TESTS SHOW SPF INCREASES STRENGTH IN LIGHT STEEL FRAME CONSTRUCTION!

The National Association of Home Builders Research Center released test results of SPFD sponsored rack and shear testing of SPF between steel stud panels. SPFD's Building Envelope Committee promulgated the research study in an effort to increase knowledge of SPF's structural properties in the growing light of the steel frame construction market. NAHB Research Center conducted the tests in accordance with ASTM E-72 Standard Methods of Conducting Strength Tests of Panels for Building Construction on four different wall assemblies. Each 8' x 8' wall panel was constructed with 20-gauge (33 mil) structural light-weight steel framing as follows:

- **Test 1.** 7/16" OSB (front side) and 1/2" drywall (back side) with R-19 fiberglass batt insulation in wall cavities.
- **Test 2.** 1/2" drywall (both sides) with R-19 batts in wall cavities.
- **Test 3.** 7/16" OSB (front side) and 1/2" drywall (back side) with SPF in wall cavities.
- **Test 4.** 1/2" drywall (both sides) with SPF in wall cavities.

The OSB sheathing was fastened with No. 8 x 1/14" rock board screws spaced 6" on center at edges and 12" on center in the field. Drywall was fastened with No. 6 x 1/14" drywall screws spaced 12" on-center at edges and in the field. All drywall joints were spackled and taped, and all drywall screws were covered with one coat of drywall compound.

Racking Test Results

Specimen	Max. Racking Load (lbs)	Max. Racking Deflection (in.)	Max. Racking Set (in)
OSB with R-19	4,800	1.045	0.516
OSB with SPF	6,000	0.767	0.142
Drywall with R-19	2,400	0.856	0.413
Drywall with SPF	5,380	0.945	0.407

As evidenced by the results shown on the table above, SPF significantly increased rack and shear strength of both panels. However, proportionally more strength was added to the drywall faced panels, i.e. the weaker panels more than the stronger OSB sheathed panels. NAHB Research Center said it is significant that "the racking deflections and sets for the SPF specimens were consistently lower than racking deflections and sets for the conventional specimens at a given load. It should also be noted that failure of the SPF-filled OSB specimen was due to buckling of the steel frame as opposed to failure of the sheathing."

A special thanks goes to Foam Enterprises for supplying the spray polyurethane foam for this project.

For a copy of the complete study, contact SPFD @ 1-800-523-6154.

SPFD NOTES

SPFD WELCOMES NEW MEMBERS

Adkinson Construction and Roofing,
1322 Logan Street, Chillicothe, IL 61523
Tel: 309/274-5563
Contact: Chris Adkinson

Cold Jet, Inc., 455 Wards Corner Rd., Loveland, OH 45140
Tel: 513/831-3211 Fax: 513/831-1209
Contact: David Eddy

SAC of America, Inc., 27 Governor Street, Ridgefield, CT 06877
Tel: 203/438-8144 Fax: 203/431-4888
Contact: Stephen J. Thompson

Waterproofing by Coastal Coatings, Inc., 218 Benchmark Trail, Belton, TX 76513
Tel: 817/547-1527
Contact: Brett Matney

Our goal is to have the most up-to-date database possible. Please advise us when you have a change of company name, address, phone or fax number or company representative. You may fax any changes to Sherry Norman at 202-296-7005.

IMPORTANT NOTICE

It is imperative that anyone who takes Accreditation courses ***must*** be enrolled in the Accreditation Program. If you are not sure whether you are enrolled or not, please contact Sherry Norman, Manager of the Accreditation Program @ 800-523-6154 for assistance.

INTRODUCTION

The above study was initiated by the Polyurethane Foam Structural Quality Assessment Committee of The Society of The Plastics Industry, Inc. It was ultimately funded by the Polyurethane Foam Contractors Division Steering Committee and the Polyurethane Division Rigid Urethane Foam Group. The objective was to establish the structural value of spray in place polyurethane foam used in wood frame wall constructions. The original plan called for three phases. The first was a paper review of all available data, the second was laboratory evaluation and the third was full model testing.

OBJECTIVES

The original plan intended to quantify the structural value quality of the sprayed polyurethane foam (SPF) . The tests were to show that the sprayed polyurethane foam could replace building components such as studs, sheathing and corner bracing. Once statistical data is collected , we will make comparisons to identify the market opportunities that (SPF) would fulfill. Increasing concerns about energy issues, global warming and the earth's environment has led to many new innovations and construction techniques. The huge market of newly built homes appeared to be a good potential for sprayed polyurethane foam use. The National Assn. of Home Builders Research Center was selected to carry out the plan.

