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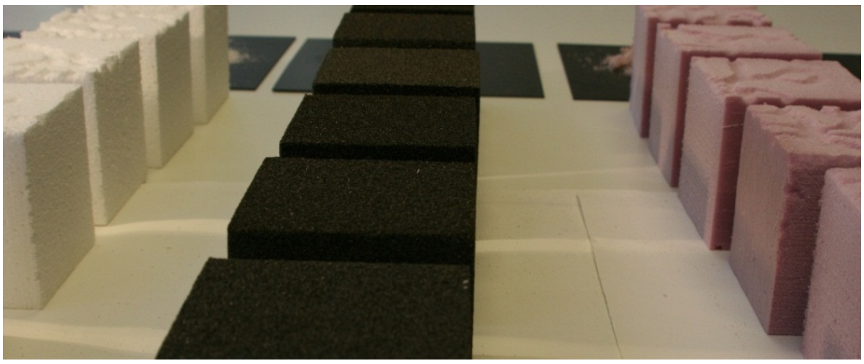
Abstract: A total of 2250 *Camponotus ligniperda* workers and 120 ant larvae were used in 3 experiments investigating the ability of the insulation materials expanded polystyrene (EPS), extruded polystyrene (XPS) and foamglas to withstand excavation and nest construction. The three experiments investigated time until initiation of excavation, level of damage after 5 days of excavation and the effect of elevated temperatures on level of excavation. EPS and XPS was excavated by ants and showed similar properties in terms of ability to withstand initiation and establishment of nests. Foamglas did not experience any nest construction and was significantly less influenced by the ants in terms of weight removed, relative loss of insulation material, area excavated and category nest score. Ants showed a general preference for heated insulation, and heated EPS and XPS blocks experienced significantly higher levels of ant damage compared to cold blocks. As there was no nesting activity in foamglas, no difference between hot and cold insulation could be detected.



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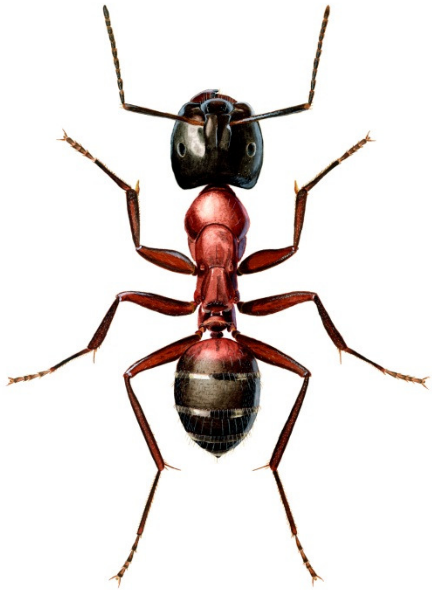
Introduction

Ant societies are important elements in most terrestrial habitats. They aid in nutritional recycling and play a regulatory role in the community through its interactions with plants, animals, fungi and microorganisms (Hölldobler & Wilson, 1990; Douwes *et al.*, 2012). Under natural conditions they establish and construct advanced nests which give them the opportunity to perform efficient foraging at the same time as it provides protection against environmental factors and predators. Ant colonies are long lasting, grow relatively slowly and may become large (Mallis & Hedges, 1997; Douwes *et al.*, 2012). Colonies of common ant pest species often contain several thousand to more than 10 000 individuals (Akre *et al.*, 1994; Hansen & Klotz, 2005). They utilize concealed spaces and most species manipulate their nesting site by excavation or construction of well-defined areas for specific tasks. The location of a nest is determined by the structure of the habitat, suitability and availability of nest substrate in combination with abiotic factors such as temperature and moisture levels (Hölldobler & Wilson, 1990; Klotz *et al.*, 1998; Chen *et al.*, 2002; Buczkowski, 2011; Mankowski & Morrell, 2011).



Picture 1: *Camponotus ligniperda.*
Illustration: Halvard Elven.

Carpenter ants (*Camponotus* spp., Picture 1) have strong jaws and construct nests in wooden materials such as partially broken down tree-trunks or stumps, living trees and hard dried wood (Hansen & Klotz, 2005). This habit of nest construction leaves them in skirmish with humans when the ants move into buildings (Akre & Hansen, 1990; Fowler, 1990) to utilize the wide array of nesting materials available (Picture 2). Living inside a building also excludes natural vertebrate predators and competitors at the same time as it offers elevated temperatures and favorable microclimatic conditions.

