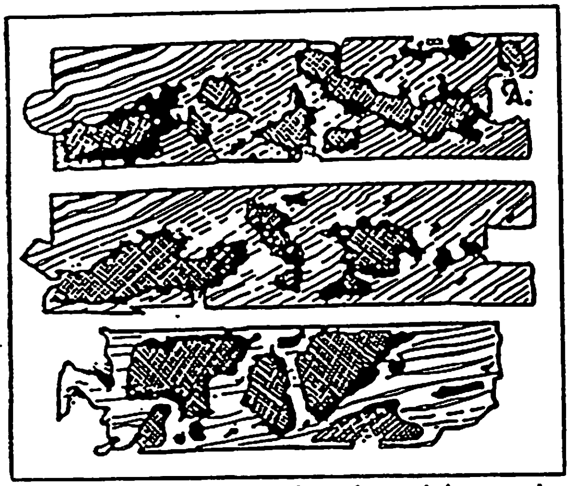

FIGURE 1-15. Cross-section of wood damaged by drywood termites. A. Point of entry.

established in one place may extend their galleries into adjacent boards, books or furniture. Adjacent colonies sometimes coalesce. Drywood termites have been found to attack all types of wood used in buildings and furnishings. Even so, it takes a very long time for drywood termites to cause serious weakness in structural timbers in houses. Damage to furniture, trim, hardwood floors, etc., can become significant in much less time.

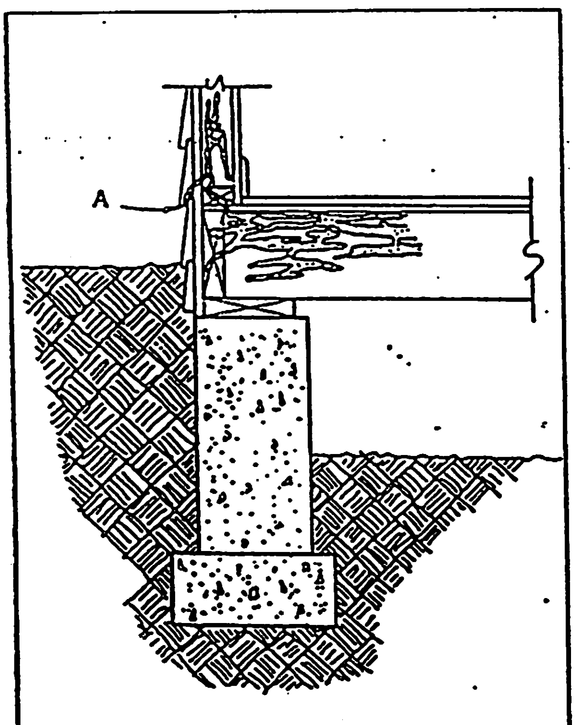

FIGURE 1-16. Dampwood termite invasion of a house. A. Point of entry.

DAMPWOOD TERMITES

■ MODE OF LIFE AND SOURCES OF INFESTATION IN BUILDINGS

The dampwoood termites form a distinct habitat group. They locate their colonies in damp, sometimes decaying wood. However, once they are established, some species can extend their activities into sound and even relatively dry wood if they maintain contact with damp wood. Representatives of several families of termites fall into this group, so their type cannot always be identified by the appearance of the insects themselves.

Dampwood termites generally do not require contact with damp ground but do require wood with a high moisture content. Beach houses are particularly susceptible because of the moist soil and high humidity. Infestation of buildings generally requires wood-to-earth contact, a condition contrary to modern construction standards. The paired reproductives usually enter the wood directly and establish colonies. Once a colony is established, its members can move rather long distances through wood, but they do not generally forage outside of wood (Fig. 1-16).

Although some species of dampwood termites have been transported long distances inside infested wood, it is not likely that this is a primary source of infestation in buildings. The infested wood would have to be incorporated into the structure in such a way that it remained in contact with a constant source of moisture. What more often happens is that the swarmers, which may be quite numerous in areas where they occur, establish new infestations in structures built in the proximity of natural and structural colonies.

■ DISTRIBUTION

The areas where dampwood termites occur most commonly and are of geatest economic importance are the Pacific Coast states and northern Nevada, Idaho and Montana west of the continental divide. They occur in the immediate coastal areas and in the higher elevations with good amounts of rainfall. They are particularly common in northern California and in western Oregon and Washington.

There are other species which occur in the semi-arid and desert regions of the Southwest and in the extreme southern tip of Florida and the Caribbean area.

■ GENERAL CHARACTERISTICS

Since there are several different families of termites represented in this category, it will be necessary to discuss each one separately.

The species which occur along the Pacific Coast west of the continental divide (family Hodotermitidae) are very distinctive and will not be confused with other types. They are the largest termites found anywhere in this country. The nymphs can be recognized by their size, even when no swarmers or soldiers are present. The larger ones are 9/16 to 3/4 inch (15-20mm) long. The swarmers are up to an inch (25mm) in length including the wings. The veins are prominent along the front edge of the wing. They also are more numerous than similar veins in the wings of subterranean termites. Figure 1-17A illustrates the size and venation of a typical wing of members of this family of termites. The swarmers vary in color from yellowish brown to dark brown, depending on the species. They fly at dusk during most months of the year, but tend to be most common in late summer and early fall. The soldiers are quite large, 9/16 to 3/4 inch (15-20 mm) long, and have very large, dark, rectanglar heads with large jaws (mandibles).

The dampwood termites of the dry southwestern areas are in the drywood termite family (Kalotermitidae), but they require much more moisture than other species in the family, though less than subterranean species. They are larger than most subterranean termite species, the swarmers being 1/2 inch (12 mm) in length, including wings. Figure 1-17B shows the wing of a desert dampwood termite. The swarmers are dark brown in color and are thought to fly in the late afternoon during the summer (Weesner, 1970). The reproductives penetrate soil to enter moist wood under or on the surface of the ground, and thereafter the colony remains entirely in the soil. The workers do not build shelter tubes from the soil to wood above the ground, greatly restricting the amount of structural damage they can inflict. The soldiers are generally typical of the large-headed, large-jawed types and would not be distinctive except to a specialist.

Since the dampwood termites of southern Florida and the Caribbean are members of the subterranean family Rhinotermitidae, they resemble the native subterranean species. They are somewhat larger than most subterraneans and have wings that are broader (Fig. 1-17C). They swarm during the winter months. Also, the soldiers have heads (Fig. 1-18) that are more

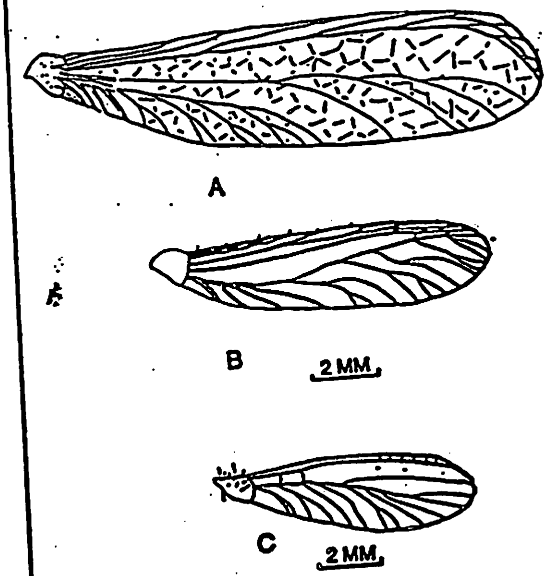

FIGURE 1-17. Wings of three families of dampwood termites. A. Hodotermitidae (West Coast). B. Kalotermitidae (Southwest). C. Rhinotermitidae (Florida and Caribbean).

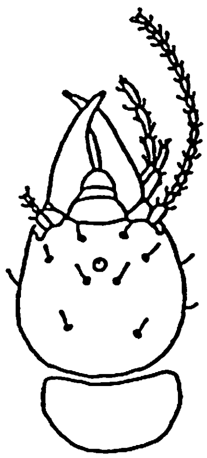

FIGURE 1-18. Head of Florida dampwood termite soldier.

rounded than those of native subterraneans. In fact, the soldiers could be confused with those of the Formosan subterranean termite (Fig. 1-8B), according to Miller (1967), though they lack the conspicuous enlarged opening on the top of the head.

SIGNS OF INFESTATION

The most obvious sign of infestation is, of course, swarmers. These are not likely to be encountered by building inspectors outside of infested wood, though the shed wings could be found in spider webs, etc. There is little external evidence of the presence of dampwood termites in wood. The most obvious places to look for evidence are places where wood is in contact with the ground or where there is obviously a plumbing or rain leak that provides a constant supply of moisture. Because of the close association of this type of termite with decaying wood, it is more reasonable to look for evidence of decay first and for these termites secondarily. Cracks and crevices in the infested wood might be sealed with fecal pellets and soft fecal materal, and, in drier wood, there might be an accumulation of fecal pellets under the infested wood.

DAMAGE CHARACTERISTICS AND POTENTIAL FOR DESTRUCTION

The appearance of wood damaged by dampwood termites on the West Coast will vary according to the amount of decay present in the wood. If the wood is comparatively sound, the tunnels or galleries will tend to follow the annual rings, the soft, early wood being eaten first, as is the case with the subterranean termites. If the wood has a considerable amount of decay, the galleries or tunnels will be much larger in diameter and will pass through both early wood and late wood. There is much variation in size and shape of galleries. Some are round in cross-section, some are oval, and some quite broad. The surfaces of the galleries have a velvety appearance, and they sometimes are covered with dried fecal material. Figure 1-19A shows typical feeding damage on a piece of wood.

FIGURE 1-19. A. Wood damaged by dampwood termites. B. Dampwood termite pellets.

Fecal pellets, about 1/25 inch (1 mm) long and colored according to the kind of wood being eaten, may be found throughout the workings. They are usually hard, elongate, rounded at both ends, and slightly hexagonal in cross-section from being compressed in the rectum before being voided (Fig. 1-19B). There are traces of six longitudinal ridges, but they are not so distinct as those of drywood termite pellets. If the wood is extremely damp, the pellets are often spherical or irregular and may stick to the sides of the galleries. In drier conditions, the pellets collect in the bottom of certain galleries, or the termites may throw them outside. They also use the pellets, stuck together with wet fecal material, to wall off unused portions of their workings and to seal cracks and crevices in the wood being consumed.

The desert dampwood and Florida dampwood termite damage is similar to subterranean damage, taking into account the high moisture content and decay in the wood. The desert dampwood termite produces distinctive black pellets that are shaped like bonbons.

There is not as great an economic hazard from the Pacific Coast dampwood termites as from drywood and subterranean termites, but they can cause considerable damage in structures, particularly since they are associated with fungal infection. If environmental conditions are proper, they can cause damage greater than that from subterranean termites in the same areas, because they have more of a tendency to work their way upward from the foundation to the roof (Ebeling, 1975).

The dampwood termites of the desert Southwest and southern Florida are very rarely of any economic importance in structures. Those of the Southwest only enter and attack wood below ground and thus have few points of entry in a reasonably constructed building. They are found mostly in older, crawl space homes. The Florida species occurs only in the coastal region of the southern tip of Florida and in some Caribbean islands. Since it only attacks decaying wood, it is of little economic concern. The decay would be of greater importance than the termites.

TREE-NESTING (ARBOREAL) TERMITES

■ MODE OF LIFE

Tree-nesting termites are characterized by their habit of building carton nests on trees. They also build their nests on posts, in or on buildings and, sometimes, on the ground. These above-ground nests are connected to the ground by broad shelter tubes on surfaces below the nest. During dry weather, these termites are said to abandon the nests and return to the soil. A single colony also may occupy more than one nest. The nests are quite distinctive in their appearance, being dark brown, globular in shape and covered with a fine, continuous outer shell which is thin and brittle. How arboreal colonies are founded is not known. Entire colonies have, however, been observed moving overland en masse with the primary reproductives in the middle of the process with large numbers of soldiers and workers (Araujo, 1970).

■ SOURCES OF INFESTATION IN BUILDINGS

The nests of these termites are rarely found in occupied buildings. This type of termite nest is common on trees near houses in the U.S. Virgin Islands and Puerto Rico. The termites invade buildings by extending their shelter tubes from the soil through foundation crevices and over surfaces to reach wood. In dark corners, storage areas and roof voids, they have been known on rare occasions to construct their carton nests indoors (Fig. 1-20). They more commonly invade abandoned buildings and rough wooden shelters. As indicated previously, it is not known how the colonies are orginally established.

■ DISTRIBUTION

Arboreal termites exist in many places in the tropics. So far as this manual is concerned, they are considered only in the U.S. Virgin Islands and Puerto Rico, where they sometimes invade buildings and cause some structural damage.

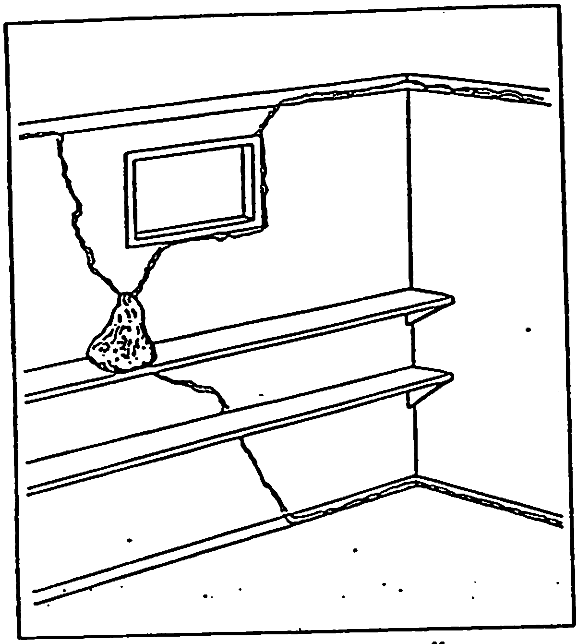

FIGURE 1-20. Carton nest on wall.

Several species occur in the Pacific islands and build typical tree nests, but they have not been reported to damage buildings. There has been one report of damage to construction timber while in storage.

GENERAL CHARACTERISTICS

All of the tree-nesting termites belong to the most highly advanced family, Termitidae. The damaging species all belong to the same genus, so they may be described as a group.

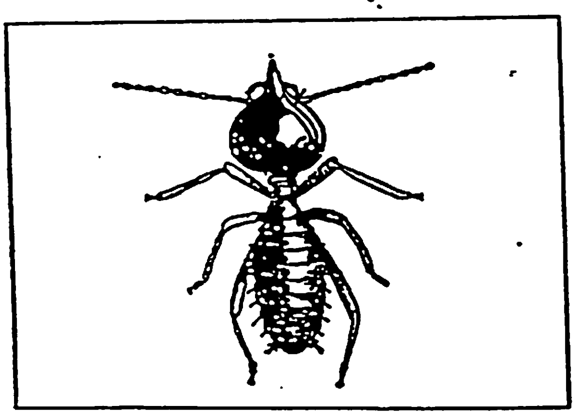

FIGURE 1-21. Soldier of tree-nesting termite.

The reproductives are a little larger than subterranean species and have wings that are opaque instead of nearly transparent. There are two prominent longitudinal veins at the front of the wings, with no cross veins as in subterraneans. The veins in the hind portion of the wings, however, are pigmented and conspicuous instead of unpigmented as most subterranean species. Their bodies are dark brown to black in color, with wings to match. They swarm during the day in the spring.

The soldiers are quite distinctive and will, along with the unique type of nest, adequately serve to identify this type of termite. Their heads are rounded and drawn out in front into a long snout with an opening at the end (Fig. 1-21). This type of soldier is called a nasute. Nasutes eject an iritating and sticky fluid from the snout as their means of defense of the colony. They have very small mandibles.

SIGNS OF INFESTATION AND DAMAGE CHARACTERISTICS

Most often, the signs of tree-nesting termite infestation will be very similar to those afforded by subterranean termites. Tree-nesting termites build shelter tubes of wood debris and fecal material which may be seen on surfaces and in crevices. The wood itself may be damaged very much like that attacked by subterranean termites. They more frequently tend to attack wood that has been damaged by other termites or by fungi, but they will damage sound timber. They appararently attack all types of wood. On rare occasions, there may be a nest constructed on a wall or in an attic space, but this would not be the usual means of discovery.

POTENTIAL FOR DESTRUCTION

There is very little recorded information on the economic losses in buildings caused by tree-nesting termites. In modern, inhabited structures, they are very rarely a problem. Where much concrete and metal is used in construction, they are apt to be found in wood trim, etc. L. F. Martorell (personal communication, July 1975, Department of Entomology, University of Puerto Rico, Rio Piedras, Puerto Rico) indicates that if these termites cause damage, it is most often in old, poorly constructed buildings.

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CHAPTER TWO

TERMITES: THEIR PREVENTION AND CONTROL

SUBTERRANEAN TERMITES

Much research on termite biology and habits and many years of experience in their control indicate that the most effective and economical time to provide for protection of houses against subterranean termites is during the planning and construction stages. That is not to say that existing houses cannot be adequately protected, but the cost of treatment often is several times more, and the results are sometimes less satisfactory.

As yet there is no foolproof method of construction or treatment against infestation by subterranean termites. There are, however, many measures that can be taken to decrease the likelihood of initial attack and to control existing infestations. Good design, conscientious construction procedures with supplemental use of chemically pressure-treated wood, and soil treatment can provide adequate protection at a reasonable cost.

Whatever methods are employed to prevent or control subterranean termites, one rather simple principle is involved: prevention of their simultaneous access to food and moisture (Rambo, 1980). This principle includes the following kinds of procedures: the elimination of food through proper design and construction (or modification of existing conditions) and through the application of sanitation at building sites; the control of moisture through adequate clearance, drainage and ventilation; the exposure of termite shelter tubes through the use of impenetrable barriers between the soil and the structural wood; and the use of chemicals for direct control, for creation of barriers by soil treatment, and for the preservative treatment of wood. These procedures are directly related to denying the environmental requirements (food, moisture and protection) of termites.

■ PREVENTION

Wherever subterranean termites occur, con-

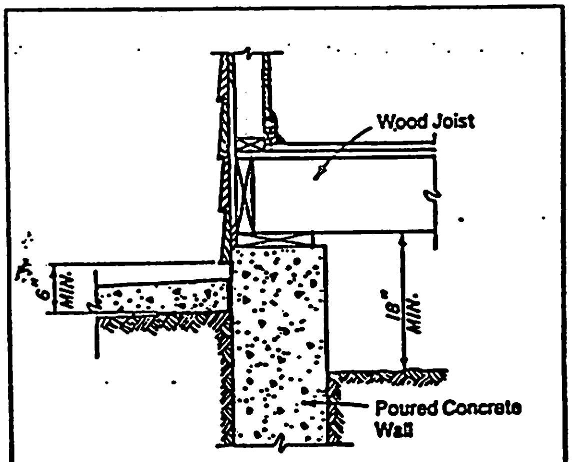


FIGURE 2-1. Poured concrete foundation walls or piers that are easily inspected offer complete protection against termite infestation. Proper clearance of eight inches (20 cm) should be provided between the dirt fills and the framing members; also, a clearance of six inches (15 cm) from the wood siding to the fills should be provided. Modified from USDA.

sideration should be given to the hazard which they represent. This hazard will vary with the geograpic location (Fig. 1-6), the type of construction being employed, and the building site itself.

In areas where subterranean termites represent only a moderate hazard on the average, the liability of attack is increased when houses are erected where woodland (the natural habitat of termites) formerly stood, or where old, infested buildings have been torn down. It is well to keep this in mind when determining the extent of preventive measures needed.

GOOD DESIGN

The first consideration, of course, comes in the design of the structure. It is important to be aware of the potential points of entry by termites (Fig. 1-9). No current type of construction in and of itself forms an adequate physical barrier to subterranean termite entry. There are degrees of resistance to their penetration, however.

WALL AND PIER (CRAWL SPACE) FOUNDATIONS

All foundations should be constructed as termite resistant as possible to prevent hidden attack on wood above them. This is one of the most important preventive measures to be considered. Foundations may be rated in order of relative resistance to penetration by subterranean termites as follows (Beal et al, 1989):

1 Poured concrete foundations (Fig. 2-1), properly reinforced, prevent large shrinkage or settlement cracks. (Cracks 1/32 inch [(0.8 mm)] or more in width will permit the passage of termites.)

2 Hollow-block or brick foundations and piers:

a. Capped with a minimum of four inches (10 cm) of reinforced poured concrete (Fig. 2-2).

b. Capped with precast solid concrete blocks, and joints completely filled with cement mortar or poured lean grout.

c. Top course of blocks and all joints completely filled with concrete. (Where hollow blocks are not filled, no protection is provided.)

3 Wooden piers, or posts used for foundations or piers, pressure-treated with an approved preservative by a standard pressure process.

Only types 1 and 2a have any significant protective value.

In considering any of these foundation types, keep in mind that for every departure from an uninterrupted, smooth and solid concrete foundation, one or more access points for termites are introduced. Openings for windows, doors and utility pipes are included.

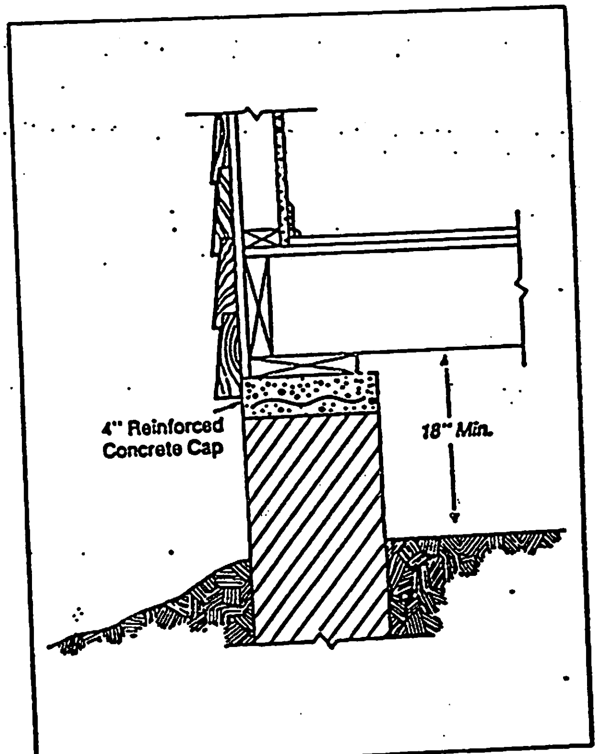


FIGURE 2-2. A reinforced poured-concrete cap on masonry walls or piers prevents hidden attack by termites. A minimum of four inches (10 cm) should be provided between the outside finished grade and the lower horizontal joint of the cap; also, a clearance of six inches (15 cm) from wood to the ground should be provided. Minimum clearance of 18 inches (46 cm) under the floor joists will allow inspection for the presence of termite tubes or for possible cracking of the cap. Adapted from USDA.

Brick veneers on the outside of any of the basic types add hidden entry potential.

CONCRETE SLAB-ON-GROUND FOUNDATIONS

For many years, concrete slab-on-ground construction was considered to be safe from termites. This is far from the case. On the contrary, it is one of the most susceptible types of construction. Termites enter through cracks and joints and around pipe openings. They build tubes over the edges of the slabs, especially when the slabs are built with little clearance above the outside grade.

There are three basic types of slab-on-ground construction. They vary in their sus-

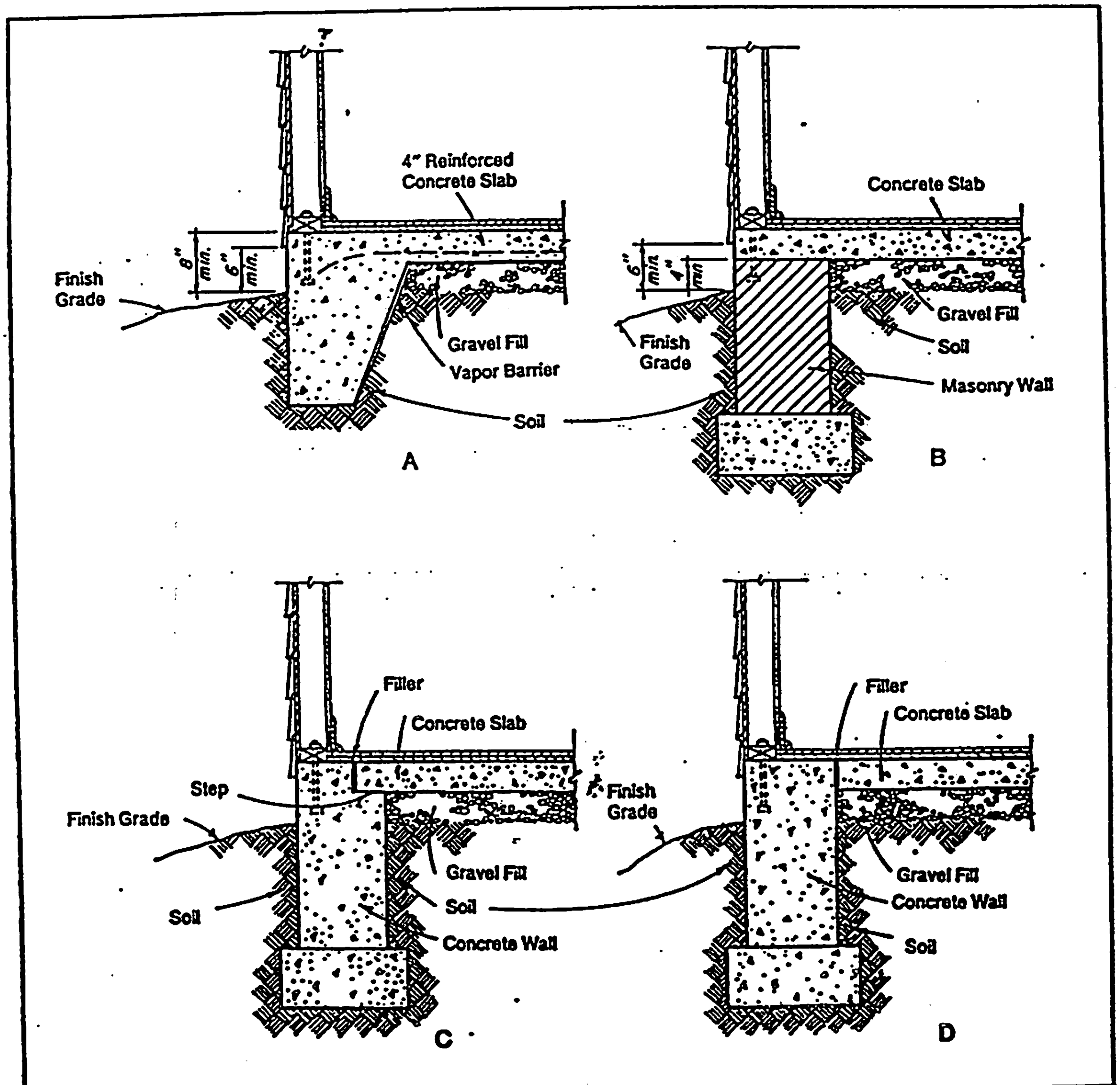


FIGURE 2-3. Slab on ground construction. A. Monolithic slab. B. Suspended slab. Floating slab type of construction in which the slab rests on the ledge of the foundation wall. C. Or is independent of it. D. The expansion joints in C. and D. are particularly vulnerable to termite entry. Courtesy USDA.

ceptibility to invasion by subterranean termites. The type most resistant to entry by termites is the monolithic slab (Fig. 2-3A). In this type, the floor and footing are poured as one continuous operation, so that there are few points which might allow hidden termite entry. Termites may, however find entry around plumbing and other utility pipes or through cracks which sometimes develop in spite of reinforcement.

The second type is the suspended slab that extends across the top of the foundation wall (Fig. 2-3B). This provides some protection from termite entry through voids or vertical cracks in the foundation, but there are other possible entry points, as in the monolithic slab, as well as over the edge of the slab on the outside. The third type is the floating slab. In this type, the slab may rest on a ledge of the foundation (Fig. 2-3C) or be independent of it (Fig. 2-3D). This is the most likely to be invaded by subterranean termites. The expansion joints where the slabs contact the foundations are often invaded. The joints should be sealed with roofing grade coal tar pitch, since this is the sealer most resistant to termite attack.

However, it is subject to penetration by termites and to pulling away from the concrete when there is sufficient temperature change. Soil beneath such joints should always be treated with insecticide. When perimeter insulation extends upward through joints such as these, it makes termite entry even easier. This subject will be discussed in greater detail later.

RAISED ATTACHMENTS OR APPURTENANCES OF CONCRETE OR MASONRY

Attachments and appurtenances to the main foundation require special consideration. It has been a common practice in the past for many structures such as concrete steps, porches, patios, breezeways, carports and terraces to be built over earth fills. This brings the level of soil into close proximity to the wooden members of the structure (Fig. 1-9).

Termite colonies in these fills appear to be the sources of over half the subterranean termite infestations of structures (Ebeling, 1975). These attachments and appurtenances should be constructed so as to be open for ventilation and inspection, or so as to expose the upper part of the concrete foundation or the cap of the masonry foundation. Attention to this structural detail alone would significantly reduce the access of most subterranean termites to buildings and save many millions of dollars in repair costs (Spear, 1970).

Ornamental attachments to buildings such as porte cocheres, trellises, buttresses, etc., should be constructed so as to rest on concrete or masonry foundations that extend at least six inches (15 cm) above exterior grade or any adjoining soil. This clearance prevents hidden access to the wood by termites in the soil. Exposure to outside weather conditions also discourages the construction of shelter tubes to reach these wood members. Planters attached to houses have been a particular problem. They should have a clear gap of at least two inches (5 cm) between the planter and the house structure. If they must be attached, they should be firmly anchored and constructed as an integral part of the foundation so as to provide no hidden access between the planter and the house. The soil level should not reach within 8 inches (20 cm) of the lowest wooden structural members of the house.

FOUNDATION INSULATION

The foregoing discussion has dealt with design features that might reduce risk of termite attack. There is one rather common practice in certain areas that provides termites with easy, hidden access to structures. This is the practice of using insulation composed of semi-rigid batts of expanded polystyrene or polyurethane against foundations. Such batts are designed to retain heat in buildings constructed with crawl spaces and particularly with slab floors containing perimeter heat ducts.

This insulation material has no food value for the termites, but it does provide them with needed shelter and is very easily penetrated by them (Sperling, 1967). The crevices between the insulation and the foundation against which it is laid also will provide a concealed access route for termites. If this insulation system is used, it is essential that soil treatment, to be discussed later, be specified.

SUB-SLAB OR INTRA-SLAB HEAT DUCTS

The perimeter heat ducts mentioned above also create problems in termite control, even when no insulation is involved. They are not recommended for use in any areas where subterranean termites occur. These heat ducts are incorporated into the slab or are placed just beneath the slab (Fig. 2-4A and B).

If termites make entry through cracks in the ducts or through openings around the heat registers, they are extremely difficult, if not impossible, to safely treat with soil insecticides, the only current method. If this type of heating system is specified, it is essential to also specify soil treatment, during construction, to be detailed later.

CLEARANCE BETWEEN WOOD AND SOIL

Clearance between wood and soil is an often-neglected aspect of construction that needs to be carefullly considered. The minimum clearance between outside finish grade and the top of a floor slab should be 8 inches (20 cm) with at least 6 inches (15 cm) exposed (Fig. 2-3A and B). This clearance provides a means of visual inspection for termite shelter tubes constructed on the outside of the wall.

Further, it exposes such shelter tubes to the drying effects of wind and sun and to the erosion resulting from splashed rain or irrigation water. In crawl spaces, the minimum clearance between the ground and the bottoms of floor joists should be 18 inches (45 cm); such clearance for beams and girders should be 12 inches (30 cm; Fig. 2-5). This provides physical separation of the soil containing the termites from the wood of the strucutre. It also allows adequate air movement for ventilation of the crawl space and room for crawling to make a visual inspection of all wood surfaces, piers, and foundation walls for evidence of termite shelter tubes or wood damage.

The exterior finished grade level of houses over crawl spaces should be equal to or below the level of soil underneath the structure

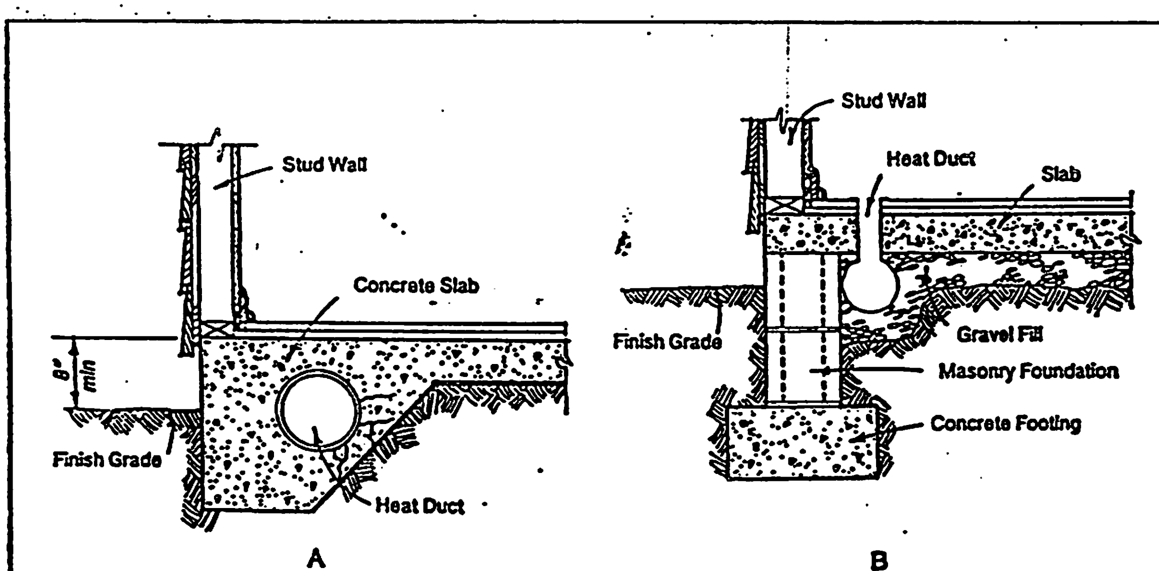


FIGURE 2-4. A. Heat duct imbedded in monolithic slab with cracks allowing termite entry. B. Heat duct under supported slab with joint around heat duct which allows termite entry. Adapted from Terminix and NPCA.

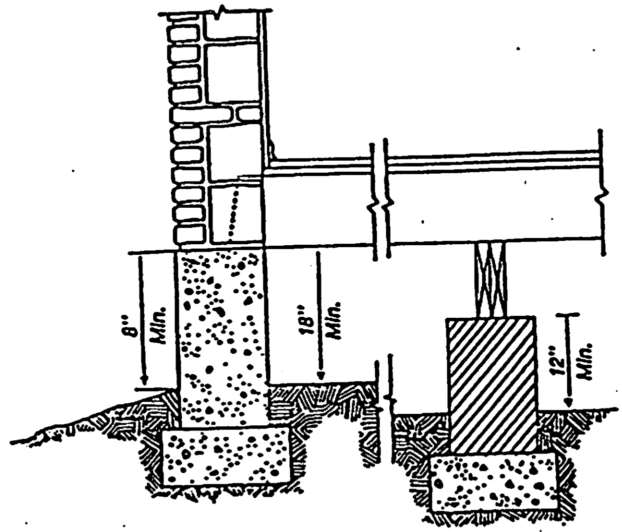


FIGURE 2-5. Where the superstructure of a building is masonry, provide for adequate clearance between the wood and ground both outside and inside the building. Adapted from USDA.

