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DEMONSTRATION OF FULL HEIGHT BASEMENT INSULATION CONSTRUCTION METHODS

Demonstration of Full Height Basement Insulation Construction Methods

Volume I - Final Report

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This project was prepared by Buchan, Lawton, Parent Ltd. for the Ontario Home Builders' Association Steering Committee on Full Height Basement Insulation with representation from Canada Mortgage and Housing Corporation, Canadian Portland Cement Association, Ontario Ministries of Energy and Housing, Low Rise Forming Contractors' Association, Ontario Concrete Block Association, Ontario New Home Warranty Program, and the Society of the Plastics Industry of Canada.

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Executive Summary

In the summer of 1991 Buchan, Lawton, Parent Ltd. was issued a contract by the Ontario Home Builders' Association Steering Committee on Full Height Basement Insulation (FHBI) with representation from Canada Mortgage and Housing Corporation, Canadian Portland Cement Association, Ontario Ministries of Energy and Housing, Low Rise Forming Contractors' Association, Ontario Concrete Block Association, Ontario New Home Warranty Program, and The Society of the Plastics Industry of Canada, to carry out a demonstration of FHBI construction methods.

The project consisted of design development, construction, and follow-up testing and inspection of ten typical single-family house basements in Southern Ontario. One non-typical house was also investigated. A range of builders participated in the project constructing houses and commenting on their experiences. This is a final report consisting of results from the construction phase and the soak test phase.

Of the schemes tested, six were insulated from the exterior, four from the interior, and the additional house had an insulating block wall scheme. General findings from the construction phase were that interior insulation schemes were favoured over exterior ones, but that both systems have different detailing problems for which training is required to resolve.

Rigid glass fibre insulation was found to be easier to apply to exterior walls with commonly-found irregularities than were rigid polystyrene materials. Panelized above-grade insulation protection products offer some advantages over site applied ones, but they tend to be difficult to adapt for residential use.

Composite geotextiles wall drainage panels and ledge blocks require further development to improve their applicability to residential construction. Other basement design configurations (ie. modifications to the methods tried) may solve some of the problems encountered by builders in this project.

The soak testing indicated that for the basement systems demonstrated and the soil conditions at these sites, the moisture handling methods were generally successful in limiting leakage problems. Soil conditions on the test sites provided fair to good drainage.

Care must be taken to avoid gaps with the drainage or insulation materials and finish detailing where moisture ingress can be concentrated. It is evident that builders and trades persons require more technical information and experience on the use of materials where moisture handling is important.

Résumé

Au cours de l'été de 1991, la maison Buchan, Lawton et Parent Ltd. était mandatée par le Steering Committee on Full Height Basement Insulation de l'Ontario Home Builders' Association, sur les instances de la Société canadienne d'hypothèques et de logement, de l'Association canadienne du ciment Portland, des ministères de l'Énergie et du Logement de l'Ontario, de la Low Rise Forming Contractors' Association, l'Ontario Concrete Block Association, du Régime de garanties des logements neufs de l'Ontario, et de la Société des industries du plastique du Canada, pour mener une opération témoin concernant les méthodes de construction de sous-sols isolés sur leur pleine hauteur.

L'opération consistait à élaborer, construire et effectuer des essais de suivi et l'inspection du sous-sol de dix maisons individuelles types du sud de l'Ontario, de même que d'une autre considérée comme non caractéristique. Toute une gamme de constructeurs y ont participé en réalisant les maisons et en faisant part de leurs observations. Voici le rapport définitif livrant les résultats obtenus lors de la phase de la construction et des essais d'imbibition.

Parmi les sous-sols mis à l'essai, six étaient isolés de l'extérieur, quatre de l'intérieur, et le sous-sol de l'autre maison comportait des murs en blocs isolants. Les conclusions générales qui découlent de la phase de construction indiquent que la préférence va à l'isolation intérieure plutôt qu'à l'isolation extérieure, mais que les deux techniques comportent des problèmes d'exécution différents que la formation permet de régler.

Les panneaux de fibre de verre rigides, a-t-on constaté, se mettent en oeuvre plus facilement sur les murs extérieurs présentant des irrégularités courantes que les panneaux rigides en polystyrène. Les panneaux de protection de l'isolant au-dessus du niveau du sol procurent certains avantages par rapport aux produits mis en oeuvre sur le chantier, mais se révèlent généralement difficiles à adapter aux bâtiments résidentiels.

L'emploi de panneaux d'évacuation recouverts d'un géotextile et de blocs d'assise devra faire l'objet de travaux d'élaboration plus poussés pour pouvoir mieux s'appliquer à la construction résidentielle. D'autres techniques (modifications des méthodes éprouvées) pourront régler certains problèmes qu'ont rencontrés les constructeurs dans le cadre de cette opération témoin.

Les essais d'imbibition indiquent que pour le sous-sol et la composition du sol des emplacements retenus, les méthodes visant à éliminer l'humidité ont généralement réussi à limiter les problèmes d'infiltration. La composition du sol assurait une évacuation des eaux jugée de bonne à passable.

Il faut prendre soin d'éviter de créer des vides entre les matériaux d'évacuation ou d'isolation et le revêtement de finition où l'infiltration d'humidité risque de se concentrer. Il est évident que les constructeurs et les corps de métiers ont besoin d'information technique supplémentaire et d'expérience quant à l'utilisation de matériaux aux endroits où il importe de contrer l'infiltration d'humidité.

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1.0 Introduction

1.1 Background

In response to a proposal to review the Ontario Building Code (OBC) in 1990 to require FHBI on new Part 9 residential buildings, the need arose to demonstrate the feasibility of FHBI. This was one of a series of comprehensive research projects on the technical and economic feasibility of FHBI being guided by the OHBA Steering Committee on FHBI.

The work to date has included:

- a theoretical analysis of moisture and thermal performance,
- estimation of incremental costs associated with FHBI,
- a survey of builders installing FHBI at time of construction, and
- a demonstration construction project of eleven recommended designs.

Buchan, Lawton, Parent Ltd. was issued a contract in July, 1991 by the Ontario Home Builders' Association to carry out the field demonstration (ie. phase II) of the FHBI Demonstration project. Contec Construction Services was subcontracted to assist with the construction inspection work.

The demonstration project involved the construction of four interior insulated basements, six exterior insulated ones, and one non-typical house with an insulating concrete block foundation. The Ontario Home Builders' Association was responsible for recruiting builders in Ontario to build the FHBI design concepts. To offset the cost of participating in the study, OHBA offered builders a grant intended to compensate them for schedule delays and other additional costs. In many instances manufacturers donated materials.

In consultation with the Steering Committee, Buchan, Lawton, Parent Ltd. finalized design details and specified appropriate materials. The demonstration houses were adapted from the builders' standard plans and are to be sold and occupied.

Construction of the houses was started late in August 1991 and all but one was completed in early December 1991. The remaining house was completed early in May 1992. Soak tests were done during May. Detail sketches and specifications were provided to the builders and guidance on site was given where required. Photographs, videos and written inspection forms were used to document the construction process. Builders' comments were recorded.

This document is a final report on the project at the completion of the design, construction, and soak test phases. A construction documentation report with specifications, site visit notes, photographs and builders' comments accompanies this report under a separate cover.

1.2 Purpose and Objectives

1.2.1 Purpose

The primary purpose of this demonstration project was to document the buildability and construction of ten basements with FHBI built to specifications recommended to control moisture problems.

A secondary purpose was to document construction methods for possible use in a technology transfer program.

1.2.2 Objectives

The objectives set out for the project were to:

1. Finalize design details for ten demonstration basements recommended by the Steering Committee,
2. assist builders during the construction phase while monitoring conformance to design specifications,
3. document builders' experiences and the construction process, and
4. conduct follow-up inspections and soak testing in the spring after completion of the construction phase.

1.3 Scope of Work

Since it was not feasible to try out every combination of structure type, building material, geographical location, and soil type, the scope of this project has been limited to demonstrating ten basement designs the Steering Committee wanted to see. An additional basement design (using insulating concrete blocks) was added later in the project, but incremental cost was absorbed by the manufacturer and results were not compared directly with the other basements because of differing test conditions. Each basement was required to comply with standards which surpass the OBC with the intent of demonstrating advanced construction for solving common technical problems.

The scope was limited by the type of houses being built in the Ontario market today and by those offered by builders for inclusion in the project. The majority of houses were two-storey, brick veneer on cast-in-place concrete foundations. Two houses with siding, having brick front facades, were included in this group however.

Moisture-related problems are common and since insulated basements can be expensive to repair, especially where insulation and finishes are damaged and leak location is obscure, moisture handling methods and materials were of great interest to the Steering Committee. Above-grade finishing of exterior insulation, ledge detailing, and air barrier detailing etcetera were other concerns.

The Steering Committee did not make time and cost analyses a part of the scope of work. The nature of the project does not allow for equal basis comparison.

1.4 Organization of this Report

This report is laid out as follows:

- Section 2 discusses the basement designs
- Section 3 is a report on the construction phase
- Section 4 contains conclusions
- Section 5 lists recommendations
- Appendix A contains site inspection reports, builders' notes and photographs
- Appendix B contains the specifications provided for the basement designs

2.0 Basement Designs and Specifications

Each basement was designed to provide RSI 2.1 (R12) full height and to avoid moisture related problems. Using a builder's existing practice as a starting point, basement wall details, header details, and some window details were developed with the intent of adapting the Committee's interest in the builder's situation. Specifications compatible with the Code and according to manufacturer recommendations were created for each main basement element. Subject to Steering Committee approval, design schemes and specifications were finalized and provided to the builders.

The following discussion describes the designs which were used. Items which relate to all basements are discussed firstly followed by a detailed description of each basement including sketches. Specifications for key basement elements are included in Appendix B.

2.1 General Design Considerations

OHBA's original request for proposals suggested the construction of ten basements which were somewhat different than those which were actually built. The reasons for the changes included:

- an interest on behalf of a major funding partner in the study (CMHC) to see a greater number of exterior insulation schemes demonstrated, and

- new materials entering the marketplace which made alternate configurations for the demonstration more appealing.

The committee's desire to demonstrate both interior and exterior systems was driven by the advantages each hold. While interior systems are viewed to be less expensive, more attractive from a sales point of view, and more adaptable to current practices, exterior systems are considered to be technically superior. Such advantages have been considered to include minimization of the need for interior finishing, minimizing the potential for concealed condensation, improved ability to ensure air barrier continuity, improved drying, minimization of thermal bridges (if insulating ledge block is used), improved drainage on the exterior (if free-draining insulation is used), the added benefit of thermal mass, and temperature stability for the structure.

After much discussion with the Steering Committee, the following designs were finalized:

Interior Insulated Basements:

- I - 1 poured concrete, brick clad, interior batt insulation, air gap drainage panels for exterior moisture handling;
- I - 2 poured concrete, brick clad, interior EPS I insulation, composite geotextile drainage panels for exterior moisture handling;
- I - 3 poured concrete, siding, interior batt insulation, flashed exterior glass fibre drainage layer for exterior moisture handling;

1 - 4 concrete block, brick clad, interior XEPS II insulation, exterior hanging PVC sheet dampproofing,

Exterior Insulated Basements:

E - 1 poured concrete, brick clad, exterior EPS II insulation with polymer modified mesh reinforced parging above grade;
E - 2 poured concrete, brick clad, exterior insulation XEPS III with polymer modified chopped fibre reinforced parging above grade;
E - 3 poured concrete, brick clad, exterior XEPS IV with cement-faced type IV insulation above grade;
E - 4 poured concrete, brick clad, exterior rigid glass fibre insulation with conventional cement parging on metal lath above grade;
E - 5 poured concrete, brick clad, exterior rigid glass fibre insulation with cement board above grade;
E - 6 poured concrete, siding, exterior XEPS III insulation with treated plywood above grade and composite geotextile drainage layer below grade,

Additional Basement Design:

A - 1 insulating concrete block, siding, dampproofing, various moisture handling materials.

Foundation

The desire of the Committee was to demonstrate cast-in-place concrete and concrete block foundations which were conventionally constructed. Elements of good construction practice were specified and plasticizers were permitted, if it was the builder's common practice to use them, with the requirement that their use be disclosed.

Dampproofing

Included with Code dampproofing for exterior insulated basements, mastic was specified for sealing the exterior footing/wall joint and caulking was specified for the slab perimeter to act as an air barrier and as a radon stop. Where another material (ie. geotextile composite or air gap membrane) was to be used in lieu of conventional dampproofing, conventional dampproofing was specified for any portion of the wall still in contact with soil or landscaping.

Backfill

Native backfill was used in all cases. In accordance with good construction practice, basements not having manufactured material considered capable of handling bulk water (ie. some form of drainage layer) were only specified in situations where the native backfill was free-draining.

Moisture Handling Systems

There was a strong desire to avoid using free-draining backfill for drainage. Free-draining fill is expensive to import and native soils are costly to remove from the site and therefore, granular backfill is usually not used except in extreme situations. Moisture being held within soil can enter via cracks, tie rod holes, or by wicking. Particularly with interior insulated basements, there is often significant additional cost associated with moisture damage to insulation and drywall.

Four main types of manufactured moisture handling systems were demonstrated: a high density polyethylene air gap barrier, rigid glass fibre drainage layer, a composite geotextile drainage layer, and a hanging PVC sheet barrier. These materials are discussed in more detail below. Typically, the geotextile composites have been developed for the commercial market. Consequently, their suitability for application on houses may be limited by their configuration despite the appropriateness of their technical concepts.

Materials which fell within predetermined generic classes and which were donated by the manufacturer were given preference. In general, manufacturers of these systems tried to supply their lowest cost system because this was felt to be most appropriate for the residential market.

Susceptibility to mechanical damage, ultraviolet deterioration and undesirability in terms of aesthetics indicates that these materials must be placed entirely below grade. Thus, this dictates that a band of conventional dampproofing be applied to cover the area of wall extending from the top edge of the moisture handling material up to grade level. In addition, the top edge of the material must be sealed to prevent water migration behind it.

Insulation

The selection of materials for basement insulation was largely governed by the range of insulation materials and manufacturers available on the market. Meetings with members of The Society of the Plastics Industries of Canada were held on this matter. Members donated insulation materials to the project which they considered most appropriate to this application.

The range of interior and exterior insulations used included glass fibre batts, rigid glass fibre, expanded polystyrene types I and II, and extruded polystyrene types II, III, and IV. The requirement for thermal resistance was R-12 as required by the 1990 Code (for upper basement walls). Exterior insulation schemes required above-grade protection, ledge blocks, and window detailing. Interior insulation schemes were similar to current practice used for upper wall Code insulation except for moisture handling details for lower walls.

The result of the insulation selection process was a sampling of nearly all common insulation types currently available on the market. This provided a good range of thermal performances, density, installation methods, and market cost.

A recent study of builders using interior FHBI shows that moisture problems in basements are prevalent and that the cost of repairs and the difficulty of finding sources is substantially increased for full height interior insulated basements. Moisture, which may be trapped within the wall assembly, may accumulate from leaks, wet materials and air leakage. Therefore, facilitating drainage along the floor slab perimeter is an important part of interior insulation schemes. Rigid glass fibre insulation was specified as a drainage path for the interior insulated basements in this study though a trough or groove would have been equally acceptable.

Ensuring continuity of the air barrier was an important consideration below grade to minimize for radon gas entry since infiltration will tend to occur at the basement level. A bond break between the floor slab and the foundation wall can circumvent the air barrier which would otherwise be formed by the concrete. On the exterior insulated basements here, concrete formed the air barrier with a bead of sealant applied between the floor slab and the foundation wall. On interior insulated systems an interior polyethylene air barrier was accomplished by applying acoustical caulking to the poly at the top and bottom of the basement stud wall and by using a gasket below the bottom plate.

Installing FHBI also has some more subtle implications. Installing full height insulation calls for insulation protection, and for interior systems, air and vapour barriers and drywall are required. Electrical outlets must also be installed. Air/vapour seal electrical boxes were specified to simplify establishing an effective air barrier. This detailing was also included where applicable.

Above-grade Insulation Protection for Exterior Systems

A number of above-grade exterior insulation treatments were identified as part of an addition to the scope of work carried out for CMHC. Of these, a short list of products currently widely available and economically feasible for the housing market was made.

It was desirable to demonstrate a variety of different generic finishing options which may be grouped as follows: conventional parging on metal lath, polymer modified pargings including chopped fibre reinforced and mesh reinforced, and panelized materials including prefinished insulation, cement board and plywood. Again, manufacturer products were selected based on conformance to CMHC's research interests and based on donation of materials to the project.

Technical considerations included in the assessment of options to demonstrate included durability with respect to mechanical damage, and thermal movement of the coating and its substrate, and ease of application.

Ledge Blocks

The use of exterior insulation necessitates a method of deflecting water over the top joint and finishing the upper edge of the insulation. On masonry clad houses, the most popular method is the masonry ledge block. On siding houses construction methods can be altered to avoid this requirement.

During the design stage, it appeared that ledge blocks were out of production. While two manufacturers were approached to develop concepts, it became more feasible to allow builders to source their own materials. This allowed builders to pursue their preferences and afforded more variation in ledge block form.

The main technical concerns related to ledge blocks included a water shedding profile, block dimensions, and thermal bridging. Insulating blocks were not available except at heavy cost premiums for this project, so the thermal bridging was not addressed. The actual ledge blocks builders found are discussed later in this report in the sections corresponding to the relevant basements.

2.2 Detailed Description of the Basement Designs

Having addressed design issues generally, one must examine the designs individually to understand the specifics of what was done in each case. On page 38 following the basement design sketches, a table provides a summary of design configurations.

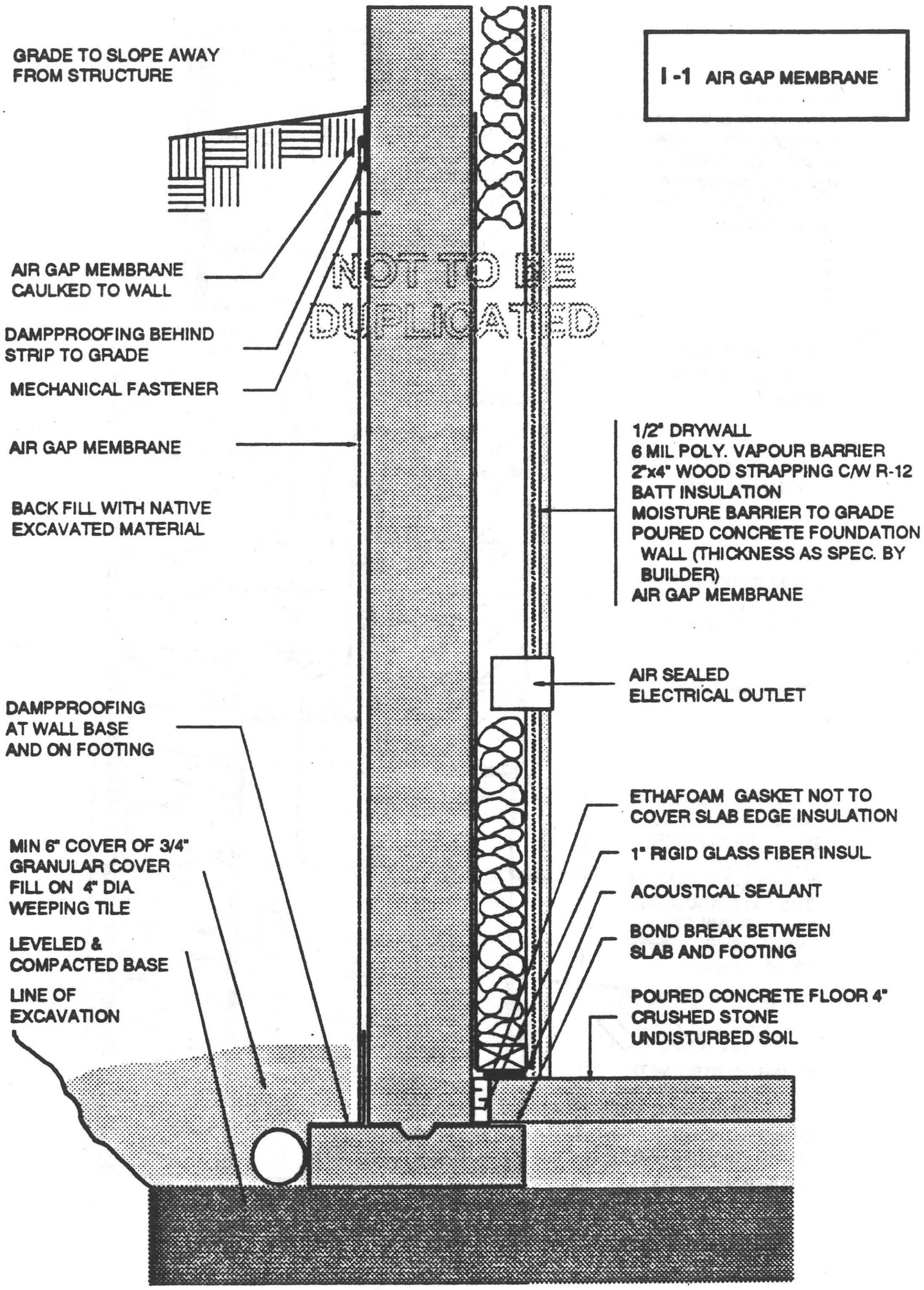
2.2.1 Basement I - 1 Air Gap Membrane

This basement design had an interior insulation scheme on a cast-in-place concrete foundation which supported a two-storey brick clad house. The insulation was conventional glass fibre batts and wood studs. The more unusual aspect of this system was the premanufactured dampproofing membrane.

