RESEARCH REPORT

COMPARISON OF UNDER-FLOOR INSULATION SYSTEMS

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Comparison of Under-Floor Insulation Systems

Final Report

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This study was conducted for Canada Mortgage and Housing Corporation (CMHC) under Part IX of the National Housing Act. The analysis, interpretations and recommendations are those of the consultant and do not necessarily reflect the views of CMHC.

ABSTRACT

The purpose of this study was to monitor and evaluate the thermal and economic performance of three under-floor insulation products over a heating season. Instrumentation was installed in four houses, three with under-floor insulation and one with no insulation beneath the slab. Data was gathered from February to June 2004. The temperature profiles through the floor for bubble pack and steel-skinned polyurethane insulations were compared to the performance for no insulation and 50 mm of XPS, which are materials with known properties. The effective RSI-values for in-situ performance for the three insulations were calculated from the monitored data. The material cost, in conjunction with the in-situ thermal resistance was used to compare the cost/benefit performance of the three insulation materials.

EXECUTIVE SUMMARY

This study was undertaken to evaluate the thermal performance of under-floor insulation products available to the building industry. Basement floor-slabs in three houses were insulated with different products including double-layer bubble pack with an intermediate foil layer, steel skinned 44mm polyurethane panels, and 50mm extruded polystyrene. A fourth house with no under-slab insulation was used as a control. Basements slabs in all four houses were instrumented and monitored. Each of the houses was analyzed using data gathered every two weeks, starting in February 2004.

Resistance temperature detectors (RTDs) were used for measuring temperature. Each house was equipped with two sets of four sensors plus an indoor temperature for a total of nine per house. Each set of four sensors was aligned vertically to measure the thermal gradient from the top of the slab through the insulation and into the soil below. One stack of sensors was installed in the center of the slab and the second stack of four sensors was installed near the edge of the slab about one metre from the foundation wall. A single sensor was installed one metre above the floor slab at the centre of the room to read basement air temperature. Readings were taken from each sensor in each of the four homes on the 1st and 15th of each month.

The effective RSI-value of the bubble pack and polyurethane panels was tested with no insulation and 50 mm of XPS as reference points. The RSI-values for all three materials was assumed to be unknown and calculated. To verify that the procedure was accurate materials with known properties were then compared to published values. The values calculated from field measurements are given in Table 5.1 below. These values are for in-situ performance and therefore include all modes of heat transfer.

Insulation Product	Thermal Resistance (RSI)
44 mm Steel-Skinned Polyurethane	2.56
50 mm XPS	2.13
Bubble Pack	0.40

Table 5.1: RSI of Three Insulation Materials

Bubble pack insulation showed performance that was similar in nature to an uninsulated floor. There was little temperature difference between the inside of the basement and the ground below, the ground temperature varied with indoor temperature, and the ground under the insulation was warmer than expected for undisturbed deep ground temperatures.

The steel-skinned polyurethane panels performed similar to 50mm of XPS. There was a wide temperature difference between the inside of the basement and the ground below, the

ground temperature appeared to be influenced much more by ambient conditions than by indoor temperature fluctuations, and the ground temperatures were closer to expected undisturbed ground temperatures.

RÉSUMÉ

La présente étude avait pour objectif d'évaluer la performance thermique des produits d'isolation disponibles dans le commerce pour isoler les planchers de sous-sol. Les dalles de sous-sol de trois maisons ont été isolées avec différents produits, dont un film à bulles d'air à double paroi doté d'un film métallique intermédiaire, des panneaux de polyuréthane de 44 mm revêtus de métal et des panneaux de 50 mm de polystyrène extrudé. Une quatrième maison sans isolant sous la dalle a servi de maison de contrôle. Les dalles de sous-sol des quatre maisons ont été dotées de capteurs et surveillées. On a ensuite analysé chacune des maisons à l'aide des données recueillies à toutes les quinzaines, à compter de février 2004.

Des détecteurs de température à résistance (DTR) ont été employés pour mesurer la température. On a équipé chaque maison avec deux ensembles de quatre capteurs, en plus d'un capteur de température intérieure, ce qui donne neuf capteurs par maison. Chaque ensemble de quatre capteurs a été placé verticalement de manière à mesurer le gradient de température depuis le dessus de la dalle à travers l'isolant et jusque dans le sol sous-jacent. Un jeu de capteur a été placé au centre de la dalle, tandis qu'on posait le second près de la rive de la dalle à environ un mètre du mur de fondation. On a placé un capteur simple à environ un mètre au-dessus de la dalle au centre de la pièce afin d'enregistrer la température dans le sous-sol. Les lectures ont été enregistrées depuis chaque capteur dans chacune des quatre maisons le 1^er^ et le 15^e^ jour de chaque mois.

La valeur RSI effective du film à bulles et des panneaux de polyuréthane a été mesurée en fonction de points de référence suivants : aucun isolant et l'isolant de 50 mm de polystyrène extrudé respectivement. La valeur RSI des trois matériaux a été présumée inconnue et calculée. Afin de confirmer l'exactitude de la méthode d'essai, on a comparé les propriétés des matériaux ayant des propriétés connues aux valeurs publiées. Les valeurs calculées en fonction des mesures à pied d'oeuvre sont présentées dans le tableau 5.1 ci-dessous. Ces valeurs s'appliquent à la performance in situ, et comprennent donc tous les modes de déperdition de chaleur.

Produit isolant	Résistance thermique (RSI)
Polyuréthane de 44 mm revêtu d'acier	2,56
Polystyrène extrudé de 50 mm	2,13
Film à bulles	0,40

Tableau 5.1 : Valeurs RSI de trois matériaux isolants

L'isolant de film à bulles a affiché une performance comparable à celle d'une dalle non isolée. La différence de température était négligeable entre l'intérieur du sous-sol et le sol sous-jacent, la température du sol variait avec les variations de température intérieures, et

le sol sous l'isolant à bulles était plus chaud qu'on l'aurait cru pour un sol non remanié à cette profondeur.

La performance des panneaux de polyuréthane revêtus d'acier a été semblable à celle des panneaux de polystyrène extrudé de 50 mm. Les différences de température entre le sous-sol et le sol sous-jacents étaient importantes, la température du sol semblait davantage subir l'influence des conditions du milieu que les fluctuations de température intérieure et la température du sol s'approchait beaucoup plus des températures attendues dans un sol non remanié.

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1.0 INTRODUCTION

In recent years, interest has grown in the residential marketplace for building products that contribute to energy conservation. This interest has resulted in the development of several new under-floor insulation products ranging from foil-faced bubble pack to reclaimed insulated steel door cut-out panels. Some of these products are variations of well known materials while others are relatively unknown to the building industry. As the number of products available to consumers increases so does the confusion surrounding their performance. While many of these products are very good, not all have had their thermal performance independently verified.

The purpose of this study is to field measure the performance of three under-floor insulation products available on the market today. Each product was analyzed during the heating season for their thermal performance. A comparison of thermal performance and capital cost provides a relative measure of the value of these products.

2.0 METHODOLOGY

2.1 Insulation Products

This study involved monitoring four new houses in Paris, Ontario. The basement slab of the first house was left uninsulated, while the remaining three slabs were insulated. All four houses are located on the same block, have a basement floor area of roughly 112m^2 (1200ft^2) and contain a single storey above grade with a full height basement directly below.

Figure 2.1: Typical Test House

Three insulation products were evaluated in this study. Each product varies in thickness, cost and thermal performance. They are:

House	Material	Brand Name	Manufacturer
2	Bubble Pack	Ultra CBF Concrete Barrier rFOIL	TVM Building Products
3	Polyurethane	Insta-Panels	Insta Insulation
4	Extruded Polystyrene (XPS)	Styrofoam SM	DOW Chemical

Table 2.1: Insulation Summary

Figure 2.2 shows the installation of the bubble pack, which consists of a reflective foil sandwiched between two layers of 7.9mm (5/16”) thick clear bubble pack. Figure 2.3 shows the installation of polyurethane panels, which are 44.5mm (1 _”) of polyurethane insulation with a steel skin on either side. They are in fact reclaimed cut-outs from steel-skinned doors. Figure 2.4 shows the installation of 50mm (2”) of extruded polystyrene.

Figure 2.2: Ultra CBF Concrete Barrier rFOIL

Figure 2.3: Insta-Panels

Figure 2.4: Styrofoam SM

2.2 Instrumentation

Starting on December 22nd 2003, the four houses were instrumented with temperature sensors to monitor the thermal performance of each basement floor slab. All temperature sensors used in the study were resistance temperature detectors (RTDs) and were chosen for their accuracy, resolution, and ability to eliminate errors from varying lead lengths. The RTDs were soldered to 24 gauge four conductor wire. One coat of epoxy, shrink tubing and three coats of a rubberized coating were then applied to protect them against mechanical and moisture damage (see Figure 2.5).

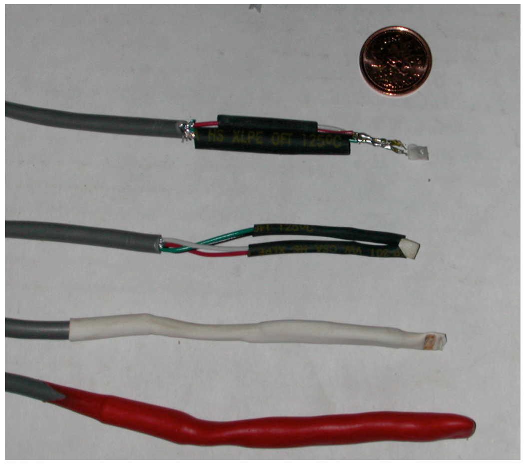

Figure 2.5: RTD Assembly Process

Temperature sensors were installed at two different locations in the basement of each of the four houses. Temperature sensors were installed near the center of the basement far from the foundation walls and the other approximately one metre in from the foundation wall (see appendix for exact locations). Each sensor set contains four RTDs that are distributed vertically throughout the floor assembly (see Figure 2.6). From bottom to top they are located as follows:

1. Approximately 150 mm in soil below granular base
2. On top of the granular base affixed to the underside of the insulation
3. Affixed to the top of the insulation immediately below the concrete slab,
4. Immediately below (approx. 10 mm into) the surface of the concrete slab

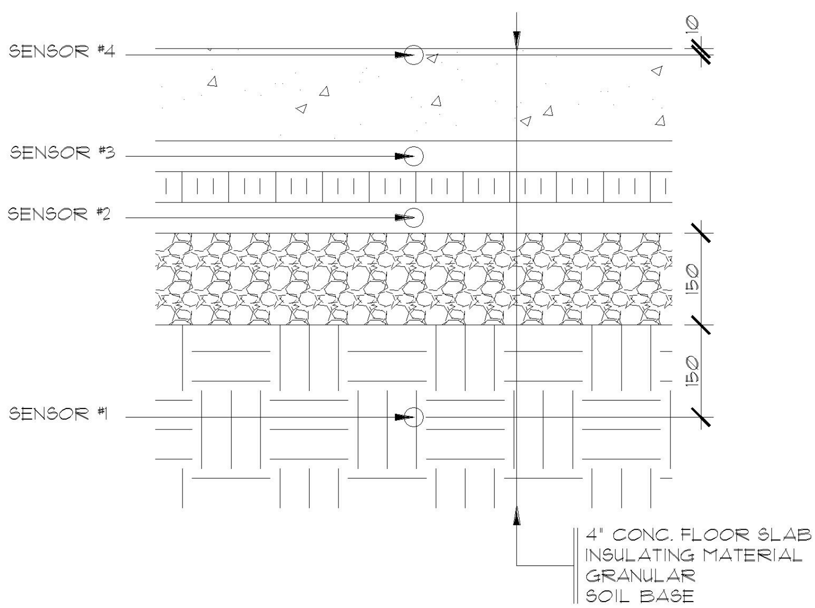

Figure 2.6: Cross Section of Sensor Locations

The first two sensors were installed at both locations (center and edge) several days before the insulation was put into place. The leads of these sensors were run over the granular base to the foundation wall, up through plastic tubing and out through the foundation wall to the metering box (see Figure 2.7).

