STONETILE (CANADA) LTD.

TEST PROGRAM TO EVALUATE THE "STONETILE" CLADDING SYSTEM

Submitted To:

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CA-12207

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AGRA
Earth & Environmental

STONETILE
Exterior Cladding System

Evaluation Report

Executive Summary

Introduction

The STONETILE system is an innovative residential and commercial exterior cladding system. The system is comprised of concrete tiles individually mounted to standard residential sheathing or commercial steel stud wall systems. Various stone surface finishes and colours are available providing a wide range of architectural stone-like facades. The system also features many specific tile sections, such as cornices, lentils, and key stones, that give the appearance of historic architectural designs. The system is finished with the placement of a sand-coated flexible grout between the tiles to provide the appearance of mortar.

Test Program

AGRA Earth & Environmental was commissioned to evaluate the performance of the STONETILE system and materials. The evaluation consisted of testing designed to determine the following parameters.

Material Physical Properties

The Physical property testing of the tile concrete material indicated a high early strength concrete mix (>30 MPa at 4 days) at a density consistent with normal concrete. The surface finish of the tile provided for low water absorption with negligible shrinkage. Given the rapid strength gain of the concrete, the minimal shrinkage, and the minimum plant curing time of 72 hours, production and installation of the tiles can be carried out very quickly without concern over the concrete quality or stability.

Strength of the Anchor System

The Stonetile anchor system is comprised of two raised galvanized strip anchors imbedded in the back on the tile The raised profile provides a 1/4" gap between the tile and substrate. Each strip anchor has a screw mounting hole at the top to attach to the substrate and prongs at the bottom to interlock with the tile below. The tests, designed to measure the force required to pry the anchors from the tile and shear the anchor from the substrate, indicated the strip anchors provided significantly more strength (ie. a safety factor of 22) than what was required to support the system. It should be noted that the load imparted to the supporting substrate by STONETILE is approximately 6 lbs/ft^2 as compared to residential stucco at 7.5 lbs/ft^2.

Overall System Performance

The durability of the system was evaluated by observing the systems response to wind load, and water penetration. Further, although the grout between the panels is primarily an architectural feature, tests were performed to measure the grout-tile bond strength and the grout's response to cyclic movement.

Overall, the system was unaffected by 80 km/hr wind loading. Even though water penetration behind the tiles would be effectively drained away, no water penetration was observed. The grout material chosen for the system was well bonded and the cyclic deflection test results suggest a long life span can be expected.

Building Science

From a building Science perspective, the STONETILE system provides a drained and ventilated 'rain screen' cladding for both commercial and residential buildings. Unlike 'face-seal' systems, STONETILE cladding does not solely rely on the exterior surface to shed water. Water penetration can be tolerated through effective drainage. The gap between the tile and substrate, provided by the strip anchor, also allows for ventilation and evaporation of penetrated moisture or condensation.
The relatively small size of the tiles will also allow for minor building movement (ie. natural settling, wind movement) without excessive movement in the tiles. Since each tile is independently anchored, overall building movement will occur incrementally at each tile rather than the wall section acting as a monolithic mass. This will reduce the stress on the tiles and strain in the grout.

Conclusion

The STONETILE exterior cladding system is an innovative, well designed, flexible, architectural exterior finish for both commercial and residential buildings. The components and materials meet or exceed strength and stability requirements and the overall tile design incorporates many proven and sound building science technologies. Given the relatively new nature of the product, and since the oldest project was completed in 1990, no data was available to confirm expected long term performance.

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AGRA
Earth & Environmental

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1.0 INTRODUCTION

AGRA Earth & Environmental Limited (AEE) was retained by Stonetile (Canada) Ltd. to conduct a test program to evaluate the 'Stonetile' cladding system. The Stonetile system is an innovative concrete tile cladding system developed by Stonetile (Canada) Ltd. for use in residential and commercial construction.

2.0 DESCRIPTION OF STONETILE SYSTEM

The stonetile system consists of concrete tile with two vertically embedded metal strip anchors which hold the tile onto the substrate. The product is manufactured as 18"x 12"x 5/8" (450mm x 300mm x 16 mm) tiles, although there are a wide variety of decorative architectural mouldings and components. The system is available in various decorative stone surfaces and colours. Once installed, a flexible sealant ('grout' material) is placed into the joints between the tiles and is coated with sand to provide the appearance of mortar. Diagrams contained in Appendix 'A' illustrate the tile design and other component sections.

The strip anchors are made of 24 gauge, 25 mm wide galvanized steel. Twenty eight gauge stainless steel strip anchors are also available. These strip anchors are punched out to have a spline 6 mm wide and 3 mm deep and gang nails protruding into the concrete. The gang nails are embedded in concrete during casting. The top of the strip anchor protrudes about 10 mm above the tile with a hole for a screw that will fasten the tile to the substrate. The bottom part of the strip anchor consists of 2 prongs that protrude about 5 mm below the tile and fit behind the tile below. Thirty gauge galvanized steel channels are provided at the base, for drainage, and top, for ventilation. The strip anchors are perforated to ensure adequate ventilation, and pressure equalization with the exterior air.

3.0 TEST PROGRAM

The test program, conducted by (AEE), was designed to evaluate the following physical properties.

1. Physical properties of the concrete used to manufacture the tiles.
   - Compressive strength
   - Density
   - Water absorption
   - Shrinkage

2. The strength of the tile anchor system
   - Anchor pull-out from tile
   - Anchor shear from tile

3. Durability of Stonetile system
   - Creep of installed tiles
   - Bond strength of sealant in tile joints
   - Cyclic loading of tile joint sealant
   - Wind Load Resistance
   - Water Penetration Resistance

4.0 TEST PROGRAM RESULTS

4.1 CONCRETE PHYSICAL PROPERTIES

4.1.1 Background

In the manufacturing facility, the concrete is mixed in a continuous mixing process with tile moulds filled by an automatic dispenser. Although the mix design of the concrete is proprietary in nature and cannot be discussed in the text of this report, all materials used in producing the concrete conform to the CSA A23.1-94 concrete standard.

After the tiles are poured, they are demoulded at an age of approximately 48 hrs and racked vertically on a pallet to allow for further curing. Once racked, the pallet is wrapped on 4 sides in polyethylene with the top left exposed. A section of news print is placed on top to absorb excessive moisture that would result in drips and stains. The pallets are then shipped to the job site. The minimum time between moulding and application is 72 hrs.

4.1.2 Test Results

4.1.2.1 Concrete Compressive Strength

A series of 50 mm cubes were cast during a tile production run. Compressive strength testing was conducted in accordance with ASTM and CSA standards at 4,7, and 28 days. The test data is presented in Table #1.

4.1.2.2 Concrete Density

Density testing was conducted on the series of cubes cast for the compressive strength testing. All specimens had densities within the normal range for concrete, 135 lbs/ft^3 to 145 lbs/ft^3 (2200 kg/m^3 to 2300 kg/m^3). The test data is presented in Table #1.

4.1.2.3 Water Absorption

Water absorption testing was also conducted using the 50 mm compressive strength cubes. The data is presented in Table #1. Further to this testing, a tile was selected from regular tile production and tested as a cross reference. The tile tested had a water absorption of 6.0% with a concrete density of 2295 Kg/m^3.

4.1.2.4 Concrete Shrinkage

Shrinkage testing was conducted on rectangular prisms cast at the same time as the compressive strength samples. The data is presented in Table #1.

Table #1

CONCRETE PHYSICAL PROPERTIES

Test Age (Days)	Compressive Strength		Density	Water Absorption	Linear Shrink
	MPa	PSI			
4	32.0*	4640*	2211	6.9	0.06*
7	36.8*	5340*	2241	6.7	0.08*
28	38.2*	5540*	2241	6.4	0.09*

* - Indicates average of two specimens

4.1.3 Discussion of Test Results

Since the system design requires each panel to support only its own weight, the measured compressive strength provides more than sufficient strength to provide adequate support.

The tested density of the concrete results in a panel weight of approximately 4.2 Kg (9.25 lbs) or an installed vertical wall load of 35 Kg/M^3 (6 lbs/ft^2). As a comparison, acrylic stucco imparts an approximate vertical load of 7.5 lbs/ft^2 (residential) and 10.5 lbs/ft^2 (commercial) whereas cementitious stucco imparts an approximate load of 8.5 lbs/ft^2 (residential) and 11.5 lbs/ft^2 (commercial). Existing building structural designs, capable of supporting stucco, should not require structural modification to support the Stonetile system.

Although no recommended level of water absorption for this type of product exists, an industry standard for common concrete, is 5%. It should be noted that the 5% level reflects the concern over freeze/thaw damage in concrete exposed to ground or other moist conditions. Given that the panels are installed vertically, and both faces are exposed to air, significant water absorption should not occur.