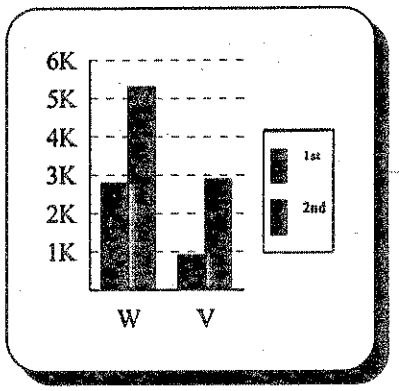
PRELIMINARIES

Coordination meetings were conducted after the initial funding was approved for Phase 1 and 2. Phase 2 required a spray applicator near the NAHB laboratory site who would support the effort. American Elasto-seal was selected and donated the labor and equipment. Foam Enterprises, Inc. donated the polyurethane foam compounds. The plan was put together by NAHB and the PFCD committees. It was determined that tests would be performed for racking (shear) resistance and also for compressive (axial) resistance. A total of 45 panels would be built using different configurations.

RACKING(SHEAR)

This test evaluates the resistance of the wall construction to wind forces on the wall. Conventional construction of walls require bracing using panels or diagonal bracing straps.

Thirty racking panels were constructed. Eighteen of these were filled with sprayed polyurethane foam (SPF). For comparison twelve control panels were constructed without (SPF). These panels were built using 2 x 4's and were 8 ft. high by 8 ft. wide. Half inch, 4 ft. x 8 ft. sheet rock was installed horizontally on the panel with the seam taped and finished. The conventional panels used half inch fiberboard sheathing or half inch plywood on the exterior walls. The chart below shows the comparison test on 16 inch on center studs with and without foam.(Expressed in pounds.)



The first two columns are for plywood siding(w) and the second two columns are for vinyl siding(v). The dark column shows the panels with no foam and the light column shows the panels with foam. As compared to the panels without foam or sheathing: the foam filled panels were 300% higher in pounds of resistance for the wood siding (T1-11) and 200% higher for the vinyl panels. ***This clearly proves that sprayed polyurethane foam adds racking strength to wall panels.*** The study also showed that 16", 24", 32" and 48" on center stud spacing contributes to the structural (racking) resistance of a wall construction.

A	B	C	D	E
16"	2,800	5,300	913	2,890
24"	2,420	6,387	-----	-----
32"	2,588	-----	-----	-----
48"	2,298	-----	-----	-----
16"	**conv. wall**		**3,853**	**5,262**

The conventional wall in the last row contained sheathing and plywood panels. The above chart shows the average values for the various configurations. The columns are:

A Stud Spacing
B SPF with Vinyl siding
C SPF with Plywood siding
D Vinyl no foam
E Plywood no foam

This shows how the strength of the foam interrelates with the sheathing strength and stud spacing. It must also be pointed out that plywood and wood fiber sheathing create the strength values that are now accepted construction.(as seen in the last row) It is clear that the use of sprayed polyurethane foam (SPF) in stud wall construction will produce a much stronger building. ***The chart shows that in the case of the wood siding and sprayed polyurethane foam, the values exceeded conventional construction without using sheathing and plywood bracing panels. Direct application to the vinyl siding with the sprayed polyurethane foam (without building paper in-between) would most likely also produce higher values similar to the foam and wood siding.***

COMPRESSIVE(AXIAL)

The second test that was performed is designed to determine if the SPF would add any strength to the compressive capabilities of the wall construction. The axial test measures the resistance of panels to a compressive load as would be imposed by the dead or live loads of overhead floors or roofs carried by the walls. The wall strength in this test comes from the stud spacing and the sheathing materials. Obviously, SPF is not as strong as wood in certain construction techniques. Adhesion of all the construction elements is important to the overall strength of these test panels. Again both wood and vinyl siding were used without sheathing for the sprayed polyurethane foam (SPF). The test was for 16" on center and also 24" on center studs. Each stud spacing variation was done with the vinyl and wood siding. Measurements were made for weightload in pounds and also deformation values. The values of the wood siding with sprayfoam were very similar for the 16" and 24" on center studs. This shows the importance of adhesion for the strength values. The 16" vs. 24" on center stud values for vinyl were not as close. The increase stud spacing showed lower strength values. This can probably be attributed to the building paper (felt) that was used between the foam and the vinyl siding. The adhesion would not be as great as the wood siding because of this "slip joint" material.