The two most common carpenter ants found in northern Europe and north Scandinavia, *Camponotus herculeanus* Linnaeus, 1758 and *Camponotus ligniperda* Latreille, 1802 both inhabit buildings (Collingwood, 1979; Birkemoe, 2002; Hansen & Klotz, 2005). Carpenter ants are of concern as pests in forested areas, and of great economic importance (Rust & Su, 2012). People gets stressed by having ants in their buildings, ants may weaken carrying structures or reduce insulation (Fowler, 1990; Akre & Hansen, 1990; Mallis & Hedges, 1997). In Norway the direct cost of professional carpenter ant control was estimated to

Picture 2: Damage in expanded polystyrene caused by Carpenter ants (*Camponotus ligniperda)*

$1.5 million in 2007 (Ottesen *et al.*, 2009), but taking into account the private control efforts and the material and labor needed to repair the buildings, this problem constitutes a major cost for the Norwegian society. In other parts of the world, similar figures are higher and the estimated cost of carpenter ant control in Washington and New Jersey State in USA was $25 million and $12.6 million in 1980, respectively (Hansen & Klotz, 2005). This clearly should provide a base for detailed studies regarding material preference, nest site location and nest expansion. However, only a few scientific studies have described nests in buildings, tried to pinpoint potential solutions or find ways to minimize the impact from this pest (Butovitsch, 1976; Klotz *et al.*, 1995; Birkemoe, 2002; Ottesen *et al.*, 2009), and most registered damage is based on information from professional pest controllers (Mallis & Hedges, 1997).

Relatively few ant species inhabit buildings (Hölldobler & Wilson, 1990; Mallis & Hedges, 1997; Douwes *et al.*, 2012) and an even smaller number cause damage to structures there (Akre & Hansen, 1990; Fowler, 1990). Many of the damage causing species also depends on prior damage to successfully get a foothold inside, but some are fully capable of establishing themselves in buildings in prime condition. Carpenter ants are among the most ferocious structure excavators known (Hansen & Klotz, 2005), and we therefore selected *C. ligniperda* as our study insect, believing that it represent the outermost limit of damage inflicting capability among the ants.

This study aims to investigate the ability of foamglas to withstand nest excavation activity from carpenter ants by comparing it to two of the most widely used insulation materials in Norwegian buildings. By allowing a controlled number of carpenter ants to establish themselves in standardized cubes of insulation the damage was quantified to provide a measure of ability to withstand attack. The combined effect of elevated temperatures and insulation type was also explored to simulate a situation often encountered by carpenter ants establishing in buildings in cool climate areas.

Materials and methods

Collection and handling of ants

Ants were collected in collaboration with pest controllers in May and the beginning of June. Nests in buildings were located, and infested structures were opened to gain access to the ants. Ant workers were collected using a slow running vacuum cleaner and by transfer of densely populated insulation or building materials to large collection boxes. We used ants from three separate locations in Tønsberg municipality, Norway, and ants from different colonies were never mixed. Ants were stored for up to 4 days in darkness at 10 °C until the experiments started. Feather tip forceps and small glass vials were used to handle the ants during transfer from collection boxes to the experimental ant containers. Ants had constant access to honey-water (approximately 25% honey diluted in tap water) during both storing and experimentation. The honey-water was made accessible for the ants through glass tubes closed with a cotton wick. The honey-water soaked cotton allow the ants to feed when needed. At the end of each experiment the numbers of living and dead ants were counted to ensure no bias in the measured ability to withstand excavation due to variation in ant mortality.

Experimental units and test facilities

<u>Ant boxes:</u> Tests were performed in 10.8 L white plastic buckets or in transparent rectangular 21.0 L boxes (Picture 3). The lids sealing off these ant boxes had two small openings (ø=3.0 cm) allowing transfer of ants and visual inspection of activity. These openings were closed by dense rubber corks during the experiment. To allow replacement of air, the center of the bucket lid had a larger opening (ø=8.4 cm) which was permanently closed by a fine mesh cover. The squared boxes had a narrow gap between the box and the lid to allow ventilation.

Picture 3: Boxes used for testing of insulations ability to withstand carpenter ant (*Camponotus ligniperda)* nest excavation

<u>Insulation blocks:</u> Three different types of insulation were used in the experiments. Foamglas (T4+, Foamglas, Tessenderlo, Belgium), polystyren insulation with normal density (Jackopor 80 – EPS , JACKON Insulation GmbH, Steinhagen, Deutchland) and polystyren insulation with high density (Jackofoam 200 – XPS, JACKON Insulation GmbH, Steinhagen, Deutchland) were tested for their ability to withstand ant excavation. Jackopor and Jackofoam are hereafter denoted as EPS (**E**xpanded **P**oly**S**tyrene) and XPS (e**X**truded **P**oly**S**tyrene), respectively. Standardized insulation test units, measuring 10×10×10cm, were cut from larger blocks of insulation.

<u>Test facilities:</u> All experiments were performed in the facilities at the Norwegian Institute of Public Health. The three experiments were performed under different temperature and light conditions. The extensive test for nest establishment was conducted at a temperature average of 25.5±0.1 °C and a lightcycle of 12:12 hour, light:dark. The temperature during the nest construction initiation experiment was 21.9±0.1 °C and ants experienced a natural light cycle (approximately 17:7 hour, light:dark) obtained through daylight windows. The same light regimen was used for the heat preference experiment, but temperatures were then adjusted to accommodate temperature differences inside the boxes.

Measurement of damage

The damage caused by the carpenter ants was quantified in four different ways:

1) The blocks were weighed before and after the experiments and the difference between the two measurements were used to calculate the weight loss.

