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THERMAL DAMAGE TO CONSTRUCTION MATERIALS BY TERMITES (ISOPTERA)

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Abstract Wood construction materials were exposed to eastern subterranean termites, *Reticulitermes flavipes*, for 8 wk to determine termite damage and changes in thermal properties. Termite tunnels allowed heat to flow unobstructed through the sample resulting in ~35% increase in temperature (damaged vs. undamaged) despite a small amount (6.7% consumed) of damage. Once damaged (3.1% consumed) by termites, plywood was the most thermally damaged with a temperature increase of 74% (damaged vs. undamaged samples). Insulation was significantly the most damaged with ~12% of the material removed by termites. Termites excavated rigid board insulation and consumed the paper which lined the outside surface; they also scarified the aluminum foil surface. In rigid foam board insulation termites formed extensive tunnels resulting in temperature increasing ~27% (damaged vs. undamaged).

Key Words insulation, wood, plywood, *Reticulitermes falvipes*

INTRODUCTION

Reticulitermes flavipes (Kollar) is a species of subterranean termite well known in North America for the damage it causes to homes and other buildings. The damage is most commonly thought of in terms of weakening a structure, making infested areas prone to collapse (Harris, 1965; Johnston et al., 1979). Water damage is also associated with these termites, as they bring moisture up from the soil into their galleries within the structure (Hickman, 1971; Grube and Rudolph, 1999).

One aspect of damage that has been overlooked is the change in the thermal properties of a structure. This is a concern in any structure built in a climate that varies from the comfortable human range of roughly 20-25°C. Materials damaged by subterranean termites are typically filled with galleries or, in the case of wood, laminar spaces where spring wood has been eaten away (Forschler, 1999). These spaces may facilitate the transfer of heat through a material, compromising the material's capacity for insulation. If material in an exterior wall is compromised, it will cost more to maintain a comfortable temperature range within the structure. In this way, termite damage can be even more costly than is generally believed.

In most American homes, exterior walls of structures are made up of structural lumber and siding material (5-ply plywood), as well as other internal components. These siding materials are processed from wood, and so may be consumed by subterranean termites. Taken together, these two building materials are the most common exterior wall components in use that termites are capable of consuming. Another class of building material highly relevant to thermal transfer is insulation (rigid foam board). While most types of insulation are based on plastics, and thus cannot constitute a food source for termites, the soft texture found in many types of insulation makes them easy for the termites to tunnel through (Bultman et al., 1972; Hickin, 1972; NPCA, 1993). In fact, the insulatory qualities of insulation materials confer an appreciable amount of internal temperature stability, making them an almost ideal habitat for termites. While termites may not be able to effectively consume most types of insulation, they can still tunnel into and cause significantly damage (Guyette, 1994; Smith and Zungoli, 1995a, 1995b; Ogg, 1997).

The first objective of this experiment was to determine the relative damage to each of the building materials by subterranean termites. This would give some indication of each material's susceptibility to termite damage. The second objective was to determine differences in the rate of heat transfer and, consequently, temperature change between damaged and sound samples of each building material.

MATERIALS AND METHODS

Termites

Five colonies of *R. flavipes* were field collected in Gainesville, FL. Buckets were filled with moistened corrugated cardboard. Termites accessed cardboard rolls through holes in the sides and bottoms of the buckets. Cardboard rolls containing termites were returned to the lab. Termites were removed from the cardboard by separating the corrugated cardboard and allowing the termites to fall into a plastic bucket. Worker termites of at least 3rd instar were aspirated into groups of 300 workers with a 1% soldier population for use in the experiments.

Termite Damage to Construction Materials.

Three building construction materials were tested: pine 2x4s, 5-ply plywood, and rigid foam board insulation. Rigid foam insulation and 5-ply plywood had a thickness of 1.2 cm (15/32 inch). The 2x4s were cut across the grain to a thickness of 1.27 cm (0.5 inch). Each material was cut into samples of 4 x 4 cm for exposure to termites. The building materials were oven-dried at 40°C for 24 h and preweighed.

Moistened sand (10% water content) was evenly distributed inside a 0.74 L plastic container. A sample of construction material was placed on a square of linoleum (7.5 x 7.5 cm) located on the surface of the sand. The linoleum provided a barrier between the moistened sand and the building materials which were subsequently placed on the tile. Termites were placed on the moistened sand next to the linoleum and the building material. The containers were then lidded and stored in the laboratory at ~23°C. Control arenas having no termites were prepared in the same manner. The arenas were opened 8 wk after setup. Sand and termites were brushed off the surface of the building materials and galleries. Materials were then oven dried at 40°C for 24 h and re-weighed to calculate termite damage. A digital image of the building materials were taken to record the visible damage caused by termites.

