

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

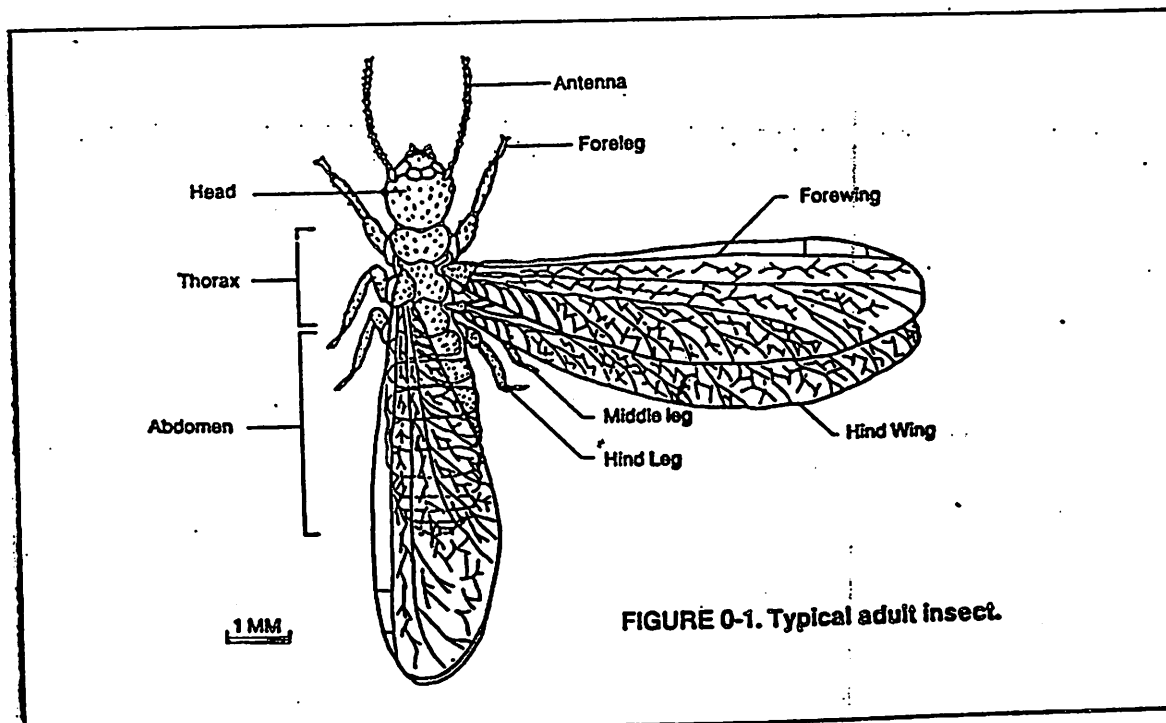
The insects form the largest class in the Animal Kingdom. More than three fourths of all kinds of animals known to science are insects. Almost a million kinds have already been named, and several thousand more are discovered and classified each year. Fortunately, only a small percentage of the many kinds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



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 with 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.

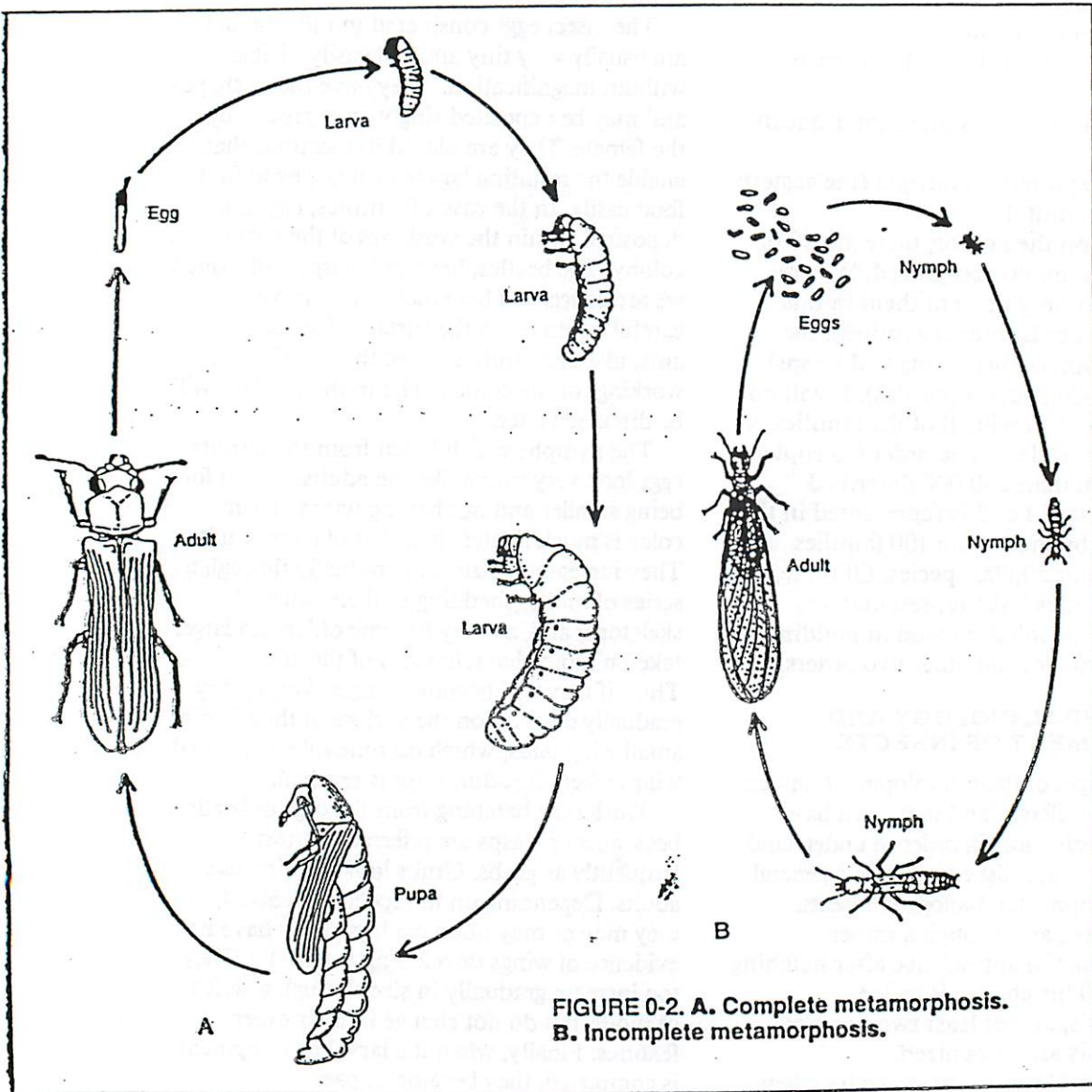
The larvae hatching from the eggs of beetles, bees, ants or wasps are referred to most frequently as grubs. Grubs look nothing like adults. Depending on the species involved, they may or may not have legs. They have no evidence of wings developing externally. They too increase gradually in size through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

¹Some 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.



