Criteria for Conducting and Recording Small-Scale Tests of Steel Stud Wall Panels

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Preface

Current design standards for axial loadbearing steel studs in Canada and the United States permit the carrying capacity of the studs to be influenced by the type of sheathing used. The sheathing, if capable, is deemed to provide torsional and lateral restraint to each stud to which it is adequately attached thus reducing the amount of steel bridging that would otherwise be required. Since the steel studs are the structural components of the wall assemblies, it is important that their load-carrying capacity be accurately estimated. The parameters which influence the structural design of stud wall systems dependent on sheathing for bracing are best determined directly from racking tests of full scale wall panels. However, this is an expensive procedure, and small-scale tests can be substituted without greatly sacrificing the accuracy of the results, which are usually conservative compared with full-scale tests.

Design standards such as CAN/CSA S136-M89 permit the use of small-scale tests "described by published, documented methods". While such methods exist, they have not been available as a standardized procedure from any known source.

The testing criteria given herein are taken verbatim from the CMHC project "Criteria for the Testing of Wall Sheathing for Load-Bearing Steel Studs", March 1990, by D.L. Tarlton, P.Eng., R.M. Schuster, P.Eng., and A.S. Zakrzewski, P.Eng.. This project was carried out with the assistance of a grant from the Canada Mortgage and Housing Corporation under the terms of the External Research Program. The views expressed are those of the authors and do not represent the official view of the Corporation.

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Criteria for Conducting and Recording Small-Scale Tests of Steel Stud Wall Panels

1. Purpose and Scope

1.1 The criteria given herein for conducting and recording small-scale tests of steel stud wall panels are intended to provide the basis for assessing the ability of sheathing and its attachments to provide lateral and torsional stability to steel studs which are required, in service, to resist axial load, with or without transverse load.

1.2 Test values obtained in accordance with these criteria are valid for design application only where the specified framing members, sheathing and attachments are essentially similar to those used in the test program from which the test values were obtained.

1.3 Where test values obtained in accordance with these criteria would not be valid for design applications because of the intended configuration, assembly, loading or use of a steel stud wall panel in service, tests shall be performed and evaluated in accordance with ASTM Standard E564 or in accordance with another recognized procedure prescribed by, or acceptable to, the authority having jurisdiction.

1.4 The suitability of a specific sheathing material for a particular application may be dependent on environmental or other factors which must be taken into consideration in addition to test results obtained in accordance with these criteria.

2. Reference Documents

2.1 **ASTM C954** - Steel Drill Screws for the Application of Gypsum Board or Metal Plaster Bases to Steel Studs From 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness (1986)
ASTM C1007 - Installation of Load Bearing (Transverse and Axial) Steel Studs and Related Accessories (1983)
ASTM E72 - Methods of Conducting Strength Tests of Panels for Building Construction (1980)
ASTM E564 - Method of Static Load Test for Shear Resistance of Framed Walls for Buildings (1976)

2.2 **CAN/CGSB-7.1** - Cold Formed Steel Framing Components (1986)

2.3 **CAN/CSA-S136** - Cold Formed Steel Structural Members (1989)

3. Summary of Method

3.1 The shear strength, shear rigidity and shear strain of a set of test specimens are determined by racking each specimen from a rectangle to a parallelogram. This is accomplished by anchoring the bottom edge of the specimen to the test fixture and applying a load perpendicular to the vertical edge of the specimen near the top. The specimen is allowed to distort in its own plane. The applied loads and corresponding deflections are measured. In a cyclic load test, opposing loads are applied at each vertical edge in a defined sequence.

4. Test Specimens

4.1 General

Test specimens shall be constructed in accordance with Figure 1 and the requirements of Clause 4.

4.2 Sheathing

4.2.1 - The type of sheathing, including the brand name, the manufacturer and all pertinent product information shall be recorded prior to testing.