The principal means of failure in this test is the crushing of the walls wood top plate. The conclusion can also be drawn that the strength for the wall section in this test method is gained primarily from the stud spacing , stud size, sheathing material and the siding .

The following chart shows the average maximum supported load strengths for the various panel configurations.

A	B
16" foam vinyl	24,000 lbs
16" foam wood	28,000 lbs
16" conv.wood	**28,667 lbs.**
24" foam vinyl	18,667 lbs.
24" foam wood	23,000 lbs.

The above column A shows the panel configuration. The B column shows the average maximum supported load in pounds,

SUMMARY

The test has positively shown that the sprayed polyurethane foam (SPF) adds strength to the wood frame wall panel. The racking test shows that the foam/wood siding material can be as strong or stronger than the conventional plywood panel/fiberboard sheathing construction technique. Special bracing for wind resistance would not be required for strength purposes when using sprayed polyurethane foam in the walls. 16" and 24" on center stud placement provides greater racking resistance than the conventional fiberboard sheathing used with plywood panels using 16" o.c stud spacing.

The 16" o. c. stud spacing using SPF in the walls without sheathing comes very close to the values of conventional panels when tested for compressive (axial) strength

The use of sprayed foam can become a major factor in reducing the cost of wood frame construction by allowing 2 x 6 replacement with 2 x 4's. The high R value also allows the R-19 wall requirements to be met with 2 x 4 construction.

NAHB RESEARCH CENTER

400 Prince George's Boulevard • Upper Marlboro, MD 20772-8731 • (301) 249-4000 • FAX 249-0305

April 15, 1992

Mr. George Sievert
Manager
Polyurethane Foam Contractors Division
The Society of the Plastics Industry, Inc.
1275 K Street, Suite 400
Washington, D.C. 20005

RE: Report for Phase 2 - Wall Panel Performance Testing

Dear George,

Enclosed are two copies of the Phase 2 report Wall Panel Performance Testing for the Testing and Adoption of Spray Polyurethane Insulation for Frame Building Construction program. We have incorporated the comments made by you at our recent meeting and we hope that this meets with your approval. Please call if you have any questions or comments.

We look forward to future work with SPI on this and other areas of interest to both of us.

Sincerely,

Edward M. Laatsch, P.E.

Enclosures

cc: Tom Kenney
Don Luebs

EML:ldm

TESTING AND ADOPTION OF SPRAY POLYURETHANE INSULATION FOR WOOD FRAME BUILDING CONSTRUCTION

Phase 2 -- Wall Panel Performance Testing

Prepared for

The Society of the Plastics Industry, Inc.
Polyurethane Foam Contractors Division
1275 K Street, NW, Suite 400
Washington, D.C. 20005

by

NAHB Research Center
400 Prince George's Boulevard
Upper Marlboro, MD 20772-8731

May 25, 1992

EXECUTIVE SUMMARY

A total of 45 wall panels (fifteen groups of three) were tested in accordance with ASTM standard test methods. Thirty panels were tested for racking (shear) resistance and fifteen panels were tested for compressive (axial) resistance. Eighteen of the thirty racking panels were filled with spray polyurethane foam (SPF) and twelve of the fifteen compressive panels were filled with SPF. The remaining panels served as controls. The Society of the Plastics Industry, Inc., provided sprayed polyurethane foam in containers listed as 1.5 pcf density.

Test Methods

These panels were tested in accordance with ASTM Standard E72, "Standard Methods of Conducting Strength Tests of Panels for Building Construction". Section 9 of the standard covers resistance of walls to compressive loads and Section 14 covers resistance of walls to racking loads.

The significance of the racking tests centers around SPF's ability to provide racking resistance for the wall against wind loading in lieu of diagonal bracing. The compressive test measures the resistance of panels to an axial load imposed by live or dead loads on top of walls, such as overhead floors or roofs.

There are two commonly used ASTM standard test methods which are applicable for determining the racking resistance of building panels, ASTM E72, Section 14 and ASTM E564. ASTM E72 is designed to evaluate the racking load resistance of sheathing materials on a standard 8 ft. x 8 ft. wood frame and E564 is designed to measure the racking performance of an entire wall assembly. The intent of these tests was to determine how SPF-filled wall panels compare with conventionally braced wall panels. ASTM E72, Section 14, was selected as the most appropriate method for purposes of this program.

ASTM E72, Section 9, was selected as the most appropriate compressive load test method. It is the recognized standard method for determining the compressive resistance of standard building panels.