The air gap membrane concept is twofold. Firstly, it is intended to act as a barrier to moisture migrating toward the foundation. Secondly, the gap created between the foundation wall and the base of the membrane is intended to facilitate soil gas venting and drainage of moisture from sources on either side of the membrane.

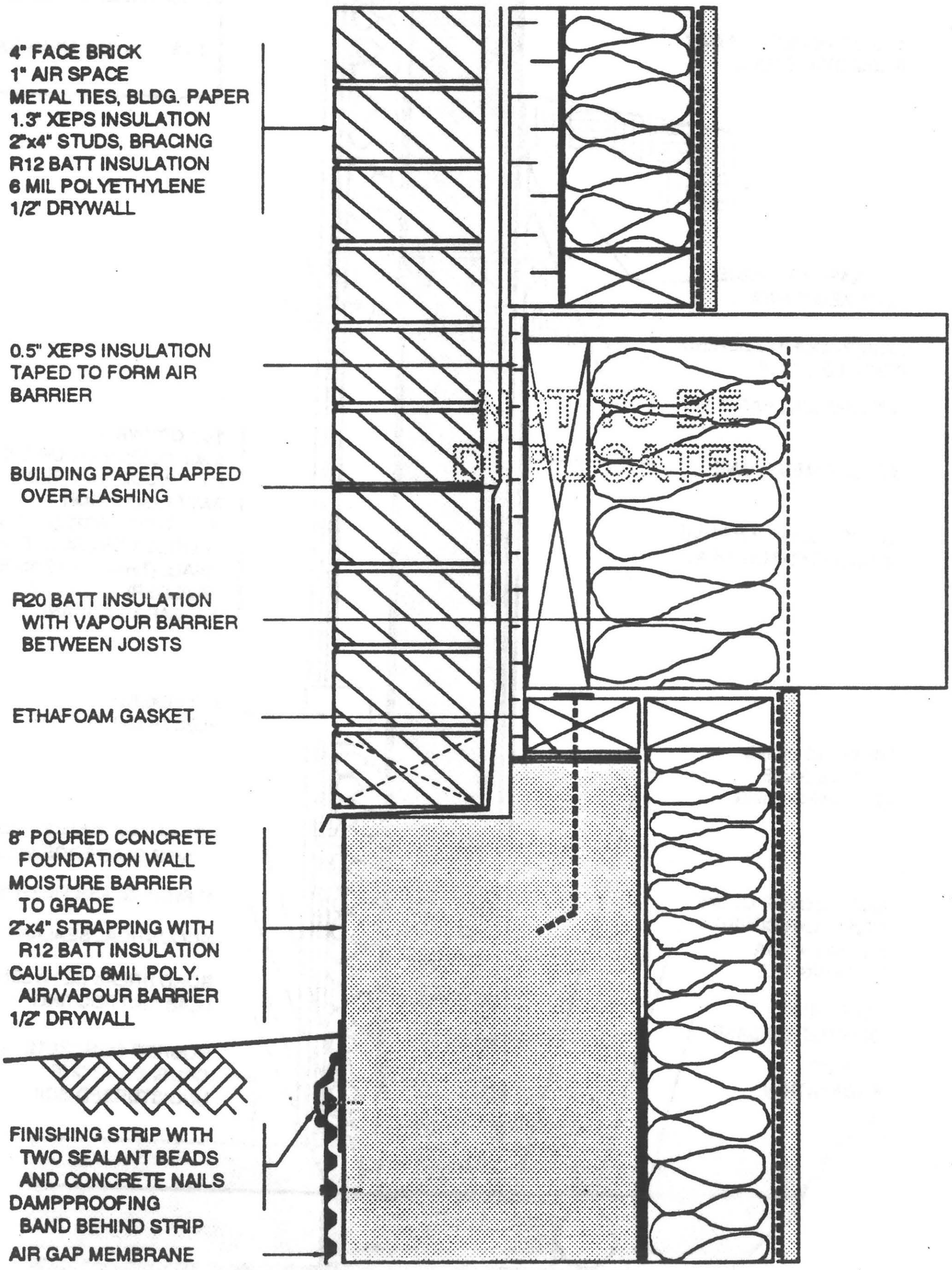
The air gap membrane product specified in this study was a dimpled polyethylene membrane which is approved as a dampproofing material. Specifically developed for low rise foundations, the product is available in 65 foot lengths and in roll widths of up to seven feet. Rolls are normally applied horizontally.

To be used in lieu of dampproofing, the Ministry of Housing authorities required that the top edge of the material be sealed below grade to prevent entry of water, backfill, vegetation etcetera. While this requirement limits venting within the air gap it is not serious because the interior insulation and air/vapour barrier will prevent vapour diffusion, condensation and soil gas entry. Water getting behind the membrane should be able to drain adequately and water should not be driven into concrete cracks assuming soil particle ingress does not clog the air gap.



I -1 AIR GAP MEMBRANE
GRADE TO SLOPE AWAY FROM STRUCTURE
AIR GAP MEMBRANE CAULKED TO WALL
DAMPPROOFING BEHIND STRIP TO GRADE
MECHANICAL FASTENER
AIR GAP MEMBRANE
BACK FILL WITH NATIVE EXCAVATED MATERIAL
1/2" DRYWALL
6 MIL POLY. VAPOUR BARRIER
2"x4" WOOD STRAPPING C/W R-12 BATT INSULATION
MOISTURE BARRIER TO GRADE
POURED CONCRETE FOUNDATION WALL (THICKNESS AS SPEC. BY BUILDER)
AIR GAP MEMBRANE
NOT TO BE DUPLICATED
AIR SEALED ELECTRICAL OUTLET
DAMPPROOFING AT WALL BASE AND ON FOOTING
ETHAFOAM GASKET NOT TO COVER SLAB EDGE INSULATION
1" RIGID GLASS FIBER INSUL
ACOUSTICAL SEALANT
MIN 6" COVER OF 3/4" GRANULAR COVER FILL ON 4" DIA WEEPING TILE
BOND BREAK BETWEEN SLAB AND FOOTING
LEVELED & COMPACTED BASE
LINE OF EXCAVATION
POURED CONCRETE FLOOR 4"
CRUSHED STONE
UNDISTURBED SOIL

I -1 HEADER DETAIL



There are two methods of finishing the top edge of the product. Rolls are available with a flat band along one end which is intended to fit flush with the wall when backfilled. Where the membrane is cut to fit a slope or fit around a window, a termination strip can be mechanically fastened to cover the end of the dimples. Alternatively, rolls without the flat band can be finished with the termination strip. The supplier suggests there is debate about whether the product can be used with an unsealed termination strip.

Authorities required a band of dampproofing which extends from behind the top of the membrane up to the grade level just as normal dampproofing would be done. A band of dampproofing is also required at the footing where the material is to be terminated.

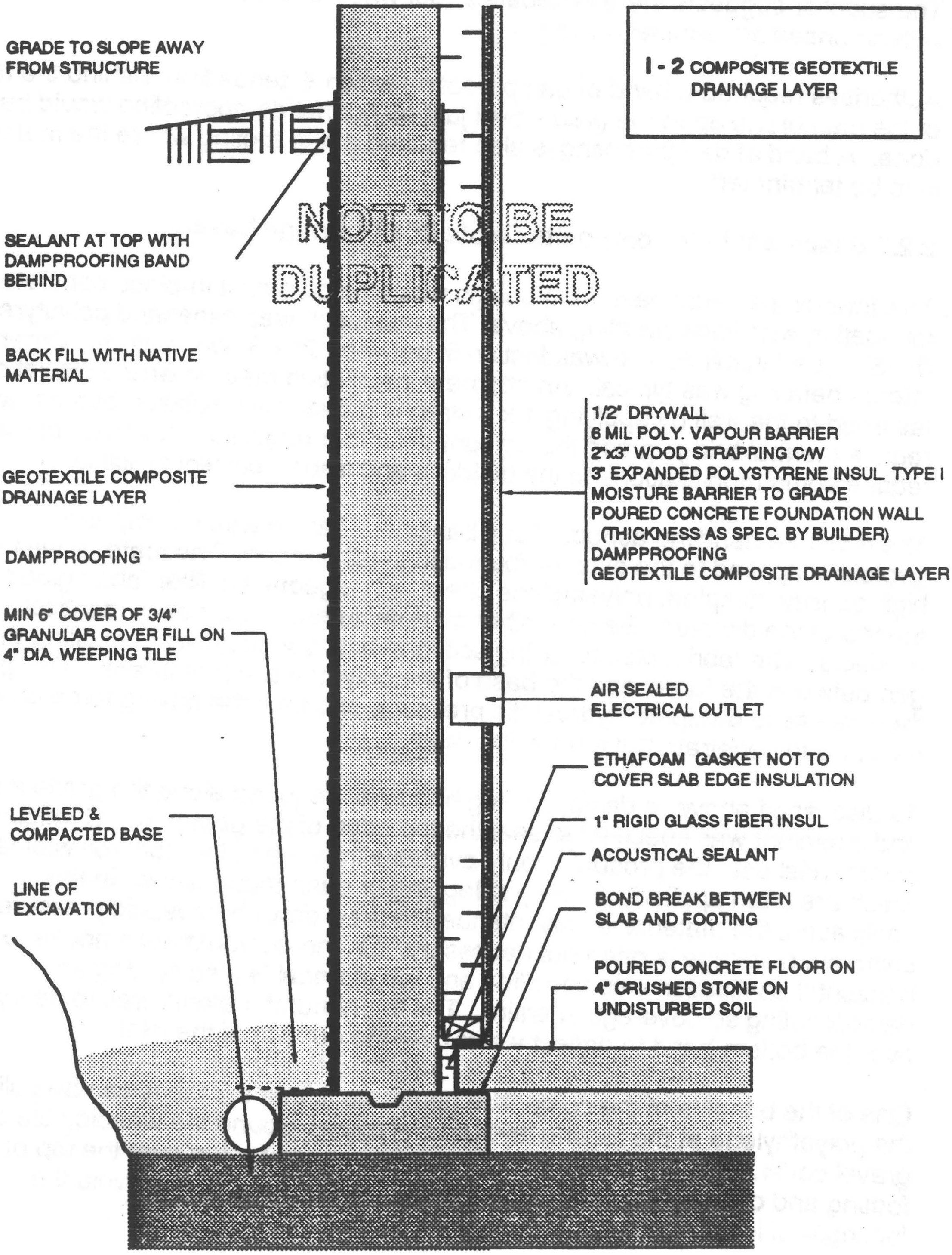
2.2.2 Basement I - 2 Composite Geotextile Drainage Layer

This interior insulated basement design was also on a cast-in-place concrete foundation with brick cladding above. The insulation was expanded polystyrene (EPS) Type I insulation. It was friction fit between 2" x 3" wood studs. Other interior detailing was typical. An alternate installation method where insulation is fastened to the wall by applying 1 x 3 strapping over the insulation boards, would reduce thermal bridging and the amount of lumber required. However, this would require some modifications to the builder's and trade's current practice.

The moisture handling aspect of this basement design was a composite geotextile applied to the exterior foundation wall surface. The material was a high density, dimpled, polyethylene sheet with a geotextile filter fabric glued onto the top of the dimples. Several other manufacturers make nearly identical products. The fabric, placed facing soil, prevents soil particles from filling the 3/8" gap between the fabric and the base of the polyethylene membrane. This gap then serves to dissipate hydrostatic pressure, and thus the driving force causing moisture to penetrate the foundation walls.

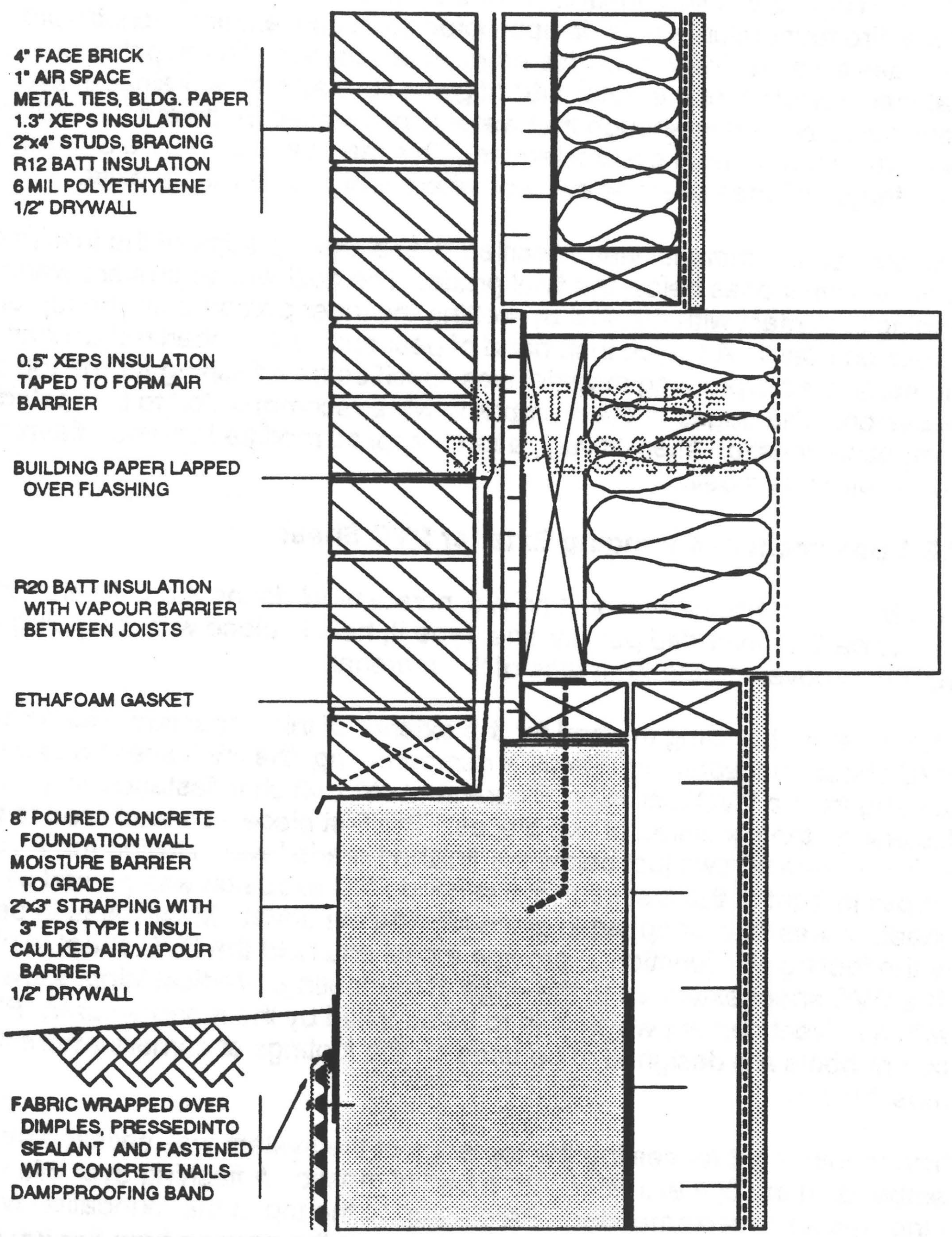
As discussed above, a dampproofing band was required along the grade level and a sealant was specified to seal the top edge of the geotextile. Configured for commercial use, the product is only available in two and four foot roll widths which are often applied vertically to lagging or deep foundations. In this application, the material is only intended to draw down hydrostatic pressure so complete coverage is often not necessary. On the demonstration house, a horizontal application was specified and the material is also serving as dampproofing so coverage is entire. The top band of material was to be lapped over the bottom band to deflect water over the outside of the joint.

One of the benefits of the composite geotextile is that the fabric can be pulled off the polyethylene at the footing level and wrapped around the weeping tile or gravel cover. The polyethylene portion left over can be run over the top of the footing and down beside the drain to deliver water directly and avoid the footing/wall intersection.



GRADE TO SLOPE AWAY FROM STRUCTURE
I - 2 COMPOSITE GEOTEXTILE DRAINAGE LAYER
SEALANT AT TOP WITH DAMPPROOFING BAND BEHIND
NOT TO BE DUPLICATED
BACK FILL WITH NATIVE MATERIAL
1/2" DRYWALL
6 MIL POLY. VAPOUR BARRIER
2"x3" WOOD STRAPPING C/W
3" EXPANDED POLYSTYRENE INSUL. TYPE I
MOISTURE BARRIER TO GRADE
POURED CONCRETE FOUNDATION WALL
(THICKNESS AS SPEC. BY BUILDER)
DAMPPROOFING
GEOTEXTILE COMPOSITE DRAINAGE LAYER
GEOTEXTILE COMPOSITE DRAINAGE LAYER
DAMPPROOFING
MIN 6" COVER OF 3/4" GRANULAR COVER FILL ON 4" DIA. WEEPING TILE
AIR SEALED ELECTRICAL OUTLET
ETHAFOAM GASKET NOT TO COVER SLAB EDGE INSULATION
1" RIGID GLASS FIBER INSUL
ACOUSTICAL SEALANT
LEVELED & COMPACTED BASE
LINE OF EXCAVATION
BOND BREAK BETWEEN SLAB AND FOOTING
POURED CONCRETE FLOOR ON 4" CRUSHED STONE ON UNDISTURBED SOIL

I-2 HEADER DETAIL



2.2.3 Basement I - 3 Insulating Drainage Layer

Also on a cast-in-place foundation, above-grade cladding on this house design was vinyl siding with brick front facade. The interior insulation scheme was glass fibre batts with typical detailing as previously discussed.

One inch rigid glass fibre insulation was utilized as a below-grade drainage layer. The entire foundation wall is dampproofed as in conventional construction since the glass fibre insulation provides no moisture barrier. The supplier of the material, asserts that the outer 1/8" of glass fibre acts as a drainage layer. The glass fibres are loose enough that water is not wicked in toward the wall more than 1/8" under normal circumstances. This material may not be adequate to draw large volumes of water away or where a high water table exist.

