

TIES IN LARGE CAVITY AND VENEER MASONRY WALLS

by

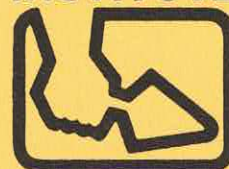
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INTRODUCTION

A cavity wall is defined as a construction of masonry laid up with a continuous air space between the wythes. The wythes are tied together with metal ties or bonding units (headers). Veneer is defined as a single framing wythe of masonry units or similar materials securely attached to a wall for the purpose of providing ornamentation, protection, insulation, etc, but not so bonded or attached as to be considered as exerting a common reaction under load.

Section 5.4.3 of CSA Standard CAN 3-S304-M78¹ limits the width of a cavity in a cavity wall to not less than 50 mm and not more than 75 mm when tied with metal ties; and not less than 75 mm and not more than 100 mm when tied with masonry bonding units. Guidelines in Section 6.2 of Reference 1 relate to minimum thickness of the wall, type of mortar joint, required support and spacing of ties for veneer walls.

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The maximum width of the cavity for this type of construction is limited to 25 mm. The type of tie suggested is a corrosion resistant corrugated metal strip of not less than 28 gauge thickness and 25 mm width. It should be stated here that the use of 28 gauge ties is not recommended. A 22 gauge tie will provide for larger compression capacity and additional resistance to corrosion. With increased cost of energy the demand for additional insulating values for wall construction has increased substantially. Additional insulation is usually accommodated in the cavity in the form of rigid or semi rigid panels of styrofoam or fiberglass. This paper examines the performance of this type of construction as it relates to the effect of the insulation on the ability of the ties to transfer wind loads to the back up system. The results of an experimental program carried out over the last two years are reported and guidelines for designing this type of wall system are provided.

GENERAL

The need for information on the effects of incorporation of additional insulation in cavity wall and veneer construction became clear when a number of buildings in Alberta, Canada, were constructed with ties attached to the back-up system as shown in Photos 1 and 2. Photo 1 shows fiberglass insulation on top of which a corrugated strip tie has been fastened by a drywall screw. Photo 2 shows ties attached on top of the Glasclad * insulation.

*Trade Name

Photo 3 indicates that Glasclad has been also called upon to perform the role of exterior sheathing. The building constructed as shown in Photo 4 experienced significant veneer deformations shortly after construction because of excessive movement and lack of adequate support. In two other cases corrective action was taken prior to the completion of the structures. The lack of understanding of the behaviour of this type of construction and the need for design guidelines were the reasons for the present study.

EXPERIMENTAL PROGRAM

a. CAVITY WALLS

Large cavities in two wythe masonry construction can be accommodated by using rod type ties to transfer the wind load to the interior wythe which is usually thicker than the exterior one. For this type of construction the most common type of tie is the three rod tie such as shown in Figure 1. The insulation is placed in contact with the interior wythe and is held in position by means of clips and/or adhesives. The capacity of this type of tie has been evaluated experimentally in Reference 2. To provide additional support for the insulation, some designers prefer to use adjustable ties, similar to Types A and B shown in Figures 2 and 3. For this type of tie portions of the cores of the back-up system above and below the tie should be filled with mortar grout, and special care must be taken to assure that the misalignment of the two parts of the tie is not greater than 15 mm.

A total of 68 specimens similar to the ones shown in Photo 5 were built using standard 190 x 190 x 390 concrete blocks and standard 90 x 190 x 57 mm bricks. Type S mortar was used to lay the units and to fill the cores of the concrete blocks. Variables included cavity width and insulation thickness. Only one type of insulation was employed, namely styrofoam SM* manufactured by Dow Chemical which is reported to have compressive strength of 300 KPa. In constructing the specimens standard procedures relating to good practice were followed.

b. VENEER WALLS

Masonry veneer walls are tied to the back-up system with a variety of commercially available ties. In this program two basic types of ties were used, namely 22 and 24 gauge corrugated strips and rod T-ties (4.76 mm adjustable veneer ties) as shown in Figure 4. Ties were attached directly to the metal studs by means of self tapping screws, as shown in Photo 5 or on top of drywall as shown in Photo 7, and were tested in both tension and compression.

Parameters investigated included cavity width, stud thickness, tie thickness, insulation thickness and type. Since only short lengths of metal studs were used, the effect of the length of the metal studs in the performance of the system was not investigated in this study. Corrugated strips were placed in such a way as to allow the insulation to provide restraint to buckling or bending of the tie. Photo 8 shows a corrugated strip tie attached to a metal stud through the joint of 50 mm thick styrofoam SM* insulation. Photo 9 shows the types of screws used to fasten ties to metal studs.

*Trade Name

C. TESTING PROCEDURE

A system consisting of two plates sliding on metal tracks was developed for testing the specimens. The system is shown schematically in Figures 5 and 6 .

In a compression test the specimen is placed in the testing machine so that the two wythes rest one on each plate with the plates separated by at least half the cavity width. Polystyrene back-up padding is placed between the brick wythe and the steel plate as shown in Figure 5 . The polystyrene is indented in the vicinity of the tie so that it will not interfere with the mode of failure. A similar indentation is provided on the load application side.

The load is applied by a hydraulic jack whose position is adjustable. Initially the system including the test specimen slides on the lubricated rollers in the metal tracks until the polystyrene back-up is compressed between the bricks and the end plate. The load is then increased gradually until the specimen fails.

In a tension test the brick wythe is held in place as shown in Figure 6 and the other wythe is pulled. Provisions are made to ensure proper load distribution. The system described above was also adopted for testing ties attached to metal studs.