Figure 2.7: Installation of First Sensors

After the insulation was installed and before the concrete slab poured, the third layer of sensors were installed (see Figure 2.8). The final sensors were installed after the concrete slab had been placed. A 15 mm deep saw-cut was made in the surface of the slab from the sensor location to the edge of the foundation wall. The RTDs were laid in the saw-cut and then grouted into place (see Figures 2.9 and 2.10). Measurements we made throughout the installation process to ensure that the sensors were installed directly over one another. In addition, each RTD was tested at the end of each stage to ensure they functioned properly. During the installation of the concrete slab in House #3 (Insta-Panels), the sensor on the insulation in the center of the basement (L1-S32) was damaged. This sensor reads "+OPEN" for the duration of the test period.

Figure 2.8: Sensor Installed on Insulation

Figure 2.9: RTD in Saw-cut

Figure 2.10: RTD Grouted Into Saw-cut

In addition to the sensors described above, an RTD was installed in each house in the center of the basement, approximately one metre above the floor slab (see Figure 2.11). This sensor is used to read the interior temperature in the basement area. These sensors were installed on either columns or in wood framed walls to conceal them from view.

In total, nine temperature sensors were installed in each house. After installation, the sensor leads were concealed in walls, floors or beams, and run through the foundation wall to a metering box mounted on the exterior of each house (see Figure 2.12).

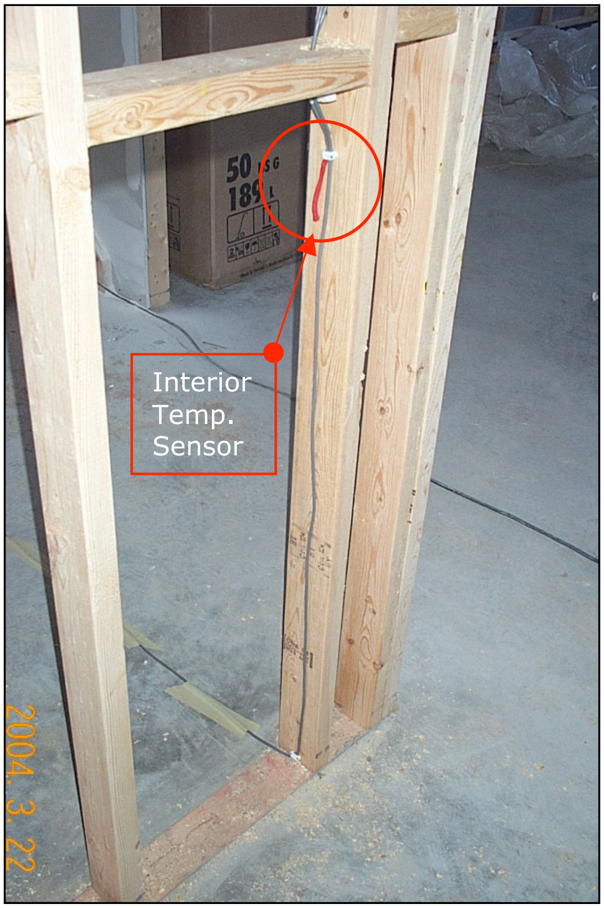

Figure 2.11: Interior Temperature Sensor

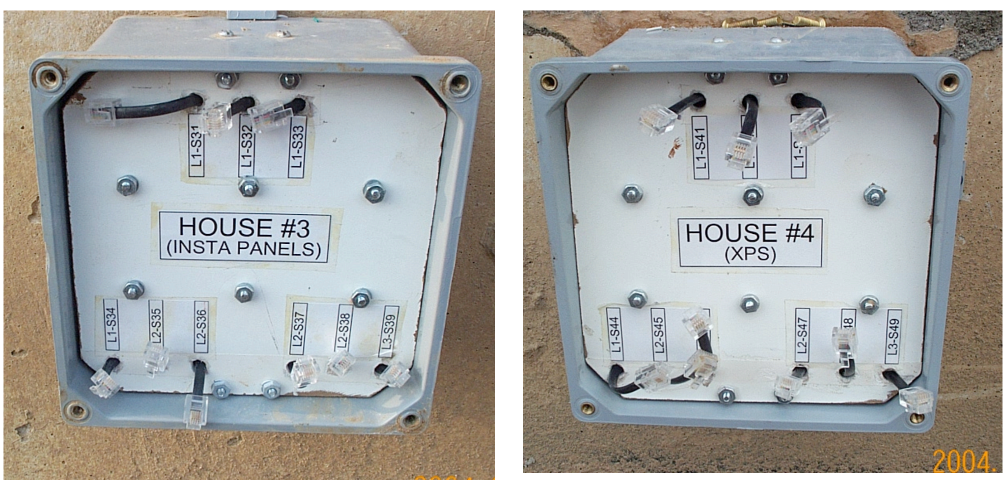

Figure 2.12: Metering Boxes

Readings were taken by "plugging in" a temperature indicator into each lead in the metering box. Measurements for 35 of the 36 temperature sensors (L1-S32 was damaged) were recorded at the beginning and the middle of each month. Readings for Houses 1 and 2 starting on February 25 and readings for Houses 3 and 4 started March 23rd, 2004.

3.0 OBSERVATIONS

Readings over the test period were graphed for all four houses, including two basement locations per house. Eight of the twelve graphs below (one graph per location) show the temperature profile through the floor slab using the stack of four points plus an interior temperature point. Reviewing these graphs provides the thermal characteristics observed for each insulation product.

A third graph (one for each house) shows the measured ground temperature versus the expected ground temperature for the undisturbed soil. The expected ground temperatures were calculated using the ASHRAE methodology for estimating undisturbed soil temperatures at any geographic location in the continental US and southern Canada, at any depth, and with variable parameters for soil type. The equation produces a sinusoidal temperature profile that varies in amplitude and has the date of maximum and minimum temperature point offset based on location, depth and soil conditions [ASHRAE, 1986].

Measurements from the house with no insulation (see Figures 3.1 to 3.3) show that:

- The four points from the top of the slab to 300mm below the slab are generally within a relatively narrow temperature band. The average temperature difference between the concrete slab and the deep soil temperature is about 1.2C^{o}.
- The largest temperature difference was in most cases between the basement air and the top of the slab. The only insulation present at this location is the air film at the surface of the slab. A horizontal air film with heat flow in a downwards direction is generally given an R-value of RSI-0.16 (R-0.9) [ASHRAE, 2001].
- All of the recorded temperatures, including the deep ground temperature, appear to be somewhat influenced by the basement temperature. The influence of this temperature is especially evident at the end of the measurement period when the space temperature drops and so do the temperatures at all slab and ground points.
- Figure 3.3 shows the measured soil temperature under the centre of the house and the expected soil temperature for undisturbed ground. A ground temperature of between 12^{o}C and 14^{o}C was attained over the monitoring period. The measured temperatures are much higher than the expected values for undisturbed soil.
- All of these trends are typical of an uninsulated floor slab.