2) The relative damage in terms of weight removed divided by initial weight, expressed in percentage.

3) The excavated area of the insulation test cube surface was measured with 1 cm^2 accuracy.

4) Nests were categorized according to complexity of the excavation, using a score of **0** for no damage, **1** for initiated excavation with attack of the edges only, **2** for distinctly excavated nest structure with horizontal chambers and corridors and **3** for complex nest structures having both horizontal chambers and horizontally and vertically excavated corridors.

Experiment 1 – initiation of nest construction

Ten test units (10×10×10cm) of each of the three insulation types were individually assigned to 30 separate buckets (3x10). The insulation blocks were all positioned in the center of the buckets with one side of the test cube horizontally aligned with the bucket bottom (Picture 4). 25 carpenter ants were then added to each bucket and initiation of attack was measured by registration of presence or absence of excavated insulation pieces. The insulation blocks were inspected after 3, 6, 9, 22 and 31 hours. After 31 hours the numbers of living and dead ants were counted and excavation was quantified using visual inspection and category nest score (for category description see "measurement of damage" above).

Picture 4: Positioning of insulation blocks in test buckets.

Experiment 2 – ability to withstand nest construction

Eight test units (10×10×10cm) of each of the three insulation types were individually assigned to 24 separate buckets (8x3). The insulation blocks were positioned in the center of the buckets with one side of the test cube horizontally aligned with the bucket bottom (Picture 4). 50 carpenter ants were then added to each bucket and the ants were allowed to try to establish themselves in the insulation blocks for 5 days. After these five days the numbers of living and dead ants were counted, and the damage inflicted was quantified according to the four methods described above.

Experiment 3 – effect of temperature on establishment

Sixteen test units (10×10×10cm) of each of the three insulation types were assigned to 24 squared plastic boxes (16/2x3). Two and two test units of the same type were positioned 13 cm apart in the same box (Picture 5). The boxes were then placed on top of electric heating cables and positioned to ensure elevated temperature in only one of the two insulation blocks. The general temperature in the room was kept low by air-condition allowing an approximate temperature gradient of 5 °C between the two insulation blocks. 25 carpenter ant workers were then added to each bucket together with five ant larvae. The ants were allowed to try to establish themselves in the insulation blocks for three days. Three times a day the ants resting on or within 1 cm of the cold and warm insulation blocks were counted. Eventual movement of larvae from the exposed outside to the safety within the insulation block was also scored. After the three days of nest establishment the numbers of living and dead ants were counted, and the damage inflicted on the insulation blocks quantified according area excavated.

Picture 5: Positioning of insulation blocks in test boxes.

Statistical analysis: The data was analyzed in SigmaPlot 12 (Systat Software Inc. San Jose, California, USA). Data were checked for normality and multiple comparisons were done by ANOVA, while pairwise comparisons were done by t-tests. If tests for normality failed, we used Mann-Whitney rank sum test and Kruskal-Wallis analyses of variance. Significance level was set to 0.05, and differences between multiple comparisons were identified using tukey- or tukey type post-hoc tests.

Additional testing: The Norwegian Institute of Public Health wants to prevent excessive use of pesticides in residential- or public buildings, and novel toxic free pest control solutions are of general interest for the Department of Pest Control. Building materials capable of withstanding ant attack may contribute to reduced establishment, reduced structural damage and limit the pesticide exposure for people using the buildings. In parallel with the ordered comparison between EPS, XPS and Foamglas we also tested other commonly used insulation materials (GLAVA and ROCKWOOL) and two different mixtures of EPS-pellets and concrete (EPS pellets mixed with 12.5% concrete and EPS pellets mixed with 25% concrete). Details of these experiments are not described, but they were performed as experiment 1 and 2. Figures comparable to figure 1, 2 and 3A-D showing the full test range, are given in the appendix at the end of this report.

Results

The collected ants all belonged to the species *C. ligniperda*. A total of 2550 worker ants and 120 larvae were used in the experiment. The overall mortality in the different test boxes was 27.6±2.3%. No difference in mortality was observed between the three insulation treatments in either of the three experiments (Experiment 1 – Kruskal-Wallis ANOVA: H=1.285, p=0,526; Experiment 2 – ANOVA: F=0.049, p=0.952; Experiment 3 – ANOVA: F=0.812, p=0,458).

Experiment 1 – initiation of nest construction

The first sign of excavation appeared after 3 hours in EPS and 6 hours in XPS (Figure 1). Polystyren insulation showed an increase in the number of insulation cubes being excavated by carpenter ants until the 22 hour check. At this time 50 % of both EPS and XPS insulation blocks showed signs of nesting activity, while foamglas appeared undamaged.