TEST RESULTS AND ANALYSIS

a) ADJUSTABLE TIES

The results obtained from compression tests are given in Table 1. Results of tension tests carried out with Type A and B ties are summarized in Table 2.

The results obtained indicate that insulation is not effective in reducing the effective length of the rod tie as it relates to buckling and bending . For the adjustable ties

and for overall cavities of up to 140 mm the most common types of failure were failure of the brick masonry in flexure and pushing of the tie through the mortar joint. The average compressive failure load for Type A ties was 1.55 kN with a minimum of 0.51 kN and a maximum of 3.38 kN. For Type B ties the corresponding values were 1.51 kN average, 1.03 kN minimum and 2.33 kN maximum. The average tension failure load 2.23 kN for Type A and 1.85 kN for Type B. For a number of specimens tested in tension failure occurred as a result of excessive flexure of the tie rather than pull-out as shown in Photo 5. The average tensile capacity was 1.79 kN for Type A and 1.77 kN for Type B. The results indicate that, provided the tie is placed at the centre of the brick thickness, the capacity will be the same in tension and compression.

b. ADJUSTABLE WIRE VENEER TIES

The results obtained from this part of the test program together with other pertinent information are summarized in Table 3 to 5. Table 4, which summarizes the results of compression tests of adjustable wire veneer ties, indicates that two distinct types of failure exist: tie buckling and failure initiating at the flange of the metal studs. The capacity of the system is a function of the cavity width and the thickness of the metal stud. The average capacity was 2.66 kN with a minimum of 1.09 kN and a maximum of 4.35 kN. Because of the shape of the tie and the fastening employed to secure the tie to the back-up system, the capacity of the tie in tension is affected by the position of the screw and the thickness of the metal stud. The dependence on these factors is clearly shown in the results

in Table 3. The location of the screw as given in this table is defined by the distance from the tie bend.

c. CORRUGATED STRIP TIES

The compression capacity of corrugated strips in specimens with large cavities was very low. For an overall cavity width of approximately 95 mm the 24 gauge ties failed at an average load of 0.27 kN. The incorporation of 25 mm and 50 mm Glasclad insulation had no effect on the capacity of the ties.

Corrugated strip ties, 22 gauge and 25 mm wide, used in conjunction with a 95 mm overall cavity width failed at an average compressive load of 0.42 kN and, as can be seen from Table 5, no increase in the capacity was achieved by the presence of the Glasclad insulation. However, specimens in which the corrugated strip ties were attached to the metal studs through the joint of two slabs of styrofoam SM insulation demonstrated an increase in capacity of the order of 80% for the 22 gauge ties and 100% for the 24 gauge ties. The average failure load for the 22 gauge ties with 25 mm thick insulation and 95 mm cavity width was 0.61 kN. For the 50 mm thick insulation the average failure load was 0.75 kN. For the 24 gauge ties the corresponding failure loads were 0.52 kN and 0.54 kN.

SUMMARY AND CONCLUSIONS

The following conclusions are made from the results obtained.

1. Rod type ties used in cavity or veneer walls can carry substantially higher loads than corrugated strips.
2. Adjustable cavity ties should be grouted in the back-up wall and placed at the centre of the width of the mortar joint in the brick in order to produce similar capacities in tension and compression. They can be used to hold the insulation in place, provided that the misalignment of the two parts of the tie is not more than 15 mm.
3. Adjustable wire veneer ties have large capacities in compression; however, care is required in fastening the tie to metal studs which are less than 20 gauge in thickness. The position of the screw should be as close to the tie bend as practically possible.
4. Corrugated strips cannot provide adequate capacity when used in large cavities, and their use should be limited to cavities no more than 40 mm except when they are used in conjunction with insulation which has a compressive strength of at least 300 kPa and elastic modulus of 20 MPa. The ties should be attached directly to the metal stud or other back-up system and in no case should they be placed on top of the insulation.

Further research is required to develop suitable ties for use on top of insulation. These ties should have provisions for either compressing the insulation locally in such a way as to avoid additional compression under loads or transferring the service load from the tie to the metal studs or other back-up systems. For insulation with a compressive strength greater than 300 kPa provision can be made for spreading the load over a large area so that ties can be attached on top of the insulation and fastened through to the metal stud. The required plate size and fastening procedure could be established by further research.

ACKNOWLEDGMENTS

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REFERENCE

1. CSA Standard CAN3-S304-M78, "Masonry Design and Construction for Buildings". Canadian Standards Association 178 Rexdale Boulevard, Rexdale, Ontario, Canada.
2. Hatzinikolas, M, Longworth, J., Warwaruk, J.,
"Ties in Two Wythe Cavity Wall Construction" Proceedings
Second Canadian Masonry Symposium Ottawa, 1980.
3. Hatzinikolas, M., Longworth, J., Warwaruk, J., "Corrugated
Strip Ties in Curtain Wall Construction" Proceedings of
the Second North American Masonry Conference, University of
Maryland College Park, Maryland, August, 1982.



Photo 1 Corrugated strip tie attached on top of insulation using dry wall screw.



Photo 2 Glasclad insulation with attached brick ties.