(Fig. 2-2) so that water drains away from the foundation and cannot leak through and become trapped. If this much clearance is not feasible, the outside grade line should be at least 6 inches (16 cm) below all outside woodwork.

The outside grade lines of houses with basements should also be at least 6 inches (15 cm) below all exterior woodwork. The walls should be water-proofed and provided with a drainage system to prevent leaks. This clearance for both types of construction permits inspection of the outer surface of the foundation and exposes any termite shelter tubes to the effects of weather. Where the superstructure is of brick or other masonry, the outside grade line should be equal to or below the level of soil underneath, or a minimum of 8 inches (20 cm) below the top of the foundation (Fig. 2-5) for the same reasons indicated previously.

If a masonry foundation is capped with 4 inches (10 cm) of reinforced concrete (Fig. 2-2) the minimum grade line should be at least 4 inches (10 cm) below the uppermost horizontal joint. This will force termites making hidden entry through foundation voids into the open, where they may be seen by an inspector before they reach the wood. An added advantage to all such clearance between wood and soil is that it reduces the danger of decay.

Concrete carport, garage, porch and entrance slab floors attached to houses should be sloped to drain water away from the foundation. If they span more than 3 feet 6 inches (1 m), they should be reinforced to prevent cracking. The level of soil under such slabs should be at least 8 inches (20 cm) below framing members and 6 inches (15 cm) below any wood siding (Fig. 2-1).

VENTILATION UNDER BUILDINGS

Proper ventilation under buildings with crawl spaces is important in reducing subterranean termite activity because of lowered humidity and more rapid drying of soil. The lower humidity discourages shelter tube construction, and drier soil forces termites deeper to locate moisture, with the added advantages of reducing risk of decay and beetle attack.

The ventilators should be large enough and so distributed as to prevent dead air pockets from forming. Corner areas are particularly susceptible to poor circulation, so ventilators should be within 10 feet (3 m) of all corners in order to get the best cross ventilation. Ventilator openings on the front side of houses are

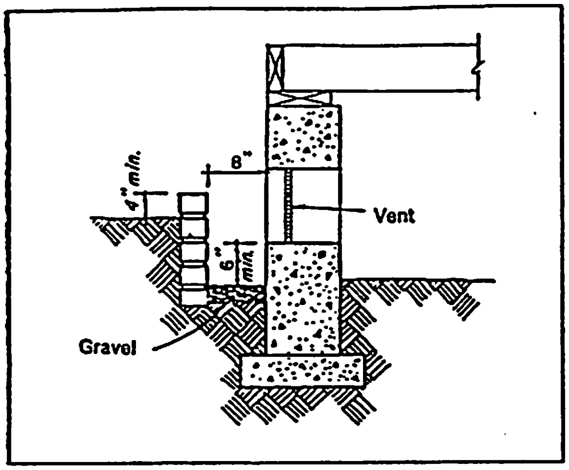


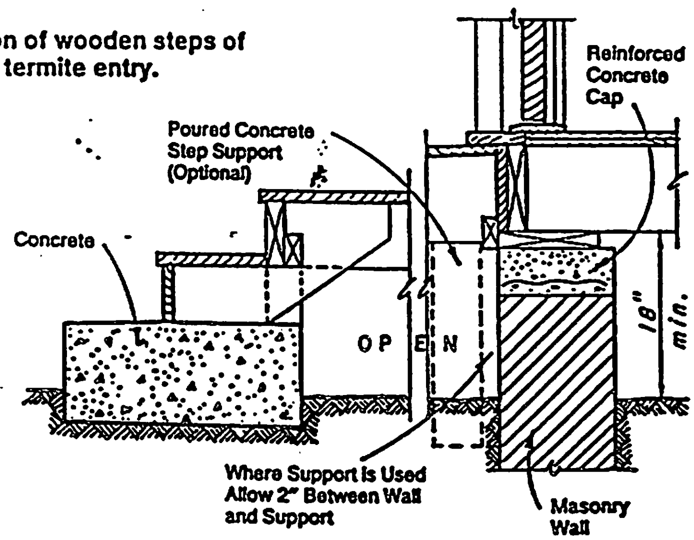
FIGURE 2-6. Ventilator well.

often avoided for aesthetic reasons. This will create no problems so long as those placed in other areas can be arranged to prevent dead air spaces. The size and number of openings needed depends to a certain extent on soil moisture, average humidity, air movement, and construction features. The general rule is to provide 1/150 of the ground area beneath the dwelling in net free area of ventilator opening. In order to function properly, the ventilators should be at least 3 inches (7.6 cm) above the outside grade and below the bottom of floor joists.

Since the usual outside dimensions of foundation ventilators are 8 inches x 16 inches (20 x 40 cm), the distance between the outside grade and the top of the foundation must be a minimum of 11 inches (28 cm) on any wall containing ventilators. Should it be impractical to provide this amount of clearance, wells may be constructed around ventilators to prevent water from entering the crawl space through them (Fig. 2-6). The wells should be deep enough to provide 6 inches (15 cm) of clearance below the bottom of the ventilator. The well should be constructed as far away from the wall as the height of the ventilator. The bottom of the well should be covered with loose gravel to provide drainage. Any ventilator more than one-half below grade will provide only about one-third as much ventilation as one above grade. Additional ventilators should be specified to compensate for this.

In areas of high humidity and high water tables, it is advisable to cover the ground under crawl space construction with a vapor barrier. A vapor barrier provides much better conditions for reducing termite activity than might be expected by reliance on ventilators alone.

FIGURE 2-7. Construction of wooden steps of porch to prevent hidden termite entry. Adapted from USDA.



When a vapor barrier is installed, the amount of net free ventilation opening required is reduced to 1/1500 of the area covered by the building. However, no fewer than four ventilators should be installed. These should be placed to allow the greatest possible cross ventilation.

When landscaping is specified, shubbery and other plantings should be placed far enough from ventilator openings to permit free circulation of air. They should be far enough away from foundation walls to permit later inspection of wall surfaces for the presence of termite shelter tubes.

The manner in which wood is used in construction can have much to do with its durability. When it is exposed to wetting from rain, etc., on the exterior of the building, it is also placed in jeopardy of fungal attack.

EXTERIOR WOODWORK

Wooden porches and steps create points of special concern. Porch supports, such as piers, adjacent to a house should be separated from the foundation proper by a clear gap of 2 inches (5 cm) to prevent hidden access by termites. Where wooden steps are used they should not rest directly on the ground. The carriages should rest on a concrete base that extends at least 6 inches (15 cm) above grade (Fig. 2-7).

In construction where pier foundations are used, it is often desirable to close the spaces between the piers with wood lattice or skirting. Whenever this is done, the woodwork should be separated from the piers and the soil by a clear gap of at least 2 inches (5 cm) to eliminate easy or hidden access for termites.

It has been a common practice in the past for exterior door frames and jambs to be placed before concrete floors of garages, basements, etc., have been poured. Very often the frame or jamb is partially imbedded in the concrete or even extends through it to the soil, making a perfect hidden entry point for termites. When this procedure is followed on the outside, the pockets formed around the wood collect water and make ideal conditions for termites and fungus. Avoid this mistake in designing, or in choosing a design for a house.

Whenever window frames or other openings near or below outside grade are made of wood, particular attention should be paid to making the foundation wall surrounding the wood as impervious to termites as possible. The methods described in the discussion of the resistance of foundation walls in general apply here. Also, the level of the bottom of the window well

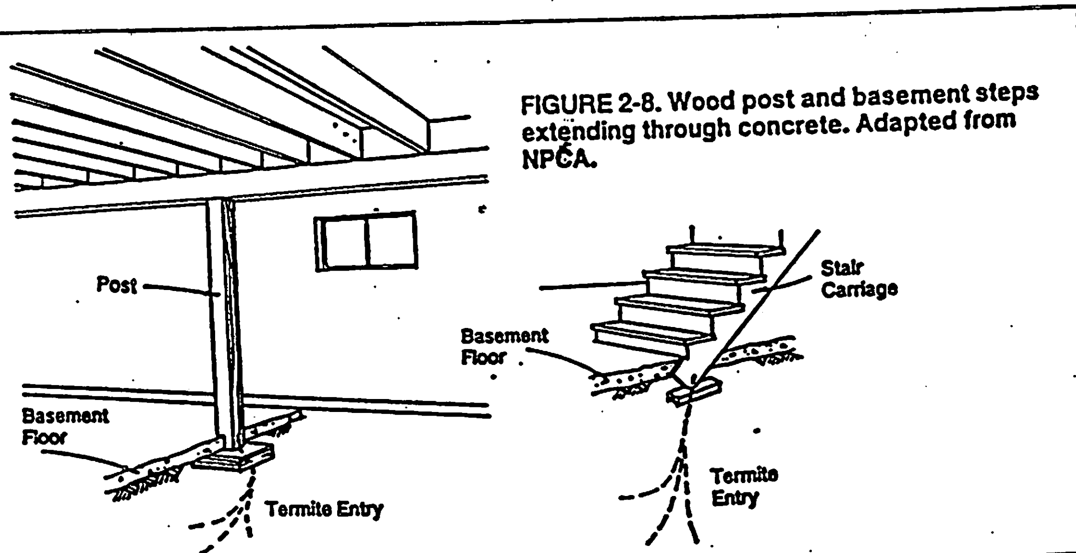


FIGURE 2-8. Wood post and basement steps extending through concrete. Adapted from NPCA.

should be at least 6 inches (15 cm) below the nearest wood.

WOOD USED IN BASEMENTS

Wooden support posts, stair carriages, or partition walls used in a basement should be put into place after the slab floor is poured. If they extend into or through the concrete, they are subject to hidden attack by termites (Fig. 2-8). Under no circumstances should untreated wooden screeds be imbedded for nailing partition wall plates to the floor.

Finished basement rooms present special problems if precautions are not taken. Infestations of termites in such areas are difficult to detect and to control. Any wood used below grade that is not pressure-treated, particularly that in contact with masonry or concrete walls or floors, is subject to attack by termites. Add to that the fact that the wood in such areas is in danger of decay as well.

These factors indicate the necessity for chemically treating the soil beneath the floor and along the outside of the foundation wall during construction. Soil treatment will be discussed later under chemical controls. In addition, any wood in contact with masonry or concrete below grade should be chemically impregnated with a standard wood preservative, the details of which will be discussed later. You will recall that all wooden framing members should be at least 8 inches (20 cm) above the outside grade.

UTILITY CONDUITS AND STEEL SUPPORT COLUMNS

Plumbing and other utility conduits in crawl spaces need to be installed carefully to prevent the creation of conditions conducive to termite invasion. All such conduits should be suspended clear of the ground in crawl spaces. Preferably, this would be from girders and joists to provide maximum clearance above ground.

Under no circumstances should wooden blocks or stakes be used to support such conduits. Termites will feed on the wood and follow it up to the conduits and then build shelter tubes over the conduits to wooden members above. Mention will be made later concerning the chemical treatment of soil around plumbing that extends from soil to wood.

Where pipes or steel support columns extend through concrete floors or foundation walls, the space around them should be carefully sealed with dense cement mortar to discourage the entry of termites through such crevices. Chemical treatment of the soil beneath such spaces is also important.

GOOD CONSTRUCTION PRACTICES

The value of good design of buildings can be completely voided by improper construction practices. If good design specifications are not followed, they might as well not exist. There are many construction practices that tend to increase the liability of subterranean termite invasion of structures.

Some of them have been so common that it will take great effort to break old habits. Any real progress can be made only when those carrying out and supervising the construction really understand the important role they play in termite prevention. Since termite attack does not usually occur in the first several years of a building's existence, the finger of guilt is hard to point.

Only by understanding the special needs and having a professional concern for the long-term quality of the construction can this phase of termite prevention ever be accomplished. Instruction, motivation, and supervision of construction workers to avoid these flaws can be a very important factor in the prevention of attack by subterranean termites (Spear, 1970).

The first step in the construction of any building is the preparation of the site. The battle against termites also begins here. Subterranean termites live in the naturally occurring cellulosic material in or on the soil. In site preparation, it is necessary to remove as much of this natural food as possible.

All tree stumps, logs, large roots, and accumulations of surface vegetation should be completely removed from the site to be occupied by the building. If the soil has been previously occupied by a structure, such as in urban renewal areas, any wood debris which remains should be removed. Under no circumstances should any wood-containing debris be buried on or near the site. Initially, this clearing of debris may increase the pressure from termites seeking new food sources, but if proper barriers have been incorporated in the building, it will eventually reduce the termite population seeking entry.

Most soil is favorable to the development of subterranean termites. It has already been stated that good ventilation beneath a structure is important in removing water vapor given off by the soil and thus speeding the drying process. Poor site drainage that allows water to accumulate underneath or adjacent to a house can completely void any benefit derived from good ventilation.

The same principle holds when the fill under slab construction stays wet because of poor drainage. The soil surface at the site should be sloped so that water will drain quickly away from the building. This remains equally important when there is a vapor barrier on the soil of a crawl space. Poor provision for surface water removal is a very common construction fault.

When eave gutters and downspouts are installed, ensure their proper function. Connect the downspouts to drain pipes that take the roof water to a storm sewer or open drainage well away from the house. The benefit of downspouts is voided when they concentrate or pond water next to foundations. When surface drainage is poor because of flat terrain, or where there is a basement, the use of drainage tile around the foundation is beneficial.

As construction proceeds, no wood or paper products or scrap lumber should be incorporated into the earth fill. Such materials are food for termites and might even provide channels through chemical bariers, which will be discussed later. The incorporation of stones or chunks of mortar or concrete larger than 4 inches (10 cm) in diameter in backfill around foundations will adversely affect the ability to apply soil chemicals after the grade is established. This will be clarified when the process is later discussed.

It has been emphasized previously that concrete and masonry construction is particularly susceptible to termite attack. This susceptbility is often increased because of flaws left by incomplete compaction of concrete or mortar when it is installed, by inadequate or faulty installation of reinforcing materials, or by careless bonding of masonry units where it will not show. When wooden forms and grade stakes are left in place after concrete is poured, they provide easy penetration for termites (Fig. 2-9). This is one of the most common construction errors.

When construction is complete, there should be no wood scraps left in a crawl space. The "rule of thumb" is that every piece of wood that can be picked up between the tines of a common garden rake should be removed.

Poor attention to the requirements for clearance between wood and soil, particularly on the outside, is another common error. A lack of appreciation of its importance is no doubt the primary reason for this. There is no additional cost involved if the foundation has been properly designed to allow for the clearance.

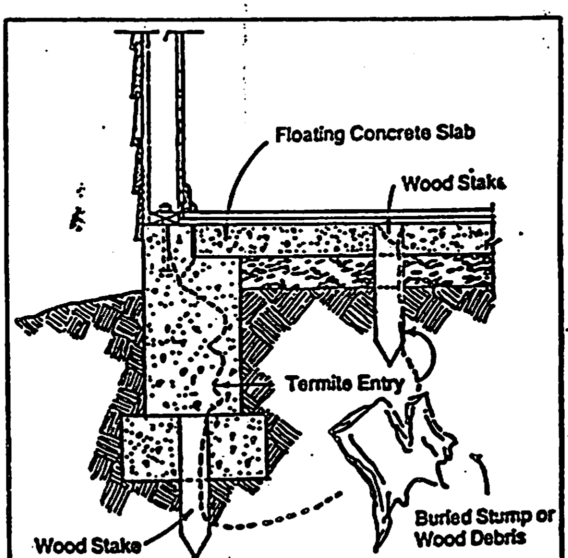


FIGURE 2-9. Wooden grade stakes left in concrete provide termite entry. Adapted from USDA.

These are a few examples of the more common construction faults which relate to subterranean termite prevention. There are as many possibilities as there are design specifications related to this purpose. Careful attention to the details of construction specifications is the only long-term answer to this problem.

DIRECT METHODS OF PREVENTION

The prevention of subterranean termites in structures by good design and construction is very difficult, if even possible. Complete dependence on this method would be quite expensive and, of necessity, would result in buildings that would not be very attractive by our current standards. This has led to the common use of chemical treatment of soil around or under the foundations of buildings to supplement good practice in modern building design and construction. It is, however, not a substitute, but a supplement. Another method which may reduce the susceptibility of wooden structures to termite attack is the use of chemically-treated and naturally-resistant woods.

Let us look first at the use of woods naturally resistant to termite attack. These woods contain materials called extractives in their heartwood. These extractives include many kinds of compounds, some toxic and some repellent to termites. Only the heartwood is resistant and, in most cases, the wood must be used above ground and protected from weathering to remain resistant.

The practice of using these woods in construction is very old and in many parts of the world was the sole means of defense against termites until very recent times. This practice has been almost completely replaced by wood preservatives, soil insecticides, more durable construction materials, and better construction methods. It still has a minor place as a supplement to other measures where the woods include (Beal et al., 1989): baldcypress, eastern red cedar, chestnut, Arizona cypress, black locust, redwood, osage orange, black walnut, and Pacific yew. None of these woods is immune to termite attack, and they are not as reliable as pressure-treated wood.

It has been the practice in the past to apply, by dipping, brushing, or spraying, so-called wood preservatives to wood framing timbers at building sites. Some of these materials are quite effective when applied under pressure to saturate a good portion of the timbers. When applied on the site by the means cited above, most offer little resistance to termites and provide a false sense of security.

Dipping, brushing, or spraying, with one exception, should not be considered effective means of treating wood for the prevention of termites. The exception to this rule is a borate salt compound formulated to be applied in water solution to unseasoned wood by dipping and restricted drying. It is sold under the trade names Tim-Bor and Bora-Care. If properly applied, it will penetrate deep into the center of wood. When such treated wood will be exposed to wetting, it should have its surface treated with water repellent often enough to prevent leaching of the borate salt.

"Pressure-treated wood" is wood that has been impregnated with an approved chemical by a standard process. The chemicals and their uses are given in:

1 Federal Use Specification TT-W-571 (current revision).
2 Standard T1-49 of the American Wood Preservers' Association.
3 Standards of the National Woodwork Manufacturers' Association.

The preservatives, such as pentachlorophenol and metallic salt mixtures, are primarily fungicides to prevent decay. They act against termites mostly as repellents to feeding or as stomach poisons.

Naturally-resistant or pressure-treated wood should not be considered a termite barrier, but only protection for those parts actually constructed from such wood. The termites will build shelter tubes over resistant or treated wood to get at untreated wood above it. They are thus forced into the open and more easily detected. Even if all the wood in a structure were pressure-treated, subterranean termites would tube over it to reach cellulose-containing materials used inside the building.

In the contiguous states, the use of pressure-treated or resistant wood as a part of termite prevention can only be justified when decay or drywood termites are serious problems and protection from them is also deemed necessary. This usually would involve foundation sills and wood used below grade, as in finished basements. In tropical areas, where drywood termites are also a serious threat, it is feasible to use pressure-treated wood for all framing lumber.

CHEMICAL SOIL TREATMENT

Subterranean termites live in the soil. They require the moisture found there, and they also find the protection which they need from drying out and from attack by natural enemies. When the normal food sources found in the soil are removed at a building site, the termites seek other sources of cellulose.

It has been explained previously that they build shelter tubes over impervious surfaces to reach wood above ground if the surrounding environment is not too harsh. The soil under concrete slabs and in crawl spaces is usually habitable by termites, even in reasonably drained and ventilated construction. Long experience has shown that termites are quite capable of penetrating or bypassing most, or all, of the physical barriers erected as defense against their assault on wood in buildings.

This knowledge led to the development of methods to render the soil adjacent to house foundations toxic and/or repellent to termites. The persistence and effectiveness of insecticides has been studied for many years, particularly as it related to the control of soil-dwelling agricultural pests.

Prior to World War II, methods of incorporating insecticides into soil to prevent termites in buildings had been developed. Many of the chemicals used had serious limitations as to their toxicity to plants and warm-blooded animals and in their lack of persistence in the soil. After the war, many new synthetic organic insecticides became available, and many were tested for their effectiveness against subterranean termites.

The group of chemicals known as chlorinated hydrocarbons were found to be outstanding in their persistence and effectiveness. They are also quite safe to use around plants and, with proper care, are no threat to people or other animals. The U.S. Forest Service established field tests in southern Mississippi as the chlorinated hydrocarbons and other insecticides became available, and has maintained field tests until the present time. (Kard et al., 1989).

Among all of the materials tested, four were outstanding and were extensively used for soil treatment until the mid 1980's, when they were withdrawn from the market because of controversy by environmentalists over their safety. Aldrin, chlordane, dieldrin, and heptachlor had been 100 percent effective for two or more decades when they were taken away. These tests were conducted in an area which has an average annual rainfall greater than 65 inches (approximately 1.6 m). In spite of this, tests conducted 17 to 21 years after the applications (Smith, 1968 and 1969) indicated that the insecticides had moved only a few inches.

Since in practice they are placed on soil under buildings where there is a minimum of weathering, erosion and other distrubances, the treatment presents a minimal hazard to the environment. Since the tests were being conducted in only one location, the Forest Service, between 1964 and 1966, established additional field tests in seven locations selected to represent major soil types and rainfall patterns in the United States (Carter, et al., 1970).

Because the loss of the use of chlorinated hydrocarbons, several insecticides in different groups of chemicals, particularly organophosphates and pyrethroids, have been tested as replacements for previously used soil insecticides (Kard et al., 1989). Five of them, chlorpyrifos (Dursban), cypermethrin (Demon and Prevail), fenvalerate (Tribute), isofenphos (Pryfon), and permethrin (Dragnet and Torpedo), have been 100 percent effective for 5 or more years at most sites when tested in a manner equivalent to treating soil under a concrete slab. All of them except cypermethrin (under test only 8 years), when applied at the recommended label rate, have been effective under concrete slabs for 10 or more years at one or more of the four test sites (Rambo, 1990).

These termiticides are not as persistent in the soil as the chlorinated hydrocarbons and require very careful attention to label directions when they are applied if reasonable control is to be expected. In addition, there are more stringent regulations related to pressure used during application and a number of applicator safety equipment recommendations to be considered.

The purpose of soil treatment is to establish a barrier of chemically treated soil adjacent to all surfaces of the building foundation over which, or through which, termites might gain entry into the wood of the structure. Obviously, the barrier must be applied very thoroughly and uniformly to block all routes of termite entry. This requires that treatment must also be applied around all pipes or utility conduits making contact with the ground and the wood. When this soil treatment is performed during construction of the foundation as a preventive measure, it is called "pretreatment." This is the most economical and effective time to apply soil insecticides.

All of the currently registered soil termiticides are applied as a water emulsion prepared by mixing a specified volume of emulsifiable concentrate of the insecticide with a specified volume of water. Directions for mixing the concentrates with water are given by the labels on the containers and they should be followed very carefully.

The insecticides and the recommended concentration for each are as follows:

- chlorpyrifos (Dursban) 1%
- cypermethrin (Demon) 0.25-0.5%
- (Prevail) 0.3-0.6%
- fenvalerate (Tribute) 0.5-1%
- isofenphos (Pryfon) 0.75%
- permethrin (Dragnet and Torpedo) 0.5-1%

The rates and methods of application (Beal et al., 1989) vary with the type of construction and the area to be treated. Pressure should not be high enough to allow misting or excessive splashing of the termiticide. Consult label directions for pressure recommendations.

1. Slab-on-ground buildings: Soon after the gravel or dirt fill has been placed and tamped, treat the soil with one of the diluted chemicals before the concrete slab is poured. The chemical is applied with a power sprayer, but it may be necessary to loosen or to trench (discussed later) the soil to get penetration to the footing and good dispersal in the soil in contact with the treated elements.

The soil is treated as follows:

■ Apply 4 gallons (15 liters) of chemical per 10 linear feet (3 m) to the soil in critical areas under the slab, such as along the inside of foundation walls, along both sides of interior partition walls and around all plumbing or utility conduits that will penetrate the slab. (You will recognize these as the primary points of termite entry.)

■ Apply 1 gallon (4 liters) of chemical per 10 square feet (1 sq m) as an overall treatment under the slab and attached entryways, garages, carports, porches and terraces where the fill is soil or unwashed gravel.

■ Apply 1.5 gallons (6 liters) of chemical per 10 square feet (1 sq m) to those areas where the fill is washed gravel or other coarse, absorbent material, such as cinders.

■ Apply 4 gallons (15 liters) of chemical per 10 linear feet (3 m) of trench for each foot (30 cm) of depth from grade to footing along the outside of foundation walls after all grading is finished. Portions of soil adjacent to the main foundation which will be underneath attached porches, terraces, etc., should be treated at this rate before the concrete slabs are poured. This treatment is accomplished by digging a shallow trench approximately 6 inches (15 cm) wide along the outside of the foundation. Where the top of the footing is more than 12 inches (30 cm) below the surface, treatment must be extended to the top of the footing by the use of crowbars or a grouting rod inserted at close intervals in the bottom of the trench. (The details will be given in part 2 following.)

■ Apply 2 gallons (7.5 liters) of chemical per 10 linear feet (3 m) of wall at or near the footing into voids in masonry blocks or foundations. If voids have been capped, drill holes into them near the footing and inject the chemical to form a continuous barrier. See Figure 2-10 for a cross-sectional view of the completed chemical barrier.

2. Crawl space houses: The soil under or around crawl space houses should be treated as follows:

■ Apply 4 gallons (15 liters) of chemical per 10 linear feet (3 m) of trench along the inside of foundation walls, along both sides of interior partitions and around piers and plumbing (Fig. 2-11).

■ Apply 4 gallons (15 liters) per 10 linear feet (3 m) of trench for each foot of depth from grade to footing along the outside of foundation walls, including the part beneath entrance platforms, porches, etc., after all grading and/or filling is completed. This treatment is accomplished by digging a shallow trench approximately 6 inches (15 cm) wide along the outside of the foundation.

Where the top of the footing is more than 12 inches (30 cm) deep and where large volumes of chemical must be applied, make holes no more than 1 foot apart in the bottom of the trench to the top of the footing, using a grouting rod. The rod holes will permit better distribution of the chemical by providing access to the soil at depths below the trench. The grouting rod is a pipe, usually ½ inch (13 mm) or greater in diameter and about 4 feet (1.2 m) long, with a point and openings near the tip. As the grouting rod is inserted into the soil, the chemical is

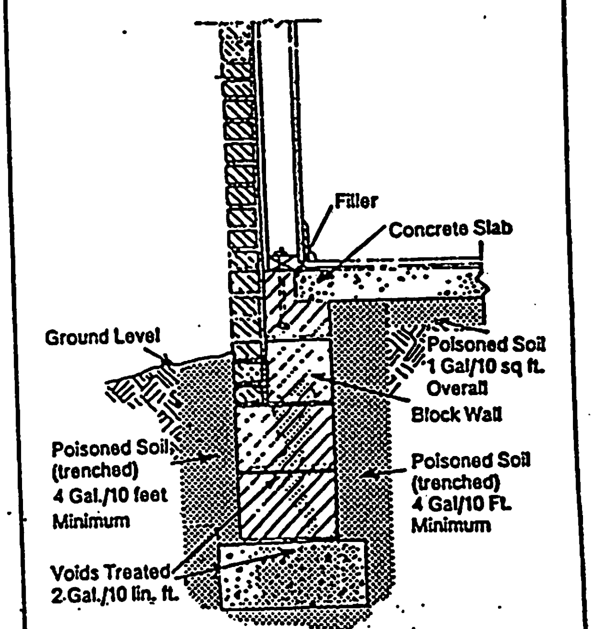


FIGURE 2-10. Application of chemical to slab construction. Adapted from USDA.

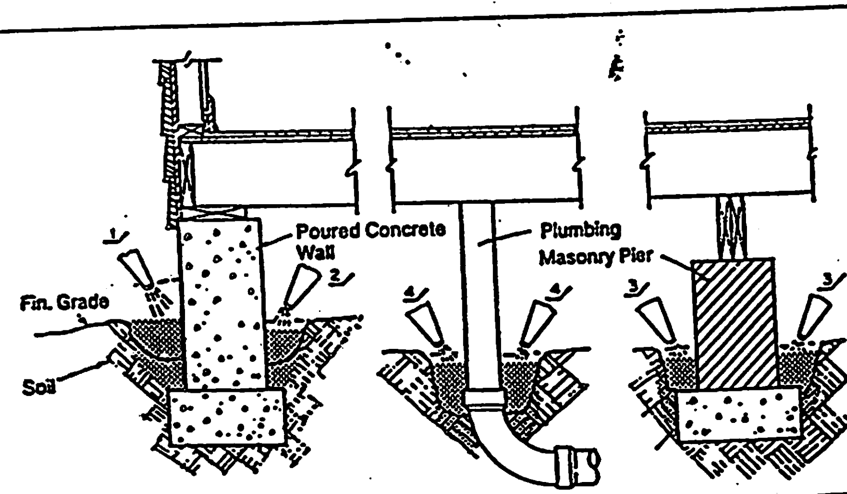


FIGURE 2-11. Application of chemical to crawl space construction. Soil treatment (1) along outside and (2) inside foundation wall (3) around pier and (4) plumbing. Adapted from USDA.

injected through it under pressure.

Any excess chemical which backs up around the rod is held next to the foundation in the trench. The grouting rod injections may need to be closer together in hard-packed clay soils than in light, sandy soils. When the rodding is completed, refill the trench, saturating the soil with chemical. Some label directions indicate that a thin layer of untreated soil should be placed on top of the treated soil.

■ Apply 4 gallons (15 liters) per 10 linear feet (3 cm) along and against the inside and outside foundation walls of porches and other raised appurtenances, using shallow trenches to retain the chemical against the foundations. The trenches should be refilled and treated as indicated above.

■ Apply 1 gallon (4 liters) per 10 square feet (1 sq m) of soil surface as an overall treatment, only where the attached concrete platforms and porches will be on fill or ground. Do not apply an overall treatment in crawl spaces.

■ Apply 2 gallons (7.5 liters) of chemical per 10 linear feet (3 m) of wall at or near the footing into voids in masonry blocks or foundations. If voids have been capped, drill holes into them near the footing and inject the chemical to form a continuous barrier.

3. Basement houses: Soil under the entire area of the basement floor, under adjacent entrance, porch, garage and carport slabs and around the perimeter of the basement wall should be treated (Fig. 2-12).

▸ Soil under the basement floor and other slabs is treated under slab-on-ground construction (Part 1 above).

▸ The soil outside of the basement wall is treated as in crawl space construction (Part 2 above).

▸ Where there are voids in masonry foundations, treat as in Parts 1 and 2, above. Keep in mind that the insecticide is applied in the foundation wall at or near the footing, not from the top of a high basement wall.

4. Multi-level houses are treated according to the individual component parts, using the specifications which apply to each. They are very difficult to treat properly if infested later.

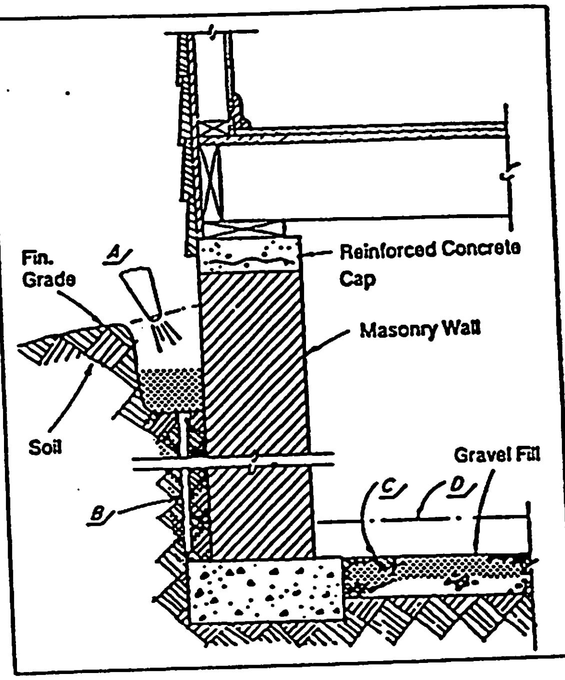


FIGURE 2-12. Application of chemical to the soil and around a house with a full basement. A. Soil treatment along the outside of the foundation; B. Pipe and rod hole from the bottom of trench to the top of the footing to aid distribution of chemical. C. Treatment of fill or soil beneath a concrete floor in basement. D. Position of concrete slab after chemical has been applied. Adapted from USDA.

Soil type and the amount of moisture present may have an effect on the acceptance of liquids at the rates recommended. When a soil will not accept the correct volume of insecticide formulation, some labels provide for adjusting the concentration of toxicant upward and applying a lower volume. For example, five gallons of 0.5 percent cypermethrin is the equivalent of 10 gallons of 0.25 percent cypermethrin in terms of actual insecticide available. Proper distribution of the lesser volume might be more difficult, and distribution is the key to the success of such a manipulation. At the present time, label directions must be followed, and most do not allow adjustments of this type. It is hoped that such leeway might eventually become available to knowledgeable applicators.

It is important to be aware of several general precautions and other considerations. The Environmental Protection Agency requires that treated soil to be covered by a concrete slab be protected with a polyethylene sheet or other waterproofed material, unless the concrete is to be poured on the day of the treatment. This is to avoid washing away of insecticide by rain.

It is equally important to protect the treated soil from any disturbance which might break the continuity of the insecticide barrier. The layer of treated soil provided by the overall treatment of fill under slabs is probably less than 2 inches (5 cm) thick, and most of the chemical is in the top 3/4 inch (2 cm) of soil (Beal and Carter, 1968). Something as simple as a board being dragged across a treated fill can create a line of untreated soil turned from underneath by the furrow. That is why it is essential that final treatment on the outside of foundation walls be done after all grading and other soil disturbance has been completed.

If large stones or chunks of concrete or mortar, as well as wood scraps are incorporated in dirt fill adjacent to foundation walls, problems in proper soil treating result. When the chemical is applied in a trench, or if rods are used to inject the toxicant to the footing, obstructions to downward movement create "shadows" of untreated soil below the obstruction (Fig. 2-13). Lateral movement of chemicals in many soils is so restricted that there might not be overlap between holes, even with extra treating on each side of the obstruction.

