RESEARCH REPORT

Renovation Strategies for Brick Veneer Steel Stud Construction: Task 1 Brick Ties

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RENOVATION STRATEGIES FOR BRICK VENEER STEEL STUD CONSTRUCTION TASK 1: BRICK TIES

Prepared for

Jacques Rousseau
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NOTE: **DISPONIBLE AUSSI EN FRANÇAIS SOUS LE TITRE:**

MÉTHODES DE RÉNOVATION POUR CONSTRUCTIONS À OSSATURE D'ACIER ET PLACAGE DE BRIQUE ÉTAPE NO 1: ATTACHES DE BRIQUES

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Disclaimer

This study was conducted by the Building Engineering Group of the University of Waterloo with the assistance of Trow Consulting Engineers Ltd. 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.

BRICK VENEER/STEEL STUD RENOVATION STRATEGIES FOR WALL CONSTRUCTION

TASK 1:
BRICK TIES - OPTIONS FOR REMEDIATION

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December, 1992

ACKNOWLEDGEMENTS

This study is part of a larger R&D project to investigate renovation strategies for Brick Veneer/Steel Stud Systems for the Canada Mortgage and Housing Corporation. We would like to thank Mr. Jacques Rousseau for initiating and directing this unique project. Unique in that it involves the collaboration of government, a university, private consultants and 5 suppliers of masonry ties.

We would like to thank the tie manufacturers/distributors that took part in the demonstrations; Mr. Ken Banks, Mr. Ken Crooks and Mr. Stephen Getz of Dur-O-Wall Ltd., Mr. Pat Sweeney of Blok-Lok Ltd., and Mr. Robert Lloyd-Rees, Mr. Eric Jokinen, and Mr. Dennis Parry of Cintec Canada.

We greatly appreciated the assistance of Mr. Larry McQuaig and Mr. Louis Reginato of Trow Consulting Engineers Ltd., Cambridge office, in managing the demonstrations and in preparing this report.

We would like to thank the local property manager, Mr. Nick Lang, for his assistance. Thanks are also due to the tenants of the anonymous condominum building. We apologize for any inconvenience and hope the demonstrations prove to be of value.

EXECUTIVE SUMMARY

Over the last 10 years, the performance of the clay brick veneer/steel stud (BV/SS) enclosure system for multi-storey residential buildings has received a great deal of attention. Many buildings have BV/SS enclosures and many of these have experienced or are experiencing problems. Not only is repair expensive, but there is also 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 the self-tapping screws. It is particularly difficult to decide on the form and extent of remedial action. The design professional faces a real dilemma when choosing an appropriate building repair strategy. If legal action is involved, there is considerable pressure to prescribe an overly conservative, "Cadillac" solution. On the other hand, there is 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. There have been numerous building investigations and attendant litigation, notably the Alderney Manor case in Dartmouth, Nova Scotia. Large sums have been spent on R and D studies and field investigations. CMHC has been a prime mover in initiating much of the work in Canada.

The primary *objective* of this research project is to develop various strategies for the remediation and thus the control or avoidance of problems in existing BV/SS wall systems. Five tasks were identified :

Task 1 : Initial Exploratory Study
Task 2 : Tie-Stud Attachment
Task 3 : Tie-Penetration Considerations
Task 4 : Demonstration Panels
Task 5 : Field Trials

This report documents the work conducted in Task 1, the initial exploratory study.

The main *objective* of the first task of this R&D project was to identify, demonstrate and assess the methods of providing supplemental ties to BV/SS buildings. Of particular interest were retrofit procedures that could be conducted from the interior. A secondary objective, common to all repair systems, was to develop procedures for locating the stud from both the interior and the exterior.

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

Dur-O-Wal Ltd., Mississauga, Ontario
Fero 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 this demonstration task the practical difficulties of locating the studs for both exterior and interior retrofit were assessed.

After the installation demonstrations, the third step involved wall investigations to view 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 vapour retarder, the exterior sheathing and other building components. Most of the repair systems 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.

Interior Retrofit

The four interior retrofit methods were all demonstrated relatively successfully. Each method is different and each has advantages and disadvantages. The table titled, "Comparison of Interior Retrofit Systems", summarizes and qualifies the attributes of each method.

With the exception of INT2, the web mounted bracket, the repair methods demonstrated were all feasible. The use of repair method INT2 would only be practical if large amounts of the interior gypsum board were to be removed.

The Cintec anchor, at $9.00 per tie, is much more expensive to buy than Dur-O-Wal's epoxied rod anchor or Blok-Lok's HRT80 tie, which are $3.00 and $3.75 per tie respectively. Too much weight should not be put on the cost of the individual tie. Tie spacing and thus the total number of ties, and installation cost are probably of greater importance than the purchase price of each tie. A major cost will be the labour to install the ties and to return the wall to its intended state.

The aesthetics of the repair, or visibility, 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 repairs INT3 and INT4, approximately 15mm diameter, can be patched fairly readily. The much larger hole, approx. 35 mm, for the Cintec anchor could be decreased by reducing the diameter of the end washer.

All individual remedial tie methods involve damage to the air barrier and vapour retarder. While the drywall can be repaired, the 4 or 6 mille poly, if any, cannot be repaired. However proper sealing of all holes can be done and suitable finishes can be specified and used. In most cases, the provision of an air barrier, especially the sealing of the perimeter joints, is likely to be an important requirement. By doing tie remediation and air sealing at the same time a good overal repair can be achieved.

No damage to the brick veneer should occur with an interior repair but care must be taken to limit the pre-drilled hole to 2/3 or 3/4 of the brick depth. Also impact drills should be used with care.

Thermal bridging, although it cannot be eliminated, can be minimized with the use of ties with small mass. As with other components in a steel stud system, corrosion is a concern. The repair method used should not promote or accelerate corrosion, although the consequences of breaking the galvanizing near the tie connection needs to be studied further. For these reasons a stainless steel tie is preferred especially if the remedial tie is being introduced into a less than ideal environment.

Comparison of Interior Retrofit Systems

	INT1 Cintec Cementitious Sock (22mm)	INT2 Dur-O-Wal Bracket & Exp. Anchor	INT3 Dur-O-Wal S.S. Rod in Epoxy	INT4 Blok-Lok Helifix HRT80
INSTALLATION				
Ease	*	-	*	*
Time	*	*	*	+
Visibility of Damage	*	-	+	+
Weather Limitations	-	*	-	*
Effect on Tenant	-	-	-	-
REPAIR CHARACTERISTICS				
Strength of Connection	*	+	*	?
Ductility of Connection	-	+	-	+
Air Leakage	*	+	*	*
Various Thicknesses of Stud	*	*	*	?
Moisture Drip	+	+	-	+
Potential for Corrosion	+	+	+	*
Effect of Corrosion on Connection	*	*	*	-
Thermal Bridging	-	-	-	-
COSTS				
Cost of Tie	$ 9.00	$ 4.00	$ 3.00	$ 3.75
Cost of Labour**	?	?	?	?
Relative Cost of Making Good	*	-	+	+

* 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.

Exterior Retrofit

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. The table titled, "Comparison of Exterior Retrofit Systems", summarizes and qualifies the attributes of each method.

A common concern is whether the stud can be located with the appropriate degree of accuracy. Various methods for finding the stud from the exterior are identified in the report.

All repair methods, with the possible exception of the larger Cintec repair (EXT1), are feasible and practical methods to tie brick veneer to steel stud. The large 65 mm dia. hole needed for the Cintec tie in repair method EXT1 is aesthetically unacceptable and expensive to do and repair. This repair is, however, suitable if existing ties have to be removed and replaced.

With the exception of the two Cintec anchors, the purchase price for ties ranges from $2.50 to $4.00 per anchor. The Cintec anchors are priced at $15.00 and $9.00 per anchor. These 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 the damage to the exterior sheathing, the air barrier (if involved) and the steel stud is both difficult to assess and difficult to avoid. Repair method EXT3, the Dur-O-Wal toggle clips, is unacceptable for use with compressible exterior sheathings as the toggle clips with either cut a large hole in this sheathing (providing a passage for air leakage) 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, EXT4, EXT5 and EXT7 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.

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.

Comparison of Exterior Retrofit Systems (Continued)

	EXT5 Dur-O-Wal Drill and Tap & Exp. Anchor	EXT6 Dur-O-Wal S.S. Rod in Epoxy	EXT7 Blok-Lok Helifix HRT80
INSTALLATION			
Ease	*	*	*
Time	*	*	*
Visibility of Damage	*	+	+
Weather Limitations	*	-	-
Effect on Tenant	*	*	*
REPAIR CHARACTERISTICS			
Strength of Connection	?	*	?
Ductility of Connection	*	-	+
Air Leakage	*	+	*
Various Thicknesses of Stud	?	*	?
Moisture Drip	+	-	+
Potential for Corrosion	*	+	*
Effect of Corrosion on Connection	-	*	-
Thermal Bridging	*	+	*
COSTS			
Cost of Tie	$ 2.50	$3.00	$ 3.75
Cost of Labour**	?	?	?
Relative Cost of Making Good	*	+	+

* 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)

	EXT5 Dur-O-Wal Drill and Tap & Exp. Anchor	EXT6 Dur-O-Wal S.S. Rod in Epoxy	EXT7 Blok-Lok Helifix HRT80
INSTALLATION			
Ease	*	*	*
Time	*	*	*
Visibility of Damage	*	+	+
Weather Limitations	*	-	-
Effect on Tenant	*	*	*
REPAIR CHARACTERISTICS			
Strength of Connection	?	*	?
Ductility of Connection	*	-	+
Air Leakage	*	+	*
Various Thicknesses of Stud	?	*	?
Moisture Drip	+	-	+
Potential for Corrosion	*	+	*
Effect of Corrosion on Connection	-	*	-
Thermal Bridging	*	+	*
COSTS			
Cost of Tie	$ 2.50	$3.00	$ 3.75
Cost of Labour**	?	?	?
Relative Cost of Making Good	*	+	+

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CONCLUSIONS

An assessment of the relative merits of each repair method has been provided. There is no optimal solution. Each method has both advantages and disadvantages. Moreover each repair situation is unique and may require a unique solution. This report can be used to advantage in arriving at a solution. The comparison tables that have been developed provide a useful vehicle for evaluating supplemental tie systems.

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 procedures are available to address this common problem.

Whether the need for remedial brick ties is due to improper tie selection, corrosion, 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 an interior or an exterior repair method will depend on numerous factors, the most important of which are cost, access, timing and the type of repairs that are needed. All things considered, the choice of repair system does depend on the overall state of the building, the costs of alternative strategies and the needs of the owners and tenants of the building.

RECOMMENDATIONS

There are many areas of concern that have been not dealt with in detail and there are issues that have not been considered in this report. Before using any of the tie systems demonstrated we recommend some key questions need to be asked, e.g.,

1) What is the installation cost?

2) What is the cost of making good?

3) What are the performance characteristics of the connections in the steel stud flange?

4) How does the installation of remedial anchors affect the stiffness of the wall system?

5) What about tie penetration considerations such as air leakage, corrosion potential, etc.?

In this report the focus has been on identifying and demonstrating possible remedial tie systems. Item 3 above will be the focus of the next task, Task 2, of this study. Item 5 will be addressed in Task 3 and items 1 and 2 will be studied further in the field trials planned in Task 4.

We recommend that some of the above issues be resolved before this report be given wider distribution.

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1. INTRODUCTION

1.1 Background

Over the last 10 years, the performance of the clay brick veneer/steel stud (BV/SS) enclosure system for multi-storey residential buildings has received a great deal of attention. Many buildings have BV/SS enclosures and many of these have experienced or are experiencing problems. Not only is repair expensive, but there is also 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 the self-tapping screws. It is particularly difficult to decide on the form and extent of remedial action. The design professional faces a real dilemma when choosing an appropriate building repair strategy. If legal action is involved, there is considerable pressure to prescribe an overly conservative, "Cadillac" solution. On the other hand, there is 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. There have been numerous building investigations and attendant litigation, notably the Alderney Manor case in Dartmouth, Nova Scotia. Large sums have been spent on R and D studies and field investigations. CMHC has been a prime mover in initiating much of the work in Canada.

The primary objective of this research project is to develop various strategies for the remediation and thus the control on avoidance of problems in existing BV/SS wall systems. Five tasks were identified :

Task 1 : Initial Exploratory Study
Task 2 : Tie-Stud Attachment
Task 3 : Tie-Penetration Considerations
Task 4 : Demonstration Panels
Task 5 : Field Trials

This report documents the work conducted in Task 1, the initial exploratory study.

1.2 Objectives of Task 1

In many existing BV/SS wall systems the lateral ties between brickwork and steel studs are an issue, i.e.,

- the wrong tie may have been used. Clause 9.2 in the CAN3-A370-M84 standard, regarding the use of strip ties, is often either violated or loosely interpreted
- the tie is corroding or likely to corrode
- the tie has been incorrectly installed

Complete replacement or even enhancement of the existing tie system can be a very expensive and difficult process: difficult because typically the stud has to be located working blind from the outside, and expensive because the brickwork must somehow be properly re-attached to the stud with minimum damage.

The main objective of this first task of the research study was to identify, demonstrate and assess the methods of providing supplemental ties on BV/SS buildings. Of particular interest were retrofit procedures that could be conducted from the interior. A secondary objective, common to all repair systems, was to develop procedures for locating the stud from both the interior and the exterior.

1.3 Scope and Approach

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

Dur-O-Wal Ltd., Mississauga, Ontario
Fero 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 by the tie manufacturers and distributors on an existing BV/SS building. In this demonstration task the practical difficulties of locating the studs for both exterior and interior retrofit were assessed. Three of the five companies participated in these demonstrations and they are listed below :

Company	Date of Demonstration	Number of Methods		Contact Person(s)
		Interior	Exterior	
Cintec	June 8, 1992	1	2	Mr. Robert Lloyd-Rees Mr. Eric Jokinen Mr. Dennis Parry
Blok-Lok	June 11 1992	1	1	Mr. Pat Sweeney
Dur-O-Wal	June 17, 1992	2	4	Mr. Ken Banks Mr. Ken Crooks Mr. Stephen Getz

After all the demonstrations were conducted, the third step was an investigation inside the wall to view the repair methods. 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 vapour retarder, the exterior sheathing and other building components. Inspection of most of the repair systems from the exterior was also conducted by removal of small sections of the brick veneer.

The fourth and final step was to compare each retrofit system on the basis of cost of the installed tie, to describe the method of installation and to assess the effectiveness of each retrofit procedure.

This report documents the work conducted in the tasks described. A video has also been prepared to supplement this report.

2. DESCRIPTION OF BUILDING AND BRICKWORK

The building used for the demonstrations is a 9 storey multi-unit residential building located in southwestern Ontario. The building is approximately 4 years old.

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 in a large room containing exercise equipment and a jacuzzi. Photo 1 shows an exterior view of this wall. Photo 2 shows an interior view of this wall.

Figure 1, shows the composition of the wall :

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

In the remainder of this report the thickness of the stud will be referred to as stud thickness not gauge. The use of both SI and English units is used where applicable.

The brick veneer is interrupted at every floor, supported on shelf angles.

Although this is a 9 storey building the ties that were used are residential corrugated strip ties. The CSA Standard CAN3-A370-M84 restricts the uses of standard corrugated strip ties as follows :

1) use in buildings not exceeding 11 metres in height (Clause 9.2.1.1)
2) use with the maximum unsupported length of tie between the veneer and its structural backing of 25 mm (Clause 9.2.1.2 (b))

Because the wrong ties have been used and because of installation problems, some supplementary ties need to be installed. These deficiencies make this building suitable for this project to physically demonstrate various remedial methods for installing supplementary ties.

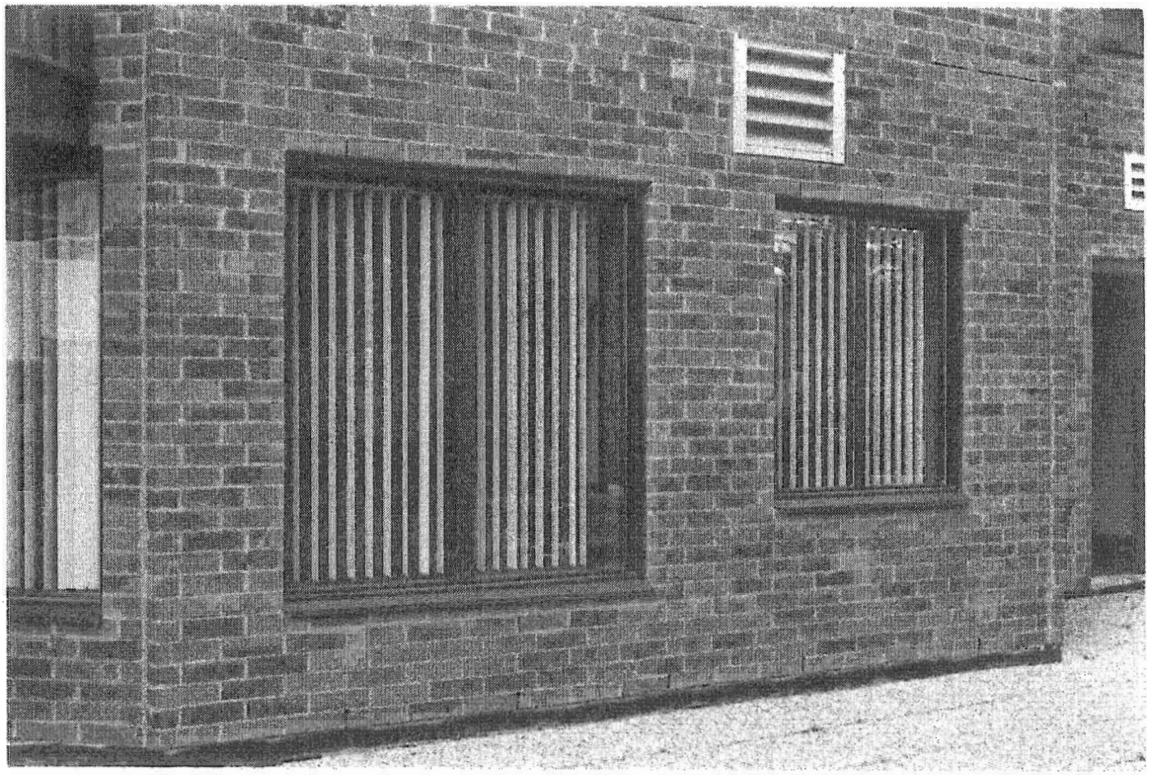

Photo 1 - Exterior of Wall Used for Demonstrations

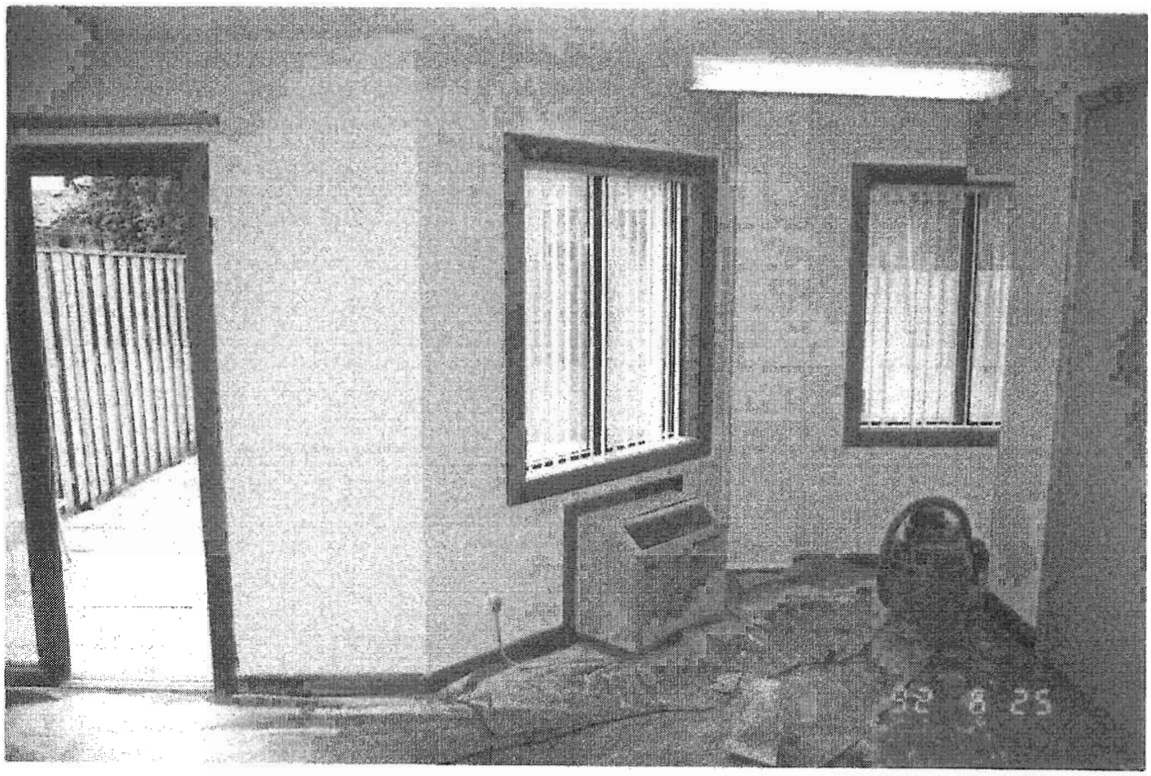

Photo 2 - Interior of Wall Used for Demonstrations

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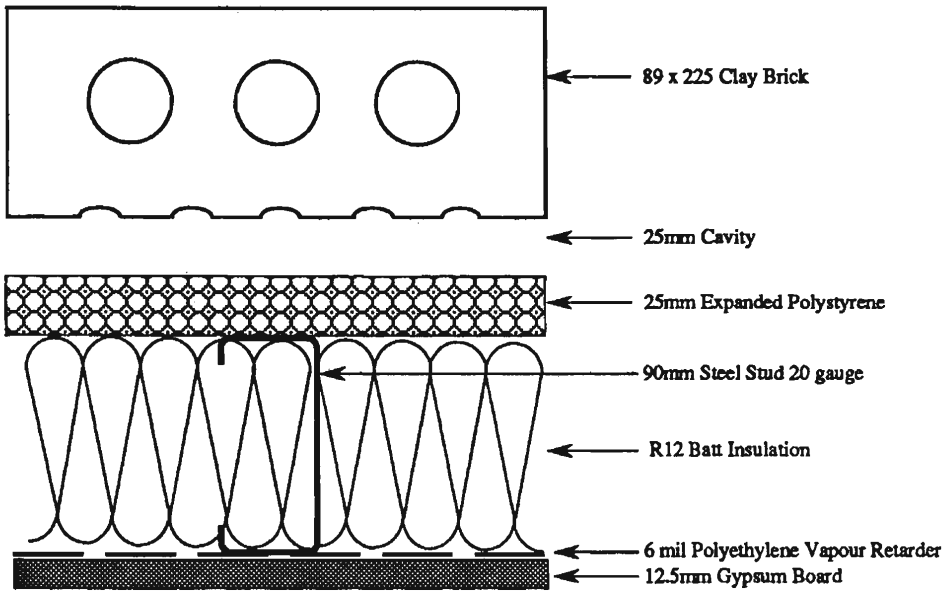
FIGURE 1 --- Cross Section of Brick Veneer/Steel Stud Wall



3. LOCATING THE VERTICAL STEEL STUDS

Properly locating and penetrating the stud has a bearing on the reliability and effectiveness of any of the repair procedures. Therefore a common concern with all the retrofit tie systems was how to locate the vertical steel studs.