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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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 descendants 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.

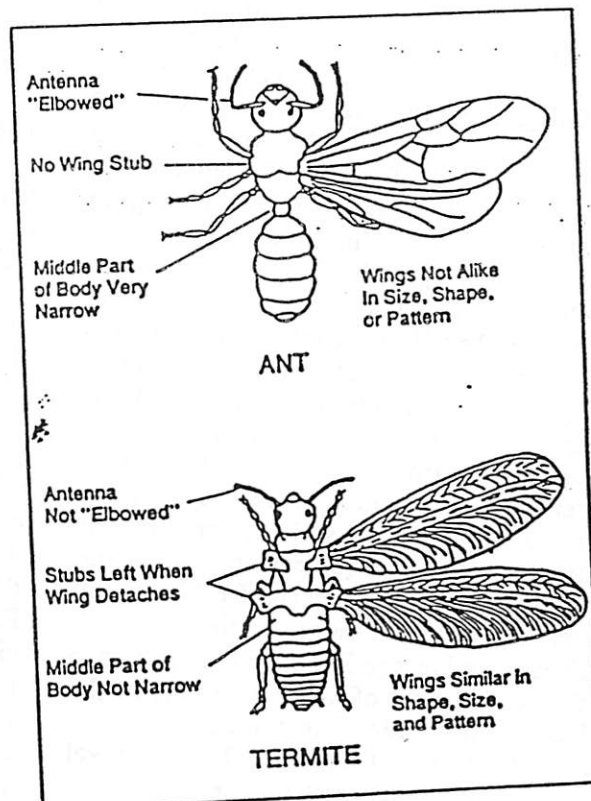


FIGURE 1-1. Winged termite and winged ant compared.

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

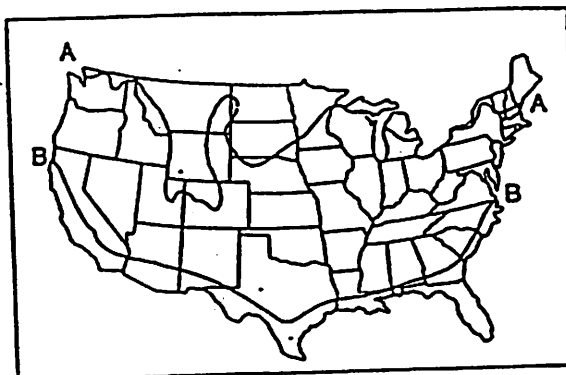


FIGURE 1-2: Subterranean termites are found in the areas below line A-A; drywood termites are found in the areas below line B-B.

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.

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 swarmer. 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.

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

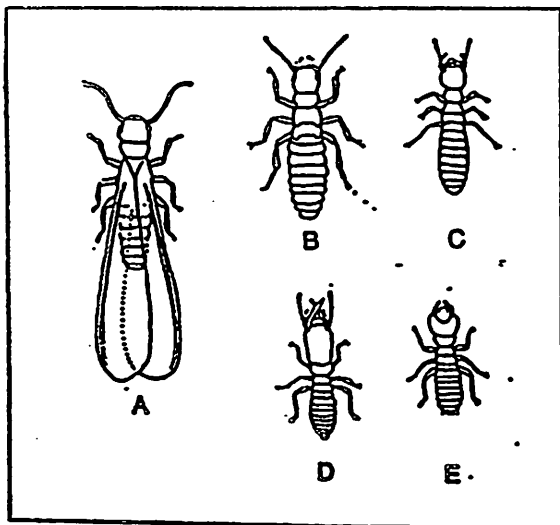


FIGURE 1-3: Primary (A) and supplementary (B&C) reproductives, soldiers (D), and worker (E) termites."

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,

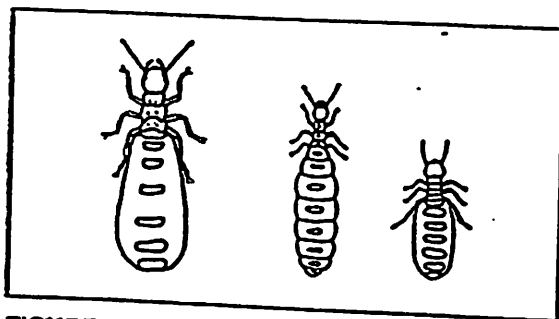


FIGURE 1-4. Primary and replacement queens enlarged from egg development.

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.

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 swarmer, 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 swarmer 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 sol-

diers, 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, dry-wood 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

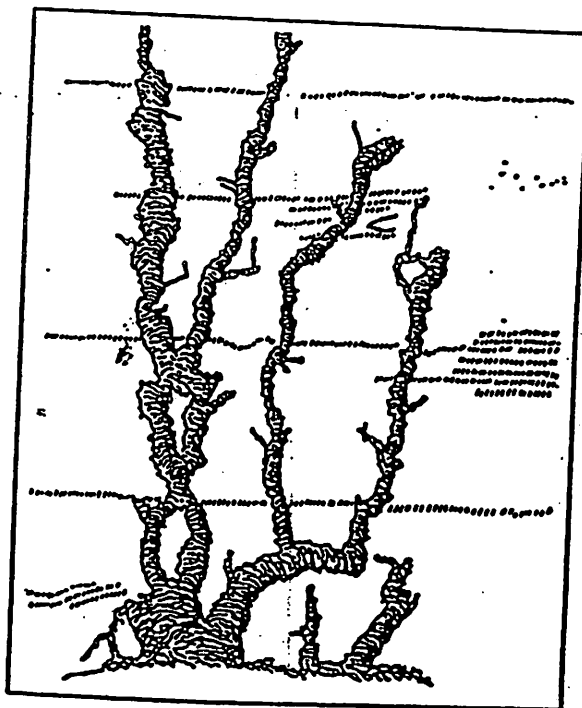


FIGURE 1-5. Termite shelter tubes on foundation wall.

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 ter-

mites 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 $\frac{1}{8}$ to $\frac{1}{2}$ 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

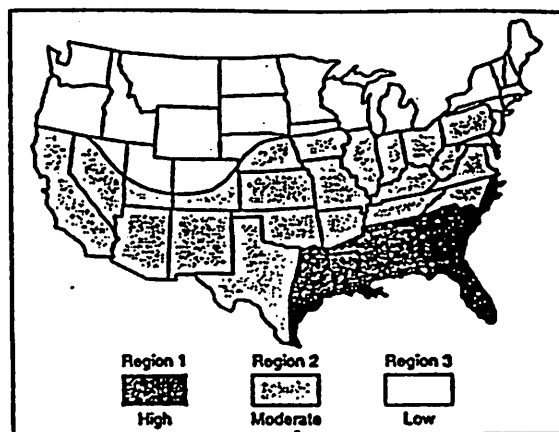


FIGURE 1-6. Geographic distribution of subterranean termite hazard regions. Modified from U.S.D.A.

between families and species for this to be valid in most areas.

