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Development of the Sand Barrier Method of Excluding Termites

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DEVELOPMENT OF THE SAND BARRIER METHOD OF EXCLUDING TERMITES

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Abstract

Studies were undertaken to evaluate the technical and commercial feasibility of developing sand barriers as a non-toxic method for protecting homes in Canada from subterranean termites. Laboratory studies determined that sand composed of particles in the range of 0.22 to 6.3 mm are effective barriers when at least 50% of the mixture by weight is in the range of 1.4 to 2.8 mm, and no more than 25% is in the range of 0.22 to 1.4 mm, and no more than 50% is in the range of 2.8 to 6.3 mm. Field tests on five potentially commercial products in Ontario had an overall efficacy of 96% after two years. It was concluded that sand barriers at least 10 cm thick could be used for the protection of posts in the ground, as a shallow perimeter barrier around homes, or as a pre-construction, sub-slab application for structures with slab-on-grade construction. However, the cost of retro-fitting full depth installations in existing homes with basement type construction would not be commercially competitive with chemical control methods.

Executive Summary

Subterranean termites are the most destructive structural insect pests. Over twenty percent of Canadians now live in termite infested municipalities. With continuing trends toward urbanization and the continuing spread of urban infestations, termites are becoming an increasing problem in Canada. Termites are most prevalent in southern Ontario and southern British Columbia. Because termites are an introduced pest in Ontario, the housing stock has not been chemically pre-treated to prevent termites. Also because of the age and density of the housing in Toronto there has been extensive damage.

Conventional termite control entails the use of large amounts of persistent termiticide to create a toxic barrier in the soil under the foundation of a structure. This large quantity of toxicant in close proximity to human habitation creates health hazards and environmental concerns. The Urban Entomology Program in the Faculty of Forestry at the University of Toronto was established to find alternatives to the chemical barrier method of control.

Sand barriers have been proposed as a non-toxic alternative to the chemical barrier method of control. Very coarse sand particles are too large for termites to move but the interstices between the particles are too small for the termites to crawl through. Sand barriers have recently been commercially developed in Hawaii and Australia. These commercial products use highly uniform particles within a very narrow particle size range. Because of the relatively small size of the Ontario market, such a highly screened product does not appear commercially feasible. Local commercialization therefore appears to depend on a more precise determination of wider particle size limits.

Laboratory penetration bioassay studies were conducted using the eastern subterranean termite, *Reticulitermes flavipes*. These studies determined that four standard soil separates from 1.4 to 2.8 mm are impenetrable. Further studies with mixtures revealed that a broader range of particle sizes can be used when the distribution is within certain limits. General guidelines for the distribution limits of effective particle sizes were defined as any uni-modal distribution with less than 25% fines (1.4 to 0.22 mm), with the modal separate in the range of 1.4 to 2.8 mm, with this range constituting at least 50% of the mixture, and with coarse particles (2.8 to 6.3 mm) constituting no more than 50% by weight.

Field tests were conducted with five potential barrier sands supplied by southern Ontario firms. The overall failure rate of these tests after two years was only 4% even though all five materials were slightly outside recommended distribution limits. The field tests indicated that barriers should be at least 10 cm in thickness. It was concluded that such wider profile barrier sands provide a substantial reduction in risk of termite attack and that when used in conjunction with non-wood foundations the level of protection would likely be comparable to chemical barriers.

The cost of retrofitting sand barriers to existing structures with basement foundations would not be competitive with chemical treatment. Retrofit applications therefore would probably be limited to cases where there are special health concerns such as chemical hypersensitivity or special environmental concerns such as a near by well. The most likely applications of sand barriers would be post hole applications, shallow perimeter applications around structures, and preventative pre-construction applications for structures with slab-on-grade type construction.

Résumé

Les termites souterrains sont les plus destructeurs des insectes qui s'attaquent aux structures. À l'heure actuelle, plus de vingt pour cent des Canadiens vivent dans des municipalités qui en sont infestées. Compte tenu de l'urbanisation croissante et de la progression des infestations dans les villes, les termites constituent de plus en plus un problème au Canada. On trouve des termites surtout dans le sud de l'Ontario et de la Colombie-Britannique. Comme ces insectes ont été introduits en Ontario, le parc résidentiel n'a pas été protégé par des produits chimiques contre les dommages qu'ils peuvent causer. Toronto a lourdement souffert des infestations à cause de l'âge et de la proximité des habitations.

Les exterminateurs ont habituellement recours à de grandes quantités de termicides rémanents qui forment un bouclier toxique dans le sol, sous les fondations d'une structure. La présence d'une grande quantité de cette substance toxique près de bâtiments habités entraîne des risques pour la santé et suscite des préoccupations à l'égard de l'environnement. C'est donc pour trouver des solutions de rechange à cette méthode de contrôle toxique que la faculté de foresterie de l'université de Toronto a mis sur pied un programme d'entomologie urbaine.

L'une des solutions non toxiques proposées en remplacement de la méthode chimique est le bouclier de sable. Quand les grains de sable sont très gros, ils ne peuvent être déplacés par les termites et les interstices qu'ils forment entre eux sont trop étroits pour que les insectes puissent s'y glisser. Des boucliers de sable ont récemment été commercialisés à Hawaii et en Australie. Le sable est composé de grains très homogènes dont la taille doit respecter des limites très serrées. Étant donné la petitesse relative du marché ontarien, un produit nécessitant un tel degré de criblage ne saurait être viable du point de vue commercial. Pour commercialiser le bouclier de sable sur ce marché, il faudrait que l'on puisse déterminer avec plus de précision les limites de taille des particules de forte granulométrie.

Des épreuves biologiques de pénétration ont donc été menées en laboratoire à l'aide du termite souterrain <u>Reticulitermes flavipes</u>. Ces épreuves ont permis de déterminer que quatre fractions du sol s'échelonnant entre 1,4 et 2,8 mm sont impénétrables. De plus amples épreuves portant sur des mélanges de sable ont révélé qu'il est possible d'avoir recours à une gamme plus variée de tailles lorsque leur distribution demeure à l'intérieur de certaines limites. Les limites de distribution générales des tailles efficaces ont été établies à toute distribution unimodale composée de moins de 25 p. 100 de sable fin (entre 1,4 et 0,22 mm), la fraction modale se situant entre 1,4 et 2,8 mm et constituant au moins 50 p. 100 du mélange, et de sable grossier (entre 2,8 et 6,3 mm) constituant au plus 50 p. 100 du poids.

Des essais sur le terrain ont été menés pour cinq types de sable devant servir de bouclier et fournis par des entreprises du sud de l'Ontario. Le taux d'échec global de ces essais après une période de deux ans n'a été que de 4 p. 100, malgré le fait que les cinq types de sable excédaient tous légèrement les limites de distribution recommandées. Ces essais ont permis d'établir que les boucliers doivent avoir une épaisseur d'au moins 10 cm. Les chercheurs concluent que des boucliers comportant une plus large gamme de types de sable permettaient d'obtenir une réduction substantielle du risque d'infestation et que si ce genre de bouclier était utilisé en association avec des fondations réalisées avec d'autres matériaux que le bois, le niveau de protection serait comparable à celui des boucliers chimiques.

Doter de boucliers de sable des structures existantes dont les fondations forment un sous-sol coûterait trop cher pour pouvoir concurrencer le bouclier chimique. Les applications en rattrapage devraient donc se limiter essentiellement aux cas où des risques particuliers pour la santé, comme l'hypersensibilité aux produits chimiques, ou des répercussions environnementales, comme la présence d'un puits à proximité, sont à craindre. Le bouclier de sable serait probablement le plus utile pour les trous destinés à recevoir des poteaux, les applications peu profondes autour des structures et les applications préventives précédant la construction d'ouvrages pourvus de dalles sur terre-plein.

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Particle Size and Frequency Distribution Limits for Aggregate Mixtures Used as Barriers for Subterranean Termites (Isoptera: Rhinotermitidae)

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ABSTRACT Penetration bioassays indicated that four standard soil separates from 1.4 to 2.8 mm are impenetrable by the eastern subterranean termite, *Reticulitermes flavipes* (Kollar) (Isoptera: Rhinotermitidae). The two separates on either side of this range were penetration resistant, i.e, 1.18-1.4 mm and 2.8-3.35 mm. However, a much broader range of particle sizes can be used as effective barriers when the distribution of particle sizes is within certain limits. Theoretical calculations based on spheres in the most-packed configuration and experimental penetration bioassays of aggregate mixtures indicated an upper limit of 6.3 mm. A lower limit of 0.22 mm was established as the smallest useful particle for locking into interstitial spaces of spheres 1.4 mm in diameter. General guidelines for the limits and distribution of effective particle sizes for mixtures used as *Reticulitermes* spp. barriers are defined as any uni-modal distribution with less than 25% fine particles (1.4 to 0.22 mm), with the modal separate in the range of 1.4 to 2.8 mm, with this range constituting at least 50% of the mixture, and with coarse particles (2.8 to 6.3 mm) constituting no more than 50% by weight. This wider particle size range should allow more producers to provide an acceptable product at lower production cost which in turn will reduce cost to consumers. These factors should facilitate more widespread commercial development of aggregate barriers, providing a commercially viable, non-chemical option for subterranean termite control.

KEY WORDS Termite control, *Reticulitermes flavipes*, aggregate barriers, sand barriers

Introduction

Ebeling & Pence (1957) were the first to report on the use of aggregates with particle sizes approximately in the range of 1-3 mm as barriers for the exclusion of subterranean termites. However in the late 1950s there was little interest in non-chemical approaches to termite control. Tamashiro et al. (1987a,b) rediscovered the fact that termites are unable to tunnel through aggregates of certain sizes. They recognized the commercial significance of this finding and working with an aggregate manufacturer in Hawaii, Ameron HC&D, developed a manufactured basaltic product, "Basaltic Termite Barrier" (BTB), which has now gained a substantial share of the pre-construction termite treatment market in Honolulu. In Australia, an aggregate barrier produced by E.B. Mawson Ltd. (Cohuna, Victoria) under the name "Granitguard" was recently accredited (Anon. 1990; French 1991). A summary of research on aggregate materials and effective particle sizes is presented in Table 1. Olkowski (1988) and Daar (1990) provide some practical information on methods of sand barrier installation.

Prior research has proceeded on the assumption that the effective particle size range is that range which encompasses the soil separates which when independently tested are impenetrable. This assumption is really only valid for defining the lower end of the particle size distribution. The lower limit of effective particle size is indeed a function of particle size, that is, at a certain size particles become either too big for termites to grip or too heavy for termites to excavate with their mouth parts. The upper size limit however is only indirectly a function of particle size. The upper size limit is determined by the packing of particles and the resulting dimensions of the interstitial spaces. For aggregate barriers to be effective interstitial spaces must be smaller than the cross-sectional dimensions of small worker head capsules. The abdomen, though wider than the head, is much softer and can be squeezed through any opening passable by the head capsule. Mixtures, unlike separates, having a gradation of particle sizes, are able to pack in configurations which more effectively occupy interstitial spaces. Therefore, theoretically, barrier mixtures could contain particles of any size above the lower size limit as long as a gradation of particle sizes fills all the interstices.

In order to assist aggregate producers in responding to this commercial opportunity it would be useful to provide them with more broadly defined limits of the effective particle size distribution by determining the allowable quantities of particles smaller and larger than the effective particle size range. This information will enable producers to minimize production cost and maximize yield from various quarry sources. Thus, the objectives of this paper are to experimentally demonstrate that a wider effective particle distribution can be achieved with mixtures and to approximate the general parameters of such a wider distribution.

Materials and Methods

Penetration bioassays were performed in large test tubes, 2.5 X 25 cm. The bottom 2 cm of the tubes were filled with 2% agar and covered with a disc of filter paper. After the agar set, a 10 cm layer of test sand was poured into the tubes. The aggregate was separated into sieve fractions (separates) with a Ro-Tap sieve-shaker for five minutes. This layer was capped with a disc of Whatman No. 1 filter paper. Above the test sand was a 2 cm layer of fine brick sand which was then moistened and above this, another 2 cm layer of 1.5% agar. 200 *Reticulitermes flavipes* (Kollar) termites were introduced at the top and supplied with a folded piece of filter paper for food. The top of the tube was plugged with a ball of steel wool through which the termites are unable to tunnel. The tubes were placed vertically in a test tube rack. After three weeks the test tube rack was placed on its side so that the termites could challenge the test material laterally. Each treatment had five replicates. The depth of penetration was recorded periodically for 50 days (Table 2).

To determine the allowable quantity of sub-optimal sized particles which can be mixed with barrier sand, No. 12 sand (1.7 to 2.0 mm) was used as the barrier material and mixed (weight to weight) with No. 20 sand (0.85 to 1.0 mm) in the following proportions (No. 12:20): 100:0, 90:10, 85:15, 80:20, 75:25, 70:30, 65:35, 60:40, and 0:100. The sand was thoroughly mixed by shaking in a cloth bag. The source of the sand was Kew Beach, Lake Ontario, Toronto. The penetration bioassays were set up as in the previous test except that the test layer was reduced to 5 cm (Table 3).

In a third test, a two-tailed dilution was conducted in which barrier particles were mixed with increasing amounts of both larger and smaller sized particles. Equal amounts of Nos. 10, 12, and 14 (2.36 to 1.4 mm) were used as the barrier (B) and mixed with increasing amounts of mixtures comprised of larger (L) particles (Nos. 6, 7, 8; 4.0 to 2.36) and smaller (S) particles (Nos. 16, 18, 20) in the following proportions (L:B:S): 5:90:5, 10:80:10, 15:70:15, 20:60:20, 25:50:25, 30:40:30, 40:20:40, 45:10:45, 50:0:50. 200 termites were used per replicate with three replicates per treatment. The depth of penetration was recorded periodically for 64 days (Table 4).

In a fourth test, various proportions of larger sized particles (L) were mixed with two ranges of barrier sized particles (B). A barrier mixture (Nos. 10, 12, 14 = 2.36 to 1.4 mm) was mixed with larger particles (Nos. 7, 8 = 3.35 to 2.36) and a barrier mixture (Nos. 10, 12, 14 = 2.36 to 1.4 mm) was mixed with larger particles (Nos. 6, 7, 8 = 4.0 to 2.36 mm) each in the following proportions (L:B): 10:90, 20:80, 30:70, 40:60, 50:50, 100:0, 0:100. Each replicate had 200 termites with three replicates per treatment. The depth of penetration was recorded periodically for 64 days (Tables 5 & 6).