The objective is to locate the stud with a reasonable degree of precision, to establish on what side the web lies (if possible) and to do so as quickly and with as little physical damage as possible. The ease with which this can be done is very much dependent whether done from the interior or the exterior, on floor height and 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.

In this demonstration project, various methods of stud location were used. This section of this report summarizes the procedures used and outlines suggested procedures for locating the vertical studs.

3.1 From the Interior

The methods used to locate studs from the interior were very similar and are summarized below.

1) Locate and mark the likely positions of studs at known positions, i.e., adjacent to windows, doors etc.
2) If possible obtain design drawings and estimate the location of other studs.
3) a) Confirm these positions with a metal detector
OR b) Open up the wall and confirm the location of the flange and the direction of the C channel with a hammer and nail or spike, etc.
5) Transfer these positions up and across the wall and mark with a chalk lines.

3.2 From the Exterior

Locating the steel studs from the exterior was found to be more difficult than from the interior. Two methods of locating the studs were demonstrated. The first involved the use of a metal detector to locate the steel studs while the second method involved saw-cutting the mortar joint in the expected vicinity of the steel studs. The latter method is preferred and is described in the detailed procedure later in this section.

The success of the method involving the metal detector will depend to a large degree on the particular metal detector, the experience and competence of the user, and the type of the tie system. In some respects, the small diameter ties in some of the retrofit systems allow for a larger margin of error in locating the extremities of the steel stud flange than the larger diameter tie systems, as the larger diameter ties require greater precision in locating the flange of the stud in order to make an effective connection and to avoid drilling into the web section of the steel stud. However, when using a metal detector to locate the stud it was found that the studs could not be located accurately enough for the smaller ties. This is illustrated in Photo 3 which shows a steel stud that was found with a metal detector. It was found that the steel stud was not centered on the 65mm dia. core hole, but was offset by up to 20mm. With the large 65mm dia. core used in this connection the stud was found accurately enough to install the tie. However, this indicates that for tie systems involving small holes in the brick veneer the use of a metal detector to locate the studs may result in missing the stud altogether.

Suggested Procedure for Locating the Studs from the Exterior

1) Guess/assess (use common sense) the location of those studs of known position i.e. adjacent to windows, doors etc.
2) If possible obtain design stud spacing and estimate the location of other studs.
3) If location of the studs is still ambiguous, use the nondestructive methods of locating the studs on the interior described earlier and transfer these locations to the exterior.
4) Saw-cut the mortar joint in the estimated vicinities of the ties.
5) Prodding with a thin rod will determine the exact location of the steel stud, as well as the position of the web of the steel stud.
6) Use a chalk line to map the position of the vertical studs up the wall to the next shelf angle (see Photo 4).

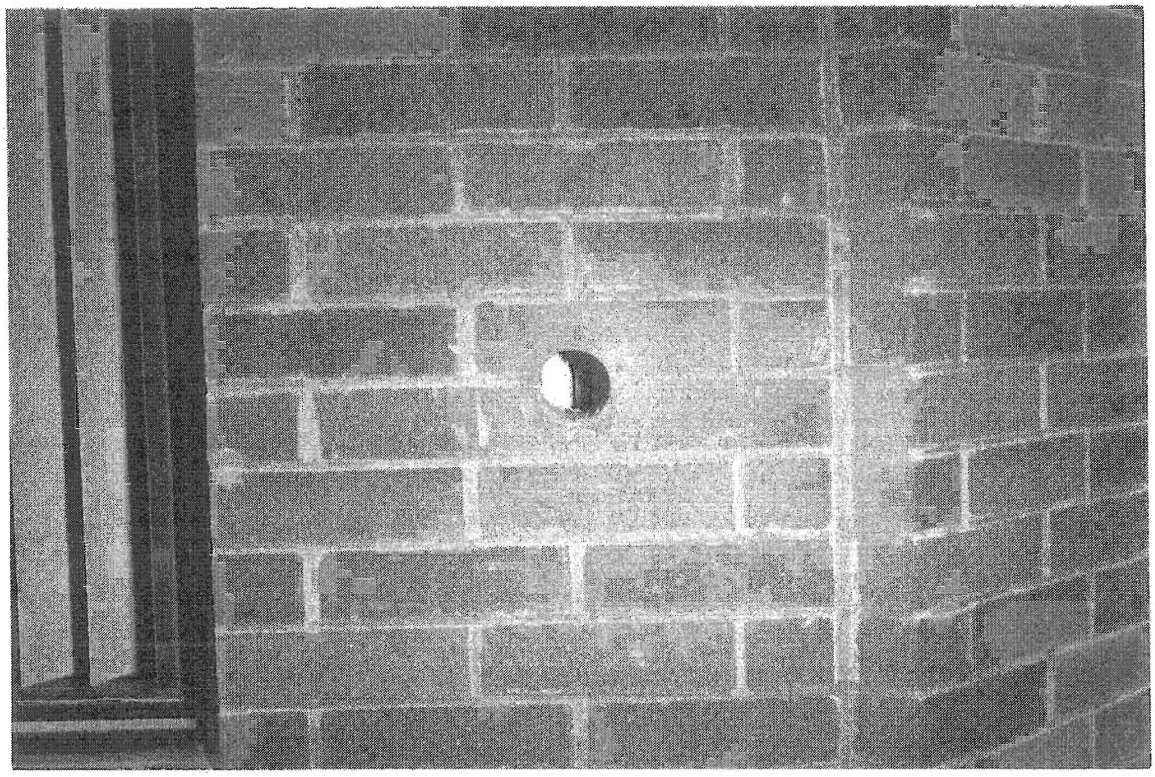


Photo 3 - View of Steel Stud Offset in 65mm dia. Core

Photo 4 - Location of Studs by Saw-Cutting the Mortar Joint

4. DESCRIPTION OF INTERIOR REPAIR METHODS

Four different interior retrofit systems were demonstrated, namely :

INT1 Cintec Cementitious Sock with a 22 mm hole
INT2 Dur-O-Wal side mounting bracket and expansion anchor
INT3 Dur-O-Wal Stainless Steel Rod and Sleeve with Epoxy
INT4 Helifix HRT80 tie Dry Fix

The following sections discuss the tie, the installation procedure, and the installed costs of the ties and the likely performance of the tie system. Some additional information on the tie systems is provided in Appendix A.

For each tie system, the installations times have been tabulated. The times observed for these four tie systems varied from 100 seconds to 225 seconds. These times were estimated from review of the video and do not include any setup time or switching from one step to the next. Therefore these times are not an accurate indication of the repair times per tie. Accurate installation times could better be established in a larger demonstration project.

4.1 INT1 - Cintec 22 mm

4.1.1 Tie Description

The Cintec cementitious sock anchor employs both a mechanical attachment and chemical bond. The tie consists of an 8mm O.D. , 6mm I.D. stainless steel cylinder with a polyester sock on each end. The tie is inserted in the pre-drilled holes in the brick veneer and the steel stud. Presstec grout, a one component mix of Portland cement, graded aggregate and additives, is injected under pressure to fill and inflate the sock. Grout passes through the expanded sock mesh to provide chemical bond to the brick and the expansion of the sock in the voids of the brick and within the steel stud develops mechanical attachment. Figure 2 illustrates the Cintec 22mm tie repair.

4.1.2 Installation Procedure

After location of the stud, a 22mm dia. steel core on an extension was used to drill through the gypsum board, polyethylene, both flanges of the steel stud and the expanded polystyrene sheathing. A 7/8" (22mm) dia. hole was drilled with hammer drill action and a masonry drill bit. The depth of this hole was approximately 65mm stopping short of the exterior face of the 90mm thick brick veneer. The depth of the hole was then measured in order to size the tie and position of the sock. Before installing the tie, a 35mm dia. hole had to be cut into the gypsum board to accommodate the washer on the end of the tie. A cementitious grout was pumped into the sock which inflates the sock from the rear of the sock to the front.

Table 1 lists the steps in the repair procedure and the observed times for each step in the repair.

FIGURE 2 : Repair Method INT1 - Cintec Cementitious Sock with a 22mm Hole

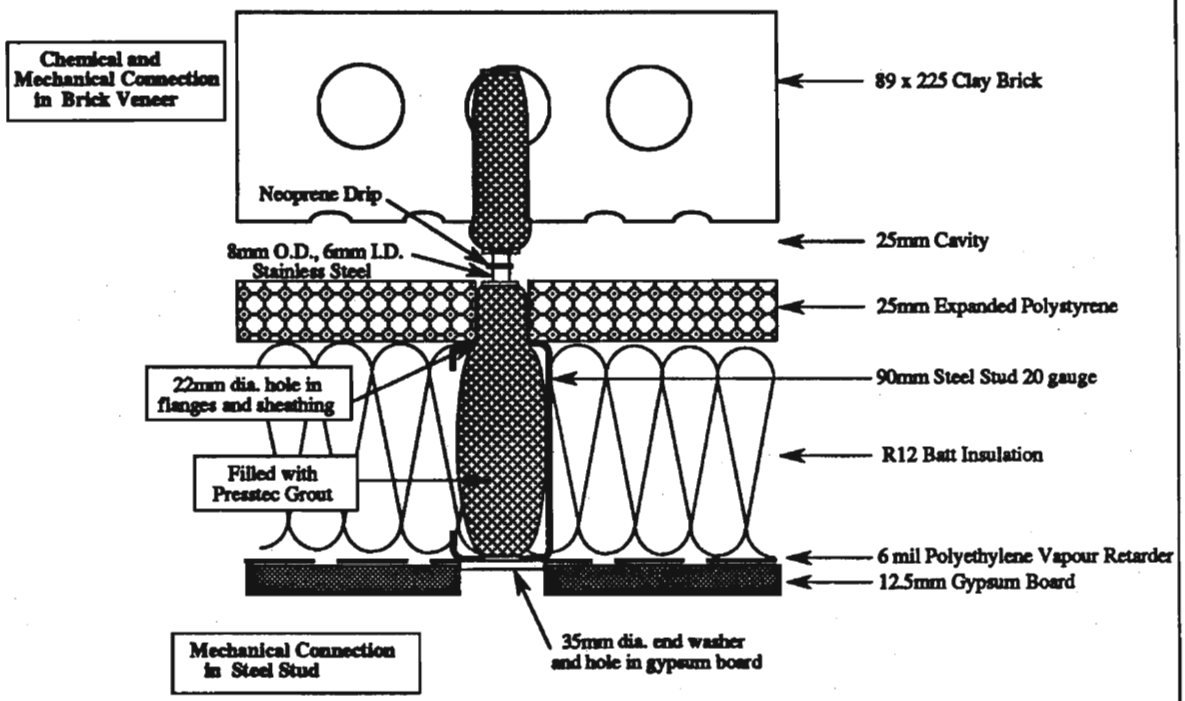


Table 1 --- INT1-Cintec 22mm Installation Procedure and Times

STEP #	DESCRIPTION	TIME (sec)
1	Locate Stud	
2	Drill Through Steel Stud Flanges - 22 mm dia. core on extension - regular drill	60 seconds
3	Drill Into Brick Veneer - 22 mm dia. masonry drill bit - hammer drill - mark distance on drill bit	120 seconds
4	Measure up sock system	
5	Mark and cut drywall to recess 35 mm dia. end washer	30 seconds
6	Insert tie into hole	
7	Inject Grout	15 seconds
8	Repair Hole	
	Total Observed Time for Repair	225 seconds

4.1.3 Cost

The contractor's cost for this tie, which includes the tie unit and the grout, was estimated by Cintec Canada to be $ 9.00 per unit. The labour cost to install the tie cannot be adequately estimated. Grouting costs depend on the efficiency and the scale of the operation. The cost of repairing the interior wall might be slightly higher for the large 35mm dia. drill holes.

4.1.4 General Comments

Installation - With this repair method it is important to locate the flange correctly, as the width of the flange is only 41mm and the drill hole in the flange is 22mm dia. In both repairs demonstrated locating the flange was successfully accomplished. After locating the flange, the remainder of the repair is relatively straight forward and a high degree of quality control can be maintained. A critical step is proper preparation of the grout. As installation is restricted to approved Cintec installers, this should not be a problem. When inserting the tie into the hole, care should be taken to ensure that the sock is not torn in any way as this would render the tie useless. Photo 5 shows that the repair does not create a mess.

Strength of Connection - The washer on the end of the tie bears up against the inner flange of the stud. The grouted sock should engage both flanges of the stud. Of the two demonstrations only one engaged the outer flange(see photo 6). The strength of this connection to the steel stud has not been documented but should be adequate if the proper sock length is chosen so the grout mechanically locks the two flanges together. The 65mm long connection in the brick should be adequate in resisting compression loads but the high reliance on the chemical bond of the milk grout that passes through the sock to the brick needs to be documented.

Damage - The damage to the interior is limited to a 35mm dia. hole that is necessary for the washer to bear on the steel stud. The cutting of 22mm dia. holes in the flange of the steel stud will have an impact on stud stiffness. However the grouted anchor may also stiffen the stud. Note that the exterior sheathing will have a 22mm dia. hole. This hole will be filled by the grouted sock, if the sock is long enough to reach the sheathing. If this hole is not closed a passage for air leakage and water penetration will have been created.

Thickness - The thicker the web and flanges of the stud, the stronger the connection. With thinner studs this grouted fix will have a relatively greater influence in stiffening the wall system.

Drip - The neoprene drip, if placed in the middle of the air cavity, will adequately prohibit water from travelling down the tie to the interior.

Potential For Corrosion - The components of this repair are not susceptible to corrosion or deterioration over time. Extensive corrosion of the steel stud flange would have to occur for this connection to become inadequate. We do not know what the effect, if any, the grout materials will have on corrosion.

Thermal Bridging - In relative terms, this repair results in a high degree of thermal bridging.

Weather Limitations - There may be some limitations on installation in cold weather as the temperature of the grout is required to be 7 Celsius at the time of injection and has to be kept above 5 Celsius for twenty four hours following injection.

Air Leakage - No increase in air leakage should occur if the sock is manufactured so that the expanded sock effectively blocks the hole through the sheathing and steel stud.

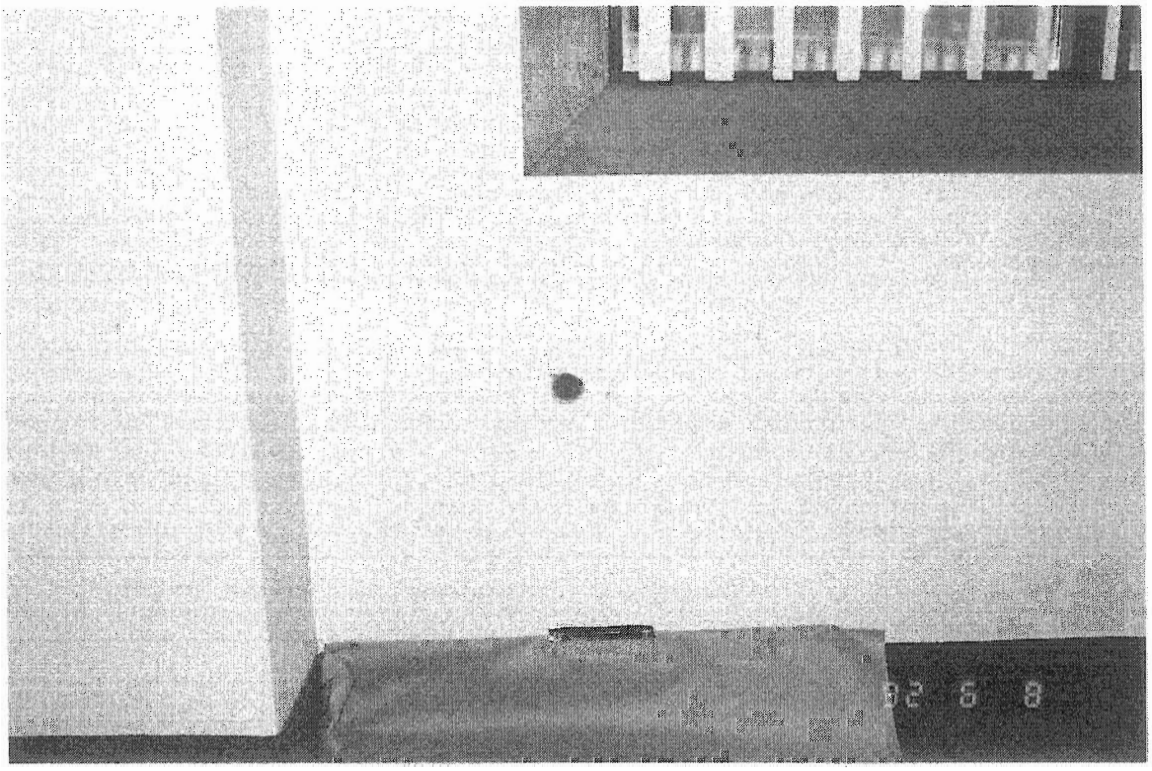


Photo 5 - View of Finished INT1-Cintec Repair

Photo 6 - View of INT1-Cintec Connection with Stud Web Cut Away

BEG

4.2 INT2 - Dur-O-Wal Side Mounting Bracket and Expansion Anchor

4.2.1 Tie Description

The tie used in this repair method has components made of brass, steel, and stainless steel. Photo 7 shows these components. This repair method uses a brass expanding shell to provide the attachment in the brick. This brass unit is threaded onto a 1/4" (5.5mm) dia. 304 stainless steel rod. On this rod is a neoprene drip in line with the theoretical centerline of the air cavity to prevent the passage of moisture down the rod. A 3mm thick steel angle with legs of length 50 and 70 mm is attached to the web section of the steel stud with three TEK screws. The leg of this steel angle that is parallel to the brick veneer has an oversized slot which holds the other end of the threaded rod. A nut and washer threaded, but not tightened, on the rod on each side of this leg of the angle to give a tension and compression attachment but to allow both vertical and horizontal movement. Figure 3 illustrates the INT2 - Dur-O-Wal repair system.

4.2.2 Installation Procedure

This tie would likely be used in cases where the interior gypsum board would have to be removed, making access to the steel stud possible. However, in this demonstration a gypsum board section just large enough to install the tie was removed. Before removing this section of gypsum board the stud was located by cutting a small hole around the area indicated by a stud locator. This allowed identification of the web side of the stud on which the steel angle would be attached. A 300mm x 400mm section of drywall would then be cut out on the web side of the stud.

Using a 1/2" dia. masonry drill bit and rotary action only, a hole was drilled into the brick veneer. The drilled hole in the brick was aligned with the web of the stud. The drill bit was marked so that the depth of the hole is 70mm short of the exterior face of the 89mm brick. A washer at the interior end of the brass expanding shell stops the insertion of the tie at the face of the drilled brick. The brass expanding shell on the threaded rod is expanded in the brick and torqued to 50 to 100 in lbs. The bracket is then located on the steel stud and three TEK screws are installed with a miniature hand held Makita drill. The two nuts and washers on each side of the angle are tightened slightly to provide a tension/compression connection that permits movements in the plane of the brick veneer.

Table 2 lists the steps in the repair procedure and the observed times for each step in the repair.