Racking Test Results

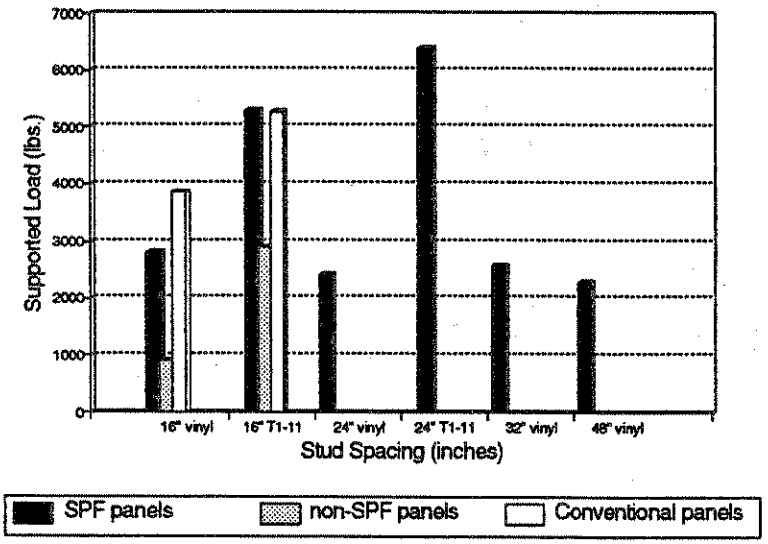
The racking test results showed that the SPF panels with textured plywood siding (T 1-11) had greater racking resistance than the conventional T 1-11 siding, with 16" on center stud spacing. The SPF panels with vinyl siding applied direct to the studs provided an average of 70 percent of the racking resistance of the conventional sheathed vinyl siding panels for all stud spacing.

The racking panels described as "conventional" construction in these tests are representative of standard building practice. However, the conventional 4 foot wide plywood sheathing corner brace covers half of the 8 ft. wide test panels whereas, in reality, the percentage of wall covered by plywood bracing would be much less. As a result, the total racking resistance of the

conventional panels tested would meet or exceed the racking resistance of similar field elements and the SPF panels could meet or exceed the racking resistance of conventional field construction.

Based on the results of the SPF panels with vinyl siding and stud spacings of 16", 24", 32" and 48" on center, stud spacing does not appear to be a major factor in total racking resistance. The figure below shows the maximum racking loads resisted for all ten sets (30 panels) of racking tests.

Racking Test Results
Maximum Supported Load vs. Stud Spacing



There were three distinct failure mechanisms in all of the racking panels. These were failure of gypsumboard sheathing at the taped joint and fasteners, failure of the panel base plate in flexure, and failure of the SPF material itself.

Compressive Test Results

The compressive load tests did not show any increase in the strength of the panels due to SPF. No mechanism developed in the test panels to transfer the applied axial loads from the wall plates, studs and sheathing to the SPF material. The principle mode of failure was crushing of the top plate at the studs. Adding SPF did not appear to contribute to compressive resistance of the panels nor did it adversely affect their performance.

1.0 INTRODUCTION

In 1989, the Society of the Plastics Industry, Inc. (SPI), Polyurethane Foam Contractors Division contracted the NAHB Research Center (Research Center) to conduct a research program entitled "Testing and Adoption of Spray Polyurethane Insulation for the Home Building Industry". The first phase of the program consisted of a feasibility study consisting of a detailed literature review and an engineering analysis of the strength and thermal properties of building panels with sprayed polyurethane foam (SPF). Phase II of the program consisted of laboratory testing to verify conclusions of the engineering analysis in the first phase. This report presents the results of Phase II.

Laboratory tests were performed to investigate the comparative racking and axial strengths of wall constructions containing SPF, panels without SPF, and conventionally constructed control panels. Fifteen groups of three test panels representing a total of 45 wall panels were built. These panels were tested in accordance with the methods specified in ASTM Standard E72, "Standard Methods of Conducting Strength Tests of Panels for Building Construction". Section 9 of the standard covers resistance of walls to compressive (axial) loads and Section 14 covers resistance of walls to racking (shear) loads.

The significance of the racking load tests centers around the ability of the SPF to provide racking resistance against wind loading in lieu of panel or diagonal bracing used in conventional construction. The axial test measures the resistance of panels to a compressive load as would be imposed by the dead or live loads of overhead floors or roofs carried by the walls.

