METHODS OF CONSTRUCTING DRY, FULLY INSULATED BASEMENTS

Report on Phase 1 of the

ONTARIO BASEMENT RESEARCH PROJECT

SCANADA CONSULTANTS LIMITED

Ottawa, April, 1991

DISCLAIMER

1. INTRODUCTION : RECHERCHE DE L'OHBA VISANT À AMÉLIORER LES CONSTRUCTIONS SOUS LE NIVEAU DU SOL

L'Ontario Home Builders' Association a commandé un projet de recherche et de démonstration ayant pour but d'étudier les aspects essentiels de la performance des murs de fondation. Ce projet vise précisément à s'attaquer aux causes des fuites d'eau et à examiner la faisabilité d'isoler intégralement les murs de fondation au moment de la construction.

La recherche de l'OHBA est financée collectivement par les ministères du Logement et de l'Énergie de l'Ontario, ainsi que par le Régime de garantie des logements neufs de l'Ontario; par la Société canadienne d'hypothèques et de logement et le Conseil national de recherches; de même que par l'Association canadienne du ciment Portland, l'Ontario Concrete Block Association et la Society of the Plastics Industry.

Les responsables du Régime de garantie des logements neufs de l'Ontario signalent que les fuites d'eau au sous-sol constituent le principal motif de plainte de la part des propriétaires. Les constructeurs en conviennent et en connaissent les conséquences : Frank Gianone, ex-président de la Toronto Home Builders's Association, estime qu'un sous-sol sur trois subit des problèmes d'humidité donnant lieu à des plaintes ou à des rappels, au cours de la première année suivant la construction; en moyenne, le sous-sol d'une maison neuve subit deux fuites en l'espace de deux ans. Ses chiffres indiquent qu'à la suite d'un rappel, le sous-sol entraîne en moyenne des réparations variant entre 300 et 500 $. Ni le constructeur ni l'acheteur ne considèrent les techniques d'exécution d'aujourd'hui comme acceptables.

Isoler intégralement les murs intérieurs n'augmentent peut-être pas les cas de fuite, mais les constructeurs savent pertinemment bien que la présence d'isolant ajoute considérablement au coût du repérage et de colmatage des fuites et de remise en état. Importent encore plus les effets à long terme pouvant mettre en cause l'isolant : la prolifération de moisissure et la pourriture du bois pouvant découler de l'humidité de la construction, les fuites d'eau ou les inondations depuis l'extérieur ainsi que la condensation de la vapeur d'eau à l'intérieur s'accumulant de façon excessive ou simplement emprisonnée trop longtemps. Par la même occasion, les attentes sont de plus en plus élevées quant à la façon dont le sous-sol se comporte comme aire habitable saine ou tout au moins comme aire pouvant facilement devenir habitable. L'objectif consiste à en arriver à ce que le constructeur réalise et l'acheteur obtienne des murs isolés intégralement, avec la conviction de pouvoir compter sur un milieu habitable sec.

Étendue et méthode : La recherche de l'OHBA se fait en deux étapes. **La phase I**, étude de la documentation dont le présent rapport tire des conclusions, s'inspire largement de l'expérience des constructeurs à pied d'oeuvre et d'études en ce sens, de même que des principes théoriques de la science du bâtiment dont la solidité a été éprouvée par des essais ou la mise en pratique au Canada ou ailleurs. Les nombreux systèmes envisagés sont reproduits sous forme de tableaux synoptiques à l'Annexe 1. **La phase 2** pourra porter sur divers moyens d'assurer la diffusion technologique des systèmes réalisables.

Le comité directeur de l'OHBA a été d'un précieux secours à cet égard; en effet, ses membres actifs comptent des représentants expérimentés regroupant des coffreurs de béton, des spécialistes en isolation et en pose de membranes d'étanchéité de même que des constructeurs et des recherchistes. Les auteurs ont aussi tiré avantage de l'utile contribution d'autres experts et promoteurs de systèmes innovateurs. De plus, ils ont puisé librement parmi les commentaires des membres du comité, des recherchistes indépendants, les fiches techniques de produits exclusifs ou la documentation, - laquelle est consignée à l'Annexe 1 - toujours dans l'optique d'apporter des solutions éprouvées à la construction de murs de sous-sol secs, isolés intégralement.

La tâche de trouver et de choisir de tels systèmes améliorés a été répartie en sous-tâches individuelles :

i) Évaluer la «constructibilité», les compétences requises des exécutants, et les coûts (en cas d'emploi dans un grand ensemble) de recourir à divers types de murs de sous-sol isolés intégralement, d'abord en fonction des **murs en béton** disponibles ou de toute évidence prêts pour être adoptés par l'industrie.

ii) Étudier leur sensibilité à l'humidité de la construction et remédier à la situation, le cas échéant.

iii) Étudier et régler la question de l'évacuation de l'eau depuis l'extérieur, ainsi que leur comportement en cas d'inondation et de problèmes consécutifs.

iv) Étudier et régler leur capacité à éviter l'accumulation d'un surplus de condensation et d'emprisonner longtemps l'humidité de toute provenance.

v) Étudier et régler la capacité à longue échéance des types de murs à économiser l'énergie.

vi) Évaluer les solutions **innovantes** qui semblent intrinsèquement acceptables (mais pas nécessairement sanctionnées par le code du bâtiment), économiquement réalisables par les constructeurs en général et rendant les sous-sols conformes aux objectifs établis.

vii) Répéter les étapes précédentes en fonction des murs **en blocs de béton.**

viii) Recommander, de concert avec l'industrie, les options les plus judicieuses et les plus économiques. L'industrie pourra alors puiser parmi les options avancées, en faire la démonstration en service et procéder à leur utilisation.

La recherche de l'OHBA porte, rappelons-le, uniquement sur les murs de sous-sol en béton ou en blocs de béton. C'est d'ailleurs ce que privilégient la plupart des constructeurs ontariens. Certaines méthodes ou systèmes relevés ici pourraient, bien sûr, se prêter à d'autres matériaux structuraux des sous-sols. Le but consiste simplement à trouver des moyens pratiques de construire des murs de sous-sol secs, isolés intégralement.

7. CONCLUSION : DES CHOIX JUDICIEUX À PORTÉE DE LA MAIN PERMETTENT DE BIEN RÉALISER DES MURS DE SOUS-SOL

Les constructeurs d'habitations vous le confirmeront : avant d'exiger l'isolation intégrale des murs de sous-sol pour contrôler le mouvement de la chaleur, déterminez comment mettre un terme aux fuites et contrôler le mouvement d'humidité. Il est conclu ici que des éléments et modèles simples permettent d'accomplir tout ça, moyennant un certain prix, sans compter qu'elles s'inscrivent tout à fait dans les techniques contemporaires de construction à pied d'oeuvre.

Seulement deux principales démarches peuvent être recommandées pour éliminer la présence d'eau : d'une part, celle qui touche la mise en oeuvre d'isolant côté extérieur et, d'autre part, celle qui touche la mise en oeuvre d'isolant côté intérieur.

1) Il est plus facile de mettre en oeuvre l'isolant par l'extérieur; en effet, le matériau isolant peut aider grandement à contrer l'infiltration d'eau souterraine et à assurer la gestion de toute l'humidité, en plus de protéger tout type de matériau d'étanchéité contre les dommages causés lors du remblayage. (En outre, si une certaine quantité d'eau s'infiltre à l'intérieur, les réparations pourraient ne pas coûter plus cher que c'est présentement le cas.) Sur la foi de l'expérience acquise à ce jour sur le terrain, les partisans de l'isolation extérieure au sein de l'industrie sont convaincus que les matériaux d'aujourd'hui appliqués à l'état humide n'ont pas besoin d'être remplacés par d'autres bons matériaux d'étanchéité. En guise de conclusion, la préférence devrait certes aller aux membranes ou pellicules à l'état sec, mais il ne saurait être question d'en faire une exigence générale.

2) L'isolation intérieure est beaucoup plus exigeante, puisqu'elle suppose d'éliminer par des moyens sûrs l'eau ou l'humidité qui risquerait de s'infiltrer par la paroi extérieure du mur. En l'occurrence, la présence d'isolant n'aide pas, mais pourrait même ajouter considérablement au coût de réparation si des fuites étaient décelées ou si les moyens d'éliminer l'humidité se révélaient inadéquats. En Norvège, seul autre pays où la plupart des maisons reposent sur des murs de sous-sol, on est arrivé à la conclusion il y a deux décennies que l'étanchéité devait être assurée par une membrane usinée appropriée. Puis, on s'est mis à penser qu'il faudrait peut-être faire appel à une membrane à dépression alvéolaire qui, tout en ajoutant peu au coût, crée un espace d'air entre la membrane et le mur,

   - assurant un deuxième moyen de prévenir les fuites depuis l'extérieur, et toute liberté de drainage;

   - agit tel un dispositif de compensation et d'évacuation conditionné par le sol, destiné à éliminer l'humidité de la construction ainsi que toute humidité provenant de l'intérieur ou au-dessus du niveau du sol.

Les ingénieurs et les spécialistes de la science du bâtiment attestent que ce moyen simple a été tout à fait éprouvé sur le terrain. Il est recommandé pour les murs de sous-sol devant être isolés intégralement côté intérieur. Il est recommandé de préférence pour les murs en blocs de béton et autres types de construction, malgré le fait qu'ils n'ont pas tellement d'humidité à dissiper et qu'une membrane ordinaire robuste ferait tout aussi bien l'affaire.

En fin de compte, là où le refoulement d'eaux d'égout pose un risque réel, les murs de sous-sol isolés de l'une ou l'autre manière devraient être pourvus d'un dispositif de protection contre les inondations situé de 300 à 500 mm au-dessus de la semelle, comme l'indique la section 2.1

Assortis de la mesure de protection contre l'eau tout indiquée, les murs en béton ou en blocs de béton donneront sensiblement les mêmes résultats. En cas d'isolation extérieure, le recours à des blocs décoratifs confère à la paroi intérieure du mur un aspect fini.

Pour les murs pourvus d'isolant extérieur recouvert d'un placage de maçonnerie, il est recommandé de prévoir une coupure thermique conforme aux dispositions de la section 4.5 ou l'équivalent. Compte tenu de cette coupure thermique, l'isolant pleine hauteur joue bien son rôle. Sur le plan thermique, les résultats diffèrent très peu selon qu'il s'agit d'un mur isolé de l'intérieur, de l'extérieur ou dans sa masse.

Le défi d'assortir d'un parement robuste, esthétique et économique la portion hors du sol de l'isolant extérieur, quelle que soit la saison de la mise en oeuvre, est présenté à la section 4. La conclusion est qu'on pourra dorénavant respecter cette exigence en élaborant des systèmes en panneau monopièce solin-parement. Le PVC ou les hauts polymères peuvent bien se comporter sur ce plan, alors que les composants ciments-fibres de bois et particulièrement les pouzzolanes-fibres de bois semblent très prometteurs.

En résumé, les choix de systèmes soumis à l'étude de l'industrie de la construction, pourvu que les mesures de protection contre l'eau et de protection thermique soient adoptées selon les indications, se répartissent comme suit, généralement par ordre de coûts ascendants (Annexe 3). La situation par rapport au code du bâtiment doit faire l'objet d'une vérification. Pour référence rapide, le numéro de l'article traitant des systèmes apparaît en premier :

6.1.1 Matelas intérieur de fibre minérale-plastique laminé

5.4.2 Plastique cellulaire extérieur - PSE, type 2 (ou plus élevé)

5.3.3 Plastique cellulaire intérieur - PSE, type 1 (ou plus élevé)

5.3.1 Ossature de bois-fibre minérale intérieure, drainage

5.4.1 Panneau extérieur de drainage, en fibre de verre

... et des choix maintenant à la portée de la main, ou maintenant acceptés et disponibles; certains semblent avoir été tout à fait éprouvés en service en Amérique du Nord et à l'étranger :

6.2.1 Panneau de drainage extérieur en PSE

6.3.3 Béton isolant en PSE-fibrociment

6.2.2 Polyuréthane projeté à l'extérieur et protégé

... et finalement, compte tenu surtout du coût, ces matériaux semblent prometteurs :

6.3.2 Bloc de béton isolant

6.3.1 Coffrage de mur intégral en PSE

Les tableaux qui suivent reprennent les comparaisons de ces systèmes, les choix à la portée de la main pour bien construire des murs de sous-sol.

Résumé des cotes de performance des systèmes de murs de sous-sol

(6 = cote de passage)

Conception	Description	Type de mur	Protection extérieure	Contrôle humidité construct.	Contrôle condens. et	Contrôle gaz sout.	Constructibilité, tolérance	Coût
Cas de base (isolation intégrale)								
5.2	Ossature bois-fibre min. (protection bitumineuse)	in situ	4,5	5	5,5	6	6	7
Systèmes intérieurs prêts à la mise en service								
5.3.1	Fibre min., ossature bois, prot. alvéolaire, avec espace d'air	in situ	10	7,5	8	8	7	7
5.3.2	Fibre min., ossature bois, membrane	bloc	9	8	8	8	7	7
5.3.3	Protection plastique cellulaire, espace d'air	in situ	10	8,5	8	8	8,5	7
5.3.4	Plastique cellulaire, membrane	bloc	9	8,5	8	8	8	7
Systèmes extérieurs, prêts à la mise en service (coupure thermique derrière le placage de maçonnerie)								
5.4.1	Fibr. min. drainage prot. bitum.	in situ ou bloc	8	10	10	7,5	8	7
5.4.2	Plastique cellulaire, protection adhésive	in situ ou bloc	8	10	10	7	7,5	7,5

Résumé des cotes de performance des systèmes de murs de sous-sol
(6 = cote de passage)

Conception	Description	Type de mur	Protection extérieure	Contrôle humidité construct.	Contrôle condens.	Contrôle gaz sout.	Constructibilité, tolérance	Coût
Nouveaux systèmes intérieurs								
6.1.1	Fibre min.-poly lam membr. avec espace d'air (prot. sur bloc)	in situ ou bloc	10	8	8	8	8	8
Nouveaux systèmes extérieurs (coupure thermique derrière placage de maçonnerie)								
6.2.1	Panneau drainage EPS, Prot. adhésive	in situ	8	10	10	8	8	8
6.2.2	Polyuréthane projeté et protégé, sans membr.	in situ ou bloc	10	10	10	8,5	7 (hypothèse)	6,5
Systèmes muraux isolés (peut-être sans coupure thermique supp. derrière placage de maçonnerie)								
6.3.1	Coffrage mural PSE, membrane	intégral	10	10	10	8		
6.3.2	Bloc isolé, membrane	intégral	10	10	10	8	s'en remettre au fabricant	
6.3.3	Béton PSE-fibrociment membrane espace d'air	in situ intégral						

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Report to *Ontario Home Builders' Association* from Scanada, Ottawa, April 1991

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1. INTRODUCTION: THE OHBA PROJECT TO UPGRADE BELOW-GRADE CONSTRUCTION

The Ontario Home Builders' Association has commissioned a research and demonstration project to investigate critical aspects of basement wall performance. Specifically, this project addresses the problems of water leaks and examines the feasibility of installing full-height insulation at the time of construction.

The OHBA project is supported by Ontario's Ministry of Energy, Ministry of Housing, and New Home Warranty Program; by the Canada Mortgage and Housing Corporation and the National Research Council; and by the Canadian Portland Cement Association, the Ontario Concrete Block Association and the Society of the Plastics Industry.

Ontario Warranty Program officals report that basement water leaks are the most common major complaint of home buyers. Builders agree, and know the price: Frank Gianone, past president of the Toronto Home Builders' Association, calculates that 1 out of 3 basements suffer moisture problems that involve complaints or call-backs in the first year after construction; indeed, the average new basement suffers two leaks within two years. His figures suggest that $300-$500 of call-back repair is exacted by the average basement. Neither builder nor buyer can consider today's practice to be acceptable.

Full-height interior insulation may not increase such leakage incidents, but builders know that its presence can add considerably more to the cost of finding and repairing leaks and making good. More important are the longer term effects in which the insulation application can be involved: the fungus growth and wood rot that can result from construction moisture, water leaking or flooding from outside, and condensation of indoor water vapour, accumulating excessively or simply trapped too long. At the same time, there are rising expectations concerning how the basement must perform as healthy, livable space, or at least readily-made-livable space. The aim is to achieve practicable, fully insulated wall assemblies that the builder can build, and the buyer can buy, with confidence that dry, livable space can be maintained.

Scope and method: The OHBA project is proceeding in two phases. ***Phase 1***, the "paper study" now concluded in this report, has drawn strongly upon industry's direct field experience and other field-based studies, as well as on building science theory that has proven its soundness in tests or practice in Canada or other cold countries. The many systems that have been considered are listed in matrix form in Appendix 1. Phase 2 may involve various means of technolgy transfer of the practicable systems.

The OHBA Steering committee helped greatly in this process; its active members included experienced representatives from concrete formers to insulation and membrane specialists as well as builders and researchers. Other specialists and proponents of innovative systems were also brought in as useful, all to good effect. The authors have drawn freely from the committee, the proprietary sources and from independent researchers and the literature - all as listed in Appendix 1 - always with particular respect for field-proven solutions to the business of producing dry, fully insulated basements.

The task of finding and selecting such upgraded systems was broken into these individual tasks:

i) Assess the "buildability", sensitivity to workmanship, and cost potentials (in large project usage) of various full-height-insulated basement wall concepts, firstly those based on ***concrete wall*** constructions, and available or clearly ready for industry adoption.

ii) Explore and resolve their sensitivity to construction moisture.

iii) Explore and resolve their control of water from outside, and their sensitivity to flooding and ensuing problems.

iv) Explore and resolve their ability to avoid excessive condensation and the prolonged entrapment of moisture from any source.

v) Explore and resolve the long term ability of the configurations to conserve heat energy.

vi) Evaluate, as well, ***innovative*** solutions that seem intrinsically acceptable (but not necessarily code-approved as yet), economically available or nearly so to builders generally, and ready to provide basements that meet the objectives.

vii) Repeat the foregoing as applicable for ***concrete block*** walls.

viii) Recommend, with industry, the most clearly sound and economical options. The industry can then choose from these and move forward into field demonstration and use.

The OHBA project encompasses only concrete and concrete block-based basement constructions, as noted. Most Ontario builders use these constructions. Some of the upgrading methods or systems that are brought forward here may of course be effective for other basement structural materials as well. The goal is simply to find practical methods of constructing dry, fully insulated basements.

2. BASIC REQUIREMENTS AND EXPECTATIONS

It is easy to demand that any selected basement systems be able to perform well in the worst conditions even if built in an area where such conditions should never occur; and that it provide fully livable space even if it will be used as a utility or storage basement in a given case. Such overdesign is bad economics and therefore bad engineering. Avoiding that, the intent in this project is to select systems offering safe "general purpose" performance capabilities ready for most sites and expected drainage conditions, with a further upgrade as an option where still worse conditions may be expected, as noted below. The performance requirements are introduced in this section and addressed in more detail with the design approaches in Section 3.