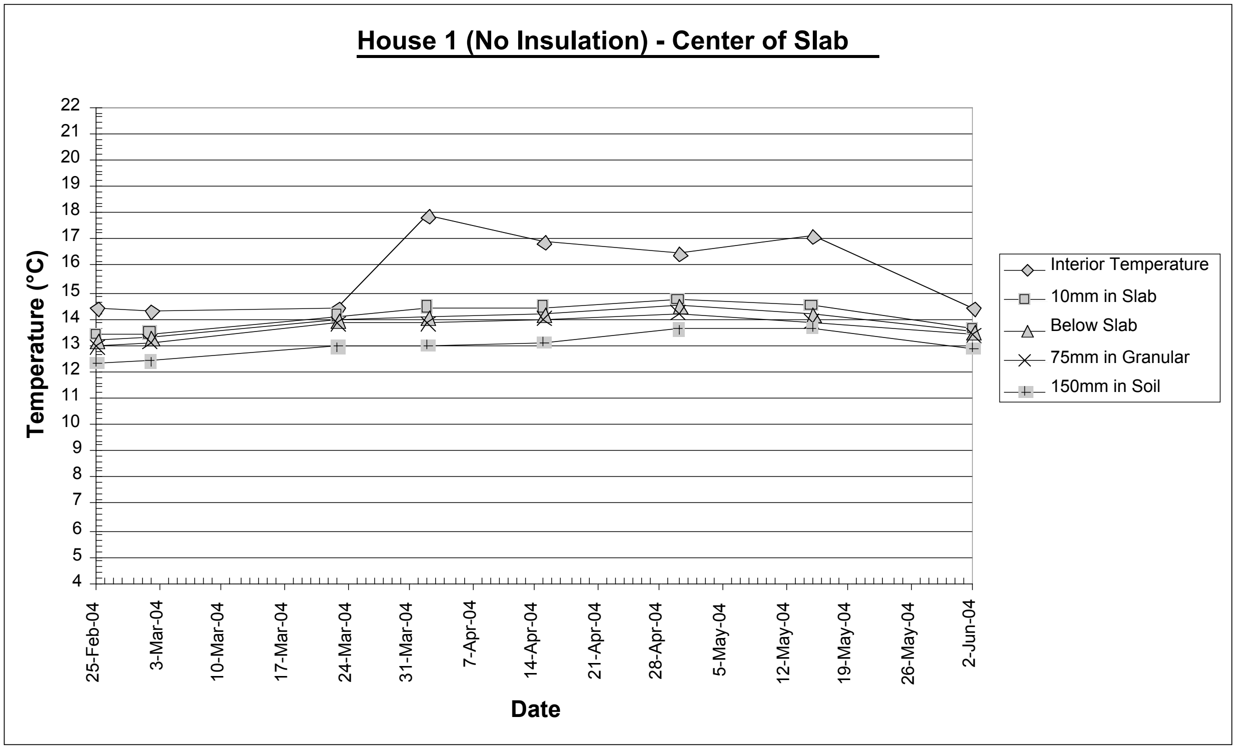

Figure 3.1: House #1 Temperatures at Center of Slab

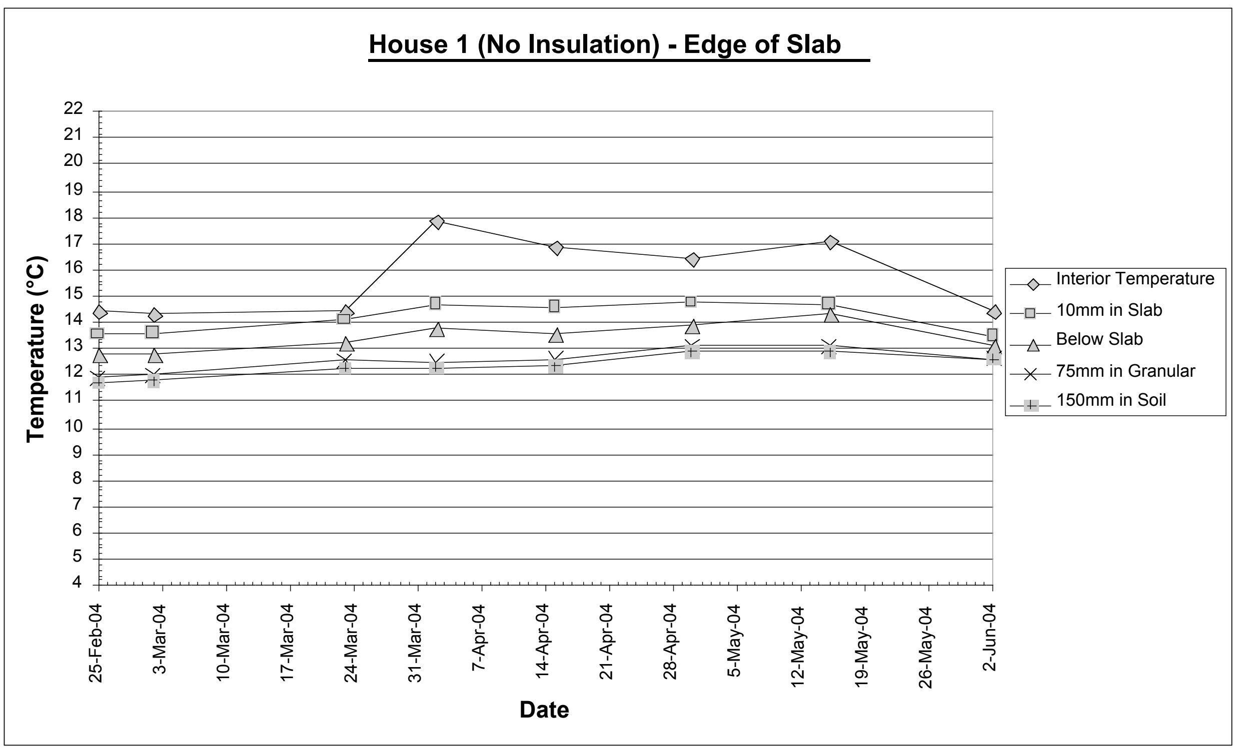

Figure 3.2: House #1 Temperatures at Edge of Slab

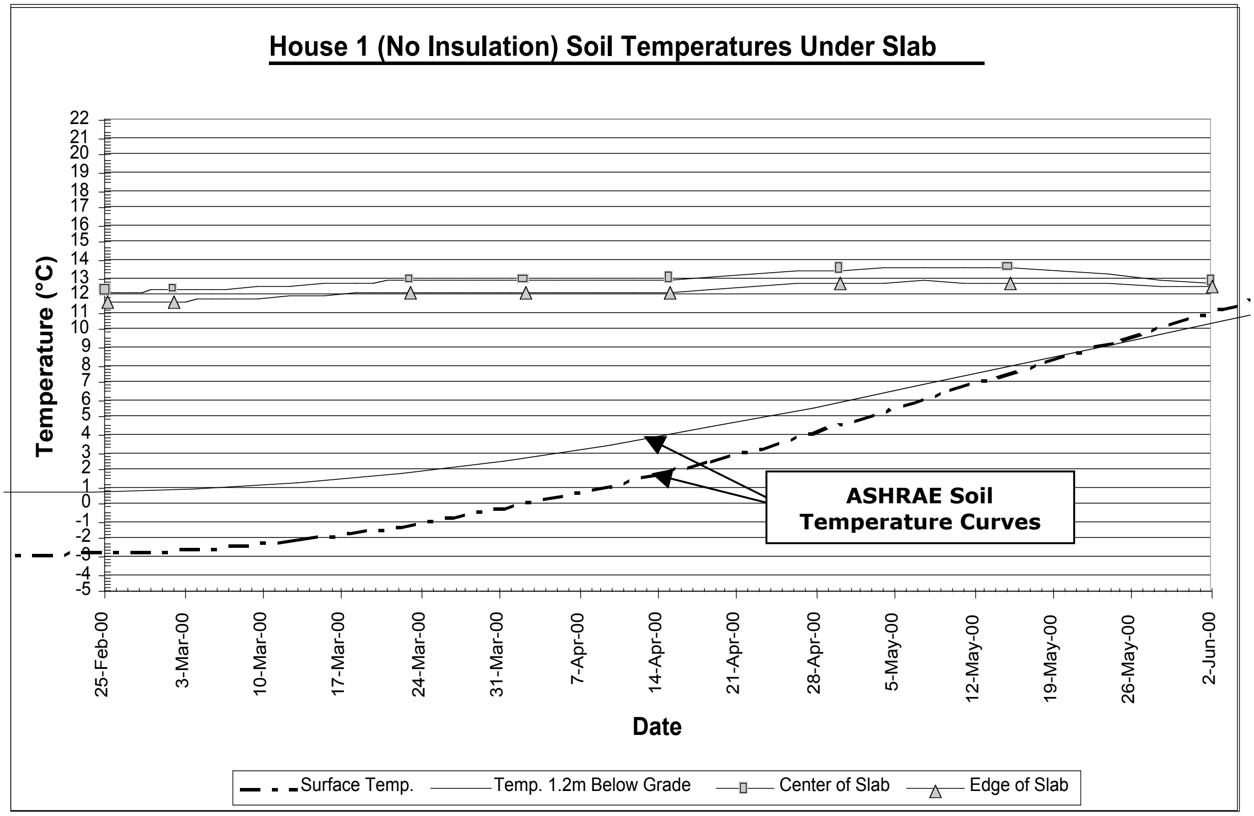

Figure 3.3: House #1 Soil Temperatures

Measurements from the house with bubble pack insulation (see Figures 3.4 to 3.6) show the following:

- The four points from the top of the slab to 300mm below the insulation have a temperature differential slightly greater than that observed with no insulation. The average temperature difference between the slab and the deep soil temperature was 2.7C^{o}, about double the value of the uninsulated slab.
- All of the recorded temperatures, including the deep ground temperature, appear to be influenced by the basement temperature. The influence of this temperature on the ground is evident during most measurement periods, as the ground temperatures generally move in the same direction as the slab temperature.
- As in the house with no insulation, the measured ground temperatures were higher than expected. Under the bubble pack insulated slab, the ground temperature was around 11^{o}C at the beginning and 14^{o}C to 15^{o}C at the end of the test period.
- The temperature trends through the bubble pack insulated floor are similar in nature to those of the uninsulated floor.