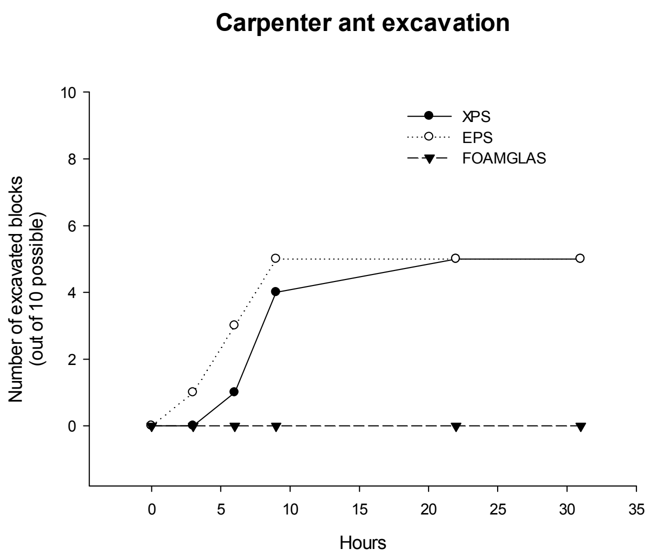


Figure 1: Carpenter ant excavation in EPS, XPS and Foamglas insulation. The x-axis represent time in hours from release of ants and the y-axis represents the number of blocks (out of 10 possible) showing sign of excavation.

Visual inspection and categorical score of nest structures after 31 hours revealed a significant difference between the three insulation types (ANOVA on ranks: H=13.24, $p<0.001$) and the following tukey type comparison identified foamglas to be significantly less excavated compared to EPS and XPS (Figure 2). Both EPS and XPS had nests belonging to the advanced type including chambers and corridors (Picture 6), while foamglas only had one identifiable bite mark in the insulation block.

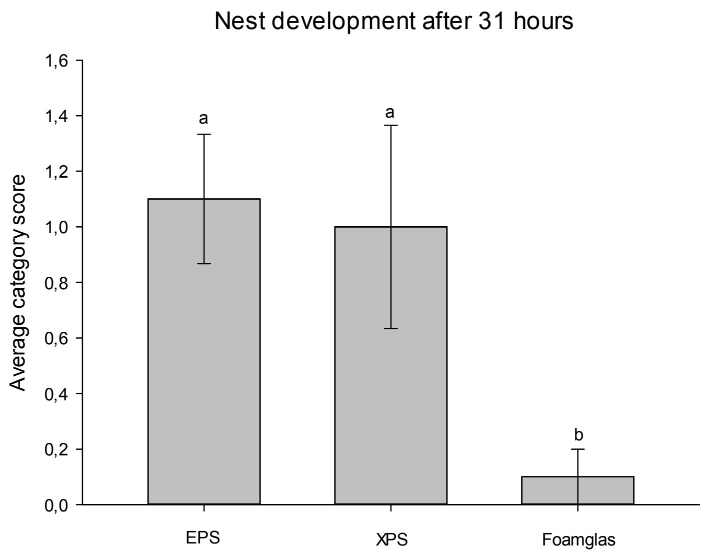


Figure 2: Carpenter ant excavation in EPS, XPS and Foamglas insulation blocks. The average category score ± SE is based on a value of 0 for no damage, 1 for initiated excavation with attack of the edges only, 2 for distinctly excavated nest structure with horizontal chambers and corridors and 3 for complex nest structures having both horizontal chambers and horizontally and vertically excavated corridors. 10 blocks of each insulation type was used and damage was scored after 31 hours. Treatments significantly different from each other are denoted by different small letter (a and b).

Experiment 2 – ability to withstand nest construction

After 5 days of access to the three insulation types, advanced ant nests (Picture 6) were found in 7 out of 8 EPS insulation blocks, in 8 out of 8 XPS insulation blocks and in 0 out of 8 foamglas insulation blocks. Large amounts of small pieces of excavated EPS and XPS were found in connection with the nesting activity, whereas the buckets with the foamglas blocks only showed small amounts of fine dust originating from ant activity and movement on the outer surface of the insulation. The comparison of the weight loss showed a significant difference between the three insulation types both in terms of absolute and relative values (absolute values – ANOVA: F=9.279, p<0,001; relative values – ANOVA on ranks: H=13.242, p<0,001). The following tests identified foamglas to be less suceptible to ant excavation compared to EPS and XPS (Figure 3 A and 3 B). Foamglas showed no sign of excavation while EPS and XPS had an average of 53.7±10.4 cm^2 and 51.0±7.5 cm^2 of the down facing contact surface (100 cm^2) excavated. Ants never attacked the other 5 sides of the cube. This difference between EPS, XPS and foamglas was significant (ANOVA on ranks: H=14.304, p<0,001) with equal and higher level of damage on the two polystyrene products (Figure 3 C). The nest category score also showed significant differences between the three insulation products (ANOVA on ranks: H=18.027, p<0,001) with foamglas being significantly more able to withstand excavation compared to the two polystyrene products (Figure 3 D). EPS had one advanced category 3 nest showing nest structures in both the horizontal and the vertical plane. The remaining 6 nests were horizontal in its arrangement. XPS had 8 category 2 nests with horizontally arranged chambers and corridors only. Foamglas had no nests. The average category score was 1.9±0.3, 2.0±0.0 and 0.0±0.0 for EPS, XPS and foamglas, respectively.