■ 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

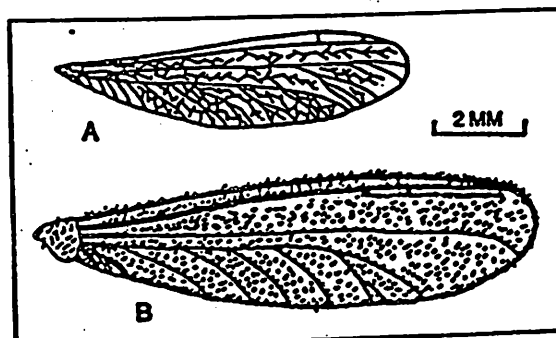


FIGURE 1-7. A. *Reticulitermes* wing. B. *Coptotermes* wing.

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 swarmer from those of native species is by the larger size [up to $\frac{3}{8}$ 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.

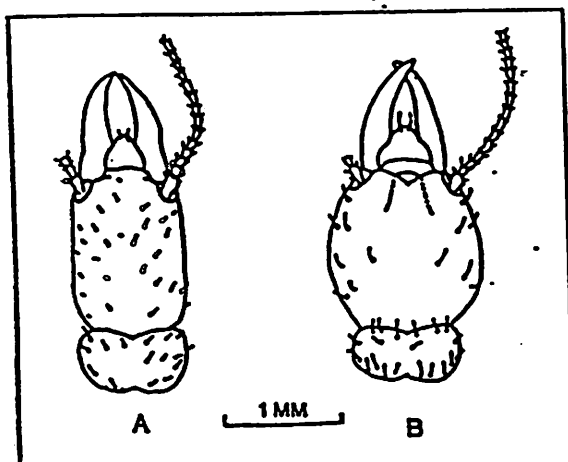


FIGURE 1-8. A. Head of native subterranean soldier. B. A Formosan subterranean soldier.

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 swarmer 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

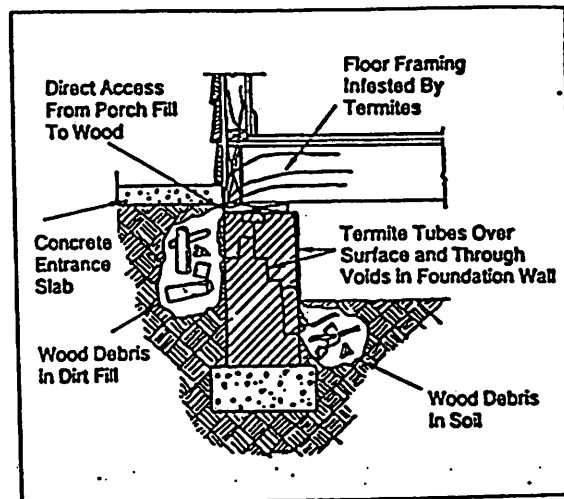


FIGURE 1-9. Cross-section of house showing points of termite entry.

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,

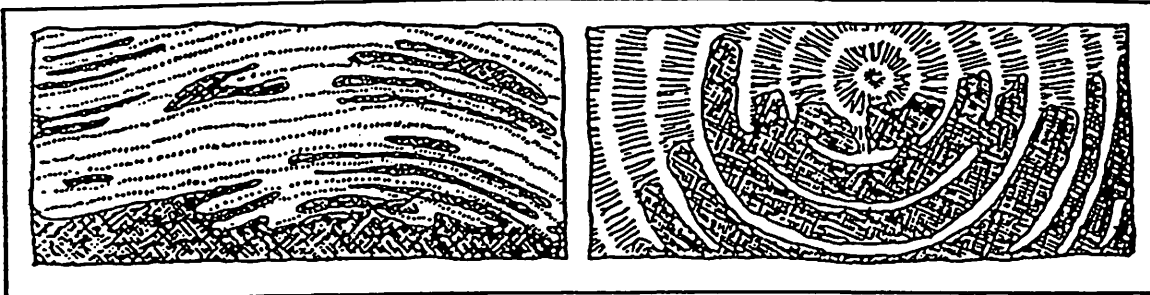


FIGURE 1-10. Cross-section of wood damaged by subterranean termites.

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 con-

taining 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,

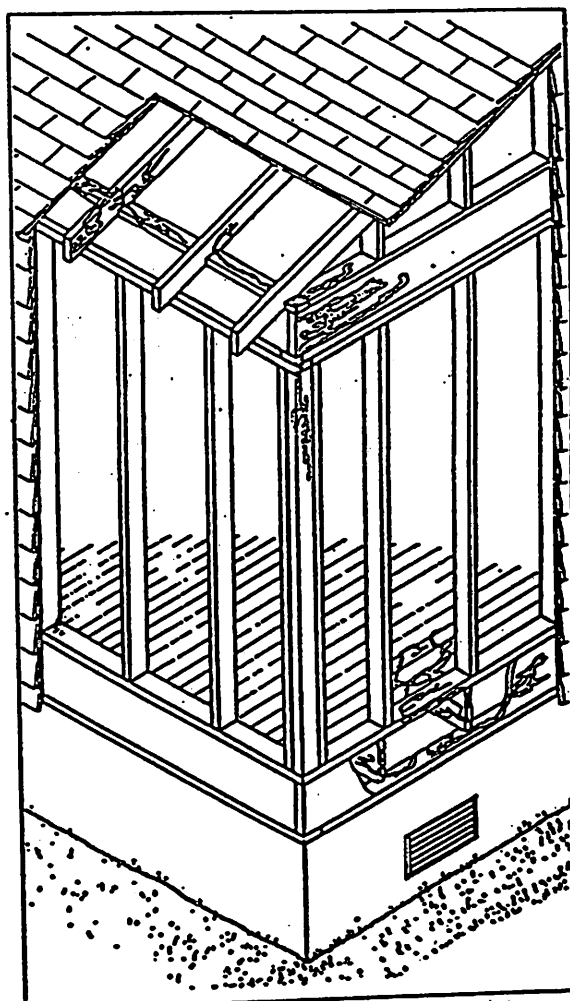


FIGURE 1-11. Drywood termite infestation in house attic and substructure.