FIGURE 3 : Repair Method INT2 - Dur-O-Wal Side Bracket and Expansion Anchor

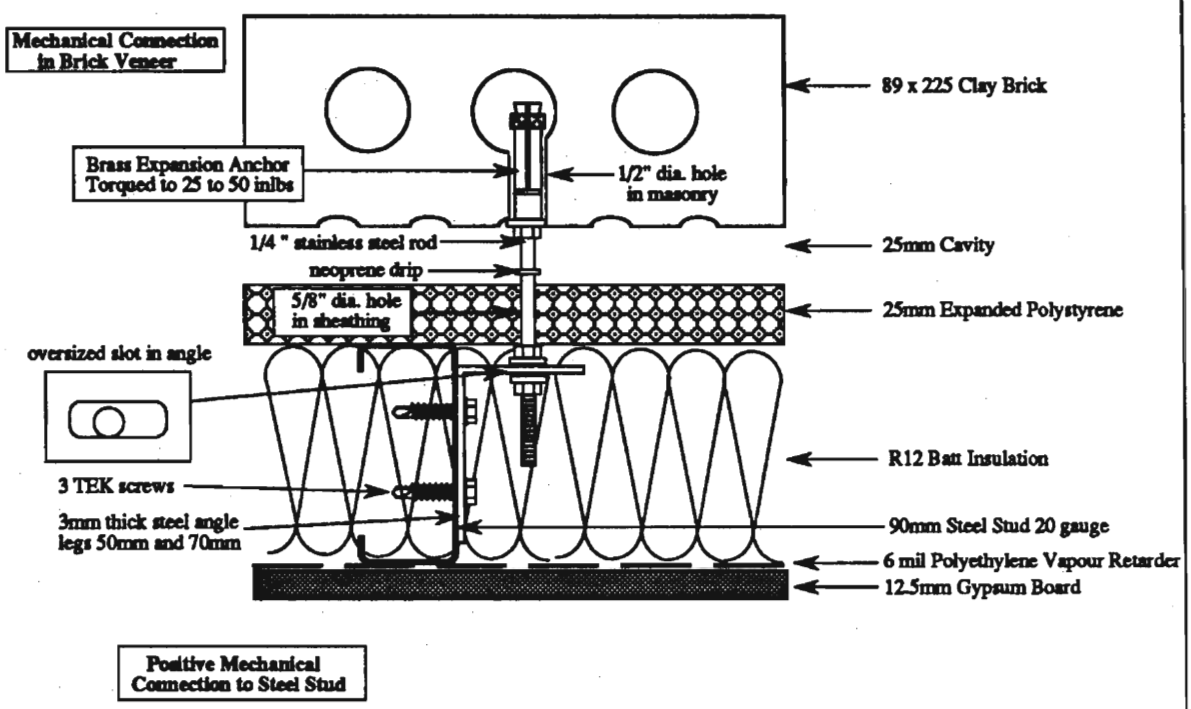


Table 2 --- INT2-Dur-O-Wall Side Mounting Bracket and Expansion Anchor

STEP #	DESCRIPTION	TIME (sec)
1	Locate Stud and determine orientation of C channel	
2	Cut 300mm x 400mm hole in the gypsum board and 6 mil polyethylene	60 seconds
3	Drill Into Brick Veneer - 1/2" dia. masonry drill bit - rotary drill action - mark distance on drill bit	60 seconds
4	Install Expansion Anchor and torque to 50 to 100 in lbs	20 seconds
5	Position and fasten steel angle to the web of the steel stud with 3 TEK screws	60 seconds
6	Adjust nuts around leg of steel angle	
7	Repair Hole	
	Total Observed Time for Repair	200 seconds

4.2.3 Cost

The contractor's cost for this tie was estimated by Dur-O-Wal Ltd. to be $ 4.00 per unit. The labour cost to install the tie cannot be adequately estimated. However, the installation cost will likely be higher than the other connections as a large section of drywall has to be removed. The repair cost of returning the interior wall to its original state could be considerably higher than any of the other systems. However, the cost of this repair strategy may be warranted if replacing the interior drywall is already part of the repair strategy for the entire wall, hence eliminating the cost of repairing the wall.

4.2.4 General Comments

Installation - This repair method requires the removal of at least a 200mm x 400mm section of gypsum board at each tie location or the removal of all the interior gypsum. This repair is thus likely limited to situations where all the interior gypsum board has to be removed to correct other problems with the wall. In locations near window openings or partition walls this repair could not be conducted.

Strength of Connection - The orientation of the steel stud channel is needed as the steel plate is fixed to outside of the web (see Photo 8). There is a very reliable positive attachment to the steel stud. The steel bracket and its connection to the brick veneer will increase the stiffness of the wall system. The performance of the expansion anchor connection in the brick has been thoroughly tested and proven over time. This repair system allows for horizontal and some vertical wall movement while being capable of resisting tension/compression loadings.

Damage - The damage to the gypsum board and vapour barrier has already been noted as being extreme. There is no significant damage to the steel stud or to the brick veneer. The 5/8" dia. hole in the sheathing can easily be sealed with a urethane foam.

Thickness - This repair system is not limited to any range of stud thicknesses, as the TEK screws can be installed in any thickness of stud.

Drip - The neoprene drip, if placed in the middle of the air cavity, will adequately prohibit water from travelling down the tie to the interior.

Potential For Corrosion - The components used in this repair, with the exception of the steel plate, are not susceptible to corrosion. The effect on limited corrosion around the TEK screw connection to the web of the steel stud is unknown.

Thermal Bridging - Relative to other tie systems, a significant amount of thermal bridging will occur at this connection as the threaded rod bridges the air cavity.

Air Leakage - As access to the stud space is required in this repair method any holes that are put through the sheathing could be sealed.

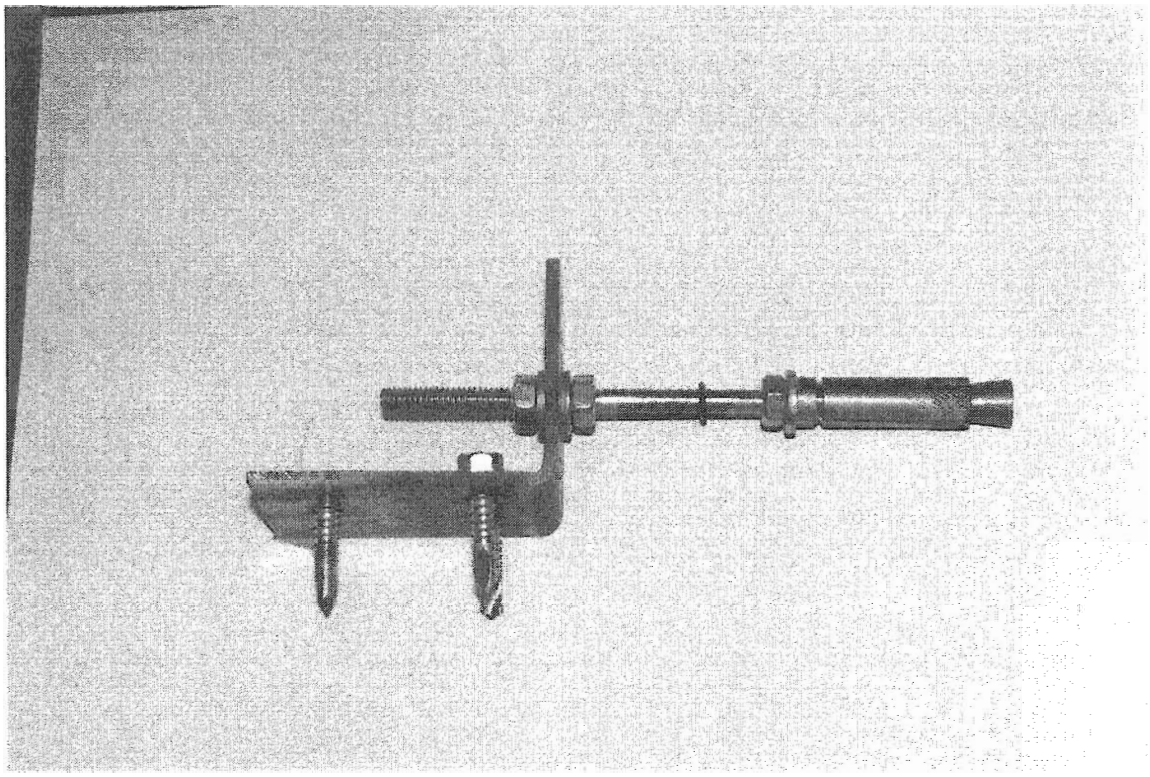


Photo 7 - INT2 - Dur-O-Wal Side Mounting Bracket and Expansion Anchor

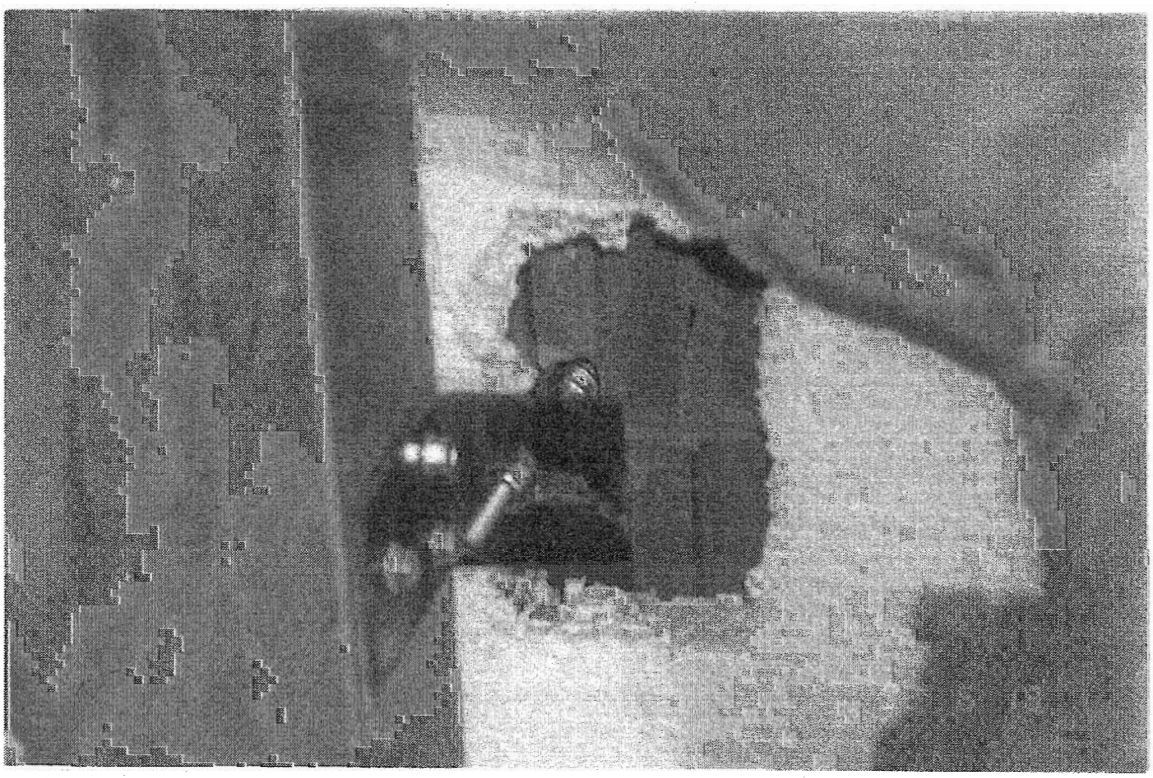


Photo 8 - View of Installed INT2 - Dur-O-Wal Repair

BEG

4.3 INT3 - Dur-O-Wal Stainless Steel Rod and Sleeve with Epoxy

4.3.1 Tie Description

The components of this tie are made from stainless steel and an epoxy. A 1/4" dia. stainless steel anchor rod of 10 1/2 inch length is inserted in a 3/8" dia. stainless steel wire mesh screen of 10 1/2 inch length that is filled with a high thixotropy, two component epoxy. The anchor rod is threaded 50 mm on each end. A 1/4-20 hex nut and 1/4 flat washer on the threaded end of the rod lays flush against the steel stud. Figure 4 illustrates the INT3 - Dur-O-Wall repair system.

4.3.2 Installation Procedure

After location of the stud a 5/8" dia. steel drill bit was used to drill through the gypsum board and polyethylene. A 3/8" dia. steel drill bit was used to drill through both flanges of the steel stud. A 3/8" dia. hole was drilled with rotary drill action only and a masonry drill bit. The depth of this hole was approximately 65mm stopping short of the exterior face of the 90mm thick brick veneer. Outside of the wall, the wire mesh screen was filled with epoxy so that the epoxy had uniformly made contact with the inner diameter of the wire mesh. After blowing the drill fines out of the hole, the epoxy filled wire mesh tube was then set in the pre-drilled hole in the wall. Before insertion, the anchor rod was buttered with epoxy. The anchor rod, with nut and washer threaded on, was then inserted by rotating to assure intimate contact between threads and adhesive. After the anchor rod is inserted, the nut and washer are forced against the steel stud.

As the anchor rod is inserted into the wire mesh, the epoxy protrudes through the mesh and after setting provides a mechanical/chemical fix on both the steel stud flange and the brick. The section of the wire mesh in the air cavity was taped to prevent epoxy from exiting the wire mesh in the cavity. The threads on the anchor rod result in an improved bond between the anchor rod and the epoxy.

Table 3 lists the steps in the repair procedure and the observed times for each step in the repair.

FIGURE 4 : Repair Method INT3 - Dur-O-Wal Stainless Steel Rod and Sleeve with Epoxy

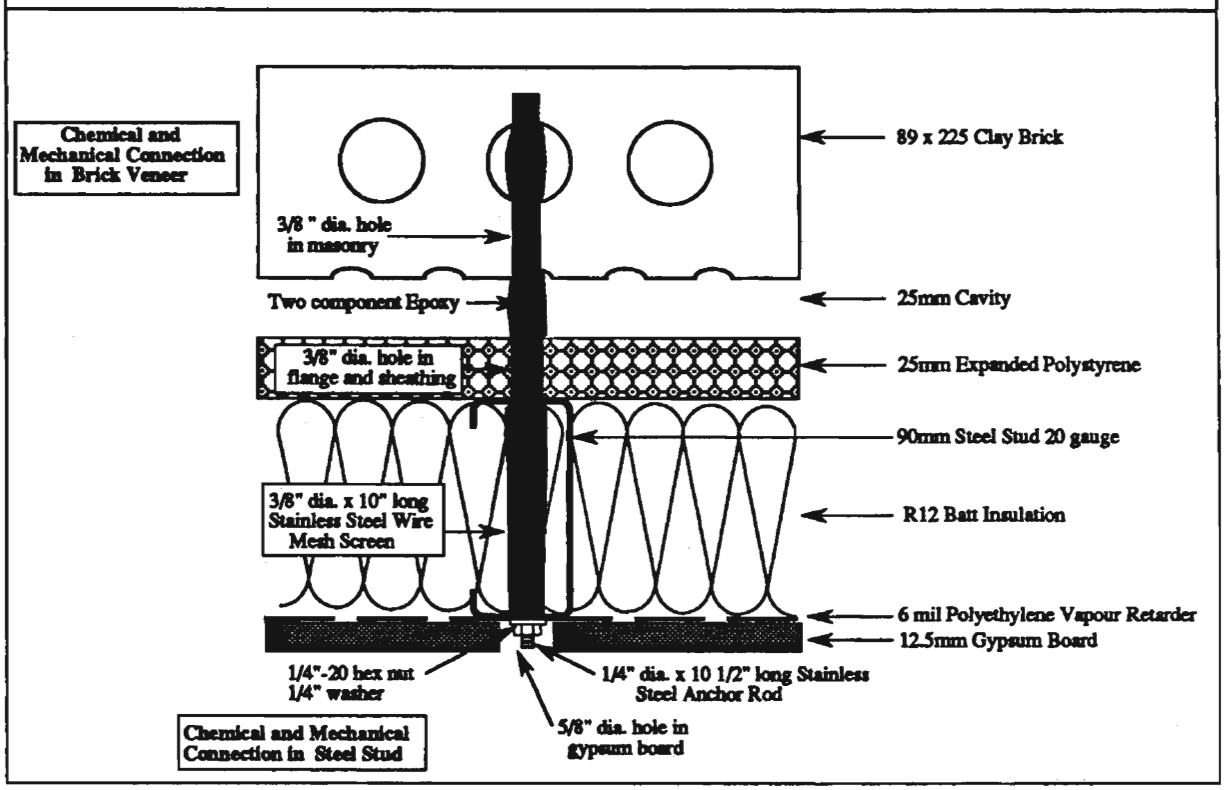


Table 3 --- INT3-Stainless Steel Rod and Sleeve with Epoxy

STEP #	DESCRIPTION	TIME (sec)
1	Locate Stud	
2	Drill Through Gypsum and Steel Stud Flanges - 5/8" dia. in gypsum, 3/8" dia. in flanges - rotary drill action only	40 seconds
3	Drill Into Brick Veneer - 3/8" dia. masonry drill bit - rotary drill action - mark distance on drill bit	90 seconds
4	Blow debris out of hole	10 seconds
5	Fill wire mesh with epoxy outside of the wall	50 seconds
6	Position filled wire mesh in the wall	10 seconds
7	Insert anchor rod into wire mesh by rotating slowly	15 seconds
8	Repair Hole	
	Total Observed Time for Repair	215 seconds

4.3.3 Cost

The contractor's cost for this tie, which includes the tie itself and the epoxy, was estimated by Dur-O-Wal Ltd. to be $ 3.00 per unit. The labour cost to install the tie can not be adequately estimated. As the epoxy is distributed in easy-to-use self-mixing cartridges there would be minimal, if any, extra labour cost due to the use of an epoxy system. The repair cost of returning the interior wall to its original state would be similar to most other systems.

4.3.4 General Comments

Installation - This repair method has a highly reliable installation technique as the metal sleeve is filled with epoxy outside of the wall and installation of the steel mesh into the hole ensures that the steel stud and brick veneer have been penetrated. The two part epoxy is provided in a dual cartridge that ensures proper proportioning and mixing through the dispensing nozzle (see Photo 9).

Strength of Connection - The epoxy that is displaced by the insertion of the anchor rod provides a mechanical connection to both flanges of the steel stud. The nut on the end of the anchor rod bears on the steel stud flange giving it strength in tension. The amount of epoxy displaced will determine the strength of this connection (see Photo 10). The connection in the brick is the chemical bond between the brick and the epoxy, the strength of which has not been tested.

Damage - The 5/8" dia. hole in the interior gypsum board is minimal damage that can be readily repaired. The hole in the flange of the stud is much smaller than in the Cintec INT1 repair and it is doubtful that the stiffness of the backup has been altered. The 3/8" dia. hole in the sheathing is partially sealed by the epoxy but some air leakage at this point is likely to occur.

Thickness - The influence of stud thickness on the performance of this repair system is likely minimal, thus making this method usable over the full range of stud thicknesses.

Drip - There is no drip for moisture on this repair system. Water could flow down the epoxied mesh and increase the amount of moisture in the wall.

Potential For Corrosion - The epoxy may seal the area of the flange that this connection relies upon from any corrosion due to ingress of moisture. Neither the mesh nor the rod are susceptible to corrosion as they are made of stainless steel.

Thermal Bridging - As the steel rod is continuous from within the brick veneer to the inner flange of the steel stud, significant thermal bridging may occur. The moderating effect of the epoxy around this anchor is likely negligible.

Weather Limitations - There may be temperature limitations on installation due to the use of an epoxy. However, as the repair is done from the interior this may not be a significant

problem. Low-odour epoxy used if there are tenants may result in increased costs and longer set times.

Air Leakage - The epoxy that protrudes out of the wire mesh screen will, to some degree, block the hole through the sheathing.

