NYSERDA--96-12

STRUCTURAL INSULATED PANELS PRODUCED FROM RECYCLED EXPANDED-POLYSTYRENE (EPS) FOAM SCRAP

Report 96-12

NYSERDA

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State of New York
George E. Pataki
Governor

Energy Research and Development Authority
F. William Valentino
President

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Final Report

Prepared for

THE NEW YORK STATE
ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

Robert M. Carver
Project Manager

BASF CORPORATION
Mt. Olive, NJ 07828

Thomas Greeley
Project Manager

and

STRUCTURAL INSULATED PANEL ASSOCIATION
Washington, DC 20005

Shari Bush
Project Manager

Prepared by

STEVEN WINTER ASSOCIATES, INC.
50 Washington Street
Norwalk, CT 06854

Alexander Grinnell
Project Manager

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NOTICE

ABSTRACT

STRUCTURAL INSULATED PANELS PRODUCED FROM RECYCLED EXPANDED POLYSTYRENE (EPS) FOAM SCRAP

This report documents a research project undertaken to assess the feasibility of using scrap reground expanded polystyrene (EPS) in the manufacture of structural insulated panels (SIPs) in order to save material costs and reduce the amount of EPS waste products to be disposed.

The project team, managed by Steven Winter Associates, Inc., a Norwalk, Connecticut-based building systems research and consulting firm included: Thermal Foams, Inc., a Buffalo-based manufacturer of EPS products; BASF Corp., the world's largest producer of EPS beads; Oak Ridge National Laboratory, which performed thermal tests (ASTM C-518); RADCO, Inc. which performed material properties tests: density (ASTM C-303), flexural strength (ASTM C-203), tensile strength (ASTM D-1623), and transverse load test of SIPs panels (ASTM E-72) .

The report documents the manufacturing and testing process and concludes that there was relatively little difference in the thermal and structural characteristics under normal loading conditions of the panels tested with varying amount of regrind (from 10% - 25%) and those made with 100% virgin beads.

The report recommends that additional tests be undertaken, but suggests that, based on the test results, reground EPS can be successfully used in the cores of SIPs in amounts up to 25%.

Keywords: Structural Insulated Panels, Building Materials, Recycling, Expanded Polystyrene, Structural Testing, Thermal Testing

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SUMMARY

Steven Winter Associates, Inc. was contracted by the New York State Energy Research and Development Authority (NYSERDA) to evaluate the feasibility of using recycled expanded polystyrene (EPS) foam scrap in structural insulated panels (SIPs).

The use of structural insulated panels (SIPs), building elements used to form the exterior walls, roofs, and floors of residential and commercial buildings, has grown into an industry of over 80 manufacturers that currently produce approximately 32 million square feet of panel per year.

The popularity and growth of SIPs stems in part from their excellent structural and energy performance characteristics, as well as the simplicity of the construction process. SIPs have recently been shown to have superior energy performance attributes when compared to conventional frame construction.

Manufacturers of SIPs have not to date used recycled scrap EPS in the core of their structural panels because of the lack of test data on the potential structural and energy performance of SIPs made with reground material. The purpose of the test program was to provide this much-needed data, so the use of recycled scrap among New York State SIPs manufacturers would be encouraged and the problem of finding disposal sites for their scrap would be ameliorated.

The project was divided into four phases with associated tasks:

1. **Planning and Organization** - A management plan was prepared and a subcommittee of the Structural Insulated Panel Association was formed to monitor the project.

2. **Panel Fabrication** - EPS scrap was collected, mixed with virgin EPS beads and molded into blocks of EPS material. Sheets (slabs) of varying thicknesses of SIPs material were cut from the block and either sent to testing labs or used as the core for SIPs panels which were, in turn, tested. Samples were produced and tested with the following percentages of reground EPS scrap:

- 0% Recycled EPS, 100% virgin EPS
- 10% Recycled EPS, 90% virgin EPS
- 15% Recycled EPS, 85% virgin EPS (2 samples tested)
- 20% Recycled EPS, 80% virgin EPS
- 25% Recycled EPS, 75% virgin EPS

3. **Testing** - A series of tests were conducted at various facilities to evaluate the feasibility of using recycled EPS foam scrap in SIPs:

Thermal Performance (ASTM C-518) - Based on conductivity measurements of 18 foam samples (three each of the six mix configurations) the variability within each of the six mixes was small, ranging from 1 to 3% of the mean value.

Density (ASTM C-303-90) - The variation in density values of foam samples tested was small, varying from 0.98 lbs/cu ft for the 0% regrind to 0.95 lbs/cu ft for the 25% mix, a difference of about 3%. The densities were well within the range of 0.90 to 1.15 lbs/cu ft, the normal range for SIPs cores.

Flexural Strength (ASTM C-203-92) - There was very little difference in flexural values from one mix to another. A number of mixes with varying percentages of regrind exceeded the breaking and flexural strength of the mix with 0% percent of reground material.

Tensile Strength (ASTM D-1623-78) - Test values indicate some variations in tensile values between mixes, but in the reverse order of what may be expected. There appeared to be more of an integral bond as the percentage of the regrind in the mix increased.

Transverse Load Capacity of Panels (ASTM E-72) - At normal deflection limits for wall and floor panels of L/180, L/240, and L/360 (L=length of span), the panels made with varying mixes performed in remarkably similar fashion. Some of the panels containing regrind in their core proved stiffer than those without regrind.

At ultimate load (failure) the panels with regrind performed less well than the panels with no regrind. However, their load-carrying capacity in pounds per square foot divided by three (the prevailing safety factor employed by code agencies) exceeded 50 psf, which is a value in excess of most residential wall and floor loading requirements.

Other Test Results - Tests run by BASF in its own laboratory in Canada on flexural strength and R-values resulted in values that were in a similar range to those developed by ORNL and RADCO. Tests run by Ashland Chemical for a SIPs producer, Korwall, Inc., showed very similar characteristics across the range of panels with varying mixes in their cores. A different tensile test (ASTM C-297) was used than that run by RADCO (ASTM D-1623), which tested sections of panels rather than cores.

As a result of this testing program, it appears that there was very little difference in the overall performance of the EPS samples tested for thermal and physical properties with mixes of reground material that varied from 10 to 25%.

SIPs panels tested exhibited very similar structural characteristics under normal loading conditions. Panels with reground material, subject to ultimate (failure) loading, performed less well than panels without regrind, but within normal structural loading requirement limits. A few panels were damaged during shipment, which may or may not have affected their performance.

One limitation to the amount of reground material that can be used in EPS cores is related to the increase in difficulty of cutting the molded block by means of hot-wires. As the percentage of regrind increases, small amounts of regrind are fused into hard particles by the steam used in the block molding process. These hard particles cause the hot-wire cutter to "chatter," leaving the surface of the slabs (cores) cut from the block with varying degrees of irregularity. For this reason, percentages of regrind in excess of 25% may require a different molding and cutting process.

The tests of EPS core and panels fabricated by Thermal Foams, Inc. represent one manufacturer's product during one manufacturing run. Other manufacturers use different equipment and different manufacturing processes. The use of reground EPS will have to be based on individual manufacturers' capabilities and considerably more testing will have to be undertaken to establish the performance of SIPs to the satisfaction of governing code agencies. Nevertheless, the testing program undertaken in this research project suggests that reground EPS may be successfully used in structural insulated panels in amounts up to 25% of the core material.

4. **Technology Transfer and Information Dessemination** - The results of the research and testing program were widely diseminated by the Structural Insulated Panel Association (SIPA) through newsletters and conferences. The results were also announced to members of the National Association of Home Builders at their January 1996 show in Houston, Texas. In addition, press releases were sent to over 100 newspapers, magazines, and periodicals leading to articles in local, Buffalo, New York newspapers and publications including *Architectural Record*, *Construction Specifier*, and *Rural Builder.*

In addition to these activities, a preliminary analysis was performed to project the cost savings attributable to using reground material in SIPs. The annual dollar savings to Thermal Foams for using reground material in 100,000-square feet of panel was calculated to range from $8,250 to $19,250 for reground mixtures of 10% and 25%, respectively.

Section 1

INTRODUCTION

OBJECTIVE

The primary objective of this research and demonstration project was to determine if structural insulated panels (SIPs) made with varying amounts of reground expanded polystyrene scrap (EPS) from construction industry products will perform, from a structural and energy efficiency standpoint, as well as SIPs made with 100% virgin materials. A secondary objective was to inform and educate the SIP industry and the public at large of the potential benefits of using recycled products.

Potential Benefits

SIPs have been recently shown to have superior energy performance attributes when compared to conventional frame construction with fibrous insulation. Tests conducted by the Florida Solar Energy Center have shown SIP construction to result in seasonal energy savings of 14 to 20%. Early results of similar tests at the National Renewable Energy Laboratory have shown similar performance characteristics.

A recent Structural Insulated Panel Association (SIPA) market study indicates that for many reasons (such as high utility costs, cold climate, and high labor costs), New York State is one of nine states with the highest ranking for SIP market and growth potential. Demonstrating the use of recycled EPS in SIPs will show its potential as both an energy saving and environmentally responsive product, which could lead to greater use.

BACKGROUND

Structural Insulated Panels

SIPs are primary building elements used to form the exterior walls, roofs, and floors of residential and commercial buildings. Panels consist of a core of foam insulation, usually expanded polystyrene, sandwiched between skins of sheathing, usually oriented strandboard (OSB). Panels vary in thickness, typically 3.5 to 12 inches, and are produced in sizes up to 8 by 24 feet.

SIPs were first introduced in the 1950s by Dow Chemical. This technology has grown into an industry that produces approximately 32 million square feet of panels per year throughout the US, and is growing at an estimated annual rate of 20 to 25%. There are approximately 80 to 90 manufacturers in the US. About 40 of these belong to SIPA and produce an estimated 90% of all panels nationwide.

SIP Performance

Recent popularity and growth of SIPs stem in part from their excellent structural and energy performance characteristics as well as the simplicity of the construction process. The foam provides excellent resistance to thermal conductivity and the entire panel assembly results in reduced air infiltration. Panels offer resistance to both axial and bending loads and are suitable for use as roof, wall, and floor structural elements.

EPS and SIPs

Expanded polystyrene is used as the core material in an estimated 80% of all SIPs nationwide. EPS beads are produced by four manufacturers: BASF, Huntsman Chemical Co., ARCO Chemical Co., and StyroChem International, Inc.. BASF, a participant in this research project, is the world's largest producer. Beads are expanded and molded into billets by blockmolders, who fabricate these into sheets to be used as cores for lamination into SIPs. Thermal Foams, Inc., another participant in this project, is a blockmolder that also produces SIPs by laminating EPS to OSB sheathing.

Recycling EPS

EPS is used predominantly as protective packaging and insulation in the construction industry. Packaging usages include: food, medical products, appliances, electronics, photographic equipment, etc. Construction applications include: foundation, wall, and roof insulation; exterior insulation and finish systems (EIFS) (such as Sto and Dryvit); and in SIPs.

Whereas the packaging industry uses unmodified EPS, the construction industry uses EPS that has been treated to lower the surface burning characteristics of the individual products. For this reason, the only suitable supply of EPS scrap to be used in SIPs would come from construction product manufacturers and applicators.

The EPS packaging industry has formed a trade association - the Association of Foam Packaging Recycles - to promote recycling guidelines. In 1994, this association of approximately 115 independent foam manufacturers collected over 30 million pounds of scrap, 12% of all EPS packaging. More than one half of this material was recycled back into new protective foam packaging.

Manufacturers of building insulation have begun to use significant amounts of reground scrap in insulation products, particularly in non-structural roof insulation. Whereas certain properties such as density and strength of the foam product are monitored by manufacturers to ensure minimum quality standards, building code agencies are primarily concerned with the surface burning and material integrity performance of these products because the use is non-structural.

Manufacturers of exterior insulation and finish systems (EIFS) have to date not used reground EPS because of concerns about quality control, although this could change with the benefit of an appropriate testing program and the satisfactory performance of the EPS foam in the field.

Until the initiation of this study, SIP manufacturers, while they may have experimented with the use of regrind, had not marketed products using it. There are several reasons for this: panels made from different percentages of regrind have not been tested for thermal and structural qualities by code-approved testing agencies, and, in the absence of these tests, the various state and regional model code agencies that control the use of SIPs, such as ICBO, SBCC, BOCA, and CABO, have not approved their use.

Project Team

Project team members included: Steven Winter Associates, Inc. (SWA), a New York State corporation specializing in architecture/engineering research and consulting, which provided overall management.

Thermal Foams, Inc., a Buffalo-based manufacturer of EPS products, including SIPs, which manufactured the foam samples and panels tested.

Structural Insulated Panel Manufacturers Association (SIPA), the SIP industry's Washington-based trade association whose members monitored the project and which will disseminate information regarding research results.

BASF Corporation, Mt. Olive, New Jersey, the world's largest producer of EPS beads, which provided technical support to the project.

Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee, which conducted thermal testing on the foam samples.

Resources, Applications, Designs and Controls, Inc. (RADCO), Long Beach, California, an independent testing laboratory, which provided structural testing on the foam core and SIPs and the evaluation of test results.

Section 2

PROJECT DESCRIPTION

FABRICATION OF PANELS

Collection and Regrinding of Scrap

EPS scrap is collected on a continuing basis by Thermal Foam Inc. Scrap from construction projects is segregated from that produced by packaging departments. The scrap for the NYSERDA project was collected from both roof insulation and SIPs core materials. In addition, scrap material was obtained from Thermal Foams/Syracuse, Inc. to use in the second of two mixes using 15% regrind. The concept was to obtain the regrind from a different source to assess whether the source of the foam scrap had any bearing on the performance of the mix. The collected scrap was reground using a rotary grinder that shredded the regrind into approximately 1/16 to 1/4 in. particles. Dust was removed and the reground material was bagged, marked and subsequently deposited in a hopper to be mixed with virgin material.

Molding of Foam Blocks

Virgin beads were pre-expanded in a vertical agitating cylinder-type pre-expander. Reground material was introduced to a stream of virgin beads in a screw conveyor type mixer/meter driven at controlled speeds to produce 1% tolerance/accuracy. The percentage of mix was controlled by a variable speed auger. The mixture of regrind and virgin beads was fed by air pressure to a hydraulically driven, vacuum-assisted block molding machine where the virgin beads expansion was completed during a steam curing at a temperature of 220°F for approximately 6 minutes. The block molder was evacuated between moldings to ensure that residual material from one molding operation would not contaminate another. Blocks 4 'x 16' x 32" were produced by the block mold with varying mixes from 0 to 25% regrind; they were stacked and identified as to regrind content, resin manufacturer, date, and block number. This process was monitored by Thomas Greeley of BASF and Alexander Grinnell of Steven Winter Associates, Inc.

Production of Foam Slabs (Sheets)

The molded block was cut into two 8-ft sections. One of the two blocks was flipped, and then both blocks were hot-wire-cut into 4' x 8' slabs (sheets) in thicknesses of 2 inches or 5.5 inches. These in turn were cut into 2' x 4' pieces or other sizes depending on the testing requirements. Flipping the blocks meant that the EPS sheets used for the SIPs core would come from different parts of the two blocks (see Appendix E for diagram). Each side and each part of all slabs were individually marked to ensure that tests of varying mixes would utilize slabs cut from the same parts of the blocks. This process was monitored by Alexander Grinnell of Steven Winter Associates, Inc.

Production of Panels

After a curing time of four weeks, the EPS sheets (cores) with varying mixes of regrind were laminated to 7/16" x 4' x 8' oriented strand board (OSB) sheets to make 24 SIPs.

The laminating process was undertaken in accordance with R-Controls® standard specifications and quality control procedures. Equipment included Black Brothers glue spreaders and flat platen presses. The adhesive used was Ashland Chemical Co.'s ISO-Set, which is a polymer-based adhesive. The panels remained in the press for two hours, which was greater than the recommended minimum cure time of 40 minutes.

Packaging and Shipping of EPS Test Samples and Panels

Foam samples were boxed and sent by United Parcel Service to the various parties doing or sponsoring the tests. Eighteen of the twenty-four SIPs were placed on six pallets with a stack of three panels each. Each stack of three panels was encased with plywood sides and tops for protection and then strapped with polypropelene straps. The panels were shipped to Long Beach, California, by Yellow Freight. Unfortunately, some of the panel stacks broke open during shipping, and several panels slid around the trailer and sustained damage to their corners. RADCO made adjustments to their testing apparatus to accommodate the damaged panels.

TESTING PROGRAM

Transverse Loading and Material Properties

The tests undertaken by RADCO in its Long Beach, California labs included:

- Density tests of EPS samples per ASTM C-303-92
- Flexural tests on EPS samples per ASTM C-203-92
- Transverse tests on the SIP panels per ASTM E-72
- Tensile test of EPS samples per ASTM C-1623-78.

Descriptions of these tests, including an analysis of the tests results by RADCO, are in Appendix A.

Thermal Testing

Testing performed by Oak Ridge National Laboratories included ASTM C-518, Standard Test Method for Steady State Heat Flux Measurements and Thermal Properties by Means of Heat Flow Meter Apparatus. Test results can be found in Appendix B

Construction Testing

In addition to the tests described above, the team developed a procedure that would determine if the SIPs produced using different percentages of reground EPS would perform in the field in the same way as a normal production panel without any reground material in its core. To this end, six SIPs were manufactured according to Thermal Foams' normal specifications (as a supplier of panels under the trade name of R-Control) in each of the six regrind percentages from 0 to 25%. It was decided that rather than build an isolated wall section as part of a construction demonstration, the panels would be used in the construction of a new addition to the Thermal Foams plant. The panels were erected under the supervision of one of Thermal Foams' superintendents who is experienced in the construction of houses and commercial properties using SIPs. According to the installation crew, the panels containing regrind performed no differently than the panels with no regrind in terms of handling, installing, connecting, and finishing.

POTENTIAL COST SAVINGS FOR THERMAL FOAMS, INC.

A preliminary analysis was performed to project the cost savings attributable to using reground material in Thermal Foams' SIPs. The key assumptions of this analysis are outlined as follows.

- The use of a mix of 15% reground material and 85% virgin beads has been estimated by Thermal Foams, Inc. to save approximately $0.025/bd ft (12″ x 12″ x 1″) of panel.
- Savings per square foot of 5.5″ SIPs Panel Core = $0.025/bd ft x 5.5″ = $0.1375/sq ft
- Savings per 4′ x 8′ panel = $0.1375/sq ft x 32 sq ft = $4.40/panel
- Savings per panel as a percentage of foam costs : $\frac{\$\,4.40}{\$22.00} = 20\%$
- Savings per panel as a percentage of panel sales price : $\frac{\$\,4.40}{\$96.00} = 4.6\%$
- Potential yearly savings for Thermal Foams, Inc. if a mix of 15% reground material was used in all panels sold: $0.1375/sq ft x 100,000 sq ft (estimated panel production) = $13,750
- Estimates of yearly savings if a mix of 10%, 20%, and 25% reground were used in all panels sold:

10% mix	=	$ 8,250
20% mix	=	$16,041
25% mix	=	$19,250

TECHNOLOGY TRANSFER AND INFORMATION DISSEMINATION

The results of the program have been, and will continue to be, widely disseminated to panel manufacturers, builders, architects and designers, the media, and other interested parties. The following briefly chronicles work in this area to date:

- The Spring 1995 issue of "Spotlight on SIPA News," the newsletter of the Structural Insulated Panel Association (SIPA), included an article about the study, describing the approach and the significance of this recyclable product to the SIPs industry.
- In September 1995, SWA collaborated with NYSERDA's public affairs department to release information to the press regarding the SIPs/recycled EPS foam project. Two press releases were developed for broad distribution: one for national distribution and one for New York State distribution. The information released explained the significance of the research, the project approach, and explored the product benefits and the potential environmental benefits that may result from widespread use of the recycled EPS foam. SWA has since continued to pitch the recycled EPS foam research story to members of the press.
- In November 1995, the SIPA Fall '95 Conference included an informational session during which Steven Winter, president of Steven Winter Associates, Inc. and Tom Greeley, project manager for the BASF Corp. presented preliminary findings of the recycled EPS foam research to assembled SIPA members. The session served as a forum for promoting awareness of the development of a new recycled EPS foam product and to encourage future participation by SIP manufacturers and suppliers in the distribution and use of such a product.
- The Fall 1995 SIPA newsletter included a full-page update of the recycled EPS foam research project. The story featured a photo of the molding of the recycled EPS for test purposes.
- In January 1996, SWA and NYSERDA collaborated in the development of a press release announcing the results of the study: describing how SIPs containing up to 25 percent of reground scrap EPS are essentially as energy efficient and strong as panels made with 100 percent virgin EPS. The release was sent to over 100 members of the press, including business, energy, and environmental correspondents with trade and mainstream publications.
- In January 1996, SWA staff began drafting technical articles suitable for publication in environmental newsletters and journals as well as in national and regional trade and consumer publications.