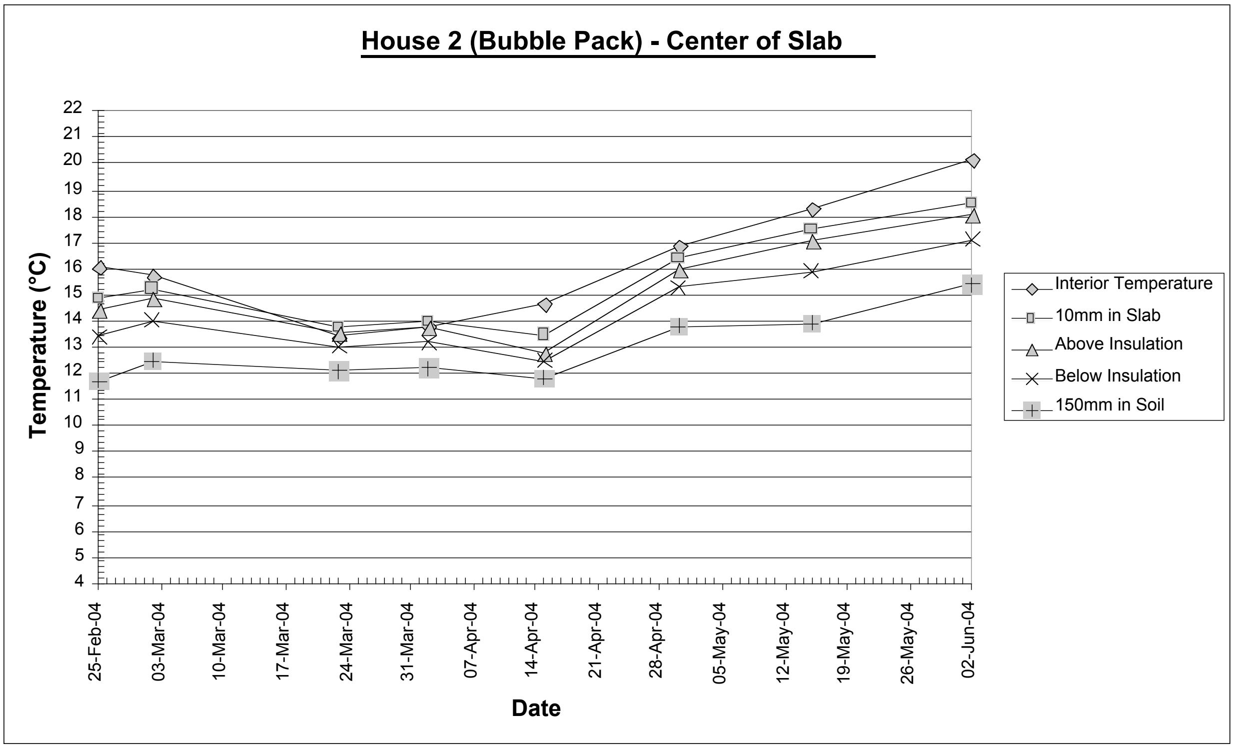

Figure 3.4: House #2 Temperatures at Center of Slab

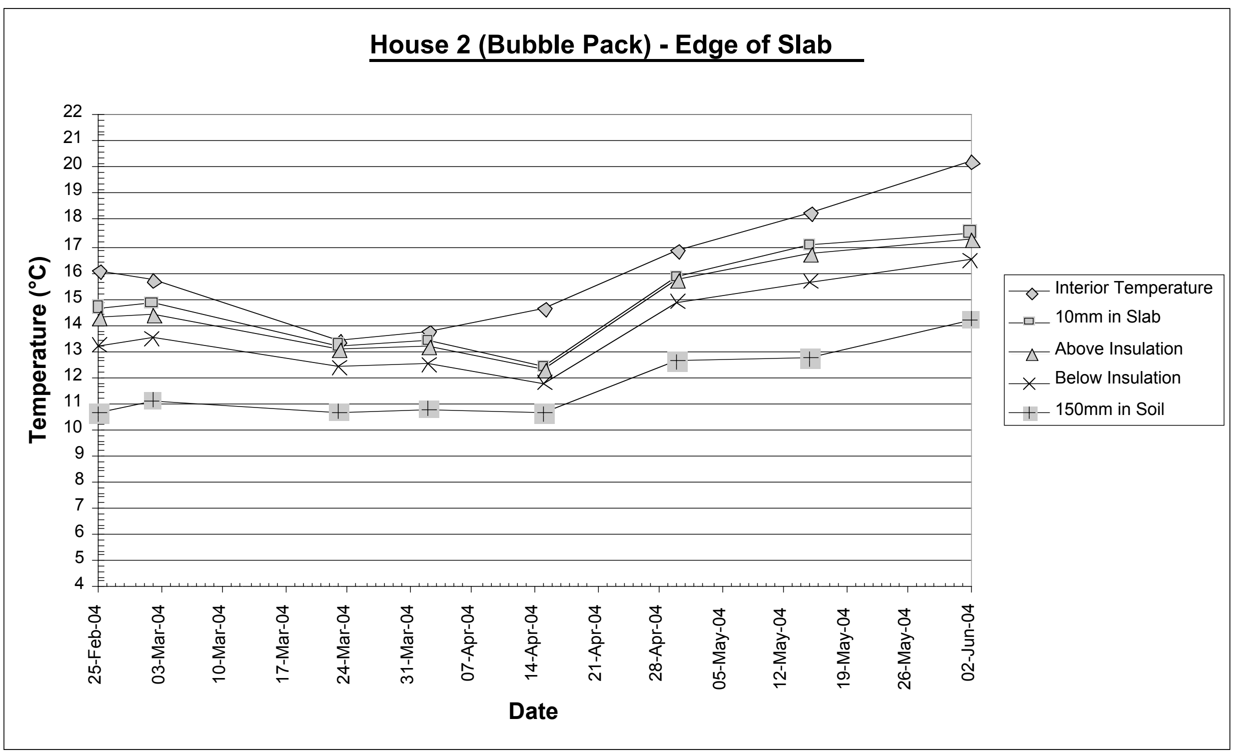

Figure 3.5: House #2 Temperatures at Edge of Slab

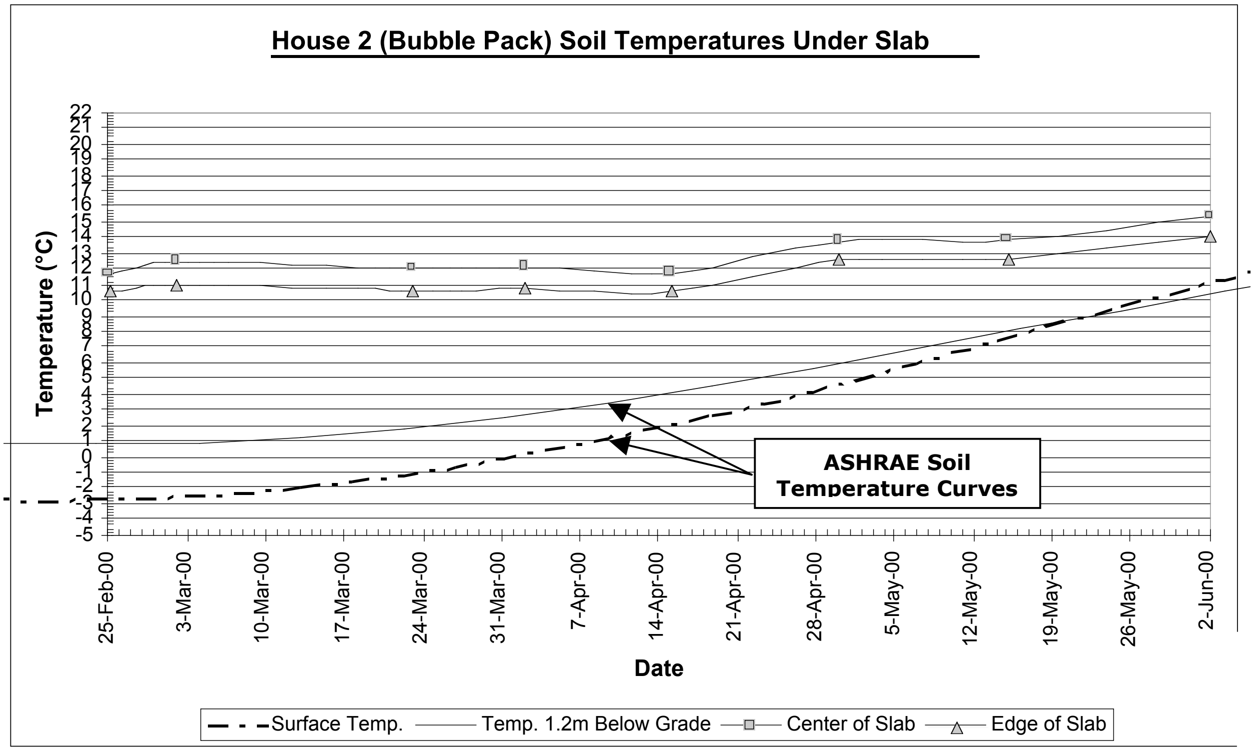

Figure 3.6: House #2 Soil Temperatures

Measurements from the house with steel-skinned polyurethane installed (see Figures 3.7 to 3.9) show a different pattern than was observed in the first two houses. They show the following:

- The four temperatures from the top of the slab to 300mm below the slab appear to be separated into two regions. The first region contains high slab temperatures that closely follow the pattern of space temperature. The second region contains low ground temperatures that rise slowly as the weather warms. The average temperature difference between the slab and the deep soil was 7.2C^{o}.

- The measured ground temperatures are higher than normal for undisturbed ground temperatures at that depth at the beginning of the test period (4.5 to 6^{o}C vs. ~2^{o}C). At the end of the measurement period temperatures rise closer to normal values (approx. 11^{o}C). This suggests that there is some heat loss from the house to the ground when the ground is cold and that heat loss is reduced as the ground temperature rises.

- It would appear that natural ground temperatures have more influence on the soil temperature measured 300mm below the insulation than do indoor temperatures. The ground temperature rose slowly over the test period ending near the expected ground temperature for that depth.

- The temperature trends through the steel-skinned polyurethane insulated floor are similar in nature to those of the XPS insulated floor.