Any wood debris incorporated in the back-

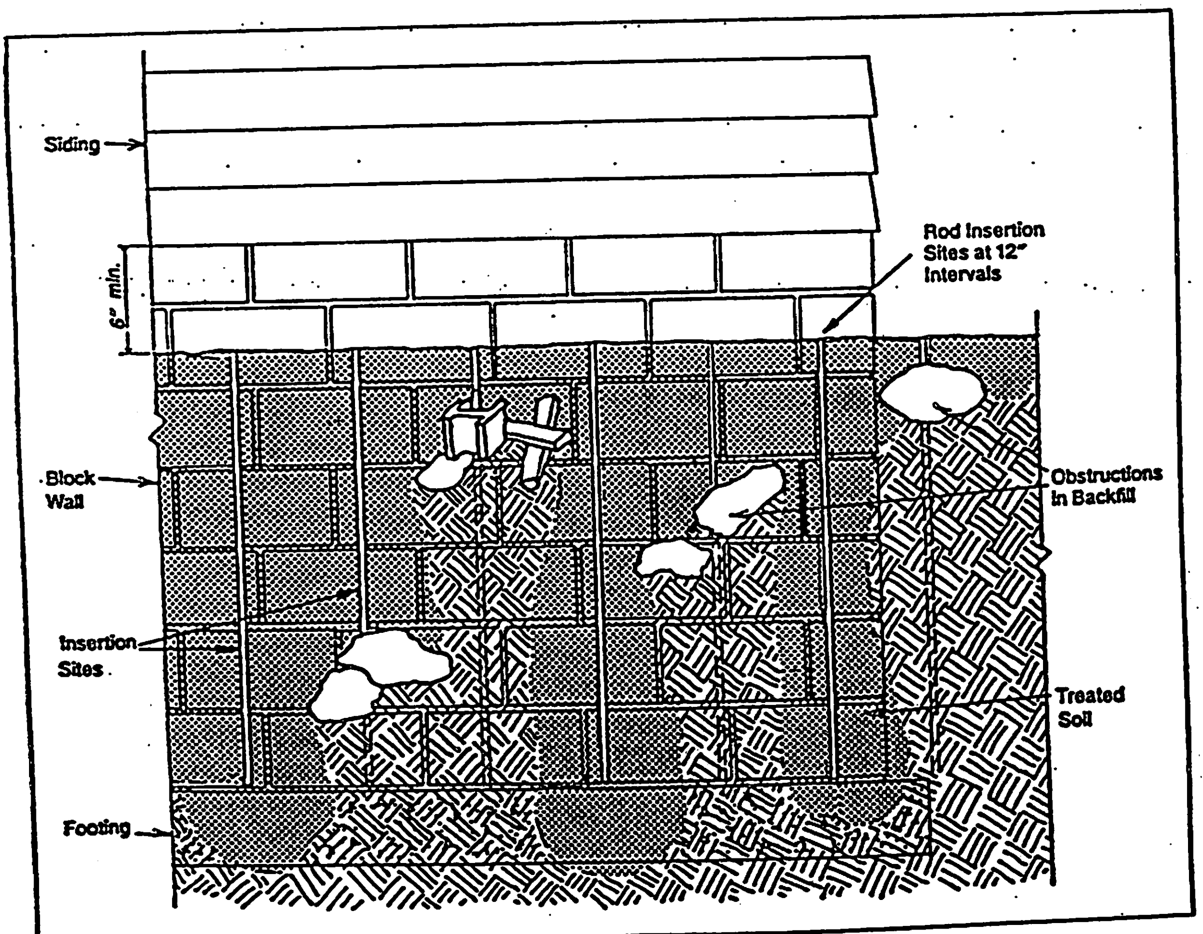


FIGURE 2-13. Obstructions in backfill prevent complete treatment of soil to the footing.

fill serves as food for termites and also might well extend from the face of the wall into untreated soil. This will allow termites outside of the chemical barrier to consume the wood and increase their population. Ultimately, they will penetrate the length of the wood debris and be in contact with the foundation. Any tiny crack or crevice greater than 1/32 inch (0.8 mm) will allow entry into the wall. The higher population of termites increases their persistence and thus pressure against chemical and physical barriers.

Treatments should not be made when soil is excessively wet or immediately after heavy rains in order to obtain good penetration into the soil and to avoid possible run-off of the chemical. Best penetration results when the soil is damp but not excessively wet or dry. Once the insecticide emulsion which has been applied to the soil has "broken" (the water has left the globules of insecticide oil solution), it is then stable in the soil. The insecticide adheres so tightly to the soil particles that the soil essentially must be moved in order for the chemical to move. The recommended insecticides are almost insoluble in water, so leaching is not a problem.

One step in the treatment that is often misunderstood is that of applying the chemical to the voids in foundations. The recommendations indicate that it should be applied at or near the footing. The purpose of this treatment is not to generally flood the surfaces of the voids. Rather, it is to concentrate the chemical on top of the footing so that any joints, cracks or other openings in the footing will allow the soil on the underside to be saturated with the chemical that seeps through.

If the soil on both sides of the foundation is treated properly, the only entry route left for termites is through the bottom of the footing. Treating the soil below any openings through the footing blocks that one last route. If grade stakes have been left in the footing, it is doubtful that sufficient chemcial will soak into the small crevices around them to saturate the soil. This emphasizes the need to remove such stakes during construction.

Although tests have shown that there is only slight movement of the chemicals laterally or downward through soil, there should be concern for the possibility of contamination of wells on building sites. This is particularly true when the soil contains layers of gravel or if it tends to crack severely during periods of drought.

Where this is the case, it is doubtful that chemical treatment should be attempted if the well is within 50 feet (15 m) of the house. In such a case, it is safer to rely on physical barriers to the termites which were mentioned in the discussions of foundations, slabs, etc. Where the well is at least 100 feet (30 m) away, no practical danger exists.

If the house is between 50 and 100 feet (15 and 30 m) from the well, it is possible to treat safely by removing all of the soil adjacent to the perimeter of the building nearest the well by digging a trench 6 inches (15 cm) wide down to the footing. The soil so removed should be placed in a container and mixed with the prescribed amount of chemical. After it has dried, it can be replaced in the trench, which has been lined with a heavy plastic film.

One of the problems most often encountered when preventive soil treatment is being applied by a pest control firm is the lack of good coordination between the builder and the soil treater. There have been many cases where concrete was poured before the fill was treated. Or foundation voids were capped before they had been treated. Should there be such an occurrence, the lack of treatment should not be ignored.

Rather, the concrete slab should be drilled and treated as will be described in the section on treating existing structures. The foundation likewise should be drilled and treated. The soil treater should be allowed ample time to do a thorough and complete job. A poor job is worse than none at all: it creates the false impression of security from termite invasion. In fact, later termite breaching of a poor treatment very often results in the need for a complete retreatment because of the difficulty in determining the exact extent of previous treatment. This is primarily a problem with slab construction, the most difficult and expensive to treat.

There is another concern that often arises in determining the procedures for coordinating the soil treatment with the construction schedule: how many trips to the site does it take for a treatment to be completed? There is no simple answer, but the theoretical minimum is two trips.

The first is to treat foundation voids (if any) and the soil to be covered by the building and and its attachments. The second trip is needed when all exterior grading and landscaping is completed. In practice, there are very few construction schedules that would allow such a few trips to complete the treatment. If there are several houses being constructed simultaneously in a development, the treater might do small segments of the jobs on numerous occasions when he is at the development site. If the job is a single dwelling isolated from others being treated in the vicinity, more careful planning is necessary.

For slab-on-ground construction, the first part of the treatment is usually applied when the foundation or its forms (monolithic) are in place and all of the fill has been completed. On that trip the treatment under the slab and in any foundation voids is applied. The second part of the treatment occurs when all of the fills, grading and foundations have been completed for carports, entrance platforms, etc., attached to the main foundation. The soil to be covered is treated. The third and final part of the treatment would be to the soil outside the foundation after all grading and landscaping is completed. Basement and crawl space construction would require similar steps in treating. Basically, when foundations are at least partially completed; when grading, fills and foundations for attached concrete slabs are completed and, if applicable, the basement floor is ready for the concrete to be poured; and when the outside grade is completed. Since protection of treated fills is required if the concrete is not poured the day of treatment, it is common to closely time the treating of dirtfills with the pouring of concrete. Careful coordination is critical and is often the weak spot in the system.

The question is often raised as to how to determine whether or not an adequate soil treatment has been applied. The ultimate test is afforded by the termites. If they breach the chemical barrier, it obviously was not adequate. Such a test could involve years of waiting and could include damage to the structure.

Soil treatment is recognized as an effective and essential type of protection. Unfortunately, there is little if any physical evidence of its presence. For this reason, efforts have been made to devise tests to determine that the desired treatment was actually applied to the soil.

There is currently a controversy over the correct procedure to follow in taking and handling soil samples for chemical analysis. The complexity of the compounds and the soil types and chemistry make a simple, accurate field test procedure unlikely. It is likely that immunoassay test kits, based on color reactions, will become available for the common termiticides. These field test kits will not determine the exact amount of pesticide found in a sample, but can detect very low levels and indicate the simple presence or absence of termiticide.

Even laboratory-analysed samples will not determine whether or not termite control will be obtained at the tested site, since soil samples are taken from scattered locations and only one untreated spot is enough to allow termite entry. They can determine whether or not a treatment has been applied at the site and thus have value in quality control work.

Other attempts have been made to develop methods to indicate the presence of the chemical. One involved the addition of dye to the treating liquid (Berzai, 1964). Some pest control firms place termite-susceptible wooden stakes in treated areas around buildings and examine them periodically to determine the presence or absence of termite activity. An attempt was also made to develop a practical bioassay technique to determine the amount of soil insecticide present (Coleman, 1966). This involved using live fruit flies as test animals exposed to soil samples. There are many practical limitations to the method, and it has never been widely used.

At present, the only accurate methods of determining the amount of insecticide present in soil samples all involve laboratory analysis. The accuracy of the analyses has been greatly increased in recent years, and the cost has not become unreasonably high, considering the improvement of the results. Finding generally accepted procedures for sampling and for handling and analyzing the samples is an important concern at present. Another problem lies in the lack of available research data on the breakdown of termiticides in soil. This needed research is in progress and more accurate information should be forthcoming. Once the needed data and procedures are available, laboratory analysis of soil samples may be widely used for regulatory and quality control purposes.

Efforts have been made to test building elements as to their resistance to termite attack. A wood-cement composite structural building board called "Century Board" (U.S. Patent 3,271,492 — 1966) has been field and laboratory tested and found to resist termite attack (Allen and Dolan, 1970). In this case, the Portland cement coating on the wood elements forms a physical barrier which the termites are unable to penetrate.

Several experiments involving the use of insecticides added to concrete at the time of mixing have shown that this is an effective method of rendering the surface of concrete toxic to termites. Gay and Wetherly (1959) substituted a 0.5 percent emulsion of dieldrin for the normal mixing water to prepare a termite-proof concrete.

The insecticide did not affect the strength of the concrete. A 75-percent dieldrin wettable powder added to concrete so that the concentrations of the toxicant in cement blocks were approximately 0.1 and 1.6 percent by weight resulted in 100 percent mortality to native subterranean termites exposed to the block surfaces for one minute a week after mixing (Allen et al., 1961). After 16 months, the newly cracked surfaces of laboratory-aged mixtures were equivalent in toxicity to the original surfaces of new mixtures (Allen et al., 1964).

Since termites conceivably might tube over the surface of insecticide-treated concrete before receiving a lethal dose, it was necessary to test treated concrete for such tube building. R. H. Beal (1971), of the U.S. Forest Service, Southern Forest Experiment Station, Gulfport, Mississippi, found in field tests that, after five years, concrete blocks incorporating chlordane at concentrations of 0.5 percent or more were not tubed over.

Blocks containing as little as 1/8 percent dieldrin were not tubed over. Such treatments in actual structures should be equally effective. However, at the time of this writing, chlordane and dieldrin are banned for any type of termite control. Since the tested pesticides are no longer available, substitutes which are as effective will have to be found if this system is to be considered further.

Since termite shields were for many years recommended for the prevention of subterranean termite attack it is logical that some comment be made on the current position of termite control specialists related to metal shields. To put it quite bluntly, termite shields have very rarely been of any practical value against termites. This is primarily because they were rarely installed properly. More often than not, they were damaged or altered during the construction process to the point that they were valueless, even if they were properly installed.

Add to that the fact that they can be breached by termites if they are left undisturbed long enough. The best that could be said for termite shields is that they forced termites out into the open where they could be seen. Because of the many practical problems with termite shields, they are no longer recognized as adequate physical barriers to termites.

■ INSPECTION

Any structure built entirely or in part of wood in areas where subterranean termites occur should be inspected at least annually for active infestations, regardless of physical and chemical preventive measures employed in its construction. Obviously, if no special barriers were incorporated, the need for inspection is more critical.

Even the best physical barriers currently employed may be breached by termites. Very careful application of soil insecticides is sometimes not effective in stopping termites under some circumstances. In addition, there may have been changes which have occurred subsequent to construction that have altered the integrity of termite barriers. For example, one or more service or repair persons may have left termite-prone conditions after working underneath or around the structure. The homeowner may have disturbed treated soil or placed wood on the ground near or under the structure. Vegetation may have grown over or through chemical barriers to provide termite access. Settlement cracks may have occurred in foundation walls or concrete floors.

If property is inspected annually, very little serious damage will result from subterranean termites before they are discovered and treated. They work slowly enough that their presence can be detected and the infestation controlled before structural weakness in timbers could result. In certain locations, or in certain conditions, it might be reasonable to inspect twice annually. Certainly, any situation of a supicious nature should be investigated as soon as it is observed, and reported by the building occupant.

THE INSPECTOR

A good inspector for termites must be willing and able to get into dark, dirty, hidden and often confined areas of a structure. He must be very conscientious and diligent in his examination because the evidence is sometimes very subtle and difficult to detect with only casual observations. In addition, he must have a good understanding of termite biology, habits and capabilities, as well as being thoroughly familiar with building design and practice.

THE PURPOSE OF AN INSPECTION

An inspection should determine the presence or absence of termites within the limitations of generally accepted inspection practices. Obviously, an inspection that would give absolute assurance of the presence or absence of termites would require the opening of walls and foundations to gain access to all structural members. This could easily cost more than an actual termite control treatment. Since most infestation will be revealed by careful visual inspection and sounding of structural members in accessible areas, this is the accepted basis on which inspection reports are made.

An inspection should determine the route of entry used by any termites that are found. It should also reveal conditions that are conducive to attack where none has yet occurred. Where damage is found, its extent should be determined and recorded.

THE EQUIPMENT REQUIRED

There is some variation in the equipment required, depending to some extent on personal preference, but also on the usual problems encountered in a given area. The most basic piece of equipment is a good light. This usually means one that is battery-powered, since cord-supplied electric lights are of limited practicality in many areas of buildings. The light must be reasonably lightweight and compact because of the confined spaces which must be reached.

A hammer is essential in sounding structural timbers, but has little value or none at all in examining finished wood. One or more slender probes, such as a knife, an awl, an ice-pick, or a screwdriver are used to test wood for the presence of termite damage or to scrape in narrow crevices to reveal termite shelter tubes. A slender piece of spring steel or a hacksaw blade is needed to insert underneath sills adjacent to possible dirt fills to determine whether there is soil in contact with wood on the hidden side. Protective clothing in the form of coveralls, bump cap and gloves is essential for safety as well as hygiene.

Some inspectors require such items as masons' rubber kneepads and compact dust respirators. Access to attics or other high areas usually requires a strong 6-foot stepladder. Finally, a good inspector will have a measuring tape for careful location of possible hidden spaces and to pinpoint damage sites. A clipboard and cross-section or grid paper complete the equipment list. The latter items are for reporting information and drawing a sketch of the structure to show the location and types of infestation and damage. Electronic listening devices and moisture meters will be of value in some situations, but a discussion of their proper use is beyond the scope of this manual.

THE INSPECTION PROCEDURE

For the inspection of structures in general, there are four parts to be considered: the examination of the exterior, the interior, the attic and the substructural area (basement or crawl space). Before beginning the actual examination, the inspector should interview the occupant of the house. The occupants' observations on things such as damage seen, plumbing or rain leaks, termite swarms, etc., can be extremely helpful.

EXTERIOR INSPECTION

First, make a circuit of the complete exterior, pacing or measuring the dimensions of the structure and recording an accurate outline on cross-section or grid paper. Include any attachments such as porches, patios, etc. This will enable you to more easily spot hidden, often inaccessible areas that might be overlooked when making interior and substructure inspections.

Note and record on the building outline any moist areas adjacent to the house and any evidence of improper drainage which might create dampness in the substructure.

Check for the number, size, condition and location of foundation ventilators. If there is an access to a crawl space, note whether it is wood and whether the frame is in soil contact. Watch for termite tubes between the frame and the foundation. This is a common entry point for termites.

Examine the entire foundation wall very carefully. Watch for termite shelter tubes on the surface. They are sometimes difficult to spot if soil has splashed onto the surface or if the tubes are in crevices, corners, etc. Look for vertical cracks in the wall and check them carefully for termite signs.

Note any vegetation such as vines, trees, grass, etc., in contact with the house or blocking ventilators. Note any cellulosic materials, particularly lumber or firewood, that is adjacent to the foundation. Adequate space for inspection should be provided or the obstructed area should be noted on the report.

Note the distance between the exterior grade and wooden structural members—including doors and windows set in the wall and wood siding. If there are decorative wood framed attachments to the house such as pilasters, arches, buttresses, etc., particularly if they are finished with stucco, note whether or not they are on foundations with adequate clearance. If they are hollow, note whether or not there is access for inspecting the interior. This is a common termite activity center. If they cannot be inspected, note the inaccessible areas on the drawing.

Particularly watch for earth-to-wood contacts and for wood embedded in or extending through concrete. Check such areas very carefully, including carefully probing into the wood surface to determine interior termite damage.

If the exterior of the foundation is finished with stucco or plaster, check by pounding carefully below the top of the foundation for a hollow sound indicating where basal stucco is loose. Loose basal stucco provides hidden access for termites and should be noted on the drawing.

Where there are structures or slabs attached to the main foundation, check for shrinkage cracks at the point of contact and carefully examine them for termite shelter tubes. If there is an attached planter, watch for soil above the sill line and for hidden access for termites between the planter and the house.

There are certain points involved with slab-on-ground construction that should be stressed. These include more likelihood of inadequate clearance between outside grade and wood and of earth fills being in close proximity to wood. Where there is a high exterior grade and loose stucco on a slab foundation, there is reason for particular concern. Sometimes there are access panels to plumbing under older slab houses. These should be removed so that under areas may be inspected.

In spite of the fact that the termites usually originate from the soil, do not forget to look up, particularly where Formosan subterranean termites are found. They often build shelter tubes or extend carton material on the outside of houses well above ground when they are working inside the walls. This happens less frequently with native species.

Also, look for discolored or stained areas which might be a sign of decay from a rain leak, which could also be an above-ground source of water for subterranean termites. Use an extension ladder, if necessary, to make a careful inspection above ground. Also, open and examine for termite signs the inside of any exterior electrical meter and fuse boxes set into walls.

Finally, note any fence or gate posts that are in contact with the soil and the house, particularly if there is wood siding. Examine them very carefully for evidence of termite activity and for shelter tubes extending from them to the house.

Record all of the information in your report and on the building outline as you go, so nothing is left to memory and forgotten as you evaluate the inspection later.

INTERIOR INSPECTION

Slab-on-ground construction is the most difficult type to inspect adequately for evidence of subterranean termite activity. Most of the termite entry points on the interior are hidden by floor coverings and interior finish and trim. This places a great deal of pressure on an inspector to make a very thorough inspection. A positive attitude and a willingness to try can do much to reduce the limitations that would otherwise result.

The most critical areas to inspect are the outside perimeter walls and areas over any known or suspected joints or cracks in the slab, especially expansion joints. The crevices between wood trim and the floor and wall are the primary points to examine. A good light played on the crevices or any area being inspected will reveal any signs of shelter tubes or sealing with soil or carton. If the crevice is large enough, insert a slender probe into it and attempt to drag out any soil, etc., that might not otherwise be visible.

Tap lightly on the surface of the baseboard, shoe molding, etc., to detect hollow sounds. Should a suspicious area be discovered, discreetly probe into the surface with a slender, pointed instrument to discover the extent and depth of damage. The same procedure is followed higher up on the walls inside of and around built-in cabinets and around door and window trim. Even the ceiling-wall joint should be examined, especially if it is covered by molding. It is not uncommon for Formosan subterranean termites to extend carton material onto the wall surface when they are working inside.

This is less common with native species. Sometimes the only evidence of termite activity on walls are slightly raised areas on the surface which crumble upon contact to reveal that termites have consumed the paper from between the gypsum and the paint on plasterboard. Wood fiber composition board is likewise damaged, the evidence being as subtle as that on plasterboard. Proceed in an orderly fashion throughout the house so that no wall section is overlooked.

Areas around plumbing and utility pipes, or open areas in the slab for plumbing, are also critical. If plumbing hatches are removable, they should be opened. Look not only for termite shelter tubes or carton material, but also for evidence of leaks or condensation. An above-ground moisture source can allow an infestation to flourish, even if the soil is later treated. Look for wooden form boards and stakes that may have been left in plumbing accesses through slabs and examine them carefully by probing and prying them out.

Finally, check floor coverings, including all types of carpets and tiles as well as wood. Look for slightly darker areas or split or raised areas on wood. Sounding, probing and discreet prying up small splinters where damage is suspected will serve to locate termite activity in wooden floors. Where carpets are concerned, the usual evidence is holes which have resulted from the termite consumption of the vegetable fiber carpet backing, leaving the wool or synthetic fibers loosened to be picked up by the vacuum cleaner.

Typical carton and soil material is found in the exposed opening. Termite damaged membrane floor coverings and tiles show irregular sunken areas where pressure has been exerted on them. Termites tunnel between the mastic and the top surface of a few types of such coverings, particularly linoleum.

Interior inspection of crawl space construction is not nearly so critical as with slab-on-ground. Evidence is usually more abundant in the crawl space than on the inside of the house, so damaged areas not found inside will likely be discovered in subsequent crawl space inspection. Inspection of the same general areas and in the same manner as those described in slab construction are the rule here as well.

It is probably not necessary to spend the same amount of time in this type as in slab construction. Concentrate on areas next to raised porches, terraces, planters, etc., where the soil line on the outside might be high. Also, areas around plumbing should be carefully examined, particularly for leaks.

Basement construction presents a combination of both slab-on-ground and crawl space inspection requirements. This is particularly true when the basement is finished. Inspection of the first floor of such a house is described for crawl space construction. Basement inspection will be covered with substructural area inspection.

■ ATTIC INSPECTION

Subterranean termites are not found in attics as often as they are in other parts of structures. However, no inspection should be considered complete without a close examination of attic space. It is not uncommon to find shelter tubes of subterranean termites in portions of the attic directly above earth-filled porches, hearths and closed-in concrete porches or patios.

The entire perimeter of the house should be inspected in a manner which will allow examination of the roof, wall and ceiling members which can be seen from the attic. Also, inspect around chimneys and plumbing vent pipes that penetrate from below. If there are rain leaks, particularly where there are flat roofs, subterranean termites will nest entirely in the attic space and work their way down into the wood of the structure. Watch for this possibility. There are often many things that can limit the ability of an inspector to make an adequate inspection of an attic.

In many areas, blown insulation obstructs the view of much of the wood. Sometimes there is little clearance in attics of low-pitched or flat-roofed houses. Excessive bracing may make inspection very difficult or impractical. Be sure to note any such limitations to visual inspection and sounding of wood. Should there be no access to an attic space, estimate its accessibility from the exterior and recommend the construction of an access opening if it seems practical.

■ SUBSTRUCTURAL AREA INSPECTION

Crawl space inspection is probably less difficult than many attic inspections, but it is nevertheless often not given proper attention. It involves crawling over broken bricks, chunks of concrete and other hard, sharp objects. It may be dirty and damp and confined in many areas. These conditions discourage careful inspection by poorly motivated inspectors.

Since subterranean termites can be detected more easily in crawl spaces than in other areas, it is an important portion to examine carefully. The size of the house will determine how the inspection should be carried out. Keep in mind that all perimeter foundation walls, all pillars, all interior bearing walls, all chimney bases and hearths, and all pipes making contact between soil and wood must be inspected. This might well mean making several trips back and forth across a crawl space in order to get a close look [no more than 10 feet (3 m) away] at all areas.

A good light can help reduce some crawling, but it is important to get close enough to see evidence that may be obscure. Having already examined both the exterior and interior, the inspector should have certain strategic points well in mind. These usually will be the location of earth-filled porches, patios, planters, damp areas, bathrooms and water-connected appliances.

Proceed in a regular pattern along foundation walls, around piers, underneath bathrooms, etc. Note the surfaces of the foundation wall and other masonry for shelter tubes. Check the wood on top of the foundation, piers, etc. for shelter tubes. Whenever they are found, try to trace them to their origin so that the point of contact with the soil or the moisture source may be determined.

Look for shelter tubes between the foundation and the sill, between the joists and the sill, and in any crevices or corners created by the joining of structural members. If double joists or laminated beams are involved, shine the light as deeply as possible into the crevices between the components to look for termite shelter tubes where the joist or beam contacts the foundation.

If it is not possible to see into such crevices, insert the thin probe or blade into them as deeply as possible in an attempt to dislodge any termites or their workings that might be present. Sounding and probing, with a good light to illuminate the area being examined, are critical.

As the inspector moves from one area to another, he should watch for wood debris, tree stumps, form boards and wooden stakes on or in the soil. Wood supporting plumbing lines or heating ducts should be inspected for infestation. Any such termite sources should be reported.

Areas around bathrooms, kitchens and sites of water-connected appliances should be examined carefully for signs of termites and water leaks that might allow them to survive above ground. Examine the pipes making contact with the wood or passing through the foundation wall to deterine whether termite tubes are on them.

During the course of the inspection, note any areas where clearance is less than 18 inches (45 cm) between the bottoms of floor joists and the soil and less than 12 inches (30 cm) between wooden beams and girders and the soil. Provision of adequate clearance is part of treatment, so the area involved should be carefully indicated on the diagram. Should any areas be inaccessible to inspection because of low clearance or foundation walls with no access openings, note these carefully on the report.

Basements may be easier to inspect than crawl spaces, but they incorporate features that require special consideration. A basement, if finished so that masonry or concrete walls are obscured, is inspected much as is slab-on-ground construction. When the basement is unfinished, or only roughly finished, a slightly different technique is involved.

The primary points of inspection are the base of the foundation wall at the junction with the floor and the top of the wall where wooden structural members rest on it. Look for termite shelter tubes on the wall, usually emerging from the floor joint. Inspect the plates of wooden partition walls and the bases of wooden support posts and stair carriages.

Note whether or not the wood is embedded in the concrete and probe very carefully if it is. Examine built-in wooden cabinets, shelves, etc., that are in contact with foundation walls or over slab joints or cracks. If there are wooden windows and doors set in the walls, examine the joints and crevices around them and sound the wood for hollow, damaged areas.

If there is a closed ceiling in a basement, it is not possible to examine the wood resting on top of foundation walls unless the ceiling is composed of suspended panels. In such a case, panels near the perimeter of the building should be lifted to allow inspection of sills, joists and beams resting on the wall. The inspection procedures described for crawl space construction apply here. Where this part of the structure cannot be inspected, note the inaccessibility on the report.

Termites also enter basements around plumbing and utility lines that pass through the floor or the foundation walls. Look for evidence of termites and for water leaks in these areas.

All other aspects of the inspection would be as described for crawl spaces.

INSPECTION OF GARAGES AND STORAGE AREAS

Although garages and storage areas may be separated from the house itself, they should be inspected. One of the problems often encountered in an inspection is that stored materials may obscure the view or the access of the inspector. All wooden members resting on the foundation should be inspected. Shrinkage cracks between concrete floors and foundation walls provide easy entry for termites. Voids in concrete block or brick foundations also allow termite entry.

If concrete foundations have vertical cracks, they become vulnerable. The same exterior conditions observed in other areas may occur around garages and storage areas. Watch for inadequate clearance between grade and wood and for termite tubes on the outside of the foundation. Piles of trash or stored firewood or lumber adjacent to outer walls are also hazards to note.

CONTROL

When a careful inspection has revealed that termites are infesting a structure, or that conditions exist which probably will lead to eventual infestation, control measures should be taken. The purposes of such measures are to immediately terminate damage to the structure and its contents and as completely as practical, to provide the equivalent of the proper design, construction and preventive treatment that could have been incorporated at the time the building was erected.

In practice, control measures tend to be based more on chemical treatment than on structural alterations. However, chemical treatment and mechanical alteration are both essential phases of termite control, and should be used in proper proportion.

The extent of treatment provided should be based on several factors. First, the type and quality of the construction involved is an important consideration. Some types, as discussed under "Good Design," are much more resistant to attack than others. The care with which the building was constructed, assuming good design, is also critical.

Second, the incidence of termite infestation varies from one area to another. If termites are rare in the location in question, a very minor amount of treatment may suffice; in other areas, the most complete treatment may hardly be satisfactory. Finally, economic considerations of the property owner must be incorporated into the decision. The purpose of treatment is to reduce economic loss. Simply put, the cost of treatment designated should not be out of proportion to the value of the property being protected.

MECHANICAL ALTERATIONS

Mechanical alterations, as related to termite control, have been defined (Rambo, 1980) as: any mechanical measures which render a structure less susceptible to termite attack or which render the immediate surroundings of a structure less favorable for termites. These measures include sanitation, breaking earth-to-wood contacts, installing physical barriers to termites, replacement and repair of damaged wood, providing adequate drainage, clearance and ventilation, and providing access for inspection of all vulnerable areas.

The discussion of mechanical alterations and the following discussion of chemical control will be of a very general nature. It would not be practical, or even necessary, to provide detailed information on such a complex subject. An excellent and definitive reference on the subject "Approved Reference Procedures for Subterranean Termite Control," published by the National Pest Control Association (Rambo, 1980), provides the details needed by those interested.

SANITATION

Sanitation, as used here, applies to the removal of all wood, paper and other cellulosic debris from the soil under or near the house. It is quite common for wood scraps to be left under buildings during construction. Property owners sometimes store firewood or lumber on the ground under or next to the house. This material provides an easily available soure of food for termites and sustains the colony until they can forage for new sources, including the structure itself.

OTHER MECHANICAL ALTERATIONS

The other procedures included in this category are more nearly associated with structural improvements that will increase resistance to termite entry, or will make termite activity more easily noticed. For example, a structure may have wooden members extending below concrete floors or in contact with the soil. These members should be cut off and concrete or masonry installed to support all wood above adjacent floor slabs or soil. The reader will recall that clearances of this type were discussed under the heading "Good Design."

Earth-filled appurtenances (such as porches) which abut foundations are a major source of termite entry. One of the best ways to correct this problem is to provide ventilation and permit access for treating and for inspection by constructing a tunnel to remove earth which contacts wood. An alternate method, often used on the West Coast, is to place a barrier of concrete, called a "seal-off," between the earth fill and the framing of the building proper.

In some cases the grade may be lowered to provide clearance between wood and soil. The construction of concrete or masonry gutters in an excavated trench below wood siding is an example. In other cases soil should be removed from crawl spaces with clearance less than that recommended.

Additional foundation ventilators often are needed to provide the recommended amount of net free ventilation area and to reduce dead air spaces. A vapor barrier applied to the soil surface can be used instead of additional ventilators in most cases.

Where drainage is a problem it can be handled in many ways. The construction of retaining walls and the excavation of soil to increase the flow of ground water away from houses is sometimes feasible. Simply directing roof water into drain lines emptying downgrade might solve the problem.

Providing access for thorough inspection and treatment is a very common necessity, especially when additions have been made to the original structure.

CHEMICAL TREATMENT OF THE SOIL

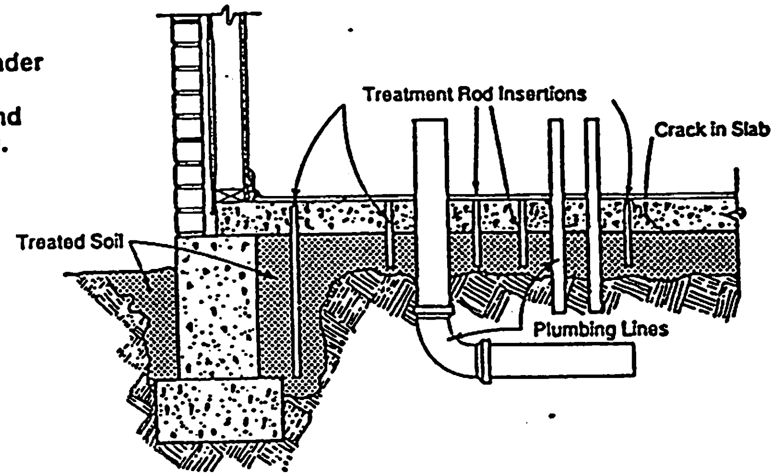
As indicated previously, chemicals are probably the most important factor in corrective termite control in all parts of the country.

The insecticides, concentrations and application rates are the same for control as for pretreating. The methods of application to soil in crawl spaces and adjacent to the outside of foundations are essentially the same as in pretreating. A combination of shallow trenching and grout rodding to the footing is the most common method. The thoroughness of dispersal is still the essential feature.

The treatment of slab-on-ground construction, or of dirt-filled extensions of raised construction, presents the greatest challenge to the termite controller. These types of construction are the most expensive to treat and are less certain of protection by the treatments than any others. The best way to treat the soil is by drilling a series of holes vertically through the slab. The holes should allow injection of the chemical into the soil below all joints, cracks or openings around plumbing.

The proper distance between holes is determined by the type of soil, its moisture content, and the experience of the applicator as treating proceeds. Again, the chemical barrier must be complete in order to be effective. The advantage of vertical drilling is that the chemical may be flooded over the surface of the soil. It is not uncommon for a space, due to soil settlement, to exist below any slab construction other than

FIGURE 2-14. Treatment under concrete slab with vertical rodding at joints, cracks and openings around plumbing.



floating slabs.

Termites may build tunnels over the bottom of such slabs from areas quite removed from joints or cracks. When such spaces are present, this requires rather extensive chemical treatment on the fill surface to reduce termite entry above treated soil. Special rod tips are available for this purpose. By using a grouting rod, the chemical also may be injected as deeply as needed into the soil to saturate it to the footing, etc. (Fig. 2-14).

In drilling vertically through slabs, there are hazards of drilling through radiant-heat pipes, hot air ducts and plumbing, or the possibility of ruining a vapor barrier, as well as the expense and liability incurred in removing tile, parquet, etc. To avoid these hazards, many applicators prefer to treat under slabs by drilling horizontally through the foundation at a height that allows rods to be inserted immediately below the slab.

This method is inferior to vertical drilling because there is very little downward movement of the chemical below the application point except in very loose, sandy soil. Also, if the holes in the foundation are too low, there may be untreated soil above the point of application.

Horizontal rodding is accomplished by using long treating pipes [up to 20 feet (6 cm) long] which are inserted and pushed through the fill as the chemical is applied. If they remain in the proper horizontal and vertical plane, accuracy of application is good. Unfortunately, such long pipes are sometimes deflected in the soil and may move into areas far removed from those anticipated.

A series of horizontal holes at rather close intervals will allow "short rodding" by inserting rods only a short distance into the fill and injecting the chemical to flood the soil between the application points. This method also has the disadvantage of not ensuring deep treatment below the point of injection. Most slab-on-ground houses present situations that preclude using either long rods or short rods exclusively. Figure 2-15 shows a typical example of a plan of rodding.

■ TREATMENT OF FOUNDATIONS

It was mentioned in the discussion of foundation types and their resistance to termite entry that termites use voids in foundations and flaws in footings to pass from the soil to the wood above the foundation. They often are able to accomplish this completely undetected when there is no physical barrier to force them into the open. Foundation treating of existing structures requires that the chemical be injected into all voids in the foundation wall, piers, chimney bases, etc., at or near the footing.

The chemicals, concentrations and rate of application are the same for treating existing structures as in pretreating. With some foundations the voids may be very regular and predictable, as in the case of hollow concrete blocks, coursed bricks or veneers. They also may be disconnected and irregular, as in the case of some brick foundations and rubble stone foundations. The treatment is applied by drilling enough holes deep enough and close enough together that the chemical will reach all parts of the footing surface.

Drilling should be as near the footing as is practical so that most of the insecticide reaches the footing instead of being absorbed on the surfaces of the masonry units. The primary purpose of treating the foundation voids is to puddle the chemical on top of the footing so that it may seep into any faults and treat the soil beneath.