The next series of tests examined coarser barrier mixtures and it was therefore necessary to perform the test in wider containers. These tests were conducted in 14 oz. (400 ml) Dixie Styroware beverage cups (5.5 X 8.5 X 12 cm). A 1.5 cm layer of 2% agar was poured in the bottom of the cups, capped with a filter paper disk, then the 4 cm layer of the test barrier, capped with a filter paper disk, then 2 cm layer of moist brick sand and a 1 cm layer of 2% agar and a disk of filter paper for food. 100 termites were introduced to each cup. Four 1 cm slits were made in the top rim of each cup with a hot knife to provide air circulation and the cups were covered with petri dish lids. Three different barrier (B) mixtures were made up with equal parts as follows: Mix 1 (Nos. 8, 10, 12, 14), Mix 2 (Nos. 7, 8, 10, 12, 14), Mix 3 (6, 7, 8, 10, 12, 14). Each of these mixtures was then mixed the next larger (L) standard sieve separate, e.g. No.7, No.6, or No.5 respectively in the following proportions (B:L): 100:0, 75:25, 50:50, 25:75, 0:100. Each treatment had three replicates.

Since the termites attempt to penetrate along the surface of the cup the maximum depth of penetration can be observed. Maximum depth of visible penetration was recorded at intervals for 72 days (Tables 7, 8, 9).

A sixth set of experiments tested seven different uniform profile barrier mixtures consisting of equal parts as follows: Mix 1 (Nos. 8, 10, 12, 14 = 2.8 to 1.4 mm), Mix 2 (Nos. 7, 8, 10, 12, 14 = 3.35 to 1.4 mm), Mix 3 (Nos. 6, 7, 8, 10, 12, 14 = 4.00 to 1.4 mm), Mix 4 (Nos. 5, 6, 7, 8, 10, 12, 14 = 4.75 to 1.4 mm), Mix 5 (Nos. 4, 5, 6, 7, 8, 10, 12, 14 = 6.3 to 1.4 mm), Mix 6 (Nos. 3, 4, 5, 6, 8, 10, 12, 14 = 8.0 to 1.4 mm), Mix 7 (Nos. 2, 3, 4, 5, 6, 8, 10, 12, 14 = 9.5 to 1.4 mm). Two hundred termites were used per replicate with four replicates per treatment. Penetration was recorded periodically for 71 days (Table 10).

Penetration of up to 2.0 cm can occur with "impenetrable barriers" merely as a result of the looseness of surface packing. Consistent penetration deeper than 2.0 cm indicates that termites are actually dislodging particles and capable of tunnelling through the test material (see Su et al. 1991). Impenetrable materials were therefore defined as average penetration less than 2.0 cm and no replicate with penetration greater 3.0 cm. Any material with an average penetration greater than 2.0 cm or any single replicate with penetration greater than 3.0 was classified as penetrable. Penetration data were also analysed by ANOVA procedures run on CoHort Software (CoStat Ver. 4.1). A one-way completely randomized model was used to compare means of maximum depth of visible penetration. Duncan's Multiple Range Test and Tukey's Honestly Significant Difference were used as means tests at a significance level of 0.05.

Results

The results of the penetration bioassays are shown in Tables 2-10. It will be seen that Duncan's multiple range test, Tukey's test and the score (based on mean and maximum penetration) gave the same cut off point between penetrable and impenetrable in Tables 5, 7, 8 and 9. In Tables 2, 3, 6, and 10 Duncan's test agreed with the score. In Table 4 the score gave a more conservative cut off. Since the score was usually validated by the other tests but was more conservative, it was used to define the limit of impenetrability for the various mixtures.

Table 2 shows that the four impenetrable separates are p7/c8 (2.8-2.36 mm), p8/c10 (2.36-2.0 mm), p10/c12 (2.0-1.7 mm), and p12/c14 (1.7-1.4 mm). The separates on each side of this range p6/c7 (3.35-2.8 mm) and p14/c16 (1.4-1.18 mm) were not completely penetrated (10 cm) within 73 days and can therefore be considered "penetration resistant". In contrast all replicates of separates coarser than 3.35 mm or finer than 1.18 mm were fully penetrated within 1 week.

Table 3 indicates that impenetrability was lost when fine particles constituted 35% or more of the aggregate mixtures. This was confirmed again with a wider particle size distribution in the two-tailed dilution test (Table 4).

Table 5 shows that coarse particles in the range of 2.36 to 3.35 mm could constitute at least as much as 50% of the aggregate mixture without losing impenetrability. Each subsequent test (Tables 6, 7, 8, 9, 10) confirmed the permissible volume of coarse particles and demonstrated a further extension of the upper size limit. Thus Table 6 indicates that particles in the range of 4.0 to 2.36 mm can constitute at least 50% of an impenetrable mixture. Table 7 indicates that all mixtures from 3.35 to 1.4 were impenetrable. Unexpectedly, the 100% 3.35-2.8 mm sand was also not penetrated in this test (Table 7) in contrast to the results obtained in Table 2. This may have been because of a difference in sand types. The aggregate tested in Table 2 was a crushed material whereas that tested in Table 7 was natural beach sand. Alternatively the difference in penetration may have resulted from width of the bioassay containers (test tubes versus cups). This bioassay was conducted in much wider cups and therefore the interstices at the barrier-cup interface may have been smaller than at the barrier-test tube interface. Table 8 is interesting in showing that particles 4.0 to 3.35 can constitute as much as 75% of a impenetrable mixture. This indicates that the modal separate in an impenetrable mixture can actually be two screen sizes above the 2.8 mm limit for effective separates. Table 9 indicates an upper limit of 50% in the range of 4.7 to 4.0 mm. Table 10 shows that Mixture 5 composed of equivalent weights of particles passing Tyler No. 3 and caught on eight sieves, Nos. 4, 5, 6, 7, 8, 10, 12, and 14 was an effective impenetrable barrier. In other words, particles 6.3 to 4.75 mm can constitute 12.5%, and the range of 6.3 to 2.8 could constitute as much as 50% of an impenetrable mixture.

Discussion

Penetrability of Separates. Based on laboratory studies Su et al. (1991) reported that six soil separates from 1.0 to 2.36 mm were least penetrated by *Reticulitermes flavipes*. Su & Scheffrahn (1992) amended the range of impenetrable separates to 1.7 to 2.8 mm based on test tube penetration studies exposed to field foraging populations. This later study however did not involve a test of particles 1.4 to 1.7 mm. In the present study we determined that four standard separates are impenetrable to *Reticulitermes flavipes* populations from Toronto. These were: p7c8, p8c10, p10c12, p12c14 (p=passing, c=caught on, # = Tyler No.), corresponding to 2.8-2.36, 2.36-2.0, 2.0-1.7, and 1.7-1.4 mm respectively. Thus our study agrees with the Su and Scheffrahn (1992) on the upper limit of 2.8 mm but includes one lower separate for a lower limit of 1.4 mm. The 1.4 mm lower limit was also appropriate for *Coptotermes formosanus* Shiraki as indicated by Su et al. (1991). One separate above this range, i.e., p6c7 (3.35-2.8) and one separates below this range, i.e., p14c16 (1.4-1.18) are "penetration resistant", i.e., termites failed to penetrate 5 cm within 1 month, as also found by Su et al. (1991). In the present study, particles in the 3.35 to 2.8 mm range were impenetrable in tests conducted in wide cups rather than test tubes (Table 7). All previous studies have been conducted in relatively narrow test tubes which with the coarser particle sizes may have resulted in larger and more continuous spaces at the test tube interface. Thus some doubt remains as to whether the 2.8 mm limit is a consequence of inter-particle interstices or aggregate-interface interstices.

Variation in Range of Impenetrable Separates by Taxa. A serious consideration in most tropical parts of the world is that soils are inhabited by a several different taxa of subterranean termites. This concern also applies to the southern tier of states in the U.S. where both *Coptotermes formosanus* and *Reticulitermes* spp. are found from Texas to Florida and *Reticulitermes* spp., *Amitermes* spp. and *Paraneotermes simplicicornis* (Banks) are found from Texas to California, and *Heterotermes aureus* (Snyder) in Arizona and California. Other subterranean species occur as well but are not structural pests. The studies of Tamashiro et al. (1991) and French (1989) suggest that the smallest effective separate for *Coptotermes* spp. may be one size coarser than that for *Reticulitermes*. The studies by Pallaske & Igarashi (1991) and Myles (1991) suggest that both the effective upper and lower separates are shifted down one sieve size for *Heterotermes* spp. compared to *Reticulitermes* spp. An ecologically unusual termite of the American southwest, *Paraneotermes simplicicornis*, is the only subterranean kalotermitid and is much larger than other subterranean termites was found to penetrate particles smaller than 2.0 mm (Myles 1991). Another unusual subterranean termite, *Mastotermes darwiniensis* Froggatt, of northern Australia is also very large compared to most subterranean termites and notoriously destructive--it is likely that this termite would require a coarser particle size range.

Penetrability of Mixtures. Su et al. (1991) and Su & Scheffrahn (1992) reported that two aggregate mixtures in the ranges of 1.7 to 2.36 and 1.18 to 2.8 mm were both impenetrable by *R. flavipes* in lab and field trials. They did not describe the particle size distributions within these ranges. However, not unexpectedly, impenetrable separates when mixed form impenetrable mixtures. Tamashiro et al. (1991) reported that a commercial "sandblast" sand with 50% from 2.8 to 1.7 mm, 34.3% from 1.7 to 1.4 mm, and 15.2% passing 1.4 mm was an effective barrier mixture against *Coptotermes formosanus*.

Results of the present study demonstrated that substantial quantities of particles outside the range of impenetrable separates can be incorporated into impenetrable mixtures. Furthermore, a surprisingly wide range of particle sizes is permissible, especially toward the coarser end of the particle size distribution. Thus effective aggregate termite barriers need not be limited in composition to the four effective separates. Various mixtures comprised of particles from 6.3 to 0.85 mm in diameter were impenetrable. This range encompasses eleven standard sieves, i.e., passing No. 3 (¼" = 6.3 mm) and caught on Nos. 4, 5, 6, 7, 8, 10, 12, 14, 16, 18, and 20.

Two tests indicated that barrier impenetrability begins to break down when fine particles reach or exceed 35% of the mixture by weight. Thus fine particles less than 1.4 mm must be kept to 30% or less, and preferably since fines increase weight without contributing to bulk (because they occupy interstices), they should be kept to a minimum. Theoretical considerations (see below) also provide justification for setting the maximum limit of fines at no more than 25%.

The upper limit of the particle size distribution for mixtures is considerably above the upper limit for separates. The penetration bioassays indicated that mixtures could contain as much as 75% No. 6 (4.00 to 3.35 mm), 50% No. 5 (4.75 to 4.00 mm), or 12.5% No. 4 (6.3 to 4.75 mm). Therefore, assuming a tapering frequency distribution, coarse particles (2.8 to 6.3 mm), can constitute up to 50% of the barrier mixture.

Thus any uni-modal distribution with less than 25% fine particles, with the modal separate in the range of 1.4 to 2.8 mm, with this range constituting at least 50% of the mixture, and with coarse particles (2.8 to 6.3 mm) constituting no more than 50% should be an effective barrier against *Reticulitermes flavipes*. Examples of aggregate profiles based on these limits are shown in Figures 1-4.

It is likely that such barriers would be effective against other subterranean termites of the genus *Reticulitermes*. Furthermore, it seems likely that barrier mixtures would also be effective against a wider range of subterranean termite species in many regions where the termite fauna is more diverse. However, additional confirmation with field trials of specific mixtures in various regions is certainly warranted.

Theoretical Limits on Particle Size. Theoretical limits on particle size for uniform sized aggregates can be calculated on the assumption of spherical shaped particles in most-packed and least-packed configurations (Figures 5 & 6). Measurements of computer-generated illustrations provided estimates of the relationship of between particle diameter and maximal and minimal interstitial pore diameters as: $I_{max} \approx P/2.35$ and $I_{min} \approx P/6.5$ where P = particle diameter.

Since $P \approx 6.5 \times I_{min}$ for the most-packed configuration and $P \approx 2.35 \times I_{max}$ for the least-packed configuration, it was possible to obtain estimates of P_{max} by setting I equal to the average worker head capsule width, 1.03 mm (Su et al. 1991). This gave theoretical upper limits of effective particle size of 6.7 mm in the most-packed configuration and 2.42 mm under the least packed configuration. Theoretically barrier mixtures could contain particles even above the 6.7 mm limit as long as the mixture contains the appropriate number and size of particles to occupy the interstices.

For the interface between the barrier and a rigid plane Figure 2 shows that the larger interstices are actually present in the most-packed configuration with the interface interstice, $I_{i,max} \approx P/2$. Therefore particles in the most-packed configuration would be penetrable along the interface when $P \approx 2 \times 1.03$ mm (worker head width) = 2.06 mm. This interface pore space due to packing irregularities may be the limiting factor in determining the upper particle size limit. Observations seemed to confirm that with coarser barrier materials termites always penetrated along the glass barrier interface in the penetration bioassays. Thus, in installations around houses, pipes which cross the barrier could be points of vulnerability with barriers composed of overly coarse particles.

Since in reality particles are not spheres and packing is somewhere between the most and least packed configuration it is reasonable that the observed limit for the coarsest effective separate fell within the theoretical limits, i.e., 2.8 mm. However it is interesting that theory suggests a much higher uniform particle size limit may be possible if packing is optimized and interfaces are controlled. More importantly, with mixtures a higher size limit can be expected due to interstitial closure by the gradation of particle sizes. Further theoretical work on the effect of composition of mixtures on interstitial pore space would be desirable.

For the effective particle size range of 1.4 to 2.8 mm, the I_{max} range is 0.6 to 1.2 mm and the I_{min} range is 0.22 to 0.43 mm, or a total interstitial pore diameter range from 1.2 to 0.22 mm. The maximal interstitial particle size was estimated as $(I_{max} + P)/2$. Therefore $(1.2 + 2.8)/2 = 2.0$ mm was estimated as the maximal interstitial particle size for barrier particles 2.8 mm in diameter. Consequently, for barrier particles 1.4 to 2.8 mm locking interstitial particles can range from 0.22 to 2.0 mm. Particles below the 0.22 mm would be too small to lock into interstitial spaces and should therefore be completely eliminated from the mixture. Particles in the range of 0.22 to 1.4 mm could occupy interstices and therefore would not weaken the barrier as long as their proportion of the mixture not exceed interstitial occupancy. Most interestingly, particles 2.0 to 1.4 represent an overlap zone, which are impenetrable and also serve to occupy the interstices at the upper end of the mixture.

Theoretical Limit on Maximum Weight of Fines. Two theoretical maxima for the weight of fines, were calculated on the basis of spheres in the least-packed, $W_{f,l,max}$, and most-packed, $W_{f,m,max}$, configurations. The least-packed maxima was defined as one minus the ratio of the volume of a sphere to the volume of a cube, $W_{f,l,max} = 1 - [4/3\pi r^3]/(2r)^3 = 0.4764$. The most packed maxima was defined as one minus the ratio of the volume of a sphere to the volume of a rhombic dodecahedron, $W_{f,m,max} = 1 - [4/3\pi(\sqrt{2}\ell)^3]/16\ell^3 = 0.25952$, where ℓ = the length of an edge of the rhombic dodecahedron (see Coxeter 1961). Thus, theoretically, the limit for the allowable quantity of fines is between 26 to 48% of the weight of the mixture.