4.2.2 - Thickness shall be determined as the average of four measurements taken around the perimeter of each sheathing element in a test specimen. Sheathing thickness shall be representative of that used in actual construction.

4.2.3 - The height and width dimensions of a sheathing element shall be 610 mm (+3 -0).

4.2.4 - All edges shall be cleanly cut. Taped or finished edges, as on uncut sheets of gypsum board, shall not be permitted.

4.2.5 - Care shall be exercised to avoid damage to sheathing elements, particularly their corners, when assembling and installing test specimens.

4.3 Steel Studs

4.3.1 - Steel Studs shall conform to CAN/CGSB-7.1 and shall have no cut-outs.

4.3.2 - Steel studs shall have a depth of 92 mm, a flange width of 41 mm, a thickness of 1.2 mm and be 603 mm (+0 -3) in length.

4.4 Steel Track

Steel Track shall conform to CAN/CGSB-7.1 and shall have a depth compatible with the steel studs, a minimum flange width of 30 mm and a thickness of 1.2 mm. The upper track shall be 610 mm (+0 -3) in length. The lower track shall be 710 mm (+5 -0) in length.

4.5 Steel Screws

4.5.1 - Steel Screws shall conform to ASTM C954. Penetration beyond joined materials shall be not less than 3 exposed threads.

4.5.2 - Studs shall be connected to the tracks with one 10-16 x ½ inch Phillips Low Profile Pan Head screw at each corner on each track flange, (a total of eight fasteners per specimen).

4.5.3 - Sheathing shall be connected to the studs and tracks with the same type of fastener to be used in actual construction. If not otherwise specified, gypsum board shall be connected with 6-20 Phillips Bugle Head screws; fibreboard or plywood shall be connected with 8-18 Phillips Trumpet Head screws; cementitious board shall be connected with 8-18 Phillips Wafer Head screws. A total of 16 fasteners per test specimen are required.

4.6 Assembly of Test Specimens (Figure 1)

4.6.1 - A template shall be used to locate the position of the screw holes on the outside face of each sheathing element. See Figure 1.

4.6.2 - Holes shall be accurately drilled through each sheathing element to permit entry of a screw connector. The hole diameter shall match the screw size.

4.6.3 - The track/stud frame shall be assembled using a jig to ensure accuracy. Dimensions given in Figure 1 are exact, unless noted.

4.6.4 - Each sheathing element shall be fastened to the track/stud frame with carefully driven fasteners inserted in the pre-drilled holes of the sheathing. Fasteners shall be secure but not overtightened.

5. Loading System and Instrumentation

5.1 Unidirectional shear load shall be provided by a hydraulic jack attached to an upright of the test fixture. Cyclic loading requires a second hydraulic jack attached to the other upright of the test fixture so as to provide shear load in the opposite direction. Each jack shall be powered by a separate pump.

5.2 The maximum force to be exerted by the hydraulic jack depends on factors such as the type of sheathing, its condition (e.g. wet or dry), and the size of sheathing screws. For the majority of cases, a hydraulic jack and its pump shall be capable of exerting a load of at least 7.5 kN. A load cell connected to each hydraulic jack shall be calibrated to at least 10 kN.

5.3 A digital strain indicator connected to the load cell by means of a switch-and-balance unit is recommended. The read-out accuracy shall be ± 5 N.

5.4 Dial indicators (or other deformation measurement system) with an accuracy of ± 0.02 mm are recommended for the measurement of deflections. For a static load test (unidirectional load) two dial indicators are required. One indicator, located near the top of the specimen, is used to measure deflection. The second indicator, located at the bottom, is used to determine whether the specimen moves relative to the base of the test fixture. In cyclic load tests two additional dial indicators are required, at the opposite end of the test specimen.