2.1 Site conditions: Exposure to water from outside the basement

Basic requirement: All selected basement systems must be capable, as built, of handling soil moisture and run-off conditions as found across Ontario. It is of course a given that grading, placement and connection of perimeter drains and granular cover of same, and disposal of run-off from roof and above-grade walls, must be done properly. The performance of the basement wall itself should not, however, depend on the use of particular backfill; normal economical backfill practice with native soils should continue to be accepted. A basic requirement is that the concrete itself be kept dry, free of liquid water, "wicking" and freeze-thaw spalling.

Special requirement for a degree of "floodproofing": In traditional practice in basement construction, the builder could assume that his job was only to keep surface water away from the house and to keep soil water from penetrating the wall on its way to the perimeter drain and municipal system. It was the municipality's job to take it away from the house and site. That is not always a safe assumption: municipalities are often failing in handling run-off, and insulated or finished basements are not tolerant of the resulting floods. The climatic and other reasons for this failure need not be discussed here, but it should be noted that some practices can certainly worsen the municipal drainage problem: Improper surface grading, roof water disposal directly to the perimeter drains, and indeed the presence of soil shrinkage cracks, granular backfill (or soil drainage mats): all can undermine the normal soil storage effect and hit the municipal drains with the full onslaught of rain and run-off.

House builders do not design the municipal systems but do have to be concerned with their capacity to handle run-off, just as auto and tire producers have to build for road conditions albeit they don't build the roads. Other studies and surveys are in progress concerning the considerable incidence of basement flooding, from back-up of overloaded municipal drains, in today's housing projects. Reviews of the draft findings and discussions with the research engineers have led to this response:

- Recommend a moderate flood-retarding option that can be used with any of the selected wall configurations where drain back-up may be expected.

  As will be seen, the Swedish approach is the preferred measure: thoroughly dampproof or floodproof the basement wall to say 300 to 500mm above the footing. (If higher, the wall and floor might need to be reinforced against potential hydrostatic head. The 330-500mm height will apparently accommodate practically all back-up incidents.) Proprietary techniques are available allowing "dry" installation of such a band in any season, as will be noted later. Depending on the likelihood of back-up, the builder can augment this safeguard with a sump pump and check valve as permitted in the municipality.

- Emphasize always the need to slope the grade away from the house, dispose of roof run-off likewise, and so avoid the tendency to dump surface water too quickly or totally into the perimeter tile and municipal drains, expecting them to handle it all.

2.2 Other moisture and durability considerations:

Construction moisture, especially the thousands of litres of excess water in a fresh concrete basement, can subject interior insulations and framing to a moisture overload. Winter condensation from indoor sources can continue to add moisture to the interior insulated cavity. This threat is worsened by the tendency in today's houses to operate at higher relative humidities and less depressurization than the traditional levels; the combined effect is to load the cavity with more moisture if there are air leaks. As well, leakage from above grade can be a problem, especially from poor flashing under masonry veneer. Another stubborn problem is "summer transfer": inward movement of near-grade and above-grade moisture. These points will be considered with the particular design approaches in Sections 3 and 5.

Summer condensation on earth-cooled interior concrete surfaces can foster mould growth, and the problem can even be worsened by generously ventilating the basement in summer. Full-height insulation, interior or exterior, keeps the wall surfaces warm and greatly reduces the problem; it is not further addressed here.

2.3 Energy efficiency:

Appendix 2 presents the results of a computer analysis of basement heat losses conducted by the Institute for Research in Construction (IRC), of the National Research Council, for this study. The Ontario plan to require RSI 2.1 (R12) for the full height of the basement wall is taken here as a given, i.e., this study is not itself concerned with the economic analysis or justification of that requirement. The study mandate did, however, include a comparison of energy efficiencies provided by increasing the insulation coverage to that level, and this is provided in the Appendix.

IRC used what may be the finest-grid finite element modelling yet developed for this purpose, "KOBRU86". The results differ somewhat from those of earlier Canadian finite element analyses, which used a coarser grid and some different basic assumptions[1]. From Appendix 2, some results of the new modelling are:

1) Concerning the "base cases", using interior insulation extending down 2 ft. (600mm) below grade: Increasing the insulation from R8 to R12 (from RSI 1.4 to RSI 2.1) is not very effective, saving only 4% in total basement heat loss.

2) Placing R12 full depth on the interior, or on the exterior in the configuration with no thermal bridge, saves 24-25% over R8 2 ft. down; 21-22% over R12 2 ft. down.

3) Placing brick veneer directly on the concrete, however, creates a thermal bridge and "radiator" fin (the brick) that bypasses exterior insulation rather severely. While IRC did not analyse this item rigorously, it appears that this configuration, used with R12 full height, exterior, may save no more energy than does R8 interior to 2 ft. below grade. This should be analysed more definitively, but the performance would still fall short even if the bridge effect were found to be considerably less serious. Analytical precision is not the issue.

4) Placing just an R1.6 (RSI 0.28) thermal break under the brick restores the performance close to that of 2). This is considered further in Section 4.

The housing industry should have the analyses confirmed or refined, and projected to yield annual heating savings so that the cost-benefits of the energy-saving improvements can be considered. (Using simple proportionality, and the annual heating losses developed in the earlier IRC work[1], it would seem that the annual saving in extending R12 insulation all the way down the basement wall might be roughly 29 kWh/yr./meter perimeter in southern Ontario conditions - a dollar's worth of gas per meter perimeter, with 65% furnace efficiency.)

2.4 Livability requirements or expectations:

As this study took shape, the authors first proposed a classification into "rough utility" basements on the one hand and "ready-to-finish" on the other, or even into finer distinctions of the levels of finish and "livability" offered by the various basement wall systems. All of the systems being essentially equal in surface temperature (with the R12 full-height configuration as a given, and no substantial thermal bridging), the essential livability factors are the interior surface smoothness, flatness and abuse-resistance that the wall systems offer, and their ease of accepting electrical circuits and outlets.

As the work progressed, however, the team decided not to divide the systems into two camps, utility vs. ready-to-finish, or degrees in between, nor consider the marketing value that might accrue to the more finished versions. It was agreed that such considerations would draw budget away from the simple and urgent focus on upgrading basements to avoid moisture problems while providing full, permanent insulation value.

2.5 Buildability and cost requirements:

"Buildability" of basement wall systems may be considered in two ways: 1) the ease with which a wall may be built properly, without highly skilled trades; 2) its tolerance of construction error or damage. Both aspects of buildability are important and are considered in the next sections.

The cost criteria for acceptability of improved new systems are not easily established. On the one hand, Ontario builders are said to face about $300 to $500 per house for basement call-backs and repair, on average, in the warranty period. If the leakage incidence were allowed to stay as is, the presence of full height interior insulation would drive the repair/make-good costs considerably higher - say to $700 or more on average?

On the other hand, the present failure rate can not be enhancing reputations, particularly in today's tightening markets and a return of respect for value and quality. Buyers wanting assurance of dry and livable, or potentially livable, basements - far beyond the warranty period - and builders wanting a marketing "edge" by offering just that, should both win with upgrading measures even if they have to cost considerably more than today's unsure practices. On an avoided cost basis alone - with no cost assigned to goodwill or marketing edge - the builder wins with upgrades costing up to $700 or more. The buyer may assign much more value than that to the assurance of permanently dry, energy conserving performance.

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1. G.P. Mitalas, Calculation of Basement Heat Loss, National Research Council, NRCC 23378 (ASHRAE Transactions, 1983, v. 89, Part 1B, p. 420-437). The analytical method was substantially validated against several "mimic box" calorimeter recordings of actual heat losses in coastal, Ontario and prairie basements as well as test hut losses at NRC Ottawa. Various soils, water table and moving water conditions affect the loss rates considerably, so that comparison of models and actual below-grade losses is not always simple, especially for part-height insulations. The Mitalas method was incorporated in the "Hot 2000" model, the current mainstay of house heat loss analysis in Canada.

3. MEETING THE REQUIREMENTS WITH INTERIOR AND EXTERIOR INSULATION APPROACHES

It is instructive to consider how the requirements can be met adequately - the physical principles respected - for the rather different main configurations in turn: the interior vs. exterior placements of insulation. With that done, it is relatively easy to consider the other insulation placements to complete this Section.

While the following is essentially generic in tone, reflecting familiar materials and practices, some well-proven proprietary components of unique advantage are introduced at this stage. (Drawings of individual components and configurations are reserved for the later sections and appendices.) For simplicity, the following first addresses concrete basements as the example under discussion; concrete block is then addressed near the end of this section.

3.1 Separating the structural and water control functions:

Considerable study was first devoted to ways in which the concrete itself could be made more crack-resistant and watertight. Crack control joints, light reinforcing (top and bottom steel, and around windows) and the use of plasticizers in the mix, were all reviewed by Becker Engineering, in ascending order of promise. Reviews of field experience discouraged any further consideration of control joints for house basements. The use of light reinforcing is generally respected, from experience in western Canada, but is still fussy and costly and does not assure great improvement in crack resistance/water resistance. The plasticizers show the most promise in reducing shrinkage cracking and construction moisture problems, and in providing a superior hardness and smooth appearance where the concrete is exposed on the inside (i.e., with exterior insulations). However, their status in competitive pricing, supply and simple technical guidance is not considered good across Ontario, especially for small builders. Further, they may not by themselves assure the rather substantial improvement in water resistance that basements need.

Midway in the study, therefore, the OHBA Committee and the consultants agreed to the approach long established in the "folk engineering" process of housing evolution: Let the structural material (concrete, concrete block or other) simply be structure, and let the water control function be assigned to another material layer. And make the latter work, even if it has to cost considerably more than today's sprayed tar "dampproofing" ("black magic," the Swedes were calling it dismissively, 30 years ago). That being decided, the team proceeded in its consideration of candidate components and system configurations, from successful practices everywhere in cold-country basement construction.

3.2 Insulation placement: interior vs. exterior approach:

The singular distinction between system configurations is where the insulation is placed: on the interior side of the foundation wall, as has been normal, or on the exterior. Technically, the latter presents the least conflicts with physics and is generally more tolerant of flawed workmanship (except above grade). Nevertheless the interior approach can be made to work adequately and presents some advantages, especially where wiring-in and finishing the basement may be a desired option. The requirements and functions are considered here for each approach in turn.

Dampproofing: keeping the concrete and the interior dry: The conventional, wet-applied asphaltic dampproofings are discounted: they are cheap, but offer poor on-site assurance of constituent quality and thickness, poor bonding to wet, dirty, cold or friable surfaces, and very little extensibility and crack sealing ability even when properly applied. Spray application appears to worsen all of these weaknesses. At the same time, these dampproofings inhibit the drying of construction moisture, and also tend to trap other moisture that enters the concrete from inside or out.

The goal must be to form a safe, complete and durable dampproofing, preferably with a dry membrane process oblivious in application to temperature and wall condition, and able to withstand practically any amount of wall cracking. There are different needs and demands posed by the two main approaches:

> ***Using the interior insulation approach:*** The dampproofing on the wall exterior must first withstand the brunt of backfilling. The membrane must therefore be tough and resilient. Deeply formed texturing adds "give". A proprietary "air gap membrane" is particularly advantageous, in that its deeply dimpled form absorbs abusive backfilling with minimal damage, and its "air gap" allows water to drain away freely even if some damage were to allow spot leaks through the membrane. As noted below, this dimpled membrane is also uniquely capable of condensing and

draining away moisture from within the concrete: construction moisture, "summer transfer" moisture, and condensation. (Appendix 1.)

Using the exterior insulation approach: The job is much easier. The insulation protects the dampproofing from damage from backfilling; construction moisture can escape inwards; the control of water entry above grade can be more readily assured by the exterior insulation, cladding and flashing. Self-draining insulations and closed cell types can each take over much of the dampproofing job, in their different ways: the first can drain freely so that water scarcely touches the dampproofing; the latter bars and sheds water itself, and bridges cracks that form in the concrete and its direct dampproofing. However, the closed cell materials can trap water that can work its way inward through joints, so that it should be adhered to the concrete with an adhesive dampproofing, or incorporate its own drain slots there, or be used with a proper membrane damproofing.

Resisting flooding: As mentioned earlier, a 300-500mm high band of flood-resisting protection is desirable in areas where overloaded drainage systems may back up - which is not a rare occurence in some municipal areas and situations. The following measures should be considered:

Using the interior insulation approach: A double thickness of normal dampproofing material, with "6 mil" polyethylene film rolled into it, should be able to bridge most cracks and provide a durable flood retarding band. Because of its limited height it should not interfere with the escape of construction moisture or condensation. On the other hand it is a wet and laborious process with attendant limitations in application, and may be prone to damage from backfilling.

An improved "floodboot", using a reinforced polyethylene membrane and expansive sealants, can do the job with none of these limitations when protected under the air-gap membrane. It was designed to complement that membrane in such high-risk areas. (Appendix 1.)

Using the exterior insulation approach: A flood retarder band can be used as above. Alternatively, where a membrane or film dampproofing is used with exterior insulation, it itself can be sealed at the wall-footing joint and atop the footing to provide flood resistance.

Dissipating construction moisture: There is some experience with excessive wetting of interior insulations and framing from the water given off from fresh concrete walls. This is seen even where the insulation reaches only 600mm below grade. Full height applications demand new approaches.

> ***Using the interior insulation approach:*** Western builders now using full height mineral fibre insulation/wood framing may leave the bottom half exposed for six months or so, with no drywall and with the polyethylene v.b. folded upward for that period of drying. That awkward practice interferes with efficient housing production. The need is for an exterior dampproofing that will ***accept, condense and drain away*** the construction moisture; the dimpled air-gap membrane, noted above, is well conceived to do that.

> ***Using the exterior insulation approach:*** Most of the construction moisture is free to escape inward to the indoor air. The exterior insulation will prevent outward movement if it is a closed cell type, but its inside surface will remain above dewpoint temperature (except while the concrete is very wet) and so will not accumulate condensation. Some construction water vapour will migrate outward through open cell or fibre insulations and will be dissipated in that direction as well as to the indoors.

Managing condensation from indoor air: This involves two critical measures requiring thought and care, especially with interior insulation: 1) keep indoor air from leaking significantly into and through the insulation or insulated cavity (where it can sweep over surfaces well below its dewpoint temperature, depositing condensate) and 2) design so that the annual drying regime from such space is greater than the condensation or wetting regime. A third requirement plays only a minor part and is easily met in providing for 1): retard water vapour diffusion from indoors into the insulation or insulated cavity.

> ***Using the interior insulation approach:*** The time-honoured Crocker method[1] allows drying to the outdoors through the above-grade portion of the wall. It has been adopted successfully in full-height usage, given that construction moisture is first dissipated and given careful attention to air sealing/convection blocking over the entire interior surface and joints. If wood framing is used through the insulation, it must be reasonably dry in the first place; the foregoing measures for outward removal of construction moisture must be followed, and it is

recommended that all the wood be spaced clear of the concrete, including the sole plate. A draining air-seal should support the sole plate, as shown in the details of Section 5.

Using the exterior insulation approach: Exterior insulations easily avoid excessive condensation if the dampproofing membrane (or the insulation itself, if closed cell) acts as an air and vapour retarder on the warm side of the insulation. (Cold-side cladding or protection above grade may trap some condensate, but not much since there is no flow-through of air; summer draining and evaporation takes care of it.)

Providing effective insulation:

Using the interior insulation approach: This placement can readily provide full coverage, with essentially no thermal bridging, and little or no convection "short circuiting" or bypass effects if the insulated cavity is filled and the insulation is pressed firmly against the wall. The insulation effectiveness will therefore equal its R rating, given it's kept reasonably dry as discussed earlier.

Using the exterior insulation approach: The effectiveness here can also be complete, with the placement itself tending to minimize convection and bypass effects. The insulation must resist excessive damage and compression from backfill, and take-up of water, or must be protected accordingly on the soil side. There are two other phenomena which can reduce the insulation value, one significantly:

1) Moisture in self-draining insulations: The draining pathways in the oriented mineral fibre types appear to stay in the outermost 3mm or so, according to the manufacturers' testing and field monitoring. With the thicker installations the proportional loss in thermal resistance is slight, and the manufacturers offset the loss by making the insulation with slightly higher R-value than called for (e.g., R13 for R12).

2) Thermal bridge through concrete into brick veneer: As was reported in 2.3, this heat flow path may substantially reduce the efficacy of exterior insulation, losing much of the intended value of full height installations. A simple thermal break insert can resolve this well enough, as indicated in the preliminary analysis in Appendix 2. Practical thermal breaks are suggested in Section 4.

Considering finish and livability:

Using the interior insulation approach: The usual arrangement of wood framing (or wood or metal battens or inset nailers, on cellular plastic insulation) and gypsum wallboard can offer a wall that is nicely ready for finishing. Wood framing also accepts electrical circuits and outlets most readily. It may be necessary to restrain or shim the framing to provide the planarity that the buyer expects in a ready-to-finish wall.

Using the exterior insulation approach: The exposed interior of the concrete or block is appropriate for utility space only, not for readily finishable living space. (Architectural block walls can avoid this shortcoming, as can the use of special formwork and plasticizers for forming concrete walls.)

More important, however, is the problem of economically and ruggedly finishing the exterior insulation above grade. Especially with brick veneer above it, finishing the above-grade portion of the exterior insulation configuration is one item that penalizes its cost and acceptability and thus favours the interior approaches in business. The favoured coverings, and the most promising new ones, are addressed in Section 4.

Buildability and cost factors: These are considered more specifically with the individual systems in the next sections. Judgements are taken on the differences between the two basic configurations, and especially on their requirements for careful workmanship, i.e., their tolerance of error or damage without inviting failure in moisture or thermal resistance.

Using the interior insulation approach: Where mineral fibre/wood frame is used, the demand for care is especially great regarding the interior placement and sealing of the air-vapour barrier and top and bottom air seals, the complete filling of the cavity and firm pressing of the insulation against the concrete, and the placement of the moisture barrier on the inside of the concrete to stop at grade, not higher. (Were it not for construction moisture and the building code, that barrier might better be omitted.) On the exterior, the requirement for careful flashing and drip edge clearance under the brick veneer, and top-edge sealing of the dampproof membrane, are practically the only points requiring thought and care if the air-gap type of membrane is used. All materials and skills are familiar except the simple air-gap membrane, relatively new to Canada.

Using the exterior insulation approach: Below-grade, everything is less sensitive, more foolproof. Poor placements or fits will not even reduce the thermal value appreciably since convection currents or bypasses are blocked off. Above grade, special care is required to achieve satisfactory appearance and ruggedness of the cladding, as mentioned earlier and as pursued in Section 4.

3.3 Adapting for concrete block wall construction:

As introduced in Section 3.1, the concept of separating the wall structural function and material from the water control function and material is not easy with wet-applied "paints" that try to bond to the wall. For two decades, others have taken the singular step to a dry, mechanically secured membrane dampproofing that is oblivious to the nature of the wall under it. The distinction between concrete and concrete block is almost removed. The air-gap dimpled membrane is strongly favoured as a foolproof dampproofing and to dissipate construction moisture from concrete, but the latter is not a primary factor with concrete block. A tough, backfill-resistant membrane of plain form can do the job. A snap-lock-top hanging membrane is now available, as introduced in Appendix 1.

