RESEARCH REPORT

DRY AND COMFORTABLE FLOORS IN EXISTING BASEMENTS

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FINAL REPORT

DRY AND COMFORTABLE FLOORS IN EXISTING BASEMENTS

Prepared For

CANADA MORTGAGE AND HOUSING CORPORATION

by

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March 31, 2004

RÉSUMÉ

Une étude documentaire a été réalisée afin de déterminer quelles possibilités s'offrent à un propriétaire-occupant qui souhaite revêtir la dalle de plancher de son sous-sol. Étant donné que les sous-sols présentent souvent d'importants problèmes d'humidité qui excluent le recours à certaines options, les responsables de cette étude se sont penchés sur deux types de situation :

1. Absence de problèmes déclarés d'infiltrations d'eau au sous-sol, mais possibilité de condensation durant le printemps et l'été.
2. Possibilité d'infiltrations d'eau fortuites ou sporadiques et (ou) de mouvements d'humidité à travers la dalle de plancher.

De plus, on a limité l'étude aux solutions qui ne nécessitaient pas de travaux d'excavation considérables dans le sous-sol ou autour des fondations. En fonction de cette démarche, trois types de problèmes d'humidité ont été définis puis appariés avec les options de revêtement disponibles pour la dalle de sous-sol :

Problèmes d'humidité mineurs – C'est la forme de mouillage la plus bénigne. Cette situation correspond à l'absence de problème déclaré d'infiltration dans le sous-sol, malgré le fait qu'il puisse se produire une certaine condensation au cours du printemps et de l'été sur le plancher ou à d'autres endroits dans le sous-sol lorsque le taux d'humidité relative à l'intérieur est élevé et que certaines zones du plancher (ou d'autres parties du sous-sol) atteignent une température inférieure au point de rosée. Les problèmes d'humidité mineurs sont les moins destructifs. Dans ce genre de situation, on propose les solutions suivantes :

- peinture et revêtement
- revêtement de sol jetable et facile à nettoyer
- revêtement de sol classique
- faux plancher; non isolé
- faux plancher; isolé
- tapis de drainage et nouveau support de revêtement de sol

Problèmes d'humidité moyens – Ce genre de mouillage est un peu plus sérieux. Le mouillage se produit principalement par action capillaire dans la dalle de plancher, bien que certains épisodes de condensation puissent aussi se produire. Pour les situations où le plancher est exposé à des risques moyens de mouillage et où la surface du sol peut être scellée, on retiendra les mêmes solutions que celles données précédemment pour les problèmes mineurs. S'il n'est pas possible de sceller le plancher convenablement, on devra faire appel aux options suivantes :

- peinture et revêtement
- faux plancher; non isolé
- faux plancher; isolé
- tapis de drainage et nouveau support de revêtement de sol

Problèmes d'humidité majeurs – Cette situation est la plus grave et survient lorsque le mouvement d'humidité se produit par infiltration d'eau et peut-être aussi par action capillaire à travers la dalle. Il peut aussi se produire de la condensation. Dans le cas des sous-sols dont le plancher est exposé à d'importantes sources d'humidité potentielles et où le niveau de la nappe phréatique peut être abaissé, on pourra alors utiliser la même liste d'options que pour les problèmes d'humidité mineurs. Si, toutefois, il est impossible d'abaisser suffisamment le niveau de la nappe phréatique, il faudra s'en remettre aux options suivantes :

- peinture et revêtement
- faux plancher; non isolé
- faux plancher; isolé (nota : en présence d'importants problèmes d'humidité, l'espace créé par le support de revêtement de sol devrait être dépressurisé au moyen d'un petit ventilateur qui évacue l'air à l'extérieur)

- tapis de drainage et nouveau support de revêtement de sol (nota : en présence d'importants problèmes d'humidité, l'espace créé par le support de revêtement de sol devrait être dépressurisé au moyen d'un petit ventilateur qui évacue l'air à l'extérieur)

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ABSTRACT

A literature survey was carried out to identify options available for finishing basement floors in existing houses which are subject to minor, moderate or major types of moisture problems. The following six types of floor finishing options were identified: paints and coatings, cleanable and disposable coverings, conventional area coverings, built-up floor systems, non-insulated built-up floor systems and insulated drainage mats with a new sub-floor. The suitability of each of these floor finish options was assessed for the three classes of moisture problems.

EXECUTIVE SUMMARY

A literature survey was carried out to survey options available for finishing basement floor slabs in existing houses. Since many basements have significant, pre-existing moisture problems which preclude some options from consideration, the project looked at two specific types of conditions:

1. No overt basement water leakage problems, but with the possibility of spring and summer condensation.
2. Possibility of incidental or sporadic water leakage and/or moisture movement through the floor slab.

In addition, the scope of the project was restricted to solutions which did not involve major excavations within the basement or around the foundation. Using this approach, three sets of moisture problems were defined, along with the options available for finishing the floor slab:

Minor Moisture Problems - This is the most mild form of basement floor wetting. The condition exists when there are no overt basement water leakage problems, although spring and summer condensation may exist on the floor or on other locations in the basement when the indoor relative humidity is high and portions of the basement floor (or other parts of basement) are below the dew point. Minor moisture problems are the least destructive type of basement floor wetting. For this type of condition, the following floor finishing options exist:

- Paints and coatings
- Cleanable and disposable coverings
- Conventional area coverings
- Built-up floor systems; non-insulated
- Built-up floor systems; insulated
- Drainage mats & new sub-floor

Moderate Moisture Problems - This is a more pronounced situation. Wetting occurs mainly due to capillary action through the floor slab although some condensation may also take place. For applications where the floor is exposed to moderate moisture threats and in which the floor surface can be sealed, then the same list of floor options shown for minor moisture problems can be used. If the floor can not be successfully sealed, then the following floor options exist:

- Paints and coatings
- Built-up floor systems; non-insulated
- Built-up floor systems; insulated
- Drainage mats & new sub-floor

Major Moisture Problems - This is a more extreme condition and occurs when moisture transport takes place by water leakage (bulk transport) and possibly by capillary action through the slab. Condensation may also occur. For applications where the floor is exposed to major moisture threats and in which the water table can be lowered, then the same list of floor options shown above for minor moisture problems can be used. If the water table can not be successfully lowered, then the following options exist:

- Paints and coatings
- Built-up floor systems; non-insulated
- Built-up floor systems; insulated (note: if major moisture problems exist, the sub-floor space should be depressurized using a small blower which exhausts to the outdoors)
- Drainage mats & new sub-floor (note: if major moisture problems exist, the sub-floor space should be depressurized using a small blower which exhausts to the outdoors)

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SECTION 1
INTRODUCTION

1.1 BACKGROUND

For many Canadian homeowners, upgrading the basement represents a relatively inexpensive means to expand the size of their living space. However, basements are exposed to potentially significant moisture threats which may impede their usefulness as finished space and could result in expensive repair work. While some basements are obviously unsuited for conversion into finished spaces because of their history of flooding (due to sewer back-ups, sump pump failures or other reasons), millions of other basements have *some* history of moisture-related problems which may, or may not, affect plans for development of the space. For example, at a recent meeting of home inspectors from across Canada, it was concluded that between 20% and 50% of Canadian basements (which the inspectors had visited) demonstrated some type of moisture problem (Fugler, 2002). Prairie basements tended to be dryer while those in coastal regions tended to have a higher incidence of problems. Also, moisture problems tended to be more common in older houses, compared to newer structures. This means that the impact of any potential wetting of the basement has to be considered in planning development of the basement space. Of course, this includes both the basement walls as well as the basement floor slab.

Over the last few decades, there has been a considerable amount of research directed at improving the performance of house basements to improve their durability, moisture resistance and overall functionality. However, almost all of this effort has focussed on the basement wall system. Very little has been directed at the basement floor slab. The purpose of the basement floor is to provide a stable bearing surface and restrict the entry of air, moisture, insects and soil-originated contaminants into the house (such as radon, methane, liquid water, water vapour, etc.). In new construction, the overall quality of floor slabs in most houses is somewhat variable, but overall is generally good (at least when the house is initially finished). However, the situation in existing houses can be much more problematic. The vast majority of basement floors in existing Canadian houses are constructed of concrete, typically 75 mm (3") thick. In some older houses, the concrete may have been placed directly on the undisturbed soil, while in houses constructed within the last few decades, it was usually placed on top of a 100 mm (4") layer of granular fill. In some newer houses, the slab may have been placed on top of polyethylene which rests on the undisturbed soil or granular fill. Although the polyethylene would likely have been damaged during construction by shovels, foot traffic and wheelbarrows, many of the resulting holes would have been filled by the concrete as it was being placed - which may create small pathways for capillary action if direct soil-to-concrete pathways exist.

In most cases, the floor slab was cast in one piece although in some older houses, the slab may have been cast in two or more separate pieces with discrete boundaries between the adjacent pieces (known as "cold joints"). Also, some older houses may have all or a portion of their floor slabs cast directly on top of an earlier floor.

In practice, the basement floor slabs in older houses are often of questionable quality due to poor construction practices or degradation which has occurred since the house was built. As a result, problems due to condensation, water leakage and soil gas intrusion are common. This creates a dilemma for many homeowners who view an unfinished basement as a relatively inexpensive way to increase the useable living area of their home and therefore need to address the issue of floor slab performance. For most homeowners, as well as contractors, there is considerable uncertainty about what to do with an existing floor slab to create an acceptable finished floor surface. Many people (who are often oblivious to the types of issues described above) view an imperfect floor slab as merely an aesthetic issue and attempt to "fix" the slab by simply applying carpets or vinyl flooring directly onto the slab and hoping for the best. Given the potential for moisture accumulations below, within or on top of the floor slab this can create a multitude of problems. Guidance is required on how to select an appropriate floor system for basement floors in existing houses.

1.2 OBJECTIVES

The purpose of this project was to specify, if possible, preferable floor finishing systems for existing basements for two specific types of conditions:

1. No overt basement water leakage problems, but with the possibility of spring and summer condensation.
2. Possibility of incidental or sporadic water leakage and/or moisture movement through the floor slab.

1.3 SCOPE

The scope of this report was restricted to solutions which did not involve major excavations within the basement or around the foundation since this was felt to involve a level of effort and cost which exceeded the scope of this project.

1.4 REPORT ORGANIZATION

Section 1 of this report provides a general introduction and background to the issue of selecting a suitable floor covering for a basement floor slab. Section 2 reviews the various moisture transport mechanisms by which moisture (in liquid or vapour form) can reach the slab and discusses how to evaluate the moisture threat to which a basement slab is exposed. Section 3 summarizes the different floor finish options available. The suitability of each floor system option is then discussed in Section 4 and which analyzes the strengths and weaknesses of each alternative. Section 5 summarizes the conclusions and recommendations.

