RESEARCH REPORT

Renovation Strategies for Brick Veneer Steel Stud Wall Construction: Task 3 Some Performance Considerations

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RENOVATION STRATEGIES FOR BRICK VENEER STEEL STUD WALL CONSTRUCTION - TASK 3

Some Performance Considerations

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Part IX

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Executive Summary

Background

Many buildings with brick-veneer, steel-stud enclosure walls have experienced or are experiencing problems. Most of the problems are due to moisture from a variety sources such as rain penetration or air leakage. Repair is expensive and there is considerable uncertainty as to the level and extent of deterioration and damage, especially the potential for corrosion of metal components. Tie deterioration is one consequence, not necessarily the only consequence, and any remedial work must address the cause as well as the consequences of a moisture related problem. In many existing BV/SS wall systems, the condition and the effectiveness of the lateral ties connecting brickwork and steel studs are of concern.

Because of the importance of the long-term performance of the lateral attachment between the brick veneer and the steel stud backup, a comprehensive research, development and demonstration program was initiated. With funding and input from CMHC, an extensive program of work was undertaken to develop various strategies for the remediation and, thus, the control or avoidance of problems involving the lateral ties in existing BV/SS wall systems. The five related tasks are as follows:

Task 1: Brick Ties - Options for Remediation

Task 2: Four Remedial Tie Systems--Development and Conformance Testing

Task 3: Some Performance Considerations

Task 4: Dinal Remedial Tie System

Task 5: Summary Report

Objectives

The main objective of Task 3 was to identify and assess the likely performance of the BV/SS wall system after the lateral ties had been remediated. Presumably it was cost effective to provide either full or partial replacement of the existing ties. Furthermore trade-offs are necessary. Any remedial solution must improve the situation; structural integrity and durability should not be impaired.

This Task 3 report documents the likely performance of BV/SS walls after tie remediation with particular regard to thermal bridging, installation damage, drainage, corrosion and torsional stiffness of the steel studs. Since any remedial tie will penetrate the cavity, various layers of material, some of the thermal insulation and the stud space, it was also necessary to address specific issues such as air leakage, water penetration and the potential for the use of cavity fillers .

The work on this Task 3 project was carried out at the same time as Task 4. Some laboratory testing was conducted but the major effort involved reviewing the literature, soliciting industry input, analysis, and consulting with knowledgeable individuals both in private practice as well R and D organizations.

The major conclusions and recommendations may be categorized as follows:

Thermal Considerations

The relative effect of different tie systems and the overall effect of remedial ties on heating energy costs are small; probably less than 2 per cent variation. The most important thermal consequence is the additional thermal bridging provided by the new ties. It was confirmed that the heavier or thicker the tie the more significant the thermal bridge.

As is the case for the existing ties as well as the remedial ties, the potential for a serious moisture related problem exists in those BV/SS walls with all the thermal insulation within the stud space. In which case it is likely that tie remediation is neither a sufficient nor a suitable solution.

Compared with an exterior fix, an interior fix causes the temperature of the tie within the stud space to be warmer. Accordingly, an interior fix may be preferred to an exterior fix insofar as thermal bridging is concerned.

It is clearly a relative disadvantage to only have thermal insulation in the stud space. Control of moisture is less of an issue when the temperature within the stud space is high and stable. Therefore, in order to keep the temperature of the stud and stud space above a dew point, the wall system should incorporate a thermal break between the stud and the air cavity.

Installation Considerations

Most of the problems with BV/SS as well as other wall assemblies are due to moisture penetrating the wall from different sources such as air leakage or rain penetration. The corroded ties are the result, not the cause of the wall problem. When considering retrofitting, the work should not be done in isolation but as part of an overall project of airtightening the building envelope which was the cause of the problem in the first place. Retrofit ties for an interior fix will penetrate the air barrier of a BV/SS wall if this air barrier is located near the interior face. Air leakage is highly undesirable and it is strongly recommended that at all remedial tie locations this air barrier be resealed. It follows that the remediated wall must incorporate a continuous and effective air barrier

For BV/SS walls with an air barrier at the interior face, it is unlikely that an exterior fix with retrofit ties will affect this air barrier. However installation induced damage may affect the barrier to inward water movement to the inner back-up portion of the wall--this is especially a concern with the Helifix remedial tie.

The *Helifix* tie has an impact on air leakage that is an order of magnitude larger than the other ties. Blok Lok Ltd. should devise other methods of reducing the impact that the installation of *Helifix* ties will have on the existing BV/SS wall.

Drainage Considerations

It is unlikely that the presence of the remedial ties will worsen the overall drainage capability of the wall. If rain water penetration is excessive, every measure should be taken to reduce the amount by, for example, repointing.

Even though the *Helifix* tie contains a series of natural drips, the installer should ensure that the tie does not have an excessive slope downward to the interior; otherwise, water might travel across the cavity.

In the case of the *Dur-O-Wal* interior fix, care should be taken to seal the hole in the exterior sheathing with epoxy so that water cannot penetrate. In order to facilitate proper sealing, the retrofit tie installer should also keep the diameter of the drilled hole to a minimum. The plastic bushing, in the case of the *Dur-O-Wal threaded bolt and expansion anchor*, should prevent water from traveling across the tie to the interior. A neoprene drip could be added to the rod of the *Dinal* tie at the cavity location in order to divert water down into the cavity.

Corrosion

When masonry ties are attached by means of self tapping screws to the framing, the galvanized coating of the steel studs is damaged, leaving the underlying steel unprotected from moisture and corrosion. As most tie systems rely heavily on a tight interface connection, any corrosion of the steel stud at this interface will reduce the strength of the tie. Of the five tie systems tested the Dinal tie is the least affected by interfacial corrosion.

A two flange connection (an interior fix) has some built-in reserve against corrosion. If the connection at one flange should corrode and fail, then resistance is still available from the connection at the other flange.

The *Dur-O-Wal threaded bolt and expansion anchor* will be more vulnerable to corrosion at the tie/flange interface compared to the ties made solely of stainless steel, because the tie itself consists of dissimilar metals.

Galvanized steel ties do not satisfy the Level III requirements of the CSA-CAN3-A370 Standard.

Torsional Stiffening Considerations

If the torsional resistance of the steel studs is, for some reason, inadequate the installation of retrofit ties offers an opportunity to provide some torsional restraint. This method of torsional stiffening will be quicker and much less expensive than opening up the wall and installing lateral steel bridging and repairing top and bottom connections.

An interior fix will provide more torsional restraint to the steel stud than the use of an exterior fix.

The issue of torsional stiffening needs additional research and development. Both analytical work and physical experimentation is needed.

Cavity Fill

At this time we doubt whether many BV/SS systems are well suited to the use of a cavity filler (either a cementitious or an insulating material) largely because of the lack of a suitable sheathing at the outside of the steel stud framing.

Comment

This Task has been of value because a number of issues, some of them new, have been identified and to some extent quantified. The potential for torsional stiffening or bridging remediation by means of new ties is certainly important. The assessment of installation damage and the possible consequences for post-remediation performance is also of value. Also it needs to be stressed that tie remediation implies improvement and it follows that serious consideration must be given to the use of stainless steel in most, if not all, cases where tie remediation is required. Finally it must not be forgotten that, if full or partial repair of the existing ties is carried out, it constitutes only one step in the overall remediation of an existing BV/SS wall.

Résumé

Contexte

De nombreux bâtiments comportant des murs à ossature d'acier et placage de brique ont connu ou connaissent des problèmes dont la plupart sont attribuables à l'humidité provenant de l'infiltration d'eau de pluie ou de fuites d'air. Non seulement les réparations se révèlent-elles coûteuses, mais on ne peut pas établir avec certitude l'ampleur de la détérioration et des dommages, en particulier de la corrosion des composants métalliques. La détérioration des attaches en est une conséquence, mais pas nécessairement la seule, si bien que tous les travaux de réhabilitation doivent s'attaquer à la cause aussi bien qu'aux conséquences des méfaits de l'humidité. Dans de nombreux systèmes de murs existants à ossature d'acier et placage de brique, l'état et l'efficacité des attaches latérales raccordant la brique aux poteaux d'acier constituent un motif de préoccupation.

En raison de l'importance de la performance à long terme du raccordement latéral du placage de brique au mur de fond à ossature d'acier, un programme d'envergure de recherche, de développement et de démonstration a été lancé. Grâce au financement et à l'apport de la SCHL, un programme étendu de travaux a été entrepris dans le but d'élaborer différentes stratégies de réhabilitation et, par conséquent, de contrôler ou d'éviter la manifestation de problèmes dans de tels murs. Les cinq tâches connexes s'énoncent comme suit :

Tâche 1 : Attaches de la brique - Options de réhabilitation
Tâche 2 : Quatre systèmes d'attaches - Élaboration et essais de conformité
Tâche 3 : Aspects de la performance
Tâche 4 : Système d'attache Dinal
Tâche 5 : Rapport sommaire

Objectifs

Le principal objectif de la Tâche 3 consistait à désigner et à évaluer la performance probable du système de mur à ossature d'acier et placage de brique après la consolidation des attaches latérales. Il se révélait présumément efficient de prévoir le remplacement intégral ou partiel des attaches en place. De plus, des mesures de compromis s'imposaient. Toute solution devait améliorer la situation, sans pour autant compromettre la solidité structurale et la durabilité.

Le rapport de la Tâche 3 fait état de la performance probable de murs à ossature d'acier et placage de brique après la consolidation des attaches, en mettant un accent particulier sur les ponts thermiques, les dommages lors de la pose, le drainage, la corrosion et la résistance à la torsion des poteaux d'acier. Puisque toute attache de réhabilitation pénètre la cavité, différentes couches de matériaux, une partie de l'isolant thermique et les espaces entre les poteaux, il a aussi fallu régler des questions précises concernant notamment l'étanchéité à l'air, l'infiltration d'eau et la possibilité d'avoir recours à des obturateurs de cavité.

Les travaux de recherche portant sur la Tâche 3 ont été exécutés en même temps que la Tâche 4. Des essais en laboratoire ont été menés, mais le plus clair du travail consistait à revoir la documentation, à solliciter les points de vue de l'industrie, à se livrer à de l'analyse et à consulter des gens avertis autant du secteur privé que des organismes de recherche et de développement.

Les principales conclusions et recommandations peuvent se répartir comme suit :

Aspect thermique

L'effet respectif de différents systèmes d'attaches et l'incidence générale des attaches de réhabilitation sur les frais d'énergie de chauffage sont faibles, correspondant probablement à un écart de 2 %. La conséquence thermique la plus importante réside dans les ponts thermiques supplémentaires qu'occasionnent la pose des nouvelles attaches. Les essais confirment que l'importance du pont thermique est directement fonction du poids ou de l'épaisseur de l'attache.

Comme c'est le cas autant pour les attaches existantes que pour les attaches de consolidation, le risque de sérieux problèmes d'humidité existe dans les murs à ossature d'acier et placage de brique avec tout l'isolant thermique présent dans les espaces entre les poteaux. En pareil cas, il est probable que la réhabilitation des attaches ne constitue une solution ni suffisante ni convenable.

Comparativement à la pose par l'extérieur, la pose par l'intérieur a pour effet d'élever la température de l'attache dans les espaces entre les poteaux. En conséquence, la pose par l'intérieur est préférable à la pose par l'extérieur pour ce qui est des ponts thermiques.

Mettre en oeuvre de l'isolant thermique uniquement dans les espaces entre les poteaux constitue manifestement un désavantage relatif. Le contrôle de l'humidité porte moins à conséquence lorsque la température dans les espaces entre les poteaux est élevée et stable. Par conséquent, dans le but de maintenir la température des poteaux et des espaces entre eux au-dessus du point de rosée, le système de mur doit compter sur une coupure thermique intercalée entre les poteaux et la lame d'air.

Pose

La plupart des problèmes que connaissent les murs à ossature d'acier et placage de brique de même que les autres murs sont imputables à la présence d'humidité s'expliquant par les fuites d'air ou la pénétration d'eau de pluie. La corrosion des attaches en est le résultat, non la cause. Au moment d'envisager la réhabilitation, les travaux ne doivent pas s'effectuer isolément, mais bien s'inscrire dans un projet global d'étanchéité à l'air de l'enveloppe du bâtiment où se situe l'origine du problème. Les attaches de consolidation se posant de l'intérieur traversent le pare-air du mur à ossature d'acier et placage de brique s'il se trouve près de la face intérieure. Les fuites d'air sont vraiment à éviter, de sorte qu'il est fortement conseillé de resceller tous les endroits des attaches de consolidation. Il s'ensuit que le mur réhabilité doit incorporer une pare-air continu et efficace.

Quant aux murs à ossature d'acier et placage de brique avec pare-air disposé côté intérieur, il est peu probable que la pose d'attaches de l'extérieur lui nuise. Par contre, les dommages causés par la pose risquent de nuire au pare-vapeur en repoussant le mouvement d'eau vers le fond du mur, situation particulière que pourraient occasionner les attaches de consolidation Helifix.

L'attache Helifix influe sur l'étanchéité à l'air par un ordre de grandeur supérieur aux autres attaches. Blok Lok Ltd. devra concevoir d'autres méthodes en vue d'atténuer l'incidence que la pose des attaches Helifix exerce sur un mur à ossature d'acier et placage de brique.

Drainage

Il est peu probable que la présence des attaches de consolidation empire le drainage général du mur. S'il s'introduit de l'eau de pluie de façon excessive, tout devra être mis en oeuvre pour réduire l'infiltration en procédant, par exemple, au rejointoiement.

Même si l'attache Helifix comporte une série de larmiers naturels, le poseur doit veiller à ne pas lui imprimer une pente trop prononcée vers l'intérieur, sinon l'eau risquerait de traverser la cavité.

Quant aux attaches Dur-O-Wal se posant de l'intérieur, il faut prendre soin d'obturer le trou pratiqué dans le revêtement intermédiaire au moyen d'époxy pour éviter toute infiltration d'eau. Pour en faciliter le scellement, le poseur doit réduire au minimum le diamètre du trou foré. Dans le cas du boulon fileté et de la coquille d'expansion Dur-O-Wal, la bague plastique doit empêcher l'eau de cheminer le long de l'attache jusqu'à l'intérieur. Il suffit s'ajouter un larmier de néoprène à la tige de l'attache Dinal à l'endroit de la cavité pour acheminer l'eau au bas de la cavité.

Corrosion

Lorsque les attaches de la maçonnerie sont fixées à l'ossature à l'aide de vis autotaraudeuses, le revêtement galvanisé des poteaux d'acier est endommagé, laissant l'acier sous-jacent sans protection contre l'humidité et la corrosion. Comme la plupart des systèmes d'attaches comptent fortement sur un raccordement serré, toute corrosion du poteau d'acier à cet endroit amoindrira la résistance de l'attache. Parmi les cinq attaches testées, l'attache Dinal est la moins touchée par la corrosion.

Le raccordement des deux ailes (pose de l'intérieur) incorpore une marge de protection contre la corrosion. Si le raccordement à une aile finissait par se corroder et défaillir, le raccordement à l'autre aile offrirait toujours de la résistance.

Le boulon fileté et la coquille d'expansion Dur-O-Wal offrent moins de résistance à la corrosion à l'interface attache-aile comparativement aux attaches fabriquées exclusivement d'acier inoxydable, étant donné que l'attache proprement dite se compose de métaux dissemblables.

Les attaches en acier galvanisé ne satisfont pas aux exigences du Niveau III de la norme CSA-CAN3-A370.

Résistance à la torsion

Si, pour quelque raison que ce soit, la résistance à la torsion des poteaux d'acier ne suffit pas, la pose d'attaches de consolidation permet quelque peu de faire obstacle à la torsion. Cette façon de procéder s'exécute plus rapidement et coûte meilleur marché qu'éventrer le mur pour le pourvoir d'entretoises en acier et réparer les raccordements supérieurs et inférieurs.

La pose de l'intérieur confère aux poteaux d'acier une meilleure résistance à la torsion que la pose depuis l'extérieur.

La question de la résistance à la torsion mérite davantage de recherche et de développement. Il faut approfondir à la fois les travaux analytiques et expérimentaux.

Remplissage de la cavité

À ce stade-ci, nous doutons que de nombreux systèmes de mur à ossature d'acier et placage de brique se prêtent bien à l'utilisation d'un produit de remplissage de la cavité (matériau cimentaire ou isolant) en l'absence surtout d'un revêtement intermédiaire convenable sur l'extérieur de l'ossature d'acier.

Observations

Cette tâche s'est révélée utile puisqu'elle a permis de relever des aspects, dont certains nouveaux, et de les quantifier dans une certaine mesure. Les possibilités de résistance à la torsion ou de réhabilitation des entretoises qu'offre la pose de nouvelles attaches revêtent assurément de l'importance. L'évaluation des dommages occasionnés lors de la pose et les conséquences possibles de la performance après coup s'avèrent également utiles. Il faut faire ressortir que la réhabilitation des attaches suppose une amélioration et il s'ensuit qu'il faut sérieusement envisager l'usage d'acier inoxydable dans la plupart sinon tous les cas où la consolidation des attaches s'impose. Finalement, il ne faut se rappeler que le remplacement complet ou partiel des attaches ne constitue qu'une étape de la réhabilitation générale d'un mur à ossature d'acier et placage de brique.

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Acknowledgments

This report represents the deliverable for the third task in an extensive R&D project to investigate strategies for the remediation of existing Brick Veneer/Steel Stud enclosure wall systems. The project was initiated and funded by Canada Mortgage and Housing Corporation (CMHC). We would like to thank Mr. Jacques Rousseau of CMHC who was responsible for managing this unique project; unique in that it required the collaboration of government, a university, a number of consultants, and numerous companies involved in the brick masonry business.

We would also like to thank the tie manufacturers/distributors for supplying us with their brick ties and special installation equipment. In particular the following people gave freely of their time and assistance.

Mr. Ken Crooks	Dur-O-Wal Limited
Mr. Pat Sweeney	Blok Lok Limited
Ms. Ellen Hall	Dinal Incorporated

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1. Introduction

1.1 Background

Over the years, the performance of clay brick veneer /steel stud (BV/SS) enclosure systems (Figure 1.1) for multi-storey residential buildings has received a great deal of attention. Many buildings of BV/SS construction have experienced or are experiencing problems. Most of the problems are due to moisture from a variety sources such as rain penetration or air leakage. Repair is expensive and there is considerable uncertainty as to the level and extent of deterioration and damage, especially the corrosion of metal components (i.e., the ties, the stud system and self-tapping screws). Tie deterioration is one consequence, not necessarily the only consequence, and any remedial work must address the cause as well as the consequences of a moisture related problem. Therefore, it may be difficult to decide on the form and extent of remedial action. If legal action is involved, there is considerable pressure to prescribe a conservative, and thus relatively expensive solution. There is also the question of knowing what to do about those BV/SS walls that have yet to exhibit a visible problem but are known to be vulnerable and likely to experience problems.

In many existing BV/SS wall systems, the condition and influence of the lateral ties between brickwork and steel studs are of primary concern. In practice, one or more of the following have occurred:

- ties have been omitted or incorrectly spaced,
- the wrong type of tie has been used,
- the tie is corroding or likely to corrode and/or
- the tie has been incorrectly installed.