Concrete block presents one further concern: potential leakage from any amount of water backup. Where cast-in-situ concrete may present just one significant leakage path - between wall and footing to the floor slab/wall joint - the block wall may present direct leakage paths at mortar joints. The base zone flood protection, generally recommended in the earlier discussion, may be considered as a requirement for concrete block, whether exterior or interior insulated. The membrane dampproofing just noted can be sealed at the footing/wall joint as well, for flood protection, while doing away with any need for wet pargings and wet dampproofings.

Unless concrete block cores are blocked or capped at grade level or just below, it is known that convection in them, outside full height insulation, can depress the frost line appreciably (IRC). In clay or silty clay areas, adfreezing-lifting is a factor to consider. Core blocking, or the use of a hanging membrane as noted, can lend assurance against that.

3.4 *Reviews of other insulation configurations*

The scope of this study covered a few basic configurations with a few materials, comprising a great many combinations addressing the control of moisture flow with the control of heat flow, on a structure of concrete or concrete block. As shown in Appendix 1, the 91 theoretical combinations are quickly reduced to 70 distinct ones meriting some consideration. During the work, this number was increased again by the introduction of 3 more components of considerable or even "breakthrough" importance: the exterior barrier-drain ("air-gap membrane"), proven in Norway's basements for 22 years; the self-draining expanded polystyrenes; and new EPS-fibre-cement insulating concretes. The first three are discussed in the evaluations, while the last was brought to this study too late for anything but a mention below, and strong recommendations for further consideration.

The foregoing discussion dealt with how the interior and the exterior insulation configurations can each be made to perform well; several of these are brought forward for individual evaluation and recommendation in Section 5. Other configurations of varying merit or promise are briefly reviewed as follows, and are not pursued further in the more detailed sections:

1) Combination of R12 exterior insulation below-grade and interior insulation to 2 ft. below grade. Intended to avoid moisture problems while also avoiding the cost and disruption of cladding exterior insulation above grade (Section 4), this two-step approach does not quite meet the requirement of providing R12 effectively full-height. As seen in Appendix 2, the thermal bridge from indoors up and out through the concrete makes the whole performance only 82% as good as R12 full height. It would seem, however, that it could be brought much closer in at least two ways:

    1) in combination with concrete block with insulated cores extending appreciably below grade;

    2) using say R16 on the interior of a concrete wall, extending say 3 ft. down.

    The builder will note that two sets of on-site operations are required, and the interior is still not prepared for finishing as livable space. (However, neither does it require the installation of electrical circuits, a "penalty" faced by full-framed interior installations.)

Builders may wish to have this combination investigated further, thermally, to bring it up to the requirements and make it a valid option.

2) Sandwich: Whether precast or in-situ, concrete can be cast to form two "wythes" with insulation sandwiched between them. The insulation can be a self-draining type or a closed-cell barrier, acting effectively as an exterior insulation outside the structural inner wythe of concrete.

   Technically, the sandwich approach can well meet the moisture and heat control goals of this project, while offering the considerable advantage of not having to further protect the insulation, inside or out. It does not meet the criteria for this project, however, in that it is neither available now nor likely to become so, economically, in the near future. Precasting economics remain questionable for house basements, in transport and on-site handling operations. Site casting (horizontal, or in full-height tie-less forms) is promising but would require considerable development to fit the housing construction industry.

3) Insulation in formwork: It is feasible to install insulation in the wall forms, to produce an exterior-insulated wall as the formwork is stripped. The final performance, and the need for protection of the above-grade insulation, remains the same as in the usual two-step operation. Installing the insulation would be tedious work unless tie-less forms were developed. This approach would then be appropriate. Form life would be greatly extended since the insulation forms the outer plane and no stripping is required there.

4) Insulating concrete: New developments in EPS-fibre-cement concrete are just now being introduced, apparently with a very good balance of insulating and structural properties and with backing from major concrete interests. A CCMC listing has been obtained. The building industry will be interested in the development: An insulating, structural concrete that could offer the R12 value in one homogeneous wall, ready for simple finishes and membrane moisture control, could be a remarkably attractive option.

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1. C.R. Crocker, House Basements, Canadian Building Digest 13, National Research Council, Ottawa 1961. See bibliography note in Appendix 1.

4. PROTECTION OF EXPOSED EXTERIOR INSULATION

4.1 The problem

The weak link in placing the basement wall insulation outside is in providing protection for the above-grade portion. The problem is to achieve impact resistance and durability without sacrificing economy and all-season buildability. The problem is not new: no economical wall sidings have been developed, at least until recently, that can stand up well to usage near grade - stand up to the bicycle pedals, lawn mowers, dog chains dragging around corners, water back-splashing, and even small grass fires. The job of protecting exposed basement insulation poses even worse demands: damage resistance against impact and indentation must be provided over insulations which may offer little support; and the cladding has to extend down into the wet ground and endure that condition too.

Recent developments offer immediate promise, if not off-the-shelf availability. Reviews of today's favoured materials and developments, and the fast-developing new ones in Canada and the USA, have been rewarded with encouraging findings.

4.2 Evaluation criteria

The various materials/systems for above-grade protection can be assessed roughly against the demands of the job they face, and against each other. While no attempt has been made here to define quantitative values - abrasion resistance, flame spread, water absorption and so on - a general knowledge of the material qualities and field histories (in comparable usage) has allowed usefully qualitative judgements. Performance criteria can be considered as follows:

a) Damage-resistance - including resistance to impact at all temperatures, indentation, abrasion: The "pass" performance level may be set historically by the traditional 19mm wood siding/corner trim. It would be preferable to exceed that criterion by a good margin, but higher performance can be costly to attain. Wood sidings are still doing reasonably well, even near grade, on 100 year old houses: a reasonable standard.

b) Water resistance, basic durability - especially the buried portions: Asbestos-cement board has set a high level, a desirable criterion that should be matched as closely as practicable.

C) Ease of maintenance and repair: Generally, materials that rely on paints or thin coatings would not be considered acceptable; integral colouring and ultraviolet resistance are the qualities that candidate materials should offer, and do. Repairability is an equally important attribute in this severely exposed usage. It may involve using matching pastes for spot patches, or replacement of small panels or cut-out-and-replace.

d) Buildability...in winter too: Moisture is at the root of almost all durability problems in building materials and components. There is a special set of moisture-related problems that arises from one practice that is slow to go away: building in cold weather with wet-applied processes. Such applications are often bedeviled with incomplete curing in the first place, or accelerated corrosion or other degradation because of doping the wet mixes to hasten their "cold cure". The former at least shows up quickly, and can be re-done; the latter can work insidiously.

In any case, site-applied wet processes tend to be poorly controllable or inspectable, and demand careful workmanship in what are often difficult working conditions. Where dry panellings are available to replace them, those will generally score higher on buildability, especially in all-season operations. That's one of the reasons why building production continues to evolve toward more assembly of "dry" components manufactured off-site.

e) Formability: Thicker insulations stand proud of the wall plane above, requiring the covering to cap the top of the insulation with a return extending under the wall. The requirement is common also to masonry veneered walls, where the heavy veneer must bear directly on the foundation and be carefully flashed over the top of the insulation. The protruding covering must be attractive and resistant to damage in that conspicuous and vulnerable top zone.

Formability is also desirable at vertical corners, internal and external, and at vertical joints. Of course, all of this does not have to be formed into the cladding panels: separate pieces can be used to cap, corner and join flat cladding panels. Those pieces, however, must be at least as robust as the panels; flimsy metal flashings and joint battens will not do. Further, reliance on separate caps and jointings is more demanding of anchorages and fasteners, as well as labour. It may be generally preferable to build with one-piece components, formed to cover from just below grade to closure behind the cladding or veneer at the top, and to offer vertical joints and corners too. Corners should be rounded and made especially resistant to damage. High scores should be given to those single materials which can be formed, on site or in the factory, to do it all.

f) Fire Safety: These claddings at grade should offer reasonable resistance to, say, small grass fires. Although there are no code requirements, history would suggest that the performance of wood can be taken as a minimum, a generally accepted "pass." Self extinguishing plastics such as polyvinyl chloride (PVC) also define a passable level.

g) Potential Economy: There appears to be little information on installed costs of some newer fibre-cements, but considerable experience with the stuccos and polymer cements on fibre mesh. In the evaluations here, builder's costs of labour-intensive stucco-on-metal-lath are taken as a "pass". Comparative values for the potential costs of fibre-polymer-cements are judged from some knowledge of the materials as well as manufacturing and installation characteristics. The comparative values of the PVC's are assumed from manufacturers' claims and general reviews of the processes.

4.3 Notes on the cladding systems

Stuccos, polymer-cements and PVC's are all familiar materials needing little comment here. There is considerable opinion in the industry that the site-applied polymer-cements (often referred to as "latex-cements") require fibre mesh reinforcing in such usage, and particularly so if used to clad the mineral fibre insulations without further backup. Such reinforcing or equivalent is desirable, if not indeed a necessity, for polymer-cements on EPS insulation as well. These points are reflected in the evaluation table which follows.

Fibre-cement panel materials can perhaps no longer be considered as fully familiar products since asbestos-cement has fallen from favour. The newer materials generally match its formability and exceed its resilience, while retaining its fire safety, water resistance and economy closely enough. Glass fibre and certain synthetic high polymer fibres have taken the place of asbestos fibres, but further developments have been coming into their own over the past decade and more, as noted next.

Wood fibre-cements - "mineralized" cellulose fibre-cement composites - are coming into their own after many years of development and refinement, in the western world and in the Philippines, Malaysia and Japan. Portland cements bind such fibre remarkably well, yielding an attractive product with high strength, resiliency, resistance to fire and water, formability, and nailability/workability on site. With polymer modifiers and other proprietary "enhancers", wood fibre-cements are now the basis of some of the more attractive wall sidings and claddings in the U. S. market. From there, they are available in Canada at least as flat panels suitable for above-grade insulations terminating under the wall cladding.

Wood fibre-pozzolans appear to promise the most for the least, and perhaps not very far from now. Under development in Canada, these use pozzolans as strong binders in place of portland cements. (Pozzolans - finely divided siliceous/aluminous powders - are the predecessors of portland cement, in use in construction in Italy since early Roman times. They are named after their original source rock in Pozzuolana.)

The pozzolans appear to offer strong advantages: they may cost considerably less than portland cement, while eliminating its heavy energy consumption and release of carbon dioxide in its manufacturing process. In the Canadian work, which is proprietary, the powder is produced from waste steel mill slag, but it is not limited to that source.

4.4 A first comparison of the above-grade claddings

Table 1 offers first judgements on comparative ratings, out of a possible 10 points in each category. A "pass mark" of bare acceptability is 6. Of course, the categories themselves could be weighted but that is not attempted here. All judgements are based on the foregoing points of criteria, material developments, and potential concepts. The knowledge base was derived largely from industry, and is not offered as definitive. It can be seen that above-grade cladding can be done well (at a considerable price, as suggested in the examples in Appendix 3) and that both quality and cost could become somewhat favourable if exterior insulation were to be introduced in tract building in substantial volume. There is, however, one further critical consideration, addressed next.

4.5 Stopping the thermal bridging through masonry veneer

As discussed earlier, masonry veneer presents a highly conductive path and "radiator" fin for heat flow from indoors to outdoors, picking up the heat from the conductive concrete or block on which it sits. While a full-height insulation on the interior of the concrete cuts off that path, an exterior insulation is substantially bypassed.

Since much of Ontario uses masonry veneer on at least portions of the house, it is important to cut off that thermal bridge if the advantages of exterior insulation are to be made broadly available. Recent developments in Ontario suggest that two practicable solutions could be implemented now. Figures 1 and 2 illustrate the two developments; each may have some proprietary content.

The first seems to meet both the intent and the letter of the Ontario Building Code; the second, the intent but perhaps not the letter. Preserved wood stub walls are accepted under masonry veneers, however, in conjunction with preserved wood foundations. The wood bearing plate on concrete is not in any way less acceptable.

The lightweight insulated concretes are readily engineered as a bearing "ledge block", as shown. The unitary flashing/cladding piece protects the protruding block as well as the above-grade insulation, while the block offers firm support for the cladding. (Credit for this concept belongs to J S Consultants, Tottenham, Ontario. As they pointed out, the unitary cladding could easily incorporate a drip edge at the ledge knee, but in any case it should be cleanable and/or coloured to mask the inevitable staining from the masonry and mortar above it.)

Performance / Material/System	Damage Resistance	Water Resistance, Basic Durability	Ease of Maintenance/ Repairability	Buildability		Formability	Potential Economy	Fire Safety	Notes
				Warm Weather	Cold				
Stucco on metal lath (12mm)	7	7-8	7-8	6	3	7-8	6	10	covers all insulations
Site applied polymer-cement on fibre mesh (6mm)	7-8	8	8	7	4	8-9	6-7	9	covers all...
Site applied fibre-polymer-cement (no mesh; 3mm)	7	8	8	7-8	5	8?	8	7	on rigid EPS or similar
Factory-applied polymer-cement on rigid insul. panel (no mesh; 6mm)	7-8	8	8	8	8	8-9	8	7	on rigid EPS or similar
PVC or other high polymer panelling	7-8	10	7-8	9	9	10	8-9	6-7	covers all...
Fibre-cement panelling generally	8	8-9	8	8	8	8	7-8	9	covers all...
Wood-fibre-cement panel	8-9	8-9	8	8	8	8	7-8	9	available USA. covers all...
Wood fibre-pozzolan panel	8-9	8-9	8	8	8	8	8-9?	9	fast-developing; covers all...
Wood-fibre-cement/ pozzolan shaped panels with PVC corners, jointings	8-9	8-9	8-9	8-9	8-9	9-10	8-9	9	could be offered now (USA); covers all...

TABLE 1 RATING THE ABOVE-GRADE PROTECTION OPTIONS

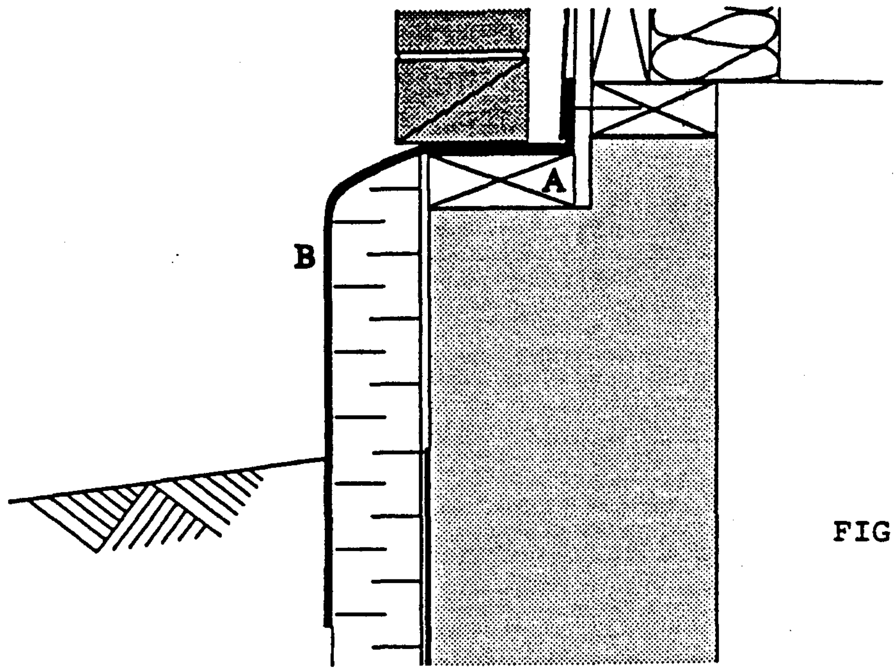


FIG. 1

A. Preserved Wood Bearing/Thermal Break

B. Wood Fibre-Cement Cladding

C. Insulating Concrete Ledge Block/Thermal Break

D. PVC or Equivalent Cladding

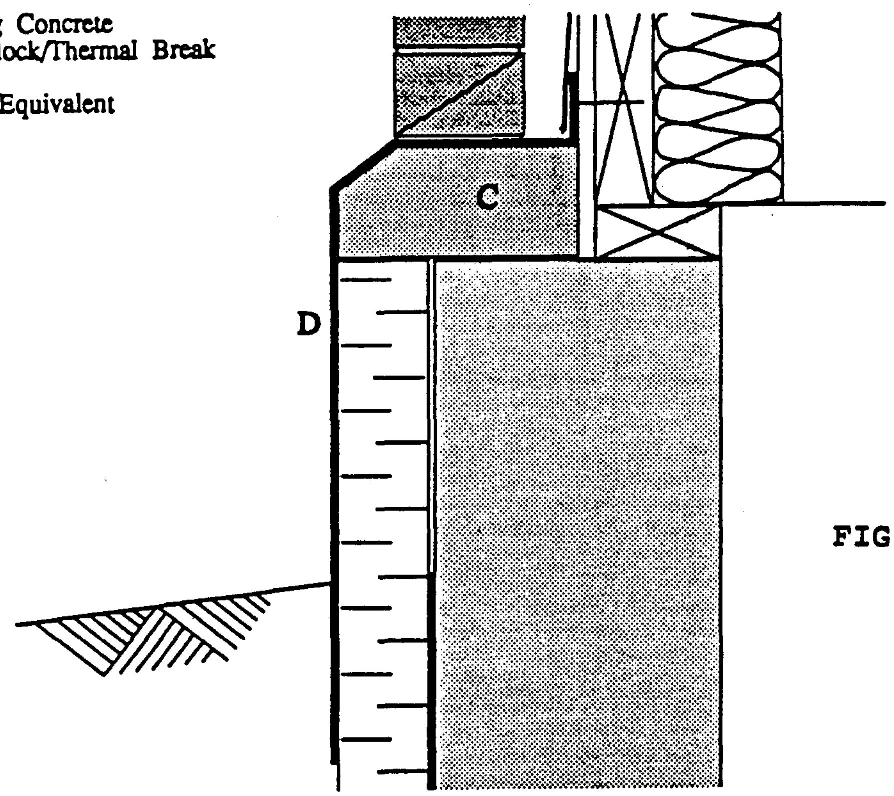


FIG. 2

Drawings here represent concepts. Details, including supports and fasteners, must be specified by others.

5. FIELD-READY, FIELD-PROVEN BASEMENT SYSTEMS

5.1 Evaluating the individual systems:

"Field-ready, field-proven" means readily buildable with techniques and components that are: available to Ontario builders; field proven in years of usage here or in similar cold-country conditions elsewhere (as whole systems or as proven components that can be put together knowledgably); referenced in the Ontario Building Code or acknowledged as meeting or exceeding its requirements; able to offer much better assurance of trouble-free performance, as well as energy efficiency, than offered by today's usual basement construction practices.

In the following evaluations, house drainage and municipal drainage are assumed to be adequate. Where risk of back-up is too high, base-of-wall "floodproofing" is intrinsically providable with a few systems but a flood retarder band would have to be added to most.

All systems except the base case provide assurance of fully effective, full height insulation value just as described, so they are not individually rated on that in their listings.

Costs are assessed in Appendix 3, using industry estimates checked in part against work-study data on similar elements. The ratings given here are comparative, with today's practice deemed acceptable on average, to the builder, despite the callback realities and their likely direct cost with full-height insulation in place (Section 3.2, Buildability and cost factors).