Picture 6: Visualization of nest excavation. Chambers and corridors were found in EPS and XPS but not in foamglas. Excavated insulation is seen in the background.

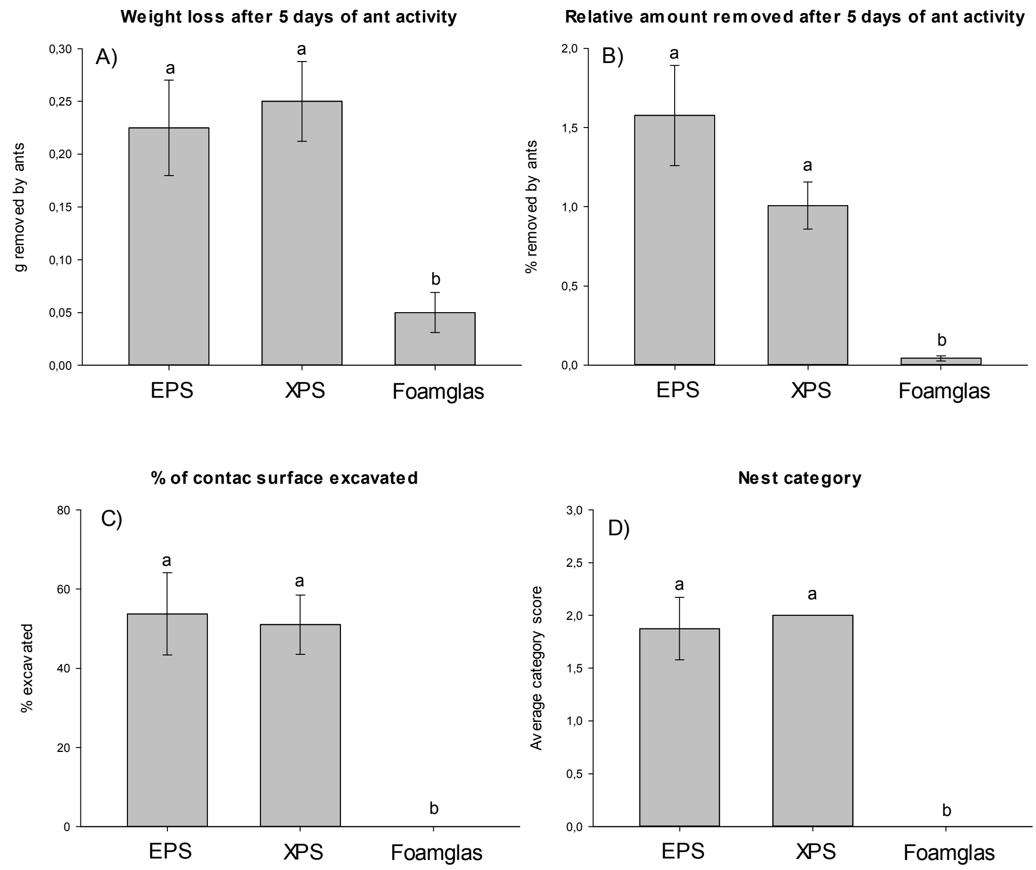


Figure 3: Average damage ± SE from carpenter ant (*Camponotus ligniperda*) excavation in EPS, XPS and Foamglas insulation blocks. A) Weight loss in grams, B) Relative weight loss in %, C) Area of contact surface excavated and D) Category score based on a value of 0 for no damage, 1 for initiated excavation with attack of the edges only, 2 for distinctly excavated nest structure with horizontal chambers and corridors and 3 for complex nest structures having both horizontal chambers and horizontally and vertically excavated corridors. 8 blocks of each insulation type was used and damage was quantified after 5 days. Treatments significantly different from each other are denoted by different small letter (a and b).

Experiment 3 – effect of temperature on establishment

A distinct temperature gradient was established between heated and cool insulation blocks. The cold blocks had an average temperature of 19.8±0.3 °C compared to hot blocks which had an average of 24.8±0.6 °C. The ants showed an overall preference for higher temperatures (Mann-Whitney rank sum test: $T=29612.3$, $p<0,001$) with an average number of 9.0±0.3 resting near the heated insulation blocks compared to 1.4±0.2 near the cold blocks. This heat preference was observed regardless of insulation type in the test boxes (Figure 4 A). The general heat preference also resulted in an increased nesting activity in varm blocks compared to cold blocks for both EPS and XPS, but not for Foamglas (t-test EPS: $t=26.750$, $p<0.001$; t-test XPS: $t=6.080$, $p<0.001$; Mann-Whitney rank sum test Foamglas: $T=72.000$, $p=0.72$, Figure 4 B). Larvae were moved from the outside of the blocks to the newly constructed nest within two days of excavation and 15 out of the 16 nests with larvae were located in the hot insulation blocks. Some nesting activity also took place in cold insulation blocks of the EPS and XPS (Figure 4 B).