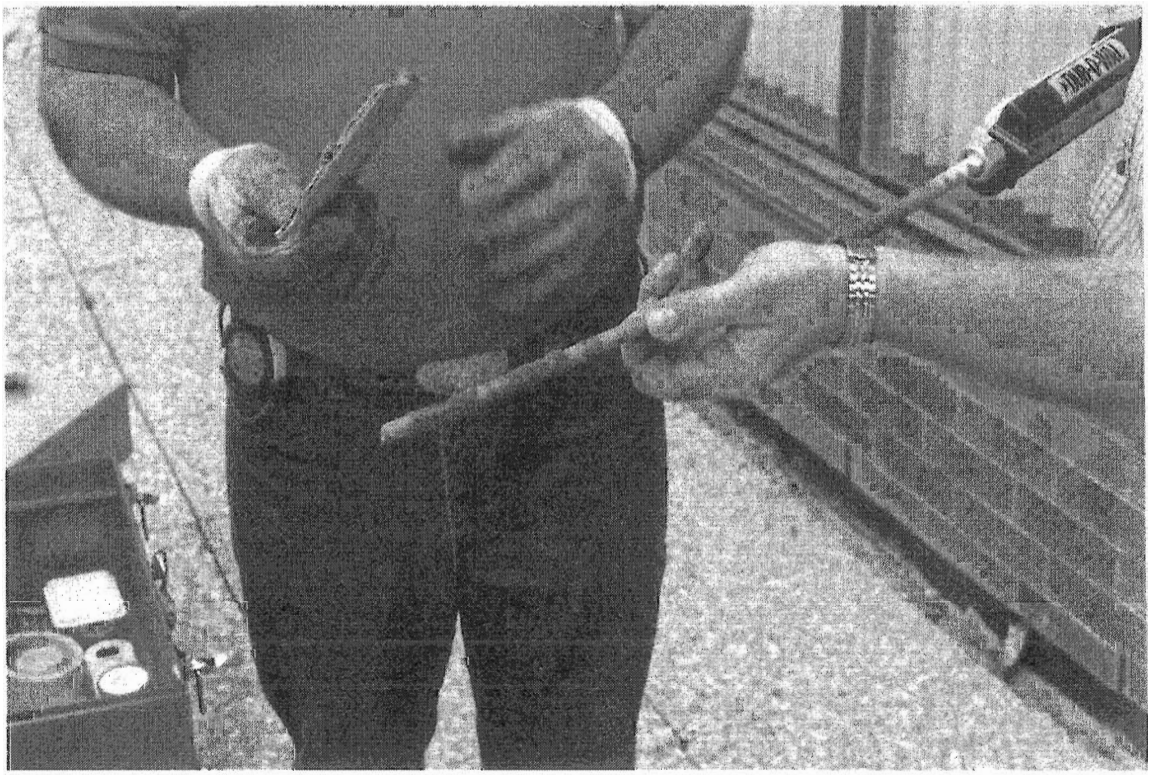


Photo 9 - Epoxy Being Injected Into the Stainless Steel Mesh

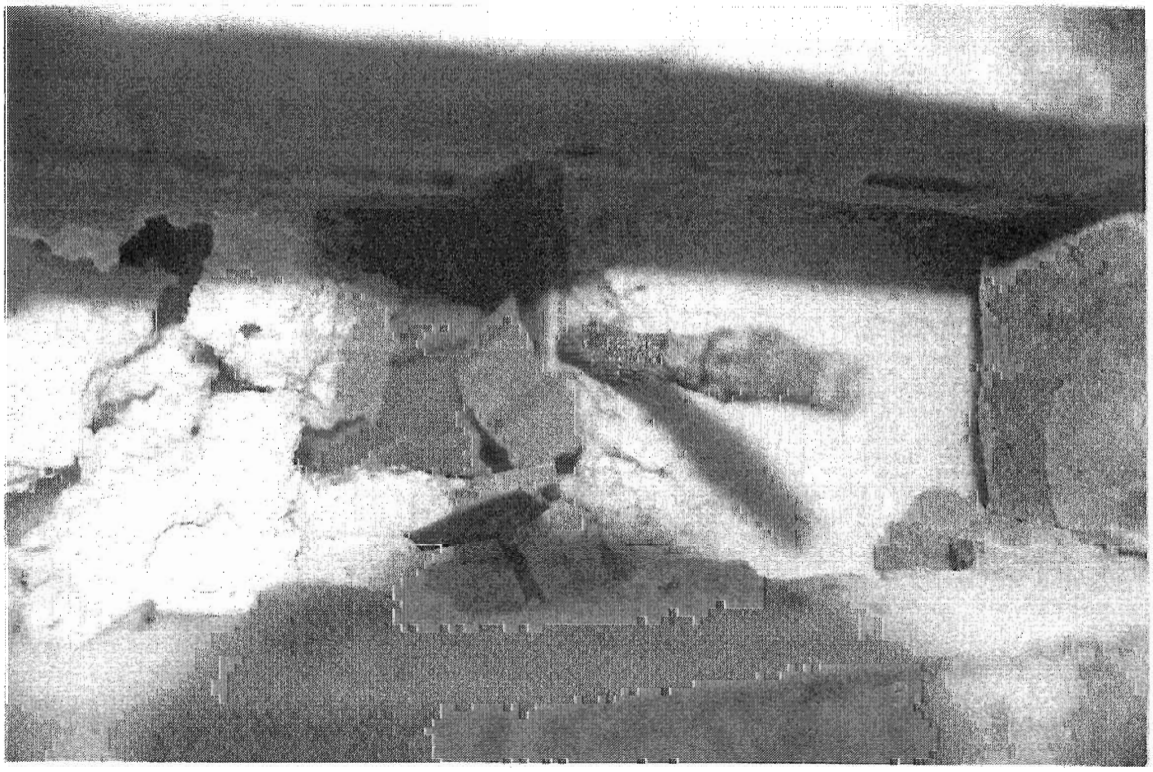


Photo 10 - Exterior View of INT3 - Dur-O-Wal Repair After Brick Removal

BEG

4.4 INT4 - Helifix HRT80 Tie Dry Fix

4.4.1 Tie Description

The Helifix HRT80 tie is a 8.0 mm dia. helical device manufactured from Grade 304 stainless steel. When installed, the HRT80 tie threads itself in the smaller pre-drilled hole and this provides a mechanical fix to the steel stud and the brick masonry. Figure 5 illustrates the INT4 - Helifix HRT80 repair.

4.4.2 Installation Procedure

After location of the stud, a 6.5mm dia. steel drill bit was used to drill through the gypsum board, polyethylene and both flanges of the steel stud. A 6mm dia. hole was drilled with hammer drill action and a masonry drill bit. The depth of this hole was approximately 65mm stopping short of the exterior face of the 90mm thick brick veneer. The HRT80 tie was then installed with hand held hammer tool or an impact drill. The HRT80 tie is installed so that approximately 8mm is exposed and engages the inner flange of the steel stud.

Table 4 lists the steps in the repair procedure and the observed times for each step in the repair.

FIGURE 5 : Repair Method INT4 - Helifix HRT80 Tie Dry Fix

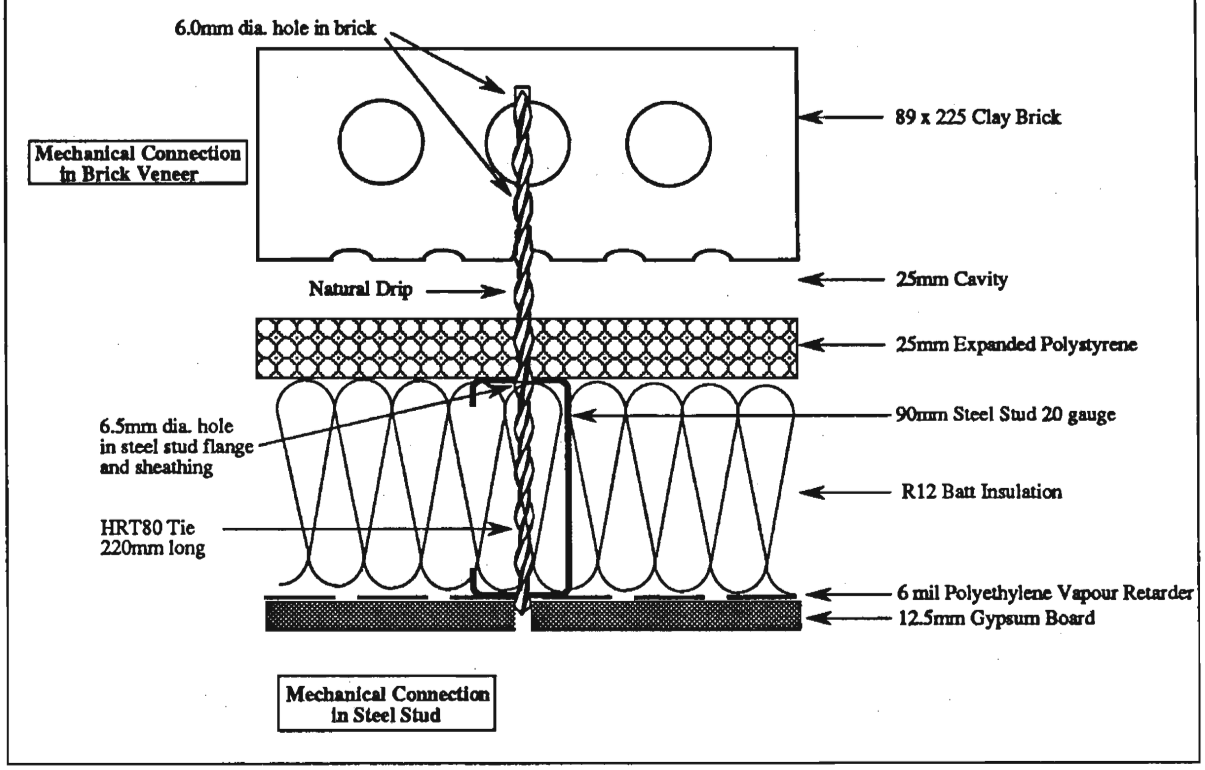


Table 4 --- INT4 Helifix HRT80 Tie Dry Fix

STEP #	DESCRIPTION	TIME (sec)
1	Locate Stud	
2	Drill Through Steel Stud Flanges - 6.5mm dia. steel drill bit - rotary drill action only	15 seconds
3	Drill Into Brick Veneer - 6mm dia. masonry drill bit - hammer drill action - mark distance on drill bit	25 seconds
4	Drive HRT80 tie through the steel stud and into the brick	60 seconds
5	Repair Hole	
	Total Observed Time for Repair	100 seconds

4.4.3 Cost

The cost for this tie, which includes the tie itself and the polyester resin, was estimated by Blok-Lok Ltd. to be $ 3.75 per unit. The labour cost to install the tie can not be adequately estimated. As the polyester resin is distributed in easy-to-use self-mixing cartridges there would be minimal, if any, extra labour cost due to the use of a chemical system. The repair cost of returning the interior wall to its original state would be similar to that for other systems.

4.4.4 General Comments

Installation - This installation of the HRT80 tie with hand tools is a relatively quick and neat process. However, power tools can easily, and should, be developed to fully take advantage of the speed of this repair. The important factor in determining the success rate of this repair method is the proper alignment when drilling the hole and subsequent installation of the tie.

Strength of Connection - The Helifix tie achieves a mechanical fix by threading into the steel stud and the brick veneer. Both flanges of the stud are engaged (see Photos 11 and 12). The effectiveness of this connection needs to be determined. The strength of the HRT80 tie to the brick masonry has been documented while the strength of HRT80 dry installed in mortar has not been tested. The strength of the HRT80 connection to the steel stud also needs to be determined.

Damage - Damage from drilling a 6.5mm dia. hole to the interior gypsum board, to the polyethylene, to the steel stud, to the sheathing and to the brick veneer is minimal.

Thickness - The strength of the connection between the HRT80 tie and the steel stud will undoubtedly depend on the thickness of the steel stud. This should be tested to determine the range of thickness that result in adequate performance.

Drip - The continuous, helical thread provides a natural drip for water that will prohibit water from making its way down the tie and into the stud space.

Potential For Corrosion - As the tie is stainless steel the only concern of corrosion is of the steel stud system itself. The probability and effect of corrosion at the tie/flange connection needs to be determined as this tie system, as any screw system, relies heavily on a small amount of metal.

Thermal Bridging - As the tie is continuous from the brick veneer to the inner flange of the stud a thermal bridge is created, although the small cross-sectional area of this tie limits this somewhat.

Air Leakage - The small hole in the steel stud and the exterior sheathing may increase slightly any flow of air between the stud space and the cavity.

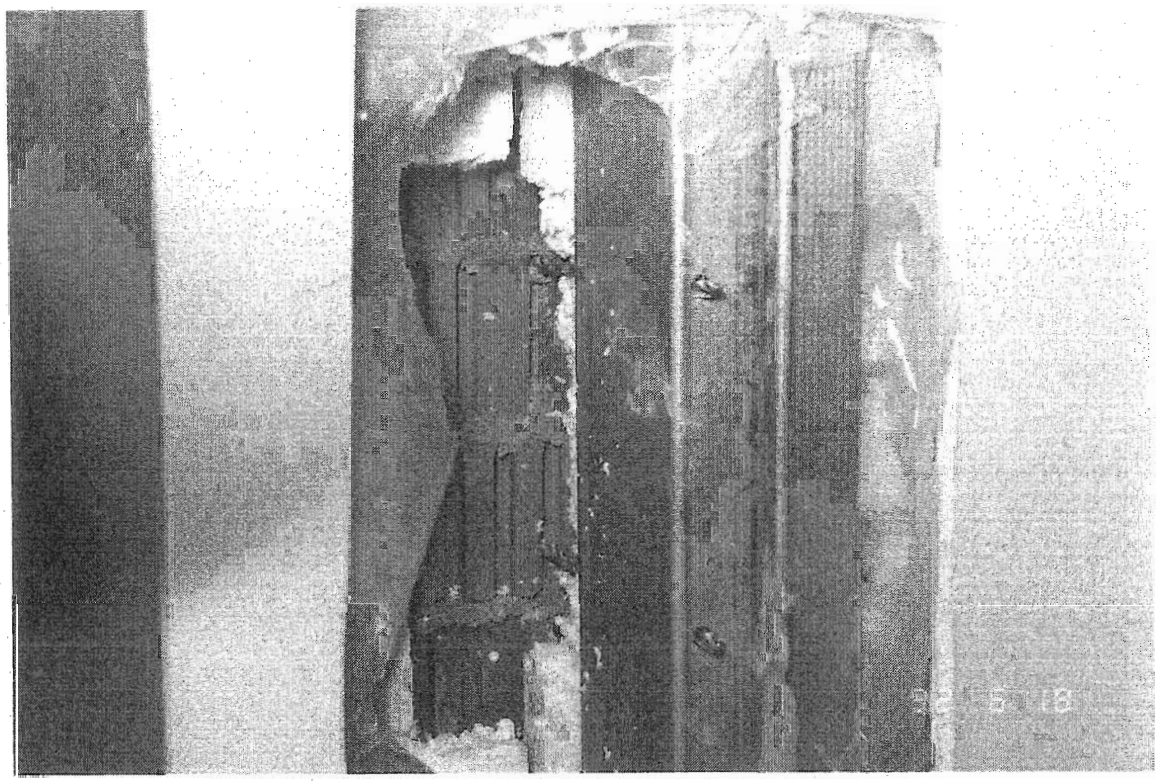


Photo 11 - View of INT4 - Helifix HRT80 Repair

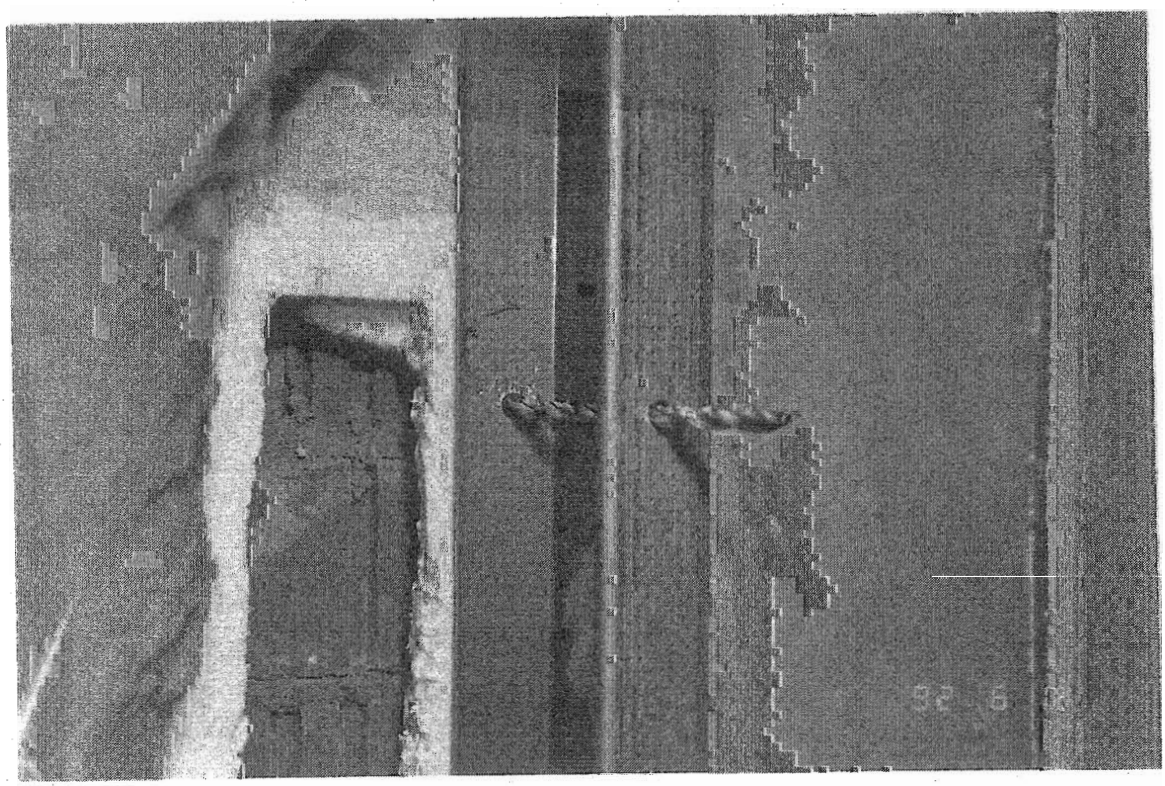


Photo 12 - View of Double Flange Connection in Repair INT4

BEG

5. DESCRIPTION OF EXTERIOR REPAIR METHODS

Seven different exterior retrofit systems were demonstrated, namely :

EXT1 Cintec Cementitious Sock with 65 mm Hole
EXT2 Cintec Cementitious Sock with 22 mm Hole
EXT3 Dur-O-Wal Toggle Clips and Expansion Anchor
EXT4 Dur-O-Wal Threaded Bolt and Expansion Anchor
EXT5 Dur-O-Wal Drill and Tap Bolt and Expansion Anchor
EXT6 Dur-O-Wal Stainless Steel Rod and Sleeve with Epoxy
EXT7 Helifix HRT80 Dry Fix in SS, Polyester Resin in BV

The following sections describe the tie, the installation procedure, and the installed costs of the ties and also comment on the likely performance of the tie system. Some additional information on the tie systems, if available, can be found in Appendix A.

For each tie system, the installations times have been tabulated. The times observed for these seven tie systems varied from 70 seconds to 225 seconds. These times were estimated from review of the video and do not include any setup time or switching from one step to the next. Therefore these times are not an accurate indication of the repair times per tie. These times could better be established in a larger demonstration project.

5.1 EXT1 - Cintec 65 mm Cementitious Sock

5.1.1 Tie Description

This Cintec cementitious sock anchor has a much larger sock in the brick than the interior anchor described earlier and the exterior anchor described in the next section. This repair method is meant to be used where existing ties are to be replaced. Like the interior anchor, this tie connects in-situ materials together using both a mechanical and chemical bond. The tie consists of a 10mm O.D. , 8mm I.D. stainless steel section with a polyester sock on each end. The tie is inserted in the pre-drilled holes in the brick veneer and the steel stud. Presstec grout, a one component mix of Portland cement, graded aggregate and additives, is injected under pressure inflating the sock. Grout passes through the expanded sock mesh to provide the chemical bond and the expansion of the sock in the voids of the brick and around the steel stud flange result in a mechanical attachment. Figure 6 illustrates the Cintec 65mm tie repair system in BV/SS.

5.1.2 Installation Procedure

After location of the stud, a 2 5/8" (67mm) dia. diamond tip core was used to drill through the clay brick. The hole was then cut in the sheathing to locate the stud exactly. A 22mm dia. hole was drilled into the outer flange of the steel stud with a steel drill bit. The depth of the hole was measured in order to size the tie and position of the socks. After the tie was inserted into the hole a cementitious grout was pumped into the anchor which inflated both the exterior and interior sock.

Table 5 lists the steps in the repair procedure and the observed times for each step in the repair.

FIGURE 6 : Repair Method EXT1 - Cintec Cementitious Sock with 65mm Hole

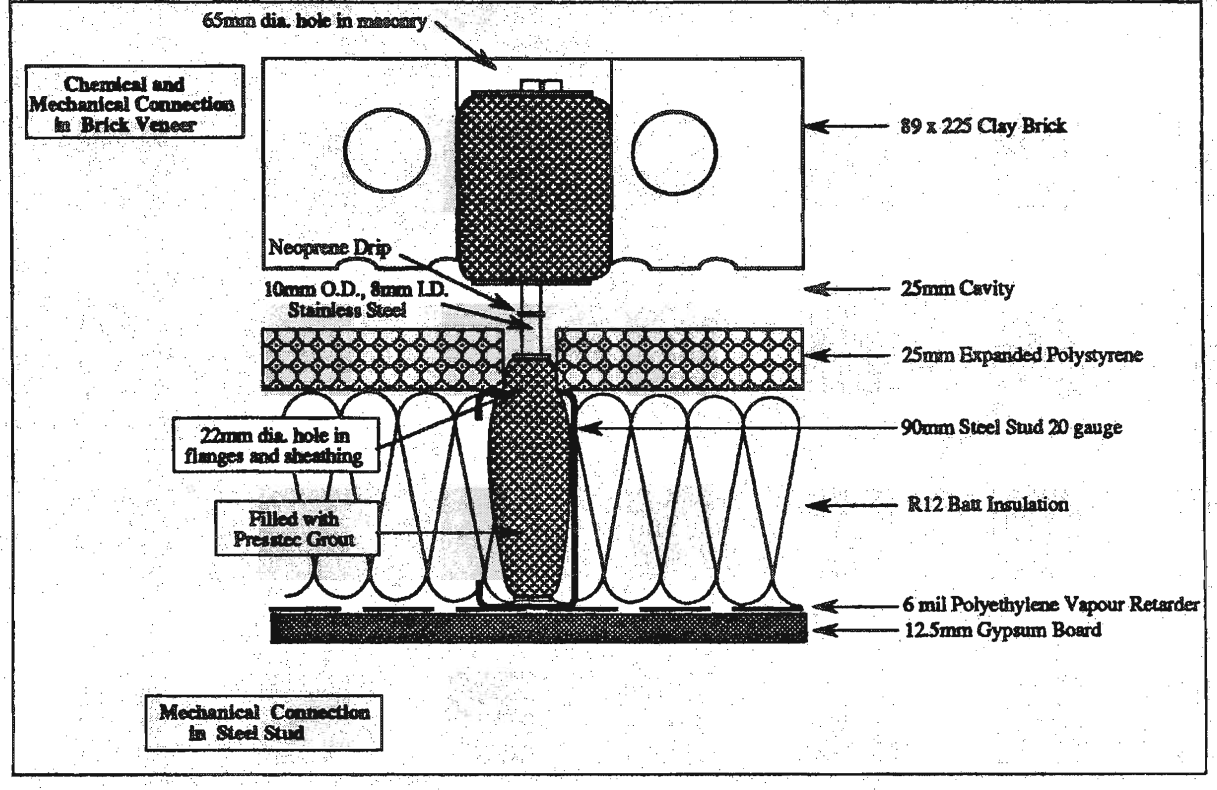


Table 5 --- EXT1-Cintec 65 mm Cementitious Sock

STEP #	DESCRIPTION	TIME (sec)
1	Locate Stud	
2	Drill Through Brick Veneer - 2 5/8" (67 mm) dia. diamond tip core - hammer drill	90-180 seconds
3	Cut hole in sheathing to locate stud	10 seconds
4	Drill Into Outer Flange of Steel Stud - 22 mm dia. steel core bit	30 seconds
5	Measure up sock system	
6	Insert tie into hole	
7	Inject Grout	30 seconds
8	Repair Hole	
	Total Observed Time for Repair	205 seconds

5.1.3 Cost

The contractor's cost for this tie, which includes the tie unit and the grout, was estimated by Cintec Canada to be $ 15.00 per unit. The labour cost to install the tie can not be adequately estimated. The grouting stage of this repair may result in increased labour costs. Enough ties to use a batch of grout would be prepared up to the grouting stage. The grout would then be prepared and the grouting process would require returning to the different locations on the exterior wall, perhaps on different floors. The cost of repairing the exterior wall to an acceptable status, if possible, would be much higher than any of the other systems.