5.2 Today's typical interior practice: the base case to be substantially upgraded

If judgements could somehow be assigned wherein a rating of 6 out of a possible 10 points indicates a bare "pass", a probable adequacy, then the typical basement construction might be evaluated as follows. Its leakage problems and callbacks mark today's practice a failure in that respect. Its other "moisture management" attributes are also judged to be on or below the acceptable or pass level, based on considerable field experience. (The configuration of this base case and all the following systems is described from the outside in.):

Base case - Typical interior-insulated construction, but with full-height R12: Wet-applied dampproofing/concrete/interior moisture barrier to grade/wood frame with full thick R12 mineral fibre insulation/polyethylene/drywall

- Exterior damproofing...even if properly applied... 4-5

- Handling construction moisture... 4-6

- Controlling condensation (including summer transfer)

- Readiness for control measures for soil gases, radon... 6

- Buildability with minimal training...tolerance of error... 6

- Cost, production of basement wall-per-dollar...allowing for callbacks 7

- Base floodproofing...must add where needed

The evaluation judgements would of course mean more if the individual items were weighted to reflect their importance. The cost factor might be weighted strongly, for example. Weighting is not attempted here.

"Controlling condensation" includes the ability not to trap condensate in the lower portions of the insulated cavity, far from the drying zone to the outdoors through the concrete above grade. "Summer transfer" is included in this phenomenon, referring to the tendency to absorb summer rainwater into the concrete in and warm upper soil zone, pass it inward, "down the temperature slope" through the wall and interior insulation, to condense and run down the back of the polyethylene vapour retarder. This reverse-flow moisture transfer and accumulation may well be a substantial part of the wet cavity problem observed in insulated basement walls. It is the main reason why the following mineral-fibre configurations are drained at the sole plate.

The selected systems are evaluated next, in the same manner as just done. The main configurations are sketched at the end of this section.

5.3 Field-ready, field-proven interior insulated systems

5.3.1 ***Concrete/mineral fibre/wood frame:*** barrier-drain ("air-gap membrane") /concrete/moisture barrier to grade/wood frame with R12 mineral fibre, with drained sole/polyethylene/dry wall. (Fig.3)

- Exterior dampproofing with no special backfilling...	10
- Handling construction moisture...	7-8
- Controlling condensation...interior fully sealed, drained	8
- Readiness for control measures for soil gases, radon...	8
- Buildability with minimal training...tolerance of error	7
- Cost, basement-per-dollar...	7
- Base floodproofing...must add where needed	

5.3.2 ***Concrete block/mineral fibre/wood frame:*** configured as 5.3.1, except that plain barrier membrane can suffice and can act as base flood retarder if sealed at footing-wall joint.

- Exterior dampproofing with no special backfilling...	9
- Handling construction moisture...	8
- Controlling condensation... interior fully sealed, drained	8
- Readiness for control measures for soil gases, radon...	8
- Buildability with minimal training... tolerance of error	7
- Cost basement-per-dollar...more or less regional...	7
- Base floodproofing can be incorporated in barrier	

5.3.3 ***Concrete/cellular plastic:*** Barrier-drain ("air gap" membrane)/ concrete/cellular plastic(EPS Type 1,2,3 or 4)/wood furring or inset nailers/ drywall. (Fig. 4)

- Exterior dampproofing with no special backfilling...	10
- Handling construction moisture...	8-9
- Controlling condensation...	8
- Readiness for control measures for soil gases, radon...	8
- Buildability with minimal training...tolerance of error...	8-9
- Cost effectiveness, basement-per-dollar (with Type 1 EPS)	7
- Base floodproofing...must add where needed	

5.3.4 ***Concrete block/cellular plastic:*** Configured as 5.3.2. Plain barrier membrane or air-gap type.

- Exterior dampproofing with no special backfilling...	9
- Handling construction moisture...	8
- Controlling condensation...	8
- Readiness for control measures for soil gases, radon...	8
- Buildability with minimal training...tolerance of error	8
- Cost effectiveness, basement-per-dollar (with Type 1 EPS... regional...)	7
- Base floodproofing...can be incorporated in barrier	

5.4 Field-ready, field-proven exterior insulated systems

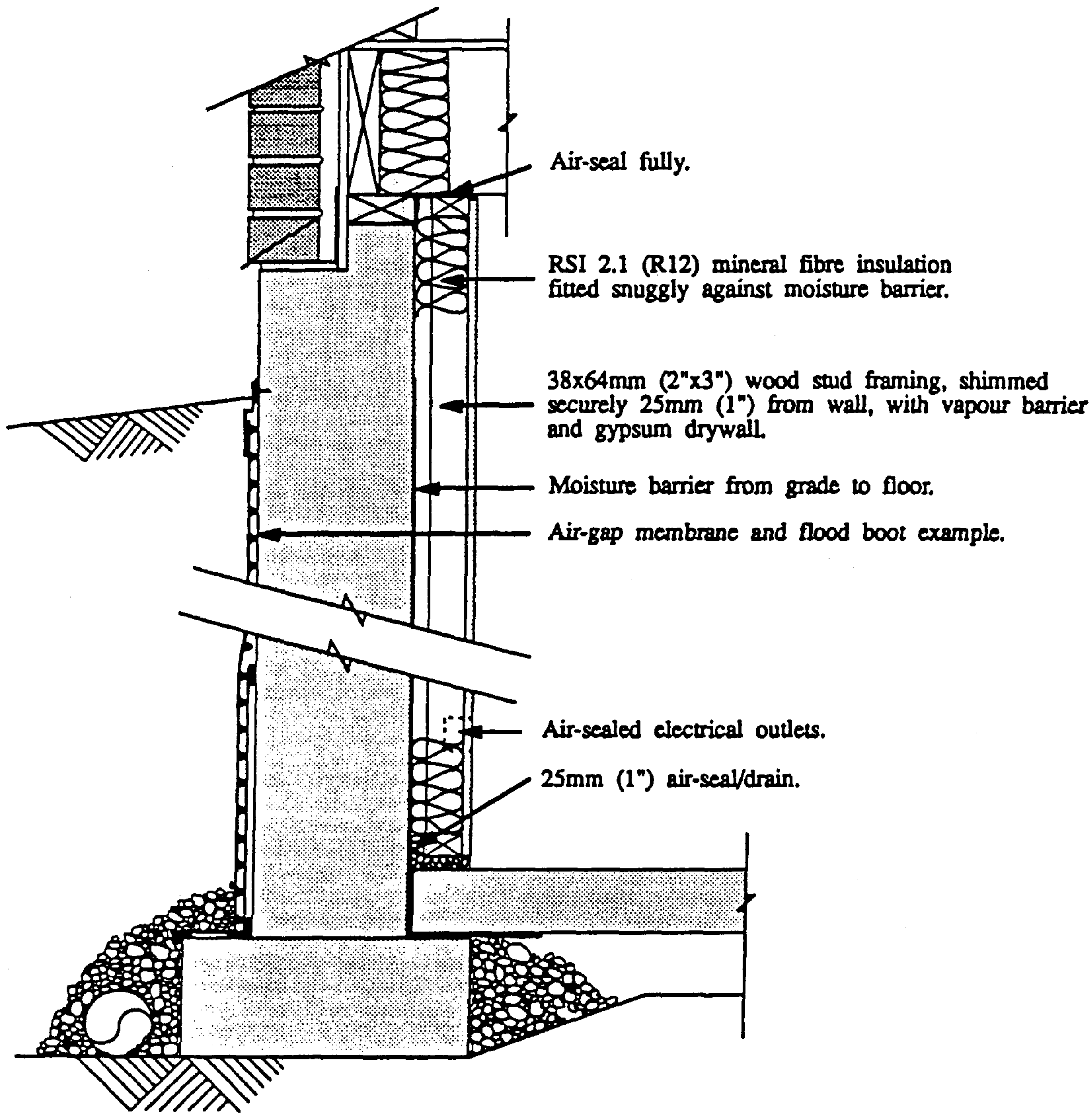
5.4.1 ***Combined insulation-drainage system:*** Glass fibre draining insulation, R13 /dampproofing at least to code minimum/concrete or concrete block. (Insulation protects dampproofing against backfilling damage and handles soil moisture primarily by itself, according to manufacturer.) (Fig. 5)

Above grade: As in Section 4, stucco/metal lath or polymer modified fibre-cement. Thermal break under brick (insul. concrete or preserved wood as per Section 4)

- Exterior dampproofing with no special backfilling...	8
- Handling construction moisture...	10
- Controlling condensation...	10
- Readiness for control measures for soil gases, radon...	7-8
- Buildability with minimal training...tolerance of error	8
- Cost, basement-per-dollar	7
- Base floodproofing...must add where needed	

5.4.2 ***Cellular plastic:*** Type 2 (or higher, type 3 or 4) cellular polystyrene /barrier membrane or adhesive dampproofing/concrete or concrete block. Above grade: polymer-modified fibre cement; thermal break under brick veneer (as per Section 4) (Fig. 6)

- Exterior dampproofing with no special backfilling...	8
- Handling construction moisture...	10
- Controlling condensation...	10
- Readiness for control measures for soil gases, radon...	7
- Buildability with minimal training...tolerance of error	7-8
- Cost, basement-per-dollar	7-8
- Base floodproofing...may incorporate in adhesive applic.	



Drawings here represent concepts.
Details, including supports and fasteners, must be specified by others.

FIGURE 3 - Interior Mineral Fibre

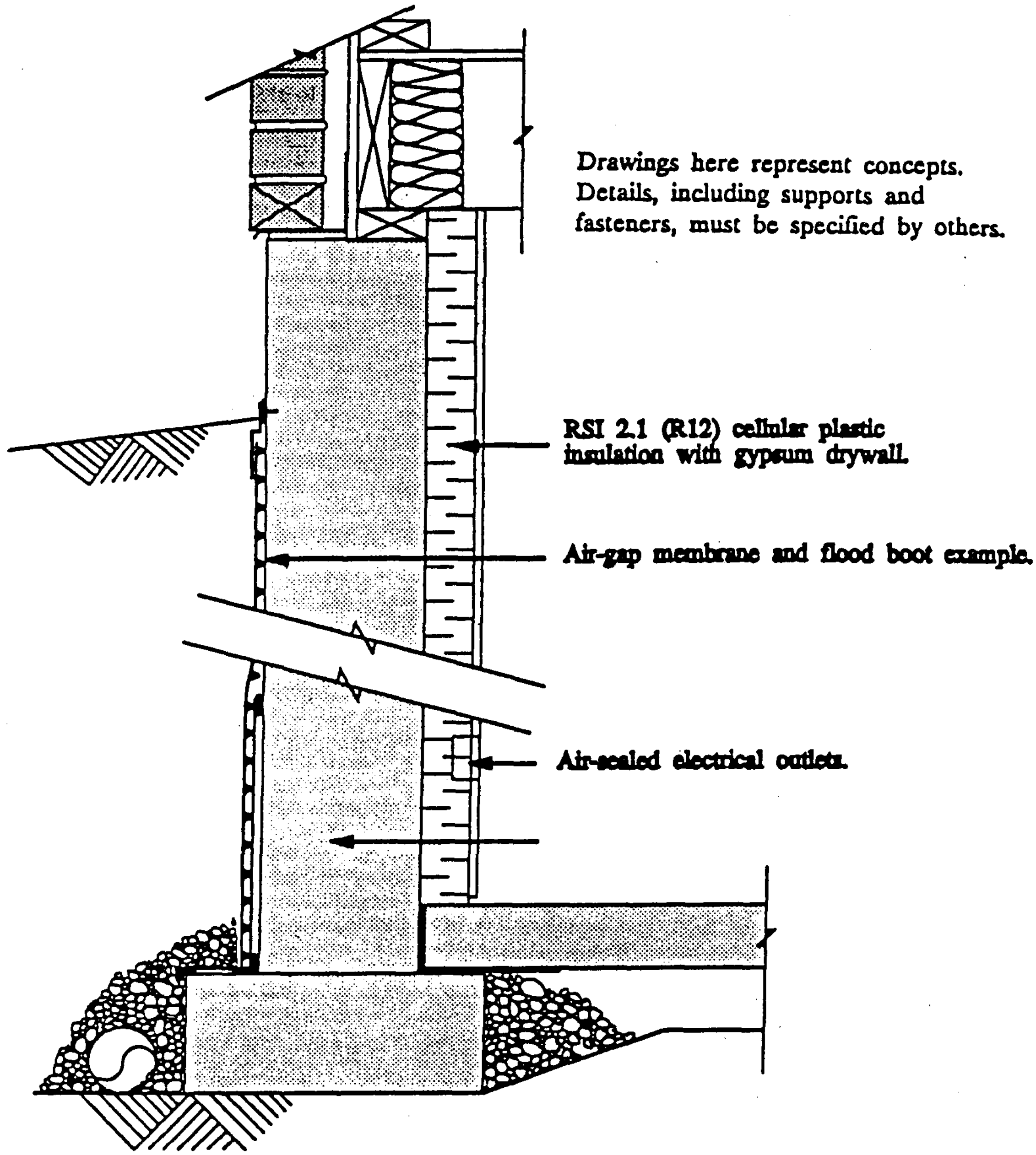
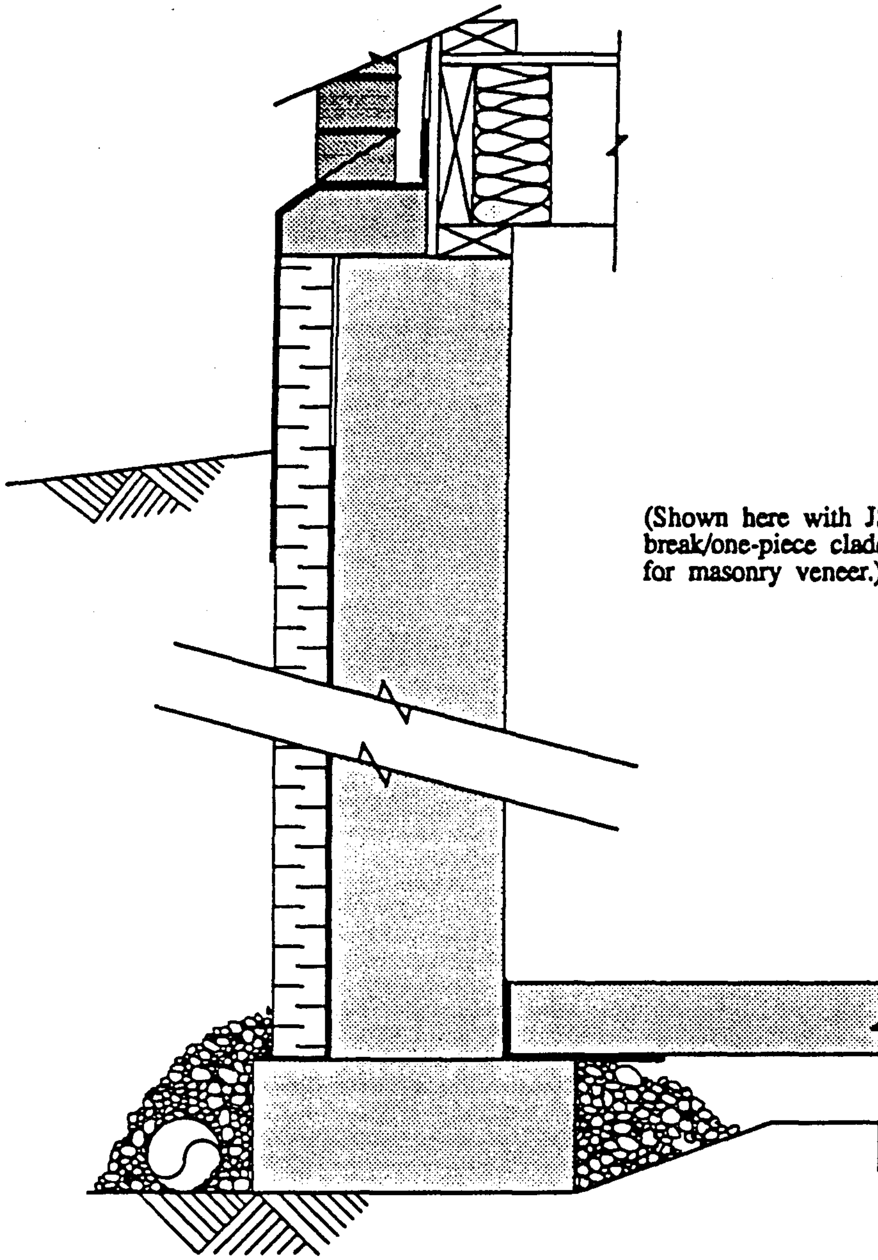


FIGURE 4 - Interior Cellular Plastic



(Shown here with JS thermal break/one-piece cladding for masonry veneer.)

Drawings here represent concepts. Details, including supports and fasteners, must be specified by others.

FIGURE 5 - Exterior Draining Glass Fibre

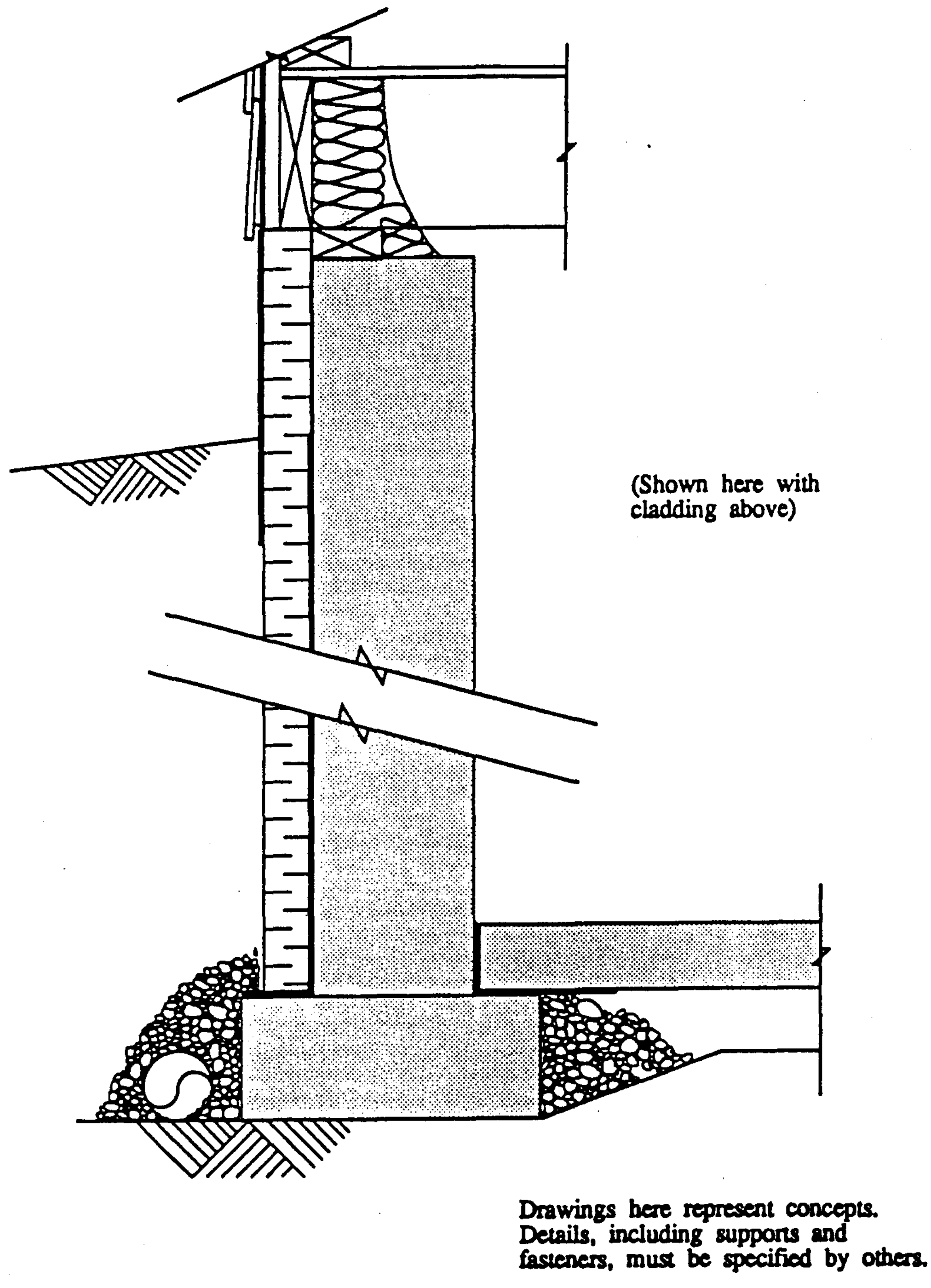


FIGURE 6 - Exterior Cellular Plastic

6. NEW SYSTEMS TO MEET THE PERFORMANCE REQUIREMENTS

Although some of the following are not yet familiar in Ontario, and some may not be "code-approved", the components in these configurations should be capable of good performance.