Because of the importance of the long-term performance of lateral attachment between the brick veneer and the steel stud backup, a comprehensive research, development and demonstration program was developed. With funding and input from CMHC, an extensive program was initiated to develop various strategies for the remediation and, thus, the control or avoidance of problems in existing BV/SS wall systems. A number of tasks were formulated:

Task 1: Brick Ties - Options for Remediation
Task 2: Four Remedial Tie Systems--Development and Conformance Testing
Task 3: Some Performance Considerations
Task 4: Dinal Remedial Tie System
Task 5: Summary Report

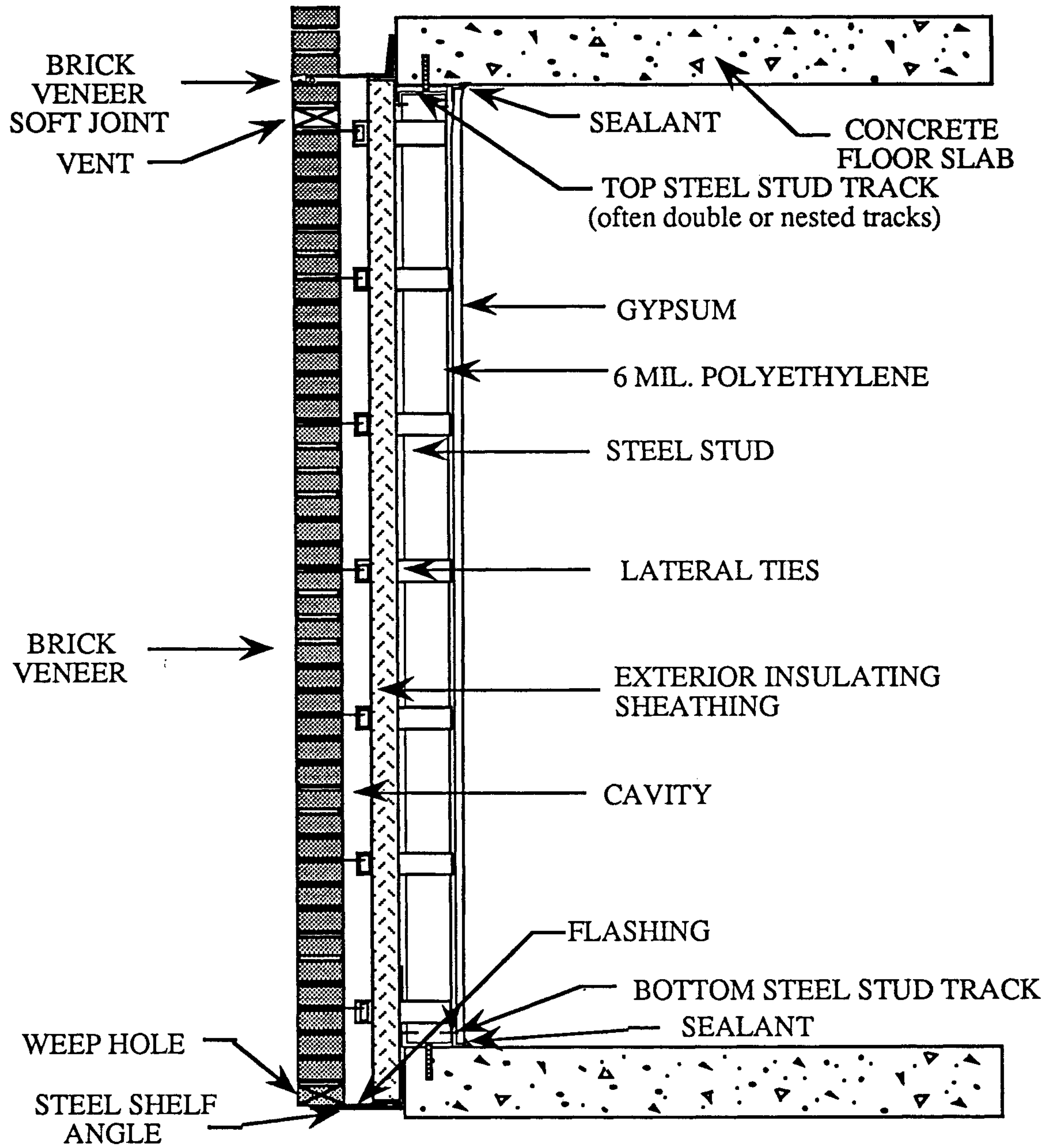

Figure 1.1: Cross-Section of a Typical BV/SS Wall

Task 1 has been completed and is documented in the CMHC report titled " Task 1 : Brick Ties - Options for Remediation." The main objective of the first task of the research study was to identify, demonstrate, assess and document methods of providing supplemental ties on BV/SS buildings. Of the eleven remedial strategies considered, seven tie systems were exterior installations and four were interior approaches.

Task 2 has also been completed. The report is entitled " Task 2 : Four Remedial Tie Systems --- Development and Conformance Testing." This task involved a test program to establish and document the structural performance of four retrofit tie systems; two were interior fixes and two were exterior fixes.

Task 4 entitled " Task 4 : Dinal Remedial Tie System" involves the testing of the Dinal tie system for remediation. It is a supplementary to the Task 1 and 2 reports because this tie system has only been recently developed.

This report documents the work conducted in Task 3 in the " Task 3 : Some Performance Considerations." This task involved the testing and/or assessment of the likely performance of BV/SS walls after remediation with particular regard to temperature, air leakage, drainage, corrosion and stiffness. This report is intended to be a stand-alone document, but additional details of the remedial tie systems are available in the Task 1, 2 and 4 reports.

1.2 Objectives

The objective of this portion of the overall project was to test and/or assess the likely performance of BV/SS walls after remediation. Since the remedial tie penetrates the building paper, sheathing and/or insulation and stud space, issues such as temperature, air leakage and drainage due to the tie bridging the exterior building envelope need to be assessed. The effects of poor thermal conditions, air tightness and drainage may result in moisture in the building envelope, increasing the potential for corrosion. An additional objective was to assess the feasibility of cavity infills and some of the incidental benefits of adding remedial ties.

1.3 Approach and Scope

The performance assessment of the walls after remedial ties have been installed is limited to laboratory and analytical studies. The effect on air leakage characteristics as a consequence of the installation of each remedial tie system was determined by performing air leakage tests on test panels.

A description of the five retrofit tie applications is presented in Chapter 2. Thermal considerations, documented in Chapter 3, were analyzed to determine the effects the remedial ties have on the thermal properties of the wall and the potential for condensation. Three typical wall constructions were analyzed to determine relative thermal consequences. Chapter 4 presents the results of laboratory tests to determine the effects the retrofit ties have on air leakage. The control of moisture is discussed in Chapter 5. The corrosion potential of each tie system is assessed in Chapter 6. The effect on flexural and torsional stiffness of the steel stud due to the installation of the retrofit ties is discussed in Chapter 7. Chapter 8 considers the potential for and the consequence of filling an existing cavity with insulation. Chapter 9 documents the main conclusions and recommendations.

2. Remedial Tie Systems

2.1 The Five Tie Systems Tested

Five retrofit tie systems were chosen for further assessment because of their potential as remedial methods for BV/SS wall systems. Four were chosen on the basis of the 11 retrofit tie systems evaluated in Task 1. The fifth tie system was the subject of Task 4 of this project. The five retrofit tie systems examined in this task are(followed by their letter code designation):

- Helifix Interior Tie (Figure 2.1) HI
- Dur-O-Wal Stainless Steel Rod and Sleeve with Epoxy (Interior Tie) (Figure 2.2) **DI**
- Helifix Exterior Tie (Figure 2.3) **HE**
- Dur-O-Wal Threaded Bolt and Expansion Anchor (Exterior Tie) (Figure 2.4) **DE**
- Dinal Exterior Tie with Molly Nut and Acrylic Seal (Figure 2.5) **D**

The Helifix HRT80 tie is a helical device manufactured from Grade 304 stainless steel. The Helifix tie is installed by means of an impact drill, via a smaller pre-drilled hole in the flange of the steel stud. With an interior fix application (Figure 2.1), the tie is anchored to both flanges of the steel stud and mechanically fixed in the brick veneer. With an exterior fix application (Figure 2.3), the tie is anchored only to one flange and is anchored in the brick veneer with a polyester resin.

The Dur-O-Wal Stainless Steel Rod and Sleeve with Epoxy (Figure 2.2) has a 1/4" diameter, stainless steel anchor rod which is inserted into a 3/8" diameter, stainless steel wire mesh screen that is filled with a high-thixotropy, two-component epoxy.

The Dur-O-Wal Threaded Bolt and Expansion Anchor (Figure 2.5) uses a brass expanding anchor to provide attachment in the brickwork. This brass unit is threaded onto a 1/4" diameter 304 stainless steel rod. The connection to the steel stud is provided by a threaded lag bolt.

The Dinal exterior tie (Figure 2.5) uses a 3/16" plated, threaded steel rod with an expanding Molly Nut fastener which provides attachment to the steel stud. An expandable rubber seal, within the exterior sheathing, provides resistance to water and air movement.

Each retrofit tie bridges the envelope either partially or entirely. In an exterior fix application, the ties bridge between the brick and the outer flange of the steel stud. In an interior fix application, the entire envelope is bridged. These bridges will affect the wall with respect to temperature, air leakage, drainage and stiffness. Moisture may be present in the wall assembly due to vapour diffusion, air leakage, poor drainage or may even be built-in (e.g., rain wetting or snow deposition during construction). In the following chapters, each of these issues is assessed.

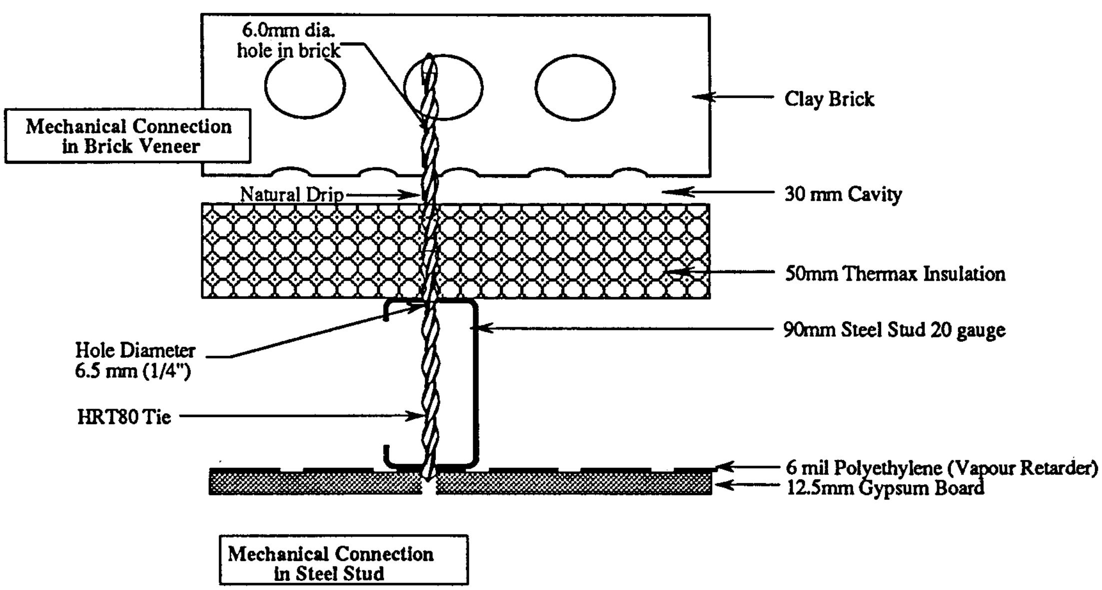

Figure 2.1: Helifix HRT 80 Tie Dry Fix (Interior Fix) - HI

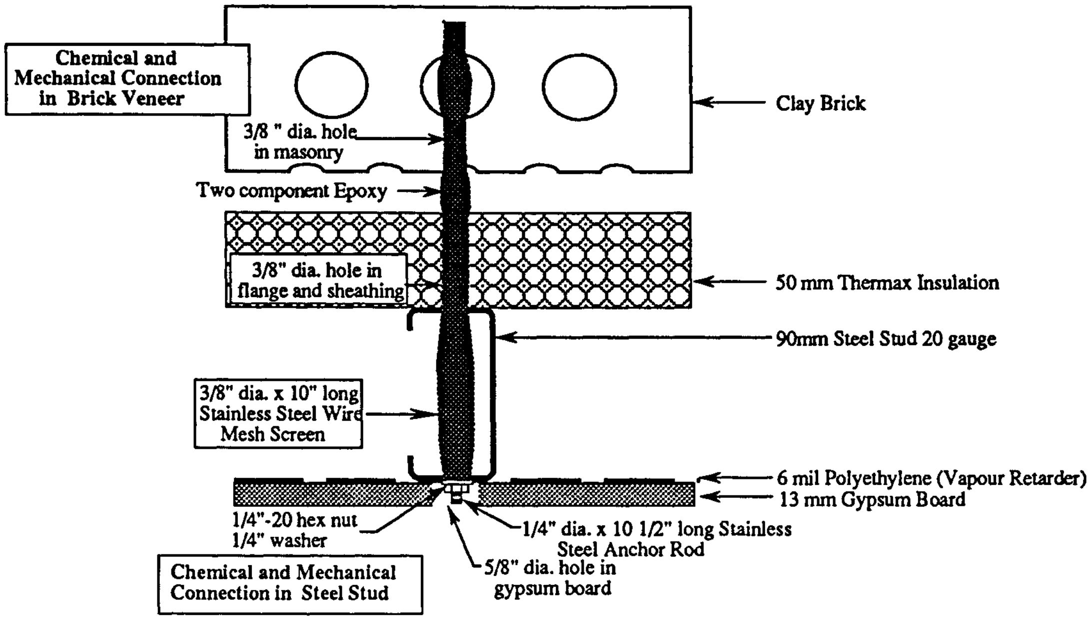

Figure 2.2: Dur-O-Wal Stainless Steel Rod and Sleeve with Epoxy - DI

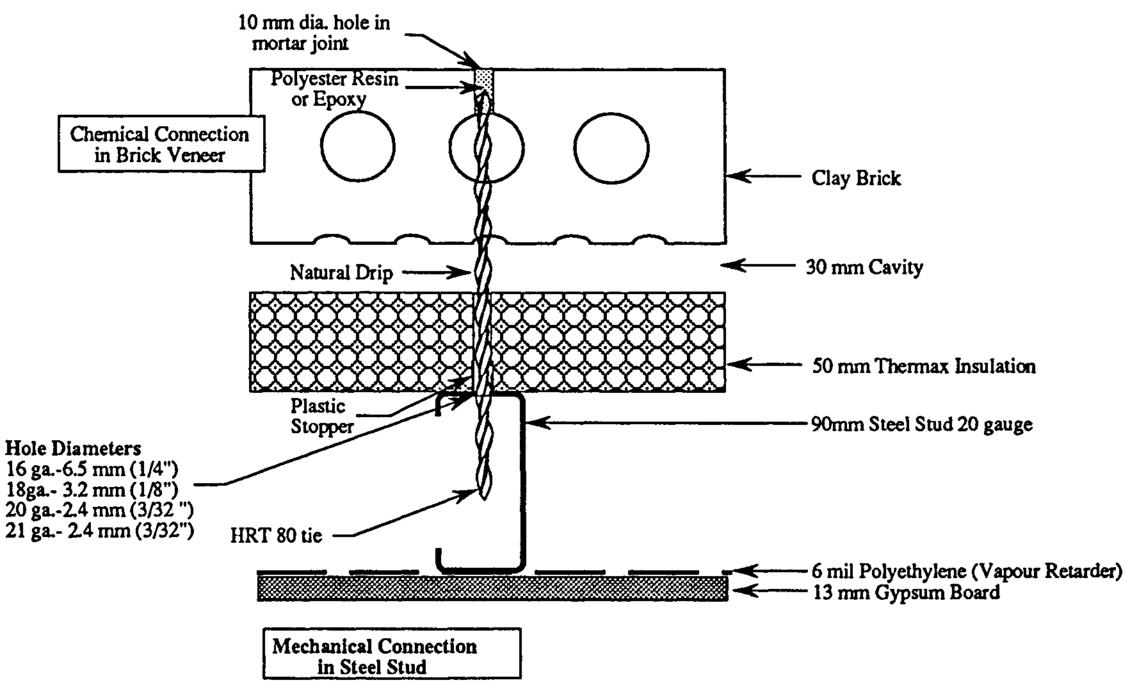

Figure 2.3: Helifix HRT 80 Tie Dry Fix (Exterior Fix) - HE

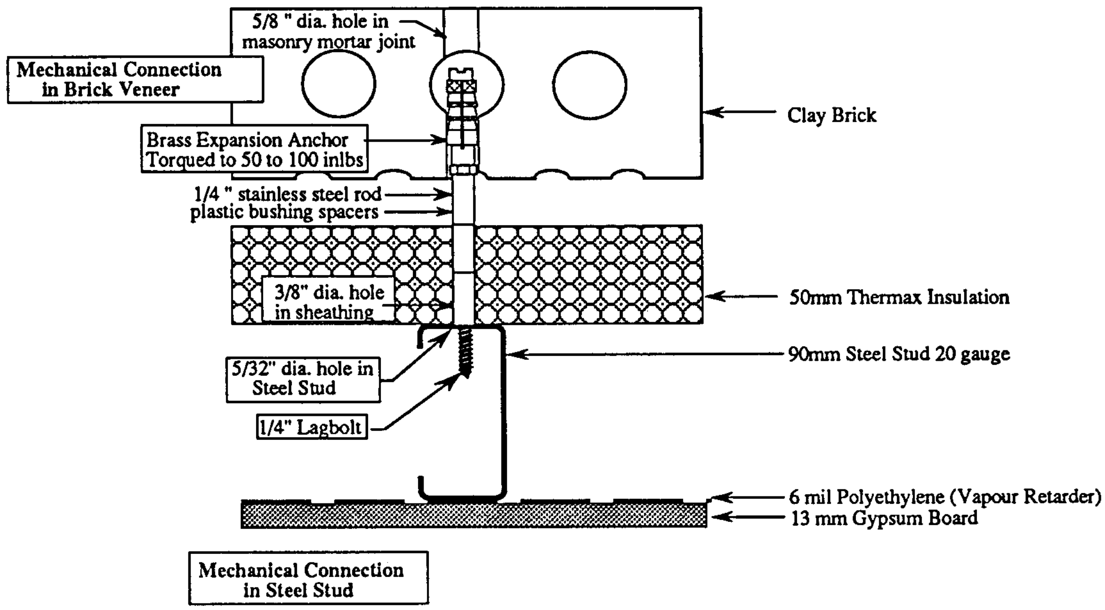

Figure 2.4: Dur-O-Wal Threaded Bolt and Brass Expansion Anchor - DE

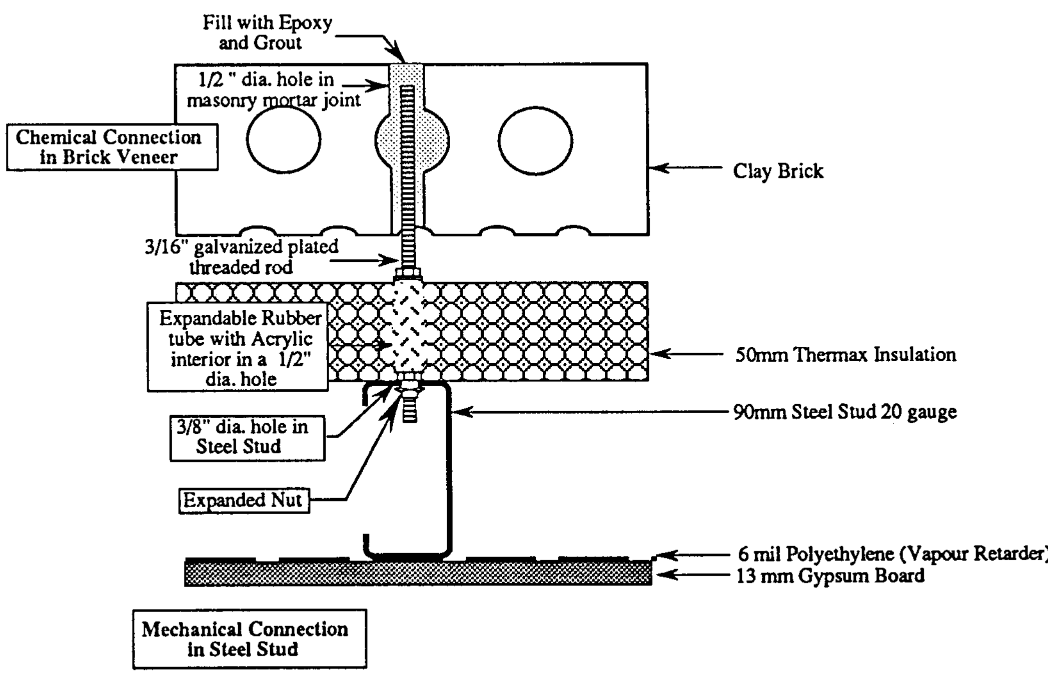

Figure 2.5: Dinal Exterior Tie - D

3. Thermal Considerations

3.1 Introduction

Being metal, the ties in each of the five retrofit tie systems are good thermal conductors. Moreover, each remedial tie constitutes an intrusion through the envelope. Therefore, the retrofit ties can effect wall temperatures through thermal bridging. This in turn has implications for the following:

1) Localized effects within or on the exterior or interior surface of the wall such as condensation, moisture accumulation, frosting or dusting;
2) General effects such as on energy usage, i.e., heat flow.

