

RESEARCH REPORT



Renovation Strategies for Brick Veneer Steel Stud Wall Construction: Task 5 Summary Report



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**RENOVATION STRATEGIES FOR
BRICK VENEER STEEL STUD
WALL CONSTRUCTION - TASK 5**

Summary Report

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Part IX

Canada Mortgage and Housing Corporation, the Federal Government's housing agency, is responsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living conditions in Canada. As a result, the Corporation has interests in all aspects of housing and urban development and growth and development.

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This publication is one of the many items of information published by CMHC with the assistance of federal funds.

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This study was conducted by the Building Engineering Group, University of Waterloo, for Canada Mortgage and Housing Corporation under Part IX of the National Housing Act. The analysis, interpretation, and recommendations are those of the consultants and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

Executive Summary

In many buildings with brick veneer, steel-stud framed enclosure walls (BV/SS), the condition and influence of the lateral ties between the brickwork and steel studs are the cause of some 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 commissioned by CMHC, the work was undertaken by the Building Engineering Group (BEG). BEG was contracted to conduct an extensive program of work to develop various strategies for the remediation and, thus, the control or avoidance of tie related problems in existing BV/SS wall systems.

The **objective** of the overall project was to identify and evaluate those tie systems that had some potential for use as supplemental or replacement ties in existing BV/SS enclosure walls. A number of tasks were formulated and the following five task reports have been produced:

Task 1: Brick Ties - Options for Remediation. The main objective of the first task of the research project 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 (or fixes) and four were interior approaches.

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 methods permitted installation from inside the building (interior fixes) and two were exterior repair methods (exterior fixes). These four tie systems were chosen from the eleven considered in Task 1. Numerous design and code related issues are addressed in detail in the Task 2 report.

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 considerations such as thermal bridging, condensation, drainage, corrosion and stiffness (both flexural and torsional).

Task 4: Dinal Remedial Tie System. This task involved the testing and assessment of the Dinal tie system for the purpose of tie remediation. The Dinal tie was not available when Tasks 1 and 2 were initiated and the Task 4 report should be regarded as a supplement to the Task 2 report.

Task 5: Summary Report. A synthesis of the work done in Tasks 1, 2, 3, and 4 and written for a wider audience than the research community

Over a period of more than two years a considerable amount of work, both experimental and theoretical, was done. Some of the more general conclusions are as follows:

1. Tie remediation is demonstrably feasible and most concerns regarding locating the studs or working blind during installation can readily be resolved.
2. Tie remediation is practical and economic strategy. Eleven different methods have been demonstrated and five tie systems have been subjected to extensive testing for the purposes of development and conformance.
3. Tie remediation can be conducted from either the outside or the inside of the building.
4. The installation of supplementary ties can be used to contribute to:
 - Torsional stiffening or in-plane restraint to the steel stud framing. This is important because inadequate bracing is a common problem.
 - Structural safety with regard to the accommodation of seismic, impact or explosive load because of the ductility of certain tie systems,
 - Upgrading the wall for compliance purposes.
5. Performance attributes such as durability, corrosion and air and moisture control need to be properly considered.

Tie-specific conclusions and recommendations are as follows:

1. Design capacities for five tie systems—two interior and three exterior fixes—are provided (Table 3.3). This information is suitable for preliminary design. Proper conformance testing is still required by the suppliers of each tie system.
2. The Dinal tie performs remarkably well. However it is strongly recommended that stainless steel versions of this tie be used for remediating existing tie systems in enclosure walls. The long term durability of the rubberized washer is another concern.
3. The two Dur-O-Wal tie systems worked well. The lagbolt tie (Exterior Fix) should not be used with studs less than 20 gauge. With the epoxied tie (Interior Fix) damage to the epoxy results in a relatively brittle failure mode. Because of the use of dissimilar materials, corrosion may be an issue.
4. The two Helifix applications only satisfied all structural safety and serviceability criteria when connected to studs of 16 gauge or thicker. Relatively lower capacity and low stiffness make it more difficult for the Helifix tie to meet the requirements of the recent Masonry Connector Standard. It is strongly recommended that installation procedures be improved in order to improve tie performance,

particularly to reduce slippage or slack displacement and to increase initial stiffness.

5. Improvements can readily be made. Installation procedure and corrosion avoidance are just two aspects that need to be addressed.
6. Cyclic preconditioning, for example 1000 pullout/push-in cycles to a load of about 33 percent of the service load, should be incorporated in any conformance testing program.

There are a number of technical advantages to working from the interior. Not only is it easier to locate the studs but, when working blind, it is preferable to have the brickwork as the second or further component to be connected. Stiffening of the studs to compensate for inadequate bracing is more effective as two flanges are involved.

Finally it needs to be emphasized that tie remediation cannot be done in isolation. Any renovation strategy must include the restoration of or the provision of an air barrier and the effective control of moisture.

Résumé

Dans de nombreux bâtiments comportant des murs à ossature d'acier et placage de brique, l'état et l'influence des attaches latérales raccordant la brique aux poteaux d'acier sont motifs de préoccupation. En raison de l'importance de la performance à long terme du raccordement du placage de brique au mur de fond à ossature d'acier, la SCHL a commandé un programme étendu de recherche, de développement et de démonstration. Les travaux ont été confiés au Building Engineering Group (BEG) mandaté pour mener une recherche étendue visant à élaborer différentes stratégies de réhabilitation et, par conséquent à contrôler et à éviter la manifestation de problèmes d'attaches dans de tels murs.

L'objectif de la recherche générale consistait à désigner et à évaluer les systèmes d'attaches se prêtant à la consolidation ou au remplacement des attaches des murs à ossature d'acier et placage de brique. Un certain nombre de tâches ont été formulées et les cinq rapports d'étape suivants ont été produits :

Tâche 1 : Attaches de la brique - Options de réhabilitation. Le principal objectif de la première tâche du projet de recherche était d'identifier, de démontrer, d'évaluer et de documenter les méthodes de pose d'attaches supplémentaires dans des bâtiments avec murs à ossature d'acier et placage de brique. Parmi les onze stratégies de réhabilitation envisagées, sept systèmes d'attache requéraient une pose de l'extérieur et quatre une pose de l'intérieur.

Tâche 2 : Quatre systèmes d'attaches - Élaboration et essais de conformité. Cette tâche comportait un programme d'essais destinés à établir et à étoffer la performance structurale de quatre systèmes d'attaches, dont deux nécessitent une pose depuis l'intérieur du bâtiment et deux des réparations de l'extérieur. Ces quatre systèmes d'attaches ont été choisis parmi les onze envisagés lors de la Tâche 1. Le rapport de la Tâche 2 traite en détail de nombreux aspects reliés aux règles de calcul et au code.

Tâche 3 : Aspects de la performance. Cette tâche s'entendait de la mise à l'essai et/ou de l'évaluation de la performance probable des murs à ossature d'acier et placage de brique réhabilités, l'accent étant surtout placé sur les ponts thermiques, la condensation, le drainage, la corrosion et la résistance (à la flexion et à la torsion).

Tâche 4 : Système d'attache Dinal. Cette tâche supposait la mise à l'essai et l'évaluation du système d'attache Dinal pour fins de consolidation. L'attache Dinal n'existait pas lorsque les tâches 1 et 2 ont été amorcées; c'est pourquoi le rapport de la tâche 4 doit être considéré comme un complément au rapport de la Tâche 2.

Tâche 5 : Rapport sommaire. Ce rapport fait la synthèse des travaux effectués lors des Tâches 1, 2, 3 et 4 et est destiné à un plus vaste public que le secteur de la recherche.

Au cours d'une période s'échelonnant sur plus de deux ans, beaucoup de travaux, tant expérimentaux que théoriques, ont été effectués. Voici d'ailleurs certaines conclusions générales qui s'en dégagent :

1. Les opérations de démonstration attestent de la faisabilité de la réhabilitation et de la facilité de régler les aspects concernant le repérage des poteaux et le travail à l'aveuglette au cours de la pose.
2. La stratégie de consolidation constitue une stratégie pratique et économique. Onze différentes méthodes ont été éprouvées et cinq systèmes d'attaches ont été soumis à des essais poussés aux fins de développement et de conformité.

3. La consolidation des attaches peut s'effectuer aussi bien de l'extérieur que de l'intérieur du bâtiment.
4. La pose d'attaches supplémentaires permet :
 - o d'ajouter à la résistance à la torsion ou en plan de l'ossature d'acier. Cela revêt de l'importance puisque le manque de contreventement constitue un problème répandu.
 - o d'ajouter à la sécurité en ce qui concerne les charges sismiques, les charges d'impact ou les charges explosives en raison de la ductilité de certains systèmes d'attaches.
 - o d'améliorer l'état du mur pour des besoins de conformité.
5. Les caractéristiques de performance tels la durabilité, la corrosion, le contrôle de l'air et de l'humidité doivent être pris en considération comme il se doit.

Les conclusions et recommandations propres aux attaches se formulent comme suit :

1. Les valeurs de calcul de cinq systèmes d'attaches (deux nécessitant une poste de l'intérieur et trois de l'extérieur) sont fournies (Tableau 3.3). Cette information se prête aux règles de calcul préliminaires. Les fournisseurs de chacun des systèmes d'attaches devront toutefois faire effectuer des essais de conformité appropriés.
2. L'attache Dinal se comporte remarquablement bien. Par contre, il est fortement recommandé d'utiliser des attaches en acier inoxydable pour la consolidation de murs existants. La durabilité à long terme de la rondelle caoutchoutée constitue cependant un autre motif de préoccupation.
3. Les deux systèmes d'attaches Dur-O-Wal ont bien fonctionné. L'attache à tire-fonds (pose extérieure) ne doit pas s'employer avec des poteaux d'épaisseur inférieure à 20. Avec l'attache revêtue d'époxy (pose intérieure), l'endommagement de l'époxy entraîne une rupture fragile. En raison de l'emploi de matériaux dissemblables, la corrosion risque de poser un problème.
4. Les deux attaches Felifix ne satisfaisaient à tous les critères de sécurité et de tenue en service que lorsqu'elles étaient raccordées à des poteaux d'épaisseur 16 ou plus. Une capacité et une rigidité relativement moindres font que l'attache Helifix peut difficilement répondre aux exigences de la récente norme touchant les connecteurs de maçonnerie. Il est fortement recommandé d'améliorer les modes de pose dans le but d'accentuer la performance des attaches surtout en vue de réduire tout glissement ou déplacement en raison du raccordement lâche et d'accroître la rigidité d'origine.
5. Des améliorations peuvent être apportées facilement. Le mode de pose et les précautions visant à éviter la corrosion ne sont que deux aspects à régler.
6. Le préconditionnement cyclique, par exemple en procédant à 1 000 cycles d'arrachement/d'enfoncement sous une charge représentant environ le tiers de la charge en service, devra être intégré à tout programme d'essais de conformité.

Poser les attaches de l'intérieur procurent des avantages sur le plan technique. Non seulement est-il plus facile de repérer les poteaux, mais lorsqu'on travaille à l'aveuglette, il est préférable que le placage de brique ne soit pas le premier élément à raccorder. Accroître la rigidité des poteaux pour compenser les contreventements inadéquats s'avère plus efficace lorsque le raccordement se fait aux deux ailes.

Enfin, il faut souligner que la consolidation des attaches ne saurait se faire isolément. En effet, toute stratégie de rénovation doit comporter la réhabilitation du pare-air ou sa mise en place et le contrôle efficace de l'humidité.



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Acknowledgments

This report is a summary of 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 initiating and 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 various tie manufacturers/distributors for their cooperation and for supplying us with their brick ties and special installation equipment. In particular the following people gave freely of their time and assistance.

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Mr. Pat Sweeney of Blok Lok Limited
Ms. Ellen Hall of Dinal Incorporated
Mr. Robert Lloyd-Rees of Cintec Canada

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Mark Postma and Chantal Wegner, while graduate students at the University of Waterloo, worked on this project. Mark Postma co-authored the reports for Tasks 1 and 2. Chantal Wegner co-authored the reports for Tasks 3 and 4. Their energy, enthusiasm and technical input were not only greatly appreciated but also invaluable.

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1. Introduction

1.1 Background

Over the last fifteen years, the performance of clay brick veneer /steel stud framed (BV/SS) enclosure systems, especially on multi-storey residential buildings, has received a great deal of attention. A section through a representative BV/SS wall is shown in Fig.1.1.

Many buildings with exterior walls of BV/SS construction have experienced or are experiencing problems. 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, screws, etc.). It is often difficult therefore 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, fix. 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 a concern. In practice, one or more of the following may 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.

Remediation of one or more tie related issues can be extremely expensive. For instance, if the work is done from the outside, brickwork, perhaps all the brickwork, has to be removed. If however the work is done from the inside then the costs of occupant inconvenience and, possibly, relocation have also to be considered.