An experimental unit was defined as a plastic arena with a building material, sand, linoleum, and 300 termites. Each building material (n=3) was evaluated using five termite colonies with five replications per colony. The experiment had a total of 150 experimental units.

Thermal Imaging.

The cleaned and oven dried building materials were photographed with an infrared (IR) thermal imaging camera (FlexCam®; Fluke Corporation. Everett, WA). A tripod held the thermal camera in place ~53 cm above a building material. An enamel container filled with dry sand (2000 g builders sand) was placed on a hot plate and heated to 52ºC. The building materials were tightly fitted to a pre-cut hole in a sample of rigid foam insulation (10 x 10 cm) to prevent heat from the sand and hot plate from affecting the upper surface of the building material being measured by the thermal imaging camera. The building material, with the rigid foam insulation surrounding it, was placed on the heated builder's sand and thermal images were taken at 0, 5, 10, and 15 min. The digital file associated with the image included a thermal map of surface temperatures for the building material and a record of the minimum, maximum, and average surface temperatures.

Data Analysis

Percentage damage from pre and post weights of each sample of building construction material was calculated, arcsine square root transformed, analyzed by one-way analysis of variance, and means separated with SNK (*P*= 0.05; SAS Institute 2003). The initial temperature and the maximum temperature reached during 15 minutes of heating for each building material was recorded, and the mean temperature increase for the upper surface of the building material was calculated. Significant differences in temperature for damaged and undamaged products were determined with Student's t-test (*P*=0.01). The percentage increase in temperature of a damaged sample in relation to the temperature of the same material not damaged by termites was calculated.

RESULTS

All three building construction materials were damaged by termites. Termites tunneled into the insulation, removed the plastic, and caused significantly more damage by tunneling in the insulation than by consuming either the wooden 2x4 or plywood samples (Table 1). Plywood samples were significantly the least damaged of the construction materials.

Table 1. Percentage damage and surface temperature increase for building materials heated for 15-min. Damaged materials were exposed to eastern subterranean termites (n=300) for 8 wk.

Material	Damaged/ Undamaged	% Damage	Initial Temp	Mean Highest Surface Temp	Temp Increase[a]	% Temp Increase[b]
2x4	Undamaged	-	24.2±0.25	28.8±0.12	4.5±0.24	-
	Damaged	6.7 ± 0.75b	24.9±0.24	31.0±0.15*	6.1±0.28*	34.8
Plywood	Undamaged	-	24.1±0.23	25.7±0.15	1.6±0.20	-
	Damaged	3.1 ± 0.33c	24.8±0.24	27.5±0.11*	2.7±0.29*	74.0
Insulation	Undamaged	-	23.4±0.04	27.4±0.08	4.0±0.10	-
	Damaged	12.1 ± 1.10a	23.6±0.10	28.7±0.14*	5.1±0.19*	27.1

*; significantly difference between damaged and undamaged (P = 0.01, Students t-test). [a]Mean temperature increase at the upper surface (4 x 4 cm) when lower surface was exposed to hot plate at 52°C for 15 minutes. [b]In relation to material not damaged by termites (undamaged).

Timbers

The rings of lighter, spring wood and darker, summer wood were obvious in the visible spectrum images (Figure 1A). However, the rings were not noticeable in the thermal images (Figure 1C) indicating no noticeable difference in heat transfer between spring and summer wood. The thermal images of undamaged 2x4 samples showed uniform heat transfer through the wood at 0, 5, 10, and 15 min with the average surface temperature of the representative sample increasing from 23.9-24.4°C (Figure 1C). After 15 min of heating, the representative undamaged 2x4 sample had a narrow range of temperatures across the surface, ranging from 23.8-25.2°C.

For the samples exposed to termites, they ate ~7% of the 2x4 samples causing characteristic damage (Table 1). The damage in the 2x4s took the form of distinct lamellar tunnels excavated in the wood, following the annular rings in the wood (Figure 1A). The thermal images of damaged 2x4 samples (Figure 1B) showed a greater overall heat transfer compared with undamaged samples. There were distinct localized hot spots in the images of the damaged 2x4s that coincided with the location of termite tunnels that allowed heat to pass through more rapidly. After 15 min of heating, the representative damaged 2x4 sample had a wide range of surface temperatures, ranging from 24.5-30.6°C.

For all the 2x4 samples at the start of the experiment, the mean temperature of was ~24°C (Table 1). During the heating period, the average maximum surface temperature reached was 28.8°C for undamaged and 31°C for termite damaged samples. The temperature increase was significantly greater (35%) for damaged over undamaged 2x4 samples.

Plywood

Samples of plywood showed fairly wide bands of spring and summer wood, indicating a fairly oblique, longitudinal cut across the wood rings in at least the upper layer (Figure 2A). Thermal images of the undamaged samples (Figure 2C) showed almost uniform heat transfer, indicating no noticeable difference in heat transfer for spring and summer wood areas of the representative plywood sample. Also the images showed little rise in temperature from 0 through 15 min from 23.4 to 23.8°C indicating plywood is a good insulating material. After 15 minutes of heating the undamaged representative plywood sample had a narrow range of temperatures (min=23.3 °C; max=25.2°C) across the surface.