- In January 1996, results of the test were disseminated at the National Association of Home Builders' Show in Houston. The Builders' Show is the largest building industry conference in the US, attracting over 60,000 attendees. Test results were distributed at two seminars and a SIPA reception of SIP industry leaders, and were also provided to media in attendance.
- The 1996 SIPA workshop series, cosponsored by the US Environmental Protection Agency, had its kick-off workshop March 15, 1996 at the Log Home Living and Timber Frame Home Show in Philadelphia. Results of the study were included in the workshop presentation.
- The March 1996 issue of *Architectural Record* carried an announcement of the tests and test results.
- The May 1996 issue of *Rural Builder* included an illustrated description and summary of the testing program.

Section 3
CONCLUSIONS

THERMAL PROPERTIES

Conductivity measurements of the three sets of six EPS foam samples tested with from 0 to 25% regrind showed very small (1 to 3%) variations from the mean value. While in two cases there was a slight fall off in the insulation value of foam samples with regrind, in one series the R-value of the samples with reground was very close to or higher than the sample without reground. Accordingly, it seems quite clear that based on the test data, R-values are not significantly affected by the use of regrind.

DENSITIES OF THE EPS SAMPLES

The testing for density performed by RADCO on the three sets of EPS foam samples in accordance with ASTM C-303 indicated very little difference in the density of the samples. Average densities of the panels using reground were equal to or not less than 97% as dense as the samples without reground.

FLEXURAL STRENGTH

Average flexural strength values for the foam core samples taken fell within a narrow range between 25.54 and 27.91 psi. In half of the tests the samples with regrind exhibited higher flexural strength than the samples without reground. Tests performed by BASF for its own use confirmed the narrow range of results.

TENSILE VALUE

Tensile value tests showed some variations in the test results, but almost in the reverse of what might be expected. All of the values for tensile strength of the foam core with regrind exceeded those of the samples without regrind. This indicates that there seemed to be more of an integral bond as the percentage of regrind in the mix increases. Both the flexural and tensile tests indicate good consistency between mixes and support a hypothesis that EPS foam would perform well as the core material in SIPs.

TRANSVERSE LOAD TESTS

Transverse load tests of the panels performed by RADCO indicated quite similar structural performance of the panels with varying amounts of regrind at the deflection limits of L(length)/180, L/240, and L/360 which are normal deflection limits depending on individual building codes and the type of structural assemblies represented. It was only at ultimate load failure points that variations in the mixes became more evident. The 0% regrind version had an average ultimate load capacity at failure of 275 psf, which, if a safety factor of 3 were applied, would translate to a possible design value range of 85 - 90 psf. The 15 - 25% mixes fell into a possible design value range of 45 - 60 psf, which, while significantly lower, exceeds most normal design values.

The reasons for the decrease in ultimate load capacity is not clear and cannot be attributed to the performance of the core alone, as a number of other factors have to be considered including:

- The panels were fabricated with a mix of skins, supplied by both Huber and Weyerhauser. The use of a single manufacturer would have been preferable to minimize variations.
- In a few instances, delamination of the core and OSB skins occurred simultaneously with failure of the panel suggesting a possible deficiency in the adhesive bond.
- The shipping and packing control could be improved as some of the panels broke loose during shipping, although it is not clear what effect this had.

However, not withstanding the differences in ultimate load capacity, it appears that the panels tested performed satisfactorily under normal loading conditions. They were also used in the erection of an actual building without any apparent problems.

One limitation to the amount of reground material that can be used in EPS cores is related to the increase in difficulty of cutting the molded block by means of hot wires. As the percentage of regrind increases, small amounts of regrind are fused into hard particles by the steam used in the block molding process. These hard particles cause the hot-wire cutter to "chatter," leaving the surface of the slabs (cores) cut from the block with varying degrees of irregularity. For this reason, percentages of regrind in excess of 25% may require a different molding and cutting process.

The tests of EPS core and panels fabricated by Thermal Foams, Inc. represent one manufacturer's product during one manufacturing run. Other manufacturers use different equipment and different manufacturing processes. The use of reground EPS will have to be based on individual manufacturers' capabilities and considerably more testing will have to be undertaken to establish the performance of SIPs to the satisfaction of governing code agencies. Nevertheless, the testing program undertaken in this research project suggests that reground EPS may be successfully used in structural insulated panels in amount up to 25% of the core material.

APPENDIX A: RADCO Report

RADCO

MEMORANDUM

DATE: November 8, 1995

TO: ALEX GRINNELL, STEVEN WINTER & ASSOCIATES

FROM: J. D. WALDMAN, RADCO Don Waldman

SUBJECT: ANALYSIS OF SIP AND FOAM TESTING PERFORMED BY RADCO FOR SWA.

WE ARE INCLUDING A SERIES OF GRAPHS TO HIGHLIGHT ANY SIGNIFICANT DIFFERENCES BETWEEN THE PRODUCT MIX WHICH MAY HAVE AN IMPACT ON THE REPORTING SWA HAS TO SUBMIT. OUR OBSERVATIONS ARE AS FOLLOWS::

FOAM

DENSITY:

AS YOU MAY HAVE SEEN IN THE REPORT OF THE TEST RESULTS THERE WAS NO DIFFERENCE IN THE DENSITIES OF THE FOAM SAMPLES SUBMITTED TO RADCO. THE CONSISTENCY FROM ONE MIX TO THE NEXT FOR THOSE SPECIFIC AREAS OF THE MOLD IS QUITE EVIDENT.

FLEXURAL VALUES:

THESE TESTS ALSO PROVIDED VERY LITTLE DISTINGUISHING FEATURES FROM ONE MIX TO THE OTHER. THIS IS EVIDENT ON THE TWO CHARTS INCLUDED ON FLEXURAL RESULTS. THE FIRST CHART IS BASED ON THE RADCO TEST RESULTS ONLY AND SHOWS THE SPREAD OF FLEX VALUES FOR EACH ALONG WITH THE AVERAGE VALUE FOR EACH. THESE VALUES ARE IN A VERY NARROW RANGE AND CAN ASSUME TO BE CONSISTENT BETWEEN MIXES. WHEN THE RESULTS OF THE BASF TESTS, WHICH YOU FORWARDED TO US, ARE INCLUDED IN THE SECOND CHART, THERE IS CONFIRMATION OF THE CONSISTENCY.

TENSILE VALUES:

THESE CHARTS SHOW SOME VARIATION BETWEEN MIXES, BUT ALMOST IN REVERSE OF WHAT MAY BE EXPECTED. THE RADCO VALUES INDICATE THAT THERE SEEMS TO BE MORE OF AN INTEGRAL BOND AS THE PERCENTAGE OF REGRIND IN THE MIX INCREASES. AS A POINT OF REFERENCE, RADCO PERFORMED THE TENSILE TESTS UTILIZING ASTM-D1623 AS WE WERE MORE CONCERNED WITH THE FOAM'S PERFORMANCE INSTEAD OF HOW GOOD A BOND THERE WAS BETWEEN THE SKINS AND THE CORE. THE SECOND CHART INDICATES THE RESULTS OF THE TENSILE TESTS PERFORMED BY ASHLAND USING C-2[illegible]. THE RESULTS PLOTTED BY RADCO ARE ONLY THOSE WHICH WERE INDICATED TO HAVE 100% FAILURE THROUGH THE FOAM. THOSE RESULTS SHOW A CONSISTENCY IN VALUES BETWEEN MIXES. WE ASSUME THAT THEY TESTED FULL PANEL THICKNESS BUT DO NOT KNOW WHAT SIZE PANELS KOR-WALL WAS FABRICATING.

RADCO

PANELS

TRANSVERSE LOAD TESTS.

IT IS IN THESE TESTS, AT THE ULTIMATE FAILURE POINT, THAT VARIATIONS IN THE MIXES BECOME MORE EVIDENT. AS CAN BE SEEN, THE 0% VERSION HAS AN AVERAGE ULTIMATE OF APPROXIMATELY 275psf, WHICH WOULD RELATE TO A POSSIBLE DESIGN VALUE OF 85 - 90psf. THE 15 - 25% MIXES FALL INTO A POSSIBLE DESIGN VALUE RANGE OF 45 - 60psf. IF THESE WERE BASED ON FOAM DIFFERENCES ONLY, WE COULD ASSUME THAT THERE IS A SIGNIFICANT DROP OFF DUE TO THE INCREASED LEVELS OF MIX. HOWEVER, SUCH AN ASSUMPTION CAN ONLY BE VALIDATED WITH A MUCH GREATER LEVEL OF TESTING AND CONTROL OF MANY FACTORS. THE CHART ON LOAD VALUES AT L/180 DOES NOT SHOW THE SAME LEVEL OF DIFFERENCES AS UNCOVERED IN THE ULTIMATE FAILURE RESULTS. HOWEVER, THE ACCEPTANCE OF VALUES IS BASED ON EITHER THE RESULTS AT L/180 OR AT 1/3 OF ULTIMATE, AND IN CASES WHERE THE RANGE BETWEEN VALUES IS GREATER THAN AVERAGE ± 15%, THE LOWEST VALUE FOUND BECOMES THE BASIS FOR ACCEPTANCE. THE AREAS WHICH COULD HAVE AFFECTED THE VALUES INCLUDE:

1) THE PANELS WERE FABRICATED WITH A MIX OF SKINS (SUPPLIED BY HUBER AND WEYERHAUESER). USE OF ONLY ONE SOURCE FOR THE OSB WOULD BE PREFERABLE TO MINIMIZE THE VARIATIONS RESULTING FROM THOSE SOURCES.

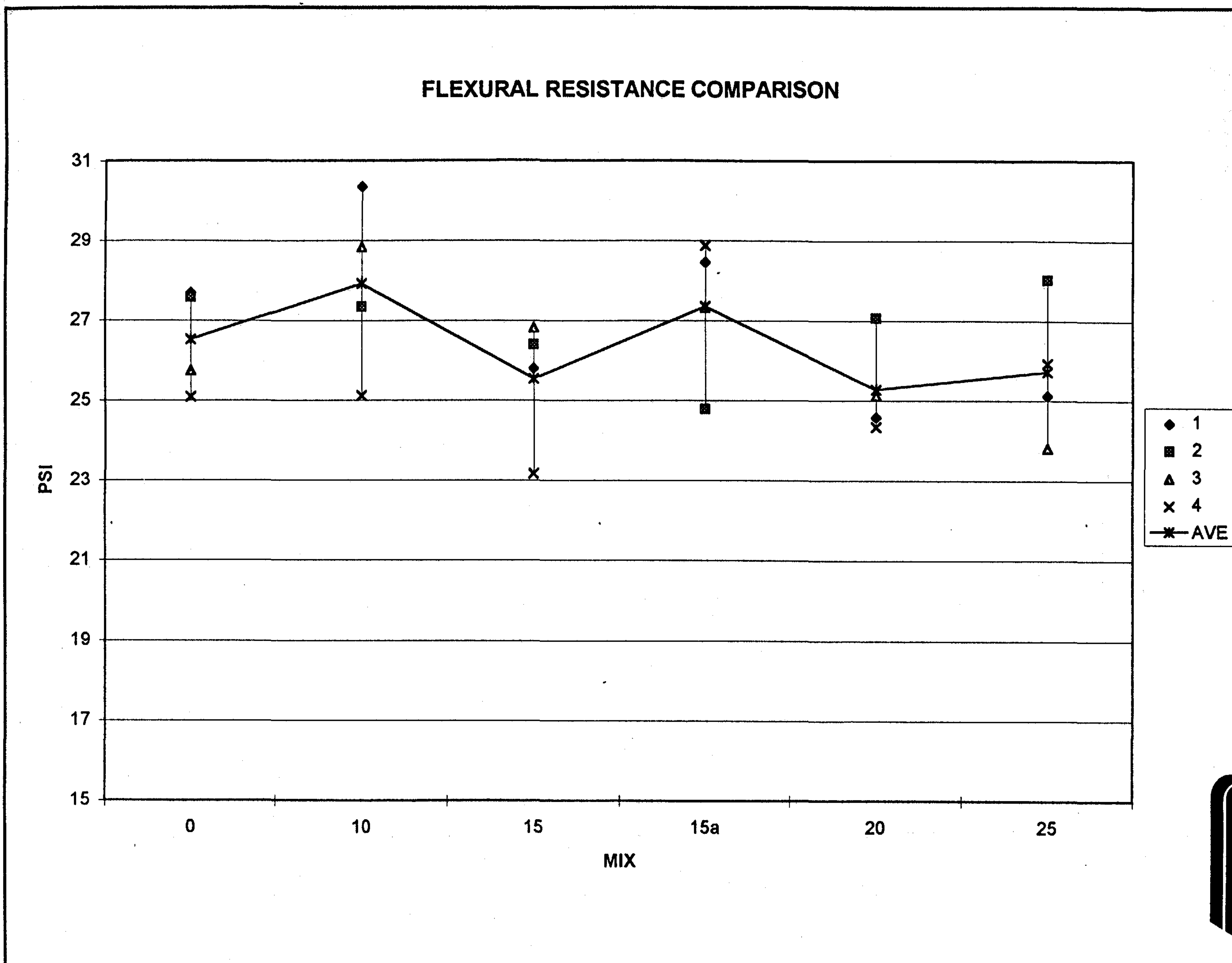
2) THE CONTROLS OF THE APPLICATION OF THE ADHESIVE MIGHT BE QUESTIONED AS SOME OF THE PANELS TESTED DELAMINATED (AND ALSO AS FOUND BY ASHLAND IN THE KOR-WALL SAMPLES THEY TESTED).

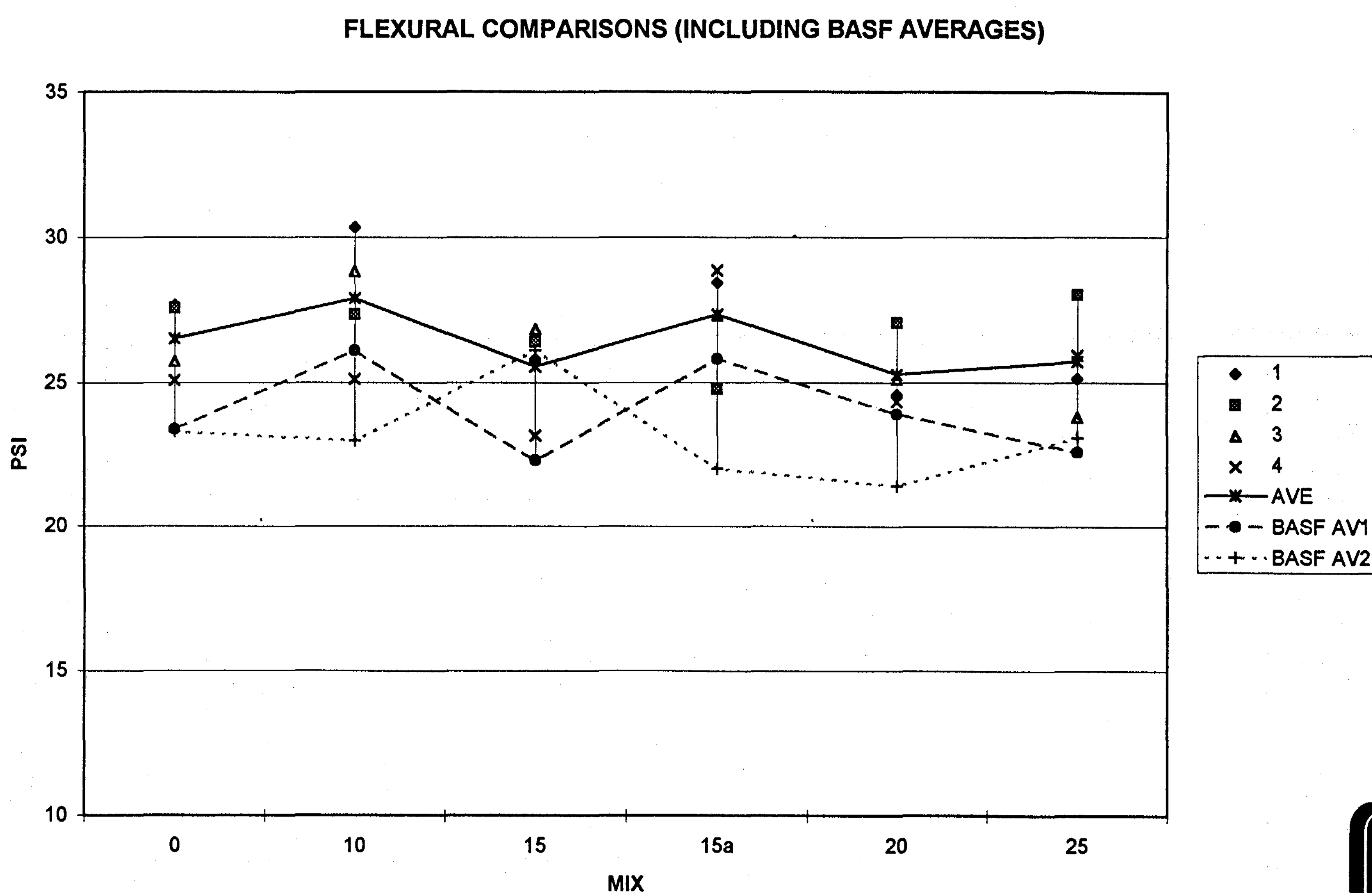
3) SHIPPING AND PACKAGING CONTROLS WERE LACKING AND AS A RESULT SOME OF THE PANELS WERE DAMAGED IN TRANSIT, ESPECIALLY AT THE ENDS AND CORNERS. THIS RESULTED IN THE REQUIREMENT TO INSERT TOP AND BOTTOM PLATES INTO THE PANELS FOR TESTING TO MINIMIZE THE DAMAGE DONE TO THE PANELS. THERE IS NO WAY OF DETERMINING WHETHER THESE STRESSES AFFECTED THE PERFORMANCE, ALTHOUGH IT IS LIKELY THAT WAS NOT THE CASE.