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

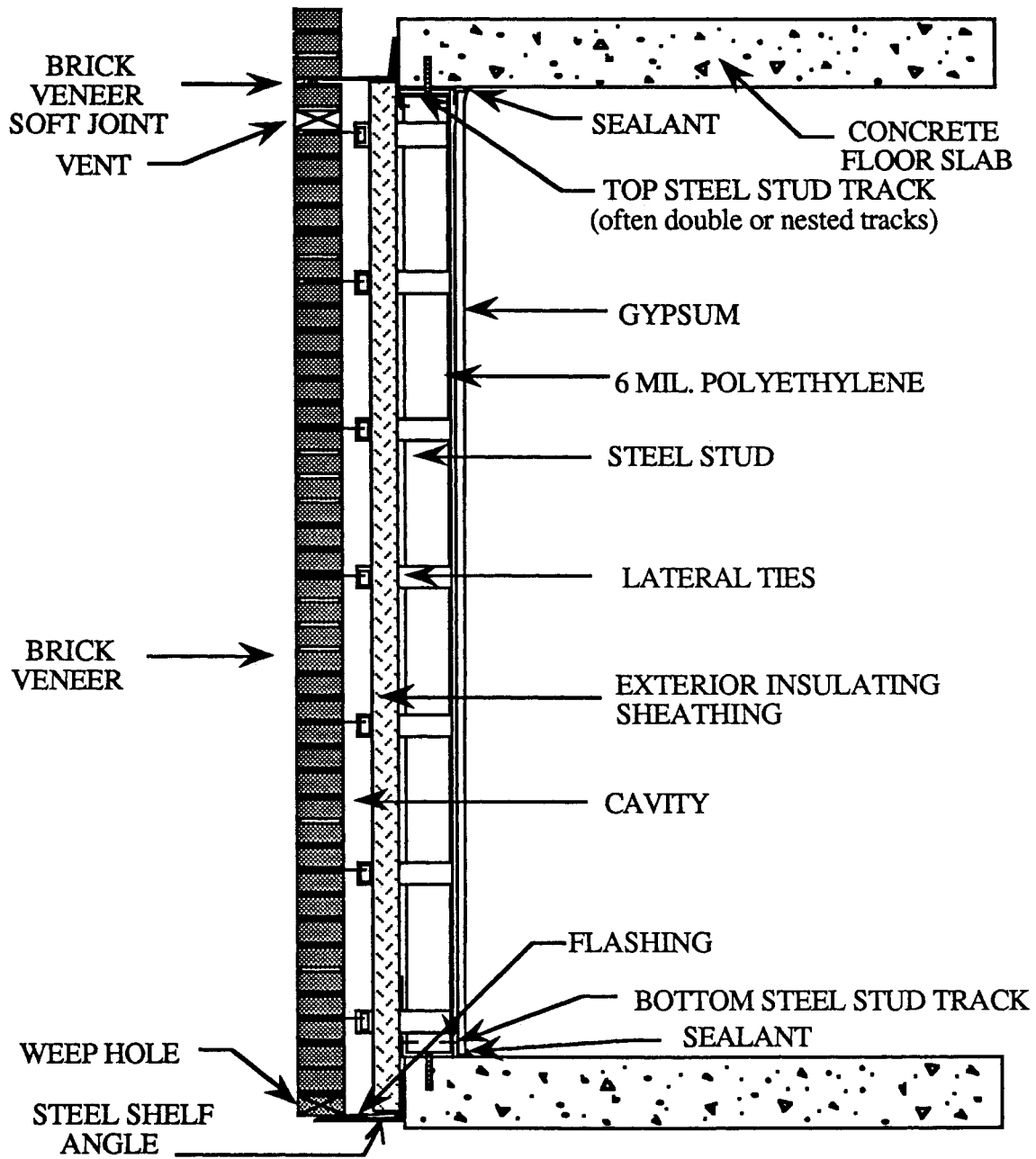


Figure 1.1: Cross-Section of a Representative BV/SS Wall

A number of tasks were formulated and the following task reports have now been produced:

Task 1: Brick Ties - Options for Remediation.¹ The main objective of the first task of the research project 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 (or fixes) and four were interior approaches.

Task 2: Four Remedial Tie Systems—Development and Conformance Testing.² This task involved a test program to establish and document the structural performance of four retrofit tie systems; two methods permitted installation from inside the building (interior fixes) and two were exterior repair methods (exterior fixes). These four tie systems were chosen from the eleven considered in Task 1.

Task 3: Some Performance Considerations.³ This task involved the testing and/or assessment of the likely performance of BV/SS walls after remediation, with particular regard to temperature, drainage, corrosion and stiffness (both flexural and torsional).

Task 4: Dinal Remedial Tie System.⁴ This task involved the testing and assessment of the Dinal tie system for the purpose of tie remediation. The Dinal tie was not available when Tasks 1 and 2 were initiated, and the Task 4 report should be regarded as a supplement to the Task 2 report.

1.2 Objectives

The **objective of the overall project** was to identify and evaluate those tie systems that had some potential for use as supplemental or replacement ties in existing BV/SS enclosure walls.

The **objective of this final report (Task 5)** is to provide a relatively brief summary of the work done in this project. This summary is directed at all building professionals including the research community. The intent is to synthesize the relevant results and to facilitate the transfer of this technology.

All five Task reports are available from the Canadian Home Information Centre, 700 Montreal Road, Ottawa, Ontario, K1A 0P7, for those interested in details of the testing or other issues.

1.3 Approach and Scope

The scope of the project was limited to those tie systems that could be installed from the exterior without removing the brick veneer or, if an interior repair method was desired, with the minimum of damage to the drywall and interior finishes. Both interior and exterior repair methods, i.e., working exclusively from the inside or the outside of the building, were to be investigated. The tie systems were to be commercially available in Canada.

The first task was to identify all those tie systems that were being sold as remedial ties or that seemed to have some potential for use as a remedial tie. The practical feasibility of using each tie had then to be demonstrated in the field, and the relative merits and demerits of each tie system had to be documented. This work is briefly documented in Chapter 2.

The next step involved selecting those tie systems that were better suited, on the basis of cost, ease of installation and likely performance, to tie remediation. These tie systems were then subjected to physical testing in order to establish the mechanical properties of the tie-to-steel-stud connection (Tasks 2 and 4). The nature of the tie-to-brickwork connection was, in each case, assessed and appropriate strength and displacement values developed for the purposes of design. Also in Chapter 3 some emphasis is placed on providing design guidance and practical advice to both suppliers and potential users of the remedial tie systems.

In Chapter 4 the likely in-service performance of five remedial tie systems is briefly discussed. The Task 4 report should be consulted for details as to torsional stiffening of the framing and the quantification of the impact of installation by means of air-leakage testing. Some concluding comments are provided in Chapter 5.

2. Demonstration

2.1 Introduction

The main objective in the first R&D task was to identify, demonstrate and assess methods of providing supplemental ties to BV/SS buildings. The ties were to be commercially available in Canada. Even if a particular tie system had not been previously used for remedial purposes, every tie system with some potential for remedial use was to be considered. Of particular interest were retrofit procedures that could be conducted from the interior. A secondary objective, common to all repair systems, was to review procedures for installation with particular attention to locating the steel stud from both the interior and the exterior.

2.2 Procedure

Four consecutive steps were involved. **First**, the major manufacturers and distributors of masonry tie systems in Canada were canvassed to identify those systems that were then (mid 1992) commercially available and suitable for tie retrofit in BV/SS systems. The following companies were approached :

Dur-O-Wal Ltd., Mississauga, Ontario

Ferro Holdings Ltd., Edmonton, Alberta

Cintec Canada, Nepean, Ontario

Blok-Lok Ltd., Weston, Ontario

Hilti Fastening Systems, Bramalea, Ontario

The **second** step involved the actual on-site demonstration of installation procedures on an existing BV/SS building by the tie manufacturers and distributors. In these demonstrations the practical difficulties of locating the steel studs for both exterior and interior retrofit were assessed. Three of the above five companies participated in these demonstrations. In total, 11 tie systems—4 installed from the interior and 7 installed from the exterior—were assessed.

After the installation demonstrations, the **third** step involved opening up the walls and investigating each repair method. Large sections of interior gypsum board were removed to inspect the connections of the tie systems in the brick and the steel stud and to assess the damage to the polyethylene, the exterior sheathing and other building components. Most of the installations were also examined from the exterior.

The **fourth** and final step was to compare each retrofit system, to describe the method of installation, and to assess the effectiveness of each retrofit procedure.

2.3 Description of Building and Enclosure Wall System

The building used for the demonstrations is a 9 storey multi-unit residential building located in southwestern Ontario. The building was built in 1987/88. The building structure comprises cast-in-place, reinforced concrete floor slabs, columns and shear walls. The section of non-structural external wall on which the demonstrations were made is located on the ground floor.

The enclosure wall is composed of the following elements:

- 90 mm clay brick veneer
- 25 mm cavity
- 25 mm expanded polystyrene insulation (exterior sheathing)
- 89 mm steel stud (0.9 mm or 20 gauge) framing
- 89 mm fibreglass batt insulation
- 6 mil polyethylene
- 12.5 mm gypsum board (interior sheathing)

The brick veneer is supported on shelf angles at every floor. Although this is a 9 storey building, the ties that were initially used are residential corrugated strip ties. The CSA Standard CAN3-A370-M84 ⁵ restricted the use of standard corrugated strip ties as follows:

- 1) to buildings not exceeding 11 metres in height (Clause 9.2.1.1)
- 2) to walls with the maximum unsupported length of tie between the veneer and its structural backing, no greater than 25 mm (Clause 9.2.1.2 (b))

Since the ties did not conform to code and as they were not installed properly, the installation of supplementary ties was thought to be one likely component of any remediation to this building. These deficiencies also made this building suitable for the physical demonstration of various methods for installing supplementary ties. One of the tie systems demonstrated could be used in the actual remediation of the building. In fact, subsequent to this demonstration task, all the exterior brickwork was removed and the ties and brick veneer were replaced, at considerable cost.

2.4 Locating the Vertical Steel Studs

Properly locating and penetrating the steel stud has a bearing on the reliability and effectiveness of any of the repair procedures. The objective is to locate the stud with a reasonable degree of precision and to establish on which side the web lies (if possible). This is to be done as quickly and with as little physical damage as possible. The ease with which it can be done is very much dependent upon whether the work is to be done from the interior or the exterior, on the floor height, and on the nature of the facade, i.e., many windows, straight runs, etc. The degree of precision in locating the stud and the determination of the position of the web are important in order to ensure that the tie is installed in the flange as close to the web as possible

without damaging the web. Note that there is some advantage to using smaller diameter remedial ties in that they not only require less effort to install but also require less precision in penetrating the flange of the steel stud, e.g., drilling into the web section of the steel stud should be avoided.

In this demonstration project, various methods of locating the steel stud were used. From inside the building the following methods were found to be useful in locating the steel studs:

- 1) Identify likely positions, e.g., adjacent to windows, doors etc.
- 2) If possible, obtain design drawings to establish likely stud locations.
- 3) Use a metal detector.
- 4) Confirm the presence of the stud and the location of the web with a hammer and nail or spike.

Locating the steel studs from the interior was found to be easier than from the outside. Two methods of locating the steel studs from the exterior were demonstrated. The first involved the use of a metal detector. The second method involved saw-cutting the mortar joint in the expected vicinity of the steel studs. The effectiveness of the metal detector approach will depend on the particular metal detector, the experience and competence of the user, and the type of the tie system. However it was found that a metal detector was not too effective when used on the exterior.

To locate the steel studs working from the exterior, it is preferable to use one or more of the following procedures:

- 1) Locate likely steel studs, e.g., adjacent to windows, doors, cross-walls, etc.
- 2) Working from the interior use a nondestructive method (metal detector) to locate the steel studs and transfer these locations to the exterior.
- 3) Saw-cut a horizontal mortar joint and prod with a thin rod to determine the exact location of the steel stud, as well as the position of the web.

In general, locating the steel stud is not a significant problem.

2.5 Interior Repair Methods

Four different interior retrofit systems were demonstrated, namely :

- Cintec Cementitious Sock with a 22 mm hole(see Figure 2.1)
- Dur-O-Wal side mounting bracket and expansion anchor(see Figure 2.2)
- Dur-O-Wal Stainless Steel Rod and Sleeve with Epoxy(see Figure 2.3)
- Helifix HRT80 tie Dry Fix (see Figure 2.4)

The four interior retrofit methods were all demonstrated relatively successfully. Each method is different and each has advantages and disadvantages. Table 2.1, "Comparison of Interior Retrofit Systems," provides a comparative summary and qualifies the attributes of each method.

With the exception of the Dur-O-Wal tie with the side or web mounted bracket, the repair methods demonstrated were all feasible. The use of a web repair method would only be practical if large amounts of the interior gypsum board were to be removed.

An estimate of the cost per tie for each remedial tie system has been given in Table 2.1. However, too much weight should not be placed on the cost of an individual tie, as tie spacing, the total number of ties, and the installation cost will all have a significant impact on the overall cost of remediation. A major cost of remediation will be the labour to install the ties and to return the wall to its intended state.

The aesthetics of the repair will undoubtedly be an important factor in the choice of a repair system, particularly when the repair is conducted from the interior. The size of hole in the interior gypsum board with the Dur-O-Wal epoxied sleeve repair and with the Helifix tie was approximately 15mm diameter, and this can be patched fairly readily. The much larger hole, approx. 35 mm, required for the Cintec anchor is not as easily repairable.

All remedial tie installations from the interior involve damage to both the air barrier and the vapour retarder. While the drywall can be readily repaired, the 4 or 6 mil polyethylene, if any, cannot. However, proper sealing of all holes can be accomplished and suitable finishes can be specified and applied. In most remediation situations, ensuring an adequate air barrier, particularly the sealing of the interior perimeter joints, will be a mandatory requirement.