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 out-

side 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 $\frac{1}{2}$ to $\frac{3}{8}$ 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

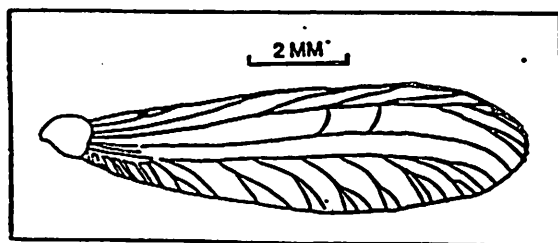


FIGURE 1-12. Drywood termite wing.

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 $\frac{1}{2}$ s 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 $\frac{1}{16}$ 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 them-

selves 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.

■ 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

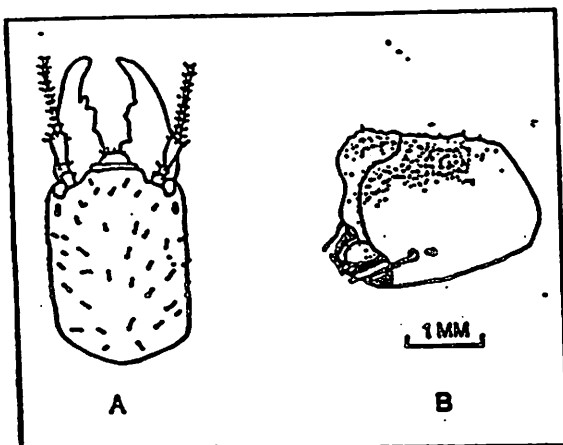


Figure 1-13. A. Heads of western drywood termite. B. Powderpost termite soldiers.



Figure 1-14. Drywood termite pellets.

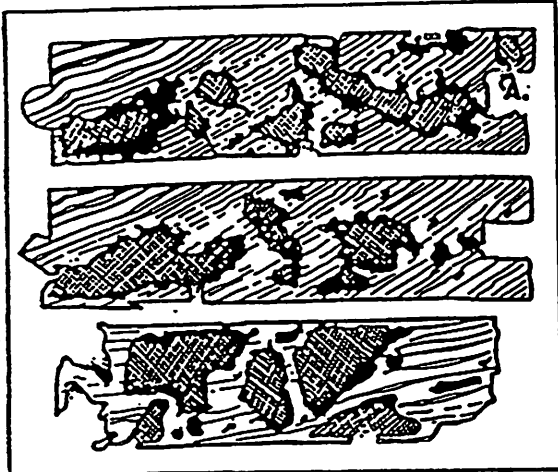


FIGURE 1-15. Cross-section of wood damaged by drywood termites. A. Point of entry.

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

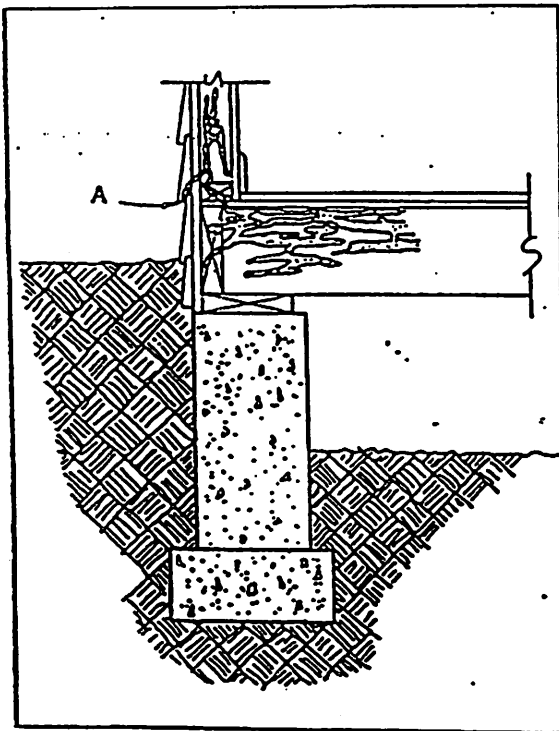


FIGURE 1-16. Dampwood termite invasion of a house. A. Point of entry.

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.

DAMPWOOD TERMITES

MODE OF LIFE AND SOURCES OF INFESTATION IN BUILDINGS

The dampwood 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 greatest 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 $\frac{1}{16}$ to $\frac{3}{4}$ 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, $\frac{1}{16}$ to $\frac{3}{4}$ inch (15-20 mm) long, and have very large, dark, rectangular 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 spe-

cies, the swarmers being $\frac{1}{2}$ 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

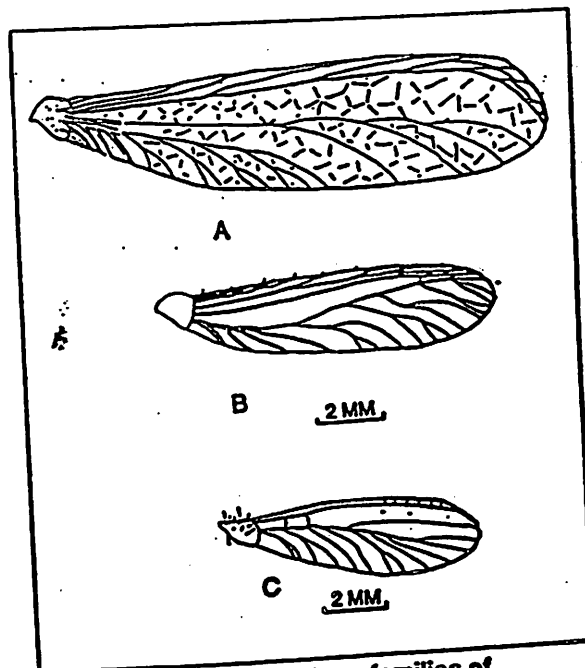


FIGURE 1-17. Wings of three families of dampwood termites. A. Hodotermitidae (West Coast). B. Kalotermitidae (Southwest). C. Rhinotermitidae (Florida and Caribbean).

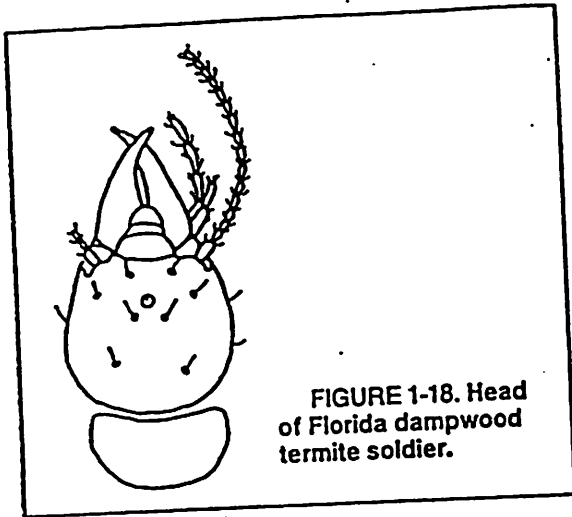


FIGURE 1-18. Head of Florida dampwood termite soldier.