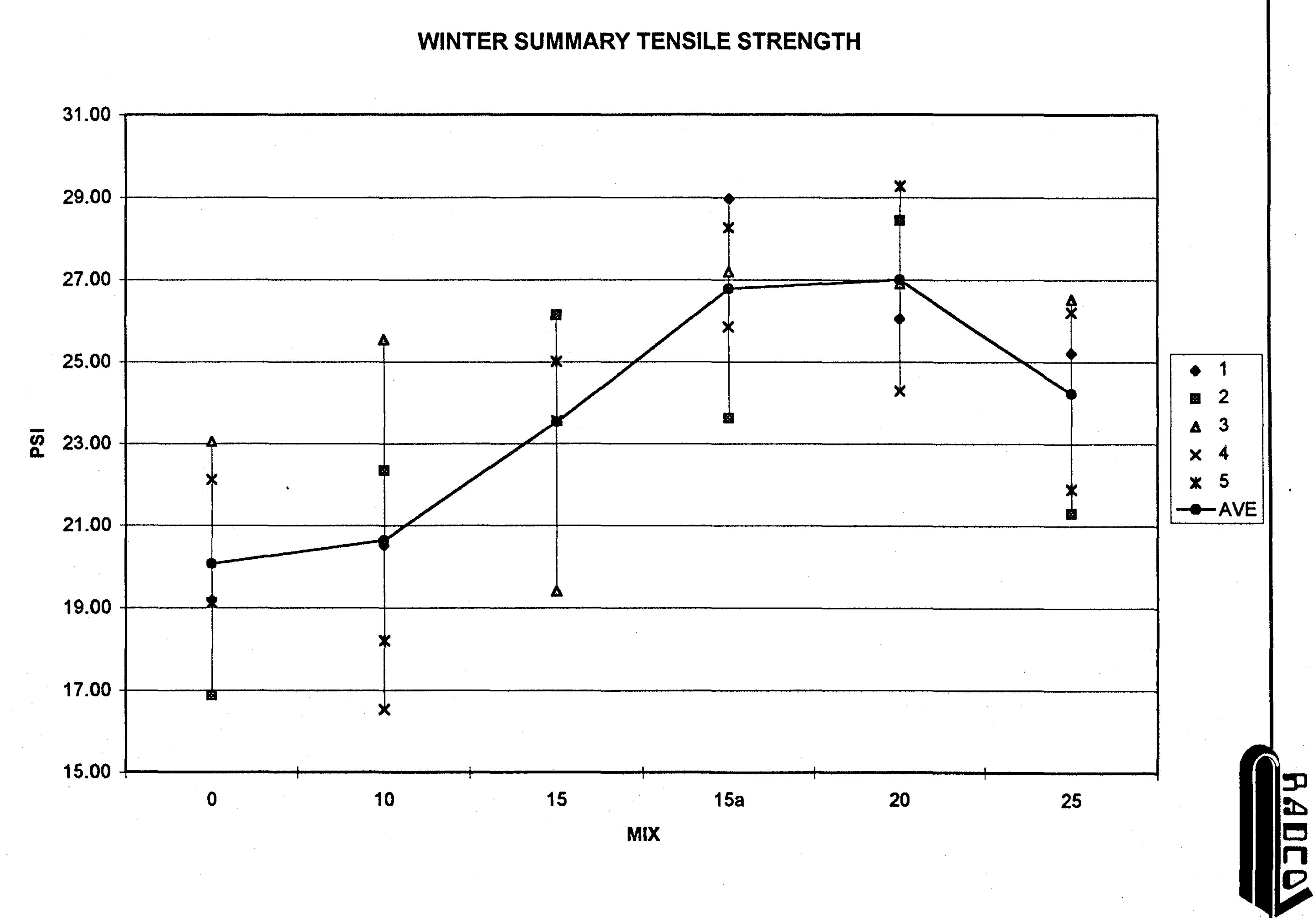
4) THE TYPE OF REGRIND PROCEDURES UTILIZED BY THERMAL FOAM CAN NOT BE ASSUMED TO PROVIDE SIMILAR RESULTS WHEN PANELS ARE MADE BY OTHER MOLDERS. IN FACT, THE SAME TYPE OF CONSISTENCY MAY NOT BE LIKELY TO OCCUR AT THERMAL FOAM FROM DAY TO DAY.

SUMMARY

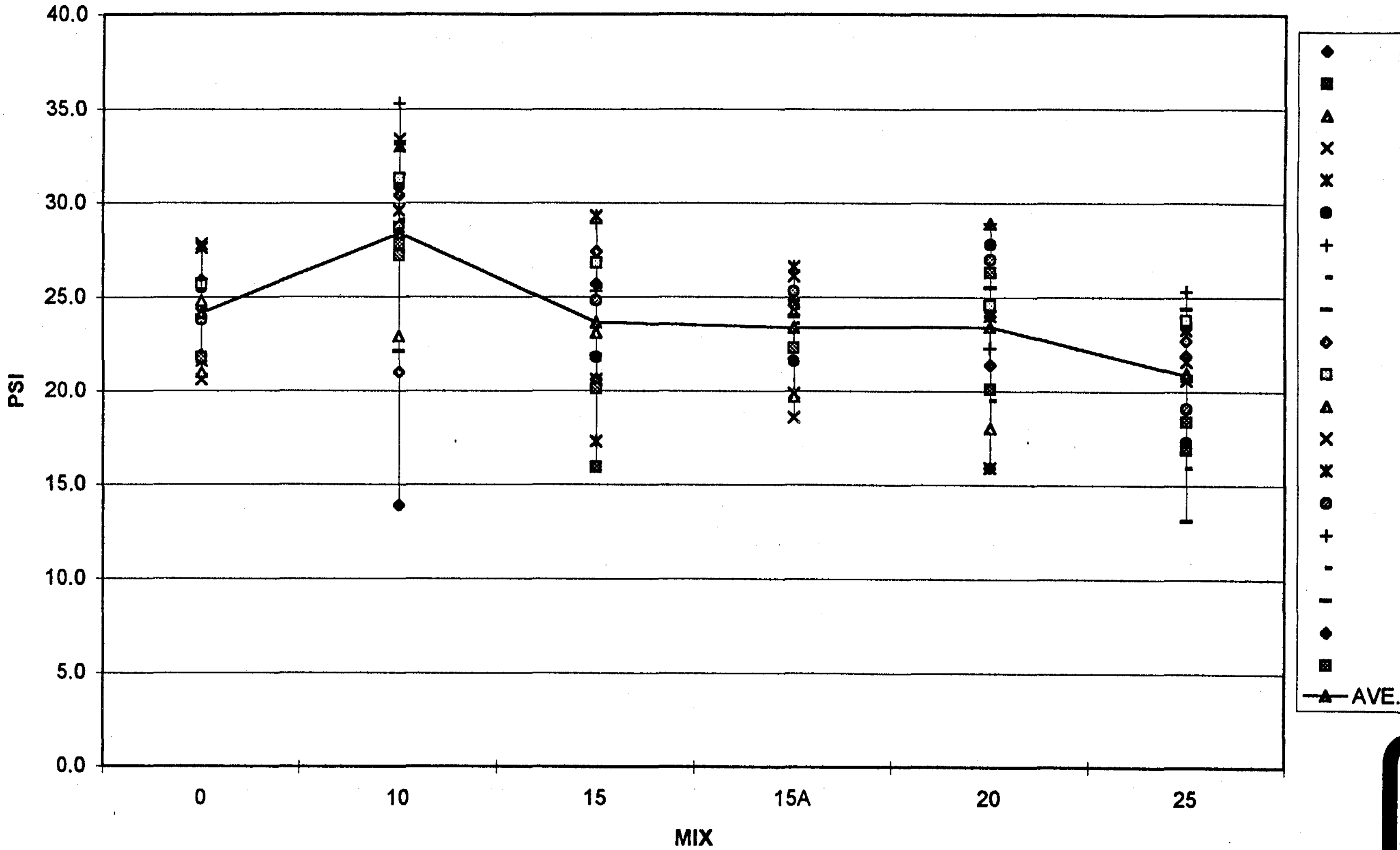
BASICALLY, THE RESULTS SHOWED A MUCH GREATER LEVEL OF CONSISTENCY IN THE FOAM TESTS THAN COULD BE EXPECTED. IT IS ONLY IN THE FULL SCALE TESTS WHERE THE DIFFERENCES ARE SEEN, AND AT THAT ONLY IN THE ULTIMATE FAILURE LOADS.


FLEXURAL RESISTANCE COMPARISON
PSI
31
29
27
25
23
21
19
17
15
0
10
15
15a
20
25
MIX
1
2
3
4
AVE

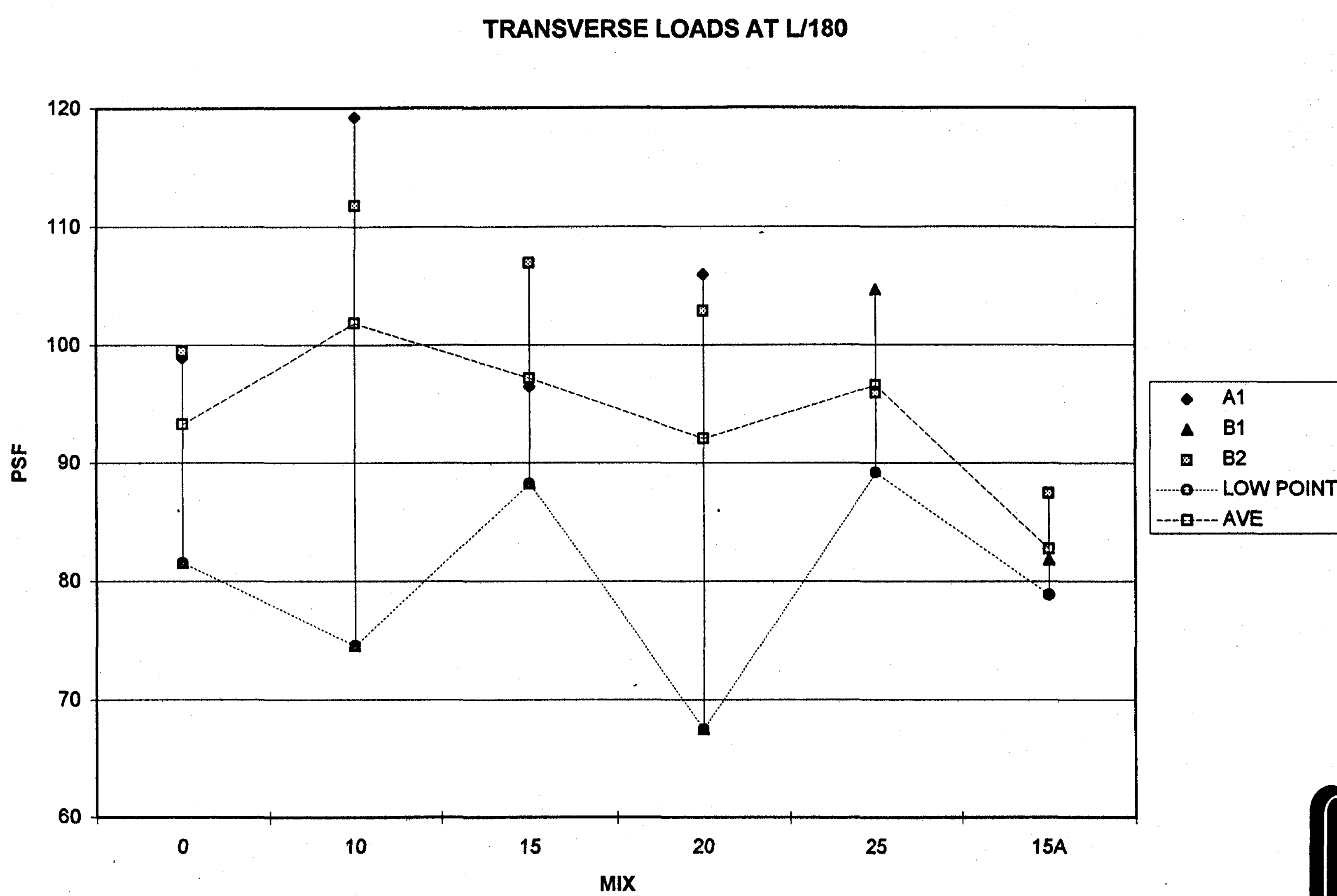

FLEXURAL COMPARISONS (INCLUDING BASF AVERAGES)
PSI
35
30
25
20
15
10
0
10
15
15a
20
25
MIX
1
2
3
4
AVE
BASF AV1
BASF AV2


WINTER SUMMARY TENSILE STRENGTH
PSI
31.00
29.00
27.00
25.00
23.00
21.00
19.00
17.00
15.00
0
10
15
15a
20
25
MIX
1
2
3
4
5
AVE
RADCO

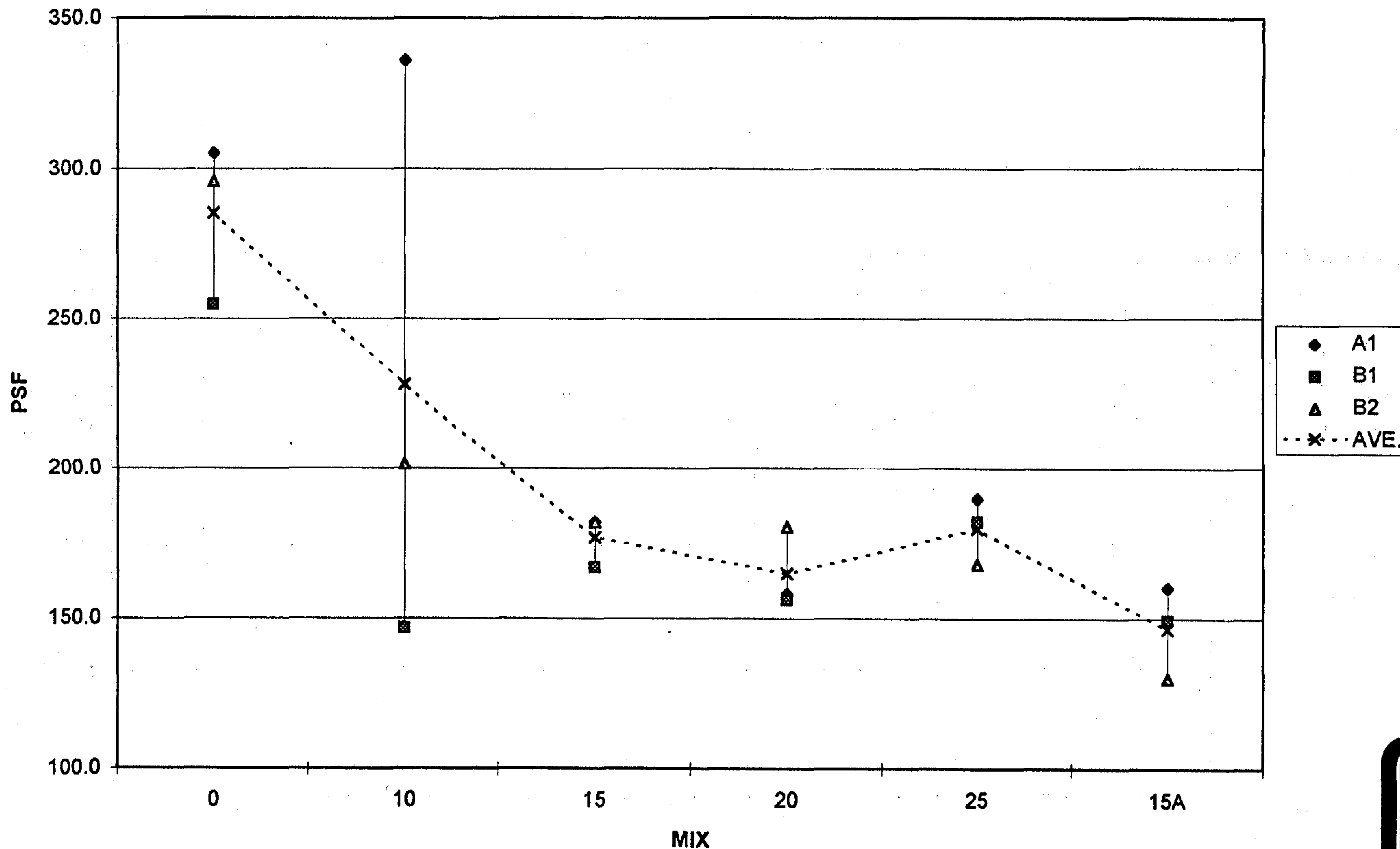
ASHLAND CHEMICAL TENSILE TESTS



RADCO


TRANSVERSE LOADS AT L/180
120
110
100
90
80
70
60
PSF
0
10
15
20
25
15A
MIX
A1
B1
B2
LOW POINT
AVE

TRANSVERSE ULTIMATE LOADS



RADCO

RADCO

MEMORANDUM

DATE: November 13, 1995

TO: ALEX GRINNELL, STEVEN WINTER & ASSOCIATES

FROM: J. D. WALDMAN, RADCO Don Waldman

SUBJECT: UPDATE ON ANALYSIS OF TRANSVERSE TESTS

AS DISCUSSED, THE FOLLOWING IS A FURTHER CLARIFICATION OF THE RESULTS OF TESTING ON THE PANELS.

1) DESIGN REQUIREMENTS

DEPENDING ON THE FINAL APPLICATION, CODE REQUIREMENTS DICTATE DIFFERENT OPTIONS FOR PANELS, DEPENDING ON THEIR UTILIZATION.

A) FOLLOWING ACCEPTANCE CRITERIA FOR SANDWICH PANELS AS FOLLOWED BY ICBO-ES (THE ONLY SERVICE WITH WRITTEN REQUIREMENTS), THE MAXIMUM LOAD ALLOWED ON PANELS IS EITHER:

1) THE AVERAGE ULTIMATE LOAD DIVIDED BY 3, OR

2) THE LOAD DURING TEST AT A DEFLECTION OF THE UNSUPPORTED LENGTH OF THE PANEL DIVIDED BY 180.

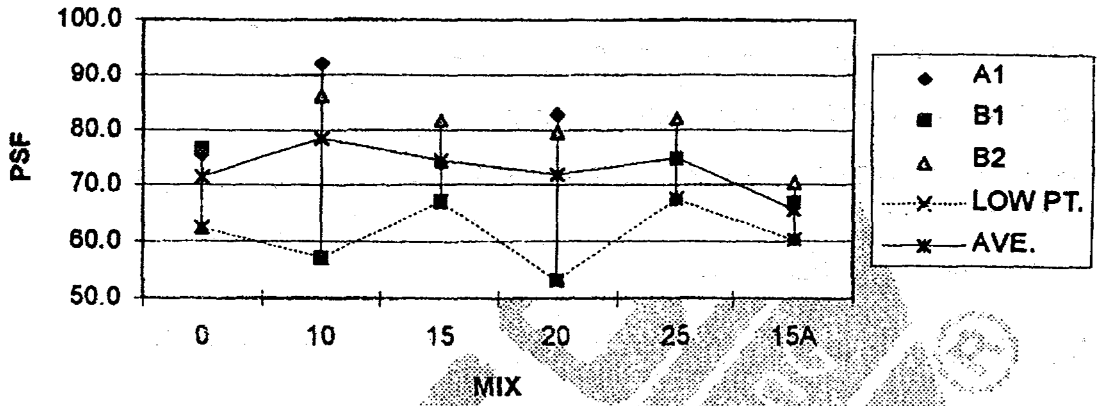
NOTE: THE AVERAGE IS ONLY APPLICABLE IF THE RANGE OF TEST VALUES IS REASONABLE (AVERAGE ± 15%). OTHERWISE, THE LOWEST VALUE OBTAINED IN TESTING THREE PANELS BECOMES THE VALUE UTILIZED.

B) FOR FLOOR APPLICATIONS, THE CRITERIA MAY BE LIMITED TO VALUES OF L/240 OR L/360.

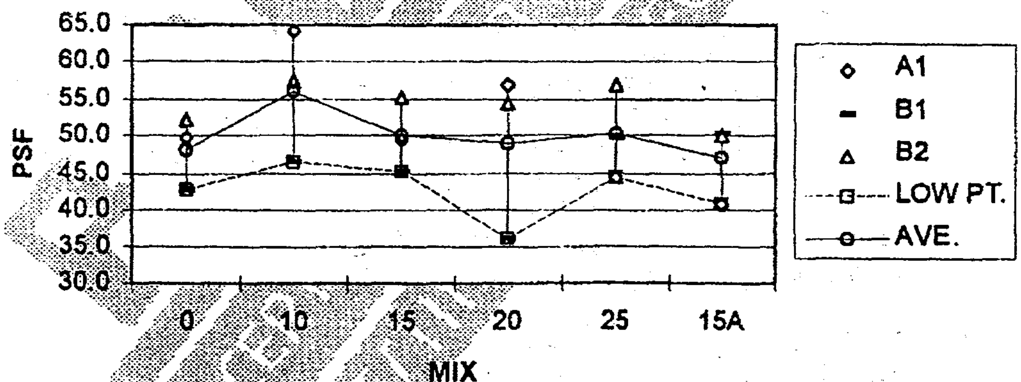
C) USUALLY, FOR EXTERIOR WALL APPLICATIONS, THE ACCEPTABLE LOADS ARE LIMITED TO L/180.

