

CINTEC

Designed Anchor Systems

TEST DATA

The background of the entire page is a vibrant orange and yellow sunset sky. At the bottom, there is a silhouette of several ancient stone structures, possibly a ruin or a temple, with some openings that are illuminated from within, creating a warm glow. The overall mood is one of historical significance and durability.

SECURING THE PAST FOR THE FUTURE

BRE Technical Consultancy
Structural Integrity Division



CLIENT REPORT:

Moisture/Temperature cycling tests
On the Cintec remedial wall tie

for: Cintec Ltd.,
Factory Road, Newport, S. Wales NP20 5FA

by S K Arora

November 1990

Enquiry Number 02831

Building Research Establishment
Garston, Watfoed, Herts. WD2 7JR
Telephone 0923 894040
Fax 0923 664096

INTRODUCTION

This report gives results of pull-out tests on Cintec Harke remedial tie embedded in a clay brick, having been subjected to accelerated moisture/temperature cycling over a period of three months. The object of the exercise was to test the long term performance of the tie anchors under conditions of wetting by rain of the external walls of a structure into which they would be incorporated followed by drying.

THE ANCHOR SYSTEM

The literature supplied by the manufacturers of the system, Messrs Cavity Lock Systems Ltd. of Newport, Gwent, describes Cintec-Harke replacement wall tie as a cementitious anchor. The standard design is a long stainless steel hollow tube of 8mm O.D.¹ x 1mm thickness provided with a mesh polyester fabric sleeve or a 'sock' of required diameter at each end. A specially designed cementitious grout is injected into the socks through the tie under pressure in predrilled position(s) in the cavity wall requiring replacement tie(s). The pressure is maintained until the inflated socks are hard and the grout milk with bonding agents are driven out to give good bond between the inflated sock and the background material. The grout is a Presstec or S.T.M.A. grout¹.

EXPERIMENTAL DETAILS

The anchor used in the pull-out tests was a special design of 165-175mm long 8mm O.D. x 1mm stainless steel hollow tube, with an 85mm long sock provided at one end only which would inflate to a diameter of approximately 22mm. The background material chosen for the test specimens was a flat faced solid wire-cut facing clay brick of 212mm x 100mm x 65mm size. The anchor sock was embedded through one of the 212mm x 65mm faces to its full depth, with the steel tube coming out through the other face. Three spare specimens were also prepared with the anchor sock embedded to a lesser depth of around 60mm, with the remaining part providing a bulge of anchor material into a reamed out hole of 40mm diameter. This was done to test a situation where a positive re-entrant tension fixing is to be provided in a wall, in case the grout to brick bond fails.

The specimens made with the said brick supplied by BRE were prepared by the manufacturers at their own premises and delivered to BRE three days later.

The test programme assumed that a masonry wall in reality would be exposed to rain such as to saturate it fully with water at least once a year. Trials were made to ensure wetting of the brick in a water tank to saturation followed by drying in an electric oven heated to 40°C(±2°C) temperature, to a constant weight. A half hour soak in a water tank followed by a minimum of two days of drying was found sufficient to meet the requirements.

The BRE contract stipulated 20 pull-out tests on brick/anchor specimens, five each to be tested at: seven days cure after construction of the specimens, and then after 10, 20 and 40 cycles of wetting/drying of the specimens. A further three specimens of 60mm embedment length referred above

were also tested after 40 wetting/drying cycles.

The pull-out testing was carried out on a standard Universal Testing machine with a maximum load capacity of 20 Tonnes, calibrated to BS 1610: 1985 Grade 2. The test brick was placed in a small restraining rig made out of a rectangular hollow steel section designed to hold the brick firmly along its 'anchored' face. A side load of about 3.5 N/mm² pressure was applied on the bed faces to simulate condition of confinement of the brick in a real wall. Vertical restraint was provided by small wedge strips keeping the top surface of the brick tightly parallel against the upper part of the frame.

TEST RESULTS

Clay brick

For the clay brick used, trial tests indicated a water absorption after a 1/2 hour soak of 15.0%, which approximates the full saturation value after a 24 hour soak of 17.5% for the same brick. Its compressive strength was indicated to be 43.3 N/mm².

Brick/anchor specimens

The pull-out values obtained in the 20 standard and three extra tests carried out are tabulated below.

Tie Pull-out values in KN

Specimen No.	After 7 days cure	Number of wetting/drying cycles		
		10	20	40
1	10.45	7.56	10.45	9.10 (9.79)
2	12.23	10.23	10.23	11.00 (6.23)
3	10.68	8.45	10.23	10.00 (8.01)
4	10.45	10.68	10.90	12.90
5	10.90	10.68	8.45	9.79
Mean	10.94	9.52	10.10	10.56 (8.01)
c.o.v. %	7.00	15.00	9.00	14.00 (22.00)

Note:- The bracketed values are for the three extra tests involving anchors of the limited embedment length of 60 mm.

A one way analysis of variance of the tabulated values for the 20 standard tests has shown that the wetting/drying treatment given did not affect the pull-out performance of the tie in the background material tested in any significant way. Mean pull-out value for these specimens was 10.28 KN. Regression analysis of the data (for a linear as well as polynomial fits) further confirmed a lack of a significant correlation between the pull-out performance and the wetting/drying treatment given.

The failure of the system tested was typically by a pull-out of the steel tube from the anchor grout (Figure 1), sometimes accompanied by splitting of the brick in the plane of the anchor.

As to the three extra specimens, the mean pull-out value of 8.01 KN, when compared with the corresponding value given for the standard specimens, suggests that the apparent deterioration in performance was only due to the reduced length of embedment of the anchor. The failure here was typically by a rupture of the anchor grout at the interface between the embedded part to the bulging part, accompanied by a pull-out of the steel tube again (Figure 2).

CONCLUSIONS

1. The experiments show that the pull-out performance of the test anchor/clay brick combination tested would not be affected adversely in any significant way in the conditions of exposure to rain simulated in the manner described.
2. The failure of the standard specimens was typically by pull-out of the steel tube from the anchor grout.
3. The pull-out performance of the anchor/brick system tested appears to be directly proportional to the length of embedment of the anchored sock.

REFERENCE

1. Private communication, Mr Owen/Mr James, Messrs Cavity Lock Systems, Factory Road, Newport, Gwent.

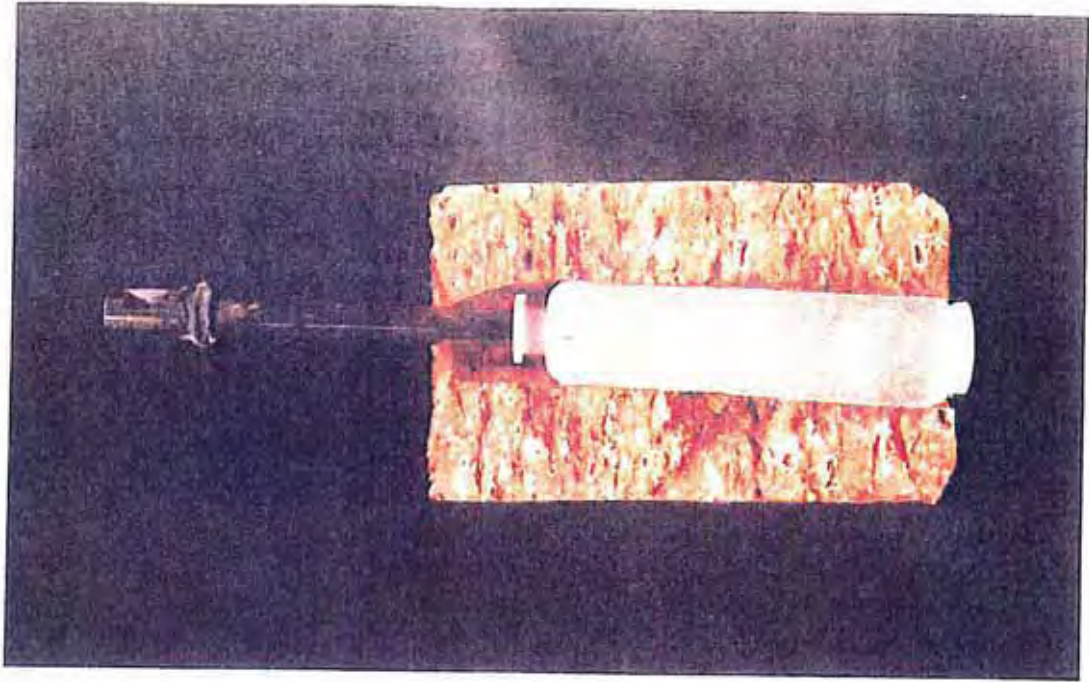


FIGURE 1 TYPICAL FAILURE MODE FOR THE STANDARD SPECIMEN

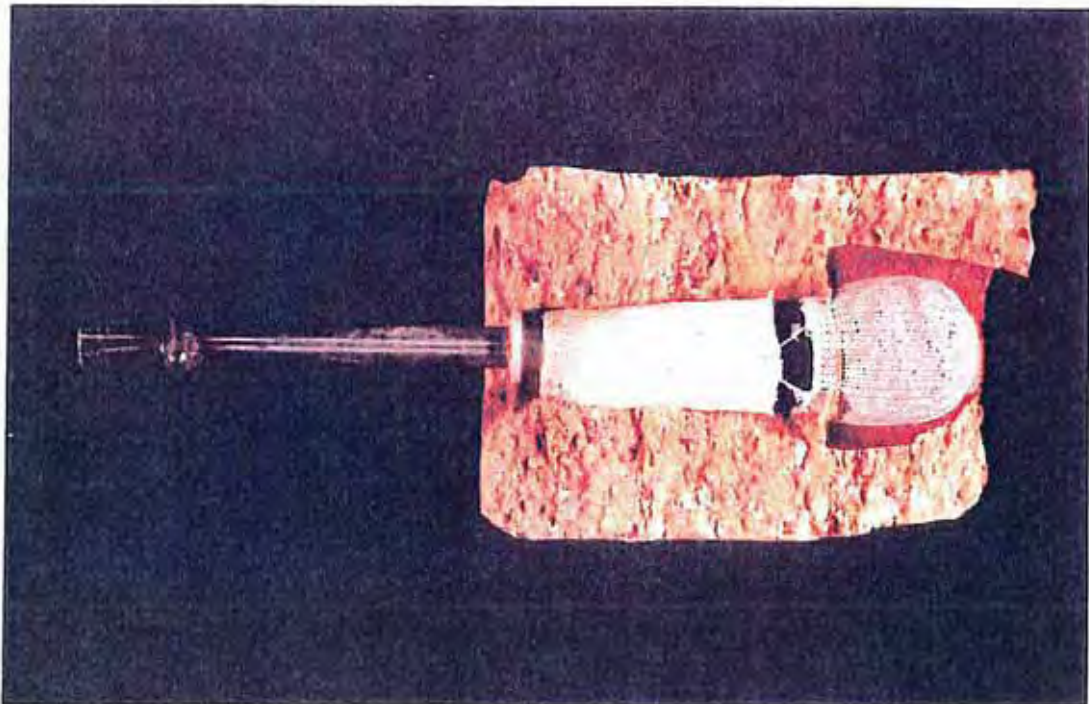


FIGURE 2 TYPICAL FAILURE MODE FOR THE EXTRA SPECIMEN

Building Research Establishment

Garston Watford WD2 7JR
Telephone 0923 894040 Telex 923220 Fax 0923 664010

Direct line 0923 667
GTN 3532

Mr. J. Dymmock
Cavity Lock System
Factory Road
Newport
Gwent
NP9 5FA

your reference

our reference

BRE/67/50/1

date

23/11/93

Sent by FAX to : 0633 246110

Dear John

Fire testing of Cintec's remedial cavity wall ties.

In the latest test in our fire test rig with a static dead load on each tie of 1.3kN your tie survived a two hour test without failure of any of the three replicate samples.

All three samples are now placed in the upper half of the wall and would have reached several hundred degrees in the part of the tie nearest the fire face.

This indicates that this tie system can, when installed using the correct techniques, be recommended for repair work to buildings having a fire period requirement of up to 2hrs.

Yours sincerely



R.C. de Vekey

Head of Masonry Structures Section, Structural Design Division, Geotechnics and Structures Group

The BRE logo consists of the letters 'BRE' in a white, serif font, centered within a dark, rectangular background that has a grainy, textured appearance.

BRE

Fire Test for Wall Ties

by Mr D Chehal & Dr R.C de Vekey

Technical Director, Centre for Masonry Construction, Construction Division

FULL TEST DATA IS AVAILABLE ON REQUEST

A FIRE TEST FOR WALL TIES

D Chehal and Dr. R C deVekey

SUMMARY

A diverse range of connectors, termed wall ties, restraint ties or cavity connectors, are used in industry to link cladding masonry to either inner leaves of load bearing masonry or to frames of timber, concrete or steel. Their function is to support the cladding and transfer loads arising from wind, impacts, seismic events etc. to the main structure of the building. Many of these connectors have fixing mechanisms or structural components that are made from heat sensitive materials such as resins, plastics and low-melting alloys. Other products use mechanical devices that might be affected by thermal expansion of the components. However, until now, no widely publicised tests have been carried out on the performance of masonry cavity connectors exposed to fire conditions. Under the terms of the EC Construction Products Directive, CEN standards are being drafted for the specification of cavity connectors and resistance to fire is one of the essential requirements for which performance tests are required. Eventually fire performance data will be necessary in order to design in accordance with the forthcoming CEN Code of Practice. The successful application of performance evaluated products will reduce the risks to the public attempting to escape from burning buildings, and to the fire fighting services dealing with the fires. Therefore, BRE has initiated such tests to assess the behaviour of cavity connectors under the effects of fire. In the future it is hoped that the test methodology described in this paper can be extended to other products such as general fixings, support angles, and hangers and straps.

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To be presented at the Autumn 1993 meeting of the British Masonry Society, at British Ceramic Research Ltd. Stoke on Trent, 9th - 10th November 1993

Date Oct 1993
Project No. GD0457
WIF Ref. CDS03/07
File No. BRE 74/1/6

Building Research Establishment
Structural Design Division
Masonry Construction Section
Garston, Watford, WD2 7JR
Telephone 0923 894040, Telex 923220
Fax 0923 664010

ArconTEST, Incorporated

architectural conservation testing and laboratory testing

10 Alcorn Avenue, Suite 103, Toronto, Ontario M4V 1E4

☎ (416) 922-5013 fax (416) 922-1681 e-mail pmarek@Arcontest.com

Report on the Uni-directional Freeze-thaw Performance of Cintec Masonry Anchors

To EN772-Part 22 [Methods of Test for Masonry Units] - Part 22
[Determination of freeze-thaw resistance of Clay Masonry Units]

Prepared for CINTEC NORTH AMERICA

September 2001

Introduction

ArconTEST Incorporated was retained by Cintec International Limited to assess the unidirectional freeze-thaw resistance of Cintec grouted masonry anchors. Examples of the proprietary anchor and grout system were installed within a purpose-built brickwork wallette using standard procedures, which after a curing period of 30 days was subjected to a standard 100 cycle unidirectional freeze-thaw testing procedure.

Samples of the proprietary Presstec grout were cast in four-inch and two-inch square standard molds to allow compressive strength testing of the two-inch cubes, and freeze-thaw testing of the four-inch cubes within the test chamber alongside the test wallette.

Uni-directional Freeze-thaw Test

Background

Materials being used in outdoor conditions are subject to extreme variations in weather conditions. A typical Ottawa winter season characteristically goes through 100 freeze-thaw cycles. Although many products are fully frost-resistant after curing, it is often beneficial to determine at what point in time adequate frost resistance occurs. Premature exposure to frost cycling in many cases leads to material failure and costly replacement.

The purpose of freeze-thaw testing is to provide a standard relative determination of the resistance of building materials to harsh climatic fluctuations such as are found in Canada.

The uni-directional freeze-thaw testing chamber was constructed to conform to European Standard EN 772 - Part 22 (Methods of Test for Masonry Units - Part 22: Determination of freeze-thaw resistance of Clay Masonry Units). Its primary purpose is to test the durability of clay masonry units, either with mortar joints or without (using suitable spacers or sealant). This standard is a combination of the German and British test standards that have been used for several years, and now supersedes the previously-used Dutch standard. This methodology has been found to more closely match the field conditions experienced on buildings than can be achieved by using the omni-directional ASTM C-666-92 rapid freeze-thaw testing methodology.

While this standard test is not specifically designed to test mortar (or grout) durability, it is being used by mortar and grout research groups as a relative performance indicator of masonry assemblies containing mortar, grout and unit masonry.