The measured shrinkage of the panels during curing appears to be minimal. No effect on the performance of the system is expected.

4.2 TILE ANCHOR SYSTEM

4.2.1 Background

The Stonetile anchor system incorporates two 24 gauge galvanized strip anchors cast vertically into the back of the tile (see diagrams contained in Appendix 'A'). Twenty eight gauge stainless steel strip anchors are also available.

4.2.2 Test Results

4.2.2.1 Anchor Pull-Out from Tile

The test comprised restraining a test tile and measuring the force required to pull one set of strip anchor prongs from the panel. Testing was conducted on three specimens with an average pullout strength of 1195 N (268 lbs)

4.2.2.2 Anchor Shear from Panel

The test comprised restraining a test panel and measuring the amount of force, acting parallel to the tile surface, required to either pull both strip anchors from the tile or, the force required to rip through the screw holes at the top on the anchors. In all cases the failure occurred at the screw holes in the strip anchor with the loading mechanism ripping through the screw hole. Testing was conducted on three specimens with the maximum average shear force of 937 N (210 lbs).

4.2.2.3 Steel Stud Anchor System

To facilitate fastening of the Stonetile system to steel stud walls sheathed with exterior drywall, testing was conducted using an 28 gauge galvanized steel mounting 'Omega' strip. The strip, as shown in the diagram in Appendix 'B', is attached through the drywall into the steel studs behind using 1-1/4" #6 sheet metal screws. The strip anchors are then attached to the raised section of the Omega Strip with 1/2" sheet metal screws. Please note that the Omega strip is attached at each steel stud location with one screw in the top and bottom flanges. Testing indicated tan anchor bar shear strength of 265 lbs (1192 N).

4.2.3 Discussion of Test Results

As shown in the installed tile creep test results (presented later), there is no vertical tile-to-tile loading. Therefore, the tile will only be supporting its own weight. Since each tile weighs in the order of 9.25 lbs (4.2 Kg), and the anchor bar system is capable of supporting 210 lbs (shear in wood) and 265 (shear in Omega strip), based on self weight dead loading, the anchor

system has an apparent shear safety factor of 23 (in wood) or 28 (with Omega strip).

4.3 DURABILITY OF STONETILE SYSTEM

4.3.1 Background

As with any system, component properties do not realistically represent how a construction may perform in the field. In light of this, various tests were conducted on the Stonetile system to evaluate field performance under installed and extreme conditions.

4.3.2 Test Results

4.3.2.1 Creep of Installed Tiles

The Stonetile system is designed such that each tile supports only its own weight. The tiles also incorporate a bevelled edge around the perimeter back edges. The bevelled edges are dosigned to crush if contacted by an adjacent panel. This 'crush zone' protects each tile by not allowing any significant load to be transferred from tile to tile (see attached diagram Appendix 'B'). To evaluate the potential for installed tiles to slump or creep under there own weight, a 4.5 meter plywood test wall was constructed. The wall was comprised of 14 full size tiles installed one on top of the other in accordance with field installation instructions. All the tile joints were caulked and sanded as per field conditions. Once constructed, five digital micrometers (accuracy +/- 0.01 mm) were installed to measure vertical deflection at various heights in the test panel. Monitoring of tile movement was conducted over a 6 week period. The test data indicated no appreciable deflection at any individual tile location, on the test panel as a whole.

4.3.2.2 Bond Strength of the Between-Tile Grout

Although the between-tile grout provides some water penetration resistance, its purpose is mostly for architectural appearance. Taking this into account, the grout must still provide acceptable long term resistance to weathering, cracking, and stresses applied by the expansion and contraction of the tiles under thermal loads and building movement.

The grout used in the Stonetile system is 'Dymonic Urethane' caulking supplied by Tremco. Acceptable durability of Dymonic Urethane caulking was proven by others in independent test programs.

In order to evaluate the bond strength of the grout, test specimens, comprised of a 2-panel (or 3-panel) section, were restrained in a universal testing machine (see diagram Appendix 'B'). The force required to split the grout and pull the tiles apart was measured. For the test, the grout joint was installed in the same manner as normally conducted in the field.

Test results indicated the samples attained an average ultimate tensile bond strength of 800 N (180 lbs) for a 450 mm long grout joint and 420 N (95 lbs) for a 300 mm long grout joint. Please note that, at maximum load, the grout separated from the tiles and/or split through the

centre. This failure mechanism suggests the tile bond was strong enough to attain the ultimate strength of the grout.

4.3.2.3 Cyclic Loading of the Grout Joint

Since all buildings are subject to settlement and movement due to cyclic heating/cooling of the exterior surface, the joints in any exterior cladding system will be subject to movement as well. In order to evaluate the durability of a grout joint, test specimens, comprised of a 2-tile (or 3-tile) section, were mounted in a universal testing machine (see drawing Appendix 'B') and subjected to a cyclic compression and elongation of 1 mm at a frequency of 6 hertz. Testing was conducted at 21°C with the grout joint monitored for initiation of caulking separation, separation migration, and number of cycles. The test data is shown in Table #2.

Table #2

CYCLIC COMPRESSION/ELONGATION TESTING OF GROUT JOINT
(6 HZ, +/- 1 mm)

Sample Size	Specimen Number	Total Cycles	Failures Observed
12" x 18"	1	43,200	3 Points of Separation, (10 mm, 75 mm, 17 mm)
	2	10,800	2 Points of Separation (25 mm, 13 mm)
12" x 12"	1	86,400	2 Points of Separation (6 mm, 6 mm)
	2	72,000	Complete Failure

Notes: The 12" x 12" samples were the 2-tile configuration, The 12" x 18" samples were the 3-tile configuration with a complete tile over two 1/2 tiles.
(See drawing Appendix 'B')

4.3.2.4 Wind Load Resistance

A 2 m x 2 m wall section was constructed and mounted to a pressure chamber in order that loading under windy conditions could be simulated. The test pressure was raised to a level that would be produced by a 230 km/hr wind velocity (both positive and negative pressure). Test results indicated no appreciable effect on the stonetile system. Testing was conducted

in accordance with ASTM E330.

4.3.2.5 Water Penetration Resistance

The water penetration test was conducted using the same wall section used in the wind load resistance test. After 30 minutes of water spray at a spray rate of 3 L/min/m^2 (4 Gal/hr/ft^2), under a constant air pressure, no appreciable water penetration through the Stonetile system. Testing was conducted in accordance ASTM E331

4.3.3 Discussion of Test Results

Since there was no apparent creep of the tiles under their own weight, it can be assumed that, given a stable substrate, only movement of the structure itself would compromise the integrity of the system.

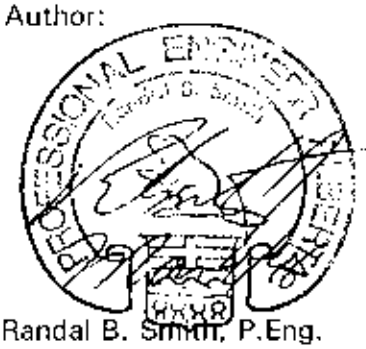
The bond strength test data indicated the grout to be well bonded to both tile edges. The cyclic testing indicated that, at the test temperature, the grout can withstand long durations of minor cyclic deflection (+/- 1 mm). Not only does the Tremco 'Dymonic Urethane' grout appear to be well suited to this application but, given present construction practices and acceptable levels of deflection, there is no reason to suspect that a properly installed grout joint would fail prematurely. Although flexible sealants do require some maintenance in most exterior panels systems, the grout in the Stonetile system is primarily an architectural feature. If damage to the grout occurs, the integrity of the system would not be severely compromised and repairs could be performed easily.

The tiles performed well in the wind load test with no appreciable damage or deflection and the system did not permit water leakage into the building under water spray and wind. Please note that, given the 'rain screen' style of the tile design, any water penetration through the grout would drip down the back of the tiles and would exit via flashing along the base course of tiles. Further, the gap between the wall and the back of the tiles provides an air space for pressure equalization in windy conditions and also ventilation to evaporate any moisture buildup. In addition, the primary requirement of the grout relates to maintenance and aesthetic appearance, rather than the overall performance.

5.0 GENERAL COMMENTS AND CONCLUSIONS

From a performance perspective the Stonetile exterior cladding system appears well suited to the Canadian and U.S. climates. The curtain wall style of the design provides for effective water shedding and can also accept minor water penetration without damage to the system or substrate. Since the system is comprised of small tiles, minor building movements can be absorbed through incremental movements between the tiles and the grout can be easily repaired or replaced. The anchor method and tile material properties provide a strong, resilient and well supported cladding system for both residential and commercial applications.