WE ARE INCLUDING CHARTS ON THE RESULTS ON LOADS AT L/360 AND L/240 FOR YOU TO HAVE SOME FEELING OF THE RELATIONSHIP BETWEEN THE VARIOUS MIXES. AS CAN BE SEEN, THE ULTIMATE DIVIDED BY 3 STILL GIVES VALUES IN EXCESS OF 50psf AT THE GREATEST MIX AMOUNT (OTHER THAN THE 15% WITH THE OUTSIDE SOURCE OF SCRAP) WHICH IS A VALUE IN EXCESS OF MOST WALL DESIGN REQUIREMENTS, EXCEPT WHEN SATISFYING EXTREME HURRICANE LOAD CRITERIA. IF THE VALUES FOUND IN THE TEST CAN BE ASSUMED TO BE CONSISTENT FROM ONE MOLD TO THE NEXT, THE LEVEL OF REGRIND MAY NOT BE A SIGNIFICANT DETERRENT FROM SATISFYING DESIGNERS WHO REQUEST PANELS FOR THEIR REQUIREMENTS.

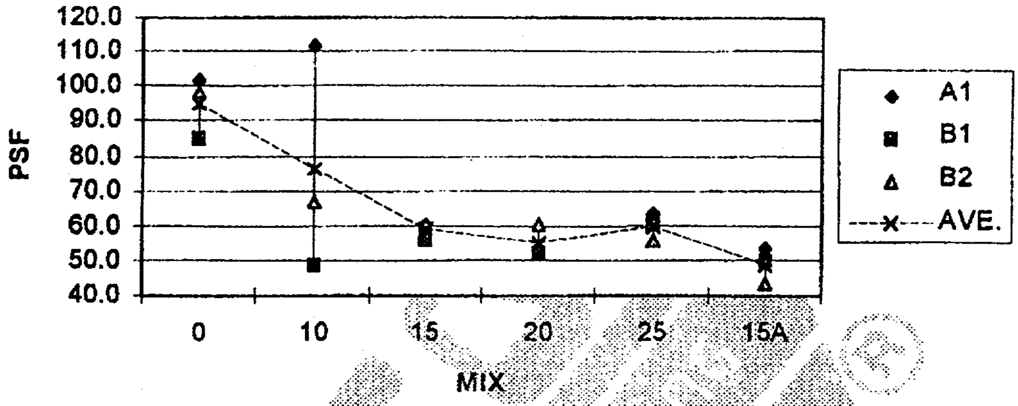
TRANSVERSE LOADS AT L/240



TRANSVERSE LOADS AT L/360



TRANSVERSE TEST RESULTS AT ULTIMATE/3



RADCO

RADCO TEST REPORT
Test Report No. RAD-1625
Project No. C-5886
Lab No. TL-2057

STRUCTURAL PANEL & EPS FOAM TESTING

Prepared for

STEVEN WINTER ASSOCIATES
50 Washington Street
Norwalk, CT 06854

by

RADCO
Resources, Applications, Designs and Controls, Inc.
Listing and Testing Division
3220 E. 59th Street
Long Beach, CA 90805

Prepared by:

Sanjay "Jay" Mishra, Manager
Testing Laboratories & Code Interface Services

Submitted by:

J. Donald Waldman, P.E.
Chairman

Issued: September 1995

TABLE OF CONTENTS

1.0 INTRODUCTION

At the request of Steven Winter Associates, RADCO conducted a series of physical tests on Structural Insulated Panels (SIP) and associated Expanded Polystyrene foam (EPS) samples to evaluate differences, if any, between various foam samples submitted to RADCO's laboratory. The testing requested for the evaluation was as follows:

- Transverse tests on the SIP panels per ASTM E-72
- Density tests on EPS samples per ASTM C-303
- Flexural tests on EPS samples per ASTM C-203
- Tensile tests on EPS samples per ASTM D-1623

2.0 MATERIAL

The material received by RADCO included 18 each 4'x8'x6½" SIP panels (3 each of 6 foam combinations) and 24 EPS 4'x4'x2" samples (4 each of 6 combinations). The SIP panels consisted of two 7/16" thick Oriented Strand Board (OSB) skins adhered to a 5½" thick EPS core. The OSB skins were from two sources, Weyerhaueser and Huber. Per information supplied to RADCO, the foam combinations were identified by the level of regrind material utilized in the molding of the blocks from which all material was cut. A schematic of how the material was cut from each block is included in Appendix A along with identification of where the samples tested by RADCO were located. The molded blocks were cut in half by Thermal Foam into 48"x96"x32" half blocks. Each half was identified as A or B along with the level of regrind material. In each ½ block, there were two 4'x8x5½" cores which were used for the SIP panels and one 4'x8'x2" EPS slab for RADCO's foam testing. Each of the EPS slabs was cut in half and marked either A1, A2, B1, or B2 (in addition to the mix designation) for transfer to RADCO and each of these pieces was cut into four 2'x2'x2" pieces resulting in 24 pieces received for further cutting for the necessary test samples. The mix designation was as follows:

0 RAD	- 0% Regrind	
10 RAD	- 10% "	
15 RAD	- 15% "	(RADCO designation Mix A)
155 RAD	- 15% "	(RADCO designation Mix B)
20 RAD	- 20% "	
25 RAD	- 25% "	

Each of these 24 were then further subdivided into four quadrants marked a, b, c and d (see sketch in Appendix A). Density tests were conducted on each one of these 96 samples. Flex and tensile tests were conducted on selected samples out of these quadrants.

The test descriptions and results are outlined in the following sections. Detailed results are included in the Appendices.

3.0 ASTM STANDARD C-303, DENSITY OF PREFORMED BLOCK-TYPE THERMAL INSULATION

3.1 TEST EQUIPMENT

1. Steel rule graduated to 1mm.
2. NSK vernier caliper model DC-6.
3. Fisher/Ainsworth model LC-5500 electronic digital scale.

3.2 PROCEDURE

The specimens were conditioned for a minimum of 40 hours at 73.4 ± 4°F and 50 ± 5% relative humidity. Dimensions and weights were measured as defined in ASTM C-303.

3.3 RESULTS

The average results of the densities are as follows. Dimensions and the recorded weights and calculated results are shown in Appendix B. (All dimensions in millimeters).

% REGRIND	AVERAGE DENSITY (pcf)
0%	0.98
10%	0.96
15% - MIX A	0.98
15% - MIX B	0.95
20%	0.95
25%	0.95

4.0 ASTM STANDARD C-203, BREAKING LOAD AND FLEXURAL PROPERTIES OF BLOCK-TYPE THERMAL INSULATION

4.1 EQUIPMENT

1. Steel rule graduated to 1mm.
2. NSK vernier caliper model DC-6.
3. United Table Model Electromechanical Testing Machine Model No. TM-20.

4.2 PROCEDURE

Four (4) test specimens 12"x3"x2" (actual thickness of samples) were cut from selected samples and were conditioned for a minimum of 40 hours @ 73.4 ± 4°F and 50 ± 5% relative humidity. Method 1, Procedure A of C-203 was utilized for the test with a span of 10" between supports topped by ¾" round steel rods, and a cross head speed of 0.17 in./min. with a pressure radius of ¾". Load was applied until breaking occurred. The set-up ratios were as follows :: a) Span-to-depth (L/d) = 5; b) Span-to-width (L/b) = 3.33; c) Width-to-depth (b/d) = 1.5.

4.3 TEST RESULTS

REGRIND %	BREAKING STRENGTH (lbs)		FLEXURAL STRENGTH (psi)		AVE. DEFLECTION RATIOS	
	AVERAGE	STD. DEV.	AVERAGE	STD. DEV.	DEFL./DEPTH	DEFL./SPAN
0%	21.01	1.13	26.52	1.3	0.266	0.053.
10%	22.27	1.97	27.91	2.23	0.306	0.061
15% MIX A	20.17	1.49	25.54	1.64	0.282	0.056
15% MIX B	21.84	1.55	27.35	1.84	0.303	0.06
20%	21.32	0.93	26.83	1.03	0.298	0.059
25%	20.23	1.47	25.72	1.76	0.262	0.052

5.0 TENSILE PROPERTIES OF RIGID CELLULAR PLASTICS - ASTM D 1623 -78

5.1 EQUIPMENT

1. Steel rule graduated to 1mm.
2. NSK vernier caliper model DC-6.
3. United Table Model Electromechanical Testing Machine Model No. TM-20.
4. Suitable Grips and fittings.

5.2 PROCEDURES

ASTM D 1623, Type C, was selected in lieu of ASTM C-297 to emphasize the comparisons between the foam samples rather than evaluate the capability of the panel adhesion. Five specimens (4"x4"x2") from each foam type were prepared and bonded to metal plates for insertion into the test fixture. The specimens were conditioned for 40 hrs. prior to test and the testing was performed at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5% RH. The load was applied at 0.02 in./min. Such that failure occurred between 3 and 6 minutes.

5.3 RESULTS

The results obtained are outlined as follows:

REGRIND VALUE	TENSILE STRENGTH (PSI)		ELONGATION (%)	
	AVERAGE	STD. DEV.	AVERAGE	STD. DEV.
0%	20.072	2.50	4.70	1.08
10%	20.632	3.53	5.57	1.36
15% - MIX 'A'	23.532	2.55	4.00	0.32
15% - MIX 'B'	26.775	2.12	5.97	2.31
20%	26.994	1.96	4.69	0.84
25%	24.224	2.46	3.96	0.82

6.0 TRANSVERSE LOAD TESTS PER ASTM E-72

6.1 EQUIPMENT

1. Digital Manometer, 0.1 inch of water column increment readings.
2. Digital dial indicators, 4" travel with 0.0001" resolution.
3. Computerized data acquisition system.
4. 5.0 hp Vacuum pump.

6.2 PROCEDURES

The Transverse Load Tests were performed utilizing option 3 of the referenced standard, which calls for uniform load applied by vacuum. Due to damage to some of the panels in shipment, the tests were conducted on panels with top and bottom plates (nominal 2x6) inserted by RADCO prior to testing.

Each panel was placed horizontally in a reinforced 2x12 wooden frame such that top and bottom plates rested on a ¾" steel rod placed on a metal skin laying on a 3½" wide support surface. The test chamber was completed through the use of a 6 mil thick polyethylene sheet draped over the test panel, folded over the edges of the test fixture, and sealed to the floor. The load was applied by evacuating the air below the test specimen. The applied load was measured with the digital manometer. Deflection measurements were taken at three locations across the mid-point of the panels and at the center of each end to record any vertical movement at those locations.

Load was applied in pre-set increments, held for 5 minutes, and returned to zero after each load increment. The panels were allowed a five minute recovery period before taking the zero load deflections and proceeding to the next increment. After taking the last deflection and set readings, the panels were then loaded to failure.

The average panel deflections and sets were calculated as follows:

Ave. Panel Defl. (& set) = Ave. Midpoint Defl. - Ave. Endpoint defl.

6.3 RESULTS

Test results for each panel are included in Appendix E and Appendix F. Included are descriptions of the OSB utilized for each panel, ultimate load at failure and method of failure. Load/deflection curves are include for each regrind mix series.

The summary of the average load/deflection results are as follows:

AVERAGE DEFLECTIONS FOR TRANSVERSE TESTS (in.)								
LOAD(psf)	0RAD	10RAD	15RAD	155RAD	20RAD	25RAD	AVE.	S.D.
0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.8	0.109						0.109	
26.0		0.120	0.126	0.132	0.134	0.128	0.128	0.005
41.6	0.215						0.215	
52.0		0.251	0.259	0.276	0.273	0.256	0.263	0.011
62.4	0.323						0.323	
78.0		0.387	0.392	0.455	0.431	0.387	0.411	0.031
83.2	0.439						0.439	
104.0	**0.564**	**0.540**	**0.535**	**0.663**	**0.600**	**0.539**	**0.573**	**0.050**
124.8	0.708						0.708	
130.0		0.733	0.697	0.910	0.803	0.655	0.759	0.100
145.6	0.900						0.900	
156.0			0.939	1.392	0.961	0.853	1.036	0.242
166.4	1.009						1.009	
182.0			0.982			1.218	1.100	0.167
Failure Load (psf)	285.3	227.9	176.9	146.5	164.8	179.9	196.890	51.054

Appendix A

Foam Cutting, Sample Selection & Photographs

The figures included in this Appendix indicate: a) The location in the original mold where the foam used for the SIP panels was located, and b) the location of the foam slabs forwarded to RADCO.

Based on information provided to RADCO, the original mold was 4' wide x 16' long x 32" high. The mold was bisected into 2 blocks, designated 'A' & 'B', each 4'x8'x32".

The panels were fabricated at Thermal Foam and forwarded to RADCO for the test.

The slabs selected for forwarding to RADCO were 4'x8'x2" as cut from blocks A & B. These were then cut in half (4'x4'x2") resulting in RADCO receiving 4 pieces for each product mix, each identified as to product mix, A or B, and location within the half. For handling and selection of test material, each piece was cut into 4 each 2'x2'x2" samples, and marked for reference

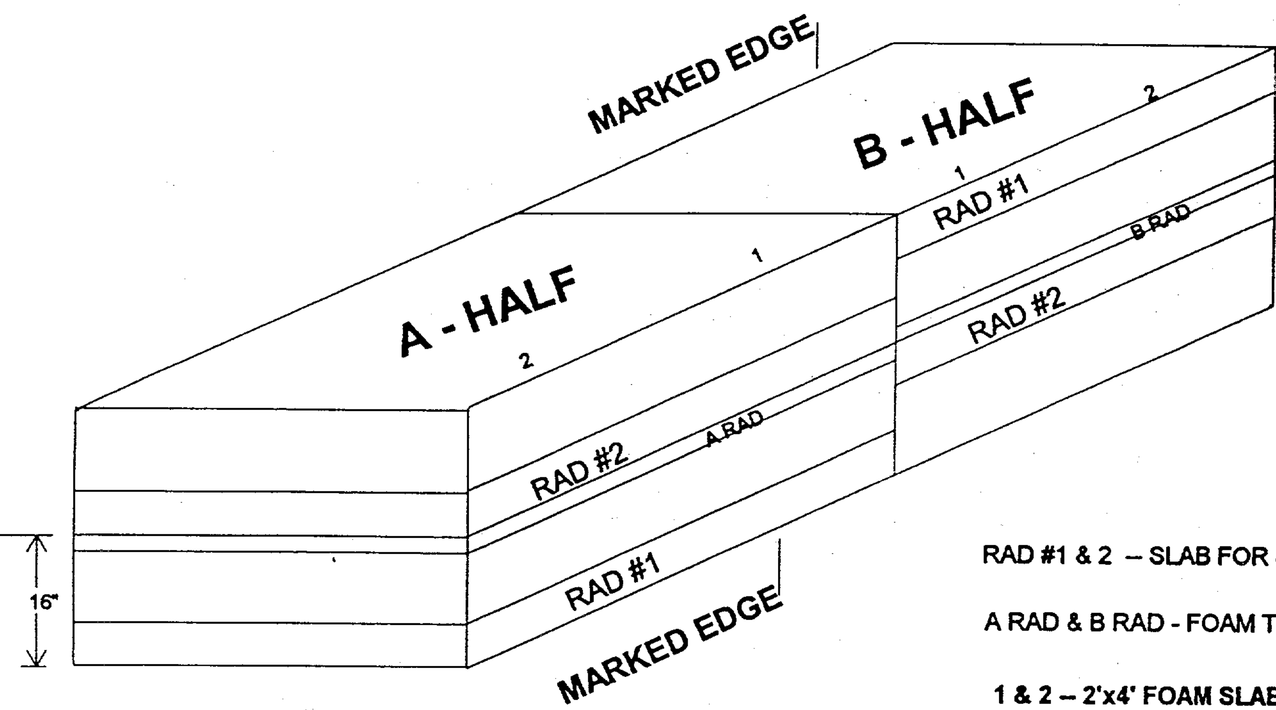
The resulting 96 pieces were first checked for density, and then samples for the flexural and tensile tests were cut from them following the pattern shown in the second figure. The result was 8 samples for each test selected from the same location in the mold for each product mix. To complete the test, the same samples from each mold were utilized.

Photographs of the tensile test setup and the transverse load test setup are included.