Materials to be tested are fitted into a thermally-insulated stainless steel frame which is mounted into the front of the testing chamber so that one face of the test panel is exposed to freeze-thaw cycling. The number of cycles and test parameters may be custom programmed to suit the purpose of the test and the characteristics of the material(s) being tested.

Apparatus

Since January 1999 ArconTEST's laboratory has been equipped with a fully-automated uni-directional environmental chamber for testing the freeze-thaw resistance of material assemblies up to 580 x 630mm in face area and up to 280mm in thickness. This unidirectional freeze-thaw testing apparatus was developed as a part of our research to aid in determining the durability and frost resistance of mortars.

The uni-directional freeze-thaw apparatus is capable of generating a cold stream of air within the chamber to lower the temperature of the face of the specimen to -15°C . This temperature is reached within one hour of the beginning of the test. The initial freeze cycle is six hours in duration to fully freeze the specimen. Thawing at the end of each cycle is achieved by blowing a stream of warm air against the face of the test panel for twenty minutes, followed by spraying a two minute flood-coat of 25°C water which re-saturates the face of the specimen and starts the next cycle. After the initial cycle each subsequent freeze period is 120 minutes in duration.

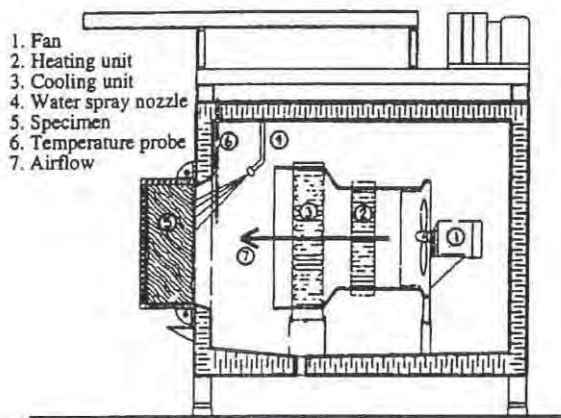


Figure 1 Schematic of Test Apparatus

Methodology

Freeze-thaw Wallette

The two-brick thick wallette, which was constructed before anchor installation, was built within an insulated stainless steel frame using a relatively high initial strength cement-gauged bedding mortar known to be durable under freeze-thaw testing. The bedding mortar was formulated using 1-part white Portland cement, 1-part dolomitic lime putty and 6-parts of concrete sand. The back of the wallette was encased in 50mm thick rigid insulation. The perimeter of the wallette was insulated from the frame with 25mm rigid insulation. The gap between the wallette and frame was sealed with a strip of adhesive membrane to prevent water entry during testing. The wallette was damp-cured for seven days then allowed to dry at room temperature for 21-days before drilling and installation of anchors.

Nine test anchors were installed in the fully-cured masonry in accordance with standard Cintec installation methodology. Three anchors were installed within holes drilled through the mid-section of the face and six holes drilled through the sides of the wallette. All anchors consisted of a stainless steel rod and expandible fabric socklet that contains the proprietary grout injected under low pressure through a plastic feeder tube along and to the back of the anchor.

Once all the anchors were installed, the completed unit was damp-cured for 7-days and then left aside at room temperature and approximately 50% RH for a total of 34 days to achieve the final test strength. The test wallette was then conditioned by water soaking for seven days before the commencement of the freeze-thaw test (total of 41 days).

The test consisted of 100-cycles of freezing and thawing of the exposed surface of the wallette within the test chamber. The chamber temperature cycled between -15 to +15C as required by the standard. The specimen was photographed before testing began and then periodically examined for damage during the course of the test, and after the selected number of cycles had been completed (five, 25, 50 and 100-cycles).

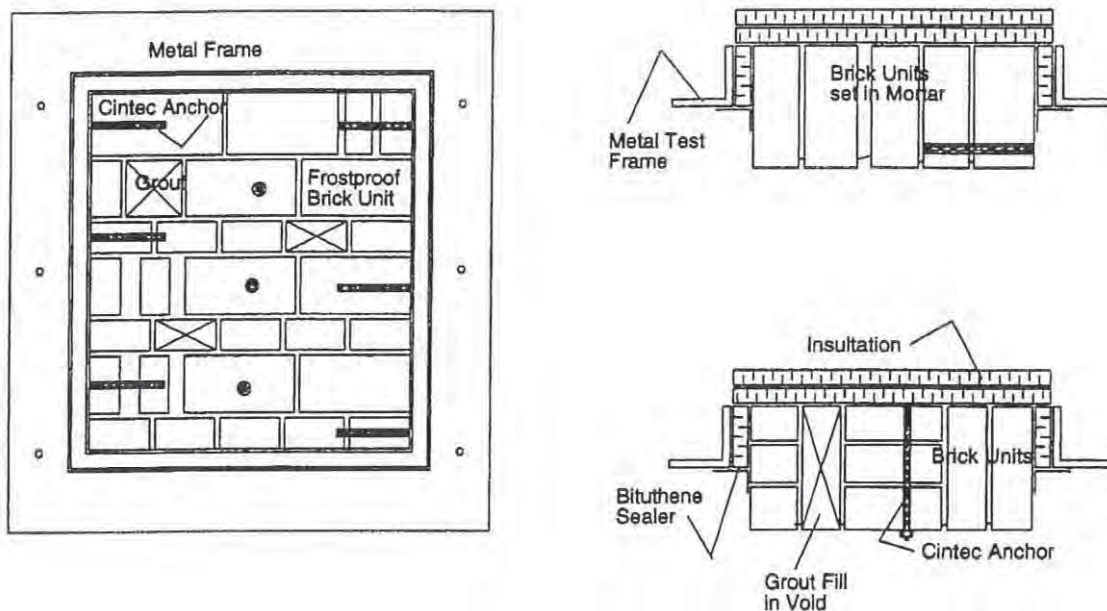


Figure 2 Schematic of Wallette with Cintec anchors

Freeze-thaw Testing of Grout Cubes

Three four-inch square standard cubes were cast for freeze-thaw testing within the chamber.

The cubes were cured after casting in a similar manner to the wallette, then dried and weighed before being immersed in water for 24 hours. The cubes were placed on the floor of the freeze-thaw cabinet and were exposed to the same cycling as the wallette.

Any changes in the weight of the cubes were recorded after 50 and 100 cycles.

Compressive Strength Testing of Grout

Nine two-inch standard cubes were cast of the grout in order to check their compressive strength at three, seven and 28-days after casting.

The cubes were wet cured after casting, then tested in accordance with the requirements of ASTM C-942 - Standard Test Method for Compressive Strength of Grouts for Placed-Aggregate Concrete in the Laboratory.

Test Results

Table 1 Freeze-thaw Testing

Specimen Type	Observations, Comments				
	Before Testing	After 5 cycles	After 25-cycles	After 50-cycles	After 100-cycles
Walette A	intact	intact	intact	intact	intact

Table 2 Weight Change of Freeze-thaw Walette

Specimen Type	Weight before testing		Weight after testing (100 cycles)	
	Dry	After 7 days of soaking	After 7 days of soaking	Dry
Walette A	173.15 kg	174.50 kg	174.59 kg	173.06 kg

Table 3 Freeze-thaw Testing of 4-inch Grout Cubes

Specimen	Dry Weight (grams)	Weight after 24 hours of immersion (grams)	Weight after 50 Cycles of Freeze/Thaw (grams)	Weight after 100 Cycles of Freeze/Thaw (grams)
Sample 1	1941.99	2043.65	2043.65	2045.13
Sample 2	1964.20	2002.37	2002.35	2003.19
Sample 3	1914.14	2054.41	2054.40	2054.56

Table 4 Compressive Strength Testing of 2-inch Grout Cubes

Wet Curing - Time Lapse		Sample 01	Sample 02	Sample 03	Average
3 days	MPa	30.39	27.05	30.91	29.45
	psi	4405	3920	4480	4268
7 days	MPa	36.29	37.23	37.40	36.97
	psi	5260	5395	5420	5358
28 Days	MPa	47.44	46.30	47.92	47.22
	psi	6875	6710	6945	6843

Discussion

No appreciable loss of grout or encasing brickwork was observed after the full 100-cycle test. No grout degradation or delamination of the grout from the brickwork was noted after the test.

The Presstec grout cubes which were placed on the floor of the freeze/thaw cabinet and subject to 100 freeze-thaw cycles displayed no evidence of damage or weight loss.

The average compressive strength of cast grout cubes, after 28 days of curing was found to be approximately 47 MPa.

Conclusions

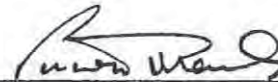
The anchor grout and installed anchor system installed within a brick wall performs satisfactorily when tested to the requirements of European Standard EN772 Part 22 (Methods of Test for Masonry Units - Part 22): Determination of freeze-thaw resistance of Clay Masonry Units).

ArconTEST Incorporated

per



Spencer Higgins M.Arch
Conservation Architect



Pawel Marek M.A.
Conservator

Photographic Documentation



Figure 3 Wallette A before testing

Photographic Documentation



Figure 4 Wallette A after 100 freeze-thaw cycles

Photographic Documentation

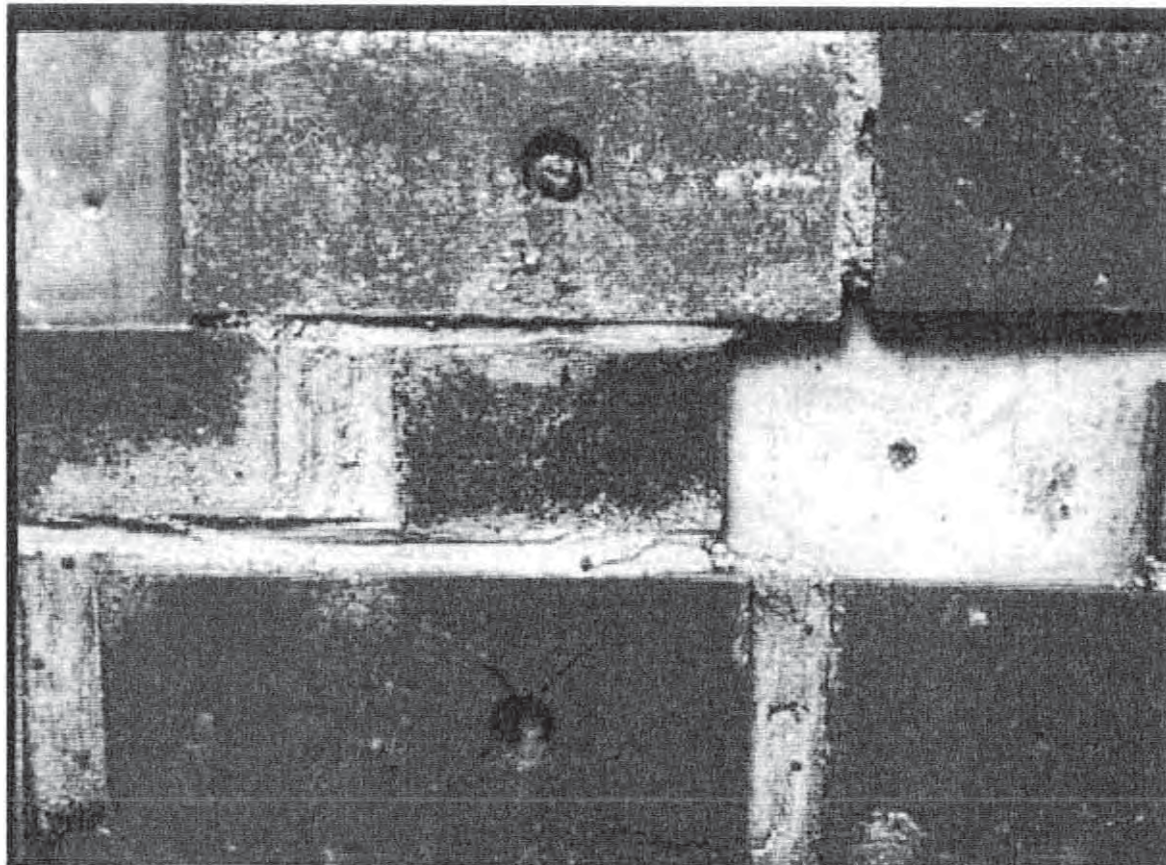


Figure 5 Wallette A after 100 freeze-thaw cycles, detail

Photographic Documentation

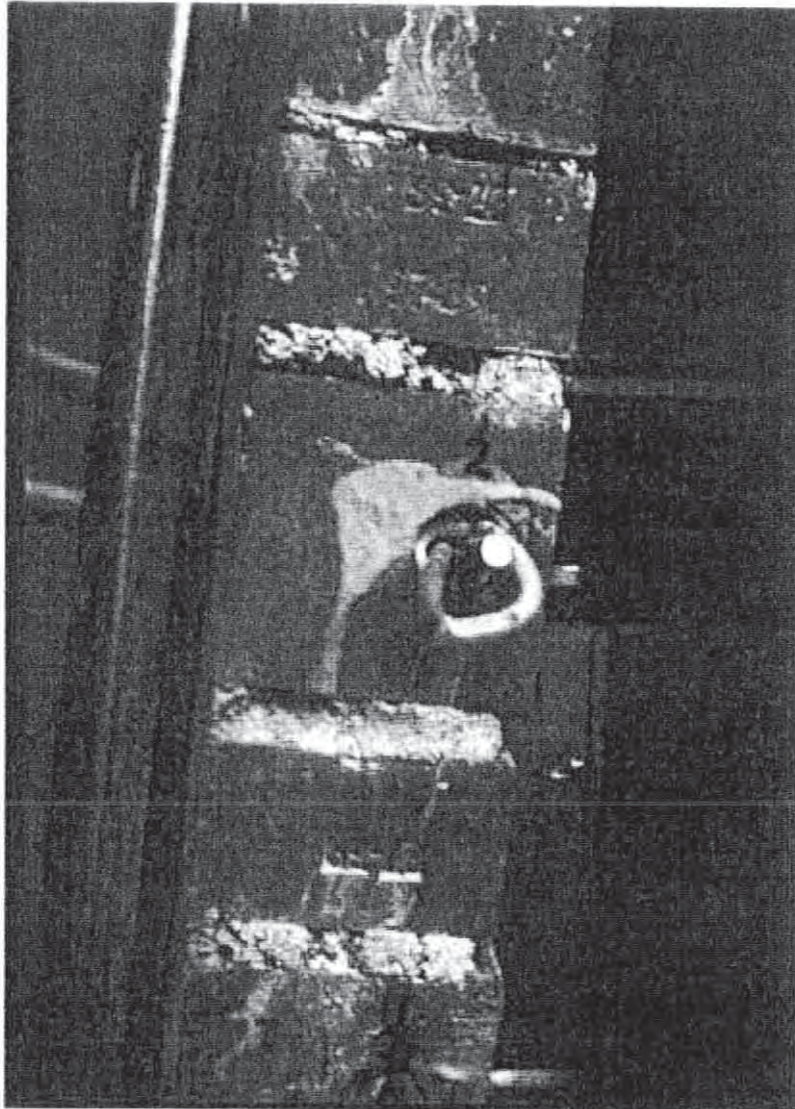


Figure 6 Side-mounted anchor before testing

Photographic Documentation

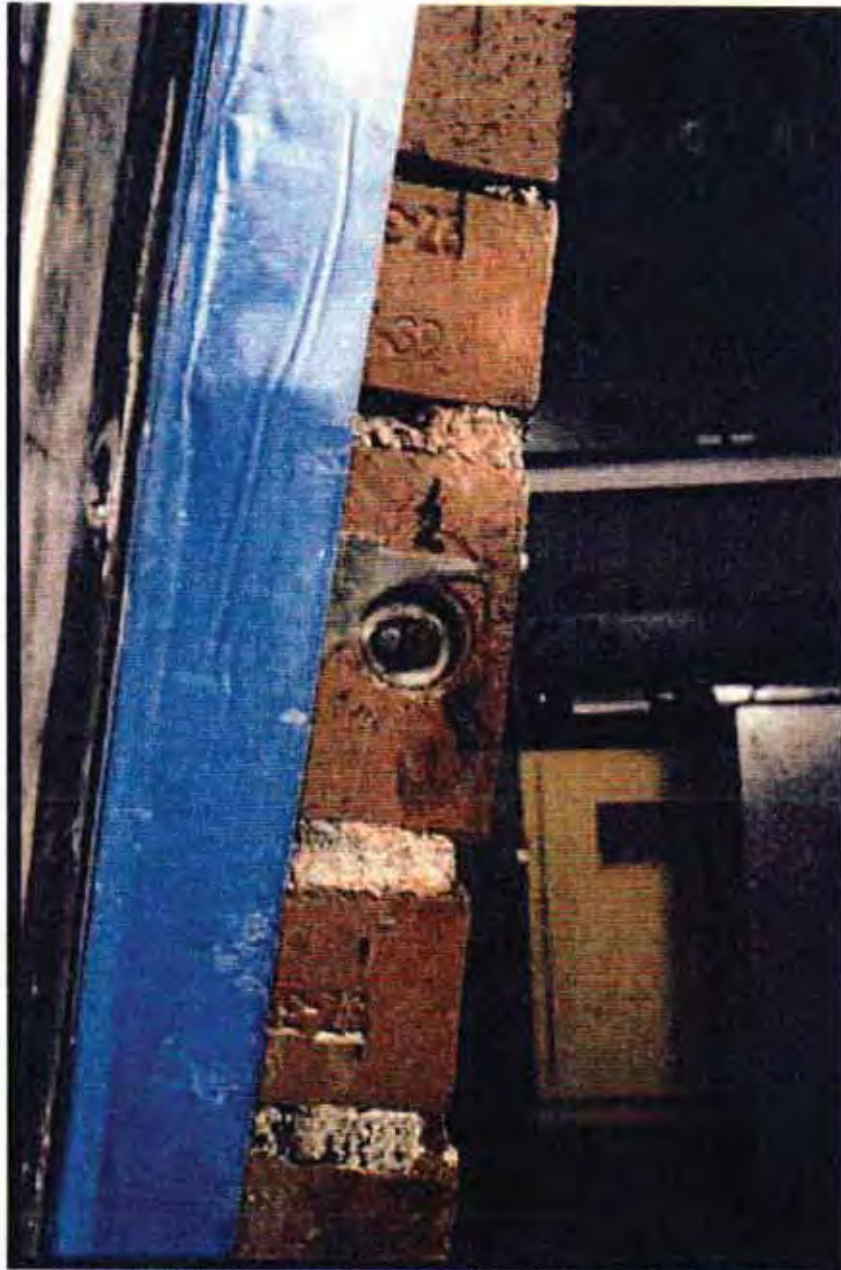


Figure 7 Side-mounted anchor after 100 freeze-thaw cycles



Environmental investigation on the Behaviour of Cintec Anchors subjected to Ultimate Load Test – Ottawa Parliament West Block Rehabilitation Project

Dr. Hugues M. Vogel, E.I.T.
Dr. Aftab Mufti, CM, P.Eng.