Damage to the brick veneer should be minimized. Care must be taken to limit the depth of the pre-drilled hole to 2/3 or 3/4 of the brick depth to avoid punching through. Also impact drills should be avoided or used with care, as damage to the brick can occur.

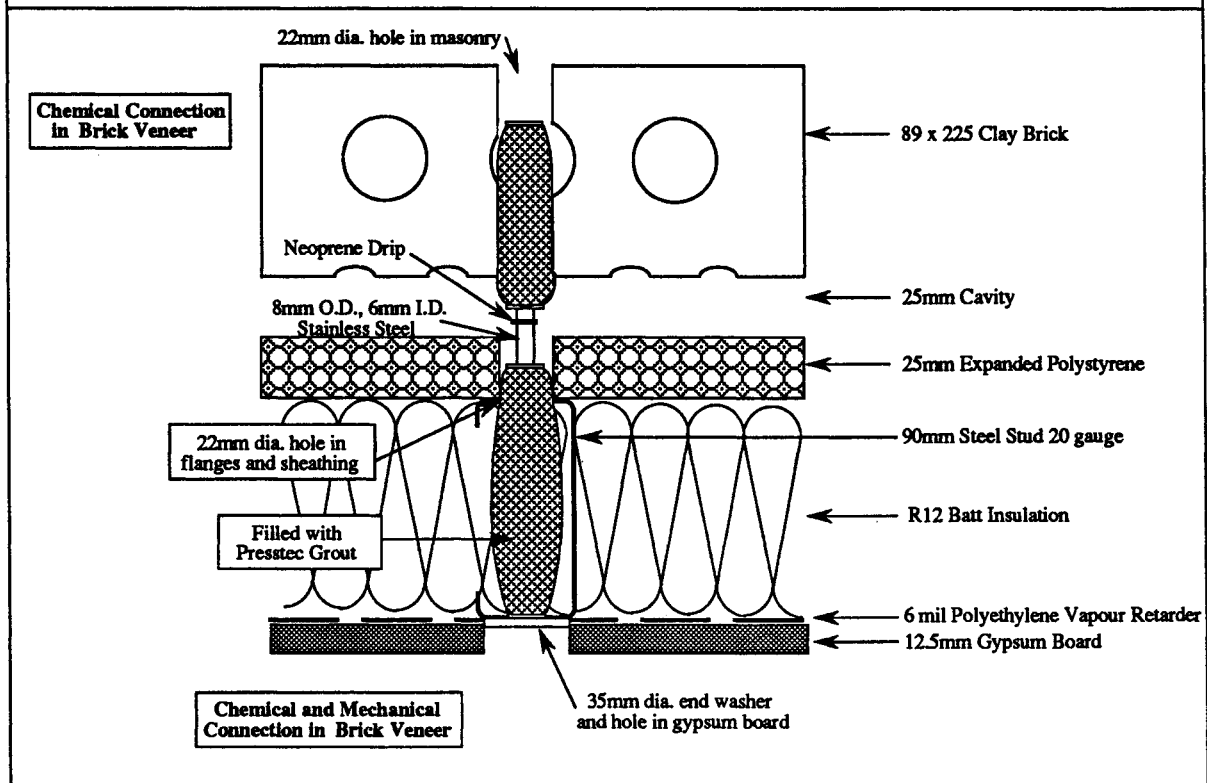
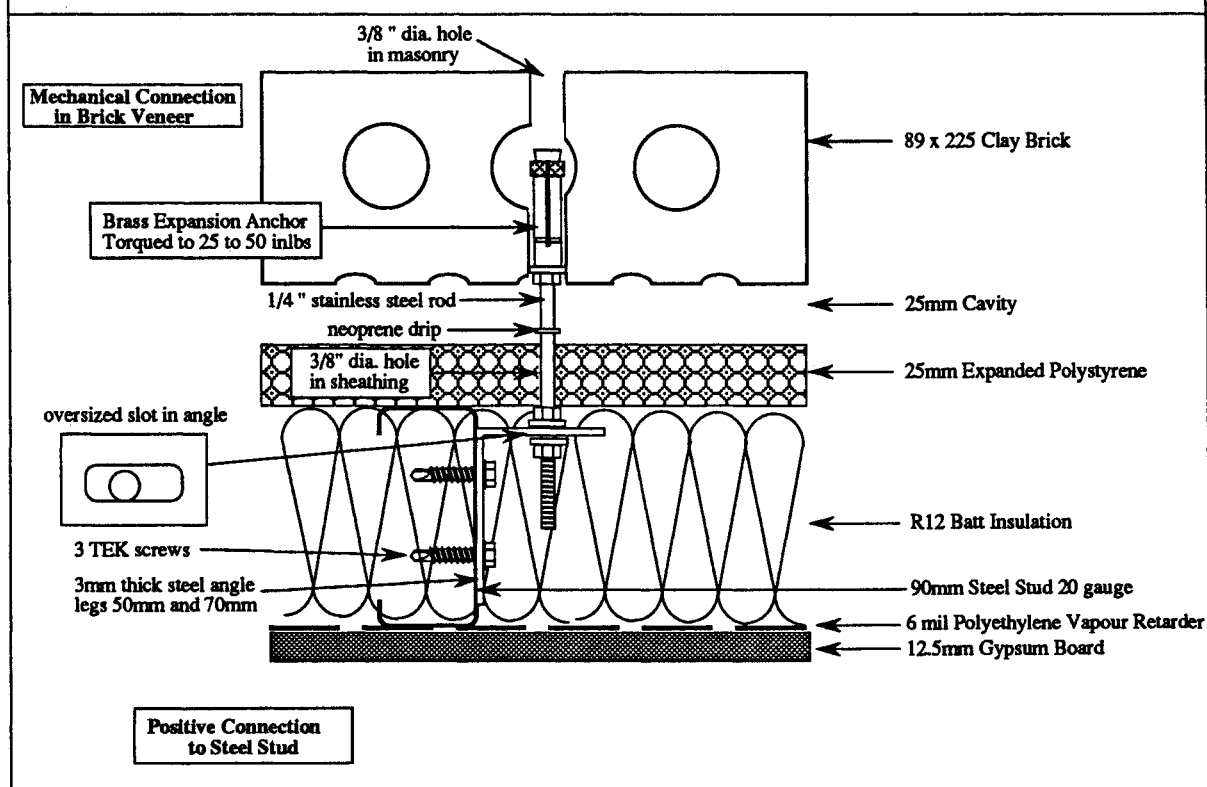
FIGURE 2.1 : Repair Method - Cintec Cementitious Sock with a 22mm Hole**FIGURE 2.2 : Repair Method - Dur-O-Wall Side Bracket and Expansion Anchor**

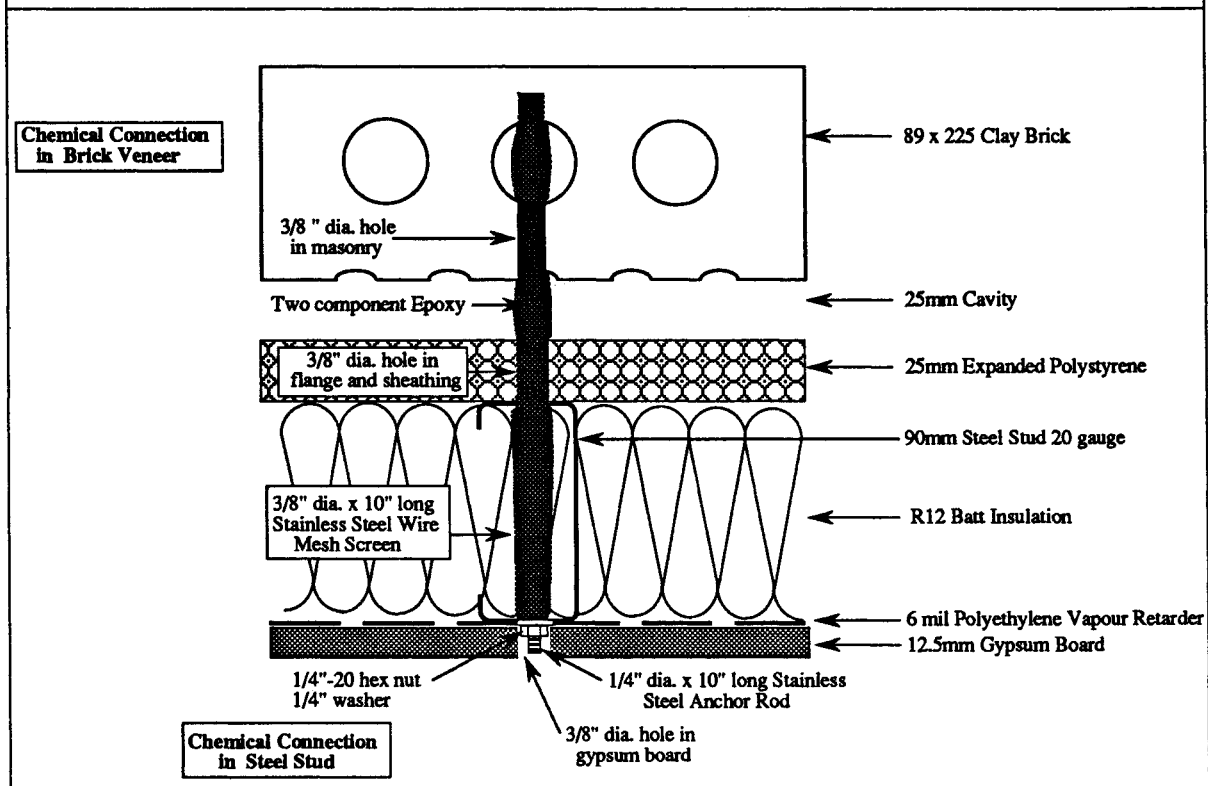
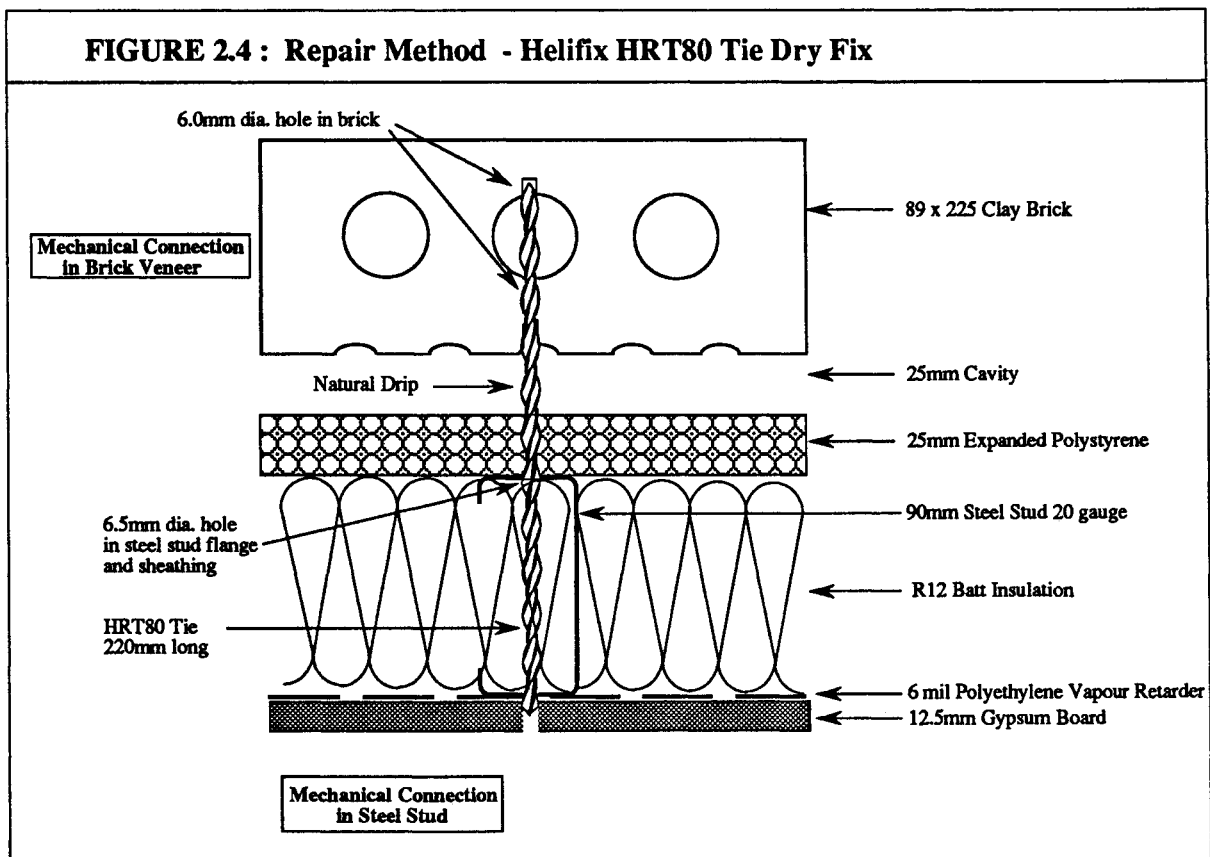
FIGURE 2.3 : Repair Method - Dur-O-Wall Stainless Steel Rod, Sleeve with Epoxy**FIGURE 2.4 : Repair Method - Helifix HRT80 Tie Dry Fix**

Table 2.1: Comparison of Interior Retrofit Systems

	Cintec Cementitious Sock (22mm)	Dur-O-Wal Bracket & Exp. Anchor	Dur-O-Wal S.S. Rod in Epoxy	Blok-Lok Helifix HRT80
INSTALLATION				
Ease	*	-	*	*
Time	*	*	*	+
Visibility of Damage	*	-	+	+
Weather Limitations	-	*	-	*
Effect on Tenant	-	-	-	-
REPAIR CHARACTERISTIC				
Strength of Connection	*	+	*	?
Ductility of Connection	-	+	-	+
Air Leakage	*	+	*	*
Various Thicknesses of Stud	*	*	*	?
Moisture Drip	+	+	-	+
Potential for Corrosion	+	+	+	*
Effect of Corrosion on Connection	*	*	*	-
Thermal Bridging	-	-	-	-
COST				
Cost of Tie	+/- \$ 9.00	+/- \$ 4.00	+/- \$ 3.00	+/- \$ 3.75
Cost of Labour**	?	?	?	?
Relative Cost of Making Good	*	-	+	+

Note:

* satisfactory, or of no relative difference

+ relatively positive, or beneficial or better

- relatively negative, or worse

? not known, or still to be determined

** the scale of the repair and the current status of these approaches affect this answer and make it difficult to provide any kind of assessment.