A further theoretical calculation of the weight limit for fines was calculated on the assumption of the largest possible single interstitial particle occupying each interstice for the least-packed configuration of particles 2.8 mm in diameter. In this configuration there is a one to one relationship of particles to interstices. The volume of a 2.8 mm sphere to the volume of the estimated corresponding maximum interstitial particle, (2.8/2.35 = 1.2; 2.8 + 1.2/2 = 2.0). Thus, using r = 1.4 and r = 1.0 the limit was calculated as (volume of a sphere = $4\pi r^3/3$; $W_{f,max} = 4.19/(4.19 + 11.49) = 0.267$) or 27% of a mixture. This estimate agreed closely with $W_{f,m,max}$ of 26% above.

Appropriately, the observed failure of barriers when fines were increased from 30 to 35% of the weight of the mixture fit within the theoretical limits, 26 to 48%, for most-packed and least-packed configurations. The theoretical limits suggest that in the interest of caution the maximum allowable quantity of fines should be defined as 25%.

Commercial Development. It is interesting to note that the two commercial products, BTB and Granitguard (Table 1), which are marketed for regions where *Coptotermes* spp. are present have upper limit of 2.36 mm which is at least one sieve size lower than necessary. BTB has a lower limit of 1.18 mm which is one sieve size below the 1.4 mm lower limit for effective separates and Granitguard has a lower limit of 1.7 mm which is one sieve size above the 1.4 mm limit. Nevertheless, the present study has shown that these products are within the limits are effective aggregate mixtures for termite barriers. Because these products have very narrow distributions within the range of effective separates there should be little concern for quality control of the product since there is a very wide margin of safety. However, the manufacturers may be able to reduce production cost without any loss of effectiveness by widening the particle size distributions, especially toward coarser particle sizes.

One of the main problems limiting the widespread commercial development of sand barriers is the large haulage cost. Large haulage cost dictates that producers must be located near major urban markets. Therefore for widespread commercial development to take place, many producers will have to get involved, supplying local products for each local market. Thus many producers will need to assess feasibility.

There are several undesirable commercial consequences of producing an aggregate product that has an unnecessarily narrow particle size range: longer production time, greater labour and energy costs, and more wear on sieves and machinery. Because of the lower yield of product from the quarry source there are higher short-term production costs as well as long-term costs associated with the build up, storage, and the re-processing needed to utilize accumulated by-product. These higher production costs necessarily translate into higher consumer cost which if too high, suppresses market size and inhibits commercial feasibility. It is hoped that the wider particle size limits of effective mixtures will lead to a larger number of producers supplying local markets and more widespread use of aggregate barriers for termite control.

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Table 1. Review of research on aggregate barriers for termite control.

AUTHOR	LOCALITY	TERMITE	SAND TYPE	EFFECTIVE SIZE
Ebeling & Pence 1957	California	Reticulitermes hesperus	sand	approx. 1-3 mm
			volcanic cinders	Mesh 6-16 tamped
			slag (sinter)	same
Ebeling & Forbes 1988	California	Reticulitermes hesperus	sand	10-16 Mesh, 1.6-2.5 mm
			sand	6-16 Mesh if tamped
			sand blast sand	12-16 Mesh
			volcanic cinders	10-18 Mesh
Ebeling 1989	U.S.A.	termites	sand blast grits	10-16 Mesh
			sand	12 grit
			sand mixture	C6 to 16 with less than 5% each tail
Smith & Rust 1990	California	Reticulitermes hesperus	decomposed granite	0.84-2.36 mm
Tamashiro et al. 1987	Hawaii	Coptotermes formosanus	basalt gravel	1.7-2.4 mm
			sand blast sand	82% btwn. 1.4-2.36 mm
Tamashiro et al. 1987	Hawaii	Coptotermes formosanus	gravel substrates	1.4-2.36 mm
			sand blast sand	0.07"-0.09"
Tamashiro et al. 1991	Hawaii	Coptotermes formosanus	basaltic sand	1.7-2.8 mm
			sandblast sand	50% 1.7-2.8 mm & 50% passing 1.7 mm
Ameron HC & D 1987	Hawaii	Coptotermes formosanus	Basaltic Termite Barrier	95+% passing 2.36 mm & < 10% p. 1.18 mm
French 1989	Australia	Coptotermes acinaciformis	basalt or granite	1.6-2.4 mm
		Coptotermes lacteus	basalt or granite	1.6-2.4 mm
Anon. 1990	Australia	subterranean termites	granite screenings	100% passing 2.4 mm & 0-6% passing 1.7 mm
Pallaske & Igarashi 1991	Germany	Reticulitermes santonensis	glass splinters	0.5-3.5 mm
		Heterotermes indicola	glass splinters	0.5-3.0 mm
		Reticulitermes santonensis	glass globules	0.8-3.0 mm
		Heterotermes indicola	glass globules	0.5-3.0 mm
Su et al. 1991	Florida	Coptotermes formosanus	fossilized coral	1.7-2.36 mm
		Reticulitermes flavipes	fossilized coral	1.0-2.36 mm
		both species	fossilized coral	1.18-2.8 mm mix
Su & Scheffrahn 1992	Florida	Coptotermes formosanus	quartz & coral	2.0-2.8 mm
		Reticulitermes flavipes	quartz & coral	1.18-2.8 mm
		both species	quartz & coral	2.0-2.8 mm
Myles 1991	Arizona	Heterotermes aureus	Horticulture sand	1.18-1.7 mm
			Basaltic Termite Barrier	1.18-2.36
		Paraneotermes simplicicornis	mortar sand	2.0-4.0 mm
Myles and Grace 1991	Canada	Reticulitermes flavipes	sand	2.8-1.4 mm
Myles 1992	Canada	Reticulitermes flavipes	aggregate separates	1.4-2.36 mm
			aggregate mixtures	40+% 1.4-2.36 mm & < 30% p. 1.7 mm & < 50% 2.36-6.3 mm

Table 2. Penetration of soil separates (10 cm layer) by *Reticulitermes flavipes*.

		Distance tunneled (cm)				
passing/caught on[a]	particle size (mm)	Mean[b]	Max.[c]	Dun.[d]	Tuk.[e]	Score[f]
p4/c5	4.75-4.00	10.00	10.0	a	a	P
p5/c6	4.00-3.35	10.00	10.0	a	a	P
p6/c7	3.35-2.80	3.64	5.0	c	b	P
p6/c8	3.35-2.36	2.32	4.8	d	bc	P
p7/c8	2.80-2.36	0.88	2.0	e	c	I
p8/c10	2.36-2.00	1.04	1.3	e	c	I
p10/c12	2.00-1.70	0.68	0.9	e	c	I
p12/c14	1.70-1.40	1.28	1.6	de	c	I
p14/c16	1.40-1.18	8.12	9.9	b	a	P
p16/c18	1.18-1.00	10.00	10.0	a	a	P

[a] Tyler Number
[b] Mean depth of penetration (cm.) of 5 replicates
[c] Maximum depth of penetration (cm.) of 5 replicates
[d] Duncan's multiple range test, same letters indicate nonsignificant ranges at P = 0.05
[e] Tukey's Honestly Significant Difference, same letters indicate nonsignificant ranges at P = 0.05
[f] I = Impenetrable (Mean < 2.0 cm. and Max. < 3.0 cm.), P = Penetrable (Mean > 2.0 cm. or Max. > 3.0 cm.)

Table 3. Termite penetration of aggregate mixtures (5 cm layers) with increasing proportions of fine particles[a].

Composition (%)		Distance tunneled (cm)				
0.85-1.0 mm	2.0-1.7 mm	Mean	Max.	Dun.	Tuk.	Score
0	100	0.16	0.3	d	b	I
10	90	0.40	0.5	d	b	I
15	85	0.26	0.4	cd	b	I
20	80	0.36	0.5	cd	b	I
25	75	0.72	1.0	bcd	b	I
30	70	0.84	1.1	bcd	b	I
35	65	1.50	4.0	bc	b	P
40	60	1.62	5.0	b	b	P
100	0	5.00	5.0	a	a	P

[a] See footnotes under Table 2

Table 4. Termite penetration of aggregate mixtures (10 cm layers) with increasing proportions of both fine and coarse particles[a]

Composition (%)	Distance tunneled (cm)				
4.0-2.36/2.36-1.4/1.4-0.85 mm	Mean[b]	Max.	Dun.	Tuk.	Score
5 /90/ 5 %	0.66	0.8	ab	a	I
10/80/10	0.56	0.9	b	a	I
15/70/15	1.80	2.7	ab	a	I
20/60/20	1.00	1.2	ab	a	I
25/50/25	1.20	1.9	ab	a	I
30/40/30	0.46	0.6	b	a	I
35/30/35	2.00	3.6	ab	a	P
40/20/40	3.00	3.6	a	a	P
45/10/45	2.40	5.1	ab	a	P
50/ 0/50	2.90	4.3	a	a	P

[a] See footnotes under Table 2
[b] Based on three replicates

Table 5. Termite penetration of aggregate mixtures (10 cm layers) with increasing proportions of particles 3.35 to 2.36 mm[a].

Composition (%)		Distance Tunneled (cm)				
3.35-2.36 mm	2.36-1.4 mm	Mean[b]	Max.	Dun.	Tuk.	Score
0	100	0.80	1.3	bcd	bc	I
10	90	0.37	1.1	cd	bc	I
20	80	0.07	0.2	d	c	I
30	70	1.03	1.7	bc	bc	I
40	60	1.43	1.8	b	ab	I
50	50	1.10	1.6	bc	bc	I
100	0	2.50	3.1	a	a	P

[a] See footnotes under Table 2
[b] Based on three replicates

Table 6. Termite penetration of aggregate mixtures (10 cm layers) with increasing proportions of particles 4.0 to 2.36 mm[a].

Composition (%)		Distance tunneled (cm)				
4.0-2.36 mm	2.36-1.4 mm	Mean[b]	Max.	Dun.	Tuk.	Score
0	100	1.33	1.6	b	ab	I
10	90	1.20	1.5	b	ab	I
20	80	1.47	1.9	ab	ab	I
30	70	0.93	1.2	b	ab	I
40	60	0.80	1.0	b	ab	I
50	50	0.70	1.6	b	b	I
100	0	2.53	4.0	a	a	P

[a] See footnotes under Table 2
[b] Based on three replicates

Table 7. Termite penetration of aggregate mixtures (4 cm layers) with increasing proportions of particles 3.35 to 2.8 mm[a].

Composition (%)		Distance tunneled (cm)				
3.35-2.8 mm	2.8-1.4 mm	Mean[b]	Max.	Dun.	Tuk.	Score
0	100	0.30	0.4	a	a	I
25	75	0.33	0.4	a	a	I
50	50	0.36	0.7	a	a	I
75	25	0.40	0.5	a	a	I
100	0	0.60	0.7	a	a	I

[a] See footnotes under Table 2
[b] Based on three replicates

Table 8. Termite penetration of aggregate mixtures (4 cm layers) with increasing proportions of particles 4.0 to 3.35 mm[a].

Composition (%)		Distance Tunneled (cm)				
4.0-3.35 mm	3.35-1.4 mm	Mean[b]	Max.	Dun.	Tuk.	Score
0	100	0.53	0.8	b	b	I
25	75	0.87	1.2	b	b	I
50	50	0.53	0.8	b	b	I
75	25	0.97	1.1	b	b	I
100	0	4.00	4.0	a	a	P

[a] See footnotes under Table 2
[b] Based on three replicates

Table 9. Termite penetration of aggregate mixtures (4 cm layers) with increasing proportions of particles 4.75 to 4.0 mm[a].

Composition (%)		Distance tunneled (cm)				
4.7-4.0 mm	4.0-1.4 mm	Mean[b]	Max.	Dun.	Tuk.	Score
0	100	0.67	0.9	c	b	I
25	75	0.53	0.6	c	b	I
50	50	0.93	1.2	c	b	I
75	25	2.30	4.0	b	ab	P
100	0	4.00	4.0	a	a	P

[a] See footnotes under Table 2
[b] Based on three replicates

Table 10. Termite penetration of uniform profile aggregate mixtures (4 cm layers)[a].

Mixture	particle size range	Distance tunneled (cm) Mean[b]	Max.	Dun.	Tuk.	Score
1	2.80-1.4 mm	0.4	0.5	c	b	I
2	3.35-1.4 mm	0.88	1.2	bc	ab	I
3	4.00-1.4 mm	0.85	1.5	bc	ab	I
4	4.75-1.4 mm	1.10	1.3	bc	ab	I
5	6.30-1.4 mm	0.98	1.1	bc	ab	I
6	8.00-1.4 mm	1.90	4.0	ab	ab	P
7	9.50-1.4 mm	2.63	4.0	a	a	P

[a] See footnotes under Table 2
[b] Based on four replicates

FIGURE LEGEND

Fig. 1. Coarsest, finest, and middle range distributions for effective sand barriers against *Reticulitermes* spp.

Fig. 2. Example of an effective sand barrier particle size distribution with a broad range of particle sizes tapering off at both ends.

Fig. 3. Broadest and flatest recommendable particle size distribution for an effective sand barrier.

Fig. 4. Low-end and high-end particle size distributions for effective sand barriers.

Fig. 5. Relationship of particle size, P, to interstitial pore diameter, I, and interface pore diameter, i, for least-packed configuration of spheres.

Fig. 6. Relationship of particle size, P, to interstitial pore diameter, I, and interface pore diameter, i, for most-packed configuration of spheres.