5.1.4 General Comments

Installation - This repair method is meant to be used when over-coring existing ties to remove them prior to installation of a new tie. The hole required in the brick veneer is quite large and may be labour intensive if proper equipment is not used (see Photo13). One step in the installation process that is critical is the proper preparation of the grout. As the installation of this repair system is limited to approved Cintec installers, this should not be a problem. There is a built-in flexibility with this system as the tie can be put in on an angle since a large core is made to expose the stud leaving room for adjustment. When installing this tie into the hole caution should be used so that the sock is not torn in any way as this would render the tie useless. The exterior brick should be cleaned off shortly after injection of the grout as the grout sets quickly.

Strength of Connection - The connection to the steel stud is limited to the exterior flange of the steel stud. It is advantageous to have the sock long enough to adequately engage this outer flange, even with a varying cavity width (see Photo 14). There is a chance that with a varying cavity width that the sock would not engage the outer stud at all. The strength of this connection to the steel stud has not been documented. The tensile and compressive performance of the connection in the brick should also be documented.

Damage - The damage to the brick veneer is extreme and likely unacceptable when installing supplementary ties. Both the cutting of 22mm dia. holes in the flange of the steel stud and the insertion of this rigid tie will have an impact on stud stiffness. The damage to the exterior sheathing is a 22mm dia. hole that is filled up with grout if the sock is designed to include the sheathing. If not, a large passage for air leakage has been created.

Thickness - Although the thickness of steel stud will affect the strength of the connection and the impact of the damage to the flange on the stiffness of the stud wall, there is no limitation to any particular thicknesses.

Drip - The neoprene drip if placed in the middle of the air cavity will adequately prohibit water from travelling down the tie to the interior.

Potential For Corrosion - The components of this repair are not susceptible to corrosion or deterioration over time. An unforeseeable large amount of corrosion of the steel stud flange at the connection would have to occur for this connection to become inadequate in resisting

the required loads. The impact on the rate of corrosion that the moisture and/or chemicals in the grout is unknown.

Thermal Bridging - The amount of thermal bridging is minimal at this tie repair as the steel section is continuous from inside the brick to only the outer flange of the steel stud. The potential of a moderating effect of the grout around the steel section is unknown.

Weather Limitations - There may be some limitations on installation in cold weather as the temperature of the grout is required to be 7 Celsius at the time of injection and kept above 5 Celsius for twenty four hours following injection.

Air Leakage - No increase in air leakage should occur if the sock is manufactured so that the expanded sock effectively blocks the hole through the sheathing and steel stud.

Photo 13 - Interior View of EXT1 - Cintec Repair

Photo 14 - Exterior View of EXT1 - Cintec Repair

5.2 EXT2 - Cintec 22 mm Cementitious Sock

5.2.1 Tie Description

Like the two previous Cintec anchors, this tie connects in-situ material together using both a mechanical and chemical bond. The tie consists of a 8mm O.D., 6mm I.D. stainless steel section with a polyester based sock on each end. The tie is inserted in the drilled holes in the brick veneer and the steel stud. Presstec grout, a one component mix of Portland cement, graded aggregate and additives, is injected under pressure inflating the sock. Milk grout passes through the expanded sock mesh to provide the chemical bond and the expansion of the sock in the voids of the brick and around the steel stud flange result in a mechanical attachment. Figure 7 illustrates the Cintec 22mm tie repair system.

5.2.2 Installation Procedure

After location of the stud, a 22mm dia. diamond tip core was used to drill through the clay brick. The hole was then cut in the sheathing to locate the stud exactly. A 22mm dia. hole was drilled into the outer flange of the steel stud with a steel drill bit. The depth of the hole was measured in order to size the tie and position of the socks. After the tie was inserted into the hole a cementitious grout was pumped into the anchor which inflated first the exterior sock and then the interior sock.

Table 6 lists the steps in the repair procedure and the observed times for each step in the repair.

FIGURE 7 : Repair Method EXT2 - Cintec Cementitious Sock with 22mm Hole

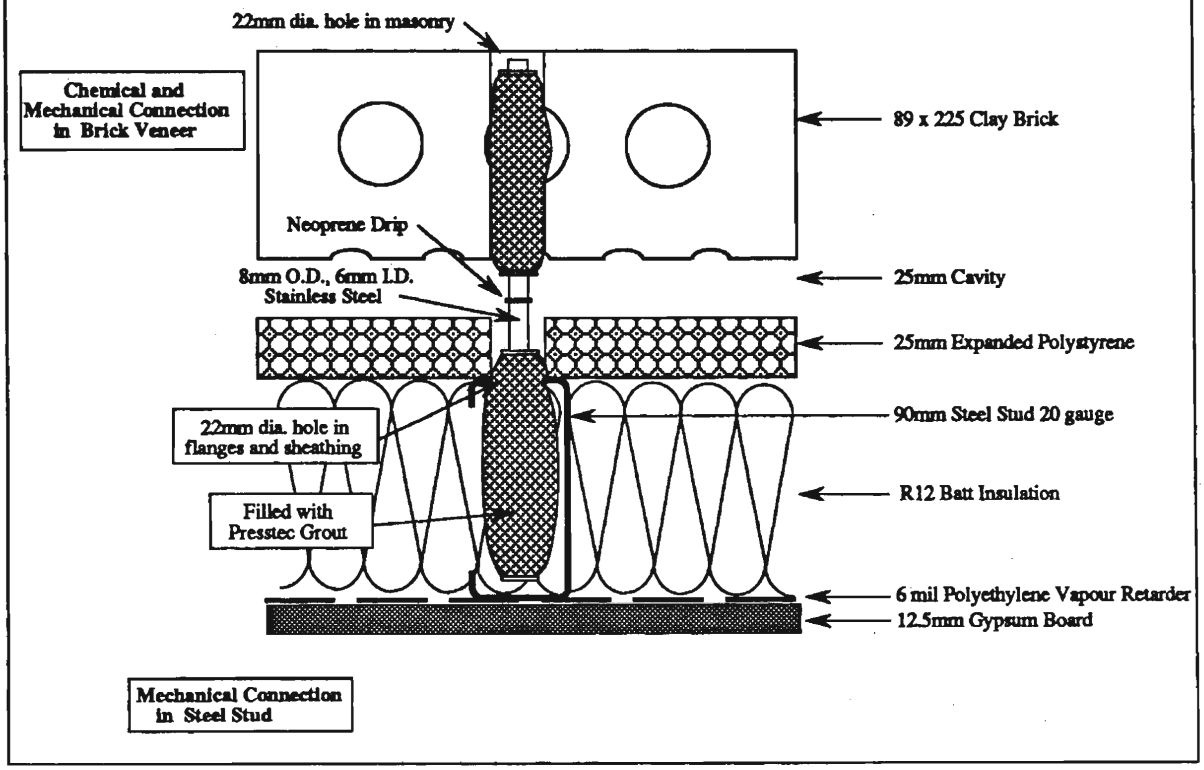


Table 6 --- EXT2-Cintec 22 mm Cementitious Sock

STEP #	DESCRIPTION	TIME (sec)
1	Locate Stud	
2	Drill Through Brick Veneer - 22 mm dia. diamond tip core - hammer drill	45 seconds
3	Cut hole in sheathing to locate stud	10 seconds
4	Drill Into Outer Flange of Steel Stud - 22 mm dia. steel core bit	30 seconds
5	Measure up sock system	
6	Insert tie into hole	
7	Inject Grout	30 seconds
8	Repair Hole	
	Total Observed Time for Repair	115 seconds

5.2.3 Cost

The contractor's cost for this tie, which includes the tie unit and the grout, was estimated by Cintec Canada to be $ 9.00 per unit. The labour cost to install the tie can not be adequately estimated. The grouting stage of this repair may result in increased labour costs. Enough ties to use a batch of grout would be prepared up to the grouting stage. The grout would then be prepared and the grouting process would require returning to the different locations on the exterior wall, perhaps on different floors. As the 22mm dia. hole is slightly larger than most of the exterior tie systems, the cost of repairing the exterior wall to an acceptable status may be slightly greater than most of the repair systems.

5.2.4 General Comments

Installation - This repair is very similar to the EXT1- Cintec repair with the exception of a much smaller 22mm dia. hole in the brick. The demonstration of this repair method was successful but very dependent on the proper location of the stud. With any repair method, the larger the hole in the steel stud, the more important the correct locating of the stud becomes. When installing this tie into the hole caution should be used so that the sock is not torn in any way as this would render the tie useless. One step in the installation process that is critical is the proper preparation of the grout. As the installation of this repair system is limited to approved Cintec installers, this should not be a problem. There is a built-in flexibility with this system as the tie can be put in on an angle. The exterior brick should be cleaned off shortly after injection of the grout as the grout sets quickly.

Strength of Connection - The connection to the steel stud is limited to the exterior flange of the steel stud. It is advantageous to have the sock long enough to adequately engage this outer flange, even with a varying cavity width (see Photo 15). There is a chance that with a varying cavity width that the sock would not engage the outer stud at all. The strength of this connection to the steel stud has not been documented. The tensile and compressive performance of the connection in the brick should also be documented.

Damage - The damage to the brick veneer is repairable and acceptable provided proper colour matching of the brick veneer is possible. Both the cutting of 22mm dia. holes in the flange of the steel stud and the insertion of this rigid tie will have an impact on stud stiffness. The damage to the exterior sheathing is a 22mm dia. hole that is filled up with grout if the sock is designed to include the sheathing. If not, a large passage for air leakage has been created.

Thickness - Although the thickness of steel stud will affect the strength of the connection and the impact of the damage to the flange on the stiffness of the stud wall, there is no limitation to any particular thicknesses.

Drip - The neoprene drip if placed in the middle of the air cavity will adequately prohibit water from travelling down the tie to the interior (see Photo 16).

Potential For Corrosion - The components of this repair are not susceptible to corrosion or deterioration over time. An unforeseeable large amount of corrosion of the steel stud flange

at the connection would have to occur for this connection to become inadequate in resisting the required loads. The impact on the rate of corrosion that the moisture and/or chemicals in the grout is unknown.

Thermal Bridging - The amount of thermal bridging may be significant at this tie repair as the steel section is continuous from inside the brick to inside the stud space. The potential of a moderating effect of the grout around the steel section is unknown.

Weather Limitations - There may be some limitations on installation in cold weather as the temperature of the grout is required to be 7 Celsius at the time of injection and kept above 5 Celsius for twenty four hours following injection.

Air Leakage - No increase in air leakage should occur if the sock is manufactured to such a length that the expanded sock effectively blocks the hole put through the sheathing and steel stud.

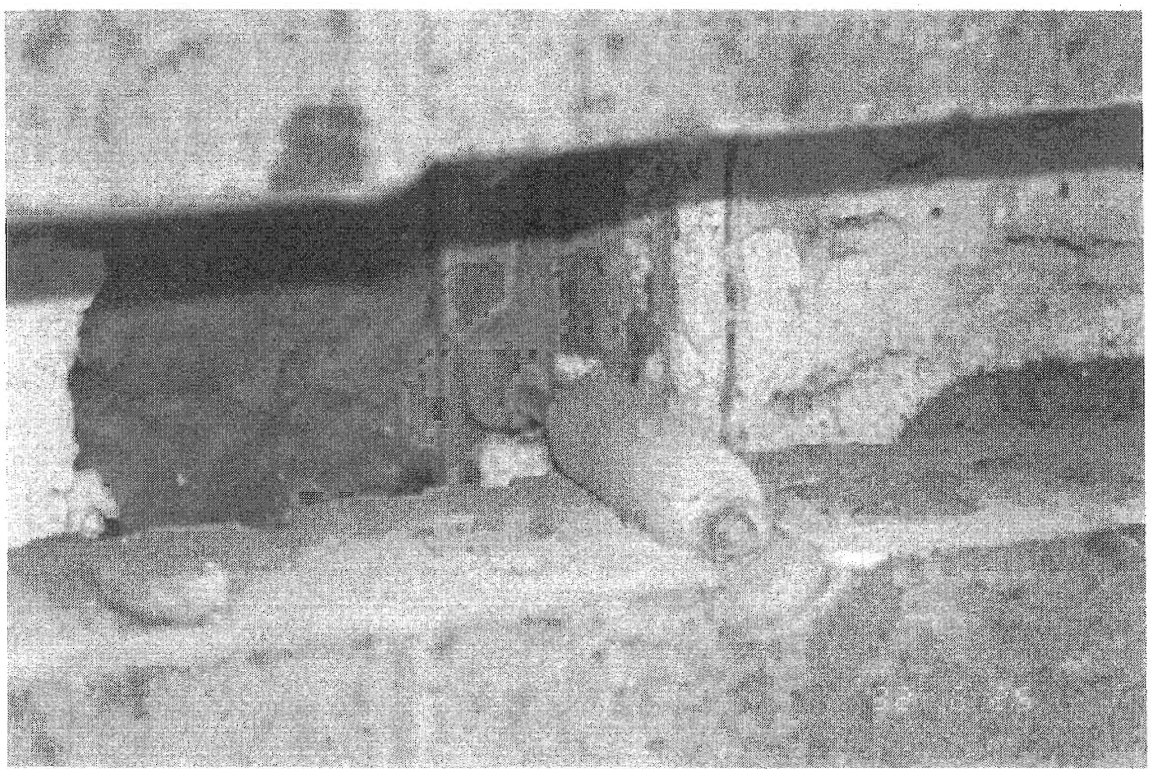


Photo 15 - Exterior View of EXT2 -Cintec Repair System

Photo 16 - Interior View of EXT2 - Cintec Repair System

5.3 EXT3 - Dur-O-Wal Toggle Clips and Expansion Anchor

5.3.1 Tie Description

The tie used in this repair method has components made of brass and stainless steel. This repair method uses a brass expanding shell to provide the attachment in the brick. This brass unit is threaded onto a 1/4" dia. 304 stainless steel rod which has a neoprene drip in line with the theoretical centerline of the air cavity to prevent the passage of moisture down the rod. The connection to the steel stud is provided by two 3/16" 304 stainless steel spring toggles that clamp onto the outer flange. Figure 8 illustrates the EXT3 - Dur-O-Wal repair system.

5.3.2 Installation Procedure

Using a 5/8" dia. masonry drill bit and rotary action, a hole was drilled into the brick veneer at a joint location. A 5/8" dia. hole was also drilled in the outer flange of the steel stud using a metal drill bit and no pre-drilled hole. Any debris in the hole was then blown out. The toggle clips on the end of the 1/4" anchor was then pushed into the hole until the inner toggle was past the flange of the steel stud and the outer toggle was in the cavity. Using the Dur-O-Wal key tool the toggle clips were slowly pulled together. The toggles broke through the expanded polystyrene sheathing and were torqued to 35 in lbs on the steel stud flange. The brass expansion anchor unit was then inserted in the hole and using the Dur-O-Wal key tool the expansion shells were expanded engaging the brick. This expansion anchor was torqued to 25 to 50 in lbs.

Table 7 lists the steps in the repair procedure and the observed times for each step in the repair.

FIGURE 8 : Repair Method EXT3 - Dur-O-Wal Toggle Clips and Expansion Anchor

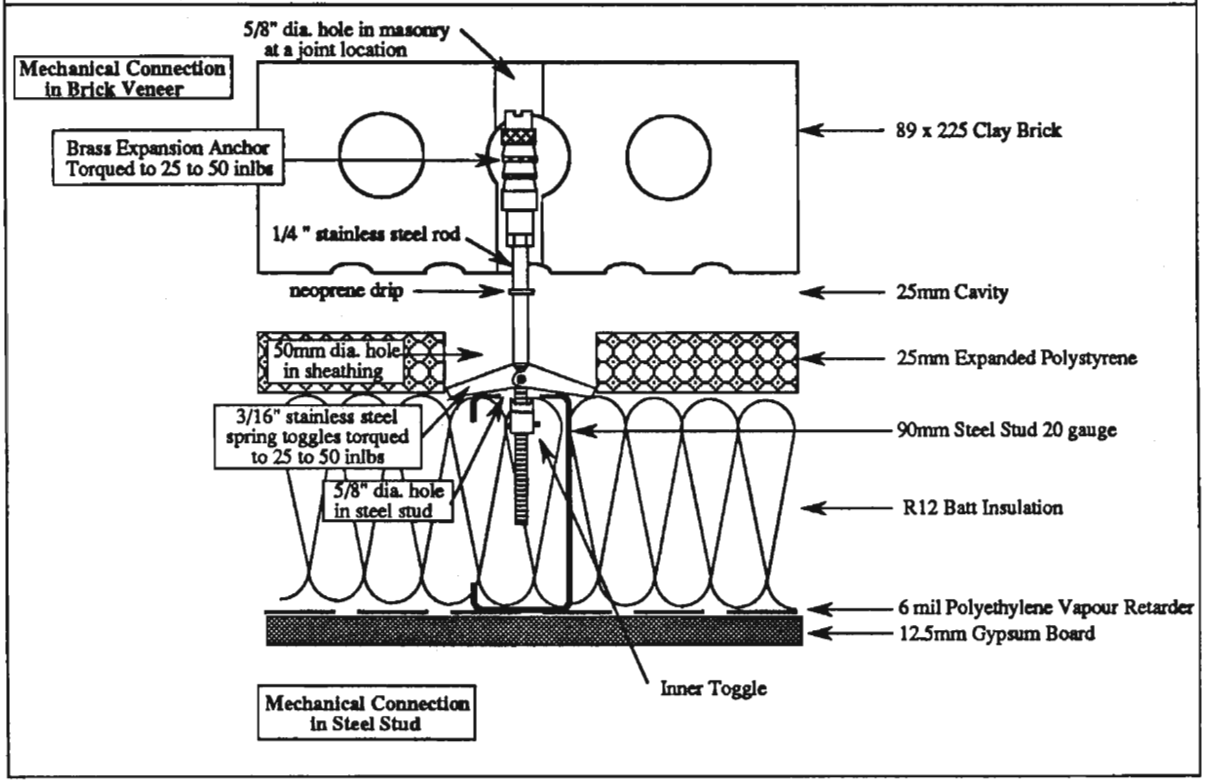


Table 7 --- EXT3-Dur-O-Wal Toggle Clips and Expansion Anchor

STEP #	DESCRIPTION	TIME (sec)
1	Locate Stud	
2	Drill Through Brick Veneer Mortar Joint - 5/8" dia. masonry drill bit - rotary drill action	70 seconds
3	Drill Through Outer Flange of Steel Stud - 5/8" dia. steel bit	15 seconds
4	Blow debris out of hole	10 seconds
5	Insert toggle clips on anchor rod into the hole, tighten the toggle clamps until hitting the steel stud, torque to 35 to 50 in lbs.	90 seconds
6	Install Expansion Anchor and torque to 25 to 50 in lbs	40 seconds
7	Repair Hole	
	Total Observed Time for Repair	225 seconds

5.3.3 Cost

The contractor's cost for this tie was estimated by Dur-O-Wal Ltd. to be $ 3.00 per unit. The labour cost to install the tie can not be adequately estimated. The labour cost of installing this tie would be average, as there are no complicated procedures and the entire installation can be conducted at the same time. The 16mm (5/8") dia. hole is an average hole size and the cost of repairing the exterior wall to an acceptable status will be similar to most of the repair systems.

5.3.4 Comments

Installation - After the proper holes have been drilled into the wall the installation process uses all hand tools to install the tie. In one of the two demonstrated repairs, there was some difficulty in installing the toggle clips when the bed joint of the brick veneer is not fully laid. There is full flexibility in this repair method by adjusting either the positioning of the toggle clips and/or the brass expansion anchor (see Photo 17).

Strength of Connection - This repair system engages just the outer flange of the steel stud. By using the toggles, a reliance on threaded mechanical connectors to the steel stud is eliminated. During the interior investigation inside the wall the toggle clips were observed to be tightly fixed to the flange of the steel stud. The strength of the connection may depend on the type of exterior sheathing used. With the expanded polystyrene the toggles cut through and bore directly on the flange of the steel stud. If the sheathing was exterior gypsum board the toggles would be torqued on to the sheathing and then the connection relies on the structural integrity of the sheathing which is likely prone to moisture degradation. The performance of the expansion anchor connection in the brick has been thoroughly tested and proven over time.

Damage - The damage to the brick veneer is minimal and repairable in this repair method. The 5/8" (16mm) dia. hole in the steel stud flange will have an impact on stud stiffness and the potential for web crippling at this connection point. The damage to the sheathing for this repair method is highly dependent on the type of sheathing. The 50mm dia. hole that was created in expanded polystyrene sheathing results in significantly increasing air leakage and negatively affecting the performance of the overall pressure equalized rainscreen (see Photo 18).

Thickness - The thickness of the stud will affect the strength of the stud flange but does not limit the use of this tie to any particular thicknesses. This repair method is meant for use with stud thicknesses of 20 and lighter.

Drip - The neoprene drip if placed in the middle of the air cavity will adequately prohibit water from travelling down the tie to the interior.

Potential For Corrosion - As all the tie components are stainless steel or brass there is no concern of corrosion of the tie itself. Corrosion of the steel stud at this connection is not of significance due to the large bearing area of the toggle.

Thermal Bridging - The installation of the toggle necessitates the anchor rod penetrating well into the stud space. This may cause some thermal bridging effects.