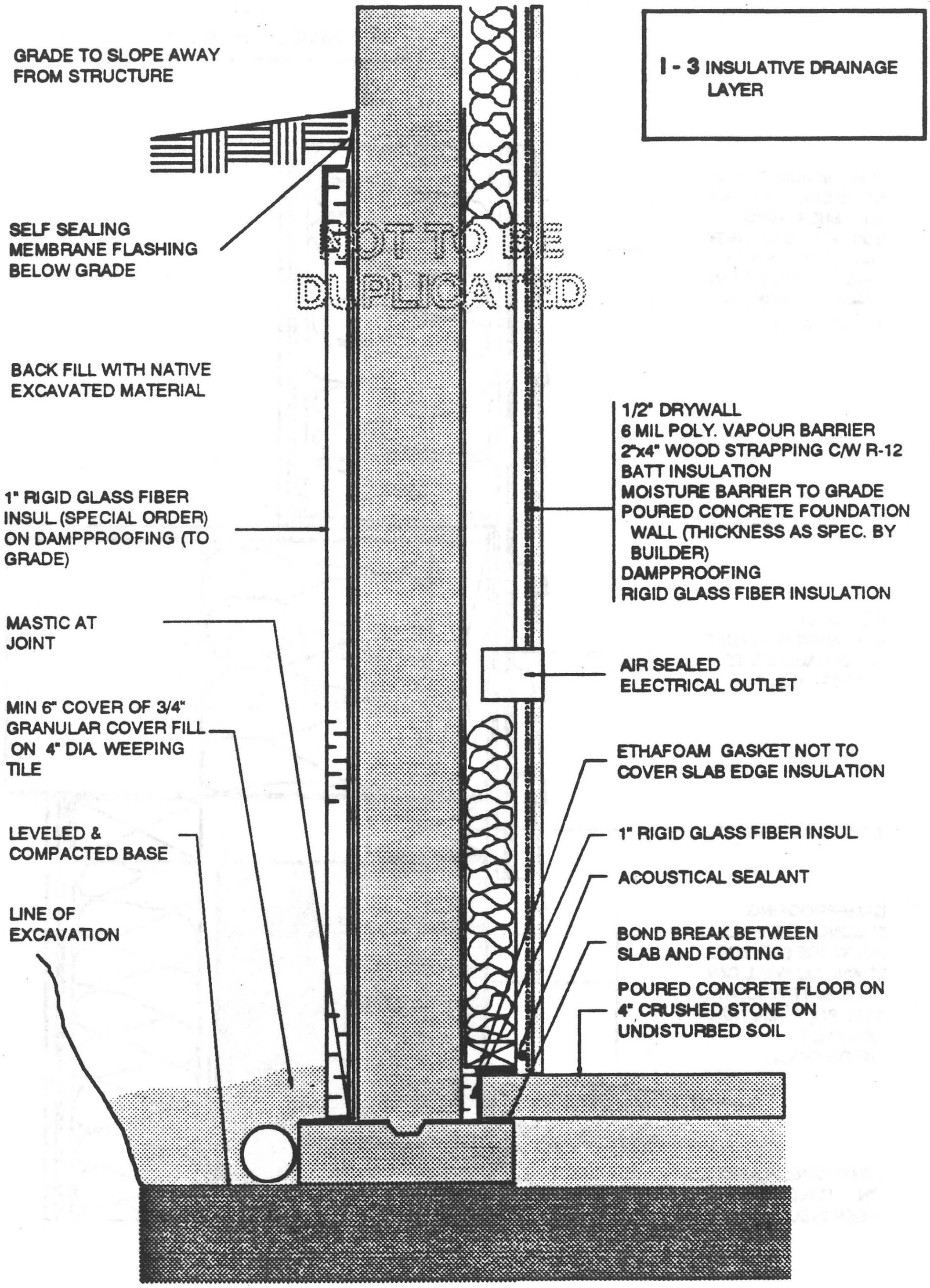
A waterproofing material was specified to seal the top edge of the insulation about twelve inches below the final grade. The goal was to prevent water from coming in contact with the wall by wetting the inner portion from the top of the insulation board. A twelve inch band of peel and stick rubberized asphalt sheet membrane waterproofing material was specified as a flashing for the top of the insulation. The edges of the membrane were recommended to be sealed with a compatible mastic. Alternatively, a torch applied modified bitumen flashing would not require this mastic.

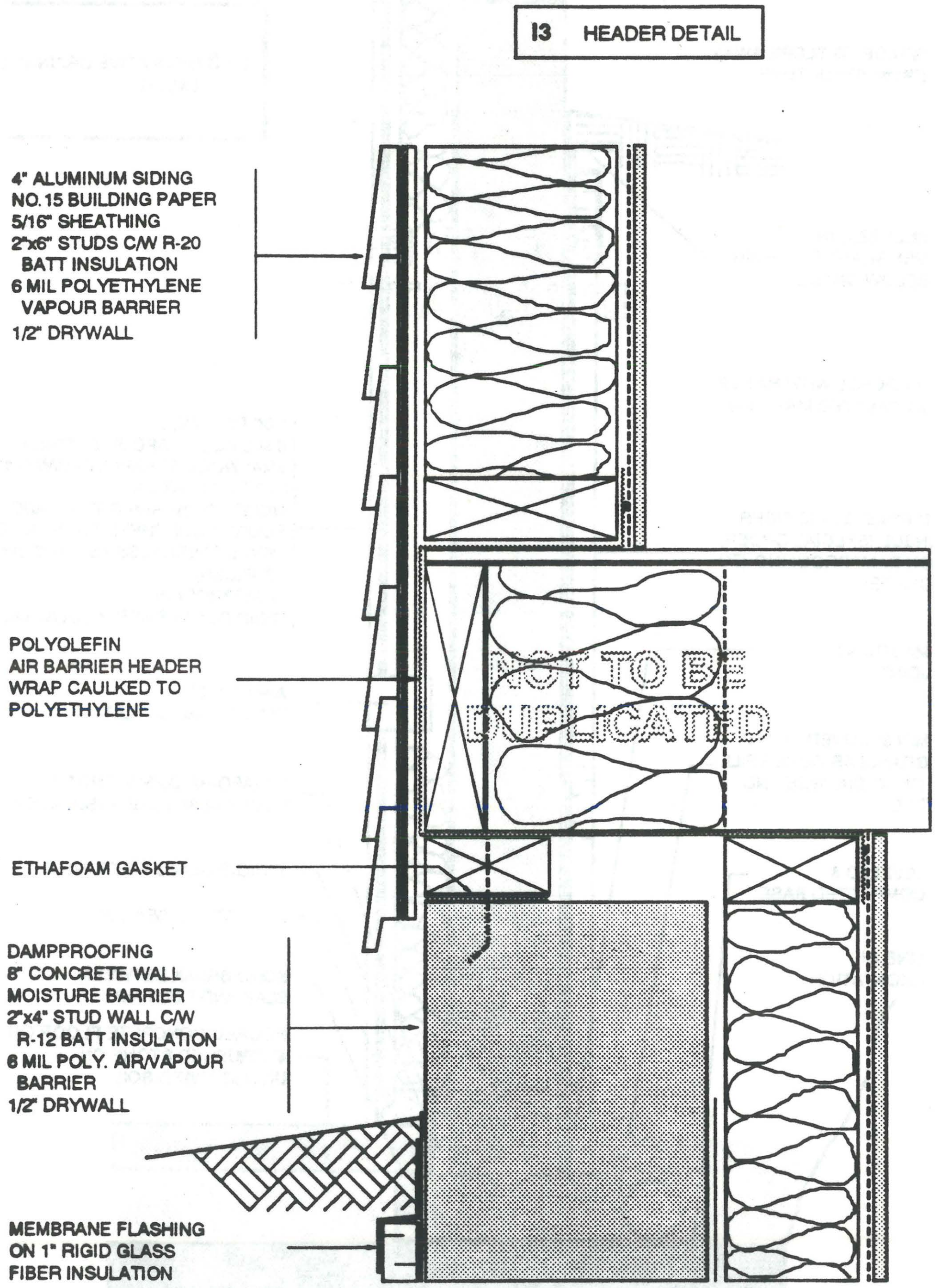
2.2.4 Basement I - 4 Hanging Exterior PVC Sheet

This brick clad house was built on a concrete block foundation. Interior insulation was to be 2.5" extruded polystyrene Type II, held in place with strapping which fits into grooves on the front face of the material.

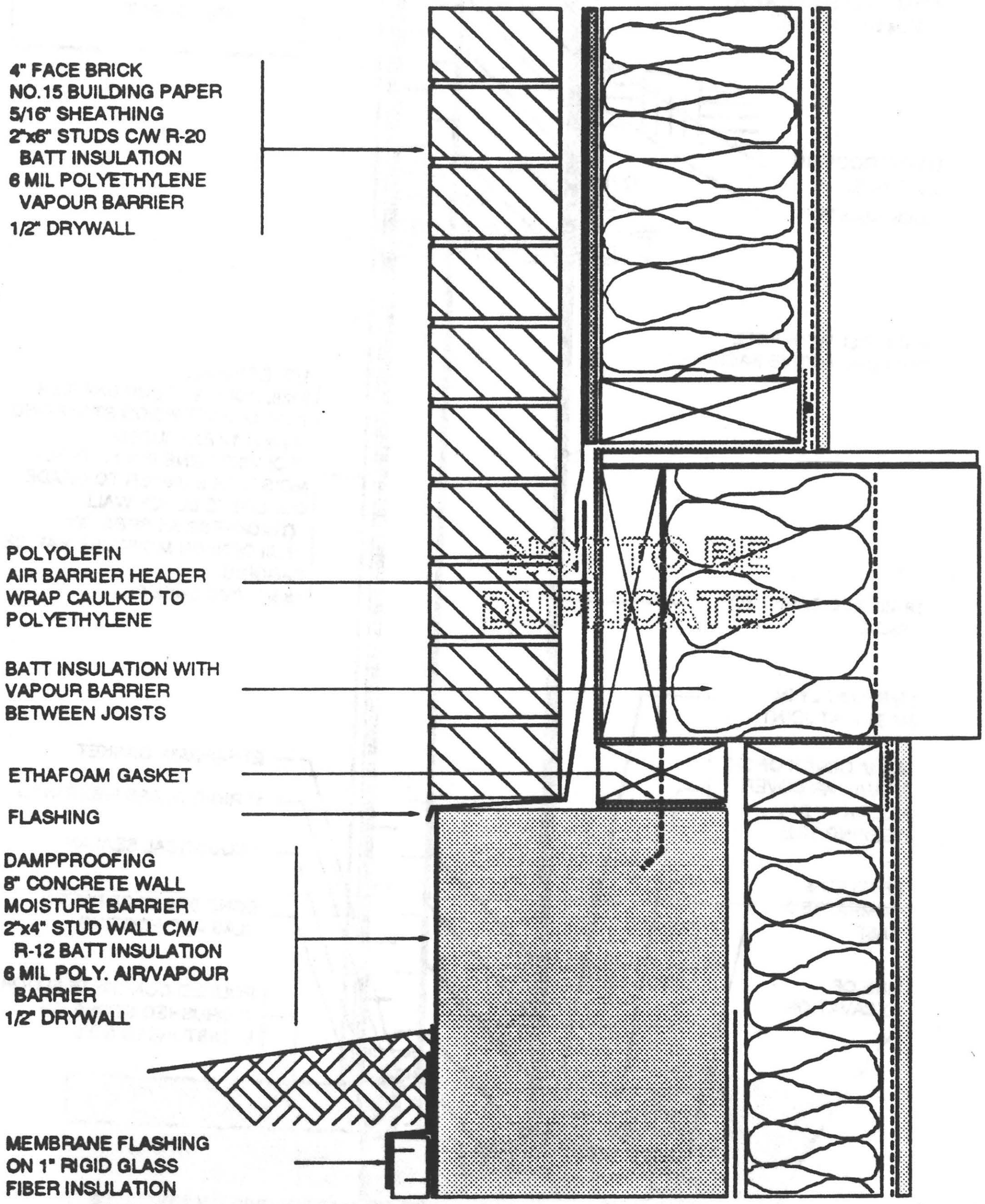
The moisture handling method for the exterior of this basement was an 18 mil PVC sheet. Accepted for use as a dampproofing, the PVC sheet was designed to hang from a PVC extrusion securement strip which is fastened to the wall. The fastening strip consisted of two pieces. The first piece was anchored to the wall with concrete screws just below the finished grade level. Rolling the PVC sheet across in front of the first strip, the second PVC extrusion was placed over the sheet. It was then snapped in place binding the sheet. Mastic was to be placed at the footing/wall junction to provide a seal and hold the PVC sheet in place. The PVC sheet extended to the edge of the footing. Vertical joints were sealed with a solvent cement which was to be supplied by the manufacturer. PVC corner boots are designed to be used on the footings at corners where the sheet must be cut.

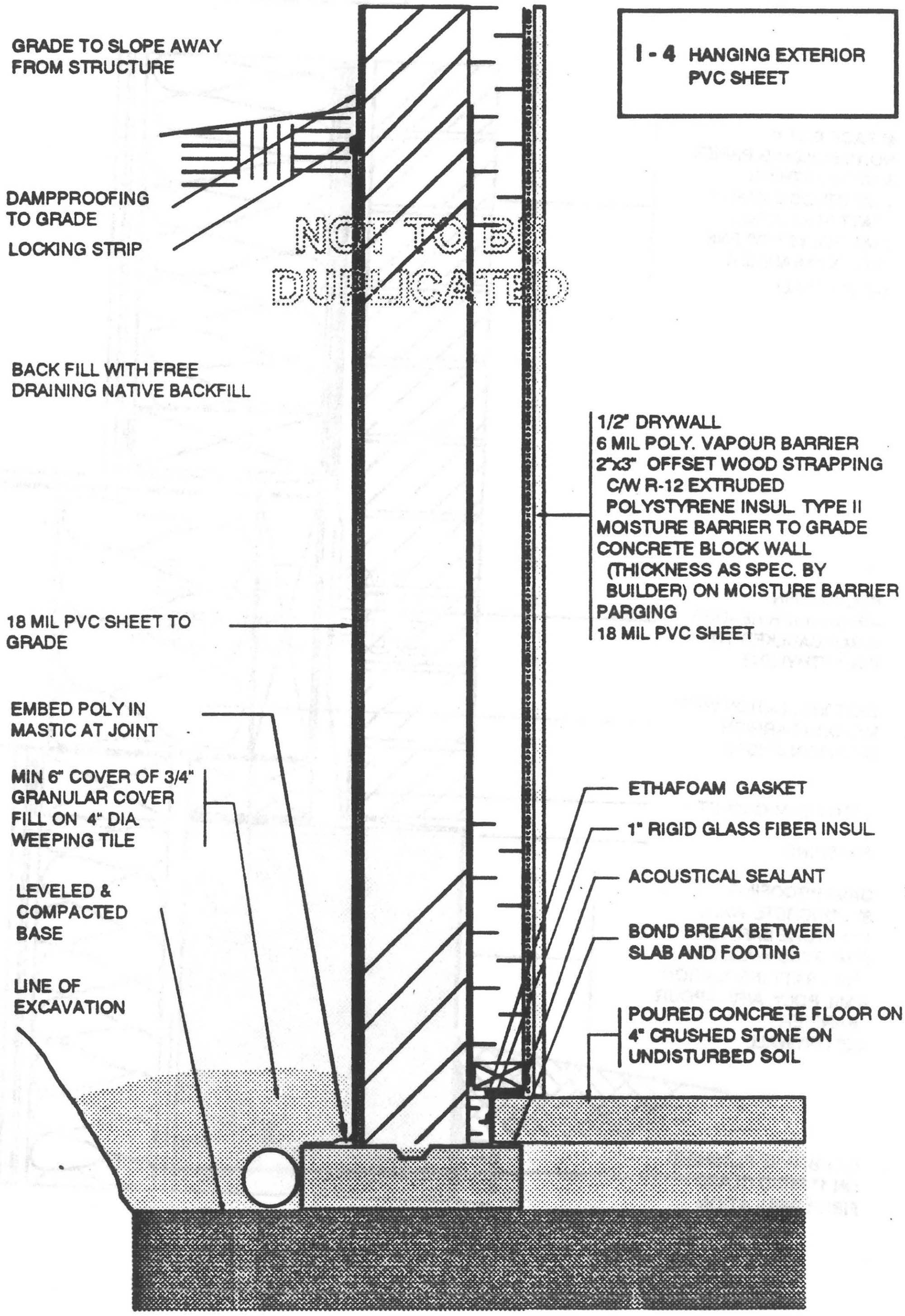
The requirement for sealing the top edge of the system was satisfied by embedding the first extrusion into a bed of mastic. A flashing over this fastening strip was also recommended. Parging up to the top of the foundation was then to be applied. Spray dampproofing was to cover the parging from the top of the PVC sheet up to grade level.


I - 3 INSULATIVE DRAINAGE LAYER
GRADE TO SLOPE AWAY FROM STRUCTURE
SELF SEALING MEMBRANE FLASHING BELOW GRADE
BACK FILL WITH NATIVE EXCAVATED MATERIAL
1" RIGID GLASS FIBER INSUL.(SPECIAL ORDER) ON DAMPPROOFING (TO GRADE)
MASTIC AT JOINT
MIN 6" COVER OF 3/4" GRANULAR COVER FILL ON 4" DIA. WEEPING TILE
LEVELED & COMPACTED BASE
LINE OF EXCAVATION
1/2" DRYWALL
6 MIL POLY. VAPOUR BARRIER
2"x4" WOOD STRAPPING C/W R-12 BATT INSULATION
MOISTURE BARRIER TO GRADE
POURED CONCRETE FOUNDATION WALL (THICKNESS AS SPEC. BY BUILDER)
DAMPPROOFING
RIGID GLASS FIBER INSULATION
AIR SEALED ELECTRICAL OUTLET
ETHAFOAM GASKET NOT TO COVER SLAB EDGE INSULATION
1" RIGID GLASS FIBER INSUL
ACOUSTICAL SEALANT
BOND BREAK BETWEEN SLAB AND FOOTING
POURED CONCRETE FLOOR ON 4" CRUSHED STONE ON UNDISTURBED SOIL

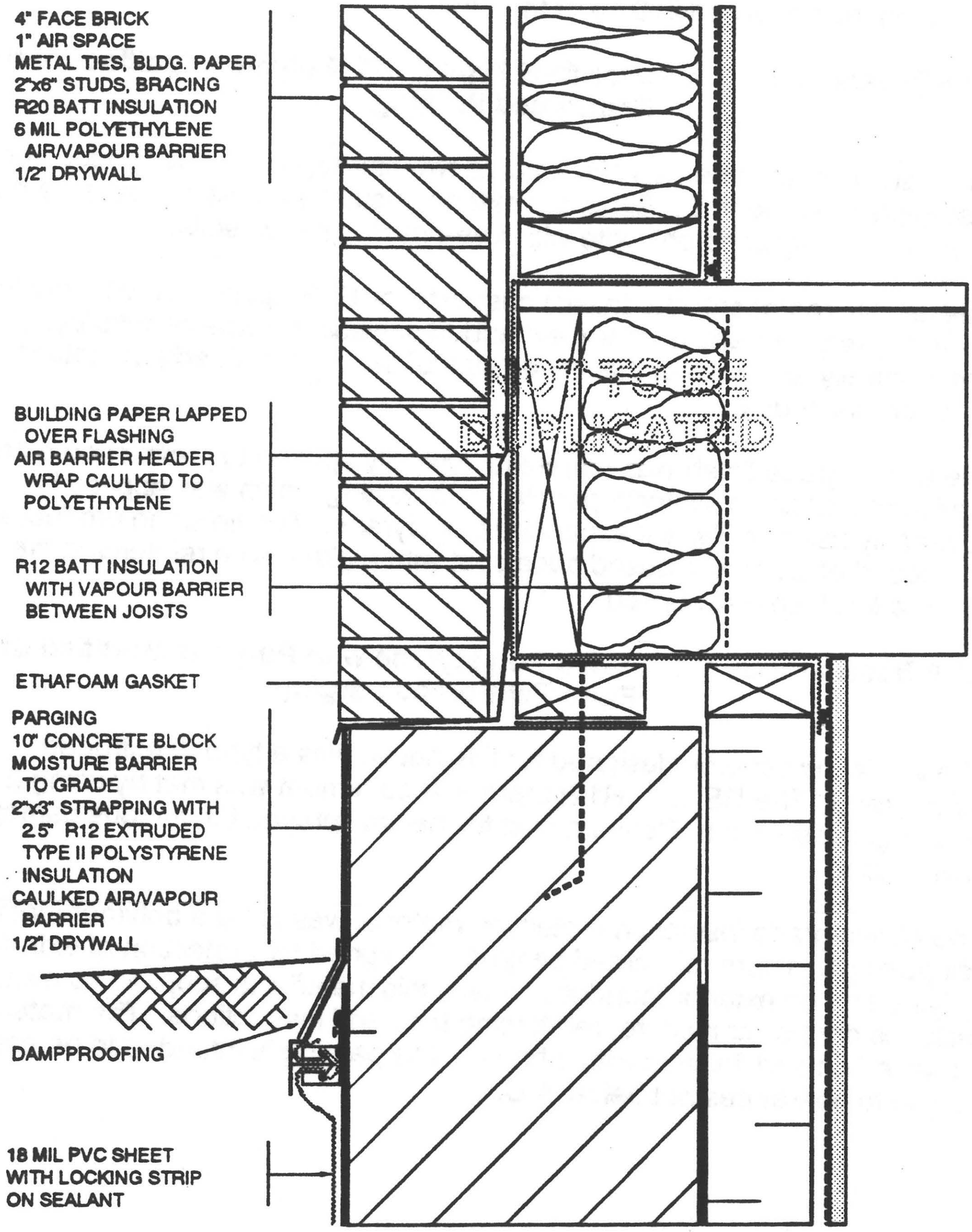

I3 HEADER DETAIL
4" ALUMINUM SIDING
NO. 15 BUILDING PAPER
5/16" SHEATHING
2"x6" STUDS C/W R-20 BATT INSULATION
6 MIL POLYETHYLENE VAPOUR BARRIER
1/2" DRYWALL
POLYOLEFIN AIR BARRIER HEADER WRAP CAULKED TO POLYETHYLENE
ETHAFOAM GASKET
DAMPPROOFING
8" CONCRETE WALL
MOISTURE BARRIER
2"x4" STUD WALL C/W R-12 BATT INSULATION
6 MIL POLY. AIR/VAPOUR BARRIER
1/2" DRYWALL
MEMBRANE FLASHING ON 1" RIGID GLASS FIBER INSULATION

I3a HEADER DETAIL




I - 4 HANGING EXTERIOR PVC SHEET
GRADE TO SLOPE AWAY FROM STRUCTURE
DAMPPROOFING TO GRADE
LOCKING STRIP
NOT TO BE DUPLICATED
BACK FILL WITH FREE DRAINING NATIVE BACKFILL
1/2" DRYWALL
6 MIL POLY. VAPOUR BARRIER
2"x3" OFFSET WOOD STRAPPING C/W R-12 EXTRUDED POLYSTYRENE INSUL. TYPE II
MOISTURE BARRIER TO GRADE
CONCRETE BLOCK WALL (THICKNESS AS SPEC. BY BUILDER) ON MOISTURE BARRIER
PARGING
18 MIL PVC SHEET
18 MIL PVC SHEET TO GRADE
EMBED POLY IN MASTIC AT JOINT
MIN 6" COVER OF 3/4" GRANULAR COVER FILL ON 4" DIA WEEPING TILE
LEVELED & COMPACTED BASE
LINE OF EXCAVATION
ETHAFOAM GASKET
1" RIGID GLASS FIBER INSUL
ACOUSTICAL SEALANT
BOND BREAK BETWEEN SLAB AND FOOTING
POURED CONCRETE FLOOR ON 4" CRUSHED STONE ON UNDISTURBED SOIL

I - 4 HEADER DETAIL



Because this system does not drain away soil moisture, it was specified for use on sites with free-draining native soils. This material was not intended to be used as waterproofing here.