SECTION 2
MOISTURE AND THERMAL CONSIDERATIONS AFFECTING THE BASEMENT FLOOR SLAB

2.1 COMMON PROBLEMS WITH BASEMENT FLOOR SLABS

One of the basic problems with selecting an appropriate basement floor system is that the existing concrete floor slab has to be used and its integrity and overall quality can range from excellent to virtually unusable. Not only is the quality of the basic concrete highly variable but the damage which it may have experienced over its life is highly variable. "It is well to remember that good concrete is made of cement, water and aggregate and that poor concrete is made of the same materials." (NRC, 1968). Since the scope of this project deals with existing houses, we have to accept, and deal with, the quality of the floor slab, assuming replacement of the slab is not an option.

Moisture-related problems are also a function of the type of construction used for the basement wall. For example, many older rubble-style foundations tend to have a higher incidence of moisture problems, in part, because of the absence of any dampproofing on the exterior of the foundation walls or weeping tile drainage system around the foundation (EMR, 1983).

There are several types of problems which the floor slabs in existing house basements can experience. These include:

a) Cracking - This is generally caused by swelling of the underlying soil due to changes in the soil moisture content, by gradual unloading of the underlying soil or by shrinkage during the curing process. Since residential floor slabs are almost never reinforced with steel rebar or wire mesh, they are particularly vulnerable to upward movement since the concrete on the upper portion of the slab is placed into tension. While concrete is fairly strong in compression, it is very weak in tension, making it quite vulnerable to cracking under these conditions.

b) Dampness - The floor slab can become wet for various reasons such as poor drainage below the slab, moisture migration through the slab, leaking drainage tiles (particularly where the perimeter weeping tiles meet the leaders below the slab), non-existent or improperly functioning capillary breaks between the underlying soil and the slab, high water tables, inadequate ventilation, and possibly other factors.

c) Surface degradation of the concrete slab - Surface degradation, such as dusting and spalling, is primarily caused by poor quality materials or inadequate workmanship. Unfortunately, it has been (and continues to be) common practice to add excess water to the concrete to enhance its ability to flow. This can seriously degrade the concrete's strength and durability. Excess water also increases the amount of shrinkage that can occur resulting in increasing cracking. This not only degrades the appearance of the surface but reduces its ability to control the ingress of moisture, air, contaminants and insects.

d) Mold growth - Mold growth requires five sets of conditions to be satisfied: food to sustain growth, a source of moisture, a suitable temperature (above 5 °C), a source of infection and a source of oxygen. In a typical house basement, the latter three conditions are available in concentrations necessary to support mold growth. Thus, controlling mold growth largely depends on removing or reducing the availability of moisture or eliminating the food source. Since mold will grow on most cellulose surfaces, such as newspapers or cardboard boxes stored on top of the basement floor or finish floor finishes laid directly on the floor, the most effective control mechanism is usually reduction of moisture levels. Research sponsored by CMHC in Wallaceburg, Ontario showed that "moisture problems were not usually related to the interior relative humidity but rather to localized issues such as local geomorphology, downspout location, window well flooding, cracks or leaks in the foundation, plumbing problems and grading problems" (CMHC, 1996). One of the disturbing findings of the Wallaceburg study was that several houses not identified as "moisture-troubled", were found to have mold infestations when inspected carefully.

e) Air leakage through the slab - Air infiltration forces are at their maximum over the lower portions of the house (although this is mitigated somewhat by the flow resistance created by the soil), so air leakage through the floor slab is more common than often thought. Since this air can be heavily contaminated by water vapour, radon, methane and other soil gases, infiltration through the slab is very undesirable. Most air leakage occurs through penetrations in the slab (such as teleposts, plumbing lines, cracks, joints between the slab and the walls, etc.). Obviously, holes which permit air leakage can also allow water leakage if the water table is sufficiently high.

2.2 MOISTURE SOURCES CAPABLE OF AFFECTING THE BASEMENT FLOOR SLAB

The basement floor slab is located at the bottom of the structure, basically on top of a hole in the ground. Ground water is present in the underlying and surrounding soil while surface water is constantly being supplied around the perimeter of the foundation. In the vast majority of cases, the ground water level is normally below the level of the floor slab, unless the house has been incorrectly located in an area with a high water table or the ground water level has risen due to very heavy precipitation. However, moisture is still present in the soil between the top of the water table and the bottom of the floor slab, although the soil is normally unsaturated. In this condition, moisture is theoretically able to move vertically from the soil to the slab due to capillary action. To control capillary action, one of two strategies is normally employed: an impermeable layer or a capillary break. An impermeable layer normally consists of a material in which there are no open pores through which liquid water can move by capillary action. A good example is polyethylene. However, impermeable layers have only been used for the last few years in any significant numbers and are not common in most older houses. A capillary break takes the opposite approach compared to an impermeable layer. Rather than attempting to use a material with non-existent pores, an impermeable layer uses a material in which the pores are so large that they will not support capillary action. The classic example of this is the use of granular material below the slab. Granular material has the further advantage that it provides a levelling surface on which to place the concrete and permits irregularities in the underlying soil to be filled in. This is by far the most common method of controlling moisture transport by capillary action through basement floor slabs although, based on the authors' personal observation, a small but significant portion of existing houses were constructed with their floor slabs placed directly onto the underlying soil.

Moisture movement by capillary action does not always occur in a uniform fashion over the slab surface but may be concentrated in discrete locations such as the perimeter. For example, the latter situation may occur when liquid water in the soil is wicked up through the footings to the slab, since capillary breaks (underneath the footings or between the footings and the slab) are seldom used.

A good indication that capillary action is, or has been, taking place is the presence of efflorescence on the slab. Efflorescence is caused by the movement of liquid water through a porous masonry material (such as a concrete floor slab). The water dissolves soluble salts which it transports to the surface of the slab where the water evaporates leaving crystalline, whisker-like deposits known as efflorescence. Fortunately, this is not an indication of structural problems with the masonry, since efflorescence does not normally affect strength, only the appearance.

Another potential source of moisture is bulk transport from precipitation (rain and melting snow) which drains down the exterior of the foundation wall or which percolates through the soil. Under normal circumstances, this water is intercepted by the perimeter drain (weeping) tile at either the bottom of the footing or the top of the footing (depending on the placement of the weeping tile). The weeping tile is perforated so that liquid water is free to enter. It then drains to solid leaders which run through the footings and under the floor slab to the floor drain (in older houses) or the sump pit (in most newer houses). If a floor drain is used, the weeping tile water enters the drain where it is free to drain to the municipal sewer. If a sump pit is used, the weeping tile water enters the pit where it is pumped by the sump pump to a suitable location outside the house. In some parts of the country, the weeping tiles are plumbed such that they do not enter the house but are connected directly to the storm sewer. One advantage of this configuration is that the risk of sewer back-ups is eliminated. In theory, any of these systems should be able to drain water in the surrounding soil away from the house

In reality, several factors can arise which can compromise the ability of the drainage system to function properly. First, the drainage tiles may be damaged or clogged with soil. In older houses, clay tiles were often used. These may have been damaged during the backfilling operation or at some point since construction. For example, it is not uncommon to find clay tiles which have been completely crushed. Newer houses use plastic drainage tiles which are less susceptible to this problem. Both types of tiles however, are vulnerable to gradual infiltration of fine-grained soils such as silts into the tiles which can partially or completely plug the tiles. Another complication which can compromise the ability of the drainage system to operate correctly is leakage at the joint between the solid leader tiles below the floor slab and the solid leader which penetrates through the footing. If this connection is not watertight, which is the case in many instances, water can leak at the connection and pool immediately below the connection. This is a particularly troublesome problem because the water is concentrated in one (or more) discrete locations, rather than being distributed over the entire floor area in a relatively uniform manner.

The performance of the drainage system also depends on the location of the drainage tile, i.e. whether it is located at the base of the footings or on top of the footings. Obviously, the tiles can only drain water which is at, or above, the lowest level of the tile. The current edition of the National Building Code of Canada (NRC, 1995), as well as previous versions, require that the drain tile be located at the base of the footings to provide the maximum drainage potential. However, in some areas of the country (such as some locations in the prairies) it has been common practice for many years to place the drainage tile on top of the footings (ostensibly to reduce the size of the excavation and to provide some nominal protection to the tiles during construction). This raises the maximum ground water level which can exist before the drainage system starts to function and thereby increases the basement's susceptibility to moisture problems.

Houses which use sump pits to discharge drainage system water to the outdoors are intended to discharge their water at a location where it can easily drain to the street and ultimately to the municipal storm water system. This requires correct grading of the soil from the point of discharge to the street. In some houses, this is not provided to an adequate degree which results in all or some of the water discharged by the sump pump draining back towards the house. This can result in continuous circulation of the water from the soil to the drainage system and back to the soil (a good indication of this problem is that the sump pump runs on a continuous or near-continuous basis). Obviously, this is not an acceptable situation and is one which should be corrected if proper drainage for the basement floor slab, as well as the rest of the foundation, is to be achieved.

In many houses, particularly those in older neighbourhoods which have separate sanitary and storm sewers, the floor drain and weeping tiles drain directly into the storm sewer. Since there is no sump pit or sump pump, there is no danger of continuous circulation of the sump water. However, these types of systems are vulnerable to storm sewer back-ups which can result in basement flooding. This situation typically develops during major summer storms when the municipal storm sewer is overwhelmed by surface water. This can cause the sewer to back-up into basements resulting in severe flooding and damage to basement contents.

Another potential leakage area is cold joints in the foundation concrete. A cold joint is formed whenever concrete is cast against existing concrete which has already had an opportunity to cure. Unfortunately, they tend to be prone to leakage. Cold joints can be created if the slab was cast in more than one section; this is occasionally found in older houses particularly when the original foundation was expanded. In addition, a cold joint normally exists between the floor slab and the footings and between the floor slab and the basement wall. If the basement wall has been insulated, the slab/wall joint may not be easily accessible making repairs difficult to carry out successfully.

2.3 REDUCING THE MOISTURE THREAT

It should be apparent that the greatest threat to the functionality of most basements (and basement floor slabs) is from moisture, either in liquid or vapour form. Therefore, it is worth reviewing some of the options for reducing this threat to manageable levels.

2.3.1 Grading and Surface Drainage

Providing proper grading and surface drainage is the easiest and most obvious method of directing precipitation away from the foundation, yet many houses have their grades sloping towards the house thereby increasing the moisture loading to which the foundation is exposed. The most common cause of this problem is settling of the backfill material within the 1 m to 2 m (3' to 6') strip around the foundation. This is further aggravated by the fact that many homeowners place flower beds or gardens with very permeable soil immediately adjacent to their houses. Permeable soils allow water to drain freely so there is little opportunity for surface run-off even if the grading is sloped well away from the house.

Another potential problem is the termination of the roof downspouts. The ends of the downspouts should be located outside the backfill region since it tends to be more permeable to water flow than the undisturbed soil outside of the backfill region. Splash blocks are also useful in this regard and help to reduce erosion. Roof runoff water should not be allowed to drain directly into the foundation weeping tile or in the immediate vicinity of the foundation.