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 material, 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.

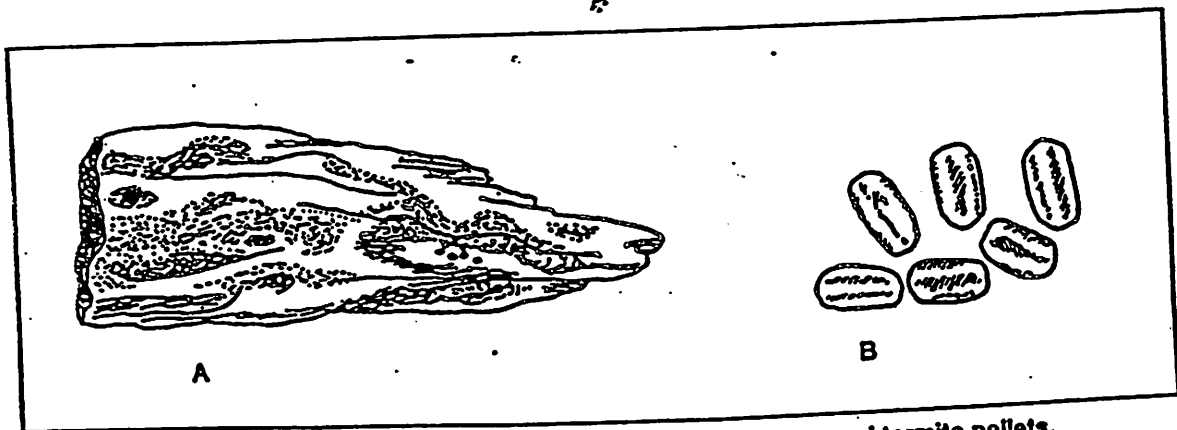


FIGURE 1-19. A. Wood damaged by dampwood termites. B. Dampwood termite pellets.

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 originally 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.

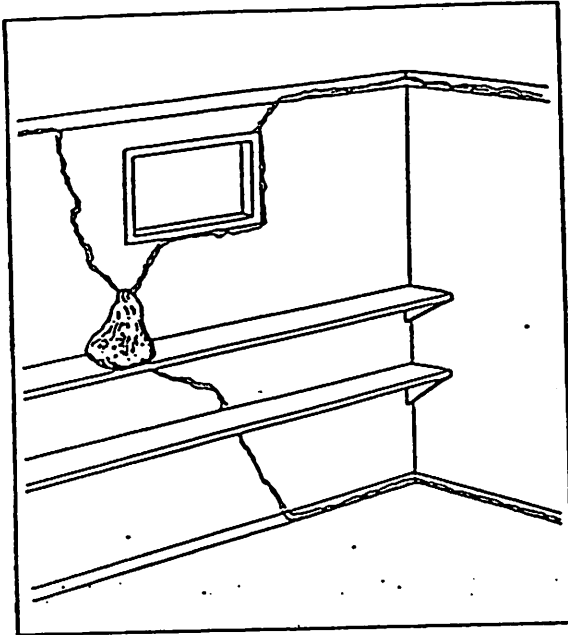


FIGURE 1-20. Carton nest on wall.

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.

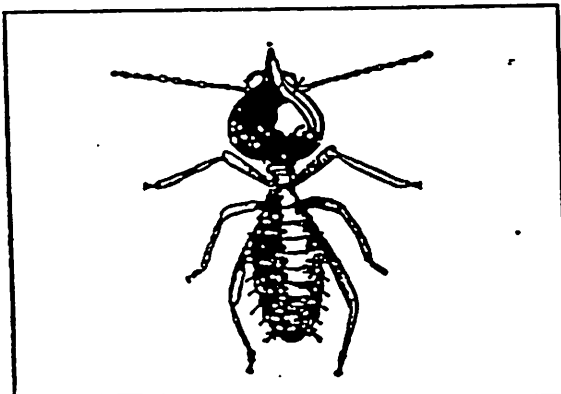


FIGURE 1-21. Soldier of tree-nesting termite.

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 irritating 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 apparently 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-

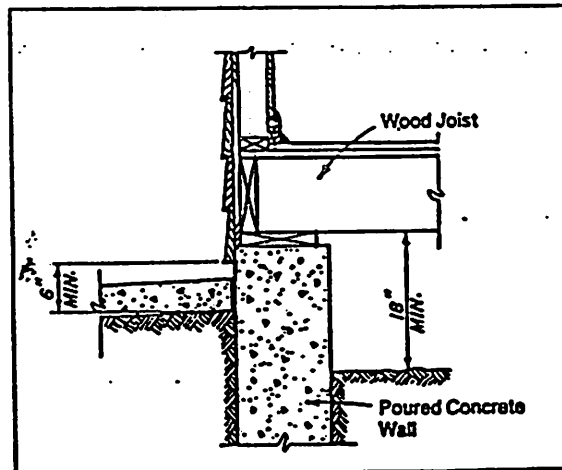


FIGURE 2-1. Poured concrete foundation walls or piers that are easily inspected offer complete protection against termite infestation. Proper clearance of eight inches (20 cm) should be provided between the dirt fills and the framing members; also, a clearance of six inches (15 cm) from the wood siding 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 geographic 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 $\frac{1}{32}$ 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.

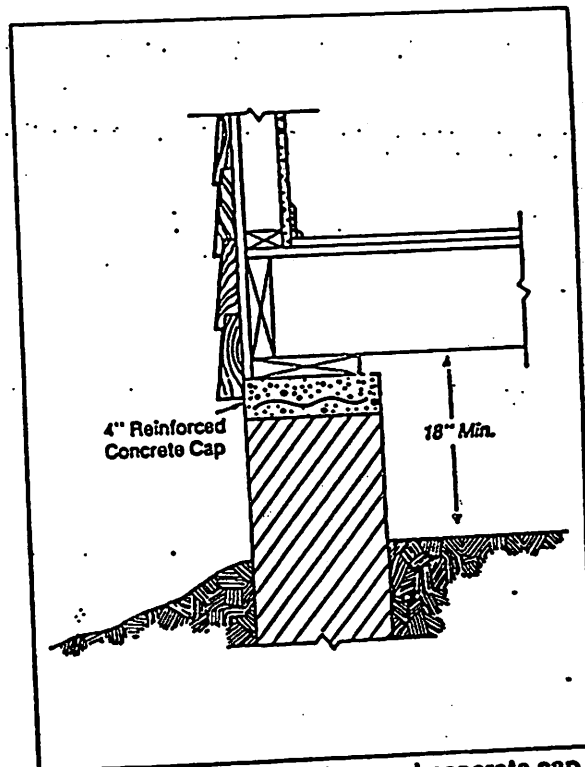


FIGURE 2-2. A reinforced poured-concrete cap on masonry walls or piers prevents hidden attack by termites. A minimum of four inches (10 cm) should be provided between the outside finished grade and the lower horizontal joint of the cap; also, a clearance of six inches (15 cm) from wood to the ground 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 con-