RADCO

RAD-1625

FOAM SOURCE FOR TESTING



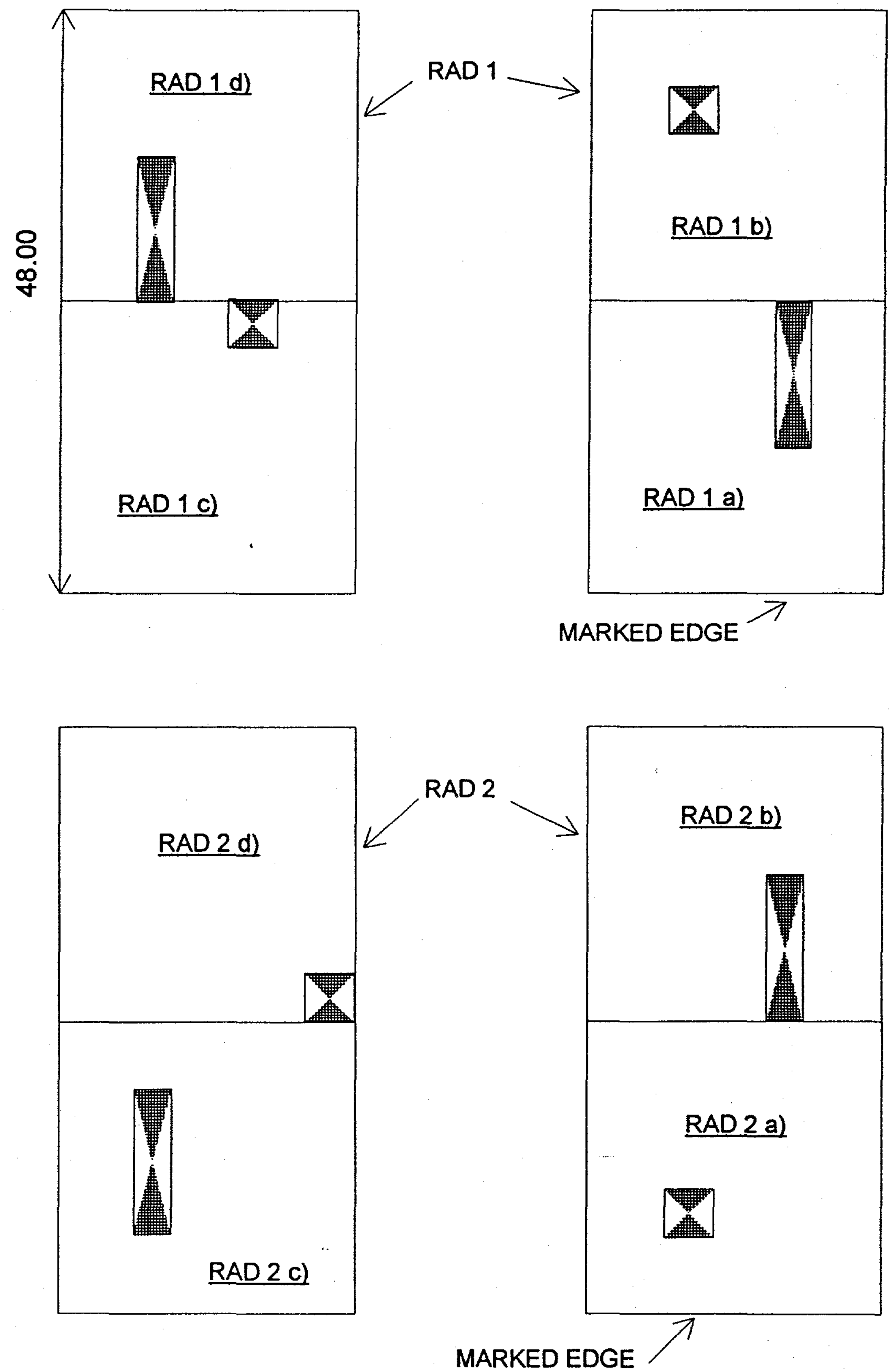
RAD #1 & 2 – SLAB FOR SIP

A RAD & B RAD - FOAM TEST

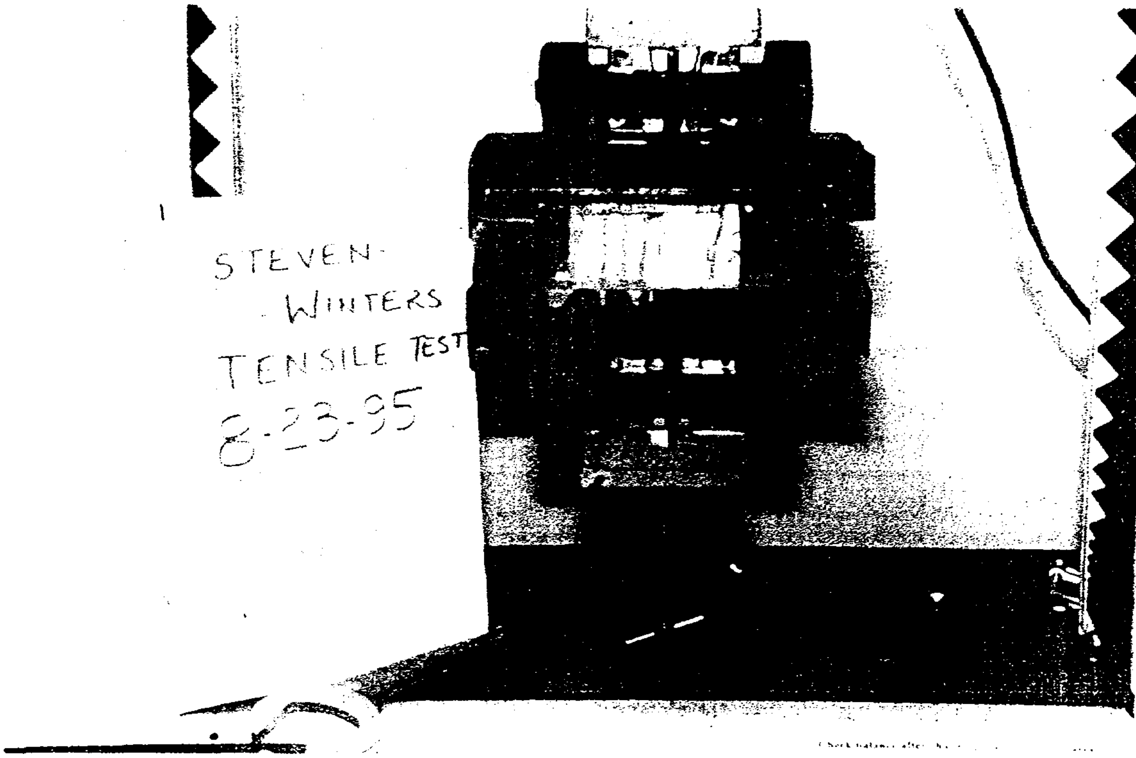
1 & 2 – 2'x4' FOAM SLAB I.D.

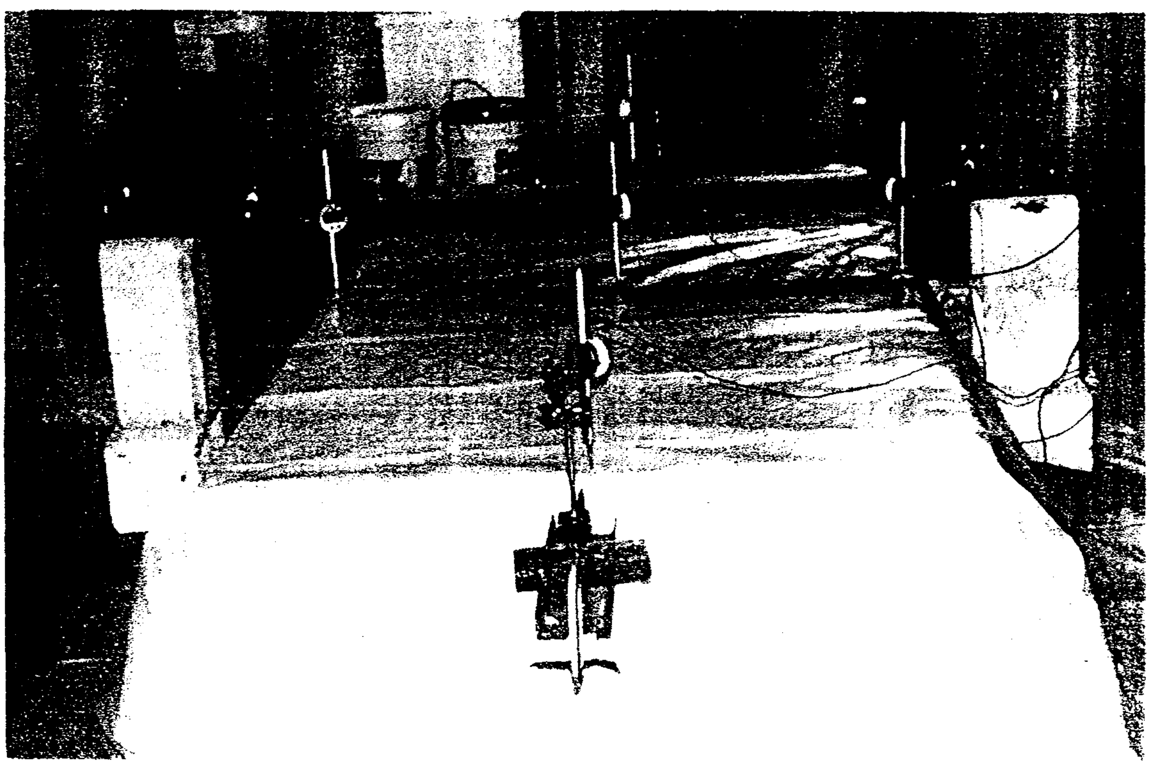
SAMPLE ALLOCATION

RAD-1625



TYPICAL TEST SETUP - TENSILE TEST ON EPS FOAM, ASTM D-1623





TYPICAL SETUP-TRANSVERSE LOAD TEST ON SANDWICH PANELS ASTM E-72

APPENDIX B

DENSITY VALUES

0% Regrind

SAMPLE	LENGTH	WIDTH	THICK.	WEIGHT (gms)	DENSITY (kg/m^3)	DENSITY (pcf)
0A RAD1	605	603	50	286.6	15.71	0.98
0A RAD1	605	609	50	297.7	16.16	1.01
0A RAD1	608	609	50	294.1	15.89	0.99
0A RAD1	608	603	50	299.0	16.31	1.02
Average					16.02	1.00
Std. Dev.					0.27	0.02
0A RAD2	607	603	50	281.7	15.39	0.96
0A RAD2	609	609	50	297.9	16.06	1.00
0A RAD2	609	603	50	273.5	14.90	0.93
0A RAD2	609	609	50	308.9	16.66	1.04
Average					15.75	0.98
Std. Dev.					0.77	0.05
0B RAD1	607	604	50	303.4	16.55	1.03
0B RAD1	607	608	50	287.4	15.57	0.97
0B RAD1	608	608	50	292.5	15.83	0.99
0B RAD1	604	607	50	267.7	14.60	0.91
Average					15.64	0.98
Std. Dev.					0.80	0.05
0B RAD2	600	603	50	291.5	16.11	1.01
0B RAD2	608	609	50	281.4	15.20	0.95
0B RAD2	610	609	50	291.4	15.69	0.98
0B RAD2	608	603	50	263.2	14.36	0.90
Average					15.34	0.96
Std. Dev					0.75	0.05

10% Regrind

SAMPLE	LENGTH	WIDTH	THICK.	WEIGHT (gms)	DENSITY (kg/m^3)	DENSITY (pcf)
10A RAD1	607	604	50	302.8	16.52	1.03
10A RAD1	607	608	50	276.5	14.98	0.94
10A RAD1	607	608	50	297.0	16.10	1.00
10A RAD1	607	604	50	272.2	14.85	0.93
Average					15.61	0.97
Std. Dev.					0.82	0.05
10A RAD2	607	605	50	290.4	15.82	0.99
10A RAD2	608	609	50	274.6	14.83	0.93
10A RAD2	609	609	50	290.0	15.64	0.98
10A RAD2	609	603	50	262.4	14.29	0.89
Average					15.14	0.95
Std. Dev.					0.71	0.04
10B RAD1	606	608	50	284.6	15.45	0.96
10B RAD1	606	604	50	298.9	16.33	1.02
10B RAD1	608	609	50	272.3	14.71	0.92
10B RAD1	609	603	50	300.0	16.34	1.02
Average					15.71	0.98
Std. Dev.					0.79	0.05
10B RAD2	608	604	50	273.6	14.90	0.93
10B RAD2	608	608	50	295.6	15.99	1.00
10B RAD2	609	608	50	271.1	14.64	0.91
10B RAD2	609	605	50	294.5	15.99	1.00
Average					15.38	0.96
Std. Dev.					0.71	0.04

RAD-1625

15% Regrind - Mix 1

SAMPLE	LENGTH	WIDTH	THICK.	WEIGHT (gms)	DENSITY (kg/m^3)	DENSIT Y (pcf)
15A RAD1	606	610	50	283.9	15.36	0.96
15A RAD1	606	604	50	280.0	15.30	0.95
15A RAD1	608	609	50	296.6	16.02	1.00
15A RAD1	608	603	50	286.6	15.63	0.98
Average					15.58	0.97
Std. Dev.					0.33	0.02
15A RAD2	608	608	50	278.1	15.05	0.94
15A RAD2	606	603	50	279.7	15.31	0.96
15A RAD2	609	608	50	293.9	15.87	0.99
15A RAD2	608	605	50	268.5	14.60	0.91
Average					15.21	0.95
Std. Dev.					0.53	0.03
15B RAD1	606	608	50	292.3	15.87	0.99
15B RAD1	606	603	50	297.8	16.30	1.02
15B RAD1	608	608	50	291.2	15.75	0.98
15B RAD1	608	603	50	312.8	17.06	1.06
Average					16.25	1.01
Std. Dev.					0.59	0.04
15B RAD2	608	608	50	285.1	15.42	0.96
15B RAD2	609	604	50	298.0	16.20	1.01
15B RAD2	609	608	50	275.2	14.86	0.93
15B RAD2	608	603	50	291.7	15.91	0.99
Average					15.60	0.97
Std. Dev.					0.59	0.04

RADCO

RAD-1625

15% Regrind - Mix #2

SAMPLE	LENGTH	WIDTH	THICK.	WEIGHT (gms)	DENSITY (kg/m³)	DENSITY (pcf)
155A RAD1	606	603	50	274.2	15.01	0.94
155A RAD1	606	609	50	299.7	16.24	1.01
155A RAD1	609	609	50	280.3	15.12	0.94
155A RAD1	609	603	50	296.2	16.13	1.01
Average					15.62	0.97
Std. Dev.					0.65	0.04
155A RAD2	607	603	50	274.9	15.02	0.94
155A RAD2	608	608	50	291.2	15.75	0.98
155A RAD2	605	608	50	263.8	14.34	0.90
155A RAD2	608	605	50	297.9	16.20	1.01
Average					15.33	0.96
Std. Dev.					0.82	0.05
155B RAD1	605	608	50	286.7	15.59	0.97
155B RAD1	606	603	50	264.4	14.47	0.90
155B RAD1	608	608	50	288.1	15.59	0.97
155B RAD1	608	603	50	272.2	14.85	0.93
Average					15.12	0.94
Std. Dev.					0.56	0.03
155B RAD2	608	603	50	274.7	14.99	0.94
155B RAD2	609	608	50	270.6	14.62	0.91
155B RAD2	608	608	50	291.2	15.75	0.98
155B RAD2	609	603	50	265.4	14.45	0.90
Average					14.95	0.93
Std. Dev.					0.58	0.04

RADCO

RAD-1625

20% Regrind Mix

SAMPLE	LENGTH	WIDTH	THICK.	WEIGHT (gms)	DENSITY (kg/m^3)	DENSITY (pcf)
20A	605	608	50	291.2	15.83	0.99
20A	605	603	50	277.4	15.21	0.95
20A	609	608	50	292.3	15.79	0.99
20A	609	603	50	274.3	14.94	0.93
Average					15.44	0.96
Std. Dev.					0.44	0.03
20A	608	608	50	285.2	15.43	0.96
20A	609	608	50	279.2	15.08	0.94
20A	609	608	50	296.1	15.99	1.00
20A	604	608	50	266.6	14.52	0.91
Average					15.26	0.95
Std. Dev.					0.62	0.04
20B	606	604	50	271.1	14.81	0.92
20B	606	608	50	287.6	15.61	0.97
20B	608	608	50	278.3	15.06	0.94
20B	608	604	50	283.8	15.46	0.96
Average					15.23	0.95
Std. Dev.					0.37	0.02
20B	608	608	50	273.3	14.79	0.92
20B	608	603	50	271.7	14.82	0.92
20B	608	608	50	267.9	14.49	0.90
20B	608	603	50	279.1	15.23	0.95
Average					14.83	0.93
Std. Dev.					0.30	0.02

25% Regrind Mix

SAMPLE	LENGTH	WIDTH	THICK.	WEIGHT (gms)	DENSITY (kg/m^3)	DENSITY (pcf)
25A	606	609	50	297.5	16.12	1.01
25A	606	603	50	265.5	14.53	0.91
25A	608	608	50	286.9	15.52	0.97
25A	608	603	50	281.8	15.37	0.96
Average					15.39	0.96
Std. Dev.					0.66	0.04
25A	607	603	50	287.6	15.71	0.98
25A	608	608	50	282.3	15.27	0.95
25A	608	608	50	288.2	15.59	0.97
25A	609	606	50	281.4	15.25	0.95
Average					15.46	0.96
Std. Dev.					0.23	0.01
25B	606	609	50	285.1	15.45	0.96
25B	607	604	50	310.7	16.95	1.06
25B	609	608	50	291.4	15.74	0.98
25B	607	603	50	311.2	17.00	1.06
Average					16.29	1.02
Std. Dev.					0.81	0.05
25B	610	604	50	291.0	15.80	0.99
25B	608	608	50	311.7	16.86	1.05
25B	605	608	50	291.3	15.84	0.99
25B	608	602	50	305.9	16.72	1.04
Average					16.30	1.02
Std. Dev.					0.56	0.04

APPENDIX C

FLEXURAL TEST RESULTS

RADCO

RAD-1625

The following values were obtained:

SAMPLE NO.	WIDTH (")	THICK (")	BREAK LOAD (lbs.)	Max. Defl. (in)	FLEXURAL STRENGTH (psi)	Maximum Strain (in/in)	DENSITY (pcf)
0A RAD1 a	3.03	1.99	21.99	0.56	27.68	0.067	0.982
0A RAD2 c	3.01	1.99	21.92	0.54	27.57	0.065	0.945
0B RAD1 a	3.01	1.99	20.45	0.53	25.74	0.063	1.030
0B RAD2 c	3.00	1.98	19.69	0.49	25.09	0.058	0.980
Average		1.99	21.01	0.53	26.52		0.98
Std. Dev.			1.13		1.30		
0% Mix :: Average Deflection to Depth Ratio = 0.266 : Average Deflection to Span Ratio = 0.053.							
10A RAD1	3.01	1.99	24.15	0.62	30.35	0.074	1.03
10A RAD2	2.98	1.99	21.55	0.63	27.34	0.075	1.00
10B RAD1	3.11	1.99	23.55	0.59	28.83	0.070	0.97
10B RAD2	3.02	1.98	19.82	0.59	25.11	0.071	0.92
Average		1.99	22.27	0.61	27.91		0.98
Std. Dev.			1.97		2.23		
10% Mix :: Average Deflection to Depth Ratio = 0.306 : Average Deflection to Span Ratio = 0.061.							
15A RAD1	3.03	1.97	20.22	0.52	25.80	0.062	0.96
15A RAD2	3.04	2.00	21.29	0.55	26.40	0.066	0.99
15B RAD1	3.03	1.97	21.11	0.61	26.82	0.073	0.99
15B RAD2	2.99	1.98	18.04	0.56	23.17	0.066	0.93
Average		1.98	20.17	0.56	25.54		0.97
Std. Dev.			1.49		1.64		
15% Mix #1 :: Average Deflection to Depth Ratio = 0.282: Average Deflection to Span Ratio = 0.056.							

RAD-1625

SAMPLE NO.	WIDTH (")	THICK (")	BREAK LOAD (lbs.)	Max. Defl. (in.)	FLEXURAL STRENGTH (psi)	Maximum Strain (in/in)	DENSITY
155A RAD1 a	3.10	1.98	23.00	0.623	28.45	0.074	0.95
155A RAD2 c	3.05	1.98	19.80	0.598	24.78	0.071	0.90
155B RAD1 a	3.03	1.97	21.47	0.649	27.31	0.077	0.97
155B RAD2 c	3.06	1.98	23.09	0.527	28.87	0.063	0.98
Average		1.98	21.84	0.599	27.35		0.95
Std. Dev.		0.00	1.55		1.84		
15% Mix #2 :: Average Deflection to Depth Ratio = 0.303: Average Deflection to Span Ratio = 0.06.							
20A RAD1 a	3.02	1.99	19.60	0.569	24.58	0.068	0.99
20A RAD2 c	3.03	1.97	21.28	0.613	27.06	0.073	1.00
20B RAD1 a	3.00	1.97	19.52	0.556	25.12	0.066	0.92
20B RAD2 c	3.03	1.97	19.08	0.627	24.34	0.074	0.90
Average		1.98	19.87	0.591	25.27		0.95
Std. Dev.		0.01	0.97		1.23		
20% Mix #1 :: Average Deflection to Depth Ratio = 0.298: Average Deflection to Span Ratio = 0.059.							
25A RAD1 a	3.05	1.98	19.93	0.584	25.13	0.069	1.01
25A RAD2 c	3.01	1.99	22.13	0.563	28.02	0.067	0.97
25B RAD1 a	3.00	1.98	18.57	0.412	23.81	0.049	0.96
25B RAD2 c	2.98	1.99	20.30	0.520	25.93	0.062	0.99
Average		1.98	20.23	0.520	25.72		0.98
Std. Dev.		0.01	1.47		1.76		
25% Mix :: Average Deflection to Depth Ratio = 0.262: Average Deflection to Span Ratio = 0.052.							