March 2012



Solutions for Civil and Heritage Infrastructure



Environmental investigation on the Behaviour of Cintec Anchors subjected to
Ultimate Load Test - Ottawa Parliament West Block Rehabilitation Project

By

Dr. Hugues M. Vogel, E.I.T.

Dr. Aftab Mufti, CM, P.Eng.

Agricultural & Civil Eng. Building

RM.A250 – 96 Dafoe Road

Winnipeg, MB, Canada R3T 2N2

Prepared for:

Dr. Jocelyn Paquette, Conservation Engineer, PWGSC

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Executive Summary

This document provides a report on the results obtained from pullout tests performed on Ohio sandstone masonry blocks instrumented with anchors provided by PWGSC and installed by Cintec Canada Ltd. The masonry blocks were provided by Public Works and Government Services Canada (PWGSC) to represent material that needs to be repaired in the West Block structure found on Parliament Hill in Ottawa.

The performance of 10 samples kept under ambient conditions was compared to that obtained from 25 samples subjected to weathering conditions typically found in the Canadian climate. Out of these 25 samples, a total of 10 were subjected to 150 dry freeze-thaw cycles and a total of 15 were submitted to 150 rapid (wet) freeze-thaw cycles. The cycles were designed in accordance with the North American standards governing the evaluation of environmental weathering. A total of three embedment lengths, referred to as sock lengths, were investigated for the anchors. These include 75mm and 150mm for ambient conditions and dry freeze-thaw cycles as well as 75mm, 150mm and 200mm for the rapid freeze-thaw cycles.

Visual inspections performed on the samples prior to and after weathering did not reveal any signs of degradation or any significant weight loss during cycling. Similarly, the pullout tests did not reveal any influence of weathering on the capacity or the performance of the anchors. The Cintec anchors were tested to failure and the loads achieved with a 9mm diameter A325M stainless steel anchor body was well above expectations by a factor of 9 and no bond loss between the grout and the Ohio sandstone masonry blocks. The first type of failure consisted of steel failure in the threaded rod immediately above the washer placed at the bottom of the grouted portion of the anchor. The second consisted of steel failure in the threaded rod within the gauge length extending from the surface of the stonework to the anchorage plates used for loading. Results for the capacity of anchors with 75mm sock lengths revealed slightly more variability than those obtained for anchors with 150mm sock lengths. The use of 150mm sock length was also not found to provide additional improvements on the capacity of the repair technique when compared to that achieved with 75mm sock lengths. The same observation was made for anchors with 200mm sock lengths but more research is required to confirm the result for this specific embedment length. All of the samples have been sectioned and pictures have been taken to provide a visual documentation of damage incurred during pullout testing.

1. Introduction

Historic buildings are an important part of history. They are a tangible record of cultural heritage and provide current society with a visual record of the art and skill of ancestry. Stone masonry buildings built in Canada before the twentieth century were not designed to the extent of requirements found in current building codes. As a result, there is a growing need for evaluating different strengthening techniques that can maintain structural integrity of heritage structures throughout Canada. The technique investigated in this document consists of inserting a Cintec anchor into the stonework and securing the structural components against movement. The strength and performance of the anchorage system was evaluated based on an extensive experimental program designed to account for the influence of weather conditions expected in the Canadian climate.

2. Background

This project was designed to evaluate the compatibility of using an anchorage system to secure the stone walls of the West Block building located on Parliament Hill in Ottawa, Canada. The West Block is one of three buildings on Parliament Hill and is an asymmetrical structure built in the Victorian High Gothic style with load bearing masonry walls. The main part of the structure was constructed by 1875 and some additional segments were added during the course of the last century. The construction history of the structure is summarized in Figure 1 along with an overall view of the building in 1875 as well as in its current state. It currently accommodates suites for House of Commons Members of Parliament along with different committee and ceremonial rooms, which renders its preservation vital from the perspective of preserving democratic institutions. Since most of this structure has already passed its design life, Public Works and Government Services Canada (PWGSC) has been committed to providing an evaluation of the structural state of the building through masonry surveys in the final stages of the second millennium. They have also started investigating possible strengthening techniques to conserve the structure in the early years of the third millennium.

3. Compatible Strengthening Technique for Heritage Structures

The West Block building, like many other historic stone masonry structures in Canada, was constructed with two-wythe stone walls. The walls, shown in Figure 2(a), include a rubble core separating an inner limestone wythe from an outer sandstone wythe. Masonry surveys performed by UMA Engineering Ltd. for PWGSC between 1994 and 1996 suggest that the long-term exposure

of the building to harsh Canadian weather has caused the outer wythe to separate from the rubble core at several locations on the structure. The separation is shown in Figure 2(b) and the severity of this deterioration was further evaluated by PWGSC with an additional survey in 2005. A summary of the results from this survey are shown in Figure 3.

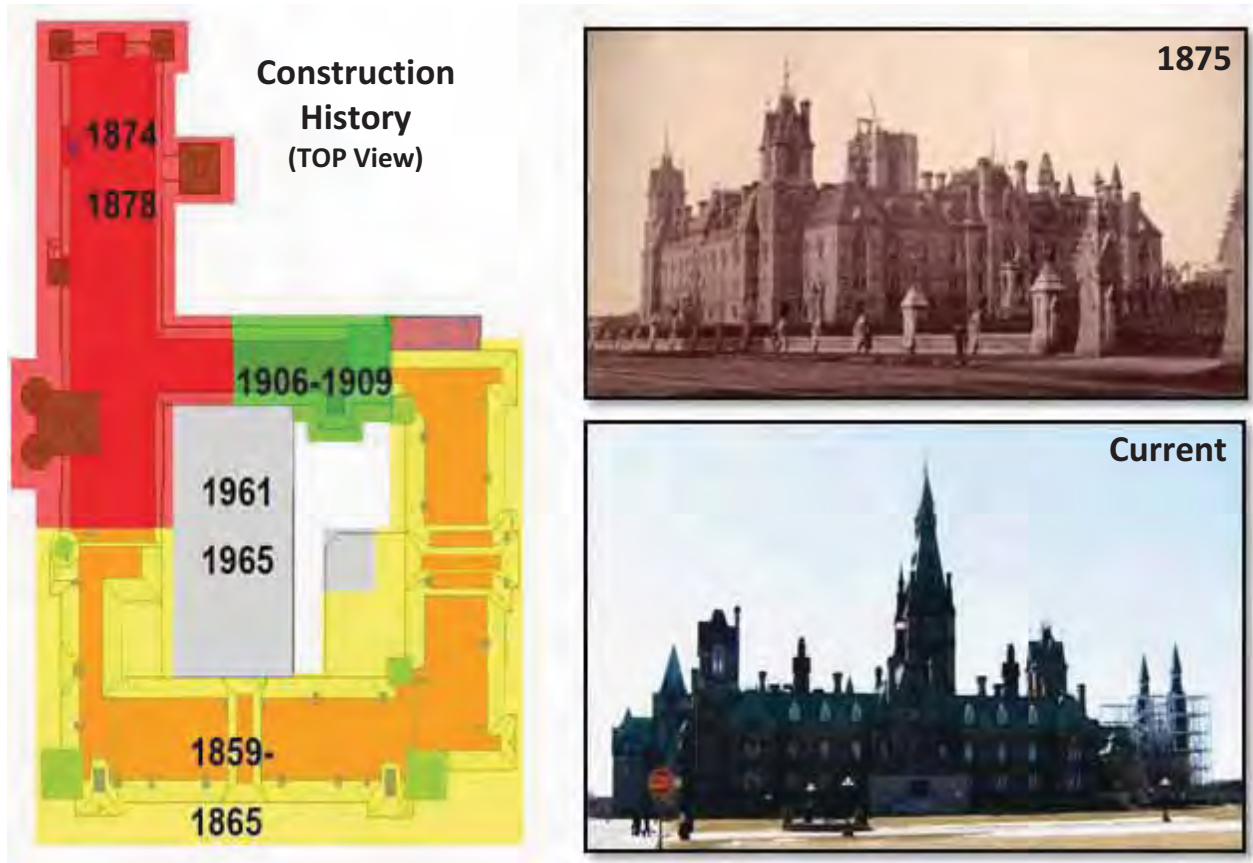


Figure 1 – West Block Structure: Construction History and Overall View

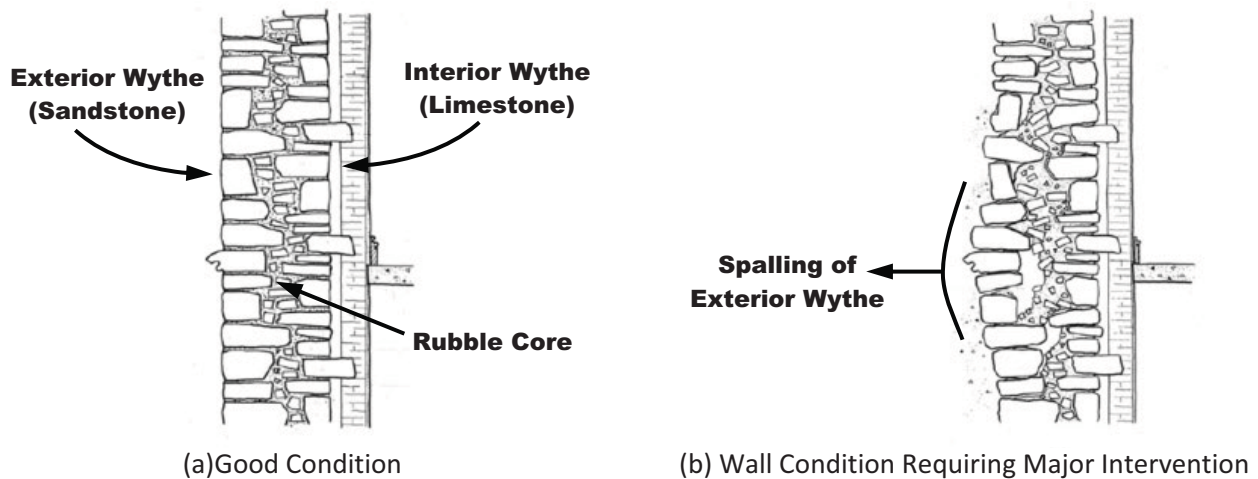


Figure 2 – West Block Structure Wall Details and Conditions

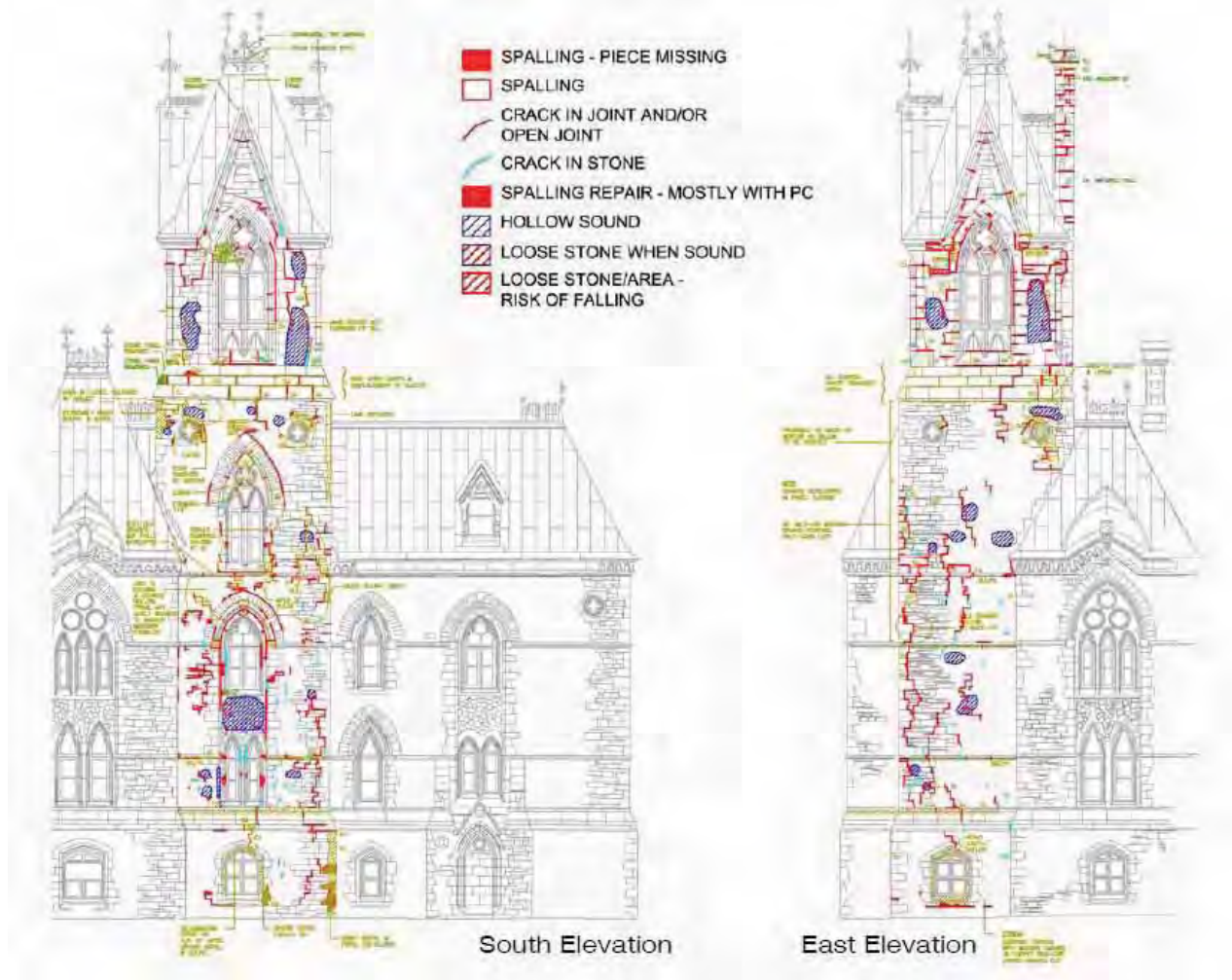


Figure 3 – Outer Sandstone Wythe Deterioration Severity (PWGSC Masonry Survey 2005)

As shown in Figure 4(a), the separation of the wall segments can be repaired or prevented by anchoring the outer wythe (sandstone) to the inner wythe (limestone). This strengthening technique requires the insertion of anchors, and therefore foreign materials, within the stonework. These materials should be chosen with care to prevent any detrimental impact on the stonework. Many researchers (Benedetti and Castoldi 1982, Benedetti and Pezzoli 1996, Tomazevic et al. 1993, Tomazevic et al. 1996) have conducted experimental investigations on the use of steel ties to strengthen heritage stone masonry structures. Although steel ties are susceptible to corrosion, most rehabilitation techniques are designed to limit moisture uptake and protect the anchorage system from detrimental weathering conditions. Research from Binda et al. (1997) and Tomazevic (1999) has also suggested that the use of grout to secure the ties in anchorage systems improves

compatibility with the stonework and can provide additional improvement on the strengthening of masonry structures.