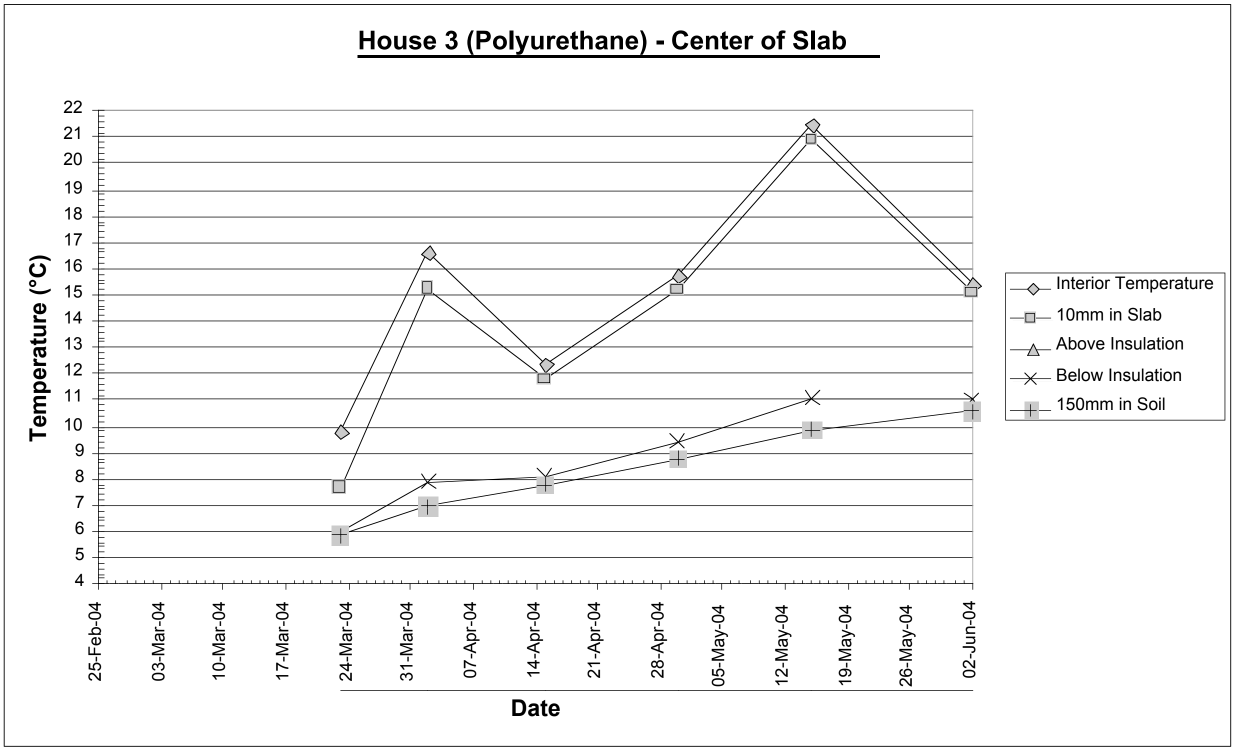

Figure 3.7: House #3 Temperatures at Center of Slab

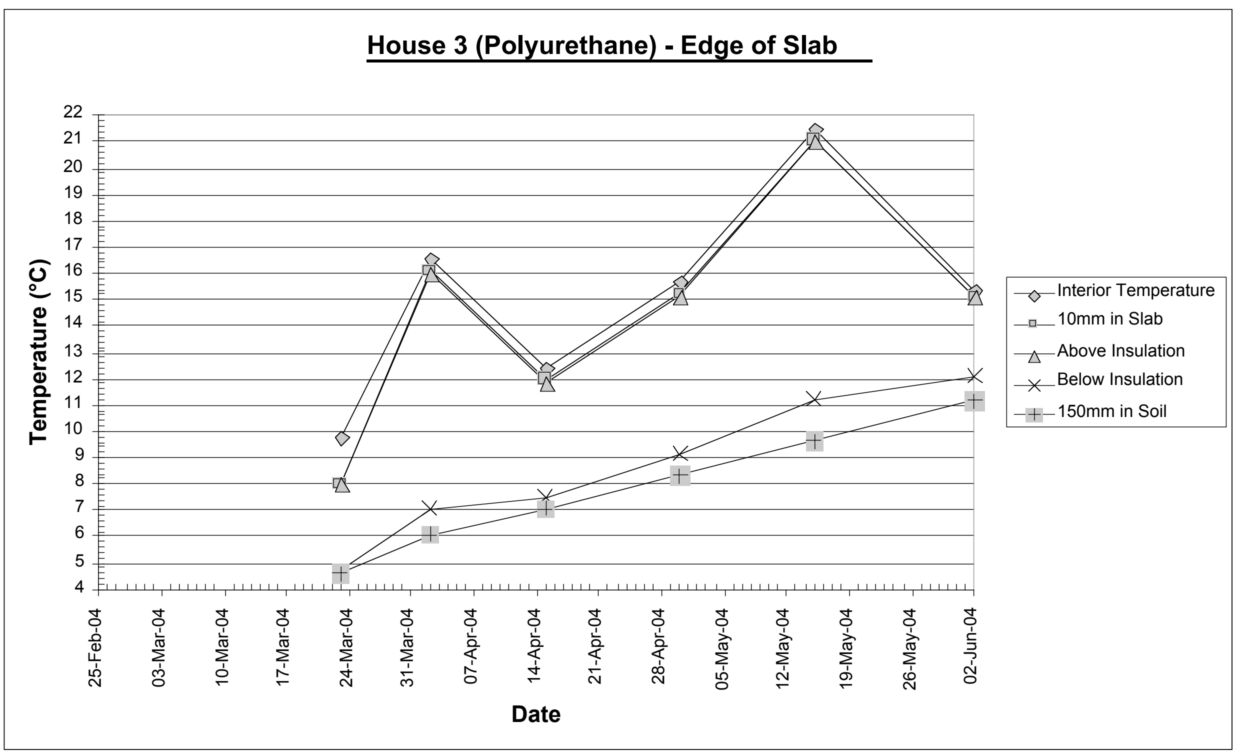

Figure 3.8: House #3 Temperatures at Edge of Slab

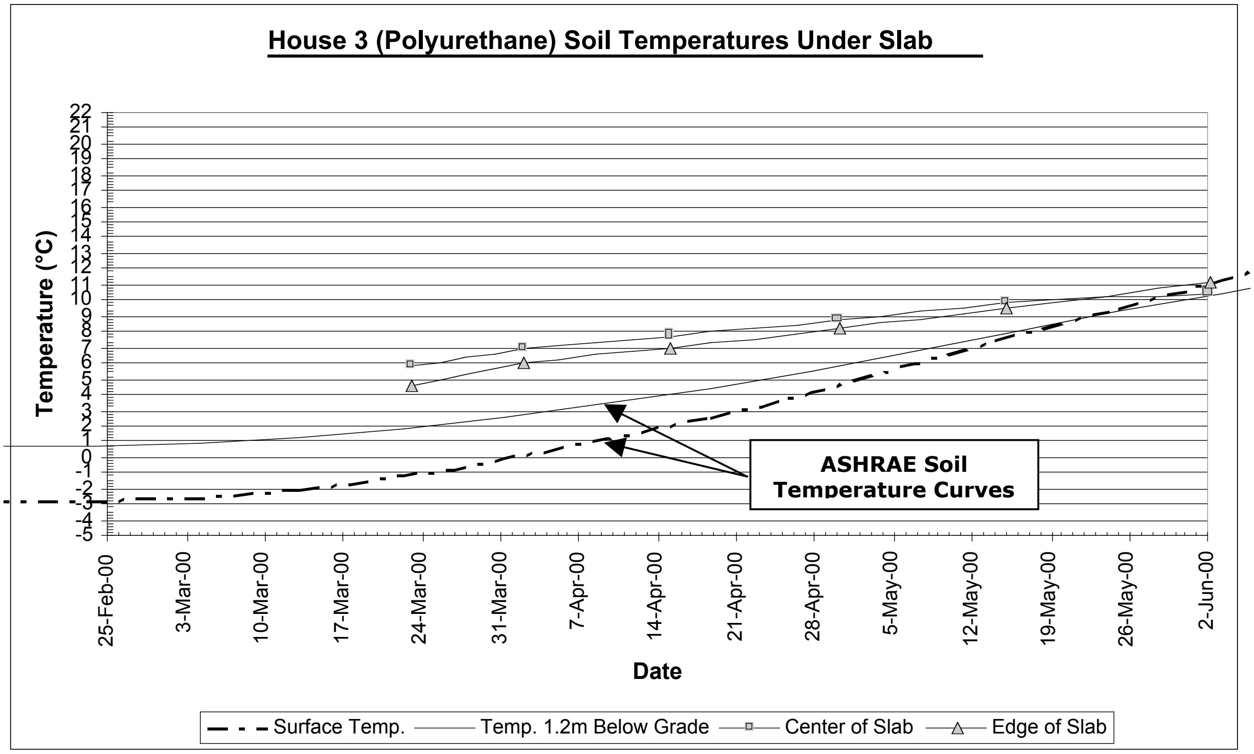

Figure 3.9: House #3 Soil Temperatures

Measurements from the house with 50mm (2”) of extruded polystyrene insulation (see Figures 3.10 to 3.12) showed a similar pattern to what was observed in the house with the polyurethane. They show:

- The four temperatures from the top of the slab to 300mm below the slab are separated into two regions. The first region contains high slab temperatures that closely follow the pattern of space temperature. The second region contains low ground temperatures that rise slowly as the weather warms. The average temperature difference between the slab and the deep soil was 6.4C^{o}.

- The measured ground temperatures are higher than normal for undisturbed ground temperatures (at a depth of 1.2 m (4 ft)) at the beginning of the test period (6 to 7^{o}C vs. ~2^{o}C). The measurements rose to about normal temperatures at the end of the test period (approx. 10^{o}C). This suggests that there is some heat loss from the house to the ground when the ground is cold and that heat loss is reduced as the ground temperature rises.

- It would appear that natural ground temperatures have the largest influence on the soil temperature measured 300mm below the insulation. The ground temperature rose slowly over the test period ending near the expected ground temperature for that depth.

- The trends discussed above are indicative of an insulated floor slab.