■ TREATMENT OF WOOD

In the past, this has been a very minor step in subterranean termite control, but it has a real place in modern control procedures. Most of the termiticide used for soil treatment can also be applied by injection into wood. In addition, there are a number of other compounds and formulations that are marketed for this purpose. Label directions indicate that small diameter holes should be drilled at intervals into wood infested by termites and the insecticide injected with tapered nozzles under pressure into the termite galleries discovered.

Another product, containing the active ingredient sodium borate (Bora-Care), has recently been registered for teatment of wood in place. It is applied by brush or spray and when the recommended volume has been applied, it penetrates throughout the wood. This provides permanent treatment if the wood is not exposed to wetting.

The purpose of these treatments is to quickly kill the termites which would otherwise be cut off from the soil by the chemical barrier there. If there is sufficient moisture in the wood, these termites might survive long enough to find an alternate source of moisture above ground and continue their damage. This procedure has special importance when treating for Formosan subterranean termites, which

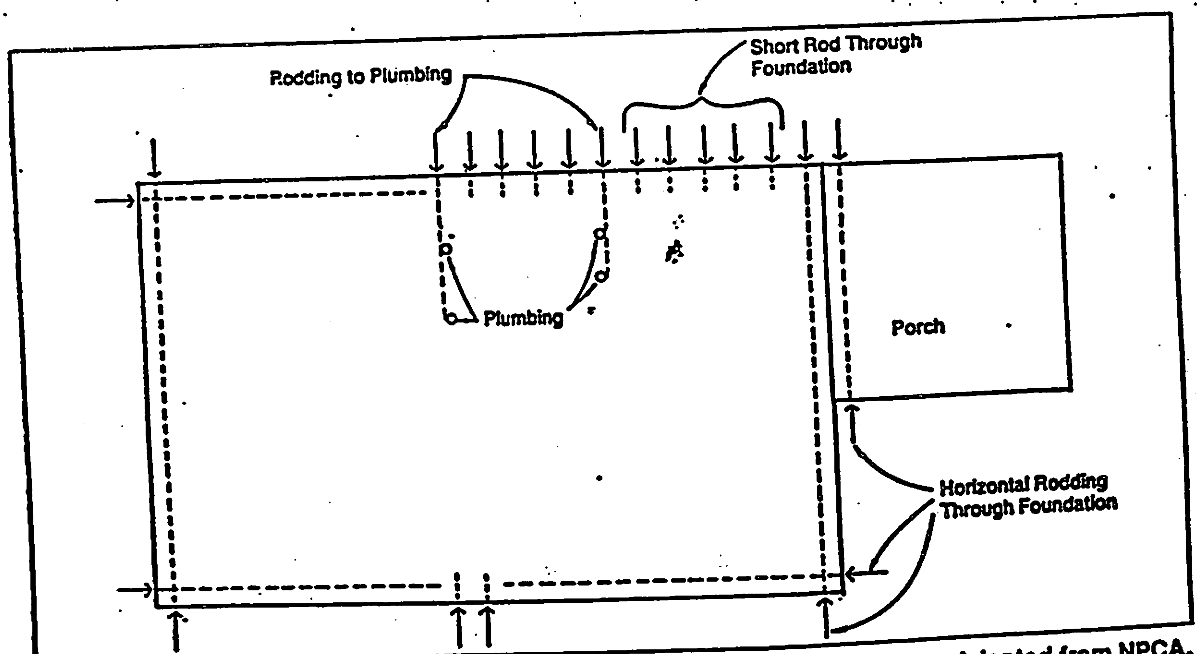


FIGURE 2-15. A plan for long- and short-rodding under a slab-on-ground house. Adapted from NPCA.

fill construction cavities with carton which holds moisture for long periods, even without an above-ground water supply. Also, if swarmers are present in moist wood, they may swarm out as much as 6 weeks after the soil has been treated and create questions about the effectiveness of the treatment.

Another use of this procedure occurs when there is a well or cistern in the crawl space and the soil cannot, according to the termiticide labels, be treated. Wood treatment provides some protection, even though it cannot replace soil treatment.

There are also times when subterranean termites have established a colony in wood without ground contact when there is a rain or plumbing leak to provide a constant supply of moisture. In addition to stopping the moisture source, treating the infested wood will speed up the control of the termites.

The use of chemically-treated wood in repair and in replacement of damaged wood is also considered as part of the control process. The application of spray- or brush-coats of insecticides onto wood, except for the borate salt solution mentioned above, are not effective for termite control. Primarily wood that has been pressure-treated with standard chemicals by standard procedures should be considered useful. Whenever such wood is cut into or sawed, the exposed surfaces should be retreated with two brush coats of wood preservative.

Other methods of subterranean termite control have been tried in the past, and some new ones are being investigated. To complete the picture, we need to look briefly at them.

OTHER TERMITE CONTROL PROCEDURES

Fumigation has been tried for the control of subterranean termites, but it generally has been unsatisfactory, except for the control of aerial (no ground contact) infestations of Formosan subterranean termites. Methyl bromide and sulfuryl fluoride (Vikane) are both used successfully. Formosans require about four times the dosage of Vikane needed to control drywood termites, which will be discussed later.

Arsenical dusts blown into shelter tubes have been successfully used to control several species of termites in Australia, but this procedure has not met with success when tried against our native species. No extensive testing has been attempted, and with the present concern over the toxicity of arsenic, none is likely.

Many laboratory studies have demonstrated the possibility of controlling subterranean termites through the use of pathogens. Both bacteria and fungi have been toxic to termites, but no field trials have yet been successful (Lund, 1971). The interest in this approach to control has continued (National Science Foundation, 1975; Zoberi and Grace, 1990) and may yet lead to some practical success.

The relationships of ants with termites have been studied. Though ants are considered to be among the major natural enemies of subterranean termites, studies have shown that not all species are antagonistic. Some species, however, have been reported to destroy colonies of termites (Beard, 1973). It is conceivable that manipulation of ant colonies might be used as an applied biological control measure against termites in situations where the ants would not be undesirable.

Two companies have marketed a species of entomogenous nematodes (*Steinernema feltia* Filipjev) known to infect and kill subterranean termites. Because they are not chemical pesticides, the EPA did not require their registration. Laboratory and field tests conducted by the USDA Forest Service Gulfport laboratory indicate that these nematodes do not eliminate or control termites when applied in the prescribed manner (Mauldin and Beal, 1989).

You may recall that termites communicate by laying down a pheromone trail. The active substance in this pheromone has been successfully synthesized and tested with several of our native subterranean termite species, as well as with the Formosan subterranean termite. They all responded positively, though to varying degrees (Matsumura, et al., 1972). The fact that it is possible to produce a single synthetic pheromone that acts strongly on several species of termites offers a possibility for practical field application.

A new approach to subterranean termite control was introduced when the use of poisoned blocks of wood which are acceptable to termites was found to be practical by Esenther and Gray (1968) and Esenther and Beal (1974). Beard (1974) modified their technique and had encouraging results. In general, the system consists of treating wood bait blocks with a slow-acting insecticide such as Mirex, and exposing the blocks in the vicinity of termite activity.

In most of the tests, the bait blocks had been partially decayed by fungus known to be attractive to termites. The use of decayed blocks increased the feeding by termites and probably speeded control. The excretion of Mirex-poisoned fecal material and the eventual disintegration of dead, poisoned termites added to the chances for physical contact with the poison in the workings. In the tests which were cited above, there was a significant reduction of termite activity or actual death of individual colonies. The amount of insecticide exposed in the environment by this method is extremely small. Mirex is no longer on the market due to environmental concerns.

There has been a concerted effort to find a replacement toxicant. This has become much more important since the spread of the Formosan subterranean termite. They have extremely large colonies spread over a large area so it is difficult to control them. If a non-repellent, slow-acting termiticide could be found to incorporate into the bait-block control program, it might be possible to eradicate entire colonies. The USDA Forest Service has conducted a number of laboratory and field studies (Mauldin et al., 1985; Jones, 1988) as well as some university researchers (Su et al., 1985; Su and Scheffrahn, 1990). Many of the candidate toxicants have been insect growth regulators which tend to cause an over-population of soldiers and/or presoldiers and, at some levels, cause the death of the termite gut fauna, resulting in their starvation.

So far, none of the field tests have provided adequate control. The search continues, using new slow-acting materials as they become available. An example is GX071, belonging to a new class of delayed action insecticides, the fluoroaliphatic sulfones (Su and Scheffrahn, 1988). Laboratory tests with this material are encouraging and field tests will follow.

Physical control of subterranean termites has been unsuccessfully attempted through the use of termite shields, as indicated previously. Recently, there has been renewed interest in this method because of the rediscovery that precisely-sized particles of sand and gravel will prevent tunneling by subterranean termites. When Ebeling and Pence (1957) first discovered the phenomenon, it was not pursued because of the availability of cheap and effective soil toxicants.

As tighter restrictions on the use and availability of termiticides have developed, new interest in the technique has emerged. Ebeling and Forbes have developed a system for using a layer of 12 grit (2.5-1.6 mm) sand-blasting sand to form a barrier against the western subterranean termite adjacent to house foundations. In Hawaii, researchers have determined that basaltic particles in size ranging from 1.7 to 2.4 mm will prevent the penetration of Formosan subterranean termites. Ebeling and Forbes indicate that the smallest particles are too large for the termites to push aside, and the largest particles are not large enough to allow these insects to crawl between them. Tamping the sand in place improves it effectiveness. We may well see this technique grow in its use.

DRYWOOD TERMITES

Wherever drywood termites are considered to be a major problem, serious consideration should be given to taking all economically feasible steps to prevent their attack on structures. This would, in general, be the Pacific area, southern coastal California, southern Florida, and the Caribbean area. Because these termites are of secondary importance in most areas where they generally occur, there has been less research done on methods of prevention and control than on the more important subterranean type.

Incipient infestations that are transported in infested articles outside their natural distribution areas do not pose serious threat of damage. Wherever they occur, outside of the high hazard areas mentioned above, their presence is more of a nuisance than a serious threat of rapid structural damage. Of course, they should not be ignored whenever they are discovered, but the extent of prevention and control measures should be geared to the actual potential for damage and the value of the property being protected.

■ PREVENTION

It is neither as practical nor as economical to prevent drywood termite attack as it is to prevent subterranean termites. There are, however, several measures that can be taken to reduce the chances of attack. The effectiveness of these measures is variable, and probably none of them used alone would be sufficient for entirely effective prevention. A discussion of the various measures and their effectiveness follows.

■ SANITATION

The very careful examination of any article of furniture, wooden crates, cellulosic building materials, etc. will help prevent the introduction of an existing infestation into a house under construction or into one already existing. Early infestations are difficult to discover, so thoroughness is essential.

In addition, it is helpful to examine all potential outdoor infestation sources nearby and to remove as many as possible, including stored lumber, firewood, scrap lumber, or dead branches or scars on living trees near the structure. Since it is common for drywood termite swarmers to be carried by the wind and to be attracted by lights when they swarm at night, this preventive measure is of limited value. In general, the older the neighborhood houses and the more old trees present, the more liability to infestation exists.

■ EXCLUSION

In the past, some authors have recommended screening vents to attics and crawl spaces to exclude drywood termite swarmers (Snyder, 1969). This is not satisfactory, since the screening must be 18 to 20 mesh to exclude the termites. Even when new, mesh of this small size greatly restricts normal movement of air, and it very quickly becomes clogged with dust and cobwebs.

Keeping a good, continuous coat of paint or varnish on all outside wood surfaces and keeping all cracks and joints tightly caulked might help some in preventing establishment of new infestations. Although drywood termites can penetrate through a flat surface, they much prefer to wedge themselves into a crevice to start boring. There are so many routes of entry other than exterior surfaces, however, that painting and caulking should not be relied upon very heavily. Drywood termites can enter under siding, through wood shingles, or between and underneath shingles or tiles and sheathing.

■ CHEMICAL TREATMENT OF WOOD

There have been reports of the successful prevention of drywood termite infestation in framing timbers by soaking the timbers in vats of wood preservative before construction. Others have suggested spraying or brush-coating all of the wood framing in a structure after it is erected but before it is closed in. Until recently, these preservatives have been organic chemicals which penetrated only the outermost portions of the treated wood.

Wood treated with organic preservatives by dipping or spraying before construction begins requires the brush application of preservative to each cut or notched surface in order to maintain the barrier against termite entry. The borate salt solution (Bora-Care), mentioned in the discussion of subterranean termite control, is also available for drywood termite control. It can be applied after all the cuts have been made in the wood and the structure is at the "dried in" stage. Since it diffuses deep into the wood and does not leave unless leached out, it offers a great measure of protection for wood that is used in protected locations. These methods have not, until now, been in wide or general use.

Pressure-treated wood is protected against drywood termite attack. Its use for all framing members, and possibly even for sheathing, subflooring, exterior doors, windows, and exterior trim, might well be justified in the high hazard areas mentioned previously.

Even with this method, there are limitations. Every place on the surface of pressure-treated wood that is cut, bored, notched, or split during the construction process must be retreated with a brush or spray application of the preservative. The difficulty of ensuring adequate treatment of such places has been a great limitation to the value of pressure-treated wood in the prevention of drywood termites.

DESICCATING DUST APPLICATION

Certain fluoridated silica aerogel dusts (Dri-die 67) have been found to be effective in preventing drywood termite attack. Ebeling and Wagner (1964) described a system of applying such dusts during construction in attics, crawl spaces, and wall voids to prevent drywood termites. The silica aerogel has a monomolecular layer of ammonium or magnesium fluorosilicate which gives it an electrostatic charge, resulting in a more efficient deposit on dusted surfaces and efficient "pickup" by insects crawling over them.

Insects are protected from desiccation by a very thin waxy layer on the surface of their external skeleton. Sorptive dusts, such as the silica aerogels, absorb enough of the protective wax layer to cause a lethal rate of water loss. For termites, only a barely visible film of such dust is necessary to protect wood.

The dust is applied at the rate of 1 lb. per 1,000 sq ft (0.45 kg/93 sq m) to attic spaces. An electric dust blower or a water-type fire extinguisher, commercially available for the application of insecticide dusts, is used to disperse the dust in a high velocity airstream. The unusually light weight of this dust allows it to coat wood surfaces evenly throughout the attic and into its extremities. Under-area framing is likewise treated. Ebeling and Wagner (1964) also encouraged the application of fluoridated silica aerogel to wall voids at the rate of about 1.25 lb per 1,000 sq ft (0.57 kg/93 sq m) of floor space. Since this type of dust is inorganic, it should not deteriorate and should be effective for the life of the building. In addition to killing drywood termites, it is lethal to many other insect pests that inhabit the treated areas.

USE OF STEEL OR CONCRETE CONSTRUCTION

The use of steel, concrete, stone, or brick in construction offers excellent protection from drywood termites. This type of construction will not, however, prevent infestations of wooden trim and built-in fixtures or of wooden furniture inside the buildings.

INSPECTION

Structures should be inspected annually for the presence of drywood termites. The longer they have infested a building, the more difficult their control. At first their galleries are extended rather slowly and may be easily accessible for treatment. Later they may extend their workings into framing within walls, and control becomes much more difficult and more expensive.

Many of the same principles and procedures discussed under inspection for subterranean termites apply equally for drywood termites. The same equipment is used and the same areas are inspected. There are enough differences in specifics, however, to require some detailed discussion of them. Be sure to record all damage on the outline of the structure as you proceed.

The extent of drywood termite infestation in a building needs to be determined as fully as possible. An appropriate control method can only be chosen when the extent of infestation is known. Unless a general fumigation of the whole structure is planned, the extent of each of the one or more infestations in the building needs to be carefuly delimited for treatment.

Only in this way can less than complete fumigation produce satisfactory control.

■ EXTERIOR INSPECTION

As with subterranean termites, it is important to make an accurate diagram of the structure. Careful measurement of outside dimensions will reduce chances of overlooking inaccessible or hidden portions of the building. It becomes even more imporant to observe the roof structure and any dormers, new extensions, etc., that might not be accessible from the main attic space.

The inspector should move around the structure slowly while observing the sides of the house from roof to ground. The roof eaves, rafters, and trim should be closely observed for evidence of damaged wood, and especially should be checked for fecal pellets dropping from above. Pellets will be too scattered to be observed on the ground, but they are often caught in spider webs and on ledges. It may be necessary to use a ladder to closely observe areas high on the side of the house.

If there is wood siding, it should be carefully examined for areas of damage and for pellets. The same is particularly true for window frames, sills, and sashes, which are quite vulnerable to attack, especially where the exterior of the house is stucco, masonry, or non-cellulosic material. A meter box set into the side of a house should be opened and examined on the interior for the presence of drywood termite fecal pellets.

The foundation of the house needs careful inspection if ventilator openings have wooden frames that might be infested. A wooden access and its frame also should be carefully checked for drywood termite damage. If there is a plumbing inspection door set into the foundation of a slab-on-ground house, open it and inspect for evidence of drywood attack in any wood involved.

■ INTERIOR INSPECTION

The occupant of the house should be carefully questioned as the interior inspection begins. Asking about any areas of damage or suspicious looking areas might well speed up the process of locating termite activity.

Proceed in a logical order when inspecting each room, so that no area is overlooked. Starting at the door, examine it and its frame and trim very carefully for signs of drywood termite damage. Sound it very carefully with the handle of a probe or with your knuckles. Look for fecal pellets that may be in crevices or in more conspicuous places beneath the place where the door stands open, if it is an interior door. Move to the baseboard in a clockwise or counterclockwise direction.

The baseboard on the perimeter walls of houses is a common site of infestation. If there is a wooden floor, examine it carefully as you proceed. Notice whether or not there are any "oddly" placed scatter rugs, tables, etc. If the house is for sale, especially, the owner is not likely to go out of the way to disclose damage. The unusual arrangement may be covering up floor damage. If damage is found in flooring, note its position carefully on the diagram so that, if there is a subarea to be inspected, the underside may be more thoroughly examined. Window sills are an excellent place to look for fecal pellets indoors. Also examine any molding at the ceiling. If there are wood fiber composition ceiling panels, they can be infested, and also should be carefully examined. The evidence may be very subtle and will require very careful inspection. Sound and probe to delimit any infestations discovered.

In the bathroom area, find and remove the plumbing inspection panel. Look inside for drywood termite pellets. The kitchen also requires some special attention. Built-in cabinets are often infested. In addition to examining them externally, remove the drawers and open the doors to look inside. Termites often infest the counter tops on their undersides, so look up as well as for pellets on shelves. Look at the floor covering to see if there is evidence of damaged flooring underneath that may have given way in small areas and left small, irregular depressions in the linoleum or tile. Record any suspicious areas so that they may be inspected on the underside.

Places that are warm, such as enclosures around hot water heaters or trim around wall furnaces, should be very carefully checked for termite activity.

Exposed beams, wood paneling, and parquet flooring are also subject to attack and require special attention.

Wooden furniture and other articles are often the source of infestation indoors. Be sure to examine underneath them for signs of pellets. If a piece of furniture is infested, check the wood floor under it to see if the infestation has moved down into it.

ATTIC INSPECTION

Upon entering the attic, look over the entire area below the roof rafters, ridge pole, etc., for any accumulations of fecal pellets. Move around the perimeter of the building at the junction of the roof rafters and the wall plate. Notice particularly whether there are pellets in this area. Any evidence here probably means the infestation is also in the wall below. Examine all rafters and the ceiling joists below in a pattern that will not allow any to be overlooked. Check the top plates of all partition walls and all support framing between rafters and joists. Use a hammer to sound the wood and a probe to explore suspicious areas for cavities.

Heavy piles of termite pellets can mean that there is extensive termite activity in the area or it can mean that carpenter ants have moved into termite galleries and are removing the pellets to enlarge their nest area. Probe into wood when this condition is found so that the insects involved can be determined.

If portions of the attic are inaccessible for inspection, make a note on the diagram and recommend that access be provided. Inaccessibility can be caused by anything such as roof extensions, firewalls with no access doors, carports, dormers, etc. When a complete attic is inaccessible due to lack of an access opening, determine whether or not there is sufficient space between the roof and the ceiling so that it can be inspected. If so, recommend that access be provided before an inspection report is completed.

Many attics have blown-in insulation between the ceiling joists. This limits the inspector's ability to make a complete inspection and should be noted on the report. Termite pellets can be seen on top of the insulation when they fall from above, so the remainder of the inspection can proceed as usual.

SUBSTRUCTURAL AREA INSPECTION

Inspection of crawl spaces for drywood termites primarily involves examining the sills and joists at the perimeter of the building. Pellets often accumulate on top of the sill or on the soil below.

If the wood floor on the interior of the house is infested, look carefully at the subflooring and the floor joists below it for additional damage.

Basements that are unfinished are inspected much like crawl spaces. If they are finished, they are inspected much like the interior of the house above.

INSPECTION OF GARAGES AND STORAGE AREAS

These areas are particularly subject to drywood termite attack. In California, Ebeling (1975) found that when garage doors are usually left standing open during the day, there is a higher incidence of infestation. As with subterranean termite inspection, stored articles may make inspection difficult. Nevertheless, all exposed wood should be inspected both inside and outside. Wood shelves and cabinets should not be overlooked. Sounding and probing are also needed to confirm and pinpoint infested sites.

CONTROL

The control method to be used for a particular drywood termite infestation is determined primarily by the extent of their activities. If there are only a few infested areas and they do not appear to have been extended into walls, inaccessible parts of the attic, etc., treatment would be quite different than if the infestation is widespread and partly inaccessible.

In the latter case, there is no choice but to fumigate the entire structure, an expensive procedure. Other cases may be treated less expensively, though less effectively, by other methods. Whatever method of control is used, it is advisable to consider treating the attic with desiccating dust to reduce chances of reinfestation.

THE DRILL-AND-TREAT METHOD

If the infestation has been carefully delimited by sounding and probing and it all appears to be accessible to treatment, the drill-and-treat method can provide satisfactory control if the applicator is very skilled and conscientious.

The traditional method involves drilling 1/4 inch (7 mm) holes at 1-foot (30cm) intervals into infested members so that access to all termite galleries is provided (Fig.2-16). An insecticide is then applied into the holes. There are dust formulations of boric acid, silica aerogel, and bendio-carb (Ficam) presently labeled for drywood termite control. Only small amounts should be applied: about 1 ounce (28 cc) of dust is enough to treat 15 to 30 holes. Too much dust will plug the galleries, and they will be walled off by the termites and isolated. The treatment holes are plugged with wooden dowels or corks. This method relies on the habit of grooming among termites.

Through grooming, only a few termites with insecticidal dust on their bodies can spread it to all of the colony.

There are a number of insecticides which can be injected into drywood termite galleries as water emulsions. They include the organophosphate, chlorpyrifos (Dursban); a carbamate, propoxur (Baygon); and three pyrethroids, cypermethrin (Demon); fenvalerate (Tribute), and permethrin (Dragnet).

Chlorpyrifos is also available as a solution in a pressurized container (Whitmire PT 270 Dursban).

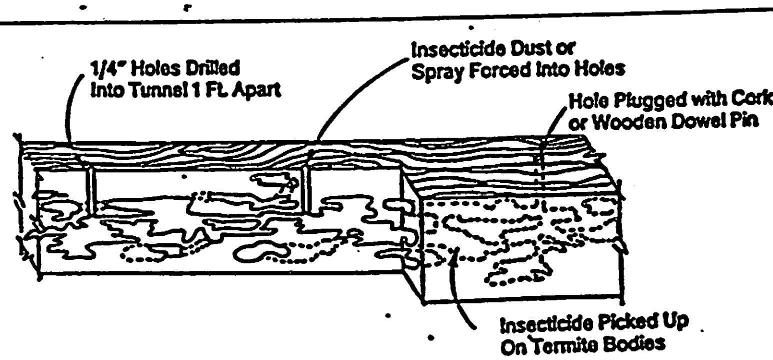
FUMIGATION

Although fumigation is generally recognized as the most effective treatment for drywood termites, there are some negative factors that should be considered. Fumigation is a hazardous procedure and should be undertaken only by experienced and licensed fumigators. It offers no protection against future infestation of the treated structure. It is necessary for the occupants of buildings being fumigated to vacate the premises for at least a day and, in some cases, for several days. Finally, it is an expensive procedure that, in some areas, must be repeated at intervals of 5 to 7 years because of reinfestation.

The basic procedure is to enclose the entire structure in a gas-tight tarpaulin made of nylon fabric coated with rubber, neoprene or plastic. Where fumigations are not performed on a regular basis, tarpaulins are replaced by heavy plastic sheets. The edges of the tarpaulins are rolled together and clamped at close intervals with strong steel clips. The bottom edge is held in close contact with the soil and against the house foundation with sand or with long, slender, sand-filled canvas bags which are called "sand snakes."

Stucco structures with flat roofs are sometimes sealed with special gas-tight paper over

FIGURE 2-16. The drill-and-treat method of drywood termite control.



outer doors, windows and ventilators if the fumigator believes a satisfactory seal can be obtained without the labor of "tarping."

By whatever method the building is enclosed, the exterior wood such as window and door frames, siding and trim must be effectively exposed to fumigant. These exterior members could support small infestations that might not be controlled if the fumigant were applied only to the interior of the building.

The fumigants most commonly used to fumigate structures for drywood termites are sulfuryl fluoride and methyl bromide. They are introduced into structures through long plastic or copper tubes leading from large cylinders of compressed gas. Electric fans circulate the fumigant to prevent stratification. Sulfuryl fluoride is generally used at the rate of 1 lb per 1000 cubic feet (0.45 kg per 28 cu m) of building space and methyl bromide at 2 to 3 lbs per 1000 cubic feet (0.91 to 1.36 kg per 28 cu m). The gas usually remains in the building for 24 hours. The choice of actual dosage and exposure time is based on many factors, such as temperature, air movement, condition of tarpaulins, porosity of the soil under the building, etc. All this means that the knowledge and experience of an expert fumigator is needed to ensure success.

Sulfuryl fluoride has certain advantages over methyl bromide and has become the most widely used fumigant for drywood termite control. It is more penetrating and effective against two of the common termite species (Stewart, 1966; Bess, 1971; and Minnick, et al. 1972) and it has the added advantage that it is not necessary to remove any furnishings from the house during exposure. Methyl bromide costs less than sulfuryl fluoride, but rubber products containing residual sulphur must not be exposed to it. A reaction between methyl bromide and sulfur produces a compound with a garlic-like odor that may persist for years. Foam rubber is the worst offender and it is present in some carpet pads and upholstered furniture. Some kinds of leather are also susceptible, and shoes, for example, must be removed from the building.

In those situations where an entire building is not to be fumigated and there are drywood termite-infested articles in the building, they can be removed and fumigated separately. They either should be wrapped in a gas-proof tarpaulin or placed in a fumigation vault when they are exposed to the fumigant. The rate and duration of exposure are determined by the conditions during fumigation.

■ APPLICATION OF SILICA AEROGEL AFTER OTHER TREATMENT

Following treatment, most termite control technicians recommend attic dusting with silica aerogel to prevent reinfestation (Ebeling, 1975). In cases where termites survive treatment or were not detected for localized treatment, attic dusting provides a means of limiting the spread of surviving colonies. Also, during the swarming season, houses are subject to reinfestation from colonies outside the building. Any wood coated with the silica aerogel film would be protected from new infestation.

■ NON-CHEMICAL CONTROL

Because of public concerns over pesticide toxicity and sensitivity to chemicals, there has been an effort to find alternatives to their use in the control of drywood termites (Hall, 1988). Some of these methods are controversial, but have won over some users in the pest control industry and have been touted in the media.

One of the oldest of these non-chemical methods involves the use of high-voltage, low-amperage electricity applied to wood with a hand-held, AC-pulsing generator called the Electro-Gun. It has been in use since the early 1980s and is said to provide control of drywood termite infestations which are in accessible wood (Beck, 1987), a characteristic shared with the drill-and-treat method. It is also used by fumigators to re-treat local re-infestations.

Forbes and Ebeling have described a system for heating the air inside infested buildings to temperatures that are lethal to insects. Dubbed "thermal pest eradication," it involves blowing 140-150° F air from a portable propane furnace through a flexible duct into the infested building which has been at least partially covered with a tarpaulin. The temperature within the infested wood must reach at least 120° F for thirty minutes and this may take up to six hours. The system has been contracted to Isothermics, Inc. of Anaheim, CA, to provide licensing, training, and consulting services to the pest control industry.

Finally, the other extreme of temperature has been incorporated into a system for freezing termites in wood. Liquid nitrogen is forced into wall and ceiling voids which have been found to contain drywood termite activity through the use of fiber optics. In the Blizzard System, as it is called, liquid nitrogen is applied through small holes drilled into the voids. About 40 minutes later the temperature of the wood has dropped below 0° F, which freezes the termites. Only those areas of the structure which are accessible for inspection and for confining liquified nitrogen are suitable for this control procedure.

DAMPWOOD TERMITES

Prevention of, inspection for, and control of dampwood termites is primarily a matter of following the same measures used against wood decay. Since these termites must maintain contact with damp wood and damp wood decays, it follows that preventing or eliminating dampness in wood will prevent or control dampwood termites.

Because some species of these termites sometimes enter wood through soil, it is helpful to treat the soil as for subterranean termites to prevent their establishment in those locations, primarily in the desert Southwest, where the termites display this habit.

TREE-NESTING TERMITES

Tree-nesting termites can be prevented from entering buildings by treating them in the same manner as recommended for subterranean termites. Inspecting for tree-nesting termites would be very similar to inspecting for subterranean termites, since they build shelter tubes. They do build carton nests indoors occasionally, and these should be looked for. Once they have entered a building, they can be controlled by directly treating the carton nest (indoors or outdoors) with insecticides (personal communication, July 1975, Luis F. Martorell, Professor Emeritus, Department of Entomology, University of Puerto Rico, Rio Piedras, Puerto Rico).

There are at present four formulations of termiticides that may be applied in this way. They include water emulsions of cypermethrin (Demon), fenvalerate (Tribute), and permethrin (Dragnet). Chloropyrifos is available as a solution in a pressurized container (Whitmire PT 270 Dursban).

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CHAPTER 3

WOOD-BORING BEETLES

INTRODUCTION

Beetles, belonging to the order Coleoptera, vary in length in this country from less than 1/25 inch (1 mm) up to about 3 inches (76 mm). Most of those which attack wood in structures are very small, less than 1/4 inch (6 mm) long. There are a few such species that approach 1 inch (25 mm) in length.

All beetles have chewing type mouthparts in both the adult and larval stages. The most characteristic feature of the beetles is the structure of the wings. Most beetles have four wings, with the front pair thickened, leathery, or hard and brittle, usually meeting in a straight line down the middle of the back, covering the thin, membranous hind wings which are folded under the front wings when at rest. The order name, Coleoptera, means "sheath wings" and refers to the characteristic front wings.

Figure 3-1 shows a typical adult beetle with the wings on one side spread to show their structure. Beetles undergo complete metamorphosis during their development. The damage by beetles to wood is primarily done by the larval stage (Fig. 0-2A).

Among wood-boring beetles, the larvae are all yellowish-white with dark mandibles (jaws) and sometimes with other dark areas or structures. This stage is always found inside the wood and is rarely seen, except for the larger species, even when damaged wood is split open.

The order Coleoptera is the largest order and contains about 40 percent of the known insect species. There are more than 30,000 U.S. species in over 100 families. We will be concerned with only a very few of these. There are three families which contain species that all are commonly considered to feed on seasoned wood. Other families have a few species of significance as pests of seasoned wood. Several other families have representatives which damage wood during seasoning and might later be encountered in structures. Still other families have species that do all of their damage to wood before it is seasoned. However, when the wood has been milled and placed into use, the damage done earlier is still visible and must be recognized.

The damage to wood that is done by beetles varies according to the species involved, but all types of beetle damage are different than that done by termites. When beetles have completed their development and have become adults inside of wood, they bore holes to the outside which are known as exit holes or flight holes.

These holes vary in size and shape according to the beetle involved. The real damage to the wood is discovered only when it is exposed by prying or splitting open the surface. In the case

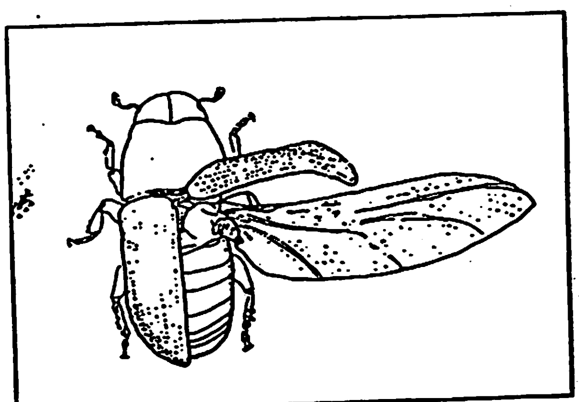


FIGURE 3-1: Typical adult beetle with the wings on the right side spread to show their structure. From Certification Training Manual for Structural Pesticide Applicators edited by R. Kaae and E. D. Young, Kellogg West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

of the more important wood-boring species, there are many galleries of different diameters, running primarily with the grain of the wood. They are most often packed with wood fragments and fecal material called "frass".

Some species of minor importance in structures do not fill their galleries with frass, but leave them clear and push the debris to the exterior through openings left in the surface. The function of wood-boring beetles in nature is the same as that of termites. They help reduce dead wood to a form that can be utilized for new growth by plants.

The amount of damage that might be inflicted to wood by beetles in any given location will vary according to many factors. Some of these factors include the presence or absence of certain beetle types in the area in question, the type of wood (hardwood or softwood), the part of the wood involved (sapwood or heartwood), and the environmental conditions present at the infestation site. As each family of beetles is discussed, these factors will be considered and related to the problem of evaluating the potential damage to the wood in the structure.

There are a number of wood-inhabiting beetles which will not be mentioned. Some of them could conceivably cause minor damage to wood later used in houses or could infest wood in a superficial way after it is incorporated into a house. Adults of these beetles could also emerge indoors from firewood. It is important to concentrate on those beetles which actually cause damage that might lead to structural weakness or which might require replacement of wood for aesthetic reasons. The approach of the author in the following pages will be to describe and discuss the important types that they may be identified as such and their potential for damage determined.

When an inspector encounters beetles or damage that does not fit the descriptions of those discussed here as having economic significance, there should be a reluctance to prescribe any preventive or control procedures until there is confirmation from a reliable source that the evidence encountered does, in fact, indicate a need for action. An example of a reliable source for confirmation would be the entomology department of a state university.

POWDERPOST BEETLES

The most important group of beetles that attack seasoned wood in such a way that preventive and control measures against them should be employed are the powderpost beetles. The term "powderpost" refers to a type of damage in which the inner portion of wood is eventually converted to a mass of powdery or pelleted frass held together by a thin outer shell of surface wood which is itself penetrated by numerous exit holes.

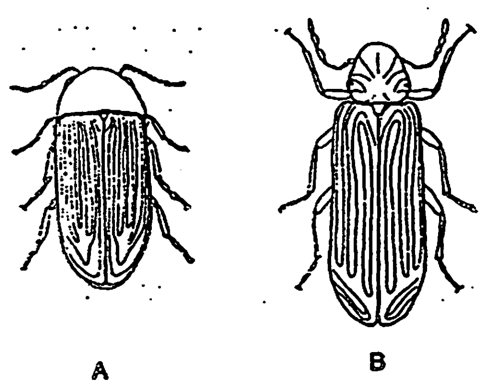
Damage of such an extent usually requires that several succeeding generations of beetles reinfest the same piece of wood. There is no general agreement among specialists in the field as to exactly which beetles should be classified as "powderpost beetles," or even that the term should be used.