6.1 *Interior Insulated Systems*

6.1.1 ***Mineral fibre-plastic laminate blanket***: barrier drain (or plain membrane if on concrete block)/concrete or block/R 12 industrial blanket secured with spaced furring (ready to receive wallboard if buyer wants to finish)

- Exterior damproofing with no special backfilling...	10
- Handling construction moisture...	8
- Controlling condensation... interior fully sealed, drained	8
- Readiness for control measures for soil gases, radon...	8
- Buildability with minimal training... tolerance of error	8
- Cost, basement-per-dollar... as "starter" basement...	9
- Base floodproofing can be incorporated in barrier	

6.2 *Exterior Insulated Systems*

6.2.1 ***Self draining cellular plastic***: Draining type EPS/ adhesive dampproofing, or membrane/concrete or concrete block. Above grade: polymer-fibre-cement with (under masonry veneer) thermal break as per Section 4.

- Exterior damproofing with no special backfilling...	8-9
- Handling construction moisture...	10
- Controlling condensation...	10
- Readiness for control measures for soil gases, radon...	8
- Buildability with minimal training...tolerance of error...	8
- Cost, basement-per-dollar...probably...	8
- Base floodproofing... may incorporate in adhesive application	

6.2.2 ***Protected sprayed polyurethane***: Drain mat or equiv./ spray urethane to R-12/concrete or concrete block. Above grade: prefinished polyurethane or EPS panel with (under masonry veneer) thermal break as per Section 4.

- Exterior damproofing with no special backfilling...	10
- Handling construction moisture...	10
- Controlling condensation...	10
- Readiness for control measures for soil gases, radon...	8-9
- Buildability with minimal training...tolerance of error...refer to manufacturer	
- Cost, basement per dollar	6-7
- Base floodproofing...largely integral	

6.3 In-Wall Insulated Systems

6.3.1 ***EPS-Integral Wall Form:*** Plain or air gap membrane/EPS-integral wall form system with polymer-cement finishes.

- Exterior dampproofing with no special backfilling... 10
- Handling construction moisture... 10
- Controlling condensation... 10
- Readiness for control measures for soil gases, radon... 8
- Buildability with minimal training...tolerance of error... refer to manufacturer
- Cost basement-per-dollar...refer to manufacturer
- Base floodproofing...must add where needed (?)

6.3.2 ***Insulating Concrete Block***: Plain or air gap membrane/EPS-aggregate multi-cored concrete block, R12. Rather similar system field-proven in Scandinavia.

- Exterior dampproofing with no special backfilling... 10
- Handling construction moisture... 10
- Controlling condensation... 10
- Readiness for control measures for soil gases, radon... 8
- Buildability with minimal training... tolerance of error... refer to manufacturer
- Cost basement-per-dollar...refer to manufacturer
- Base floodproofing...add where needed.

6.3.3 ***EPS-Fibre-cement insulating concrete***: Air gap or plain membrane/structural EPS-fibre-cement wall system, R 12. As mentioned in Section 3.4, this new, stronger insulating concrete appears extremely promising.

7. CONCLUSION: GOOD CHOICES ON HAND TO BUILD GOOD BASEMENTS

The homebuilder's position is confirmed: Before requiring the full-height insulation of basement walls to control heat flow, determine how to stop leaks and control moisture flow. It is concluded here that simple components and configurations can do all of that, at a price; they work, and they fit readily into today's site building practices and skills.

There are just two main approaches that can be recommended for water control: that required for exterior insulation placement, and that for interior:

1) The job is easier with exterior insulation: the insulation itself can help greatly with controlling soil water and all moisture management, and it protects any type of dampproofing from backfill damage. (Further, if some water does leak through to the indoors, there may be no more costly repair job than is now the case.) On the basis of field experience to date, industry proponents of exterior insulations are satisfied that today's wet-applied dampproofings need not be replaced with good dampproofings. The conclusion here is that dry membranes or films are much to be preferred but can not be suggested as a general requirement.

2) Interior insulations are much more demanding, requiring sure control of water and moisture beginning with the wall exterior. The insulation does not help with that, and its presence can add considerably to repair costs where leaks occur or even if moisture control is inadequate. The only other country that puts basements under most of its houses, Norway, concluded two decades ago that the dampproofing must be a proper, factory-produced membrane. The next thought was that it might must as well be vacuum-formed into a dimpled air-gap membrane, which adds little cost and which, in its dimple-formed space between membrane and wall:

   - provides a second line of defence against any possible leaks from outside, draining freely;

   - provides a soil-cooled condenser and drain to remove construction moisture and any moisture emanating from indoors or above grade.

   Engineers and building scientists attest that this simple concept is thoroughly field proven. It is recommended as a requirement for concrete basements receiving full height interior insulation. It is recommended as a preferred approach for concrete block and other constructions as well, although these do not have much construction moisture to be dissipated and a tough, plain membrane can do the job if all is well.

Finally, in site conditions or municipal situations where drain back-up is considered a tangible risk, basements with either placement of insulation <u>should have a base flood retarder</u> added to 300 -500 mm above the footing, as in Section 2.1.

Given such appropriate water protection as just outlined, there is no strong distinction between concrete and concrete block. Where exterior insulation is used, architectural block can add the benefit of a finished interior appearance.

Regarding exterior insulation cases with masonry veneer over, the recommended requirement for a thermal break should be as shown in Section 4.5, or equivalent. Given that break, the full-height insulation does its job. Thermally, there is very little difference between exterior, interior or in-wall placement of basement insulations.

The challenge of providing a tough, attractive and economical cladding for the above grade portion of exterior insulations, for all-seasons installation, is confronted in Section 4. The conclusion is that this can now be met by developing one-piece flashing-cladding panel systems. PVC's or other high polymers can serve well, while wood fibre-cements and especially wood fibre-pozzolans appear to be very promising contenders.

In summary, the recommended system choices for the housebuilding industry's consideration, given that the above water and thermal protection measures are incorporated as stated, can be listed as follows, generally in order of ascending costs (Appendix 3). Code approval status must be checked. For quick reference, the systems' Section numbers are noted first.

6.1.1 Interior mineral fibre/plastic laminate blanket

5.4.2 Exterior cellular plastic - Type 2 EPS (or higher)

5.3.3 Interior cellular plastic - Type 1 EPS (or higher)

5.3.1 Interior mineral fibre/wood frame, drained

5.4.1. Exterior draining glass fibre

...And further choices now at hand, or some may now be accepted and on hand; some appear to be fully field-proven in North America or abroad:

6.2.1 Exterior draining EPS

6.3.3 EPS-fibre-cement insulating concrete

6.2.2 Exterior protected sprayed polyurethane

...And finally, depending perhaps mainly on costs, these appear promising:

6.3.2 Insulating concrete block

6.3.1 EPS-integral wall form

The concluding tables, overleaf, repeat the comparative judgements on these systems, the choices on hand or at hand to build good basements.

Summary of Performance Ratings of Basement Systems

(6 = "pass")

Design	Description	Type of Wall	Exterior Damp-proofing	Handling Const. Moisture	Control of Condensation & Summer Trans.	Control of Soil Gases	Buildability, Tolerance	Cost
Base Case (full hgt.)								
5.2	Interior min. fibre, wood frame (bitumen dp)	in-situ	4.5	5	5.5	6	6	7
Field-ready interior systems –								
5.3.1	Min. fibre, wood frame, dimpled air-gap dp	in-situ	10	7.5	8	8	7	7
5.3.2	Min. fibre, wood frame, barrier	block	9	8	8	8	7	7
5.3.3	Cellular plastic, air-gap dp	in-situ	10	8.5	8	8	8.5	7
5.3.4	Cellular plastic, barrier	block	9	8.5	8	8	8	7
Field-ready exterior systems – assuming a thermal break under masonry veneer –								
5.4.1	Draining min. fibre, bitumen dp	in-situ or block	8	10	10	7.5	8	7
5.4.2	Cellular plastic, adhesive dp	in-situ or block	8	10	10	7	7.5	7.5

Summary of Performance Ratings of Basement Systems

(6 = "pass")

Design	Description	Type of Wall	Exterior Damp-proofing	Handling Const. Moisture	Control of Condensation	Control of Soil Gases	Buildability, Tolerance	Cost
New interior systems –								
6.1.1	Min. fibre-poly laminate, air-gap dp (barrier, on block)	in-situ or block	10	8	8	8	8	9
New exterior systems – assuming a thermal break under masonry veneer –								
6.2.1	Draining EPS, adhesive dp	in-situ or block	8	10	10	8	8	8
6.2.2	Protected spray-polyurethane outboard drain, no dp	in-situ or block	10	10	10	8.5	7 (assume)	6.5
In-wall insulated systems – may need no further thermal break under masonry								
6.3.1	EPS wall form, barrier	integral	10	10	10	8	refer to	
6.3.2	Insulated block, barrier	block	10	10	10	8	manufacturer	
6.3.3	EPS – fibre-cement concrete, air-gap dp	in-situ integral						

APPENDIX 1

STUDY SCOPE AND SOURCES

APPENDIX 1

STUDY SCOPE AND SOURCES

SCOPE

Initially, some 70 combinations or configurations of insulation, moisture control measures and structural material were seen to be within the scope of this study; these are shown in the following matrix. (The Y symbol denotes a configuration deserving considerable study: 38 in all. The vertical bar symbol denotes a configuration of similar distinction, but where the study for a preceding one pertains fairly well and need not be repeated fully: 32 configurations.)

The scope became even broader, by about 20 potential combinations, when it was found in the first month that the barrier and drain types of moisture control must be opened further to a distinctly separate classification, the barrier-drain or dimpled "air-gap membrane". On the other hand, the study soon became greatly simplified with the decision that the wall structural material itself need not be a primary consideration in moisture control, so that it became unnecessary to study concrete and concrete block options separately and fully for example. With those "learning curve" refinements in mind, the early matrix as reproduced here represents the actual scope rather well.

WATER PROTECTION \ INSULATION		CONVENT	INTERIOR FULL			EXTERIOR FULL			COMBINED		FORMS		SANDWICH	
		2 ft. below grade	(1) Min. wool, wood	(2) Same, no wood	(3) Cell. styrene, no wood	(1) Min. wool drain	(2) Cell. styrene	(3) Spray ureth.	(1) On concrete	(2) On insul. core block	(1) Insul. in form	(2) Int./ext. insul. form	(1) Min. wool drain	(2) Cell styrene
CONVENTIONAL	CONCRETE	Y e	Y e	Y	Y	Y e	Y	Y	Y e		Y?	Y	Y?	I
	BLOCK	Y e	Y	Y	Y	Y	I	I	Y e	Y				
BARRIER	CONCRETE	Y	Y	Y	Y	I	I	I	Y		I	Y	I	I
	BLOCK	I	I	I	I	I	I	I	I	Y				
EXT. DRAIN	CONCRETE	Y e	Y	Y	Y		Y	Y			I	Y		Y
	BLOCK	I	Y	Y	Y		I	I						
SPECIAL CONCRETE		Y	Y	I	I	I	I	I	I	I	I	I	I	I

MATRIX OF ORIGINAL SCOPE

SOURCES

As stated in the introduction to this study, the knowledge base has been drawn primarily from industry itself, including those researchers involved ultimately with field-proven components and systems. The various government representatives are here considered as part of the housing production industry. The industry sources are given below, first listing the Steering Committee of this Ontario Home Builders' Association project, inclusive of some stand-ins and specialists who participated. A bibliography of helpful literature is given last.

Basement Study Steering Committee

Ali Arlani, Ministry of Housing

Marion Axmith, Society of the Plastics Industry

Steve Belej, SPI/BASF Canada

Gord Chiarot, Sandbury Building Corporation

Darcy Courville, Ontario Concrete Block Association

Enrico DiNino, Ministry of Energy

Peter Goldthorpe, Ontario Home Builders' Association

Ludwik Hajduk, Canadian Portland Cement Association

Tom Kerwin, Canada Mortgage and Housing Corporation

Robert Marshall, Ontario New Home Warranty Program

Mark Patamia, Ontario Concrete Block Association

Harold Piccininni, Low Rise Forming Contractors' Association

Alan Todd, SPI/~~BASF Canada~~ BF GOODRICH CANADA.

Lou Viola, Low Rise Forming Contractors' Association

Ed Wahbe, National Research Council

Keith Wilson, SPI/Fiberglas Canada

Sources by component or function:

- Listed in no particular order -

Heat flow from house basements

M.C. Swinton and Gint Mitalas, Institute for Research in Construction; David Greeley and Keith Wilson, Fiberglas Canada
DOW CHEMICAL CANADA.

Draining mineral fibre insulation

(Glass Fibre) Keith Wilson, Fiberglas Canada; Don Onysko, Forintek Canada

(Mineral Fibre) Hans Sundh, Norwegian Building Research Institute; Dr. Ingemar Höglund, Royal Institute of Technology, Stockholm.

Draining EPS insulation

André St. Michel, BASF Canada, and Dr. Ingemar Höglund, Royal Institute of Technology, Stockholm.

Laminated Mineral Fibre Interior Blanket

David Jackson, Total Laminating; Keith Wilson, Fiberglas Canada

EPS (Expanded Polystyrene) insulation, general

André St. Michel, BASF Canada

Extruded cellular polystyrene

Susan Beamish, Dow Chemical; also SPI representatives.

Spray-applied polyurethane system

Tom Harris, Steve Belej, BASF Canada; Steve Reesor, Great Northern Industries

Above-grade protection of external insulations:

General: Dave Greeley, Fiberglas Canada; Todd Hallam, Dryvit Systems Canada; Jeff Christian, Oakridge Labs; Tom Kerwin and Don Fugler, CMHC; Ned Nisson, Energy Design Update.

Moulded PVC's: Alan Todd, B F Goodrich; Keith Wilson, Fiberglas Canada

Wood fibre-cement and wood fibre-pozzolan panel developments: Don Onysko, G. Shields, Forintek Canada.

Thermal break under masonry veneer: Jan Sulkiewicz, J S Consultants: insulating concrete ledger block with one-piece flashing-cladding concept. (Also Rick Martin, Primeau Argo Block, and John DeVer, Boehmers, on insulating concrete ledger options.)

Concrete, plasticizers and reinforcing options:

Dr. N.K. Becker, P.Eng., Becker Engineering; Ludwik Hajduk, Canadian Portland Cement Association

Concrete block, architectural block, pargings:

Darcy Courville, Ontario Concrete Block Association; Mark Patamia, Ontario Concrete Block Association.

Insulating concrete, EPS-fibre-cement

André St. Michel, BASF Canada, and Francon Lafarge representatives.

EPS integral form systems

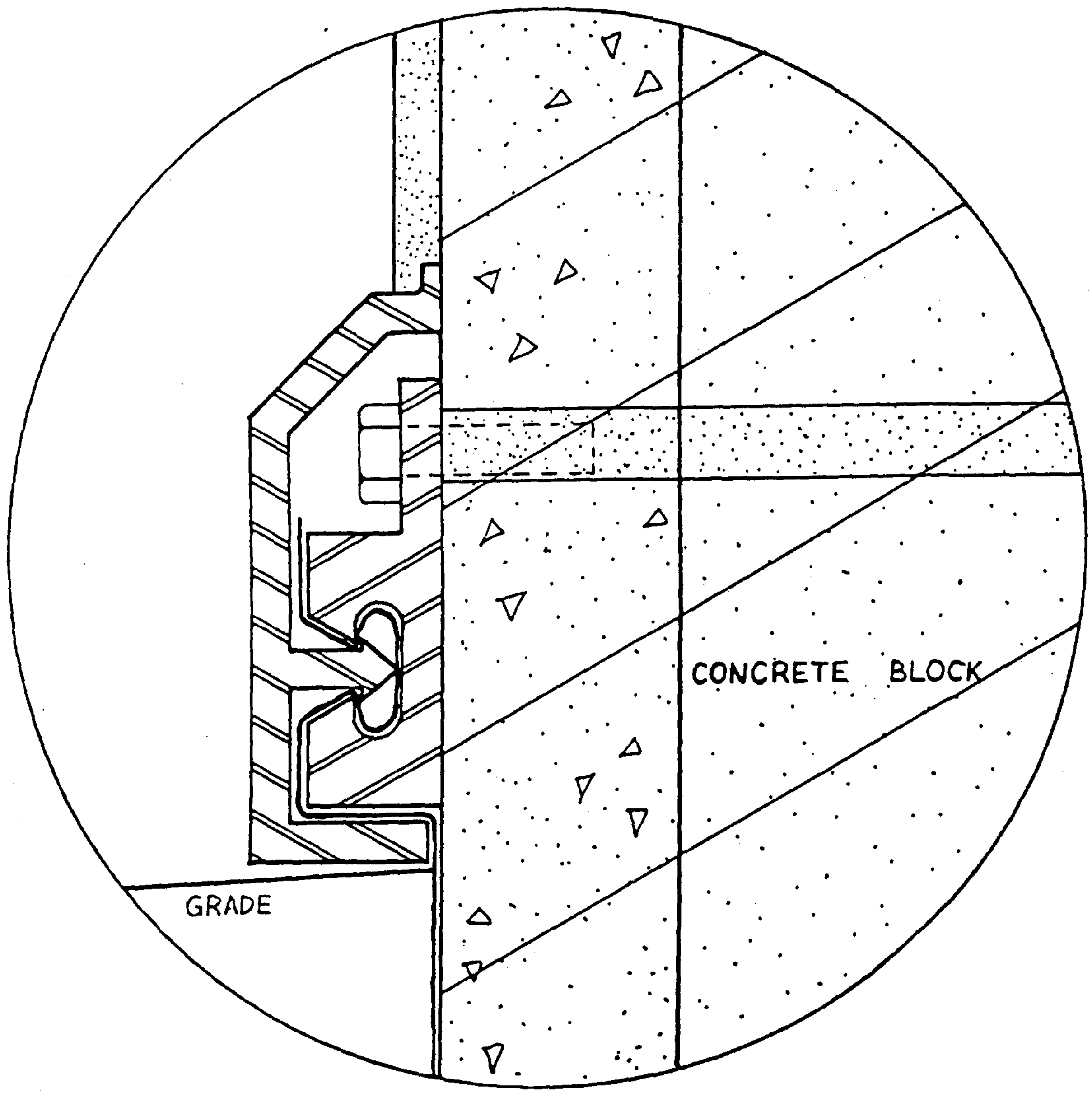
Allan Hill, Permaform of Canada Ltd.