2.6 Exterior Repair Methods

Seven different exterior retrofit systems were demonstrated, namely :

- Cintec Cementitious Sock with 65 mm Hole (see Figure 2.5)
- Cintec Cementitious Sock with 22 mm Hole (see Figure 2.6)
- Dur-O-Wal Toggle Clips and Expansion Anchor (see Figure 2.7)
- Dur-O-Wal Threaded Bolt and Expansion Anchor (see Figure 2.8)
- Dur-O-Wal Drill and Tap Bolt and Expansion Anchor (see Figure 2.9)
- Dur-O-Wal Stainless Steel Rod and Sleeve with Epoxy (see Figure 2.10)
- Helifix HRT80 Dry Fix in SS, Polyester Resin in BV (see Figure 2.11)

The seven exterior retrofit methods were all demonstrated relatively successfully. As with the interior repairs, each repair is different and each has advantages and disadvantages. Table 2.2, "Comparison of Exterior Retrofit Systems," provides a comparative summary of the attributes of each method.

All repair methods, with the possible exception of the larger Cintec repair, are feasible methods to tie the brick veneer to the steel stud. The large 65 mm diameter hole needed for the Cintec tie repair method is aesthetically unacceptable and expensive. This repair would possibly be suitable if existing ties have to be removed and replaced.

The unit cost of the Cintec anchors is considerably more than the other tie systems. These unit prices do not include the cost to install the ties and to return the wall to its intended condition.

Except for the Cintec anchors, damage to the brick veneer is usually restricted to the mortar joint and this can readily be filled with mortar. However, damage to the exterior sheathing and the steel stud is both difficult to assess and difficult to avoid. The repair method using Dur-O-Wal toggle clips is unacceptable for use with compressible exterior sheathings, as the toggle clips will either cut a large hole in this sheathing or the sheathing will have to be relied upon for compression in the connection.

The strength of the tie connection will typically depend on the strength of the connection of the tie to the steel stud, rather than to the brick. The three connectors that rely on a screw type connection need to be adequately tested for strength under both static and cyclic loading. The threaded connections are also more vulnerable to corrosion.

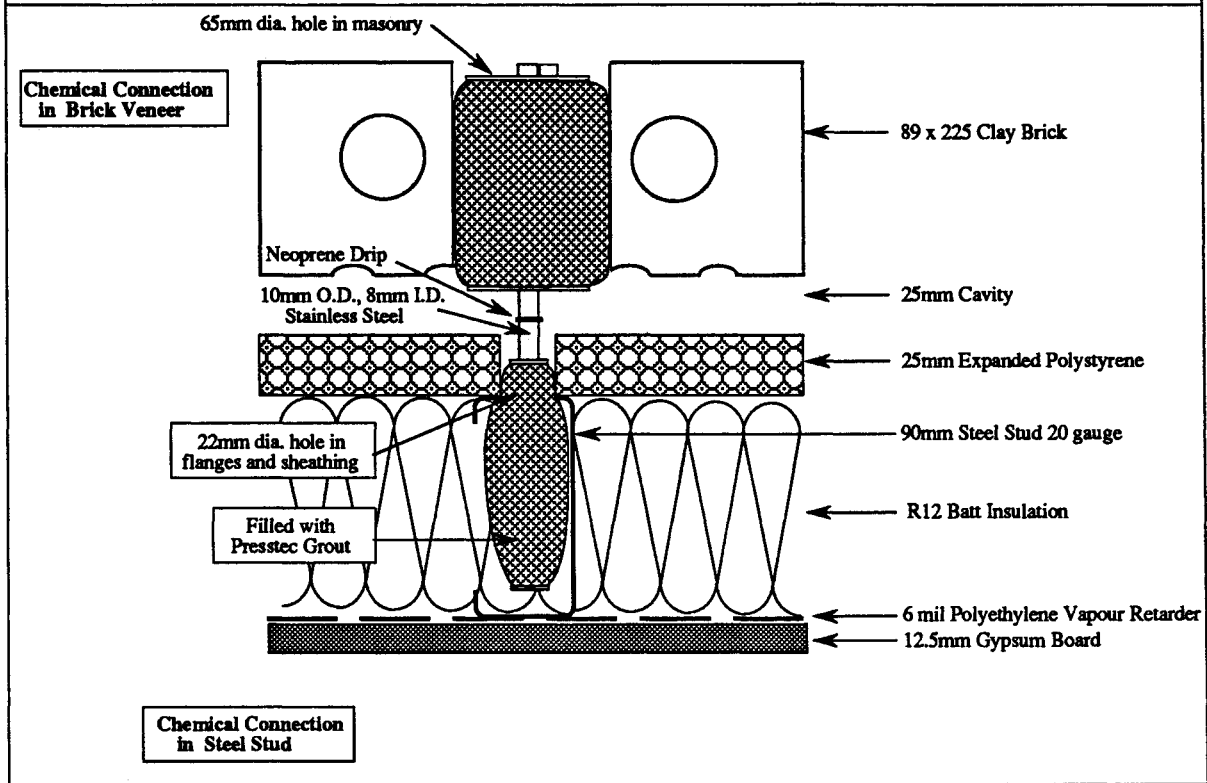
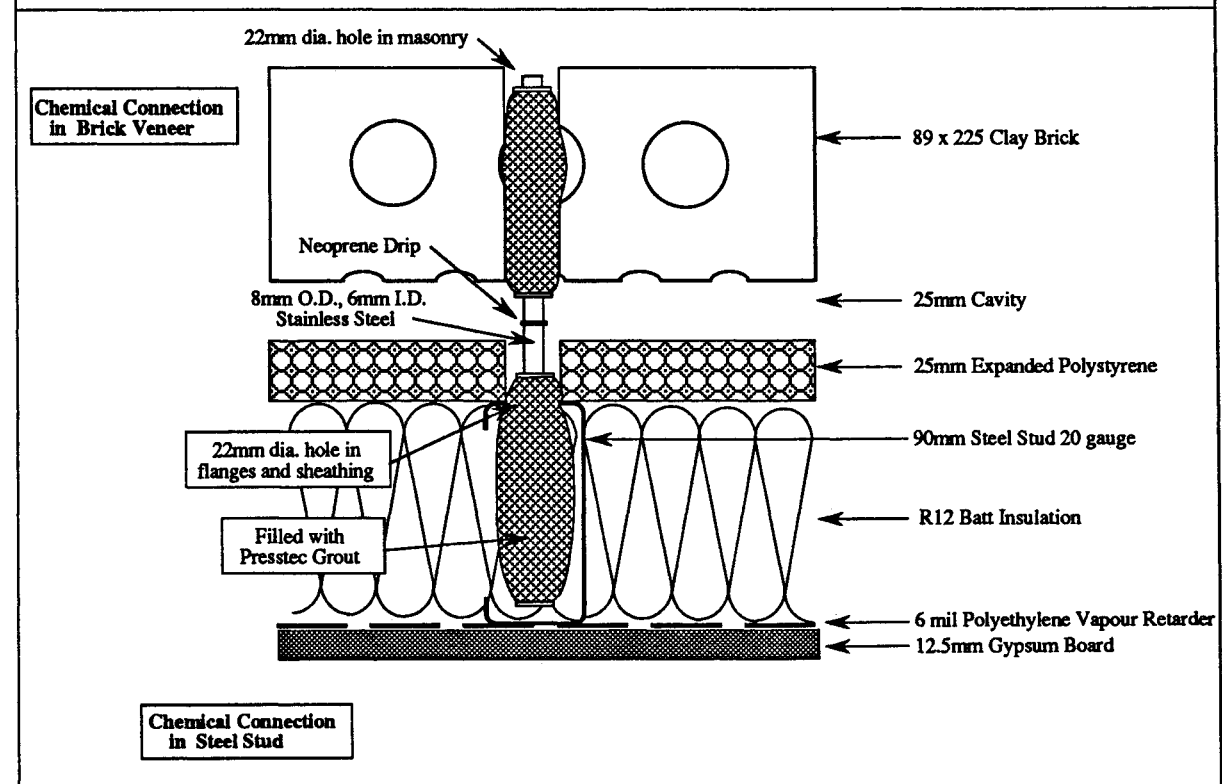
FIGURE 2.5 : Repair Method - Cintec Cementitious Sock with 65mm Hole**FIGURE 2.6 : Repair Method - Cintec Cementitious Sock with 22mm Hole**

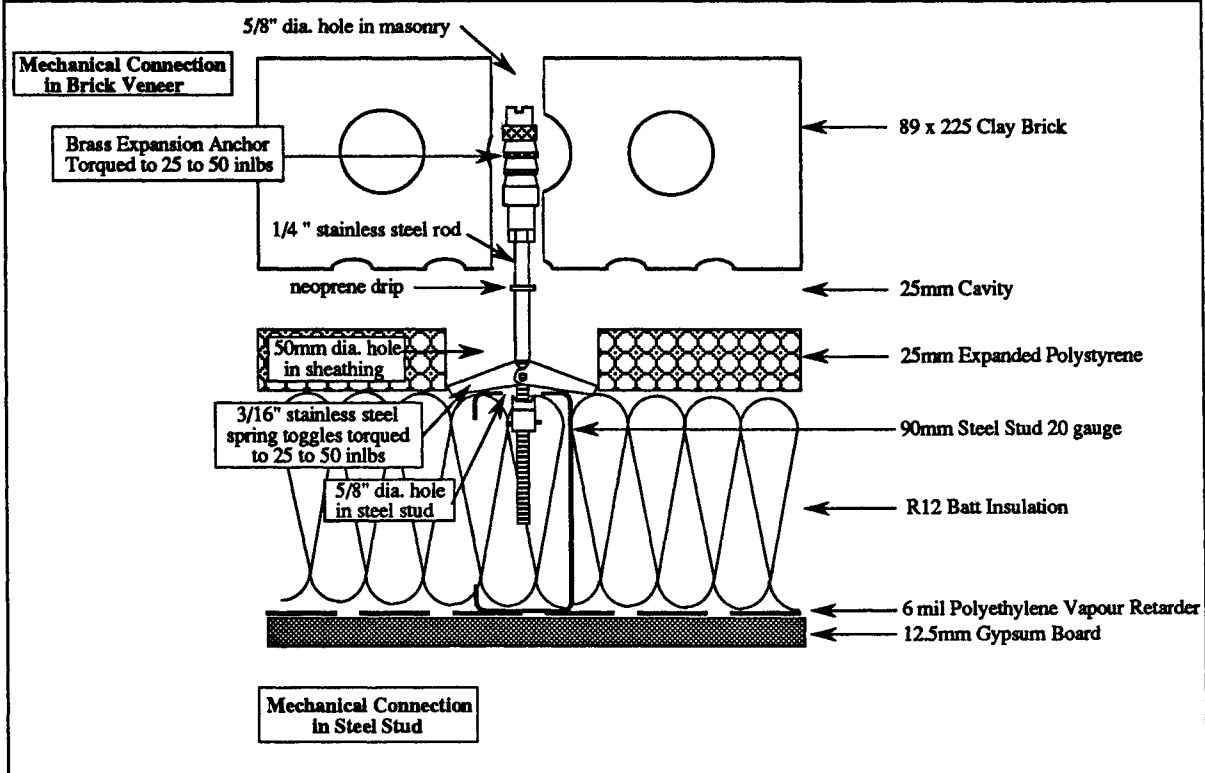
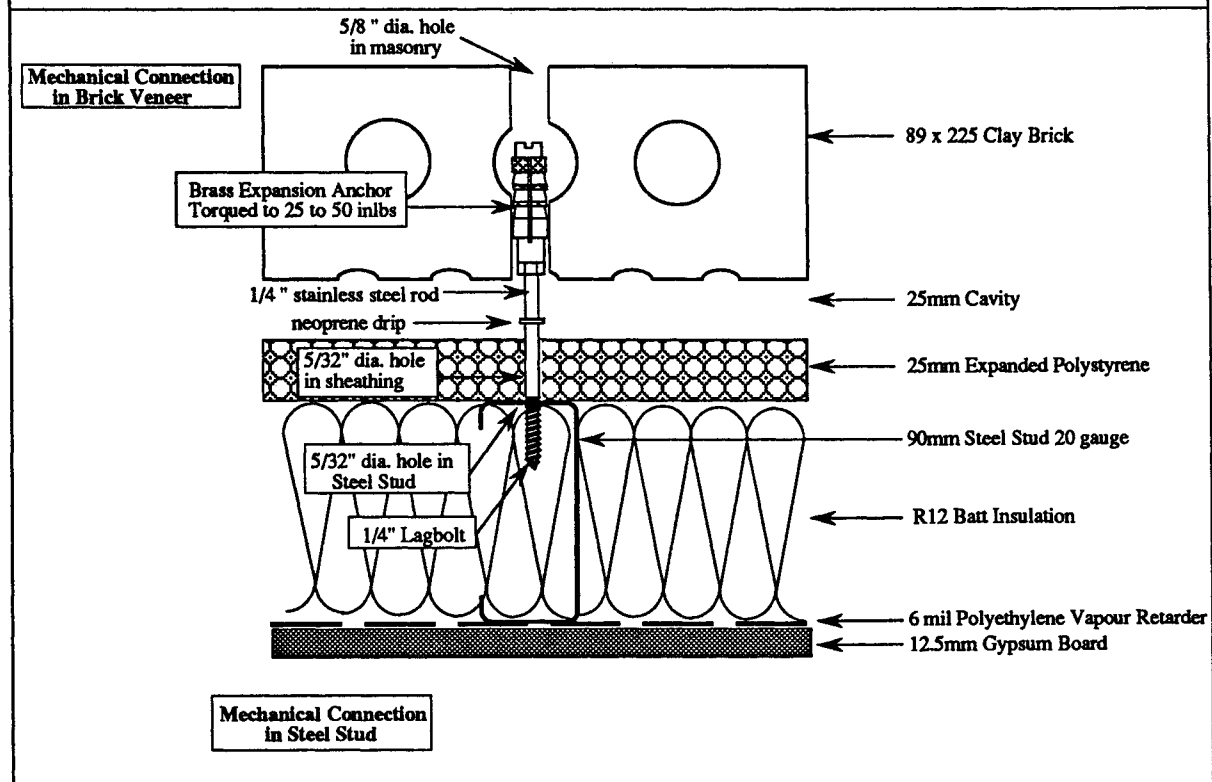
FIGURE 2.7 : Repair Method - Dur-O-Wall Toggle Clips and Expansion Anchor**FIGURE 2.8 : Repair Method - Dur-O-Wall Threaded Bolt and Expansion Anchor**