Author:



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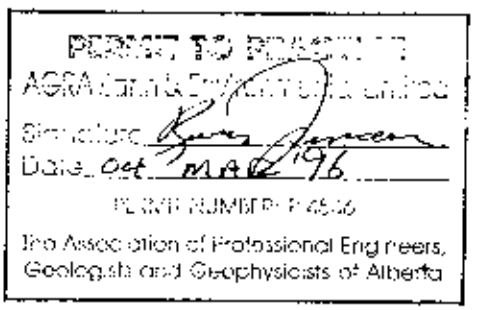


APPENDIX 'A'

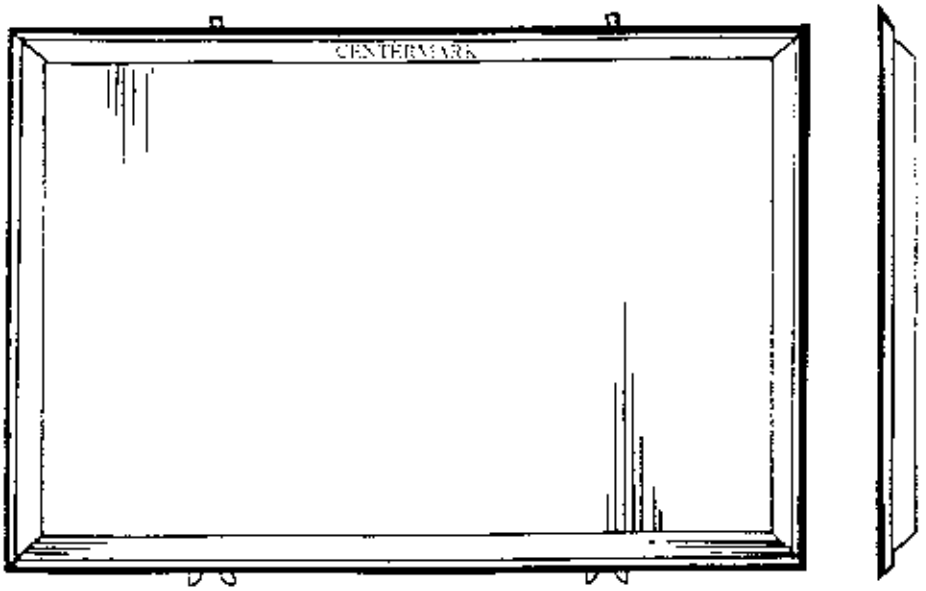
SYSTEM DRAWINGS

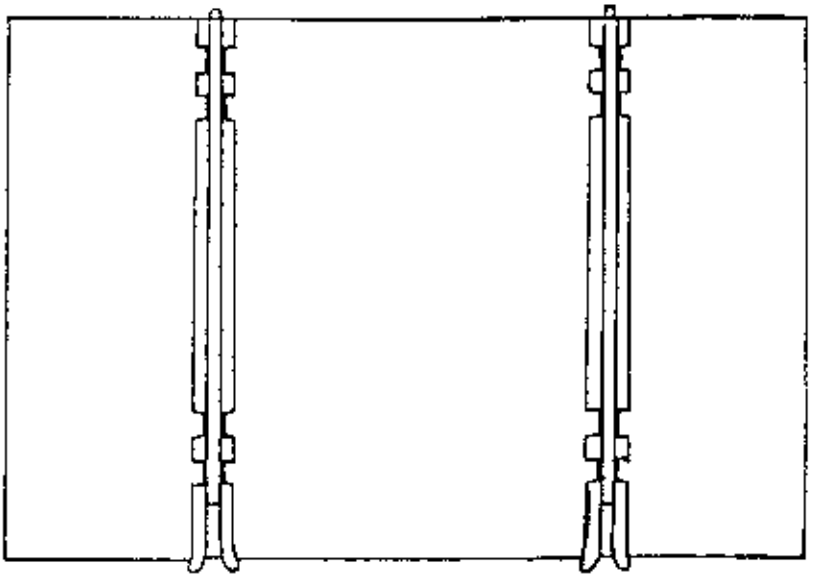
STONETILE

505mm x 458mm

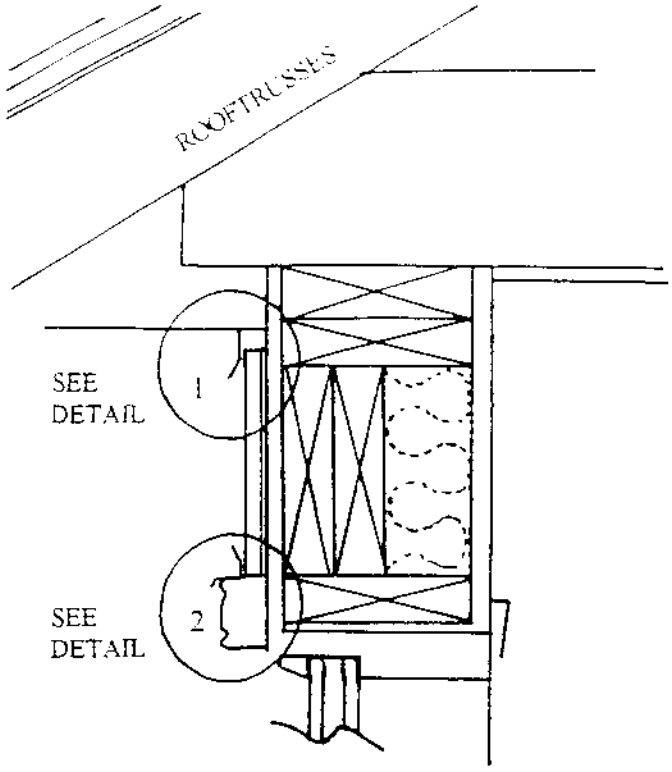
(12"x18")