APPENDIX D

TENSILE STRENGTH VALUES

RADCO

RAD-1625

Specimen No.	Length (in)	Width (in)	Thickness (in.)	C.S. Area (in^2)	Maximum Load (lbs)	Elongation (in.)	Tensile Strength (psi)	Elongation (%)
0A 1 c)	4.000	3.930	1.993	15.720	301.60	0.126	19.186	6.32
0A 2 a)	3.975	3.980	1.973	15.821	267.10	0.095	16.883	4.82
0A 2 d)	4.000	3.965	1.995	15.860	365.70	0.089	23.058	4.46
0B 1 c)	3.985	3.980	1.968	15.860	350.73	0.090	22.114	4.57
0B 2 a)	3.975	3.980	1.990	15.821	302.50	0.066	19.121	3.32
Average							20.072	4.70
Std. Dev.							2.50	1.08
10A 1 c)	4.000	3.990	1.990	15.960	327.54	0.133	20.523	6.68
10A 2 a)	4.020	3.970	1.990	15.959	356.54	0.099	22.340	4.97
10A 2 d)	4.040	4.025	1.980	16.261	415.45	0.139	25.549	7.02
10B 1 c)	3.960	3.995	1.985	15.820	261.60	0.110	16.536	5.54
10B 2 a)	3.960	4.000	1.975	15.840	288.46	0.072	18.211	3.65
Average							20.632	5.57
Std. Dev.							3.53	1.36
15A 1 c)	4.020	4.000	1.989	16.080	378.51	0.078	23.539	3.92
15A 2 a)	4.010	4.025	1.990	16.140	421.86	0.075	26.137	3.77
15A 2 d)	4.010	4.020	1.969	16.120	312.88	0.079	19.409	4.01
15B 1 c)	4.010	4.025	1.978	16.140	380.34	0.074	23.565	3.74
15B 2 a)	4.060	4.085	1.985	16.585	414.83	0.090	25.012	4.53
Average							23.532	4.00
Std. Dev.							2.55	0.32
155A 1 c)	4.060	4.055	1.992	16.463	476.80	0.095	28.961	4.77
155A 2 a)	4.040	4.030	1.990	16.281	384.61	0.169	23.623	8.49
155A 2 d)	4.050	4.010	1.986	16.241	441.39	0.168	27.178	8.46
155B 1 c)	4.008	4.021	1.975	16.116	416.67	0.081	25.854	4.10
155B 2 a)	4.020	4.060	1.985	16.321	461.23	0.080	28.260	4.03
Average							26.775	5.97
Std. Dev.							2.12	2.31

Specimen No.	Length (in)	Width (in)	Thickness (in.)	C.S. Area (in^2)	Maximum Load (lbs)	Elongation (in.)	Tensile Strength (psi)	Elongation (%)
20A 1 c)	3.995	4.020	1.986	16.060	418.50	0.068	26.059	3.42
20A 2 a)	3.995	4.015	1.985	16.040	456.04	0.095	28.432	4.79
20A 2 d)	4.015	4.015	1.970	16.120	433.76	0.107	26.908	5.43
20B 1 c)	4.005	4.015	1.992	16.080	390.72	0.108	24.298	5.42
20B 2 a)	4.030	3.990	1.985	16.080	470.70	0.087	29.273	4.38
Average							26.994	4.69
Std. Dev.							1.96	0.84
25A 1 c)	4.020	3.975	1.990	15.980	402.93	0.070	25.215	3.52
25A 2 a)	4.000	4.020	1.989	16.080	342.49	0.066	21.299	3.32
25A 2 d)	3.995	4.040	1.972	16.140	427.96	0.100	26.516	5.07
25B 1 c)	3.970	4.040	1.979	16.039	420.33	0.091	26.207	4.60
25B 2 a)	4.020	4.060	1.979	16.321	357.14	0.065	21.882	3.28
Average							24.224	3.96
Std. Dev.							2.46	0.82

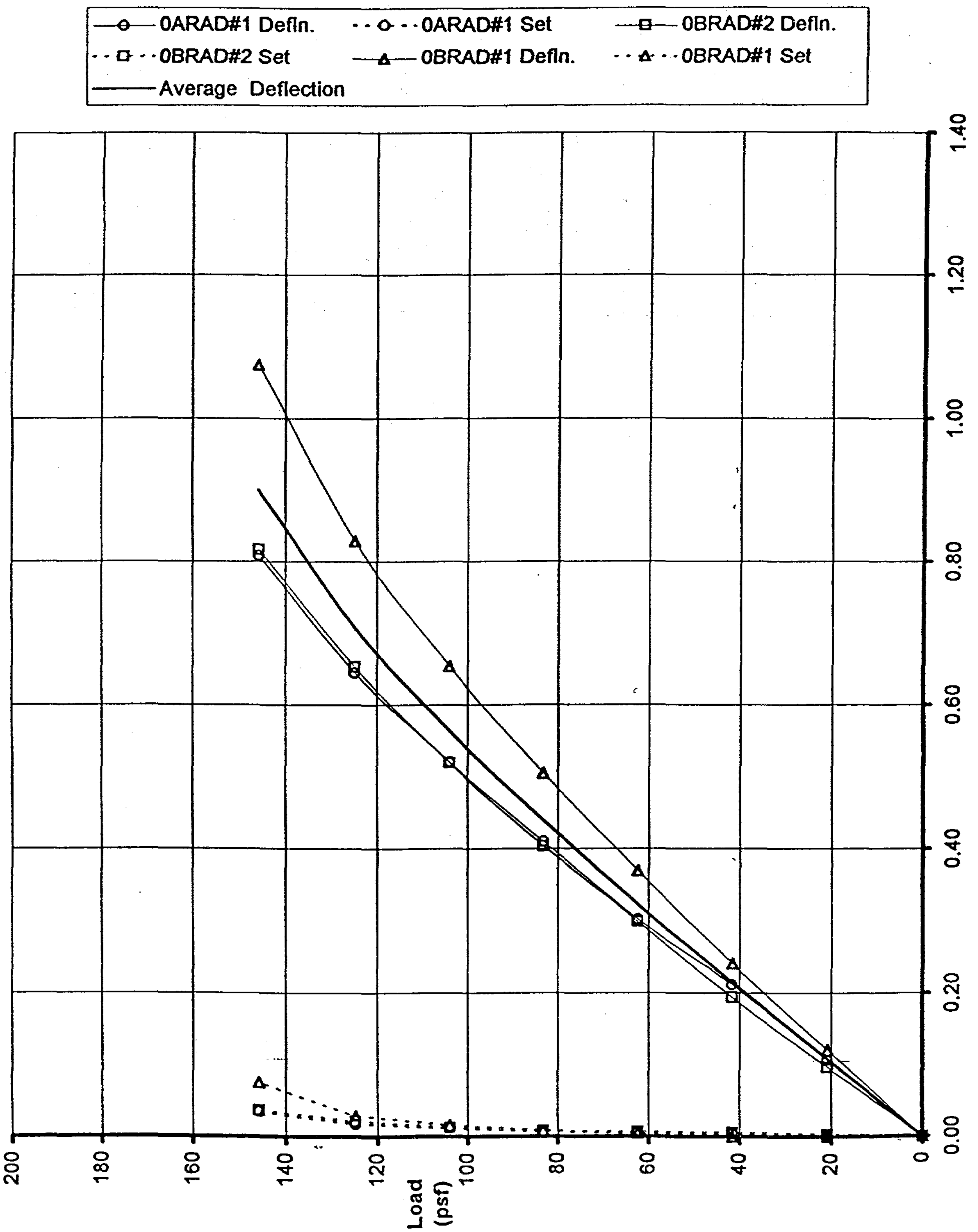
APPENDIX E

TRANSVERSE TEST RESULTS

Transverse Load Test on Sandwich Panels, ASTM E-72 - 0% RECYCLED EPS

Load		Deflections (in.)						
		0ARAD#1	0ARAD#1	0BRAD#2	0BRAD#2	0BRAD#1	0BRAD#1	Average
in. of H2O	psf	Defln.	Set	Defln.	Set	Defln.	Set	Deflection
0	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	20.8	0.107	0.001	0.097	0.003	0.121	0.000	0.109
8	41.6	0.211	0.003	0.194	0.005	0.241	0.000	0.215
12	62.4	0.302	0.006	0.298	0.006	0.369	0.004	0.323
16	83.2	0.410	0.007	0.404	0.008	0.505	0.009	0.439
20	104.0	0.521	0.012	0.519	0.013	0.653	0.016	0.564
24	124.8	0.645	0.017	0.653	0.021	0.828	0.029	0.708
28	145.6	0.808	0.035	0.817	0.037	1.075	0.075	0.900
32	166.4	0.904		0.915		1.209		1.009

TRANSVERSE LOAD TEST, ASTM E-72 - 0% RECYCLED EPS



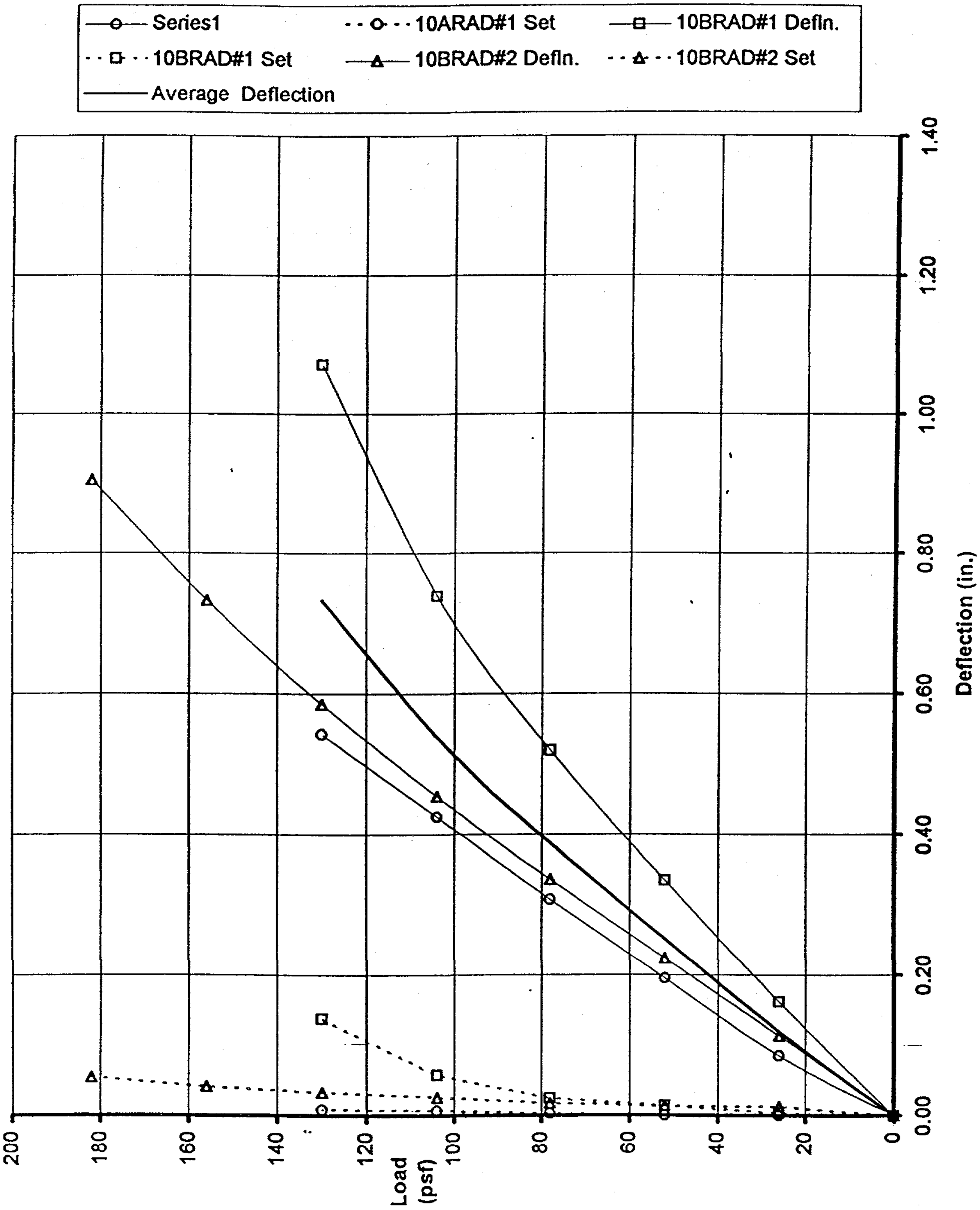
Transverse Load Test on Sandwich Panels, ASTM E-72 - 10% RECYCLED EPS

Load		Deflections (in.)						
		10ARAD#1	10ARAD#1	10BRAD#1	10BRAD#1	10BRAD#2	10BRAD#2	Average
in. of H2O	psf	Defln.	Set	Defln.	Set	Defln.	Set	Deflection
0	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	26.0	0.085	0.000	0.162	0.003	0.114	0.013	0.120
10	52.0	0.195	0.000	0.333	0.014	0.223	0.014	0.251
15	78.0	0.307	0.003	0.519	0.025	0.335	0.018	0.387
20	104.0	0.425	0.007	0.738	0.058	0.455	0.026	0.540
25	130.0	0.543	0.009	1.071	0.138	0.585	0.033	0.733
30	156.0					0.732	0.041	
35	182.0					0.905	0.055	

RADCO

RAD-1625

TRANSVERSE LOAD TEST, ASTM E-72 - 10% RECYCLED EPS

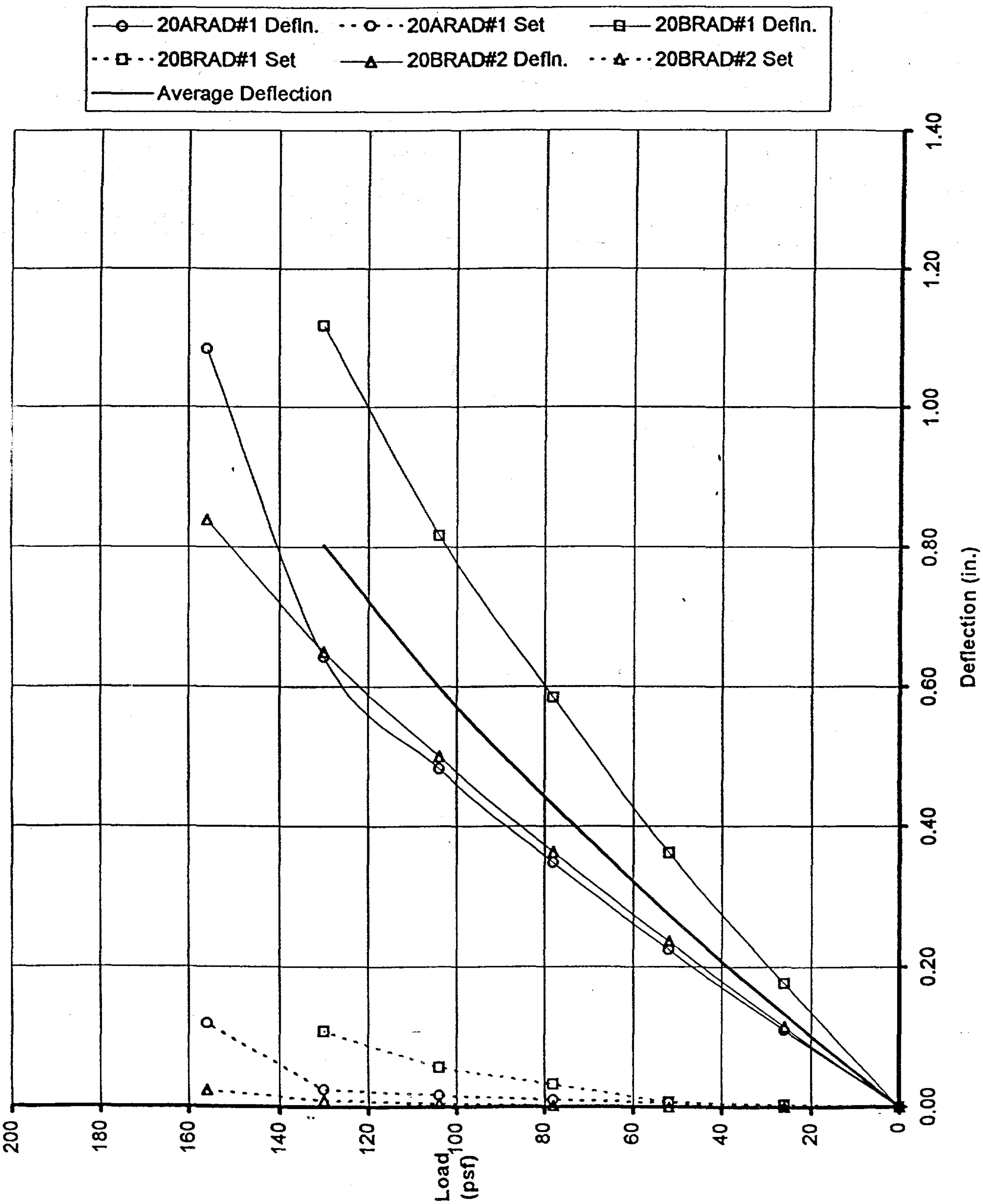


WINTER2.XLS - Chart

Transverse Load Test on Sandwich Panels, ASTM E-72 - 20% RECYCLED EPS

Load		Deflections (in.)						
		20ARAD#1	20ARAD#1	20BRAD#1	20BRAD#1	20BRAD#2	20BRAD#2	Average
in. of H2O	psf	Defln.	Set	Defln.	Set	Defln.	Set	Deflection
0	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	26.0	0.109	0.003	0.176	0.003	0.115	0.000	0.134
10	52.0	0.223	0.005	0.361	0.007	0.235	0.000	0.273
15	78.0	0.347	0.010	0.584	0.032	0.363	0.002	0.431
20	104.0	0.482	0.016	0.816	0.056	0.500	0.005	0.600
25	130.0	0.642	0.025	1.117	0.108	0.650	0.009	0.803
30	156.0	1.083	0.118			0.838	0.024	

TRANSVERSE LOAD TEST, ASTM E-72 - 20% RECYCLED EPS



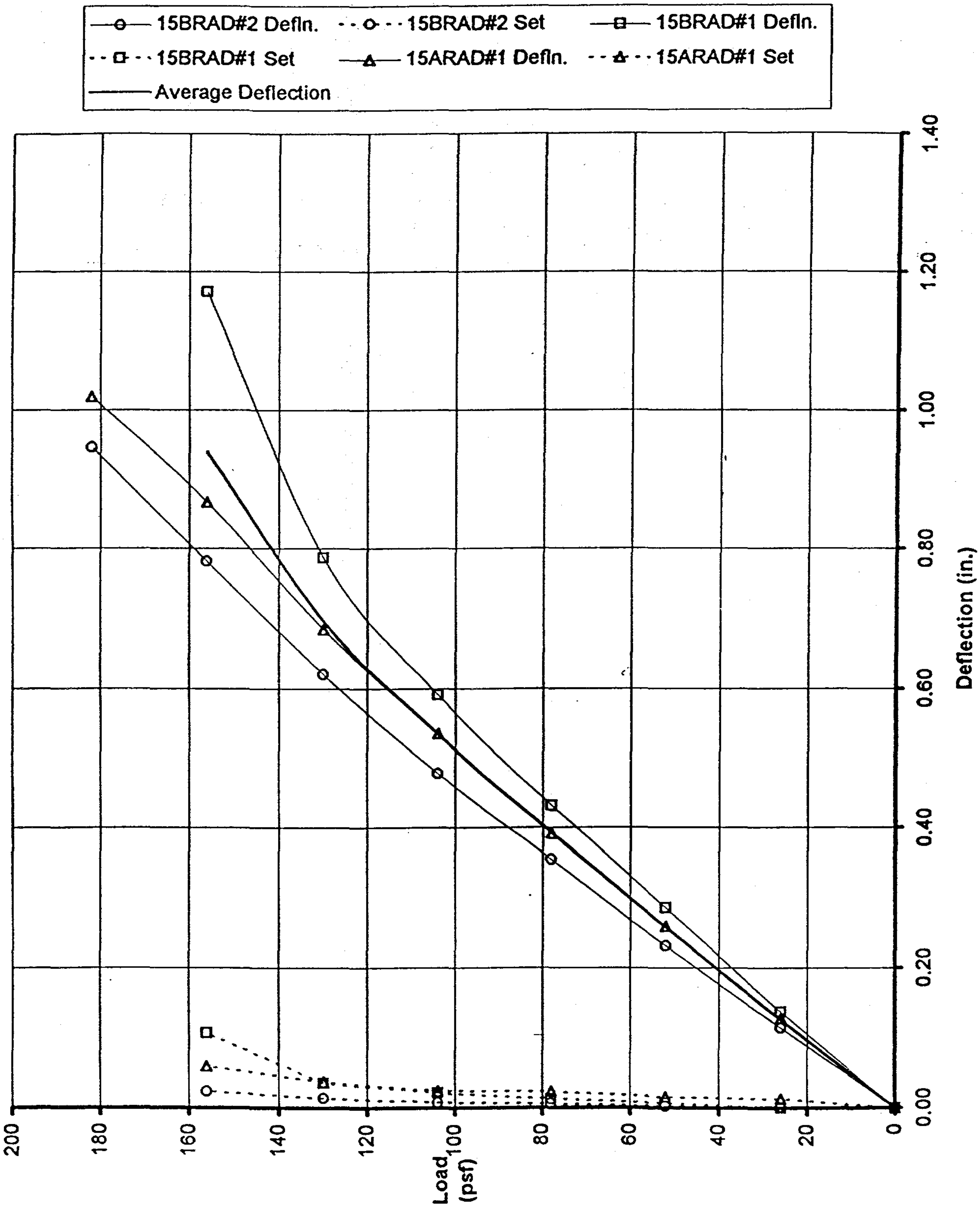
Transverse Load Test on Sandwich Panels, ASTM E-72 - 15% RECYCLED EPS, MIX A