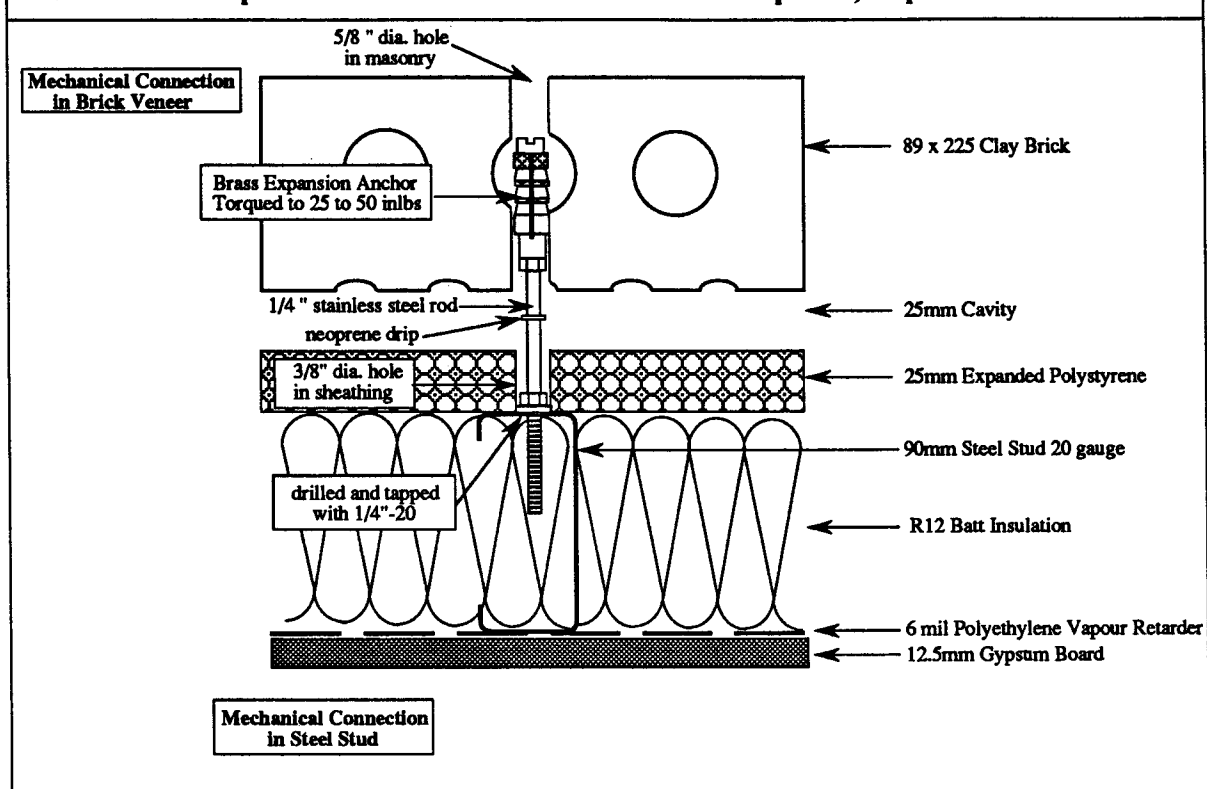
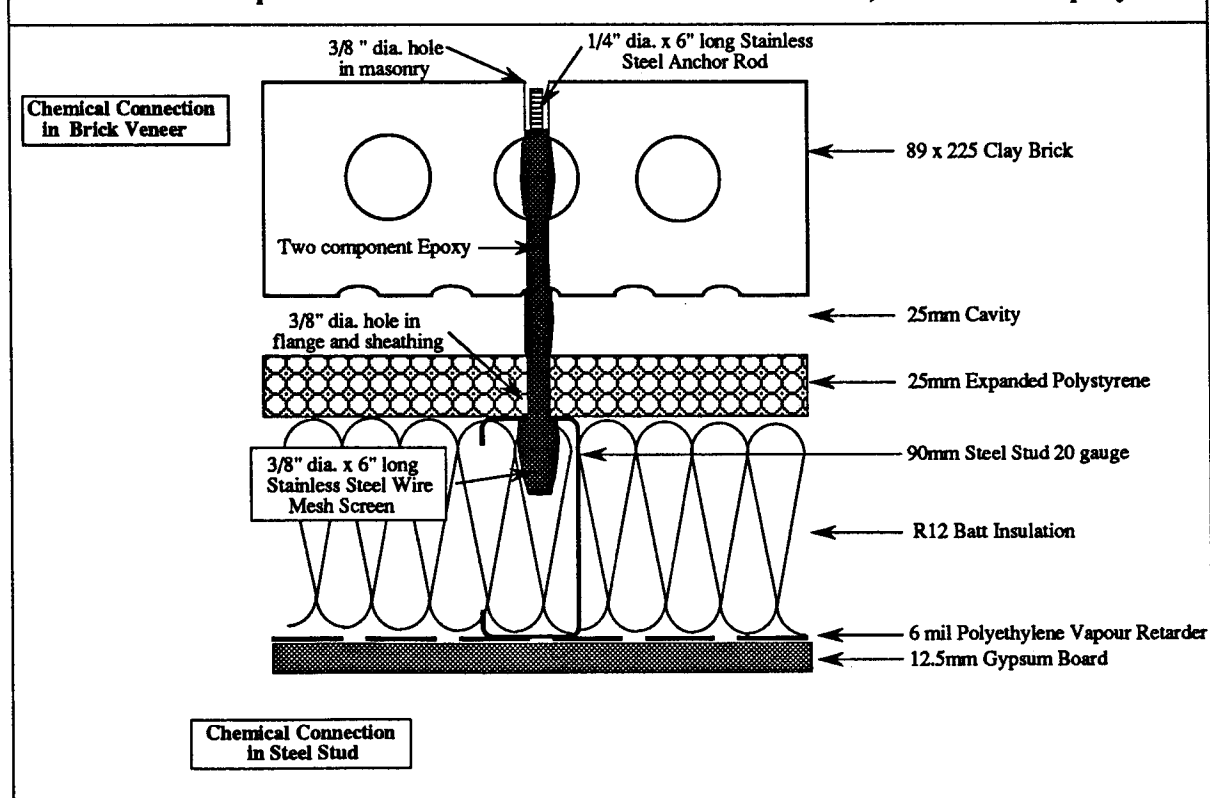
FIGURE 2.9: Repair Method - Dur-O-Wall Drill and Tap Bolt, Expansion Anchor**FIGURE 2.10 : Repair Method - Dur-O-Wall Stainless Steel Rod, Sleeve With Epoxy**

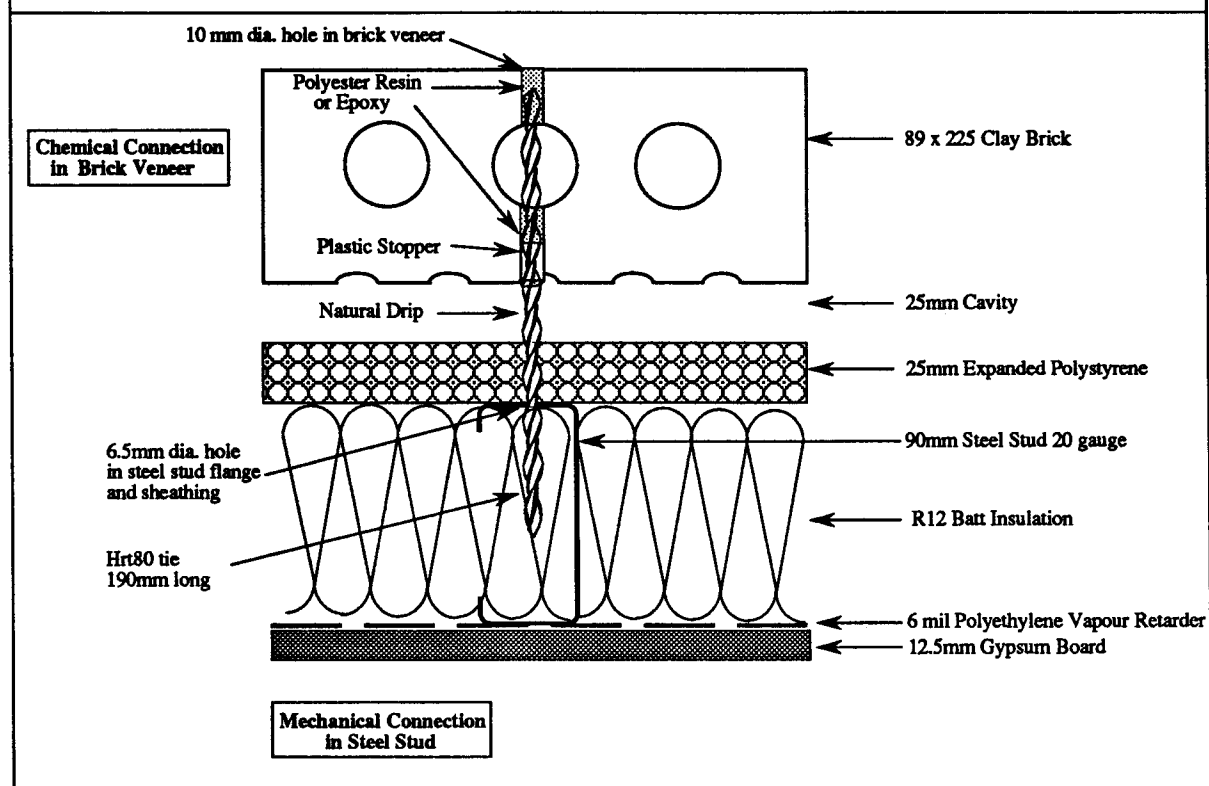
FIGURE 2.11 : Repair Method - Helifix HRT80 Dry Fix in SS, Polyester Resin in BV

Table 2.2: Comparison of Exterior Retrofit Systems

	Cintec Cementitious Sock (65mm)	Cintec Cementitious Sock (22mm)	Dur-O-Wal Toggle Clips & Exp. Anchor	Dur-O-Wal Threaded Bolt & Exp. Anchor
INSTALLATION				
Ease	-	*	*	*
Time	-	*	*	*
Visibility of Damage	-	-	*	*
Weather Limitations	-	-	*	*
Effect on Tenant	*	*	*	*
REPAIR CHARACTERISTIC				
Strength of Connection	*	*	?	?
Ductility of Connection	-	-	*	*
Air Leakage	*	*	*	*
Various Thicknesses of Stud	*	*	*	?
Moisture Drip	+	+	+	+
Potential for Corrosion	+	+	*	*
Effect of Corrosion on Connection	*	*	*	-
Thermal Bridging	*	*	*	*
COST				
Cost of Tie	+/- \$ 15.00	+/- \$ 9.00	+/- \$ 3.00	+/- \$ 3.00
Cost of Labour**	?	?	?	?
Relative Cost of Making Good	-	*	+	+

Note:

* satisfactory, or of no relative difference

+ relatively positive, or beneficial or better

- relatively negative, or worse

? not known, or still to be determined

** the scale of the repair and the current status of these approaches affect this answer and make it difficult to provide any kind of assessment.