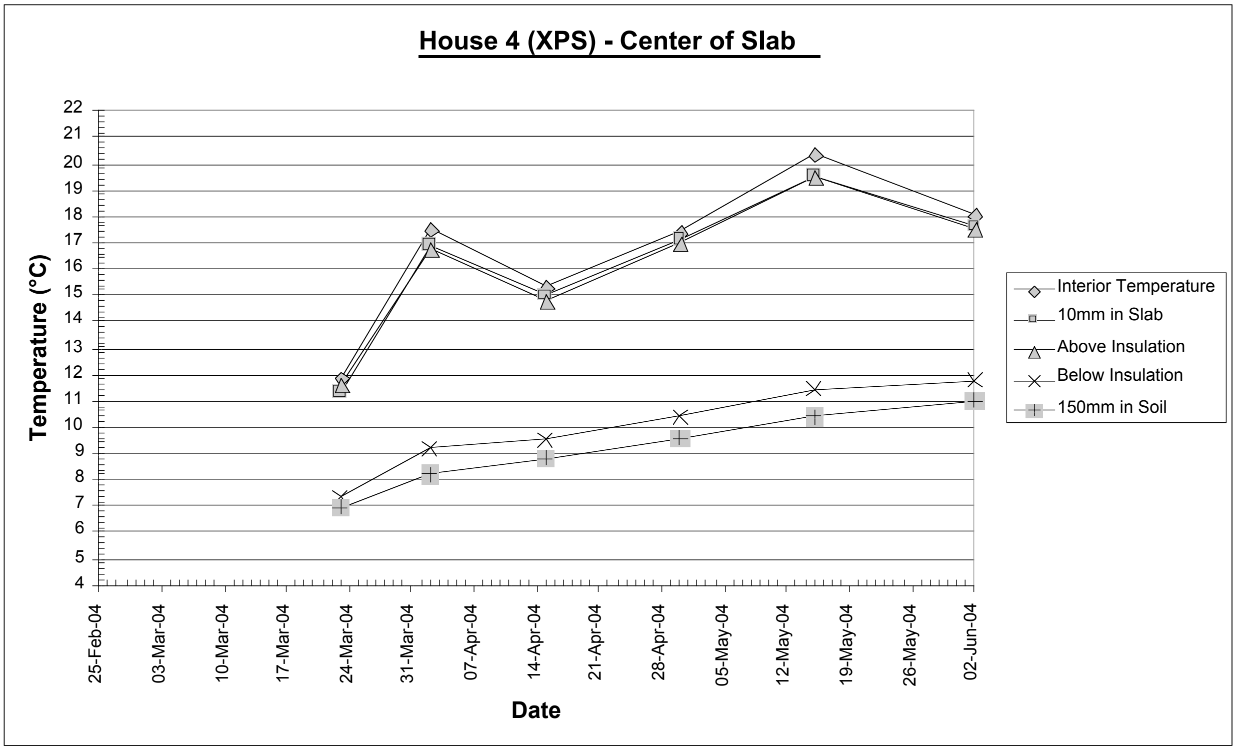

Figure 3.10: House #4 Temperatures at Center of Slab

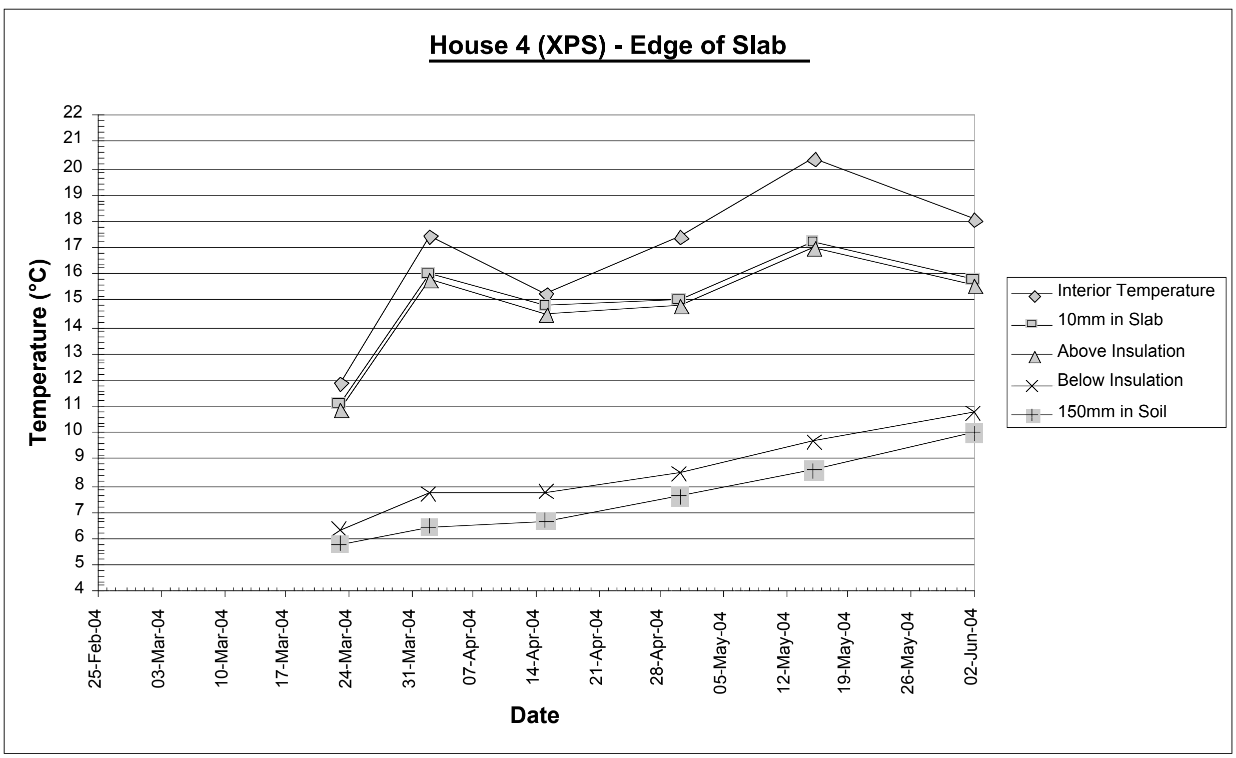

Figure 3.11: House #4 Temperatures at Edge of Slab

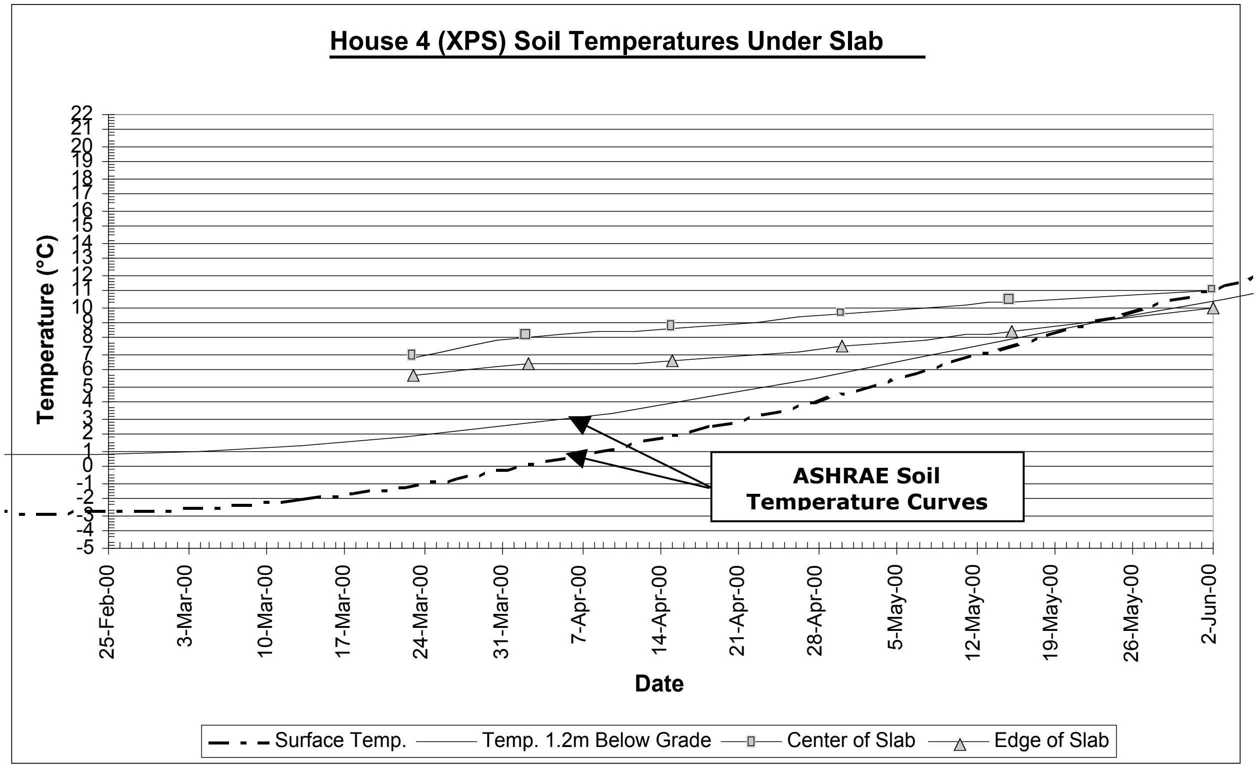

Figure 3.12: House #4 Soil Temperatures

4.0 ANALYSIS

4.1 Thermal Performance

Analyzing the bimonthly monitored data presented in Section 3 gives the insulation performance for each house. An analysis of each house has been provided below.

To determine the insulating value of the unknown materials (bubble pack and steel-skinned polyurethane), the heat flow through the floor for each data set was first calculated using the known conductance of the airfilm and the concrete. The heat flow through layers of material in series is equal through all layers at any given point in time at steady state. *(Note: The basement temperatures varied slowly and the capacitance of the concrete slab was sufficiently small (approx 215 kJ/m^2/C^o or 10.5 BTU/ft^2/F^o) to allow using an assumption of steady state heat flow at each measurement set.)* The known heat flow was then used to calculate the thermal resistance (RSI) value (inverse of conductance (RSI = 1/C)) of the insulation material. The same methodology was used for the XPS. Checking the XPS values against published values verified that the measurements and the calculation methodology were valid.

A physical sample of the concrete used for the house slabs was measured at a density of 2412 kg/m^3. The published U-value of 15 W/m^2/C^o based on a slab thickness of 100mm has been used for all calculations [ASHRAE, 2001]. A U-value of 6.25 W/m2/C° was used for the airfilm based on a horizontal surface and a downward flow of heat [ASHRAE, 2001]. All calculations were based on an area of 1m^2. The formula below was used to calculate the heat flow through both the concrete and the airfilm for both locations in each of the three insulated houses for each measurement set.

$$q = u \cdot a \cdot \Delta t$$

Where,

q = Heat Flow (W)
u = Conductance (W/m^2/C°)
a = Area (m^2)
Δt = Temperature gradient (C°)

The RSI-values for all three insulation materials were calculated for each data set and then averaged for all data sets per house, including each of the two locations, to determine an overall average RSI-value. The results of these calculations are provided in Table 4.1.

House #3 had a damaged sensor above the insulation layer in the center of the slab. To estimate a temperature at that location, the temperature drop across the slab at the edge was multiplied by the ratio of temperature drops across the airfilm at the centre versus the edge. The result was then subtracted from the temperature at the top of the slab.

Insulation Product	RSI (m^2-C°/W)	Standard Deviation	R-Value (h·ft^2·°F/Btu)	Standard Deviation
Bubble Pack	0.40	0.37	2.3	2.1
Steel Skinned Polyurethane	2.56	1.74	14.5	9.9
Extruded Polystyrene	2.13	1.00	12.1	5.7

Table 4.1 Calculated U-Values

The calculated thermal resistance for XPS is about 12% above the CCMC published long term value of RSI-1.86 (R-10.6) [CCMC, 2003]. New foam insulating materials typically have a higher insulating value than the long term thermal resistance accepted for code compliance. Finding the experimental RSI-value for XPS came close to the expected value gives confidence that the RSI-values for all insulating materials tested are reasonable.

As can be observed in table 4.1, there is a relatively large standard deviation for all materials. Some possible reasons for this include:

- a relatively large difference in conditions between each of the data sets
- a relatively small number of readings at similar conditions
- temperature readings that could be relatively close together
- potential for some non-steady state conditions

The steel-skin polyurethane had a measured thermal resistance 14.3% to 22.5% higher than the values provided by the manufacturer (based on ASTM C 518 tests) for material aged 2 days and 19 days respectively. As with XPS, the results are reasonably close to the published values, providing confidence in the calculated values.

The manufacturer of the bubble pack suggests that the total thermal resistance of the product is the average of the conductive and radiative resistance to heat transfer. When tested in accordance with ASTM 236 they found a conductive resistance of only RSI-0.67 (R-3.8). A thermographic test determined an RSI value of 1.76 (R-10) for the reflective barrier. Finally, taking an average of the two values the manufacturer calculated a blended RSI value of 1.2 (R-6.9).

The calculated thermal resistance of the bubble pack, based on the measured results from these tests, is RSI-0.40 (R-2.3). The measurements were made in-situ and so this value includes all modes of heat transfer (conductive and radiative) for the entire product under actual operating conditions.

There are two main reasons for the difference between the manufacturer's claims and the in-situ test results. Theoretically a reflective barrier requires an air gap between the foil and the radiating surface to function. Any conductive paths (such as the edges of the bubbles) that come in contact with the foil will reduce the radiative properties. Secondly, the greater the temperature difference between the radiating surface (concrete slab) and the foil, the greater the potential value of the radiant barrier. If the temperature difference is small the radiative component of heat transfer will be less than the 50% assumed when the average was used to calculate the blended R-value.

The measurements show that the ground under the bubble pack is heating and cooling in response to temperature changes in the house. Therefore, heat is passing through the bubble pack as a result of all modes of heat transfer. Because the ground remains closer in temperature to the slab, there is very little radiant energy to reflect and therefore any reflective properties would have a minimal impact on thermal performance. Still, the product adds an insulating value roughly two times that of an uninsulated floor.

Comparing the RSI-values obtained in the calculations shows that the steel-skinned polyurethane panels, with a thickness of 44 mm, are about as good, if not slightly better, than 50 mm of XPS. The bubble pack provides only 20% the insulating value of 50 mm of XPS.