6. Test Procedure

6.1 General

6.1.1 - Prior to testing, assembled specimens not intended for high humidity or water immersion tests in accordance with Clause 6.4 shall be kept for at least 24 hours at a temperature of 22°C (+2 -2) and 40% (+2 -2) relative humidity.
Note: *Deviation of relative humidity beyond 2% can affect shear rigidity. For example, for wafer board or gypsum board sheathing, a 5% increase in relative humidity reduces the shear rigidity by approximately 3%, while a 5% decrease in relative humidity increases the shear rigidity by approximately the same amount.*

6.1.2 - Test specimens shall be examined prior to installation in the test fixture. Cracks, damaged corners, or surfaces excessively damaged by screw heads will affect test results and specimens exhibiting same shall be rejected or refurbished.

6.1.3 - When the test specimen is secured in the test fixture, the dimensions **c**, **d**, **h** and **j** as defined in Figure 3 shall be recorded to the nearest millimetre. The dimensions **c** and **d** are the average of measurements taken at each set of screws (3 sets on each side of the specimen, totaling 6). All dimensions shall be measured from the underside of the lower track.

6.1.4 - In cyclic tests, the dimensions **h** and **j** shall be determined for the instrumentation at each end of the specimen and each end must be positively identified (e.g. "East" and "West").

6.1.5 - Testing shall be performed at a temperature of 22°C (+2 -2) and relative humidity of 40% (+2 -2).

6.1.6 - Dial indicators and digital strain indicators shall be set to zero prior to testing.

6.1.7 - A load equal to approximately 8% of the expected failure load shall be applied, the deflection recorded and load then removed. After a 1 minute interval, reset all dials and strain indicators to zero. For the cyclic load test, the procedure shall be repeated in the opposite direction.
Note: *If the expected failure load is not known, a trial run to obtain an indication of the expected failure load and the corresponding deflection is recommended.*

6.2 Static Test

6.2.1 - Three identical specimens shall be tested. If the value of a result in any of the three tests deviates by more than 10% from the average obtained from the three tests, a fourth test shall be performed and the average values from all four tests shall be determined.

6.2.2 - Should a premature failure occur due to an unusual weakness of the test specimen resulting from undetected damage, incorrectly driven screws, etc., the test shall be invalidated and repeated using another specimen. The test report shall record any such occurrence.

6.2.3 - Apply load in increments as follows:
(a) eight increments equal to 10% of the estimated load at 30 to 40 second intervals,
(b) two increments equal to 5% of the estimated failure load,
(c) further increments equal to 3.5% of the estimated failure load until failure occurs.

6.2.4 - Beginning with the ninth load increment read and record load and deflection twice, the second time two minutes after the first reading. Maintain the load at a constant level.

6.2.5 - After each load increase:
(a) record the value of the load and the corresponding deflection,
(b) visually inspect the test specimen on each side, particularly at each corner, and record the occurrence and location of any cracks, tears, sheathing deformations or other distress.

6.2.6 - The failure load shall be the maximum load that can be sustained by the specimen. When the behavior of the specimen under load indicates that the specimen might fail suddenly and damage the deformation-measuring apparatus, that apparatus shall be removed and the load increased continually until the maximum load that can be applied to the specimen is determined.

6.2.7 - After failure has occurred, the load shall be decreased to zero and the deflection measured after 2 minutes. The mode of failure and condition of the test specimen shall be recorded.

6.3 Cyclic Test

6.3.1 - Load shall be applied and raised in increments as follows:
(a) one increment equal to 20% of the estimated failure load,
(b) four increments equal to 15% of the estimated failure load.
The highest load applied will therefore be 0.8 of the estimated failure load.

6.3.2 - For each load increment there shall be five load cycles, as follows:
(a) load the specimen to the required value at a rate of approximately 1000 N/min,
(b) record the actual load and corresponding deflection,
(c) visually inspect each corner of the test specimen on each side and record the occurrence and location of any cracks, tears, deformations or other distress,
(d) reduce the load to zero, record the deflection and immediately apply an equal load in the opposite direction as in (a) above,
(e) repeat steps (b) and (c),
(f) reduce the load to zero and record the deflection after 2 minutes.
Repeat the sequence for each of the remaining load cycles unless failure occurs in the interim.