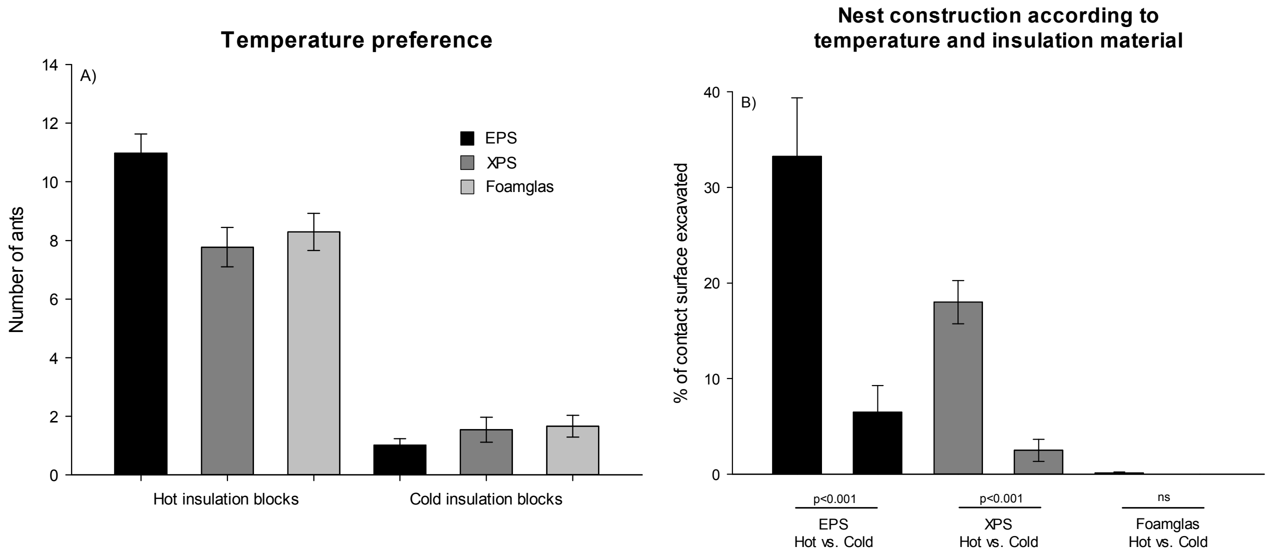


Figure 4: Average ± SE A) aggregation and B) damage from carpenter ant (*Camponotus ligniperda*) excavation in EPS, XPS and Foamglas insulation blocks. Damage is quantified according to area of contact surface excavated. 16 blocks of each insulation type was used in a pair vise choise situation with cold (19.8±0.3 °C) and varm (24.8±0.6 °C) blocks as options. Damage was quantified after 3 days. Black bars represent EPS, dark grey represent XPS and light grey represent foamglas.

Discussion

In all tests performed, Foamglass T4+ proved to be more capable of withstanding carpenter ant establishment when compared to both of the polystyrene products. Nests were never found in foamglas, while the majority of the polystyrene blocks were occupied and guarded by ants. The minor signs of ant activity on foamglas are likely to represent failure to excavate or a result of aggressive behavior, i.e. soldier ants attacking everything from forceps, glass vials or the insulation blocks when handled in the experiments. Some variation was also observed between EPS and XPS, but in all excavation cases the distinct nest structures typical for an ant society could be observed (Tschinkel, 2005). The variation between the two polystyrene products was not large enough to prove any difference between them. These findings coincide well with observations from the field where ant nests are often found in polystyren (Birkemoe, 2002).

The ants purpose of the excavation was to construct shelter and protection for the individuals present in the test boxes. During the experiments more and more ants moved from the outside to the inside of the insulation blocks resulting in a near natural situation with the majority of workers staying hidden in the nest. On some occasions we also observed that the ants carefully positioned the pieces of excavated material around the glass vial with honey water as if trying to protect or hide their food source. This is likely a result of the unnatural situations without vegetation, soil and detritus in the test boxes, but it shows that the excavated insulation may be used by the ants. We tested *C. ligniperda* in this study and found distinct differences in their behavior when facing different types of insulation. Other insulation excavating species such as *Camponotus herculeanus*

Latreille, 1802, *Lasius niger* Linnaeus, 1758 or *Formica fusca* Linnaeus, 1758 may show similar nest building variation according to material properties. However, as we selected one of the strongest excavators for our experiments it is likely that the insulations ability to withstand attack may be higher when other species are trying to establish themselves. Small differences in habitat preferences across closely related species are known to occur (Klotz *et al.*, 1998) and it is likely that there are interactions between species specific traits and the insulation encountered. Further studies are needed to reveal any similarities or differences across species and insulation types.