On-site construction considerations

Gord Chariot, Sandbury homes; Robert Marshall, Ontario New Home Warranty Program; A.J. Bower, Morrisburg builder.

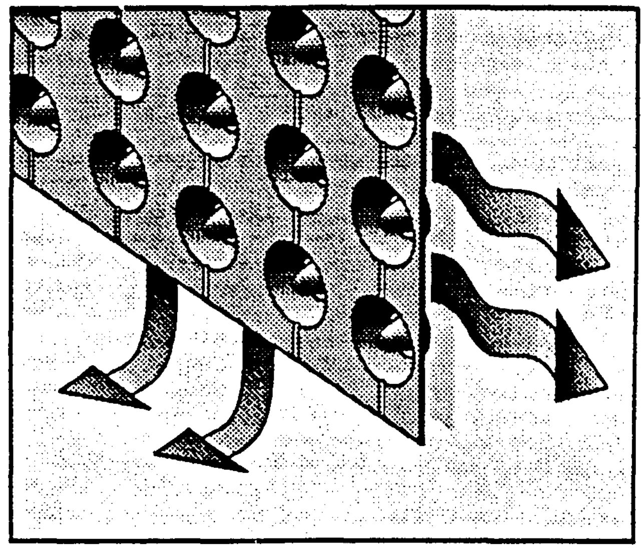
Dampproofing and flood retarding systems

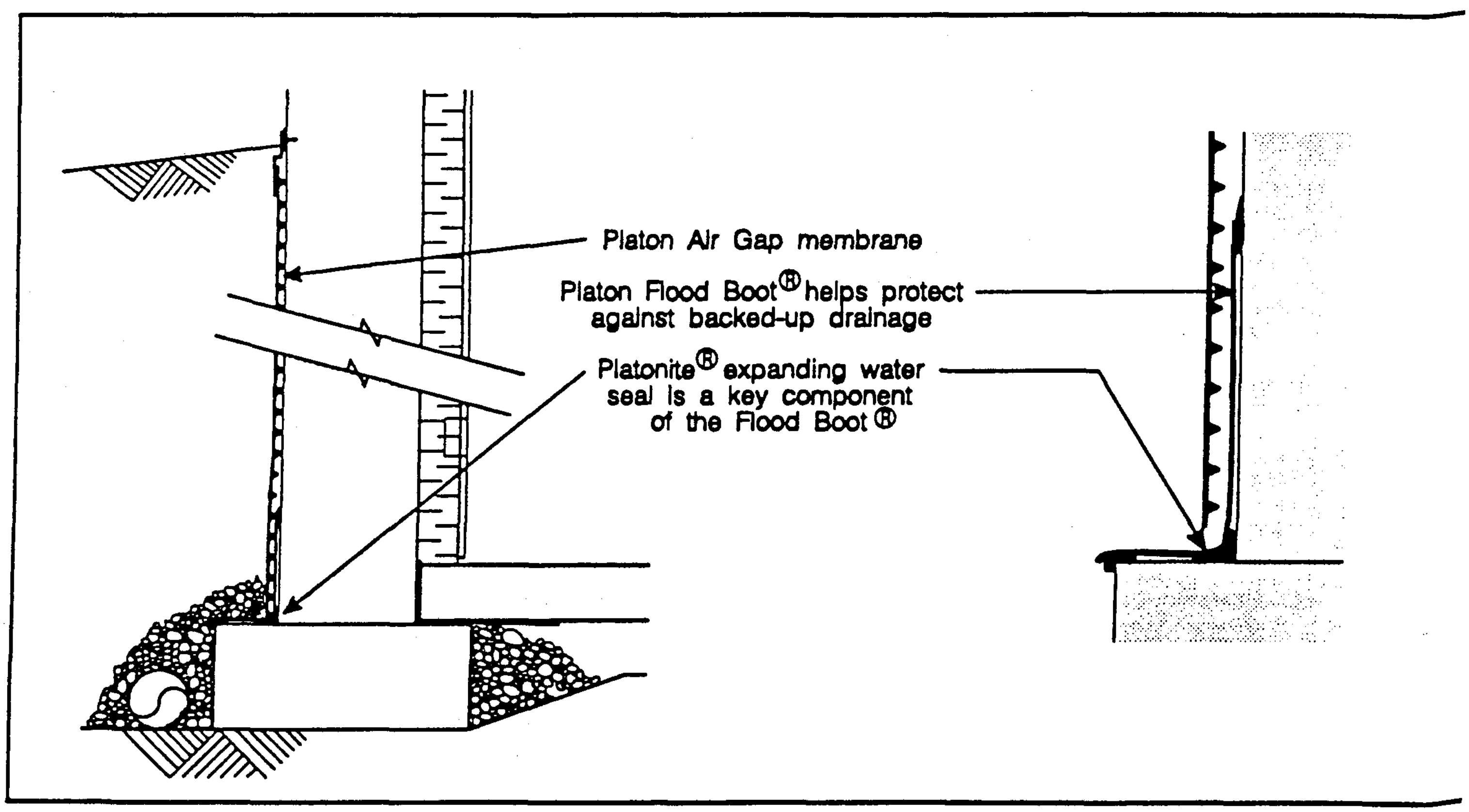
Hanging barrier membrane, "snap lock" top moulding with PVC or other membrane (can be sealed at base to act as flood retarder): Alan Todd, B.F.Goodrich; G. Kappeler, Bruce Shorney, Kapshor Technologies. Concept:



Dampproofing and flood retarding systems, continued:

"Air gap" dimpled membrane, or barrier-drain: Ed Wahbe, NRC; Frank Romagna, Platon Canada; Richard Waterhouse, Platon Division, Isola AB, Norway; Hans Sundh, Norwegian Building Research Institute; Dr. Ingemar Höglund, Royal Institute of Technology, in Stockholm; Brent Anderson, P.Eng, Minneapolis. (Concept sketch here includes optional Platon "floodboot" for cases where risk of drain backup is unduly great.)





Carmody, J.C., Shen, L.S., Huang, Y.J. and Parker, D.S. The Cost Effectiveness of Foundation Insulation Measures: Results from the Building Foundation Design Handbook. ACEEE 1988 Summer Study on Energy Efficiency in Buildings. Proceedings from a Panel on Single-Family Building Technologies. 1988.

A finite difference model was coupled with a "benchmark" whole building simulation model to provide relatively accurate and detailed optimization capabilities. Cost optimization led to a series of suggested insulation configurations for various regions of the U.S.A. which depend upon the specific climate conditions in each city. An excellent method which actually focuses on "real" costs and simplifies to single specific measures per climatic region. Excellent charts summarizing the research.

Crocker, C.R. House Basements. Canadian Building Digest no. 13. National Research Council Canada, Ottawa. 1961.

A practical discussion of the basics of basement physics, construction and retrofit of the interior. The benefits of insulation, moisture and vapour barriers and proper drainage, dampproofing and backfilling as they relate to the home builder and buyer are presented.

Crocker, C.R. Moisture and Thermal Considerations in Basement Walls. Canadian Building Digest no. 161. National Research Council Canada, Ottawa. 1974.

A more detailed discussion (than CBD 13) of methods for the control of moisture and heat flows in below-grade spaces. Moisture sources, the principles of moisture migration in soils and basement construction materials and methods for the control of moisture movement are presented as are heat flow dynamics and various methods for insulation placement.

Deacon, P.C. Glass Fibre as a Draining Insulation System for the Exterior of Basement Walls. From American Society Testing Materials STP 789. 1983.

A discussion of methods for calculating the complex heat-loss patterns in basements. A two dimensional, finite element heat transfer analysis was applied to a modelled section of basement wall and floor. Various configurations of insulation were compared under assumed steady-state conditions and the overall total heat flow per metre measured.

A useful aside is a discussion of the drainage characteristics of the mineral fibre insulation. A test apparatus was developed to establish the water flow paths through the mat. Conclusions indicate that only the outer 6 to 8 mm of a 50 mm mat actually conduct water, with only the first 3 to 4 mm conducting any significant volume.

Edvardsen, Knut I. New Method of Drainage of Basement Walls. Byggmesteren, Oslo. 44 (18): 24-27. 1972. (National Research Council Technical Translation 1603 in 1975).

A very brief discussion of the relevant (at that time) Norwegian Codes relating to dry basements followed by research results on the drainage capabilities of thin (20 mm) glass fibre insulation mats. This report is one of the first to examine external insulation and water drainage with mineral wool insulation.

Elmroth, A. and Höglund, I. New Basement Wall Design for Below-Grade Living. Byggförlager, Stockholm. 1971. National Research Council Technical Translation 1801.

This report is partly a discussion of the results of investigations of "more up-to-date construction principles" for external basement walls and partly a suggestion for suitable new designs to facilitate incorporation of new technology to improve basement wall performance. An excellent description of the various states of new Swedish basement construction technology in 1971. A detailed study of mineral fibre combined drainage and insulation layers.

Hagentoft, Carl-Eric. Heat Loss to the Ground from a Building - Slab on the Ground and Cellar. Report TVBH-1004 of the Dept. of Building Technology, Lund Institute of Technology, Sweden. 1988.

A technical paper on the numeric calculation of the below grade heat loss.

John, N.W.M. Geotextiles. Chapman and Hall, New York, N.Y. 1987.

A British synthesis of the types, roles, applications and design techniques for geotextiles in engineering. The book "...collates the most useful aspects of our current understanding of the behaviour of geotextiles" and includes excellent diagrams and charts coupled with good commentary of use and design. However there is no mention of costs and applications to structural design are strictly retaining walls.

Koerner, R.M. Designing with Geosynthetics. second ed. Prentice Hall Inc., Englewood Cliffs, N.J. 1990.

An enthusiastic, "textbook" style, presentation of the latest applications of geosynthetics. Many excellent photographs and diagrams detailing the designs of various systems.

Maehle, Eiliv. Drenering, Fakttvern og Isolasjon au Rom Under Bakken. Hovedoppgare vod Institut for Bygningsteknik, NLH. Norway. 1983.

An examination of the performance of mineral wool ("rock wool") below grade as a drainage and insulation layer. Though available only in Norwegian, discussions with the engineers involved with the project revealed unsatisfactory performance (high saturation in the lower portions of the insulation) observed in the tests. These tests were performed on standard mineral wool blankets and the results are not transferable to glass fibre, semi-rigid board.

Quaid, M.A. and Anderson, M.O. jr. Measured Energy Savings from Foundation Insulation in Minneapolis Single Family Homes. ACEEE 1988 Summer Study on Energy Efficiency in Buildings. Proceedings from a Panel on Single-Family Building Technologies. 1988.

This study was undertaken to; isolate and measure the actual energy savings from foundation insulation and, survey homeowners to discover their motivations and perceptions regarding the work, to identify concurrent changes that might affect the savings analysis, and to discuss any problems with the insulation that might have arisen. A discussion of about 20 homes in which the only retrofit was performed on foundation insulation. Quality statistical survey.

Timusk, J. Control of Decay and Heat Losses in Basement Walls. Proceedings: CSCE Ontario Region Conference on Building Science. London, Ont. 1982. pgs. 18-27.

A nicely rounded admonishment to "stand back (and) take a fresh look at the overall [basement] system". The author presents a brief discussion of the need for an atmospheric pressure capillary break against the foundation wall to control the infiltration of water. A presentation of information on the influence of mineral wools as drainage layers and a short bibliography of related Scandinavian publications.

Timusk, J. Insulation Retrofit of Masonry Basements. A project funded by the Ontario Ministry of Municipal Affairs and Housing. 1981.

A detailed presentation of the factors involved in energy saving using insulation in basements. Discussions of moisture and energy flows, retrofit options, advantages and disadvantages of both interior and exterior insulation, and a detailed method for evaluating the energy savings potential and payback periods of various retrofit configurations are all presented.

van Rijn, G.J. A Liquid Water Permeance test for Dampproofing on Plywood in Preserved Wood Foundations. A Forintek Canada Corp. report for the Canadian Forestry Service. Ottawa, ON. 1988.

van Rijn, G.J. Testing the Performance of Dampproofing for Preserved Wood Foundations. A Forintek Canada Corp. report for the Canadian Forestry Service. Ottawa, ON. 1989.

The performance of various types of dampproofing for use in PWF were evaluated using a water permeance test and two types of conditioning which emulated service conditions of backfill abrasion and joint movement. Nine tests were conducted on six films and three coatings with various attachment materials on jointed and continuous plywood specimens. One useful conclusion states "...plywood joints are difficult to dampproof with coatings alone."

van Rijn, G.J. Control of Moisture in Preserved Wood Foundations. A Forintek Canada Corp. report for the Canadian Forestry Service. Ottawa, ON. 1984.

Presents results of tests on the performance of four preserved wood foundation units in Ottawa monitored for moisture content over a period of one year. Compared present construction practices and an alternate approach using semi-rigid glass-fibre insulation as a capillary break between backfill and PWF. A useful conclusion states "...PWF specimen using the semi-rigid insulation has shown much greater control of moisture."

van Rijn, G.J. Performance Criteria and Testing of Dampproofing for Preserved Wood Foundations. A Forintek Canada Corp. report for the Canadian Forestry Service. Ottawa, ON. 1987.

Development of performance criteria for moisture barriers or dampproofing is discussed. Four levels of dampproofing are proposed which are site specific regarding geotechnical and weather conditions. Test methods are discussed and the results of a manufacturers survey are presented.

Veldhuijzen van Zanten, R., ed. Geotextiles and Geomembranes in Civil Engineering. A.A. Balkema Pub. Rotterdam, Neth. 1986.

A manual which deals with geotextiles from "start to finish". A Dutch view of the state of the art and future trends. Discussions of Dutch projects, developments and technology are accompanied by many examples of world-wide use. Very limited in scope for foundation drainage however, with primary focus on earth dam and dike drainage.

Wolfgram, K.J. The Experimentally Determined Effectiveness of Insulation Added to the Exterior of Residential Foundations. Proceedings from Session VIb, no. 2. ASHRAE/DOE Conference on Thermal Performance of Building Envelope. Las Vegas, Nev. 1982.

Calculations based on ASHRAE methodology for energy/cost savings using insulation were compared to actual field tests of six homes in Newark, OH. Cost effectiveness of retrofit and energy savings per degree-day were established.

A Guide to Construction of Cast-in-Place Concrete Basements for Housing and Small Buildings. HUDAC Technical Research Committee. 1975.

A document to provide builders with information which will aid in the prevention of failures in cast-in-place concrete basements. A detailed examination of the then current necessary practices to ensure proper basement construction. Includes discussions of admixtures, placement techniques, damp- and water-proofing, formwork and sizing of walls and footings.

A Survey of Minnesota Home Exterior Foundation Wall Insulation: Moisture Content and Thermal Performance. Minnesota Dept. of Public Service, Energy Division. 1988.

A study conducted on the condition of exterior foundation wall insulation 6 to 24 inches below grade on Minnesota homes. Samples tested included extruded polystyrene, mineral fibre board, moulded expanded polystyrene (beadboard), polyisocyanurate and spray applied urethane. Moisture absorptions, thermal characteristics and physical damage are all presented. The value of above grade protection also discussed.

Advances in Basement Technology. Prepared for Canada Mortgage and Housing Corporation by The Becker Engineering Group and Scanada Consultants Ltd. 1989.

A presentation of the present state of practice for basement construction and an examination and rationalization of the future developments necessary for significant improvements in construction and quality.

Basement Condensation: Field Study of New Homes in Winnipeg. Prepared for Canada Mortgage and Housing Corporation by UNIES Ltd. Winnipeg, MAN. 1987.

A report investigating the causes of excessive condensation in new basements in the Winnipeg area. Fourteen basements were assessed and remedial action suggested as well as recommendations for future changes to Building Code requirements. Not an exhaustive study but does provide evidence of the value of exterior insulation/drainage layers with exposed interior concrete.

Basement Foundation Design Handbook. Prepared by the Underground Space Centre, University of Minnesota and Martin Marrietta Energy Systems Inc. for Oakridge National Laboratory, Oakridge Tenn. and the U.S. Dept. of Energy. 1988.

The handbook contains a set of typical residential foundation construction details and recommends cost-effective insulation levels for a variety of basements, crawl spaces and slab-on-grade foundations for most U.S. regions. Details are accompanied by critical design information needed for specifying structural integrity, thermal and vapour controls, subsurface drainage, dampproofing and waterproofing, backfilling and compaction, and decay, termite and radon control measures.

Basement Installation Practice Manual. HUDAC Technical Research Committee. 1980.

A short pictorial presentation of do's and don'ts for basement construction techniques.

Design Guide for Dry Basements in New Homes. Prepared for U.S. Dept. of Housing and Urban Development by AMAF Industries, Inc. 1981.

A manual for home builders which presents methods to prevent leaks and lower moisture in basements without substantially increasing construction costs. No discussion of future developments presented.

Effects of Insulation on Basement Walls. Energy, Mines and Resources Canada Building Energy Technology Transfer (BETT) program publication No. 85.03. 1985.

A survey of the statistical incidence of problems, together with an evaluation of the technical processes. Useful area includes a discussion of the limited findings of the survey.

Energy Design Update. J.D. Ned Nisson, ed. A monthly newsletter from Cutter Information Corp. Vol. 7 (1988), Nos. 2, 7, 9 and 10 and Vol. 8 (1989), Nos. 2 and 5.

Brief abstracts on various products and research activities in the U.S.A. in the energy efficient housing field.

External Insulation of Basement Walls - Phase II Report and External Insulation of Basements. HUDAC Technical Research Committee. 1981 and 1982.

The full project consisted of insulation attachment field trials, examinations of various protective techniques for exposed insulation, a full scale test of one basement with various insulation methods, and assessment of the costs involved. The report is a general and theoretical presentation of the results which includes a discussion of the principles of heat loss and moisture control and practical commentary on "do's and don'ts". The External Insulation of Basements report is a "public information brochure" simplifying the content of the Phase II report. Phase III involved the funding of specific projects run by individual manufacturers (no final report produced).

Field Performance of Gravel Pad Drainage Installations Under Basements. Prepared for HUDAC by Scanada Consultants Ltd. 1977.

A study of gravel footing pads for drainage to examine their performance in practice and to assess their suitability as alternatives to traditional footing and drainage tile systems.