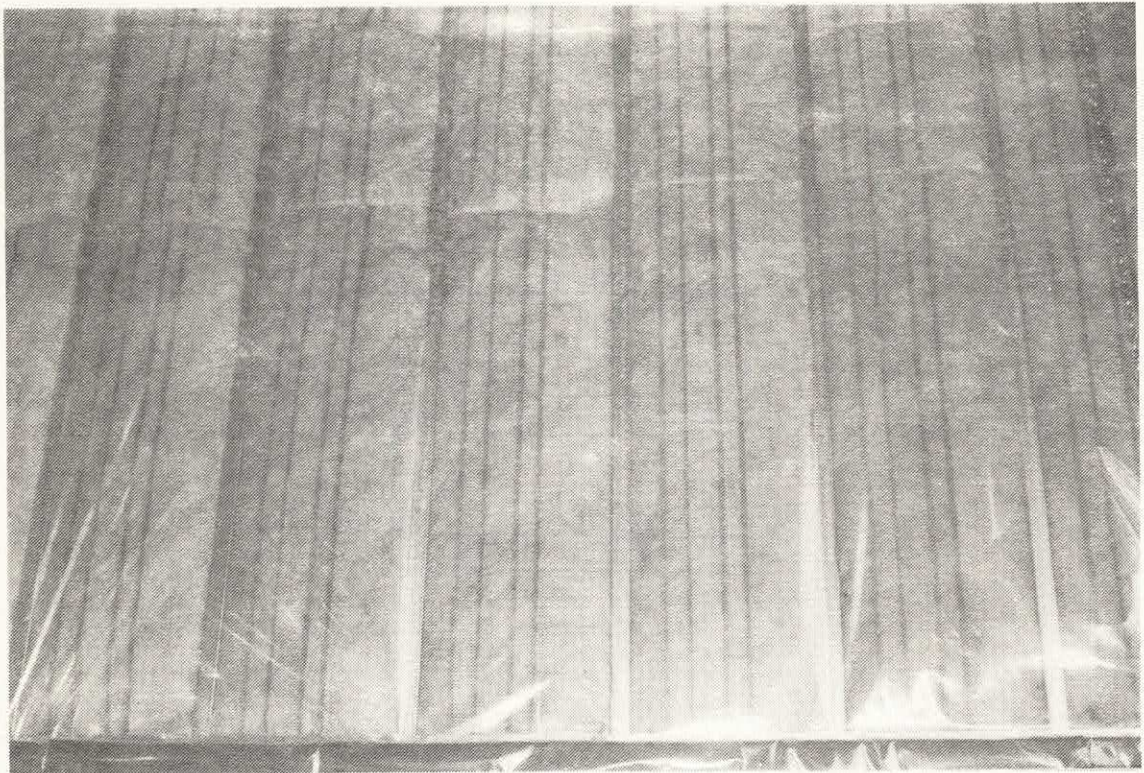


Photo 3 Glasclad insulation applied as exterior sheathing in conjunction with steel stud back up wall system.

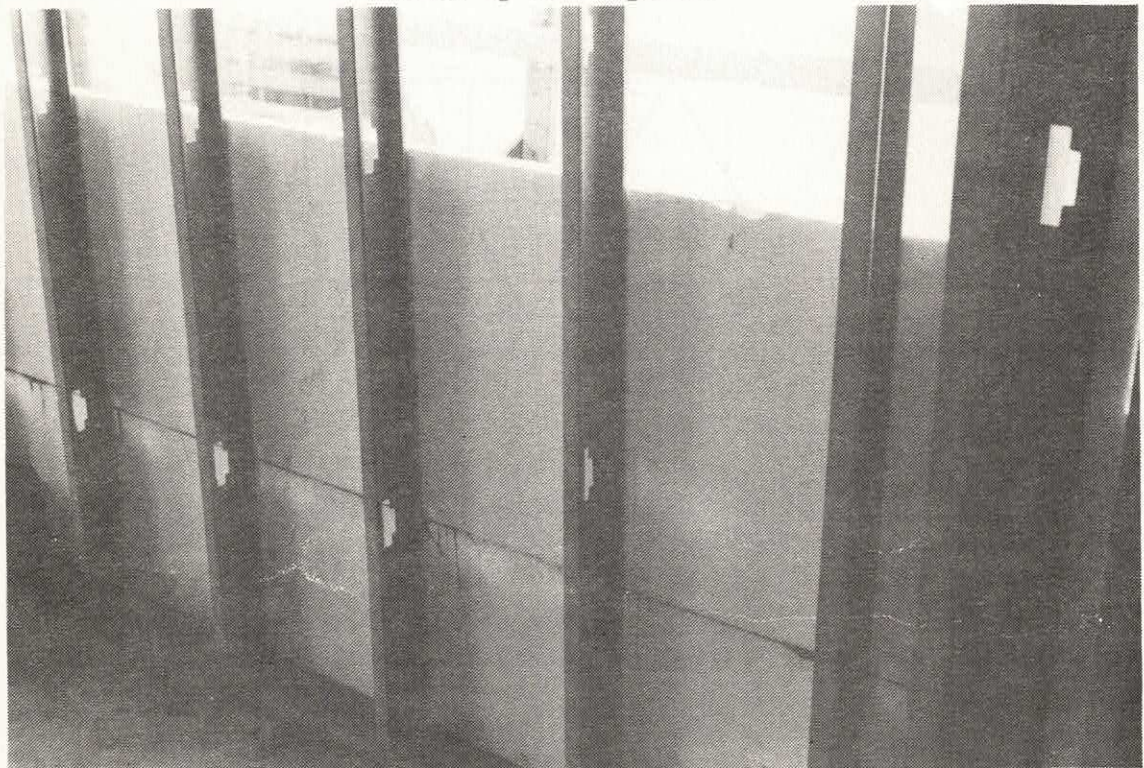


Photo 4 Styrofoam insulation as exterior sheathing in veneer application.