The discussion that follows is directed at the use of a retrofit tie system. There is, of course, already a tie system within the wall i.e., the one in need of remediation. The intent in this section is to assess what effect the remedial tie system has on the performance of the existing wall system. Some of what follows also applies to ties in general.

3.2 Description of Thermal Bridging

Thermal bridging occurs where an isolated element with a lower thermal resistance (or higher thermal conductance) than the adjacent components spans across the building envelope. Common building elements that may contribute to thermal bridging are masonry ties, self-tapping screws, and steel studs. The temperature of the material in a thermal bridge will differ from that of the adjacent material. When temperature differences between adjacent interior surfaces of walls exceed about 2.5 ^{o}C, discontinuous discoloration or dust marking can occur on the colder surface. Both in winter and summer, thermal bridges can also become problematic when their interior surface temperature is sufficiently low for condensation to occur. Also, in cold weather, the exterior surface temperature at a thermal bridge can be higher than that of the adjacent wall. This condition can result in visibly discontinuous drying or even wetting of the wall as a result of melting of ice or wind-driven snow and has aesthetic as well as durability implications.

In order to develop some quantitative understanding of the thermal effects of retrofit ties, it is necessary to consider some representative walls and to determine the relative impact of tie retrofit in each case.

3.3 Thermal Analysis of Typical BV/SS Wall Construction

A thermal bridge will exist when a retrofit tie is installed through the exterior building envelope. In order to quantify the relative effects of thermal bridging, three representative BV/SS wall constructions were chosen for thermal and vapour pressure analysis as shown in Figure 3.1. Wall Type 1, with batt insulation in the stud space is probably the most common. Wall Type 2 has batt insulation in the stud space as well as rigid insulation on the exterior of the stud space. Wall Type 3 has rigid insulation only on the exterior of the stud space. Wall Type 3 is currently finding some favour as a means of ensuring a warmer stud space. In some instances with Wall Type 3 the vapour retarder is placed on the outer face of the stud to better preserve the integrity of the air barrier and vapour retarder. Wall Type 2 and 3 should have similar total R values.

The effects of thermal bridging through the walls were determined by analysis using the Zone Method presented in the ASHRAE Handbook of Fundamentals.[1] This method is relatively crude. Alternatively, a more sophisticated, computer-based method or even another manual approach (e.g., UK[2] version) could be used. Because we were primarily interested in relative rather than absolute effects, we considered the ASHRAE method to be appropriate for this report. It is worth mentioning that ASHRAE is funding research and development to improve this methodology.

The ASHRAE method isolates areas around the higher conductive elements (Zone A) and the lower conductive elements (Zone B). The surface shape of Zone A is determined by the metal element. The surface is a strip of width W that is centered on the steel stud. The value of W is calculated from equation (3-1), which is empirical. For the case of BV/SS construction, W = 65mm (i.e., 38 + 2x13.5). The average transmittance per unit overall area is then calculated for each zone.

$$W = m + 2d$$

where m is the width of the metal heat path terminal (mm), and
d is the distance from the panel surface to the metal (mm)

The three zones for an example wall are shown in Figure 3.2. Zones A_1 and A_2 contain the highly conductive elements, namely, the steel stud and tie and the steel stud with no tie respectively. Zone B contains the elements with lower conductivity. Temperature and vapour pressure gradients were computed for the environmental conditions shown in Figure 3.3. (The calculations for the thermal and vapour pressures through the wall are provided in a separate Appendix that is available from CMHC).

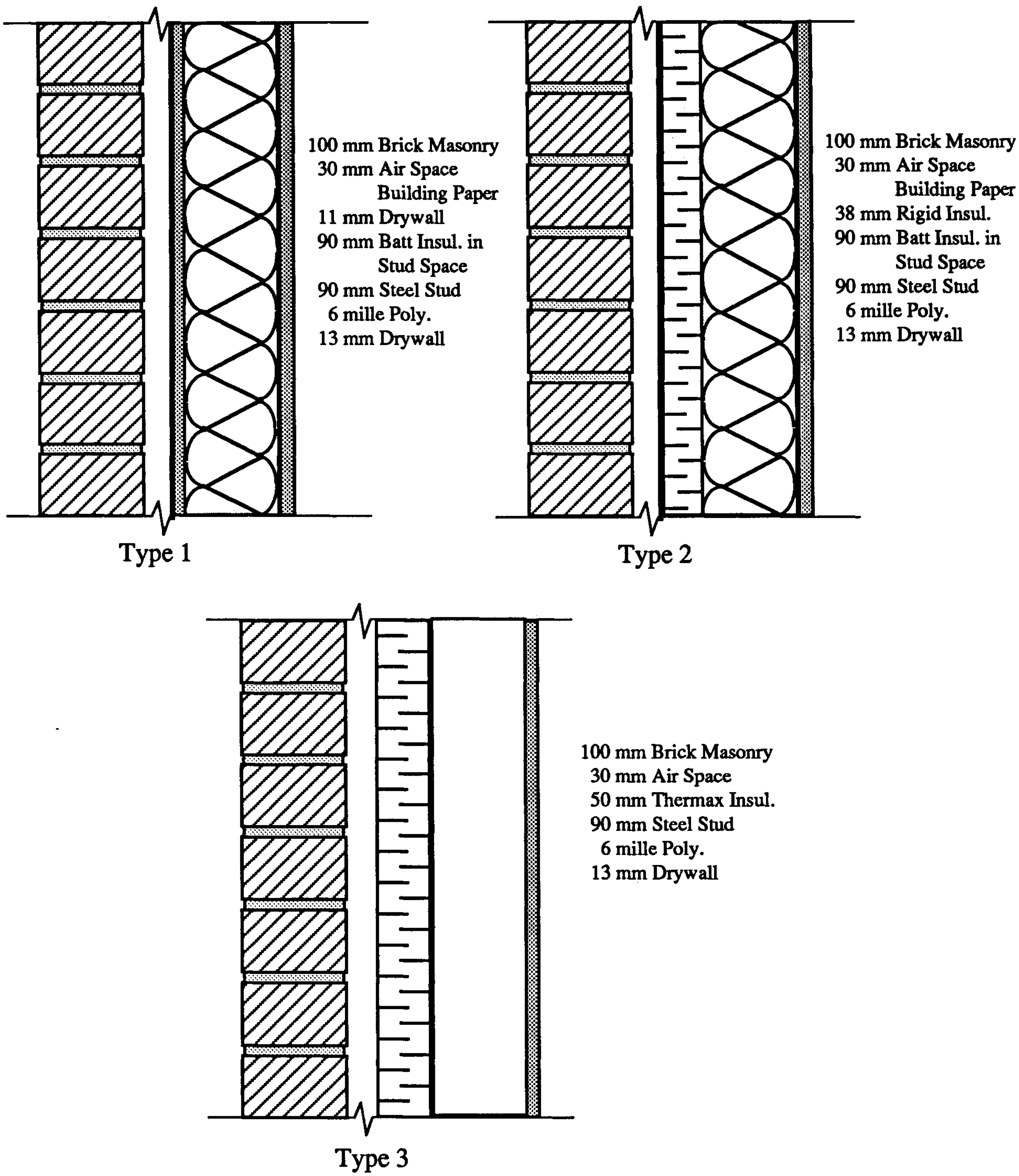

Figure 3.1: Representative Forms of BV/SS Wall Construction

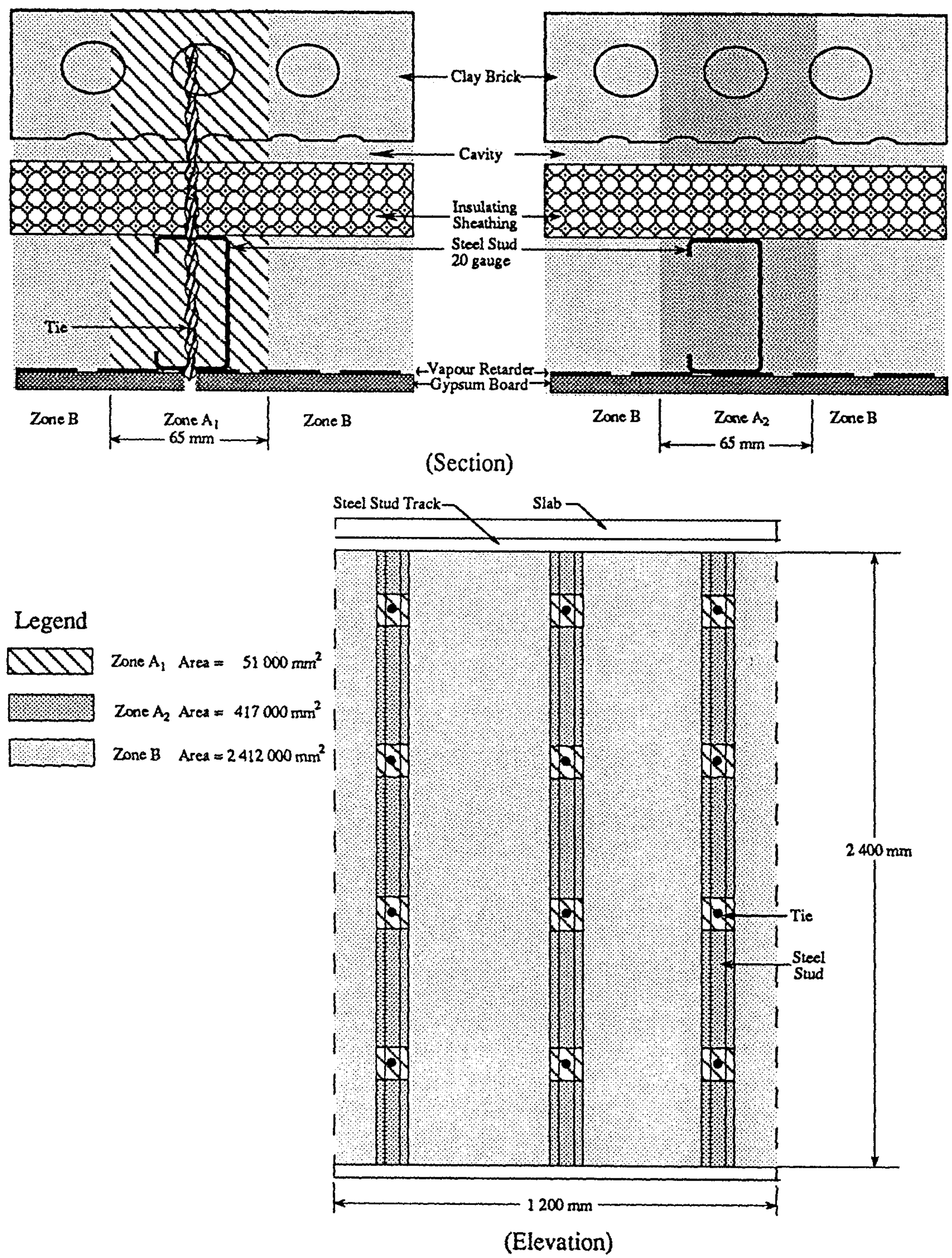

Figure 3.2 : Thermal Zones

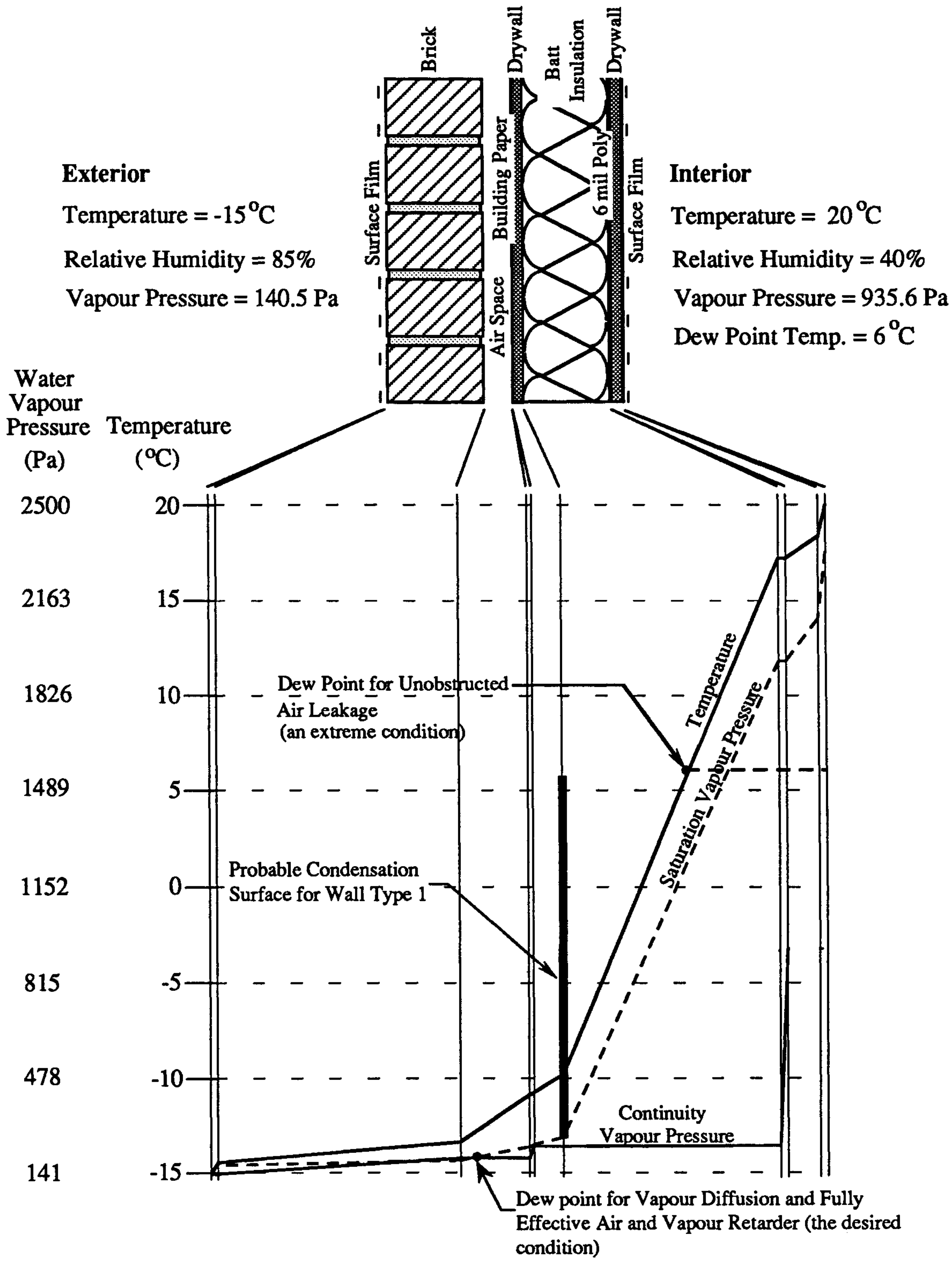

Figure 3.3 : Thermal and Vapour Gradients through a Type 1 BV/SS Wall System for a representative Winter Situation

A summary of the temperatures at each interface for each wall construction is presented in Table 3.1. The location of potential dew points due to both air leakage and vapour diffusion is highlighted. The locations of potential dew points within the building envelope are indicated by the terms VD for moisture being transported through the wall by vapour diffusion and AL for moisture being transported by air leakage. The potential for air leakage as a result of retrofit tie installation is discussed in Chapter 4.

The results from Table 3.1 prompt a number of interesting conclusions with regard to:

1) the remedial tie effects,
2) the wall type effects and
3) the general effects

3.3.1 Remedial Tie Effects

As far as the remedial ties are concerned, it is evident that the heavier/thicker the tie, such as both the Dur-O-Wal products, the greater the probability of thermal bridging being significant. This consequence is clearly evident for Zone A_1 for Wall Types 2 and 3 where the likely dew points occur within the stud space. Note that the temperature at the inside surface of the drywall for Zone A_1 is lower and that the dew point location is closer to the interior when the thicker tie is used.

Compared to an exterior fix, an interior fix using a similar tie causes the temperature of the tie (zone A) in the stud space to be slightly warmer. Accordingly, an interior fix may be preferred to an exterior fix insofar as the importance of thermal bridging is concerned.

3.3.2 Wall Type Effects

As far as the type of BV/SS wall system is concerned, the results in Table 3.1 confirm the potential disadvantages of the wall system with insulation within the stud space only, i.e., Wall Type 1. For Zones A_1, A_2 and B lower temperatures within the stud space and the inward location of likely dew points demonstrate the relative differences. Even with these representative walls, one should bear in mind that sufficient moisture must be involved to cause a problem and that the existence of a dew point is a necessary but not sufficient reason to have a problem.

Wall Type 1 (with Batt insulation in between steel studs)

Layer	Zone B	Zone A2	Zone A1 (at Tie Location)				
	Without Steel Stud or Tie	With Steel Stud	Helifix Interior Tie	Dur-O-Wal Interior Tie	Helifix Exterior Tie	Dur-O-Wal Exterior Tie	Dinal Exterior Tie
	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Air Film							
	18.27	13.26	11.16	10.18	11.64	11.06	11.49
13mm Drywall				VD, AL	VD?, AL	VD, AL	VD, AL
	17.11	8.74	6.75	5.85	6.02	5.05	5.77
6 mil Poly							
	17.11	8.74	6.75	5.85	6.02	5.05	5.77
90mm Batt Insulation between studs	AL	AL	AL				
	-9.90	4.86	2.13	1.36	1.21	-.10	.87
11mm Drywall							
	-10.88	1.03	-0.63	-0.44	-1.40	-1.73	-1.49
Building Paper							
	-11.03	0.44	-0.68	-0.46	-1.45	-1.76	-1.53
30mm Cavity	VD						
	-13.50	-9.16	-7.82	-7.68	-8.21	-8.33	-8.24
100mm Brick Masonry							
	-14.57	-13.32	-12.79	-12.55	-12.91	-12.76	-12.87
Air Film							
	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00

Wall Type 2 (with Batt insul. in the stud space and rigid insulation on the exterior)

Layer	Zone B	Zone A2	Zone A1 (at Tie Location)				
	Without Steel Stud or Tie	With Steel Stud	Helifix Interior Tie	Dur-O-Wal Interior Tie	Helifix Exterior Tie	Dur-O-Wal Exterior Tie	Dinal Exterior Tie
	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Air Film							
	18.89	17.86	13.77	11.71	14.01	12.38	13.63
13mm Drywall							
	18.14	16.43	10.65	8.25	9.99	7.27	9.36
6 mil Poly							
	18.14	16.43	10.65	8.25	9.99	7.27	9.36
90mm Batt Insulation	AL			AL		AL	AL
	0.75	15.20	7.40	4.46	6.54	2.88	5.69
25mm Rigid Insulation	VD	AL	AL		AL		
	-12.35	-9.92	-4.86	-2.70	-5.26	-3.70	-4.90
Building Paper							
	-12.45	-10.10	-4.90	-2.72	-5.29	-3.72	-4.93
30mm Cavity							
	-14.03	-13.15	-9.94	-8.82	-10.13	-9.32	-9.94
100mm Brick Masonry							
	-14.72	-14.47	-13.44	-12.93	-13.50	-13.10	-13.41
Air Film							
	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00

Wall Type 3 (with Thermax Insulation on the exterior of the stud space)

Layer	Zone B	Zone A2	Zone A1 (at Tie Location)				
	Without Steel Stud or Tie	With Steel Stud	Helifix Interior Tie	Dur-O-Wal Interior Tie	Helifix Exterior Tie	Dur-O-Wal Exterior Tie	Dinal Exterior Tie
	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Air Film							
	18.91	18.82	14.48	12.22	14.66	12.74	14.24
13mm Drywall							
	18.18	18.03	11.73	8.78	11.08	7.86	10.37
6 mil Poly							
	18.18	18.03	11.73	8.78	11.08	7.86	10.37
90mm Stud Space				VD, AL		VD, AL	
	15.08	17.45	9.21	5.63	8.43	4.25	7.52
50mm Insulation	AL	AL	AL		AL		AL
	-12.50	-12.30	-6.06	-3.47	-6.35	-4.24	-5.89
30mm Air Space							
	-14.05	-13.98	-10.52	-9.20	-10.66	-9.58	-10.43
100mm Brick Masonry							
	-14.73	-14.71	-13.62	-13.05	-13.67	-13.18	-13.56
Air Film							
	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00

VD - Dew point location due to Vapour Diffusion
AL - Dew point location due to Air Leakage

Table 3.1 : Thermal Gradients

Wall Type 1 also exhibits the lowest temperatures on the interior drywall surface parallel to the steel studs and, at tie locations (Zones A_1 and A_2), it follows that well-defined cold spots or dust marking could be experienced. This wall type is also more susceptible to possible condensation as a result of either vapour diffusion or air leakage within the drywall in Zone A_1. If condensation does occur in the drywall, there could be visible staining on the interior of the wall at these tie locations. Note that air leakage (exfiltration because of an imperfect air barrier) would also lead to condensation within the stud space for Zones A_2 and B for Wall Type 1. Water that might accumulate in these areas would be difficult to evaporate or drain away. The amount of moisture accumulation can be shown to be quite significant. The Helifix interior fix is less likely to cause condensation or marking: firstly because it is exposed to the warm interior and, secondly, because the tie has a smaller cross-sectional area than the Dur-O-Wal interior and exterior fixes and the Dinal exterior fix.