Insulating Basements, Crawl Spaces and Slabs-on-Grade. Prepared for Energy, Mines and Resources Canada by Marbek Resource Consultants Ltd. 1987.

A manual to provide contractors and do-it-yourselfers with details on how to select and carry out effective foundation and basement retrofits. A presentation of various insulation and air sealing techniques for most types of foundations encountered in Canada. Useful warnings about hazards like insects and mechanical damage to exterior applications.

Pre-production Engineering and Certification of Fiovalve Backwater Valve. Prepared by Anderson Associates Inc. for Fiodrain Ltd. 1987.

An extensive pre-production engineering investigation which would satisfy CSA certification requirements was undertaken with assistance from the Innovative Housing Grants Program, Alberta Municipal Affairs. The Fiovalve is a backwater control device used to prevent sewer backflow from overloaded or clogged municipal sewage lines.

Some Methods of Insulating Basements, Walls and Windows. Alberta/Canada Energy Resources Research Fund (A/CERRF). 1987.

A technology transfer booklet presenting highlights of studies funded by the A/CERRF. Highlights of a practical comparison of various methods for insulating exterior walls and the net benefits of doing so. Results presented on a field test of retrofitted basements with external and internal insulation and the energy savings over a one year period.

Thin Wall Foundation. Prepared by the Dept. of Civil Engineering, University of Alberta. 1990.

Studied the feasibility of building residential basement foundation walls of unreinforced concrete thinner than the conventional 200mm. Concluded that 150mm is an optimum reduced thickness for a 2400mm high wall. If 20 MPa concrete were used, 1500mm of backfill could be retained on a brick veneer supporting wall. 1800mm if non-brick veneer.

APPENDIX 2

ASSESSMENT OF THE THERMAL PERFORMANCE OF

SELECTED BASEMENT INSULATION CONFIGURATIONS

(IRC REPORT)

National Research Council Canada — Conseil national de recherches Canada
Institute for Research in Construction — Institut de recherche en construction

CLIENT REPORT

for

Scanada Consultants Limited
436 MacLaren Street
Ottawa, Ontario K2P 0M8

Assessment of the Thermal Performance of Selected Basement Insulation Configurations

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Report No: CR6301.1
Report date: 13 December 1990
Contract No. CR6301
Reference: Application for test dated
Section: Building Performance

12 pages
Copy No. 5 of 5 copies

Canada

INTRODUCTION

The Institute for Research in Construction was commissioned by Scanada Consultants Limited to investigate the thermal performance of selected basement insulation configurations. These evaluations were needed by Scanada in its basement insulation project, undertaken for the Ontario Home Builders Association.

In response to this request, the steady state heat loss performance of a number of configurations selected by Scanada was evaluated, and the configurations were ranked according to that performance.

OBJECTIVE

The objective of this study is to assess, through available analytical techniques, the steady state heat loss performance of a number of insulation placement configurations, under fixed conditions, so that fair comparison and ranking of the options could be made.

DESCRIPTION OF THE CONFIGURATIONS

The selected configurations were developed from combinations of the following design considerations:

- 2 insulation levels
  - RSI 1.4 (R8)
  - RSI 2.1 (R12)
- 5 insulation placements
  - 600m (2 ft) below grade
  - almost full depth, with a 150 mm (6") gap at the bottom
  - full depth insulation, from top of wall to slab
  - full depth from *grade* to slab (used in combination with others)
  - full depth insulation with the floor perimeter insulated 1 m (3.28 ft) wide
- 2 locations
  - interior
  - exterior
- 3 wall constructions
  - poured concrete
  - standard concrete block
  - insulated (filled) concrete block

- 3 above grade exterior finishes
  - non-brick
  - brick with no thermal break between the brick and concrete wall
  - brick with a 38 mm x 200 mm (1 1/2" x 8") wood member thermal break between the brick and concrete *(the use of wood under the brick may not meet current regulations)*

From these design options Scanada selected 18 configurations to be evaluated. These are listed in Table 1.

The configurations were evaluated on a full depth basement having a wall height of 2.45 m (8 ft), with the slab being 2 m (6 1/2 ft) below grade, and located in average soils of medium thermal conductivity. The current insulation requirement by the Ontario Building Code - RSI 1.4 applied to 600 mm below grade (R8, 2 ft below grade) - was used as the reference case, against which all other options were compared.

ANALYSIS METHOD

A pre-packaged, 2-dimensional energy analysis program was implemented. The program, developed in Belgium and made available in 1986, is called KOBRU86[1]. It was designed to analyze the effect of thermal bridges in building construction. It uses an 'energy balance technique' to solve for the temperature field and heat transfer rates in complex structures that are essentially made up of a number of rectangular shapes. This program is ideally suited to basement heat loss analysis.

The essential elements of the basement wall and slab, as set up for this investigation, is illustrated in Figure 1. The ten rectangular shapes are needed to specify the essential physical aspects of half of the basement. The other half is assumed to be a mirror image with the same performance, and thus no heat crosses the center line of the basement. The center line is specified in the program to be an adiabatic surface. The third dimension is specified to be one meter, so that all results are expressed per unit width of basement wall; i.e. per meter of basement perimeter.

The top surface of elements #1 and #2 represent the ground, where a fixed temperature is specified. As well, the lower surface of element #10, the deep earth, is specified to be at the same temperature as the ground surface. The basement indoor temperature is set to be one degree Celsius higher than the two isothermal boundaries described above, so that the reported steady state performance is expressed per degree *increment* of basement temperature above its surroundings; i.e. the units are W/(m.C).

The following points describe some of the rationale for this particular geometrical representation:

- the width of the mass of earth in element 1 and the depth in 10 are selected judgmentally to account for the "field of influence" of the basement heat loss on the earth and vice versa. The results should be insensitive to the width of elements 1 and 2 beyond the values chosen (about 9.8 m total, 32 ft), but the depth of #10 (about 5 m, 17 ft) has some influence since this is the main thermal resistance between the slab and the deep earth which is at a lower temperature than the basement air. This depth is assumed to represent the depth of the water table, and has been selected to match experimental data.

- the exterior insulation layer (#3 & 4) and the interior insulation layer (#6, 7, 8) are split up to allow different depths and thicknesses of insulation to be specified. The thermal resistance of the element is set to that of the earth or the concrete when there is no insulation in that location. The thicknesses of elements #7 and 8 were minimized when no insulation was specified, to avoid creating an internal thermal bridge through which heat would transfer more easily than in reality.

- element #8 is used to model the effect of a 150 mm (6") gap in the insulation left by some builders at the bottom of the insulated wall.

- elements #2 and #9 are needed next to the basement wall and floor to specify a 'tighter' (higher density) analysis grid through the earth adjacent to the basement, since much of the heat loss occurs through these layers; as well, the heat flow patterns are two dimensional and more complex in the earth nearest the basement. A very high density calculation grid is specified for element #5, the concrete or block wall, where the highest heat loss rates and temperature gradients can occur, and where more precision is needed.

- the detailed heat loss patterns through concrete block walls were not modelled explicitly. The thermal conductivity of the wall (element #5) was simply assumed to be half of that of the poured concrete for a standard block wall, and one fifth for an insulated (filled) concrete block.

- the thermal bridge of the brick veneer sitting on the top of poured concrete basement wall was represented by a very high conductivity material separating the top of the concrete wall (element #5) and the surroundings. The entire width of concrete at the top of the wall was assumed to be exposed to this bridge.

REFERENCE RUNS

To gain confidence in the IRC implementation of KOBRU86, three reference cases were run and the results compared to those generated in a more detailed study of basement heat loss, reported in Ref. 2. Comparisons of the two methods showed good agreement, as indicated in Table 2.

The largest discrepancy is with the partial insulation case. A 9% discrepancy was obtained for the total loss, or a 15% discrepancy for the wall loss alone. It was felt that these did not need to be reconciled further for this preliminary assessment.

RESULTS

The reference case and the 18 other configurations listed in Table 1 were simulated using the KOBRU86 program, and the results are reported in Table 3.

This table was then sorted in ascending order of heat loss to rank the cases from best to worst performance , as reported in Table 4. These results are also plotted in Figure 2, on the same page. Note that the ranking is purely on the basis of predicted steady state heat loss performance and does not reflect cost considerations nor those of buildability and marketability.

DISCUSSION OF RESULTS

The following observations can be made from the ranked results presented in Table 4 and Figure 2.

- in general, the greater savings - up to 31% saving in total over the base case - are associated with the more complex combination schemes with the higher insulation levels (presumably the more expensive configurations).

- greater levels of thermal resistance and more insulation don't guarantee a significant saving. For example, the effect of the thermal bridge at the brick/concrete interface for the exterior, full depth insulation case (case #9, 18th in the list), and the effect of cooler soil around the footings negate all savings due to greater R-value and greater coverage.

Even a relatively simple thermal break in this design can produce a 20% saving, raising it to 12th in the list.

- the combination cases that featured the *below-grade* exterior insulation only - cases ranked 4, 10, 11, and 16th - appeared to perform reasonably well. The absence of above-grade exterior insulation for these cases results in a 600 mm (2 ft) long thermal bridge up the concrete wall. This bridge is partially controlled by the air films on the inner and outer faces of the concrete wall, so that the effect of the films on the overall performance of these configurations is important. The combination cases showed potential savings of 15 to 28%, depending on insulation level and wall construction.

- The highest saving of the combination configurations is associated with the insulated (filled) concrete block. The filled cores would constitute a partial thermal break of the thermal bridge sandwiched between the insulation layers. The savings are attributed to the fact that in the reference case, with only 600 mm (2 ft) below grade insulation, the earth to the outside acts as a significant heat fin. The exterior, below-grade insulation used in the *combination cases* cuts the earth portion of the heat fin, which ultimately has a greater exposed surface area than the exposed concrete.

- increasing the insulation level from RSI 1.4 (R8), the reference case, to RSI 2.1 (R12), case 1a, does not appear to be an effective measure. This configuration is ranked 17th with only a 4% saving. Most of the remaining heat loss is getting around the insulation through the concrete and soil; the thicker insulation does not address the main heat flow path.

- insulating the floor perimeter with 1 meter of insulation produces an additional saving of 6% over the 24% saving already achieved with the full depth, RSI 2.1 (R12) option. In finished basements that already feature a space under the finished floor, insulating the perimeter may be cost-effective.

- the 6" gap left at the bottom of the wall, case 3a, rank 9th, results in only a 3% increase in heat loss over the full depth insulation configuration (case 2a, rank 8th).

In general the results confirm again that, when insulating basements, *more coverage of bare concrete* can be better than simply including thicker or more layers of insulation with the same coverage. Cutting the thermal bridges and heat fins are the best strategies for improved performance.

LIMITATIONS

The objective of this project was to establish a relative performance and ranking of basement insulation configurations, **not** to estimate annual heat loss for real basements in real situations. Although the results are expressed in terms that appear to be traditional heat loss factors, they should not be used as such without considerable caution. Therefore, in reviewing and using the information produced in this report, the following considerations and limitations should be kept in mind.

- the ranking takes into account the third decimal place in the heat loss result. This third decimal place is not significant. When interpreting the results, it may be preferable to group the options in "bins" of 5 or 10% savings.

- the heat loss values presented are effective steady-state "U-values" for a strip of basement one meter wide. Seasonal weather patterns and mass storage effects in the earth have considerable impact on the seasonal heat loss of basements. These factors were not investigated in this study. However, the effects of seasonal variations are not expected to change the order of ranking established here.

- basement placement was not considered. Such factors as proximity to other basements, snow cover, location of cleared driveways and walkways, sloped terrain resulting in varying depth below grade all have an impact on basement heat loss. These were not addressed in this study.

- extremes in soil conductivity - either high or low - will result in different heat loss rates.

- three dimensional corner effects were neglected.

For a more in depth discussion of these considerations, see reference 2.

REFERENCES

1. Standaert, P. KOBRU86 - Computer Program to Calculate Two-dimensional Steady State Heat Transfer in Objects, Described in a Rectangular Grid Using the Energy Balance Technique. Reference Manual. Maldagem, Belgium, 1986.

2. Mitalas, G.P., Basement Heat Loss Studies at DBR/NRC. DBR paper No. 1045, Division of Building Research, National Research Council Canada, NRCC 20416-2, September 1983.

Table 2. Comparison of Simulation Results From the KOBRU86 model and those Developed at IRC[2].

	FLOOR LOSS (W/(m.C))	WALL LOSS (W/(m.C))	TOTAL (W/(m.C))
RSI 1.4 (R8) Partial Depth			
IRC[2]	1.06	1.87	2.96
KOBRU86	1.11	1.59	2.70
RSI 1.4 (R8) Full Depth Interior			
IRC[2]	1.25	1.01	2.26
KOBRU86	1.27	0.98	2.25
RSI 1.4 (R8) Full Depth Exterior			
IRC[2]	1.11	1.03	2.14
KOBRU86	1.19	1.04	2.22

TABLE 3. RELATIVE PERFORMANCE OF INSULATION PLACEMENT SCHEMES

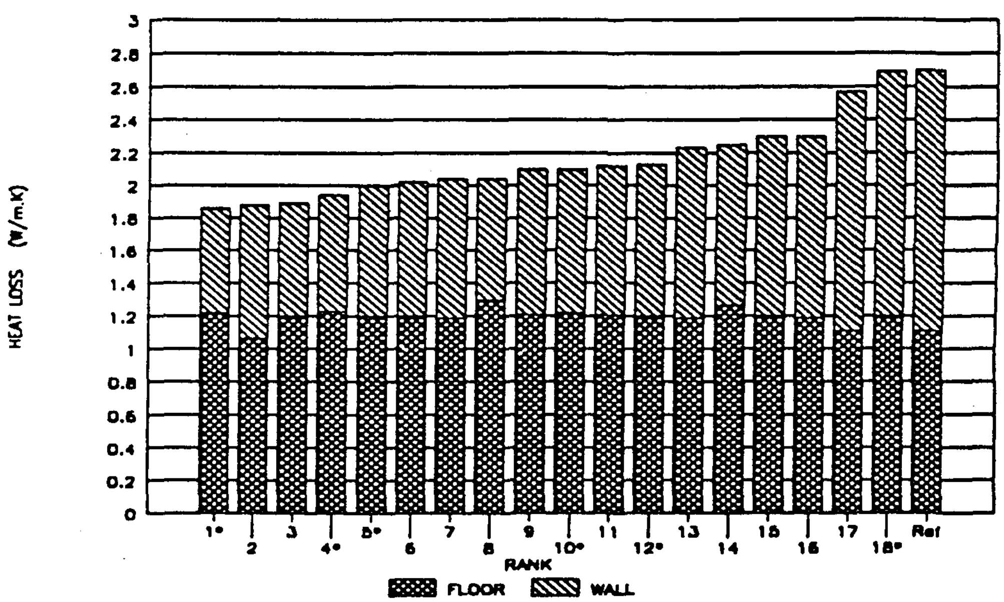
Ref No.	RSI (Rimp)	INSULATION PLACEMENT	INSULATION LOCATION	WALL CONSTRUCTION	HEAT LOSS (W/m.K) WALL	FLOOR	TOTAL	RELATIVE PERFORM.
1a	2.1 (R12)	2 ft below grade	interior	poured concrete	1.46	1.11	2.58	96%
1b	1.4 (R8)	2 ft below grade	interior	poured concrete	1.59	1.11	2.70	100%
2a	2.1 (R12)	full depth	interior	poured concrete	0.74	1.30	2.04	76%
2b	1.4 (R8)	full depth	interior	poured concrete	0.98	1.27	2.25	83%
3a	2.1 (R12)	down to 6" above slab	interior	poured concrete	0.89	1.21	2.11	78%
3b	1.4 (R8)	down to 6" above slab	interior	poured concrete	1.10	1.20	2.30	85%
4a	2.1 (R12)	full depth; no brick veneer	exterior	poured concrete	0.82	1.20	2.02	75%
4b	1.4 (R8)	full depth; no brick veneer	exterior	poured concrete	1.04	1.19	2.22	82%
5a	2.1 (R12)	full exterior; 2ft b.g. interior	combination	poured concrete	0.69	1.20	1.89	70%
5b	1.4 (R8)	full exterior; 2ft b.g. interior	combination	poured concrete	0.85	1.19	2.04	76%
6a	2.1 (R12)	b.g. exterior; 2ft b.g. interior	combination	poured concrete	0.91	1.21	2.12	79%
6b	1.4 (R8)	b.g. exterior; 2ft b.g. interior	combination	poured concrete	1.11	1.19	2.30	85%
7a*	2.1 (R12)	b.g. exterior; 2ft b.g. interior	combination	filled (insul) block	0.71	1.23	1.94	72%
7b*	1.4 (R8)	b.g. exterior; 2ft b.g. interior	combination	filled (insul) block	0.88	1.22	2.11	78%
8	2.1 (R12)	full depth + 1m floor perimeter	interior	poured concrete	0.81	1.07	1.88	70%
9*	2.1 (R12)	full; thermal bridge at brick	exterior	poured concrete	1.49	1.20	2.70	100%
10a*	2.1 (R12)	full exterior; 2ft b.g. interior	combination	concrete block	0.64	1.22	1.86	69%
10b*	2.1 (R12)	full exterior; 2ft b.g. interior	combination	concrete block	0.80	1.20	2.01	74%
11*	2.1 (R12)	full depth/brick + wood break	exterior	poured concrete	0.93	1.20	2.13	79%

☐ - Reference Case

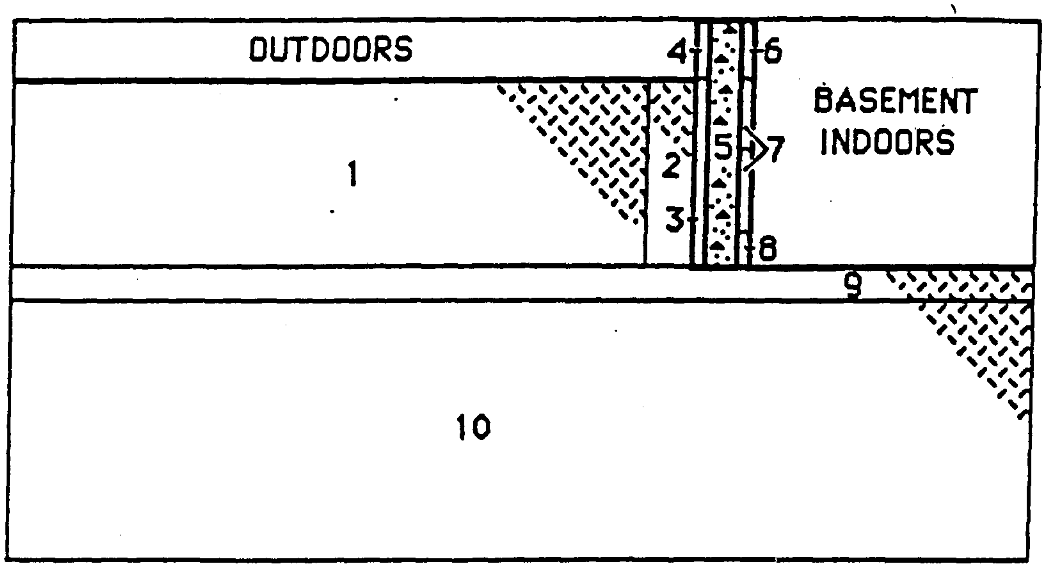
* - cases marked with an asterisk were included to give a first indication of performance. A detailed analysis of the thermal performance of concrete blocks and of the thermal bridge caused by the brick veneer in combination with exterior insulation would be needed to explicitly highlight the effects of the thermal anomalies involved in those cases.