The method of construction of the wall panels is discussed in Section 2.0 and the methods of testing are discussed in Section 3.0. The results of the tests are presented is Section 4.0, and the performance of the various panels is compared and discussed in Section 5.0. The appendices, referenced at appropriate points, contain detailed calculation procedures, data sheets, and test results for all the test panels.

2.0 CONSTRUCTION OF TEST PANELS

2.1 Panel Construction

All panels were constructed of standard 2 x 4 "stud" framing. The racking test panels were 8-feet high and 8-feet long; the axial panels were 8-feet high and 4-feet wide. Conventional half-inch thick, 4' x 8' gypsum wall board (drywall) was applied to the "interior" face of the wood framing with drywall screws. For the 8 x 8 racking panels, the horizontal joint between the sheets of drywall was taped and finished with standard drywall compound.

The panels were constructed on a flat, elevated table and squared in a wooden form prior to sheathing and subsequent SPF application. The exterior faces of the axial and racking panels were covered with either vinyl siding over 15# building paper, 5/8" thick T 1-11 plywood siding panels (textured plywood with vertical grooves at regular intervals to simulate narrower boards) or "conventional" sheathing and siding materials (racking panels only). The conventional panels consisted of a 4 x 8 sheet of 1/2" thick plywood and a 4 x 8 sheet of 1/2" fiberboard sheathing placed side by side and nailed to the framing members, covered with vinyl or T 1-11 siding. The 1/2" plywood sheathing panel represents a method of corner bracing commonly used in conventional construction, and the fiberboard sheathing is typical of non-structural sheathing used on the remainder of the structure.

The materials used to assemble the test panels, except for the sprayed polyurethane foam, were obtained at a local retail lumber outlet. The dimensional lumber was selected by testing its stiffness to assure that all 2 x 4 material fell within plus or minus 10 percent of the allowable for stud grade Spruce-Pine-Fir 2 x 4 lumber (see Appendix A for detailed calculation). All non-conforming 2 x 4s were returned to the lumber outlet.

SPI provided sprayed polyurethane foam in containers listed as 1.5 pcf density, see appendices for additional information. Application was performed by an SPI-member contractor familiar with the SPF application process. A braced wooden form was used to hold the panels upright and square during spraying operations.

Table 1 describes the fastening methods for both the racking and axial test panels. Figure 1 illustrates the configuration of the racking and axial test panels.