This product was originally developed for use as a commercial air barrier system where the 18 mil PVC sheet is used with PVC extrusions similar to the ones developed for use on the test basement exterior. The PVC sheet has a permeability rating of 0.5 perms and so it was approved as a dampproofing equivalent as contained in 9.13 of the OBC.

2.2.5 Basement E - 1 Exterior EPS Type II with Polymer Modified Mesh Reinforced Parging

This insulation scheme was placed on a two-storey, brick veneer house on a cast-in-place foundation. Since the exterior insulation does not act as a drainage layer, it was only used on a site with free-draining native soils.

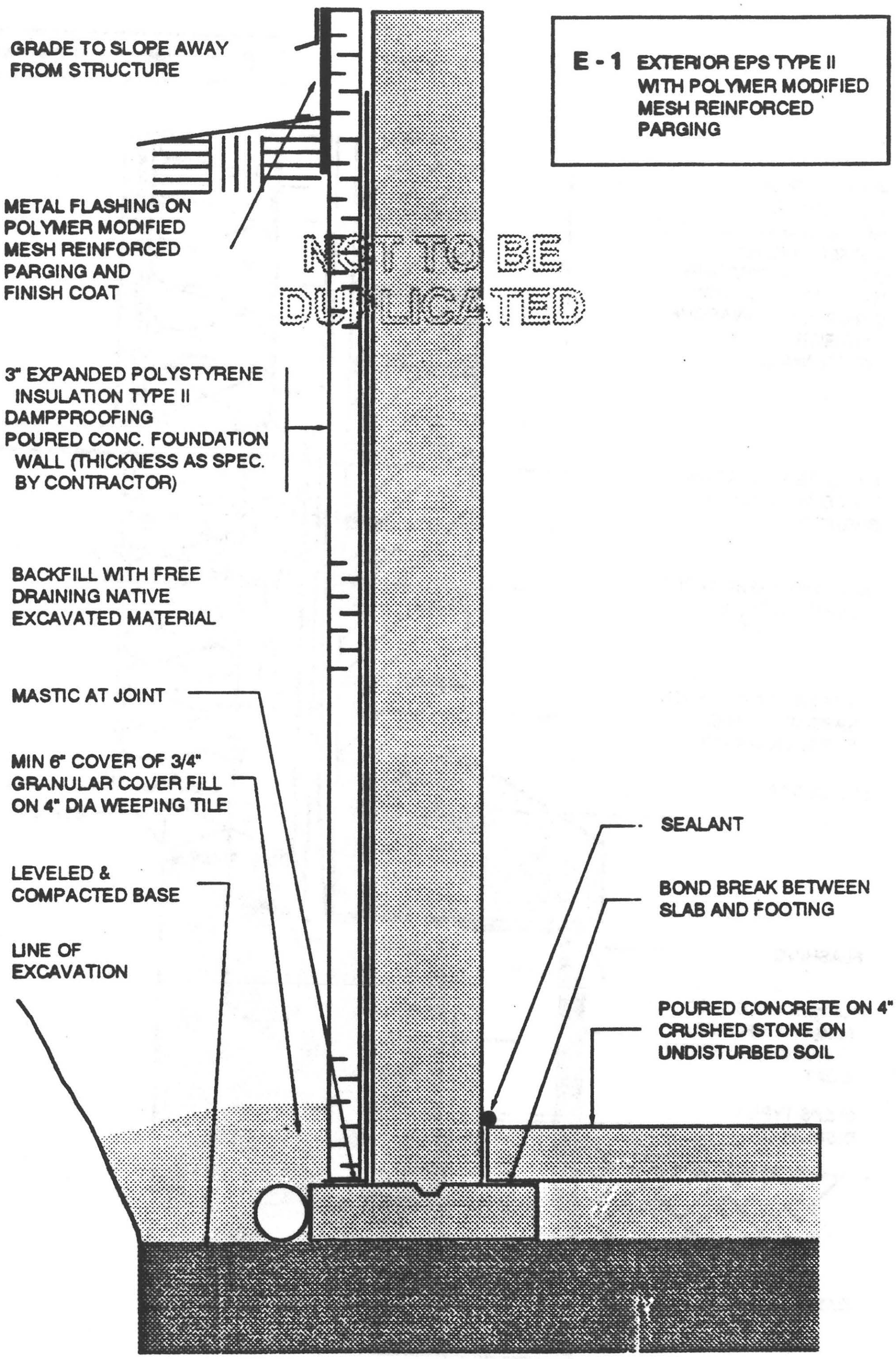
This usually represents the lowest cost exterior EPS option. To achieve the RSI 2.1 (R12) requirement, 3" of the expanded polystyrene was necessary. Unfortunately, because of the limited size of the order butt edged material was used for this house.

The above-grade finish was a material typically applied to prefinished external insulation and finish systems panels. The coating which was applied is commonly used on Type II expanded polystyrene. The finishing product was composed of an acrylic based base coat with a glass fibre reinforcing mesh onto which a finish coat is applied.

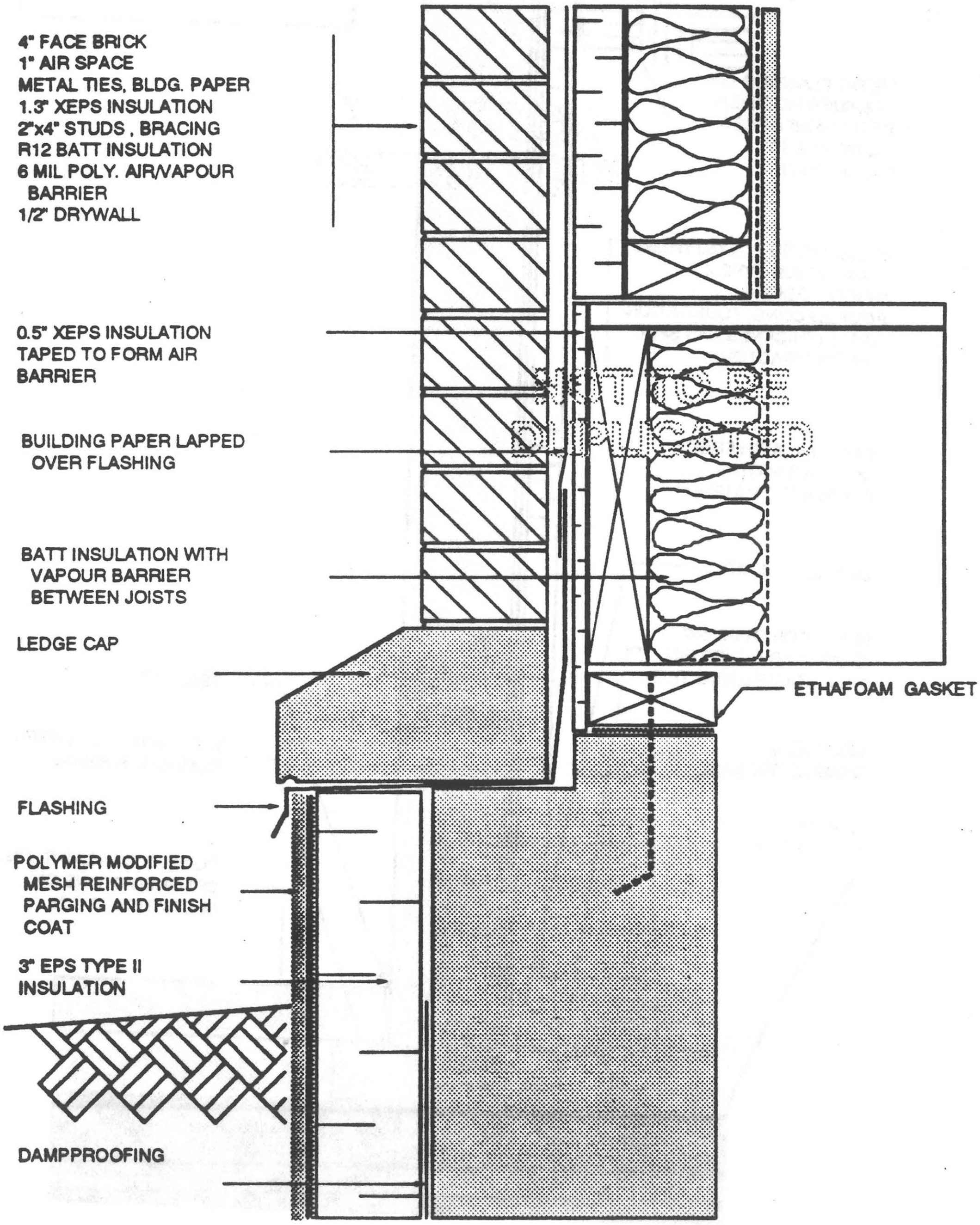
2.2.6 Basement E - 2 Extruded Polystyrene with Polymer Modified Chopped Fibre Reinforced Parging

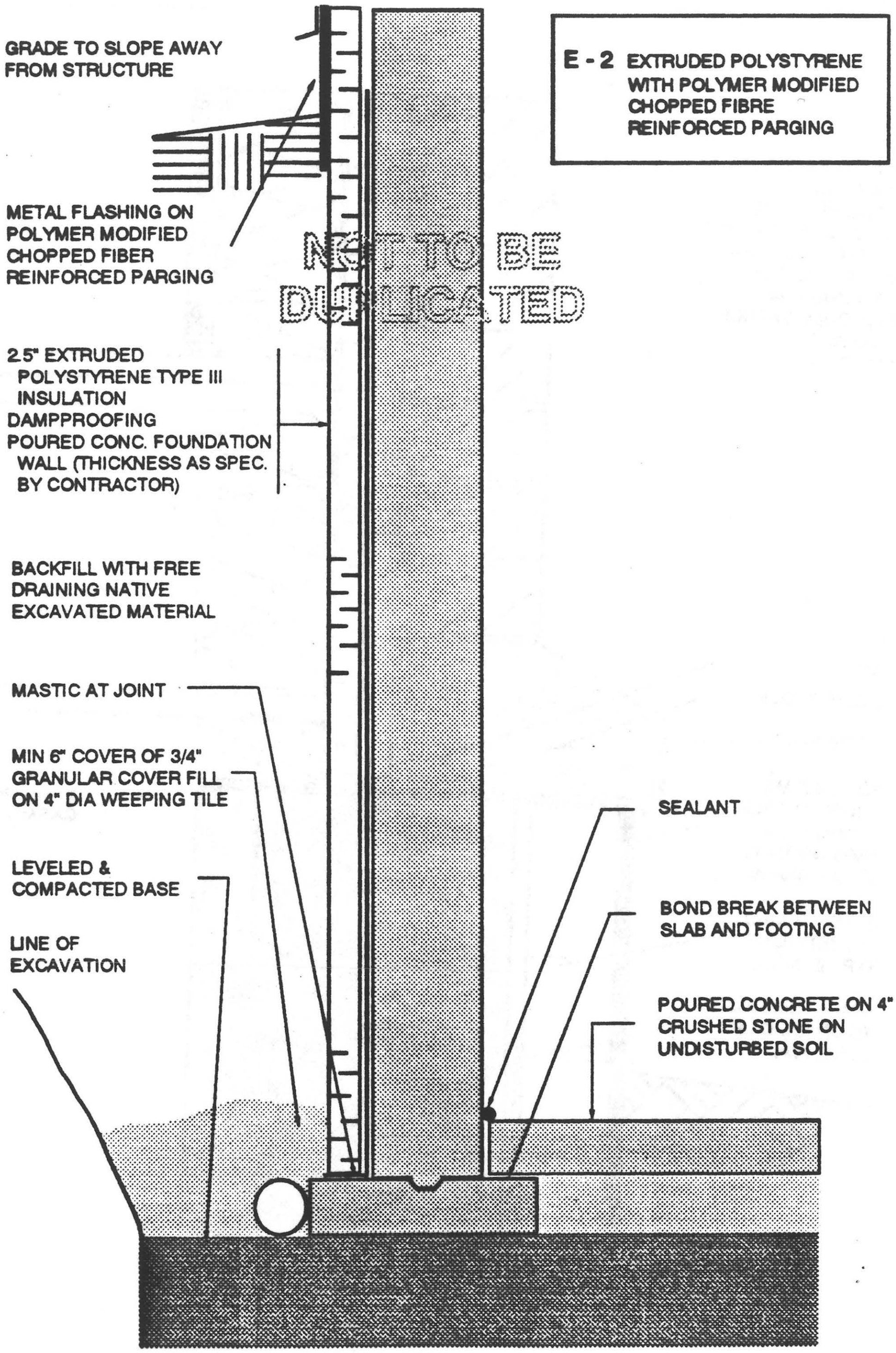
The insulating scheme designed for this house was a type III extruded polystyrene. The RSI 2.1 (R12) thermal requirement was met by using 2.5" rigid, butt edged insulation. Conventional full height sprayed bituminous dampproofing was applied.

The above-grade insulation protection material was to be a polymer modified, chopped glass fibre reinforced parging. Designed for protection of extruded polystyrene on exterior foundation walls, this material is supplied as a kit. The kit includes dry power mixture, reinforcing tape and instructions. The material was trowelled on and finished with a brush. The parging is intended to be applied only in temperatures not below 4°C.

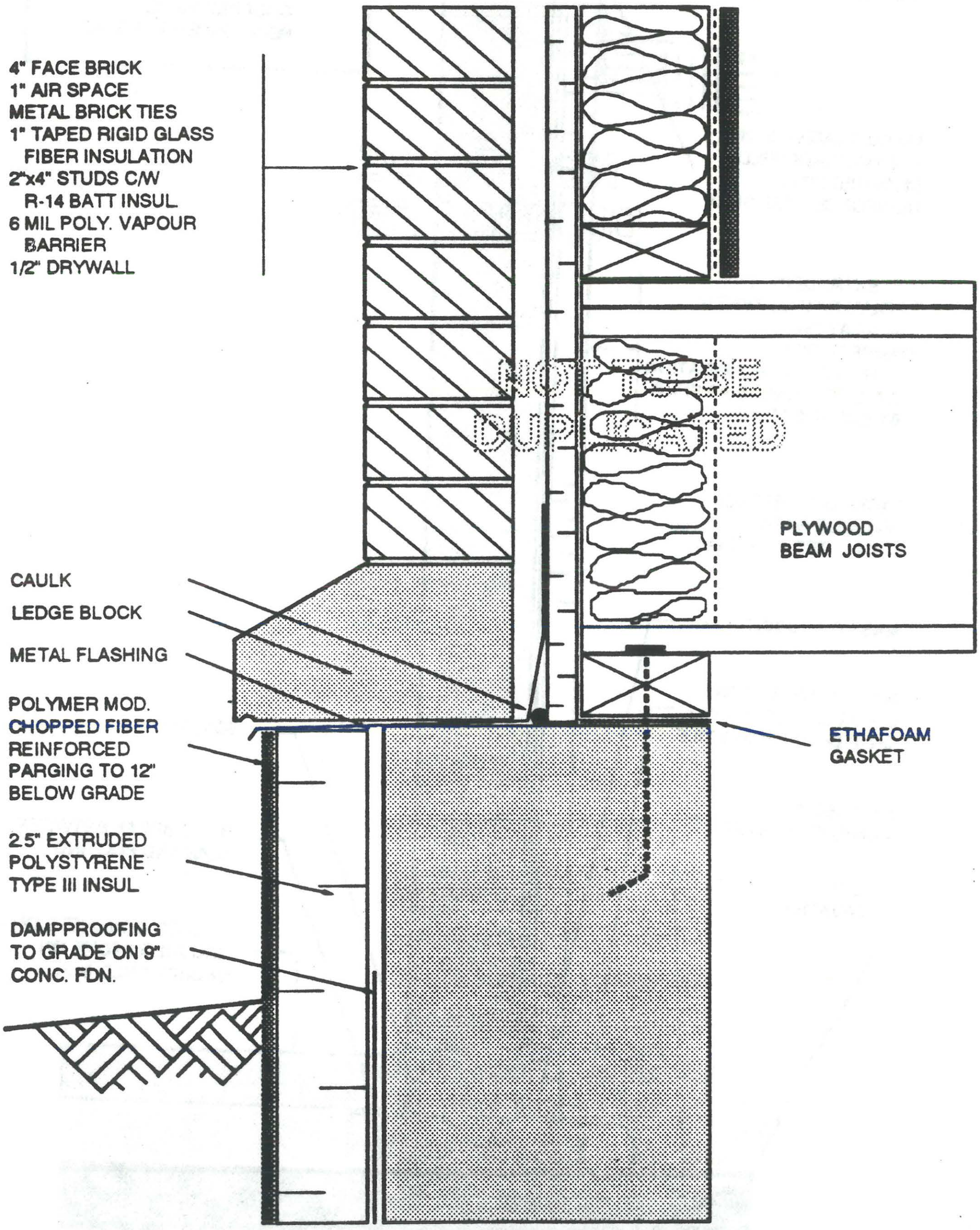

GRADE TO SLOPE AWAY FROM STRUCTURE
E - 1 EXTERIOR EPS TYPE II WITH POLYMER MODIFIED MESH REINFORCED PARGING
METAL FLASHING ON POLYMER MODIFIED MESH REINFORCED PARGING AND FINISH COAT
3" EXPANDED POLYSTYRENE INSULATION TYPE II
DAMPPROOFING
POURED CONC. FOUNDATION WALL (THICKNESS AS SPEC. BY CONTRACTOR)
BACKFILL WITH FREE DRAINING NATIVE EXCAVATED MATERIAL
MASTIC AT JOINT
MIN 6" COVER OF 3/4" GRANULAR COVER FILL ON 4" DIA WEEPING TILE
SEALANT
BOND BREAK BETWEEN SLAB AND FOOTING
LEVELED & COMPACTED BASE
LINE OF EXCAVATION
POURED CONCRETE ON 4" CRUSHED STONE ON UNDISTURBED SOIL

E - 1 HEADER DETAIL




E - 2 EXTRUDED POLYSTYRENE WITH POLYMER MODIFIED CHOPPED FIBRE REINFORCED PARGING
GRADE TO SLOPE AWAY FROM STRUCTURE
METAL FLASHING ON POLYMER MODIFIED CHOPPED FIBER REINFORCED PARGING
2.5" EXTRUDED POLYSTYRENE TYPE III INSULATION
DAMPPROOFING
POURED CONC. FOUNDATION WALL (THICKNESS AS SPEC. BY CONTRACTOR)
BACKFILL WITH FREE DRAINING NATIVE EXCAVATED MATERIAL
MASTIC AT JOINT
MIN 6" COVER OF 3/4" GRANULAR COVER FILL ON 4" DIA WEEPING TILE
LEVELED & COMPACTED BASE
LINE OF EXCAVATION
SEALANT
BOND BREAK BETWEEN SLAB AND FOOTING
POURED CONCRETE ON 4" CRUSHED STONE ON UNDISTURBED SOIL

E -2	HEADER DETAIL



2.2.7 Basement E - 3 Prefinished Polystyrene Insulation Panel

This basement design had essentially the same insulation configuration as for E - 2, but below-grade insulation was type IV extruded polystyrene. The 2.5" thick panels were butt jointed. The essential difference was that the above-grade portion of the insulation was a new prefinished cement-faced insulation panel product. Primarily developed for commercial/industrial applications, 2' x 4' panels are attached using a specially designed fastening clip.