When evaluating the damage inflicted by the carpenter ants we used 4 different types of damage assessment. A certain number of ants needs a specific area to move about and rest inside the insulation blocks. If ants are capable of excavating the insulation, the weight removed from the block does not by itself provide information regarding ability to withstand ant attack. The ants may simply stop their activity when they have enough room. In a similar manner is the relative weight loss influenced by the initial weight of the insulation block and thus does not provide information regarding the insulations ability to withstand the ants nesting activity. These numbers are however important in terms of lost insulation or damage in buildings. If we had included time as a factor it could have indicated how easily the insulation is excavated. In the initiation experiment EPS and XPS showed slightly different progress in terms of timing of the attack. This may be explained by small variations in excavation susceptibility between the two products. Ants started their excavation on the edge of the insulation and typically on the side of the cube facing down. By doing this they established the nest in the transition between the hard plastic bottom and the insulation. In both polystyrene materials the ants excavated a large proportion of this down facing surface. Normally they left the edges intact to create closed off chambers and they kept the entrance to these chambers narrow. This indicates that they produce protective areas which efficiently prevent enemies from entering and is easily defended. Multi-chambered nests may also indicate the initiation of complex nest structures with different society tasks (Tschinkel, 2005). A few of the insulation blocks also showed signs of 3-dimentional structuring of the nest, potentially allowing even more protection, greater chamber differentiation and subsequently more damage to the insulation. Including both the measure of area excavated and nest category produce a valuable quantification of damage as it directly relates to the number of ants present and it provides biologically relevant information about the use of the insulation.

The density, consistency and hardness of the material are regulating factors for the nest construction. Clearly there is a limit to what kind of material the ants are able to bite through, and hard materials may efficiently prevent ants from attacking. However, most insulation materials used today are less dense and softer than dried wood which carpenter ants are known to excavate (Fowler, 1990; Akre & Hansen, 1990; Birkemoe, 2002; Hansen & Klotz, 2005; Ottesen *et al.*, 2009), and neither of the tested materials was dense or hard enough to create such a preventive effect. Foamglas has the highest density of the three insulation types, but the clear cut difference between polystyrene and foamglas is unlikely to be explained by this parameter alone because the density and hardness is within the range of what carpenter ants are capable of excavating. The consistency, chemical properties or mechanical properties are more likely to act together with the density to prevent the attack. Compared to polystyrene the foamglas insulation has a tendency to break apart into a fine powder instead of the tiny pieces that appear when polystyrene is excavated. This may cause problems of chewing in foamglas, but also problems of clearing the chambers or corridors. A sulfourus odour is also released when foamglas is cut or handled and this chemical may have a repellent effect or it may interfere with the intricate chemical communication found among all ant species (Gullan & Cranston, 2010). A third potential factor is related to physical damage to the ants. The fine foamglas powder may attach to the cuticula of the ants and thus cause damage to the protective wax layer or otherwise interfere with necessary physiological processes. We did not observe any difference in mortality between the insulation treatments, but ants may have been pacified by such effects. Further studies are needed to identify the main factor or the potential synergisms between two or more of these elements.

All our tests were performed in a laboratory setting with relatively few ants, and the results cannot automatically be extrapolated directly into a field situation because biotic elements such as moisture or temperature may influence the properties of the insulation according to the ants' biology. However, our study offers a strong indication of foamglas being much more able to withstand excavation than the commonly used insulation types. Based on these investigations it is likely that foamglas offer a solution to several ant pest problems. Ant nesting is commonly observed in polystyrene insulation but not in Foamglas insulation. This concurs with our study, but may equally well be explained by the less frequent use, or a different use of foamglas in buildings. Field studies testing different insulation types could be performed to allow a direct comparisons between insulation types, but this is a labor intensive task and probably too costly and time consuming to be worthwhile. However, more elaborate choice experiments in a simulated natural setting would be of general interest to close the present gap between laboratory- and field studies. Our heat and insulation choice-experiment does to some extent probe into a more field near situation. Under natural conditions ants will often prefer warm over cold micro climatic conditions (Chen *et al.*, 2002) and many of the ant infestations found in cool climate areas may be a result of the elevated temperatures inside buildings (Birkemoe, 2002; Ottesen *et al.*, 2009). Ants are also known to establish their nests in close proximity to external heat sources and highly concealed nest structures are believed to be located in insulated and heated floors (Birkemoe, 2002). Although all the ants in our experiments aggregated near to the heat source they did not establish themselves in the warm foamglas insulation. This strengthens the argument for a potential preventive solution by using the less ant susceptible insulation type.

In this study we investigated three insulation types. The choice of Jackopor 80 and Jackofoam 200 was based on availability in local stores, while the Foamglas T4+ was delivered by Foamglas. Most insulation types come with a wide variety of properties and ideally all of them should have been tested for their ability to withstand ant excavation. However, as several properties of the insulation are likely to interact and influence the nest activity, it is from a research point of view more important to identify the mechanisms underlying nest substrate refusal or acceptance. This study contributes to an increased knowledge regarding carpenter ant nesting activity by pointing out potential mechanisms behind the ability to withstand ant attack. Based on the results of this study it is also made clear that there are distinct differences between the products tested and that foamglas is significantly less susceptible to ant excavation in the laboratory. Foamglas seems like a product that should be preferred to avoid ant excavation in areas with high risk of carpenter ant infestation. By its specific properties it may contribute to reduced ant establishment, smaller damage and consequently less pesticide use in indoor environments.