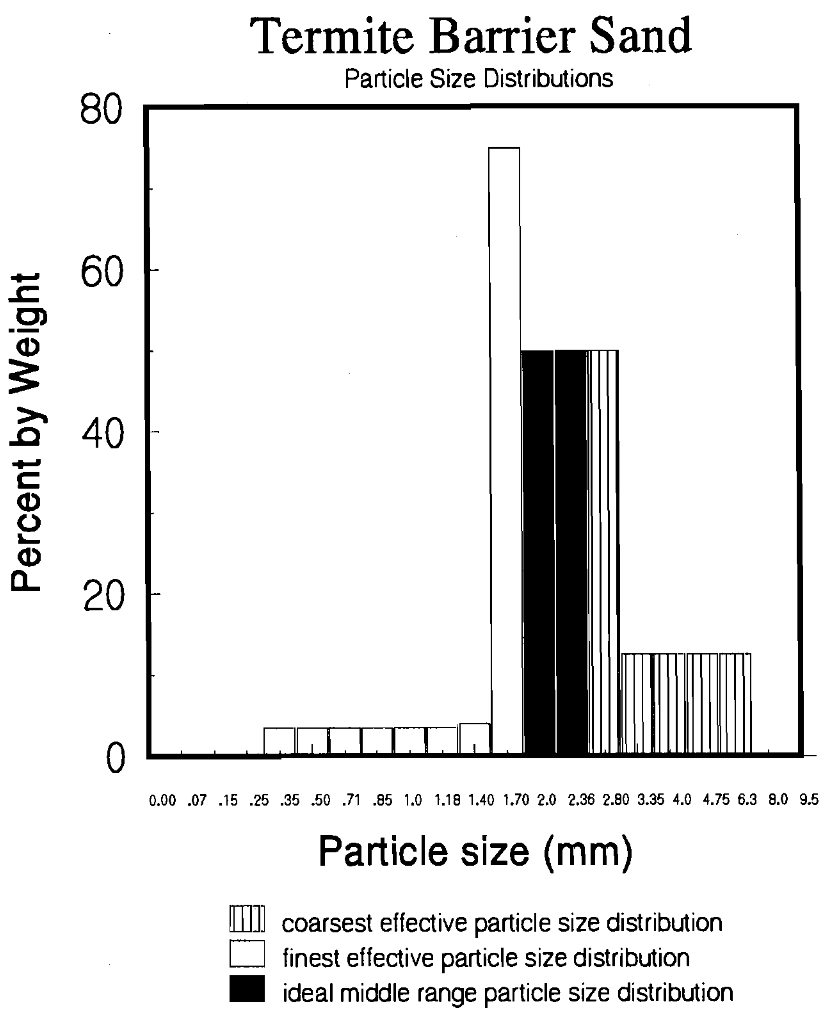

Fig. 1 - Coarsest, finest, and middle range distributions for effective sand barriers against Reticulitermes spp.

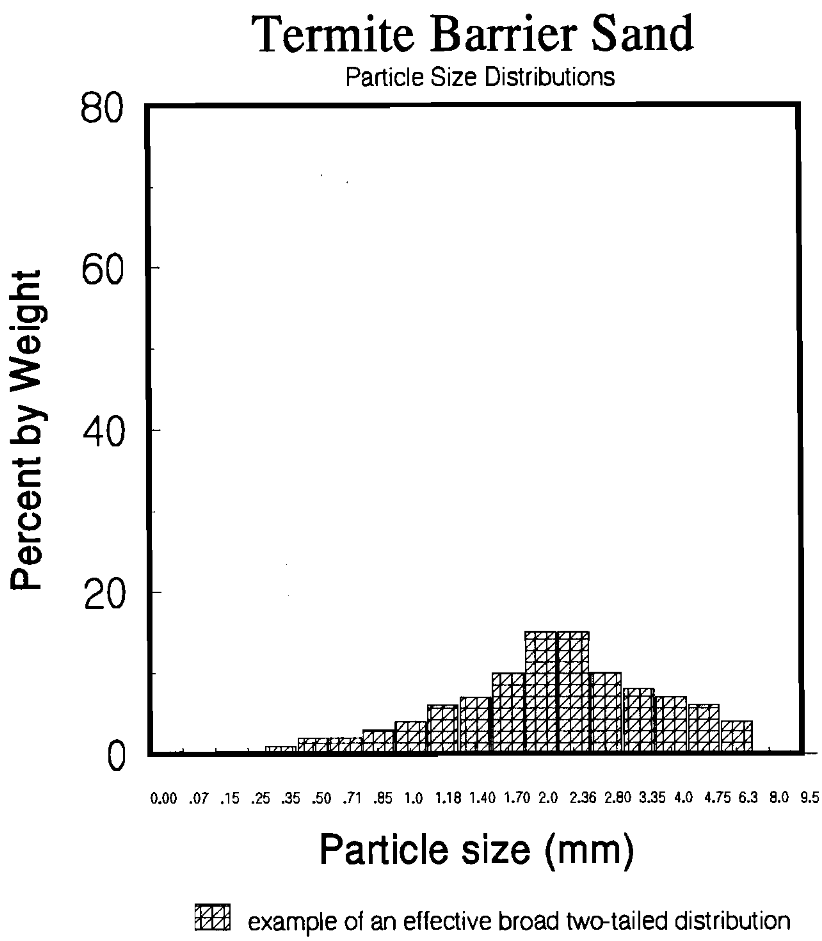

Fig. 2 - Example of an effective sand barrier particle size distribution with a broad range of particle sizes tapering off at both ends.

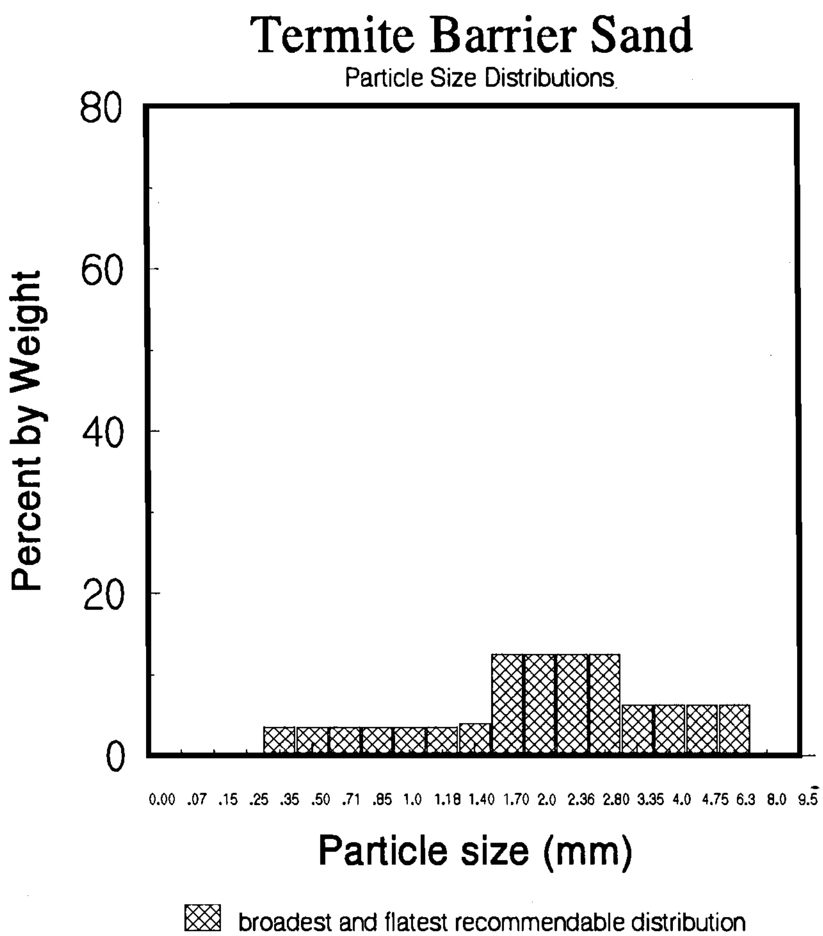

Fig. 3 - Broadest and flatest recommendable particle size distribution for an effective sand barrier.

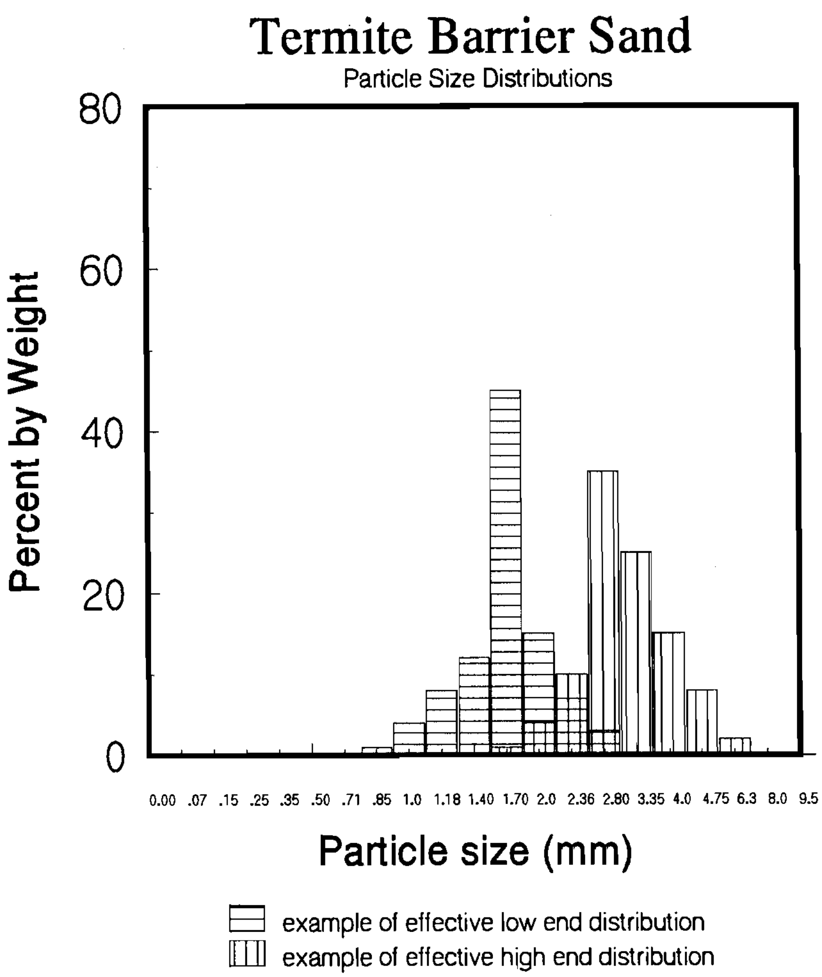

Fig. 4 - Low-end and high-end particle size distributions for effective sand barriers.

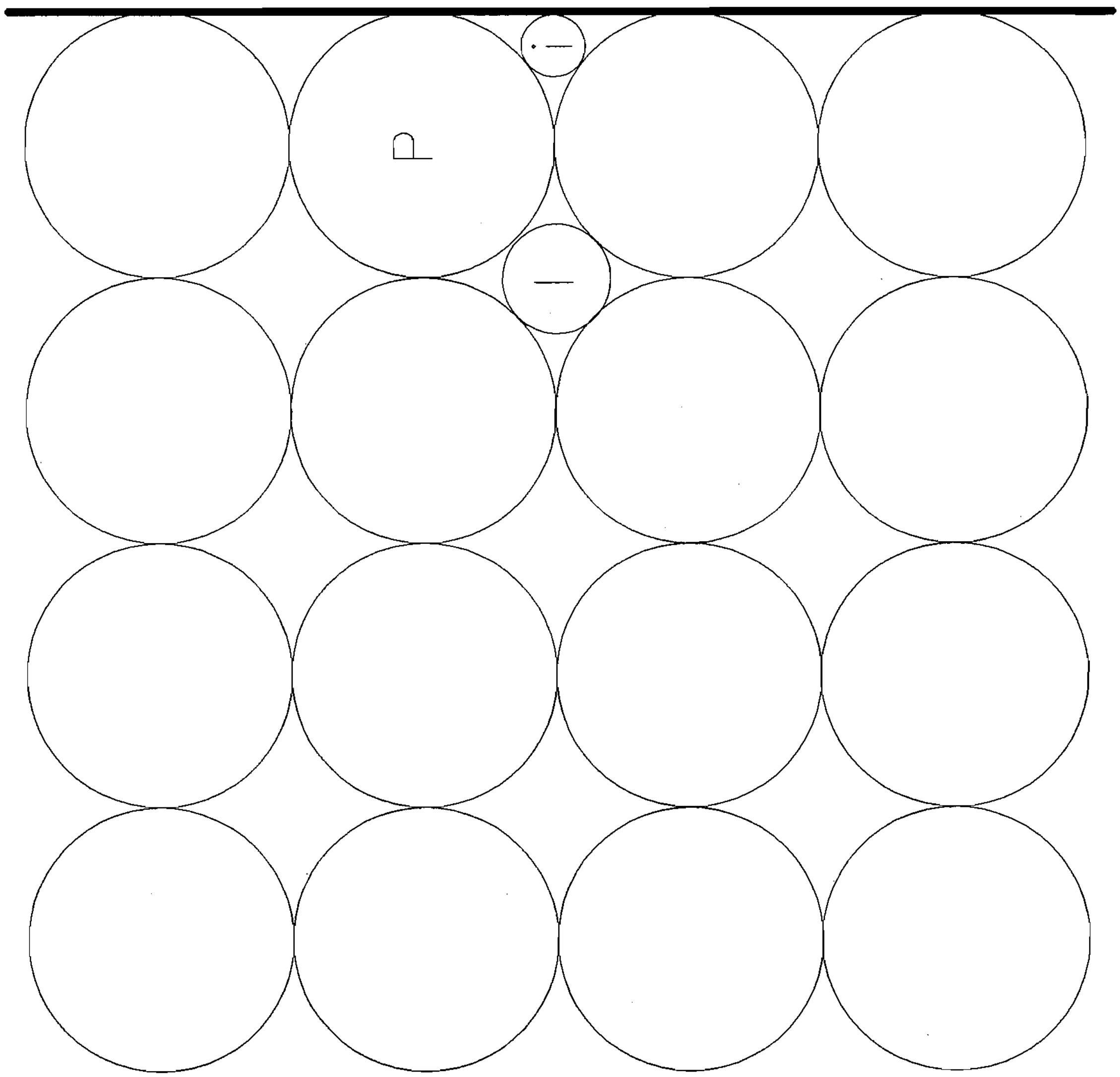

Fig. 5 - Relationship of particle size, P, to interstitial pore diameter, I, and interface pore diameter, i, for least-packed configuration of spheres.