Termites ate ~3% of the plywood samples (Table 1) causing damage similar to the damage seen in the 2x4s (Figure 2A). However, rather than excavating tunnels in spring wood as seen in the 2x4 sample, the termites tunneled between plywood layers and ate away portions of the spring wood bands in each layer. The thermal images of damaged plywood showed a greater overall heat transfer compared with undamaged samples. The damage was clearly evident as increased general heat transfer and localized hot spots in the thermal images (Figure 2B). After 15 minutes of heating, the representative damaged plywood sample had a wider range of temperatures (min=24.0°C; max=27.2°C) across the surface than the undamaged sample. For all the plywood samples, the initial mean temperature was ~24°C (Table 1). During the heating period, the average temperature maxed at 25.7°C for undamaged and 27.5°C for termite damaged plywood. This increase in temperature was significantly greater for termite damaged than undamaged plywood and represented a 74% temperature increase.

Rigid Foam Board Insulation

Undamaged samples of rigid foam board insulation were homogenous in appearance. The insulation material consisted of foam covered by a radiant barrier consisting of craft paper covered by a thin layer of aluminum. The representative undamaged sample of rigid foam insulation (Figure 3C) showed low heat transfer, and temperatures were very uniform across the entire surface. The thermal images of the representative undamaged insulation sample showed an average surface temperature increase from an initial temperature of 23.4 to only 23.8°C after 15 minutes of heating.

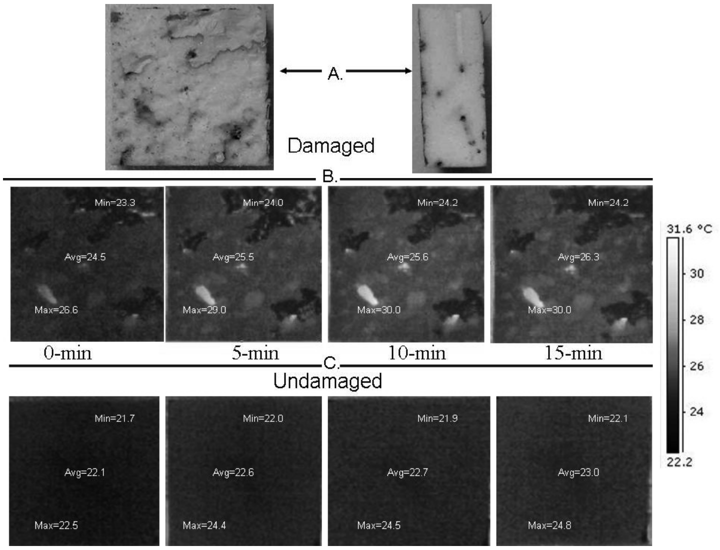

Figure 1. Images of a 2x4 sample exposed to 300 termites for 8 wk. A. Visible spectrum images of a damaged 2x4 sample. B. Thermal images of a damaged 2x4 sample heated over 15 minutes. C. Thermal images of an undamaged 2x4 sample heated over 15 minutes.

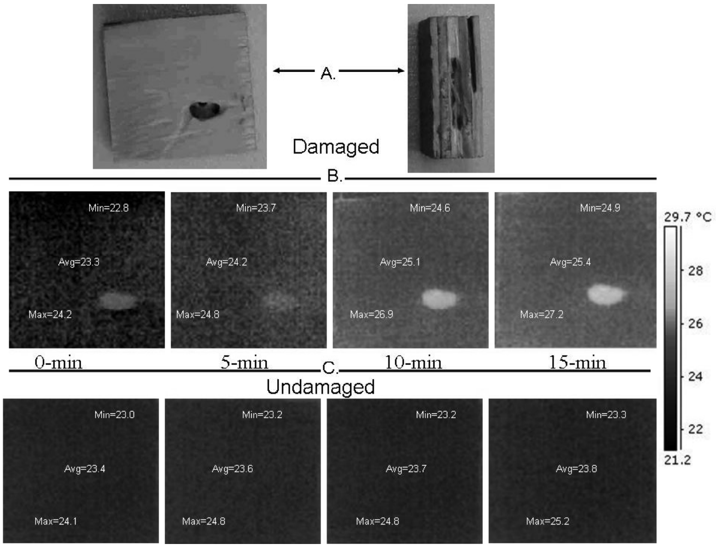

Figure 2. Images of a plywood sample exposed to 300 termites for 8 wk. A. Visible spectrum images of damaged plywood samples. B. Thermal images of a damaged plywood sample heated over 15 minutes. C. Thermal images of an undamaged plywood sample heated over 15 minutes.