BEVELEDGE

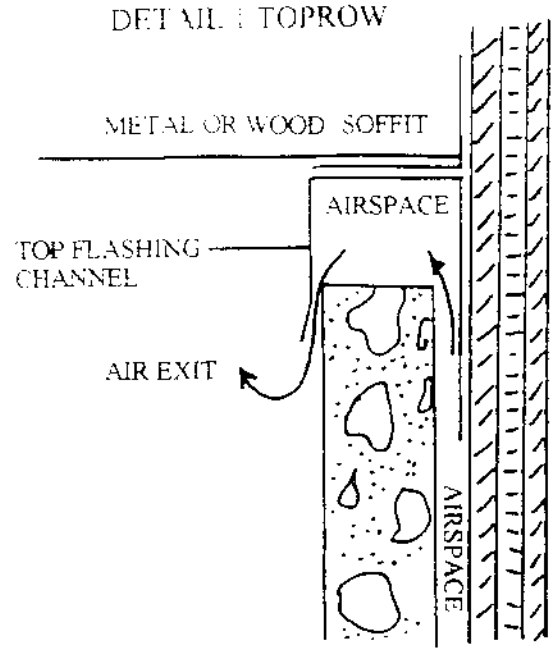


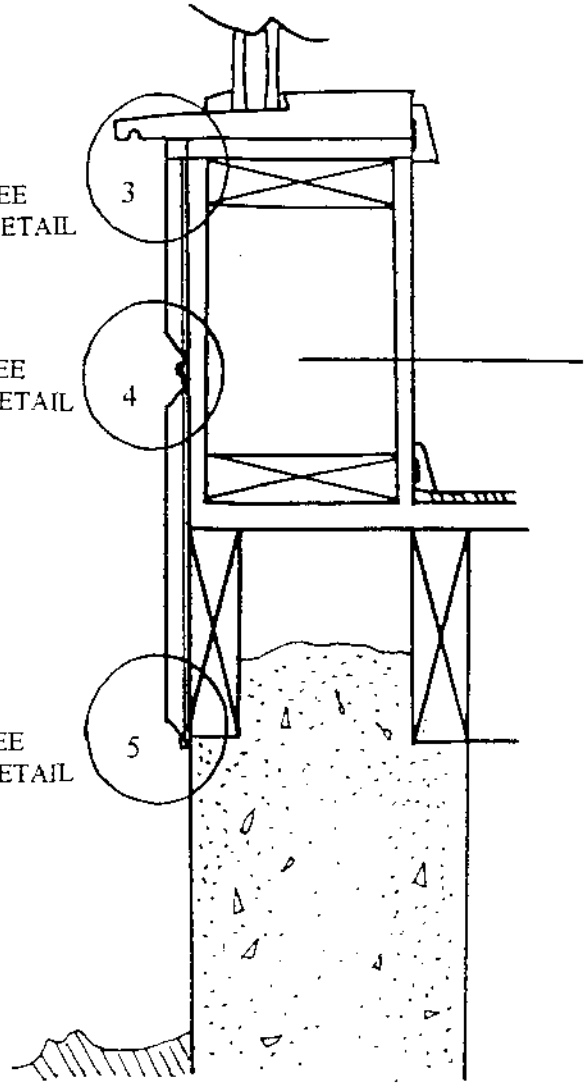


VERTICAL DETAILS



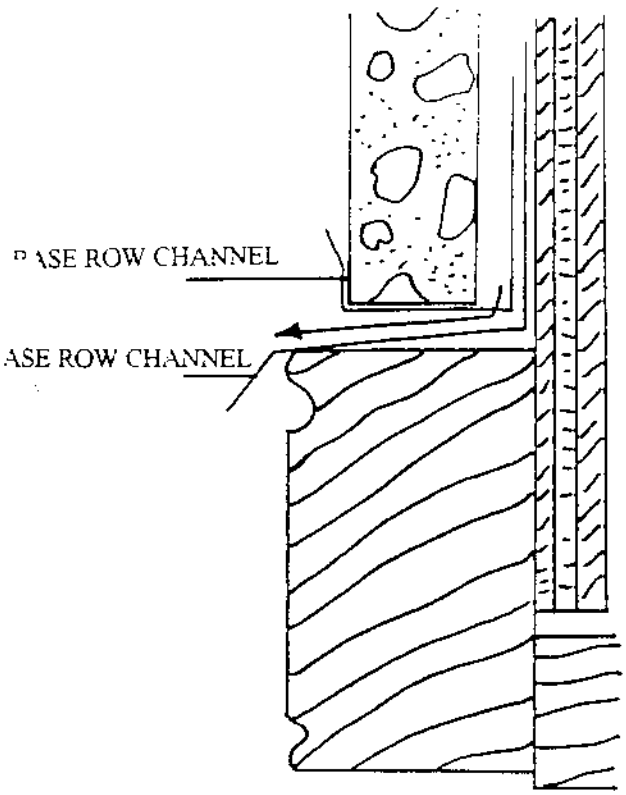
DETAIL 1 TOPROW



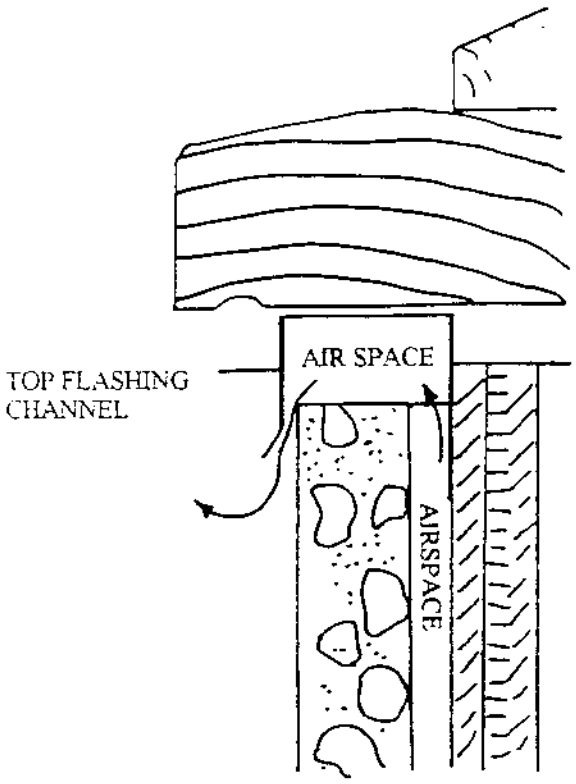


STONETILE
AIRSPACE 4mm
BUILDING PAPER
1/2" PLYWOOD OR CHIPBOARD SHEETING
2" X 4" OR 2" X 6" STUDS 16" OC. INSULATION
4 MIL POLYTHENE GYPSUM BOARD
SUBFLOOR
JOISTS
CONCRETE OR WOOD FOUNDATION