Comparison of Exterior Retrofit Systems (Continued)

	Dur-O-Wal Drill and Tap & Exp. Anchor	Dur-O-Wal S.S. Rod in Epoxy	Blok-Lok Helifix HRT80
INSTALLATION			
Ease	*	*	*
Time	*	*	*
Visibility of Damage	*	+	+
Weather Limitations	*	-	-
Effect on Tenant	*	*	*
REPAIR CHARACTERISTIC			
Strength of Connection	?	*	?
Ductility of Connection	*	-	+
Air Leakage	*	+	*
Various Thicknesses of Stud	?	*	?
Moisture Drip	+	-	+
Potential for Corrosion	*	+	*
Effect of Corrosion on Connection	-	*	-
Thermal Bridging	*	+	*
COST			
Cost of Tie	+/- \$ 2.50	+/- \$3.00	+/- \$ 3.75
Cost of Labour**	?	?	?
Relative Cost of Making Good	*	+	+

Note:

- * satisfactory, or of no relative difference
- + relatively positive, or beneficial or better
- relatively negative, or worse
- ? not known, or still to be determined
- ** the scale of the repair and the current status of these approaches affect this answer and make it difficult to provide any kind of assessment.

The ease of installation of the various repair methods varied considerably. The screw-type tie systems were relatively easy to install. The anchors utilizing epoxy or grout filler were easy to install, but the preparation and use of fillers adds complication. The toggle clip anchor should be easy to install, but the chance for problems is increased as the installation is done blind.

2.7 Conclusions

Various tie systems that are commercially available for use as remedial or supplementary brick ties in brick veneer/steel stud walls have been identified. Each repair strategy has been physically demonstrated and then comparatively assessed. It was evident that information on the likely mechanical characteristics of the tie to stud connection was needed and, at this point, the objectives and scope of Tasks 2 and 3 could be specified.

Procedures for locating the steel stud from both the exterior and the interior have been identified and documented. It was found that locating the studs from the interior is generally easier than doing so from the exterior, but practicable procedures are available to address both situations.

Whether the need for remedial brick ties is due to improper tie selection or inadequate spacing does not significantly affect which supplementary tie system should be used. However, the choice of tie system and whether an interior or exterior repair method should be used does depend on the nature and extent of all the repair work needed on the building. The impact of other building deficiencies may affect the choice of tie repair method. The choice of whether an interior or an exterior repair method is used will depend on numerous factors including cost, access, timing, and the type of other wall repairs that are needed. All things considered, the choice of a repair system depends on the overall state of the building, the comparison of the costs and benefits of alternative strategies, and the needs of the owners and tenants of the building.

3. Testing

3.1 Introduction

In Tasks 2 and 4 a comprehensive program of physical testing was conducted of five remedial tie systems. The objective was to assess likely performance and develop design values for those tie systems that seemed to have the most potential (on the basis of cost, practicality, novelty, etc.) for tie remediation. In this chapter these test programs and their results are briefly summarized.

3.2 Tie Systems Tested

The five tie systems selected were:

- Helifix HRT80, Exterior Fix (Fig. 2.11)
- Dur-O-Wal Threaded Bolt and Expansion Anchor, Exterior Fix (Fig. 2.8)
- Dinal Threaded Rod and Collapsible Fastener (Molly Nut), Exterior Fix (Fig. 3.1)
- Helifix HRT80, Interior Fix (Fig. 2.4)
- Dur-O-Wal Rod with Epoxied Sleeve, Interior Fix (Fig. 2.3)

Four of the five tie systems were demonstrated in Task 1. The Dinal tie was a more recent development, and its testing constituted Task 4. Details of the Dinal tie and its installation are shown in Figure 3.1. This tie utilizes a threaded Molly Nut (that collapses or flattens upon tightening) for mechanical attachment and a rubberized, thick washer as an air and water seal.

3.3 Test Program

Any tie connecting brick veneer and steel stud must of course be appropriately attached to both the brickwork and the light-gauge steel stud. Because the brickwork is essentially rigid in its own plane and relatively stiff out of plane, and because the behaviour of the framing is to some extent affected by the composition of the wall (particularly the sheathings), it is debatable whether a test on any individual tie is representative of actual response. Nevertheless, it is both customary and convenient to test individual ties. As the tie is either epoxied or grouted into the brick or mortar joint, it can be assumed that the brickwork-tie connection is both stronger and tighter than the tie-steel-stud connection. Accordingly, all testing was limited to the interconnection of a single tie and a steel stud.

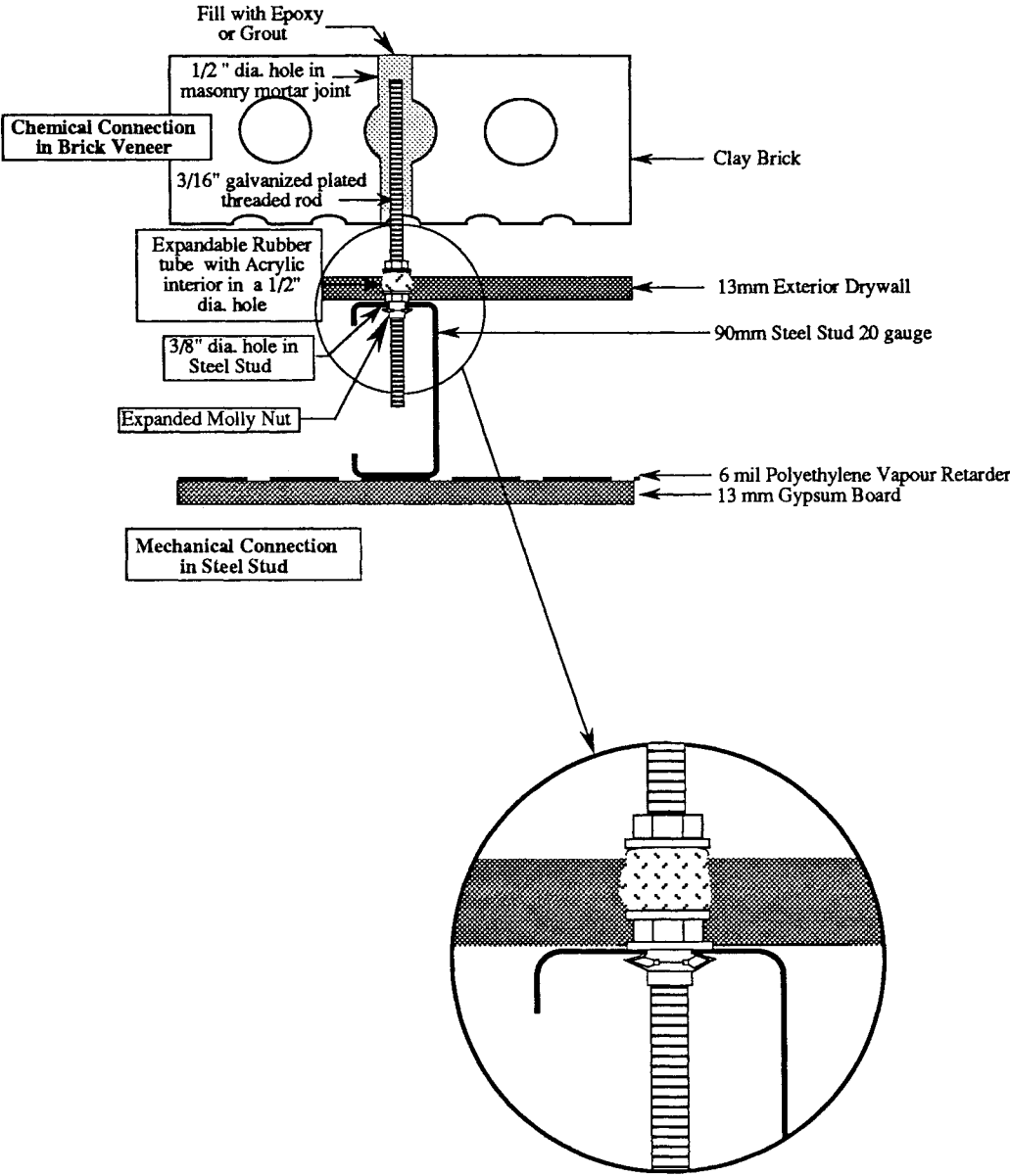


Figure 3.1 : Dinal Exterior Tie in a BV/SS System

In addition to the five remedial tie systems, the following primary variables were considered:

- **Stud:** Four different gauges of steel stud (16,18, 20 and 21) were used. Table 3.2 lists the main dimensions for the different sizes of steel stud tested.

Gauge	Thickness (inches)	Thickness (mm)	Overall web width (mm)	Overall flange (mm)
16	0.060	1.52	92	41
18	0.048	1.22	92	41
20	0.036	0.91	92	41
21	0.033	0.88	92	31

Table 3.1: Description of Steel Studs

- **Tie Location:** As these remedial ties are inserted blind, they cannot always be located at the middle of the flange of the stud. Stud deformation can affect performance, and the position of the tie relative to web of the stud needs to be experimentally assessed. Tests were carried out with ties located 10mm, 20mm, and 30mm from the web. Generally, however, tests with the tie located at mid-flange (20mm from the web) were considered to be representative, if not the average, of reality.
- **Stud Deformation and Wall System:** The cavity space, the nature of the outer sheathing and thus the unrestrained span of the tie as well as the stiffening of the stud are important variables. As many BV/SS walls are being built with insulating sheathings or with other sheathings that do little to stiffen the tie (either the rotation of the flange or flexural stiffness), we chose to test the unstiffened stud which is the conservative case. In all the tests a 50mm unrestrained span or length of tie was used. Note, however, that in compression—especially for the thinner ties or thinner studs—the probability of buckling increases as the span increases.

In an actual wall the stud will deform as a whole in flexure, the connected flange(s) will rotate, and each tie will undergo some deformation relative to the point of attachment. To simulate reality “beam” tests are necessary, and we chose to use a stud span of 400mm in an attempt to model a common vertical spacing of ties. In addition “isolation” tests were done on specimens where these overall deformations of the stud were largely eliminated. In order to differentiate between the different forms of deformation (stud flexure, flange rotation and tie displacement)

and their influence, a series of “rigid datum” tests were carried out; these were “beam” tests where, because a rigid tie was used, the tie could not contribute to the measured displacement.

The program of tests conducted in this phase of the overall project is shown in Table 3.2. In general, a minimum of five identical tests were carried out for each variable. A total of 474 tests were conducted.

3.4 Test Setup and Procedure

Figure 3.2 illustrates the setup for both the so-called beam test and the isolation test that were used in the testing program. In the beam test the likely influence of the stud, both flange and web movement, is introduced. In the isolation test the overall displacement of the stud acting as a beam is eliminated, as is most of the rotation of the flange.

Tests were conducted using a MTS electro-hydraulic test facility at the University of Waterloo. For the monotonic tension and compression tests to failure, the ties were loaded under stroke control at a rate of approximately 6 mm/min.

In those tests where cyclic pre-conditioning was initially imposed, a sinusoidal loading with an amplitude of 0.15 kN (0.33 Lbf) tension and 0.15 kN compression was applied for 1,000 cycles at 1.0 Hz. The specimen was then failed under stroke-controlled monotonic loading. During the load cycling, as well as the test to failure, the displacement of the tie and the stud was recorded. An X-Y plotter and computerized data acquisition system were used to continuously record both the load and displacement values during each test.

3.5 Interpretation of Test Results

Over the past three or four years many issues relating to masonry ties have had to be reconsidered. The 1984 version of CSA A370 Standard “Connectors for Masonry” was clearly inadequate, especially with regard to testing. A substantially upgraded standard was re-issued in mid-1994. Over the course of this project we had access to the various draft versions of the proposed standard. The test results are evaluated in accordance with the newly issued CSA A370-94 Standard.⁶

Nature of Test			Steel Stud gge.	Remedial Tie System					Datum or Rigid Tie System	Comments
Type or Setup	Pull-out(T) or Push-in(C)	Load Type		Exterior Fix			Interior Fix			
				HRT80	D-O-W	DINAL	HRT80	D-O-W		
I S O L A T I O N	T	M	16							Monotonic pull-out to failure - simulates restrained stud condition
			18			5				
			20	5	5	6	5			
			21			8				
		Pre- & M	16	5	5		5			Preconditioned - 1000 Cycles of ± .15 kN at 1Hz and then monotonic to failure
			18	5	5		5			
			20	5	5		5			
			21	5	5		5			
	C	M	16	5			3	5		Monotonic push-in to failure
			18	5			5	5		
			20	5	3	5	5	5		
			21	5		5	5	5		
Pre- & M	16							Preconditioned - 1000 Cycles of ± .15 kN at 1Hz and then monotonic to failure		
	18									
	20	5			5	5				
	21									
B E A M	T	M	16	5 *	5 *		5 *		Most comprehensive series - monotonic pull-out simulates unrestrained stud	
			18	5 *	5 *		5 *	5		
			20	5 *	5 *	5	5 *	5		
			21	5	5	5	5	5		
		Pre- & M	16						2	Preconditioned monotonic to failure
			18	5	5		5		2	
			20	5	5		5		3 +	
			21	5	5		5		3 +	
	C	M	16	5				4	4	Monotonic push-in (as above)
			18	5	5		5	5		
			20	5	5		5	5	1	
			21	5	5	5	4	5	1	
		Pre- & M	16							Preconditioned (as above) monotonic to failure
			18							
			20	5	4		5	5		
			21					5		
Total No. of Tests			125	97	44	121	69	18	TOTAL: 474	

* Indicates those tests that were repeated but with the tie located other than at the centre of the flange

+ indicates both one and two flange connections were tested

Table 3.2: Test Program

3.5.1 Strength

The new standard for masonry connectors contains two specific strength requirements:

1. The maximum strength must be greater than 1 kN,
2. The design capacity of the tie should be determined using the following Limit States procedure. Characteristic values for strength may be determined from the test results as follows:

$$P_{ch} = \bar{x} - 1.5 \cdot (\text{Standard Deviation})$$

where \bar{x} is the average value of at least five tests.