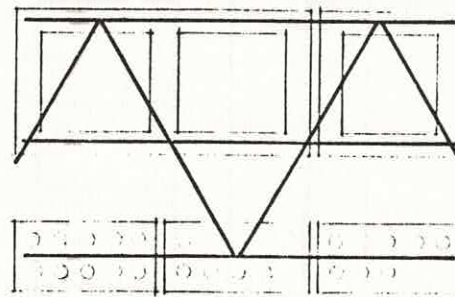
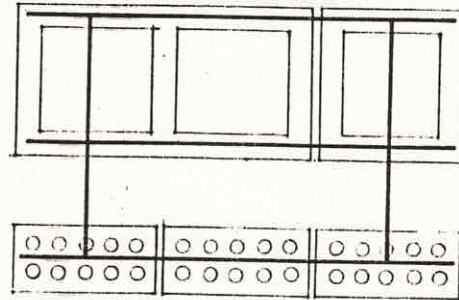
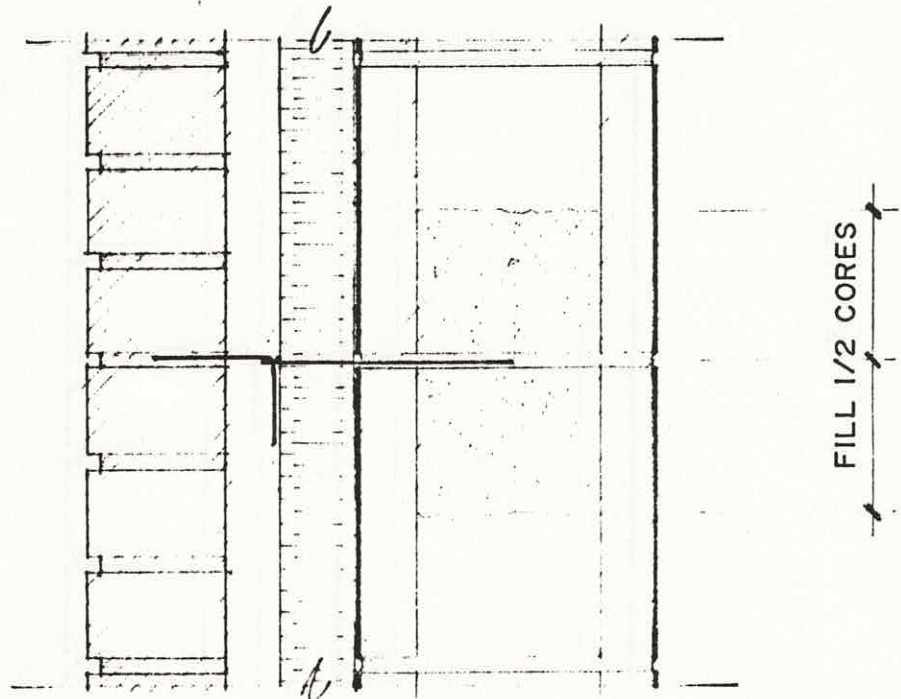
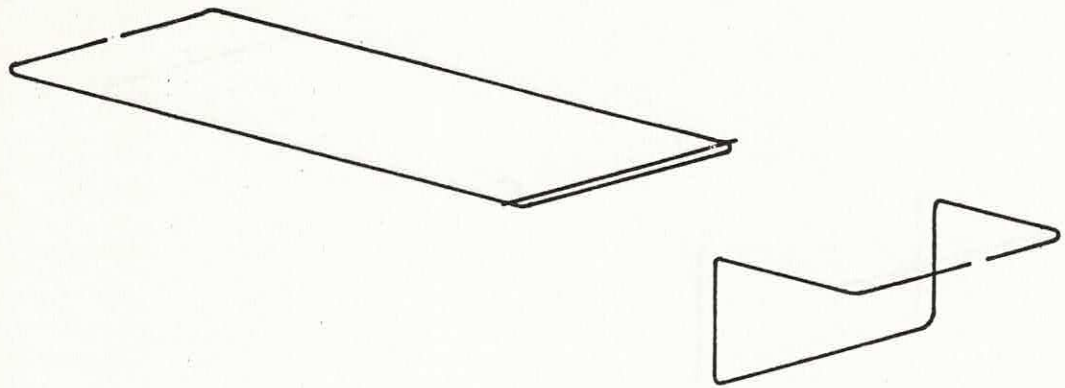
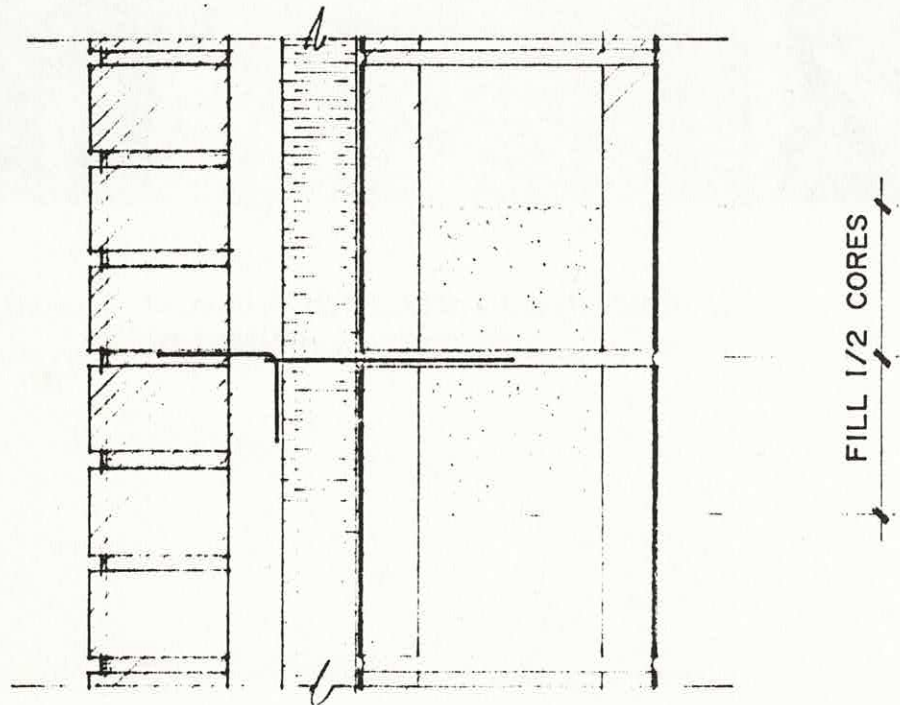
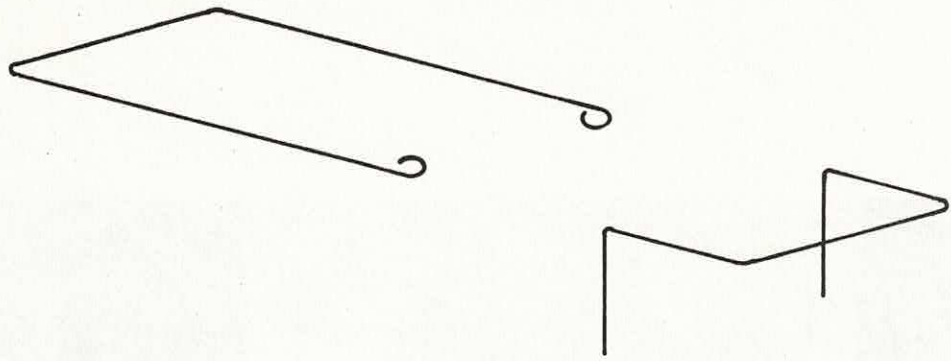