Wall Type 2 is susceptible to possible condensation as a result of vapour diffusion at the outer face of the insulating sheathing in Zone B. This water can drain away if draining insulation is used and the wall is properly constructed with weep holes free of obstructions. Air leakage could result in trapped condensation within the stud space for Zones A_1 and B for the Dinal and the Dur-O-Wal interior and exterior tie applications. Air leakage could also result in condensation within the insulation sheathing for Zones A_1 and A_2, for the Helifix tie application, but this condensation can be drained away if draining insulation is used.

Condensation could occur within the stud space of wall Type 3, in Zone A_1, for the Dur-O-Wal tie applications, due to vapour diffusion. However, it should be noted that for all cases with wall Type 3 the amount of moisture accumulation due to vapour diffusion is numerically insignificant. If air leakage were to occur, there is a possibility of condensation within or at the outer face of the insulating sheathing in Zones A_1, A_2 and B for the Dinal and both Helifix tie applications. This condensate is clear of the stud space, and drying (drainage and ventilation) will occur if the wall is properly constructed.

Of the three wall systems, Wall Type 3 with either the Helifix or the Dinal tie will perform the best with regard to thermal gradient and the potential for condensation. With both existing and new construction it is clearly a relative disadvantage to have only the stud space insulated. Control of moisture is much less of an issue when the temperature within the stud space is relatively high and stable.

3.3.3 General Effects

These results do emphasize the need for good upstream airtightness, i.e., at the interior. Clearly air sealing at or close to the interior face is an essential component of any retrofit strategy. Control of vapour diffusion is also necessary, but this is much easier to accomplish.

These numerical results also suggest that, in order to keep the temperature of the stud and stud space above the dew point, a BV/SS wall system should incorporate a continuous thermal break between the stud space and the air cavity. Introducing an insulating sheathing into an existing Type 1 wall will be difficult if not impossible. Obviously thermal bridging is, in relative terms, a much more significant issue for Type 1 wall systems.

3.4 Heat Flow through Typical BV/SS Walls - Heating Energy Considerations

If air leakage is ignored, the rate of heat flow through a specific zone is proportional to the overall thermal conductance (1/R) multiplied by the area of the specific zone. Table 3.2 lists the computed heat flow rates for the three types of BV/SS wall construction, each remediated with each of the five different retrofit tie applications. Because of their greater thermal resistance, the wall systems Type 2 and 3 respectively exhibit better heating energy savings. The relative effects on air leakage due to the installation of the different retrofit ties is discussed in the next chapter.

Table 3.2 provides numerical evidence of the relative impact of the remedial tie system on thermal performance. Different tie systems do have a measurable impact on heat flow rates . The thicker/heavier the tie the more significant the bridging and thus the greater the influence on heating costs. This is evident in Table 3.2 where the Dur-O-Wal ties contribute more than the Helifix and Dinal tie systems. Furthermore the better insulated the wall, the greater the impact the ties will have on the heat flow rate. However, in terms of overall heating cost, the differential contribution of the various tie systems, remedial or otherwise, is not particularly important—at most about 4 per cent.

Wall Type 1	Area (m^2)	Conductance (W/m^2K)	Heat Flow (W/K)	Percentage Heat Flow
Zone A1				
Helifix Interior Fix	0.051	2.105	0.107	6.03
Dur-O-Wal Interior Fix	0.051	2.342	0.119	6.66
Helifix Exterior Fix	0.051	1.992	0.101	5.72
Dur-O-Wal Exterior Fix	0.051	2.128	0.108	6.09
Dinal Exterior Fix	0.051	2.028	0.103	5.82
Zone A2	2.412	0.412	0.994	±56 %
Zone B	0.417	1.605	0.670	±38 %
Total using :				
Helifix Interior Fix	2.880	4.123	1.771	
Dur-O-Wal Interior Fix	2.880	4.359	1.783	
Helifix Exterior Fix	2.880	4.009	1.765	
Dur-O-Wal Exterior Fix	2.880	4.145	1.772	
Dinal Exterior Fix	2.880	4.046	1.767	
Average			1.771	

Wall Type 2	Area (m^2)	Conductance (W/m^2K)	Heat Flow (W/K)	Percentage Heat Flow
Zone A1				
Helifix Interior Fix	0.051	1.484	0.075	8.11
Dur-O-Wal Interior Fix	0.051	1.972	0.100	10.50
Helifix Exterior Fix	0.051	1.427	0.072	7.82
Dur-O-Wal Exterior Fix	0.051	1.815	0.092	9.74
Dinal Exterior Fix	0.051	1.515	0.077	8.27
Zone A2	2.412	0.265	0.640	±68 %
Zone B	0.417	0.509	0.212	±22 %
Total using :				
Helifix Interior Fix	2.880	2.258	0.928	
Dur-O-Wal Interior Fix	2.880	2.747	0.952	
Helifix Exterior Fix	2.880	2.201	0.925	
Dur-O-Wal Exterior Fix	2.880	2.589	0.945	
Dinal Exterior Fix	2.880	2.289	0.929	
Average			0.936	

Wall Type 3	Area (m^2)	Conductance (W/m^2K)	Heat Flow (W/K)	Percentage Heat Flow
Zone A1				
Helifix Interior Fix	0.051	1.312	0.067	8.21
Dur-O-Wal Interior Fix	0.051	1.852	0.094	11.20
Helifix Exterior Fix	0.051	1.271	0.064	7.97
Dur-O-Wal Exterior Fix	0.051	1.730	0.088	10.54
Dinal Exterior Fix	0.051	1.372	0.070	8.54
Zone A2	2.412	0.260	0.627	±76 %
Zone B	0.417	0.281	0.117	±14 %
Total using :				
Helifix Interior Fix	2.880	1.853	0.811	
Dur-O-Wal Interior Fix	2.880	2.392	0.838	
Helifix Exterior Fix	2.880	1.811	0.809	
Dur-O-Wal Exterior Fix	2.880	2.271	0.832	
Dinal Exterior Fix	2.880	1.912	0.814	
Average			0.821	

Table 3.2 : Heat Flow for the Three Types of BV/SS Wall

3.5 Other Related Research and Development

A. Kluge and R.G. Drysdale used a finite difference method of analysis in order to model a BV/SS system with an imperfect air barrier.[3] This model was verified experimentally. The analytical model was used to analyze various walls for a fixed interior temperature of 20°C, exterior temperatures of -10, -20, and -30°C, and for interior relative humidities (RH) of 30, 40 and 50%.

For a wall similar to wall Type 1, even under conditions such as -10°C and 30% RH, a dew point was found to occur within the fiberglass batt insulation and at steel-stud locations. Clearly it does not take extreme conditions for a problem to develop in this type of BV/SS wall.

Walls similar to wall Type 2 but with 25, 50, 75 and 100 mm of polystyrene insulating sheathing were also modelled. With insulation thicknesses of 50, 75 and 100 mm, there was no dew point at steel-stud locations but, under extreme conditions, a dew point could occur within the batt insulation. For an insulating sheathing with thickness of 25 mm, Kluge and Drysdale found that a dew point would occur at the steel-stud locations if the interior RH was greater than 40% and the exterior temperature was below -20°C.

For a wall similar to wall Type 3, but with 75mm of polystyrene on the outside of the studs and no insulation within the stud space, Kluge and Drysdale found that a stud space dew point could be avoided. They confirm that this Type 3 wall would perform the best with regard to preventing condensation at the stud and within the stud space area.

4. Installation Considerations

4.1 Background

Air leakage in a building involves the exchange of air between the indoor and outdoor environments through unplanned openings in the building envelope such as cracks, gaps and other apertures. Even under small pressure differences, air can readily flow through small holes in the enclosure, as long as there is an unobstructed route to the other side. The flow of air is powered by air pressure differences that may be due to one or more of the following: wind, stack effect or mechanical service systems.

Air movement can be responsible for the transfer of heat, water vapour, smoke, odour, dust and various pollution products. Both infiltration and exfiltration of air can lead to a number of problems in the performance of buildings. These problems include higher energy costs, discomfort, poor water vapour control, and the deposition of moisture within the building envelope. Infiltration leads to cold drafts and the entry of dust. Exfiltration allows warm, humid air to enter the enclosure, possibly leading to concealed condensation in the exterior walls. Moisture trapped in the building envelope often results in the deterioration of components and materials. To avoid these problems in building envelopes, air flow control is essential.

For air to flow across the enclosure there must be a continuous flow path. A perfect air barrier, located anywhere within the wall, would prevent air flow and thus render an airtight assembly. In a BV/SS wall the air barrier can be on the inside or the outside of the steel stud wall assembly. It is, however, difficult to provide and maintain a perfect air barrier especially with steel stud framing. Obviously, any remedial strategy must incorporate provisions to minimize or, preferably, avoid air leakage, and in most instances sealing of the interior face would be the most effective means of doing so.

The installation of retrofit ties involves penetrating many of the components of the wall assembly. Installation of the remedial tie requires holes to be drilled and then the "blind" insertion of the tie. Many of the materials in a wall, e.g., gypsum, building paper, "house wrap", polyethylene, etc.) are not cleanly drillable: tearing, stretching, powdering or other types of local damage could occur. The tie does not necessarily fill these holes completely. The installation of a remedial tie can have the following effects:

- the effectiveness of the air barrier can be reduced. Obviously it would be advantageous to avoid penetrating the air barrier.
- the potential for water entry can be increased or, conversely, the effectiveness of any water barrier (e.g., building paper) can be impaired.

It was thought that some attempt should be made to quantify, at least in relative terms, the possible consequences of installing each remedial tie system. Accordingly, a series of air leakage tests were done on a representative sub-assembly in the laboratory. The test, test procedure, and results are discussed. The reader should bear in mind that these tests are to measure the relative amount of damage caused by installing a remedial tie. The test does not , nor was it intended to, measure the absolute or even the relative airtightness of any wall assembly. Nor should it be presumed that the tie necessarily penetrates the air barrier. Air leakage testing has been used to quantify the relative physical impact of installing each remedial tie system—the difference in measured air leakage area is a measure of the damage done.

One particular reason for doing these tests was concern about the nature of the Helifix tie and the fact that tie is screw/impact-drilled into the wall. We were asked to develop methods of compensating for this installation-related damage.

4.2 Test Set-up

Two identical sub-assemblies consisting of a wood frame, steel studs, Thermax insulation (both sides faced with a trilaminate foil), an air space, polyethylene sheet and drywall were constructed. Details of these sealed and airtight boxes are given in Figure 4.1. The air leakage characteristics of each box was measured. A tie was then installed from one side and the air leakage test was repeated. The difference in airtightness was thus a relative measure of the effect of installing the tie. A minimum of three similar ties were installed and then tested. Each of the five different retrofit tie systems were installed and tested to determine their incremental effect, if any, on air leakage. Both interior and exterior fixes were considered in this manner.

Standard procedures were used to determine the incremental amount of air leakage as ties were installed. The Standards ASTM E283-84, "Rate of Air Leakage through Exterior Windows, Curtain Walls, and Doors"[4] and CAN/CGSB 149.1-M86, "Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method" [5] were used as guides in developing the test method.

A CAN-BEST (Canadian Building Envelope Science and Technology) Model 283A200 test kit was used to produce the monitored amount of air flow required to maintain the specific pressure difference across the center of the test panel. The apparatus consists of a rotometer, a low and a high pressure manometer, and a centrifugal fan. The rotometer has a range of 0 to 20 standard cubic feet per minute (SCFM; 1 SCFM = 0.472 L/s) and a resolution of approximately ± 0.01 SCFM. The low-pressure manometer has a range of 0 to 150 Pa and a resolution of ± 0.5 Pa, and the high-pressure manometer has a range of 0 to 500 Pa and a resolution of ± 2 Pa. In place of the built-in centrifugal fan, an external vacuum (Shop-Vac) attached to the CAN-BEST Model 283A200 was used to generate the pressure differences.

Air was either added (pressurization) or extracted (depressurization) from the centre of the stud space to create a pressure difference across the interior (drywall and 6 mil poly) and the exterior (insulating sheathing) sides (Figure 4.1). A pressure tap was used to measure the pressure differential across the layer of interest.

The object in these tests was only to measure the incremental impact of installing remedial ties. Exterior retrofit tie installations penetrate wall elements on the exterior of the stud space and it therefore follows that only the downstream air leakage characteristics are effected. These characteristics are, of course, dependent on the nature of the penetrated elements, in particular the insulating sheathing. A foil faced polyisocyanurate sheathing was deliberately chosen largely because of the relative (compared to fibreglass or mineral wool) stiffness of the facings and the insulation material and the need for repeatability of results. Only relative differences are significant. Note that other types of thermal insulation will give different results.

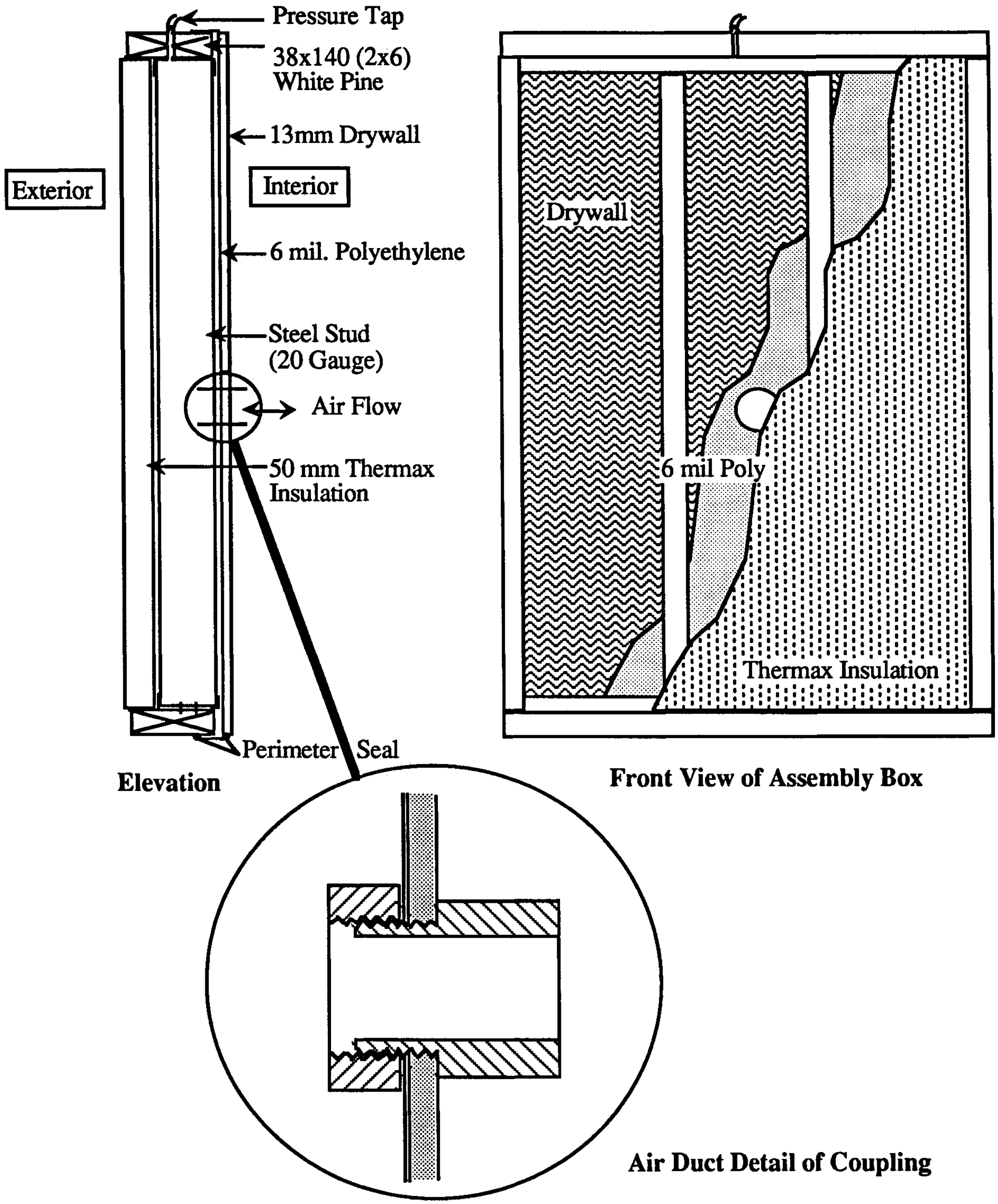

Figure 4.1 : Wall Panel Construction Details

4.3 Procedure

A series of air leakage tests was performed on one or the other test panel for each of the five different tie applications. A total of 38 infiltration and exfiltration tests were conducted. Exfiltration signifies panel pressurization and infiltration signifies panel depressurization (suction). For each exfiltration and infiltration test two sets of data were accumulated as a check on repeatability. The schedule of tests for each tie application is presented in Table 4.1.