6.3.3 - If the specimen did not fail during the cyclic test, apply the load in a single direction from zero to the highest load reached during the cyclic test at a speed of approximately 1000 N/min. Continue loading and recording as in the static test (Clause 6.2).

6.4 High Humidity or Water Immersion Tests

6.4.1 - When testing specimens subjected to high humidity, the specimens shall be first conditioned in an environmental chamber set for the desired relative humidity (e.g. 80 or 100 percent) at a defined temperature (typically 22°C).

6.4.2 - Where an environmental chamber is not available, or where it is preferred, a water immersion test may be substituted.

6.4.3 - In the water immersion test, the specimen shall be immersed flat in a container of water held at 21°C (+1 -1) with a head of 25 mm of water over the top surface of the specimen. The specimen shall be blocked so that it is raised off the bottom of the container.

6.4.4 - The specimen shall remain immersed for:
(a) 2 hours where the sheathing is gypsum board,
(b) 24 hours where the sheathing is wafer board, plywood or cementitious material.

6.4.5 - Upon removal from the water, carefully wipe the surfaces and edges of the specimen and commence load testing immediately.

7. Test Report

7.1 The test report shall include the following information:

(a) date of test and of report,
(b) names and addresses of test sponsors and test agency,
(c) names of testing personnel,
(d) identification of the materials in the specimens (manufacturer, type, source of supply and other pertinent information),
(e) dimensions of test specimen,
(f) details of attachment of test specimen in the test fixture,
(g) location of loading jacks and dial indicators and description of test equipment,
(h) list of observers,
(i) photographs of the test assembly and representative specimens (before and after testing) with descriptive captions or text,
(j) signatures of responsible persons,
(l) all raw data in tabular form.

Note: *A drawing may be used to show information required by (e), (f) and (g).*

7.2 The test report shall include the following calculations and graphs:

(a) the adjusted loads and corresponding deflections for each tested specimen,
(b) the adjusted average loads and corresponding deflections for each set of tested specimens,

Note: *Loads and deflections are required to be adjusted from those observed in order to obtain the deflection at the level of the top row of screws with the load applied at the same level.*

(c) the shear rigidity,
(d) the shear strain,
(e) a load/deflection graph for the adjusted average loads and deflections for each set of tested specimens.

Note: *Where cyclic tests are performed, a graphical representation of the hysteresis peak of the last cycle of each of the first four load increments, and a complete hysteresis curve of the last cycle of the fifth load increment is recommended to be included, in addition to the static load/deflection curve.*

7.3 Loads and deflections are required to be adjusted from those observed in order to obtain the deflection at the level of the top row of screws with the load applied at the same level. These adjusted loads and adjusted deflections are calculated as follows:

(a) from the measured dimensions c, d, h and j (Figure 3) determine $e = d - c$; $f = h - c$; and $g = j - c$ for each test specimen. (For cyclic load tests determine also $f' = h' - c$ and $g' = j' - c$ for each test specimen).
(b) calculate the adjusted load $P' = P(f/e)$, where P is the value of each recorded load for each test specimen.
(c) calculate the adjusted deflection $\Delta' = \Delta(e/g)$ where Δ is the value of the recorded deflection corresponding to each recorded load P.
(d) determine the adjusted average loads P" and corresponding deflections Δ" for each set of tested specimens. ($P'' = \Sigma P'/n$; $\Delta'' = \Sigma\Delta'/n$ where n is the number in a set).