Figure 1 Typical three rod ties in large cavity wall construction.



TYPE A

Figure 2 Type A adjustable tie in cavity wall construction supporting insulation.



TYPE B

Figure 3. Type B adjustable tie.

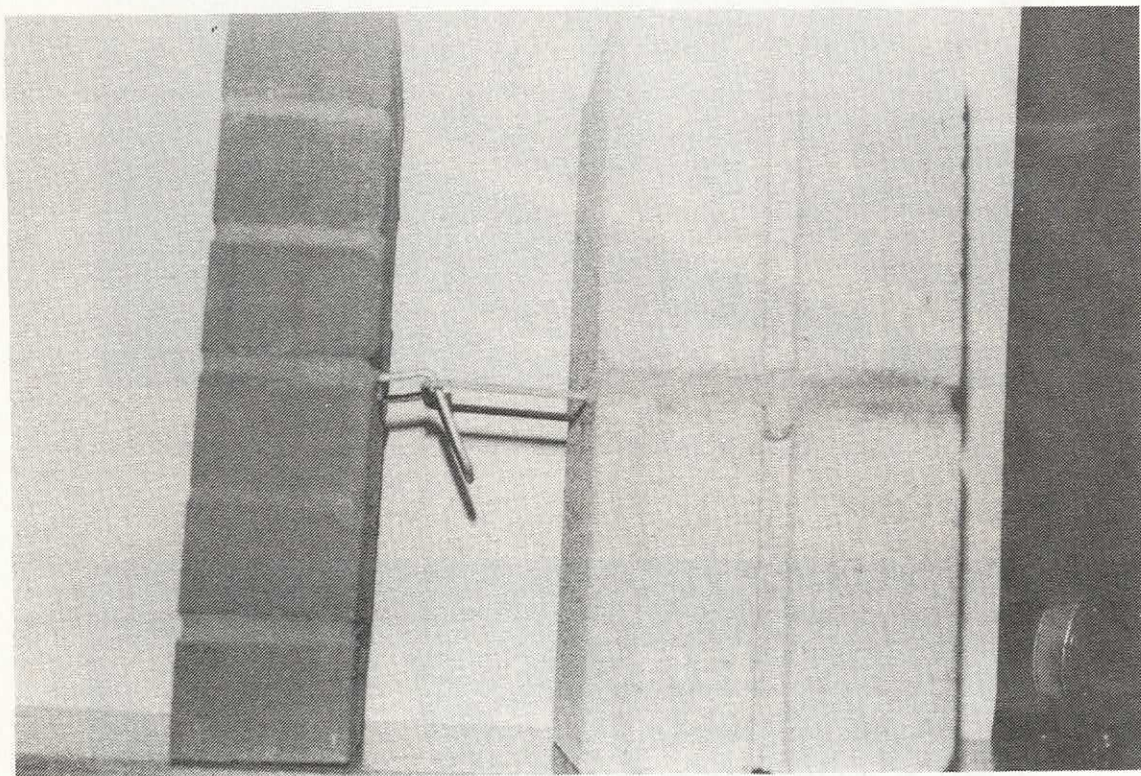


Photo 5 Excessive deflection of adjustable tie
in tension.