Table 1
Panel Fastening Schedule

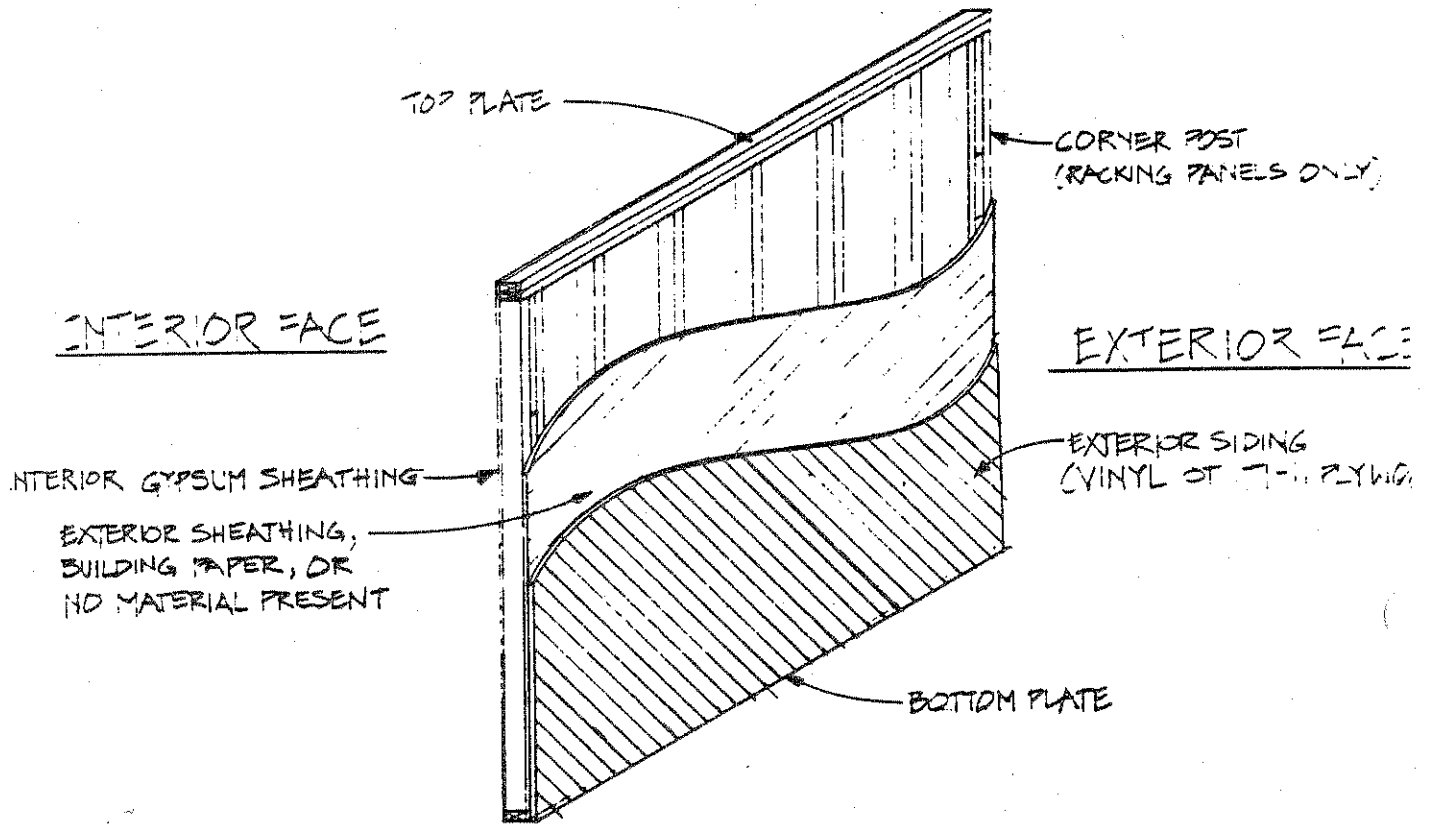
DESCRIPTION	TYPE OF FASTENER	QUANTITY AND APPLICATION
Wall Plate to Stud	16d Coated Sinker Nails	2 Nails Per Stud End
End Studs with 3/4" Spacer	16d Coated Sinker Nails	3 Per Spacer
Top Plate to Wall Plate	10d Coated Sinker Nails	2 Nails at 16 o.c.
Vinyl Siding to Frame or Sheathing	1 1/4" Roofing Nails	1 Per Stud
5/8" Textured Plywood Siding (T 1-11)	8d Ring Shank Galv. Nails	6" o.c. Along Perimeter 12" o.c at Intermediate Supports
1/2" Plywood Sheathing to Framing	8d Ring Shank Galv. Nails	
1/2" Fiberboard Sheathing (Celotex)	1 1/2" x #14 Ga Galv. Wire Staples with 7/16" Crown	6" o.c. at Intermediate Supports 4" o.c. Along Perimeter
1/2" Drywall to Framing	1 1/8" Drywall Screws	16" o.c. for Framing Spaced 16" o.c. 12" o.c. for Framing Spaced 24" c. to c.
Drywall Joint Tape to Drywall	Std. Joint Compound	2 Coats Per Seam
1" x 4" Spacer Strips for Drywall Support	8d Ring Shank Galv Nails	2 Toe Nails Per Strip
#15 Building Paper to Framing	1 1/4" Roofing Nails	8" o.c. Along Perimeter 12" o.c. at Intermediate Supports

Construction Materials

Eighteen of 8 ft. by 8 ft. panels underwent SPF application as described in Section 2.2. Each wall was placed in a squaring jig prior to spraying. SPF was sprayed into each wall cavity with a target thickness of 3" (see Appendix A for individual measured thicknesses). Overspray was removed by grinding the SPF level with the interior face of the wall. Construction was completed by affixing 1/2" thick drywall to each panel. Drywall joints and screws were then taped and spackled.

Spruce-Pine-Fir Studs Stiffness (EI) Graded to 7'-6" Span Deflection of .427"-.531"
Spruce-Pine-Fir 1" x 4" Spacer Strips
Vinyl Siding with Double 5" Course

Figure 1
Test Panel Configurations



Thirty (30) 8 ft. x 8 ft. racking panels were constructed from 2 x 4 Stud Grade Spruce-Pine-Fir studs. The studs were cut to the appropriate length to construct test panels with overall dimensions of 96" x 96". Racking panel construction is depicted in Figure 2; panel constructions are listed in Table 2.