Retrofit Tie Application	Number of Tests
Helifix Exterior Fix	
A) Plain	4
B) with plastic tube	3
C)with dense Neoprene	3
D) with soft Neoprene	3
Dur-O-Wal Exterior Fix	
A) no sealant on the tip	3
B) with sealant on the tip	4
Dinal Exterior Fix	
A through drywall	4
B) through Thermax	4
Helifix Interior Fix	5
Dur-O-Wal Interior Fix	4

Table 4.1 : Test Program

The Helifix exterior tie application produces a relatively large hole or leak area, and we were asked by the Blok Lok Company to assess different ways of reducing the impact of installation. It was suggested that either a dense or soft neoprene seal with a plastic tube be added to the end of the tie to reduce incremental air leakage (Photo 4.1 and 4.2 respectively). The four different types of tests performed on variations of the Helifix exterior tie fix are as follows:

1) Tie with no special provision for reducing air leakage
2) Plastic tube fitted over the tie
3) Tie with a dense neoprene plug and plastic tube
4) Tie with a soft neoprene plug and plastic tube

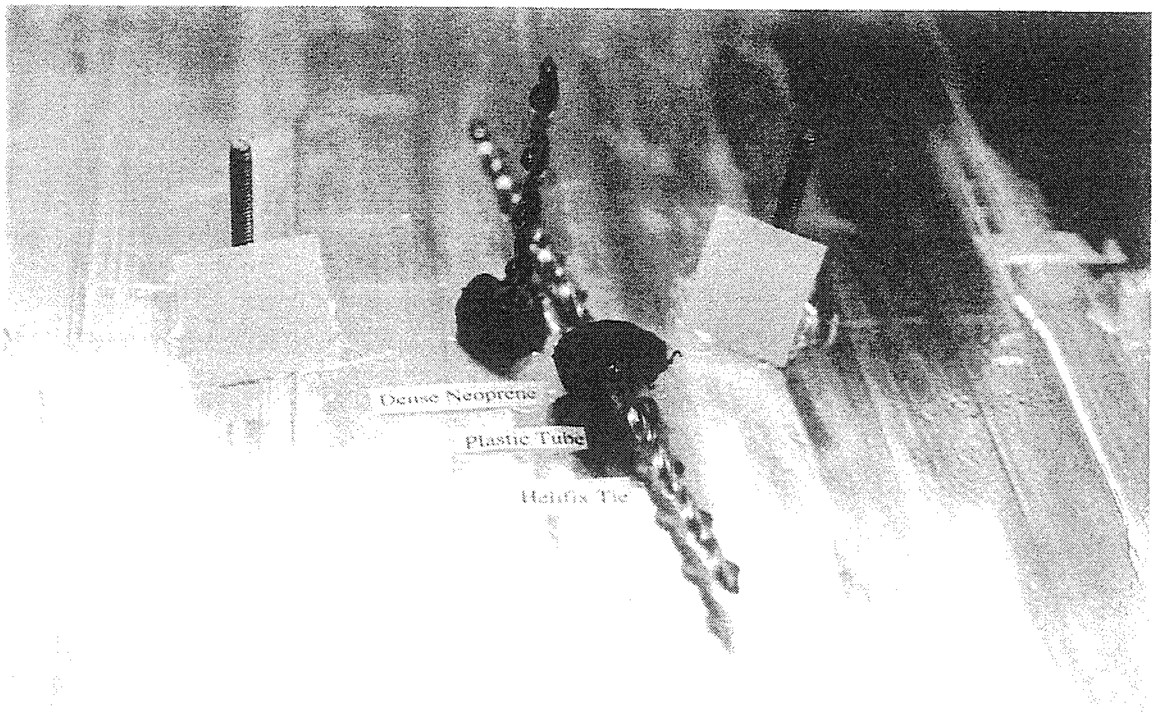

Photo 4.1: Exterior Fix Helifix Tie with Dense Neoprene Seal and Plastic Tube

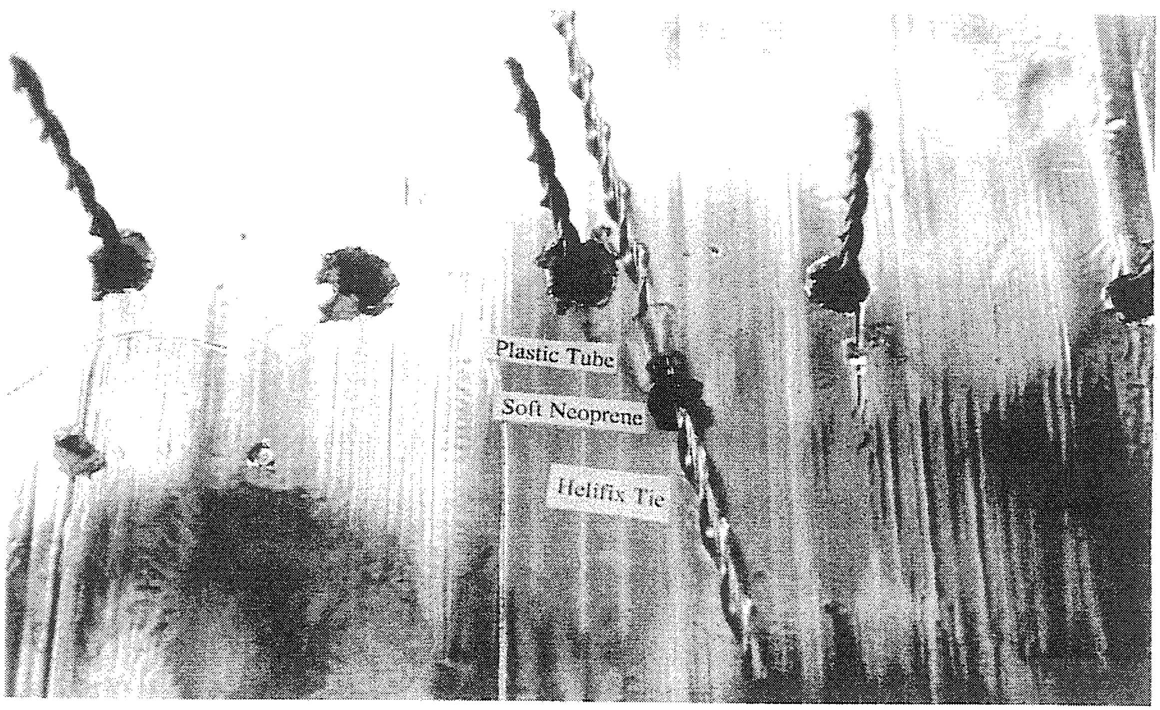

Photo 4.2: Exterior Fix Helifix Tie with Soft Neoprene Seal and Plastic Tube

For similar reasons the Dur-O-Wal threaded bolt and expansion anchor (Figure 2.4) was tested with and without Silicone Mastercraft sealant applied to the tip.

The Dinal exterior tie (Figure 2.5) was tested for installation through drywall sheathing as well as through rigid exterior insulating sheathing (Thermax). The drywall application was tested from the drywall side of the test panel in order to simulate exterior application to a wall with drywall exterior sheathing, i.e., as an exterior fix.

Only one series of tests was conducted on the Helifix interior fix (Figure 2.1) and the Dur-O-Wal interior fix using a stainless steel rod and sleeve with epoxy (Figure 2.2).

The test procedure for each type of tie application is best described in a flowchart (Figure 4.2). Before any ties were installed, initial air leakage or datum values were established. A tie was then installed and an exfiltration and an infiltration test was performed. Prior to each new tie installation, the new datum air leakage value was measured.

4.4 Data Analysis and Presentation

When the relative flow rates (Q) and related differential pressures (ΔP) for each air leakage test (Appendix B) are plotted on log-log graph paper, the data is generally linearly related. Thus, the relation between Q and ΔP across the building envelope can be represented by:

$$Q = C\,(\Delta P)^n \qquad (4.1)$$

where Q is the volumetric flow rate of air (L/s)
C is the flow coefficient (L/s-Pa^n)
ΔP is the differential pressure (Pa) and
n is a dimensionless exponent,

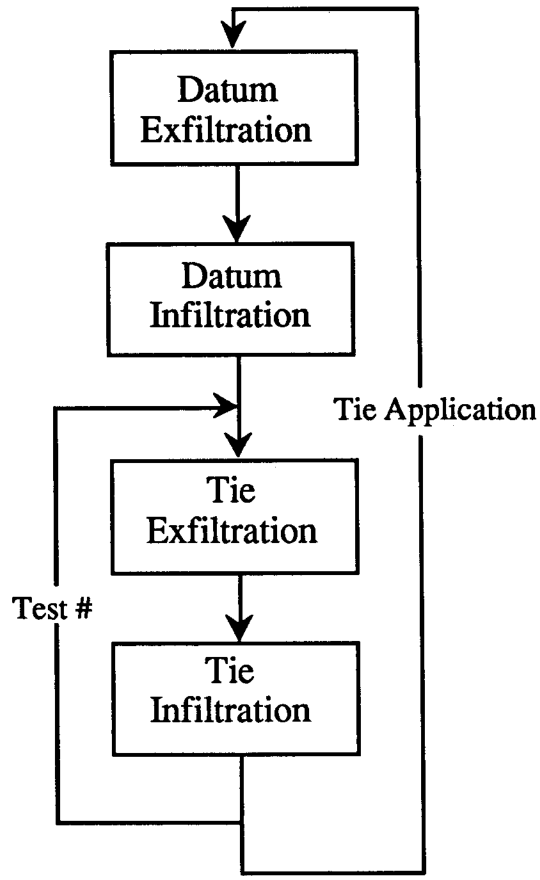

Figure 4.2 : Test Procedure Flowchart

Since the basic relationship (equation 4.1) is non-linear, the difference in air flow characteristics due to tie installation is best described in terms of equivalent air leakage area values. The Bernoulli equation to derive the equation of flow for a sharp edged orifice is:

$$Q = C_d A \sqrt{\frac{2\Delta P}{\rho}} \tag{4.2}$$

Equating equation 4.1 and 4.2 results in an equivalent area of:

$$A = \frac{\sqrt{\rho}\, C\, \Delta P^{n}}{C_d \sqrt{2}\, \Delta P^{.5}} \div 1000$$

It is customary to use Kirchoff's value for the discharge coefficient (C_d):.

$$C_d = \frac{\pi}{\pi+2} = 0.611$$

Therefore, $A = 0.001157 \sqrt{\rho} \cdot C \cdot \Delta P^{\,n-0.5}$

By definition the Equivalent Leakage Area (ELA) is the area of a single sharp-edged orifice that would yield the same rate of air flow as the combined openings in the test panel when both are subjected to a static pressure differential of 10 Pa. Therefore, CAN/CGSB-149.10-M86[5] standard gives an equation of the form:

$$ELA = 0.001157 \sqrt{\rho}\, C\, 10^{\,(n-0.5)} \qquad (4.3)$$

where ρ is the air density which is dependent on temperature and relative humidity (kg/m^3),

C is the air flow rate that would occur at reference ambient conditions and at a datum pressure of P = 10 Pa (L/s-Pa^n), and

n is a dimensionless exponent. Both C and n are derived from equation 4.1 and the test results.

For each test, the pressure in the cavity and the air flows out of the test panels, were represented using the equation $Q = C\,(\Delta P)^n$. The test values and the resulting C, n, ELA and incremental ELA values for each tie application, are provided in an separate Appendix which is available from CMHC. A sample infiltration log-log plot of flow lines using the equation $Q = C\,(\Delta P)^n$ to describe the test is illustrated in Figure 4.3. The datum line (before any tie installation) is illustrated by the bold line. As the ties are installed there is more flow, hence the higher flow lines.

According to the CAN/CGSB-149.10-M86 Standard, the ELA values should be derived at a static pressure differential of 10 Pa. Because of the inherent tightness of the test panel and the fact that a single tie did not have major impact on airtightness, it was very difficult to obtain ELA values at 10 Pa. Good (repeatable and numerically significant) results were obtained for pressures that typically ranged between 200 and 500 Pa. We were unable to test as low as 10 Pa. The 10 Pa values had to be found by extrapolation. Accordingly the static pressure differential of 250 Pa, which is within the test range, was also used as a base to calculate ELA values. Since some of the incremental ELA value at an extrapolated static pressure differential of 10 Pa resulted in negative values, only the ELA values at a static pressure differential of 250 Pa have been used to assess the relative impact of installing the different tie types. Accordingly only the incremental ELA values for static differential pressures of 250 Pa have been reported here.

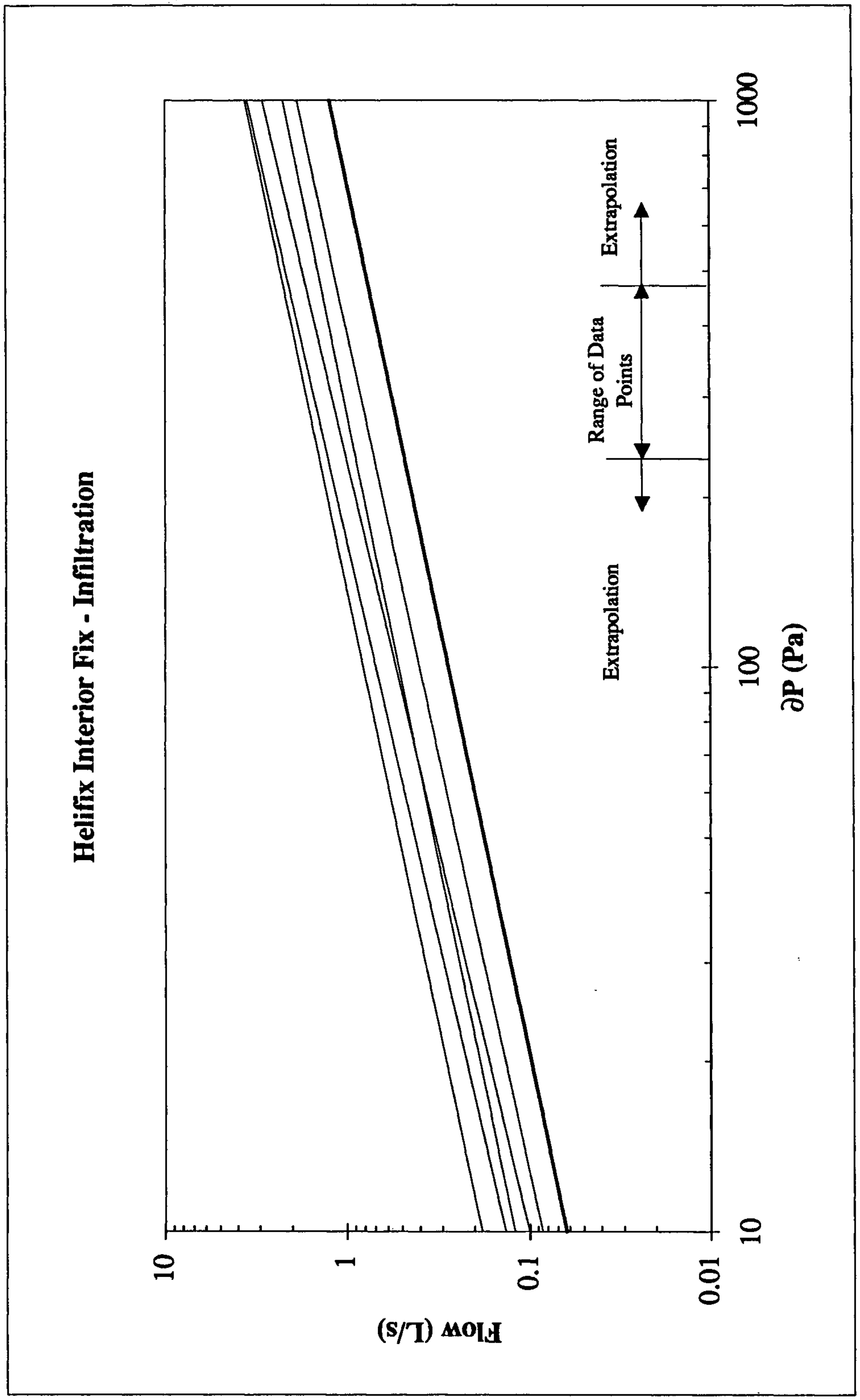

Figure 4.3 : Sample Infiltration Log-Log Plot of Flow Lines

4.5 Discussion of Test Results

The incremental ELA values at a static differential pressure of 250 Pa are presented in Table 4.2. To obtain some quantitative idea of the ELA values at 10 Pa refer to Figure 4.3 and it will be seen that the 10 Pa ELA values will be about an order of magnitude less.

There is considerable variability in the ELA values between tests for each tie. This is probably due to:

- **Irregularity in the nature and extent of installation damage.** This is, to some extent, due to the material responding in different ways to each drilled hole and the insertion and fastening of the tie.

- **Loose material causing directional behaviour.** The infiltration tests were done after the exfiltration tests. Blockage, due to loose material possibly acting as a flap, may occur during the infiltration test (suction), thus reducing the values for infiltration as compared to the exfiltration results and altering the next relative exfiltration results. If material is lodged in a hole, a strong pressure may open up the hole increasing the amount of air leakage. This may result in infiltration values being larger than exfiltration values or vice versa.
- **The airtightness of the test panel.** Some ties gave rise to very little additional air leakage, making it difficult to even measure an incremental air leakage value.

4.5.1 General Conclusions

Exfiltration nearly always gives larger ELA values than infiltration. This is likely due to the fact that under positive pressure, flaps (especially the paper or foil on the outer faces of either drywall or Thermax) will freely flap outwards—under depressurization (suction) flaps will tend to be sucked inward and provide more obstruction to air flow.

Retrofit Tie	Exfiltration ELA @ 250Pa	Infiltration ELA @ 250Pa	Exfiltration / Infiltration	Comments
1 Helifix Interior Fix	**26.2**	**19.0**	**1.4**	
	17.7	**15.0**	**1.2**	
	14.5	**10.1**	**1.4**	
	19.4	21.7	0.9	Outlier
	19.5	**12.0**	**1.6**	
Average of bold values	19.5	14.0	1.4	
2 Dur-O-Wal Interior Fix	**1.5**	**1.3**	**1.1**	
	1.7	**1.2**	**1.4**	
	3.7	**1.1**	**3.3**	
Average of bold values	2.3	1.2	2.0	
3 Helifix Exterior Fix	**15.5**	**8.4**	**1.8**	
A) Plain	**46.6**	**32.2**	**1.4**	
	22.6	**13.9**	**1.6**	
Average of bold values	28.2	18.2	1.6	
B) with plastic tube	**28.3**	**16.8**	**1.7**	
	4.4	**15.4**	0.3	Outlier
	30.1	**9.6**	**3.2**	
Average of bold values	29.2	13.9	2.4	
C) with dense Neoprene	**13.7**	**16.5**	**0.8**	
and plastic tube	2.3	-1.2	-2.0	Disregard (flap closed)
	7.4	**11.0**	**0.7**	
Average of bold values	10.5	13.8	0.7	
D) with soft Neoprene	**1.7**	**0.2**	**9.0**	
and plastic tube	0.5	**0.7**	0.7	Outlier
	6.1	**1.7**	**3.7**	
Average of bold values	3.9	0.8		
4 Dur-O-Wal Exterior Fix	**17.4**	**9.7**	**1.8**	
A) no sealant on the tip	1.5	**4.3**	0.4	Outlier (Test Problem)
	3.2	**1.0**	**3.1**	
Average of bold values	10.3	5.0	2.4	
B) with sealant on the tip	**2.0**	**0.8**	**2.6**	
	2.1	**1.9**	**1.1**	
	2.0	**1.3**	**1.6**	
	2.8	4.4	0.6	Outlier
Average of bold values	2.2	1.3	1.8	
5 Dinal Exterior Fix	**3.4**	**2.1**	**1.6**	
A) through drywall	**3.5**	**2.0**	**1.7**	
	3.2	**1.9**	**1.7**	
Average of bold values	3.3	2.0	1.7	
B) through thermax	**3.6**	-2.5	-1.4	Disregard (flap closed)
	0.3	**2.9**	**0.1**	
	2.3	10.3	0.2	Outlier (Test Problem)
	0.6	0.8	**0.7**	
Average of bold values	1.7	1.9		

Table 4.2 : Equivalent Leakage Area Values in mm²

For the Helifix tie, it would appear that an exterior fix (penetration of the insulating sheathing from the outside) is generally more leaky than the interior fix that penetrates the interior gypsum board as well as the vapour retarder and the insulating sheathing. Note that the drywall compound that was used to hide the tie and to resurface the face on the interior of the drywall after an interior fix application greatly reduced the amount of air leakage.

4.5.2 Tie-specific Conclusions

It can be seen from Table 4.2 that the Helifix tie resulted in more air leakage than the other tie applications tested. This is to be expected, given the shape of the Helifix tie and its method of installation.

ELA values for the three different attempts to modify the Helifix exterior tie are also listed in Table 4.2. The soft neoprene seal plus tube gave the best results in both the infiltration and exfiltration tests. The plastic tube by itself may not be an effective modification but using the neoprene was advantageous. However, each time a new tie was installed the neoprene plugs had to be re-tightened on the ties already in place in order to reseal the exterior hole. Loosening is caused by vibration during installation of subsequent ties. Blok Lok should devise other, better means of reducing the impact of installing the ties in BV/SS walls.

It can be seen from the interior fix test results that the Dur-O-Wal stainless steel rod and sleeve with epoxy produced much less air leakage than the Helifix interior fix. The airtightness of the Dur-O-Wal is largely due to the epoxy sealing all the holes. The ELA values for the Dur-O-Wal exterior fix are decreased when sealant is applied to the tip of the tie. Adding sealant to the tip significantly reduced the amount of infiltration and exfiltration resulting from the installation of this retrofit tie.

Neither Dinal tie application had much impact on the airtightness of the test panel, i.e., installation damage was small in both cases. If the air leakage results for the Dinal tie installed through the Thermax are compared to the exterior fixes for the other tie applications, it is clear the Dinal tie has the least impact.

In summary, it can be said that the incremental air leakage due to the installation of a retrofit tie is about the same for the Dinal and the Dur-O-Wal ties (provided a sealant is used with the Dur-O-Wal exterior fix). The Helifix tie has an impact that is an order of magnitude larger; this issue that needs further consideration by the manufacturer and supplier of this product.