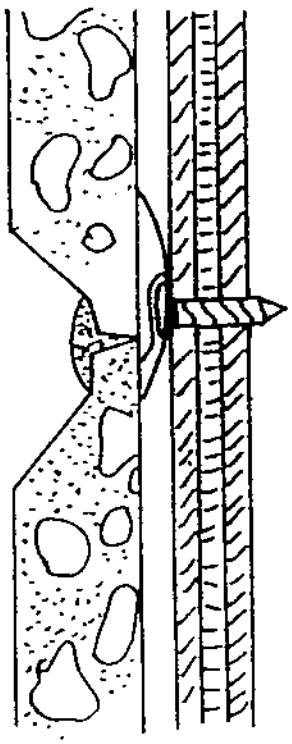
DETAIL 2 TOP OF WINDOW



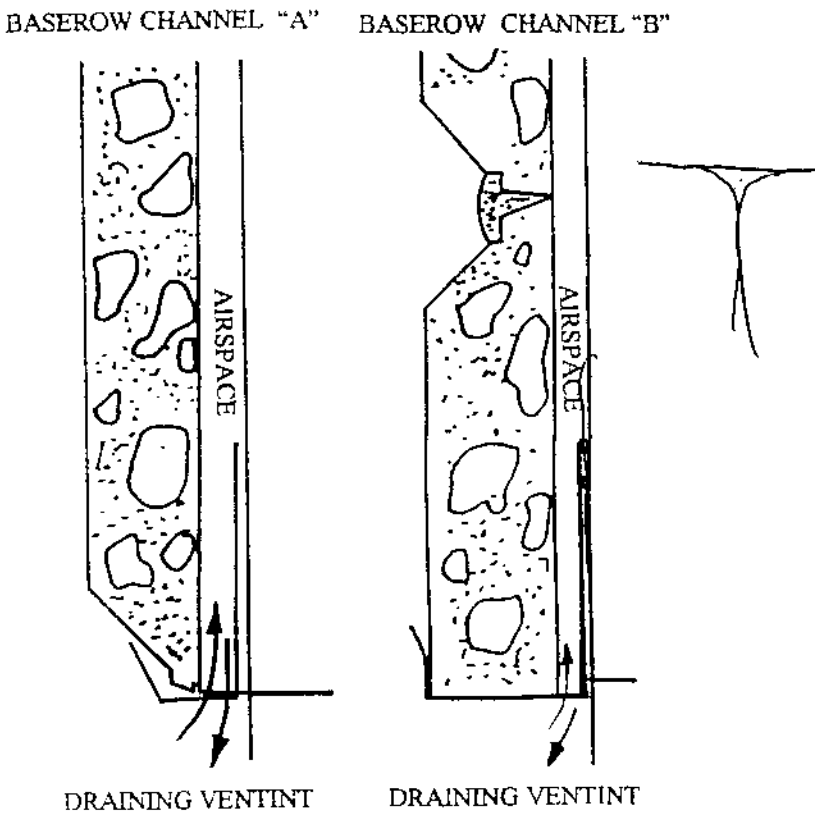
DETAIL 3 BOTTOM OF WINDOW



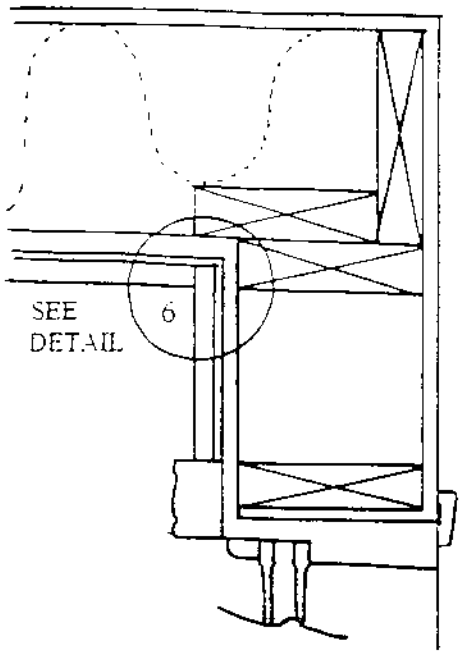
DETAIL 4 JOINT



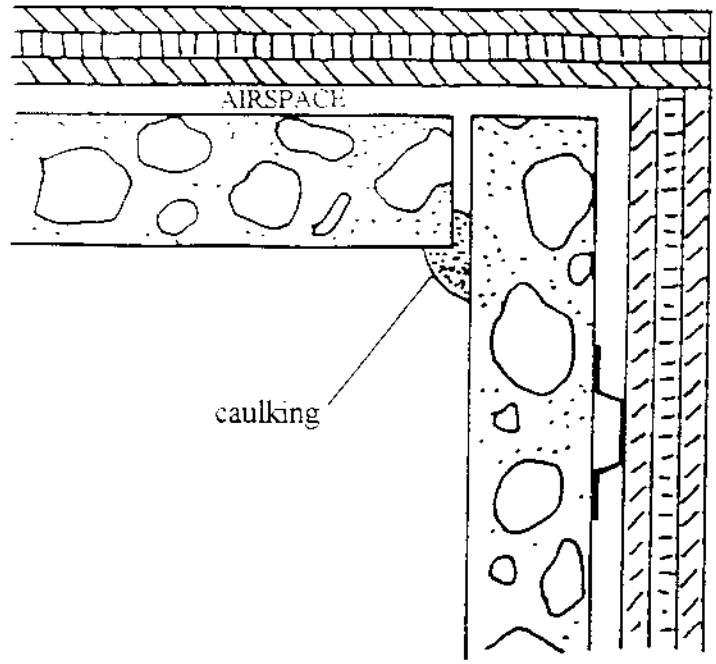
DETAIL 5 BASEROW

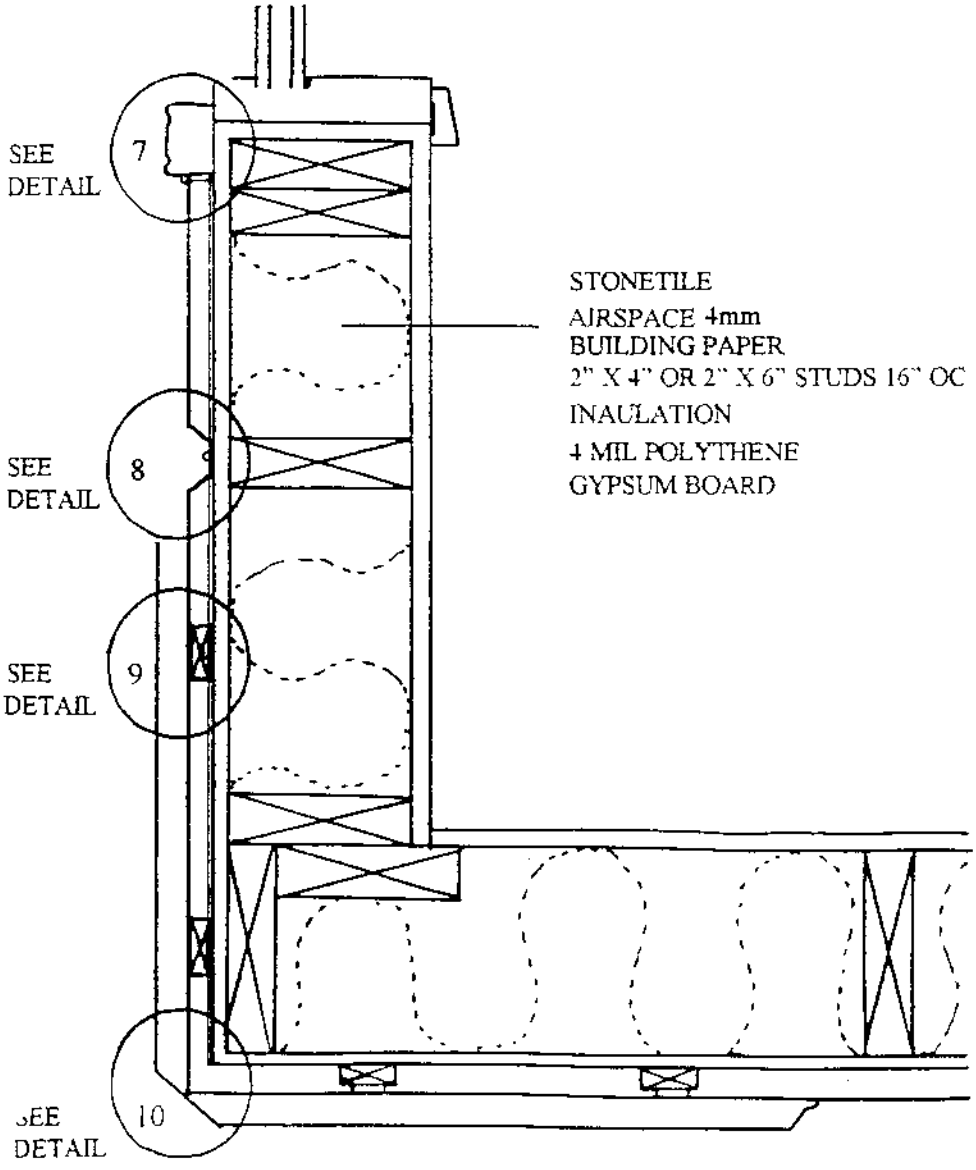


HORIZONTAL DETAILS

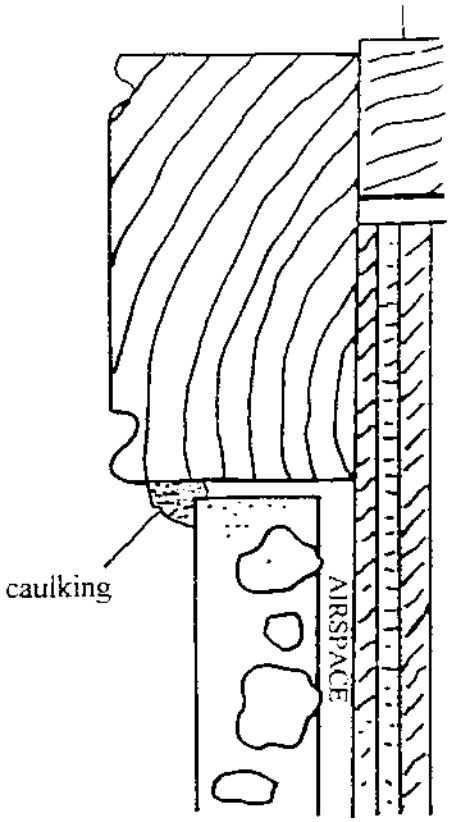


DETAIL 6 INSIDE CORNER

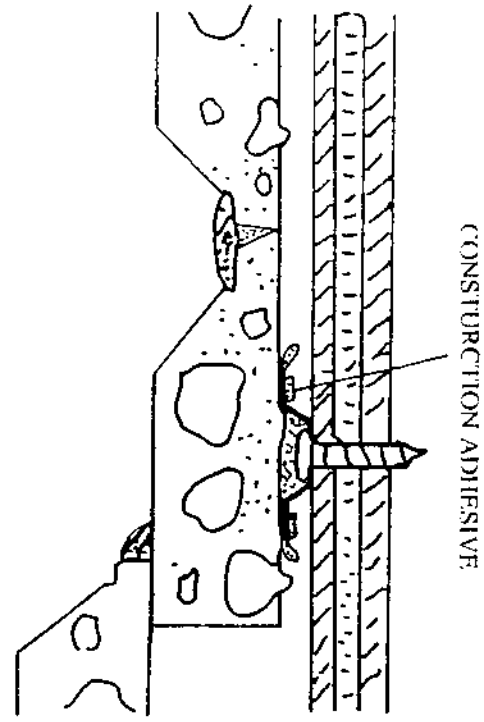




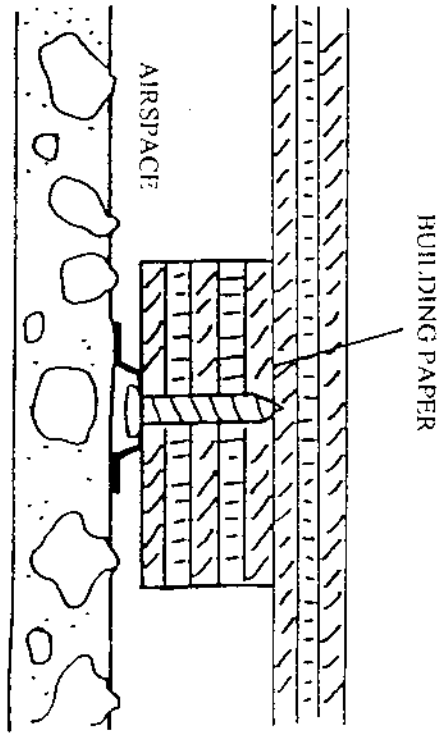
DETAIL 7 WINDOW/DOOR OPENING



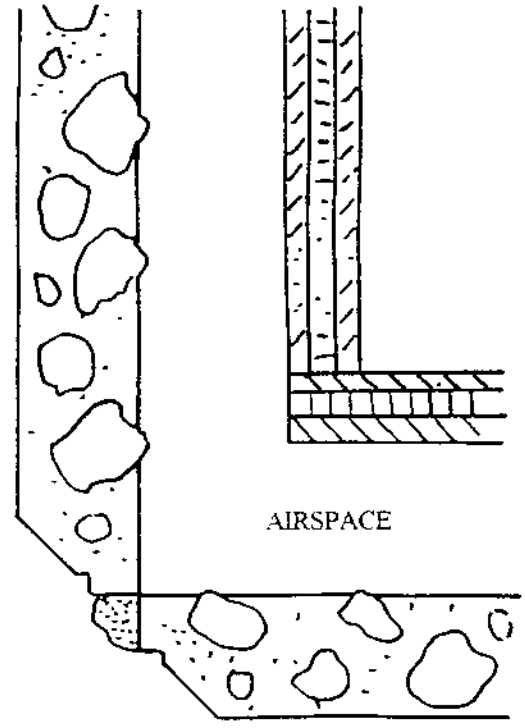
DETAIL 8 GLUETAB