The term originally applied to beetles in the family Lyctidae. Later, it became common to refer to beetles in the families Anobiidae and Bostrichidae as powderpost beetles. Their damage is quite similar to that of lyctid beetles. More recently, certain beetles in other families which cause powderposting have also been included. The author has chosen to restrict the term to the members of the first three families mentioned. They will be discussed in alphabetical order, since it would be difficult to assign them any order of economic importance on a national basis.

The lyctid powderpost beetles are sometimes said to be second only to termites in their destructiveness to wood and wood products. That may be true if all types of damage are included. It is not true if the rating is based on damage to wood in houses only.

ANOBIID POWDERPOST BEETLES

Powderpost beetles in the family Anobiidae are often referred to collectively as "death-watch beetles" or "furniture beetles". These are unfortunate choices of names, since they are misleading. Only one species of anobiid powderpost beetle found in structures is truly a deathwatch beetle. The name comes from a superstition that the sound made by the beetles tapping their heads on the wood as a mating signal is a sign that death is near. It is thought to have originated because the sounds are best heard when things are quiet as they would be late at night when someone is staying up with an ill person. The deathwatch beetle has been introduced into this country from England, but it has never become widespread or of much significance. It feeds only on decaying hardwood.



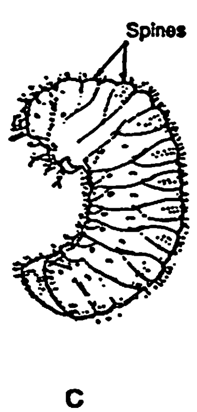


FIGURE 3-2: A. Adult anobiid powderpost beetle common in the eastern part of the country. B. Adult anobiid powderpost beetle common on the West Coast. C. Typical larva of an anobiid powderpost beetle. "A" adapted from USDA: "B" from Forest Insects by R. W. Doane et al. Copyright 1936 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.

THE COMMON FURNITURE BEETLE

The common furniture beetle, *Anobium punctatum*, is also a European species that has been introduced into this country. It has wide distribution but is not of great economic importance here. It is the most common anobiid in buildings in many parts of Europe, Australia and New Zealand. The name "furniture beetle" derives from the fact that in years past they very commonly attacked furniture. This is not so much the case today, even in Europe, where central heating in living quarters dries out the wood in furniture to a level below that which is conducive to beetle development. In this country, furniture is infested much more often by lyctid powderpost beetles than by anobiids.

■ FAMILY CHARACTERISTICS

There are more than 200 species in the family Anobiidae in the U.S. Most of them are woodborers, but relatively few are pests of wood in use. There are two common species, the drugstore beetle and the cigarette beetle, that are important pests of stored products.

The adults of species that are commonly found attacking wood in buildings range from 1/8 inch to 1/4 inch (3 mm to 7 mm) in length. They are elongate and very convex. The pronotum (segment just behind the head) is hoodlike and, when viewed from above, completely conceals the head (Fig. 3-2A and B). Their color ranges from reddish brown to nearly black. Some have short hairs of lighter color covering their bodies. Most have conspicuous grooves and/or rows of pits on their wing covers.

The larvae are grublike, C-shaped and nearly white except for a brownish head and mouthparts. They are rather hairy and have rows of small spines on the top of most segments (Fig. 3-2C). The largest species, when full grown, are nearly 7/16 inch (11 mm) long when extended.

DISTRIBUTION AND ECONOMIC IMPORTANCE

Various species are found in all of the contiguous states as pests of wood in houses. They are not reported as pests in tropical areas. They are rather minor pests in heated, occupied dwellings in most parts of the country, except in the southeastern states, where they are most common. Their prevalence in the Southeast is influenced by the fact that a high percentage of houses in the region have crawl spaces which potentially provide conditions in wood framing which are well suited for anobiid beetle invasion and development. Anobiids are particularly common in the coastal areas where the soil water table and the relative humidity are high, thus allowing the moisture content of the wood to remain relatively high, the importance of which will be discussed later. In general, the drier the climate, the less the problem. One species has been reported as common on the West Coast. In the Northeast, they are primarily found in unheated houses or outbuildings.

It is very difficult to generalize concerning the economic importance of anobiid beetles in the country as a whole. They occur more commonly in some areas than they do in others. Where they have infested a house, no matter what the extent of infestation is, the parts of the infested building that might later be invaded and the amount of damage that might be inflicted is more dependent on factors within the structure than on the environment in general. For that reason, each infestation must be evaluated separately.

BIOLOGY AND HABITS

Some anobiid species will attack both hardwoods and softwoods, others only one type. *Euvrilletta peltata* (Harris) [formerly *Xyletinus peltatus*], although the most common species is southern yellow pine framing timbers in the Southeast, actually prefers hardwoods if given a choice. Anobiids usually feed on sapwood, though heartwood adjacent to sapwood may be damaged. Both freshly seasoned and older wood are attacked. Unlike the other powderpost beetles which will be discussed, the anobiids, according to those studied, can digest the cellulose of wood cell walls with the aid of yeast cells in their digestive tracts. The wood cell contents, such as starches, sugars and proteins, are the more critical nutrients.

The females of anobiid beetles lay eggs on the surface of wood under splinters, in cracks, under debris, or in old exit holes. Relatively few eggs are laid, probably fewer than 50 for most species. There is usually a high rate of survival of the eggs, but many larvae die before they can bore into the wood in order to find food and protection from natural enemies. After the larvae have bored straight into the wood a short distance, they turn at a right angle and begin to tunnel in the direction of the wood grain. They feed first on the softer springwood (early wood) and primarily in the outer sapwood if they have a choice. As the larvae develop, they molt many times. Each time, the tunnel they bore becomes larger to accommodate the increase in size. Often, the tunnels of many larvae intersect and the wood may even become a mass of wood fragments and fecal pellets which are packed in the gallery behind the larva as it tunnels. It usually takes at least 2 or 3 years for the larva to complete its development. If the moisture content of wood is below about 14 percent, or if it has very little food value (low protein or high resin content), the life cycle is prolonged, or development ceases and the larva dies. High temperatures are also unfavorable, both because of direct effect and because they tend to dry out the wood. If the wood is slightly decayed or has a relatively high moisture content, even near the fiber saturation point (30 percent), development goes at its best rate. Dampness and moderate temperatures in crawl spaces or outbuildings are particularly suitable. In nature, they live in dead limbs or bark-free scars on trunks of trees. When larval development is complete, a portion of the gallery where feeding was occurring is enlarged and cleared of frass and pupation takes place, usually in the spring. The adults which develop from the pupae bore holes straight to the surface of the wood and emerge. Most species of anobiids are active as adults during the spring and summer months, with most of the activity occurring during the first half of the warm season of the year. They do not feed, but actively seek a mate and, once the female is fertilized, the cycle is repeated. Most species of anobiids are strong fliers, and the females can move to new sources of food to lay their eggs. In spite of this, a large proportion of the eggs that a female lays are likely to be deposited on the piece of wood from which she emerged. This results in constant reinfestation of wood until little is left except the outer surface, unless something interferes with the beetles' activities.

The adults of some species are active during the day, others only at night. These beetles are not conspicuous and are not likely to be noticed unless they are found around light sources such as on windowsills or in spider webs at foundation ventilators in crawl spaces. Some species are attracted to lights at night.

■ SIGNS OF INFESTATION

The early stages of an infestation—before the emergence of the first generation of adults—are all but impossible to detect by usual methods. Because the development time is long and there is no external evidence of the attack until adults emerge, one or more generations may occur before there is enough evidence to be readily detected. This evidence is powdery frass and tiny pellets which accumulate underneath infested wood or are found streaming from the exit holes (Fig. 3-3A and B). The exit holes are round and vary from 1/16 to 1/8 inch (1.6 to 3 mm) in diameter. If there are large numbers of holes and the powder is bright and light-colored, like freshly-sawed wood, the infestation is both old and active. Sometimes infestations die out naturally, and the frass which remains is yellowed and partially caked on the surface where it lies.

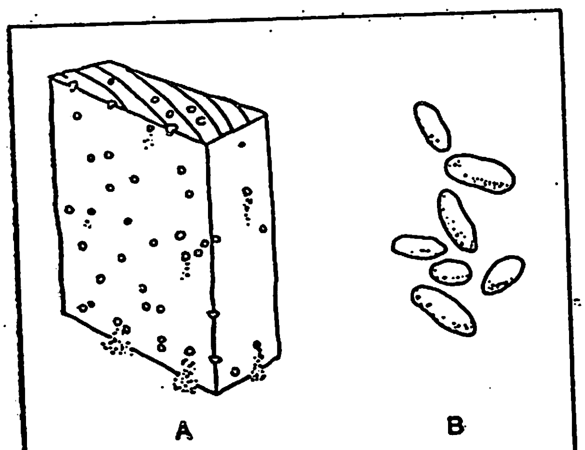


FIGURE 3-3. A. Wood infested with anobiid beetles. B. Enlarged view of fecal pellets of anobiid beetles from Certification Training Manual for Structural Pesticide Applicators, edited by R. Kaae and E. D. Young, Kellogg West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

The pellets are partially digested wood that has passed through the gut. These pellets (Fig. 3-3B) differ from those excreted by drywood termites: they are smaller and they taper toward each end. Some species produce bun-shaped pellets. Two hardwood-attacking species produce no pellets; their damage can be distinguished from that of lyctid powderpost beetles primarily by the fact that their frass is tightly packed in their galleries, whereas that of the lyctids is not.

■ CHARACTERISTICS OF DAMAGED WOOD

Tunneling is most extensive in sapwood, through it may extend into heartwood, particularly if it is partially decayed. In sound timber, damage is most severe in the outer sapwood nearest the bark, due to the higher protein content. Some plywoods are attacked, particularly if they are made with blood or casien glues which provide a source of protein for developing larvae. Synthetic adhesives appear to be toxic to small larvae.

The frass in the galleries is at least loosely packed and does not tend to fall freely from the wood unless the wood has dried out considerably since the attack occurred.

In most heavy infestations there are very tiny round exit holes, about 1/32 inch (0.6 mm) in diameter, scattered over the infested surface.

These are emergence holes of parasitic wasps, the larvae of which feed on the beetle larvae.

POTENTIAL FOR DESTRUCTION

Many factors are involved in determining the amount of damage that can ultimately be expected from anobiid powderpost beetles. The most critical factor in terms of spread of destruction is probably the amount of moisture present in the wood. Basically, the damper the wood, up to the fiber saturation point, the quicker the development. If the early stages of decay are present, damage goes even faster. Because of this, damage is usually greatest in the damper parts of houses. The extent of damage which ultimately could be done depends mainly on the proportion of sapwood to heartwood and, where wood from fast-grown trees is used, structural weakness can result. Most types of chipboard, hardboard and insulating board are not attacked.

Infestations normally increase slowly over the years, and a house is usually 10 or more years old before damage becomes obvious. With the advent of central heating and air conditioning in houses, the potential for serious widespread damage in houses decreased. The heat in the living areas, and that which rises to the attic, tends to dry out the wood of wall and roof framing and of interior trim, etc., as does cooled and dried air. If a house has no problem with excess moisture in the basement or crawl space, has central heating and cooling systems, and does not remain closed up and unoccupied for long periods, widespread, extensive damage by anobiid beetles is unlikely.

BOSTRICHID POWDERPOST BEETLES

The wood-boring species in the family Bostrichidae are sometimes referred to as "false powderpost beetles" or "large powder-post beetles." This is to distinguish them from the lyctids, which were first to be called powderpost beetles. General references designate them as "branch and twig borers" because the natural habitat of these beetles is in dead or dying branches of trees, particularly hardwoods.

FAMILY CHARACTERISTICS

The family Bostrichidae contains many species, the larvae of which bore in wood and cause typical powderpost damage.

The adult beetles are usually reddish-brown to black, the typical species found indoors being 1/8 to 1/4 inch (3 to 6 mm) long. They are elongate and cylindrical. The heads are directed downward and are hidden by the pronotum (segment just behind the head), as in the anobiids. The pronotum is often rather rough and rasp-like on the front edge. The wing covers are concave at the posterior end and, in some species, have projecting spines along the edges of the concavity (Fig. 3-4A). One destructive species is unlike the others and must be described separately. The black polycaon is a cylindrical, coal-black beetle 1/2 to 1 inch (12 to 25 mm) long. Unlike most of the species in this family, the head is prominent and extends forward. The pronotum is oval and not hoodlike and has no rough projections (Fig. 3-4B).

The larvae of bostrichids are grublike, characteristically curved and wrinkled, with the front half larger than the back half. They have six well-developed legs. The head is small and slightly darker than the creamy-white body. The mandibles (jaws) are black. They have few hairs on the upper portions of their bodies. They vary in size according to the species, most being 3/16 to 5/16 inch (5 to 8 mm) long. Figure 3-4C shows a typical example.

DISTRIBUTION AND ECONOMIC IMPORTANCE

Most of the contiguous states have recorded bostrichid species in wood indoors. Although the family has more species in the tropics than in temperate climates, none are serious pests in structures in the Pacific or Caribbean areas. One pest species native to India has become established in Florida and is encountered in imported hard- and softwoods elsewhere. The black polycaon occurs naturally in the West Coast states and, to a lesser extent, the Rocky

Mountain states. It is shipped to other parts of the country in infested wood products.

The economic importance of the bostrichid beetles in houses is much less than that of the other two families. They are most important as pests in hardwoods, and those species that attack wood of conifers rarely cause serious damage. Most of the hardwoods attacked are not those commonly used for interior floors, woodwork, and trim. Many of the species do not reinfest wood after it is seasoned, so the damage is limited to that inflicted by one generation, though that can be considerable.

■ BIOLOGY AND HABITS

Most species in this family breed in sapwood of hardwoods, but a few attack conifers. Some attack freshly cut and partially seasoned woods with the bark on; others attack relatively dry wood. These beetles can digest only the cell contents of wood, primarily starch, so are greatly restricted in the portion of the wood that can be utilized. The outer sapwood is the primary breeding site.

The females of bostrichid powderpost beetles differ from those of the other two families in that they bore into the wood and prepare "egg tunnels" for laying their eggs. The eggs are very slender and are inserted into pores in the wood that have been exposed by the cross-grain tunnel. The adults are active primarily during the summer months. The larvae which hatch from the eggs usually require almost a year to complete their development. As they grow, they molt many times and increase the size of their tunnel each time. The larvae pack the frass very tightly in the tunnel behind them as they feed. Under most circumstances, the larvae complete their development in the spring of the year following the egg laying. The larvae make the pupal cells slightly nearer the wood surface than the feeding galleries. The adults emerge by cutting straight through the surface. The adults feed on the wood as the egg tunnels are being prepared by the females. Mating occurs when the tunnel is partially completed.

Many of the adults are active during day and can be seen crawling over the wood. The black polycaon is active at night and sometimes even becomes a nuisance pest when it is attracted to lights in large numbers.

There are some exceptions to the generalizations on biology given above. Several small species that attack freshly sawn softwoods normally reach maturity in one year, but may require up to 5 years if the wood dries rapidly. They are found primarily when bark edges

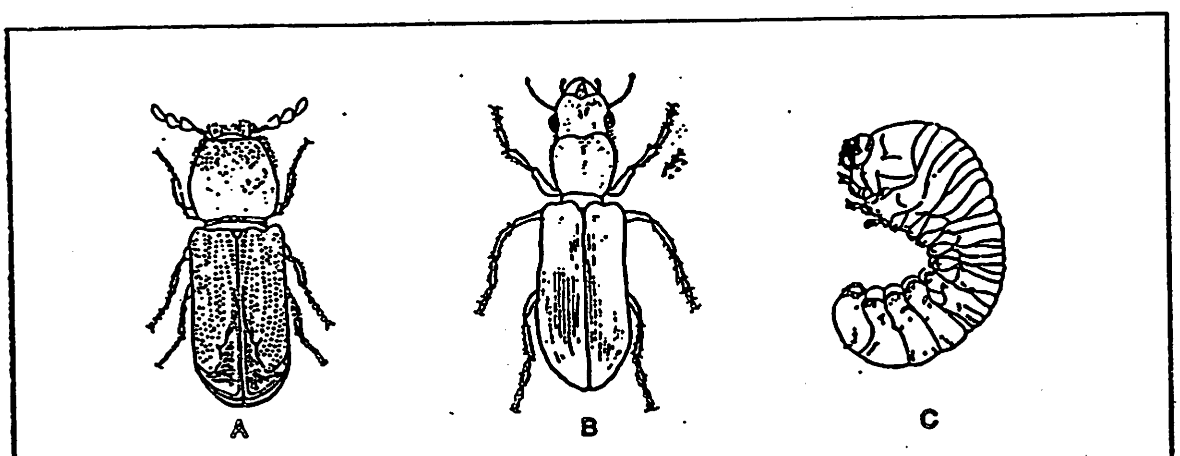


FIGURE 3-4. A. Typical bostrichid powderpost beetle. B. Black polycaon, an atypical bostrichid. C. Typical bostrichid larva. "A" and "B" from Forest Insects by R. W. Doane et al. Copyright 1936 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.

have been left on framing timbers. There are records of the black polycaon emerging from wood 20 or more years after the infested piece was incorporated into a structure (Middlekauff, 1974).

SIGNS OF INFESTATION

The first signs of infestation are the circular entry holes for the egg tunnels made by the females. They may be 3/32 to 9/32 inch (2.5 to 7 mm) in diameter. The exit holes made by adults are similar, but are more apt to be filled with frass. The frass is meal-like and contains no pellets like those found in anobiid frass. It is tightly packed in the galleries and does not sift out of the wood easily.

The adults are not often seen unless there is a very heavy infestation and the inspection is made by coincidence at a time of beetle activity.

CHARACTERISTICS OF DAMAGED WOOD

In addition to the entry and exit holes in the surface, the interior of the sapwood may be filled with very round tunnels of different sizes, from about 1/16 inch (3 mm) up to 3/8 inch (10 mm) in diameter, depending on the species involved (Fig. 3-5). If damage is extreme, the sapwood may be completely consumed. Because of the shorter life cycle of bostrichids, they often cause more extreme damage more rapidly than would an equivalent population of anobiids. They are, however, restricted to the outer sapwood, and damage will usually not extend more than an inch or two into a board. This is usually of no consequence in framing timber, but might require replacement of some flooring or trim.

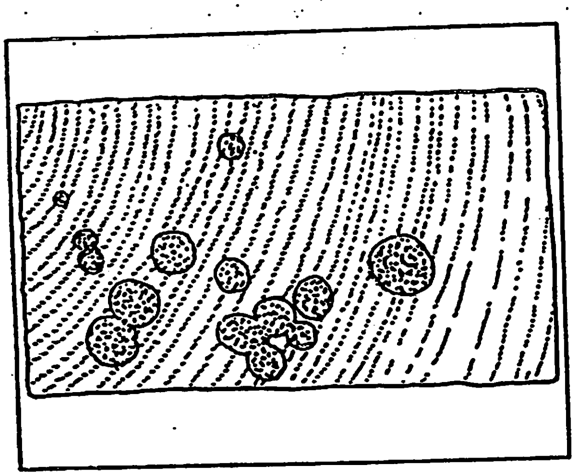


FIGURE 3-5. Damage of the black polycaon. From Certification Training Manual for Structural Pesticide Applicators edited by R. Kaae and E. D. Young, Kellogg West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

POTENTIAL FOR DESTRUCTION

The bostrichids offer very little likelihood of causing serious damage to softwood framing in a home. Because of the speed and completeness of their attack on portions of wood having a high starch content, they might cause serious damage to individual pieces of hardwood flooring or trim. There is little danger of reinfestation after the first generation emerges.

LYCTID POWDERPOST BEETLES

These were the first wood-destroying beetles to be referred to as "powderpost beetles." For that reason, some authors use the term "true powderpost beetles" when classifying them. Some authorities indicate that they are the most destructive of the powderpost beetles occurring in North America. This is true for hardwoods and products made from hardwoods. Lyctids are, however, at present much less important than the anobiid beetles as pests of wood in houses. Problems with the prevention of lyctid powderpost beetles, particularly in imported hardwoods, has led to an increase in the number of infestations in such things as hardwood paneling and trim, as well as in furniture stock, etc. This could lead to a change in their relative importance in houses.

FAMILY CHARACTERISTICS

The classification of the family was revised by Gerberg (1957). He described all 35 native species. Most of them are quite similar in appearance and biology, so that separating them to exact species is not necessary to provide adequate control recommendations. The lyctid beetles are small, slender, somewhat flattened, elongate, reddish-brown to black, and vary in length from about 1/8 inch to slightly over 1/4 inch (3 to 7 mm). The head is prominent and not covered by the pronotum as in the other two families of powderpost beetles (Fig. 3-6A). Mature larvae vary in size but are usually less than 1/4 inch (6 mm) long. They are typical, curved, wrinkled, grublike larvae. They are enlarged at the thorax and have six distinct legs. They have relatively few, light-colored hairs on their bodies. The head is slightly pigmented, and the mandibles (jaws) are darker (Fig. 3-6B).

DISTRIBUTION AND ECONOMIC IMPORTANCE

There are species of lyctid powderpost beetles found in all of the contiguous states and in all U.S. territories. Some are native, and some are established introduced species. Several species are commonly intercepted at seaports in imported wood products.

The lyctid powderpost beetles are not considered to be of any great concern in houses in the Pacific area (personal communication, May 1976, Jonathan T. Kajiwara, Entomologist, Department of the Air Force, CINCPACAF (DEMM), Honolulu, Hawaii) or in the Caribbean region (personal communication, July 1975, Luis F. Martorell, Professor Emeritus, Entomology Department, University of Puerto Rico, Rio Piedras, Puerto Rico.) In the contiguous states they are relatively common in all parts of the country, but probably are of more concern in the South than in other areas.

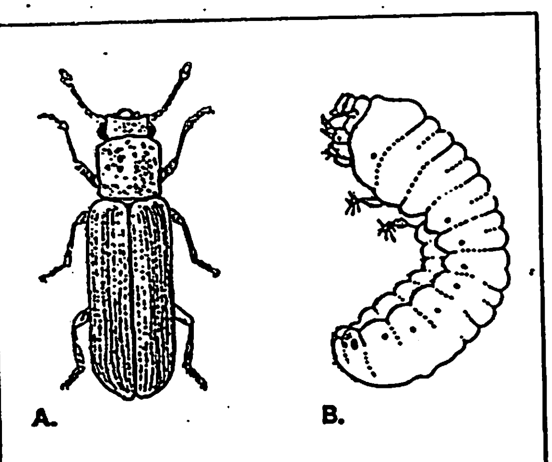


FIGURE 3-6. A. Typical adult lyctid powderpost beetle. B. Typical lyctid larva. "A" from Forest Insects by R. W. Doane et al. Copyright 1936 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.

As indicated in the introductory remarks, lyctid powderpost beetles have been much less of a problem in the past than they might be in the future. The application of knowledge of the habits of these insects to the handling of hardwood lumber and the use of contact insecticides had reduced the lyctid problem to one of comparative unimportance in relation to its status 30 or more years ago (Bletchly, 1967). Because of restrictions on the residual insecticides used to treat stored hardwood products, and because some infested hardwood is being imported, the problem is likely to remain at a significant level. There has been a concerted effort by the USDA Forest Service and university research laboratories (Barnes et al., 1989) to evaluate the potential for borate salts as wood preservatives. Much progress has been made in their use, particularly in treating unseasoned tropical hardwoods. This should eventually reduce the problem.

BIOLOGY AND HABITS

These beetles attack the sapwood of hardwoods only. Ringporous hardwoods such as oak, hickory and ash are most susceptible. Some diffuse porous hardwoods that are often attacked include walnut, pecan, poplar, sweetgum, and black cherry. Many species of tropical hardwoods are also subject to infestation.

Lyctid powderpost beetles attack wood with a moisture content between 8 and 32 percent. This means that they infest partially or wholly seasoned wood (Christian, 1940, 1941). The greatest lyctid beetle activity occurs in wood with 10 to 20 percent moisture content (NPCA, 1961). Most wood within residences would be in this range.

Their chief source of food is starch and other cell contents, such as sugar and protein. The larvae cannot digest cellulose and other components of the cell walls. Lyctids are reported not to lay eggs in sapwood with a starch content less than 3 percent, and the greater the starch content, the better they thrive. The females taste the wood to test its suitability.

The amount of starch in wood depends on the tree species involved, the season the tree is cut, and the method by which the lumber is dried. Kiln-drying retains more starch than air-drying. Also, the older the wood, the lower the starch content. If given a choice, females lay their eggs on recently dried wood.

The female places her eggs inside the springwood vessels or pores. These are exposed when the wood is sawn, or the beetle may open them by cutting across the grain of the wood surface. Some species have also been reported to deposit eggs in cracks or crevices. Most species lay an average of 20 to 50 eggs. When they hatch, the larvae bore down the vessels at first, enlarging the tunnels as they grow. The tunnels are straight and with the grain at first, but later become more irregular and often intersect other tunnels. The mature larva bores to a point just under the wood surface and forms a pupal chamber. The pupal stage completed, the adult beetle cuts its way to the surface, forming a circular exit hole. Some of the very fine, flour-like frass produced by the larva is pushed out as the adult emerges.

The greatest period of adult activity occurs in late winter or early spring. The adults conceal themselves in cracks and holes in the wood during the day and become active at night. They are strong fliers and may be attracted to lights. Indoors, they may be seen crawling on windowsills, floors, furniture, and other surfaces.

The entire life cycle for most species requires 9 to 12 months. One common native species routinely completes a cycle in about 4 months. Any of them will develop more quickly if temperature, moisture and starch content of the wood is favorable.

■ SIGNS OF INFESTATION

Wood which has been infested only a short time will show no external evidence of beetle attack. If the first generation of adult beetles has emerged, there will be circular exit holes on the surface which are 1/32 to 1/16 inch (0.8 to 1.6 mm) diameter, depending on the species of lyctid and on the nutritive value of the wood: a given species will grow larger in wood with high starch content than it will in wood with little starch. The presence of small piles of fine flour-like wood powder (frass) on or under the wood is an even more conspicuous evidence of infestation (Fig. 3-7). Even a slight jarring of the wood makes the frass sift from the holes. There are no pellets as in the anobiids, and the frass falls easily from the wood rather than being packed in as in both the anobiids and bostrichids.

It is not likely that the adult beetles will be seen by an inspector, unless dead ones are found on window sills or in spiderwebs. The larvae are, of course, always inside the wood.

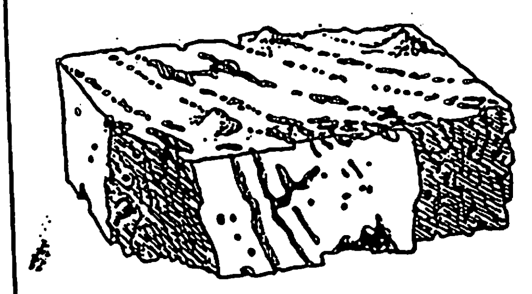


FIGURE 3-7. Wood damaged by lyctid powderpost beetle. From Certification Training Manual for Structural Pesticide Applicators edited by R. Kaae and E. D. Young, Kellogg West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

■ CHARACTERISTICS OF DAMAGED WOOD

The sapwood of infested wood has longitudinal, cylindrical galleries of various sizes, most of them about 1/16 inch (1.6 mm) in diameter. They are loosely packed with fine frass that falls freely from the wood when it is split open. If the damage is severe, the sapwood may be completely converted to frass held in by a very thin veneer of surface wood with beetle exit holes in it.

In heavy infestations there may be circular holes in the wood surface even smaller than the adult exit holes. This indicates that small wasps which are parasitic on the beetle larvae have also emerged.

■ POTENTIAL FOR DESTRUCTION

The amount of damage that an infestation of lyctid powderpost beetles can inflict is based on several factors.

The extent of infestation and subsequent damage is proportional to the starch content of the sapwood. Since heartwood is practically free of starch, it is immune.

The width of the sapwood portion of a given piece of wood will, within the limitations of the starch content, determine how much of the wood might ultimately be destroyed.

The diameter of the pores or vessels in the wood can also be a limiting factor. If they are not large enough to allow the female to insert the eggs, no infestation is likely to result. Several common lyctid species have structures for inserting eggs (ovipositors) that range from 0.076 to 0.083 mm in diameter. Hardwoods with pores having diameters greater than these are subject to attack. If the wood has had any type of coating or finish applied which closes the pores, it is not likely to be infested or reinfested. Softwoods do not have pores and usually have a low starch content, so they are essentially immune to infestation.

ROUND-HEADED BORERS

The round-headed borers belong to the family Cerambycidae, one of the largest and most important families of wood-boring beetles. More than 1,200 species have been recorded in the United States.

The larvae of all but a few members of the family live as borers in the tissues of trees and other woody plants. Species that feed under the bark of living trees may weaken and kill them, or cause defects and stains which seriously degrade lumber values. Species that attack recently felled trees, logs, or seasoned lumber also cause heavy losses.

■ FAMILY CHARACTERISTICS

The adults vary considerably in length: those encountered in seasoned wood from about 1/3 inch (8 mm) up to 2 inches (50 mm) or more. They are elongate, and usually more or less cylindrical in cross-section (some are flattened). The antennae are long, sometimes much longer than the body, giving rise to the common name "long-horned beetles." The

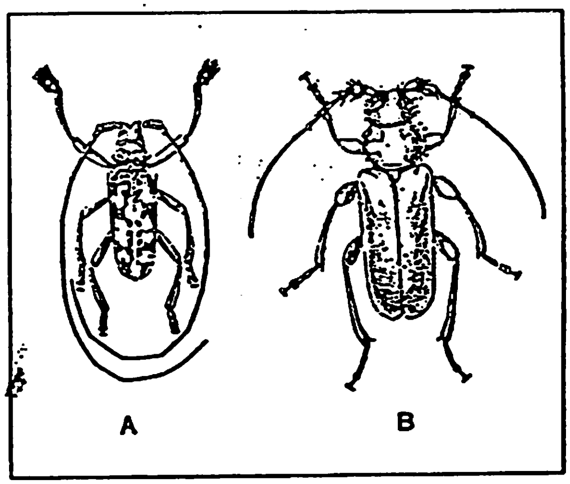


FIGURE 3-8: A. A typical sawyer. Several similar species attack coniferous wood in most parts of the country. B. The black-horned pine beetle, a blue-black species found on the West Coast. Similar species are found in other regions. Another common species, the newhouse borer of the western states, is slightly more slender and black in color. "A" and "B" from Forest Insects by R. W. Doane et al. Copyright 1936 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.

coloration of those attacking softwoods is often rather drab and unattractive (Fig. 3-8 A and B). Some species attacking hardwoods are brightly colored and conspicuously marked.

The larvae are thin-skinned and whitish to cream-colored. They are long and narrow and very markedly segmented (Fig. 3-10B). They have been described as resembling the corrugated hose of a gas mask. The front part of the body is never abruptly and conspicuously larger than the rest and they are straight, never C-shaped like the powder-post beetle larvae. When full grown, they vary in length, according to the size of the adult, from 3/8 inch (9 mm) to over 2 inches (50 mm). The head is usually partly withdrawn into the first thoracic segment and is inconspicuous except for the dark brown jaws. Many of the larvae are legless, but some have three pairs of very tiny legs on the three segments of the thorax.

DISTRIBUTION AND ECONOMIC IMPORTANCE

Species in this family are in all of the states and in all of the U.S. territories. It is important to understand, however, that they are not all of economic importance, nor are representatives found attacking wood in houses in all of these areas.

The actual economic losses to wood caused by round-headed borers is probably greater from the downgrading of hardwood lumber than from these borers' attack on softwoods. Very often their attack on framing lumber is of little importance and does not restrict its use to a great extent. This is related to the fact that most species cease their attack on wood after it is seasoned and do not usually cause enough damage during their development in the wood to render it structurally weak. Borer-damaged wood quite often is classified as utility grade and is used with no problems.

The evidence of the past beetle attack remains in the wood and must be identified as such when structural timbers are inspected. There are some species which begin their development in dying trees, logs or unseasoned lumber (particularly if the unseasoned lumber has any bark edges left on it) and are able to complete their development as the wood seasons. The adults of these borers will emerge from the wood after it has been incorporated into a structure. They will not reinfest the wood because of its dryness, but they are of great concern to property owners who find them or evidence of their activity. It is not uncommon for the adults of various species to emerge from firewood logs brought indoors. Sighting of these adults can lead to a false impression of structural attack.

One of the most common sources of non-reinfesting round-headed borers in structural timbers is lumber sawn from fire-, disease-, or insect-killed trees. Very often the salvaging of such trees cannot proceed rapidly enough to prevent the invasion and partial development of round-headed borers. If this wood is not kiln-dried, the beetles can be distributed to any location where the wood is shipped for consumption. Because kiln-drying reduces the weight of wood, any that is to be shipped long distances is usually dried and thus rendered free of insects.

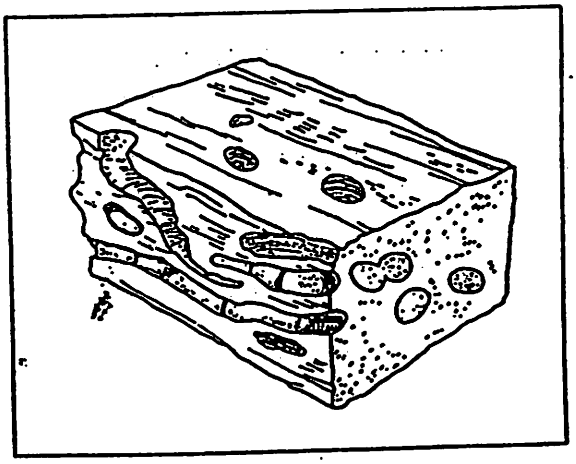


FIGURE 3-9. Round-headed borer damage. From Certification Training Manual for Structural Pesticide Applicators edited by R. Kaae and E. D. Young, Kellogg West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

GENERAL BIOLOGY AND HABITS OF FAMILY

The eggs are laid singly or in small groups on or in the bark during the spring, summer, or early fall. The eggs hatch within a few days, and the larvae begin feeding in the wood. Many species feed extensively directly under the bark before descending into the sapwood and, in some cases, the heartwood. The larval stage may last from a few months to several years. It is always prolonged if the wood has been cut into dimension lumber, which dries more rapidly. The pupal stage is passed in a cell near the surface, and the adult chews its way straight out of the wood.

The time of emergence varies with different species. It can occur outdoors any time from early spring to fall. Indoors, the climatic conditions are so different that emergence might occur at almost any season. Outdoors, the adults would mate, lay eggs, and die. Indoors, there are only two species that can reinfest dry, seasoned wood. They will be discussed separately and in more detail.

SIGNS OF INFESTATION

When long-horned beetles emerge from wood, they make slightly oval to nearly round exit holes (Fig. 3-9). If the points of exit are covered by building components, long-horned beetles will cut through such materials as plasterboard, hardboard, hardwood flooring, insulation, roofing felt and shingles, plywood, etc.

The size and shape of the holes varies with the species: they can be from 1/8 inch (3 mm) to as much as 3/8 inch (9 mm) or more in diameter. The sawyers (Fig. 3-8A) make almost circular holes from about 1/4 inch to 5/16 inch (6 to 7.5 mm) in diamater. The species of more flattened cross-section, such as the black-horned pine borer (Fig. 3-8B) and the new-house borer, make oval holes about twice as wide as high, the widest diameter being about 1/4 inch (6 mm). In some cases, there is coarse, even stringy, frass in evidence inside or around the exit holes.