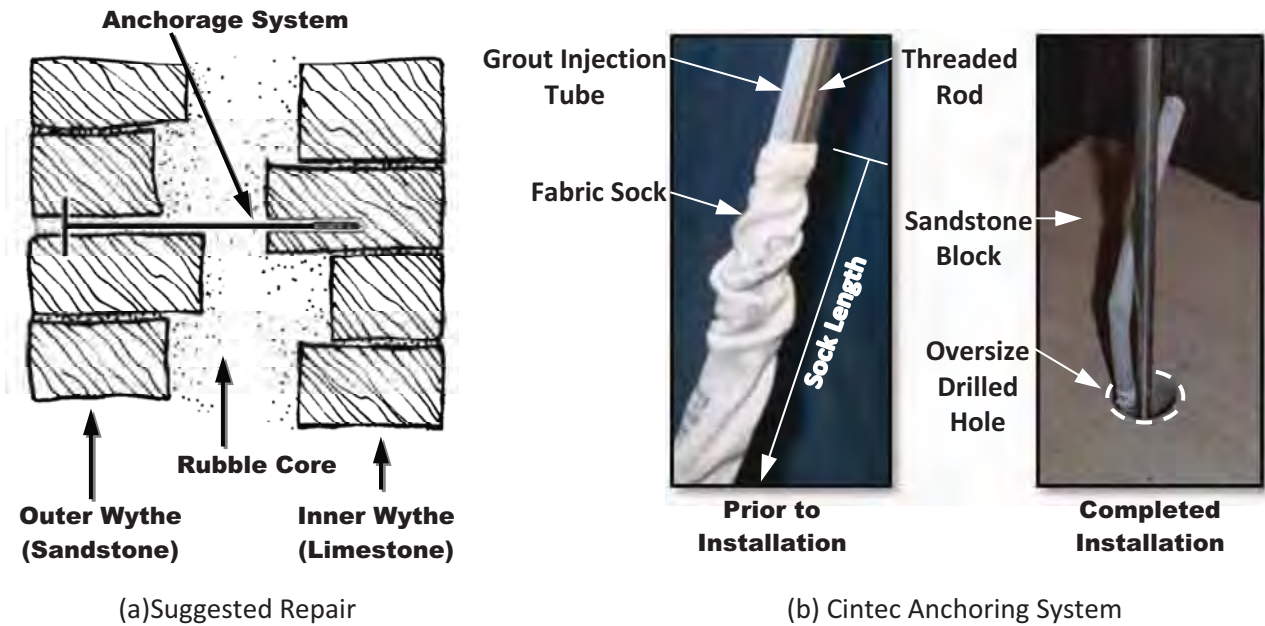


Figure 4 – Outer Wythe Reparation Scheme and Details

Based on these findings, a study was developed by PWGSC where sandstone blocks similar to the ones in the West Block building were instrumented with an anchorage system used by Cintec Canada Ltd. As illustrated in Figure 4(b), the patented Cintec anchoring system chosen for this project consists of injecting a cementitious fluid around a stainless steel threaded rod that is surrounded by a fabric sock and has been placed in an oversized hole previously drilled in the medium that requires rehabilitation.

4. Objectives of the Study

The main objective of the study outlined by PWGSC was to evaluate the performance of Cintec anchors in a material similar to the one found in the outer wythe of the West Block building, while accounting for the influence of weather conditions in the Canadian climate. The objective translates into two major benchmarks for the program:

- [1] CONDITIONG – subject the samples to weathering criteria listed in the relevant North American Standards with consideration for other international standards.

[2] TESTING – evaluating the pullout behaviour of anchors in both control and conditioned samples under static loads.

5. Experimental Program

5.1. Sample Specifications

Ohio sandstone masonry blocks similar to those found in the West Block building were provided by PWGSC as samples for the project. In order to obtain a comparative reference from the results of the study, all specimens tested in this program were 350mm wide by 350mm long by 300mm high. The anchorage system illustrated in Figure 4 was installed in the stonework by Cintec Canada Ltd. between May 2nd and 6th 2011 in the Plouffe Park shop, Ottawa. A 32mm (1 1/4in) diameter and 200mm (7 7/8in) deep hole was drilled in each of the stone blocks to allow insertion of the Cintec anchor assemblies. A total of sixteen Ohio sandstone blocks were instrumented with an anchorage system having a sock length of 75mm and another sixteen with a sock length of 150mm. Finally, an additional six were installed with a sock length of 200mm. Threaded stainless steel rods were used and a Presstec grout was injected in the fabric sock during installation.

One sample from each of the sock lengths investigated was retained by Cintec Canada Ltd. for future reference. The remaining samples were shipped to the University of Manitoba for thermal weathering and subsequent pullout testing. A list of all samples received by ISIS Canada from PWGSC on June 10th 2011 is elaborated in Table 1 along with relevant information pertaining to the parameters considered for the study. It was also requested from Cintec Canada Ltd. that two blocks of stone be left untouched without any drilling or anchorage installation. The samples are to be submitted to the same weathering tests as the blocks with anchors in order to evaluate weight loss from degradation.

5.2. Weathering Conditions

As indicated in Table 1, a total of two conditioning schemes were considered for the experimental program in this study. Thermal weathering was accomplished using CONVIRON environmental chambers capable of generating temperatures between -40°C and 40°C. The chambers are equipped with thermocouples that allow temperature fluctuations to be monitored during the cycles.

Table 1 - Sample Specifications

Specimens	Sock Length [mm]	Description / Weathering Conditions
C75-1	75	Control Samples (Ambient Laboratory Conditions) TEMPERATURE: ~20°C HUMIDITY: negligible effect
C75-2		
C75-3		
C75-4		
C75-5		
C150-1	150	
C150-2		
C150-3		
C150-4		
C150-5		
U75-1	75	Dry Freeze-Thaw Samples (ASTM E1512-01) -18°C ≤ TEMPERATURE ≤ 4°C HUMIDITY: negligible effect
U75-2		
U75-3		
U75-4		
U75-5		
U150-1	150	
U150-2		
U150-3		
U150-4		
U150-5		
R75-1	75	Wet Freeze-Thaw Samples (ASTM C666/C666M-03) -23°C ≤ TEMPERATURE ≤ 40°C HUMIDITY: 100%
R75-2		
R75-3		
R75-4		
R75-5		
R150-1	150	
R150-2		
R150-3		
R150-4		
R150-5		
R200-1	200	
R200-2		
R200-3		
R200-4		
R200-5		

The first scheme was performed in accordance with ASTM E1512 (2001) and consisted of subjecting five of the samples with 75mm sock length and five of the samples with 150mm sock length to a total of 150 thermal cycles ranging from -23°C to 40°C. The relative humidity was maintained to a negligible level

during conditioning. The extremes of temperature were maintained for 3 hours with a ramping of 1.75°C every 5 minutes. The temperature variation for these dry freeze-thaw cycles is illustrated in Figure 5 over the course of approximately 4 days.

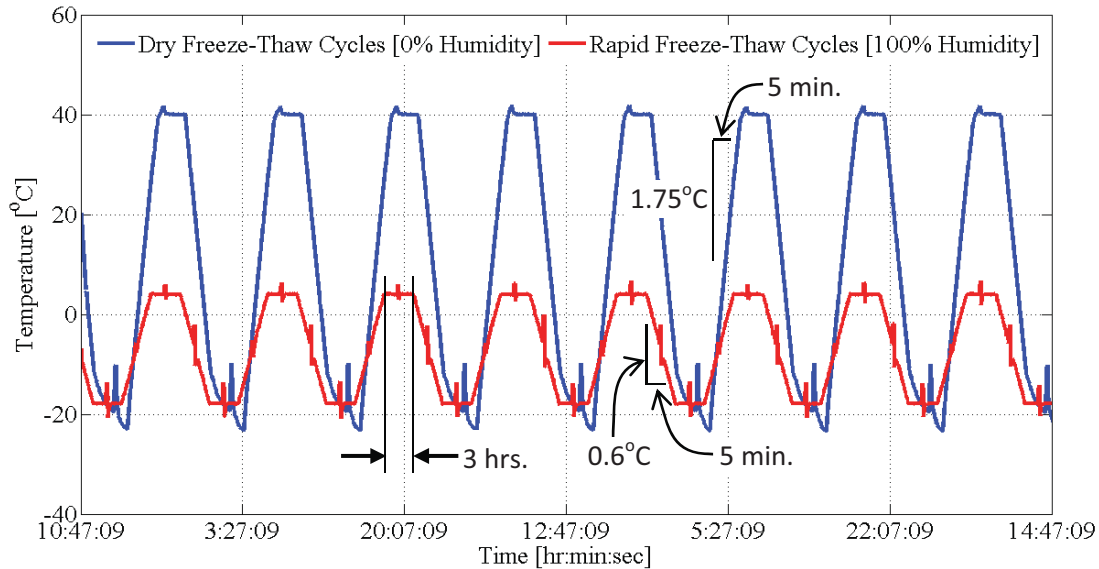


Figure 5 – Temperature Fluctuation during Conditioning: Chamber Records

The second conditioning scheme consisted of subjecting five of the samples for each of the 75mm, 150mm and 200mm sock lengths considered to a total of 150 thermal cycles ranging from -18°C to 4°C . The conditioning was performed in accordance with ASTM C666/C666M (2003), which required a relative humidity of 100% to be maintained during each cycle. As indicated in Figure 5, the extremes of temperature were also maintained during 3 hours with a ramping of 0.6°C every 5 minutes. The relative humidity for this conditioning scheme is shown in Figure 6 and indicates that it is difficult to maintain a level of 100% during each cycle. This slight discrepancy arises from the fact that temperature is generated by convection using large fans that circulate air from the back of the chamber. This flow of air creates a temporary state of drying during the ramping stages of the cycles when the temperature increases from -18°C to 4°C . There are also some fluctuations at -18°C that arise from the chamber defrosting stages. Nevertheless, the chamber was able to maintain an average relative humidity of 80% during most of the cycle durations.

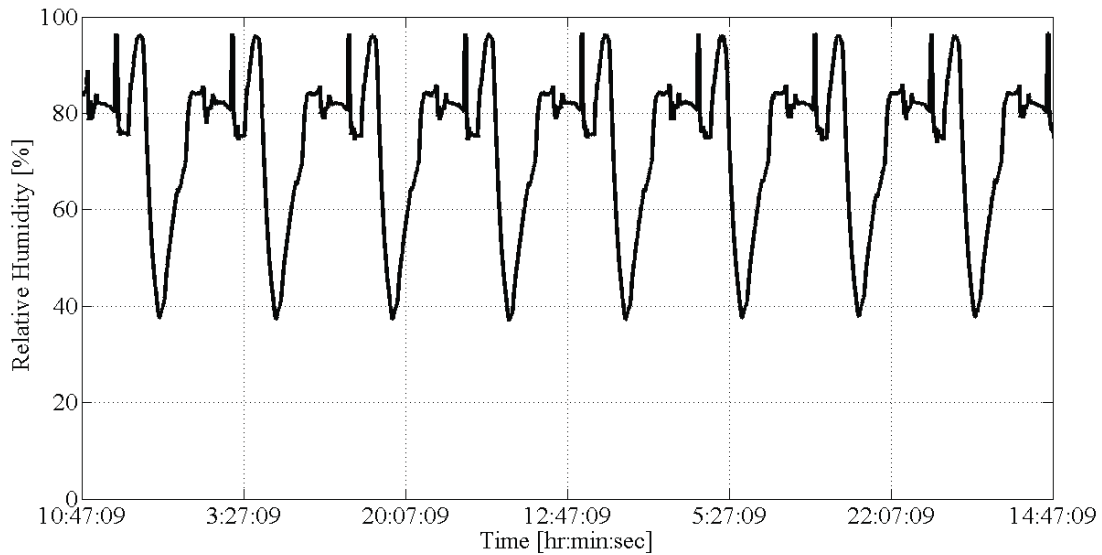


Figure 6 – Relative Humidity during Rapid Freeze-Thaw Cycles

5.1.1. Sample Preparation

It should be noted at this stage that the dry freeze-thaw cycles and the rapid freeze-thaw cycles were performed simultaneously using two chambers during a total of 2¹/₂ months (75 days). The sample layout is shown in Figure 7(a) for the dry freeze-thaw cycles and Figure 7(b) for the rapid freeze-thaw cycles. Several pertinent observations can be made from these figures. The first concerns the absence of the stainless steel rods extruding from the masonry blocks. The absence resulted from a request that rod tails be sectioned flush with the stonework and protected with insulation to prevent infiltration of cold temperature and moisture during conditioning.



(a) Dry Freeze-Thaw Cycle Chamber



(b) Rapid Freeze-Thaw Cycle Chamber

Figure 7 – Sample Layout in the Environmental Chambers

The sectioning procedure is outlined in Figure 8 and consists of four steps. The first step involves removal of the rod using a reciprocating saw equipped with a BI-Metal blade (Figure 8(a) to (d)). The rod was secured from excess vibration with a wooden jig that was fabricated from three 2in by 4in studs. A 2in outside diameter, 3/8in inside diameter washer, hand tightened with a nut, was also provided to offer additional stability during each of the sectioning procedures.



(a) Original Stone (75mm Sock Length)



(b) Sectioning Grouting Tube



(c) Rod Stabilization (2"OD -3/8"ID Washer & Nut)



(d) Sectioned Threaded Rod



(e) External PVC Confinement within Hole



(f) Insertion of Insulation around the Rod
(Silicon added to Seal the Hole)



(g) External PVC Confinement on the Stone Surface
(Silicon added to Seal the Hole)



(h) Insulating Foam against Moisture Ingress
(Expansive Insulating Foam Used)

Figure 8 – Sectioning Procedure

Once the rod was sectioned, a segment of 1in diameter PVC conduit was inserted in the stonework hole and filled with R-20 FIBERGLASS PINK® insulation (Figure 8(e) to (f)). The use of a washer and nut to stabilize the anchor during the sectioning process provided a threaded rod stub of approximately 9.5mm (3/8in) that extruded from the stone. As a result, an external 2in PVC confinement was placed on the surface of the stone and expansive insulating foam was inserted to protect the top of the rod from temperature and moisture ingress (Figure 8(g) to (h)).

The second observation that can be made from the layout shown in Figure 7 is the fact that all samples were placed sideways on wooden pallets to provide a 3° inclination with respect to the chamber floor. This inclination was provided in accordance with the fact that samples were shipped with anchors installed at a right angle from the surface of the stone. Original drawings provided by PWGSC suggest that anchors should have been installed at 3° with respect to the horizontal to prevent moisture ingress when using the repair technique in the field. A diagram of the shop drawings provided in the Request for Proposal document submitted by PWGSC can be found in Figure 9.

The third and final observation from the chamber layout relates to the height of the samples with respect to the supporting pallets. A 2in diameter segment of PVC conduit was placed under each corner of every sample to provide a 3in clearance at the base. The procedure was adopted to prevent water accumulation at the base of the samples during conditioning that would otherwise not occur under service conditions.

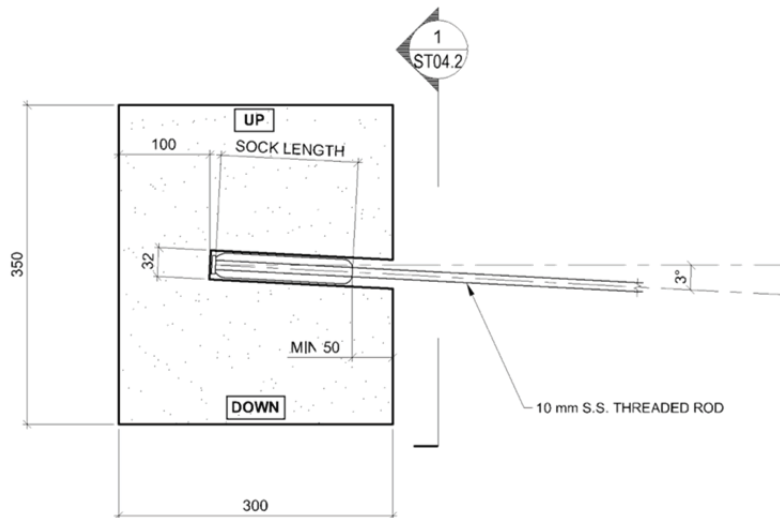


Figure 9 – Requirement for Sample Inclination: Shop Drawings (PWGSC)

5.1.2. Sample Weight Monitoring

As mentioned earlier, two masonry blocks were left untouched and submitted to the same weathering tests as the blocks with anchors in order to evaluate weight loss from conditioning. Consequently, these samples were weighed prior to and after cycling. For the samples subjected to rapid freeze-thaw cycling, an additional weight measurement was taken immediately after the misting procedure (~72 hrs) as well as immediately after conditioning to measure water absorption. The misting procedure produced a weight gain of approximately 1kg and the wet conditioning environment brought a weight gain of approximately 3kg to the masonry block. The final weight measurements for all samples were taken approximately 2 months after completion of conditioning in order to allow adequate drying. The weight loss after weathering was negligible (400g for dry freeze-thaw cycles, 200g for rapid freeze-thaw cycles).