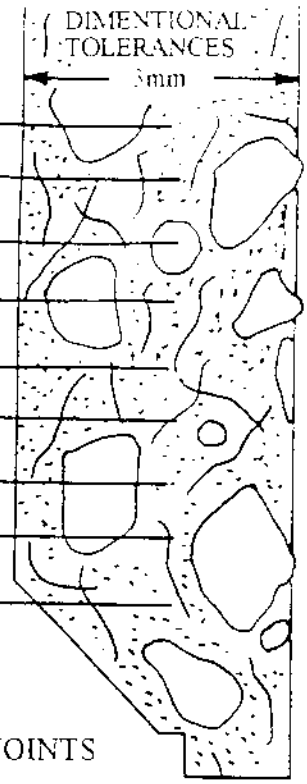
DETAIL 9 PERTRUDING CORNER TILES



DETAIL 10 OUTSIDE CORNER



CONCRETE SPECIFICATIONS PER CU M



..5 KG PORTLAND CEMENT

709 KG SAND

..78 KG GRANVEL

35 KG SUPER PLASERSIZER

0.6 KG AIR ENTERTAINMENT 5-7%

85 KG POLYPROPYLENE FIBRE

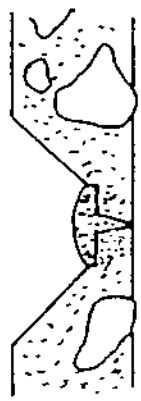
COLOUR PIGMENT

85 KG WATER (100mm SLUMP)

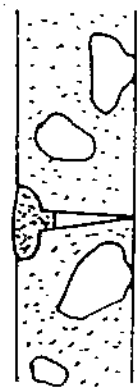
20 MPA CONCRETE

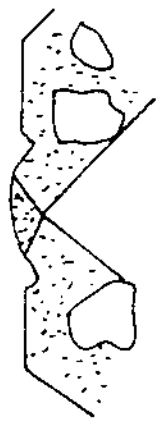
JOINTS

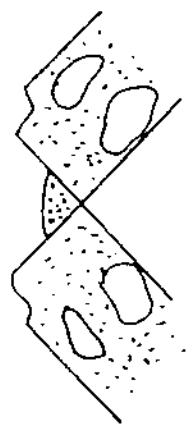
BEVEL EDGE JOINT AND CORNER DETAIL BELOW