Surface fasteners are required at corners and wherever panels are cut in width. The profile has a tongue and groove joint which is not intended to be sealed; drainage is facilitated within the joint. The insulation substrate was the 2.5" type IV extruded polystyrene product. The joint between the unfaced insulation (below grade) and faced material (above grade) was flashed with sealed polyethylene behind the upper material out over the lower material.

2.2.8 Basement E - 4 Rigid Glass Fibre with Cement Parging on Lath

This house was a two-storey, brick clad structure on cast-in-place foundation walls. A rigid glass fibre exterior insulation board product (thickness of 3") was required to meet RSI 2.1 (R12).

Similar to basement I - 3 the glass fibre material acts as a drainage layer as well as an insulation. Full height bituminous dampproofing is required to conform to the OBC.

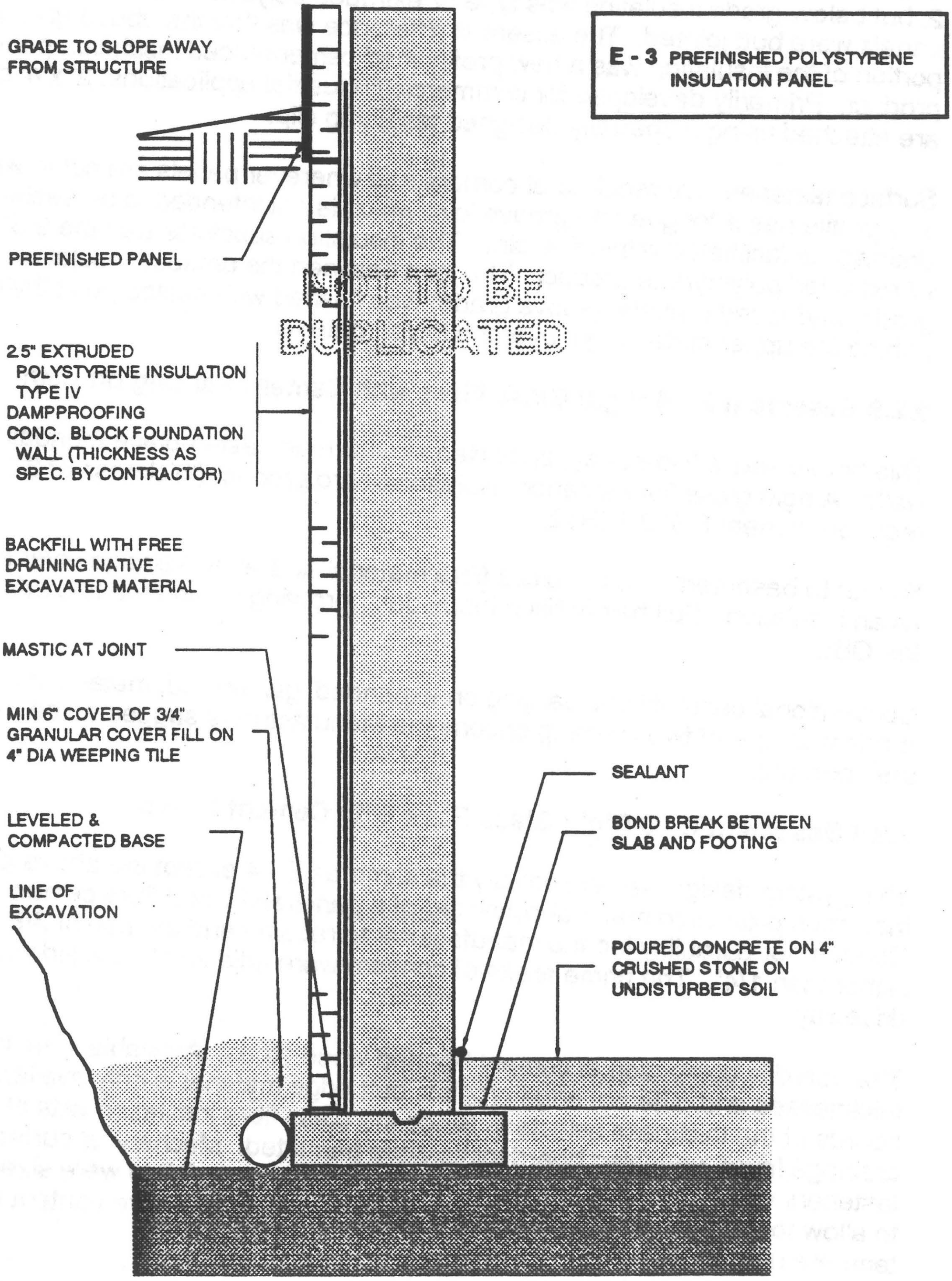
Conventional cementitious parging on expanded, galvanized, metal lath above grade was one of two finishing options the Manufacturers suggested be used with their product.

2.2.9 Basement E - 5 Rigid Glass Fibre with Cement Board

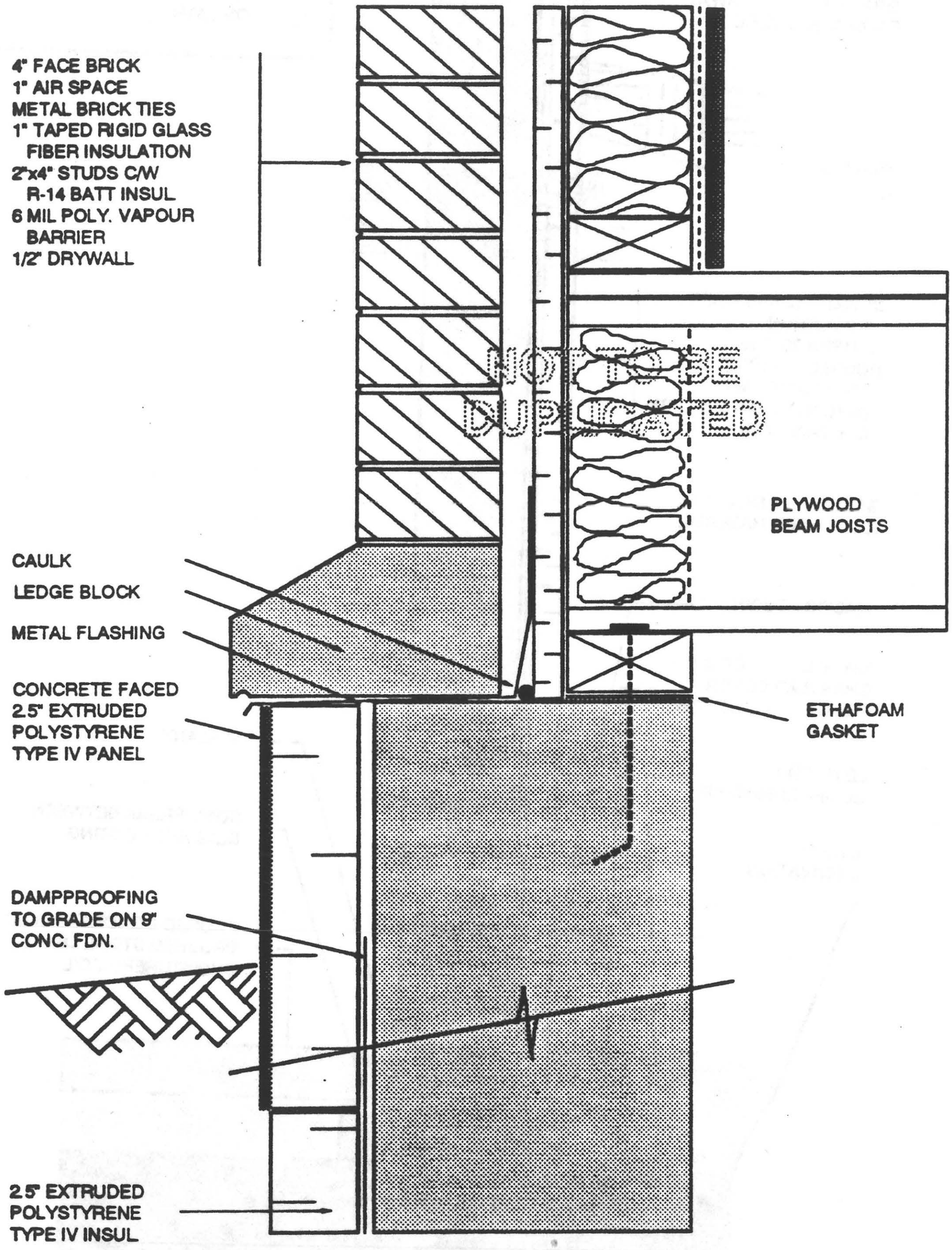
This system design was essentially the same as E - 4 except the above-grade insulation protection material consisted of a panelized wood-fibre cement board. Concern for durability led the manufacturer to recommend the use of 3/8" thick rather than 1/4". The prime areas of concern were adjacent to the sidewalk and driveway.

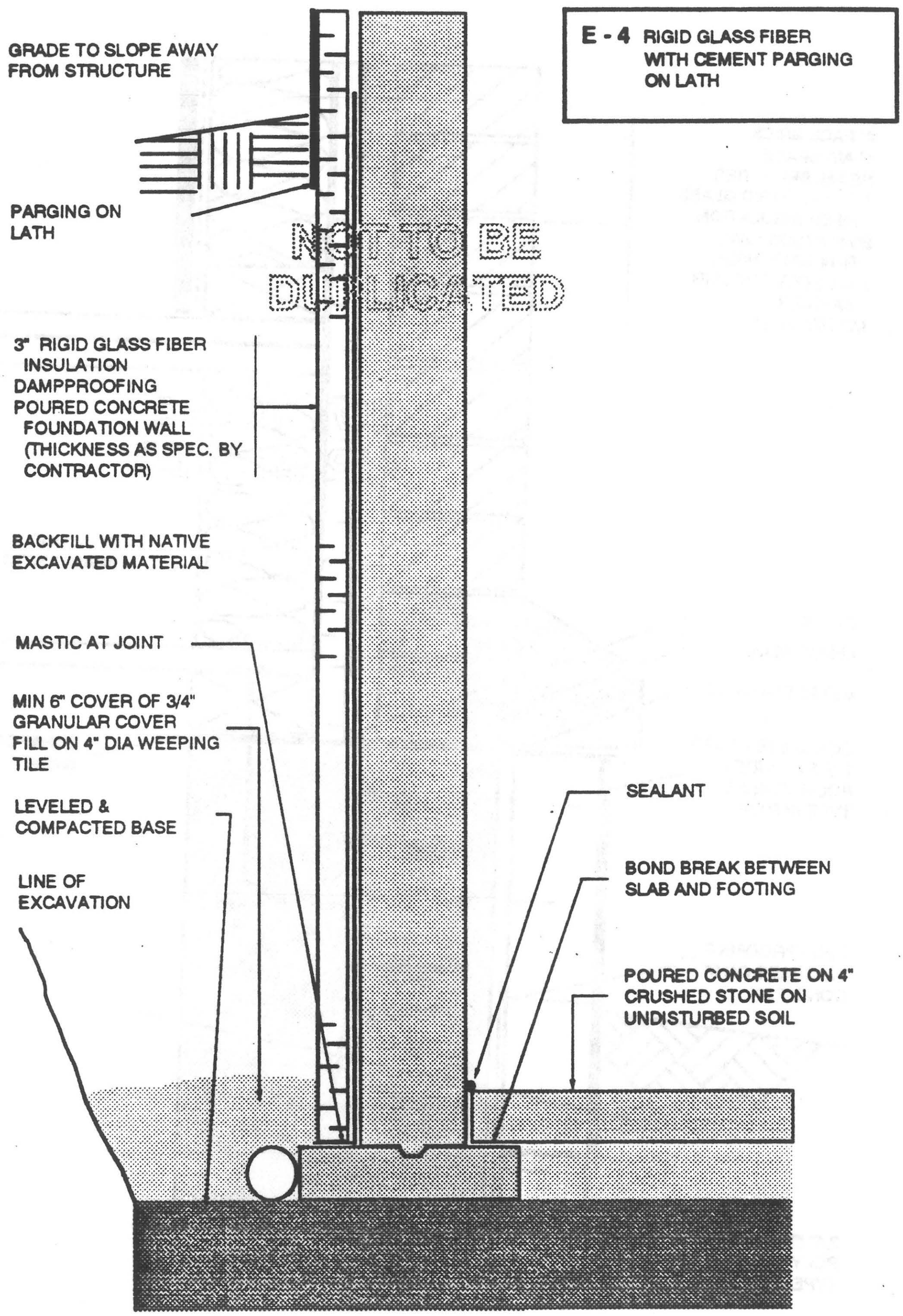
The board is composed of cement bonded wood fibres. Available in many thicknesses and different edge profiles, butt edge material is only available for boards of the thickness selected. Since the glass fibre insulation acts as a drainage layer, unsealed board joints were permitted. Mechanical surface fasteners were the recommended method of fastening. Joints were sized at 1/8" to allow for dimensional change resulting from varying moisture content and temperature variations.

The ledge block specified for capping the insulation both on this basement and on E - 4 was a standard masonry sill placed on a sloped bed of mortar.


E - 3 PREFINISHED POLYSTYRENE INSULATION PANEL
GRADE TO SLOPE AWAY FROM STRUCTURE
PREFINISHED PANEL
2.5" EXTRUDED POLYSTYRENE INSULATION TYPE IV
DAMPPROOFING
CONC. BLOCK FOUNDATION WALL (THICKNESS AS SPEC. BY CONTRACTOR)
BACKFILL WITH FREE DRAINING NATIVE EXCAVATED MATERIAL
MASTIC AT JOINT
MIN 6" COVER OF 3/4" GRANULAR COVER FILL ON 4" DIA WEEPING TILE
LEVELED & COMPACTED BASE
LINE OF EXCAVATION
SEALANT
BOND BREAK BETWEEN SLAB AND FOOTING
POURED CONCRETE ON 4" CRUSHED STONE ON UNDISTURBED SOIL