Table 2 – Sample Weight Progression

Test Stage	Dry Freeze-Thaw Sample [kg]	Rapid Freeze-Thaw Sample [kg]	
		DRY	WET
Prior to Weathering	83	81.4	82.4 ⁽¹⁾
After Weathering	82.6 ⁽³⁾	81.2 ⁽³⁾	85.4 ⁽²⁾

⁽¹⁾ After 72 hrs of misting ⁽²⁾ Immediately after weathering ⁽³⁾ 2 months after completion of weathering

5.3. Static Pullout Test Setup and Details

After conditioning, the samples were extracted from the chambers and the anchors were subjected to pullout load as described in ASTM E1512 (2001) using a 1000kN capacity MTS machine. The stones were

firmly attached to the strong floor with four threaded bars, two steel angles as well as two steel straps. A picture outlining the details of the test setup can be found in Figure 10. The figure also shows that a 45mm (~1.75in) long coupler was used to extend the threaded rod stub extruding from the stonework to the anchorage plates for loading. The stub was extended using the same portion of the threaded rod that was removed during sectioning. The figure also shows that the jig supporting the LVDT sensors was secured below the coupler to minimize external sources of displacement. Finally, a rocker bearing was inserted for load application in order to accommodate the possibility of eccentric loading.

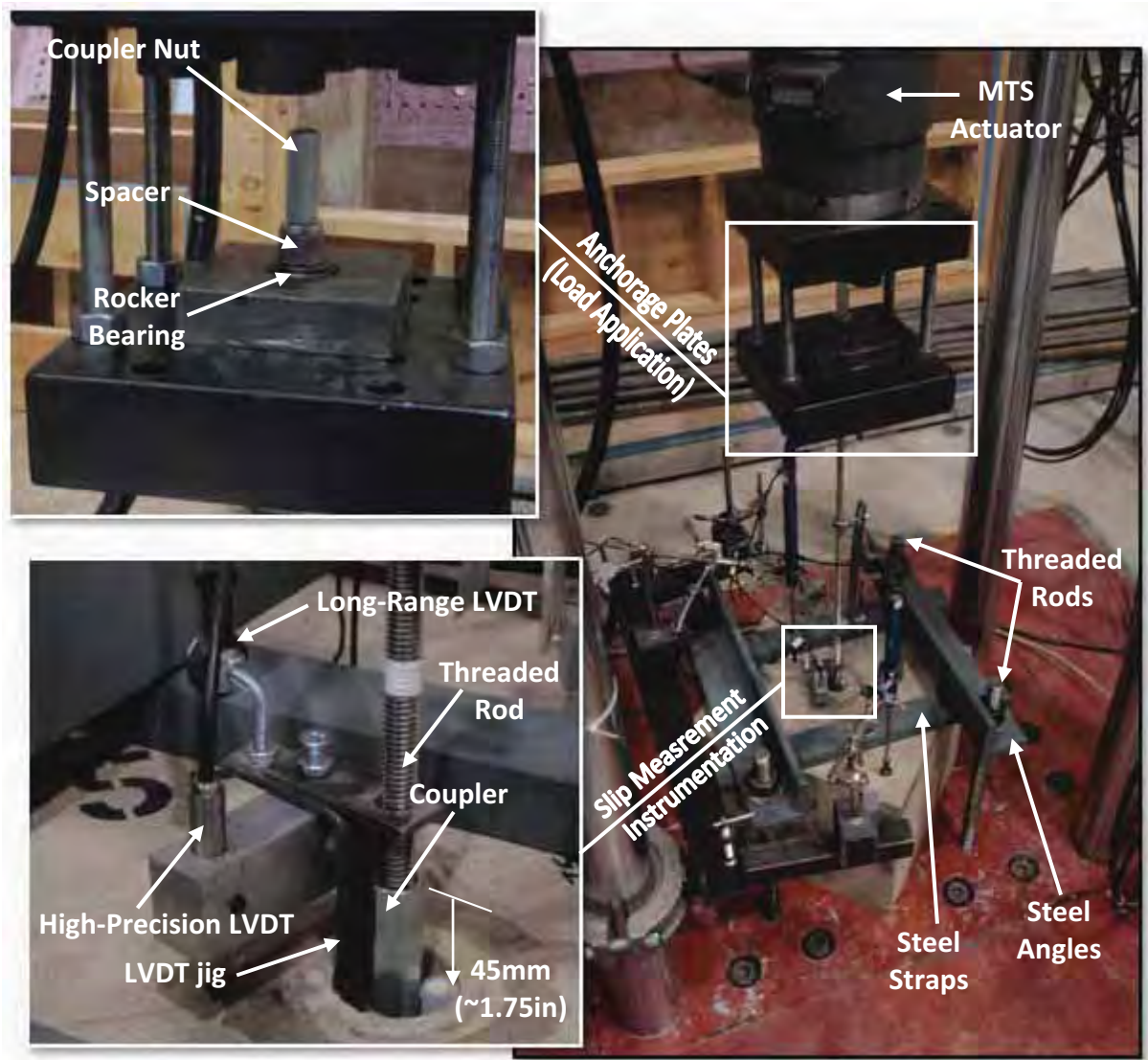


Figure 10 – Pullout Test Setup: 1000kN MTS Machine

The anchor elongation during each static pullout test was measured using two Linear Variable Displacement Transducers (LVDTs). The first LVDT was chosen to have a limited stroke of 3mm but

higher precision to monitor the relatively smaller elongation values expected at the beginning of each test. The second LVDT was chosen to have larger stroke (125mm) but sufficient precision to register elongation values beyond the stroke of the first LVDT once larger loads are reached during the tests. An additional set of two LVDTs were also used to account for movement of the stone with respect to the strong floor. Once again, the first LVDT was chosen to have smaller stroke but higher precision for the early stages of the test and the second was chosen to have larger stroke to capture movement at the end of each test. The values obtained from all these sensors were then combined to evaluate net elongation during each test.

6. Test Results and Discussion

Results from all tests performed in this project are shown in Table 3 in terms of the ultimate load and type of failure. The failure loads are consistent among all specimens and weathering conditions considered. The table also shows that two main failure types were observed. These include steel failure in the threaded rod within the grouted portion of the anchor followed by slippage but also failure of the steel in the rod between the stonework and the anchorage plates. The ultimate loads recorded during the tests are shown in Figure 11 with respect to sock length as well as in terms of weathering conditions.

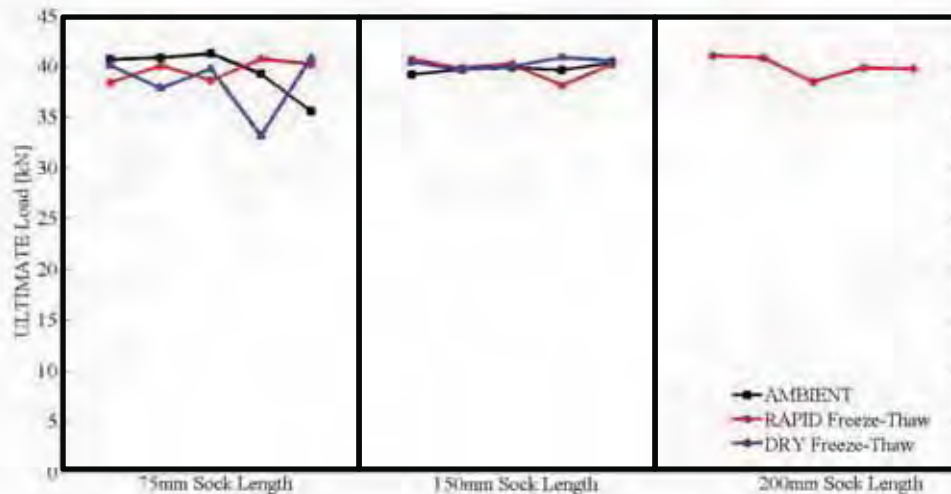


Figure 11 – Anchorage System Capacity in Ohio Sandstone (All Samples)

Results in this figure do not show sufficient evidence to conclude that rapid freeze-thaw or dry freeze-thaw conditions have any influence on the capacity of Cintec anchors embedded in Ohio sandstone masonry blocks using either 75mm or 150mm sock lengths. Figure 11 also shows that providing a

150mm sock length does not visibly improve the capacity of the repair technique from what can be achieved with a 75mm sock length. The result is also true when considering samples repaired with a 200mm sock length but more specimens need to be tested with this configuration. It should also be noted from the results of this figure that the capacity of anchors with 75mm sock length display more variability ($\pm 2.23\text{kN}$ standard deviation) than for anchors with 150mm sock length ($\pm 0.69\text{kN}$ standard deviation).

Table 3 – Pullout Test Results

Specimens	Sock Length [mm]	Ultimate Load [kN]	Failure Type	Description / Weathering Conditions
C75-1	75	40.7	Steel Failure (@Washer)	Control Samples (Ambient Laboratory Conditions) TEMPERATURE: $\sim 20^{\circ}\text{C}$ HUMIDITY: negligible effect
C75-2		40.9	Steel Failure	
C75-3		41.3	Steel Failure	
C75-4		39.3	Steel Failure (@Washer)	
C75-5		35.6	Steel Failure (@Washer)	
C150-1	150	39.2	Steel Failure (@Washer)	
C150-2		39.7	Steel Failure (@Washer)	
C150-3		39.9	Steel Failure (@Washer)	
C150-4		39.7	Steel Failure (@Washer)	
C150-5		40.4	Steel Failure (@Washer)	
U75-1	75	40.1	Steel Failure	Dry Freeze-Thaw Samples (ASTM E1512-01) $-18^{\circ}\text{C} \leq \text{TEMPERATURE} \leq 4^{\circ}\text{C}$ HUMIDITY: negligible effect
U75-2		37.9	Steel Failure (@Washer)	
U75-3		39.8	Steel Failure (@Washer)	
U75-4		33.2	Steel Failure (@Washer)	
U75-5		40.8	Steel Failure	

Table 4 – Pullout Test Results (*continued...*)

U150-1	150	40.4	Steel Failure (@Washer)	Dry Freeze-Thaw Samples (ASTM E1512-01) -18oC ≤ TEMPERATURE ≤ 4oC HUMIDITY: negligible effect
U150-2		39.7	Steel Failure	
U150-3		40.0	Steel Failure (@Washer)	
U150-4		40.9	Steel Failure	
U150-5		40.5	Steel Failure (@Washer)	
R75-1	75	38.4	Steel Failure (@Washer)	Wet Freeze-Thaw Samples (ASTM C666/C666M-03) -23°C ≤ TEMPERATURE ≤ 40°C HUMIDITY: 100%
R75-2		40.1	Steel Failure (@Washer)	
R75-3		38.6	Steel Failure (@Washer)	
R75-4		40.8	Steel Failure	
R75-5		40.2	Steel Failure (@Washer)	
R150-1	150	40.8	Steel Failure (@Washer)	
R150-2		39.8	Steel Failure (@Washer)	
R150-3		40.3	Steel Failure (@Washer)	
R150-4		38.1	Steel Failure	
R150-5		40.2	Steel Failure (@Washer)	
R200-1	200	41.1	Steel Failure (@Washer)	
R200-2		40.9	Steel Failure	
R200-3		38.5	Steel Failure	
R200-4		39.8	Steel Failure (@Washer)	
R200-5		39.8	Steel Failure (@Washer)	

It was also made apparent from the analysis of test results that considerable elongation of the threaded rod took place for both types of failure. The elongation was captured by the longer range LVDT and was

attributed to yielding of the threaded rod prior to failure. The extent of elongation is illustrated more clearly in Figure 12 and appears to be sustained under loads gradually increasing towards failure.

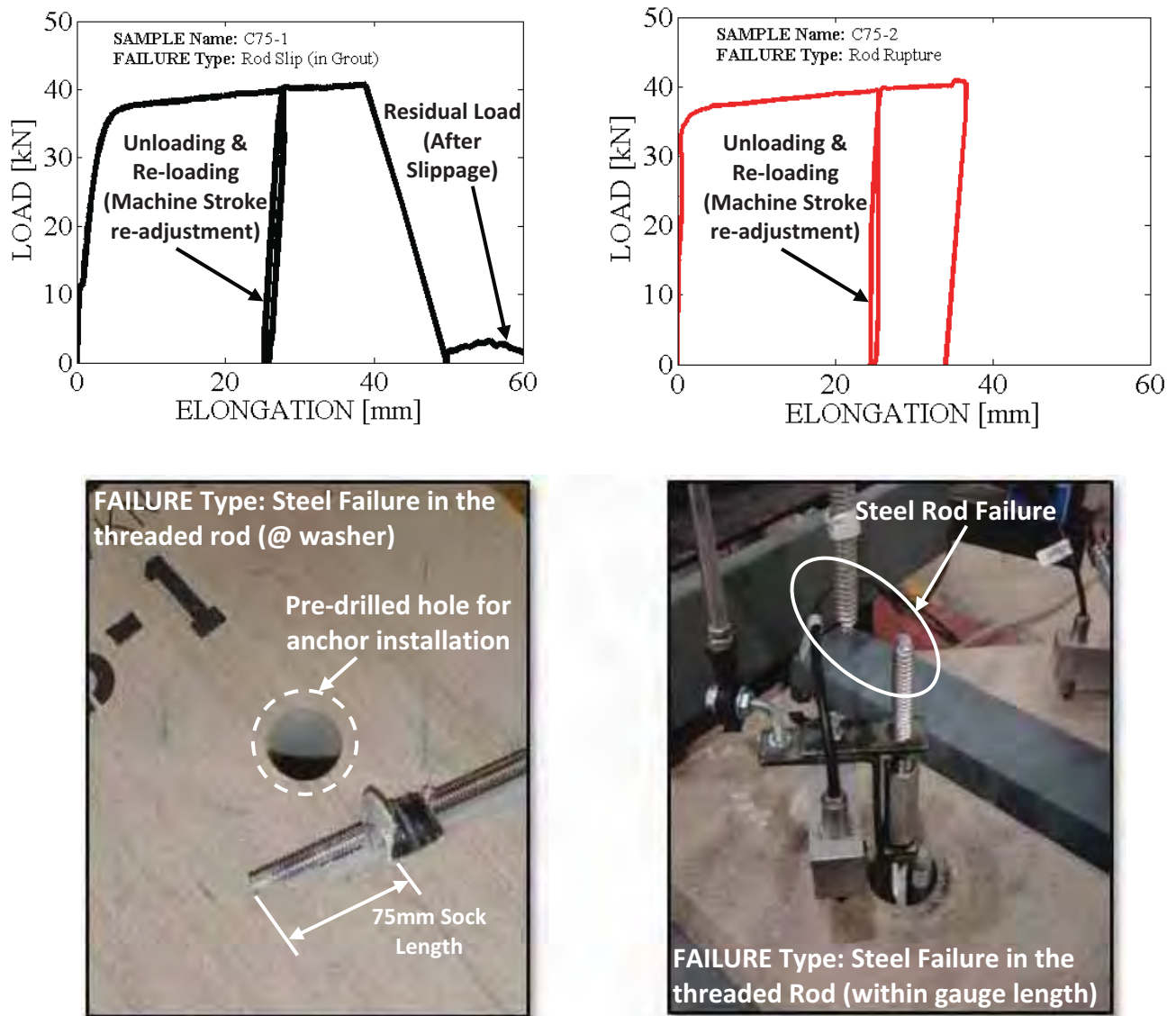


Figure 12 – Load-Elongation Behaviour (Control Samples – 75mm Sock Length)

This ductile behaviour provided by the Cintec repair technique is strongly advantageous because it provides ample warning of impending failure while sustaining a surcharge comparable to the capacity of the anchor. Figure 12 also shows that there is a slight recovery of load once the threaded rod has initiated slip within the grouted portion of the anchor. This residual load gradually reduces until the rod is completely removed from the assembly. Finally, the figure displays an unloading/re-loading stage that was required in most of the tests to re-adjust the stroke of the machine once the limit was reached. The load-elongation behaviour for all samples tested in this study can be found in Appendix A of this report.