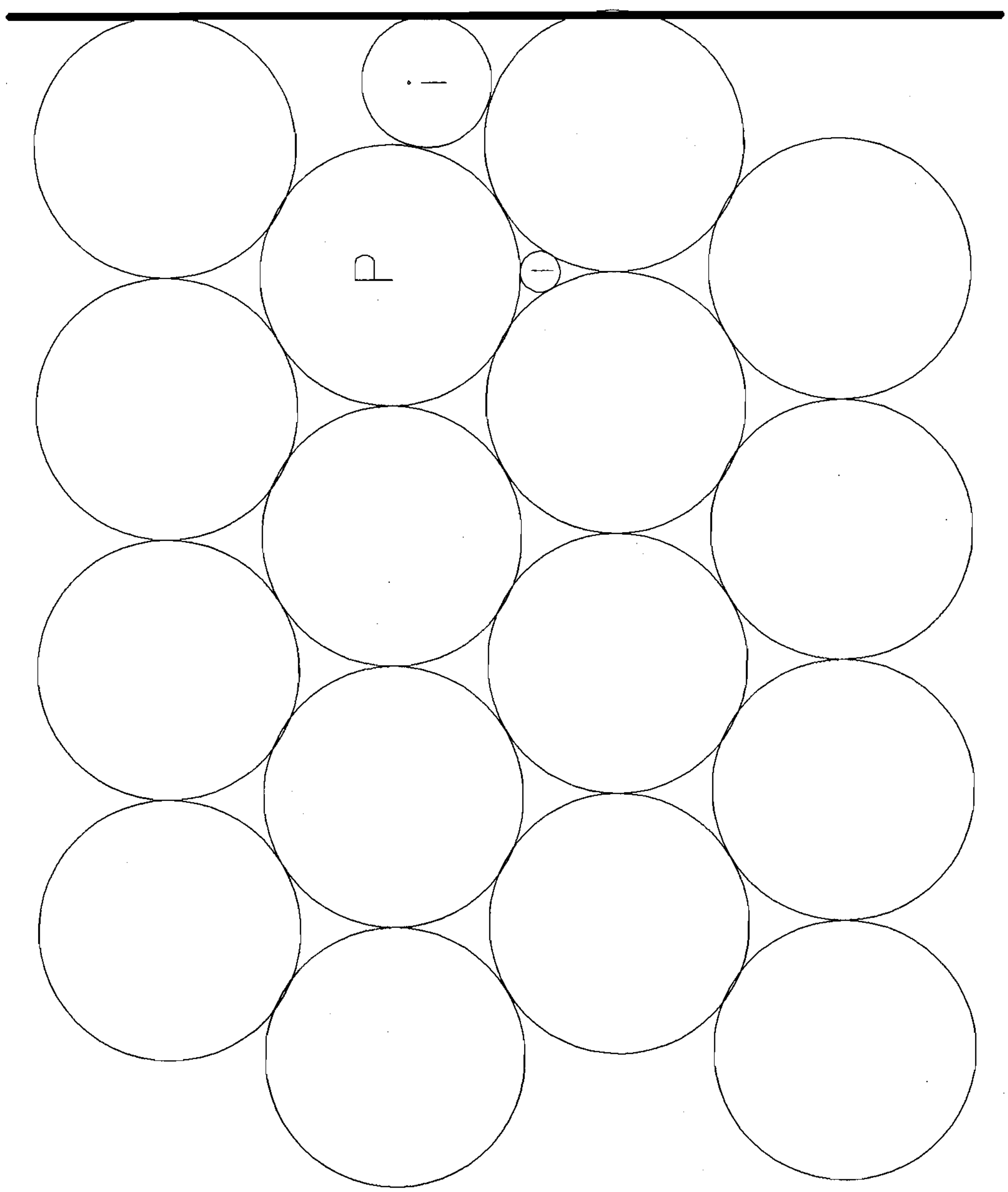

Fig. 6 - Relationship of particle size, P, to intersitial pore diameter, I, and interface pore diameter, i, for most-packed configuration of spheres.

Field Tests of Sand Barriers Against Termites in Ontario

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ABSTRACT Field tests of sand barriers for termite control were installed using five sands provided by five different aggregate producing firms in Ontario. Each of the tested aggregates was commercially available or potentially commercially available. The five sands differed in mineral type and particle size profile. Barrier layers 5, 10, 15, and 20 cm thick were tested. There were ten replicates of each thickness and the tests ran for two years. Although all five aggregates had profiles slightly broader than recommended distribution limits, the failure rates for individual sands for all thicknesses ranged from only 0% to 7.5%. Averaging the five materials the thinnest barrier layers (5 cm) had the highest failure rate, 8%, compared to 0% for the 10 cm layers, 4% for the 15 cm layers, and 2% for the 20 cm layers. The overall failure rate for all materials at all thicknesses was 4.0%. These results indicate that to achieve control against subterranean termites at greater than 96% for wood and susceptible materials in direct soil contact, sand barriers of appropriate particle size profile should be at least 10 cm thick. It is also suggested that when sand barriers are installed adjacent to building foundations that the risk of termite penetration is further reduced by a substantial factor due to the prevention of termite tunnelling along the barrier-foundation interface thereby preventing termites from discovering foundation cracks.

KEY WORDS Isoptera, Rhinotermitidae, termite control, termite barrier, sand barrier

Introduction

The most widely used method of protecting buildings from subterranean termites is to apply toxic chemical termiticides to the soil under and around the foundation. Ebeling and Pence (1957) were the first to propose sand barriers with a specific particle size as an environmental, non-toxic alternative to chemical toxicant soil barriers. Considerable research on sand barriers has appeared recently (Ebeling and Forbes, 1988; Su et al, 1991; Su and Scheffrahn, 1992). Two commercial sand barrier products have been developed: "Basaltic Termite Barrier" by Ameron HC&D in Hawaii (Tamashiro et al, 1987) and "Granit-guard" by E.B. Mawson in Australia (French, 1989).

Since subterranean termites are an increasing problem in Canada (Myles, 1992a), especially in southern Ontario and Metro Toronto (Toronto Housing Dept., 1993), we decided to research the development of sand barriers for the southern Ontario market. After locating several Ontario suppliers and conducting preliminary laboratory penetration tests on many materials we installed field tests of five selected materials that were closest to the particle size distribution limits which had been indicated by lab tests. Field tests of sand barriers were needed to determine the effectiveness of sand barriers under atmospheric and soil conditions in Ontario since it is conceivable that such effects as freezing and thawing, soil heaving, and infiltration could effect the barrier. It was also desirable to test various widths of barrier layers under field conditions.

Materials and Methods

Termite barrier sands. The five test sands were "WP2 sand" (crushed limestone screenings) from Dufferin Aggregates, Milton; "termite sand #1" (natural screened granitic sand) from W. Robert Hutcheson, Huntsville; "termite sand" (mixed limestone screening) from Franceschini Bros, Mississauga; "termite sand" (screened natural alluvial sand) from Erie Sand and Gravel, Leamington; and "Dolomite #8 untreated grits" from Steetley Quarry Products, Dundas. Previously laboratory tests had demonstrated the effectiveness of similar aggregates provided by these suppliers. However the field test materials differed slightly from the samples used in the laboratory tests. A sample of each delivered field material was sieved and the particle size profiles are shown in Figure 1.

Field plots and tests. All tests were set up on termite infested plots. Four of the tests were installed in Kincardine on September 8, 1991 (control blocks installed on October 1). One test was installed in Scarborough on October 30, 1991. Figure 2 illustrates the set up for each replicate. For each test sand there were ten replicates at four widths of the barrier layer: 5, 10, 15, and 20 cm (ca. 2, 4, 6 and 8 inches). Each replicate included its own control block. The replicates were spaced in a grid at 2 meter intervals (centre to centre). The hole for each replicate was dug with a BobCat excavator (14" bucket). A sheet of 2 ply corrugated cardboard (corrugations face down) was placed on the bottom of each hole. On top of this was placed one of four sheet metal forms used to form the barrier layer. The form size for the 5 cm barrier was 20 X 20 X 20 cm, for the 10 cm layer the form was 30 X 30 X 25 cm, for the 15 cm layer the form was 40 X 40 X 30 cm, and for the 20 cm layer the form was 50 X 50 X 35 cm (side X side X height). A layer of cardboard was wrapped around each form. The area outside the form was then backfilled. Then the inside of the form was filled to within 15 cm of the top with the test sand. A 10 X 10 cm spruce wood block having a 4 cm drill hole filled with a 12 cm long roll of cardboard, was placed in the centre of the sand. The remainder of the form was then filled to the top with test sand. The inside and outside of the form were then tamped and topped up with more backfill and test sand. The form was then pulled out.

Results

First observation. The first observation at the Kincardine plots was made on Nov. 6, 1991. At that time 40% of the controls had been attacked by termites. Some damage to the test plots had occurred which was attributed to either motorcycles or digging by dogs, however, the damage was repaired. The first observation at the Scarborough site was on May 13, 1992 at which time there was little activity at the control blocks and no failure of the test blocks.

Second observation. The second observation at the Kincardine site was July 11, 1992. At this time there was 95% activity on the controls and no failures of the test blocks. No observation was made at the Scarborough site during 1992.

Third observation. The third observation at the Kincardine plots was on October 7, 1993 at which time 100% of the test blocks had been damaged by termites. The final observation at the Scarborough site was on October 19, 1993 at which time there was little or no apparent feeding on control blocks. These two year results are presented in Table 1.

Comparison of different sands. As shown in Table 1, the five different sands differed little in their effectiveness. Total percent failure ranging from 0% for Hutcheson, 2.5% for Dufferin and Steetley, to 7.5% for Erie and Franceschini. The Hutcheson trial should not be directly compared with the others because the level of termite feeding on the control blocks at this site was relatively very light. As indicated by the asterisk in Table 1, most failures occurred at sites which had previously been disturbed. It is therefore possible that several failures may be attributable to contamination of the sand barrier with soil during repair of these replicates after the first observation.

Comparison of barrier thickness. As shown in Table 1, comparison of the totals for all test sands reveals a weak relationship between rate of failure and barrier thickness. The highest level of failure, 8%, occurred in the thinnest barriers layers, 5 cm in width. However no failures were recorded for the 10 cm barriers. A 7.5% failure rate occurred with the 15 cm layer and a 2.5% failure rate occurred with the 20 cm layers.

Discussion

Sand barriers for protection of susceptible materials placed directly in soil contact. Sand barriers might find substantial application for use in protecting such materials as wooden posts, wooden retaining walls, other wood in soil contact, or buried plastic cable (Anon., 1990). Recent reports have also highlighted the growing concern about the susceptibility to termites of polystyrene foam insulation (Myles, 1992a, Guyette, 1994). Retrofitting sand barriers to around the bases of fence posts would be fairly simple. However the barrier sand would probably provide a less stable footing. Posts might require bracing with stones, bricks or rubble before backfilling the hole with barrier sand. A metal collar around the top of the barrier might also be used to maintain the barrier (Anon., 1990).

Sand barriers for protection of buildings. Installation of sand barriers prior to building construction would be the least expensive approach and would provide the most effective protection. The substitution of barrier sand for sub-slab bedding gravel would probably be possible with little difference in cost. Methods of installation for slab on grade construction are illustrated in Anon. (1990). Methods of retrofitting barriers in crawl spaces and in perimeter trenches are illustrated in Ebeling and Forbes (1988). Retrofitting barriers around basement foundation walls are discussed in Myles (1992b). The major problem with retrofitting, however, is that there is no way of getting the barrier under the slab.

An important effect of sand barriers when used in conjunction with non-wood foundations is that the barrier will obstruct the termites' ability to tunnel and explore along the foundation surface. It is this exploratory tunnelling along the surface that leads termites to discover cracks and gain access to the structure. This interactive effect of the barrier and the foundation wall is a functional aspect which has not previously been discussed. A comparison of the independent and interactive functioning of the sand barrier and the foundation is illustrated in Figure 3. As shown in Figure 3, there are two distinct factors involved in the functional suppression of termite penetration when the barrier is used in conjunction with a non-wood foundation. Firstly, there is reduced probability of inward penetration to the foundation, secondly there is reduced probability of encountering foundation surface cracks because lateral foraging along the barrier-foundation interface is impeded. Both factors will have multiplicative effects on reducing the risk of penetration into the structure.

Advantages and disadvantages of sand barriers. Several advantages can be noted in comparison of sand barriers to chemical barriers: 1) sand barriers are non-toxic and therefore environmentally benign, 2) the surface layer of sand barriers do not present a potential dermal contact hazard to humans as do chemical barriers, 3) sand barriers do not leach through the soil and therefore to not pollute ground water as do chemical barriers, 4) sand barriers do not chemically breakdown over time as chemical barriers do and therefore give longer protection, 5) sand barriers are visible unlike chemical barriers and therefore can be more easily repaired if necessary. Disadvantages of sand barriers are that 1) they are more difficult and expensive to install in existing structures than are chemical barriers, and 2) sand is too heavy to transport long distances and therefore must be commercially developed independently for each major regional market.

Acknowledgements

This project was carried out with the assistance of a financial contribution from Canada Mortgage and Housing Corporation under the terms of the External Research Program. The views expressed are those of the authors and do not represent the official views of CMHC.

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Table 1. Failure rate of sand barriers in field tests subjected to foraging populations of *Reticulitermes flavipes* for two years (ten replicates for each thickness).

	Barrier Thickness (cm)				
	5	10	15	20	Total
		(Number Failures)			(% Failures)
Test Sands:					
A. Kincardine Site[1]					
1) Dufferin	0	0	0	1*	2.5%
2) Erie	2*	0	1	0	7.5%
3) Franceschini	2	0	1*	0	7.5%
4) Steetley	0	0	1*	0	2.5%
Kincdn. Subtotal (%)	10%	0%	7.5%	2.5%	5.0%
B. Scarborough Site[2]					
5) Hutcheson	0	0	0	0	0.0%
Scarb. Subtotal (%)	0%	0%	0%	0%	0.0%
Total (%)	8%	0%	6%	2%	4.0%

[1] heavy damage to control blocks
[2] light or no damage to control blocks
*failures which might be attributable to prior surface disturbance of the barrier

Figure Legend

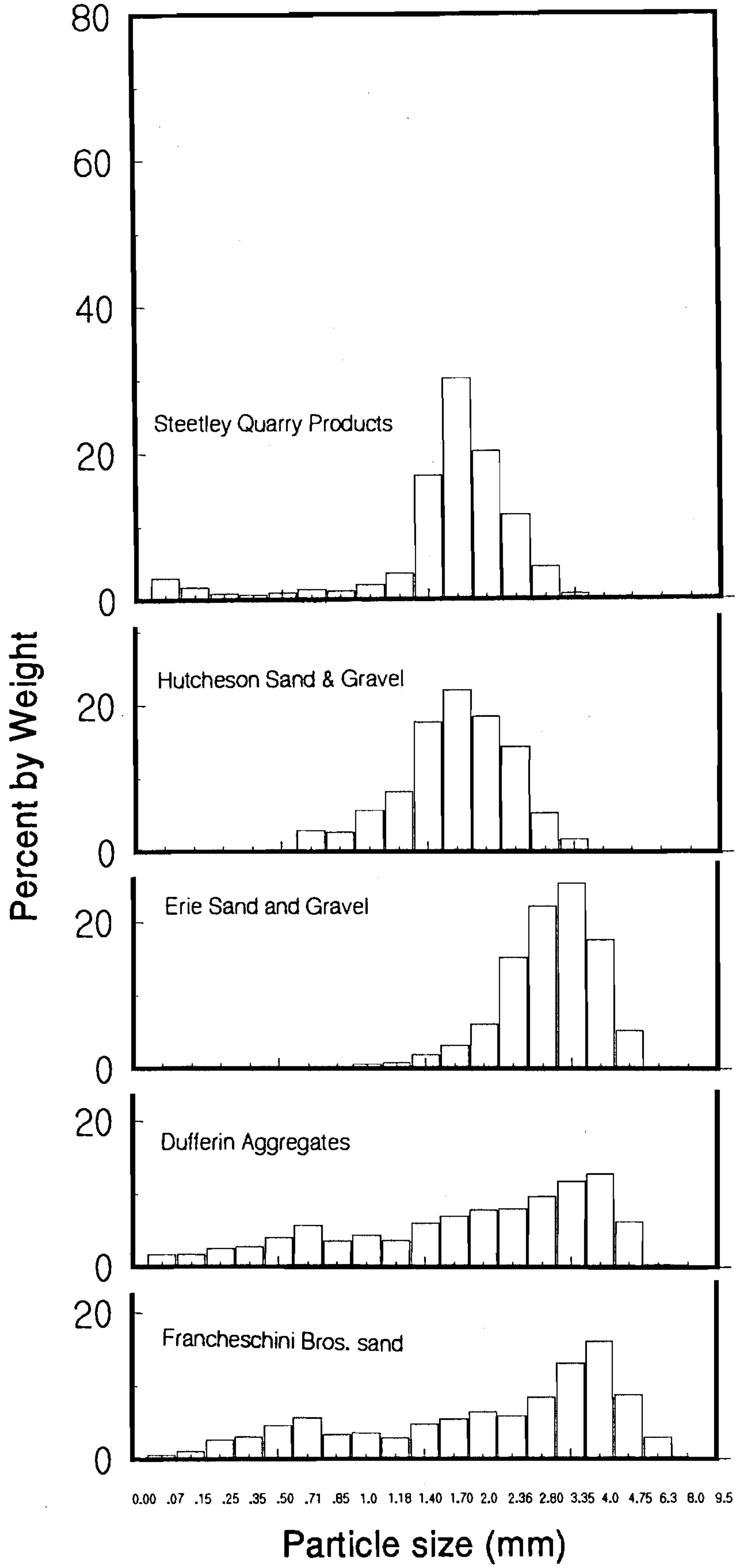
Figure 1. Particle size profiles for five sands tested as termite barriers.