TABLE 4. RELATIVE PERFORMANCE OF INSULATION PLACEMENT SCHEMES SORTED FROM BEST TO WORST PERFORMANCE

Ref No.	Rank	RSI (Rimp)	INSULATION PLACEMENT	INSULATION LOCATION	WALL CONSTRUCTION	HEAT LOSS (W/m.K) WALL	FLOOR	TOTAL	Saving % Ref
10a	1*	2.1 (R12)	full exterior; 2ft b.g. interior	combination	concrete block	0.64	1.22	1.86	31
8	2	2.1 (R12)	full depth + 1m floor perimeter	interior	poured concrete	0.81	1.07	1.88	30
5a	3	2.1 (R12)	full exterior; 2ft b.g. interior	combination	poured concrete	0.69	1.20	1.89	30
7a	4*	2.1 (R12)	b.g. exterior; 2ft b.g. interior	combination	filled (insul) block	0.71	1.23	1.94	28
10b	5*	2.1 (R12)	full exterior; 2ft b.g. interior	combination	concrete block	0.80	1.20	2.01	26
4a	6	2.1 (R12)	full depth; no brick veneer	exterior	poured concrete	0.82	1.20	2.02	25
5b	7	1.4 (R8)	full exterior; 2ft b.g. interior	combination	poured concrete	0.85	1.19	2.04	24
2a	8	2.1 (R12)	full depth	interior	poured concrete	0.74	1.30	2.04	24
3a	9	2.1 (R12)	down to 6" above slab	interior	poured concrete	0.89	1.21	2.11	22
7b	10*	1.4 (R8)	b.g. exterior; 2ft b.g. interior	combination	filled (insul) block	0.88	1.22	2.11	22
6a	11	2.1 (R12)	b.g. exterior; 2ft b.g. interior	combination	poured concrete	0.91	1.21	2.12	21
11	12*	2.1 (R12)	full depth/brick + wood break	exterior	poured concrete	0.93	1.20	2.13	21
4b	13	1.4 (R8)	full depth; no brick veneer	exterior	poured concrete	1.04	1.19	2.22	18
2b	14	1.4 (R8)	full depth	interior	poured concrete	0.98	1.27	2.25	17
3b	15	1.4 (R8)	down to 6" above slab	interior	poured concrete	1.10	1.20	2.30	15
6b	16	1.4 (R8)	b.g. exterior; 2ft b.g. interior	combination	poured concrete	1.11	1.19	2.30	15
1a	17	2.1 (R12)	2 ft below grade	interior	poured concrete	1.46	1.11	2.58	4
9	18*	2.1 (R12)	full; thermal bridge at brick	exterior	poured concrete	1.49	1.20	2.70	0
1b	Ref	1.4 (R8)	2 ft below grade	interior	poured concrete	1.59	1.11	2.70	0



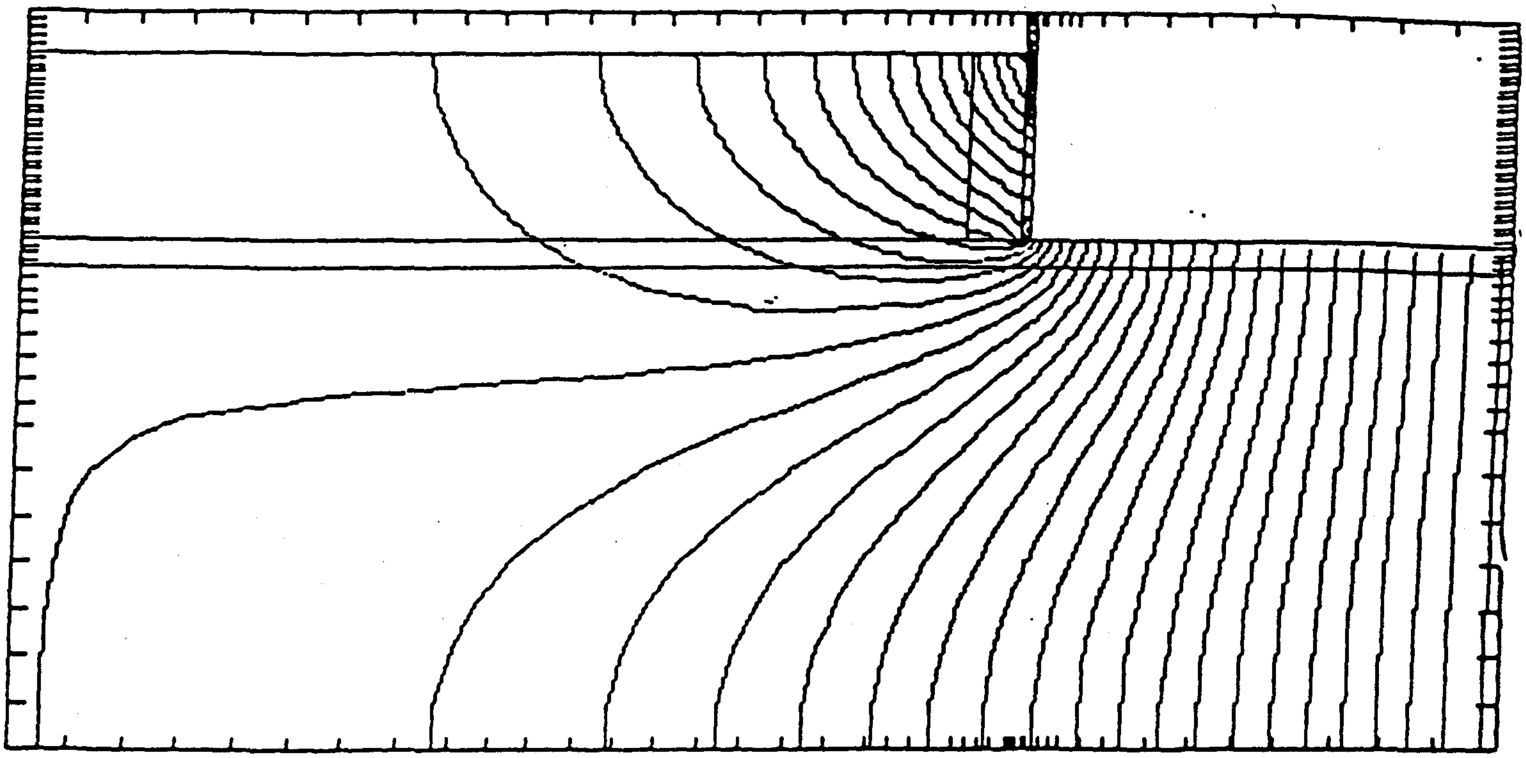
* - as in Table 3, cases marked with an asterisk were included to give a first indication of performance. A detailed analysis of the thermal performance of concrete blocks and of the thermal bridge caused by the brick veneer in combination with exterior insulation would be needed to explicitly highlight the effect of the thermal anomalies involved in those cases.

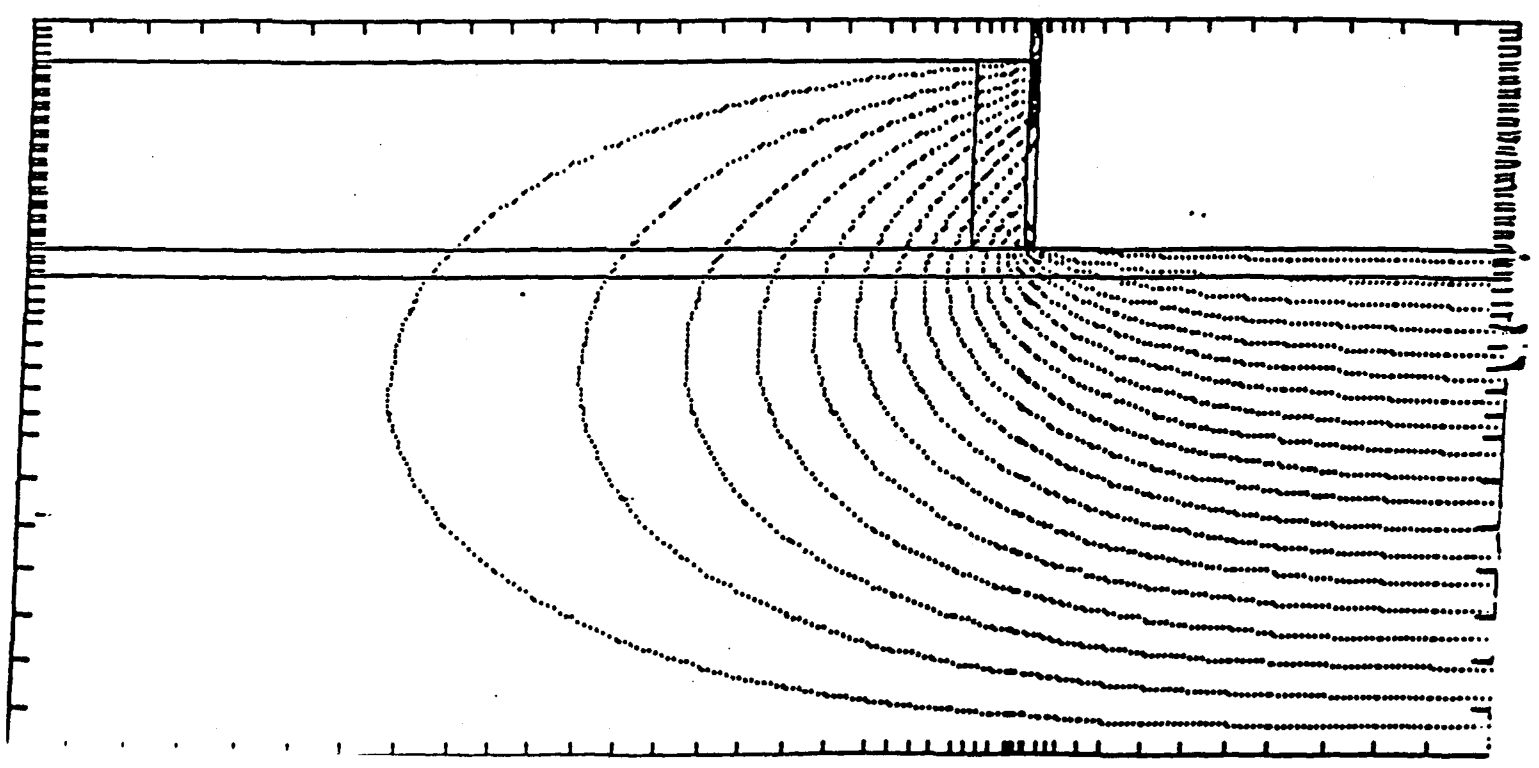


1 - earth away from wall
2 - earth next to wall
3 - exterior insulation, below grade
4 - exterior insulation, above grade
5 - basement wall
6 - interior insulation, above grade
7 - interior insulation, below grade
8 - either insulation or a 6" gap
9 - slab & sub-slab earth
10 - deep earth

Figure 1. Elements of the Basement Heat Loss Analysis

EXAMPLE HEAT FLUX LINES AND ISOTHERMS PRODUCED BY KOBRU86





APPENDIX 3

ROUGH COSTINGS

Appendix 3: Rough Costing - Comparative Costs of Systems for Dry, Fully Insulated Basements

1. Scope

This costing deals with the several main system configurations selected in the study for their field-proven capability of "permanently dry" performance, in combination with full-height R-12 resistance to heat flow through the wall. It also addresses a few of the newer material configurations that appear at least equally capable but have some components that have not yet acquired much field history. The costing does not encompass every system or variation but it is intended to bracket the range well enough.

Finally, the costing includes today's typical "code" basement, incompletely insulated (R12 to 2 ft. below grade), normally dampproofed and not always dry, so that the full dry systems can be compared in their upgrade cost increment over today's practice.

2. Method and Assumptions

a) The costing deals only with those variable measures or components that control heat and moisture flow, and of course their various adjuncts which support those components or protect their integrity. The costing is <u>not</u> concerned with: <u>constant</u> measures involved in moisture control, i.e. perimeter tile, basement floor perimeter detail and granular underfloor (as per 1990 OBC); municipal drains and connections; basement wall structure... (The study found that the structural material need not be involved with secure moisture control, except of course in supporting the dampproofing membrane, passing vapour, and in posing the initial load of construction moisture.)

b) All costing attempts to represent tract housing construction in southern Ontario.

c) Costs are taken as cost to the builder, i.e., as a subcontractor's price to builders. All figures used are taken from material quotes from manufacturer or distributor, generally with volume discounts for tract operations, and labour estimates from the insulation or dampproofing manufacturers. A few proponents quoted price-in-place directly; others used a simplified, current approximation: material, plus site labour at $40/hour.

(In some important cases Scanada checked manhour quotes against similar operations in the main work-studies*, and then total costs against the on-site tract building formula derived from them*, with good agreement. The formula:

Builder's cost = (M + 1.3 DL)(1.10)(1.10)

where M = material on site
DL = direct labour at site
1.3DL = gross-up of DL to include off-site support labour
1.10 = general overheads
1.10 = contingencies, profits

* This Scanada costing method was developed from the original NRC-HUDAC work study, A. T. Hansen, and the 2nd and third work studies, HUDAC-Scanada. Developed for CMHC and Campeau, it has been found usefully accurate on system costing also for Coscan, NRC, Ontario Warranty Program and several others.)

d) Costings are done for one example basement, rectangular, 150 ft. (45.7m) perimeter, 8 ft. wall 6.5 below grade, where total wall area is 1200 ft^2 ($111.5m^2$) and 975 ft^2 ($90.6m^2$) of that is below grade. It is recognized that more complicated basements (jogs, interior corners, slopes, attached or inset garages...) will incur slightly higher unit area costs but adequate system comparisons should be afforded by the example costing.

e) The costings are by no means definitive, up-to-the-minute, regionally pinpointed... Some component prices may only apply to high volume purchase. They are intended as meaningful estimates that give an adequate appreciation of the cost differentials in:

- increasing the insulation coverage to full height, from today's 2 ft. below grade,

- greatly increasing the resistance to water leaks, and moisture damage generally, from today's unsatisfactory level to a level that produces permanently dry basements in general usage.

3. Example Costings ($/1200sf wall; /meter of wall)

3.1 Basic Systems (without tie-filling or dampproofing, unless integral...)

a) Exterior draining mineral fibre (5.4.1)

R12 "Baseclad"	$1530	
Install @ $40/mh	160	
Protect above grade, lath & stucco	600	
Thermal break below masonry, allow	100	
	2390...52.27/m of wall	

... range say -0 / +5% for all estimates... cost taken as $54.90/m

b) Exterior cellular plastic, EPS Type 2 (5.4.2)

3.25 in. x $250/MBF x 1.2	975	
Adhesive $190/MBF x 1.2	228	
Labour @ 750SF/md @ $40/hr	512	
Protect above grade, polymer cement	400	
Thermal break below masonry, allow	100	
	2215 x 1.05	
		$50.90/m

c) Interior mineral fibre (5.3.1)

R12 mineral fibre @ $267/MSF	320	
2x4 framing, 700 BF in place, shimmed	560	
Moisture barrier & v.b.	120	
Wallboard & accessories	228	
Labour @ $40/hr, m.b, v.b, perim. sealing, rough drywall..(no filling) (no electrical)	485	
	1713 x 1.05	
		$39.40/m

d) Interior cellular plastic (5.3.3)

EPS Type 1, $190/MBF x 3.25 x 1.2	741
Strapping & accessories, $180/MSF x 1.2	216
Wallboard & accessories	228
Labour @ $40/hr, EPS 6.4 hr/MBF	307
rough drywall, sealing...	220
	1712 x 1.05

$39.40/m

e) Exterior draining cellular plastic (6.2.1)

- Draining type EPS projected to cost same as Type 1
- projected total $49.50/m

f) "Base case": Interior R12 min. fibre, half height - no dp $27.60/m

Other system costs were given as price-in-place by proponents.

3.2 Moisture Control Components

a) Tie patching...$100/house $2.20/m

b) Wet-applied bitumen but to code material spec and thickness...$120/house $2.60/m

(Parging and dampproofing of concrete block not costed)

c) Backfill-proof hanging membrane, air gap or plain, top sealed (Estimate for large builder operations...domestic manufacture may reduce further...) $19.30/m

d) Base flood retarder band, wet or dry type, est. $1.70/m

4. Results

The cost of constructing a dry, fully insulated basement are set out in the Table. Interior insulations are protected by membrane moisture control c), while exterior ones are deemed adequate with a) and b) only. (In three cases, those measures are more or less an integral part of the insulation application.)

The cost increments <u>over the base case</u> are shown separately:

a) to increase the insulation to full height; b) to increase the moisture protection to at least an adequate level. It can be seen that the requirement for full height insulation would first add about $12/m, while moisture-proofing it and the basement entails another $14, for a total upgrade cost of $26/m. Incorporating the moisture control in the insulation application might reduce this to roughly $21.

New or not-yet-accepted systems - the draining EPS or the "starter basement" mineral fibre blanket - could perhaps further reduce the upgrade cost to $19 or even $10.

COSTS OF CONSTRUCTING A DRY, FULLY INSULATED BASEMENT
($ per metre of wall)

FULL SYSTEM R12 FULL HGT	COST OF R12 FULL HGT, w SUPPORT & COVER	INCREMENT OVER R12 HALF HGT	COST OF MOISTURE CONTROL (with FLOOD RETARDER ADDED)	INCREMENT OVER NORMAL DAMPPROOFING	TOTAL SYSTEM COST (& with FLOOD RETARDER)	TOTAL INCREMENT OVER OBC (& with FLOOD RETARDER)
1. Int. EPS Type 1 (5.3.3)	39.40	11.80	19.30 (21.00)	14.50	58.70 (60.40)	26.30 (28.00)
2. Int. Min. Fibre (5.3.1)	39.40	11.80	19.30 (21.00)	14.50	58.70 (60.40)	26.30 (28.00)
3. Ext. EPS Type 2 (5.4.2)	50.90	23.30	2.20 (3.90) (tie fill only)	-2.60 (incl.)	53.10 (54.80)	20.70 (22.40)
4. Ext. Draining Mineral Fibre (5.4.1)	54.90	27.30	4.80 (6.50) (normal)	0	59.70 (61.40)	27.30 (29.00)
Not necessarily <u>established or approved</u>						
5. Ext. Draining EPS (6.2.1)	49.50	21.90	2.20 (3.90) (tie fill only)	-2.60	51.70 (53.40)	19.30 (21.00)
6. Ext. Spray urethane (6.2.2)	59.00	31.40	2.20 (3.90)	-2.60	61.20 (61.60)	28.80 (28.80)
7. Utility or "starter" basement: Int. Min. Fibre Blanket Laminate (6.1.1)	25.00	-2.60	19.30 (21.00)	14.50	42.50 (44.20)	10.10 (11.80)