Another key observation made after testing relates to the quality of the grouted portion of the anchor, particularly at the interface with the stonework within the hole that was drilled for installation. Failure is initiated by yielding of the rod, after which considerable elongation causes damage to the grout surrounding the rod during testing. Figure 13 suggests that this damage is contained in the vicinity of the rod as well as at the top of the grouted hole. It does not extend towards the interface to affect the bond between the fabric sock and the stonework. The result underlines another advantage of the Cintec anchorage system for rehabilitating structures similar to the West Block building on Parliament Hill.

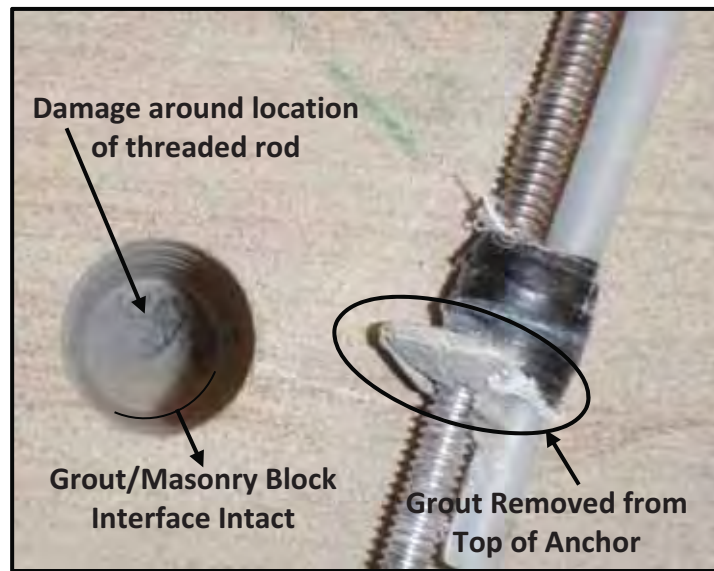


Figure 13 – Grouted Hole after Threaded Rod Pullout (Control Sample C75-1)

7. Estimation of Pullout Loads and Failure Modes

As observed in Table 3 and mentioned in the previous section, there are two main failure modes observed for the Cintec anchors embedded in the Ohio Sandstone blocks provided by PWGSC. These include steel failure in the rod between the stonework and the machine fixtures. In order to evaluate the first of these failure modes, we refer to test data provided in the BRE Technical Consultancy Report (November 1990) for Cintec anchors. The data was obtained from tests conducted on masonry samples that were instrumented with 8mm diameter steel rods grouted in 40mm diameter holes that were 60mm in length. The sample geometry is shown in Figure 14 and, using force equilibrium, can be used to derive an expression (EQ.1) for the average bond strength between the steel rod and grout.

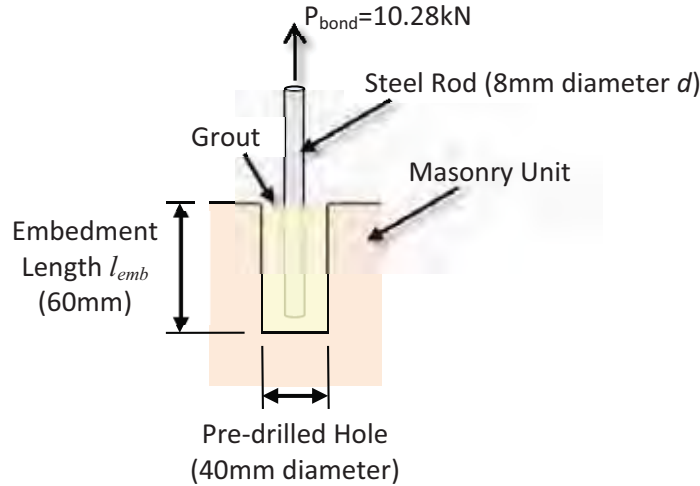


Figure 14 – Grouted Cintec Anchor Assembly (BRE Technical Consultancy Report, 1990)

$$\tau_{bond} = \frac{P_{avg}}{\pi l_{emb} d} \quad \text{EQ.1}$$

In this equation, τ_{bond} is the average bond strength between the steel rod and grout, P_{avg} is the average recorded pullout load reported in the document (10.3kN), l_{emb} is the embedment length (60mm) and d is the diameter of the pre-drilled hole (40mm). Based on this equation and the sample geometry shown in Figure 14, the average bond strength of steel rods grouted using the Cintec method can be evaluated as 6.83MPa. This value can be used to evaluate the load P_{bond} required to pull the threaded rods from the Presstec grout used in this project. The average bond strength must be multiplied by the circumferential area surrounding the rod (EQ.2). This area is a function of the embedment length chosen for the study. As mentioned in previous sections, the lengths were chosen to vary from 75mm to 150mm and finally 200mm.

$$P_{bond} = \tau_{bond} \pi l_{emb} d \quad \text{EQ.2}$$

Substituting the values for average bond strength and nominal threaded rod diameter (9mm) gives a more convenient expression for establishing the ultimate load initiated by bond failure during the pullout tests in this study (EQ.3). The embedment length remains unknown and can be substituted depending on the sample under consideration.

$$P_{bond} = 0.193 l_{emb} \quad \text{EQ.3}$$

The second type of failure is governed by yielding, and eventually steel failure in the threaded rod. The ultimate load expected from this type of failure (EQ.4) can be evaluated by considering clause 13.12.1.2 of the CISC Handbook of Steel Construction (2008) for bolts or threaded rods in tension. It should be noted that the resistance factor was not considered because we are seeking an accurate representation of the steel failure load, without any allowance for conservatism.

$$P_{\text{steel failure}} = 0.75F_u A_b \quad \text{EQ.4}$$

In this expression, $P_{\text{steel failure}}$ is the load required to cause steel failure in the threaded rod during the test, F_u is the minimum nominal strength of a bolt or threaded rod in tension and A_b is the nominal area of the bolt or threaded rod. If a nominal tensile strength of 825MPa for the stainless steel threaded rods (type A325M) after strain hardening is assumed along with a nominal diameter of 9mm, the steel failure load can be evaluated as 39.4kN. This value along with those obtained from EQ.3 when varying the embedment length from 75mm to 150mm and 200mm are summarized in Table 1 to give information on the mode of failure that is expected from the pullout tests performed on the stone blocks provided by PWGSC.

Table 5 - Strength Estimation and Failure Modes

Embedment/Sock Length [mm]	P_{bond} [kN]	$P_{\text{steel failure}}$ [kN]	Failure Mode
75	14.5	39.4	Bond ($P_{\text{bond}} < P_{\text{rupture}}$)
150	29.0	39.4	Bond ($P_{\text{bond}} < P_{\text{rupture}}$)
200	38.6	39.4	Bond ($P_{\text{bond}} < P_{\text{rupture}}$)

It should be noted at this stage that the strength values for bond of the threaded rods in the Presstec grout (P_{bond}) in Table 5 follow a linear trend with embedment length. Although this behavior is anticipated when considering the fundamentals of bond transfer, the ultimate loads observed during the pullout tests conducted on the stone blocks provided by PWGSC did not confirm this result. The ultimate loads for samples exhibiting slippage in the grout were found to be much higher and consistent with those describing steel failure in the threaded rod ($P_{\text{steel failure}}$). The outcome can be attributed to the fact that a 25mm diameter, 6.5mm thick steel washer was tapped and screwed to the tip of the threaded rod at the bottom of the grouted hole. This assembly, illustrated in Figure 15, provides additional strength and prevents the rods from slipping out of the grout at the loads shown in Table 5. It is believed that failures exhibiting slippage between the threaded rod and grout are initiated by steel

failure in the rod at the bottom of the grouted hole, immediately above the washer. This additional strength will increase the ultimate loads listed in Table 5 for bond failure to that which is equivalent to steel failure and thereby confirms the consistency obtained for pullout loads listed in Table 3 despite having used varying embedment (sock) lengths for the anchors.

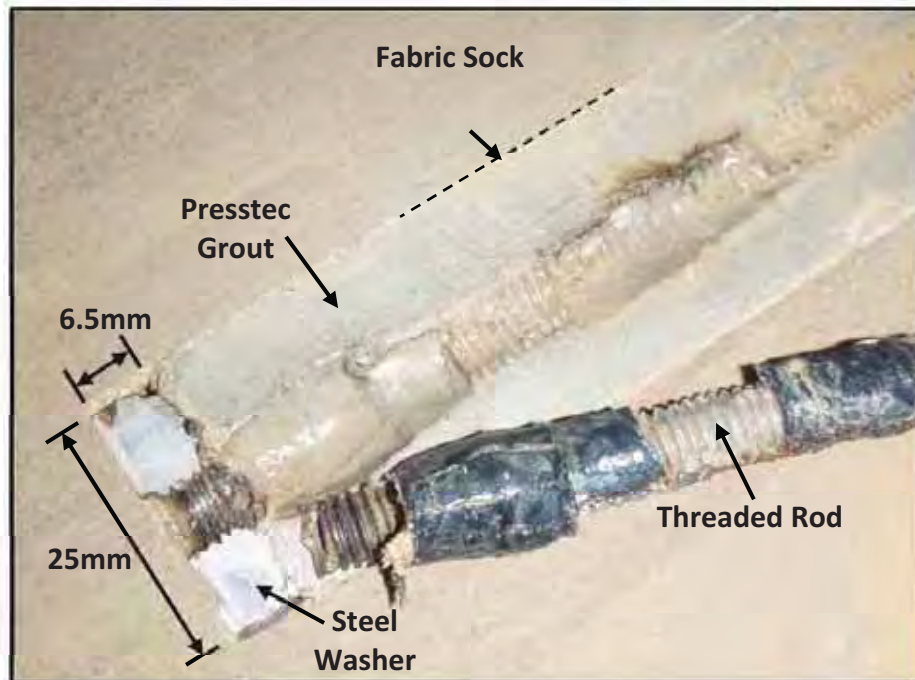


Figure 15 – Cintec Anchor Assembly with Bottom Threaded Washer

A complete illustrative documentation of the failure planes similar to the one shown in Figure 15 after testing is provided in Appendix B of this report. The illustrations do not show evidence of damage in the grouted portion of the anchor for any of the failure modes, which indicates that the Cintec rehabilitation technique is resilient despite the consideration of thermal weathering. It should be noted that the failure planes in these illustrations were exposed by sectioning the samples down the center of the grouted hole. Sectioning was performed by DiTECH International Inc. and took place at the University of Manitoba. Several pictures of the sectioning procedure are shown in Figure 16.



Figure 16 – Sectioning Procedure (DiTECH International Inc.)

8. Conclusions and Recommendations

Several conclusions and recommendations can be drawn from the findings reported in this document. They pertain to the results of pullout tests performed on Ohio sandstone masonry blocks instrumented with a Cintec anchor having various sock lengths and subjected to weathering conditions expected in the Canadian climate:

- (1) After close examination prior to and after conditioning, the masonry blocks did not reveal any form of deterioration from the application of adverse weathering environments and showed minimal weight loss due to conditioning.

- (2) The ultimate loads recorded during pullout testing are consistent among all samples in this study and do not reveal any form of evidence that would suggest a reduction in the capacity of the anchorage system in Ohio sandstone after 150 dry freeze-thaw or rapid freeze-thaw cycles.
- (3) Results indicate that the samples with 150mm sock length anchors do not provide additional capacity from that initially obtained for samples instrumented with a 75mm sock length anchor. The same outcome was observed for samples instrumented with 200mm sock lengths. The outcome is attributed to the fact that a steel washer is screwed to the threaded rod at the bottom of the grouted hole to prevent slippage.
- (4) The load-elongation behaviour of the anchorage assemblies used in this study contains a significant amount of elongation from the threaded rod prior to failure. This allows ample warning of impending failure while loads close to the capacity of the anchor are being sustained.
- (5) The amount of elongation monitored during the pullout tests is attributed to the fact that the repair technique has sufficient strength to cause yielding of the rod before any signs of slippage can be detected.
- (6) Although several of the threaded rods failed by steel failure between the surface of the stone and the gripping mechanism (anchorage plates) of the machine, the analysis provided in this report for evaluating pullout loads and failure modes suggests that steel failure also occurred at the base of the grouted hole. Once initiated, this steel failure mechanism was the cause for the excessive slippage recorded during the tests. Slippage continued at smaller loads until the rod was fully removed from the sample.
- (7) The sectioning procedure performed on the stones revealed that the damage for samples exhibiting slippage was only localized to the vicinity of the threaded rod. It was not found to radiate outward towards the interface separating the grout, the fabric sock and the stonework, which illustrates the quality of the anchorage system despite the consideration of thermal weathering.

- (8) It is recommended that future work be undertaken to expand the current project to investigate the performance of full scale multi-wythe walls under the same weathering conditions and rehabilitated with the same Cintec anchorage system.

9. References

- (1) American Society for Testing and Materials. (2007). ASTM Standard C666/C 666M-03: *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing*. Philadelphia, PA: American Society for Testing and Materials.
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- (5) Benedetti, D., & Pezzoli, P. (1996). *Shaking table tests on masonry buildings. Results and Comments*. Politecnico di Milano. Seriate: ISMES.
- (6) Binda, L., Modena, C., Baronio, G., & Abbaneo, S. (1997). *Repair and Investigation Techniques for Stone Masonry Walls*. *Construction and Building Materials*, 11 (3), 133-142.
- (7) Tomazevic, M. (1999). *Earthquake-Resistant Design of Masonry Buildings* (Vol. I). London: Imperial College Press.
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APPENDIX A

Load-Elongation Behaviour Figures

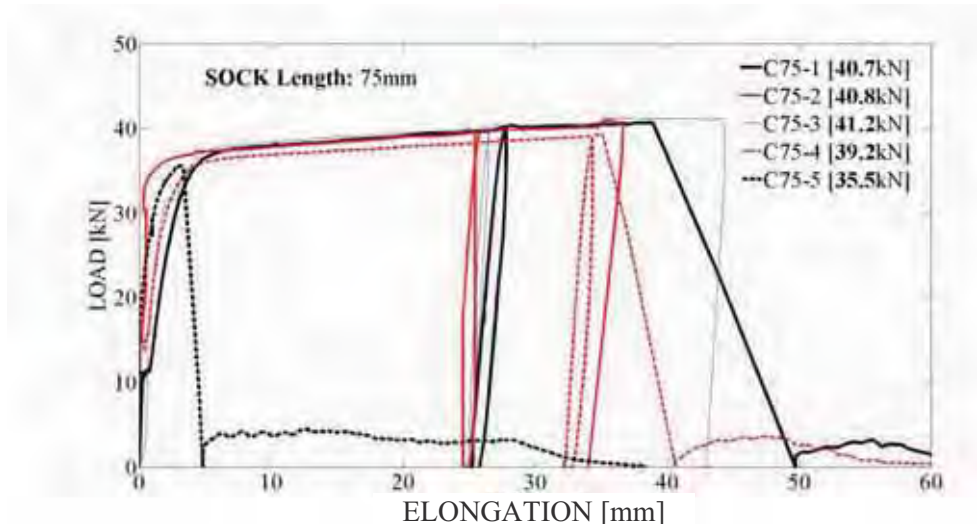


Figure A.1 - Load-Elongation Behaviour (Control Samples - 75mm Sock Length)

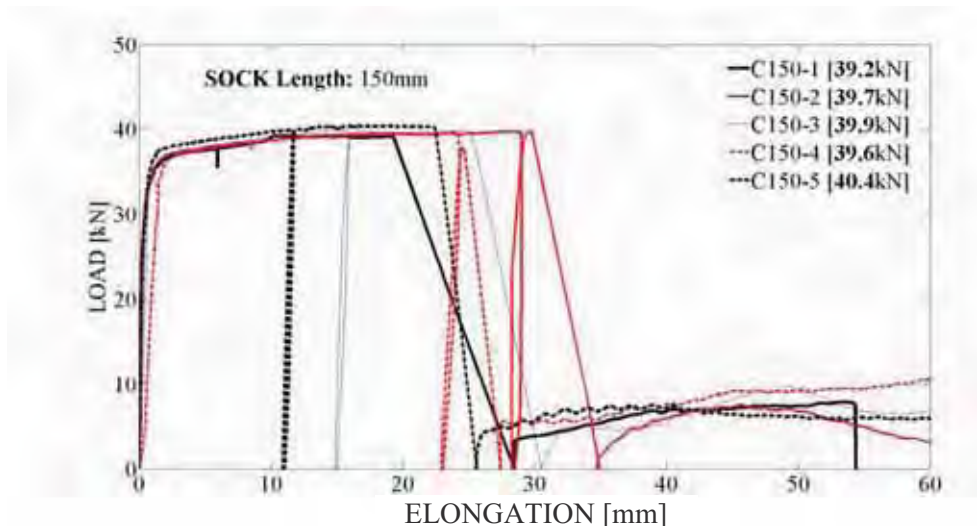


Figure A.2 - Load-Elongation Behaviour (Control Samples - 150mm Sock Length)