trary, 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-

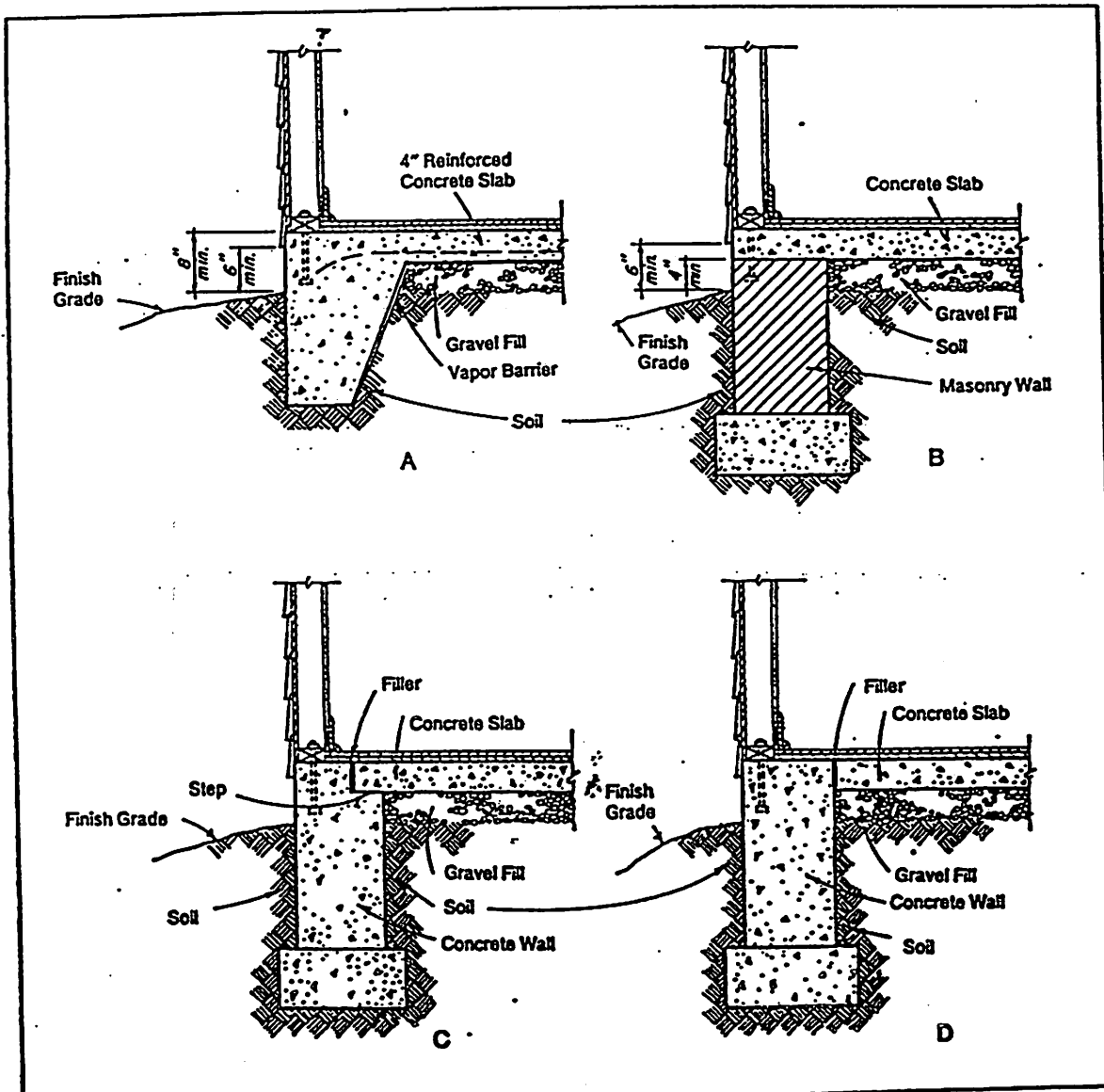


FIGURE 2-3. Slab on ground construction. A. Monolithic slab. B. Suspended slab. Floating slab type of construction in which the slab rests on the ledge of the foundation wall. C. Or is independent of it. D. The expansion joints in C. and D. are particularly vulnerable to termite entry. Courtesy USDA.

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 carefully 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 structure. 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

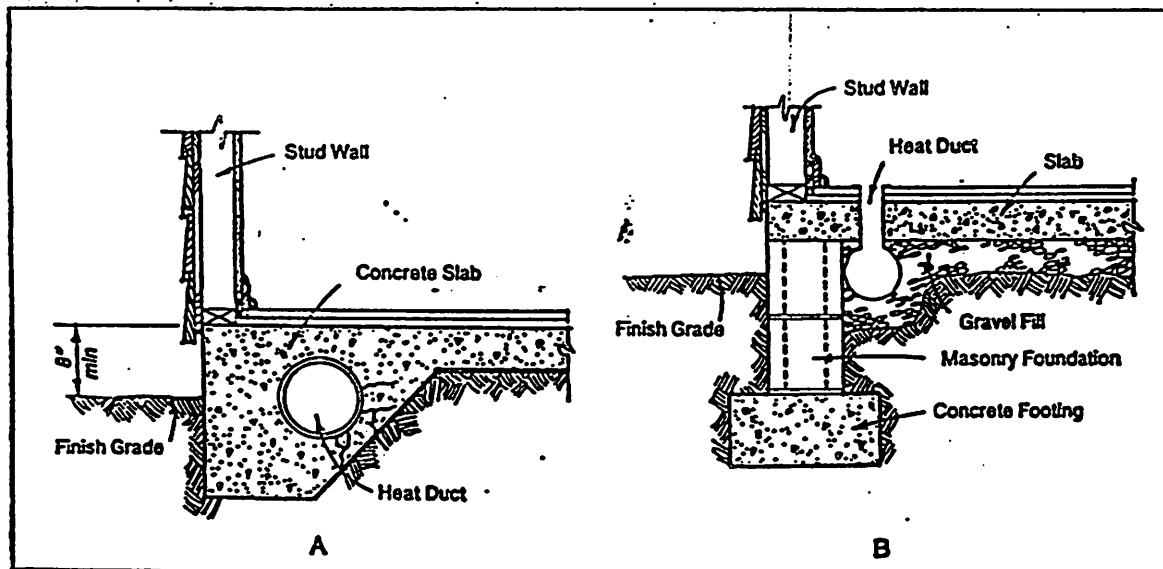


FIGURE 2-4. A. Heat duct imbedded in monolithic slab with cracks allowing termite entry. B. Heat duct under supported slab with joint around heat duct which allows termite entry. Adapted from Terminix and NPCA.