Very often, the infestation is not active in structural timbers: the only evidence of infestation is the galleries which have been cut through when the wood was sawed and planed. Because they may have been cut at oblique angle, some of the galleries may appear to be quite elongate-oval in cross section. Some may have been sawed lengthwise. The diameter in true cross-section will vary with the age of the larva that made the gallery and with the species involved. Some of the larger ones are nearly 1/2 inch (13 mm) across. Tightly packed, rather coarse frass may be present in the exposed galleries. At other times the galleries are free of frass because it was loosely packed and has fallen free of the wood.

CHARACTERISTICS OF WOOD DAMAGED BY NON-REINFESTING ROUND-HEADED BORERS

The damage is known in the lumber trade as "worm holes." The galleries wind irregularly from directly below the bark into the sapwood. Many common species attacking softwoods feed primarily in the outer sapwood, and damage is not severe. The frass produced by the larvae is packed into the galleries once the feeding has proceeded below the wood surface. If bark edges have been left on lumber, there often is much frass in evidence underneath. The texture of the frass varies from rather fine and meal-like in some species to very coarse and almost excelsior-like in other species. Figure 3-9 shows the sort of damage that is typical.

POTENTIAL FOR DESTRUCTION

The amount of damage that can be expected from non-reinfesting round-headed borers is usually not significant. Most of the damage occurs before the wood is sawn and ceases almost immediately when the wood dries. Several common species that often infest wood being salvaged from fire- or insect-killed trees do survive the processing of the wood and will continue to develop for a year or more after the wood has been utilized.

The amount of structural damage that they inflict during this time is not enough to require any treatment. The major problem that they cause is the production of exit holes when they emerge. If they happen to be in roofing, then rain leaks can result. Otherwise, little serious destruction occurs. Most of these beetles will emerge during the first year to 18 months of a house's existence. There are a few rare exceptions to this rule that might result in emergence many years after construction.

ROUND-HEADED BORERS THAT WILL REINFEST

"The old house borer [*Hylotrupes bajulus* (L)] probably ranks next to termites in importance as a pest of buildings in the eastern United States." That introductory sentence of an article on this species (St. George, 1957), published more than three decades ago, probably is still true so far as the coastal states are concerned. This quotation does not refer to actual damage inflicted on wood in houses, but to the frequency with which it is encountered. As its name implies, the old house borer attacks well-seasoned coniferous wood found in old buildings, but also attacks relatively unseasoned pine and other coniferous construction material. It does not attack hardwoods.

CHARACTERISTICS

The adult beetle is 5/8 to 1 inch (16-25 mm) long, slightly flattened, brownish-black in color, with many gray hairs on its head and the fore part of the body. The hairs are easily rubbed off. The pronotum (segment just behind the head) has a shiny ridge down the middle and a shiny raised knob on each side, giving it the appearance of a face with a pair of eyes. The wing covers sometimes bear four patches of gray that form two indistinct cross bands or spots (Fig. 3-10A).

The larva is a typical round-headed borer up to 1-1/4 inch (31 mm) long (Fig. 3-10B). There are three black eyespots (ocelli) in a row on each side of the small head (Fig. 3-10C). The eyespots can be seen with a hand lens, and will separate this species from others of similar appearance. The other species found boring in softwoods have no more than one eyespot (ocellus) on each side.

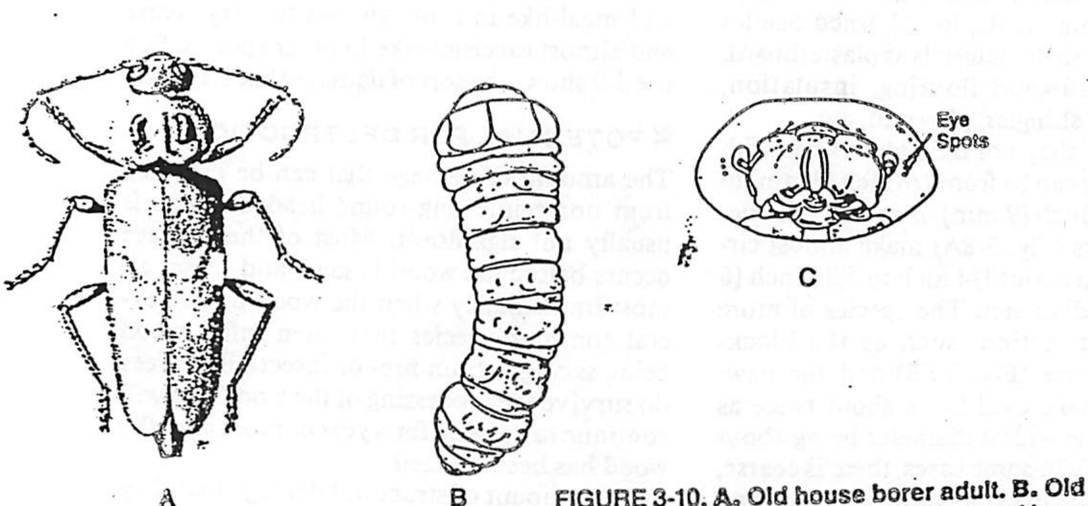


FIGURE 3-10. A. Old house borer adult. B. Old house borer larva. C. Closeup of head of larva, showing eye spots. Courtesy N.C. State University.

DISTRIBUTION AND ECONOMIC IMPORTANCE

Thought to have originated in North Africa, the species has spread to many parts of Europe, South Africa, New Zealand, Australia, South America, China, and the eastern half of the United States. An August mean temperature of about 73 degrees Fahrenheit (23 degrees Celsius) is an important factor favoring the development of the old house borer, and might be a useful criterion in predicting the future distribution of the beetle in North America (Anonymous, 1967).

The heaviest infestations occur in the states on the Atlantic seaboard, particularly the mid-Atlantic states. Since the old house borer is easily transported in infested articles, there is no reason to believe that it could not become established in the western part of the country. Its climatic requirements are such that it is not likely to become a pest in the tropics. It is strictly a pest of structures and, although it is found in barns, fence posts, and rustic buildings, it has not yet been found in logs or stumps.

It is very difficult to establish the economic importance of the old house borer. Although it is very common, particularly in new construction on the East Coast, the amount of actual damage that it does in houses is limited in most cases. It is not uncommon to find that only a few boards are infested in an entire house. The old house borer is also commonly found in untreated pine logs used in constructing log houses. Sometimes, many logs are thus infested. There is much evidence to indicate that in heated, well-ventilated, occupied dwellings the chance of reinfestation beyond the first generation is rare. Unfortunately, this is not widely recognized, and a great deal of unnecessary treatment, particularly by fumigation, is performed.

BIOLOGY AND HABITS

The eggs are laid in cracks and crevices in wood. Stacks of lumber are ideal sites. A female can lay 150 to 200 eggs, but 40 to 50 is probably nearer the average. The larvae hatch in about 2 weeks. They may crawl over the surface of the wood until they find a suitable point of entry. The young larvae feed near the surface for the first part of their lives, but penetrate deeper into the sapwood as they grow. The wood has the highest protein content near the bark. A minimum of 0.2 percent protein is required for development of old house borer larvae; the higher the level, the faster they develop.

The deeper portions of wood have little protein, and the older the wood becomes, the lower the protein content. Consequently, the greatest damage is in the outermost sapwood of new wood. Heartwood is not attacked. Pine generally has a higher protein content than spruce and fir, and so is more often attacked. The length of the larval period may be as short as 2 to 3 years in the southern part of its range but is very commonly 3 to 5 years. In areas north of Washington, D.C., the larvae usually require 2 to 3 years longer to develop. In very dry wood, such as in attics, it may take 12 to 15 years for one generation.

The larvae can digest the wood cell walls (primarily cellulose) as well as the cell contents (mostly starches, sugars, and proteins). Unlike the anobiid beetles and termites, they do not require the help of yeasts or protozoans in their guts. Wood that has been decayed by some species of fungi will be attacked by old house borer larvae (Becker, 1968). This does not apply to all species of fungi, and the larvae do not require fungal attack on wood before they will infest it.

The moisture content of the wood plays an important role in the speed of development. At moisture contents below 10 percent, the larvae develop very slowly, and it is doubtful that newly hatched larvae can survive. They develop most rapidly at moisture contents in the range of 15 to 25 percent.

Pupation occurs near the surface of the wood in spring. Adults sometimes remain in the wood for extended periods before they emerge. Their flight season extends from April to October in the South and from June to September in the North. The greatest adult activity is in June and July in most areas. The adults are strong fliers and are capable of spreading infestations from one building to another.

SIGNS OF INFESTATION

Infestation is all but impossible to detect in its early stages. The larvae are small and develop rather slowly for the first year. Since there are no external signs of infestation, infested wood is often used in construction.

As the infestation progresses, the larvae can be heard boring in the wood. They make a rhythmic ticking or rasping sound, much like the sound of a mouse gnawing. They seldom break through the surface, even though the interior of the wood may be severly damaged.

In severe infestations the frass, which is packed loosely in the tunnels, occupies a greater volume than the wood from which it was produced. When it is in tunnels near the surface of the wood, the thin surface layer may bulge out, giving the wood a blistered look. These "blistered" areas are best discovered by shining a light parallel to the surface.

When enough time has passed for the adults to have emerged (3 to 5 years in the South, 5 to 7 years in the North), there may be small piles of frass beneath or on top of infested wood. The frass is composed of very fine powder and tiny, elongate, blunt-ended pellets that often split lengthwise when dry. The exit holes made by the adults are oval 1/4 to 3/8 inch (6 - 10 mm) maximum diameter. They are not easily seen on dark or discolored wood. The holes may be made through a number of building components, including hardboard, plywood, siding, trim, plasterboard, hardwood flooring, etc., when adults emerge.

The adult beetles may be found in spider webs and on surfaces near light sources such as window sills and at ventilation openings in attics or crawl spaces. Live adults are rarely numerous enough to be seen by an inspector.

If the wood surface is probed with a sharp instrument, internal damage can be exposed. The larvae may be found when they are in the later stages of development and have reached a size which is more than 1/2 inch (12 mm) long.

CHARACTERISTICS OF DAMAGED WOOD

Damage is most often found in wood framing in crawl spaces, basements, and storage areas in the southern portion of the beetles' range. In northern areas, it is more commonly found in attic framing. The sapwood may be completely reduced to powdery frass, with the outer veneer of wood left paper thin by the larvae. The galleries are loosely filled with the frass, which falls freely from the wood when the surface is pried away. The surfaces of most galleries have

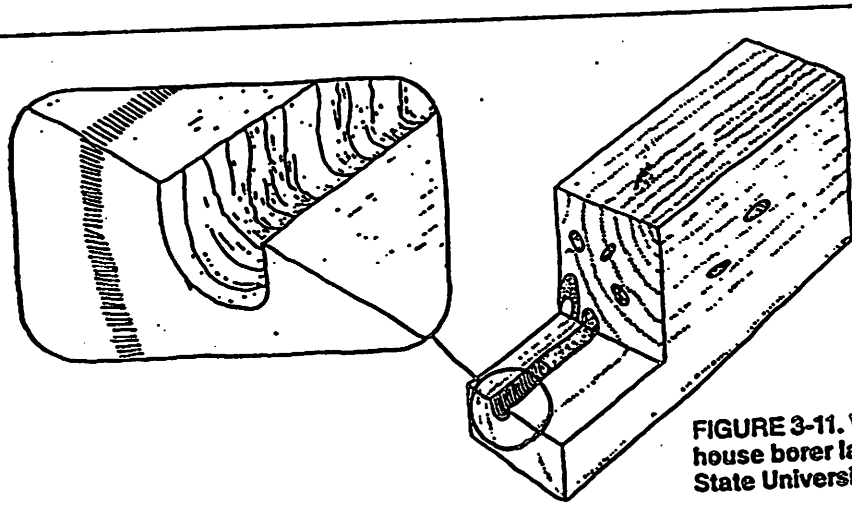


FIGURE 3-11. Wood damaged by old house borer larvae. Courtesy N.C. State University.

a very distinctive feature. They have a rippled pattern like sand over which water has washed (Fig. 3-11). Most other wood borers do not make such marks on gallery surfaces. Any marks that resemble those of the old house borer are much more coarse, and any frass that occurs is not of the same type as that produced by old house borer larvae. The galleries are oval in cross-section and may be up to 3/8 inch (9 mm) in their broadest dimension.

■ POTENTIAL FOR DESTRUCTION

The amount of damage that old house borers can cause in a structure varies with many factors.

If the building is centrally heated, has no moisture problems resulting from poor drainage or ventilation, and does not stay closed up and unoccupied for long periods, there probably is very little chance that an infestation will get any worse than it was when first discovered. As indicated previously, it is most common for only a few boards in a house to be infested. The larvae may live for many years in the dry wood.

The periodic emergence of adults through plaster, flooring, or siding may cause concern. Other than the nuisance which they create by the gnawing sounds of the larvae and the few holes made by the adults, old house borers are often no real economic concern. An exception to this occurs when the adults emerge through outdoor surfaces of logs in pine log houses. This may allow entrance of rain water that leads in some cases to serious decay problems.

In portions of houses that may have a high enough humidity to allow reinfestation of the beetles after the first and subsequent generations, serious damage can result. Since virtually all sapwood of infested boards may be disintegrated, the extent of structural damage caused depends upon the proportion of sapwood to heartwood. In small-dimensioned timbers where the amount of sapwood is extensive, structural collapse may occur in time. This sort of serious damage is most likely to occur in unheated storage areas, recreational structures which are intermittently occupied and rarely heated for long periods, or in occupied structures where structural members have relatively high moisture content because of moisture problems, and/or heating inadequate to dry out the framing timbers.

FLAT OAK BORER

The flat oak borers are much less common and of much less economic importance than the old house borers. Since they can infest dry wood in houses, however, it is important that they be recognized.

The adults are small, elongate, flattened, dull yellowish, shiny beetles about 1/3 to 2/5 inch (8 to 10 mm) long (Fig. 3-12). The larvae are typical round-headed borers that reach a length of about 1/2 inch (12 mm). They have very tiny legs and a smooth white triangular arch on the underside of the first segment of the thorax. The larvae excavate long, meandering tunnels in dry oak and hickory. The tunnels, which may be in heartwood or sapwood, are about 1/8 inch (3 mm) in diameter and are tightly packed with fine, granular frass. The larvae may continue to feed in the wood until it is riddled.

The species occurs in the entire eastern United States from New York to Florida to Texas. They often attack stored lumber and

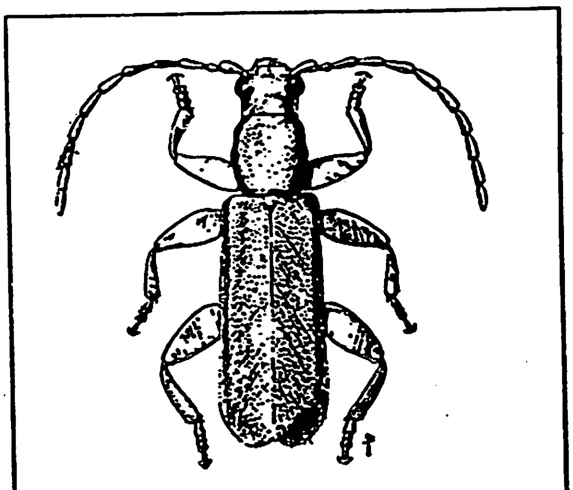


FIGURE 3-12. Adult of flat oak borer. Adapted from USDA.

have caused serious damage in several places, especially in the Gulf States.

The adults are active in mid to late summer, laying eggs in crevices of exposed wood. There normally is one generation per year in green logs under natural conditions. In dry wood, several years may be required to complete one generation.

The significant thing to keep in mind is that flat oak borers attack the heartwood of oak, as well as the sapwood. Their frass is granular and not fine like flour as is the frass of the lyctids. Although some anobiids will attack oak heartwood, their frass contains distinct pellets which will distinguish them from either of the other two types of beetles.

FLAT-HEADED BORERS

The flat-headed borers belong to the family Buprestidae. This is a very common type of wood-borer, more than 150 species and varieties having been recorded east of the Mississippi River alone.

The larvae of all species are borers in trees. Some mine leaves, twigs, branches and roots. Most of them excavate winding tunnels in inner bark, and some of the more important species tunnel through sound and decaying sapwood and heartwood. These wood-boring species are highly destructive to newly cut logs and can seriously reduce the logs' value as lumber. Attack in dry wood is not common.

■ FAMILY CHARACTERISTICS

The adults vary in length: those encountered in seasoned wood from about 1/4 inch (6 mm) up to 1-1/3 inches (33 mm) or more. They are boat-shaped and somewhat flattened (Fig. 3-13). Many are beautifully marked or metallic colored. For this reason, adults often are referred to as "metallic wood borers." The wing covers usually are ridged or roughened. Those that are found in softwoods in structures are usually dark-colored but have a metallic sheen, partic-

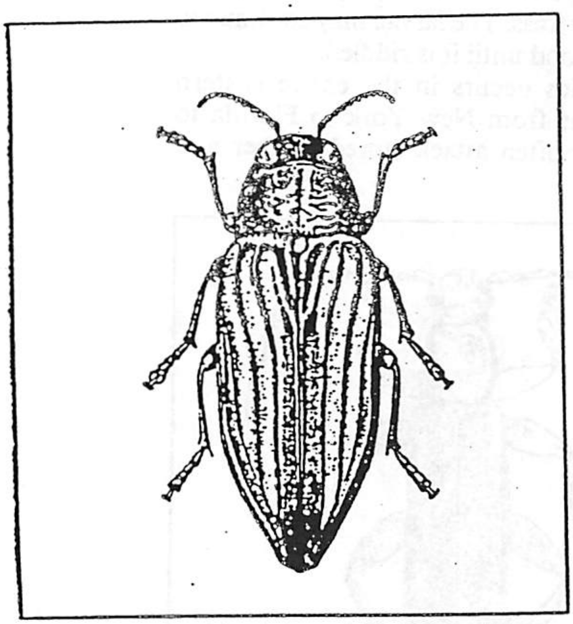


FIGURE 3-13. Adult of the golden buprestid, a typical flat-headed borer. From Forest Insects by R. W. Doane et al. Copyright 1936 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.

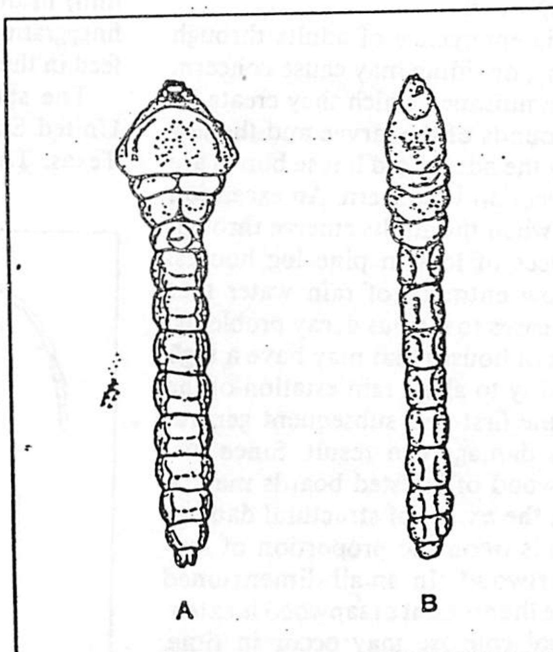


FIGURE 3-14. The larva of the golden buprestid, a typical flat-headed borer A. Top view. B. Side view. Adapted from USDA.

ularly on the underside.

The larvae are distinguished by the well developed, flattened plates on the upper and lower surfaces of the prothorax (first segment behind the head). They are whitish to yellowish, have no legs, and their abdominal segments are much smaller than those of the thorax (Fig. 3-14). The flattened area behind the head has led to the common name "flat-headed borers," though the head itself is small and retracted into the prothorax. When full grown, they may reach a length of 1 to 2 inches (25 to 50 mm), depending on the species.

■ DISTRIBUTION AND ECONOMIC IMPORTANCE

Species of this family are found in all the contiguous states and in the tropics. There are, however, only a few species that are of concern in structures. Even fewer species are active after wood has become seasoned, and they rarely emerge within buildings. Wood that has been previously damaged by the larvae is used as structural timbers, however, and the flat-headed borer must be recognized for that reason.

This is especially true when the lumber has been sawn from trees salvaged after forest fires, windstorms, or bark beetle infestations.

One species common in the eastern half of the United States is *Buprestis lineata* (F.). This species has been found frequently in untreated pine logs used in log homes.

■ GENERAL BIOLOGY AND HABITS OF THE FAMILY

Bark- and wood-boring buprestids deposit their eggs in crevices in the bark or wood or under the bark at the edges of wounds. Weakened, injured, dead or dying trees are usually attacked. The young larvae that hatch from the eggs bore first under the bark and then into the sapwood or heartwood or both. Most require 1 to 2 years to complete their development.

When *Buprestis lineata* has infested logs used in a log house, they may continue to develop and emerge up to five or six years after

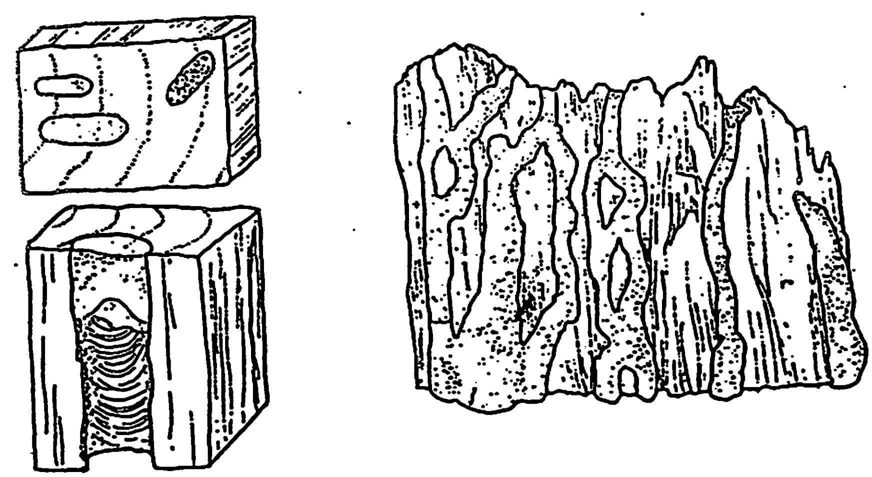


FIGURE 3-15. A. Flat-headed borer damage in wood. B. Flat headed borer tunnels under bark. From Certification Manual for Structural Pesticide Applicators edited by Kellog West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

the house was constructed (unpublished research by author). The larvae construct an elongate pupal cell near the surface of the wood. The adults cut their way out upon completion of development. There may be adults present at any time during warm weather. Upon emerging, they feed, mate, lay their eggs and are dead by the end of the season.

■ SIGNS OF INFESTATION

Wood that has been damaged by flat-headed borers is most often sawed after the damage has occurred. For this reason, the galleries are cut at oblique angles, and their cross-sections are distorted. The exact characteristics of such damaged wood will be discussed in the next section.

Exit holes made by the adults in the surface of the wood are sometimes present. They are elongate-oval, much like the exit holes made by some of the flattened long-horned beetles, such as the old house borer.

When bark edges have been left on structural timbers, the flat-headed borers will continue to develop until the wood becomes too dry. The borers can be heard chewing under the bark in houses that are only a few months old. When their activity has ceased, only the frass which they produce is found, tightly packed under the bark.

■ CHARACTERISTCS OF DAMAGED WOOD

Wood damaged by flat-headed borers has winding tunnels that are extremely flat, three to four or more times as wide as high (Fig. 3-15A). The tunnels are very tightly packed with layers of sawdust-like borings and pellets, and their walls are scarred with fine, transverse lines. The frass is somewhat like that of some round-headed borers, but the galleries are much more flattened. The tunnels of round-headed borers are no more than two to three times broader than high, and the frass is less tightly packed.

The galleries under bark edges left on structural timbers are serpentine and wander over the surface of the outer sapwood (Fig. 3-15B). They are packed with a mixture of light, wood-colored frass and brown, bark-colored frass. Western red cedar shakes and shingles sometimes have holes or tunnels made by the western cedar borer. The damage occurs before the manufacture of the shakes and shingles and will not increase.

■ POTENTIAL FOR DESTRUCTION

There is no danger of serious damage to structural timbers from the flat-headed borers. They usually have completed their development before the wood is sawed, and their damage is evaluated at the time the wood is graded. Those that might remain active in the wood rarely cause any significant additional damage. The exit holes cut by the adults may allow water to enter through siding or trim that is penetrated. Although their damage to untreated logs in pine log houses is not serious, *B. lineata* do allow the entrance of rain water into their tunnels through exit holes and this has led to some serious decay problems. Occasionally, the adults emerge through roofing materials and cause leaks. They also can emerge on the inside of houses through hardwood floors, plasterboard, etc. Since very few adults emerge, the potential for this type of damage is very low.

GOLDEN BUPRESTID

One species of flat-headed borer of relatively minor economic importance should be discussed in more detail. The adults are among the most beautiful beetles encountered in structures. Therefore, they attract much attention when found. Also, these beetles are of special interest because of their extremely long life cycles in structural timbers. The golden buprestid species occurs in the Rocky Mountain and Pacific Coast states.

The adult golden buprestids are about 3/4 inch (20 mm) long and metallic green or blue-green in color (Fig. 3-13). When full grown, the whitish larva is about 1-1/2 inch (35 mm) long. Across the wide, flattened thorax, it is about 3/8 inch (9 mm; Fig. 3-14).

Adult beetles lay eggs on trees that still bear bark. They are attracted to pitchy wood, and often lay eggs on fire scars. They sometimes lay eggs in cracks of freshly sawed lumber. Douglas fir is the preferred host tree, but golden buprestids have also been found in several species of pine, spruce and fir, and occasionally have been found in western red cedar.

Upon hatching from the eggs, the larvae bore into the wood, excavating a winding tunnel that increases in size as the larva grows. The tunnels are typically oval, up to 3/8 inch (10 mm) in width and tightly packed with powdery frass.

Under natural conditions, the length of the larval stage is from 2 to 4 years. When the larvae are incorporated into wood products, the period is considerably lengthened. There are authenticated reports of adults emerging from wood up to 50 years after it was initially infested (NPCA, 1964; Smith, 1962). When the larval development is completed, the golden buprestids construct an oval pupal cell near the surface of the wood and the adults emerge,

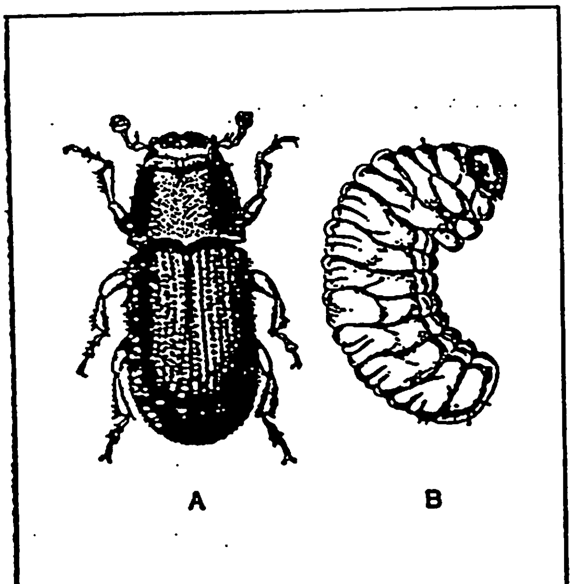


FIGURE 3-16. A. A typical adult bark beetle. B. Bark beetle larva. From Forest Insects by R. W. Doane et al. Copyright 1936 by McGraw-Hill Book Company. Used with permission of McGraw Hill Book Company.

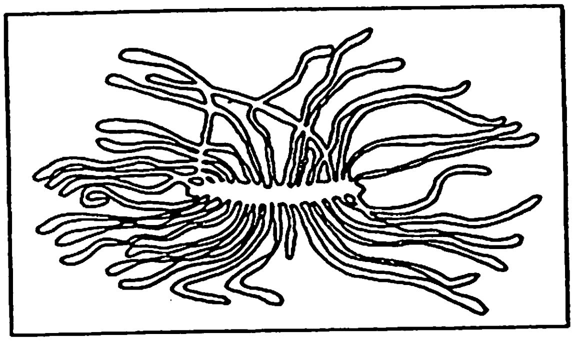


FIGURE 3-17. An example of bark beetle egg and larval galleries that are found between bark and wood. From Certification Training Manual for Structural Pesticide Applicators edited by R. Kaae and E. D. Young, Kellog West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

usually during the spring and summer outdoors, but during fall and winter indoors.

The exit hole is oval and approximately 3/16 to 1/4 inch (5 to 6 mm) across. These exit holes are usually the first evidence of the presence of the beetles, their galleries are so small in freshly sawn, unseasoned wood that they are not detectable, even when exposed on the surface. Beetles emerging from wood in structures fly away and do no further damage to the wood from which they come.

BARK BEETLES

The bark beetles, belonging to the family Scolytidae, are small, cylindrical, robust beetles. They are usually brown, reddish-brown, or black. Most of them found in association with structural timbers are no more than 1/8 inch (3 mm) long. The head is partially or completely concealed from above (Fig. 3-16A).

Although the bark beetles are among the most serious forest pests, they are of very minor importance in seasoned wood. They do not actually cause any damage to the wood, but are sometimes found in houses and in association with structural timbers. For this reason, it is important that they and their damage be recognized as of no economic importance. There are species in all parts of the country.

The eggs are laid by the female in a gallery constructed in the cambium (layer of growing cells between bark and wood). There are species that attack hardwood and softwood trees. The larvae (Fig. 3-16B) tunnel away from the egg gallery. The galleries increase in size and become tightly packed with frass (Fig. 3-17). Only the surface of the wood is slightly etched with their tunnels, and the larvae cause no structural damage. Because of their characteristic damage, they often are referred to as "engraver beetles."

When larval development is complete, bark beetles pupate at the ends of the tunnels. The adults emerge from the pupal stage and tunnel straight out through the bark. The surface of the bark is sometimes riddled with round exit holes 1/16 to 1/8 inch (1.5 inch to 3 mm) in diameter. Bark beetles cannot live in seasoned wood, so there is no reinfestation.

In nature, there may be several generations per year. When wood infested with bark beetles is sawed into lumber, the beetles left under bark edges on the lumber may survive for a year or more. As the wood dries out, some of the gritty frass produced by the beetles may sift down. The adults often emerge from fireplace logs left indoors, as well as from bark edges on lumber, but they are a nuisance only, since they will not infest seasoned wood.

AMBROSIA BEETLES

There are two different families of beetles that include species known as ambrosia beetles. They have been given this common name because of their specialized food. Ambrosia was the food of the classical gods, and these beetles grow for food a fungus known as "ambrosia" on the surface of their galleries. They do not consume the wood, and they throw out all of the frass.

They maintain open space in the galleries for themselves and their larvae to move back and forth freely during feeding on the fungus. Some members of the family Scolytidae have this mode of feeding. There is another family, Platypodidae (the flat-footed ambrosia beetles), that also shares in this habit. The adults and larvae are not seen in structures, since they abandon wood which has dried below the fiber saturation point (30 percent moisture content). Their damage is often seen in hardwood and softwood and should be recognized. Species of ambrosia beetles are found in all parts of the world.

The adult beetles bore straight into the wood of unseasoned logs for several inches and throw out all of the frass. Once inside the sapwood, the tunnel may branch and follow the curvature of one or more annual rings, or it may be unbranched and relatively straight, depending on the species. There also may be short side tunnels of the same diameter that follow the grain and in which larvae feed and later pupate. The ambrosia beetles emerge as adults through the original entry hole. The damage usually is not sufficient to cause structural weakening of the wood. Several generations may continue to extend the galleries as long as the wood remains moist enough to sustain the fungus growth. Some species extend galleries into the heartwood. Freshly cut lumber may be attacked while it is stacked and before it has dried.

As the tunnels are constructed, the walls are

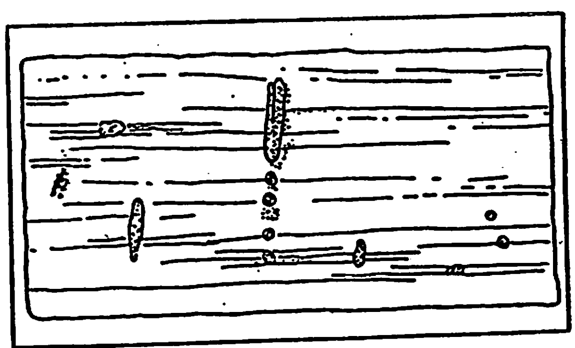


FIGURE 3-18. Wood damaged by ambrosia beetles. From Certification Training Manual for Structural Pesticide Applicators edited by R. Kaae and E. D. Young, Kellogg West, Center for Continuing Education, California State Polytechnic Universit, 1975. Used with permission.

inoculated with the fungus by the adult beetles. The fungus stains the gallery walls black, blue, or brown. The staining often spreads through the surrounding wood and is particularly obvious in lighter-colored wood species. This staining is often a greater defect than the holes themselves. It particularly limits the use that may be made of hardwoods. The beetle attack ceases when the wood dries out, and it is perfectly safe to use the wood without fear of further deterioration.

Ambrosia beetle damage seen in wood in use is characterized by circular holes and portions of tunnels between 1/50 and 1/8 inch (0.5 and 3 mm) in diameter, the size depending on the species of beetle responsible (Fig. 3-18). The tunnels, which are free of frass, run mainly across the grain and have darkly stained walls. The stain may extend into the wood in patches or streaks. All of the tunnels made by a single species are the same size, since only the adults tunnel the wood.

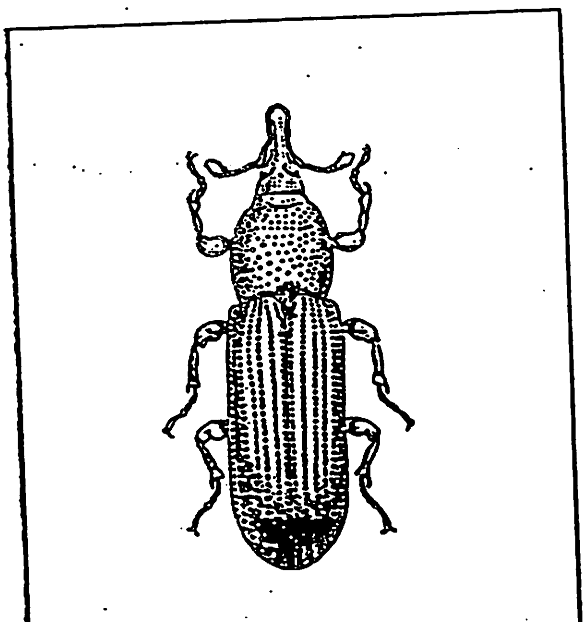


FIGURE 3-19. Wood-boring weevil adult. Some species have a shorter snout. From Forest Insects by. R. W. Doane et al. Copyright 1936 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.

WOOD-BORING WEEVILS

There is one final group of wood-boring beetles that should be briefly discussed, although they are not common and do not cause significant amounts of damage. They are, however, unique in their appearance and might cause confusion if they were detected and not recognized. These are the wood-boring weevils of the family Curculionidae.

The curculionids are sometimes called "snout beetles." They may be distinguished from the other beetles by the prolongation of the head into a snout. The wood-boring species are small, black or reddish-brown, and about 1/8 to 1/5 inch (3 to 5 mm) long. The wing covers are heavily pitted (Fig. 3-19). The larvae are whitish, grublike, legless, and about 1/8 inch (3 mm) long when full grown.