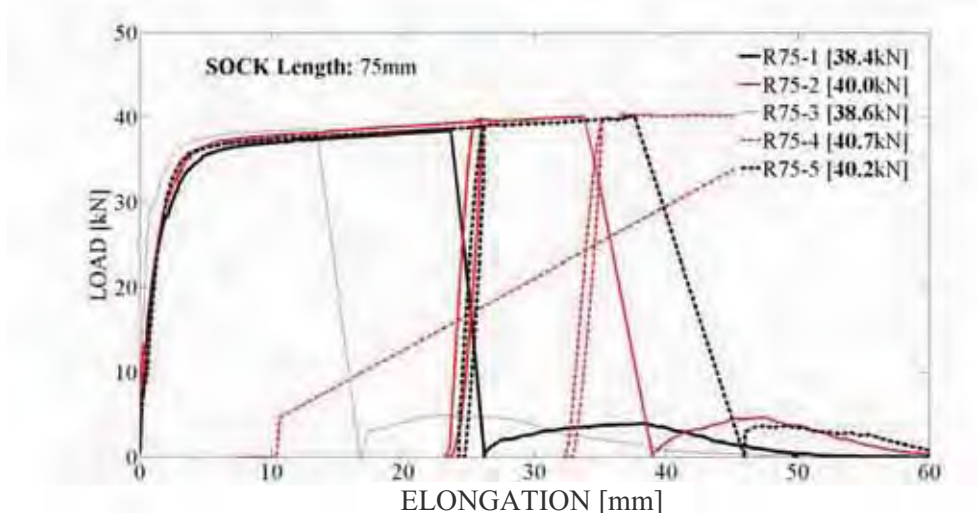


Figure A.3 - Load-Elongation Behaviour (Rapid Freeze-Thaw Samples - 75mm Sock Length)

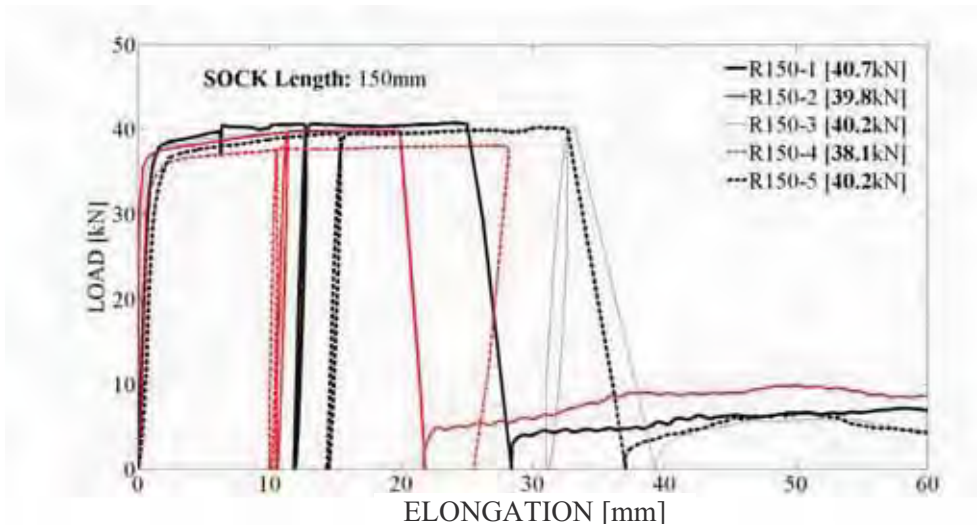


Figure A.4 - Load-Elongation Behaviour (Rapid Freeze-Thaw Samples - 150mm Sock Length)

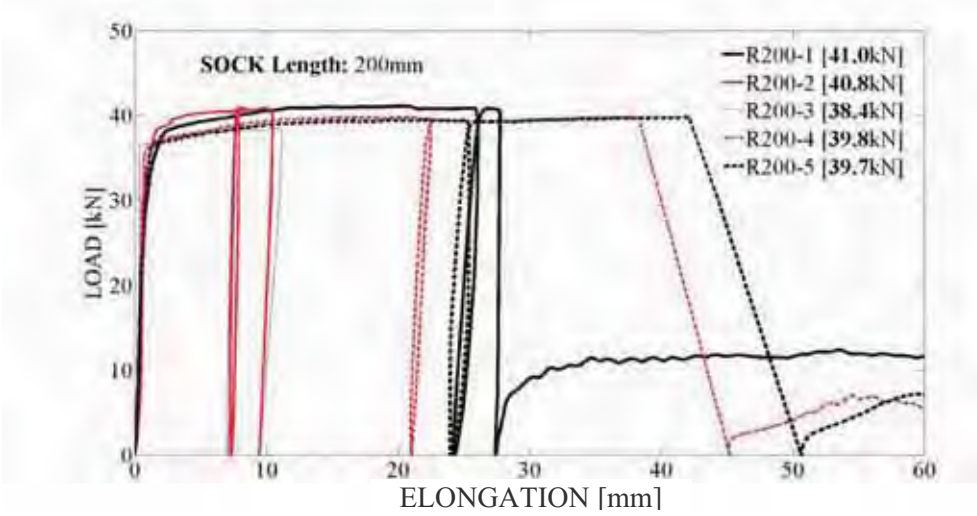


Figure A.5 - Load-Elongation Behaviour (Rapid Freeze-Thaw Samples - 200mm Sock Length)

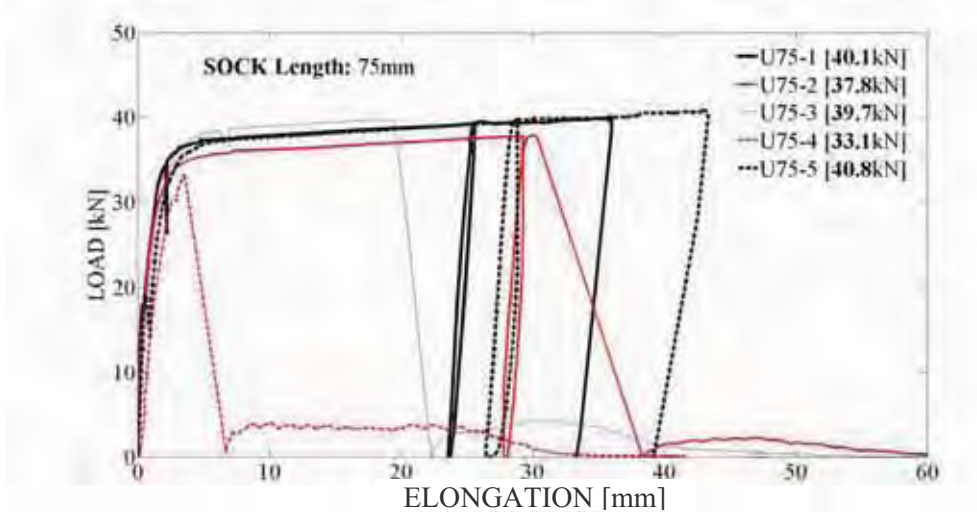


Figure A.6 - Load-Elongation Behaviour (Dry Freeze-Thaw Samples - 75mm Sock Length)

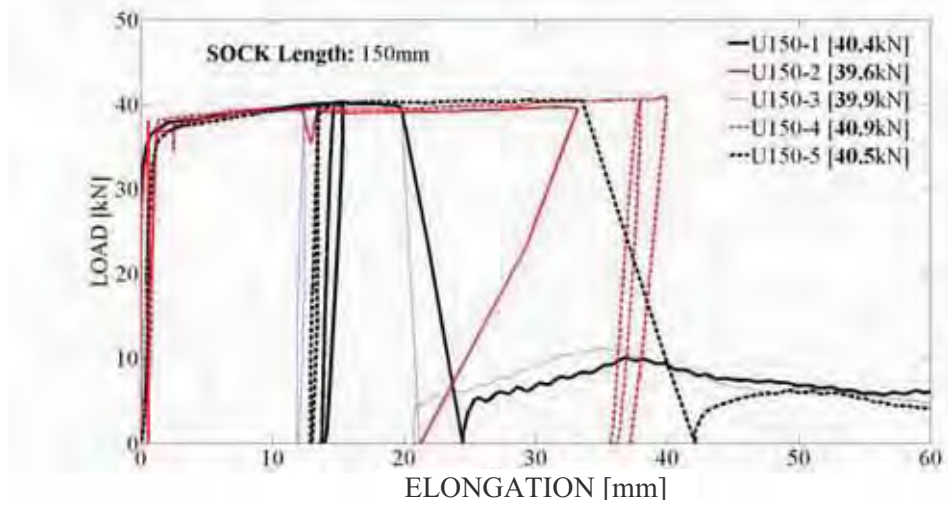


Figure A.7 - Load-Elongation Behaviour (Dry Freeze-Thaw Samples - 150mm Sock Length)

APPENDIX B

Stone Sectioning Pictures



(a)C75-1



(b)C75-2



(c)C75-3



(d)C75-4

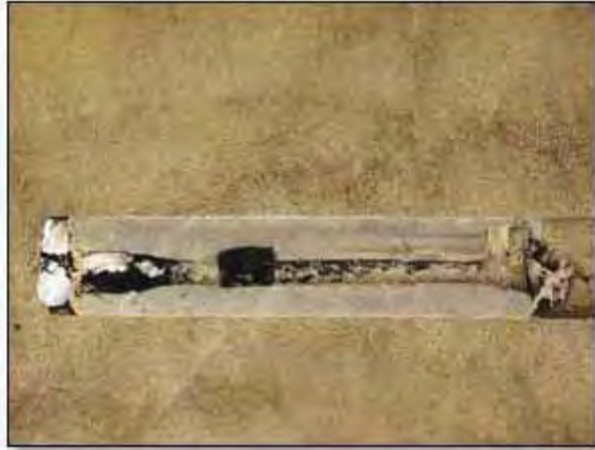


(e)C75-5

Figure B.1 – Control Samples (75mm Sock Length)



(a)C150-1



(b) C150-2



(c) C150-3

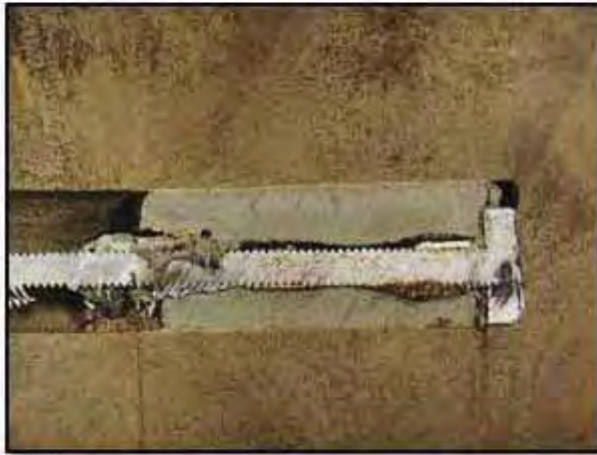


(d) C150-4



(e) C150-5

Figure B.2 – Control Samples (150mm Sock Length)



(a)U75-1



(b)U75-2



(c)U75-3



(d)U75-4

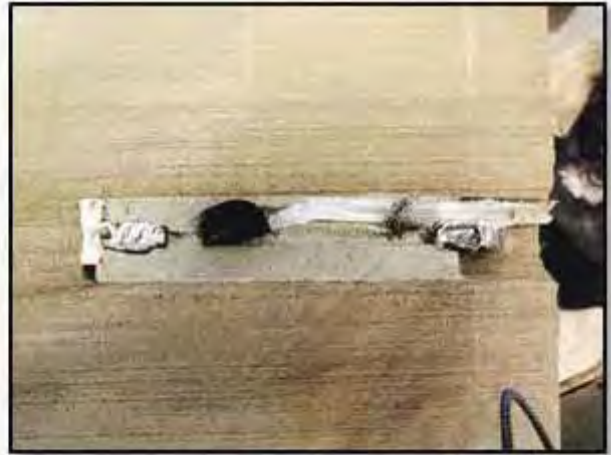


(e)U75-5

Figure B.3 – Dry Freeze-Thaw Samples (75mm Sock Length)



(a)U150-1



(b)U150-2



(c)U150-3



(d)U150-4



(e)U150-5

Figure B.4 – Dry Freeze-Thaw Samples (150mm Sock Length)



(a)R75-1



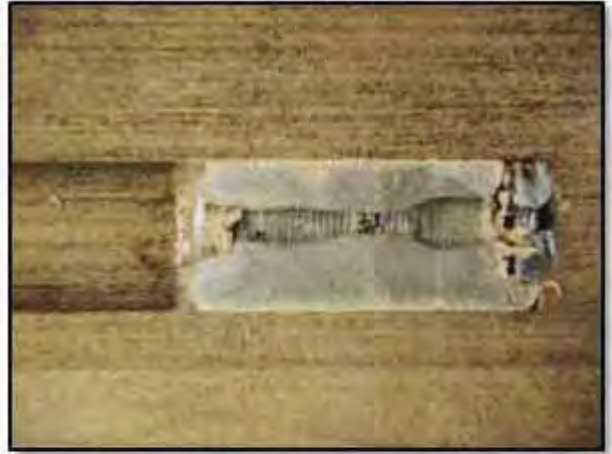
(b)R75-2



(c)R75-3



(d)R75-4



(e)R75-5

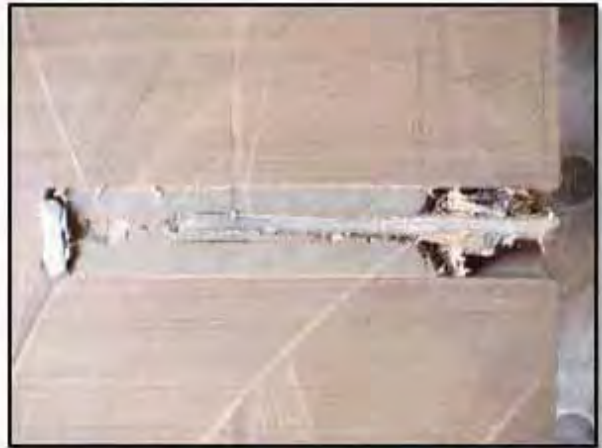
Figure B.5 – Wet Freeze-Thaw Samples (75mm Sock Length)



(a)R150-1



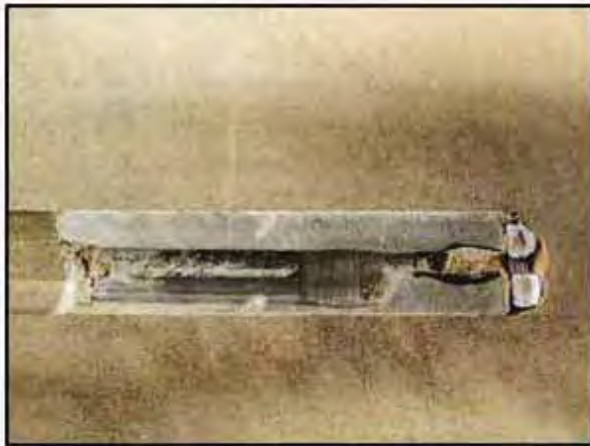
(b)R150-2



(c)R150-3



(d)R150-4



(e)R150-5

Figure B.6 – Wet Freeze-Thaw Samples (150mm Sock Length)



(a) R200-1



(b) R200-2



(c) R200-3



(e) R200-5



(d) R200-4

Figure B.7 – Wet Freeze-Thaw Samples (200mm Sock Length)

**CINTEC REMEDIAL
WALL TIE TEST (1)**



CINTEC REMEDIAL WALL TIE TEST (1)

PROJECT NO. A / 156

by

GORAN SIMUNDIC, BE, ME, MIEAust., CP Eng
Laboratory Manager

Department of Civil, Surveying and Environmental Engineering
The University of Newcastle, NSW, 2308, Australia

CLIENT: CLS Cintec Australasia Pty Ltd
P.O. Box 141
Newcastle NSW 2300

September, 1999

CERTIFICATE OF TEST

WALL TIE TEST TO DRAFT AUSTRALIAN / NEW ZEALAND STANDARD DR 97300-97302 (revision of AS 2699-1984) - APPENDIX A and AMENDMENT No. 1 to AS 3700 - 1998

Manufacturer: CLS Cintec Australasia Pty Ltd
P.O. Box 141
Newcastle NSW 2300

Job Number: A/156 - 1999

Description: Type A cavity remedial wall ties, described by the manufacturer as a "Cintec Remedial Cavity Wall Ties". The wall ties are 215 mm long, 8 mm diameter and are made of stainless steel grade 3.16. The ties are installed by drilling through the joint of the brick couplet (full brick plus two half bricks) and inserted into the full brick (in joint - brick connection) with a cavity of 50 mm, as shown in Figure 1. The drill hole size was 18 mm.