Another measure which can reduce the amount of surface water which penetrates through the soil to the basement is the use of a clay cap over the backfill. Clay is very impermeable to water, so by covering the backfill with a layer of clay, perhaps 15 cm to 30 cm thick and sloped well away from the house, the amount of water which reaches the basement can be significantly reduced. The clay can then be covered with top soil for grass or other vegetation which the homeowner may wish to plant beside the house. Although this measure has long been recognized as an example of good construction practice, it is used very infrequently in Canadian houses.

While proper grading can reduce the amount of moisture which reaches the foundation, it is also important for homeowners to occasionally check the grading to ensure that it has not subsided over time. For example, the Institute for Research in Construction (Solplan Review, 2000), recently investigated a number of exterior basement wall insulation schemes at their

Ottawa campus and carefully graded the soil away from their test structures to achieve a five percent slope away from the building (after a winter and spring of soil settlement). After a few years, the grades were check and it was found that subsidence had occurred and the soil was once again sloped towards the buildings. A similar effect can be observed around many Canadian houses.

2.3.2 Ventilation

Most basements, particularly in older houses, have ample opportunities for moisture ingress. Once moisture enters the basement, it is potentially free to evaporate and raise the relative humidity levels. Ventilation, either mechanical or natural, can help to lower humidity levels, although this is a relatively weak moisture removal mechanism compared to stopping the entry of liquid water. Ventilation can be useful provided that the humidity ratio (not the relative humidity) of the outdoor air is lower than that of the indoor air. This is normally the case in the winter, spring and fall and for a portion of the summer months (depending on location and weather conditions). However, increasing the basement ventilation rate during most portions of the summer (when the outdoor air is comparatively moist), may actually increase the moisture levels in the basement if the humidity ratio of the outdoor air is higher than that of the basement air - which is often the case for most parts of southern Canada. It is worth noting that if the relative humidity of the ambient air drops below about 70%, there is usually insufficient moisture in the air to support mold growth. However, the relative humidity can vary significantly throughout the basement as the result of temperature variations (both horizontally and vertically). For example, if the relative humidity is measured and found to be 70% in the middle of the basement and at mid-height between the floor slab and the ceiling, then in many cases, the relative humidity near the walls and in the corners may be much higher since the temperature will be lower in these locations.

Natural ventilation is typically achieved by opening basement windows. It effectiveness will depend on wind speed and direction, the moisture contents of the indoor and outdoor air, the indoor-to-outdoor temperature differential (which defines the driving force for stack action), the operation of mechanical exhaust devices (since they alter the pressure regimes which the building envelope experiences) and the type of combustion appliances in the house. Overall, the greatest infiltration forces during the winter normally occur at the bottom of the structure - an ideal situation for increasing the natural ventilation rate in the basement. During the summer, when the stack effect is much smaller or even reversed in direction (if the indoor temperature is lower than the outdoor temperature), the indoor-to-outdoor pressure differentials across the basement can be positive or negative. The moisture contents of the indoor and outdoor air are also critical. If the outdoor air is more moist than the indoor air, then ventilating the basement (with outdoor air) will raise, not lower, the basement air's moisture content. The easiest way to determine if ventilating with outdoor air will actually be successful is to use a hygrometer (which measures the relative humidity of the air). If the relative humidity goes down when ventilation is added (and assuming that the basement air temperature remains constant), then drying is taking place and the ventilation is achieving its desired goal. However, if the relative humidity increases as the result of ventilation, then the outdoor air is wetter than the basement air and attempting to ventilate will actually make the basement wetter.

Mechanical ventilation systems can also be used to provide ventilation to the basement. Most Canadian houses use exhaust-only ventilation systems which exhaust air from bathrooms and kitchens thereby depressurizing the entire house. This will induce air leakage into the house, some of which will occur through the basement thereby providing drying of the basement air - if the outdoor air is sufficiently dry. Some newer houses use Heat Recovery Ventilators (HRV) instead of exhaust-only systems. HRV's exhaust air from the house while simultaneously supplying preheated, outdoor air at the same flow rate thereby achieving a balanced configuration from a envelope pressurization perspective. As such, they do not induce infiltration into the house.

Combustion-based, space and domestic hot water heating appliances can also help to ventilate the basement if they draw their air directly from the basement. Most furnaces and hot water tanks used in Canadian houses operate in this manner. The only exceptions are those types of appliances which are known as “direct-vent” appliances. These devices have a dedicated, sealed air inlet which runs from the outdoors directly into the appliance, so that they do not use basement air.

2.3.3 Mechanical Dehumidification

Air-conditioners, both central and room models, normally dehumidify indoor air by cooling a portion of the indoor air below the dew point thereby inducing condensation from the circulating air which can then be directed to the drain. However, the ability of an air-conditioner to remove moisture depends on several factors including the degree of oversizing, air flow rate and the unit's duty cycle (which may be manually over-ridden by the occupants). Most residential air-conditioners have to run for several minutes before the condenser coil becomes sufficiently cold to lower the air temperature below the dew point. If the unit is significantly oversized, it will cycle more frequently with the result that the air temperature is seldom lowered to the dew point which reduces the amount of condensation. Also, the evaporator coil must be fully wetted before it will begin to drain any condensate. Short cycling of the air-conditioner results in some of the condensate on the coil being blown back or evaporated into the air stream when the unit starts up at the beginning of its next cycle.

Mechanical dehumidifiers are also used to reduced moisture levels particularly in the summer. They work on the same principle as an air-conditioner except their objective is to remove water vapour from the air rather than simply cooling the air. They can remove significant quantities of moisture from the basement air if desirable conditions are available. Specifically, mechanical dehumidifiers can be very effective if the relative humidity is relatively high (at or above about 70%). At lower humidity levels their effectiveness declines rapidly. For most Canadian basements, this means that they will generally be quite effective at removing moisture from the basement air during the summer months, but much less effective during the winter, spring or fall when indoor relative humidity levels are lower.

2.3.4 Adding A Sump Pit

In some cases, it may be possible to lower the floor's moisture level by adding a sump pit to improve the underfloor drainage, particularly if the slab was cast directly onto undisturbed soil with no granular material below the slab. The presence of a properly functioning sump pit and pump will lower the water table under the slab. This is discussed in more detail below.

Prior to finalizing the decision about adding a sump pit, a small test excavation should be made through the floor slab to assess the type of soil present below the slab. If the soil is primarily clay, then the addition of a sump pit may not significantly lower the water table since clay soils are relatively impermeable to water. In such a situation, the sump pit option would likely not be worthwhile. If the soil is predominately free-draining, such as granular material or silts, then the pit may be able to lower the water table to an appreciable extent and reduce the amount of water movement which occurs through the slab by capillary action.

To determine the type of soil present, a small sample of moist soil should be extracted from the test hole (approximately one handful). The soil can be formed into a small bowl-like shape and a sample of water poured into the mud bowl. If the standing water in the mud bowl leaks out relatively quickly (within approximately 60 seconds), then the soil can be assumed to be free-draining. If the water does not drain quickly out of the bowl, then the soil can be assumed to be predominately clay. However, the type of soil present below the floor slab can vary across the expanse of the floor, so a single sample will not conclusively determine the soil type.

Adding a sump pit requires excavation through the existing slab along with removal of the underlying soil to accommodate the pit plus installation of a sump pump and its associated plumbing. The discharge from the sump pit should be directed to the outdoors and care should be taken to insure that proper drainage is provided at the discharge point so that water does not drain back towards the house.

2.4 DETERMINING THE TYPE OF MOISTURE PROBLEMS EXPERIENCED BY THE BASEMENT FLOOR

This project looked at different types of basement floor wetting conditions as described in Section 1.2 and below...

Condition 1. No overt basement water leakage problems, but with the possibility of spring and summer condensation.

Condition 2. Possibility of incidental or sporadic water leakage and/or moisture movement through the floor slab.

Both are relatively mild conditions and should not be confused with more extreme examples of moisture problems which may be caused by water leakage through the basement floor or walls, or by explicit flooding events such as a sump pump failure or a sewer back-up. For purposes of classification and testing, Condition 2 events can be further sub-divided to differentiate between events which occur primarily as the result of water leakage (bulk transport) from those which result from capillary action. Also, for clarification purposes, we will re-label these events as "minor", "moderate" and "major" wetting problems.

Minor Moisture Problems - This corresponds to Condition 1 above and is the most mild form of basement floor wetting. The condition exists when there are no overt basement water leakage problems, although spring and summer condensation may exist on the floor or other locations in the basement when the indoor relative humidity is high and portions of the basement floor (or other parts of basement) are below the dew point. Minor moisture problems are the least destructive type of basement floor wetting.

Moderate Moisture Problems - This is a more pronounced situation which corresponds to Condition 2 above. Wetting occurs mainly due to capillary action through the floor slab although some condensation may also take place.

Major Moisture Problems - This is a more extreme condition and occurs when moisture transport takes place by water leakage (bulk transport), possibly with capillary action also occuring. This situation also corresponds to Condition 2 above. Condensation may also occur.

The first step in selecting a floor covering system is to assess the extent of the moisture problems which have been experienced by the basement floor (and which it presumably will experience in the future). This is critical since the resistance of different floor systems varies significantly. Further, the new floor system has to endure the worst moisture conditions which the basement floor slab is apt to be exposed to during its remaining life, not merely the average conditions. Therefore, when assessing the moisture threat for an existing floor, it is extremely useful to know as much as possible about the history of the foundation and the maximum moisture threat to which it has been exposed. This may require discussions with the building's previous owners. To assess the extent of the moisture problems, two simple tests are employed. These are described below.

Polyethylene Patch Test - This test determines whether moisture is moving through the existing floor slab by capillary action (CMHC, 1992). Pieces of clear sheet polyethylene, approximately 0.6 m

x 0.6 m (2' x 2') are laid on top of the slab and the perimeter of the polyethylene is then sealed to the floor using duct tape or other suitable material. The patches are left in place for a minimum of two to three days. If, at the end of the exposure period, there are no damp spots visible on the underside (floor-side) of the polyethylene, then it can be assumed that moisture is not moving through the slab by capillary action - at least during the test period. If condensation is present on the top (house-side) of the polyethylene, then it is originating from internal (house) sources. It is worth noting that a basement floor may appear to be dry even if moisture is moving upwards through the slab since the moisture is able to evaporate into the interior air space as fast as it is transported through the slab. When an impermeable membrane is installed over a slab (such as with the polyethylene patch test), water is able to accumulate on the surface of the slab, under the polyethylene.

Preferably, two to five patches should be used, each located on a different section of the slab. Portions of the slab which are not being considered for the new floor system can be ignored. To complement the polyethylene patch test, the slab can be examined for the presence of efflorescence. Since efflorescence can only develop when a significant amount of liquid water has been transported through the slab due to capillary action, the presence of efflorescence can be treated as an indication that capillary movement is occurring.