Many species of wood-boring weevils attack unseasoned wood only. There are several species that will attack seasoned wood, but they are most often seen in wood that is slightly damp and partially decayed. Their damage is very similar to that caused by anobiid powderpost beetles, and both types of beetles are sometimes present in the same piece of wood. They occur in all parts of the country and have been transported, even overseas, in infested lumber.

The eggs are laid in holes excavated by the female or in cracks and crevices. The larvae enter the wood and tunnel primarily with the grain in some species. In other species the tunnels are completely random in direction. The life cycle probably takes about a year. Adults emerge through exit holes that are raggedly round, approximately 1/16 inch (1.5 mm) in diameter, or elongate, irregularly shaped holes 1/16 to 1/12 inch (1.5 to 2 mm) in diameter.

These beetles attack hardwoods, softwoods, and plywood. When damage is heavy, the interior of the wood, including sapwood and heartwood, is honeycombed. The galleries, which are up to 1/16 inch (1.5 mm) in diameter, are made by the feeding of both adults and larvae. The frass is composed of very fine powder and tiny pellets and is packed in the galleries. Though similar to the damage of anobiid beetles, the pellets in the frass are much smaller, and even the largest tunnels are smaller in diameter than those of anobiids. It is also common to find the adults feeding in the wood, which is contrary to the activity of the anobiids. Their potential for damaging the wood is probably directly related to the amount of dampness and decay which is present.

PREVENTION AND CONTROL

It is important for those concerned with the prevention or control of beetle attack in wood in houses to remain aware of the requirements for initial attack to occur. You will recall that they include: the occurrence of the beetle(s) in the particular geographic region and the possibility of a local population source close enough to initiate attack in the building; in the house, the presence of wood which is susceptible to attack by the beetle(s) in question; and environmental conditions in the wood suitable for the development of the beetle species of concern.

When wood that is already infested is shipped in and used, these natural conditions do not have to exist for beetles to be found. This emphasizes the importance of understanding the biology and habits of the beetles as well as being able to recognize them and the evidence of their attack. Before any control procedures are implemented, the identification of the beetle or its damage must be positively confirmed in order to proceed intelligently.

Some infestations may have long since become inactive because of changing conditions or because the attack occurred and ceased before the wood was even milled. Some evidence of current activity is needed before control procedures are required. The presence of the three factors which might lead to attack does, however, indicate a need to consider preventive measures where no attack has yet occurred.

PREVENTION

Most of the procedures which will prevent attack on wood before it is placed into use are the responsibility of those who harvest, mill and store the wood. Those who use wood must take precautions to reduce the chances of building in a beetle infestation.

Although careful inspection is the first step in preventing the introduction of beetles into a structure, it has severe limitations. It should, however, be a specified practice. Many times wood is placed into use before beetle infestation has progressed to the point that it can be discovered, even by careful visual inspection and probing.

The other precautionary measures that may be taken to prevent introduction of beetle-infested wood include, first, the specification that all wood be kiln-dried or air-dry before its use. This eliminates or severely restricts the development of most beetle species and also is the cheapest and most practical preventive measure. Some beetles will attack and reattack wood which is well below the air-dry level, so drying will not eliminate all concern for beetle infestation.

If there is any reason to suspect that incipient infestations may be present, or if wood components are so expensive or will be so difficult to treat or replace if infestation is discovered later, it may be feasible to require further preventive measures. Wood may be positively freed of beetle infestation by heat sterilization or by fumigation. Table 3-1 (St. George, 1973) shows the times and temperatures necessary to kill beetles in wood of different thicknesses.

These data were established for lyctid beetles, but they are more than sufficient to kill most other borers present. If bostrichid beetles are involved, use the higher temperatures, since bostrichids are harder to kill with heat than are other types (Bletchly, 1967). This schedule should not be confused with a normal drying schedule, since the temperatures involved in drying alone are not always sufficient to kill many wood-boring beetles.

Fumigation of wood before use also will render it beetle-free. The gas most commonly used is methyl bromide. The wood should be stacked loosely and covered with a gas-tight

Table 3-1. *Schedule for treating wood to check damage by powderpost beetles*

Relative humidity	Lethal temperature required		Thickness of timber		Time required to overcome lag after kiln has attained lethal temperature	Additional margin of safety	Time then held at lethal temperature	Total period of exposure after kiln has attained required conditions
Percent	°F	(°C)	Inches	(CM)	Hours	Hours	Hours	Hours
100	130	(54)	1	(2.5)	½	½	1-½	2-½
			2	(5.1)	2	½	1-½	4
			2-½	(6.3)	3-¼	½	1-½	5-¼
			3	(7.6)	4-½	½	1-½	6-½
80	125	(52)	1	(2.5)	½	½	2	3
			2	(5.1)	2	½	2	4-½
			2-½	(6.3)	3-¼	½	2	5-¾
			3	(7.6)	4-½	½	2	7
	120	(49)	1	(2.5)	½	1-½	6	8
			2	(5.1)	2	1-½	6	9-½
			2-½	(6.3)	3-¼	1-½	6	10-¾
			3	(7.6)	4-½	1-½	6	12
	115	(46)	1	(2.5)	½	7-½	30	38
			2	(5.1)	2	7-½	30	39-½
			2-½	(6.3)	3-¼	7-½	30	40-¾
			3	(7.6)	4-½	7-½	30	42-½
60	125	(52)	1	(2.5)	½	1	4	5-½
			2	(5.1)	2	1	4	7
			2-½	(6.3)	3-¼	1	4	8-¼
			3	(7.6)	4-½	1	4	9-½
	120	(49)	1	(2.5)	½	2	7	9-½
			2	(5.1)	2	2	7	11
			2-½	(6.3)	3-¼	2	7	12-¼
			3	(7.6)	4-½	2	7	13-½
	115	(46)	1	(2.5)	½	9	36	45-½
			2	(5.1)	2	9	36	47
			2-½	(6.3)	3-¼	9	36	48-¼
			3	(7.6)	4-½	9	36	49-½

tarpaulin. If such fumigation is to be performed on a regular basis, it is best to use tarpaulins made of nylon fabric coated with rubber, neoprene or plastic. These are the same type used for drywood termite fumigation. Where fumigation is not performed on a regular basis, heavy polyethylene plastic sheets may be used instead of tarpaulins. The bottom edges of the cover should be sealed with sand. The usual dosage of methyl bromide for such purposes is 3 pounds per 1000 cubic feet (1.36 kg per 28 cu m) of air space. The gas should be held under the cover for about 72 hours (St. George 1973).

In areas where structural framing members are subject to beetle attack, the use of pressure-treated wood prevents damage. It is doubtful that there are any areas in the contiguous states that have enough beetle attack to justify the extra expense for such a preventive measure. If decay fungus, drywood termite and/or subterranean termite attack potential would justify pressure-treated wood, then the prevention of beetle attack would be an added benefit.

Brushing or spraying the wood with 0.5 percent lindane before it is used will protect it from attack by beetles for 10 years or more. The lindane is applied at the rate of 1 gallon per 100 square feet (4 liters per 10 sq m) of surface, or until no more is absorbed. The current availability of lindane is limited, and its future is questionable. Recently, a borate salt compound (Bora-Care) has been registered for prevention and control of wood-boring beetles, as was described under the discussion of drywood termite prevention. The same application procedure applies here. As long as the wood does not become wet periodically so that the borate salt is leached out, it will remain toxic to beetles.

For the beetles that begin their attack under bark, the removal of any bark edges from lumber before the lumber is used in construction is a good preventive measure. Many of the roundheaded and flat-headed borers feed under bark for extended periods before they enter the wood. The bark beetles confine their attack to the inner bark, and are thus eliminated by bark removal.

Use of good building design as outlined for subterranean termite prevention also applies to beetles. Good ventilation and drainage and proper clearance between wood and soil will tend to reduce the equilibrium moisture content of wood in the structure and thus render conditions less favorable for the beetle development. The need for good clearance and ventilation is most important in the Gulf Coast areas, where high humidity and mild winter climates may allow wood framing in walls and attics, as well as crawl spaces, to retain relatively high moisture levels and support greater beetle activity.

When the building is centrally heated, the drying process after construction is speeded up and the house becomes less susceptible to beetle attack more quickly, and it usually remains so as long as the house is regularly occupied and remains heated for extended periods. Vacation or recreational structures tend to be more prone to extensive beetle attack because they often are not centrally heated or are heated only intermittently for relatively short periods. Leaving structures closed and unheated for long periods allows the moisture content of the wood to rise to higher levels than would otherwise be the case.

Proper attention to good attic ventilation is even more important in the prevention of beetles than in the prevention of termites. If attics are well ventilated, in most regions they tend to dry out below the level of moisture needed for vigorous beetle attack. This is particularly true of the roof framing and sheathing.

INSPECTION

All houses which include wood as a part of the structure, or of the interior or exterior trim or built-in cabinets, should be inspected at least annually for the presence of active wood-boring beetles. The incidence of beetle infestations in houses is much lower in tropical areas and in arid regions than it is in temperate climates.

There can, however, be infestations by wood-boring beetles in any part of the United States or its territories. Wood containing beetle infestation may have been incorporated into the structure, and some damage may occur, even though the infestation might eventually die out because of unfavorable environmental conditions. Local infestation of wood in use does occur in many parts of the contiguous states.

The purposes for which inspections for beetle attack are made are similar to those involved in termite inspections. They include such things as determining the condition of the wood in the house and locating any evidence of attack by wood-boring beetles. Once evidence of attack is found, the identity of the species causing the damage must be established. Only in this way is it possible to properly assess the potential for additional damage. Finally, the inspector must determine whether or not the infestation is still active and whether there is need for repair, replacement or treatment.

Most of the beetles that cannot reinfest seasoned wood show evidence of their presence within 2 or 3 years, unless they die out sooner. Infestation of wood by beetles which can survive and reinfest seasoned wood often does not become evident for several years after a house is constructed. Anobiid powderpost beetles and the old house borer may not become evident for 10 or more years if the initial infestation was limited. This is because the relatively small number of eggs laid, the high natural mortality of the larvae, and the long life cycles involved do not produce large populations very rapidly.

The external signs of their presence do not become evident until adults have emerged in enough numbers to provide easily-seen exit holes and accompanying frass. Where damage occurs, it is seldom widespread unless the property has been neglected for a number of years. Most commonly, only a very few boards are found to be infested when inspections have been performed at reasonable intervals.

Although wood-boring beetles may spoil the appearance of wood and, when neglected for long periods, may cause serious weakening of structural timbers, they develop very slowly. When an infestation is discovered during a routine inspection (rather than as a result of the sudden collapse of a wooden member), there is rarely any need for extreme haste in providing treatment.

Basic equipment and the step-by-step procedures described for termite inspection, particularly drywood termites, apply here. The reader is referred to that section of the manual for details. Certain aspects of inspecting for beetles require special attention, and they will be detailed.

In inspecting for beetles, the evidence is often less easily seen than in termite inspection. It is necessary to visually examine all exposed surfaces of wood (painted and unpainted) and to sound or probe them for evidence of internal damage. The sounding and probing is accomplished by rapping on the surface to locate hollow-sounding areas and by probing into the surface at close intervals with a sharp instrument.

Probing is usually very limited in living areas, where damage to finished surfaces might result. Particularly in its early stages, the extent of infestation by beetles is more difficult to determine than that of termites. There are no telltale shelter tubes or fecal pellets to reveal early beetle activity. Exit holes occur at the end of the first generation of beetle attack. In many cases larvae do not expel any frass to reveal their presence until there are exit holes from which the frass can sift. Minor exceptions include the bark beetles and some of the flatheaded borers which push frass from underneath bark edges left on structural timber.

When inspecting wooden siding, shakes or exterior trim, the evidence of beetle attack is unusually obscure. The signs most often discovered are the exit holes of round-headed or flat-headed borers. The adults in many cases have emerged through the exterior wood after developing in framing timbers inside the wall. The location and pattern of occurrence of the holes can often provide evidence of which framing members are involved.

Inside the house, evidence of attack may have been noticed by the occupants, and they should be interviewed for possible clues. A systematic search of all wood surfaces inside a structure that is filled with furnishings would be time consuming and probably not extremely productive, since evidence of beetle attack, other than exit holes, usually is not present. When large larvae of some of the round-headed borers, particularly old house borers, are present in framing timbers, they may be heard gnawing in the wood. Since the sounds are not produced continuously, the aid of the occupants is essential.

When lyctid beetles have attacked hardwood flooring or interior trim, it is not unusual for only a very few scattered pieces to be involved. The small size of the exit holes and the absence of frass on the surfaces again point out the need for consulting with the occupants. They are likely to have seen and removed any frass. If the attack has occurred over a long period of time, the evidence is obviously more pronounced than in houses only a few years old.

Evidence of beetle attack is much more pronounced and more easily discovered in attics, crawl spaces and unfinished basements and storage areas than on the exterior or inside the living areas. The signs are more likely to be undisturbed, and the absence of finishes on the wood leaves more wood surface that has been exposed to reinfestation.

The common practice of insulating ceilings and floors has made inspection of many parts of structural timbers impractical. As with termite inspection, removal of insulation is usually not considered feasible unless evidence warrants closer inspection because of signs above, below or adjacent to the insulation-covered areas.

Because of the similarity in some cases of damage caused by beetles that do and do not reinfest wood, the inspector would be well advised to carry small envelopes in which to collect frass and small wood samples so that they may be very closely examined with good light and magnification. If adults or larvae are found, they should be placed in small bottles or vials filled with rubbing alcohol.

Should there be any doubt as to the identity, the specimens and a description of the situation in which they were found (including the type of wood) should be submitted to a specialist for identification. In most areas this means they should be sent to the entomology department of the state university. Only in this way can positive identification of the attacking beetles be determined. Since the beetles do not cause damage very rapidly, a delay in treatment caused by this procedure will not result in any harmful consequences, and positive identification often prevents unnecessary treatment.

The fact that beetle damage is discovered is not conclusive evidence that the infestation is still active. Depending on the type of beetles involved, it may be that the infestation has died out because the environmental conditions are not adequate for the beetles to survive. Even beetles that can reinfest seasoned wood sometimes die out for various reasons.

In order to be certain that the infestation is active, there should be fresh frass which is the color of newly sawed wood and live larvae or adults in the wood. The presence of exit holes and frass alone indicates only that the beetles have been active. The adults which made the exit holes may be the last that will emerge and the wood may not be suitable for a new generation. The humidity and temperature of the air surrounding the wood are key factors in determining the likelihood of reinfestation by beetles that initiate attack in seasoned wood.

The characteristics of beetle damage found in wood in houses is summarized in Table 3-2. This table also indicates the type of wood and the portion of the wood attacked by the various kinds of beetles. This is important in determining the potential areas which might be infested by a particular species and in evaluating the likelihood of serious structural weakening.

■ CONTROL

Treatment for the control of wood-boring beetles is really necessary only when an inspection has revealed an apparently active infestation by a species that will reinfest seasoned wood. There are times, however, when treatment may be applied when it is not a necessity from the standpoint of structural damage.

Given a free choice, most homeowners do not make the decision whether or not to invest in control procedures on the basis of potential structural damage alone. For people who can afford it, the mere fact that creatures are consuming a portion of their house may be reason enough to seek immediate treatment, no matter how inconsequential the attack. This is particularly true if signs of beetle attack, such as new exit holes or gnawing in the wood, are evident in the living areas.

If the house is being placed on the market for sale, prospective buyers will usually not accept a house that is reported to be infested with wood-boring beetles, even if they are species that will not cause structural weakness and will not reinfest the seasoned wood. Sociological

Table 3-2. *Characteristics of damage caused by common wood-boring beetles in houses*

Type of borer	Wood attacked: Part and type	Wood attacked: Condition	Recognition of damage: Exit holes	Recognition of damage: Galleries (tunnels)	Recognition of damage: Frass	Reinfestation
Anobiid powderpost beetles	Sapwood of hardwoods and softwoods: rarely in heartwood	Seasoned	Circular, 1/16 to 1/8 in (1.6 to 3 mm) diameter	Circular, up to 1/8 in (3 mm) diameter; numerous; random	Fine powder with elongate pellets conspicuous; loosely packed[1]	Yes
Bostrichid powderpost beetles	Sapwood of hardwoods primarily; minor in softwoods	Seasoning and newly seasoned	Circular, 3/32 to 9/32 in (2.5 to 7 mm) diameter	Circular, 1/16 to 3/8 in (1.6 to 10 mm) diameter; numerous; random	Fine to coarse powder; tightly packed, tends to stick together	Rarely
Lyctid powderpost beetles	Sapwood of ring- and diffuse-porous hardwoods only	Newly seasoned, with high starch content	Circular, 1/32 to 1/16 in (0.8 to 1.6 mm) diameter	Circular, 1/16 in (1.6 mm) diameter; numerous; random	Fine, flour-like, loose in tunnels	Yes
Round-headed borers (general)	Sapwood of softwoods and hardwoods; some in heartwood	Unseasoned, logs and lumber	Oval to circular, 1/8 to 3/8 in (3 to 10 mm) long diameter	Oval, up to 1/2 in (13 mm) long diameter, size varies with species	Coarse to fibrous; may be mostly absent	No
Old house borer	Sapwood of softwoods, primarily pine	Seasoning to seasoned	Oval, 1/4 to 3/8 in (6 to 10 mm) long diameter	Oval, up to 3/8 in (10 mm) long diameter; numerous in outer sapwood, ripple marks on walls	Very fine powder and tiny pellets; tightly packed in tunnels	Yes
Flat oak borer	Sapwood and heartwood of hardwoods, primarily oak.	Seasoning and newly seasoned	Slightly oval; 1/16 to 1/12 in (1.6 to 2 mm)	Oval, up to 1/12 in (2 mm) long diameter	Fine granules	No
Flat-headed borers	Sapwood and heartwood of softwoods and hardwoods	Seasoning	Oval, 1/8 to 1/2 in (3 to 13 mm) long diameter	Flat oval, up to 3/8 in (10 mm) long diameter; winding	Sawdust-like, may contain light and dark portions if under bark; tightly packed	No
Bark beetles	Inner bark and surface of sapwood only	Unseasoned, under bark only	Circular, 1/16 to 3/32 in (1.6 to 2.5 mm) diameter	Circular, up to 3/32 in (2.5 mm) diameter; random	Coarse to fine powder, bark-colored, tightly packed in some tunnels	No
Ambrosia beetles	Sapwood and heartwood of hardwoods and softwoods	Unseasoned, logs and lumber	Circular, 1/50 to 1/8 in (0.5 to 3 mm) diameter	Circular, same diameter as holes; across grain, walls stained	None present	No
Wood-boring weevils	Sapwood and heartwood of hardwoods and softwoods	Slightly damp, decayed	Raggedly round or elongate, 1/16 to 1/12 in (1.6 to 2 mm) diameter	Circular, up to 1/16 in (1.6 mm) diameter	Very fine powder and very tiny pellets, tightly packed	Yes

[1]Pellets may be absent and frass tightly packed in hardwoods

and psychological factors far outweigh practical considerations in many of these cases.

The method or methods that should be used in the control of an active infestation of wood-boring beetles depends on many things. Often it is necessary to consider the possibility of damage by the treatment as well as the probability of achieving control. Each problem must be analyzed in the light of severity of infestation, possibility of reinfestation, type of wood product being attacked, the area of the structure where attack is occurring, the speed of control needed, and the cost to the property owner, as well as the sociological and psychological factors.

For aesthetic reasons, it might be important to provide immediate control to prevent any further emergence of adult beetles from infested hardwood floors, trim or cabinetry. Likewise, if a house is for sale, immediate control might be necessary to render the property marketable. Speed is not otherwise so important when the rate of development of the beetles is considered. Several months of delay in treatment after an infestation is discovered is usually of little consequence.

■ NONCHEMICAL CONTROL

Alteration of environmental conditions in the house might one day be the only procedure necessary to eliminate some infestations of wood-boring beetles. This is an area currently under study, and information that will be of practical value should be available within a few years.

It is a well-established fact that no wood-boring beetles found in houses develop rapidly in wood that is very dry. There are indications that the most common anobiid beetles cannot establish an infestation in wood below about 15 percent moisture content. For the old house borer, the moisture requirement for establishment is probably more than 10 percent. If the use of vapor barriers, ventilation and central heat can dry wood out and keep it dry enough, the use of other control measures may not be necessary. This method would not be a rapid means of control, and probably would not completely replace others.

At the present time, it can only be recommended that every effort be made to reduce the moisture content of the wood to be protected. If wood-boring weevils are the attacking species, they can be completely controlled by removing the cause of decay and dampness in the wood. Since they are dependent upon the dampness for their survival, they will be indirectly controlled.

■ REPLACEMENT OF INFESTED WOOD

Before any chemical control procedures are considered, thought should be given to the feasibility of simply removing and replacing the infested wood. Under certain circumstances, this is more effective and economical than other methods. It would, of course, not be practical except in limited infestations.

Also, the members to be replaced would have to be reasonably accessible or the cost of labor in gaining access to them, and then repairing the damage incurred in the process, would be prohibitive. Wood in contact with the pieces removed should be carefully inspected to insure that it has not also become infested and, if not removed, would remain as a source of future damage.

■ REPLACEMENT OF STRUCTURALLY WEAKENED WOOD

Any wood in the building which has been damaged sufficiently for it to be structurally weakened should be replaced or reinforced. This is the case whether chemical control procedures for the infestation will be employed or not. If the weakened wood, or that with which it is in contact, is actively infested with beetles, it should be replaced or reinforced with pressure-treated wood, or the replacement wood should be treated by surface application of a residual insecticide as discussed under preventive measures.

■ RESIDUAL INSECTICIDES

There are a number of insecticides registered for the control of wood-boring beetles in houses. They range from an inorganic borate salt solution (Bora-Care), a stomach poison, to several synthetic organic compounds which kill on contact.

These include lindane, chlorpyrifos (Dursban), and cypermethrin (Demon). Their label directions vary as to the amounts that may be applied, the methods of application, and the sites that may be treated. The specific conditions involved with each infestation should be the guide in choosing the material to use.

Most infestations of wood-boring beetles in houses are not widespread and inaccessible. For that reason, the treatment most commonly used has been the surface application of residual insecticides to infested wood. When infestation is widespread in attics, crawl spaces and other unfinished areas, all exposed wood members are treated. This is the preferred method of control when there is no requirement that control be immediate. It sometimes takes from several months to a year or more for an infestation treated in this manner to be completely controlled, since it is not possible in most cases to get complete penetration of the insecticide into all of the infested wood.

The larvae in unsaturated areas tend to avoid the treated outer layer of wood until they complete their development, pupate, and attempt to emerge as adults. When the contact insecticides are used, most adults, in attempting to cut through the treated wood layer, are killed. If there are surfaces that are insufficiently treated or untreated because of inaccessibility, some adults may emerge. They are usually killed, however, in the process of crawling over the treated surfaces of exposed wood during the mating and egg-laying process.

Larvae hatching from eggs successfully laid on treated surfaces do not survive their attempt to bore into the wood. Thus, a high degree of success results after sufficient time has passed. Proper treatments remain effective for several years. Where the borate salt solution (Bora-Care) is used, it is said to eventually diffuse entirely through the wood and could conceiveably provide permanent protection of wood that is not exposed to wetting.

TREATMENT OF UNFINISHED WOOD

There are some differences in the way treatment is performed on unfinished wood as compared with wood with an applied finish on its surface. When raw, unfinished wood has been heavily damaged by beetles, the powdered portion should be completely removed. The frass and wood fragments should be carefully cleaned up, preferably with an industrial vacuum cleaner. If replacement or reinforcement is needed, this should be done prior to completing the treatment.

Where damage is lacking or is not severe, the surfaces to be treated should be carefully brushed to remove frass and dust clinging to the surface. Suspended wood should be pounded with a rubber mallet prior to brushing to vibrate loose frass from exit holes. Clean wood is better penetrated by insecticides, and new activity can be more easily spotted during subsequent inspections.

The currently labeled residual insecticides are, in general, to be applied as water emulsions, the percent varying with the product. The borate salt (Bora-Care) is a solution and one formulation of chlorpyrifos (Whitmire PT 270 Dursban) is a solution in a pressurized container.

If powderpost beetles are the problem, the insecticide is applied to all exposed wood surfaces by brush, or as a wet spray, to the point-of-runoff. The amount absorbed varies with the amount of damage and the smoothness of the wood surface; the rougher the surface, the more absorbed. If a sprayer is used, very low pressure and a fan-shaped spray pattern should be used. This will prevent excessive misting and bounce-back from the surface, thus reducing hazard and waste.

If old house borers or other round headed borers are being treated, a slightly different treatment procedure is used. If only limited areas are infested, especially in heavy wood members, chlorpyrifos solution (Whitmire PT 270 Dursban) should be injected into the wood through 1/8 in (3 mm) holes drilled into the infested wood according to the labeling. The formulation will move down the grain of many types of wood and will provide deeper penetration than surface spraying or brushing.

Old house borers can be treated by brushing or spraying water emulsion on infested areas to the point-of-runoff, as for powderpost beetles. Penetration of wood surfaces with paint, varnish or wax on them is not satisfactory unless the material is removed before treatment, a process not usually feasible. Treatments should be applied only to known infested areas and slightly beyond.

As indicated previously, the borate salt solution (Bora-Care) will penetrate slowly, by diffusion, deep below the surface of wood. This material will provide control of powderpost beetles and the old house borer. Label directions include the possibiity of applying the solution in attics and crawl spaces as a wet mist with a fogging device as a supplement of brush or spray application. This provides some advantage where access is limited.

TREATMENT OF FINISHED WOOD SURFACES

The beetles that attack hardwoods, the type of wood most often infested on the interior of houses, usually will not lay their eggs on finished wood surfaces. Because of this, such wood is physically protected from reinfestation except for old exit holes and cracks and crevices which allow the beetles access to unfinished areas. This greatly reduces the potential for reinfestation beyond the first generation.

The problem of treating finished surfaces of wood is rather complex. There are many types of wood finishes, and each may react differently to the chemicals. Since the treatment can damage wood finishes, it is advisable to treat a small, inconspicuous area for preliminary observation before treating infested finished wood. There is also serious doubt that the insecticides penetrate through finished surfaces, they may simply evaporate on the surface (Bletchly, 1967).

Unless the finish can be removed, the only beneficial treatment is the application of insecticide by repeatedly injecting it into the beetle exit holes in the surface of the wood and into open joints and crevices between boards. Whitmire PT 270 Dursban is presently the only available formulation for this purpose. Since this would result in good penetration of the wood only if there were many exit holes, it would be feasible only when heavy damage has occurred. If interior trim can be removed, it might be successfully treated through the unfinished surfaces by applying the insecticides as described previously for unfinished wood surfaces.

FUMIGATION

Infestations of wood-boring beetles are controlled most speedily and completely by fumigation. This is a very expensive process, and it offers no residual protection from reinfestation. It is also necessary for the residents to leave the premises for one or more days. But because of the turnover in home ownership requiring certification that structures are insect-free, fumigation has become a more common control procedure in spite of its drawbacks. In addition to acting rapidly, fumigants are useful when an infestation is very extensive or is in building locations that make other control procedures impractical.

Methyl bromide is the fumigant of choice for the control of wood-boring beetles in houses. The procedures for its use were discussed under drywood termite control, and the reader is referred to that discussion. Fumigation for wood-boring beetles is done in the same way, but instead of a concentraton of 2 pounds per 1000 cubic feet (0.91 kg per 28 cu m) of building space, 3 pounds (1.36 kg) is generally recommended, provided the temperature is above 60 degrees Fahrenheit (16 degrees Celsius).

The gas needs to be retained under the tarpaulin for only 24 hours if the space is properly sealed and a minimum of 0.5 pound per 1000 cubic feet (0.23 kg per 28 cu m) of gas remains at the end of the 24-hour period. Manufacturer's directions indicate that a higher dosage is sometimes required and additional gas may need to be added during the fumigation period. This is obviously a procedure for experienced pest control technicians only.

Sulfuryl fluoride, which is commonly used for drywood termite fumigation, is not as generally used for wood-boring beetles because it is not very effective against the egg stage. Because of some other advantages, sulfuryl fluoride has been used by fumigators for beetle control. The dosage used for control of adults and larvae is the same as that for drywood termites.

This dosage is determined by the use of the manufacturer's "Fumiguide" which is used to coordinate fumigant rates with site variables. When control of the egg stage is desirable, the manufacturer's directions call for the use of four times the drywood termite dosage to control the old house borer and ten times the drywood termite dosage to control powderpost beetles. These high dosages render the cost prohibitive and have greatly reduced general use.

Because of the expense involved in fumigating entire structures, attempts have been made to treat localized portions of buildings by covering them with plastic. Some fumigators have covered hardwood wall cabinets with plastic and released methyl bromide. Others have tried fumigating crawl spaces by sealing ventilators and covering the floor above with plastic. These producedures are not usually successful because of the rapid loss of gas through wall voids, etc.

CHAPTER 3 • REFERENCES

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CHAPTER 4

WOOD-ATTACKING WASPS, ANTS AND BEES

INTRODUCTION

The insects to be discussed in this chapter all belong to the order Hymenoptera. This is one of the largest insect orders and is beneficial to man since it contains the most important insects (the bees) involved in the pollination of plants. There are, however, a few families in the order that contain species which feed on or nest in wood.

The members of the order are characterized by having four membranous wings (some are wingless), the front pair being much larger than the hind pair. The order name, Hymenoptera, means "membrane wings" and refers to the characteristically thin, clear or translucent wings. There is a great diversity of habits and complexity of behavior represented in the order.

The ants and some of the bees and wasps, are social insects. The adults have chewing type mouthparts. The ovipositor (egg depositor) of the female, located at the tail end, is often modified into a sting (bees and wasps) or a long, slender structure (horntails). The Hymenoptera undergo complete metamorphosis during their development. The larvae of those associated with wood are all grublike, usually legless and pale, yellow-white in color with slightly darker mouthparts.

The type and amount of damage done to wood by hymenopterans varies with the particular family. Only the horntails (family Siricidae) bore in wood and make galleries packed with frass. The carpenter ants (family Formicidae) and carpenter bees (family Anthophoridae) make hollows in the wood for nesting purposes only, and keep the hollows clean and free of frass. Although the amount of damage done to wood in use cannot rank these insects as major pests, they are common enough and conspicuous enough to warrant their consideration in this manual.

THE HORNTAILS OR WOOD WASPS

Because of their superficially wasp-like appearance, the horntails are often called wood wasps. Some authors refer to them as siricids, from the family name Siricidae. In both sexes the last segment of the abdomen bears a hornlike projection. This distinctive structure gives them the widely used common name of horntails. The female bears a long, slender terminal ovipositor as well.

The following discussion of horntails in this manual is not included because they are very common wood pests or because they create a significant amount of damage to structural timbers when they do occur. Rather, this discussion is included because horntails occasionally appear in large numbers in houses constructed of infested wood.

In such cases the adults make conspicuous exit holes in finished surfaces and are very conspicuous and noisy when they fly about indoors. Equally important is the fact that wood showing evidence of past attack by horntails is sometimes included in structures. The significance of such damage should be understood by those concerned with the structural soundness of buildings constructed with such wood.

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■ FAMILY CHARACTERISTICS

There are about 50 different species of horntails in the family Siricidae, approximately 20 of them occurring in the United States. They belong to four different genera, one of which infests hardwoods. Those in all of the other genera attack softwoods, and some are common pests of coniferous trees used for construction lumber.

The adults are large, superficially wasplike insects usually an inch (25 mm) or more in length. They differ in appearance from wasps in that their bodies are broadly joined together between the thorax and abdomen rather than having a thin "waist" as do wasps (Fig. 4-1). The females are usually larger than the males and have a long ovipositor, which the males lack. Sizes of individuals vary greatly, even in the same species. The adults of the species which attack softwoods are usually black or dark metallic blue, sometimes in combination with markings which are yellowish, reddish or brown. Neither sex bites nor stings, in spite of their dangerous appearance.

The larvae are whitish to creamy yellow in color, usually cylindrical, have very short legs and on their posterior end, a small, dark horny spine which they use for packing frass behind them (Fig. 4-1C). When they are removed from their galleries, they tend to take on a slighly S-shape, with their heads bent down and their tails turned up. Depending on the usual size of the species, they may be up to 1-3/4 inches (45 mm) long.

■ DISTRIBUTION AND ECONOMIC IMPORTANCE

Species of horntails occur naturally in all parts of the contiguous states where the host trees grow. Those that attack softwoods have been dispersed in infested lumber to many areas where they do not occur naturally. Therefore, horntails may occur in wood in houses in all parts of the United States or its territories. There is one species, the pigeon tremex, which attacks hardwoods. This species is widely distributed in the United States and southern Canada. Indoors, it is found emerging from hardwood fireplace logs, but is a nuisance only and not a pest of structural wood.

Horntails are not considered to be primary forest pests, since they attack trees which are declining or dying from fire, disease or insect damage or other natural causes. They also have been reported to infest newly felled logs and freshly sawed lumber, even redwood, a species usually resistant to insects.

The major economic losses caused by horntails result from the larval and adult borings in trees. The borings reduce the quality of the lumber, leading to its being downgraded. Horntails cause damage in new structures by the emergence of adults from infested structural lumber through various finished surfaces covering the wood. Instances of damage in houses have not been very frequent, but infestations may be very serious when they do occur. Horntails are serious pests when numerous, not because of severe damge to structural members, but because the exit holes are very conspicuous and the adults are very noisy and appear to be dangerous.

■ BIOLOGY AND HABITS

Very little study of the biology of North American species of horntails has occurred. Morgan (1968) provided a comprehensive review of

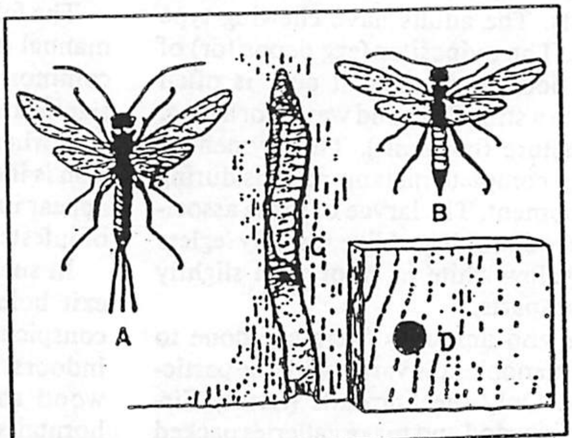


FIGURE 4-1. A. Adult female horntail. B. Adult male. C. Larva in gallery. D. Exit hole made by adult. Courtesy of University of California, Berkeley.

available literature, and much of the information reported has come from that source.

The adults are active in bright sunshine during the late spring, summer and early fall. Mating takes place in the treetops, and the females descend to the trunks of trees to lay their eggs. Horntails attack trees which are in a natural decline or have been cut recently. The female inserts her slender ovipositor into the bark and wood to a depth of 5/16 to 13/16 inch (8 to 20 mm) and deposits several eggs, withdrawing her ovipositor slightly after each egg is released. This process is repeated over a priod of about 10 days. Depending on the species, the female may be capable of laying from 300 to 4,500 eggs. At the time the eggs are laid, spores of fungus stored in special glands at the base of the ovipositor are introduced into the egg tunnel.

The fungus grows rapidly prior to the hatching of the eggs and provides the larvae with nourishment. According to Morgan (1968) the larvae do not swallow any wood, but secrete saliva which digests the fungal material in the wood, and they then ingest the predigested nutrients. The wood fragments which they have chewed off are passed behind them after the fungal nourishment has been extracted. Since the larvae depend on the fungal growth for food; the wood which is attacked must be in a condition to support its growth. This generally means that the moisture content must be above the fiber saturation point (30 percent).