This characteristic value is representative of a confidence level of 93%. Clauses 8.4.2.1.2 and 8.4.2.1.3 of the new standard require that the maximum permissible design capacity, P_w , at the service load level be calculated as follows:

$P_w = (P_{ch} / 1.67)$ for *material* failure of the metal components of the connector (i.e., a ϕ factor of 0.9 and a load factor of 1.5), or

$P_w = (P_{ch} / 2.50)$ for *embedment* failure or failure of the fasteners, or elastic buckling failure of the connector (i.e., a ϕ factor of 0.60 and a load factor of 1.5).

In these tests failure of the tie rod material did not occur. Failure always involved some damage to the stud and the latter, more conservative, criterion applies.

To these specified requirements a third has been added. To ensure repeatable, if not calculable, response under service loads the design load should not exceed the load value for linear proportionality, i.e., P_p . Accordingly the design load, P_w , cannot be greater than P_p .

3.5.2 Deformation

In an attempt to ensure structural serviceability the new connector standard, CSA A370-94, requires the following:

1. The total free play of multi-component ties, including any free play or slack between a tie component and the structural backing, when assembled, should not exceed 1.2 mm.
2. When tested under a compressive or tensile load of 0.45 kN, the sum of the displacement and free play of the tie should not be more than 2.0 mm. Displacement includes all secondary deformations of the structural backing. Secondary deformations include fastener slippage, flange rotation, bending, and

compression of load bearing insulation or sheathing. Displacement does not include the primary deflection of the structural backing (i.e., bending of the steel stud wall).

In the Standard CSA A370-94, the term “free play” refers to the measurable slack under the initial no-load (unloaded) condition. While the standard does not call for any cyclic pre-conditioning, we are of the opinion that, especially for blind and dry installed remedial ties into metal stud, some sort of check on tightness is also necessary, both during and after the application of realistic in-service levels of repeated loading. Thus, the slack displacement and overall movement before, during and after cyclic pre-conditioning also need to meet the serviceability requirements specified. Accordingly, this limiting displacement criterion was applied to tie performance before, during and after the conditioning. It follows that the 2mm criterion was also applied to the pre-conditioned test specimen. This is more stringent than actually specified in the standard.

To account for statistical variability within each test series, characteristic values for displacement may be obtained as follows:

$$\Delta_{ch} = \bar{x} + 1.5 \cdot (\text{Standard Deviation})$$

where \bar{x} should be the average displacement of at least 5 tests. Note, however, that the variability of displacement measurements can be large enough to produce distorted characteristic values.

3.6 Discussion of Test Results

3.6.1 Overall Response

Figure 3.3 illustrates a representative pullout or tension load-versus-displacement graph for a tie subjected to stroke-controlled monotonic loading. Also shown is the nature of a pre-conditioning load cycle showing both the slack (if any) and the overall cyclic displacement. Tie performance in monotonic tension can be characterized as an initial, relatively stiff, linear stage terminated by the Proportional Limit (P_p, Δ_p) which was not always well defined. Subsequent behaviour is essentially non-linear up to the maximum strength (P_m, Δ_m). With the exception of the Dur-O-Wal Exterior Fix, the other tie systems generally continued to behave in a stable and ductile manner until well after the maximum strength had been attained.

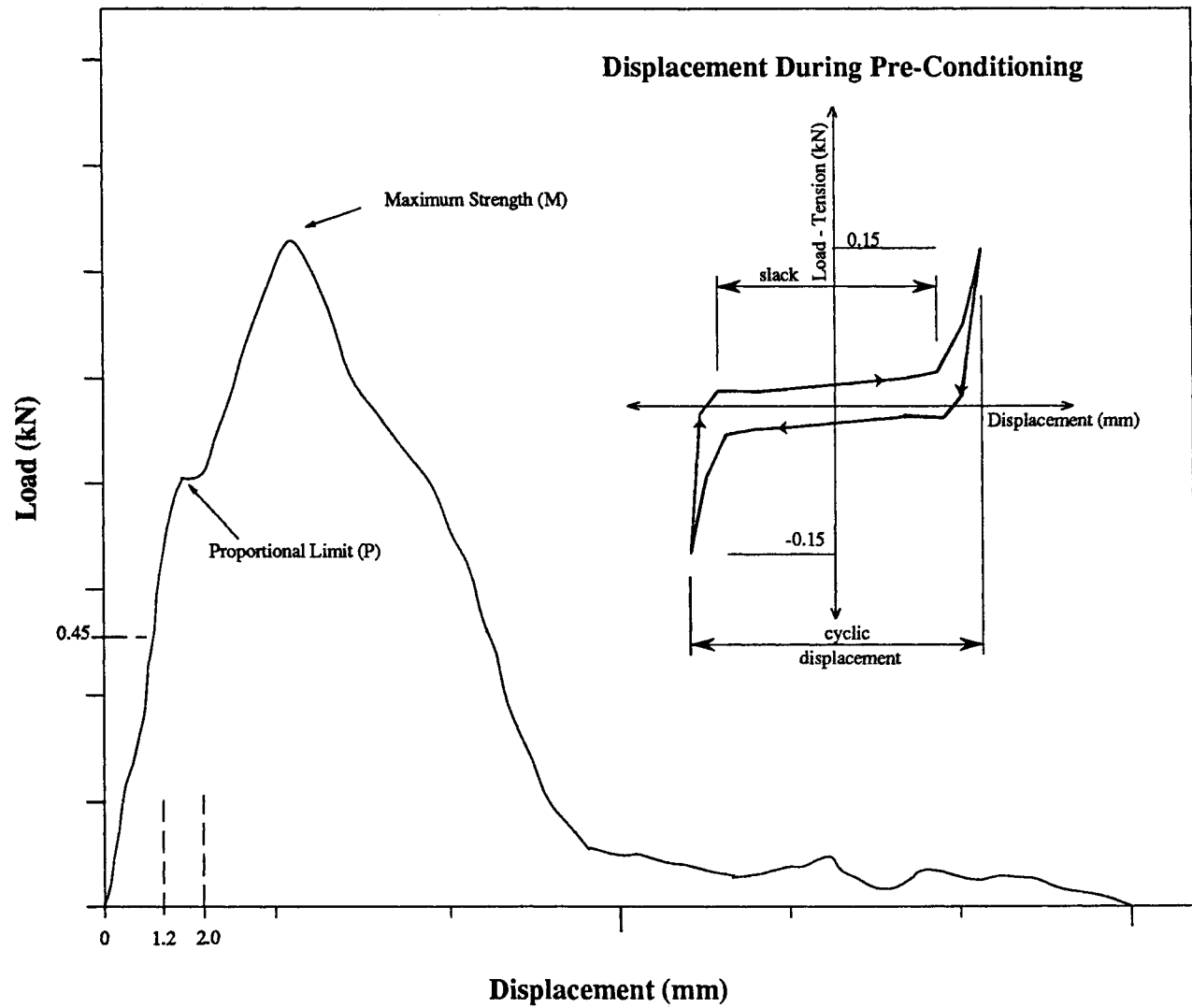


Figure 3.3: Representative Load versus Displacement Relationship

Tie response in compression or push-in is generally comparable to that in tension or pullout. In none of the push-in tests was buckling of the tie (within the 50mm span of the tie) an issue. Usually embedment failure occurred with slippage or damage at the tie-flange interface. In some cases (for example, with the Dinal and Helifix exterior fixes) failure occurred when the end of the tie touched the bottom flange and then buckled.

The nature of the tie resistance is important, as it gives some indication of the likely behaviour of the interconnected wall system when subjected to excessive loading such as wind or earthquake. If a connection is required to accommodate relatively large displacements due to accidental or abnormal loadings, such as impact or explosion, it is important for the designer to know the potential for deformation and for sustained strength at large displacements. In addition, the ability to absorb or shed energy and avoid high restraint-induced reactions is important for reasons of human safety and building damage. When a masonry connection fails in a brittle manner, not only has irreversible damage occurred but its function has been destroyed and may induce failure or detachment of one or more units. The ability of the connection system to accommodate abnormal or accidental loads without causing a safety hazard or initiating failure or even a progressive form of failure is of benefit. Ductile energy-absorbing connections, for example, would be highly advantageous in seismic areas. This characteristic preserves human safety and permits later repair.

Except for the Dur-O-Wal interior fix, the other four tie systems demonstrated ductile response which is beneficial for energy dissipation and redistribution, and thus resistance to seismic or abnormal loadings of a dynamic or impactive nature. Note, however, that with the Dinal tie most of the movement is due to the stud, whereas the displacement of the Helifix ties is mostly provided by movement of the tie relative to the stud. The Dur-O-Wal exterior one-flange connection, under tension, is relatively brittle. The Dur-O-Wal interior repair, with a two-flange connection, undergoes a significant and steep loss of resistance when the epoxy starts spalling. Although failure as such does not occur, the drop in resistance is so significant that maximum strength (P_m) should be considered the limit on useful life. Although both the interior and exterior Helifix repair methods produce connections that are not very stiff, they do possess considerable ductility.

3.6.2 Structural Serviceability

In the interest of brevity, only summary conclusions are presented.

Slack/Cyclic Displacement: The only ties to exhibit significant slack and cyclic displacement were the Helifix ties. The only tie system that did not meet the 1.2mm limit was the Helifix exterior fix (only one flange involved) and then only with the 21 gauge studs.

Limiting Displacement: Both the Dur-O-Wal Interior Fix and the Dinal tie systems readily meet the 2mm displacement at 450N criterion. Ties that rely on a screw connection tend to be

relatively flexible, largely because of slippage. On the basis of these tests, the Helifix tie can only consistently meet the 2mm limit when used with 16 gauge or thicker studs. The Dur-O-Wal Exterior fix, which employs a lagbolt with a finer thread than the Helifix, is satisfactory except when connected to 21 gauge or thinner studs. In the case of 21 gauge studs, this tie has a characteristic value that exceeds 2mm by a small margin. It should be noted, however, that the presence of sheathing would significantly reduce the value of the 450N displacements measured in these tests.

Initial Stiffness: A variety of different values could be developed. For example, 450N divided by the associated displacements at this load level is one possible definition—in fact the 2mm displacement at 450N criterion is essentially a stiffness limitation. Another preferred definition is based on the proportional limit, i.e., P_p/Δ_p . While a stiffness value may be desired for the purposes of structural analysis, these test results indicate the following:


- Values will vary greatly depending firstly on whether the loading is pullout or push-in, and secondly on the position of the tie in the flange of the stud.
- Sheathing and other wall components will have a significant influence.
- Statistical variability is high, and the development of a single characteristic value for stiffness becomes a problematic exercise.

3.6.3 Structural Safety

A summary of the governing values of the characteristic strengths, P_{ch} , and the equivalent design service load resistance values, $P_{ch}/2.5$, for all the five tie applications is presented in Table 3.3. Also presented in Table 3.2 are the characteristic values for the proportional limit load, P_p . Provided the value for maximum capacity, P_m , is greater than 1kN, then the lesser of the two values, $P_{ch}/2.5$ or P_p , represents a possible value for the service load design capacity of a specific tie connected to a particular gauge of stud.

Note that the Helifix tie develops less strength than the other tie systems tested and that, when connected to the thinner studs, the Helifix tie does not meet the minimum target strength of 1kN. Moreover, serviceability criteria have still to be applied to these strength limits in order to arrive at design values.

Fix	Type of Tie	Gauge of Steel Stud	Limiting Value of Characteristic Strength P_M kN	Equivalent Service Level Design Capacity $P_M / 2.5$ kN	Limiting Characteristic Value of Proportional Limit Load P_P kN	Tie Design Load at Service Level P_w kN
E X T E R I O R	Dinal (3/8" Ø holes)	16	-	-	-	-
		18	2.740	1.096	1.23	1.10
		20	2.385	0.954	0.80	0.80
		21	1.535	0.614	0.42	0.42
	Helifix HRT80 (6.5 mm Ø in 16 ga.)	16	1.345	0.538	0.63	0.54
		18	1.065	0.426	0.57	0.42
		20	0.730	0.292	0.20*(0.46)	0.29
		21	0.520	0.208	0.24	0.20
	Dur-O-Wall (5/32" Ø holes)	16	3.630	1.452	2.08	1.45
		18	2.155	0.862	1.22	0.86
		20	1.670	0.668	1.05	0.66
		21	1.190	0.476	0.35*(0.39)	0.39
I N T E R I O R	Helifix HRT80 (6.5 mm Ø holes)	16	1.390	0.556	0.40*(0.77)	0.55
		18	1.105	0.442	0.42	0.42
		20	1.025	0.410	0.25	0.25
		21	0.745	0.298	0.22	0.22
	Dur-O-Wall (3/8" Ø holes)	16	1.235*(2.63)	0.494(0.66)	0.73*(1.21)	0.66
		18	1.405	0.562	1.11	0.56
		20	1.245	0.498	0.62	0.50
		21	1.000	0.400	0.62	0.40

 Failure to meet code provision that P_M be not less than 1.0 kN.