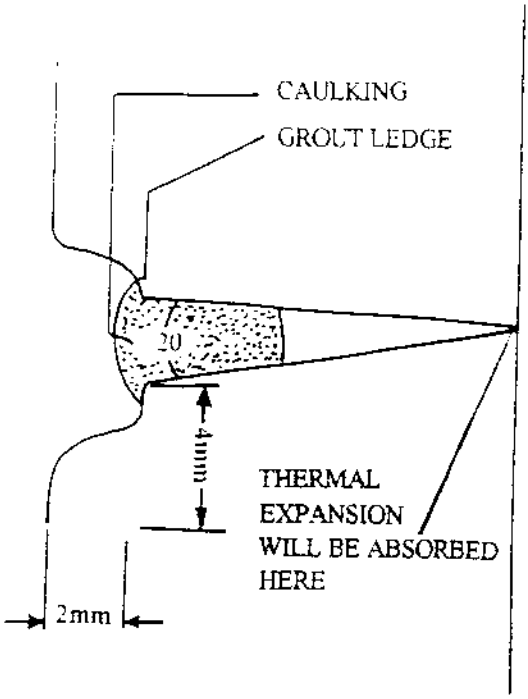
FLUSH JOINT AND CORNER DETAIL BELOW



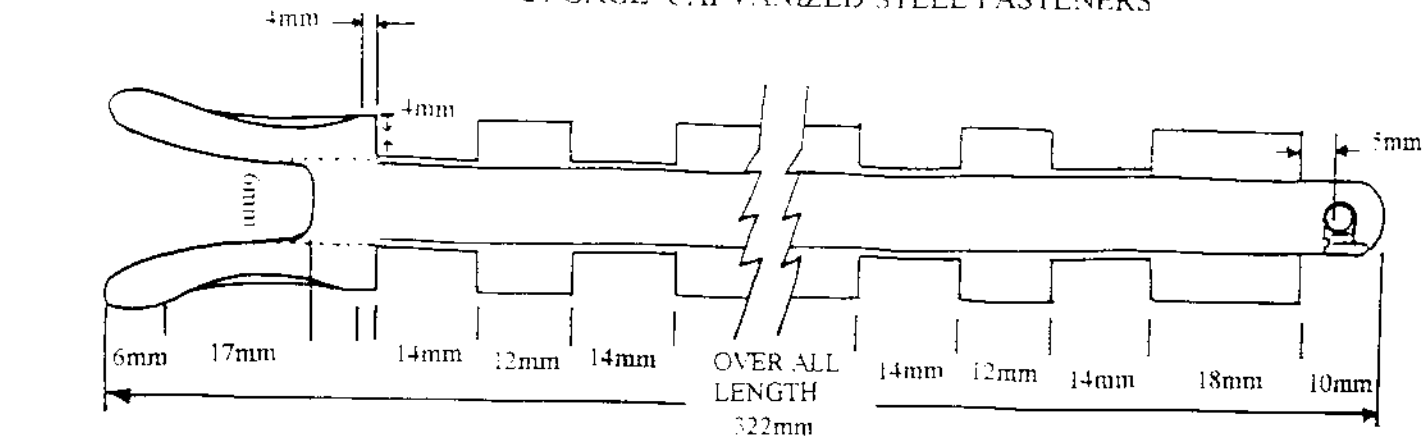


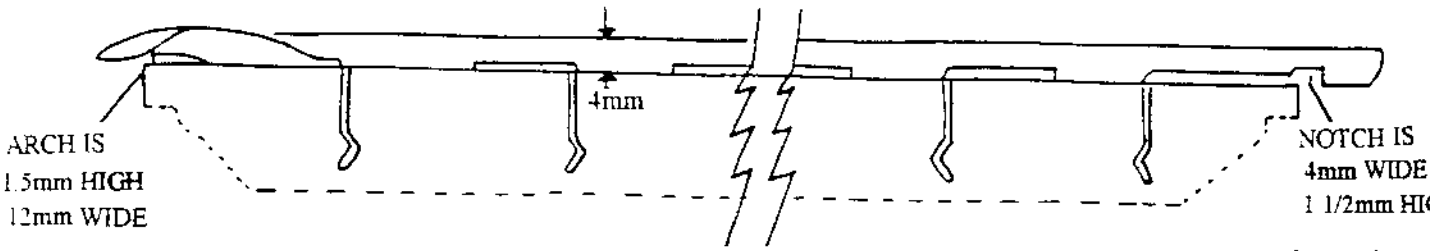


JOINT SPECIFICATIONS



24 GAGE GALVANIZED STEEL FASTENERS

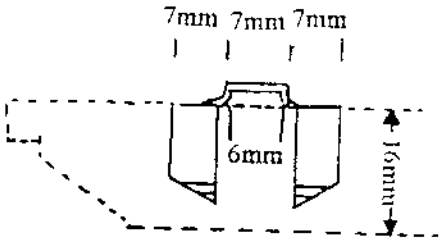




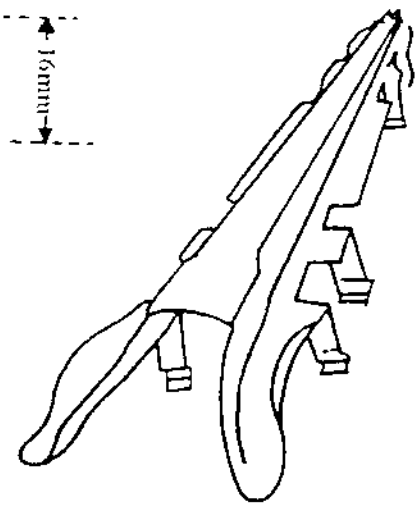
DETAIL OF FASTENE

SCREW

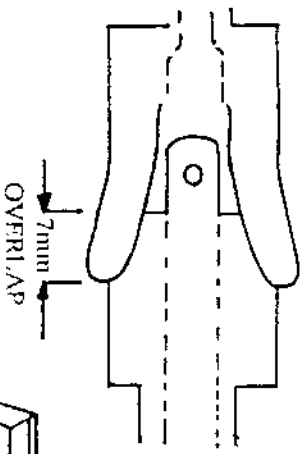
OVER LAP

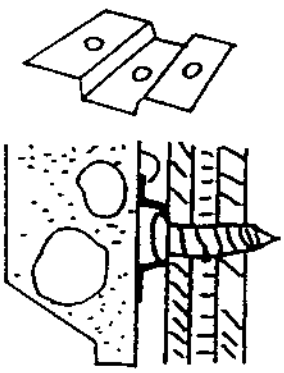


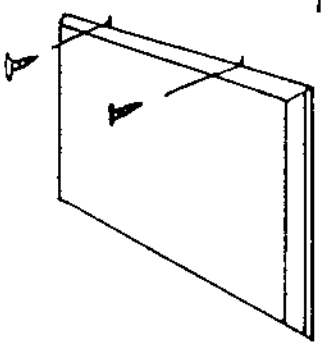
GLUETAB

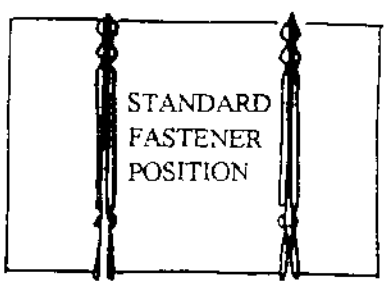


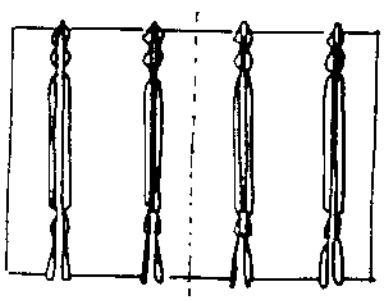
#6 5/8" mm
STAINLESS STEEL
SCREW

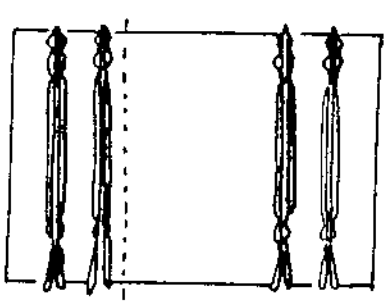




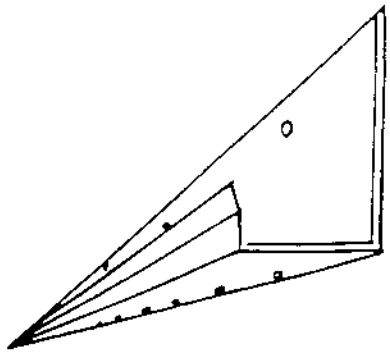




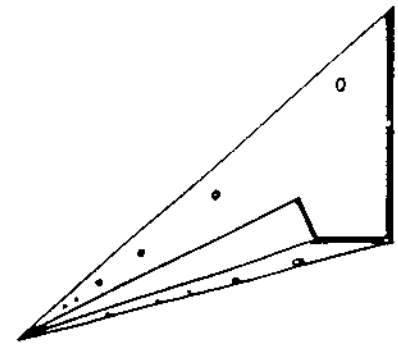




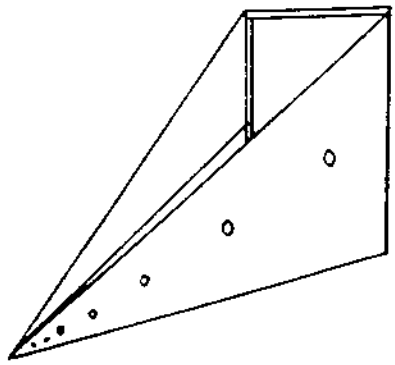
30 GAGE GALVANIZED STEEL FLASHING



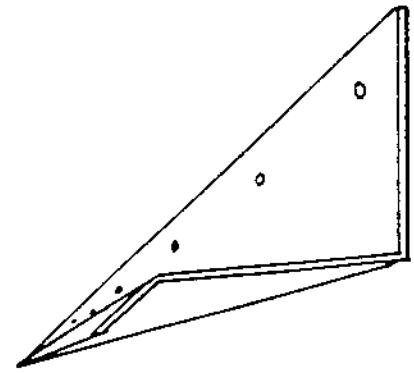
BASEROW FLASHING B



BASEROW FLASHING A

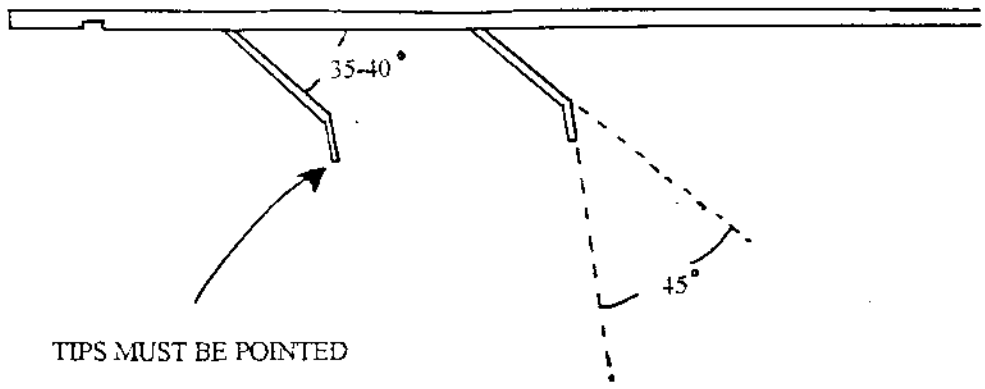


TOPROW FLASHING



STANDARD WINDOW / DOOR FLASHING

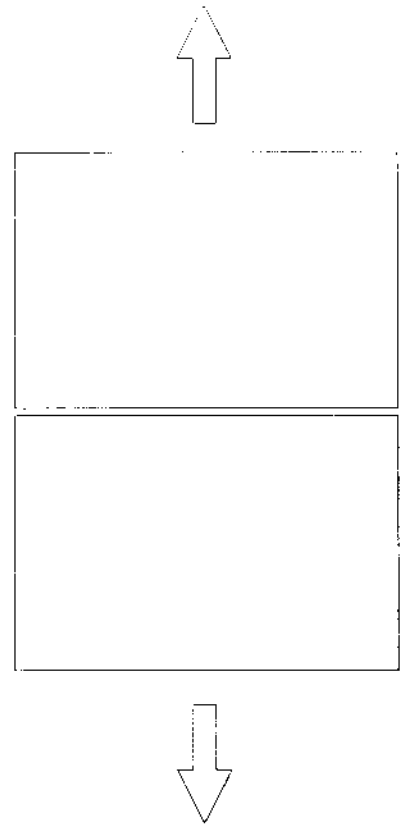
FASTENER ANGLES

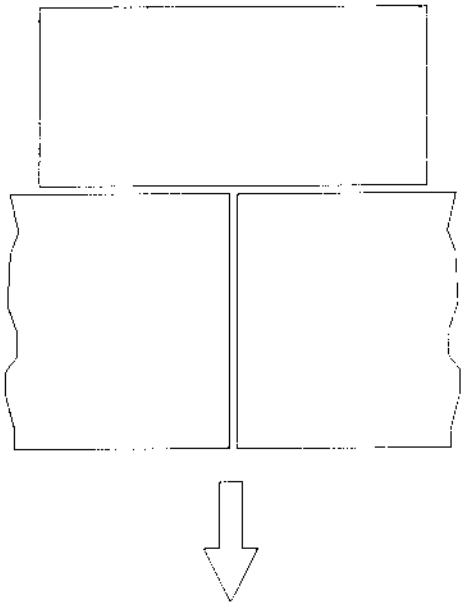


APPENDIX 'B'

MISCELLANEOUS

2-Panel Test





3-Panel Test

Notes:
- all tests performed at 21oC
- cyclic loading was conducted with a deflection of +/- 1 mm at 6 Hz