4.2 Economic Performance

A cost/benefit analysis of each insulation is best provided in terms of $\$/m^2$_RSI. In other words how much does it cost to obtain a given insulating level over a given area.

Table 4.2 compares the relative costs and the cost effectiveness of the materials tested. We see that on a pure cost per unit area basis that 50 mm of XPS is the most expensive. The bubble pack and the steel-skinned polyurethane are about 1/3 the cost. However, on a cost/benefit basis the order essentially reverses. The steel-skinned polyurethane panels have the best cost benefit ratio at under \$2.00/m^2_RSI, XPS is in the middle at \$6 to \$8/m^2_RSI and bubble pack is relatively the poorest of those tested at \$12 to \$13/m^2_RSI.

Insulation Product	Cost per Unit Area (\$/m^2)	RSI-Value	Cost Benefit (\$/m^2_RSI)
Bubble Pack	4.85 - 5.35	0.40	12.13 – 13.38
44 mm Steel-Skinned Polyurethane	4.85	2.56	1.89
50 mm XPS	12.90 - 17.22	2.13	6.05 – 8.08

Table 4.2: Cost Effectiveness of Three Insulation Materials

5.0 CONCLUSION

The effective RSI-value of two new insulation products was tested with two known cases used as reference points, no insulation and 50 mm of XPS. The measured values are given in Table 5.1 below. These values are for in-situ performance and therefore include all modes of heat transfer.

Insulation Product	Thermal Resistance (RSI)
44 mm Steel-Skinned Polyurethane	2.56
50 mm XPS	2.13
Bubble Pack	0.40

Table 5.1: RSI of Three Insulation Materials

Bubble pack insulation showed performance that was similar in nature to an uninsulated floor. There was little temperature difference between the inside of the basement and the ground below, the ground temperature varied with indoor temperature, and the ground under the insulation was warmer than undisturbed deep ground temperatures.

The steel-skinned polyurethane panels performed similar to 50mm of XPS. There was a wide temperature difference between the inside of the basement and the ground below, the ground temperature appeared to be influenced much more by ambient conditions than by indoor temperature fluctuations, and the ground temperatures were closer to expected undisturbed ground temperatures.

REFERENCES

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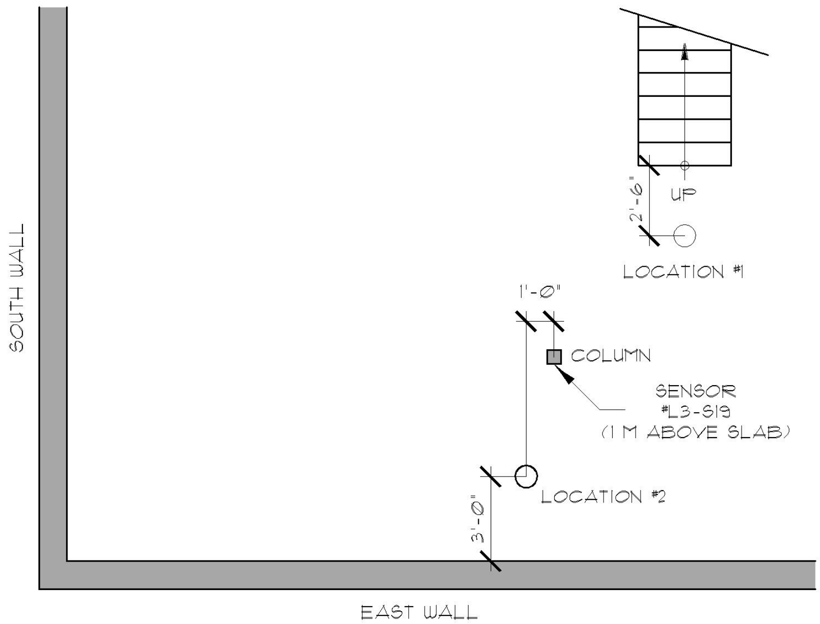
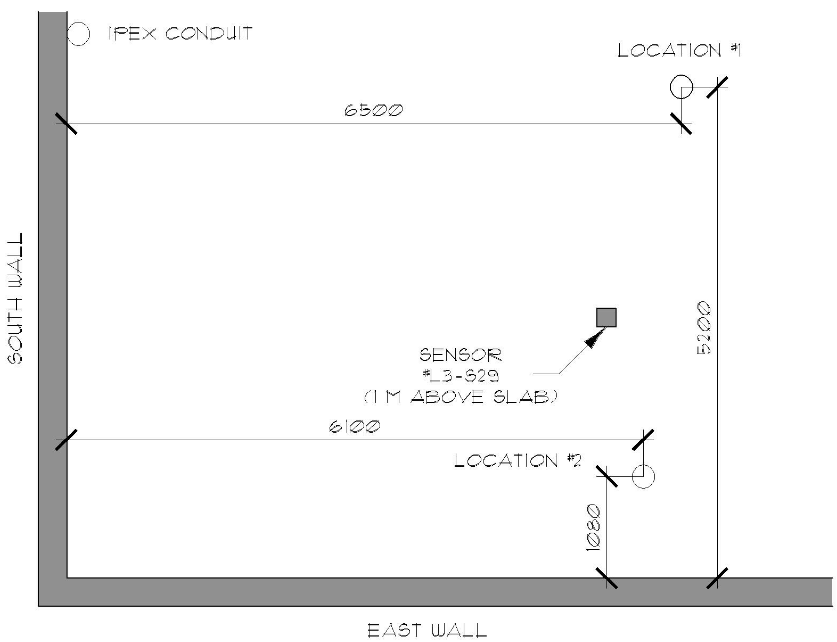
ASHRAE 2001. Handbook of Fundamentals, Chapter 25 Thermal and Water Vapour Transmission Data. Atlanta, GA

CCMC, 2003. Expanded Polystyrene Insulation Board – 07214.1. CCMC 06525-L.
Issued: 1983-06-17. Re-evaluated: 203-08-05.

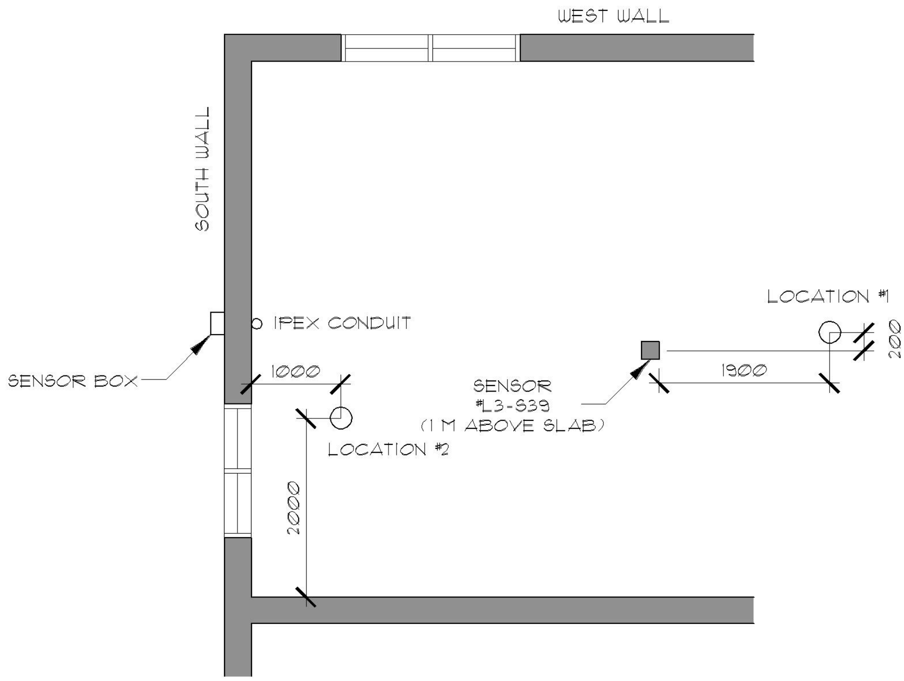
APPENDIX



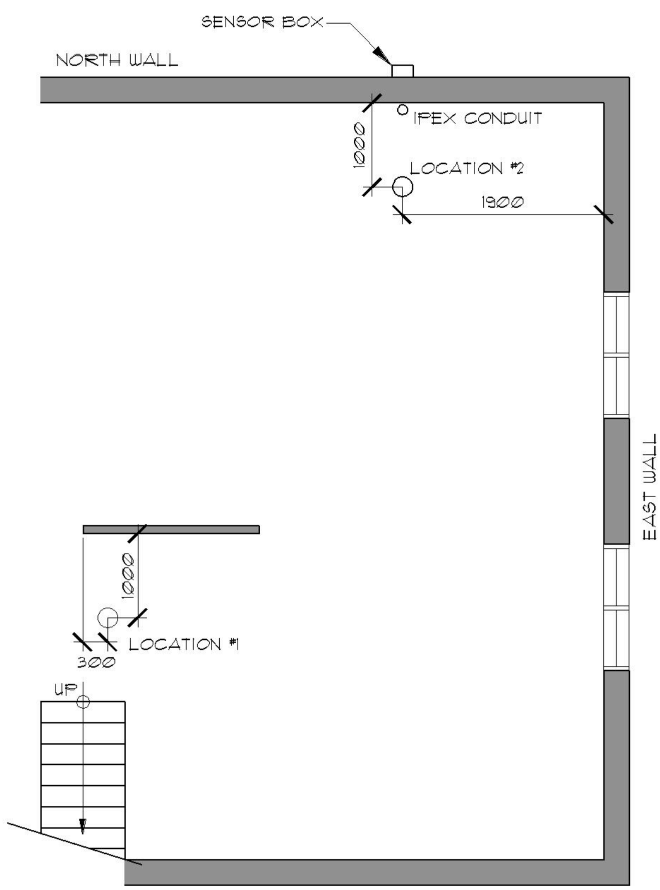
Sensor Locations for House #1 (No Insulation)



Sensor Locations for House #2 (CBF rFOIL)