Load		Deflections (in.)						
		15BRAD#2	15BRAD#2	15BRAD#1	15BRAD#1	15ARAD#1	15ARAD#1	Average
in. of H2O	psf	Defln.	Set	Defln.	Set	Defln.	Set	Deflection
0	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	26.0	0.114	0.001	0.137	0.000	0.127	0.012	0.126
10	52.0	0.231	0.002	0.286	0.006	0.259	0.015	0.259
15	78.0	0.354	0.006	0.431	0.013	0.391	0.023	0.392
20	104.0	0.478	0.008	0.591	0.022	0.536	0.025	0.535
25	130.0	0.620	0.014	0.787	0.036	0.684	0.038	0.697
30	156.0	0.781	0.024	1.170	0.107	0.866	0.060	0.939
35	182.0	0.945				1.019		

RADCO

RAD-1625

TRANSVERSE LOAD TEST, ASTM E-72 - 15% RECYCLED EPS, MIX A



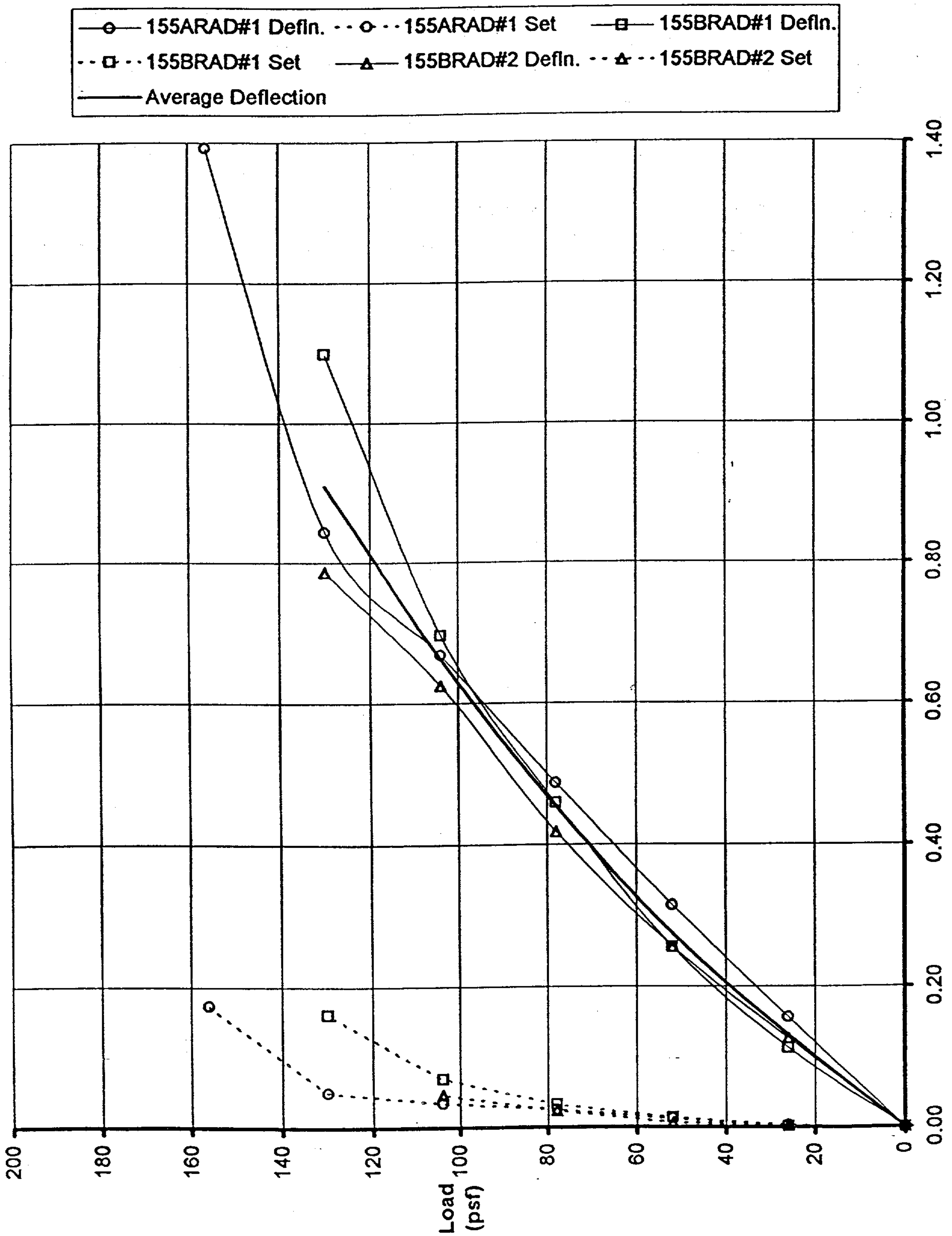
RADCO

RAD-1625

Transverse Load Test on Sandwich Panels, ASTM E-72 - 15% RECYCLED EPS, MIX B

Load		Deflections (in.)						
		155ARAD#1	155ARAD#1	155BRAD#1	155BRAD#1	155BRAD#2	155BRAD#2	Average
in. of H2O	psf	Defln.	Set	Defln.	Set	Defln.	Set	Deflection
0	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	26.0	0.157	0.003	0.113	0.000	0.126	0.002	0.132
10	52.0	0.315	0.012	0.256	0.013	0.256	0.006	0.276
15	78.0	0.488	0.025	0.459	0.033	0.419	0.023	0.455
20	104.0	0.669	0.034	0.697	0.069	0.625	0.047	0.663
25	130.0	0.844	0.051	1.099	0.161	0.787		0.910
30	156.0	1.392	0.174					

TRANSVERSE LOAD TEST, ASTM E-72 - 15% RECYCLED EPS, MIX B



WINTER5.XLS - Chart

RADCO

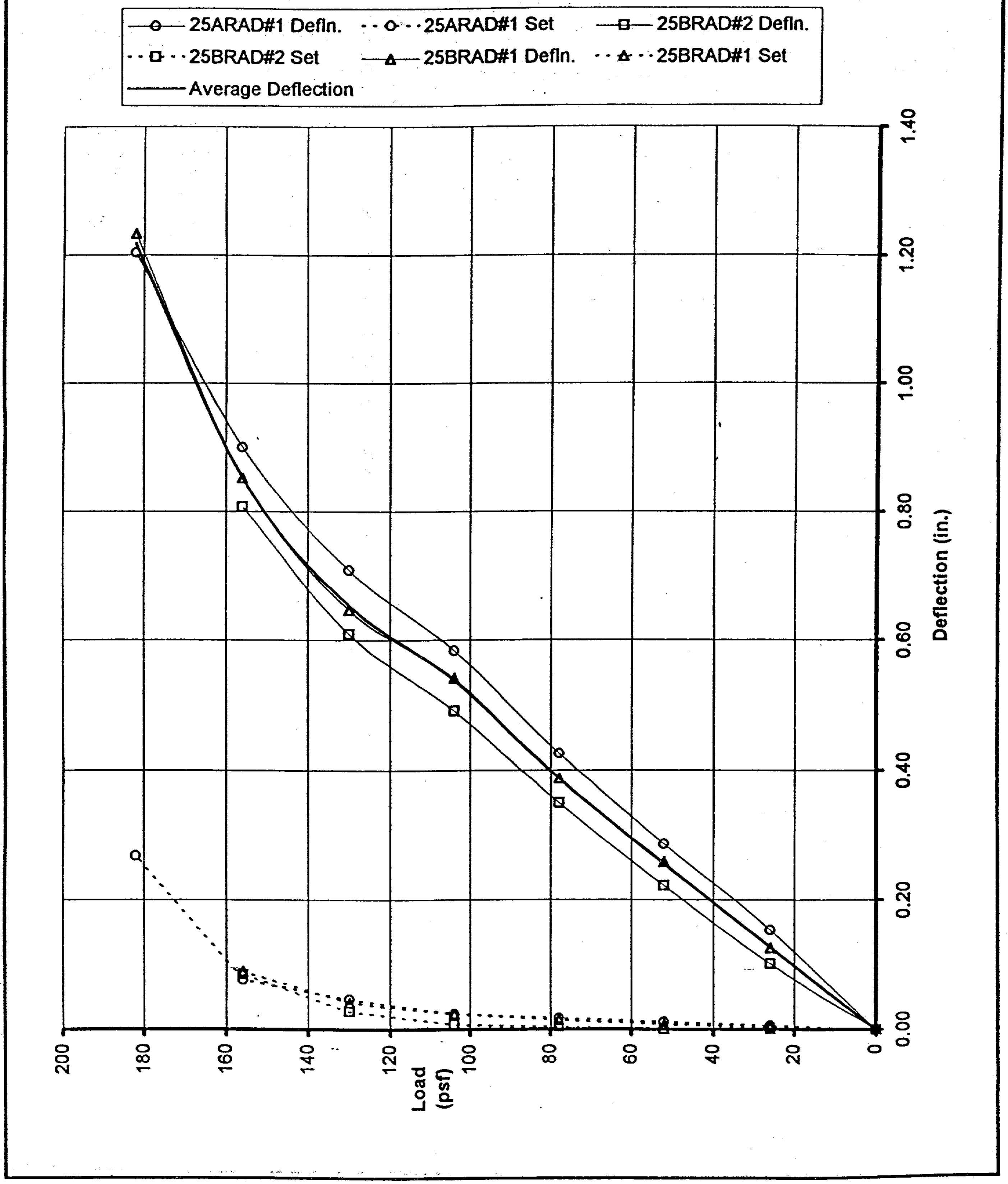
RAD-1625

Transverse Load Test on Sandwich Panels, ASTM E-72 - 25% RECYCLED EPS

Load		Deflections (in.)						
		25ARAD#1	25ARAD#1	25BRAD#2	25BRAD#2	25BRAD#1	25BRAD#1	Average
in. of H2O	psf	Defln.	Set	Defln.	Set	Defln.	Set	Deflection
0	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	26.0	0.154	0.005	0.102	0.000	0.127	0.003	0.128
10	52.0	0.286	0.011	0.222	0.000	0.258	0.008	0.256
15	78.0	0.426	0.017	0.349	0.003	0.387	0.014	0.387
20	104.0	0.584	0.024	0.491	0.007	0.542	0.023	0.539
25	130.0	0.708	0.047	0.609	0.028	0.646	0.042	0.655
30	156.0	0.900	0.077	0.807	0.086	0.852	0.090	0.853
35	182.0	1.203	0.268			1.233		1.218

RAD-1625

TRANSVERSE LOAD TEST, ASTM E-72 - 25% RECYCLED EPS



WINTER6.XLS - Chart

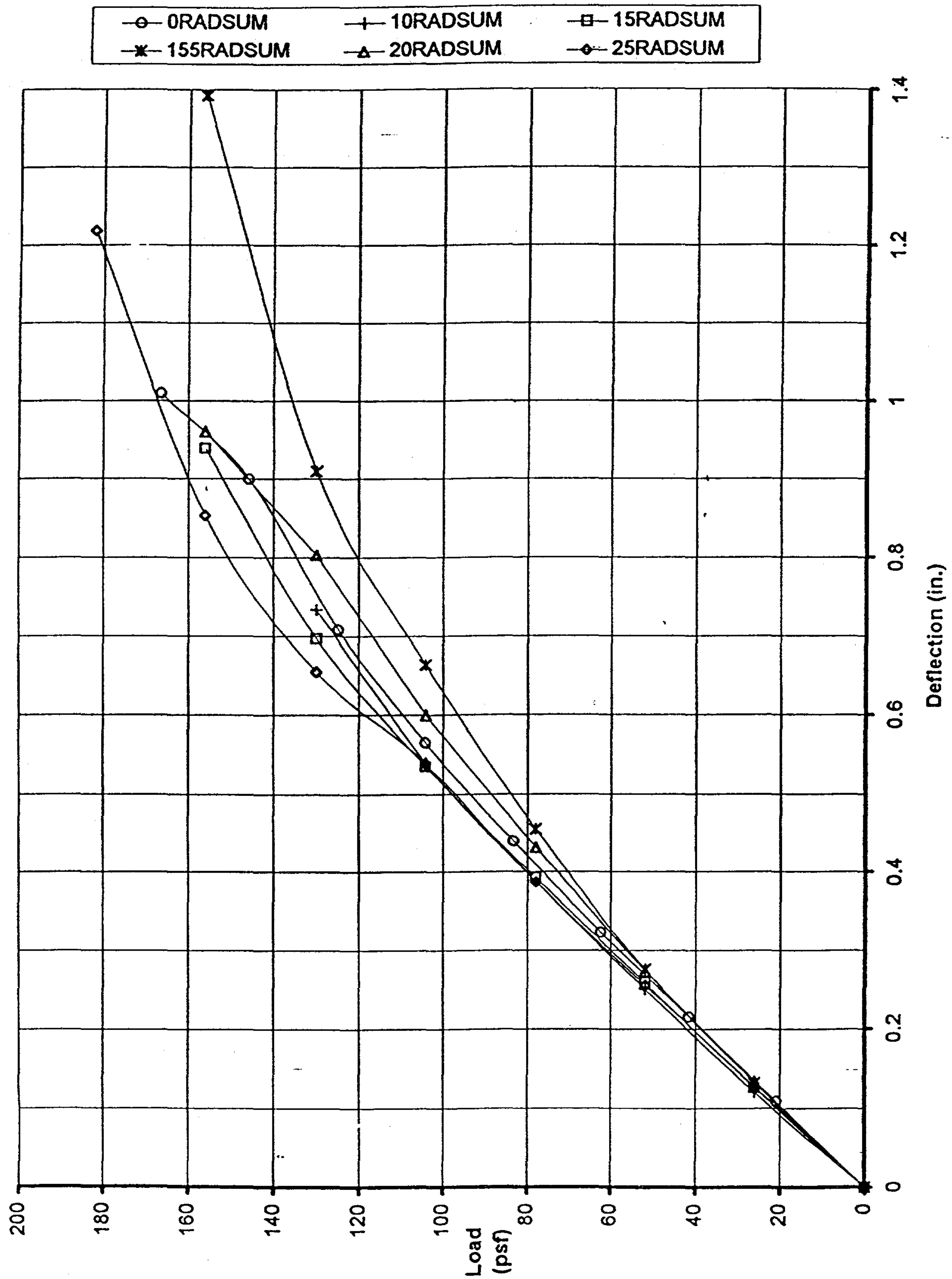
APPENDIX F

TRANSVERSE LOAD TEST RESULTS SUMMARY

RADCO

TRANSVERSE LOAD TEST SUMMARY

RAD-1625



Transverse Load Test, ASTM E-72 - RADCO Test Report RAD-1625				
PANEL IDENTIFICATION	FAILURE LOAD (psf)	OSB SKIN TYPE	OSB ORIENTATION	MODE OF FAILURE
0ARAD#1	305.24	Huber	Transverse	Both ends started to bear on the 2x4 end supports at 40" w.c pressure. Panel failed when the foam sheared along the upper skin to a point 25" in from the end. The OSB then cracked 6" from the end.
0BRAD#2	295.88	Weyerhauser	Longitudinal	OSB skin broke across the 4 ft. width approximately 4" to 6" from one end. Foam did not shear.
0BRAD#1	254.80	Huber	Transverse	OSB Skin cracked approximately 4 to 6" from one support. The panel simultaneously slipped off the roller support. There was no shear failure observed in the foam.
Average	285.31			
10ARAD#1	335.92	Huber	Transverse	Failure occured when the foam sheared at one end approximately 6" from one end along the top skin for about 24" in. The OSB skin also cracked 6" from the same end along the entire 4ft. width.
10BRAD#1	146.64	Huber	Transverse	Failure occured when the foam sheared at one end along the top skin for about 24" in.
10BRAD#2	201.24	Weyerhauser	Longitudinal	Failure occured when the foam sheared at one end along the top skin for about 24" in.
Average	227.93			
20ARAD#1	158.08	Weyerhauser	Longitudinal	Foam sheared along the top skin from one end for approximately 24".
20BRAD#1	156.00	Huber	Transverse	Foam sheared along the top skin from one end (left) for approximately 15".
20BRAD#2	180.44	Huber	Transverse	Foam sheared along the top skin from one end (left) for approximately 20".
Average	164.84			

Transverse Load Test, ASTM E-72 - RADCO Test Report RAD-1625				
PANEL IDENTIFICATION	FAILURE LOAD (psf)	OSB SKIN TYPE	OSB ORIENTATION	MODE OF FAILURE
15ARAD#1	182.00	Huber	Transverse	Foam sheared along the top skin from one end (right side) for approximately 20".
15BRAD#1	166.92	Huber	Transverse	Foam sheared along the top skin from one end (left side) for approximately 20".
15BRAD#2	182.00	Huber	Transverse	Foam sheared along the top skin from one end (left side) for approximately 20".
Average	176.97			
155RAD#1	160.16	Huber	Transverse	Foam sheared along the top skin from one end (right side) for approximately 20".
155BRAD#1	149.24	Weyerhauser	Longitudinal	Glue bond failed across the entire width of the panel, starting approx. 1" from the left end and extending into the panel for 22". 11" in from the same end was a 3" wide strip across the entire width where the foam seemed to hold and shearing occured at this location.
155BRAD#2	130.00	Huber	Transverse	Failure was a combinaion of adhesive and shear failure. Failure occured on the left end where the top OSB delaminated from the EPS to 18" into the panel Adhesive failure was confined to a 4" wide section starting approximately 3" from the edge.
Average	146.47			
25ARAD#1	189.80	Weyerhauser	Longitudinal	Foam sheared along the top skin from one end (left side) for approximately 27".
25BRAD#2	167.96	Weyerhauser	Longitudinal	Failure was a combinaion of adhesive and shear failure. Failure occured on the right end where the top OSB delaminated from the EPS to 27" into the panel Adhesive failure was confined to a 2" wide section starting approximately 2" from the edge.
25B	182.00	Weyerhauser	Longitudinal	Combination adhesive and shear failure. Foam sheared along the top skin from the left side into the panel for 32". Random locations throughout the delaminated area showed intermittent areas where the glue coverage did not appear adequate.
Average	179.92			

APPENDIX B: ORNL Report

Oak Ridge National Laboratory

P.O. Box 2008
Oak Ridge, Tennessee 37831-6092
(423)574-0329
fax(423)576-3894
stovalltk@ornl.gov

December 4, 1995

Alex Grinnell
Steven winter Associates, Inc.
50 Washington Street
Norwalk, CT 06854

Dear Alex,

We have completed conductivity measurements on the 18 foam insulation samples for the New York State Energy Office (NYSEO Agreement #4107-lABR-BR-95). The attached table and charts summarize the results. In general, we found the variability within each of the six samples to be small, ranging from 1 to 3% of the mean value. These tests were made at a mean temperature of 75°F with a 40°F temperature difference. If you have any questions, please call me.

We will hold these foam samples until February. If you would like them back, please let me know.