Test Description: The wall ties were evaluated using the performance requirements of Draft Australian / New Zealand Standard DR 97300-97302 (revision of AS 2699-1984) - Appendix A: Method for determination of characteristic strength and characteristic stiffness of type A ties and the Amendment No. 1 to AS3700 - 1998.

Test Date: September, 1999.

Classification: The ties are classified as **type A, Heavy Duty cavity ties** for a cavity width of 50 mm and in joint - brick connection.



Goran Simundic
Laboratory Manager
Department of Civil, Surveying and Environmental Engineering
TUNRA (The University of Newcastle Research Association)

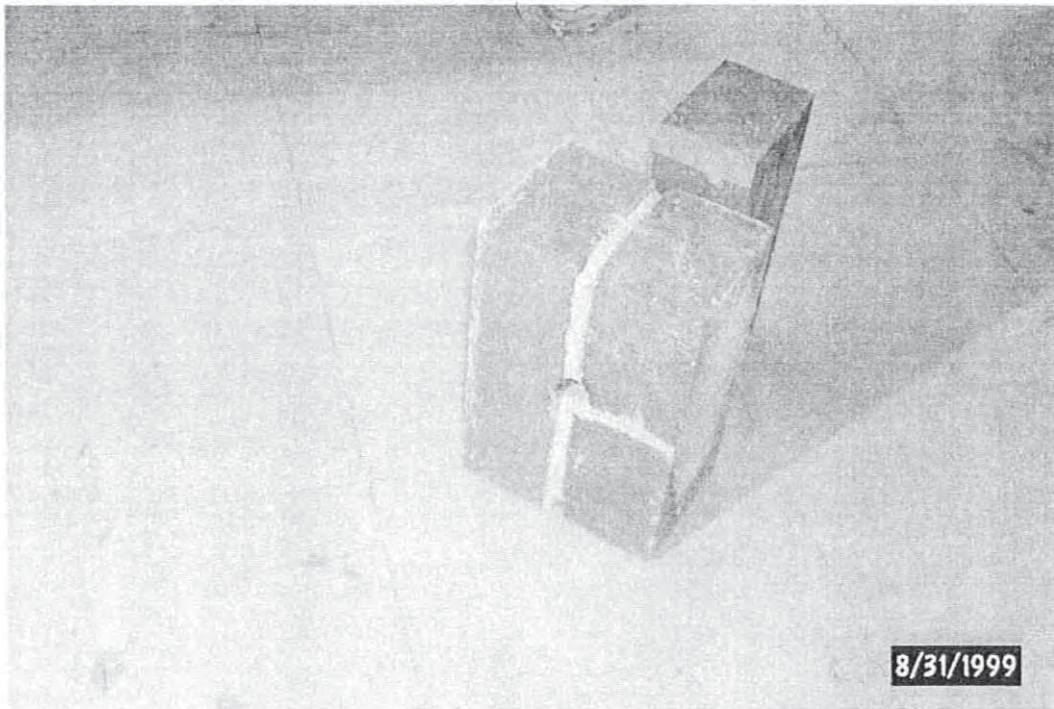
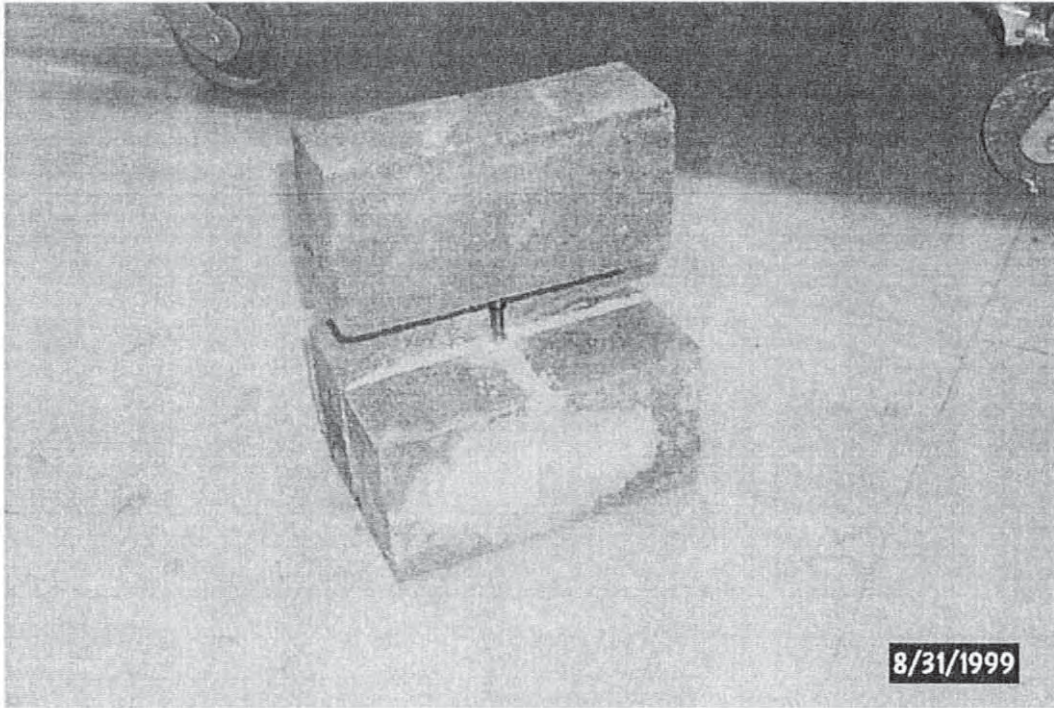


FIGURE 1. Test Specimen

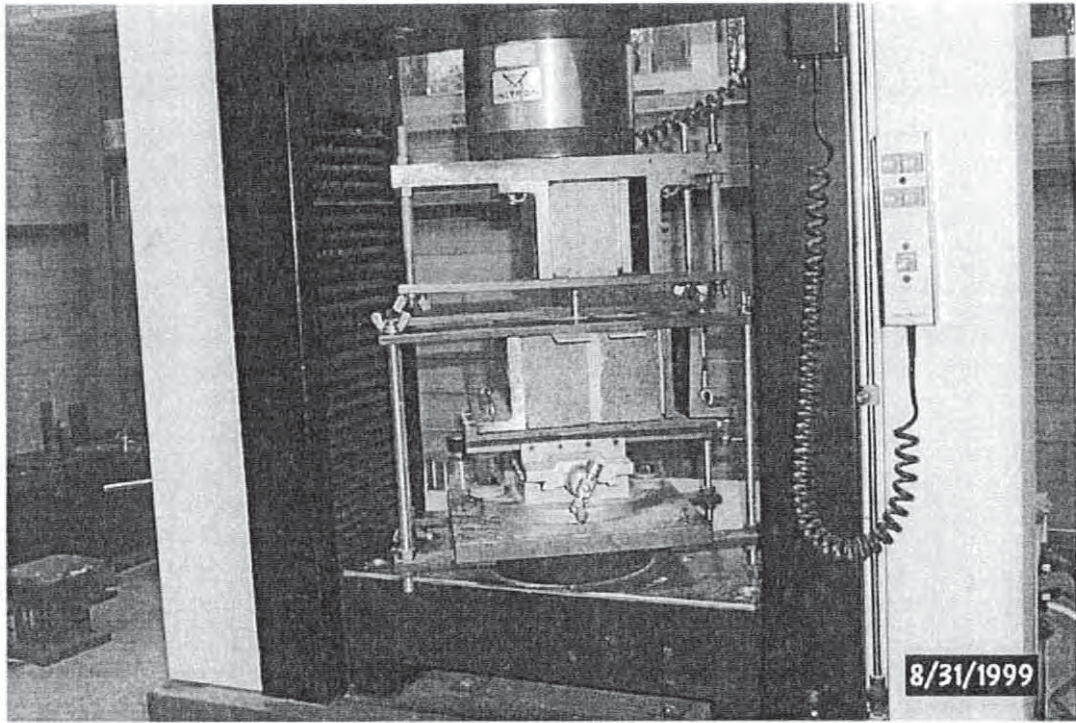


FIGURE 2. Testing Arrangement

**Type A Cavity Tie (215 mm long, d=8 mm, 50 mm cavity)
Cintec Remedial Wall Tie (in joint - brick)**

Specimen Number	Force required to induce 1.5 mm deflection or failure (N)	
	Tension	Compression
1	3172	3115
2	2991	2564
3	2915	3353
4	2754	3566
5	2712	5011
6	2243	3203

Mean:	2798	3469
Standard Deviation:	319	827
Characteristic Value:	1436	1641

Note:

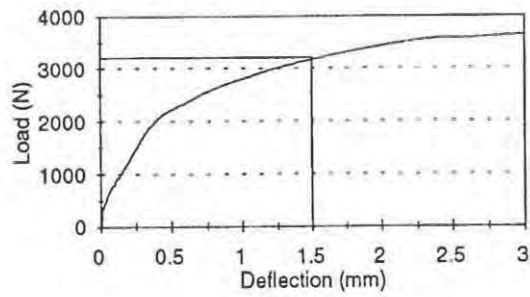
- The specimens were made in accordance with the draft Australian/New Zealand Standard DR 97300 - 97302 (revision of AS 2699 - 1984) - Appendix A.
- The mortar at the time of testing was more than 28 days old.
- The grout at the time of testing was 20 days old.
- The ties were installed by drilling through the joint of the brick couplet (full brick plus two half bricks) and inserted into the full brick (in joint - brick connection).
- The cavity between the brick couplet and the brick was 50 mm.
- The drill hole size was 18 mm.

APPENDIX A

Load - Deflection Graphs

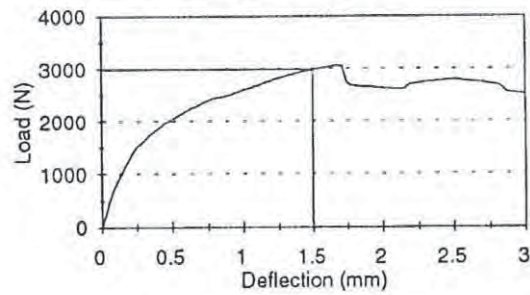
Specimen No. 1

Tension (joint - brick)



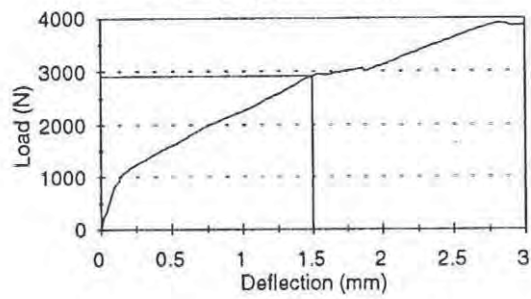
Specimen No. 2

Tension (joint - brick)



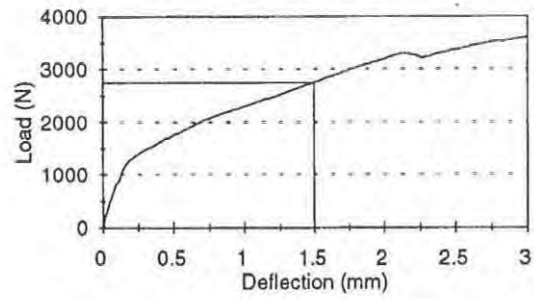
Specimen No. 3

Tension (joint - brick)



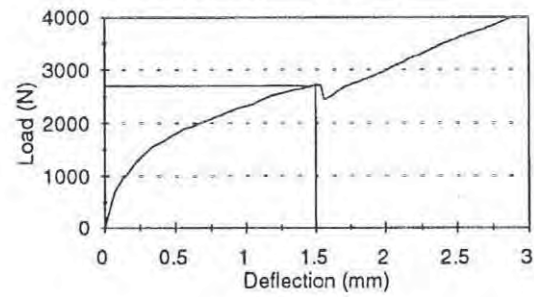
Specimen No. 4

Tension (joint - brick)



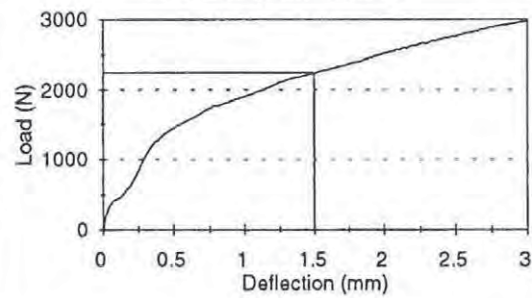
Specimen No. 5

Tension (joint - brick)



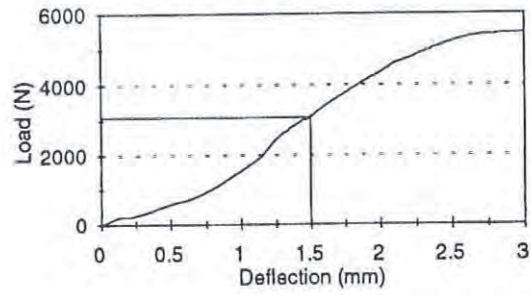
Specimen No. 6

Tension (joint - brick)



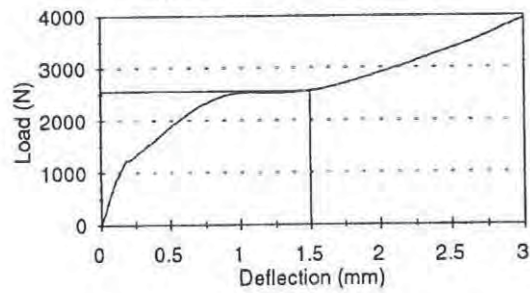
Specimen No. 1

Compression (joint - brick)



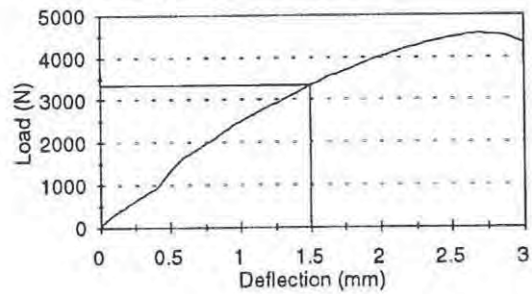
Specimen No. 2

Compression (joint - brick)



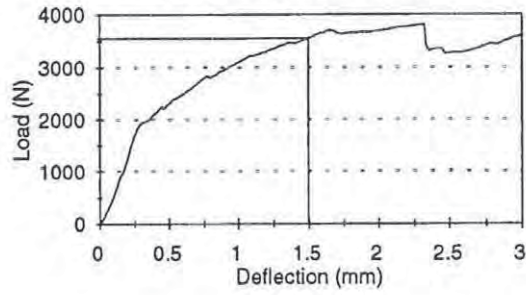
Specimen No. 3

Compression (joint - brick)



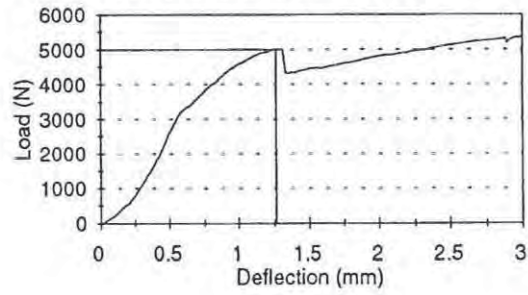
Specimen No. 4

Compression (joint - brick)



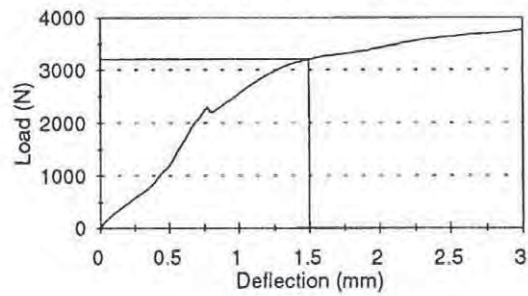
Specimen No. 5

Compression (joint - brick)



Specimen No. 6

Compression (joint - brick)



FOR FURTHER INFORMATION

TUNRA Limited
Industry Development Centre
University Drive
Callaghan NSW 2308
Australia

Phone (+61 49) 21 8777
Fax (+61 49) 21 8778
email: tunra@newcastle.edu.au

THE UNIVERSITY OF
NEWCASTLE RESEARCH
ASSOCIATES LIMITED

Incorporated in New South Wales
A.C.N. 000 710 074