Figure 2
ASTM E72 Racking/Test Panel Construction

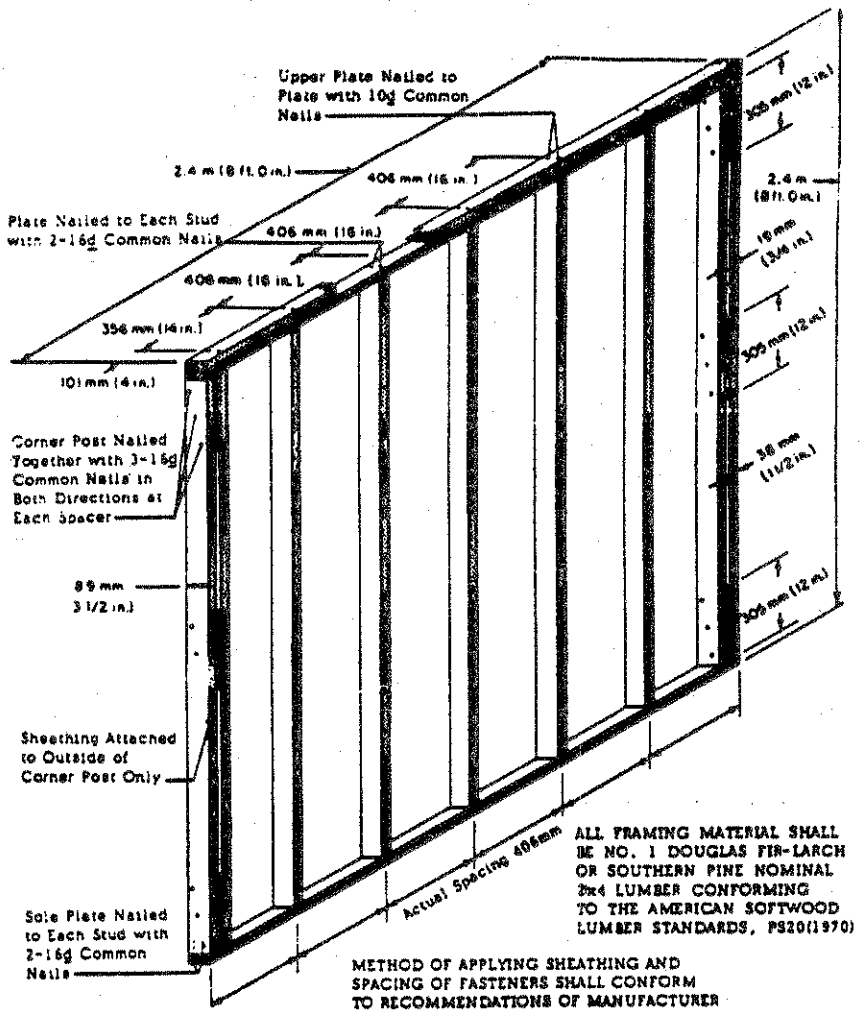


Table 2
Configurations of Racking Panels

STUD SPACING	TYPE OF SHEATHING	TYPE OF SIDING	SPF
48"	15# Building Paper	Vinyl	Yes
32"	15# Building Paper	Vinyl	Yes
24"	15# Building Paper	Vinyl	Yes
24"	None	T 1-11	Yes
16"	15# Building Paper	Vinyl	Yes
16"	None	T 1-11	Yes
16"	15# Building Paper	Vinyl	No
16"	None	T 1-11	No
16" Control	Plywood/Fiberboard	Conventional Vinyl	No
16" Control	Plywood/Fiberboard	Conventional T 1-11	No
Note: Three panels of each configuration were constructed.			

Fifteen (15) 48" x 96" axial test panels were constructed. Since the overall width of the panels was 48", only 24" and 16" stud spacings were used. There were five configurations, four contained SPF and the fifth served as a control. Axial test panel construction is depicted in Figure 3; the axial panel constructions are listed in Table 3.