- * Apparently anomalous because the standard deviation (variability of results) is large enough to distort the characteristic value. Mean value is given in brackets alongside.


Table 3.3: Tie Strength Summary

3.7 Conclusions

Superimposing all the structural serviceability and structural safety criteria on the test results, a summary table of design recommendations may be developed. In Table 3.4 the service load values recommended for design are given for each of the remedial tie systems tested. These values also apply for new construction but with the additional provision that 20 gauge or lighter steel stud framing should not be used for exterior BV/SS walls.

Stud Gauge	Design Capacity at Service Load for the:				
	Dinal Tie Exterior Repair kN	Helifix Exterior Repair kN	Dur-O-Wal Exterior Repair kN	Helifix Interior Repair kN	Dur-O-Wal Interior Repair kN
16	*	0.54	1.45	0.55	0.66
18	1.10	0.42	0.86	0.42	0.56
20	0.80	0.29	0.66	0.25	0.50
21	0.40	0.20	0.39	0.22	0.40

 Less than the 1 kN maximum strength requirement (see Table 3.3)

 Exceeds the 2 mm at 0.45 kN serviceability requirement

*Not tested but greater than 1100N.

Table 3.4: Recommended Design Values

The design values provided are conservative in that no provision has been made for any sheathing. Two other points to note are as follows:

- The Dinal tie consistently has the greatest capacity. Given that the tie rod is relatively thin and that the molly nut appears somewhat flimsy, the performance of this tie system was remarkably good.
- The Helifix tie would not appear to be particularly suitable for connection to 18 gauge or thinner steel studs. However, we believe that installation procedures can be improved, and some additional developmental work is recommended. Moreover, any restraint to flange rotation and stud deformation—such as that provided by sheathing—would significantly enhance the relative performance of the Helifix product.

The information provided in Table 3.4 is suitable for the purposes of preliminary design of a remedial strategy for a BV/SS enclosure wall. For final design, the values provided by the manufacturer or supplier of the tie must be used. Table 3.4 does not obviate the need for comprehensive conformance testing on the part of the tie supplier. Any extrapolation should be done very carefully, especially with studs thinner than 21 gauge.

4. Post-Remediation Performance Considerations

4.1 Introduction

It is evident that BV/SS walls that do not have adequate lateral connection between the brick veneer and the steel stud can be repaired relatively cheaply and quickly by installing remedial ties. Since the remedial tie penetrates the building paper, the sheathing and/or insulation and the stud space, wall performance characteristics such as temperature, air leakage, drainage, etc., will be affected. Long-term durability is also a concern, particularly any increase in the potential for corrosion. Therefore, the likely performance of BV/SS walls after the installation of supplementary or replacement ties needed to be addressed.

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. The Task 3 Report documents in some detail the work done, both analytical and experimental. Five significant performance issues were identified. Relevant conclusions and recommendations are presented in the five summary sections that follow.

4.2 Thermal Considerations

There are two obvious concerns for existing BV/SS construction. The first concern is the increase in space-conditioning energy consumption. The relative effect of different tie systems and the overall effect of remedial ties on heating energy costs are both small. The more important thermal concern is the additional thermal bridging provided by the new remedial 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 contained within the stud space. In these cases, especially in climates such as southern Ontario, it is likely that tie remediation alone is neither a sufficient nor a suitable solution.

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

If remedial or supplementary ties are needed, it is clearly a disadvantage to have all the thermal insulation within the stud space. Control of moisture is less of an issue when the temperature within the stud space is high and stable. In order to avoid excessive moisture accumulation within the stud space, the wall system should incorporate a thermal break, preferably insulating sheathing, between the steel stud framing and the cavity space. It is, however,

difficult to introduce an insulating sheathing as a retrofit procedure. This issue illustrates the fact that tie remediation by itself may not be a sufficient or even a satisfactory solution.

4.3 Installation Considerations

Installing a remedial tie causes some damage to the elements penetrated. Non-standard air leakage tests were conducted in an attempt to measure this damage and to assess its significance. The main conclusions were as follows.

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. Note that repairing a thin polyethylene will be difficult if not impossible; a more practical means of repair is to seal the drywall. It should be self-evident 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 portion of the wall—this is especially a concern with the *Helifix* remedial tie.

The *Helifix* tie has an impact on measured downstream 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.

4.4 Drainage Considerations

Drainage of water from within the wall to the outside is essential. It is important that the tie neither trap nor transport water. Installation should not facilitate water leakage into the interior of the wall. Provided the brickwork is properly sealed after tie installation, it is unlikely that the presence of the remedial ties will significantly affect either the permeability or the 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 suitable sealer coat or repointing or both.

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.

4.5 Corrosion

Corrosion is probably the most important durability concern, especially when the initial problem may have involved tie deterioration.

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.

It should be noted that galvanized steel ties do not satisfy the Level III (moderate to severe exposure) requirements of the CSA-CAN3-A370 Standard. Where remediation of corroded ties is involved, we recommend that stainless steel (or the equivalent) ties always be used. For instance, if the *Dinal* tie is to be used in the remediation of BV/SS walls, it should be made of stainless steel.

4.6 Torsional Stiffening

One of the benefits of this project has been the realization that the remedial ties can be considered to contribute to the in-plane bracing of the framing. As in Figure 4.1 (on the next page), both an interior fix and especially an interior fix provide some degree of lateral restraint to the vertical studs.

The following comments are pertinent:

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

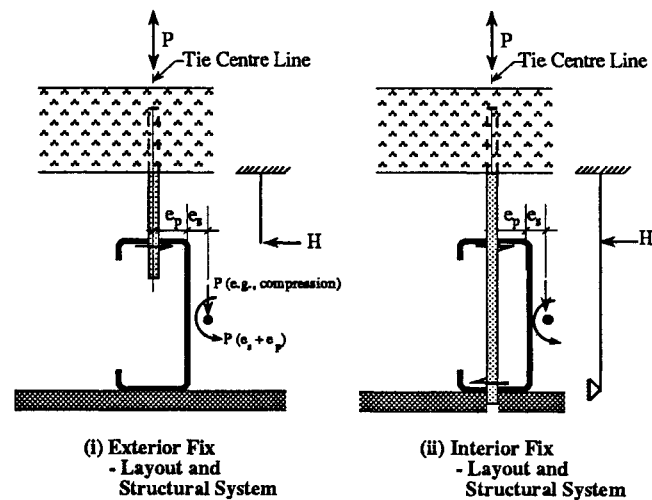


Figure 4.1: Torsional Stiffening of Framing

- An interior fix will generally provide more torsional restraint to the steel stud than the use of an exterior fix.
- Using a simplified analytical model, it was found that torsional stiffness requirements for a typical BV/SS building could be satisfied when the Dur-O-Wal interior and exterior fix are spaced at 600 mm or less. Similarly with an interior fix the Helifix ties should be installed at intervals of 400 mm or less in order to brace an otherwise unbraced steel stud assembly. The limiting stress requirements are also satisfied in each of these cases.
- The issue of torsional stiffening needs additional research and development. Both analytical work and physical experimentation is needed.

4.7 Concluding Comments

Task 3 proved to be of value because a number of issues, some of them new, were 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 useful. 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, this constitutes only one step in the overall remediation of an existing BV/SS wall.

5. Conclusions and Recommendations

The idea of remediating or supplementing the lateral ties in an existing brick veneer/steel stud exterior wall is relatively novel. Obvious obstacles are locating the vertical studs, “blind” installation, and ensuring satisfactory tie-to-stud interconnection. This project has both demonstrated and documented the feasibility and the practicality of this approach. In addition, specific design assistance has been developed and some limitations and reservations have been identified.

The project comprised four distinct phases:

- a practical real-life demonstration phase involving the tie suppliers (Task 1)
- a program of developmental and conformance testing of those tie systems with potential for future use. (Tasks 2 and 4)
- an assessment of various performance related concerns that involved specific structural, building science and other characteristics (Task 3)
- the preparation of a separate summary document (Task 5)

Important conclusions of a general nature are as follows:

1. Tie remediation is demonstrably feasible, and concerns such as locating the studs or working blind during installation can readily be resolved.
2. Tie remediation is practical. Eleven different methods have been demonstrated. Five tie systems have been subjected to rigorous testing, and design values have been developed.
3. Tie remediation can be conducted from either the outside or the inside of the building.
4. The installation of supplementary ties can be used to contribute to:
 - torsional stiffening or in-plane restraint to the framing,
 - structural safety with regard to the accommodation of seismic or explosive load due to the ductility of certain tie systems,
 - upgrading of the wall in order to comply with regulation or correction.
5. Performance considerations such as durability and air and moisture control can usually be resolved provided each issue is properly considered and dealt with.

Tie-specific conclusions and recommendations are as follows:

1. Design capacities for five tie systems—two interior and three exterior fixes—are provided (Table 3.3). This information is suitable for preliminary design. Proper conformance testing should still be provided by the suppliers of each tie system.
2. The Dinal tie performs remarkably well. However, it is strongly recommended that stainless steel versions of this tie be used for remediating existing tie systems in enclosure walls. The long-term durability of the rubberized washer is another concern.
3. The two Dur-O-Wal tie systems worked well. The lagbolt tie (Exterior Fix) should not be used with studs less than 20 gauge. With the epoxied tie (Interior Fix) damage to the epoxy results in a relatively brittle failure mode. Because of the use of dissimilar materials, corrosion may be an issue.
4. The two Helifix applications satisfied all structural safety and serviceability criteria only when connected to studs of 16 gauge or thicker. Relatively lower capacity and low stiffness make it more difficult for the Helifix tie to meet the requirements of the recent Masonry Connector Standard. It is strongly recommended that installation procedures be improved in order to improve tie performance, particularly to reduce slippage or slack displacement and to increase initial stiffness.
5. Improvements can readily be made. Installation procedure and corrosion avoidance are just two aspects that need to be addressed.
6. Consideration should be given to the beneficial effects of the sheathings on tie performance. In fact, the manner in which the steel stud wythe is designed, built and thought to act needs to be seriously re-examined. For instance, the distribution of the thermal insulation and the location of the air barrier need to be re-considered.
7. Cyclic preconditioning, for example 1000 pullout/push-in cycles to a load of about 33 percent of the service load, should be incorporated in any conformance testing program. Any tie—but especially any connection to the flange of a light gauge steel stud—must be firmly attached so that both the slack and cyclic displacement are kept to an acceptable minimum.

There are a number of technical advantages to working from the interior. Not only is it easier to locate the studs but, when working blind, it is preferable to have the brickwork as the second or further component to be connected. Stiffening of the studs to compensate for inadequate bracing is more effective as two flanges are involved. Corrosion is less of an issue and the conditions for “making good” and finishing are more favourable.

Finally it needs to be emphasized that tie remediation cannot be done in isolation. Any renovation strategy must include the restoration of or the provision of an air barrier and the effective control of moisture.

6. References

1. Postma, M.A. and Burnett E.F.P., *Renovation Strategies for Brick Veneer/Steel Stud Wall Construction- Task 1: Brick Ties - Options for Remediation*, Report for Canada Mortgage and Housing Corporation, Ottawa, Ontario, December 1992.
2. Postma, M.A. and Burnett E.F.P., *Renovation Strategies for Brick Veneer/Steel Stud Wall Construction - Task 2: Four Remedial Tie Systems-Development and Conformance Testing*, Report for Canada Mortgage and Housing Corporation, Ottawa, Ontario, August 1993.
3. Wegner, C.I. and Burnett E.F.P., *Renovation Strategies for Brick Veneer/Steel Stud Wall Construction- Task 3: Some Performance Considerations*, Report for Canada Mortgage and Housing Corporation, Ottawa, Ontario, April 1994.
4. Wegner, C.I. and Burnett E.F.P., *Renovation Strategies for Brick Veneer/Steel Stud Wall Construction - Task 4: Dinal Remedial Tie System f* Report for Canada Mortgage and Housing Corporation, Ottawa, Ontario, April 1994.
5. Canadian Standards Association, CAN/CSA A370-M84, "Connectors for Masonry", Toronto, Ontario, 1984.
6. Canadian Standards Association, CAN/CSA A370-94, "Connectors for Masonry", Toronto, Ontario, 1994.

The following publications also relate to this project. The two theses contain more details of the experimental work as well as extensive coverage of the structural implications (both analysis and design) of using remedial ties. The paper is a summary of Task 1.

- Postma, M.A., *Structural Considerations in the Remediation of Brick Veneer/Steel Stud Wall Systems*, Master's Thesis for the University of Waterloo, Waterloo, Ontario, 1993, 335 pp.
- Wegner, C.I., *Remedial Tie Systems for Brick Veneer/Steel Stud Walls*, Master's Thesis for the University of Waterloo, Waterloo, Ontario, 1994, 219 pp.
- Burnett, E.F.P., Postma, M.A. and Wegner C., *Remedial or Supplementary Tie Systems for BV/SS Wall Systems*, Proceedings of the Tenth International Brick/Block Masonry Conference, Calgary, Alberta, July 5-7 1994, p981-991.