Figure 2. Configuration of field test units.

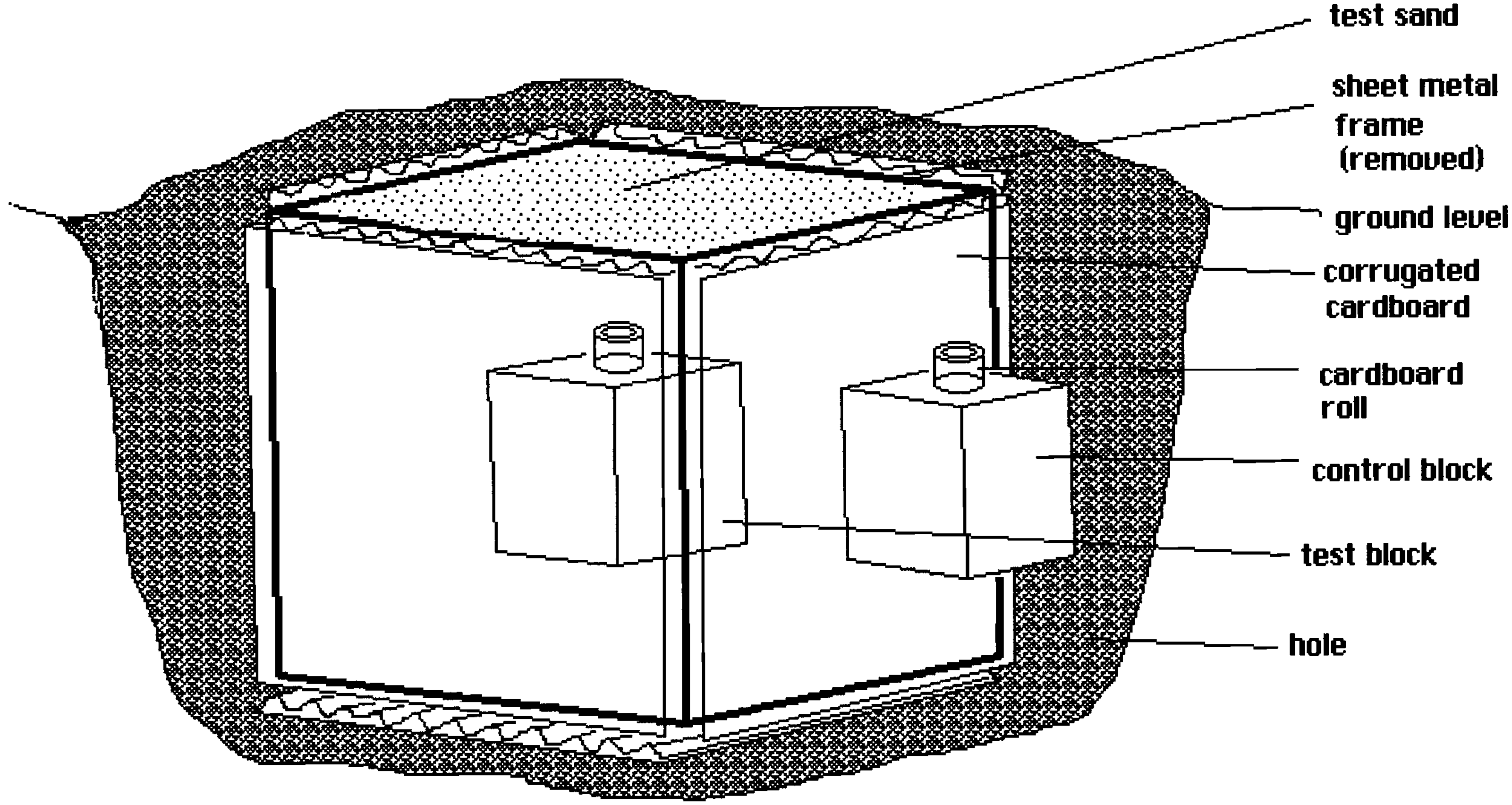
Figure 3. Independent and interactive effects of sand barrier and foundation on impeding penetration by termites.

Field Tested Barrier Sands

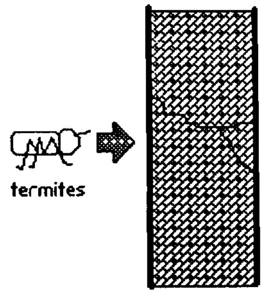
Particle Size Distributions



Configuration of Field Test Units

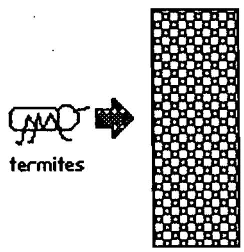


Foundation Wall only



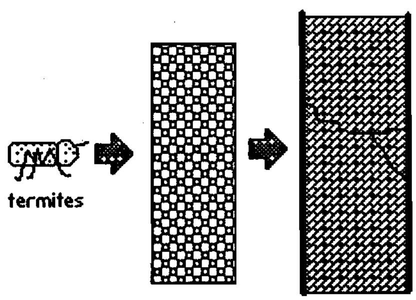
P_f = Probability of penetrating foundation

Sand Barrier only



P_s = Probability of penetrating sand barrier

Independent Sequential Penetration

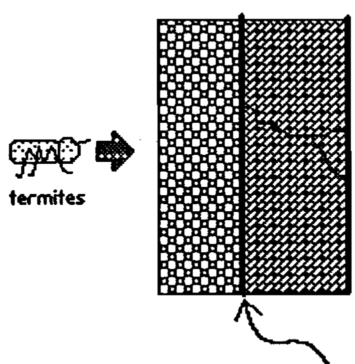


P_{sp} = Probability of sequential penetration of sand and foundation is multiplicative.

$P_{sp} = P_s \times P_f$

Example: If probability of penetrating sand is 5% and probabiltiy of penetrating foundation is 20 % then probabilty of sequential penetration is: .05 X .2 = .01 or 1%.

Interactive Sequential Penetration



P_p = Probability of penetration when the sand and foundation are in contact.

$P_p = P_s \times (P_f \times I)$

Example: .05 X (.2 X .01) = .0001 or .01%

Interactive effect (I) greatly suppresses P_f by prevention of termite movement and exploration along foundation walls.

Non-Chemical Termite Control

By Tim Myles, Ph.D.

The perception exists that termite control requires the use of pesticides. However in many cases termites could be built-out or retro-fitted out with little or no chemical pesticide. The key to termite control is not toxicity but impenetrability. A large market awaits innovators in the area of termite barriers.

A Growing Concern

Over twenty percent of Canadians live in termite infested municipalities (see Table 1). With continuing trends toward urbanization and the continuing spread of urban infestations, termites are becoming an increasing problem. Subterranean termites are prevalent in southern Ontario and southern British Columbia. They have also been reported causing damage in Medicine Hat, Alberta and were discovered in 1987 damaging homes on one block in Winnipeg, Manitoba. The scale of the problem in Ontario is such that in 1987 a research program was initiated in the Faculty of Forestry at the University of Toronto. In addition to studies on the urban ecology of termites, we are conducting research on several control strategies including wood treatment, physical barriers, and trap-treat-release methods to kill colonies. This article deals with the physical barrier methods for controlling termites.

TABLE 1
Canadian population living in termite infested municipalities

	Population	Population of municipalities with termites	Percent
Ontario	9,426,100	3,783,161	40.1
British Columbia	2,983,800	, 919,511	30.8
Manitoba	1,084,000	, 594,551	54.8
Alberta	2,395,200	, 42,290	1.8
Subtotal	15,889,100	5,339,513	33.6
Canada	25,923,300	5,339,513	20.6

The record for Ottawa, Ontario is not included because the termites presumably did not establish. The record for Creston, B.C. is considered dubious and is not included. Population data in the table is based on the Canadian Almanac & Directory 1992 for the year 1988, or the Canada Year Book 1990

Destructive Potential

To understand the basis of physical barrier control strategies it is useful to start with a brief discussion of certain features of the biology of these remarkable social insects. Individually, termites are small, delicate insects which dry out readily if removed from their humid microhabitat of soil tunnels and galleries in wood (Figure 1). If termites occurred only as individuals or in small groups, they would be of no greater concern than the common pill bugs, which one finds feeding under old boards. The destructive power of termites lies in the enormous size of their populations.

Figure 1:
Workers of the eastern subterranean termite in soil tunnels

Field studies in Wisconsin and Ontario have shown that colonies range in size from about one to nine million individuals and typically encompass a foraging territory of 1,000 to 2,000 square meters. With an estimated average daily consumption of 0.08 mg of wood per termite per day a colony of five million would consume 400 grams of wood per day or 146 kg per year. This is equivalent to about 40 eight foot lengths of 2 X 4" lumber. Assuming that the structural integrity of a board is lost when one fourth of its weight is consumed then as much as 160 eight foot 2 X 4s could be ruined per year. Thus under ideal conditions, a typical house could be severely damaged in one year.

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How Termites Enter Buildings

Fortunately colonies are usually spread over half a block or more and most of their feeding occurs outside of structures in numerous feeding sites. Feeding sites include all types of wood in soil contact, of which there are many more instances than most people realize. Principle feeding sites in the urban environments include dead portions of live trees, stumps, fences, decks, garages, firewood piles, wood retaining walls, wood edgings, scrap lumber piles, form boards left in place, compost bins, etc.

Termites are unlike other household pests such as ants and cockroaches that can fly or walk into a house. Termites can only enter by tunnelling. Termites tunnel through wood in soil contact that bridges the structure to the ground or they build shelter tubes through foundation cracks or voids or over foundation walls. They build shelter tubes of soil particles or wood fragments that they cement together with saliva. These tubes are covered runways that prevent the termites from drying out when travelling over exposed surfaces above ground. Shelter tubes are about 5 mm high and 5 to 20 mm wide (Figure 2).

Only through subterranean tunnels and shelter tubes can they maintain their lifeline with the humid soil environment. Thus a termite population is never really isolated in a structure. A structural infestation does not represent a single colony or a "nest", as many people believe. Instead, an infestation represents only a portion of a larger population interconnected by a vast system of subterranean tunnels. It is important to realize that termites always enter the yard before they enter a structure and that most of the population remains external to the structure feeding on other available sources of wood or cellulose.

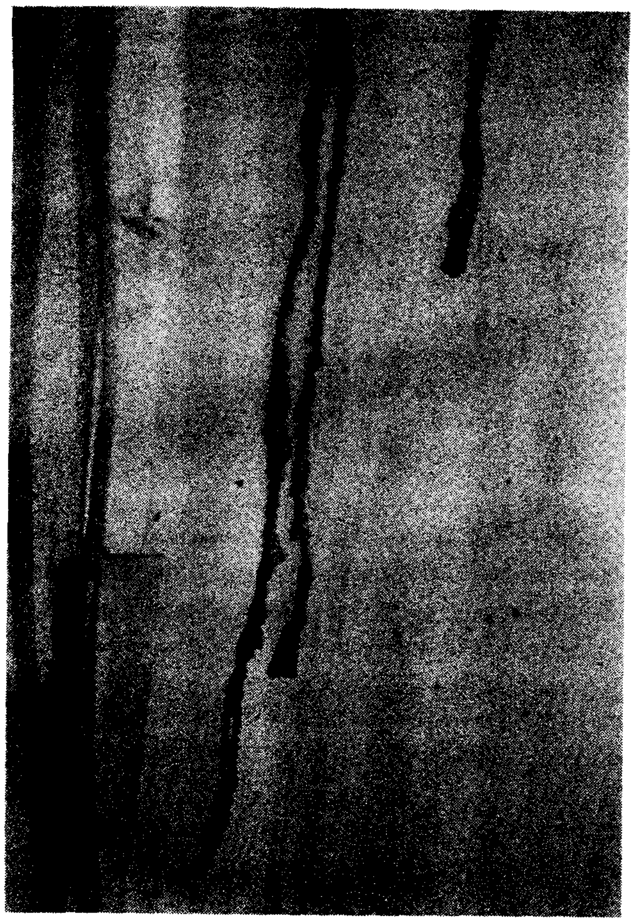


Figure 2: Shelter tubes on wall of basement

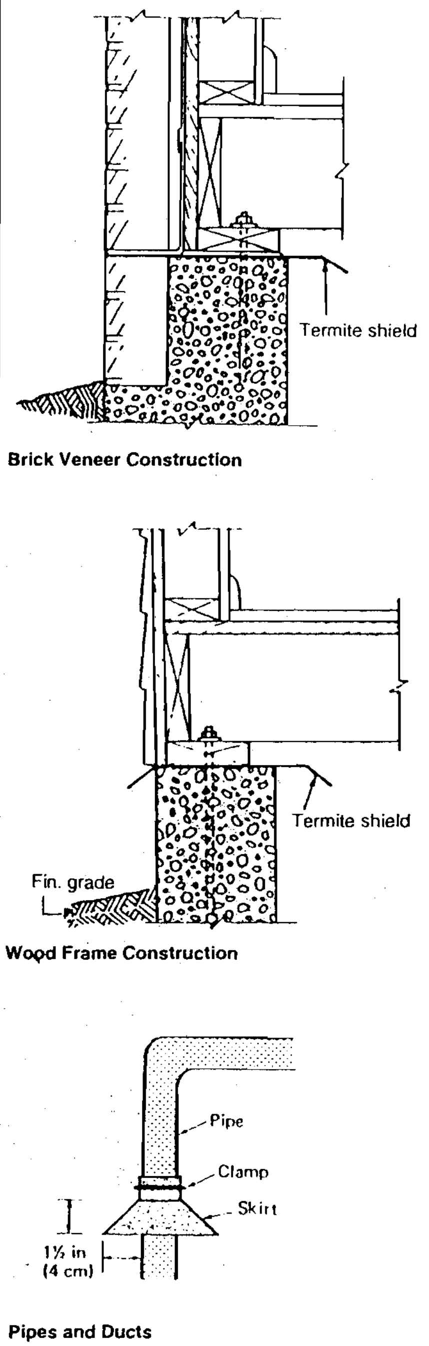
There is continual traffic between the structural wood feeding sites and the soil. Termites drink water from moist soil, tunnelling down to the water table if necessary, transport water in their foreguts, and regurgitate it on dry wood before feeding. Control is achieved when this traffic is blocked by either a chemical or physical barrier.