Air Leakage - If the toggle is used with compressible sheathing it is likely that a large hole in this sheathing will occur when tightening the toggles. This large passage is unacceptable as a potential passage for air has been created between the stud space and the cavity. When used on a rigid sheathing or directly on the flange of the steel stud this repair method would only slightly increase the potential for air flow between the cavity and the stud space

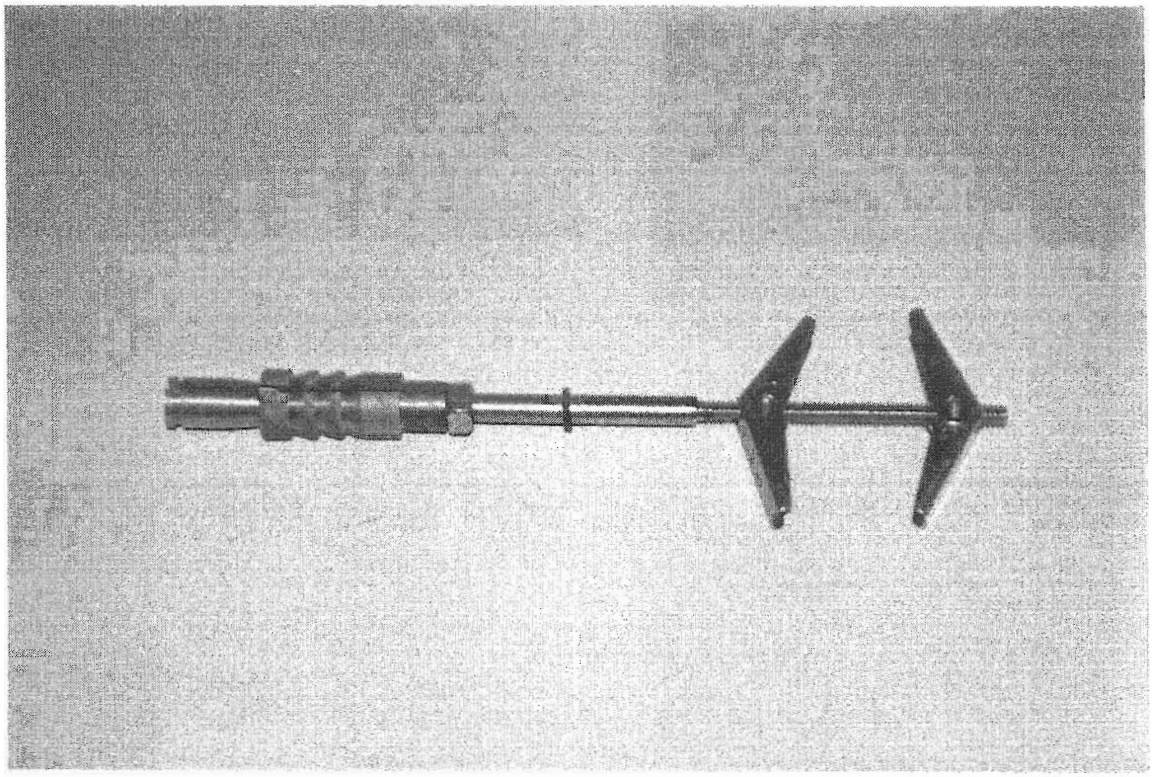


Photo 17 - The EXT3 - Dur-O-Wal Toggle Clips and Expansion Anchor

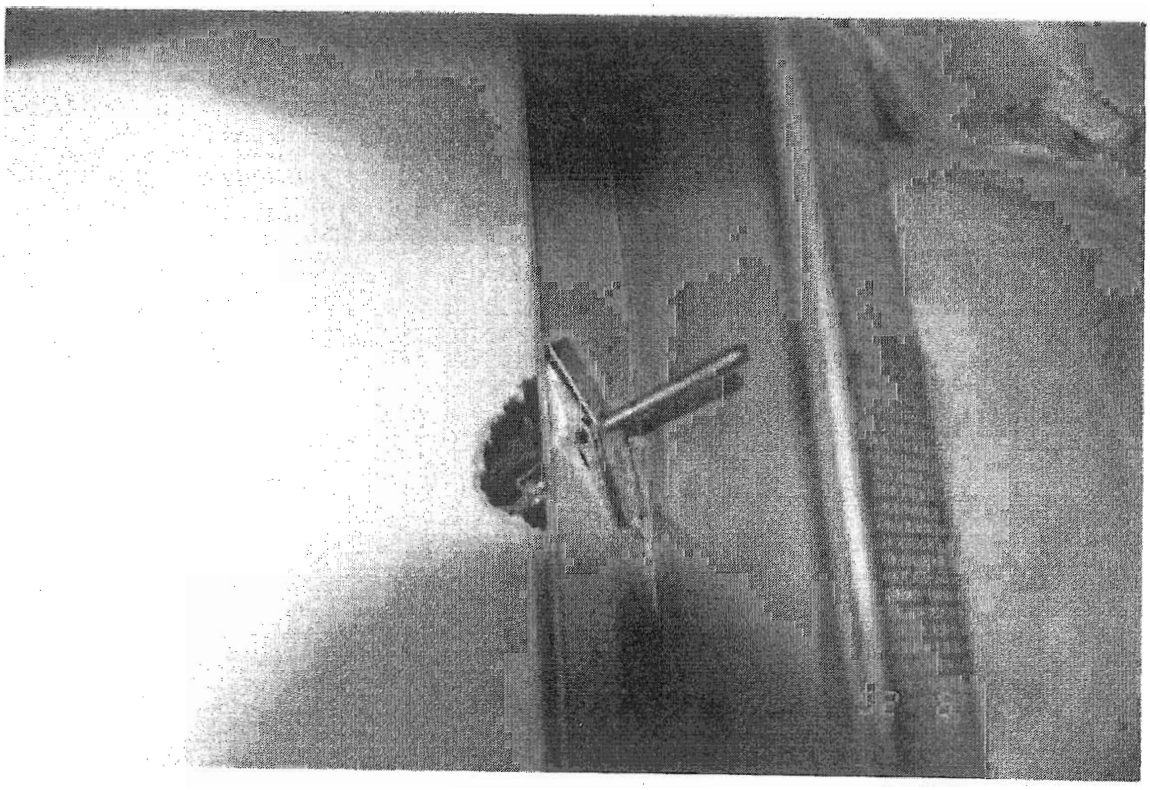


Photo 18 - Interior View of EXT3 - Dur-O-Wal Repair System

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5.4 EXT4 - Dur-O-Wal Threaded Bolt and Expansion Anchor

5.4.1 Tie Description

The tie used in this repair method has components made of brass and stainless steel. This repair method uses a brass expanding shell to provide the attachment in the brick. This brass unit is threaded onto a 1/4" dia. 304 stainless steel rod which has a neoprene drip in line with the theoretical centerline of the air cavity to prevent the passage of moisture down the rod. The connection to the steel stud is provided by a threaded lag bolt installed in a small pilot hole. Figure 9 illustrates the EXT4 - Dur-O-Wal repair system.

5.4.2 Installation Procedure

Using a 5/8" dia. masonry drill bit and rotary action, a hole was drilled into the brick veneer at a mortar joint location. A 5/32" dia. hole was also drilled in the outer flange of the steel stud using a metal drill bit. Any debris in the hole was then blown out. Bushings were put on the anchor rod to provide something to torque against when tightening the lag bolt to the steel stud. Silicone was applied to the lag bolt with the idea that this would seal the area around the connection between the lag bolt and the flange. The anchor rod was inserted, and by hand, the pilot hole was located and the tie installed. The lag bolt was torqued to 25 to 50 in lbs. The brass expansion anchor unit was then inserted in the hole and using the Dur-O-Wal key tool the expansion shells were expanded engaging the brick. This expansion anchor was torqued to 50 to 100 in lbs.

Table 8 lists the steps in the repair procedure and the observed times for each step in the repair.

FIGURE 9 : Repair Method EXT4 - Dur-O-Wal Threaded Bolt and Expansion Anchor

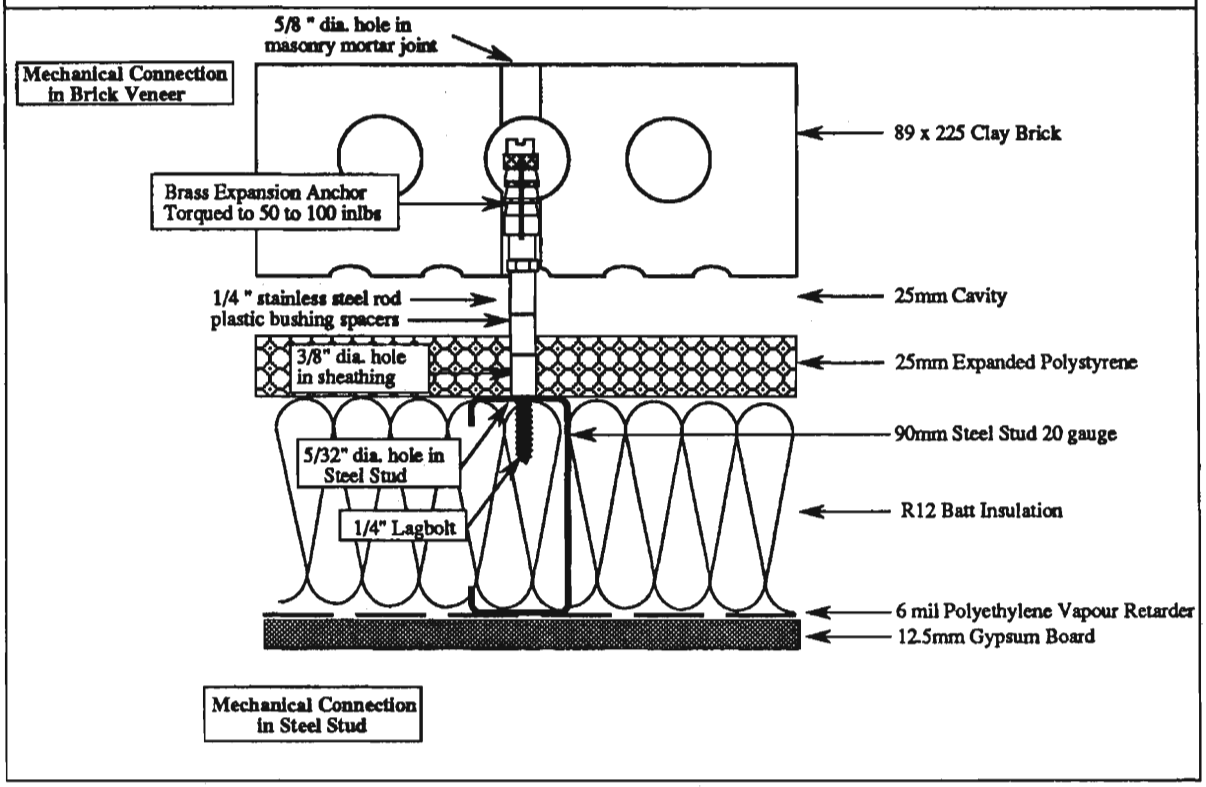

Table 8 ---EXT4 - Dur-O-Wal Threaded Bolt and Expansion Anchor

STEP #	DESCRIPTION	TIME (sec)
1	Locate Stud	
2	Drill Through Brick Veneer Mortar Joint - 5/8" dia. masonry drill bit - rotary drill action	70 seconds
3	Drill Through Outer Flange of Steel Stud - 5/32" dia. steel bit	15 seconds
4	Blow debris out of hole	10 seconds
5	Bushings were put on the anchor rod	5 seconds
6	Silicone was applied to the threads on the lag bolt	5 seconds
7	By hand the lag bolt was screwed in and then torqued to 25 to 50 in lbs	75 seconds
8	Install Expansion Anchor and torque to 50 to 100 in lbs	30 seconds
9	Repair Hole	
	Total Observed Time for Repair	210 seconds

5.4.3 Cost

The contractor's cost for this tie was estimated by Dur-O-Wal Ltd. to be $ 3.00 per unit. The labour cost to install the tie can not be adequately estimated. The labour cost of installing this tie would be average, as there are no complicated procedures and the entire installation can be conducted at the same time. The 16mm (5/8") dia. hole is an average hole size and the cost of repairing the exterior wall to an acceptable status will be similar to most of the repair systems.

5.4.4 General Comments

Installation - The installation of this tie system went very well in the two demonstrations conducted. The threading in of the lag bolt must be done by hand as "feel" is needed to locate the pre-drilled hole and properly start the thread. Although not strictly followed in the demonstrations, bushings should be installed on the anchor rod to provide resistance to torque, or create a pre-load. Putting silicone on the threads to seal around the tie to flange connection is a good idea theoretically, but proper testing of the merits of this should be investigated. Photo 19 shows the tie before installation.

Strength of Connection - With all threaded connections the cyclic performance and the slack in the connection are important considerations that should be documented. The performance of the expansion anchor in the brick veneer has been discussed previously. Photo 20 shows the lag bolt connection to the flange of the steel stud.

Damage - The 5/8" (16mm) dia. hole in the brick veneer can be considered as moderate damage.

Thickness - The strength of this tie connection will be highly dependent on stud thickness. The manufacturer recommends this repair in 1.5 mm (16 gauge) thick or heavier steel studs but adequate testing has not been conducted to date.

Drip - The neoprene drip if placed in the middle of the air cavity will adequately prohibit water from travelling down the tie to the interior.

Potential For Corrosion - Corrosion will not be a problem as all components are either brass or stainless steel. However, corrosion of the steel stud flange around the connection is important as the threaded connection relies on a small area of metal.

Thermal Bridging - The thermal bridging that occurs will not be excessive as the tie does not penetrate far into the stud space nor is the inner flange connected to the exterior by the tie system.

Air Leakage - The potential for air flow between the stud space and the cavity will be slightly increased by the 3/8" hole put in the sheathing. Both the tie and the bushings should seal this hole to some extent.

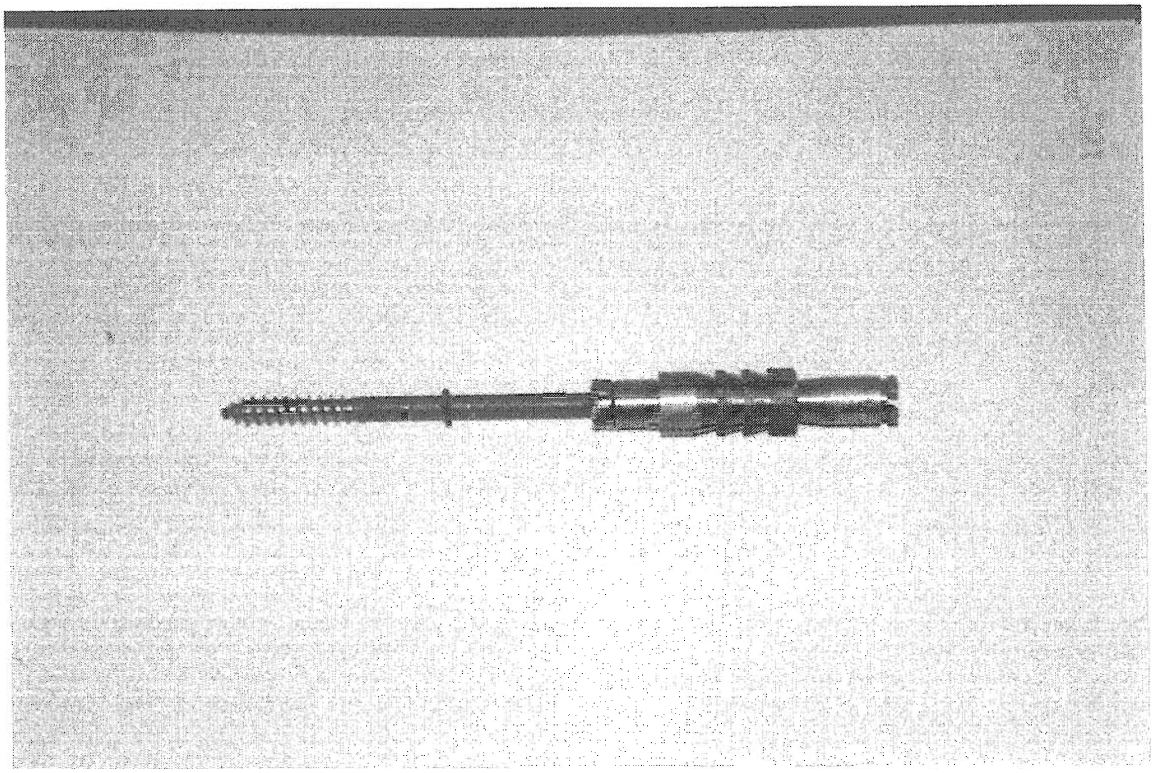

Photo 19 - EXT4 - Dur-O-Wal Tie System

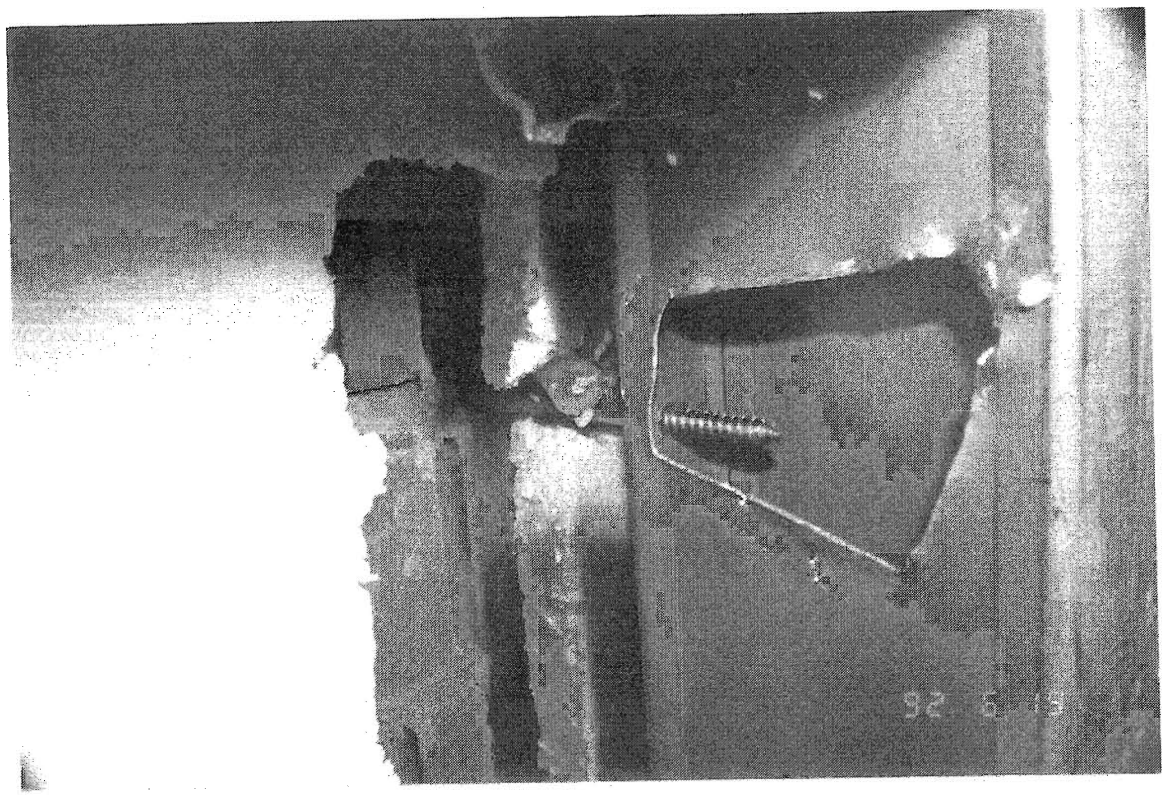

Photo 20 - Interior View of Repair EXT4 Connection to Steel Stud

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5.5 EXT5 - Dur-O-Wal Drill and Tap Bolt and Expansion Anchor

5.5.1 Tie Description

The tie used in this repair method has components made of brass and stainless steel. This repair method uses a brass expanding shell to provide the attachment in the brick. This brass unit is threaded onto a 1/4" dia. 304 stainless steel rod which has a neoprene drip in line with the theoretical centreline of the air cavity to prevent the passage of moisture down the rod. The connection to the steel stud is provided by the threaded end of the anchor rod installed in a 1/4-20 drill and tapped hole. Figure 10 illustrates the EXT5 - Dur-O-Wal repair system.

5.5.2 Installation Procedure

Using a 5/8" dia. masonry drill bit and rotary action, a hole was drilled into the brick veneer at the mortar joint location. Using a 1/4-20 drill and tap kit a tapped hole was made by hand in the outer flange of the steel stud. Any debris in the hole was then blown out. Silicone was applied to the washer on the threaded section of the anchor rod with the idea that this would seal the area around the connection between the rod and the flange. The anchor rod was threaded into this tapped hole. The threaded bolt was torqued to 25 to 50 in lbs with the washer and nut up against the steel stud flange in order to create a preload. The brass expansion anchor unit was then inserted in the hole and using the Dur-O-Wal key tool the expansion shells were expanded engaging the brick. This expansion anchor was torqued to 50 to 100 in lbs.

Table 9 lists the steps in the repair procedure and the observed times for each step in the repair.