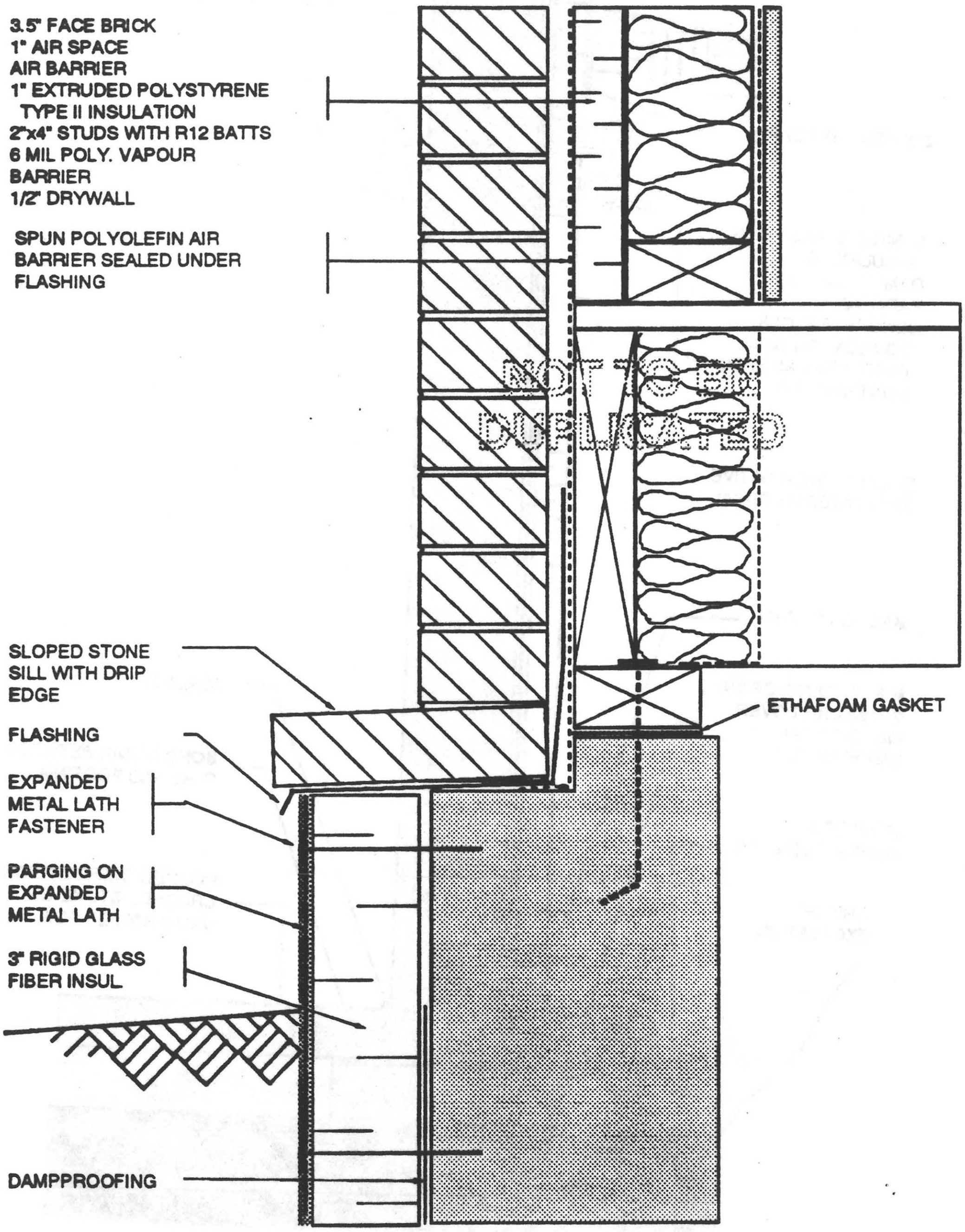
E -3 HEADER DETAIL



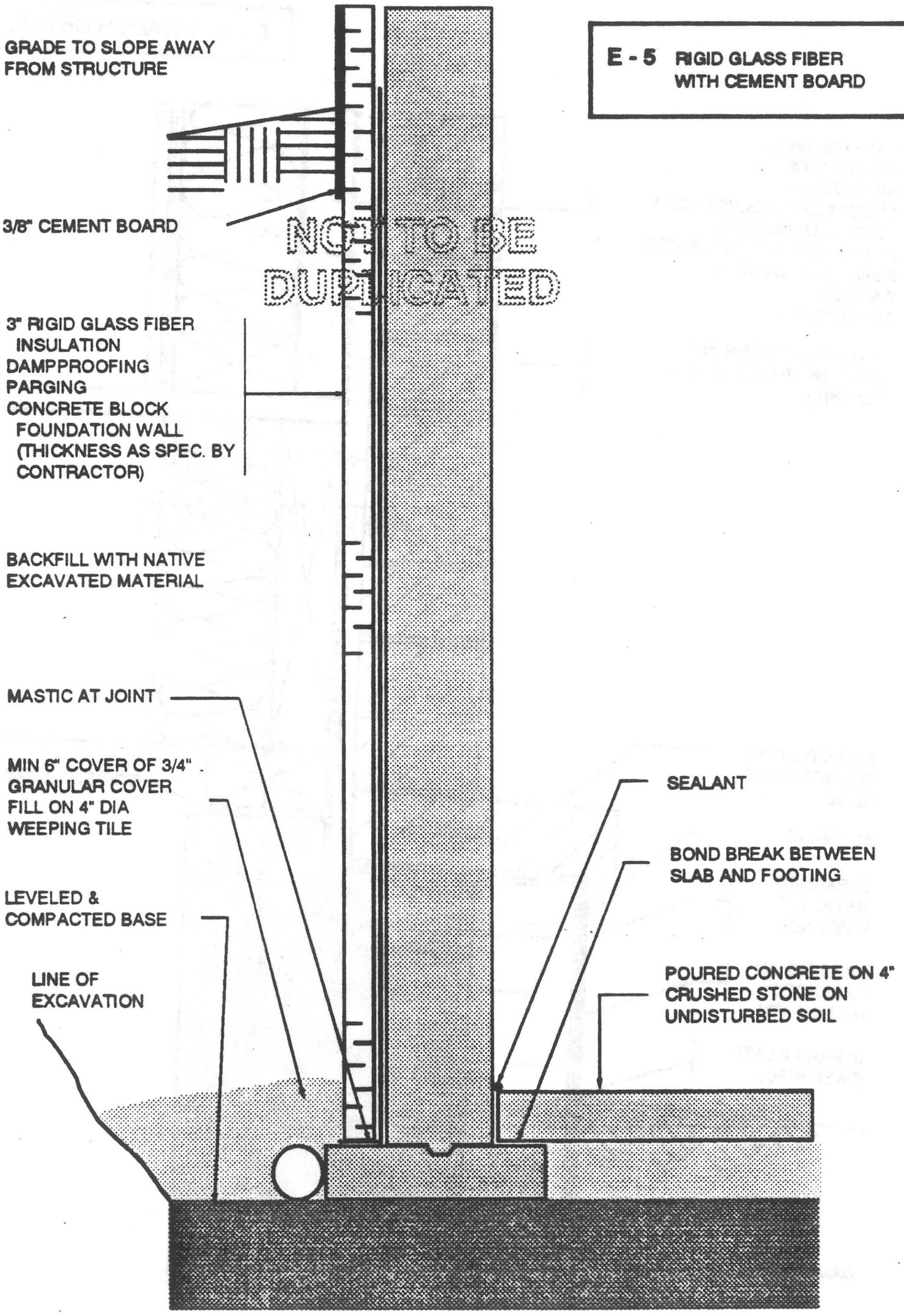


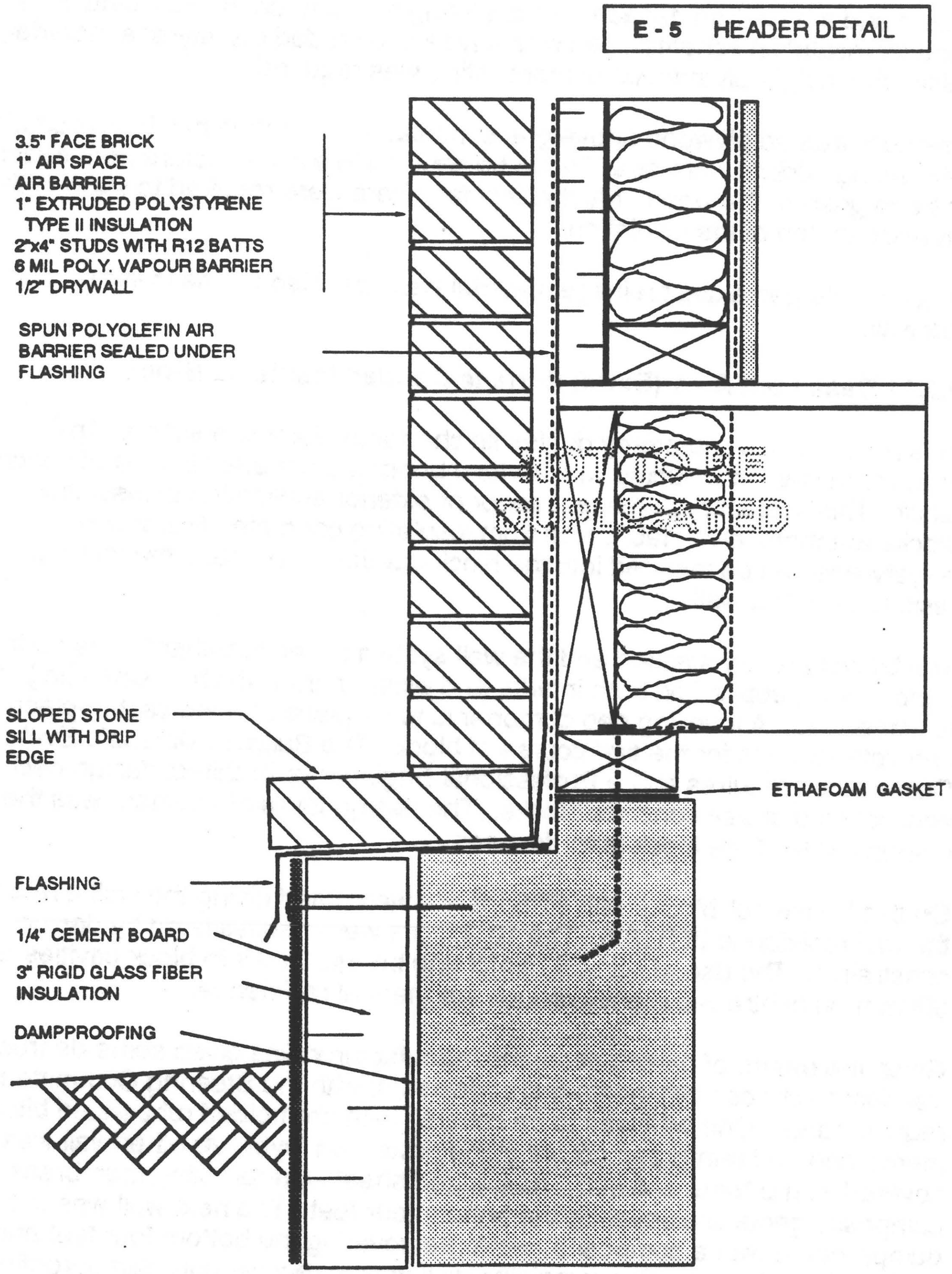
E - 4 RIGID GLASS FIBER WITH CEMENT PARGING ON LATH
GRADE TO SLOPE AWAY FROM STRUCTURE
PARGING ON LATH
NOT TO BE DUPLICATED
3" RIGID GLASS FIBER INSULATION
DAMPPROOFING
POURED CONCRETE FOUNDATION WALL (THICKNESS AS SPEC. BY CONTRACTOR)
BACKFILL WITH NATIVE EXCAVATED MATERIAL
MASTIC AT JOINT
MIN 6" COVER OF 3/4" GRANULAR COVER FILL ON 4" DIA WEEPING TILE
LEVELED & COMPACTED BASE
LINE OF EXCAVATION
SEALANT
BOND BREAK BETWEEN SLAB AND FOOTING
POURED CONCRETE ON 4" CRUSHED STONE ON UNDISTURBED SOIL

E - 4 HEADER DETAIL



E - 5 RIGID GLASS FIBER WITH CEMENT BOARD





E - 5 HEADER DETAIL
3.5" FACE BRICK
1" AIR SPACE
AIR BARRIER
1" EXTRUDED POLYSTYRENE
TYPE II INSULATION
2"x4" STUDS WITH R12 BATTS
6 MIL POLY. VAPOUR BARRIER
1/2" DRYWALL
SPUN POLYOLEFIN AIR
BARRIER SEALED UNDER
FLASHING
SLOPED STONE
SILL WITH DRIP
EDGE
ETHAFOAM GASKET
FLASHING
1/4" CEMENT BOARD
3" RIGID GLASS FIBER
INSULATION
DAMPPROOFING

2.2.10 Basement E - 6 Extruded Polystyrene Type III Insulation with Treated Plywood

This two-storey demonstration house had a cast-in-place foundation with vinyl siding and a brick front facade, necessitating two different header details. The exterior insulation scheme used was a type III extruded polystyrene material, 2.5" thick. Full height bituminous dampproofing was required.

Pressure treated plywood above grade insulation protection has been combined with siding. Joints were specified to be caulked to avoid moisture penetration into the end grain of the wood. Mechanical fasteners were required to support the plywood on top of the insulation.

A composite geotextile drainage material was specified for the lower portion of the wall.

2.2.11 Basement A - 1 (Extra) Surface Bonded Insulated Block

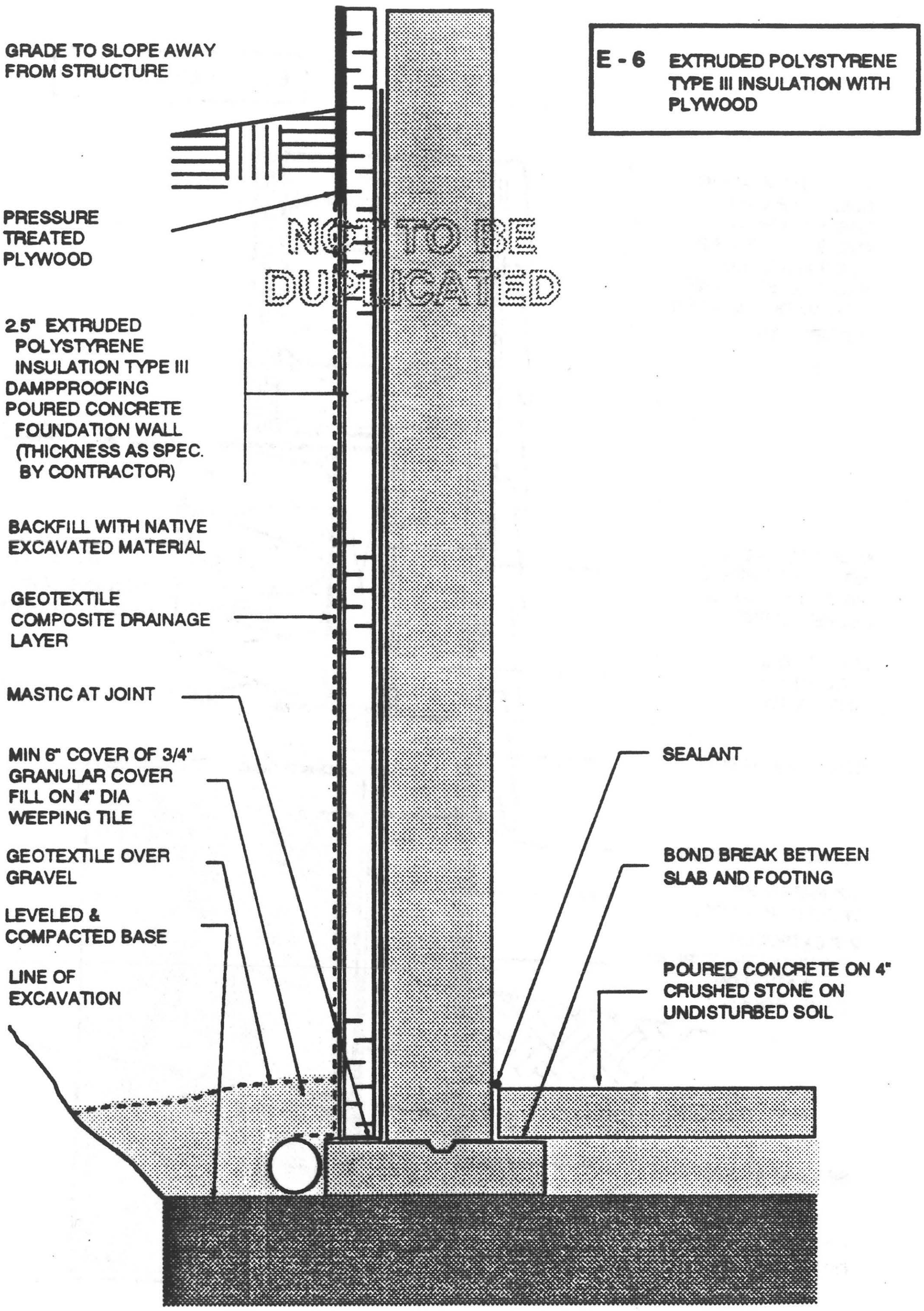
This house was a two-storey duplex finished with aluminum siding. The foundation was constructed with surface bonded proprietary insulated concrete block. This system requires no interior or exterior application of insulation. The blocks are themselves fabricated from insulating concrete. Expanded polystyrene can be inserted into the block cavities to increase the thermal resistance of the wall.

The blocks are dry stacked and the wall system is tied together by the surface bond mortar, applied on both interior and exterior, into which a reinforcing mesh is embedded. A levelling bed of mortar is to be placed on the cast-in-place concrete footings for the first course of block. The Building Materials Evaluation Commission requires that a Professional Engineer or Architect design each application of these concrete blocks. The design for reinforcement was the responsibility of the block manufacturer.

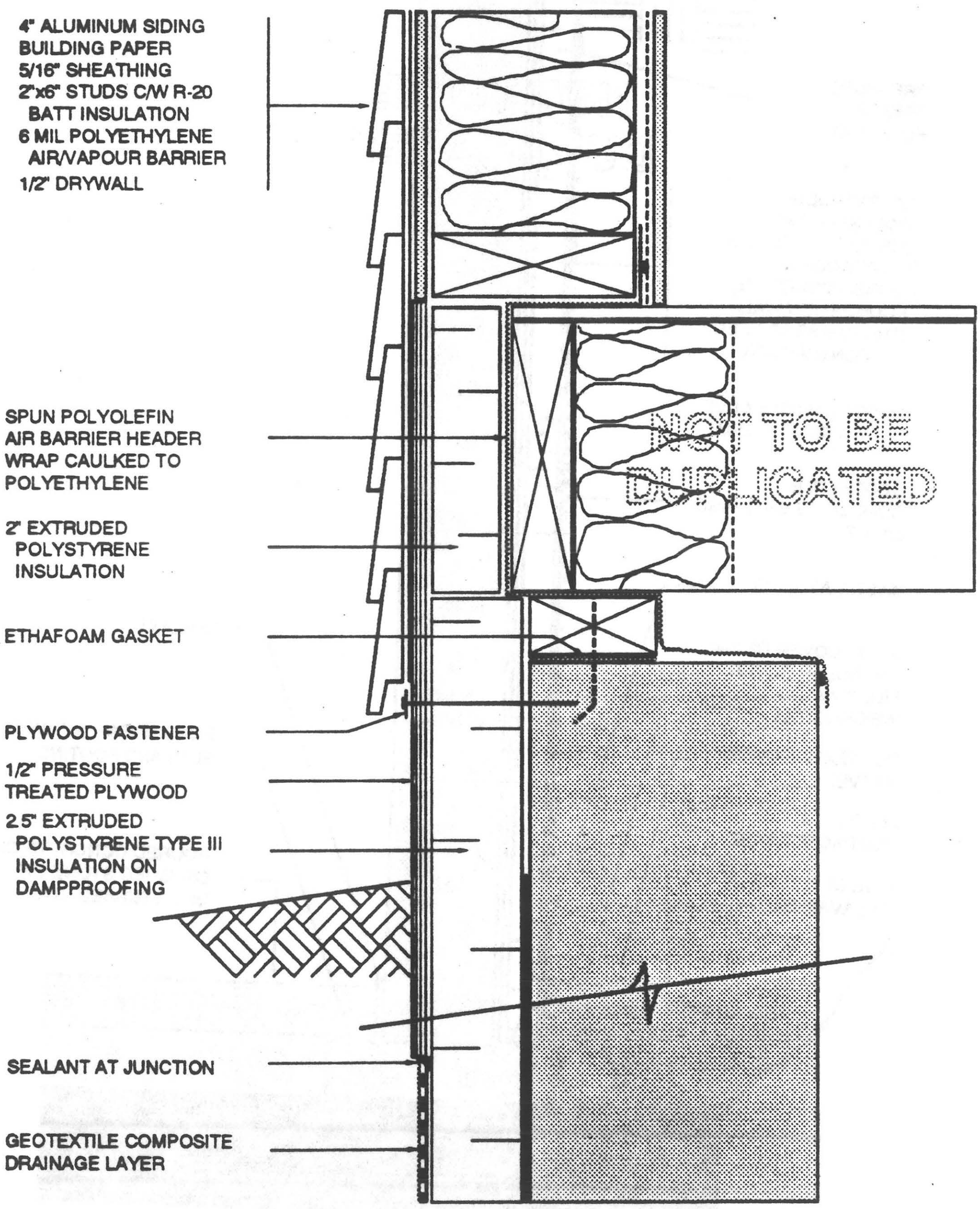
On this house 10" blocks with EPS inserts were used giving the wall a rated thermal resistance of R18.5. The 10" blocks were necessitated by design constraints. The use of vertical reinforcing bar grouted into block cavities at 600mm on centre will slightly reduce the thermal resistance.

Given the nature of participation, the manufacturer was given some degree of freedom to choose demonstrations consistent with the Steering Committee requirements. One wall was to be covered with premolded rubberized bitumen membrane and reinforced polyethylene protection layer. Another wall was to be covered with a "peel and stick" rubberized sheet waterproofing membrane with a composite geotextile covering the bottom four feet. The next wall was to be dampproofed with a composite geotextile covering the bottom four feet and sealed along the top. The remaining wall was to receive only dampproofing.

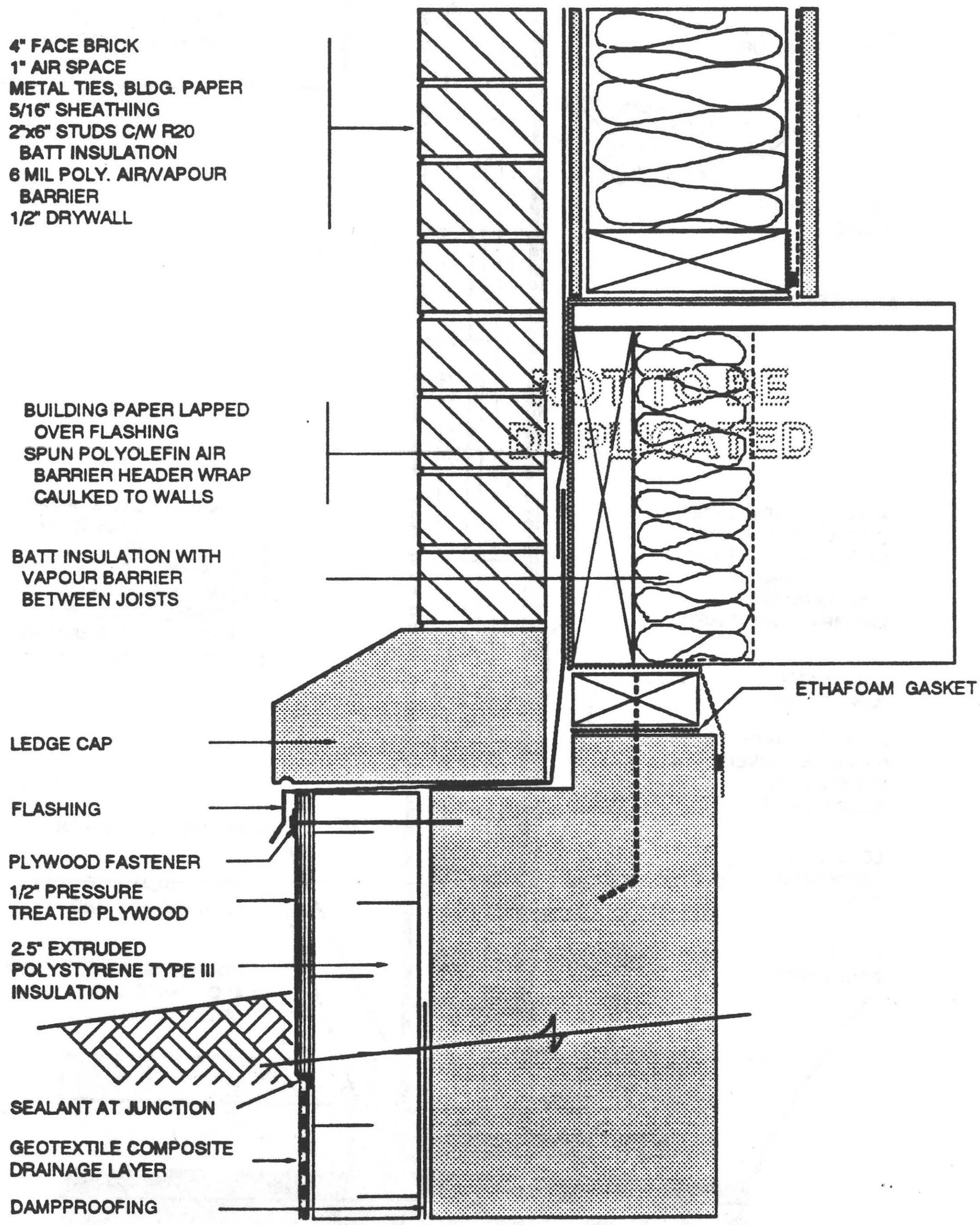
The table following the sketches provides a summary of design configurations.