Standing Water Test - This test determines whether moisture is moving through the slab due to bulk transport, i.e. water leakage (CMHC, 1992). A series of observations are made of all areas of the slab which have wet areas, to determine if there is standing water present in the damp areas. When concrete gets wet, it appearance changes and it becomes darker with a sheen present on the surface (similar to that of a clay flower pot when it gets wet). Slab wetting can occur by capillary action, water leakage from below or by water drainage from above (for example by leakage through the basement walls which results in water accumulating on the slab). However, capillary action is not capable of transporting water to the surface of the slab in sufficient quantities for standing water to develop. Therefore, the presence of standing water indicates the slab is saturated (at least in the affected area) and that an additional moisture transport mechanism is at work (water leakage from below or above). One caution with this test is that standing water which originates from leakage through the basement walls (which ultimately ponds on the floor), should not be interpreted as a test "failure", since the source of the water is not through the slab. However, wall leaks should be repaired at the earliest opportunity, not just to protect the new finish floor surface but also to protect the interior, insulated portion of the basement wall. This is particularly important for controlling mold growth since airborne mold spores are able to move from the insulated basement wall into the occupied portion of the basement and house. Once again, it is critical to know as much as possible about the history of the house. If it has recently been purchased, it is highly recommended that discussions be held with the previous occupants to access their knowledge of the floor system's history.

Using these two simple tests, the susceptibility of the basement to moisture problems can be assessed using Table 1. This information will then be used to determine the types of floor covering systems which are applicable for the basement floor slab.

Table 1
Classification Of Moisture Problems

Test	Polyethylene Patch Test	Standing Water Test
Type of moisture movement which the test exposes	Capillary action	Bulk transport
Minor moisture problems	Pass	Pass
Moderate moisture problems	Fail	Pass
Major moisture problems	Fail	Fail

Polyethylene Patch Test - To pass this test, no moisture can be observed on any of the polyethylene pieces (installed in the area where a new floor is being considered) after they have been installed for a minimum of two to three days. If condensate is observed, the test result can be classified as a "failure".

Standing Water Test - To pass this test, no standing water can be visible at any time at any location being considered for an upgraded floor. If standing water is, or has been observed, then the test result can be classified as a "failure".

Determination of whether a particular basement is exposed to minor, moderate or major moisture problems is relatively easy and only requires observation of the wetting patterns.

2.5 DEFINING ACCEPTABLE MOISTURE RESISTANCE

The purpose of the tests described in the preceding discussion was to establish the magnitude of the moisture threat to which the basement floor slab has been exposed in the past. Of course, this is not an absolute or guaranteed indicator of the future moisture threat, but it does provide a basis for making informed decisions regarding acceptable floor coverings options. Once the tests have been completed, the implications of the moisture threat can be considered. These are discussed below.

Minor Moisture Problems - Basement floors, or sections of basement floors, which are classified as having only minor moisture problems are those which have not demonstrated any evidence of moisture movement through the slab by either capillary action or bulk transfer. This is a critical conclusion since it means that there is no evidence of moisture movement from the soil through the floor slab. The only moisture which the new floor can be expected to encounter is relatively minor amounts due to surface condensation on the new floor surface (or accidental spills by the occupants). However, surface condensation is controlled by the temperature of the surface (in this case the new floor surface). The application of most types of new floor surface will raise the temperature of the floor since any flooring material or system will increase the overall thermal resistance of the basement floor (the only exception being paints or coatings applied to the existing slab since they have a negligible thermal resistance). Therefore, if historical behaviour can be assumed to provide a reasonable indication of future problems, then houses which have demonstrated only minor moisture problems with their basement floor slabs can be expected to have future problems which are equal to, or more likely less than, those experienced in the past. Thus, the moisture resistance required of the new floor system is that it be capable of exposure to relatively minor amounts of moisture resulting from surface condensation. Of course, virtually all floor system have some degree of moisture resistance since all floors, whether they are located below-grade or above-grade, will be exposed to accidental spills at various times in their life. As a first approximation, and with some restrictions (which will be discussed in Section 4), basement floors which are classified as being exposed to minor moisture problems, can be regarded as approximately equivalent to floors which are installed above-grade.

Moderate Moisture Problems - Basement floors, or sections of basement floors, which are classified as having moderate moisture problems are those which have demonstrated evidence of moisture movement through the slab by capillary action - but not by bulk transfer. Thus, unlike the case for floors with minor problems, moisture movement has been observed (and can be expected to occur in the future) from the soil through the floor slab. And obviously, spills can be expected. Thus, to keep a new floor system dry under such conditions requires that the new floor must be capable of either sealing the surface of the existing floor slab to eliminate future moisture transport or that the new floor be capable of dealing with moisture transport which occurs by capillary action from the underlying soil. This could take the form of sealing the existing floor slab against future moisture movement or could consist of construction of a cavity floor system which prevents moisture which passes through the existing slab from moving through to the new floor system.

Major moisture problems - Basement floors, or floor sections, which are exposed to major moisture problems are those which have moisture transport occurring by both capillary action and bulk transport. To keep a new floor system dry under such conditions requires that the new floor must be capable of either sealing the surface of the existing floor slab to eliminate future moisture transport (due to both capillary action and bulk transport) or that the new floor be capable of dealing with moisture transport from the underlying soil. What differentiates major from moderate moisture problems is that for major moisture problems the water table is, or has been, above the level of the existing floor slab. To seal the floor surface against a high water table requires a considerable degree of confidence in the functionality and durability of the sealer for the remaining life of the house. In many parts of the country, this level of confidence is difficult to justify since soil conditions are such that future movement of the slab (due to heaving) will always remain a possibility - with the result that a coating or other system which was applied to the existing floor slab could crack and fail. This is problematic given that some of the new floor options which will be discussed in Section 4 utilize various types of built-up floor systems which could hide water leakage (unless it was so severe that it flooded to a level exceeding that of the new floor surface). Thus, to apply a new basement floor system in houses diagnosed with major moisture problems requires that the water table be lowered below the level of the existing floor slab using the measures discussed previously. Once this has been achieved (and demonstrated to have been achieved), the moisture threat can be regarded as having been reduced from major to moderate.

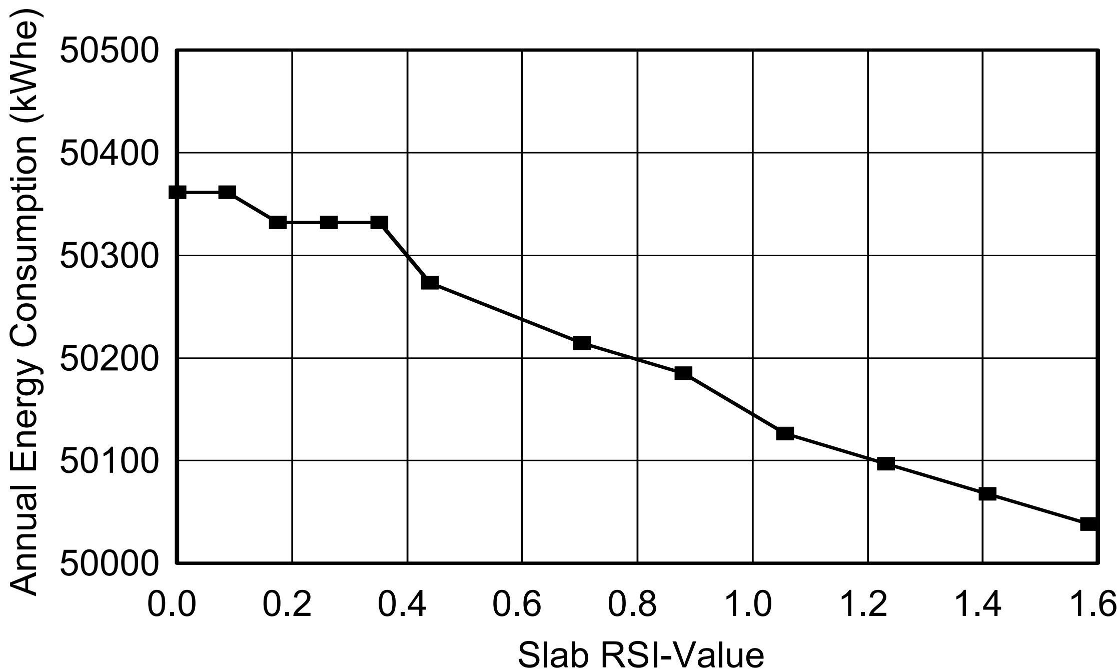
2.6 THERMAL CONSIDERATIONS

In most cases, the addition of a new basement floor system will increase the thermal resistance of the floor slab and reduce the space heating load (the sole exception is the use of paints or coatings on the slab). Therefore, it is worthwhile to consider the implications of the reduced heat loss. In most houses, the basement floor slab is the only major component of the building envelope which is not insulated. The majority of the resistance to heat loss is provided by the soil beneath the slab and around the rest of the foundation. In fact, the heat flow mechanism from a basement floor slab is quite complex. Around the perimeter of the slab, heat flows downwards and then arcs towards grade level in a circular fashion. Heat lost through the interior of the slab tends to be conducted straight downwards. The magnitude of the thermal resistance provided by the soil is quite variable because it depends on the length of the pathway through the soil (which depends on the depth of the foundation, its shape, the presence of adjacent buildings, etc.) and the moisture content of the soil (which is highly variable). Contrary to popular belief, soil provides an effective resistance to heat flow only if it is reasonably dry. Once its moisture content starts to increase, its thermal resistance decreases significantly.

Although virtually all basement slabs in existing houses are uninsulated, the impact of a new floor system (insulated or uninsulated) will be relatively modest because the soil provides some degree of insulating benefit. This is illustrated in Fig. 1 which shows the effect of floor slab thermal resistance upon the annual total energy load for a bungalow with a basement floor area of 132 m^2 (1,415 ft^2) in a house with a naturally aspirated furnace located in Winnipeg. This analysis was performed using HOT2000, version 9.1 and assumed that the entire basement floor slab was being modified. The non-uniformity of the curve is believed to be due to anomalies in the foundation heat loss models used by HOT2000.

Figure 1 shows that the energy savings due to basement floor insulation are quite modest, typically in the order of a few hundred kilowatt-hours (equivalent), which at current utility rates would be worth about $10 or $20 per year. Although these results will vary with different house designs, locations, heating systems, etc., they do illustrate that the energy savings resulting from improved basement floor insulation will generally be modest.

Fig. 1
Impact Of Basement Slab Insulation



SECTION 3
FINISH FLOOR OPTIONS

3.1 FINISH FLOOR SURFACES

Before proceeding further, it is worthwhile to consider the types of flooring options which are available today and in which the consumer may be interested. These are discussed below and summarized in Table 2 at the end of this Section. Most of this information has been obtained from various web-sites and the authors' experiences (World Floor Covering Association web-site, 2004 and Armstrong World Industries Inc. web-site, 2004).