Conventional Control

With such destructive pests, there is a strong demand for highly effective methods of control. Hence termite control has traditionally relied on persistent chemical pesticides. Soil termiticides are sprayed, rodded, and injected into the soil to create a toxic chemical barrier around the foundation of a house. The objective is to uniformly saturate an envelope of soil around the structure with a 1% emulsion of the toxicant.

The two chemical termiticides approved in Ontario are the chlorinated cyclodiene, aldrin (for perimeter use only), and the organophosphate insecticide, chlorpyrifos (Dursban TC). A recent sample of thirty completion reports from 1988 to 1991 on file at the Toronto Housing Department indicated a range from 250 to 910 litres of emulsion used per property, with an average of 570 litres. Since this is a 1% emulsion this means that an average of 5.7 litres of active ingredient were used per property. This is approximately equivalent to 170 kg of toxicant per hectare which is much more than the average 2.2

Figure 3: Illustrations of Termite Shields
(Compliments of Ontario Ministry of Environment)



kg/h used in agriculture and the 1 kg/h used in forested lands.

Yet the chemical treatment does not kill the colony. Probably no more than 5-10% of the colony actually dies, with the surviving population simply moving to forage elsewhere in the yard or neighbourhood. The termites that are in the house at the time of treatment eventually die because they are cut off from the soil moisture. It is ironic that this heavy use of insecticide is simply to form a barrier to termite movement. Clearly physical barriers could be used to achieve the same result with less environmental contamination.

Termite Shields

The oldest type of physical barrier is called a termite shield. A termite shield is simply a strip of sheet metal that is placed beneath the lowest wood structural members to prevent termites from entering the wood framework of a structure (see Figure 3). Metal post supports and saddle brackets are often used to support posts. Such brackets act essentially as a termite shield in addition to providing protection against moisture and rot.

Termite shields are widely used in the tropics and in some parts of the southern United States but have not been used in Canada mainly because sheet metal fabricators have not perceived the market and do not know how to connect with the market. Significant commercial opportunities probably exist for sheet metal fabricators (eaves trough manufacturers) to design pre-sized seamless termite shields. When properly installed termite shields are an excellent preventive measure. The shield should be some type of noncorroding metal such as aluminum. The shield can be either a simple flat piece or its effectiveness can be improved by having a projecting lip bent downward at a 45 degree angle. Adjacent pieces would have to be lapped, welded, or joined in some manner to be impenetrable to the termites. It may also be possible to design retrofitted shields that could be inserted to block termites at known entry points.

Aggregate Barriers

Certain grades of coarse sand can be used as a physical barrier to termites. Such barriers prevent termite tunnelling because the particles are too large for the termites to move and yet small enough that the spaces between the particles are too narrow for the termites to crawl through. This method has been in commercial use in Hawaii for about five years and was recently accredited in Australia. Some companies are now using sand barriers on an experimental basis in parts of the U.S.

We have conducted research on sand barriers over the past two years with support from Canada Mortgage and Housing Corporation. Our experiments have refined and confirmed previous research. We found that three grades (separates) are impenetrable. These are: Mesh 10 (with particle sizes from 2.36 to 2.0 mm), Mesh 12 (2.0 to 1.7 mm), and Mesh 14 (1.7 to 1.4 mm). Thus particles in the range of 2.36 to 1.7 mm are absolutely effective as a termite barrier. Studies of the allowable quantity of particles smaller than this range indicate that mixtures with as much as 30% smaller particles are effective barriers. However smaller particles add weight without bulk resulting in increased cost. Finer particles also result in increased dust problems during installation.

Therefore a good barrier sand should have fines below 1.4 mm reduced to 5% or less. Interestingly, our studies have shown that the upper end of effective particle size mixtures can be stretched considerably above the 2.7 mm. Effective barrier mixes can be comprised of only 40% in the 1.4 to 2.36 mm range and as much as 60% from 2.36 to 6.3 mm (6.3 mm = 1/4" Mesh). The following Ontario aggregate producers have provided suitable aggregates which have been installed in field tests: W. Robert Hutcheson Sand and Gravel Ltd., Huntsville; Dufferin Aggregates, Milton; Franceschini Brothers Sand and Gravel, Mississauga; Steetley Quarry Products Inc., Dundas; and Erie Sand and Gravel, Leamington. Prices for delivered aggregate vary depending on product, quantity, and hauling distance but generally range from $20 to $35 per tonne.

The barrier should be applied in a 15 cm (6 inch) layer. In Hawaii termite barrier sand is used in place of subslab bedding aggregate thus reducing cost of installation. Barriers can be installed during building construction as a preventative treatment or retrofitted after construction as a preventive or remedial treatment.

Post-construction installation would entail excavation of a narrow trench around the perimeter of foundation walls to the top of the footing. Small back hoe-type excavators such as the Mantis (Blackstone Equipment, Scarborough) or Bobcat could be used to excavate such trenches. Chain excavators such as certain models made by DitchWitch might also be used. In many cases a stoneslinger would probably facilitate filling of the trench with the barrier sand.

The sand should be compacted and care should be taken that the final grade slope away from the house. The top layer of the barrier can be left open and kept clean of debris. Alternatively a strip of flashing can be inserted into the sand and then capped with a concrete curb, skirt or walk. The flashing serves to block the termites if there is any settlement of the sand under the concrete, thus it would be important that the ends of the flashing be rolled together or welded. It must be emphasized that field tests are still under evaluation and that demonstration installations are still in the planning stages. I believe that sand barriers will come into use and provide virtually permanent and environmentally friendly termite protection. Some drawbacks, however, are the greater cost, possible penetration by tree roots, and termites might occasionally circumvent retrofitted perimeter barriers by tunnelling up through cracks in the floor slab.


Figure 4: Polystyrene insulation panel showing termite damage

Other Potential Barriers

A wide range of materials are under study as potential termite barriers. Examples include stainless steel wire mesh, woven and non-woven geotextile fabrics, plastic films, fibreglass, Peel & Seal self-sticking roll roofing, and synthetic foam insulation panels. An Australian company, Termi-Mesh Australia Ltd. (Malaga, WA) has recently introduced a product called Termi-Mesh which is a high grade stainless steel mesh that can be used under slabs, in perimeter trenches, in cavity walls, or to protect posts and poles in soil contact. Termi-Mesh would certainly be effective, however the details on how to install it for retrofitting infested homes with basement-type construction have not been worked out yet. Studies of this material in Canada are under discussion. In general, geotexile fabrics that resist termite penetration are eventually penetrated. Heavy vinyl and high density polyethylene films generally have not been penetrated in lab tests. However this appears to be due to their smooth surfaces. Under field conditions in the soil such liners would likely develop many small punctures and scratches which the termites could then bite through.

Lab studies and field evidence have shown that both beaded; and extruded polystyrene insulation panels provide very little resistance to termite penetration (Figure 4). Fibreglass is much more resistance to termite tunnelling. Preliminary tests indicate that Peel & Seal rubberized asphalt roofing rolls may be a promising barrier material however further study is needed to confirm its efficacy under field conditions.

Opportunities for Research and Development

Sheet metal fabricators and firms with expertise in subterranean building envelopes may want to consider investment toward research and development of products as physical termite barriers. With development of appropriate methodologies termite control could conceivably become a major area of activity for the construction trades. Manufactures of building products who would like to have the resistance of products to termite penetration evaluated are requested to contact the Urban Entomology Program.

Regulatory Constraints

A few words regarding regulatory constraints are in order. In general non-chemical pest control products are not actively regulated by the Pesticides Directorate of Agriculture Canada however under the Pest Control Products Act some regulatory action might apply. Provincial Ministries of the Environment also regulate pest control products. Housing Ministries oversee building codes and at the present time none of these non-chemical methods have been officially approved in any province. Such approval would eventually be necessary. Municipal by-laws would also need to be revised to acknowledge non-chemical treatments as fulfilling the requirements for termite control at the time of sale of a property. Such legal aspects remain to be addressed.

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TERMITE TIPS

NEWSLETTER OF THE URBAN ENTOMOLOGY PROGRAM, UNIVERSITY OF TORONTO

Number 8 September 1992

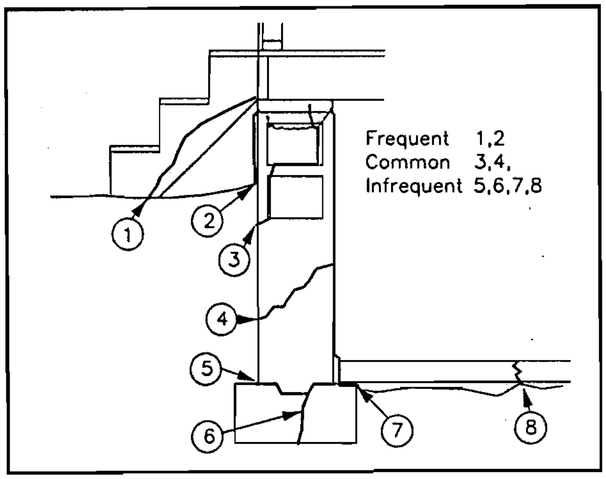
PREVENTING TERMITE PENETRATION OF FOUNDATION CRACKS

FOUNDATION CRACKS PROVIDE HIDDEN ENTRY POINTS FOR TERMITES

Subterranean termites can only infest structures by tunnelling in through the soil. Controlling termites is therefore a matter of blocking the tunnel entry points. Termites can not penetrate concrete so to gain access to wooden components supported on a concrete foundation they have three options: 1) they can tunnel through wood in soil contact, 2) they can build exposed shelter tubes up foundation walls, or 3) they can build a hidden shelter tube through a crack, concrete joint, or hollow void space. If their entry is through wood in soil contact it can generally be identified and eliminated. Similarly, exposed shelter tubes can be identified by inspection, scrapped away, and clearance improved by lowering the grade or making structural alterations. The most difficult cases involve hidden shelter tubes through foundation cracks. Hidden shelter tubes in cracks are what make termites such a nightmare for the home owner, a headache for the pest control operator, and a challenge to the researcher. By understanding the types of foundation cracks, the location of cracks, and the cause of cracks termite control efforts can be focused where they are most likely to block termite traffic through these entry points.

POINTS OF ENTRY

The various entry points of termites into a house with a basement foundation are illustrated in the figure below. These are 1) wood in soil contact, 2) exposed foundation walls above grade, 3) hollow spaces in foundation walls opened by cracks in block walls or double foundation walls with hidden voids, 4) cracks in poured concrete walls, 5) the joint between the footing and the foundation wall, 6) cracks in the footing, 7) the cold joint between the footing and the floor slab and the shrinkage gap between the floor slab and the wall, and 8) cracks in the floor slab.



BLOCKING POINTS OF ENTRY FROM EXTERIOR

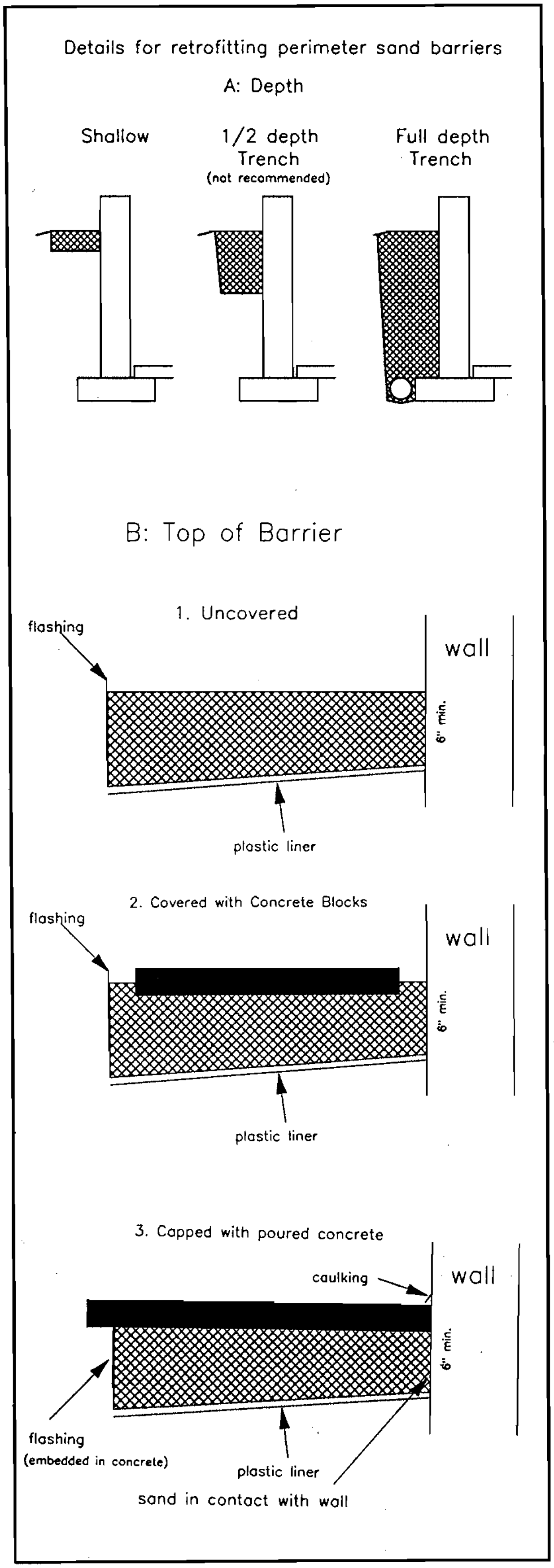
Chemical barriers: The conventional approach is to spray and inject pesticide into the soil around the foundation thus creating a persistent toxic barrier. Because of variations in soil texture and moisture, and restricted access it can be very difficult to achieve a uniform chemical barrier--even with extensive drilling of foundations and injection with long rods. Therefore re-treatments are often required.