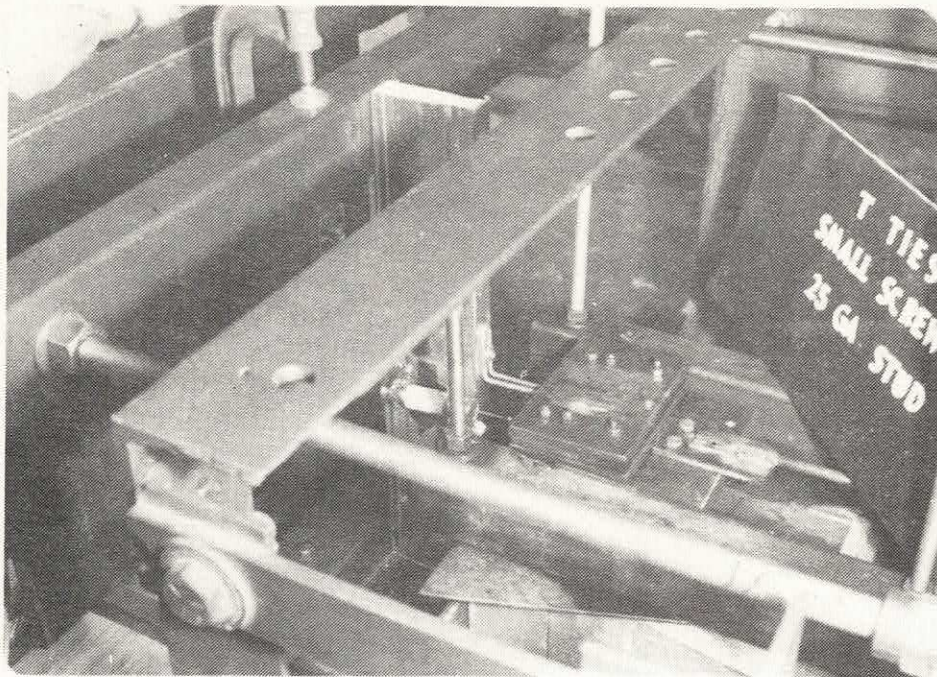


Photo 6 Wire tie attached to metal stud prior to testing.



Photo 7 Wire Tie attached through drywall to metal stud.

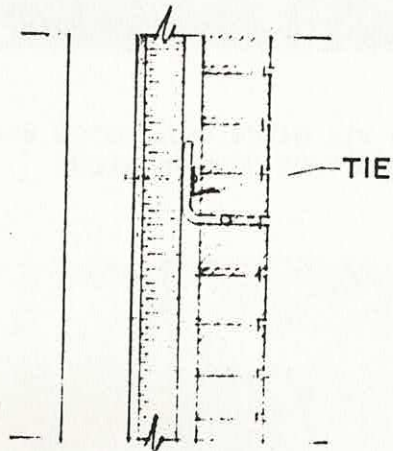
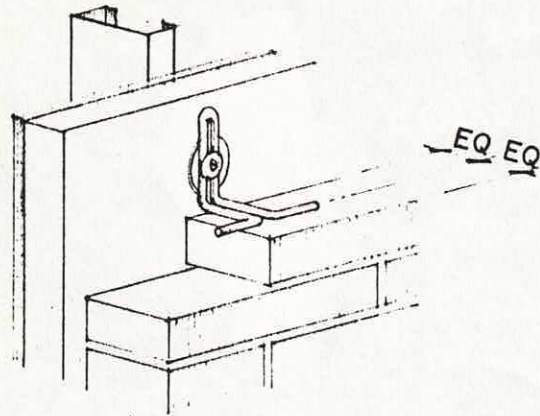


Figure 4 Adjustable wire veneer ties

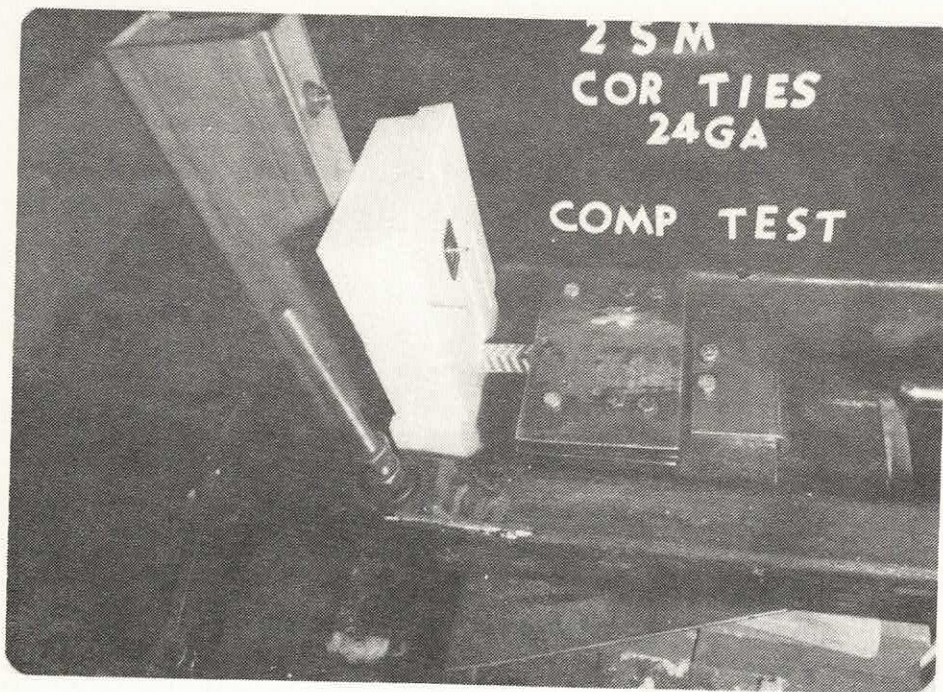


Photo 8 Corrugated strip tie attached to metal studs through the joint of styrofoam SM*