Traditionally, carpets have been the most popular type of floor covering for residential applications. Although this is still the case today, there has been a shift towards hard-surface materials such as vinyl, wood, laminates, ceramics, etc (Solplan Review, 2000).

3.2 CARPETS

Sizes

Carpets can be purchased as either stand-alone coverings or roll carpeting intended for wall-to-wall applications. They come in a wide variety of sizes; most roll carpeting comes in widths of 3.7 m and 4.6 m (12' and 15').

Materials

Tufted carpeting, which accounts for the vast majority of carpets, is made up of three layers. The tufting, or face yarn, is sewn onto a primary backing fabric generally manufactured from polypropylene. A secondary backing sheet of polypropylene or polyester is bonded to the primary backing with a liquid synthetic acrylic (latex) or other type of adhesive. The fibres used in carpets are manufactured from one, or a blend, of basic materials (nylon, olefin, polyester, acrylic, wool or cotton). About 99% of all carpet is manufactured from synthetic fibre, with nylon representing about two-thirds of this total. Wool and cotton represent about 1% of total production (Journal of Light Construction, 2001).

Most carpets are installed on top of a cushioned underpadding (usually manufactured from recycled urethane foam) to give a soft "feel" to the finished surface and to absorb most of the impact from foot traffic. In all cases, the "feel" and durability of the carpet will be affected by the quality of the underlying surface. Any loose or missing areas, ridges or other surface blemishes should be corrected before installation of the carpet.

Durability

Carpets come in various weights and materials with their durability reflected accordingly. In fact, most modern synthetic face fibres are very durable and will not wear out even with heavy traffic. Most carpet replacements are dictated not because the carpet is worn out but because the pile has become excessively compacted or even crushed. Carpets are sold for various applications depending on the level of traffic. For residential applications, carpets are normally divided into Class I and Class II types. Class I includes light-to-moderate traffic areas such as bedrooms, living and dining rooms. Class II applications include entryways, hallways and all stairways.

Installation also affects the durability of the carpet. Virtually all wall-to-wall carpeting is performed by commercial installers and not do-it-yourselfers because of the specialized tools and experience which is required. Carpet quality is determined by the type of fibre and the density of the weave (the greater the number of stitches or loops per unit area, the better the durability).

The fabric matrix of a carpet represents an ideal breeding ground for molds assuming the other conditions necessary for mold growth are met. While synthetic materials such as nylon will not support mold growth, there will be sufficient organic material trapped in the matrix for molds to grow and flourish. Therefore, carpets should only be used on a basement floor when there is a high level of confidence that the basement floor is dry and will remain dry - particularly if the carpet is permanently installed.

3.3 VINYL

Vinyl is a very versatile flooring option which is available in sheet or tile form and comes in literally hundreds of different styles and colours. Vinyl is easy to clean and generally quite wear-resistant. It is also a somewhat resilient surface in that it "gives" when walked on, in contrast to harder surfaces such as concrete or wood. This also reduces the probability of breakage when fragile objects such as glasses or plates are dropped on it. When vinyl is glued to a concrete surface (such as a basement floor), adhesion will be improved if the concrete is first etched using a mild acid.

Sizes

Sheet vinyl is typically produced in 1.83 m or 3.66 m (6 or 12 foot) wide rolls. Vinyl tiles are available in various sizes including 3.5, 4.7, 5.5, 6.3 and 7.1 cm (9, 12, 14, 16 and 18 inch) squares.

Materials

There are two basic types of material used for vinyl floor finishes. The majority of vinyl floor materials have a photographic image which is printed directly on the material which is then covered with a protective wear layer. Obviously, any pattern or style which can be photographed can be represented using this technique. The second type, which uses inlaid patterns, involves the application of colour granules from the backing layer up. The granules are applied using stencils and produce a rich and deep appearance.

Durability

Vinyl floors tend to be very durable and easy to clean using either proprietary agents or simple general purpose household cleaners. Vinyl is available with three different types of wear layers. The most basic is the no-wax wear layer which is relatively easy to clean and good at resisting stains. Urethane-coated wear layers are the second type and are superior to the no-wax types since they are more resistant to scratching. The third type, which is sold under proprietary names, is the most scratch resistance, has the best protection against staining and has the most durable shine.

3.4 CERAMIC

Ceramic tiles are very durable, wear resistant and fairly easy to clean. They are available in hundreds of different colours, styles and patterns. They are also available in gloss and matte finishes and with textured and smooth surfaces.

Durability

The durability of ceramic tiles depends on the hardness of the surface glaze and the density of the underlying ceramic body. The surface glaze, sometimes referred to as wear resistance, is measured on a numerical scale ranging from 1 to 5 with 5 being the hardest. The tile density is determined by the types of materials used to create the tile along with the firing process in which the tile was manufactured. Tiles with the highest density are the least porous and thus have the smallest capacity for water absorption.

Cleaning ceramic tiles is relatively easy, particularly if it is done on a regular basis. Generally, a gentle sweeping followed by damp mopping should suffice. Abrasive and oil-based cleaners should be avoided. Grout should be sealed after installation with an appropriate sealer to reduce long-term maintenance requirements.

3.5 LAMINATES

Laminate floors were developed to provide an economical flooring option while still offering the appearance of more expensive finishes such as hardwoods or stone. Laminates are multi-layered products which use a lower cost substrate combined with a more expensive top surface.

Sizes

Laminates are available in strips, planks or squares and can be produced in almost any type of "look" ranging from wood, tile to stone, including some exotic, expensive options (e.g. teak and bamboo).

Durability

Laminate floors are quite durable. Since they have an outer wear layer, they are quite resistant to scratches and other damage. While they are not waterproof, laminate floor surfaces are probably more resistant to water damage than traditional hardwood floors, although flooding of the floor could cause swelling. Most manufacturers guarantee their product will not fade or wear through. Laminate floors can be vacuumed and damp mopped, simple spills can be cleaned up with a damp cloth.

3.6 LINOLEUM

Linoleum is the oldest sheet flooring material available. It is manufactured from linseed oil which is boiled, mixed with various melted resins and then combined with powdered cork, wood flour, resins, ground limestone and other natural materials. The colour is provided by various types of mineral pigments. It is formed into a sheet material under high temperature and pressure.

Although almost a century and a half old, it has enjoyed a resurgence in popularity in recent years because of its natural look, the fact that it is quiet and comfortable underfoot and does not contain any synthetic chemicals - which makes it particularly popular for individuals who are chemically hypersensitive or otherwise concerned about indoor environmental issues. For example, linoleum manufactured today does not contain any formaldehyde. Also, its antistatic surface properties cause it to reject dust and make it ideally suited for rooms containing electronic equipment.

Most linoleum sold today is produced in fairly neutral colours and patterns, in contrast to vinyl flooring which is available in a multitude of colours, patterns and styles.

It is generally recommended that linoleum should be professionally installed since sheet rolls are less flexible than vinyl and special care is needed to seal the seams. Linoleum is not recommended for wet applications such as bathrooms - and basements prone to flooding.

Sizes

Most linoleum is produced in roll form, approximately 2.0 m wide (6'-6") and in various lengths. Some linoleum is also produced in tile form. Typical tile sizes are 48 cm x 48 cm (18.9" x 18.9"), 58 cm x 58 cm (23" x 23") and 33 cm x 33 cm (13" x 13").

Durability

Linoleum is an extremely durable product and is very long-wearing. In fact, as the linseed oil oxides over time, the strength of linoleum may actually increase.

3.7 HARDWOOD

Hardwood floors are available in solid or engineered styles. With a solid style, each piece of flooring is milled from a single piece of wood whereas engineered hardwoods consist of three or more layers in a cross-ply construction. Solid wood floors are generally used over a wood subfloor and are attached with nails. Engineered hardwoods are typically used in basements or over concrete slabs where the hardwood is attached to the sub-floor with an adhesive.

Hardwood flooring is available in strips, planks or parquet tiles with various types of edge treatment such as square, micro or bevelled edges. Both urethane and wax finishes are used.

Durability

Hardwoods are a natural surface although they do need to be protected against normal wear and tear. Urethane finishes are now the most popular type of surface treatment and they will last ten to fifteen years at which point a new coat can be applied. Sanding or refinishing is not normally required, unless the hardwood has sustained serious damage, or if a new colour is desired.

Hardwood floors can be cleaned with a soft broom or vacuum. To maintain the luster, the manufacturer's recommended cleaner can be used with a dry mop and a terry cloth cover. Buffing of urethane-covered floors is not recommended.

Hardwood floors are not normally recommended for wet areas such as bathrooms. Obviously, they should not be used in basements if there is any likelihood of flooding.

Table 2
Comparison Of Finish Floor Options

	Carpets	Vinyl	Ceramic	Laminates	Linoleum	Hardwoods
Damage resistance	XXX	XX	XXXXX	XXXX	XXX	XX
Moisture resistance	X	XXXX	XXXXX	XXX	X	XXX
Ease of maintenance	XXX	XXXX	XXXX	XXXX	XXXX	XXX
Stain resistance	XX	XXX	XXXXX	XXXXX	XX	XX
Fade resistance	XXX	XXX	XXXXX	XXXXX	XX	XX
Softness under foot	XXXXX	XX	X	X	XX	X
Scratch resistance		XX	XXXX	XXXX	XX	XXX
Ease of repair	X	X	XX	XX	X	XXX
Design & colour selection	XXXX	XXXXX	XXX	XX	XXX	X

Ratings:
X Very poor
XX Poor
XXX Average
XXXX Good
XXXXX Excellent

SECTION 4
FLOOR SYSTEMS FOR MOISTURE-SUSCEPTIBLE BASEMENT FLOORS

4.1 INTRODUCTION

This section reviews the various options available for moisture-susceptible basement floors. Each option is discussed and evaluated using the following format:

a) Construction details - Describes the basic design and construction details of the option along with any optional configurations.
b) Knowledge base - Summarizes supporting documentation and field experiences with the option.
c) Advantages - Details the known and perceived advantages of the option when installed in typical residential applications.
d) Disadvantages - Describes the limitations, both observed and potential, for the option.
e) Applications - Describes the suitability of the option for minor, moderate and major wetting events.
f) Costs - Summarizes the anticipated cost of the option on a relative basis, i.e. "low", "medium" or "high" cost.

4.2 OVERVIEW OF THE OPTIONS

Various options are available for covering a basement floor slab. These range from simple floor painting to "disposable" coverings to more complex, built-up floor systems which form the sub-floor upon which virtually any type of finish floor system can be installed. These have been organized into the following categories and are discussed in the remainder of this Section:

- Paints and coatings
- Cleanable and disposable coverings
- Conventional area coverings
- Built-Up floor systems; non-insulated
- Built-Up floor systems; insulated
- Drainage mats & new sub-floor

These six options are summarized in Table 3 at the end of this Section.