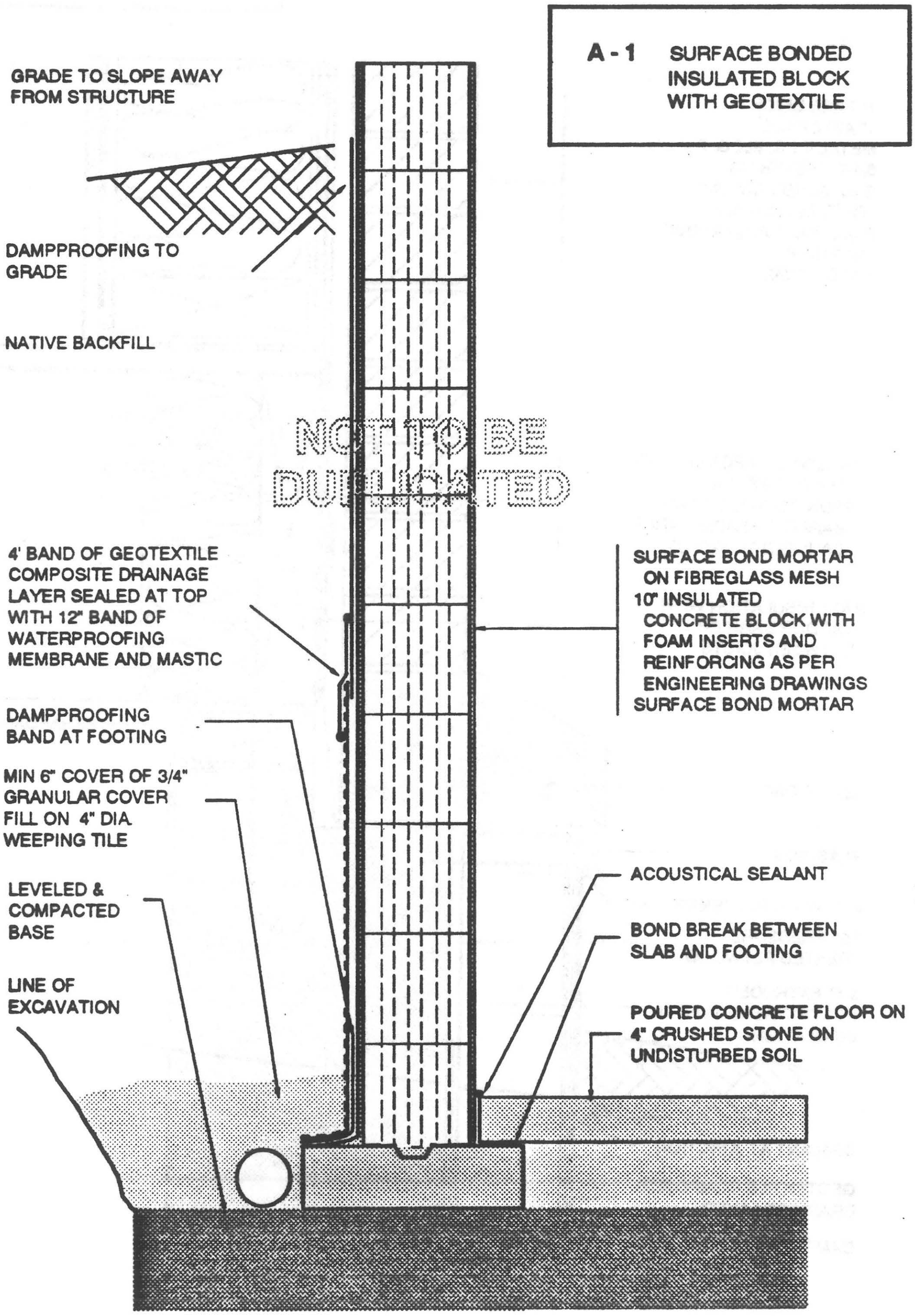

GRADE TO SLOPE AWAY FROM STRUCTURE
PRESSURE TREATED PLYWOOD
2.5" EXTRUDED POLYSTYRENE INSULATION TYPE III
DAMPPROOFING
POURED CONCRETE FOUNDATION WALL (THICKNESS AS SPEC. BY CONTRACTOR)
BACKFILL WITH NATIVE EXCAVATED MATERIAL
GEOTEXTILE COMPOSITE DRAINAGE LAYER
MASTIC AT JOINT
MIN 6" COVER OF 3/4" GRANULAR COVER FILL ON 4" DIA WEEPING TILE
GEOTEXTILE OVER GRAVEL
LEVELED & COMPACTED BASE
LINE OF EXCAVATION
E - 6 EXTRUDED POLYSTYRENE TYPE III INSULATION WITH PLYWOOD
SEALANT
BOND BREAK BETWEEN SLAB AND FOOTING
POURED CONCRETE ON 4" CRUSHED STONE ON UNDISTURBED SOIL
NOT TO BE DUPLICATED

E6 HEADER DETAIL



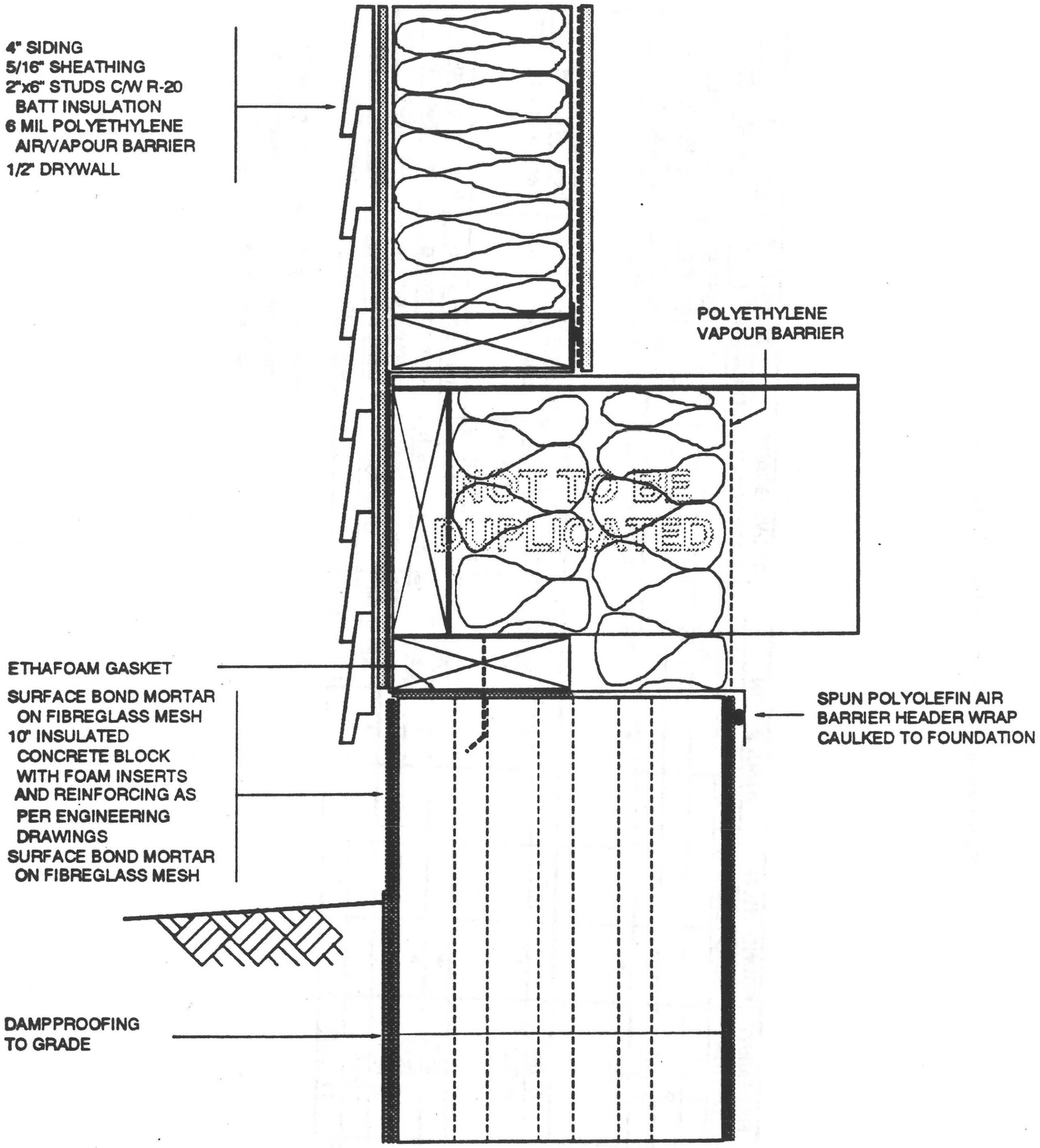
E - 6a HEADER DETAIL





A - 1 SURFACE BONDED INSULATED BLOCK WITH GEOTEXTILE
GRADE TO SLOPE AWAY FROM STRUCTURE
DAMPPROOFING TO GRADE
NATIVE BACKFILL
NOT TO BE DUPLICATED
4' BAND OF GEOTEXTILE COMPOSITE DRAINAGE LAYER SEALED AT TOP WITH 12" BAND OF WATERPROOFING MEMBRANE AND MASTIC
DAMPPROOFING BAND AT FOOTING
MIN 6" COVER OF 3/4" GRANULAR COVER FILL ON 4" DIA WEEPING TILE
LEVELED & COMPACTED BASE
LINE OF EXCAVATION
SURFACE BOND MORTAR ON FIBREGLASS MESH
10" INSULATED CONCRETE BLOCK WITH FOAM INSERTS AND REINFORCING AS PER ENGINEERING DRAWINGS
SURFACE BOND MORTAR
ACOUSTICAL SEALANT
BOND BREAK BETWEEN SLAB AND FOOTING
POURED CONCRETE FLOOR ON 4" CRUSHED STONE ON UNDISTURBED SOIL

A -1 HEADER DETAIL



Summary of Basement Design Configurations

BUILDER	BASEMENT DESIGN	FOUNDATION		INSULATION			ABOVE GRADE PROTECTION	MOISTURE HANDLING	
		CONC	BLOCK	INT	EXT	TYPE		DAMPPROOFING	DRAINAGE
MONARCH	1 (I1)	*		*		batt	n.a.	air gap membrane	air gap
MONARCH	2 (I2)	*		*		EPS I	n.a.	dampproofing	geotextile comp.
SANDBURY	3 (I3)	*		*		batt	n.a.	dampproofing	ext. glass fibre
MONARCH	4 (E1)	*			*	EPS II	polymer mod. mesh reinf. parging	dampproofing	free draining fill*
AVALON	5 (I4)		*	*		XEPS II	n.a.	hanging PVC sheet	free draining fill*
BMW	6 (E2)	*			*	XEPS III	polymer mod. chopped fibre reinf. parging	dampproofing	free draining fill*
BMW	7 (E3)	*			*	XEPS IV	cement faced	dampproofing	free draining fill*
WESTPARK	8 (E4)	*			*	glass fibre	parging/lath	dampproofing	ext. glass fibre
WESTPARK	9 (E5)	*			*	glass fibre	cement board	dampproofing	ext. glass fibre
SANDBURY	10 (E6)	*			*	XEPS III	plywood	dampproofing	geotextile comp.
IAN MALCOLM	11 (A1)		*			conc. block	n.a.	dampproofing	geotextile comp.

* may be substituted with geotextile composite or other system where native soils are not suitable

3.0 Basement Construction Phase

Each demonstration basement (excluding A- 1) was complete by early December 1991. Site visits were made at major stages of the basement construction process to document construction methods and for problem solving.

During site visits, inspection reports were maintained and photographic documentation was made. At the completion construction, builders submitted their own reports citing their experience and opinions. All of the collected information is contained in Volume II, the Construction Documentation Report.

Reviewing this information, several observations related to approaches in general were made, but specific findings were also made regarding individual basement configurations.

3.1 Interior Insulation Schemes

As the industry stands today, interior insulation schemes appear to be the most readily acceptable by builders and consumers. Materials and construction practices have been standard for many years and builders are already familiar with them. Costs tend to be less and construction sequencing makes them a more attractive option to builders than exterior systems. From a sales point of view, consumers get the added benefit of a basement which is close to finished living space quality.

On interior insulated basements, the "critical path" for house construction is not affected significantly because other construction is not dependant on framing, insulating, and finishing. These items can be done along side other tasks or whenever the required labour is on site for other work. This probably has the greatest impact on large tract builders.

Given the added work to control moisture problems, builders tended not to share a sense of urgency in addressing this issue in all houses. Many felt the problems being avoided did not justify the extra expense.

Installing a slab edge drain, such as rigid glass fibre insulation, proved to be an acceptable moisture handling measure. There is no unfamiliar work, no significant cost, and minimal additional work. However, its purpose was not well understood. Because it was not routine, it got overlooked in some cases.

Exterior moisture handling methods had varied success. The rigid glass fibre below grade did not present any problems. Detailing and application were found to be simple. The composite geotextile membranes met with more resistance. One important factor was that materials were not specifically configured for residential use. The product was only available in two and four foot wide rolls. Construction detailing and time to install could both be substantially reduced if the material was available in six or seven foot widths. Additional work is needed to see if application of material over the full wall height is even needed.

Another complication with any exterior water handling product is sloping grade, particularly on walk-out basements. Investigation of using the composite geotextile only at the base of the wall should perhaps be done in view of the fact that hydrostatic pressures are greatest at the bottom of a foundation wall. A four foot band of the material at the footing level may adequately address most moisture problems. This would also reduce the grade level finishing. In all cases, the top sealing of the drainage layer is an important aspect. The sheet applied materials appear to be easier and more successfully applied than caulking sealants.

Use of the geotextile for a weeping tile wrap was not successful. Pulling back geotextile and trimming off excess dimpled membrane proved to be tedious. One factor which complicated drainage layer installation was that typically the foundation crew had placed concrete, weeping tile and gravel in the usual routine. Subsequent installation of the drainage layer was slowed by the need to shovel gravel back off the footings and weeping tile. In practice however, drainage layer installation could probably be easily implemented into the foundation crew's job (they would install the drainage layer before placing gravel).

More complex air barrier detailing is required on interior systems than on exterior systems assuming that provision for drainage around the floor slab is provided. As many first time R-2000 builders will attest, attention to detail is required to get a continuous air barrier.

3.2 Exterior Insulation Schemes

Though technically superior, exterior insulation schemes were found to have several limitations. Type of material, construction scheduling, and cost all had impacts on builder preferences.

The availability of ledge block was a problem at the outset of the project. While they are not a new concept, their availability depends on demand, for which there is little at present. However, this problem led to some interesting solutions. Among those were concrete curb, insulating blocks, profiled bricks designed for this project, and commercially available material.

The dimensions of ledge blocks became an important issue for two reasons. Firstly, the height of the block affects brick coursing. For example, where the side wall of a house meets a front wall with a porch which has no ledge block, coursing will be a problem if the height of the ledge block is not a multiple of the height of a brick.

Secondly, ledge blocks may interfere with wall penetrations (ducts coming through the header space). It was found that depending on the dimensions of the block, a brick key which drops the masonry veneer slightly lower than the sill plate may remedy the problem.

A similar co-ordination problem to that mentioned above for installing drainage layers was typically experienced when placing insulation. Foundation crews had placed gravel on the footings, which had to be pulled back before insulation could be installed. However, it appears that this task would be delegated to the foundation crew where full height exterior insulation was standard practice.

A more significant co-ordination problem is in backfilling, which is required in two stages. Two stages are required because the above-grade insulation finishing material is applied after carpentry and masonry, but since it is applied to a foot or so below grade, additional backfill is needed. Also related to the insulation protection is the issue of damage which results from traffic during construction. Since the finish material is not applied until after the cladding is installed, insulation will likely be damaged, particularly at corners.

Application of wet applied finish materials is subject to a suitable temperature range. During cold weather, protection and warming procedures that are typically used for winter bricklaying could be used. Otherwise, winter construction is problematic. There is a delay in finishing a house because labour is required to return to the site in the spring to apply the finish coat, backfill, and landscape. Exterior insulation systems tend to lengthen the critical path, increasing the time to complete a house.

Sloping grades are complicated for any exterior applied material. Insulation will usually be stepped down as the grade falls because masonry, and thus ledge block, must be stepped. A finishing problem arises at the vertical section of stepping since ledge block cannot be applied there. The edges would likely be given the insulation finish coating, but work is made tedious and aesthetics may not be desirable.

Air barrier detailing was found to be much more simple than for interior systems. If a bond break is installed around the floor slab, only a bead of sealant there is needed. This is fast, easy, and inexpensive to do.

If a manufactured drainage layer is used, installation is more difficult than that on interior insulation systems because the material must be fastened through the insulation. Fastening a drainage layer to the insulation may not work since backfilling could cause it tear out of the insulation, so this method would not be recommended. Another method that may be worth trying is applying the drainage layer to the wall with the insulation fastened over it. However, unless the top of the drainage layer is sealed, warm air venting may occur and 'short circuit' the insulation.

3.3 Specific Notes for Each Basement

3.3.1 Basement I - 1 Air Gap Membrane

After applying dampproofing bands, the air gap membrane material was applied. The supplier installed the material, so there was no learning curve to affect the installation process. However, a number of issues came up on site which indicated that there is some disagreement as to how the material should be applied.

It was decided that since soil conditions were good (light clay) and dry, that it was not useful to demonstrate the flood boot. According to the manufacturer's representative, there is disagreement among various building departments as to how the top edge termination of the air gap membrane should be handled to be accepted as dampproofing. Two types of membrane rolls are available; one has a three inch band of flat material along the top edge and the top edge of the other one is cut through dimples. Some building departments accept the proprietary termination strip used with the latter type, whereas others require application of a sealant with the former type, and still others allow the former type unsealed. The test house, constructed in the city of Scarborough, was required to have a sealant with dampproofing from the top of the membrane to the grade level and another band at the footing level. The termination strip was used around windows where the open edge of the dimples was exposed.

Sagging from installation caused gaps at the top making sealing difficult. The sealant bead was installed only at the top edge of the membrane. At the time of inspection, the seal was broken. This method of sealing is not adequately durable and it appears that the edge of the membrane should have been well embedded into the mastic sealant during installation.

As mentioned, the product supplier installed the membrane and in this case, it resulted in an interruption of the forming crew's work such that two visits had to be co-ordinated. The delayed work was installation of gravel drain cover, window wells, and window well drains. Evidently, it would be desirable to have the forming contractor install the membrane.

Since the rigid glass fibre perimeter floor slab drain was omitted for this basement and that of I - 2, the effects of trapped moisture will need to be carefully checked.

Design Deviations

- superplasticizer added to standard residential concrete wall mix
- at exterior wall/footing joint dampproofing accumulation was relied upon in lieu of mastic
- rigid glass fibre perimeter floor slab moisture drain was omitted
- no bond break or gap was left around the perimeter of the floor slab
- taped 0.5" extruded polystyrene insulation extending across the header down to the brick key was used as an air barrier

3.3.2 Basement I - 2 Composite Geotextile Drainage Layer

Installing the composite geotextile using the methods recommended by the manufacturer proved to be problematic. The method involved horizontal placement, peeling back geotextile and meshing dimples, and fastening with concrete nails. Manufacturers of similar products suggested other means which may be better. Part of the problem also appeared to be related to lack of familiarity with the product.