4.6 Commentary

Whether or not the incremental damage due to the installation of a retrofit tie is significant or even disadvantageous must be resolved for the actual wall system involved.

For instance, if the primary air barrier is on the interior face of the steel studs, then an exterior fix retrofit tie may not affect the primary air barrier. This means that this particular retrofit has no effect on the flow of air across the wall. In this case, it could be argued that a decrease in the air tightness downstream of the primary air barrier could be beneficial in that vapour transfer and thus drying in winter, if needed, might be enhanced.

The nature and, in particular, the location of the primary air barrier is a very important consideration. In those instances where the remedial tie penetrates this barrier, then the impact of the remedial tie needs to be considered. It is therefore strongly recommended that an interior fix be properly resealed against leakage after its installation as, in many walls, the primary air barrier will have been penetrated.

If an air barrier is located close to the exterior of the wall, the installation of either an exterior fix retrofit tie could greatly affect the airtightness of the wall, since this air barrier will be penetrated. Moreover, the internal water barrier—for example the building paper—would have been penetrated and its effectiveness could be impaired.

5. Drainage Considerations

5.1 Introduction

Water that enters an exterior wall from either the interior or exterior should be drained or removed to the exterior; otherwise damage may result. This chapter discusses the need for proper drainage and how this drainage may be attained. It also examines the consequences for drainage of the five retrofit tie systems.

5.2 Drainage Provisions

The primary means of internal drainage in a BV/SS wall is the cavity or capillary break that is behind the brick veneer. Figure 5.1 illustrates the properties needed for good drainage. Proper construction and good design are necessary; for instance, the flashing must be properly installed and weepholes must be clear in order to drain water to the exterior.

If the cavity is not clear, water can be carried across the veneer by elements that bridge the cavity. Some elements that bridge the cavity are connectors, mortar dams and bulging insulation. Figure 5.2 illustrates the potential for obstructions in a BV/SS wall. In a field survey by Suter Keller Inc.[6] it was found that the cavity space was typically too small, and it was usually partially blocked with mortar fins or blocked with mortar droppings at the bottom of the wall. This condition restricts the circulation of air in the cavity, and the mortar bridging makes possible the storage and transfer of moisture across the cavity to the backup wythe.

Mortar droppings that block drainage openings can lead to saturation at these locations and therefore induce deterioration. Even where construction is carefully supervised, some mortar droppings will often partially fill the cavity at the bottom of the wall; hence, there is a tendency for the weep holes to be plugged. A variety of methods have been used to minimize mortar droppings and allow proper drainage. For instance rope or cord may be placed in the cavity by the mason and then removed before mortar droppings have hardened. Another method is to omit every third masonry unit in the course seated on the flashing. The openings serve as clean-out locations which are later filled with brick after the masonry work has been completed. These and other methods help create paths for drainage.

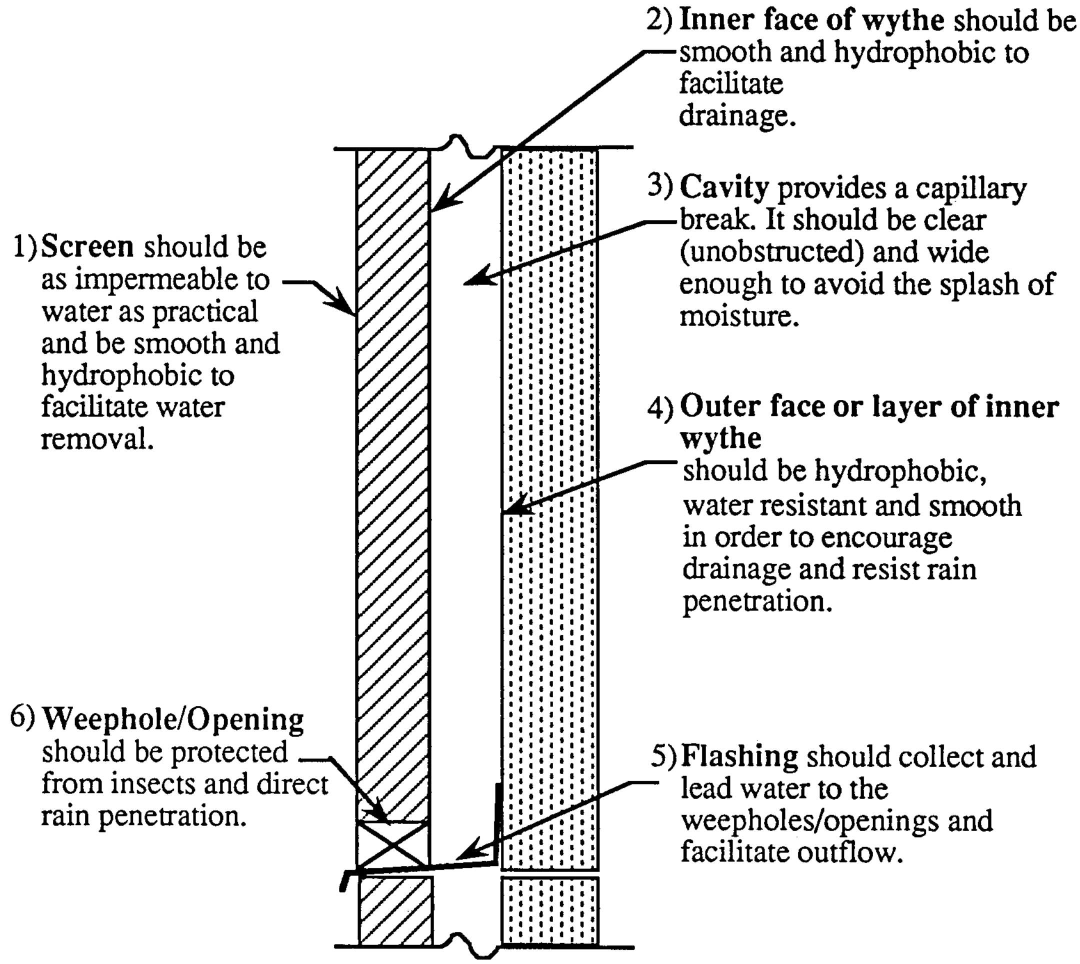

Figure 5.1: Drainage Considerations

5.3 Remedial Tie Concerns

Any tie (or other element) that crosses the cavity must be detailed and installed with care to ensure that it does not dam, bridge or channel water across the cavity into the interior portion of the building envelope. Since retrofit ties are installed after the wall has been built, no mortar will accumulate on top of the tie, as shown in Figure 5.2. The retrofit tie must not significantly increase the potential for water to be carried across to the interior after its installation.

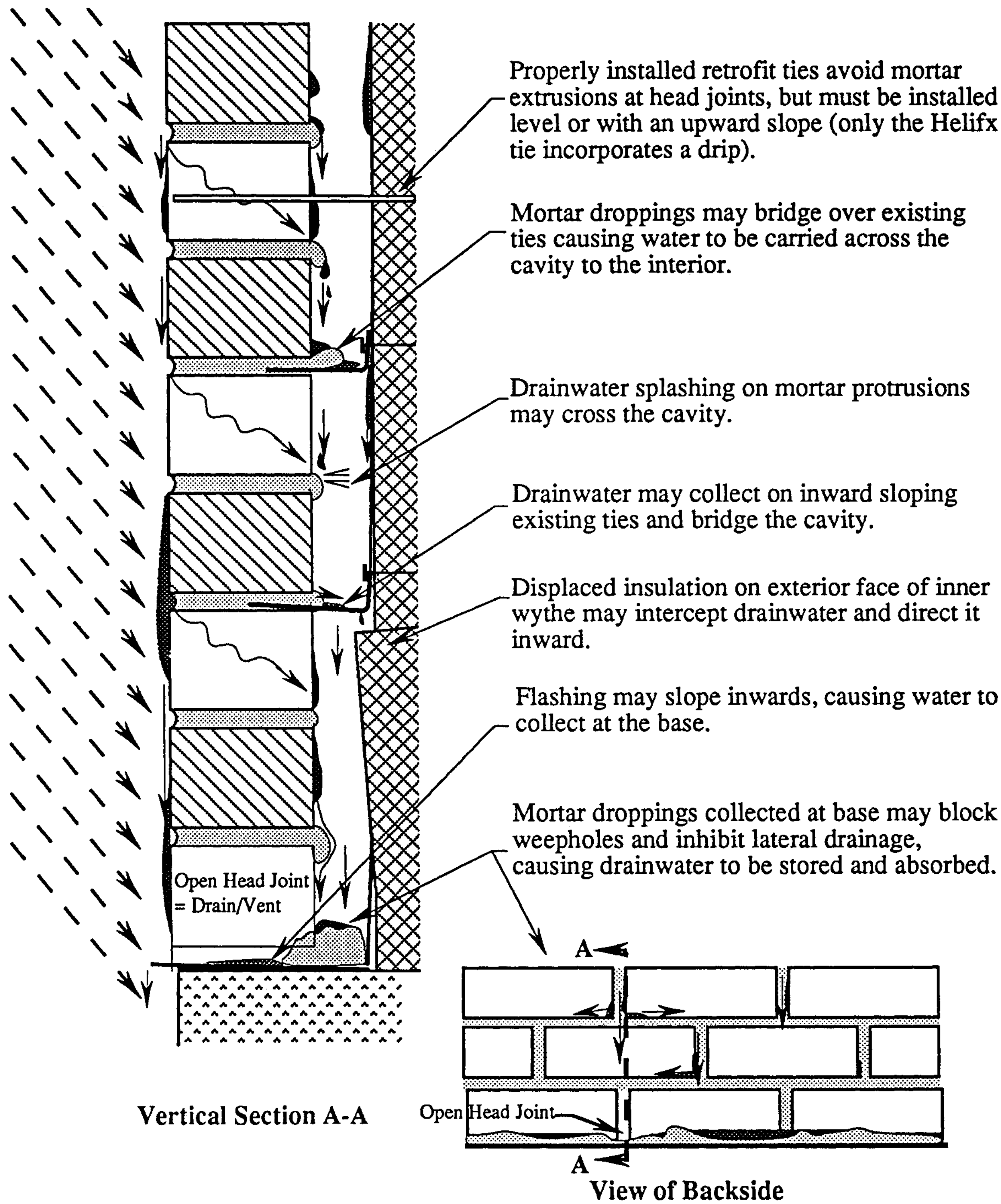

Figure 5.2 : Potential Obstructions in Walls

The Helifix interior and exterior applications have helical threads that provide a natural drip, thus reducing the chances of water making its way across the tie and into the stud space. The Helifix tie installer should ensure that the tie does not have an excessive slope downward to the interior; otherwise, water might travel across the cavity.

In the case of the Dur-O-Wal interior fix, the epoxy that extrudes out of the wire mesh tends to form an obstacle to flow and thus creates a drip in the cavity. This may cause water that forms or flows on the tie to drop down into the cavity. Care should be taken to seal the hole in the exterior sheathing with epoxy so that water will be stopped. In order to ensure proper sealing, the retrofit tie installer should also keep the diameter of the drilled hole to a minimum.

The Dur-O-Wal threaded bolt and expansion anchor has plastic bushings that are within the cavity space. These bushings should prevent water from traveling across the tie to the interior.

Any water that collects on the Dinal tie should not be carried any further than the exterior sheathing because the expandable rubber tube ought to prevent any water ingress past this point. A neoprene drip could be added to the rod of the Dinal tie at the cavity location in order to divert the water down into the cavity.

In general, it is unlikely that the presence of the remedial ties will worsen the overall drainage function. However, these additional ties do little to improve the situation. If rain water penetration is excessive, every measure should be taken to reduce this amount—for example, a suitable exterior coating can be used.

6. Corrosion

6.1 Introduction

Corrosion of metal connectors and the steel stud framing (especially the bottom track) can seriously reduce the useful life of a BV/SS wall. While the long-term performance of the framing is important and much of what follows applies to the framing, this chapter focuses on the remedial tie systems and their connection to other materials in the BV/SS walls in an existing building.

The possibility of cladding failure due to tie corrosion depends on the location and number of ties affected and the loads on the cladding. Corrosion is a process involving the deterioration or degradation of metal components. Corrosion rates will be higher where there is frequent wetting and drying as this ensures fresh supplies of oxygen in addition to moisture. Corrosion of the ties may lead to problems, some of which include cracking, rust staining and spalling in the masonry veneer, and loss of pull-out strength in the steel stud backup. That this topic is both relevant and important is evident from two recent references: the reports entitled "Review of Corrosion Resistance of Metal Components in Masonry Cladding on Buildings" by A.H.P. Maurenbrecher and R.J. Brousseau[7] and "The Performance of Cavity Wall Ties" by J.F.A. Moore.[8]

Corrosion resistance requirements tend to be dependent on past experience and involve judgment. The existing requirements may, however, be inadequate especially with changing materials and exposure conditions. The use of insulation in cavities, higher buildings. and thinner walls have increased the environmental vulnerability of wall systems.[7] In the case of galvanized ties, it has been determined that ties are likely to lose their zinc coating sooner than originally anticipated.[8] After the zinc is lost, the steel can rust rapidly, and any further satisfactory structural action of a tie is limited to only a few years. Many ties may have to be replaced.

There is a potential for corrosion of the tie within the brick veneer and across the air space at the stud location. Both areas must be considered for potential corrosion to determine the performance of the retrofit wall ties. Before the corrosion potential of the ties and their connections in the BV/SS system is discussed, the factors that increase the likelihood of corrosion and the nature of galvanic corrosion must be considered.

6.2 Factors that Promote Corrosion

Moisture within a BV/SS wall occurs as a consequence of rain penetration or condensation due to vapour diffusion or air leakage. Drainage, of course, is needed to avoid water accumulation. For all practical purposes, one must assume that moisture is present within the brick and the cavity.

One additional factor contributing to corrosion is mortar carbonation due to moisture entry through the facade. Carbonation is the reaction of atmospheric carbon dioxide, in the presence of moisture, with the alkalis in the mortar to form carbonates. The alkaline conditions in the mortar provide some initial protection against corrosion, but carbonation reduces this alkalinity. Once the mortar has carbonated, corrosion will accelerate. During the carbonation process, the pH of the mortar can fall from about 12-13 (alkaline) to 7-8 (neutral).[7] Zinc coatings dissolve in liquids with a pH below about 6. Indicator tests on samples of mortar from walls have shown that carbonation of a mortar bed can be substantially complete in about 10 years.[7] Higher porosity mortars (higher water/cement ratios and lower cement contents) will carbonate faster, as will mortars adjacent to masonry units having higher porosities.

Chlorides and other inorganic salts destroy the passivity of the mortar and cause accelerated corrosion.[9] Chlorides in mortar may occur naturally in the sand, or may be added as a set accelerator or anti-freeze to mortar, or derived from de-icing salts. A field survey by Suter Keller Inc. [6] indicates that in many older buildings the mortar has a chloride content that exceeds the ACI published threshold level of 0.2% by weight of cement. Above this level, corrosion of steel occurs. Chlorides are of particular concern with regard to cavity wall construction in maritime locations and in urban snow-belt areas where traffic/wind tunnel conditions may carry de-icing salts as high as eight to ten floors above ground. It has been found that, in extreme situations, chloride levels as low as 50 ppm can initiate failure.[10]

6.3 Galvanic Corrosion

When dissimilar materials are placed in contact, the interaction between the dissimilar materials may accelerate deterioration as a result of chemical interaction. The degree of galvanic/bi-metallic corrosion that can occur between dissimilar metals depends on the intimacy of contact, the type of electrolyte, and the voltage developed between the two metals. An electrical potential will develop causing a current to flow whenever a suitable flow path is provided.[11] Such corrosion, however, occurs only in the presence of both oxygen and water. Corrosion of the less-corrosion-resistant metal (anode) is usually increased, and attack on the more-resistant-material (cathode) is decreased. The weaker link in the chain becomes weaker. The anode is one electrode of an electrolytic cell at which oxidation is the principal reaction. The cathode is the other electrode at which a net reduction reaction occurs. Therefore, the less-resistant metal becomes the anode while the more-resistant metal becomes the cathode.[12]

The driving force (difference of potential) available to promote the electrochemical corrosion reaction is to some extent reflected by the position of this material in the galvanic series (Table 6.1). The galvanic series is a list of metals and alloys arranged according to their relative corrosion potentials in a given environment. The severity of galvanic corrosion is dependent on the aggressiveness of the atmospheric environment. Also, the further apart two metals are in the series, and thus the greater the potential difference between them, the greater is the driving force for galvanic corrosion. The metal that is higher in the galvanic series is subject to corrosion by metals lower in the series. The galvanic series provides only qualitative information and can serve only as a guideline. Table 6.2 is useful in that it gives estimates of the severity of increased corrosion for mild steel, zinc, and stainless steel in contact with other metals in different atmospheric conditions.

With bi-metallic corrosion, the relationship between the anode and the cathode surface area is very important. The risk of serious attack is great when the anode area is small in comparison with that of the cathode. A fastener whose surface is small compared to the metal to be fastened will have a high current density and, therefore, will be subject to rapid corrosion. Therefore, as a general rule, a fastener in a given environment should be lower in the galvanic series than the material to which it is to be fastened, in order to reduce the magnitude of accelerated corrosion due to dissimilar metals.

Corroded end
Anodic or active end

Magnesium
Zinc
Aluminum
Cadmium
Steel or iron
Stainless steel (Active)
Soft Solders
Lead
Tin
Nickel
Brass
Bronzes
Copper
Nickel - Copper Alloys
Stainless steel (Passive)
Silver Solder
Silver
Gold
Platinum

Cathodic or noble end
Protected end

Table 6.1: Galvanic Series [13]

Metal in contact	Steel (Carbon and low alloy)			Zinc and its alloys			Stainless steel		
	Rural	Industrial/ Urban	Marine	Rural	Industrial/ Urban	Marine	Rural	Industrial/ Urban	Marine
Aluminum and its alloys	0	0	0	0	0-1	0-1	0	0	0
Aluminum Bronzes	2-3	2-3	3	0-1	1	1-2	0	0	(0-1)
Brass	2-3	2-3	3	0-1	1	0-2	0	0	(0-1)
Cadmium	0	0	0	0	0	0	0	0	0
Cast irons	0-1	0-1	2	0-1	1	1-2	0	0	-
Copper	1-2	1-2	(2-3)	0-1	1-2	1-2	0	1	(0-2)
Cupro-nickels	1-2	1-2	3	0-1	0-1	1-2	0	1	(0-2)
Lead	0-1	0-1	0-1	0	0-1	0-1	0	-	0
Stainless Steel	1	-	2-3	0-1	0-1	0-1	...	...	...
Steel (carbon and low alloy)	...	...	...	0-1	1	1-2	0	0	0-1[4]
Zinc and its alloys	0	0	0	...	...	...	0	0	0

Table 6.2: Additional Corrosion Resulting from Contact with Other Metals [7]

Key

0 Will suffer either no additional corrosion, or at the most only very slight additional corrosion, usually tolerable in service.

1 Will suffer slight or moderate additional corrosion which may be tolerable in some circumstances.

2 May suffer fairly severe additional corrosion and protective measures may be necessary.

3 May suffer severe additional corrosion and the contact should be avoided.

Notes

Ratings in brackets are based on very limited evidence and hence are less certain than other values shown.
Dash indicates that no evidence is available and no general guidance can be given.
The table shows *additional corrosion* and the symbol 0 should not be taken to imply that the mental in contact need no protection under all conditions of exposure.

[1] Under atmospheric conditions other factors, such as area wetted, presence of spray, degree of shelter and crevices, will assume importance. Additional corrosion will depend on the relative areas of the metals in contact. If the area of carbon steel or low alloy steel is equal to that of the metal with which it is in contact, then the effect will be as shown in the table. If the area of the carbon steel or low alloy steel is small in relation to the area of the other metal, then considerable extra corrosion may result. If the area of carbon or low alloy steel is large, then the effect may not be so marked.

[2] Zinc is frequently used as a sacrificial coating on other metals. Additional corrosion will reduce the life of the coating.

[3] Crevice corrosion may occur.