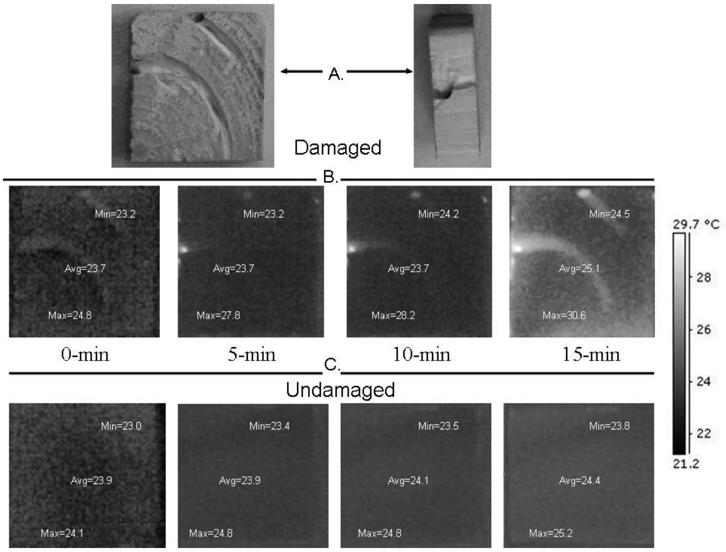

Figure 3. Images of a rigid foam insulation sample exposed to 300 termites for 8 wk. A. Visible spectrum images of a damaged rigid foam insulation sample. B. Thermal images of a damaged rigid foam insulation sample heated over 15 minutes. C. Thermal images of an undamaged rigid foam insulation sample heated over 15 minutes.

Termite-damaged rigid foam insulation was riddled with extensive termite tunnels (Figure 3A), lined with soil and fecal material. The tunnels were more extensive than those seen in any of the 2x4 or plywood material, most likely due to the soft nature of the material. The radiant barrier had been largely eaten away, exposing scarified, pitted foam. The thermal pictures of the insulation samples (Figure 3B) showed a greater degree of temperature variability across the surface of the insulation. The hotspots coincided with areas where termites had tunneled and removed the insulation material. After 15 minutes of heating, the representative damaged rigid foam insulation had a wide range of surface temperatures (min-24.2^{o}C; max 30^{o}C)

Heat transfer in damaged rigid foam insulation samples was greatly increased within the extensive tunnel system (Table 1). For all the insulation samples at the start of the experiment, the mean temperature was ~23^{o}C. During the heating period, the average maximum surface temperature reached 27.4^{o}C for undamaged and 28.7^{o}C for damaged samples. The temperature increase was significantly greater for damaged over undamaged insulation and was ~27% greater.

DISCUSSION

All building materials tested were damaged by termites. Termites consumed the wood in the plywood and 2x4 building materials. Termites excavated the foam from the rigid board insulation and consumed the paper which lined the outside surface. They also scarified the aluminum foil surface of the insulation.

Overall, there was very little correlation between the percentage damage (percentage consumed or removed) to the building construction material and the percentage increase in surface temperature caused by termite damage. Although plywood samples had the lowest percentage damage caused by termites, they had the greatest percentage increase in surface temperature. The temperature change of plywood was the least of all the materials tested. This indicates that, of the undamaged materials tested, plywood was the most resistant to heat flow through it. Once eaten by termites, plywood was the most thermally damaged. This may be due to the laminar structure of the plywood. Heat probably flows more easily with the grain of the wood, rather than against the grain. Termites tunneled with the grain and between the layers of plywood; some tunnels cut through the insulatory plywood layers allowing heat to flow through the material.

Rigid foam insulation was the most insulatory of all materials tested in its undamaged state. Although the rigid foam board was mainly composed of plastic, termites tunneled throughout the material, leaving multiple routes of rapid heat transfer from one surface of the sample to the other. Damage to the rigid foam was greatest of all the building materials and this created a network of tunnels allowing heat transfer.

The significantly greater temperature increase seen in 2x4 materials in comparison to plywood was due to the cross-sectional nature of 2x4 samples. Plywood had wood fibers mostly perpendicular to the direction of heat flow; whereas the 2x4 cross-sections had the wood fibers mostly parallel to the direction of heat transfer assayed. Termites mainly tunneled along the fibers and within the softer spring wood. These tunnels penetrated the sample allowing heat to flow unobstructed through the sample. As a result, small termite wood damage of only 6-7% was responsible to more than 30% increase in temperature.

With the increasing cost of energy, houses are being built to be more energy efficient using foam insulation as well as wooden components. The impact of termites on these building materials has been virtually overlooked. Our research demonstrates that termites can significantly impact the thermal properties of materials. Our research demonstrates the importance of termite control for home energy conservation.

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