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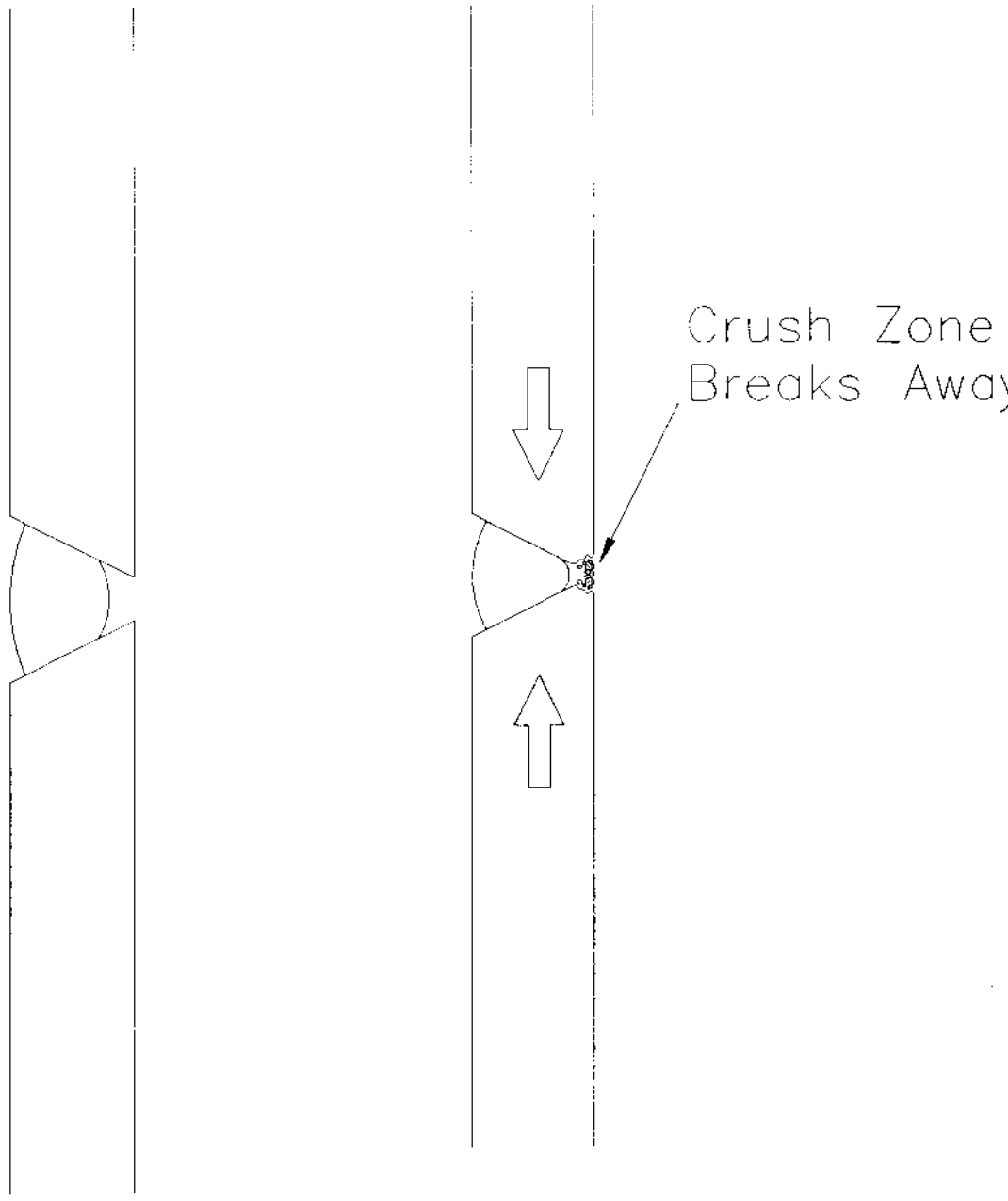
CLIENT: STONETILE Canada) Ltd	DATE: Feb 23 1996
PROJECT: Concrete Wall Tile Evaluation Project	JOB No. CA-12207
Grout Bond Test Setup	CAD FILE:
	Diagram #1 / REV. -



Installed Tile Configuration

Compressive Tile Movement

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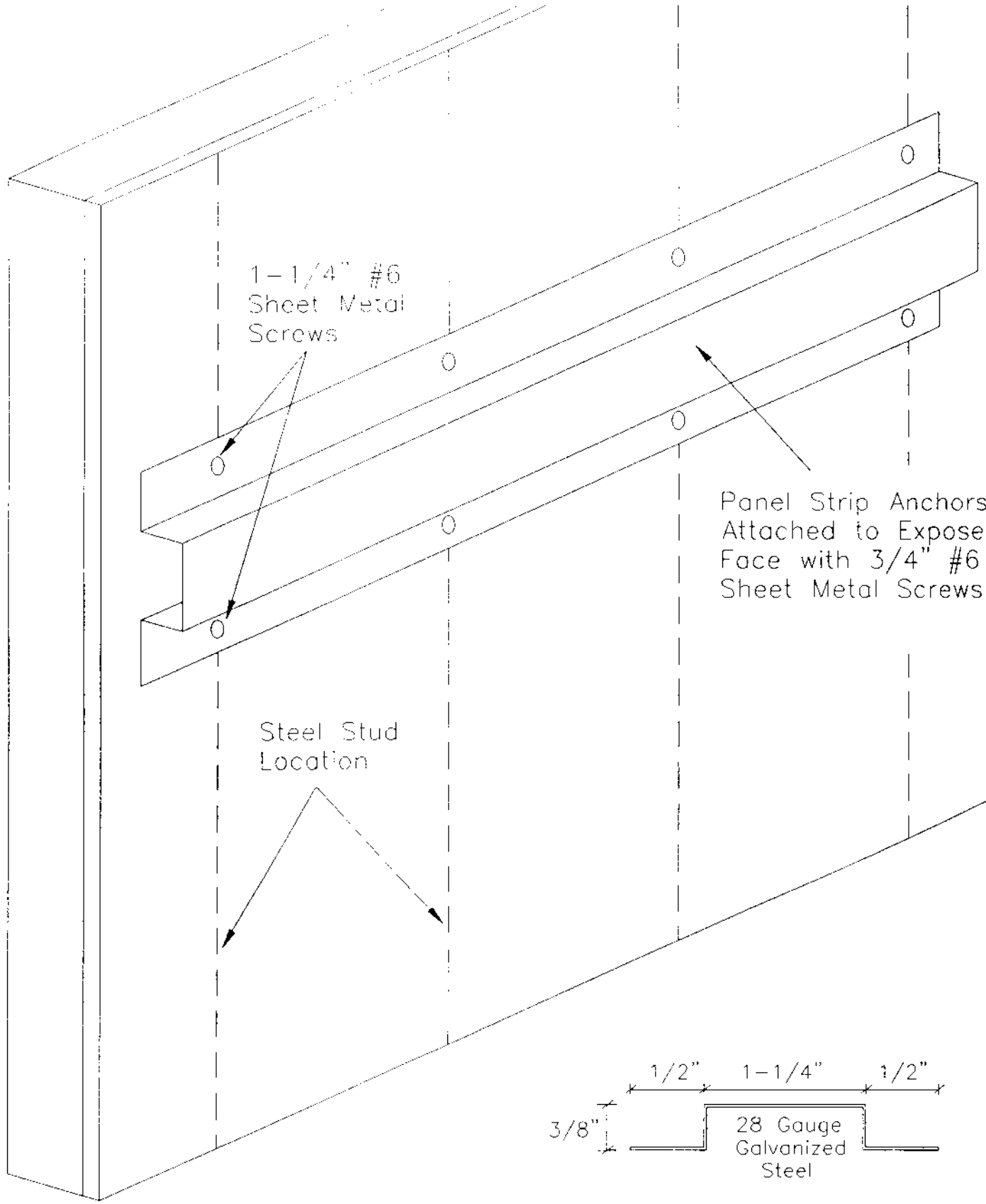
ENGINEERING & ENVIRONMENTAL SERVICES

CLIENT:	STONETILE Canada) Ltd.
PROJECT:	Concrete Wall Tile Evaluation Project
	Tile Crush Zone
DATE:	Feb 23 1996
JOB No.	CA-12207
CAD FILE:	
	Diagram #2
REV.	-



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CLIENT: STONETILE Canada) Ltd.	DATE: Feb 23 1996
PROJECT: Concrete Wall Tie Evaluation Project	JOB No. CA-12207
Steel Stud Mounting System	CAD FILE:
	Diagram #3 REV. -