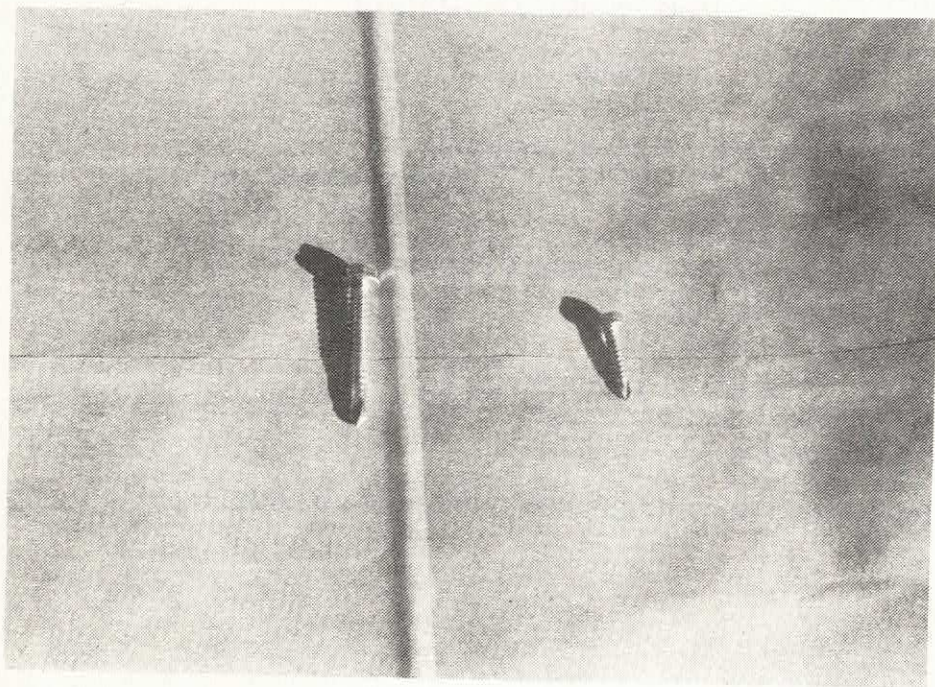


Photo 9 Types of screws used to fastened corrugated strip ties.

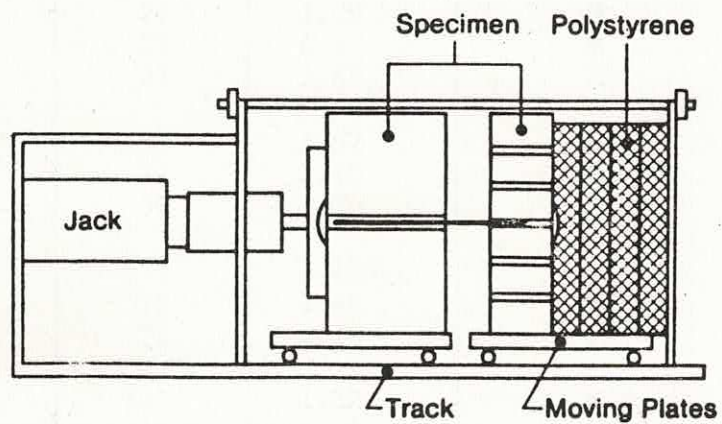


FIGURE 5 SCHEMATIC REPRESENTATION OF TESTING SYSTEM OF COMPRESSION.

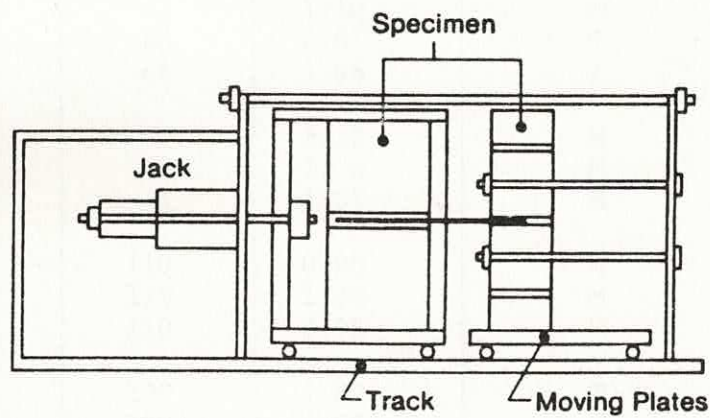


FIGURE 6 SCHEMATIC REPRESENTATION OF TENSION TEST.

TABLE 1 COMPRESSION TEST RESULTS ADJUSTABLE TIES

Type of tie	Insulation Thickness mm	Overall Cavity width mm	Failure Load kN	Failure Mode (1)
A	0	26	1.39	M
	0	27	0.93	M
	0	25	2.64	M
	0	52	1.57	M
	0	52	2.26	M
	0	50	1.70	M
	0	75	1.13	M
	0	78	1.48	M
	0	75	2.18	T
	25	101	1.52	M
	25	96	1.39	M
	25	103	1.70	M
	25	61	1.10	M
	25	60	2.61	T
	25	66	1.95	T
	25	40	3.38	M
	25	45	1.38	M
	25	41	1.61	M
	50	110	0.95	M
	50	115	1.38	M
	50	110	0.95	M
	50	100	1.67	T
	50	100	0.66	M
	50	100	1.48	M
	50	72	0.51	M
	50	68	1.10	M
	50	70	2.26	M