7.4 The shear rigidity and shear strain are calculated from the adjusted average loads and deflections for a set of tested specimens as follows:

(a) shear rigidity $q = 0.8P_u''/\Delta_{0.8}''$
where, P_u'' = adjusted average ultimate (failure) load
$\Delta_{0.8}''$ = adjusted average deflection corresponding to $0.8P_u''$
(b) shear strain $\gamma = \Delta_{0.8}''/e$

7.5 Shear rigidity, q, and shear strain, γ, shall be converted to limit shear rigidity q_o and limit shear strain γ_o for use in conjunction with CAN/CSA-S136.

$q_o = q/(2 - s/300)$
$\gamma_o = \gamma(2 - s/300)$

where s is the fastener spacing

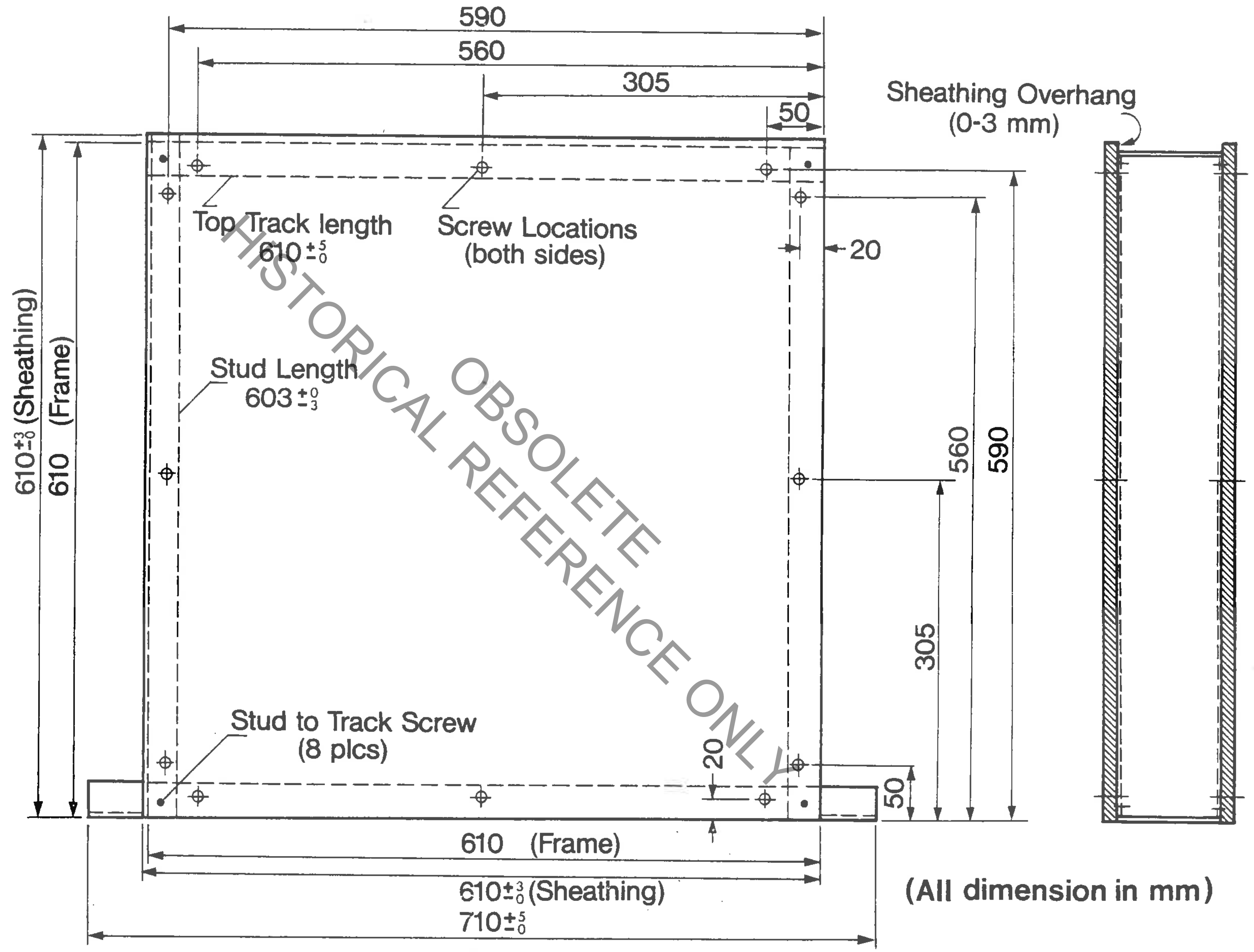
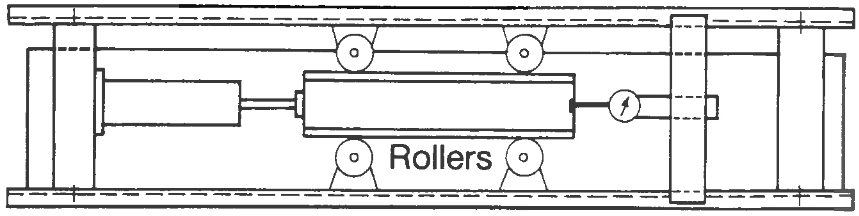