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Appendix

Figure A-1: Comparable to **Figure 1** in the report.

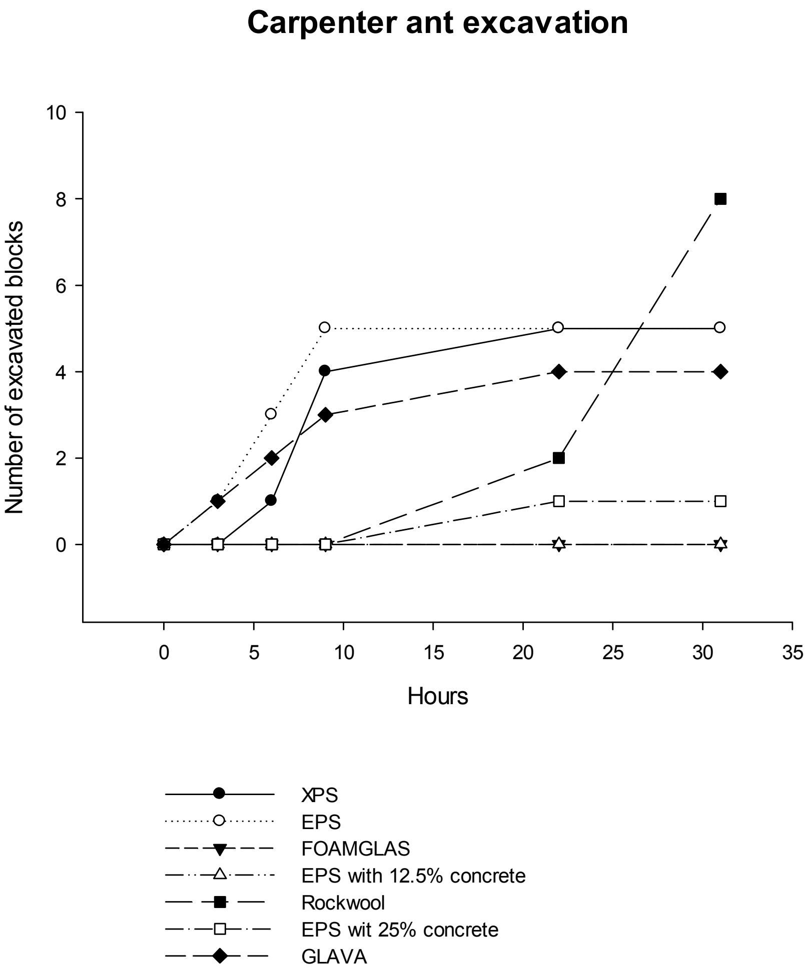

Figure A-2: Comparable to **Figure 2** in the report.

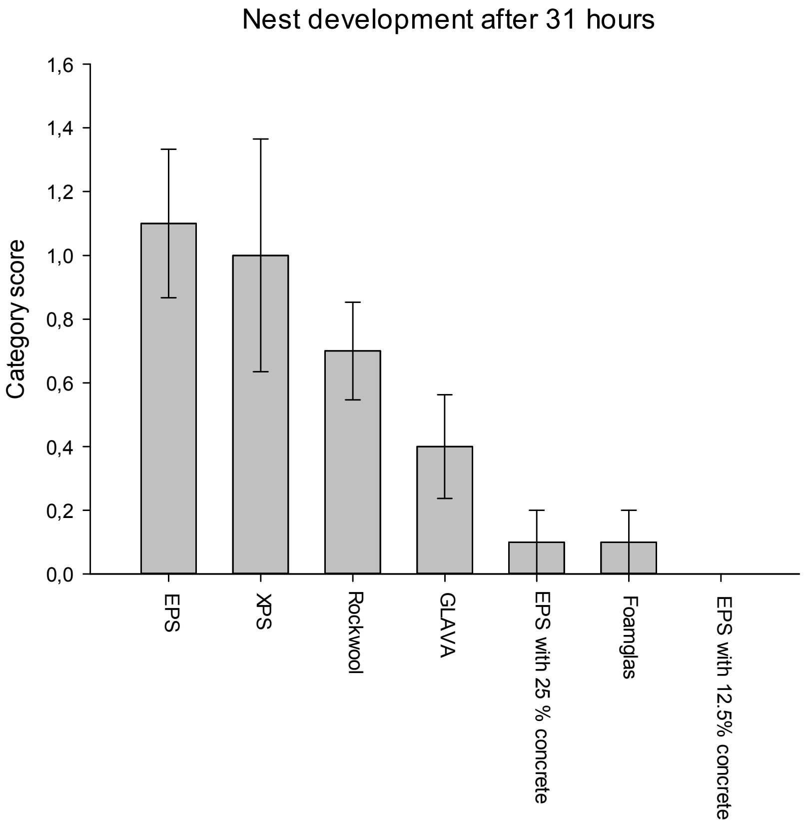

Figure A-3: Comparable to **Figure 3** in the report.