(1) M = Masonry Failure.
T = Tie Failure

TABLE 2 TENSION TEST RESULTS ADJUSTABLE TIES

Type of Tie	Insulation Thickness mm	Overall Cavity width mm	Failure Load kN	Failure Mode (1)
A	0	30	0.89	M
	0	32	2.00	M
	0	28	1.64	M
	0	54	1.77	M
	0	52	2.20	M
	0	55	1.77	M
	0	76	0.44	M
	0	82	0.64	M
	25	62	1.74	M
	25	65	2.16	T
	25	64	1.98	M
	50	99	2.05	T
	50	98	2.33	M
	75	115	2.30	T
	75	125	2.23	M
	75	112	2.39	T
B	25	52	2.80	M
	75	108	1.64	M
	75	110	1.57	M
	75	110	1.85	T
A	75	135	1.28	M
	75	135	1.11	M
	75	142	1.57	T
	75	112	2.05	T
	75	111	1.56	T
	75	113	1.64	T
	75	94	1.61	M
	75	91	1.49	M
	75	94	0.85	M

(1) M = Masonry Failure
T = Tie Failure

TABLE 2 TENSION TEST RESULTS ADJUSTABLE TIES
continued.

Type of Tie	Insulation Thickness mm	Overall Cavity width mm	Failure Load kN	Failure Mode (1)
B	25	50	1.95	M
	25	51	1.51	M
	25	50	1.34	M
	25	90	1.33	M
	25	90	1.03	M
	25	87	1.34	M
	75	121	1.51	M
	75	121	1.03	M
	75	126	2.33	M
	75	109	1.41	M
	75	110	1.80	M
	75	110	1.48	M

(1) M = Masonry Failure

T = Tie Failure

TABLE 3. TENSILE CAPACITY OF "T" TIES ATTACHED TO METAL STUDS.

Metal Stud Gauge	Size of screw mm	Location of screw from bend mm	Failure load kN	Remarks
25	2.57	23	0.51	screw pulled out
25	2.57	20	0.53	"
25	2.57	22	0.37	"
25	2.57	5	0.62	"
25	2.57	10	0.58	"
25	1.57	13	0.51	"
25	4.45	13	0.37	"
25	4.45	3	0.58	"
25	4.45	3	0.80	"
20	2.57	18	0.58	"
20	2.57	20	0.69	"
20	2.57	26	0.85	"
14	2.57	18	0.94	"
14	2.57	13	1.00	"
14	2.57	14	1.79	"
14	4.45	2	2.01	"
14	4.45	3	2.22	"
14	4.45	5	1.77	"
14	4.45	41	1.20	"
14	4.45	31	1.38	"
14	4.45	42	1.17	"
20	4.45	18	1.16	"
20	4.45	22	1.03	"
20	4.45	21	1.00	"
20	4.45	20	0.87	"
20	4.45	12	1.23	"
20	4.45	20	0.96	"
20	4.45	30	0.71	"
20	4.45	23	0.96	"
20	4.45	25	0.64	"
20	4.45	32	1.16	Ties attached on top of gypsum board.
20	4.45	28	1.16	
20	4.45	29	1.00	

TABLE 3. TENSILE CAPACITY OF "T" TIES ATTACHED TO METAL STUDS - continued.

Metal Stud Gauge	Size of screw mm	Location of screw from bend mm	Failure load kN	Remarks
20	4.45	30	0.87	Ties attached on top of gypsum board
20	4.45	38	1.23	
20	4.45	30	0.96	
20	4.45	29	0.71	Screw pulled out "
20	4.45	27	0.96	
20	4.45	28	0.69	

TABLE 4. COMPRESSIVE CAPACITY OF "T" TIES

Stud Gauge	Cavity mm	Location of mm	Failure Load kN	Remarks
25	78	2	1.16	Flange of stud failure "
25	84	11	1.09	
25	82	12	1.18	
20	83	7	2.42	" " "
20	82	10	2.60	
20	81	9	2.44	
14	80	20	3.59	Tie buckled Tie and flange buckled Flange buckled
14	83	12	3.43	
14	82	14	4.35	

TABLE 4. COMPRESSIVE CAPACITY OF "T" TIES
continued.

Stud Gauge	Cavity mm	Location of mm	Failure Load kN	Remarks
20	28	19	2.44	Stud flange bent
20	34	21	2.55	
20	36	14	2.89	
20	82	16	2.13	
20	82	7	2.33	
20	81	12	2.44	
14	34	17	3.40	Tie buckled
14	35	16	3.50	Flange bent
14	37	18	3.34	Tie buckled

TABLE 5. CAPACITY OF CORRUGATED STRIP TIES IN COMPRESSION

Tie Gauge	Cavity (including insulation) mm	Glasclad Insulation Thickness mm	Failure Load kN
24	94	no insulation	0.260
	97	"	0.215
	93	"	0.238
	89	"	0.283
	94	"	0.238
	88	"	0.283
	93	25 mm	0.260
	98	"	0.283
	94	"	0.260
	94	50 mm	0.283
	95	"	0.328
	95	"	0.283
22	96	no insulation	0.418
	99	"	0.395
	98	"	0.395
	95	"	0.440
	90	"	0.440
	93	"	0.418
	95	25 mm	0.395
	90	"	0.440
	95	"	0.373
	97	50 mm	0.395
	93	"	0.418
	98	"	0.485

TABLE 5 CAPACITY OF CORRUGATED STRIP TIES IN
COMPRESSION - continued

Tie Gauge	Cavity (including) insulation mm	SM Insulation Thickness mm	Failure Load kN
22	96	25 mm	.575
	97	"	.710
	98	"	.553
22	95	50 mm	.665
	95	"	.800
	95	"	.778
24	91	25 mm	.485
	90	"	.508
	90	"	.558
24	90	"	.530
	91	"	.598
	90	"	.485

SM = styrofoam insulation