[4] Corrosion products from the metal in contact may be deposited on the stainless steel, at best discoloring the stainless steel and at worst promoting corrosion of the stainless steel under the deposit.

[5] Effect will depend on relative areas over which water, e.g. rain or condensation, may be retained.

6.4 Code Provisions for Ties and the Steel Stud Assembly

In most existing brick clad buildings in North America, the masonry ties are galvanized mild steel. The most common coating is zinc, which provides both a protective layer and galvanic (sacrificial) protection. There are different methods of applying zinc to steel ties, but the two most common methods are hot-dip galvanizing and electroplating. The life of galvanized ties in a situation conducive to corrosion depends on the thickness and consistency of the zinc coating and the thickness of the steel.

Ties made of stainless steel are commonly specified for stone masonry, but their use in brick or blockwork is rarely specified. Stainless steel owes its corrosion resistance to its chromium content. Although stainless steel is very resistant in many situations, there are environments in which it does not work well—for example, when it is under stress in environments with high levels of chlorides.

The CSA standard on Masonry Connectors, CAN3-A370-M84, requires that ties have sufficient corrosion resistance.[14] A tie must be galvanized as specified in clause 4.2.2 of the standard. The minimum standards for galvanizing is presented in Table 6.3.

A 1993 draft of the new proposed CAN3-A370 [15] (and now the 1994 issued Standard) introduces three levels of corrosion protection, as follows:

Level I — Ties that are fabricated from unprotected carbon steel or steel whose zinc coating is less than those outlined in Table 6.4.

Level II — Ties that are fabricated from carbon steel that is hot-dip galvanized after fabrication to at least the minimum standard in Table 6.4. Other materials or coatings may be used, provided they have proven equivalent corrosion protection.

Level III — Ties that are fabricated from stainless steel material in accordance with Table 6.5. Other materials may be used, provided they have proven equivalent corrosion protection.

This standard also proposes that repair connectors be provided with Level III protection where the existing masonry connectors have experienced a corrosion-related problem. This means that for all practical purposes, if remedial ties are required because of material deterioration then stainless steel remedial ties or their equivalent must be used. Further, the proposed code, clause 11.1.2, states that all parts of a repair shall be made from the same material or compatible materials. This last clause would seem to suggest that the retrofit tie should not involve dissimilar metals.

	ASTM Standard	Coating Class
Wire ties and continuous reinforcing (hot-dip galvanized)	A 153	Class B2 458 g/m^2
Hardware and bolts	A 153	See ASTM A153
Strip, plate, bars and rolled sections (minimum thickness 3.18 mm)	A 123	610 g/m^2
Sheet (less than 3.18 mm thick)	A 123	305 g/m^2 on material 0.76 mm thick

Table 6.3: Minimum Standards for Galvanizing [14]

Type of Connector	Standard	Minimum mass of zinc coating, g/m^2
Wire ties and continuous wire reinforcing	ASTM A153 ASTM A123	458 460
Connectors made from strip, plate, bars and rolled sections thickness ≥ 3.2 mm < 3.2 mm	ASTM A123	 515 460
Conventional corrugated strip ties thickness 0.76 mm	ASTM A123	320
Hardware and bolts Class 4 Class 5	CSA G164	300 (see Note 2) 460

Notes:

1. The mass of coating is in terms of grams per square metre of surface area (on each face for sheet product).
2. Hardware and bolts exposed in the cavity space or in direct contact with masonry veneer or the exterior wythe of cavity walls shall have a mass of zinc coating not less than 460 g/m^2.
3. The minimum mass specified may exceed the required mass given in the applicable standard. The extra coating thickness is required for corrosion protection.
4. The hot-dip galvanizing process may not be able to deposit sufficient zinc on thinner steel connectors to provide adequate corrosion protection.
5. Based on mathematical calculations, 100 g/m^2 corresponds to a coating thickness of 14.1 μm.
6. See Clause 12.7 for methods of test for zinc thickness.

Table 6.4: Minimum Coating Mass for Connectors Hot-Dip Galvanized after Fabrication [15]

Material	Applicable Standard	Grade or Type
Steel wire	CSA G30.3	
Steel sheet and strip	ASTM A570	40
Steel bars, plates, angles, etc.	CSA CAN3-G40.21-M	W
Steel bolts	ASTM A307	A
Stainless steel	ASTM A666	304,316
Stainless steel wire	ASTM A580	304,316

Table 6.5: Recommended Materials for Connectors [15]

6.5 Remedial Tie Systems

The Dur-O-Wal stainless steel rod and sleeve with epoxy and the Helifix interior and exterior ties are made solely of grade 304 stainless steel. The Dur-O-Wal Threaded Bolt and Expansion Anchor comprises two metals; a brass expansion anchor and a stainless steel rod. All metal parts of the Dinal tie are made of galvanized steel.

The Grade 304 stainless steel ties, by themselves, are not very susceptible to corrosion. If, however, there are high levels of chlorides (e.g., on the sea coast), these stainless steel ties could corrode. The other main concern is the high potential for corrosion at the steel stud/tie interface. When ties are screwed or tapped in, the galvanized coating of the steel stud is damaged, leaving the underlying steel unprotected. The probability—and the practical consequences—of corrosion at the tie/flange connection, perhaps, need to be quantified. But, as the tie systems rely heavily on a tight connection, local corrosion of the steel stud at the tie connection must eventually reduce the capacity of the tie to resist load and displacement. Since the tie and the steel stud are made of dissimilar metals, the rate at which the steel stud corrodes will increase if moisture is present (Table 6.2). It has been recommended elsewhere that a connection made with dissimilar metals be insulated using non-conductive gaskets.[16] The Dur-O-Wal (interior fix) will be mostly covered in epoxy, which may seal the area at the stud/tie connection, thereby reducing the ingress of moisture.

Both the Helifix and Dur-O-Wal interior fixes are connected to both flanges of the steel stud. The outer flange is the more likely to be exposed to moisture. The inner flange connection has a better chance of staying dry and, therefore, corrosion at the inner flange location is less likely. Furthermore, the two flange connection has some built-in reserve against failure, for instance, if the connection at one flange fails, then resistance is still available from the connection at the other flange.

The Dur-O-Wal exterior fix threaded bolt and expansion anchor has a brass expanding shell threaded onto the stainless steel rod which, in turn, is screwed into the galvanized steel stud. There are two locations where dissimilar metals occur: along the brass expansion anchor in contact with the stainless steel rod. and at the stainless steel rod to galvanized steel stud interface. Since there is a good chance of prolonged wetting at the interior face of the brickwork, the brass component may have a tendency to corrode. This tie will be more vulnerable to corrosion at the tie/flange interface compared to the ties made solely of stainless steel because the tie itself consists of dissimilar metals. However, the longer the length of the stainless steel between the brass and the steel stud, the greater the resistance. Again, the probability of corrosion at the tie/flange interface is an important consideration, as this tie system is heavily dependent on a small amount of metal at the screw/stud interface.

The Dinal tie which is used in an exterior fix application, is currently made solely of a galvanized steel. This does not satisfy the Level III requirements. The greatest risk of corrosion occurs at the brick veneer/tie interface because this area retains moisture over longer periods of time. If the tie loses its zinc coating, the steel shaft can rust. It has been suggested that some warning of corrosion would be given because the volume of rust formed would generate expansive forces which would cause progressive disruption of mortar beds, probably before the structural connection is impaired.[8] It should be noted that at the tie/steel stud interface, the expanding fastener works in shear and bearing—it does not depend on interfacial bond. Thus the Dinal tie has, relative to the other ties tested, a more durable stud connection. There is no reason that stainless steel could not be used for the Dinal tie. If the tie is changed to stainless steel, it will have the same corrosion characteristics as both the Helifix and the Dur-O-Wal interior fixes as well as the Helifix exterior fix, but also a more durable connection to the steel stud.

7. Torsional Stiffness Considerations

7.1 General

When existing BV/SS walls are opened up, it has frequently been found that the light gauge steel studs have not been provided with adequate torsional restraint. Adequacy to resist lateral instability, weak axis buckling and torsion is somewhat empirically prescribed in at least two references [17, 18] as follows:

- steel bridging at a maximum spacing of 1200mm on centre is required at mid-height between floors,
- proper two screw connection of the studs to the bottom and top tracks (and proper attachment of these tracks) is needed,
- no reliance is to be placed on the interior and/or exterior sheathing.

An all-too-common scenario involves one or more of the following:

- inadequate or even a complete absence of bridging,
- improperly connected bridging,
- improper or inadequate stud to track inter-connection,
- an exterior sheathing that, in reality, provides little, if any, contribution to the torsional stiffening of the steel stud, e.g., fibreglass board insulation

Torsional restraint or the lack of bracing is a significant issue. Firstly, it is such a common occurrence. Secondly it is a clear cut and measurable deficiency. Thirdly, remedial action can be very expensive, usually involving the removal of the interior sheathing. What makes it a priority issue is the fact that the sheathings cannot, in design, be relied upon to make any contribution.

BV/SS enclosure walls will usually have a gypsum drywall interior sheathing. Many BV/SS walls will also have an insulating sheathing on the outer face of the framing. Laboratory tests [19] have shown that any composite structural action that initially exists will be dissipated by enlargement of the holes or other loosening due to the repeated cycles of lateral loading. Some materials such as glass fibre or mineral wool board insulation are not stiff enough to provide any restraint. Also, some sheathing materials (for example, gypsum drywall) can lose their structural integrity when subjected to a moist environment. Therefore, for the medium to longer term, it must be assumed that most screw-attached sheathings cannot be relied upon to provide flexural stiffening nor to provide much torsional restraint to the stud wall portion of the wall system.

Additional ties are often needed because the existing ties are either inadequate or have corroded. The need for replacement or supplementary lateral ties offers an opportunity to provide torsional restraint relatively inexpensively. It is necessary therefore to identify the issues involved for torsional stiffening.

7.2 Contributors to Torsional Restraint

7.2.1 Track to Stud Connection

In Figure 7.1 a representative drawing of the steel stud framing system is shown. The track studs must be properly attached at the top and bottom. If the stud is tight fitting and properly connected to each track, with self-tapping screws on both faces, each end is torsionally equivalent to a simply supported end support. This is a connection that cannot twist but is free to warp and there can be no transfer of longitudinal stress.

In the event that the stud and track are not snug fitting or only one screw (or even less) is provided or if improperly attached, it follows that some twist or torsional rotation could also occur at these end supports. Not only does this constitute a construction deficiency but it also complicates post-facto structural analysis.

7.2.2 Bridging to Stud Connection

As is evident in Figures 7.1 and 7.2 there are two reasons why the bridging is so important:

(i) provided the flanges and the webs of both stud and bridging are snug fitting and tightly connected, the joint so formed at mid-height can be considered to be a torsionally fixed support. Thus at this built-in joint there can be neither twisting nor warping.

(ii) full torsional restraint at mid-height means that the length of the torsional members involved is h/2 rather than h. Moreover these shorter members are fully fixed at one end. It follows that proper bridging would cause at least an eight (2^3) fold increase in the torsional stiffness of the steel stud.

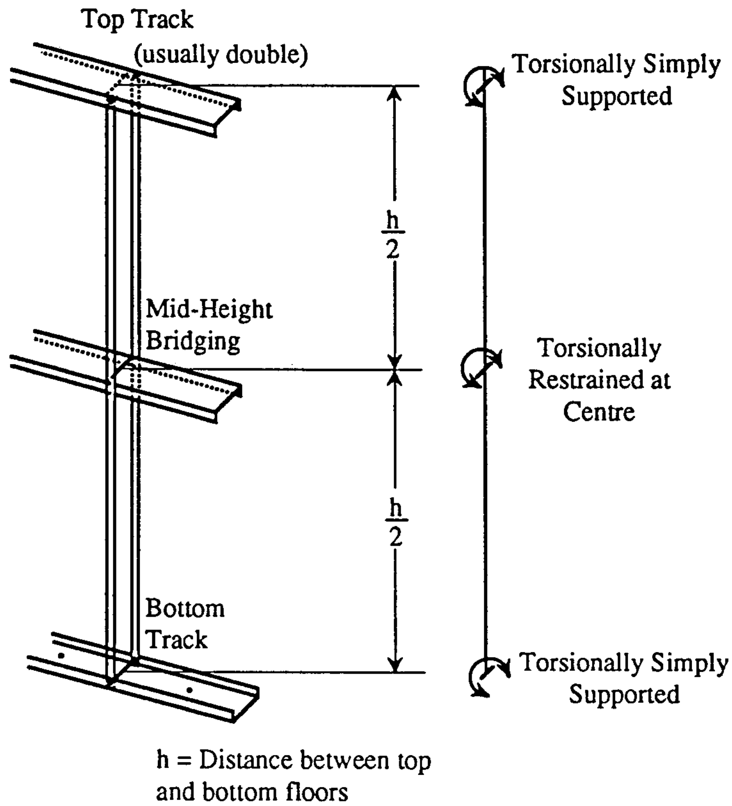

Figure 7.1: Steel Stud Framing System

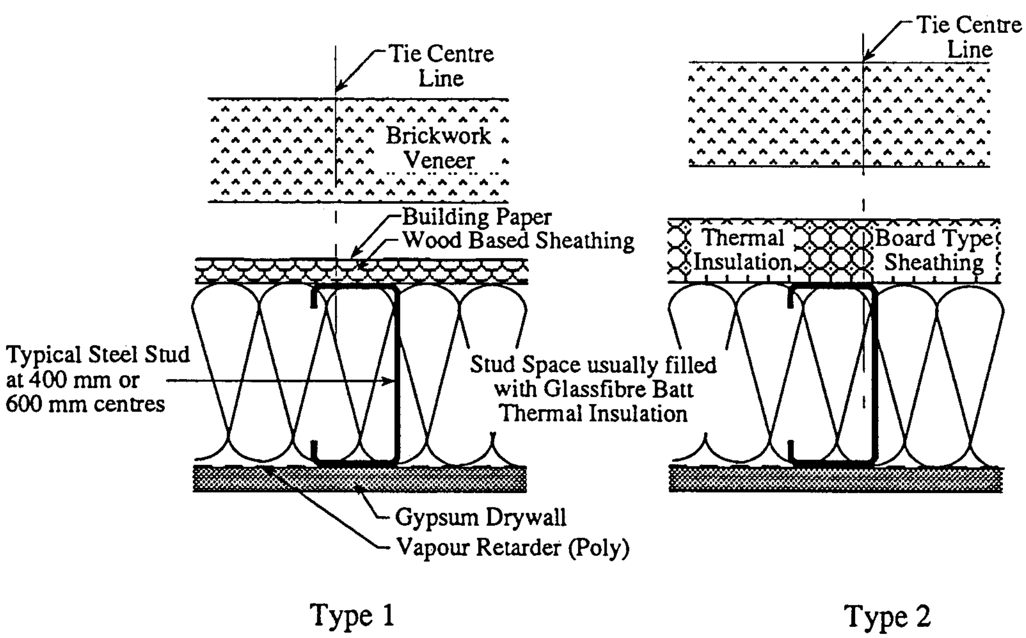

Figure 7.2: Representative Sections through Two Types of BV/SS Walls

7.2.3 Sheathing

While in design it may be appropriate to ignore the restraint to twisting provided by any sheathing, in reality and certainly over the short term, torsional restraint is available. Actually in some walls, it may be that the sheathing is providing most, if not all, of the torsional restraint that actually develops.

The mechanics whereby a torsional restraining effect is introduced is illustrated in Figure 7.3 (i) and (ii). Obviously the flange forces that develop are a function of:

- the nature of the sheathing to stud flange connection i.e., the size and location of the screw, the torque, skewness, etc.
- the snugness of the screw attachment with respect to both the steel flange and/or the sheathing. Obviously prior load history will have some bearing on the nature of the attachment.
- given that the masonry tie will connect with the stud at or close to the exterior flange, it follows that the exterior sheathing (if any) is relatively more important than the gypsum drywall on the interior. Not only will the sheathing provide stiffening to flange flexure but also it can cause the tie force to be advantageously distributed thereby reducing the torsional moment. For example, with very stiff sheathing the eccentricity of the load reduces from (e_p+e_s)to e_s as shown in Figure 7.3

While the current design recommendation is not to place any reliance on the sheathing, this is, in fact, a conservative assumption especially for twist or torsion. In re-evaluating an existing wall, the designer of the remedial solution has to judge this issue on a wall-by-wall and building-by-building basis. Obviously there is considerable merit in the use of relatively stiff (both in and out-of-plane) exterior sheathing, especially one that is not susceptible to load cycling or dampness and is also thermally efficient.

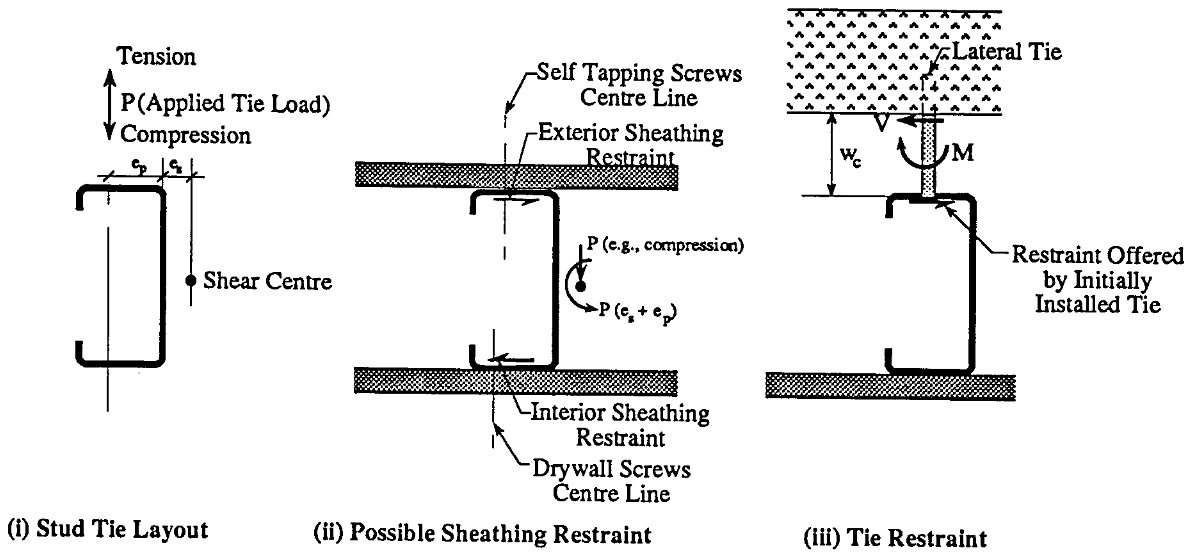

Figure 7.3: Torsional Loads

7.2.4 The Initially Installed Tie System

Because the brickwork is rigid in its own plane and because each masonry tie will have some in-plane (horizontal) stiffness in both bending and shear, it follows that each tie makes a contribution to torsionally restraining the stud. As shown in Figure 7.3 (iii), the magnitude and extent of this restraint is effected by the following:

(i) the flexural stiffness and the shear stiffness of the tie, both in the horizontal plane.

(ii) the end conditions, especially the degree of flexural fixity at the face of the brickwork and the manner of stud attachment.

(iii) the horizontal snugness (lack of slackness or free play) in the connections (stud to tie, tie to brickwork, etc.).

(iv) the span or the clear distance between stud flange and rear face of the brickwork veneer.

(v) the number of ties and their distribution along the stud.

Depending on the tie system employed, the quality of installation and its condition, there will be some torsional stiffening provided by the tie.

7.3 Evaluating the Existing Condition

To quantify the torsional restraint that collectively exists in a representative stud in a BV/SS wall is, in theory, relatively easy to do, but involves a lot of arithmetic. There are, however, two major obstacles to arriving at a reasonably accurate and trustworthy answer.

1. The first obstacle is defining precisely the structural system that is representative of the actual wall i.e., defining dimensions, end or boundary conditions and the loads involved. This can only be resolved by judicious opening up and inspection of the as-built wall system. Only then can the appropriate assumptions with regard to the collective contribution to torsional restraint from the stud end supports, bridging, sheathing and tie system be made.
2. The second concern involves confirmation that this structural modelling is reasonably correct and that the effort is worthwhile.