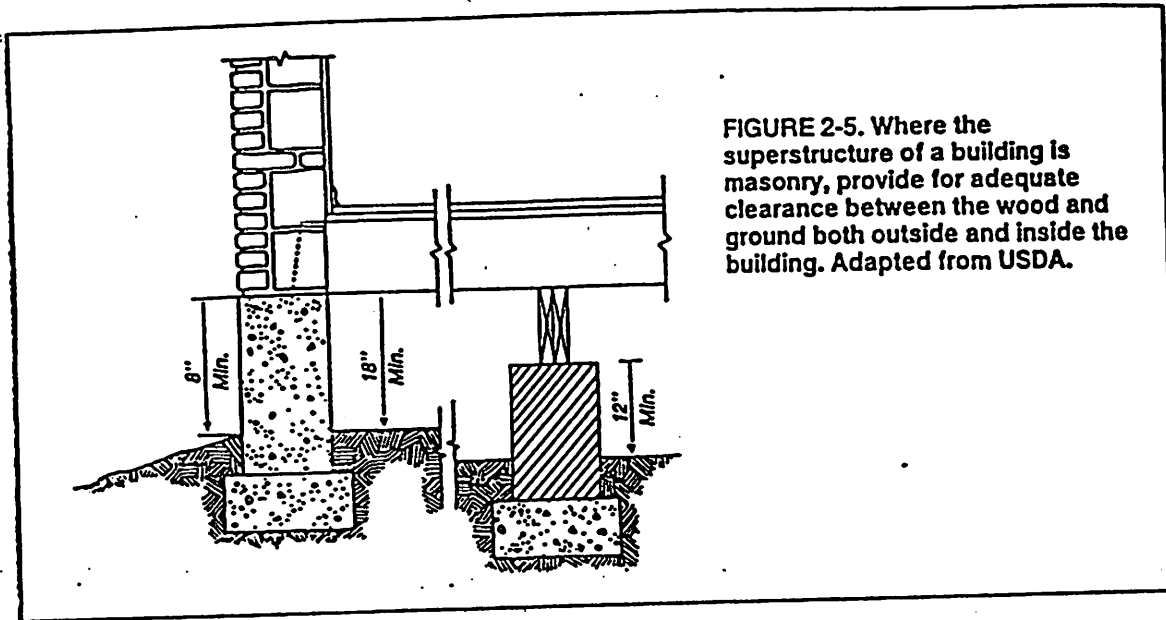


FIGURE 2-5. Where the superstructure of a building is masonry, provide for adequate clearance between the wood and ground both outside and inside the building. Adapted from USDA.

(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

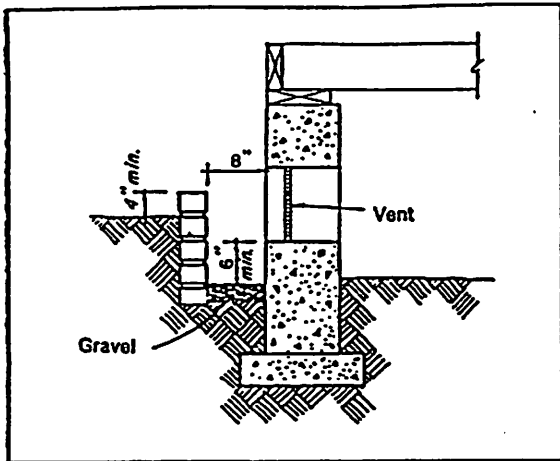


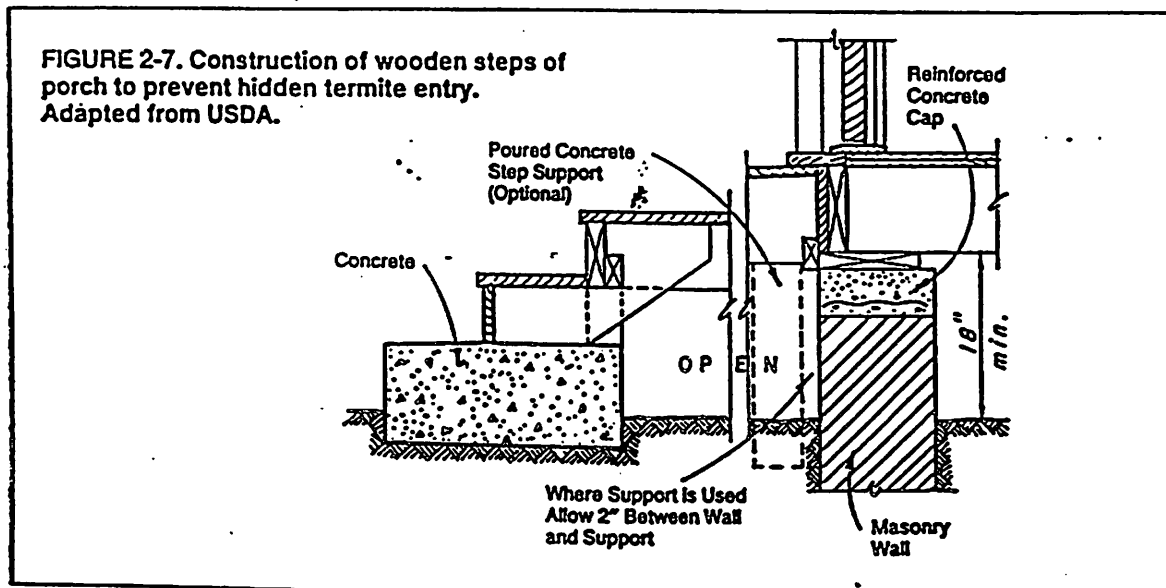
FIGURE 2-6. Ventilator well.

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.