Figure 3
ASTM E72 Axial Test Panel Construction

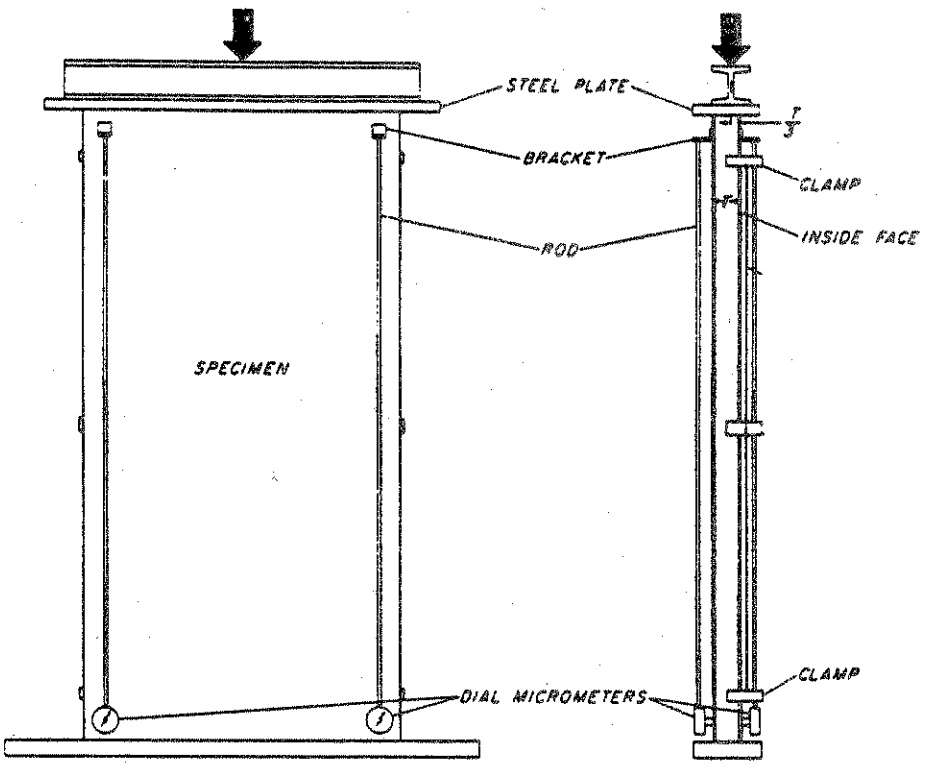


Table 3
Axial Panel Configurations

STUD SPACING	TYPE OF SIDING	SPF
24"	Vinyl	Yes
24"	T 1-11	Yes
16"	Vinyl	Yes
16"	T 1-11	Yes
16"	T 1-11	No
Note: Three panels of each configuration were constructed.		

2.2 SPF Application

Sprayed polyurethane foam was applied to 30 of the 45 panels, as noted in Tables 2 and 3. Eighteen of the 30 racking panels were sprayed and 12 of the 15 compressive panels were sprayed. Figure 4 depicts the application process. SPF application was initiated by spraying a thin layer around the inside edges of each wall cavity where the studs met the exterior sheathing. Application was then continued by spraying thin, uniform, layers into the cavity until the SPF thickness was a minimum of 3" in thickness.

Figure 4
SPF Spray Applications

After spraying was complete, the panels were removed from the spray booth and laid on a flat table for final dressing. Excess SPF was removed with a power disc sander to provide clearance for drywall installation. Drywall was then affixed to all panels with drywall screws.

The thickness of the polyurethane foam was measured and averaged for all 30 SPF panels. The average thickness was 3.025 inches. Measured thicknesses for all panels are listed in Appendix B.

3.0 TEST METHODS

Tests run by the Research Center measured the racking and compressive load resistance of both standard and non-standard wood frames with and without SPF-filled wall cavities. Control panels of standard wood frame construction were also tested for comparative purposes.

3.1 Racking Load

There are two commonly used ASTM standard test methods that are applicable for determining the racking resistance of building panels, ASTM E72, Section 14 and ASTM E564. ASTM E72 measures the resistance of standard wood frame wall panels to a racking load such as would be imposed by wind on a wall oriented at 90° to the panel. ASTM E564 measures the racking performance of entire wall assemblies, including foundation anchorage.

The intent of the racking tests was to compare wall panels filled with SPF to conventionally constructed wall panels. ASTM E72 provides a reliable, uniform procedure for determining the resistance to racking load of materials commonly employed in building construction, and has been used extensively over a period of some 40 years. ASTM E564 requires accurate modeling of the base and sill plate connections and must be run on a vertical testing apparatus in order to produce meaningful results. ASTM E72 was, therefore, selected as the more appropriate for this program.

In the Research Center's ASTM E72 racking test apparatus, the test panel is mounted in a horizontal position. The base of the apparatus is a steel channel section which is bolted to structural rails embedded in the test floor. The test panel is constrained by rollers which prevent lateral movement of the panel, but allow free movement in the plane of the panel. The adjustable panel hold-down at the loaded end also has a roller assembly in contact with the top of the panel. An electronic load cell is mounted between the load blocks on the panel and the hydraulic loading cylinder.