Physical barriers: The four main types of physical barriers are termite shields, termite barrier sands, stainless steel mesh barriers, and waterproof membrane barriers. **Termite shields** have been in use in some parts of the world for decades but the other physical barrier methods have only recently become a focus of research and commercial development. A termite shield is simply a sheet of non-corroding metal with a projecting 1" lip bent down at a 45 degree angle capping the foundation wall or concrete support piers. **Sand barriers** consist of sand mixtures in which a majority of the grain sizes are within the range of 1.4 to 2.4 mm with no more than 30 % fines (preferably less than 5% below 1.4 mm) and no more than 50% in the range of 2.4 to 6.3 mm. Five Ontario firms manufacture acceptable termite barrier sands: W. Robert Hutcheson Sand and Gravel Ltd., Huntsville; Dufferin Aggregates, Milton; Franceschini Brothers Sand and Gravel, Mississauga; Steetley Quarry Products Inc., Dundas; and Erie Sand and Gravel, Leamington.

INSTALLATION OF PERIMETER SAND BARRIERS

Sand barriers are most easily installed and most effective when put in as a preventive **"pretreatment"** during construction. In Hawaii and Australia a 6 inch layer of barrier sand is used in place of crushed stone as a bedding material beneath the slab. However, the barrier sand can not be placed beneath the footing since the footing must rest on solid undisturbed ground. The barrier sand could be used as backfill adjacent to the foundation walls provided that adequate consideration is given to surface drainage. The overhang of eaves, drainage from downspouts, the contour of the surrounding grade, and landscape watering practices should all be taken into consideration to ensure minimal drainage of surface water into full depth trenches. During backfill the barrier should be compacted at intervals of every two feet to prevent settlement later. Care must be taken that compaction does not cause cracking of the wall. A further consideration is the effect which the porous sand barrier might have on heat loss from the basement wall.

Unfortunately, termite control efforts are usually not undertaken until after the house is constructed and has become infested. In this case **retro-fitting** is needed. Retro-fitted barriers can be installed either in a shallow perimeter layer or in a full depth perimeter trench which connects to the weeping tile system. However, sand barriers should not be installed as half-depth trenches because the porous barrier sand will act as a vertical drain which, if not connected to the drainage system, could lead to water perching against the basement wall and leakage problems (see figure). The top of the perimeter sand barrier can either be left uncovered or, in places where people are likely to be walking, it can be covered with flat stones, bricks, blocks, or poured concrete to form a walkway (see figure).



Mesh Barriers and Waterproofing Membranes

A commercial stainless steel mesh barrier has been developed by an Australian company, Termi-Mesh Ltd. **Termi-Mesh** is approximately a 35 mesh material (pores sizes about 0.5 mm). Accelerated corrosion experiments and field trials in Australia indicate that it should be effective for over 50 years.
Recent tests in our laboratory indicate that **rubberized asphalt membranes** and other bituminous membranes commonly used for waterproofing exterior basement foundation walls are also impenetrable to termites and could therefore be effective termite barriers if properly installed or retro-fitted. Two basic types of waterproofing membranes are available, the adhesive peel and stick type (often used for roofing) and the trowel-applied rubberized asphalt type. The adhesive type might be more convenient to apply, especially for limited application to identified cracks. The trowel-applied rubberized asphalt however would probably give a superior seal due to its monolithic nature and firmer bonding to concrete surfaces.

Blocking Points of Entry from Interior

There are various ways of repairing cracked foundations. These include filling voids, resurfacing cracked surfaces, grouting or injecting cracks with various materials. These methods can be used from the interior of the basement and therefore do not require exterior excavation. Many homes in the Toronto area are built with hollow concrete blocks. When hollow concrete block foundation walls become cracked termites can explore throughout the interconnected hollow void space. Although such walls are normally capped with mortar, it is not uncommon for there to be many small gaps in the capping mortar which the termites may eventually find. To physically block such termite entry points the foundation walls can be drilled and the voids filled with a 3 to 1 sand to cement mixture or with *cement grout*. With solid poured concrete walls cracks can be repaired by injection of various patching compounds. Epoxy injection involves the mixture of two components which form a quick-drying, strong-bonding seal. Polyurethane is used in place of epoxy in wet cracks and reacts with water, foaming to fill the crack. The bonding of polyurethane may not be as strong as the epoxy. Injectable rubberized crack patching compounds are also newly available. Various joint sealant, polysulfides, polyurethane, silicon, and self-bonding cement mixes are available that can be used to patch cracks. Cracks should be chiselled out to a 1/2" depth and 3/4" width before patching. Injectable bonding materials have some elasticity to resist re-cracking whereas the cement mixes are likely to re-crack if soil heaving or settlement is causing ongoing foundation movement. Contractors who perform such services can be found in the Yellow Pages under waterproofing and concrete repairs & restoration. These alternative methods are presented mainly to stimulate interest in the commercial sector. It must be emphasized that these alternative approaches are not yet formally accredited in Ontario and would not suffice as adequate control procedures in the case of an active infestation at the time of sale of a property.

***TERMITE TIPS* is a newsletter on structural pest control issued by the Urban Entomology Program, Faculty of Forestry, University of Toronto, 33 Willcocks St., Toronto, Ontario M5S 3B3, Tel. (416) 978-5755, FAX 978-3834. It may be freely copied and distributed. No endorsements are implied or intended, and the opinions expressed are those of the editor and Program Director, Dr. T.G. Myles, or other sources credited or mentioned.**

TERMITE TIPS

NEWSLETTER OF THE URBAN ENTOMOLOGY PROGRAM, UNIVERSITY OF TORONTO

Number 7 June 1991

SAND BARRIERS FOR TERMITE CONTROL

SAND BLOCKS TERMITES

Rather than digging with the legs like most other burrowing animals, termites use their mouthparts to excavate their way through the soil. Because of the small size of the termites' mouths they are unable to move particles larger than about 1 mm. As particle size increases so does the size of the space between the particles. Particles about 3 mm and larger provide spaces which are large enough to allow the termites to crawl through. Thus, in order to block termites, the effective particle size range is approximately 1-3 mm (see figure below and table on reverse side). Coarse sand which is composed largely of particles within this size range can be used as a barrier around the foundation of a house to protect against subterranean termites. Such a sand barrier can also be used in perimeter trenches, crawl spaces, inside hollow masonry voids, around the bases of fence posts, poles, supporting piers, porches, decks, and retaining walls.

ADVANTAGES OF SAND BARRIERS

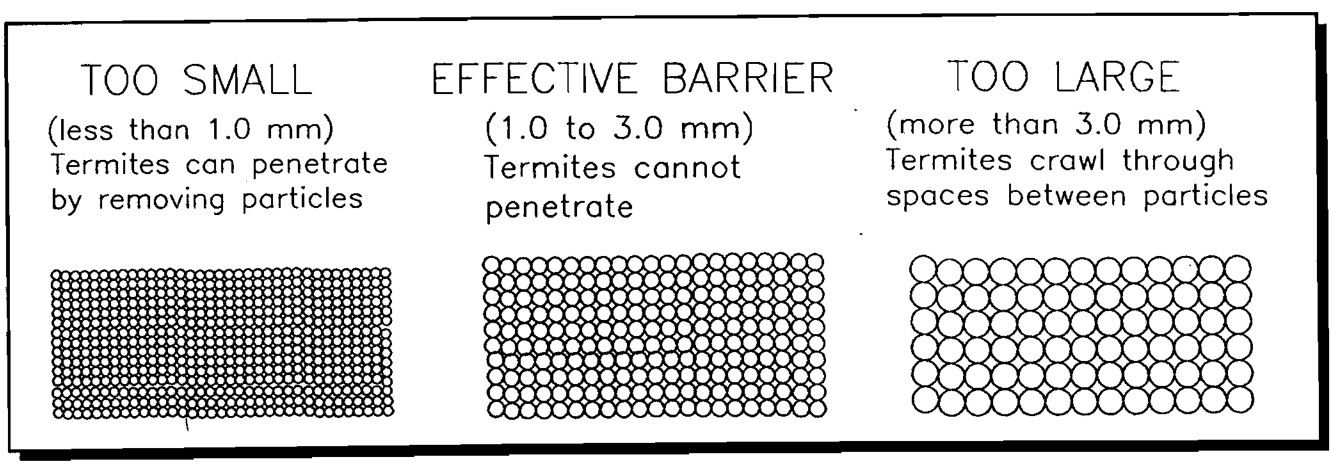
The current method of subterranean termite control relies mainly on the use of persistent chemical "termiticides" which are sprayed or injected into the soil to create a toxic chemical barrier. A sand barrier would be more uniform and therefore more effective than a chemical barrier, and would never require reapplication as chemical barriers often do. The sand barrier would also be preferable to the chemical barrier from the standpoint of reducing the health hazards associated with persistent pesticides. Another major advantage is that sand barriers are environmentally friendly and would help to greatly reduce the load of toxic chemicals in the urban environment. Furthermore, a sand barrier would likely contribute to the water-proofing of basement foundations.

GRANT TO STUDY FEASIBILITY

A $20,000 grant from the Canada Mortgage and Housing Corporation has been awarded to the Urban Entomology Program for a project entitled "Technical and commercial feasibility of developing the sand barrier method for excluding termites from homes in Canada". Among the technical problems to be addressed are: 1) Determining minimum screening profile specifications for barrier sands of various mineral types, quarry sources, etc. 2) Locating producers of appropriate sand within reasonable hauling distances of the various geographic regions across Canada that have termites. 3) Devising procedures for installing and retrofitting vertical sand barriers around homes with basement foundations.

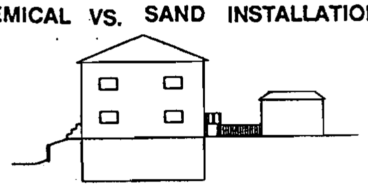
COMMERCIAL OPPORTUNITIES

Within the last three years, termite barrier sands have been commercially developed and accredited in Hawaii and Australia. Major opportunities exist for North American aggregate producers to enter the billion dollar per year termite control market. Commercial feasibility however will depend on production cost, size of local markets, hauling costs, excavation and installation costs, and whether amendments to building codes and municipal bylaws call for the use of sand barriers. For aggregate producers commercial aspects involve production, haulage, and stonethrowing. There would also be potential for a commercial bagged product that could be sold at garden shops and hardware stores for small scale uses around the home, e.g. under stacked firewood. With free trade, Canadian producers may now be able to exploit larger markets south of the border. Commercial opportunities also exist for excavating contractors, landscape contractors, renovators, sand blasting firms, and pest control operators to install barriers for remedial or preventive termite control.

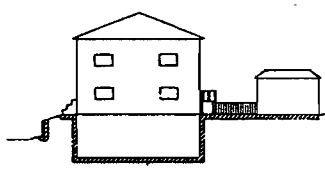


AUTHOR	LOCALITY	TERMITE	SAND TYPE	EFFECTIVE SIZE
Ebeling & Pence, 1957	California	Reticulitermes hesperus	sand	approx. 1-3 mm
			volcanic cinders	Mesh 6-16 tamped
			slag (sinter)	same
Ebeling & Forbes, 1988	California	Reticulitermes hesperus	sand	10-16 Mesh (1.6-2.5 mm)
			sand	6-16 Mesh is tamped
			sand blast sand	12-16 Mesh
			volcanic cinders	10-18 Mesh
Smith & Rust, 1990	California	Reticulitermes hesperus	decomposed granite	0.84-2.36 mm
Tamashiro et al, 1987	Hawaii	Coptotermes formosanus	basalt gravel	1.7-2.4 mm
			sand blast sand	82% btwn 1.4-2.36 mm
Tamashiro et al, 1987	Hawaii	Coptotermes formosanus	gravel substrates	1.4-2.36 mm
			sand blast sand	0.07"-0.09"
Ameron HC & D	Hawaii	Coptotermes formosanus	Basaltic Termite Barrier	95+% passing 2.36mm sieve & < 10% passing 1.18 mm
French, 1989	Australia	Coptotermes acinaciformis	basalt or granite	1.6-2.4 mm
		Coptotermes lacteus	basalt or granite	1.6-2.4 mm
E. B. Mawson's	Australia	subterranean termites	granite screenings	100% passing 2.4 mm sieve & 0-6% passing 1.7 mm
Pallaske & Igarashi, 1991	Germany	Reticulitermes santonensis	glass splinters	0.5-3.5 mm
		Heterotermes indicola	glass splinters	0.5-3.0 mm
		Reticulitermes santonensis	glass globules	0.8-3.0 mm
		Heterotermes indicola	glass globules	0.5-3.0 mm
Su et al, in press	Florida	Coptotermes formosanus	fossilized coral	1.7-2.36 mm
		Reticulitermes flavipes	fossilized coral	1.0-2.36 mm
		both species	fossilized coral	mixture 1.18-2.8 mm
Myles & Smith, unpub.	Arizona	Heterotermes aureus	Horticulture sand	1.18-1.7 mm
			Basaltic Termite Barrier	1.18-2.36
		Paraneotermes simplicicornis	mortar sand	2.0-4.0 mm
Myles et al, unpub.	Canada	Reticulitermes flavipes	aquarium sand	1.4-3.35 mm
			Pt. Pelee Beach Sand	2.0-3.35 or 1.0-2.0 mm
			Sakreet	2.0-3.35 or 1.0-2.0 mm
			WP2 sand	whole or 2.0-3.35 or 1.0-2.0

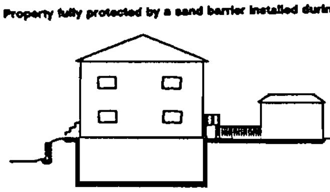
CHEMICAL VS. SAND INSTALLATION



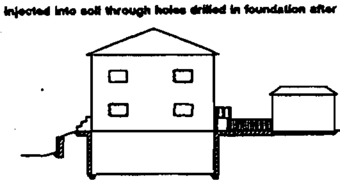
A. Unprotected property vulnerable to attack by subterranean termites.



B. Property fully protected by a sand barrier installed during construction.



C. Chemical barrier can be sprayed onto soil before construction or injected into soil through holes drilled in foundation after construction.



D. Retro-fitted sand barriers may require judicious use of pesticide only at base of footing trench.

INSTALLATION OF SAND BARRIERS

The sand barrier can either be installed before construction as a bedding material beneath a concrete slab or installed after construction in a trench adjacent to the foundation wall. Barriers in Hawaii and Australia are 4" and 6" thick, respectively. An average 40' X 40' house with a barrier 6" thick extending 8' deep in a perimeter trench would require a minimum of 53.3 cubic yards for a preconstruction installation or 23.7 cubic yards for a post-construction installation. Additional material would be required for landscape uses. Pre-construction installation cost would be offset by the cost of the replaced sub-slab aggregate. Post-construction installation (remedial control for termite infestation) would probably have to be kept under $3,000 to be competitive with chemical treatment. Sand barriers would save the home owner the costs of chemical re-application and maintenance contracts for the chemical pesticide treatment.

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