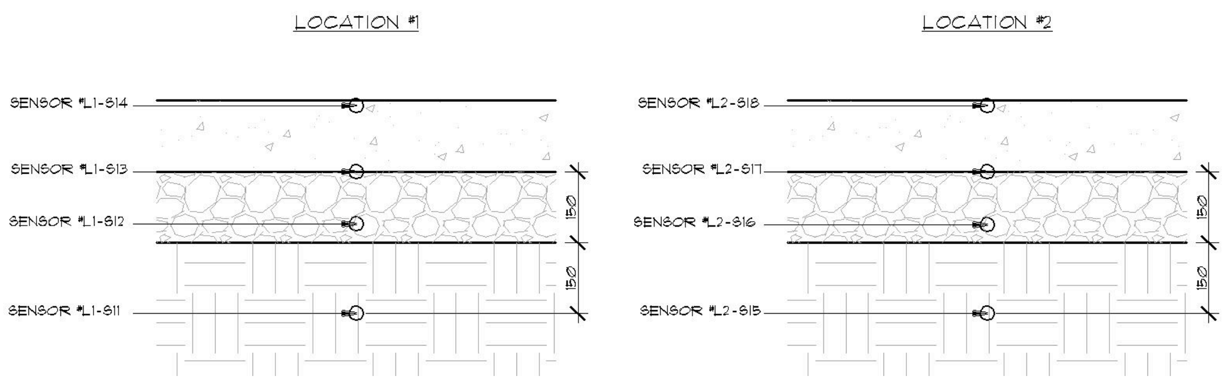
Sensor Locations for House #3 (Insta-Panels)



Sensor Locations for House #4 (Extruded Polystyrene)

House #1	Temperature Sensor Readings (°C)									Exterior
Date	Centre of Slab (Location #1)				Edge of Slab (Location #1)					Temp.
	L1-S14	L1-S11	L1-S12	L1-S13	L2-S15	L2-S16	L2-S18	L2-S17	L2-S19	(°C)
25-Feb-04	12.35	12.97	13.16	13.37	11.73	11.92	12.83	13.57	14.45	-4.50
02-Mar-04	12.41	13.09	13.28	13.44	11.79	11.99	12.80	13.59	14.30	4.90
23-Mar-04	12.96	13.80	14.00	14.10	12.31	12.56	13.20	14.08	14.40	-1.10
02-Apr-04	13.00	13.80	14.09	14.40	12.26	12.50	13.75	14.71	17.90	5.20
15-Apr-04	13.10	14.00	14.19	14.41	12.33	12.59	13.60	14.59	16.90	6.20
30-Apr-04	13.59	14.20	14.46	14.69	12.90	13.11	13.86	14.77	16.48	16.09
15-May-04	13.67	13.90	14.19	14.50	12.90	13.10	14.39	14.70	17.10	8.62
02-Jun-04	12.89	13.40	13.47	13.59	12.60	12.59	13.19	13.50	14.43	13.27

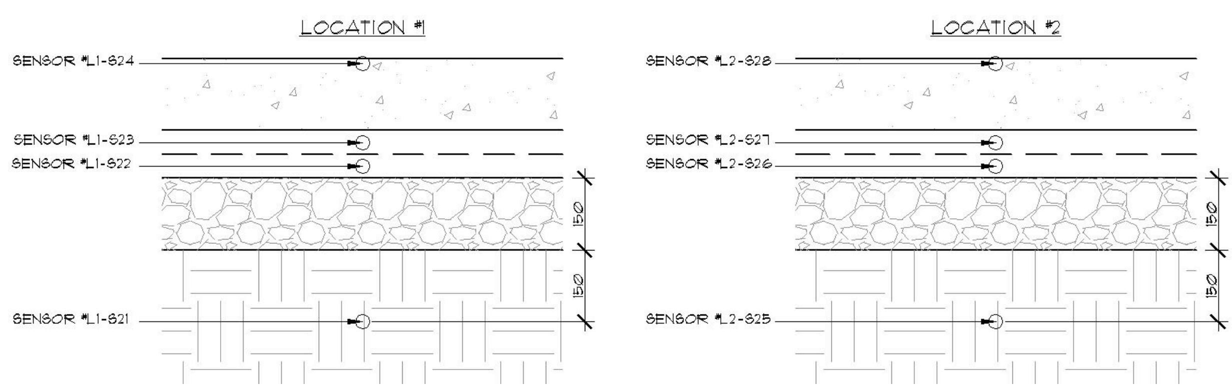
Temperature Sensor Readings for House #1 (No Insulation)



Sensor Cross Section for House #1 (No Insulation)

House #2	Temperature Sensor Readings (°C)									Exterior
Date	Centre of Slab (Location #1)				Edge of Slab (Location #1)					Temp.
	L1-S14	L1-S11	L1-S12	L1-S13	L2-S15	L2-S16	L2-S18	L2-S17	L2-S19	(°C)
25-Feb-04	11.70	13.40	14.39	14.83	10.62	13.20	14.32	14.64	16.08	-4.50
02-Mar-04	12.50	14.00	14.82	15.23	11.10	13.49	14.44	14.84	15.70	4.90
23-Mar-04	12.10	13.02	13.53	13.72	10.69	12.38	13.04	13.20	13.40	-1.10
02-Apr-04	12.20	13.20	13.79	13.99	10.80	12.50	13.20	13.40	13.80	5.20
15-Apr-04	11.80	12.50	12.79	13.45	10.60	11.80	12.30	12.41	14.67	6.20
30-Apr-04	13.79	15.30	16.00	16.39	12.60	14.90	15.70	15.79	16.89	16.09
15-May-04	13.89	15.89	17.10	17.50	12.70	15.65	16.70	17.02	18.29	8.62
02-Jun-04	15.41	17.09	18.01	18.50	14.21	16.49	17.29	17.51	20.21	13.27

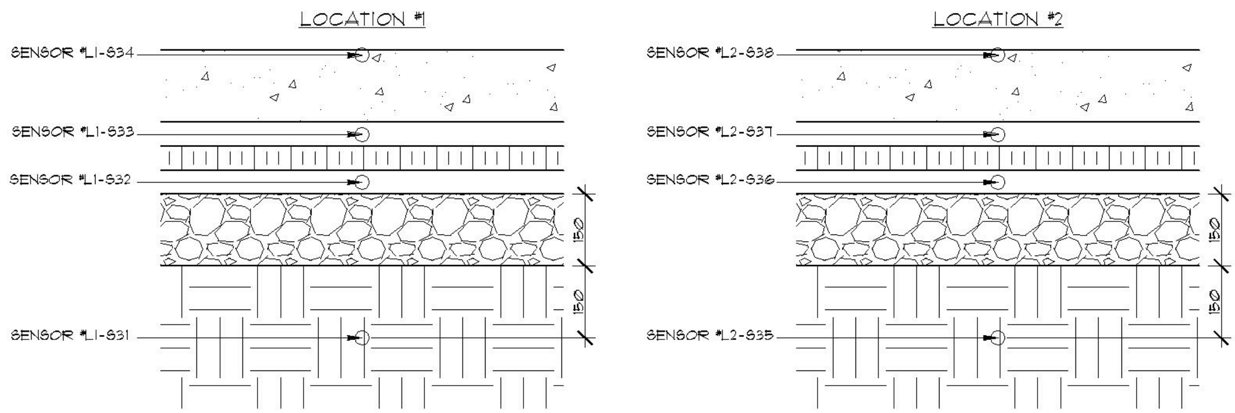
Temperature Sensor Readings for House #2 (CBF rFOIL)



Sensor Cross Section for House #2 (CBF rFOIL)

House #3	Temperature Sensor Readings (°C)									Exterior
Date	Centre of Slab (Location #1)				Edge of Slab (Location #1)					Temp.
	L1-S14	L1-S11	L1-S12	L1-S13	L2-S15	L2-S16	L2-S18	L2-S17	L2-S19	(°C)
23-Mar-04	5.89	5.96	+OPEN	7.67	4.60	4.70	7.98	8.00	9.81	-1.10
02-Apr-04	6.99	7.90	+OPEN	15.23	6.06	7.04	16.00	16.09	16.60	5.20
15-Apr-04	7.78	8.10	+OPEN	11.79	7.08	7.50	11.89	12.00	12.40	6.20
30-Apr-04	8.80	9.44	+OPEN	15.19	8.30	9.15	15.10	15.19	15.73	16.09
15-May-04	9.89	11.10	+OPEN	20.91	9.66	11.20	21.01	21.09	21.50	8.62
02-Jun-04	10.60	11.01	+OPEN	15.07	11.19	12.10	15.10	15.10	15.39	13.27

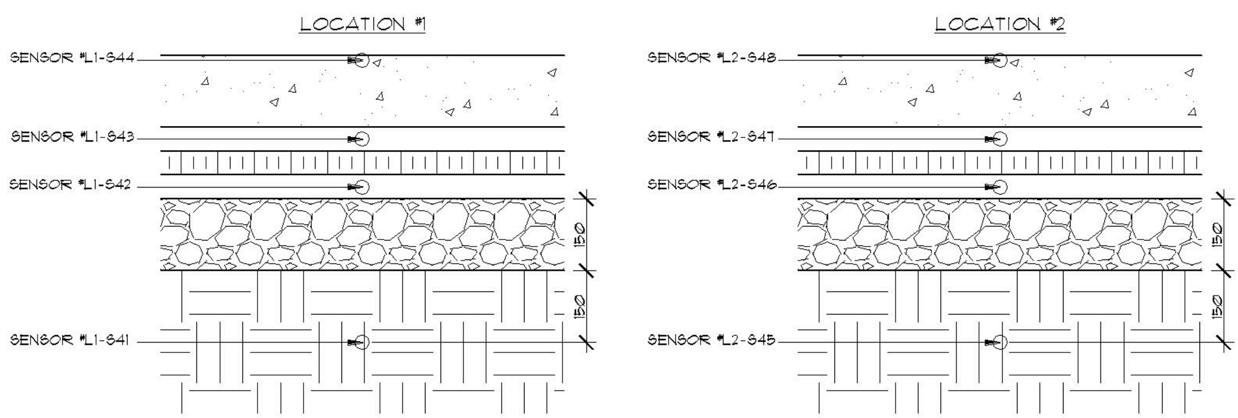
Temperature Sensor Readings for House #3 (Insta-Panels)



Sensor Cross Section for House #3 (Insta-Panels)

House #4	Temperature Sensor Readings (°C)									Exterior
Date	Centre of Slab (Location #1)				Edge of Slab (Location #1)					Temp.
	L1-S14	L1-S11	L1-S12	L1-S13	L2-S15	L2-S16	L2-S18	L2-S17	L2-S19	(°C)
23-Mar-04	6.97	7.36	11.58	11.34	5.79	6.33	10.91	11.10	11.90	-1.10
02-Apr-04	8.20	9.20	16.80	16.91	6.47	7.69	15.80	16.00	17.50	5.20
15-Apr-04	8.79	9.50	14.84	14.98	6.70	7.75	14.49	14.80	15.31	6.20
30-Apr-04	9.59	10.40	17.01	17.11	7.59	8.50	14.86	15.00	17.40	16.09
15-May-04	10.39	11.45	19.49	19.55	8.58	9.70	16.98	17.20	20.34	8.62
02-Jun-04	11.01	11.75	17.59	17.60	10.01	10.79	15.58	15.79	18.07	13.27

Temperature Sensor Readings for House #4 (DOW XPS)



Sensor Cross Section for House #4 (DOW XPS)