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, shrubbery 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 posts, 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

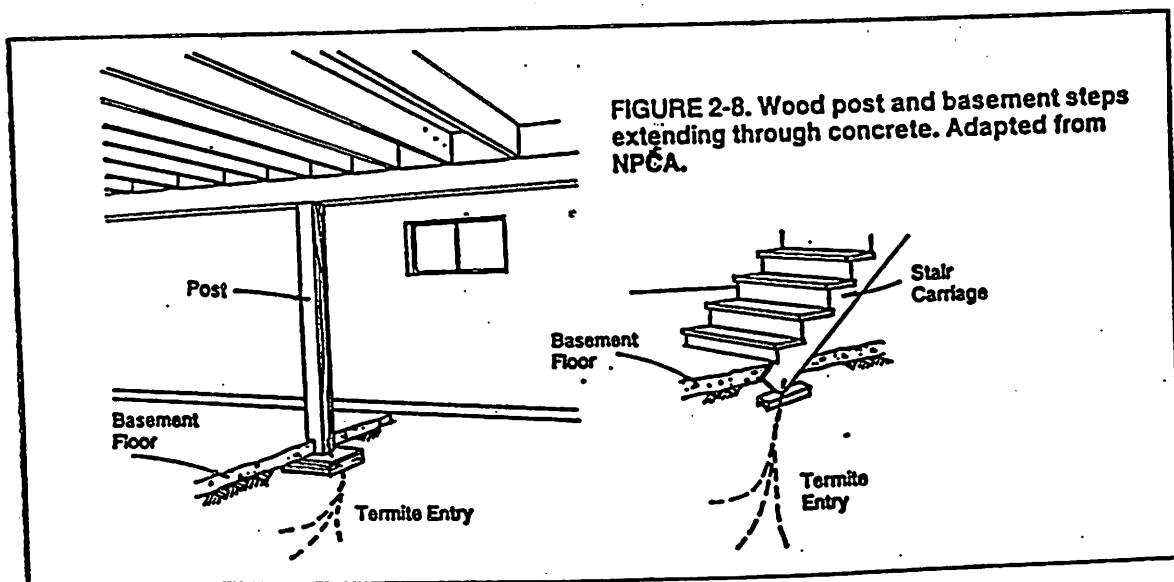


FIGURE 2-8. Wood post and basement steps extending through concrete. Adapted from NPCA.

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 barriers, 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 susceptibility 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.

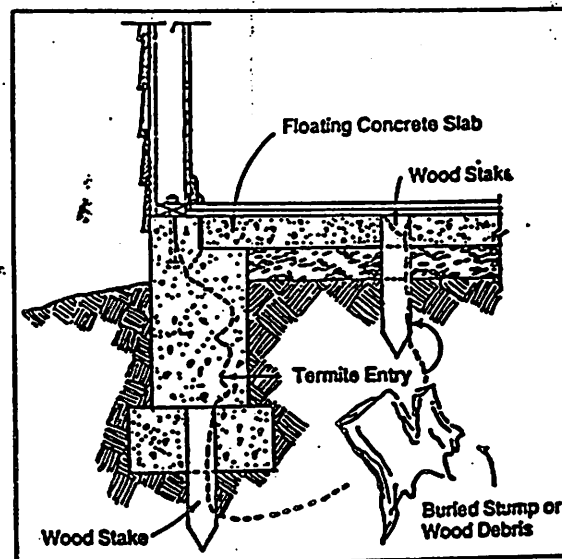


FIGURE 2-9. Wooden grade stakes left in concrete provide termite entry. Adapted from USDA.

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-con-

taining 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 subterra-

nean 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 disturbances, 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 (Dagnet 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 distribu-

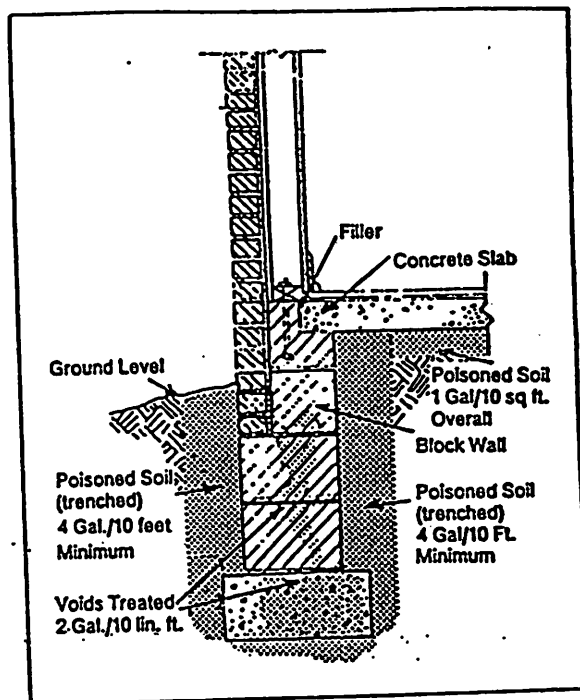


FIGURE 2-10. Application of chemical to slab construction. Adapted from USDA.

tion of the chemical by providing access to the soil at depths below the trench. The grouting rod is a pipe, usually 1/2 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

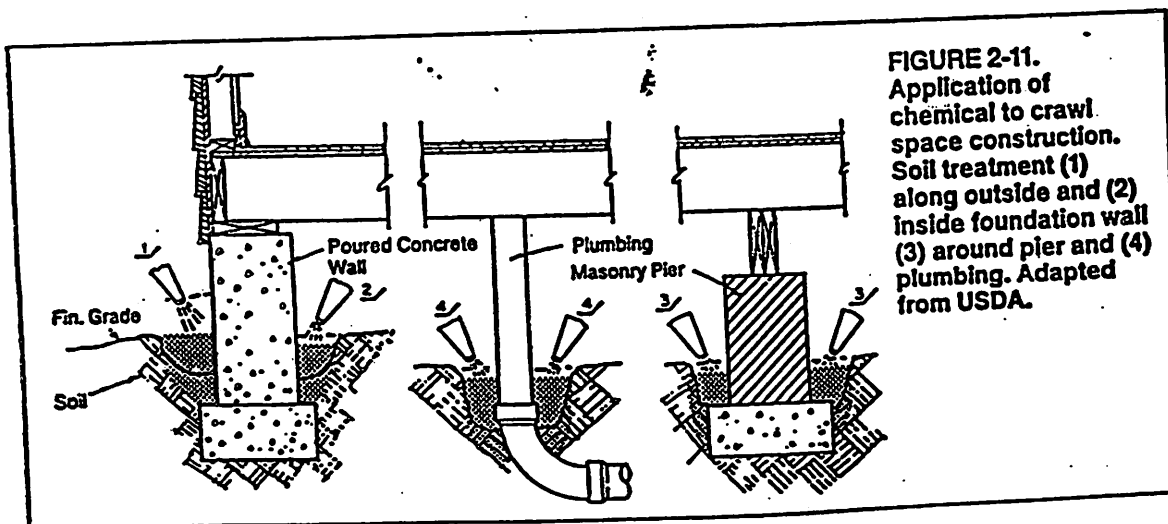


FIGURE 2-11. Application of chemical to crawl space construction. Soil treatment (1) along outside and (2) inside foundation wall (3) around pier and (4) plumbing. Adapted from USDA.