4.3 PAINTS AND COATINGS

a) Construction Details

Paints and coatings are the most basic category of basement floor treatments. Although comparatively inexpensive and easy to replace or touch-up, the existing finish may be stained or blemished - particularly if the basement has been used for storage and had various substances spilt on it over the years.

Cleaning The Existing Floor Slab - One potential problem with paints and coatings is that they generally work best when the object to be covered (the floor) is clean, free of stains and generally in good condition. If the new paint or coating is applied over a stained or painted portion of the floor, it will only adhere to the original stain or coating. Of course, a clean surface is not normally found on existing basement floors. However, stains and other blemishes can be cleaned, with varying degrees of success. Various types of stain removal products or techniques are available. Generally, these fall into two categories: mechanical methods (such as sand blasting, grinding, steam cleaning, brushing and scouring) and chemicals which act as solvents to dissolve the stains or react with them to form compounds which are less visible. One of the more common types of stains found on basement floor slabs is grease. These can be removed (or reduced in severity) by first covering the stain with a layer of sawdust or cat litter for 24 hours, then removing the sawdust or cat litter using a stiff broom. Next, dry dishwasher detergent or a commercial concrete cleaning agent should be poured on the stain and left for about 45 minutes. Boiling water can then be poured on the area and vigorously scrubbed, repeatedly if necessary. Finally, a pressure washer should be used to remove any remaining material and clean the affected area.

Epoxy Coatings - Epoxy coatings intended for industrial and commercial applications are particularly durable and long-lasting. They can be applied by the do-it-yourselfer and are available in a wide variety of colours. Although very tough, epoxies require a solid, clean and flake-free surface for proper adhesion. If not, power washing followed by an acid etch using dilute muriatic acid will be required (the acid wash is not absolutely necessary but will provide better adhesion and a longer-lasting coating). According to one paint manufacturer, they first recommend that the floor slab be checked for "rising" moisture (capillary action) using the polyethylene patch test described in Section 2. According to their web site, their product can still be applied over areas which are subject to moisture problems although the life expectancy of the product may be reduced thereby requiring touch-ups every few years (Armorpoxy, 2004). The manufacturer also suggests use of silica-based, non-skid additives if there are concerns about the floor being too slippery.

Polyurethane-Based Products - These are a series of new products which are specifically designed to function as indoor waterproofing and dampproofing, not just the latter (Ideal Products web-site, 2004). Polyurethane-based products, according to at least one manufacturer, can be applied to any masonry surface including basement floor slabs to reduce or eliminate moisture movement. Since they are quite flexible, they can bridge cracks and other surface imperfections. To illustrate their application, the product described above has three stages to the application process. First, a single-component polyurethane coating with a high solids content is applied to form the base giving a thickness of 0.36 mm $\pm$ 0.05 mm (14 $\pm$ 2 mils). Next, a single-component polyurethane elastomeric membrane is applied. Finally, a second application of the first coating is applied. Since these products are flexible, they are reported to be able to accommodate small amounts of movement.

b) Knowledge Base

The knowledge base on the performance of most paints and coatings, including stain removal procedures (for the unfinished slab) is relatively good since conventional paints have been used for years in this application. One area for which more information would be useful, particularly independent third-party results, is the performance of products such as the polyurethane-based waterproofing. The manufacturers claim that these products are capable of sealing masonry surfaces against both capillary action and bulk transport water leakage. If these can be substantiated, the product could be very useful for basement floor slabs (as well as other applications such as basement walls).

With respect to polyurethane-based products, one manufacturer's web-site contains numerous customer testimonials, however there are no known independent assessments of the product.

c) Advantages

The primary advantages of paints and coatings are that they are easy to apply (by either do-it-yourselfers or contractors), inexpensive, simple to touch-up, and do not contain or store food, or provide a comfortable habitat for molds.

Another advantage is that they do not create a problem if soil gas remediation becomes necessary in the future. Some other options, such as built-up floors, would require partial de-construction of the assembly to access the slab.

d) Disadvantages

Perhaps the greatest disadvantage of paints and coatings is that they leave the slab with a hard, industrial-like surface. This would be acceptable for applications such as workshops and laundry areas but less so for family rooms or bedrooms. Another disadvantage is that they utilize the existing floor slab surface which dictates that the slab must be in relatively good condition in terms of its integrity, finish and evenness of the surface. Cracks, holes, uneven areas, etc. must be repaired before the new finish can be applied. Also, since many existing basement floors have surface cracks and are subject to dusting, some type of surface treatment may be required.

If an impermeable paint or coating is applied to the slab surface, any moisture which condenses on the cold slab surface will not be absorbed into the concrete and can only be removed by evaporation (a slow process). Although concrete does not support mold growth itself, it can accumulate dirt and other contaminants which will promote mold growth. Aside from creating a breeding ground for molds (particularly in hidden locations), a wet concrete floor will also be slippery and create a safety hazard.

Also, some types of paints or coatings may be susceptible to damage if moisture is rising through the slab due to capillary action. This could cause the paint or coating to lift off the concrete surface.

Finally, the instructions and safety warnings for paints and coatings should be read and followed very carefully to determine if they emit volatile gases which could be ignited by an open flame such as a standing pilot light in the furnace or hot water tank. This could create an explosive situation. If there is any threat, the pilot lights (and any other sources of combustion) should be extinguished and the basement kept well ventilated during the application and curing process for the paints or coatings.

e) Applications

Suitable for basement floor slabs with minor, moderate or major moisture problems.

f) Costs

Low cost.

4.4 CLEANABLE & DISPOSABLE COVERINGS

a) Construction Details

This category includes conventional carpets and sheet coverings (such as vinyl) which are not intended to be permanently installed. They can be used in basement applications if the homeowner recognizes that they may have to be periodically removed and cleaned, or even discarded if a major wetting event occurs.

Carpet wetting can occur due to capillary action or bulk transfer through the slab or as the result of spills. In addition, there is the possibility that condensation can occur at or near the base of the carpet due to the thermal resistance created by the carpet coupled with the temperature differential through the depth of the material (the slab will normally be cooler than the basement air). As a general rule, carpets should not be installed directly over an uninsulated concrete floor slab (and recall that very few existing basements have insulated floor slabs) since any moisture which condenses at the slab/carpet interface will not dry easily and will help to create an excellent environment for mold growth within the carpet matrix. This may be significant if the slab surface has been painted or had some other type of coating applied which could impede absorption of any condensate into the slab.

If it is decided to install carpets over the floor slab, one option to reduce the threat of moisture damage may be to install the carpet over a piece of polyethylene. This has two potential effects. First, the polyethylene significantly reduces the opportunity for moisture to be wicked from the slab to the carpet. However, if the slab has not been painted or otherwise covered with a waterproof coating, the presence of the polyethylene may reduce the opportunity for the slab to act like a sponge and absorb small amounts of water which may condense on the slab surface when it is covered with a carpet. Unfortunately, there is little documented experience with the use of polyethylene under carpets. Perhaps the best approach is to first use the patch test (discussed immediately below) and then if the results of the test are satisfactory, install the polyethylene and carpet but occasionally check to verify that the carpet, slab and polyethylene are remaining dry. These checks should be performed for the first year or two following installation of the carpet and after periods of very heavy precipitation or sustained periods of very high relative humidity.

To better assess the moisture threat with a carpeted slab (with or without polyethylene), the patch test can be used first. However, after the polyethylene has been sealed to the slab (for the test), it should be covered with a large piece of carpeting to better replicate the thermal regimes which the carpet and slab will be experience. The patch can then be checked for condensation, both above and below the polyethylene.

Carpets should not extend all the way to the basement walls unless there is a high degree of confidence that the basement wall and floor will remain dry. By keeping a strip (say 0.3 m or 1') around the perimeter bare, small amounts of water leakage which may occur through the basement wall are less likely to wet the carpet. Depending on the performance of the interior waterproofing products, it may be possible to use a bare perimeter in place of polyethylene although no empirical evidence was found to support this theory.

b) Knowledge Base

Most of the knowledge base is anecdotal. For example, the authors are aware of houses which had large portions of their basement floors covered in carpets and sheet vinyl for decades without any significant problems. If wetting occurred, the carpets could be removed, dried and cleaned without major problems.

c) Advantages

Cleanable and disposable coverings are relatively inexpensive, can be easily cleaned (even though temporary removal is necessary) and can provide a soft, comfortable walking surface. The use of polyethylene or a waterproofing coating may reduce their vulnerability to minor wetting events. If disposable coverings are damaged due to wetting or other events, they can (in the worst case) be discarded and replaced.

d) Disadvantages

The most significant disadvantage is the possibility that they could provide a breeding ground for molds. With carpets, mold could potentially grow within the fibre matrix whereas with vinyl there is the possibility that mold growth could occur underneath the product if moisture is present between the slab and vinyl.

e) Applications

Suitable for basement floor slabs with minor moisture problems. While condensation is not desirable, moisture in conventional and disposable coverings will likely evaporate if present in only limited quantities and duration. In addition, they may be suitable for moderate or major moisture problem areas if used in conjunction with an interior waterproofing coating, provided the latter can be shown to function successfully and demonstrates adequate durability.

f) Costs

Low to medium cost, depending on the type of carpet or vinyl selected.

4.5 CONVENTIONAL AREA COVERINGS

a) Construction Details

This category includes conventional carpets and sheet coverings which are intended to be permanently installed in the basement. Since they can not be easily removed for cleaning, they are best restricted to applications in which there is a high degree of confidence that the basement will remain dry.

As was the case with cleanable and disposable coverings, if carpets are to be installed, one option to reduce the threat of moisture damage is to install the carpet over a piece of polyethylene to reduce moisture transport.

Likewise, carpets should not be installed directly over an uninsulated concrete floor slab since any moisture which condenses at the slab/carpet interface will not dry readily and will have an excellent environment for mold growth within the carpet matrix. In addition, the carpets should not extend to the basement wall, instead a bare concrete strip should be left exposed for a width of about 0.3 m (1').

b) Knowledge Base

Most of the knowledge base is anecdotal. For example, the authors are aware of houses which had large portions of their basement floors covered in sheet vinyl for decades without any significant problems. No major wetting events were known to have occurred, and no problems were encountered with the vinyl.

c) Advantages

Conventional area coverings are modestly priced, depending on the type of material used; further they can provide a soft, comfortable walking surface. The use of polyethylene or a waterproofing coating may reduce their vulnerability to minor wetting events.

d) Disadvantages

The most significant disadvantage is the possibility that disposable floor coverings could provide a breeding ground for molds. With carpets, mold could potentially grow within the fibre matrix whereas with vinyl there is the possibility that mold growth could occur underneath the product if moisture is present between the slab and vinyl, even though an adhesive was used to install the vinyl.

e) Applications

Suitable for basement floors with minor moisture problems. While condensation is not desirable, it presumably will evaporate if present in limited quantities and duration. In addition, conventional area coverings may be suitable for moderate or major moisture problem areas if used in conjunction with an interior waterproofing coating provided the latter can be shown to function successfully and demonstrates adequate durability.

f) Costs

Low to medium cost, depending on the type of carpet or vinyl selected.