To date very little experimental work has been done to physically study the problem. The realization that the provision of remedial or supplementary ties can also be used to stiffen the studs should give some impetus to developmental work on in-place torsional stiffness.

7.4 Torsional Restraint from Retrofit Ties

If torsional restraint of steel studs in an existing BV/SS system is inadequate, installing retrofit ties serves to provide torsional stiffening. Adding the retrofit (remedial or supplementary) ties will be quicker and much less expensive than opening up the wall and installing lateral steel bridging and repairing top and bottom connections.

Figure 7.4 illustrates the potential for restraint available if additional ties are added either from the inside or the outside. Of course these new ties will each develop a compressive or tensile transfer load, P, which produces a tendency for twist. They will, in fact, also provide for a better distribution of lateral load along each stud. However, they also provide some resistance to twist. It is therefore desirable to minimize the applied torque, to maximize the torsional restraint and to be able to quantify the results. To do so requires a combination of common sense, some practical experience with BV/SS walls, and some structural expertise.

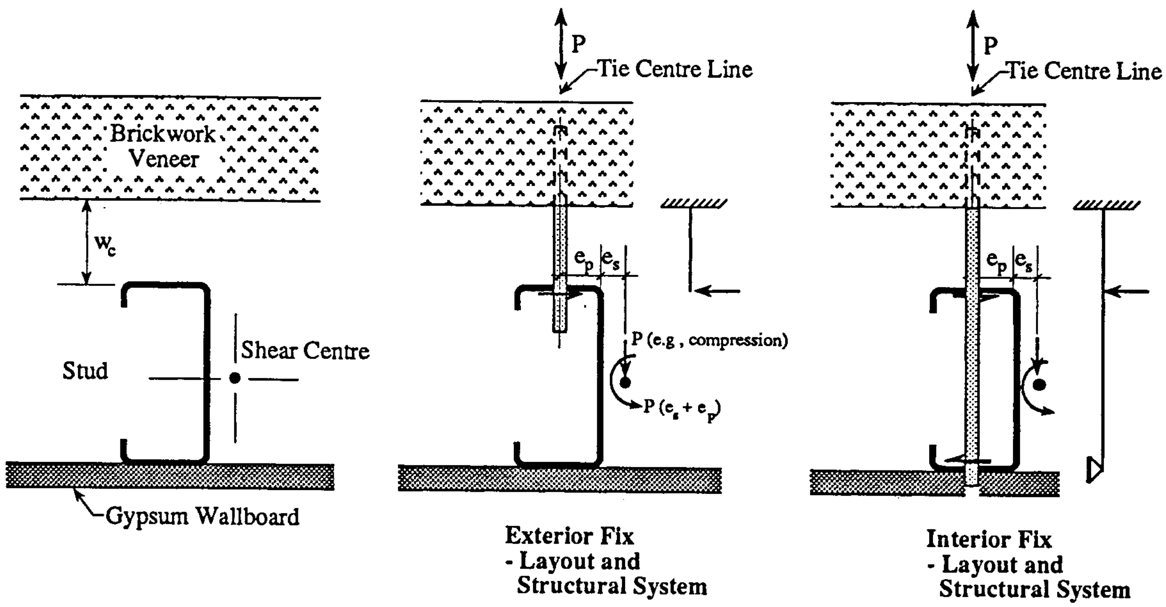

Figure 7.4: Potential for Retrofit Tie Restraint

In order to reduce the applied torque, two advantageous steps are firstly to attempt to minimize e_p (by ensuring the tie is installed nearer to the web) and secondly, by design, to reduce the value of e_s. Also it may be advantageous to maximize the flexural and shear stiffness of the tie in the horizontal plane and also to minimize w_c (the distance between stud and brickwork). Perhaps the best strategy is to use an exterior fix that penetrates both flanges of the stud. As shown in Figure 7.4, the interior fix tie will be engaged at both flanges and, provided some in-plane restraint from the warm dry side drywall can be relied upon, then the torsional stiffness of the stud will be greatly enhanced.

To obtain some idea of the contribution to torsional restraint provided by an interior or exterior fix consider the different structural systems that are developed. These sample structural models are illustrated in Figure 7.4.

In effect the torsional resistance provided by the interior and the exterior fix retrofit ties can be modelled by a cantilever and a propped cantilever respectively. Some indication of the quantitative difference between the contribution from an interior relative to an exterior fix may be obtained by considering a representative example. For a 45mm cavity and a 90mm stud width, the load required to induce a specific displacement of the tie at the location of the outer flange of the stud is 2.5 times larger for an interior than that required for an exterior fix application. Clearly the interior fix has the advantage.

7.5 Commentary

In the previous sections the issue of torsional restraint of the steel stud framing has been reviewed for two situations, namely, the existing BV/SS wall and when supplementary or remedial ties have been installed. Each contributor to torsional deformation has been identified and discussed. It is evident that the provision of remedial or supplementary ties can torsionally stiffen the steel studs.

To quantify the issue is, in theory, relatively straightforward, but this is beyond the scope of this report. As the issue of economic and effective remediation of the steel stud framing is an important concern, it is recommended that some additional analysis and the appropriate field and laboratory work be conducted. It is also recommended that this work be done with the support and involvement of the steel stud industry.

8. Cavity Fill

8.1 Background

It would be a great advantage if remediation could involve doing something to existing BV/SS walls to reduce rain wetting and water penetration relatively quickly, quietly (for the occupants' sake) and cheaply (without removing large sections of the existing wall). One option is to fill up the cavity with an appropriate filler material. It is possible to fill the cavity of a BV/SS wall with either a cementitious or an insulation material. A cementitious material such as grout could be used if there is a need to increase the stiffness of the wall. An insulating filler could also be used to increase the thermal resistance of the wall. In this section the advantages and disadvantages of a cavity filler are considered. Some experimental work conducted by the British Building Research Establishment (BRE)[20] is also discussed.

8.2 Types of Fillers

8.2.1 Cementitious Filler

The most likely type of cementitious filler is grout (preferably a low-density, air-entrained and flowable mixture). To our knowledge, grout has not yet been used in a flexible backup situation such as a BV/SS wall, but it has been successfully used in a Brick Veneer/Concrete Block (BV/CB) wall system. Of course, a grout filler can be used only if a relatively stiff and non-organic sheathing has been used on the outer face of the framing.

The advantages of filling the cavity with grout are as follows:

- it augments tensile transfer and provides a compression medium for lateral load,
- it increases stiffness and strength of the wall,
- it protects the tie from any further corrosion, and
- it increases the airtightness of the wall.

The use of a polymer-modified grout would reduce shrinkage and increase tensile strength.

The disadvantages of filling the cavity with grout are as follows:

- it increases vapour resistance at the exterior of the wall providing a greater potential for a dew point and hence condensation;

- it increases thermal conductivity; and
- it changes the wall from a screened to a mass system.

8.2.2 Insulating Filler

The advantages of filling the cavity with insulation such as urethane foam are as follows:

- it stiffens the brick veneer somewhat,
- it supplements compression transfer of lateral load,
- it increases the thermal resistance of the wall,
- it reduces the risk of exfiltration condensation, and
- it reduces the effects of thermal bridge of the steel stud.

The disadvantages of filling the cavity with insulation are as follows:

- it may increase the risk of water penetration because the insulation now bridges the cavity, and
- adds a low-heat-capacity substrate to the back of the brick.

In practical terms, the type of filler is only one issue. Two other critical issues are:

(i) the need for a suitable exterior sheathing to the steel stud. This sheathing must be compatible with or protected from the filler. It must be stiff enough to accommodate the filler during filling and hardening. Once hardened, the filler in combination with the brick veneer and the steel stud elements, must be structurally able to accommodate lateral loads, any differential movements and be safe with respect to fire and smoke.

(ii) the need to control moisture. It may be necessary to reduce the rain loading by using an appropriate sealer coating on the outer surface of the brick veneer.

At this time, we doubt whether many existing BV/SS systems are suitable for the use of a cavity filler.

8.3 Research Performed by the BRE

Full-scale water-penetration tests of brick veneer/block backup walls in houses with nine different retrofit cavity fills were conducted by the British Building Research Establishment (BRE)[20] in 1982. A realistic amount of water was applied to several houses with similar wall systems. Measurements were made of the volume of water applied, the amount of leakage into the cavity, and the penetration of water across the cavity.

On each house, walls were also tested before the installation of any cavity fill. These tests identified signs of water penetration across the cavity. The commonly observed transfer routes are illustrated in Figure 8.1.

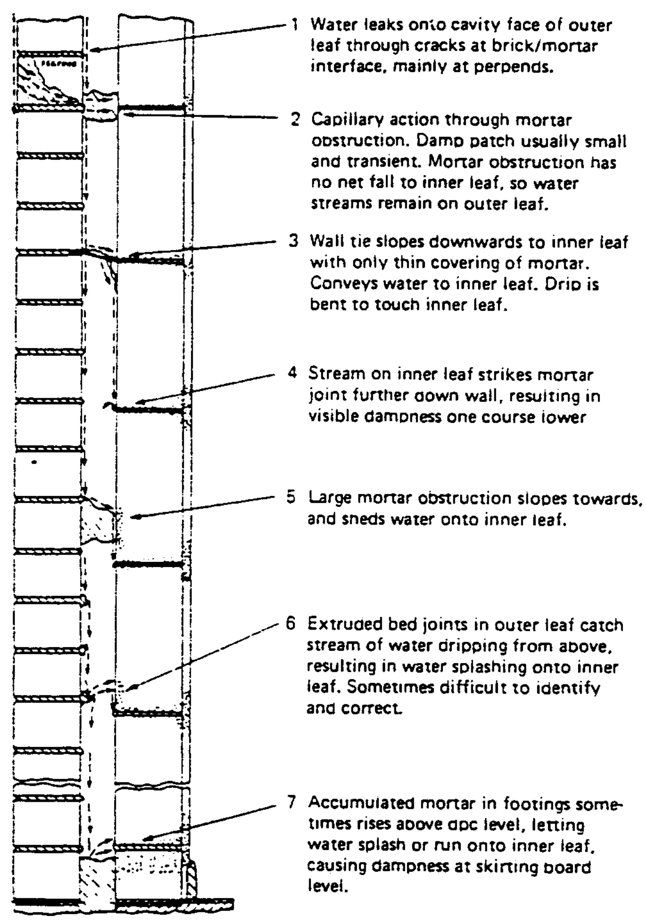

Figure 8.1: Routes for Water Penetration Across an Unfilled Cavity[20]

The cavity fillers tested were glass fibre, polystyrene foamed in-situ, polystyrene bonded beads, polystyrene granules, polystyrene loose beads, polyurethane foamed in-situ, polyurethane granules, rockwool fibre, urea-formaldehyde and siliconised perlite. These materials are all water repellent or waterproof , but their ability to accommodate and drain water are very different

Most of the fillers did not have any affect on the rate of leakage of water into the cavity. The exceptions were polyurethane foamed in-situ, where there was an appreciable decrease in leakage rate into the cavity; and urea-formaldehyde foam, where the decrease was noticeable but less pronounced. The reason for this latter decrease was presumably because of the adhesion of the foam material to the cavity side of the outer wythe.

For clear cavities, some of the insulating fillers caused a net increase in dampness due to water being carried across the cavity and wetting the backup. The siliconised perlite and urea-formaldehyde foam allowed considerable amounts of water to move across the filler space causing an increase in the moisture content of the backup wall. Polystyrene granules and polyurethane foamed in-situ also resulted in an increase in the backup dampness, but this was not as significant. Glass fibre permitted even less water to move across the filler space. The polystyrene bonded beads, polystyrene loose beads, polyurethane granules, and rockwool fibre had little effect on inner wythe dampness. The siliconised perlite and urea-formaldehyde foam performed the least well with regard to water transferred and increased dampness.

In all the test houses, damp patches occurred before the filler was installed. All fills introduced bridging paths. The fills that allowed the least water to cross had a performance equivalent to that of a clear cavity or a cavity containing very few obstructions. Those fills that allowed significant amounts of water to cross were obviously the most likely to generate problems.

The movement of water inwards through an insulation filler is dependent, on the one hand, on the basic structure of the filler material (size, orientation and packing density of the fibres and the distribution of the binder) and, on the other hand, on the moisture-related properties of the exterior surface. In the case of urea-formaldehyde foam, the bridging paths were fissures or holes in the foam. The in-situ polyurethane foam was the only cavity fill material examined that had pores that filled with water so that penetration was by capillarity through the bulk of the material.

8.4 Commentary*

The use of an insulation foam type filler has some advantages. There is probably some potential for the advantageous use of a cementitious filler, but the lack of a suitable outer sheathing to the steel stud is the main deterrent. While a foam-type insulation could be used, we are of the opinion that if it is to be used, it would be necessary to also apply an exterior, vapour-permeable, sealer to the outside of the brick to reduce water penetration into and across the brick veneer. However, the presence of a low-heat-capacity substrate behind the brickwork will increase the mean brick temperature, increase the range of thermal variation, and perhaps increase the number of freeze-thaw cycles for the brick. It is not at all clear that merely by filling the cavity the performance of the wall will be enhanced or its life increased. Moreover, any prediction is dependent on the orientation and quality of the brickwork and the geographic location of the building.

* At the present time, CMHC does not endorse the filling of the cavity

9. Conclusions and Recommendations

Remediation of any BV/SS wall requires that the cause or causes of the problem be addressed as well as the consequences. The existing tie system cannot be repaired in isolation and, obviously, work on the air barrier must also be carried out. This report focuses on the remedial tie system. The likely performance of existing BV/SS wall systems after the ties have been remediated has been tested and/or assessed. In each section of this report specific topics have been addressed in some detail.

Some of the main conclusions and recommendations are systematically summarized below.

- The most important thermal consequence is additional thermal bridging provided by the new ties. It was confirmed that the heavier or thicker the tie the more significant the thermal bridge. As is the case for the existing ties as well as the remedial ties, the potential for a serious moisture related problem exists in those BV/SS walls with all the thermal insulation within the stud space. In which case it is likely that tie remediation is not a sufficient nor a suitable solution.

- Retrofit ties for an interior fix will penetrate the air barrier of a BV/SS wall if this air barrier is located near the interior face. Air leakage is highly undesirable and it is strongly recommended that at all remedial tie locations this air barrier be resealed. It follows that the remediated wall must incorporate a continuous and effective air barrier

- For BV/SS walls with an air barrier at the interior face, it is unlikely that an exterior fix with retrofit ties will affect this air barrier. However installation induced damage may affect the barrier to inward water movement to the inner back-up portion of the wall--this is especially a concern with the Helifix remedial tie. Of the tie systems tested, the Dinal tie has the least effect on the air and water control characteristics of the wall.

- It is unlikely that the presence of the remedial ties will worsen the overall drainage capability of the wall. If rain water penetration is excessive, every measure should be taken to reduce the amount by, for example, applying a sealer coat or repointing.

- When masonry ties are attached by means of self tapping screws to the framing, the galvanized coating of the steel studs is damaged, leaving the underlying steel unprotected from moisture and, eventually, corrosion. As most tie systems rely heavily on a tight interface connection, corrosion of the steel stud at this interface will reduce the strength and stiffness of the remedial tie.

- A two flange connection (an interior fix) has some built-in reserve against corrosion. If the connection at one flange should corrode and fail, then resistance is still available from the connection at the other flange.
- If the torsional resistance of the steel studs is, for some reason, inadequate the installation of retrofit ties offers an opportunity to provide some torsional restraint. This method of torsional stiffening will be quicker and much less expensive than opening up the wall and installing lateral steel bridging and repairing top and bottom connections.
- An interior fix will provide more torsional restraint to the steel stud than the use of an exterior fix.
- The issue of torsional stiffening needs additional research and development. Both analytical work and physical experimentation is needed.
- At this time we doubt whether many BV/SS systems are well suited to the use of a cavity filler largely because of the lack of a suitable sheathing at the outside of the steel stud framing.

In conclusion, it is recommended that all manufacturers or specifiers of retrofit tie systems give serious consideration to not only the issues covered in this report, but also to structural concerns (see reports for Tasks 2 and 4). Furthermore, the changes in the revised Standard CSA-CAN3-A370 need to be taken into account especially the Level III requirements for durability.

This Task 3 has been of value because a number of issues , some of them new, have been identified and, to some extent, quantified. The potential for torsional stiffening or bridging remediation by means of new ties is certainly important. The assessment of installation damage and the possible consequences for post-remediation performance is also of value. Finally it needs to be stressed that tie remediation implies improvement and it follows that serious consideration must be given to the use of stainless steel in most, if not all, situations where tie remediation is required.

10. References

1. *ASHRAE Handbook of Fundamentals*, American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc., Atlanta, Georgia, USA, 1989, p. 22.10.

2 The Chartered Institution of Building Services, *CIBS Guide A3 Thermal Properties of Building Structures*, , London, 1980.

3 Kluge, A. and Drysdale, R.G., "The Potential for Condensation in Brick Veneer/Steel Stud Wall Systems", *Proceedings of the Fifth Canadian Masonry Symposium*, University of British Columbia, Vancouver, B.C., Canada, June 1989, pp. 467-476.

4 *Standard Method of Test for Rate of Air Leakage through Exterior Windows, Curtain Walls and Doors*, ASTM Standard E283-84, American Society of Testing and Materials, Philadelphia, Pa., USA, 1984.

5 *Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method*, CAN/CGSB Standard 149.1-M86, Canadian General Standards Board, Ottawa, 1986.

6 Suter Keller Inc., *Field Investigation of Brick Veneer/Steel Stud Wall Systems,* Report for Canada Mortgage and Housing Corporation, Ottawa, Ontario, November 1989.

7 Maurenbrecher, A.H.P. and Brousseau, R.J. , *Review of Corrosion Resistance of Metal Components in Masonry Cladding on Buildings*. Internal Report No. 640 IRC/National Research Council of Canada, Ottawa, February 1993.

8 Moore, J.F.A., *The Performance of Cavity Wall Ties*, BRE News 54, Summer 1981.

9 Keeling, D., Warren, C., Somayaji, S., Jones, D., and Heidersbach, R, "The Corrosion of Metals in Masonry Systems", *Proceedings from the Fifth Canadian Masonry Symposium, Volume 2*, Department of Civil Engineering, University of British Columbia, Vancouver, B.C., Canada, June 1989.

10 Corrosion Control Engineering Ltd., *An Evaluation of the Corrosion Resistance of Dur-O-Wal Repair Anchor*, November 1993.

11 *Standard Guide for Development and Use of a Galvanic Series for Predicting Galvanic Corrosion Performance*, ASTM Standard G82-83, American Society of Testing and Materials, Philadelphia, Pa., USA, 1989.

12 *Standard Terminology Relating to Corrosion and Corrosion Testing*, ASTM Standard G15-93, American Society of Testing and Materials, Philadelphia, Pa., USA, April 1993.

13 *Hot Dip Galvanizing for Corrosion Protection of Steel Products,* American Galvanizers Association, Inc., Washington D.C., 1989.

14 Canadian Standards Association, CSA-CAN3-A370-M84, *Connectors for Masonry*, March 1984.

15 Canadian Standards Association, CSA-CAN3-A370 draft, *Connectors for Masonry*, revised March 1993.

16 Keller, H., Trestain, T.W.J., and Maurenbrecher, A.H.P., "The Durability of Steel Components in Brick Veneer. Steel Stud Wall Systems", *Proceedings of the Sixth Conference on Building Science and Technology* , Toronto, Ontario, 1992, pp.83-104.

17 Drysdale, R.G. and Suter, G.T., *Exterior Wall Construction in High-Rise Buildings: brick veneer on concrete masonry or steel stud wall systems* , Canada Mortgage and Housing Corporation, Ottawa, 1991.

18 *Lightweight Steel Framing Design Manual*, Canadian Sheet Steel Building Institute, Willowdale, Ontario, July 1991.

19 Drysdale, R.G., Breton, N., *Strength and Stiffness Characteristics of Steel Stud Backup Walls Designed to Support Brick Veneer*, Report for Canada Mortgage and Housing Corporation, Ottawa, Ontario, December, 1991.

20 Newman, A.J., Whiteside, D., Kloss, P.B. and Willis W, "Full-scale Water Penetration Tests on Nine Retrofit Fills", *Building and Environment,* Volume 17, Number 3, pp. 175-191, 1982.