FIGURE 1: Specimen Dimensions



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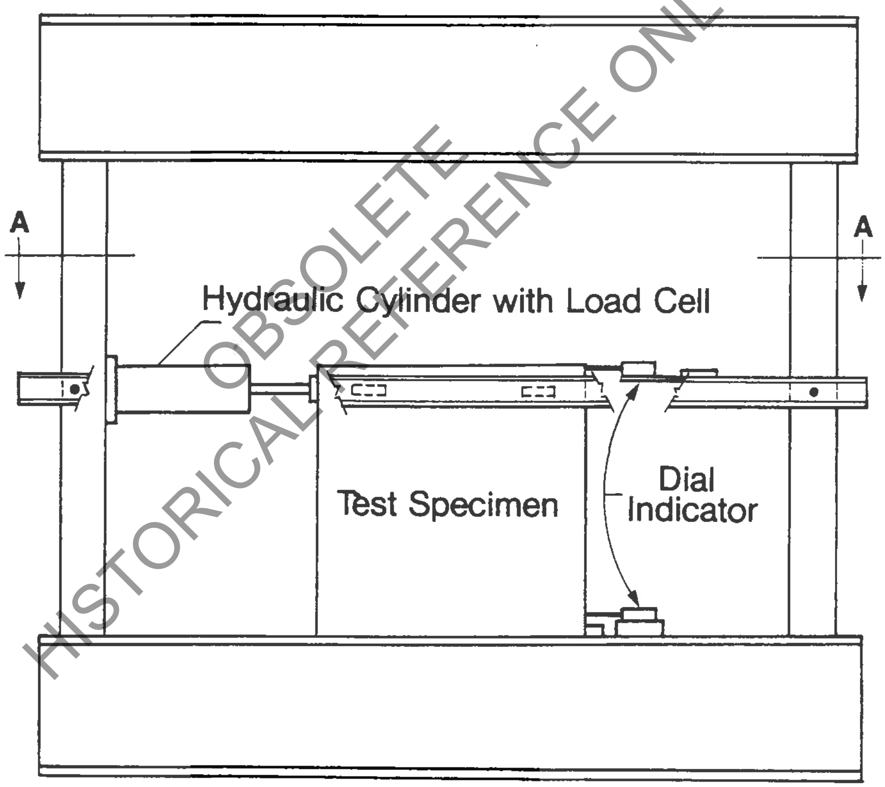
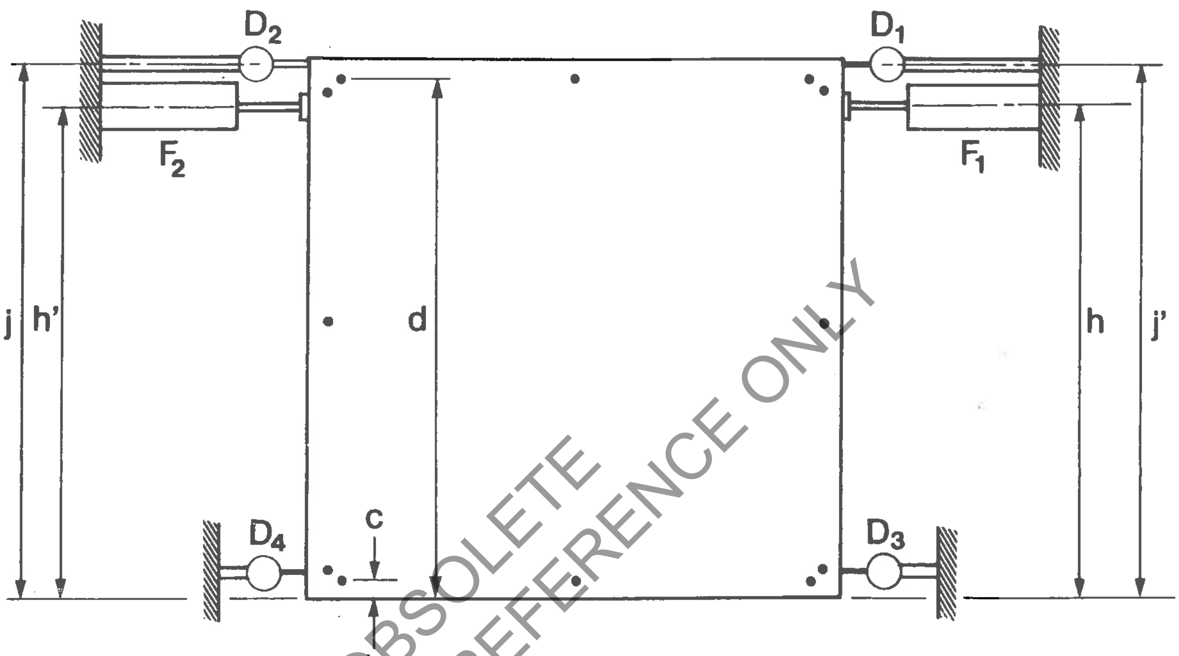