4.6 BUILT-UP FLOOR SYSTEMS; NON-INSULATED

a) Construction Details

In many cases, the existing floor slab can not be used as the base for a finished floor system because of serious moisture problems or because the floor is cracked, uneven or in generally poor condition. In some older houses, the floor may have not have been cast in one monolithic piece but rather as two or more segments, or portions of the exposed slab may have been cast on top of the original slab. Also, heaving may have occurred over a portion of the slab leaving it uneven (and possibly cracked). If the slab was cast in more than one piece, cold joints will be present which tend to be vulnerable to water leakage. Further, drainage over the slab surface may be poor because it was never cast with proper slopes toward the floor drain or sump, or because the original floor surface has been disturbed.

In such instances, a new built-up floor system can be constructed on top of the original slab to provide (in theory) a level, dry working surface on which the finish floor can be applied. A typical built-up floor system, shown in Fig. 2, consists of:

- Finished floor (any type can be used)
- Sub-floor, typically plywood or OSB
- Furring (1x4 or 2x4), typically at 16" o.c.
- 6-mil polyethylene, which functions as a moisture and vapour barrier

Although both plywood and OSB have been used as the sub-floor, it would probably be prudent to use an exterior-grade plywood since it has a greater resistance to moisture than OSB, which tends to swell if it gets wet. For example, some recent observations by the US Forest Products Laboratory on the long-term durability of plywood and OSB exposed to the elements (for fencing applications) found that the after approximately a decade of exposure, the OSB samples were all decayed while the plywood samples (which included Douglas fir, southern yellow pine and aspen plywood) showed no sign of delamination or decay (Energy Design Update, 2002).

The furring is subject to wood rot even if no overt water leakage or condensation occurs. Wood is a hygroscopic material which attempts to establish an equilibrium moisture content based on the relative humidity (and to a lesser extent the temperature) of the surrounding air. The wood moisture content is defined as the weight of water contained in a wood sample expressed as a percentage of the oven-dry weight of the wood. In living trees, the moisture content may range from about 30% to over 200%. Lumber used for residential construction is required by the 1995 National Building Code to have a moisture content which does not exceed 19% at the time of installation (NRC, 1995). Wood with a moisture content of 19% or less is generally considered as "dry". The optimum moisture content for fungal growth is around 30%. The precise threat which exists with moisture content levels in the 19% to 30% range has not been clearly defined but is believed to be non-linear with only a minimal threat in the 19% to 22% range. Assuming that 30% moisture content represents the maximum threat, the relative humidity level which would create this moisture content is about 95%, depending on the air temperature and the wood species.

Another issue to consider is the type of material to use for the furring strips. Basically, there are a couple of options. The first is wood although this raises the question of whether the furring should be treated or untreated. Although it rests on top of the polyethylene moisture barrier, there is still the likelihood that some moisture will enter the furring space and cause degradation. For this reason, some type of wood treatment may be advisable to improve the durability of the furring. Historically, CCA-treated (copper-chrome-arsenate) furring would have been recommended. However, numerous concerns have been raised about the health implications of using an arsenic-treated wood within the building envelope. Effective January 2004, the manufacture of pressure-treated (CCA) wood for residential applications ended in Canada and the United States (Solplan Review, 2004). Alternative treatment methods are now being recommended, including those which use copper azole (CA) and alkaline copper quaternary (ACA) treatments. Another type of treatment which is expected to be used in larger amounts in the future are borate based, since borate is a much more benign treatment while still offering protection against fungal attack and insect attack. Copper Chrome Borate (CCB) is one type of borate treatment.

Another option is to use a composite material designed for exposed, outdoor applications such as decks and landscaping. These composites are polymers manufactured from a combination of recycled plastic (primarily grocery bags, pallet shrink raps and related products) and wood waste (from woodworking manufacturers) in approximately equal proportions. The plastic surrounds and shields the wood from moisture and insects so that moisture absorption is extremely low. The product should not rot or deteriorate even in harsh weather. In fact, it can be used in applications in full contact with the ground. Life expectancy is currently undetermined although one manufacturer claims his product has undergone accelerated testing to simulate over 50 years of exposure to harsh weather with little adverse affect. Since these materials do not contain any toxic preservatives, it can be disposed of along with normal construction debris. Composites can be worked with standard hand and power tools and is commercially available in many common sizes. At least one product is known to have been evaluated by the Canadian Construction Materials Centre (CCMC) for exterior decking applications. As far as can be determined, it has not been evaluated for sub-floor furring applications of the type discussed in this report (CCMC, 2003).

Another impact of the built-up floor system is that it provides a modest reduction in heat loss through the slab. A typical built-up floor, of the type described above, would provide an additional thermal resistance of about RSI 0.4 to 0.5 (R-2 to R-3). The increased thermal resistance of the floor slab may also have an unintended effect of making the house slightly warmer in the summer if it is not equipped with air-conditioning. One method which some homeowners use to cool their house is to run the furnace blower occasionally during the summer to transfer some of the heat on the main floors down to the cooler basement. Since most basement walls are insulated, the primary source of cooling is the floor slab. Obviously, if the thermal resistance of the slab is increased, the utility of this option is reduced. However, this is a minor limitation of the built-up floor system.

A typical built-up floor system will add approximately 5 cm (2") to the thickness of the floor. This may cause a problem in some basements because the available headroom, before addition of the built-up floor, is limited. Also, if the new floor system extends to the landing area of the basement stairs, the riser height of the first step will be smaller than for the rest of the stairs thereby creating a potential safety hazard.

If desired, it is relatively easy to design and construct a small section of the new floor so that it can be removed for inspection purposes.

Commercially Manufactured Built-Up, Uninsulated Floor System

Indoor Air Technologies, a Canadian manufacturer, has been producing an non-insulated, built-up floor system for over a decade (Indoor Air Technologies, 2003). Marketed as the "ECHO" system, it utilizes non-insulated floor panels in conjunction with insulated wall panels for the foundation walls. The system operates by depressurizing the floor and wall cavities using a small blower which exhausts directly to the outdoors. Since the sub-floor is depressurized, there should not be any opportunity for air leakage from the soil into the living space. Exhaust rates are between 5 and 43 L/s (10 and 85 cfm)

for the entire basement. However, the system is somewhat complex and needs to be installed by properly trained contractors; it is not intended for do-it-yourself applications. The manufacturer quotes an installed price of about \$54 to \$65/m^2 (\$5 to \$6/ft^2).

b) Knowledge Base

One of the earliest known references to built-up floors was Canadian Building Digest #13 "House Basements" (NRC, 1961). It recommended the use of membrane between the concrete slab and furring strips to control the movement of moisture from the slab. CBD #13 suggested the use of an asphalt mastic, however this is no longer recommended because of the offgassing behaviour of the material.

During a major study into mold in finished basements conducted in houses in Wallaceburg, Ontario, some limited excavations were carried out to look for evidence of mold growth in insulated basement cavities (CMHC, 1996). In one case, a built-up floor of the type described here was opened and mold growth was discovered on the building paper moisture barrier which had been installed underneath the built-up floor. This could be mitigated significantly if the concealed space was mechanically depressurized (and air from the under-floor space was not permitted to enter the occupied portion of the house). This is the approach used by the ECHO system, discussed above.

A concern with any of the built-up floor options, or the drainage mat option, is that mold growth may occur within the concealed portion of the new floor structure from which mold spores might migrate to the occupied portion of the basement (as well as the rest of the house). Experience with basement wall insulation schemes has shown that the interior air/vapour barrier and interior wall finish were not able to provide complete protection against molds which were growing inside the wall system (Fugler, 2002).

c) Advantages

Non-insulated built-up floor assemblies can be successfully applied to almost any floor slab and provide a high quality surface. Floor irregularities, cracks, uneven sections, etc. can all be accommodated although this may require a fair degree of work.

d) Disadvantages

The primary disadvantage of non-insulated, built-up floor systems is cost, both for the built-up assembly and for the finish floor surface which must also be applied. In addition, there is the possibility that mold growth could occur within the assembly, which might not be easily detected.

e) Applications

Suitable for basement floor slabs with minor, moderate or major moisture problems.

f) Costs

This is a high cost option, plus it requires application of a finish floor surface in addition to the built-up assembly. Built-up floor systems, whether insulated or uninsulated, are a relatively expensive option compared to other floor alternatives. Given that basements are used for various applications, some of which may not warrant such an expensive option, it may make sense to consider the built-up floor option for only the high priority areas such as a home office, bedroom or rec room. Other areas which may be used for storage, mechanical systems or similar applications can use other, less expensive floor covering systems.

4.7 BUILT-UP FLOOR SYSTEMS; INSULATED

a) Construction Details

This type of floor system is similar to those in the previous category except that a layer of rigid insulation is also installed as part of the floor system to reduce heat loss and to raise the floor's surface temperature thereby improving comfort and condensation resistance. As shown in Fig. 3, typical construction of an insulated built-up floor would consist of:

- Finished floor (any type can be used)
- Sub-floor, typically plywood or OSB
- Furring (1x4 or 2x4), typically at 16" o.c. and air space
- Rigid insulation, typically R-5 to R-10
- 6-mil polyethylene, which functions as a moisture and vapour barrier

The issue of preservative treatment of the furring material also needs to be addressed. Since the furring is typically installed on top of the insulation, the average temperature of the furring space will be higher than it would be without the insulation. Assuming that the same amount of water is present as is the case with the uninsulated built-up floor, this would reduce the relative humidity and lower the moisture content of the furring materials. In fact, this may be the greatest benefit of insulating a built-up system in that it theoretically provides a much drier environment for the furring strips and the sub-floor (plywood or OSB).

Although the insulation within the new built-up floor should theoretically remain dry, the possibility exists that moisture may enter the insulated cavity which could lead to mold problems. Unfortunately, there is little documented information to assess the magnitude of this threat. One way of addressing this potential threat, is to depressurize the air space created by the furring using a small blower which exhausts to the outdoors. In particular, this approach should be considered if the existing basement floor has major moisture problems. Also, the use of a moisture-resistant insulation, such as extruded polystyrene (XPS), will minimize the opportunity for moisture damage of the insulation, although the cost of XPS is considerably greater than batt insulation.

Since the insulation significantly reduces the amount of heat loss through the floor, caution is required to insure the depth of frost penetration does not reach the footings. This threat will be most pronounced in frost-susceptible soils (such as fine-grained sand, silt and clay) and in houses with relatively shallow foundations such as raised bungalow designs (Ontario New Home Warranty Program, 1996). If the house has an insulated skirt around the exterior of the foundation, then frost penetration is unlikely to be a problem. Also, the comments made previously about the impact of a built-up floor system on cooling the house during the summer also apply to insulated built-up floors, to an even greater degree.

For any type of built-up floor, an inspection panel should be included in the design so the floor can be inspected occasionally for moisture build-ups.