The problems encountered were:

- having to shovel gravel off the footing
- the material was only available in roll widths of four feet, requiring application in two bands to achieve wall coverage (or three for a drain wrap)
- applying around corners was difficult because the material on the horizontal surface of the footing was required to stretch or buckle
- pulling back geotextile to mesh dimples
- sealing the top edge of the membrane

The process could be simplified by:

- having the foundation crew do the work (it is expected that this would normally be done) since they would better co-ordinate gravel placement
- cut separate lengths of composite geotextile for each wall (avoiding corners)
- butt rather than mesh dimples at joints and use the extra geotextile at the edges of the roll to cover any joints
- use a "peel and stick" waterproofing material to seal the top edge

It was felt that since a filter wrap over the drain was not necessary at this site that the composite geotextile would only need to extend the edge of the footing. Wrapping the fabric around the drain would have required three horizontal bands of material to cover the wall, further increasing the cost. Also, wrapping the drain would have required cutting a strip of dimpled membrane off along the entire length adding to work and wastage.

Hanging the drainage layer horizontally resulted in some sagging and thus gaps which could admit water, soil, and other material. The top edge of the composite geotextile was not sealed immediately and scaffolding, mortar droppings, brick fragments and top soil damaged or got behind the drainage layer. Caution during backfilling and final grading was required to avoid damaging the drainage layer. Due to cold weather and scheduling landscaping, the top sealing work was deferred until spring.

Problems with interior type I EPS insulation, square edged, was related to improper installation techniques. Wood strapping (2" X 3") was erected flush against the basement walls. The insulation, 3" thick, projects in front of the strapping because of wiring and wall surface irregularities. This presented a problem for drywalling so additional strapping was required.

The other problem was that studs were constructed 24" on centre (standard practice), but the insulation panels were 24" wide, so they had to trimmed to fit between the studs. The alternate installation methods would have eliminated these problems.

Design Deviations

- superplasticizer added to standard residential concrete wall mix
- at exterior wall/footing joint dampproofing accumulation was relied upon in lieu of mastic
- dampproofing was applied to the entire below-grade foundation wall surface instead of a band at grade level and footing level
- rigid glass fibre perimeter floor slab moisture drain was omitted
- no bond break or gap was left around the perimeter of the floor slab, so air sealing was not so critical
- an air barrier at the header was achieved by taping 0.5" extruded polystyrene insulation along the outside of the header

3.3.3 Basement I - 3 Insulating Drainage Layer

The 1" rigid glass fibre insulation drainage layer and rubberized sheet waterproofing membrane top sealing strip were fast and easy to install. Wall surface irregularities did not complicate insulation fastening. It appeared that a nine inch band of flashing would have worked as easily as the 12 inch band applied. The difficulty encountered with this basement involved air barrier detailing for the interior insulation, which is the conventional aspect of this design.

Using the rigid glass fibre perimeter slab drain was easily implemented. Sealing at the base of the wall was not a problem, but several conditions made a sealing very difficult at the top of the stud wall.

The header wrap was discontinuous at beam pockets, window, dryer and furnace duct penetrations. To further complicate the matter, tradesmen had not left enough header wrap material to facilitate sealing to the front face of the interior framed wood stud wall. The detail appears to be workable, but it does require some careful workmanship and proper planning. However, in this situation the builder caulked polyethylene to the top plate of the stud wall and the joist space.

3.3.4 Basement I - 4 Hanging Exterior PVC Sheet

Application of mastic sealant at the exterior footing/wall joint was hindered by a cool ambient temperature; the mastic material was not workable. Application was done later on a warmer day.

The main difficulty found with the PVC dampproofing material was that it was labour intensive. Workers were required to help unroll the material, hold it in place, and fasten it to the wall. It was thought that using a fastening gun would facilitate more rapid installation.

Particular attention had to be paid to backfilling to avoid damaging the PVC. The builder indicated that no problems were encountered, but had a tear occurred the damaged area would have needed patching. The material was 18mil PVC and it appeared to be reasonably durable. The backfill was placed in short lifts between compaction to minimize drag on the membrane.

Alternate air barrier detailing was required to deal with an alteration in the construction of the interior wall. As a result of available labour, a stud wall was constructed before the floor slab. The as-built detail has 2" of extruded polystyrene set on the footing with polyethylene and the 2" X 3" stud wall for interior insulation on top. The resulting gap around the perimeter of the slab provides the potential for significant air leakage. Air sealing the drywall, rather than the polyethylene, was the solution implemented. The insulation provided was profiled for use with wood nailing straps which would have made installation faster and cheaper, but the material was trimmed to fit between existing studs.

Design Deviations

- construction of the interior stud wall at the floor slab was altered such that it is not clear how well trapped moisture can be drained
- conventional electrical outlet boxes were installed in lieu of air/vapour seal plastic boxes
- the flashing recommended by the manufacturer to be put over the PVC securement strip was not installed, but is not expected to be problematic

3.3.5 Basement E - 1 Exterior EPS Type II with Polymer Modified Mesh Reinforced Parging

Poured concrete foundation wall finish had only minor forming fins and other surface irregularities, so the rigid type II expanded polystyrene insulation could be aligned reasonably well. In lieu of mechanical fasteners, gravel and fill material were relied upon to hold insulation in place. This method worked satisfactorily and alignment after full backfilling was good. Shiplapped insulation would probably have made installation easier as well as provided better moisture draining characteristics.

One difficulty encountered during the construction of the above-grade portion of the insulation was that abuse during construction resulted in damage to the top of the insulation, particularly at corners. These damaged areas needed to be repaired before the finish coating was applied.

Cold weather led the builder to postpone applying the insulation coating until spring. This had implications related to risk of insulation damage and delayed job completion. Weather protection and heaters could have been used alternatively.

The ledge cap selected was a pre-cast concrete curb with an attractive and practical smooth finish. Although it does not have a drip edge, its has bevelled profile. The cap is non-insulating, so there is a thermal bridge at this location.

The block is available in three foot lengths and joints were mortared. Durability of these joints may be questionable given the length of the blocks. Perhaps caulking will be required should the joints crack. The length of the blocks slightly exceeds the O.B.C. required spacing for weep holes. In this case, flashing was installed under the ledge cap while Code weep holes were installed in the brick veneer, where they are not really needed.

The builder found that close attention to the alignment of the ledge cap was required of the mason to allow for subsequent finish coating. It was desirable to have the cap project slightly past the coating surface and that this be consistently done in the interest of aesthetics. Difficulty in detailing at a cantilevered bay window was encountered since the ledge cap rested too high to pass beneath the floor.

A minor problem encountered involved rain water leaders, which are required by the City of Scarborough (the municipality in which the house is situated). The exterior insulation projection necessitated additional downspout elbows which also has impact on aesthetics.

Design Deviations

- superplasticizer added to standard residential concrete wall mix
- weeping tile filter wrap was not installed because it was not the builder's standard practice
- at exterior wall/footing joint dampproofing accumulation was relied upon in lieu of mastic
- no bond break between the floor slab and the foundation wall was provided

3.3.6 Basement E - 2 Extruded Polystyrene with Polymer Modified Chopped Fibre Reinforced Parging

Since no brick key was used at the top of the foundation wall, duct penetrations coming through the header interfered with the ledge block; the outside grilles would not fit above the ledge block. The builder extended the ducts out past the ledge block and installed a custom metal hood.

A custom ledge block was manufactured for this job, but the drip edge was cast into it too close to the edge such that it appears rough. The insulation finish coating was quick and easy to apply, but it appears that it was difficult to build a thick enough layer in one coat. The problem may have resulted from poor workability considering the cool ambient temperature during application. However, leaving the work until spring would have left the insulation prone to damage from landscaping work or other traffic.

Design Deviations

- filter cloth wrap on weeping tile was omitted in view of the native backfill

3.3.7 Basement E - 3 Prefinished Polystyrene Insulation Panel

Surface irregularities on the foundation walls and footing resulting from rough forming made fitting and installing the rigid polystyrene panels difficult. Mastic adhesive was used as temporary fastening, but it was not effective, possibly in part due to stresses caused by trying fit the panels tight to the wall over projections. Concrete screws and nails were subsequently used. Temporary fastening may not always be necessary, but in this case, wind tended to blow the panels down. Shiplapped insulation (which is available) would likely have made the task easier.

Since the cement-faced panels were to be installed on the above-grade portion of the foundation walls, the standard sized below-grade polystyrene panels had to be trimmed more than normal. This requirement resulted in considerable waste. In addition, the horizontal joint where plain insulation panels meet cement-faced panels required polyurethane foaming. A smooth substrate surface is particularly important with the above-grade cement-faced insulation panels since panel faces which are not flush will be readily noticeable.

Installing the finished panel above-grade foundation material required planning at the outset to optimize jointing and fastening. Despite this, a lot of cutting and fitting was done. Bays and windows were particularly difficult. Cut edge panels called for surface fastening, but in some instances fastener heads punched through. Requirement for flashings necessitated custom sheet metal work. The same problems with duct penetrations as found on E - 2 were encountered on this basement.

3.3.8 Basement E - 4 Rigid Glass Fibre with Cement Parging on Lath

This building had an attached garage which caused detailing problems ensuring continuous coverage at the garage floor slab level and at intersecting walls. This issue was dealt with on this house by installing insulation around the perimeter of the heated space and the cold storage. This configuration left two thermal bridges where the garage foundation walls intersect the house basement walls.

It does not seem to be appropriate to insulate the outside of the cold storage in light of the fact that it will be vented. Exterior insulation placement raises the potential for errors as to where insulation should be placed with respect to garages and cold storage spaces.

While fastening the metal lath into the concrete through the 3" rigid glass fibre several screw heads were sheared off despite predrilling. As a result, nails were found to be preferable.

Parging on metal lath was carried out before the ledge block was installed because of a delay in receiving the block. Placing the block after parging provided potential for damaging the parging, so care was necessary. Any damage could be easily patched however.

Design Deviations

- mastic at exterior footing/wall joint omitted; dampproofing used instead
- bond break and sealant excluded at interior footing/wall joint
- brick veneer flashed over ledge cap instead of under it

3.3.9 Basement E - 5 Rigid Glass Fibre with Cement Board

On this house, the builder handled the issue of insulation placement by terminating exterior insulation where the garage walls begin (two complete adjacent garage walls are common with the house). Insulation was then applied to the two common walls on the inside of the basement. However, there is still some degree of thermal bridging.

Wood-fibre cement board was applied to the above-grade portion of the exterior insulation. Concrete fasteners were used to fasten the material, but they were countersunk in attempt keep the fastener heads flush with face of the board. After being dampened, it was found that fastener heads pulled through the countersink holes.

Since the cement board was being placed over a flexible and compressible substrate (ie. 3" glass fibre), panels tended to bow since the boards were pulled in more tightly where fastened. Care was needed to prevent this from happening). Although drilled-in concrete nails were used, bow could be controlled better by using screws since they could be backed off where necessary.

Alignment was also a consideration. The builder felt that both alignment and bowing could be more easily addressed by the use of trim mouldings with channels into which boards could be inserted. Fastener holes could also be covered.

Since the insulation acts as a drainage layer, sealed panel joints are not necessary, but aesthetics becomes an issue. Outside corners are of greatest concern. In this installation, they were rounded to improve appearance and durability.

Design Deviations

- mastic at exterior footing/wall joint omitted; dampproofing used instead
- bond break and sealant excluded at interior footing/wall joint
- brick veneer flashed over ledge cap instead of under it

3.3.10 Basement E - 6 Extruded Polystyrene Type III Insulation with Treated Plywood

During the extruded polystyrene type III insulation installation, typical surface irregularities complicated installation, but the end result appeared to be good. On the siding walls, insulation was trimmed to 1.5" above the foundation wall to act as a thermal break at the sill plate. The extended insulation is therefore prone to damage while the carpenters are constructing the floor.

In situ soils were clay and since better draining materials appeared to be required, a composite geotextile was employed. The foundation contractor recommended against wrapping the weeping tile with filter cloth for fear it would clog. Therefore, the fabric from the drainage layer was just draped over the edge of the footing instead of wrapped around the drain. Two bands of material were required on the siding walls (one four foot and one two foot wide band) which made installation lengthy. The builder concluded that fastening the membrane through the insulation was much more difficult than fastening it to a bare wall would have been.

Because of the two different header details, one for the brick facade and one for the three siding facades, construction sequencing was complicated. On the siding facades, the pressure treated plywood, serving as above-grade insulation protection, extends to the top of the header so it could not be installed until after floor framing and therefore, rough backfilling. On the brick facade, it was prudent to install the plywood before backfilling and framing so that the insulation would be protected during subsequent construction.

One detailing problem did arise on the brick facade however. Since the plywood was to be terminated at the top of the foundation, the same four by eight foot plywood sheets extended further below grade than on the siding walls. Only a single band of composite geotextile was needed, but it was six inches short of the plywood. To cover this gap, the builder chose to fasten an eight inch wide strip of plywood over top of the drainage layer and upper plywood. This strip was not sealed, but it was tightly fastened.

The bottom of the header wrap, which was to be sealed to the top of the foundation wall, was too short in some locations which resulted in some air sealing difficulties.

Applying the plywood to outside corners was difficult to do well. Careful work was required to get a tightly fitting joint, but this was made harder by irregularity of the substrates. In some cases, additional strips of plywood were fastened at the corner as reinforcement.

While the builder found that the pressure treated plywood was expensive and not normally stocked by his usual supplier, it enabled him to give his customer a finish option. The plywood could be finished in several ways including paint or conventional parging. Combining two cladding types with exterior insulation tended to be disadvantageous both in terms of aesthetics and construction sequencing.

Design Deviations

- a filter cloth was not used at the footing

3.3.11 Basement A-1 (Extra) Surface Bonded Insulated Block

The block work for this system is unlike conventional block. Masonry units are dry laid and surface bonding mortar is applied to both interior and exterior surfaces for structural strength. It should be noted that some aspects of the demonstration of this basement should not be directly compared to the other demonstration basements because of differing test conditions. Construction was hampered by the cold and wet conditions of the winter months.

It appeared that the time required to erect a full height foundation using the surface bonded insulated blocks is similar to cast-in-place and block foundations. Under normal conditions, an insulated block wall can be constructed within four to five days. Standard masonry construction skills appeared to be adequate for this system.

Like any concrete or masonry work, the parging required on this insulated block system requires weather protection and heating during freezing temperatures. However, the field inspections suggest that there is reduced chance of leaks due to the reinforced parging on both sides of the wall. Also, there is no need for interior finishes as for interior insulation schemes, less care required in backfilling as for exterior insulation schemes, and simplified leak investigation since no wall insulation would need to be removed.

Several leakproofing systems were applied to the foundation. Cold temperatures required that walls receiving waterproofing material be primed with an adhesive type primer. Application of "peel and stick" waterproofing membrane appeared to be easy and foolproof. Waterproofing materials appeared to have some advantages in that they are more durable than the various drainage layers or dampproofing materials.

The top edge of the composite geotextile was sealed with mastic. Undulations of the horizontally applied composite geotextile made sealing the top edge difficult. It appeared that cold temperatures may have made the polyethylene membrane stiff to work with. The material developed several kinks as a result of its stiffness. Rolling the material out in advance may have reduced this problem. Also, applying a "peel and stick" membrane as a top seal would have simplified construction.

Backfill contained fine material of a sandy nature. In all likelihood, it may have been possible to avoid using a drainage layer, but a drainage layer was used to facilitate comparisons with other systems. To avoid dragging down the composite geotextile, backfill was carefully brought up to the wall at an angle rather than perpendicularly.

4.0 Soak Test

In the spring of 1992, a soak test was done on all houses in the demonstration to verify that the designs performed adequately with respect to leakage.

Springtime testing was considered appropriate for several reasons. Firstly, any settlement which was going to occur would have been well under way. Also, the foundations had approximately six months to dry so the initial moisture from construction had dissipated somewhat (and drying and shrinkage had occurred). Finally, normal soil conditions during the spring are wet so a soak test at this time of year is easier to achieve.

Consistent with the nature of the project, the soak test was intended to be a demonstration and so positive results do not represent a guarantee that no leakage will occur in the houses tested. However, for comparison purposes, consistent test methods were used from one house to the next. For each basement, a soaker hose was to be operated next to the foundation wall for a minimum of 24 hours. The hose was to be placed such that water would contact the header area and the interface between the foundation wall and the backfill to simulate a driving rain. Interior and exterior basement finishes were inspected 24 to 48 hours following the soaking to check for any moisture problems.

Notes were also made on the condition and completeness of each of the demonstration basements. Soak test inspection reports appear in the appendix.

4.1 Soak Test Results

Typically, the soaker hose was placed on one or two walls of each house. Inspections on all exposed interior and exterior basement components revealed no signs of leaks, moisture stains, or surface dampness. Three basement demonstrations require specific explanation and will be discussed below. Based on this, the basement configurations demonstrated appeared to adequately handle wet soil conditions, similar to those of a rapid spring thaw or prolonged heavy rainfall.

4.2 Basement I - 2 Composite Geotextile Drainage Layer

This system required a seal at the top edge of the composite geotextile to prevent ingress of moisture and particles behind the membrane. The basement was first tested with the top seal installation incomplete such that abundant water was directed behind the membrane. This resulted in a minor leak.

More importantly, the basement was retested with the top seal complete and no leak or moisture was evident. This served to point out the necessity of proper top sealing. In cases where water is accumulating at a high rate, any water getting behind the membrane may increase the potential for leaking.

Most construction methods used for interior schemes are presently more familiar, but moisture handling and air barrier detailing are much more important and they can also be problematic. Clearly, the products which are currently available can pose a significant number of detailing problems if builders are not familiar with them. More foolproof methods and materials are needed.

Each of the demonstrated exterior basement wall drainage methods were successful in averting leaks and dampness. However, the soak test pointed out the need for attention to detail and material use. For example, ledge blocks that shed water well rather than absorbing it must be used. Below grade, on systems where exterior polystyrene is used, moisture problems may still be encountered in the absence of quality backfill or other drainage layer material.

There is a need to check for weak spots in the as-built basements prior to backfilling. Incomplete window detailing or breaks in the insulation or drainage layer may easily occur in practice and moisture can gravitate toward these locations. A better understanding of moisture problems and materials applications is required.

The costs varied from roughly $2500 to $3300 for interior insulation schemes with moisture handling aspects and from $2300 to $5000 for exterior insulation systems with moisture handling aspects. While the houses were all in the mid-size range, they did vary in size, and finished grade levels relative to the foundations also varied; this would have some affect on cost comparisons. The upper cost limits are reached when using products that are not specifically configured for residential FHBI application resulting in inflated labour costs required for site modification and detailing. Some of the products tried out in the study fall into this category. Ideally, more ready-to-use products will be developed and their cost will match the low and mid range figures.

It must also be noted that the costs in the ranges given are not necessarily representative of actual costs on a production basis because of:

- donated materials (costs are rough estimates only)
- the "one of" nature of the demonstration basements
- lack of experience working with unfamiliar materials in some cases
- sourcing problems for some materials

6.0 Recommendations

Clearly, if Code requirements are going to include FHBI, there will be a "learning curve" as builders try to adapt to the new requirements. The technical advantages of insulating basements on the exterior to some extent seems mitigated by additional detailing problems and lack of available products to address the header area thermal bridge.

On the basis of this experience, any resistance to a requirement for FHBI will be increased by a requirement for moisture handling systems, particularly when viewed as a method of ensuring that everyone implements a moisture control method. This may be seen as an undue penalty for those currently using adequate construction practices and for those building sites where moisture is unlikely to be a problem. However, the higher standard of construction, assuming that proper training and materials are available, could probably reduce the incidence of moisture related basement problems to about one in ten overall, considering that nothing is completely foolproof.

Some technical problems appear easy to address with low cost, innovative solutions. Specifically, condensation on outside walls behind an internally insulated system can be addressed by means of a perimeter drainage gap cast into the floor slab. This necessitates however, attention to detail on the interior polyethylene (and header wraps) as this will form the air barrier. Experience from this and other projects suggests that conventional builder practices (ie. non-R-2000) still have significant difficulty in getting trades who are familiar with the construction requirement of a continuous air barrier.

Therefore, it would seem prudent to accompany any Building Code change of the nature of FHBI or moisture handling with a comprehensive training program.

In view of the fact that the Code has not historically required FHBI and moisture handling measures, authorities should consider assisting the manufacturers to develop products which solve known technical problems and can be smoothly integrated into the residential construction industry should these changes come about.