FIGURE 2: Test Fixture with Mounted Specimen (Uni-Directional Loading)



Static Load: Use F_1, D_2 & D_4
Cyclic Load: Use F_1 with D_2 & D_4
and F_2 with D_1 & D_3

NOTE: Dimensions h' and j' are measured when conducting cyclic load tests

FIGURE 3 : Instrument Positions & Test Measurements

Commentary

Comments on the specific Clauses of the Criteria are intended for explanatory purposes.

Clause 1.4 For a particular application a specific sheathing may need to be assessed for fire resistance, flame spread, durability. ease of installation, cost, and availability, in addition to the properties determined by small-scale racking tests.

Clause 4.3.2 The size of the steel stud (and track) should be kept the same for every test if comparative results are required.

Clause 4.6 The requirements of a template to locate the position of screw holes and the requirement that pilot holes be drilled in each sheathing element is aimed at eliminating as many unintentional variables from the testing as possible. Screws are not placed nor driven with the same degree of precision in the field and it might be argued that this should be taken into account when establishing design values from test results. However, because of the size factor, actual lightweight steel framed wall assemblies usually are such that a corner failure due to racking would not cause as much loss of capacity as would be the case with a similar occurrence in a small-scale test. Also, a study (Project 1201-455) sponsored by the American Iron and Steel Institute (AISI) in 1988, to determine the relationship between the number and distribution of sheathing fasteners and the shear rigidity of the wall assembly, has shown that the shear rigidity of walls of various sizes can be predicted from 600 x 600 mm specimens for any configuration of fasteners. Thus it seems reasonable to take the values obtained by test as being representative of the values that would relate to actual construction and valid for design purposes.