FIGURE 10 : Repair Method EXT5 - Dur-O-Wal Drill and Tap Bolt and Expansion Anchor

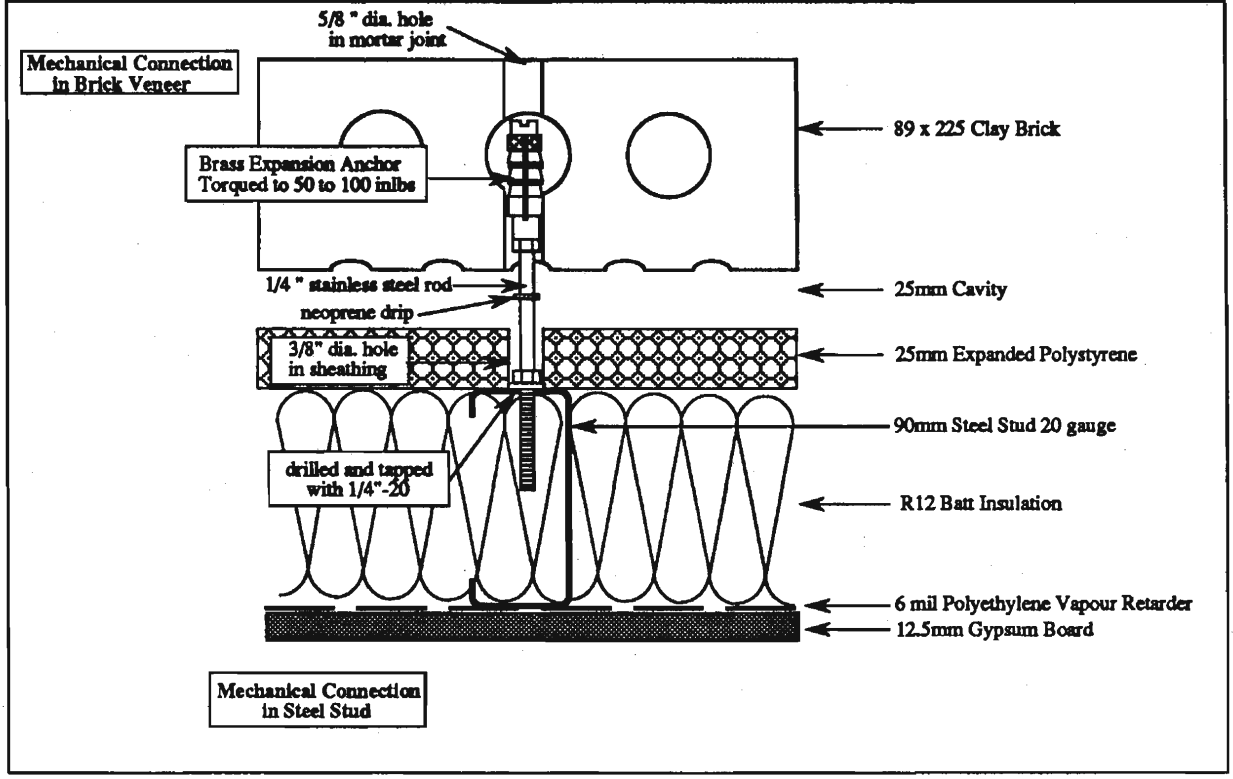

Table 9 ---EXT5 - Dur-O-Wall Drill and Tap Bolt and Expansion Anchor

STEP #	DESCRIPTION	TIME (sec)
1	Locate Stud	
2	Drill Through Brick Veneer Mortar Joint - 5/8" dia. masonry drill bit - rotary drill action	90 seconds
3	Drill & Tap a hole in Outer Flange of Steel Stud - 1/4-20 drill and tap kit	30 seconds
4	Blow debris out of hole	10 seconds
6	Silicone was applied to the washer on the anchor rod	5 seconds
7	The rod was manually threaded in and then torqued to 25 to 50 in lbs.	15 seconds
8	Install Expansion Anchor and torque to 50 to 100 in lbs	20 seconds
9	Repair Hole	
	Total Observed Time for Repair	170 seconds

5.5.3 Cost

The contractor's cost for this tie was estimated by Dur-O-Wal Ltd. to be $ 2.50 per unit. The labour cost to install the tie can not be adequately estimated. The labour cost of installing this tie would be average, as there are no complicated procedures and the entire installation can be conducted at the same time. The 16mm (5/8") dia. hole is an average hole size and the cost of repairing the exterior wall to an acceptable status will be similar to most of the repair systems.

5.5.4 General Comments

Installation - The installation of this tie system was conducted with relative ease. The tapping of the hole has to be done by hand to achieve quality results. The use of silicone on the washer that bears up against the steel stud to seal around the connection is a good idea, the merits of which should be tested. Photo 21 shows the EXT5 tie before installation.

Strength of Connection - The strength of the connection in the steel stud depends very much on the care taken by the installer to properly tap the hole and not strip the thread by torquing the connection too high, and on the stud thickness. The performance of this threaded connection under cyclic loadings and the resulting slack that occurs in this connection needs to be investigated. Photo 22 shows the connection to the steel stud.

Damage - The 5/8" (16mm) dia. hole in the steel stud, the sheathing and the brick veneer can be considered as moderate damage these elements.

Thickness - The thickness of the steel stud is also a major factor in the strength of this tie to stud connection. The distributor recommends this tie for use with studs of thickness 0.9 mm (20 gauge) and heavier.

Drip - The neoprene drip if placed in the middle of the air cavity will adequately prohibit water from travelling down the tie to the interior.

Potential For Corrosion - Corrosion will not be a problem as all components are either brass or stainless steel. However, corrosion of the steel stud flange around the connection is important as the threaded connection relies on a small area of metal.

Thermal Bridging - The thermal bridging that occurs will not be excessive as the tie does not penetrate far into the stud space nor is the inner flange connected to the exterior by the tie system.

Air Leakage - The potential for air flow between the stud space and the cavity will be slightly increased by the 3/8" hole put in the sheathing. The tie and the washer should seal this hole to some extent.

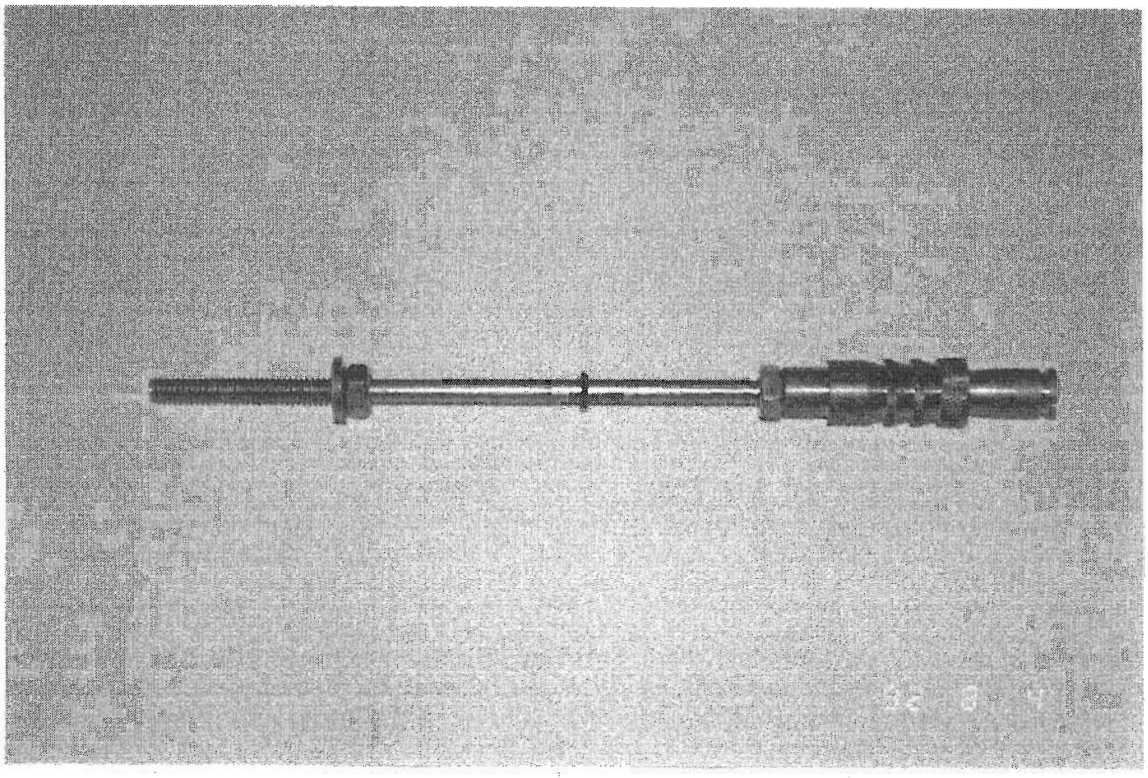

Photo 21 - EXT5 - Dur-O-Wal Tie System

Photo 22 - Interior View of Repair EXT5 Connection to Steel Stud

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5.6 EXT6 - Dur-O-Wal Stainless Steel Rod and Sleeve with Epoxy

5.6.1 Tie Description

The components of this tie are made from stainless steel and an epoxy. A 1/4" dia. stainless steel anchor rod of 6 inch length is inserted in a 3/8" dia. stainless steel wire mesh screen of 6 inch length that is filled with a high thixotropic, two component epoxy. The anchor rod is threaded 50 mm on each end. Figure 11 illustrates the EXT6 - Dur-O-Wal repair system.

5.6.2 Installation Procedure

After locating the stud, a 1/2" dia. hole was drilled with rotary drill action and a masonry drill bit. A 3/8" dia. steel drill bit was used to drill through the expanded polystyrene sheathing and the outer flange of the steel stud. Any debris in the hole was then blown out. Outside of the wall the wire mesh was filled with epoxy so that the epoxy has uniformly made contact with the inner diameter of the wire mesh. The wire mesh was then set in the pre-drilled hole in the wall. The wire mesh screen was taped at a predetermined location in order to provide a stop when inserting and to prevent the epoxy from exiting the wire mesh into the cavity. After buttering the anchor rod with epoxy, it was inserted by rotating to assure intimate contact between threads and adhesive.

As the anchor rod is inserted into the wire mesh the epoxy protrudes through the mesh and after setting provides a mechanical/chemical fix on both the steel stud flange and the brick. The section of the wire mesh in the air cavity was taped to eliminate epoxy from needlessly exiting the wire mesh in the cavity. The threads on the anchor rod result in an improved bond between the anchor rod and the epoxy.

Table 10 lists the steps in the repair procedure and the observed times for each step in the repair.

FIGURE 11 : Repair Method EXT6 - Dur-O-Wal Stainless Steel Rod and Sleeve With Epoxy

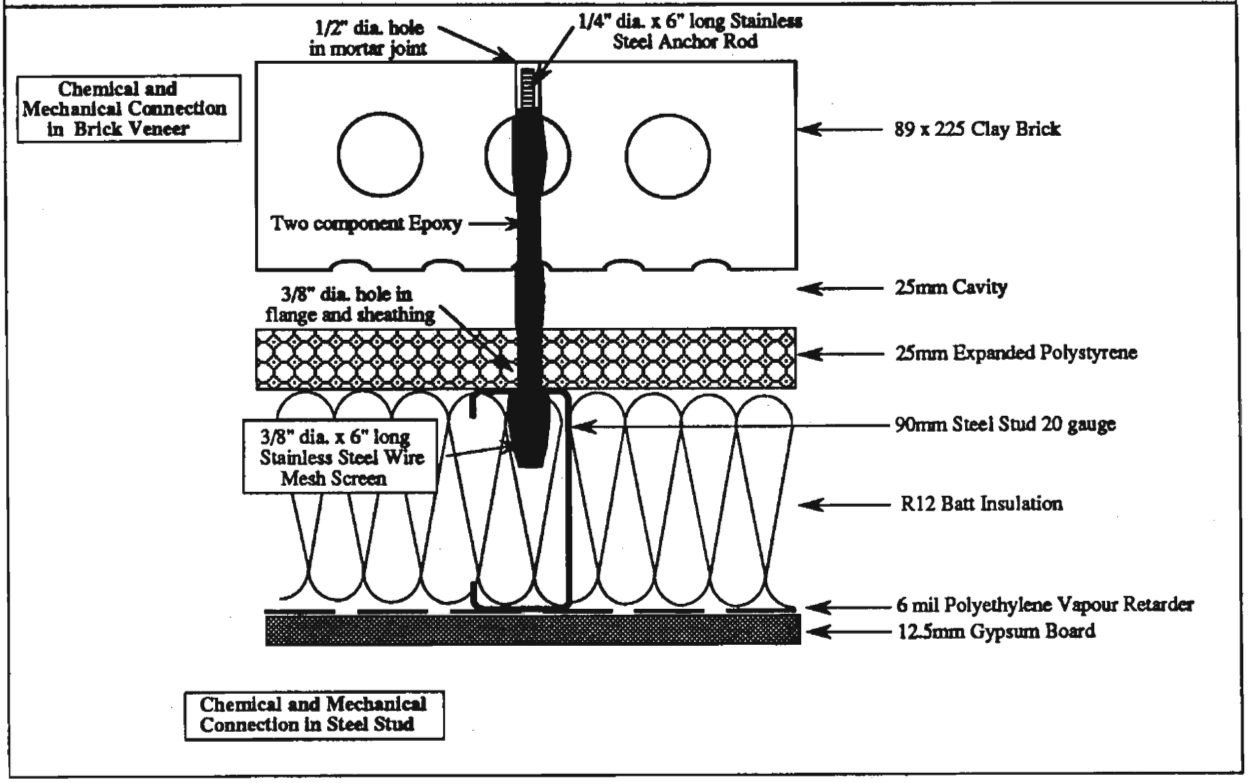

Table 10 --- EXT6-Stainless Steel Rod and Sleeve with Epoxy

STEP #	DESCRIPTION	TIME (sec)
1	Locate Stud	
2	Drill Into Brick Veneer Mortar Joint - 1/2" dia. masonry drill bit - rotary drill action	45 seconds
3	Drill Through Outer Steel Stud Flange - 3/8" dia. steel drill bit - rotary drill action only	10 seconds
4	Blow debris out of hole	10 seconds
5	Fill wire mesh with epoxy outside of the wall	50 seconds
6	Position filled wire mesh in the wall	10 seconds
7	Insert anchor rod into wire mesh by rotating slowly	15 seconds
8	Repair Hole	
	Total Observed Time for Repair	140 seconds

BEG

5.6.3 Cost

The contractor's cost for this tie, which includes the tie unit and the epoxy, was estimated by Dur-O-Wal Ltd. to be $ 3.00 per unit. The labour cost to install the tie can not be adequately estimated. The labour cost of installing this tie would be average, as there are no complicated procedures and the entire installation can be conducted at the same time. The 9.5mm (3/8") dia. hole is smaller than that required for most tie systems, however the cost of repairing the exterior wall to an acceptable status will still be similar to that of other repair systems.

5.6.4 General Comments

Installation - This repair is very similar to INT3 the interior retrofit using a rod and sleeve with epoxy. The self mixing of the epoxy makes this tie easy to install. The installation technique is identical to the interior repair except that the tie engages the exterior flange of the steel stud only. Photo 23 shows the components of the tie system before installation.

Strength of Connection - Photo 24 illustrates that the anchor rod only penetrates approx. 20mm into the stud space past the outer flange of the steel stud. The strength of this connection is unknown. The strength of the epoxy bond to the brick veneer should not be the weak link in this connection.

Damage - The damage to the building components by the 3/8" dia. hole is minimal and is filled with the epoxy. This will result in no increase in air leakage around the tie at the sheathing.

Thickness - The range of stud thickness that will give adequate pullout results needs to be determined.

Drip - This repair system does not have any drip to shed water and prohibit water from travelling down the tie and into the inner wall.

Potential For Corrosion - There is no chance of corrosion of the tie itself as the rod and mesh are made of stainless steel. The epoxy may effectively seal the stud flange from moisture and air in the area surrounding the connection.

Thermal Bridging - Thermal bridging of this tie will be minimal as the rod only extends 20mm into the stud space.

Weather Limitations - There may be some limitation on using the epoxy in cold weather situations.

Air Leakage - The epoxy should seal the hole in the sheathing and the flange of the steel stud so that only a small increase in the potential for air flow between the cavity and the stud space will result.

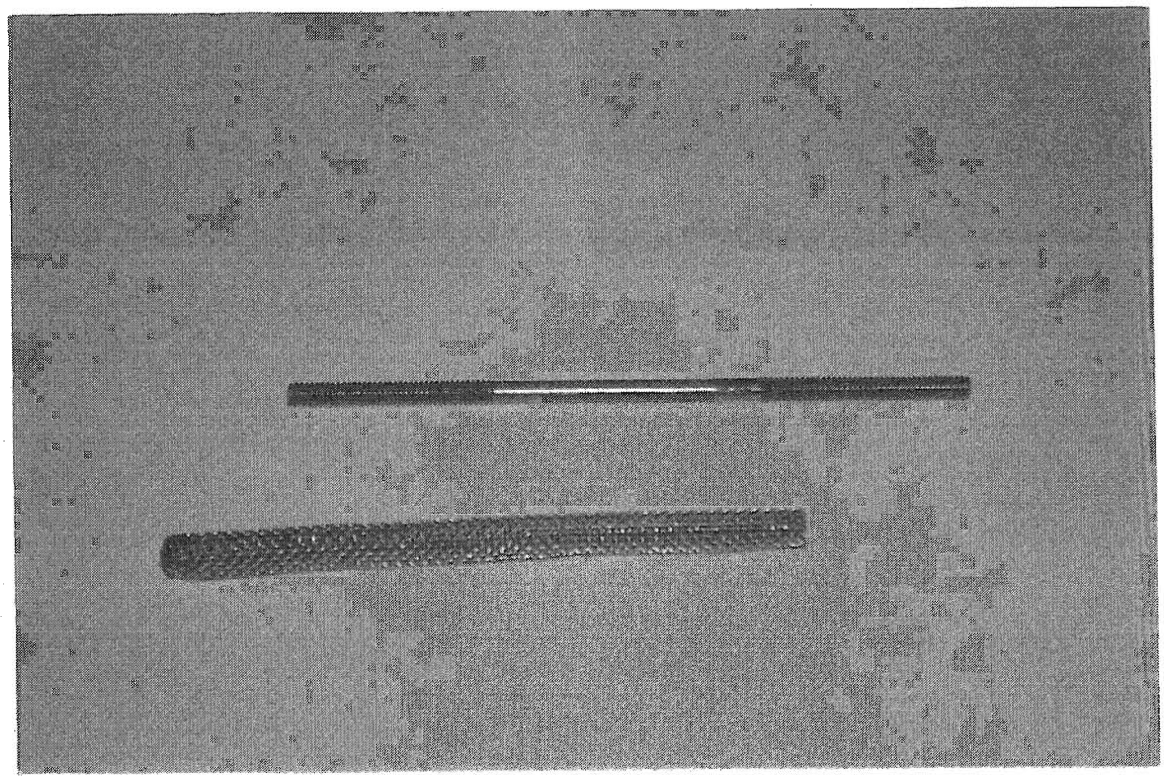

Photo 23 - Components of the EXT6 - Dur-O-Wal Repair System

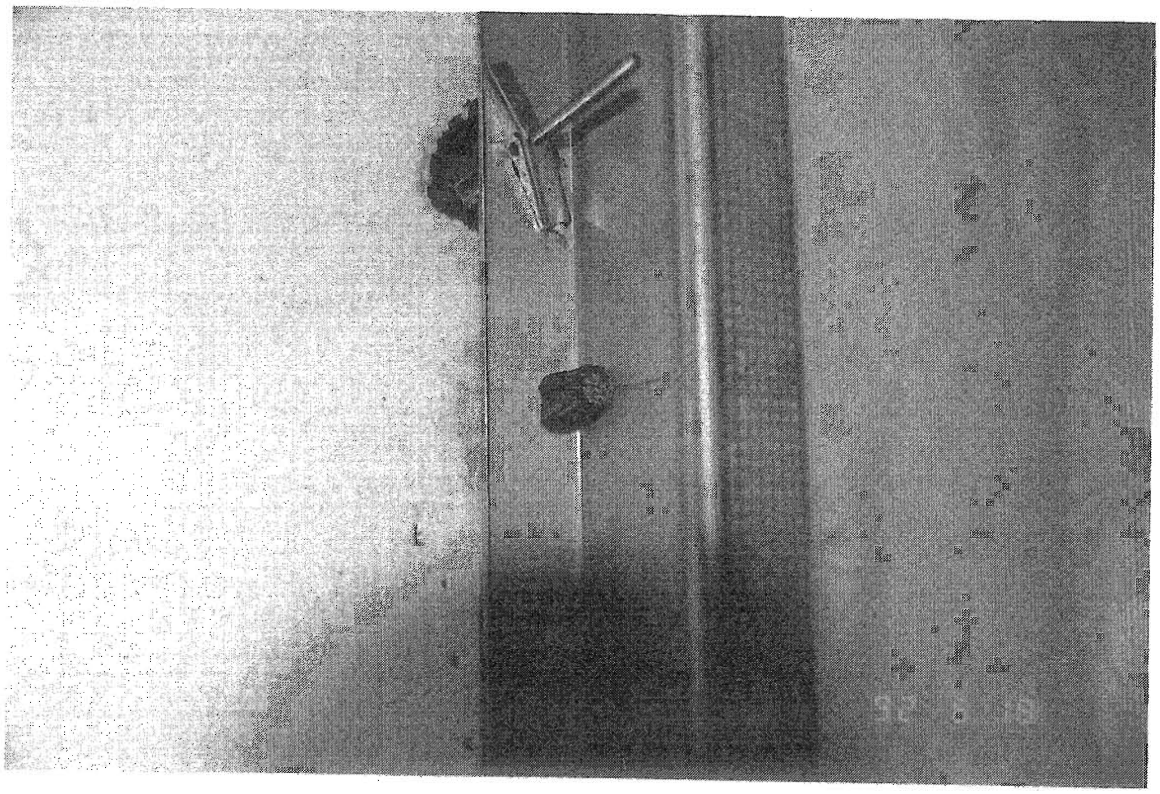

Photo 24 - Interior View of EXT6 - Dur-O-Wal Repair

5.7 EXT7 - Helifix HRT80 Dry Fix in SS Polyester Resin in Brick

5.7.1 Tie Description

The Helifix HRT80 tie is a 8.0 mm dia. helical device manufactured from Grade 304 stainless steel. When installed, the HRT80 tie threads itself in the smaller pre-drilled hole in the steel stud which gives it a mechanical fix to the flange. The volume around the HRT80 tie in the brick veneer was filled with a polyester resin. Figure 12 illustrates the EXT7 - Helifix HRT80 repair.