The young larvae bore cylindrical tunnels at right angles to the oviposition tunnel. They feed at first in the sapwood but, as they become larger, they go into the heartwood. After feeding for a time there, they turn outward and tunnel back into the sapwood. Thus, the larval tunnel is typically roughly C-shaped and from 10 to 30 inches (25 to 75 cm long) long, depending on the species.

As the larvae tunnel, they pack the frass tightly behind them. They also include in the frass their larval skins, which are shed each time they molt. There may be 3 or 4 molts, and the larval stage may require 2 or 3 years to be completed outdoors. If the wood dries out quickly, as it does in lumber sawed from infested logs, the time for development may be prolonged to 4 or 5 years.

Pupation occurs in a silken cocoon spun at the end of the larval tunnel at various depths usually 3/4 to 1 inch (18 to 25 mm) below the surface of the wood. If the tunnels are too deep, as they often are, the adult is unable to chew its way out and dies in the tunnel (Chandler, 1959). The pupal stage lasts approximately 6 weeks.

The adults make perfectly round exit holes as they emerge. The holes may be cut through many types of materials covering the wood in which they developed. Adults have been reported emerging through hardwood floors, wood siding and paneling, plaster and plasterboard, and even sheet lead of considerable thickness.

■ SIGNS OF INFESTATION

The most common evidence of horntail infestation found by inspectors is tunnels tightly packed with frass, with the tunnels visible on the surface of the wood where they have been sawed through in the milling of the lumber.

If the infestation has been active, there may be adult exit holes through the surface of structural members or through any of the materials which have been applied over the infested wood. Frass beneath exit holes is seldom reported (Ebeling, 1975). Exit holes usually appear within the first 3 years after the wood has been used in construction.

It would be pure coincidence if the inspector found live adult horntails, but dead ones might be found around screened ventilators or in spider webs. The horntails might also be described by the occupants of the house if emergence has occurred indoors at a time when they would have been noticed.

■ CHARACTERISTICS OF DAMAGED WOOD

Both the exit holes and the larger tunnels are circular in cross-section and 1/6 to 1/4 inch (4 to 6 mm) in diameter (Fig. 4-1D). There is considerable variation in the size of the tunnels because of their being made by young and old larvae and because of natural differences in the sizes of various species of horntails. The tunnels exposed by the milling of the lumber may appear to be oval in cross-section because of the angle at which they were cut.

They wind in many directions in the heartwood and sapwood and are tightly packed with coarse frass which cannot be easily jarred or shaken out, unlike that of the old house borer. The tunnels quite commonly are surrounded by soft, decayed wood. When viewed in cross-section, there sometimes is a faintly grayish staining visible in light-colored wood as a thin "halo" a few millimeters from the tunnel. This staining is associated with the fungal attack.

■ POTENTIAL FOR DESTRUCTION

The amount of horntail damage found in structural timber is usually so small as to be of no practical concern. When a live infestation is incorporated in a new building, larval development may proceed, and adult horntails eventually emerge. However, since they are unable to reinfest seasoned wood, such live infestations and any resulting damage are usually unimportant. Probably the greatest concern is the alarm caused by the dangerous looking, but harmless, adults that might emerge indoors. There is one report of a mass exodus from a housing project in Wisconsin when large numbers of horntails emerged in the new homes (Friis, 1961).

■ PREVENTION

Damage caused by horntails to wood in use can be prevented by proper kiln-drying of green lumber sawed from infested logs. Although kiln-drying will kill horntail larvae that have survived the milling operations, the relatively low value of such lumber made this treatment economically impractical in the past. There are current indications that the value of even insect-damaged lumber is great enough to warrant kiln-drying. If kiln-drying is not specified, some infested lumber will no doubt continue to be used in new construction and will result in problems with adult emergence during the first 2 to 4 years of the structure's existence.

■ INSPECTION

When inspecting a house for the presence of wood-destroying insects in general, evidence of horntail larval damage may be encountered on the surface of any of the exposed, unpainted wood. The round exit holes of the adults may be found on the outside of the structure in wood, or extending through wood or composition siding or trim. Inside, they may be encountered in any wall, ceiling or floor material or trim covering coniferous wood structural members. No special procedures, other than careful visual inspection, are necessary to determine the presence or absence of horntail damage.

Horntails are of such minor economic concern in structures that it is only important to correctly identify the evidence in order to place it in proper perspective and to reduce the property owner's or buyer's anxiety.

■ CONTROL

In most cases where structural timbers in a house are infested, no control is necessary, since the emergence of the adults marks the end of the infestation.

Exit holes exposed to the weather probably should be sealed with an appropriate filler material to prevent water seepage and subsequent decay. Those holes found indoors in living spaces should likewise be filled and spot painted. Because there can be several different emergences over a period of time as a result of different infestations and different environmental conditions in the wood, it is most practical to wait until about 3 years after a house is constructed to patch and repair damaged areas indoors.

In those rare instances where it is vital to stop the continued emergence of adults, fumigation of the structure under a tarpaulin as for drywood termite control is a possible answer. Horntails are much more difficult to kill in wood than are many other wood borers. They burrow more deeply than many, and their frass is packed extremely tightly in the galleries.

There are British reports of successful

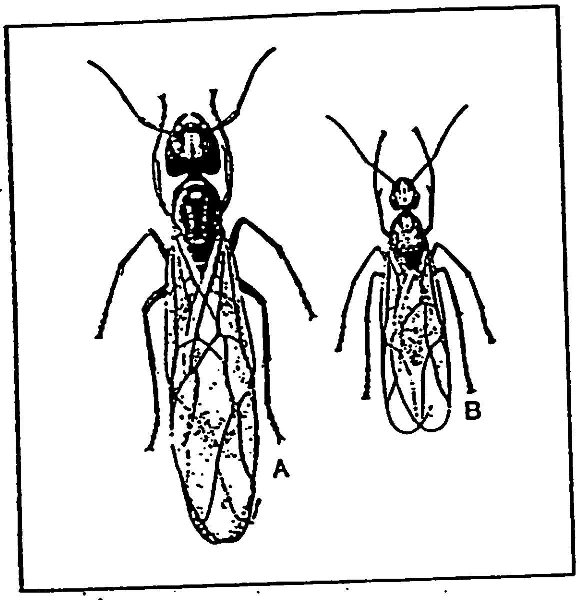


FIGURE 4-2. A. Carpenter ant queen with wings. B. Male carpenter ant. Courtesy Connecticut Agricultural Experiment Station.

fumigation of timbers up to 4 inches (10 cm) thick by using 3 pounds of methyl bromide per 1,000 cubic feet (1.36 kg per 28 cm m) applied for 24 hours at not less than 90°F (32°C) NPCA, 1964. They also report an apparently successful sulfuryl fluoride (Vikane) fumigation of an apartment house in California using 2 pounds per 1,000 cubic feet (0.9 kg per 28 cu m) for 24 hours. Any such treatments would be restricted by labeled dosage rates current at the time of application.

CARPENTER ANTS

Ants that damage wood are known as carpenter ants. As do all other ants, they belong to the family Formicidae. There are over 500 native species in this family, but only a very few of them are of any concern as destroyers of wood. All of the carpenter ants of economic importance belong to one genus, *Camponotus*, and are very similar in appearance and habits. For that reason, it is not necessary to discuss each species separately.

■ CHARACTERISTICS

Carpenter ants are among the largest species of ants that occur in the United States. Several castes or forms of adults are found in mature colonies. There are queens (winged and unwinged), winged males and several sizes of unwinged workers. The winged queens (alates) may be up to 3/4 inch (18 mm) long including the wings (Fig. 4-2A). The males are considerably smaller, being up to 7/16 inch (11 mm) long (Fig. 4-2B).

There is usually only one functional, wingless queen in a colony, and she is up to 9/16 inch (14 mm) long (Fig. 4-3A). There are several sizes of workers. The minor workers are the smallest, averaging 5/16 inch (8 mm) in length (Fig. 4-3C), though some species may be smaller. The major workers are up to 7/16 inch (11 mm) long (Fig. 4-3B) in the common species and may be slightly larger. There are several sizes of intermediate workers in between the two extremes.

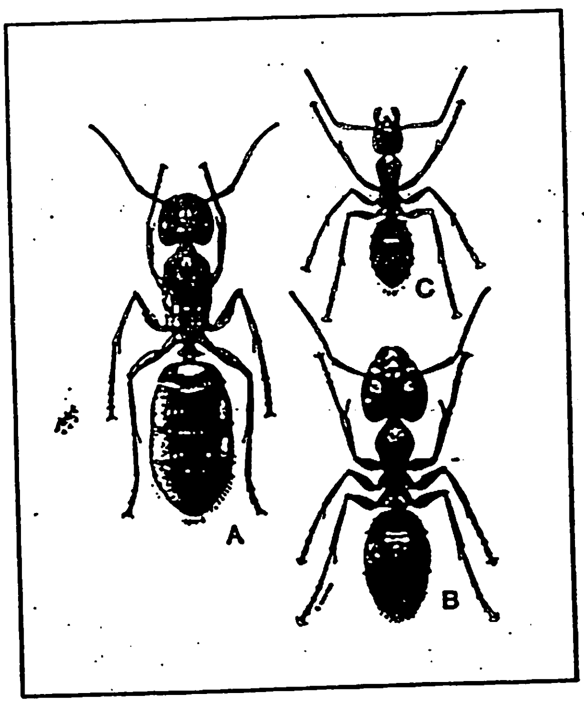


FIGURE 4-3. A. Wingless carpenter ant queen. B. Major worker. C. Minor worker. Courtesy Connecticut Agricultural Experiment Station.

The carpenter ants are typical of all ants in having a very narrow waist (unlike termites) and wings of two different sizes, the front ones much larger than the hind ones (unlike termites with equal-sized wings). The adults of those species found nesting in houses are predominantly black. However, some may be partially reddish-brown to yellowish.

The larvae are small, legless, white and grublike. They are helpless and must be moved, fed and cared for by the adults.

The pupal stage which follows larval development is completed inside tan or cream-colored silken cocoons which are often erroneously referred to as "ant eggs."

DISTRIBUTION AND ECONOMIC IMPORTANCE

Various species of carpenter ants occur in all parts of the United States, even at elevations up to 9,000 feet (2,700 m). In the Pacific Northwest and in the Northeast, they are considered to be the most common pests of wood in structures. In the Caribbean region they are of little, if any, importance in houses. They are occasionally pests in Hawaii in areas recently cleared of chaparral. Houses near wooded areas, cleared land, or brush-covered vacant lots are more likely to be invaded. Disturbing natural nesting areas triggers movement to structures (Furniss, 1944).

Carpenter ants are generally of relatively little economic importance as destroyers of wood in houses. If an infestation is of long standing, however, there may be enough damage to require extensive repairs. Usually, at most, only minor repairs are needed. Besides causing some damage to wood in buildings, carpenter ants are also nuisances in the same way that other ants are when they crawl around in houses foraging for food or water.

BIOLOGY AND HABITS

Carpenter ants, as all ants, are social insects. They live in colonies composed of individuals having different forms (castes) and performing different functions in the colony. As previously described, the adult forms in a colony consist of various sizes of workers and the wingless, egg-laying queen. When a colony has reached a certain stage of development, and at certain seasons of the year, there are also numerous winged males and females present.

The native carpenter ant that has had its biology most thoroughly studied is the black carpenter ant, *Camponotus pennsylvanicus* (DeGeer). It is very common in the eastern and central United States. Most of the information which follows applies to that species, but various reports on other native species indicate that their biology and habits are similar.

Anytime from early spring until the midsummer months, rather large numbers of winged males and females emerge from established colonies. Environmental mechanisms trigger the "swarming," since flights occur simultaneously in a general area, sometimes over a period of several days. This allows breeding of individuals from different colonies, an important genetic consideration since all of the members of a colony are usually the offspring from a single pair. Mating occurs in flight. The males die shortly thereafter, and the females begin a search for a place to establish a new colony. The female breaks off her wings just before or just after a nesting site is selected.

Carpenter ants burrow into wood to make nests, not for food. In nature, they make their nests in dead portions of standing trees, stumps, logs, or under fallen logs or stones, sometimes with galleries extending into the ground. They also nest in structural timbers if they find suitable conditions. Most species prefer to nest in moist wood that has begun to decay. They attack both hardwoods and softwoods. Laboratory experiments indicate that the black carpenter ant cannot successfully establish a colony in wood below 15 percent moisture content (Simeone, 1954). The mated female finds a small natural cavity in wood or soil, or excavates one, and seals herself in with a wood fiber mixture. Within a few days she begins to lay her first brood of 15 to 20 eggs. Under favorable temperature conditions, these hatch into larvae in approximately 3 weeks.

The queen cares for the larvae and feeds them with a fluid secreted from her mouth. This nourishment is derived from stored fat and from metabolic conversion of the now-useless wing muscles. During the two or more months required for the development of the first brood into workers, the female never leaves the brood chamber or takes any nourishment. The resulting adult workers are all very small, but immediately take over responsibility of caring for and providing food for the incipient brood and for the queen. They enlarge the nest as the colony population increases. The queen's sole responsibility then becomes egg laying.

In subsequent generations, workers of various sizes are produced. They are all females, but are undeveloped sexually and do not produce eggs. In general, the largest ants guard the nest, battle enemies, forage for food, and bring food to the nest, where it is transferred to the smaller workers. The smaller workers primarily expand the nest and care for the young. These ants cannot sting. But they have the ability to bite painfully, and can emit formic acid as an additional defense.

The food of carpenter ants consists primarily of honeydew, which is sweet, partially-digested tree sap gathered by the workers from aphids and some other insects which they find on foliage and roots of trees. Carpenter ants also feed on the remains of insects and on plant and fruit juices. When they forage inside houses for food, they are attracted to sweets and to most kinds of meats, grease and fat. Most of the food gathered by the workers is consumed instead of being carried back to the nest. Workers feed the other colony members, adults and larvae, by regurgitating food and transferring it mouth-to-mouth.

During the first year the colony remains small, consisting of the queen, about 10 to 20 workers and some immature forms. In succeeding years the population grows rapidly until it numbers 2 or 3 thousand individuals. It usually requires 3 to 6 years for this size to be reached, at which time winged reproductives (swarmers or alates) are produced each year. Swarmers usually appear in late summer, but spend the winter in the nest and emerge the following spring or summer. Colonies rarely grow larger at this point, but they indefintely continue to produce reproductives and replenish the workers which die. If the colony becomes stressed from lack of food and water, they will resort to cannibalism, and the queen, with a few workers, will survive for long periods.

Houses are very commonly infested by the movement of a colony, or part of a colony, into the structure. Fertilized queens also establish new colonies in houses. In structures, timbers that are soft, damp and partially decayed are most frequently selected as nesting sites by carpenter ants. There are some species that are capable of nesting in sound wood, but even these prefer softened wood to start a nest. Once a nest is established, the workers will extend the galleries into sound wood adjacent to the partially decayed portion.

It is not uncommon for carpenter ants to nest in houses without attacking the timbers. They simply use existing cavities, including wall voids, hollow flush panel doors, termite galleries in wood, etc., in almost any part of a house. In undisturbed areas such as attics, inside stored furniture, and on seldom-used shelves, they may establish a nest in debris or even out in the open. They sometimes nest in foamed plastic or fiberglass insulation. Consequently, carpenter ants cannot always be considered pests of wood. Occasionally, they occupy an existing cavity indoors and then expand it by invading adjacent timbers.

Whether for nesting or for foraging only, carpenter ants enter houses in many different ways. Tree branches or power or telephone lines contacting a house are a source of access. Carpenter ants get inside through cracks and crevices around windows, in foundation walls, through ventilation openings, and through heating ducts and air conditioners. They can also be brought into the house in firewood.

■ SIGNS OF INFESTATION

The most obvious sign of infestation is the sighting of large, black workers inside the house. Occasionally, a person will turn on a light in a kitchen or bathroom at night and find large numbers of the ants seeking water in the sink. During very warm weather, the ants are most active at night, and daytime activity is so reduced that there may be little evidence of the ants except after dark. The ants are active the year round if nesting in heated portions of houses; otherwise, they become inactive during cool weather.

During the spring or early summer, there may be swarmers inside or around the house. Those indoors tend to fly toward the windows and to congregate there.

There may be piles or scattered bits of very fibrous and sawdust-like frass which the ants have removed from the wood. If from decayed wood, the pieces tend to be darker and more square-ended. The frass can be distinguished from sawdust produced during construction, or from the very similar carpenter bee frass, by the fact that there are fragments of ants and other insects mixed with the wood fibers. The frass is expelled from cracks and crevices or from slitlike openings called "windows" made by the ants. The frass is quite often found in basements, dark closets, attics, under porches, and other out-of-the-way places.

The slitlike openings are themselves a positive sign of these ants when found in association with other evidence. They usually are directly above the frass.

Faint rustling and even gnawing sounds can be heard in the wood or cavity when ants are active. The sounds can best be heard when background noise is at a minimum.

On very rare occasions, there might be actual failure of wood in service. This will usually be result of some sudden excessive stress on the damaged member, such as a shift of heavy furniture, a wind storm, or a heavy snow accumulation on a roof.

■ CHARACTERISTICS OF DAMAGED WOOD

The damage to wood is discovered when the surface is broken open. The only external evidence of attack is the small, inconspicuous "windows" made in the surface by the ants.

The galleries extend both along the grain of the wood and around the annual rings. The softer, spring growth (early wood) tends to be removed first. The harder-grained summer wood is penetrated at frequent intervals, so there is complete access between the galleries (Fig. 4-4). The surfaces of the galleries are as smooth as if they had been sandpapered and are perfectly clean. The general appearance of the galleries is similar to those made by drywood termites, but there are no fecal pellets, and the frass is completely removed except for occasional deposits in unused galleries.

■ POTENTIAL FOR DESTRUCTION

Carpenter ants do not pose a serious threat to the soundness of structural timbers unless they are ignored for long periods of time. If the occupants of the house are aware of the numerous worker ants in the vicinity of the house and see the swarmers produced each spring or summer, they cannot remain unaware of the presence of an infestation. Once the infestation is discovered, control measures can simply and effectively stop the problem quickly.

If the ants are ignored, there can be destruction of wood, and expensive repairs may be needed. This most often occurs in recreational structures that remain unoccupied for long periods of time and that may be constructed in such a place and in such a way as to invite ant invasion.

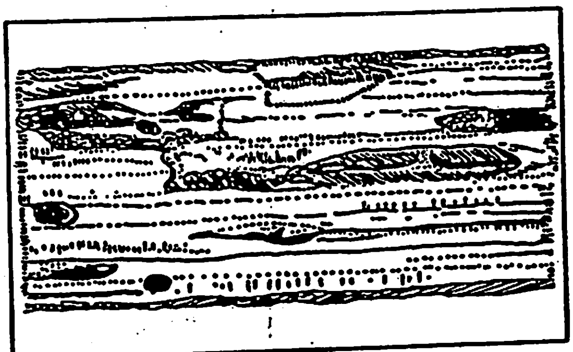


FIGURE 4-4. Carpenter ant damage. From Insects Affecting Forest Products and Other materials by W.J. Chamberlain. Used with permission of Oregon State University.

PREVENTION

The prevention of attack by carpenter ants is in many ways similar to the prevention of subterranean termite attack. Since carpenter ants are most likely to initiate attack in damp wood that has partially decayed, this condition should be avoided. Proper clearance between wood and soil, good drainage and ventilation, proper roof flashing, and tight exterior wood joints are all good preventive practices. If wood is likely to be wetted from time-to-time, it should be pressure-treated as described for subterranean termite prevention. Areas such as wooden porches and wooden support columns are particularly susceptible to decay and to ant attack. Proper maintenance of all these features is equally important.

Proper sanitation of the building site will help reduce the chance of attack. All stumps, logs, wood debris, etc., should be removed from the vicinity of the house. Firewood should not be stored near the house, and it should be carefully inspected for carpenter ants before being brought indoors.

Where the size of the lot permits, any ant colonies within 100 yards (90 m) of the house should be destroyed by removal or treatment with chemicals as will be indicated in the control section.

These procedures will not totally prevent carpenter ant attack in houses, but they will greatly reduce the incidence of invasion.

INSPECTION

Inspection for carpenter ants begins with an interview of the occupants of the property. They should be asked about the presence of ants and where they were seen. They also should be asked whether they have found any ant frass or if there are moisture problems in any part of the structure.

The most difficult and most important part of the carpenter ant control is locating the nest or nests. Once they have been found, control is relatively easy. Therefore, inspection procedures should be aimed at finding the nest sites, both indoors and outdoors.

The most obvious places to look for carpenter ants are those areas most likely to have a high moisture content. These include the bases of walls in closest proximity to the soil, wooden porch floors and columns, wood subject to plumbing leaks and condensation, window and door sills, roof edges, areas around roof flashing, and areas between roof and ceiling in flat-roofed decks or porches. Any wood in soil contact should be carefully examined, whether it be a structural member or wood debris. Inspection for these conditions would require careful examination of the outside of the structure as well as in the attic and crawl space or basement.

Since carpenter ants do not confine their nests to damp wood, it is equally important to examine the interior of the house for signs of ant activity. They have been found nesting in virtually every part of houses. The edges of floors and ceilings and window and door trim should be carefully examined. Ants commonly nest in wall voids above windows and doors and inside hollow doors. The inside of furniture in long-term storage should be carefully inspected.

In addition to the house itself, the inspector should look for ant colonies and ant activity in the yard near the house. Trees, fence posts, stumps, and logs should all be examined for signs of ants.

When the ants themselves are found, they should be observed long enough to determine the general direction in which they are traveling. It is then possible to follow them back to the nest area. If the exact site of the nest is not obvious, pounding on the wood and listening for the typical dry, rustling sound produced by the ants is helpful in pinpointing the location.

CONTROL

In order to obtain satisfactory control of carpenter ants as nuisances, it is necessary to treat all colonies both in and near the house.

Once the nests have been located, they should be treated with residual contact insecticide applied as a dust or spray. It is sometimes helpful to drill 1/4 inch (6.25 mm) holes at 1-foot (30 cm) intervals into the galleries or into the void in which the nest occurs. A nozzle fitting tightly into holes should be used to get good coverage. After treatment, the holes should be plugged with short lengths of wooden dowel—or with corks—of proper size. Dusts are particularly effective in the nests. All of the approaches and areas surrounding the nest also should be treated.

Indoors, this is best accomplished by spraying. Simply treating the areas where ants are seen and not locating and treating the nests is seldom satisfactory. Some of the ants do not leave the nest and would not be affected by such a treatment. Considering that individual carpenter ants can live for 6 months or more without feeding, it is obvious that nest treatment is essential.

Any of the insecticides which are currently labled for ant control should be effective if the nests are carefully treated. Examples of such insecticides are bendiocarb (Ficam), boric acid, chlopyrifos (Dursban), cypermethrin (Demon), diazinon, fenvalerate (Tribute), propoxur (Baygon), and sodium borate.

Indoors, galleries and wall voids can be treated with silica aerogel (Drione; Whitmire PT 230 Tri-Die) or boric acid dust, which will provide long-term residual protection if the treated areas are dry.

In order to aid in carpenter ant control and to help prevent future attacks, high moisture conditions in wood in the structure should be eliminated.

CARPENTER BEES

The common name of carpenter bees is used for two closely related groups of bees in the family Anthophoridae. One of the two groups are small, metallic-colored bees that nest in the stems and canes of pithy plants (genus *Ceratina*). They will not be treated further. The other group are all larger and belong to the single genus, *Xylocopa*. They construct nests in wood, occasionally in structural timbers, and are the subject of the following discussion.

■ CHARACTERISTICS

There are nine species of the larger carpenter bees in the contiguous states (NPCA, 1963), and at least one species in Hawaii and in Puerto Rico. The adults are generally stocky, black or blue-black in color, and up to 1 inch (25 mm) or slightly more in length. The thorax is covered with yellow, orange, or white hairs, and the abdomen, especially on the top side, is bare and shiny. The yellow-marked eastern species especially resembles bumblebees.

Some of the species have greenish or purplish reflections and, in some, the males are entirely buff or pale yellow. They may be distinguished from bumblebees by the fact that they are bare on top of the abdomen instead of covered with hair as are the bumblebees (Fig. 4-5). Also, female carpenter bees have a dense brush of hairs on the hind legs, as compared with the more openly constructed pollen baskets on the legs of bumblebees.

The larvae are white, legless, and grublike and remain entirely inside the wood. The pupae start out very light-colored and gradually darken to more nearly resemble the adults as they develop. They likewise, remain entirely in the wood.

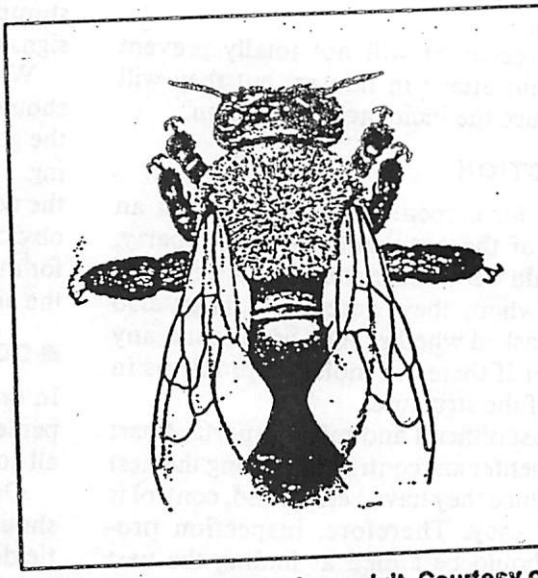


FIGURE 4-5. Carpenter bee adult. Courtesy of F. E. Wood, University of Maryland.

■ DISTRIBUTION AND ECONOMIC IMPORTANCE

Of the species of wood-invading carpenter bees in the contiguous states, only three nest consistently in structural timbers (Hurd, 1958). They are found in virtually all parts of the country and can be transported in infested wood from one area to another. There is one species in Hawaii that nests in structural timbers. It has been introduced into the Mariana Islands (Hurd, 1958). There are carpenter bees in Puerto Rico, but they are of no concern as pests in structures (personal communication, July 1975, Luis F. Martorell, Professor Emeritus, Department of Entomology, University of Puerto Rico, Rio Piedras, Puerto Rico).

Carpenter bees are most often simply nuisances in and around structures. They are confused with bumblebees by homeowners who are concerned about being stung. The male bees are very aggressive and behave as if they will attack intruders into the nest area. They do not possess stingers and are harmless. The females are not aggressive and, although they are capable of doing so, very seldom sting unless handled or otherwise seriously molested.

Structural damage by carpenter bees in occupied buildings is seldom of any consequence. They are large, noisy insects, and make rather conspicuous holes in wood. For these reasons, they attract much attention when present and should be recognized so that their relatively minor potential for damage can be properly evaluated.

■ BIOLOGY AND HABITS

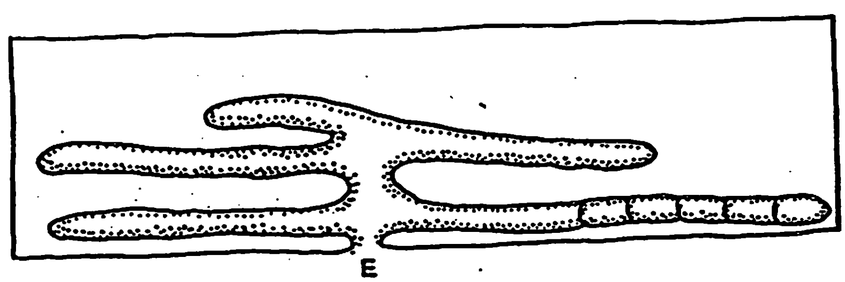
Xylocopa virginica (L.), known by the approved common name "carpenter bee," is the most prevalent wood-attacking species east of the Rocky Mountains. The biology of this species has been described in great detail (Rau, 1933; Chandler, 1958; Balduf, 1962), and the life history of this species will illustrate the life history of carpenter bees in general.

The adults overwinter in abandoned nest tunnels. They emerge in the spring, usually April or early May, and feed on nectar. Mating occurs within a few weeks, after which the males die. Activity continues year around in Florida, where there are two generations per year.

Mated females begin to prepare nests either by excavating a new tunnel or, more often, cleaning out and expanding an old gallery. Many females live two years, and often two or three females are present in each nest, but only one works and lays eggs (Gerling and Hermann, 1978). When several generations of bees have shared a common nesting site, the galleries may become quite branched and interconnected (Fig. 4-6).

The original entry is most commonly made by the female boring into the lateral face of a structural timber in a well-lighted but sheltered location. Entry is less often made on the underside or end of a board. The hole is perfectly round and approximately 1/2 inch (12 mm) in

FIGURE 4-6. Carpenter bee nests as constructed in a 1 in. by 4 in. (2.5 cm by 10 cm) board. E designates the entry hole on the narrow face of the board. Adapted from Balduf, 1962. Used with permission of the Entomological Society of America.



diameter. Except when started on the end of a board, the tunnel turns abruptly at a right angle, after being extended approximately the length of the female's body across the grain of the wood. The tunnel is extended with the grain from 4 to 6 inches (10 to 15 cm) in a new site.

An old gallery may be extended or used without further burrowing. If an old gallery is repeatedly extended by succeeding generations, it may ultimately reach 6 to 10 feet (2 to 3 m) in length. The galleries are excavated solely by the females' using their mandibles (jaws), and are almost always a constant distance from each of the two wide faces of the timber.

The female provisions the end of the brood gallery with a mass of pollen and nectar approximately the size of her abdomen and lays an egg on the mass. She seals off this portion of the gallery with a partition composed of wood pulp and saliva. The process is repeated at the rate of one a day until, usually, there are six cells in a row.

Having completed their function, the adults slowly decline, and die within a few weeks.

The development from egg to adult requires 5 to 7 weeks, depending on average temperature. Those bees which occur in the foothills and mountains along the West Coast (*Xylocopa tabaniformis orpifex* Smith) require up to 3 months to complete development. Following emergence from the pupal stage, the adult bees remain within the cells for a day or two, drying and feeding on any remaining pollen.

Because there is considerable variation in the time required for development of each stage (Simeone, 1972), there is no predictable sequence for the emergence of adults in relation to their position in the gallery. All of the adults from a single gallery, however, emerge over a relatively short period of time.

The emergence of the adults usually occurs in late summer. Although they are sexually mature, they do not mate until the following spring. They remain in the vicinity of the brood galleries, feeding on nectar and pollen, until cold weather forces them into hibernation in the old galleries. No pollen is stored, except for consumption during inclement weather, and little if any boring occurs prior to hibernation.

It is common for carpenter bees to continue to utilize the same nesting site for many years if it is a favorable one. One site was reported to be continuously used for 14 years.

■ SIGNS OF INFESTATION

There are several ways in which the inspector may determine the presence of carpenter bee attack in a structure. The most obvious one is the bees themselves. They are present around the outside of the house during the late spring and early summer and again in late summer and early fall.

Those bees present during the early part of the season are the ones which excavate galleries in the wood. Because of this, there may be burrowing sounds, which resemble a vibration on the wood surface.

In addition, there will be rather coarse sawdust-like frass being expelled from the entry holes. The frass accumulates on surfaces below the site of activity. The frass is usually the color of freshly sawed wood and varies with the species of wood under attack. There are no fragments of insects mixed with this frass, as is the case with carpenter ant frass, although it is otherwise similar.

If there has been bee activity in the area for some time, there may be yellowish to brownish streaks of fecal material on surfaces immediately below the entry holes. This streaking is most easily seen on light surfaces.

When the bees are not active, the only signs of infestation likely to be seen are the 1/2 inch (12 mm) round entry holes made by the female bees.

■ CHARACTERISTICS OF DAMAGED WOOD

Carpenter bees usually choose wood that is soft and easy to work. They particularly like California redwood, cypress, cedar, white pine, and southern yellow pine. Other woods, even hardwoods, may be chosen if they have been softened by being unprotected and exposed to the weather for extended periods of time. Bare wood is preferred. Carpenter bees avoid well painted wood and wood with bark on it. If the surface is stained or has a very thin coating of paint on it, they will attack it. They also will tunnel wood that has been pressure-treated with metallic salts for above-ground use, such as in decks.

The only external evidence of attack is the entry holes made by the females. If the wood is pried open or has been damaged by woodpeckers subsequent to bee attack, the internal galleries can be seen (Fig. 4-6). They are smooth-walled and tend to be a very uniform 1/2 inch (12 mm) in diameter. If they have been used for several generations, they become more irregular and up to 1 inch (25 mm) in diameter.

■ POTENTIAL FOR DESTRUCTION

In areas where carpenter bees are common, the amount of damage that they can do in a structure varies directly with the amount of unpainted wood surface exposed to their attack and with the suitability of the wood for their entry. In addition, there must be a nearby source of infestation, since these bees do not disperse widely from a suitable nesting site.

If the infestation is discovered before a large population has developed, very little damage of a serious nature will have occurred. It takes several years of almost total neglect for carpenter bees to cause damage serious enough to cause structural failure. East of the Rocky Mountains, such large populations of bees are most likely to occur in the southern reaches of their distribution (Balduf, 1962). They can, however, be indirectly responsible for very unsightly damage when woodpeckers attack infested wood in an effort to obtain the bees as food. When thin wood, such as siding, is so attacked, it may be completely penetrated. Decay may follow such attack in wood exposed to rain.

■ PREVENTION

The only way to prevent attack by carpenter bees is to keep all exposed wood surfaces well coated with paint. If interiors of storage areas, garages, etc., have unpainted wood exposed, doors and windows should be kept tightly closed or screened during the spring and early summer when the bees are seeking nesting sites.

Wood pressure-treated with organic preservatives such as pentachlorophenol and with heavy loadings of metallic salts is resistant to carpenter bee attack.

■ INSPECTION

The nests of carpenter bees are not difficult to locate when the bees are active. When they are not active, it is necessary to concentrate inspection efforts on those surfaces likely to be invaded. Some of the more common sites in buildings include headers, siding, roof eaves, wooden shingles, porch ceilings, window sills, woodwork, doors, etc. (NPCA, 1963). Those surfaces which are bare or poorly coated with stain or paint shoud be inspected very carefully. Well lighted but protected locations are also favored. The unpainted back sides of gable ventilators and of shutters are sometimes points of entry hard to discover.

In addition to the structure itself, the inspector should give attention to wooden poles, posts, fences, and lawn furniture in the vicinity of the house, since they may be a source of infestation.

■ CONTROL

Any insecticide labeled for bee control, applied into the entry holes will kill bees which come into contact with the residue. Dust formulations are preferred for treatment inside the nests. Carbaryl (Sevin) and boric acid formulations are available. Several days after treatment, the holes should be plugged with short lengths of dowel rod of the proper diameter, or with plastic wood. Plugging the holes without applying insecticide can lead to the production of new holes next to the plug when bees inside attempt to emerge, or nesting females seek reentry into galleries in use.

Treating the external surfaces in the vicinity of the entry holes with any insecticide labeled for bee control will discourage continued bee activity. Chlorpyrifos (Dursban), cypermethrin (Demon), diazinon, fenvalerate (Tribute), and propoxur (Baygon) are examples of registered materials. It may be necessary to repeat applications at weekly intervals during the nesting season in order to maintain control if bees are moving in from surrounding areas.

CHAPTER 4 • REFERENCES

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