Commercially Manufactured Built-Up, Insulated Floor System

A Canadian manufacturer has recently introduced a insulated panel system which has an active dehumidification system (Air Current Technologies, 2003). The system, intended for both walls and floor applications uses panels manufactured with extruded polystyrene panels grooved on one side. The grooved portion of the panel is placed against the surface to be dried. Air is then circulated by a small blower through the grooves thereby drying any moisture which is present. Using plenums connected to the panels, the air is then ducted to a small dehumidification system which dries the air and returns it to the panels.

b) Knowledge Base

One contractor reference (Journal of Light Construction, 1997), who claims to have had success with this technique when used in American houses, installs the new floor as a floating floor system in which no mechanical fasteners are used to install the new floor. Once the polyethylene and insulation have been installed, the furring and sub-floor are attached using construction adhesive. To allow for expansion, the floor system is stopped 13 mm (1/2") from the foundation walls.

With respect to the commercially manufactured panel system, the manufacturer claims that it has functioned well in vertical applications on foundation walls, but has apparently not yet been used in horizontal applications.

Unfortunately, there is little documented information available on the potential threat due to moisture collection and mold growth in this type of floor system, although theoretically there should not be a problem if the furring space is mechanically depressurized relative to the basement and the exhaust exhausts to the outdoors.

c) Advantages

Insulated built-up floor assemblies can be successfully applied to almost any floor slab and provide a high quality surface. Floor irregularities, cracks, uneven sections, etc. can all be accommodated although this may require a fair degree of work.

d) Disadvantages

The comments made previously regarding the impact of reduced headroom because of the built-up floor and the potential safety hazard which might be created in the vicinity of the stairs, should also be noted.

e) Applications

Suitable for basement floor slabs with minor, moderate or major moisture problems, although there is little documented information available. If major moisture problems are known to exist, then the furring space below the sub-floor should be depressurized by a small blower which exhausts to the outdoor. An inspection panel should also be included

f) Costs

This is a high cost option, plus this system requires application of a finish floor surface in addition to the built-up assembly. Built-up floor systems, whether insulated or uninsulated, are a relatively expensive option compared to other floor alternatives. Given that basements are used for various applications, some of which may not warrant an expensive option such as a built-up floor, in many applications it may make sense to consider the built-up floor option for only the high priority areas such as a home office, bedroom or rec room. Other areas which may be used for storage, mechanical systems or similar applications can use other, less expensive floor covering systems.

4.8 DRAINAGE MATS & NEW SUB-FLOOR

a) Construction Details

Another type of built-up floor is one which utilizes a drainage mat (sometimes called an "air-gap membrane") underneath a new sub-floor. Two alternatives exist: a) pre-manufactured panels which are now commercially available in 600 mm x 600 mm (2' x 2' sizes and b) site-constructed drainage floors.

Drainage mats are materials originally designed to create a drainage plane against foundations so that soil water reaching the mat would drain down the mat to the weeping tiles. In essence they create a dampproofing layer since the drainage space (which is typically 6 mm, or 0.25" thick) is too large to support capillary action, and (to some extent), a waterproofing layer since liquid water is not able to bridge the gap between the soil and the foundation (this assumes that the weeping tiles, as well as the associated drainage or sump pump are functioning correctly). There are at least the two commercially available products commonly used for this type of application in residential construction. The first of these is a membrane manufactured by Cosella Dorken and marketed under the name "Delta-MS" (Journal of Light Construction, 2000) which uses a high-density polyethylene (HDPE) membrane and has been in use for several years. The second is the “Platon” system which is a 24-mil HDPE, dimpled membrane and has also been in use for many years (Armtec Ltd., 2004).

Although the insulation within the new built-up floor should theoretically remain dry, the possibility exists that moisture may enter the insulated cavity which could lead to mold problems. Unfortunately, there is little documented information to assess the magnitude of this threat. As was the case with insulated, built-up floors, one way of addressing the potential moisture threat, is to depressurize the air space created by the furring using a small blower which exhausts to the outdoors. In particular, this approach should be considered if the existing basement floor has major moisture problems.

A floor system using a drainage mat add approximately 16 mm (5/8") to the thickness of the floor, so there should not be a serious problems with reduced headroom and complications with the basement stairs.

An inspection panel should also be included in the design so the floor can be inspected occasionally for moisture build-ups.

Pre-Manufactured Panels

The pre-manufactured panel option is a relatively new product designed specifically for residential basement floor applications and is now commercially available (Longlac Wood Industries Inc., 2003 and Energy Design Update, 2004). Marketed as the "DriCore" system consists of a composite panel comprised of a 16 mm (5/8") oriented strand board (OSB) which is laminated to a rigid polyethylene moisture barrier with integral cleats which are approximately 6 mm (0.25") thick giving a total thickness of 22 mm (7/8" or 0.88") The panels have a nominal size of 94 cm (24") square (actual dimensions are 92 mm, or 23.25" square) and have tongue-and-groove edges on all four sides. The panels fit together without any glue or mechanical fasteners thereby forming a floating floor assembly (although the manufacturer does recommend that in high traffic areas the panels should be secured with Tapcon screws). According to the manufacturer, DriCore panels can be used to form a subfloor for most common types of flooring including vinyl, carpeting, laminate flooring and engineering hardwood flooring.

The air space formed by the cleats provides a drainage cavity which presumably will permit water to drain to the floor drain, given the proper gradient. Since the presence of the panels impedes evaporation, the manufacturer recommends that a 6 mm (0.25") gap be left around the perimeter to promote evaporation, although it would appear that the amount of evaporation which could occur would be minor - at best. However, alternatives exist to improve the ventilating capabilities of the system using a blower discharging to the outdoors.

Site-Constructed Drainage Floors

Site-constructed drainage floors are similar to the manufactured panel option except that rolls of drainage mat are first placed on the floor and then covered with the new sub-floor (plywood or OSB). The advantages of this system, as opposed to the manufactured panels, is that the total length of seams (between sheets or panels) is reduced which should decrease the opportunity for water penetration into the new floor system. Also, the option exists for using plywood (instead of OSB) for the sub-floor.

b) Knowledge Base

Although there is considerable experience with the use of drainage mats as waterproofing membranes for foundations, there is only limited experience with their use on basement floors. No independently generated monitoring information was identified.

c) Advantages

Drainage mat assemblies can be successfully applied to almost any floor slab and provide a high quality surface. Floor irregularities, cracks, uneven sections, etc. can all be accommodated although this may require a fair degree of work.

d) Disadvantages

The comments made previously regarding the impact of reduced headroom because of the built-up floor and the potential safety hazard which might be created in the vicinity of the stairs, should be noted.

e) Applications

Suitable for basement floor slabs with minor, moderate or major moisture problems, although there is little documented information available. If major moisture problems are known to exist, then the furring space below the sub-floor should be depressurized by a small blower which exhausts to the outdoor. An inspection panel should also be included.

f) Costs

This is a high cost option, plus this system require application of a finish floor surface in addition to the built-up assembly. Given that basements are used for various applications, some of which may not warrant an expensive option such as a built-up floor, in many applications it may make sense to consider the built-up floor option for only the high priority areas such as a home office, bedroom or rec room. Other areas which may be used for storage, mechanical systems or similar applications can use other, less expensive floor covering systems.

Table 3
Summary Of Flooring Options Based On Moisture Threat

Existing Moisture Threat	Flooring Options
Minor problems	• Use Option List A.
Moderate problems	• Seal basement floor. • Re-test for capillary movement using Polyethylene Patch Test. • If sealing works, then use Option List A. • If sealing does not work, then use Option List B.
Major problems	• Lower water table to below level of existing floor surface. • Re-test for bulk water movement using Standing Water Test. • If floor passes Standing Water Test, use Option List A. • If floor does not pass Standing Water Test, use Option List B.

Acceptable Floor System Options	
Option List A	• Paints and coatings • Cleanable and disposable coverings • Conventional area coverings • Built-up floor systems; non-insulated • Built-up floor systems; insulated (see note 1) • Drainage mats & new sub-floor (see note 1)
Option List B	• Paints and coatings • Built-up floor systems; non-insulated (see note 1) • Built-up floor systems; insulated (see note 1) • Drainage mats & new sub-floor (see note 1)

Notes:

1. If major moisture problems are known to exist, the use of a blower (which exhausts to the outdoors) to mechanically depressurize the space below the sub-floor should be included.

Figures 2 and 3

SECTION 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Basement floors which have experienced moisture problems can be upgraded to improve the functionality and appearance of the floor. The upgrade options which are available depend on the severity of the pre-existing moisture condition.

Minor Moisture Problems - For applications where the floor is exposed to minor moisture threats (defined as situations in which the only moisture source is condensation), the following floor options exist:

- Paints and coatings
- Cleanable and disposable coverings
- Conventional area coverings
- Built-up floor systems; non-insulated
- Built-up floor systems; insulated
- Drainage mats & new sub-floor

Moderate Moisture Problems - For applications where the floor is exposed to moderate moisture threats (defined as situations in which the moisture sources consist of capillary action through the slab, and possibly some condensation) and in which the floor surface can be sealed, then the same list of floor options shown for minor moisture problems can be used. If the floor can not be successfully sealed, then the following floor options exist:

- Paints and coatings
- Built-up floor systems; non-insulated
- Built-up floor systems; insulated
- Drainage mats & new sub-floor

Major Moisture Problems - For applications where the floor is exposed to major moisture threats (defined as situations in which the moisture sources consist of bulk transport (water leakage) through the floor, and possibly capillary action and condensation) and in which the water table can be lowered, then the same list of floor options shown above for minor moisture problems can be used. If the water table can not be successfully lowered, then the following floor options exist:

- Paints and coatings
- Built-up floor systems; non-insulated
- Built-up floor systems; insulated (note: if major moisture problems exist, the sub-floor space should be depressurized using a small blower which exhausts to the outdoors)
- Drainage mats & new sub-floor (note: if major moisture problems exist, the sub-floor space should be depressurized using a small blower which exhausts to the outdoors)

However, a note of caution is required. This analysis has been predicated on the assumption that the moisture problems to which the basement floor slab will be exposed to in the future will be no worse than those which it has experienced in the past, or at least known to have experienced in the past. Obviously, the possibility exists that future moisture exposure will exceed those which have been previously encountered. If the probability of this occurring is unacceptable to the homeowner, then they must adopt an even more conservative approach than is suggested in this report.

5.2 RECOMMENDATIONS

A discouraging aspect of this project was the relative dearth of actual, documented experience with the various options. In particular, monitoring data was virtually non-existent and even anecdotal information was available in only limited quantities. The implication of this is that the observations and commentary contained within this report must be treated with some degree of caution since there is only limited supporting evidence. It also exemplifies the need for monitoring data to improve the knowledge base (and hopefully to consolidate the conclusions of this report). Therefore, it is recommended that efforts be made to monitor and evaluate the behaviour of the various systems under actual field conditions.

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