5.7.2 Installation Procedure

After locating the stud, a 10mm dia. hole was drilled into a mortar joint with hammer drill action and a masonry drill bit. A 6.5mm dia. steel drill bit was used to drill through the expanded polystyrene sheathing and the outer flange of the steel stud. The HRT80 tie was then installed in the outer flange of the steel stud with a hand held hammer tool or an impact drill. A polyester resin material was then injected around the tie to provide anchorage to the brick veneer.

Table 11 lists the steps in the repair procedure and the observed times for each step in the repair.

FIGURE 12 : Repair Method EXT7 - Helifix HRT80 Dry Fix in SS, Polyester Resin in BV

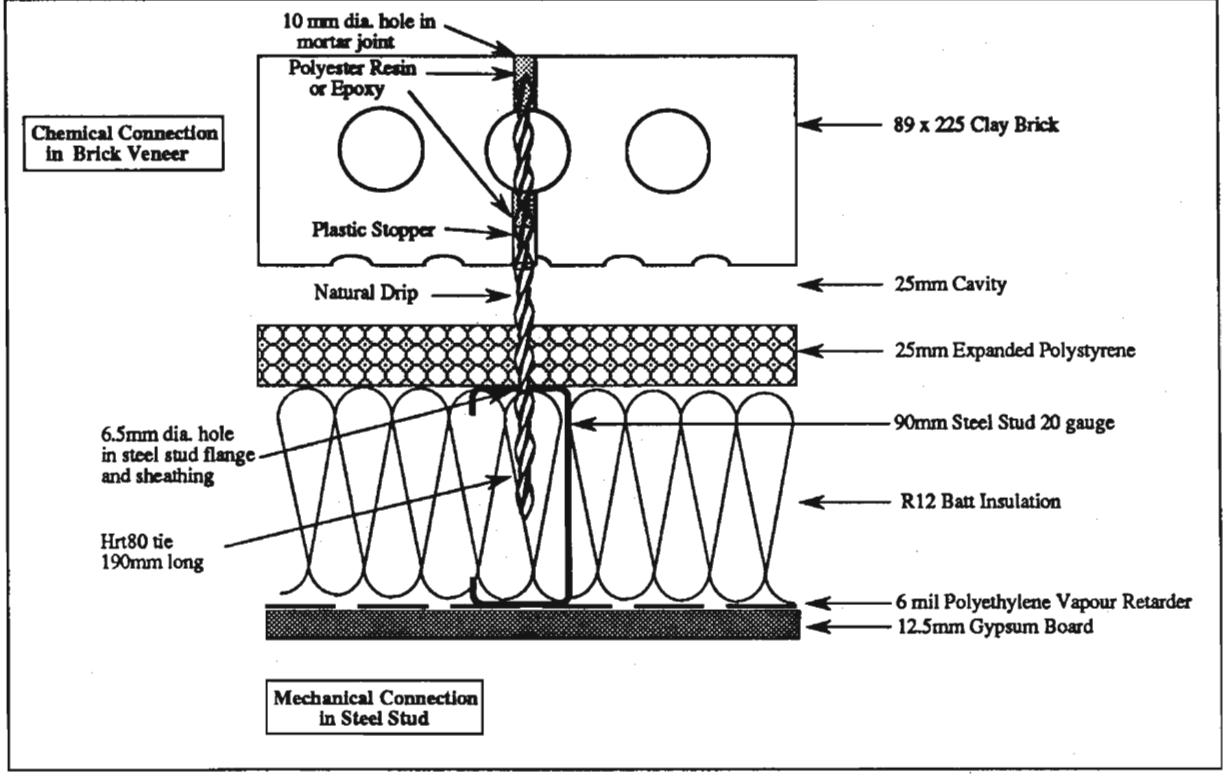

Table 11 --- Helifix HRT80 Dry Fix in SS Polyester Resin in Brick

STEP #	DESCRIPTION	TIME (sec)
1	Locate Stud	
	Drill Through Brick Veneer at Mortar Joint - 10mm dia. masonry drill bit - hammer drill action	10 seconds
2	Drill Through Outer Steel Stud Flange - 6.5mm dia. steel drill bit - rotary drill action only	10 seconds
3	Drive HRT80 tie into the outer flange of the steel stud	30 seconds
4	Inject Polyester Resin around the HRT80 tie	20 seconds
5	Repair Hole	
	Total Observed Time for Repair	70 seconds

BEG

5.7.3 Cost

The contractor's cost for this tie, which includes the tie unit and the polyester resin, was estimated by Blok-Lok Ltd. to be $ 3.75 per unit. The labour cost to install the tie can not be adequately estimated at this time. The labour cost of installing this tie would be average, as there are no complicated procedures and the entire installation can be conducted at the same time. The 10mm dia. hole is smaller than most tie systems, however the cost of repairing the exterior wall to an acceptable status will still be similar to that of the other repair systems.

5.7.4 General Comments

Installation - The installation of the Helifix tie from the exterior is as easy as the interior retrofit with the exception of injecting a polyester resin or epoxy around the tie in the brick veneer and locating the steel stud. Hand tools were used to impact the tie and thereby thread the tie into the outer flange of the steel stud. Photo 25 shows the Helifix tie and the plastic washer that stops the resin from being injected into the cavity.

Strength of Connection - The strength of the connection to the brick veneer should be adequate. The reliance of the threaded connection in just the one flange of the steel stud requires testing to be conducted. As with all threaded connections that rely on this single flange attachment, the pullout strength, the displacement at service loads and the response to cyclic loading should be determined. Photo 26 shows an interior view of the EXT7 - Helifix repair method.

Damage - The damage to the brick veneer, the sheathing and the steel stud are minimal with this connection.

Thickness - The range of thicknesses over which this tie will perform adequately is not known.

Drip - The continuous, helical thread provides a natural drip for water that will prohibit water from making its way down the tie and into the stud space.

Potential For Corrosion - As the tie is stainless the only part of the repair susceptible to corrosion and important to the strength of the connection is the area of the flange in which the tie is threaded.

Thermal Bridging - Thermal bridging will occur at this connection, however the small cross section of the HRT80 tie will be advantageous.

Weather Limitations - The use of the polyester resin or epoxy may limit the use of this repair method in cold weather situations.

Air Leakage - The small hole in the steel stud and the exterior sheathing may increase slightly any flow of air between the stud space and the cavity.

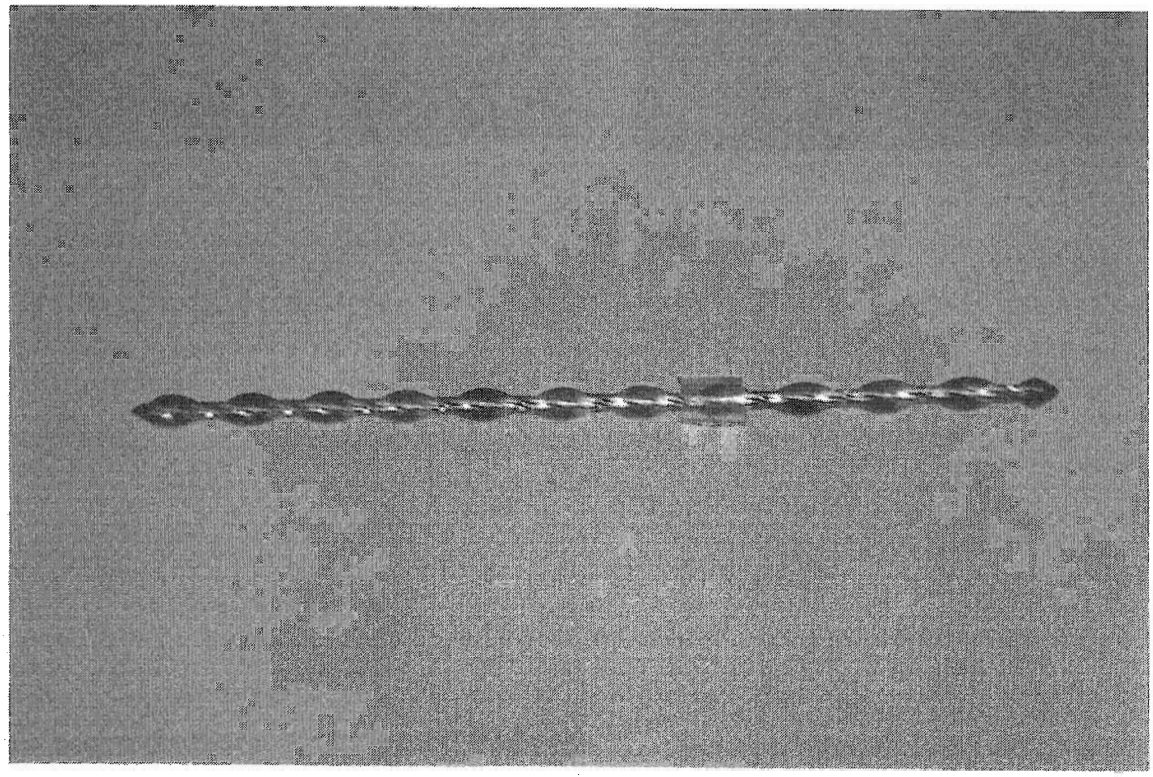

Photo 25 - Helifix HRT80 Tie and Plastic Washer

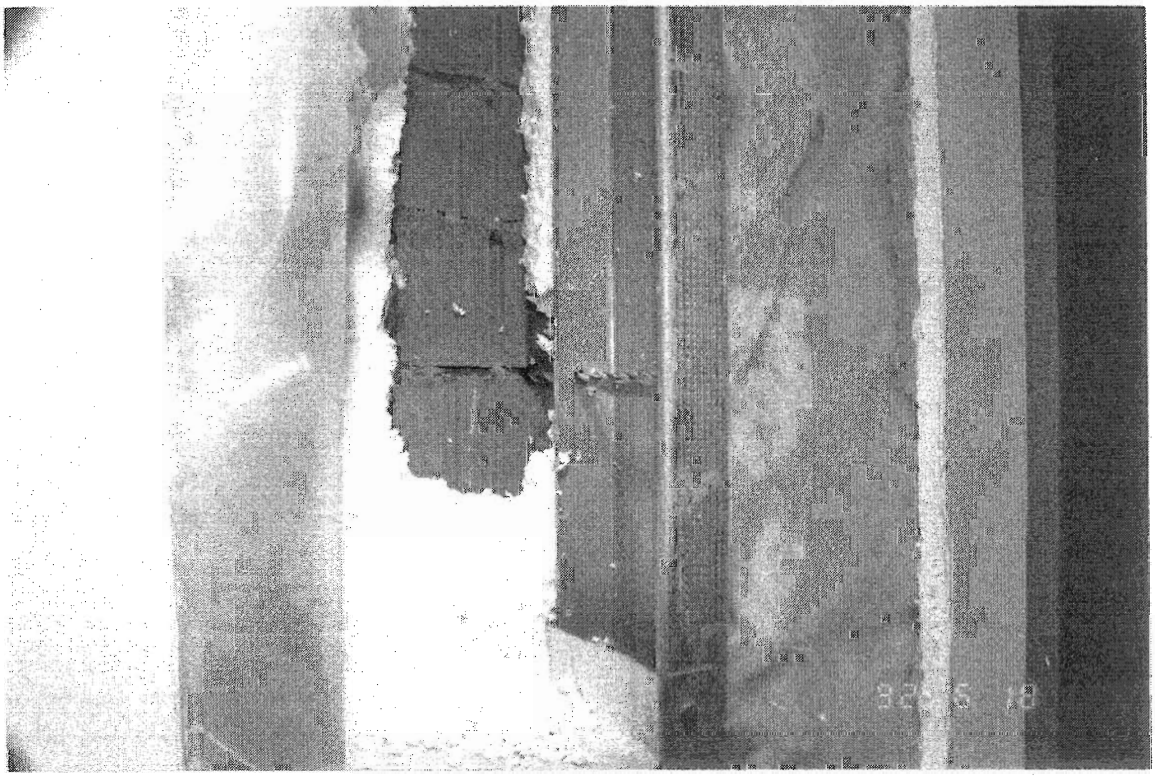

Photo 26 - Interior View of EXT6 - Helifix Repair

6. COMPARISON AND DISCUSSION OF REPAIR SYSTEMS

6.1 Overall Problem

The object of this report has been to demonstrate, document and assess various methods of installing supplementary brick ties on a brick veneer steel stud wall system. Whether the need for remedial brick ties is due to improper tie selection, corrosion, 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 on the choice of tie repair method may raise some of the following concerns :

1) If the steel stud does not have adequate stiffness, was built improperly, or is severely corroding, extensive repair of the steel stud system may be necessary. In this instance an interior repair method may be desirable as the gypsum board would have to be removed. If the wall is opened up from the interior some of the interior repair strategies demonstrated in this study might not be suitable.
2) If the brickwork needs to be repaired in any significant way, e.g., repointing, brick replacement, introduction of movement joints or sealing, then staging or scaffolding will be inevitable and an exterior repair method may be preferred.
3) If air leakage is a significant problem and the interior gypsum needs to be sealed and no exterior work is needed, an interior repair may be preferred.
4) An interior remedial approach will depend upon access, convenience and the nature of the finishes.

All things considered, the choice of repair system does depend on the overall state of the building, the costs of alternative strategies and the needs of the owners and tenants of the building.

6.2 The Merits of Interior and Exterior Repair Methods

The choice of an interior or an exterior repair method will depend on numerous factors, the most important of which are cost, access, timing and the type of other repairs that are needed. An argument pro and con interior and exterior repair methods is listed below.

INTERIOR METHODS

PROS

1) Easier to locate studs from the interior.
2) Access is easier and cheaper.
3) Interior work is likely needed to develop an air barrier.

CONS

1) Impact on Tenants: disruption, dust control and cleanup.
2) Repairs and replacement of the interior finish may be very expensive.
3) Scheduling of repairs and the need for short time span repairs will be very important in preventing cost overruns and tenant dissatisfaction.
4) Noise

EXTERIOR METHODS

PROS

1) Dust control and construction site cleanliness will be less of a concern.
2) Repairs to the brick veneer may be needed.
3) Greater flexibility in timing of repairs.
4) A less negative impact on the tenant in terms of noise.

CONS

1) Access may be expensive depending on building height, type and geometry.
2) To locate the steel studs requires more effort and will be more expensive.
3) Weather.

6.3 Comparison of Methods Demonstrated

Interior Retrofits

The four interior retrofit methods were all demonstrated relatively successfully. Each method is different and each has advantages and disadvantages. Table 12 attempts to quantify the attributes of each method.

With the exception of INT2, the web mounted bracket, the repair methods demonstrated were all feasible. The use of repair method INT2 would only be practical if large amounts of the interior gypsum board were to be removed.

The Cintec anchor, at $9.00 per tie, is much more expensive to buy than Dur-O-Wal's epoxied rod anchor or Blok-Lok's HRT80 tie, which are $3.00 and $3.75 per tie respectively. Too much weight should not be put on the cost of the individual tie. Tie spacing and thus the total number of ties, and installation cost are probably of greater importance than the purchase price of each tie. A major cost will be the labour to install the ties and to return the wall to its intended state.

The aesthetics of the repair, or visibility, 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 repairs INT3 and INT4, approximately 15mm diameter, can be patched fairly readily. The much larger hole, approx. 35 mm, for the Cintec anchor could be decreased by reducing the diameter of the end washer.

All individual remedial tie methods involve damage to the air barrier and vapour retarder. While the drywall can be repaired, the 4 or 6 mille poly, if any, cannot. However proper sealing of all holes can be done and suitable finishes can be specified and used. In most cases, the provision of an air barrier, especially the sealing of the perimeter joints, is likely to be an important requirement. By doing tie remediation and air sealing at the same time a good overal repair can be achieved.

No damage to the brick veneer should occur with an interior repair but care must be taken to limit the pre-drilled hole to 2/3 or 3/4 of the brick depth. Also impact drills should be used with care.

Thermal bridging, although it cannot be eliminated, can be minimized with the use of smaller mass ties. As with other components in a steel stud system, corrosion is a concern. The repair method used should not promote or accelerate corrosion, although the consequences of breaking the galvanizing near the tie connection needs to be studied further. For these reasons a stainless steel tie is preferred especially if the remedial tie is being introduced into a less than ideal environment.

Table 12 --- Comparison of Interior Retrofit Systems

	INT1 Cintec Cementitious Sock (22mm)	INT2 Dur-O-Wal Bracket & Exp. Anchor	INT3 Dur-O-Wal S.S. Rod in Epoxy	INT4 Blok-Lok Helifix HRT80
INSTALLATION				
Ease	*	-	*	*
Time	*	*	*	+
Visibility of Damage	*	-	+	+
Weather Limitations	-	*	-	*
Effect on Tenant	-	-	-	-
REPAIR CHARACTERISTICS				
Strength of Connection	*	+	*	?
Ductility of Connection	-	+	-	+
Air Leakage	*	+	*	*
Various Thicknesses of Stud	*	*	*	?
Moisture Drip	+	+	-	+
Potential for Corrosion	+	+	+	*
Effect of Corrosion on Connection	*	*	*	-
Thermal Bridging	-	-	-	-
COSTS				
Cost of Tie	$ 9.00	$ 4.00	$ 3.00	$ 3.75
Cost of Labour**	?	?	?	?
Relative Cost of Making Good	*	-	+	+

* 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.

Exterior Retrofits

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 12 attempts to quantify the suitability of each method.

A common concern is whether the stud can be located with the appropriate degree of accuracy. Various methods for finding the stud from the exterior were discussed in Section 3 of this report.

All repair methods, with the possible exception of the larger Cintec repair (EXT1), are feasible and practical methods to tie brick veneer to steel stud. The large 65 mm dia. hole needed for the Cintec tie in repair method EXT1 is aesthetically unacceptable and expensive to do. This repair is, however, suitable if existing ties have to be removed and replaced.

With the exception of the two Cintec anchors, the purchase price for ties ranges from $2.50 to $4.00 per anchor. The Cintec anchors are priced at $15.00 and $9.00 per anchor. These 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 the damage to the exterior sheathing, the air barrier (if involved) and the steel stud is both difficult to assess and difficult to avoid. Repair EXT3, the Dur-O-Wal toggle clips, is unacceptable for use with compressible exterior sheathings as the toggle clips with either cut a large hole in this sheathing (providing a passage for air leakage) or will depend on the integrity of the sheathing 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, EXT4, EXT5 and EXT7, 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.

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.

Table 13 --- Comparison of Exterior Retrofit Systems

	EXT1 Cintec Cementitious Sock (65mm)	EXT2 Cintec Cementitious Sock (22mm)	EXT3 Dur-O-Wal Toggle Clips & Exp. Anchor	EXT4 Dur-O-Wal Threaded Bolt & Exp. Anchor
INSTALLATION				
Ease	-	*	*	*
Time	-	*	*	*
Visibility of Damage	-	-	*	*
Weather Limitations	-	-	*	*
Effect on Tenant	*	*	*	*
REPAIR CHARACTERISTICS				
Strength of Connection	*	*	?	?
Ductility of Connection	-	-	*	*
Air Leakage	*	*	*	*
Various Thicknesses of Stud	*	*	*	?
Moisture Drip	+	+	+	+
Potential for Corrosion	+	+	*	*
Effect of Corrosion on Connection	*	*	*	-
Thermal Bridging	*	*	*	*
COSTS				
Cost of Tie	$ 15.00	$ 9.00	$ 3.00	$ 3.00
Cost of Labour**	?	?	?	?
Relative Cost of Making Good	-	*	+	+

* 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.

Table 13 (cont'd) --- Comparison of Exterior Retrofit Systems

	EXT5 Dur-O-Wal Drill and Tap & Exp. Anchor	EXT6 Dur-O-Wal S.S. Rod in Epoxy	EXT7 Blok-Lok Helifix HRT80
INSTALLATION			
Ease	*	*	*
Time	*	*	*
Visibility of Damage	*	+	+
Weather Limitations	*	-	-
Effect on Tenant	*	*	*
REPAIR CHARACTERISTICS			
Strength of Connection	?	*	?
Ductility of Connection	*	-	+
Air Leakage	*	+	*
Various Thicknesses of Stud	?	*	?
Moisture Drip	+	-	+
Potential for Corrosion	*	+	*
Effect of Corrosion on Connection	-	*	-
Thermal Bridging	*	+	*
COSTS			
Cost of Tie	$ 2.50	$3.00	$ 3.75
Cost of Labour**	?	?	?
Relative Cost of Making Good	*	+	+

* 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.

7. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

This report identifies various tie systems that are commercially available for use as supplementary brick ties in brick veneer/steel stud walls. Each repair strategy has been physically demonstrated and then assessed.

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 procedures are available to address this common problem.

An assessment of the relative merits of each repair method has been provided. There is no optimal solution. Each method has both advantages and disadvantages. Moreover each repair situation is unique and may require a unique solution. This report can be used to advantage in arriving at a solution. The comparison tables that have been developed provide a useful vehicle for comparing supplemental tie systems.

RECOMMENDATIONS

There are many areas of concern that have been not dealt with in detail and there are issues that have not been considered in this report. Before using any of the tie systems demonstrated, some key questions need to be answered, e.g.,

1) What is the installation cost?

2) What is the cost of making good?

3) What are the performance characteristics of the connections in the steel stud flange?

4) How does the installation of remedial anchors affect the stiffness of the wall system?

5) What about tie penetration considerations such as air leakage, corrosion potential, etc.?

In this report the focus has been on identifying and demonstrating possible remedial tie systems. Item 3 above will be the focus of the next task, Task 2, in this CMHC study. Item 5 will be addressed in Task 3 and items 1 and 2 will be studied further in the field trials planned in Task 4.

We recommend that some of the above issues be resolved before this report be given wider distribution.