Sincerely,

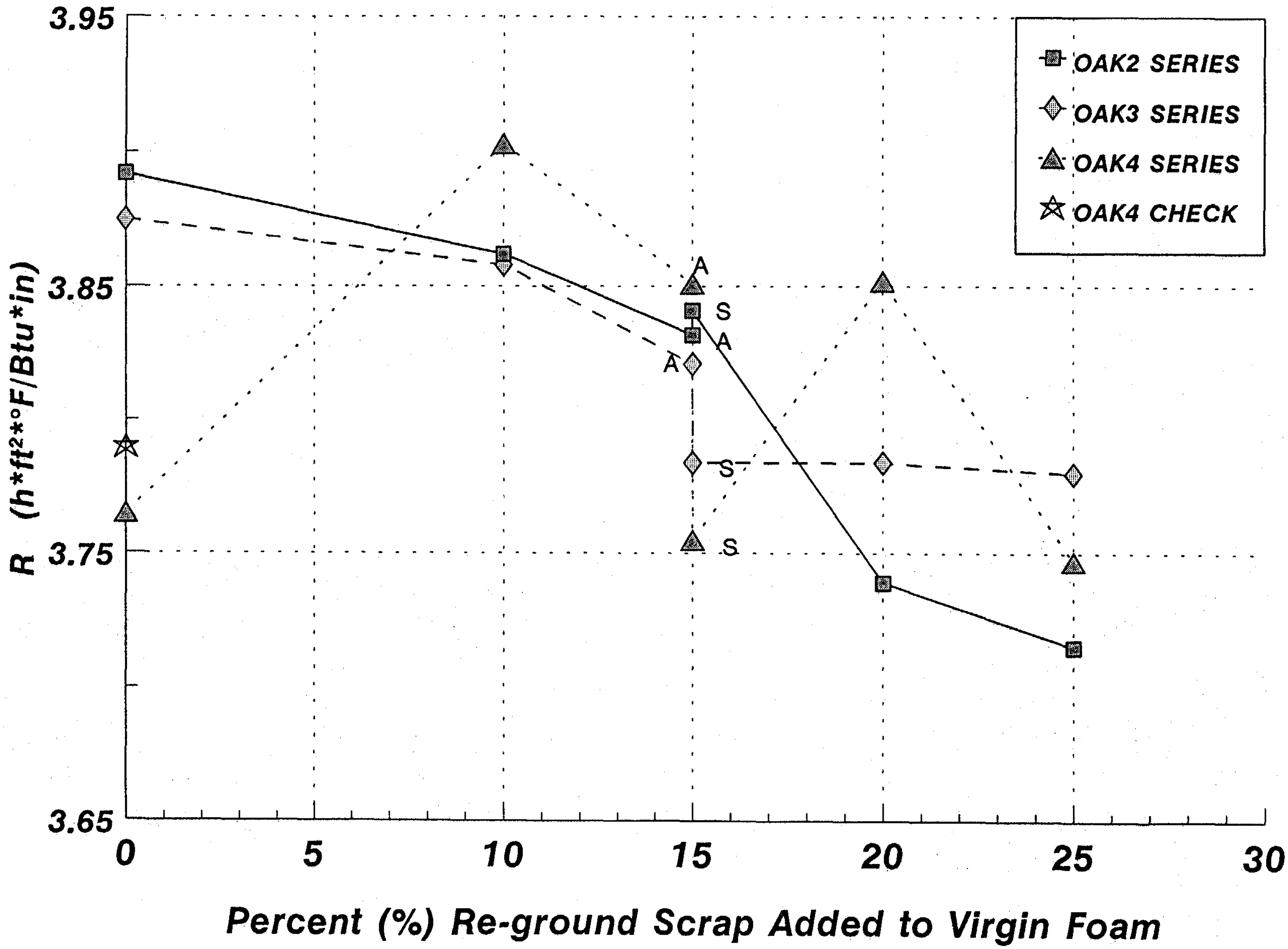
Therese K. Stovall

cc (w/encl): Jeff Christian
Fred Weaver
Ken Wilkes

STEVEN WINTER ASSOC. EPS - MEASURED IN ADVANCED R-MATIC (OCT-NOV 1995)

Specimen ID	Test Date (1995)	Test # (95-xxxx)	Test"L" (cm)	t_{mean} (°C)	Δ t (°C)	k (Btu·in/h·ft²·°F)	R (h·ft²·°F/Btu·in)
OA-OAK2	10-05	1328	5.029	23.570	21.42	0.256917	3.8923
15A-OAK2	10-06	1330	5.037	23.895	21.87	0.260952	3.8321
10A-OAK2	10-09	1331	5.027	24.020	22.14	0.258911	3.8623
15S-OAK2	10-10	1332	5.027	23.970	22.02	0.260321	3.8414
20A-OAK2	10-10	1333	5.011	23.870	22.00	0.267426	3.7394
25A-OAK2	10-11	1334	5.072	23.895	22.03	0.269201	3.7147
OA-OAK3	11-06	1347	5.027	23.880	22.02	0.25810	3.8745
10A-OAK3	11-08	1348	5.050	23.890	21.98	0.260042	3.8579
15A-OAK3	11-09	1349	5.006	23.860	21.86	0.261690	3.8213
15S-OAK3	11-10	1352	5.016	23.840	21.78	0.264248	3.7843
20A-OAK3	11-13	1354	5.022	23.860	21.90	0.264249	3.7843
25A-OAK3	11-14	1355	5.029	23.920	22.00	0.264532	3.7803
OA-OAK4	11-14	1356	5.027	23.925	21.99	0.265623	3.7647 (WILL CK)
10A-OAK4	11-15	1358	5.055	23.985	22.21	0.256233	3.9027
15A-OAK4	11-16	1359	5.057	23.820	21.88	0.259661	3.8512
15S-OAK4	11-20	1362	5.006	23.925	22.07	0.266297	3.7552
20A-OAK4	11-21	1364	5.024	23.970	22.02	0.259608	3.8520
25A-OAK4	11-21	1365	5.004	23.900	22.06	0.266881	3.7470
OA-OAK4	11-29	1366	5.027	23.860	21.86	0.263873	3.7897 (CHECK PT)

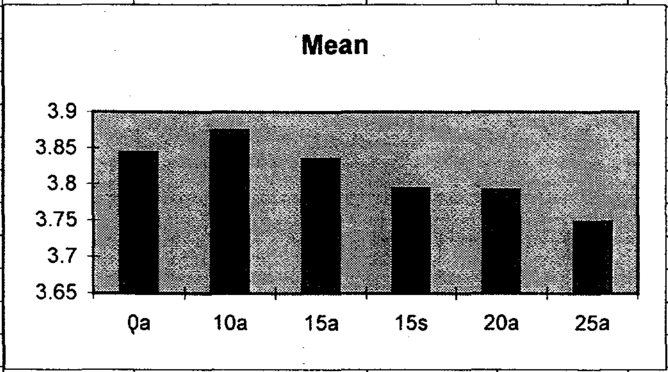
STEVEN WINTER EPS MEASURED IN ADVANCED R-MATIC, R-41.
MEASUREMENTS DONE OCTOBER - NOVEMBER 1995.

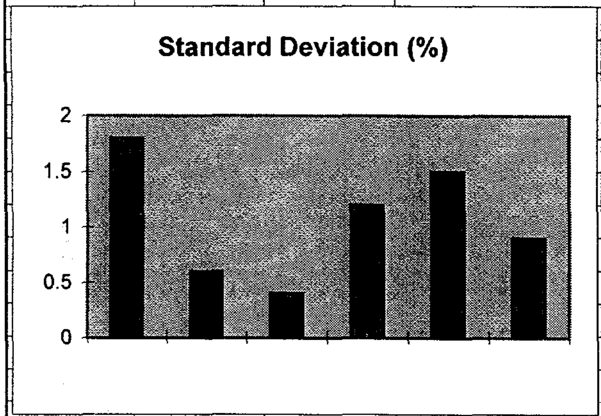


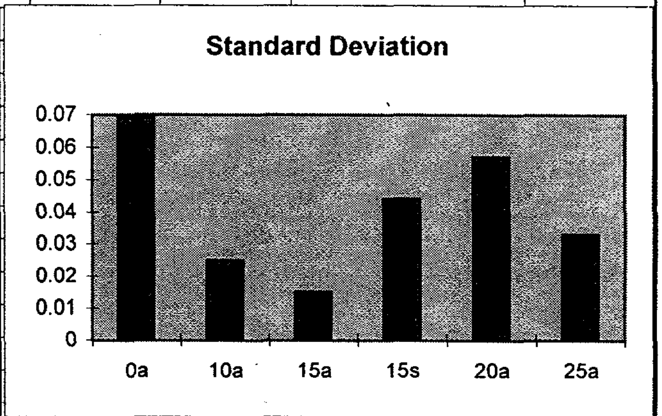
Test Results - NY ERDA Samples

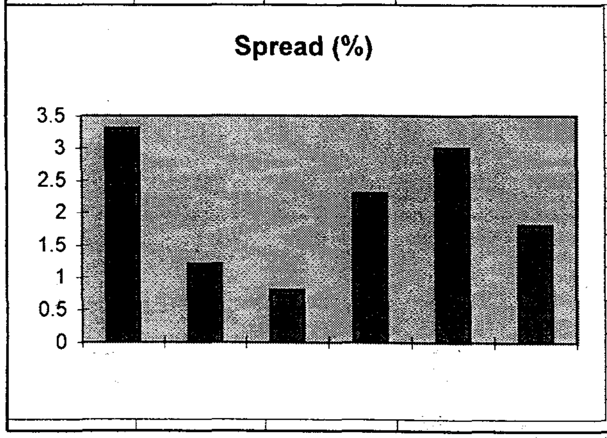
All values have typical R-value units of h-ft2-F/Btu-in.

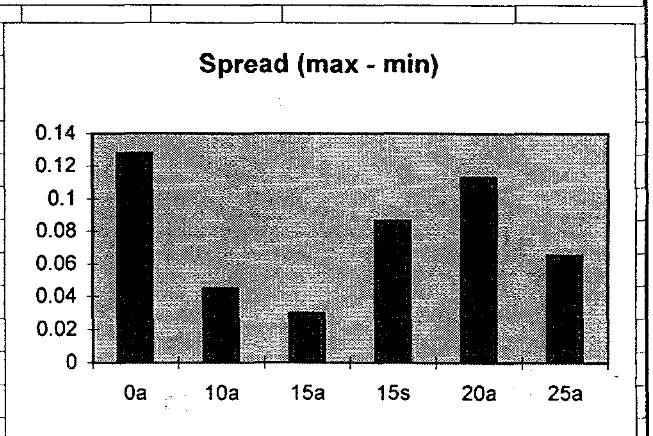
Sample ID	Mean	STD (%)	Standard Deviation	Minimum	Maximum	Spread (max-min)	Spread (%)
0a	3.8438	1.8	0.069	3.7647	3.8923	0.1276	3.3
10a	3.8743	0.6	0.025	3.8579	3.9027	0.0448	1.2
15a	3.8349	0.4	0.015	3.8213	3.8512	0.0299	0.8
15s	3.7936	1.2	0.044	3.7552	3.8414	0.0862	2.3
20a	3.7919	1.5	0.057	3.7394	3.852	0.1126	3
25a	3.7473	0.9	0.033	3.7147	3.7803	0.0656	1.8











APPENDIX C: BASF and Ashland Chemical Report

BASF Canada Inc.

BASF

September 18, 1995

BASF Corporation
3000 Continental Drive - North
Mount Olive, New Jersey
07828-1234

Attention: Thomas R. Greeley

Re: Test results on EPS samples

The samples of your boards were tested at our Toronto laboratory in accordance to the ASTM test methods.

Sample Description:
1 -- 0 A BASF 1
2 -- 10 A BASF 1
3 -- 15 A BASF 1
4 -- 15 AS BASF 1
5 -- 20 A BASF 1
6 -- 25 A BASF 1

		1	2	3	4	5	6
Density (pcf)		1.02	1.10	1.05	0.98	1.04	1.03
Comp. Strength (at 10%)							
	kpa	75.6	106.4	62.0	74.3	81.4	78.8
	psi	10.97	15.43	8.99	10.77	11.81	11.43
*Flexural Strength							
	kpa	161.3 ± 9.7	179.8 ±23.9	153.8±12.9	177.8±10.7	164.8±15.2	156±13.9
	psi	23.39±1.4	26.1 ± 3.5	22.3± 1.9	25.8± 1.6	23.9± 2.2	22.6±2.0
"R" Value		3.85	3.91	3.73	3.73	3.94	3.85

* Average values from 12 samples

As we are not an accredited testing laboratory, these results can only be used as a guideline in judging the quality of your product.

.../2

162 rue Barr, Ville St. Laurent, Québec H4T 1Y4/ (514) 341-5411 Téléfax (514) 340-1248
Siège Social: 345 Carlingview Drive, Toronto, Ontario M9W 6N9 (416) 675-3611 Téléfax (416) 674-2588

BASF Canada Inc.

Sample Description: 1 -- 0 B BASF 4
2 -- 10 B BASF 4
3 -- 15 B BASF 4
4 -- 15 BS BASF 4
5 -- 20 B BASF 4
6 -- 25 B BASF 4

	1	2	3	4	5	6
Density (pcf)	0.98	0.96	1.03	1.00	0.93	1.08
Comp. Strength (at 10%)						
kpa	89.9	70.9	97.9	58.5	73.4	83.6
psi	13.04	10.28	14.20	8.49	10.64	12.20
*Flexural Strength						
kpa	164.9 ± 12.9	158.7 ±4.9	180.2±25.1	151.5±4.3	147.6±8.8	159.4±5.2
psi	23.3±1.9	23.0 ±0.7	26.1±3.6	22±0.6	21.4±1.3	23.1±0.8
"R" Value	3.82	3.70	3.86	3.72	3.75	3.75

* Average values from 12 samples

As we are not an accredited testing laboratory, these results can only be used as a guideline in judging the quality of your product.

Regards,
BASF Canada Inc.

André St Michel

André St. Michel
Promotional Manager
Styropor

5 Pages Including Cover

To: Stan Dimmick
Company: Korwall
Fax: (817) ~~265-9665~~ 277-6743
Phone: (817) 277-6741

From: Bill Gareis
Company: Ashland Chemical
Fax: (614) 790-4039
Phone: (614) 790-4312

Subject: C-297 Tensile Test Results

Stan,

The testing has been completed on the panels that you submitted. These panels were part of the SIPA Experiment concerning recycled EPS. This fax contains the raw data from the testing. I wanted to get this data to you quickly, so I apologize that it isn't in presentation form. I will follow this fax with a formal letter. The raw data follows this note.

The test that was conducted was ASTM C-297 Tension Test of Flat Sandwich Constructions in Flatwise Plane. The test was conducted on dry samples. No cyclic aging was performed because OSB is not typically stable enough to withstand repeated water soaks.

You will notice that the data sheets have six columns. I will explain the titles and the significance of each column.

Column 1 just gives the information about the specific sample. The panels that you sent to our lab were labeled 0A, 10A, 15A, 15B, 20A, and 25B. We didn't change you labeling at all. Each of the panels was cut into many 2"X2" test samples. Twenty of these samples were then tested. We are holding the both the tested samples and the untested retains if you wish to pursue further testing.

Column 2 contains information about the force applied to the panels during testing. This number gets converted into the PSI at break, which does have some meaning for you. You can ignore Column 2.

Column 3 is the Percent Foam Failure for each sample. Obviously, you want this number to be 100% for every sample since the panel should break in the foam. This was the case with the majority of the samples, but as you can see, several samples didn't break in the foam. This fact caused us to add Column 4.

Column 4 contains the Percent Wood Failure for each sample. You will notice that the only samples that have any wood failure have no foam failure. This is because they broke in the OSB. Theoretically, with 1.0 pcf EPS, the foam should fail prior to the OSB. Unfortunately, this type of failure does occur.

Column 5 contains the Percent Substrate Failure. This is a combination of the Foam and Wood Failures. As you can see, in all cases it was 100%, which gives you one measure of the bond quality.

Column 6 contains the Force at Break (Pounds per Square Inch, PSI). This number gives you an indication of the internal bond strength of the panel.

When evaluating data from this type of test, it is important to keep in mind that where and how a panel fails can be as important as at what strength.

I will follow up this fax with a formal letter, but if you wish to discuss this further before then, feel free to phone me at (614) 790-4312

Sincerely

Bill

Bill Gareis
Ashland Chemical

ASTM C-297 TENSILE TEST RESULTS

SAMPLE	%SCALE	%FF	%WF	%SF	PSI
0A-1	69.0	100	0	100	25.9
0A-2	58.0	100	0	100	21.8
0A-3	56.0	100	0	100	21.0
0A-4	74.0	100	0	100	27.8
0A-5	73.5	100	0	100	27.6
0A-6	68.0	100	0	100	25.5
0A-7	65.5	100	0	100	24.6
0A-8	64.0	100	0	100	24.0
0A-9	69.0	100	0	100	25.9
0A-10	65.0	100	0	100	24.4
0A-11	68.5	100	0	100	25.7
0A-12	66.0	100	0	100	24.8
0A-13	55.0	100	0	100	20.6
0A-14	57.5	100	0	100	21.6
0A-15	63.5	100	0	100	23.8
0A-16	69.0	100	0	100	25.9
0A-17	65.0	100	0	100	24.4
0A-18	64.0	100	0	100	24.0
0A-19	58.5	100	0	100	21.9
0A-20	58.0	100	0	100	21.8
10A-1	37.0	100	0	100	13.9
10A-2	74.0	100	0	100	27.8
10A-3	88.0	100	0	100	33.0
10A-4	76.5	100	0	100	28.7
10A-5	88.0	100	0	100	33.0
10A-6	82.5	100	0	100	30.9
10A-7	94.0	100	0	100	35.3
10A-8	84.0	100	0	100	31.5
10A-9	59.0	100	0	100	22.1
10A-10	56.0	100	0	100	21.0
10A-11	83.5	100	0	100	31.3
10A-12	61.0	100	0	100	22.9
10A-13	89.0	100	0	100	33.4
10A-14	79.0	100	0	100	29.6
10A-15	76.5	100	0	100	28.7
10A-16	73.0	100	0	100	27.4
10A-17	77.5	100	0	100	29.1
10A-18	81.0	100	0	100	30.4
10A-19	81.0	100	0	100	30.4
10A-20	72.5	100	0	100	27.2

PANELS FROM KORWALL
Labels from Korwall

ASTM C-297 TENSILE TEST RESULTS

SAMPLE	%SCALE	%FF	%WF	%SF	PSI
15A-1	68.5	100	0	100	25.7
15A-2	42.5	100	0	100	15.9
15A-3	NA	0	100	100	#VALUE!
15A-4	NA	0	100	100	#VALUE!
15A-5	78.0	100	0	100	29.3
15A-6	58.0	100	0	100	21.8
15A-7	77.0	100	0	100	28.9
15A-8	72.0	100	0	100	27.0
15A-9	21.0	0	100	100	7.9
15A-10	73.0	100	0	100	27.4
15A-11	71.5	100	0	100	26.8
15A-12	61.5	100	0	100	23.1
15A-13	55.0	100	0	100	20.6
15A-14	46.0	100	0	100	17.3
15A-15	66.0	100	0	100	24.8
15A-16	67.5	100	0	100	25.3
15A-17	68.0	100	0	100	25.5
15A-18	58.5	100	0	100	21.9
15A-19	55.0	100	0	100	20.6
15A-20	53.5	100	0	100	20.1
15B-1	51.0	0	100	100	19.1
15B-2	52.5	0	100	100	19.7
15B-3	64.5	100	0	100	24.2
15B-4	49.5	100	0	100	18.6
15B-5	53.0	100	0	100	19.9
15B-6	57.5	100	0	100	21.6
15B-7	66.0	100	0	100	24.8
15B-8	63.0	100	0	100	23.6
15B-9	66.0	100	0	100	24.8
15B-10	33.5	0	100	100	12.6
15B-11	48.0	0	100	100	18.0
15B-12	52.5	100	0	100	19.7
15B-13	69.5	100	0	100	26.1
15B-14	71.0	100	0	100	26.6
15B-15	67.5	100	0	100	25.3
15B-16	62.0	100	0	100	23.3
15B-17	65.0	100	0	100	24.4
15B-18	64.0	100	0	100	24.0
15B-19	65.5	100	0	100	24.6
15B-20	59.5	100	0	100	22.3

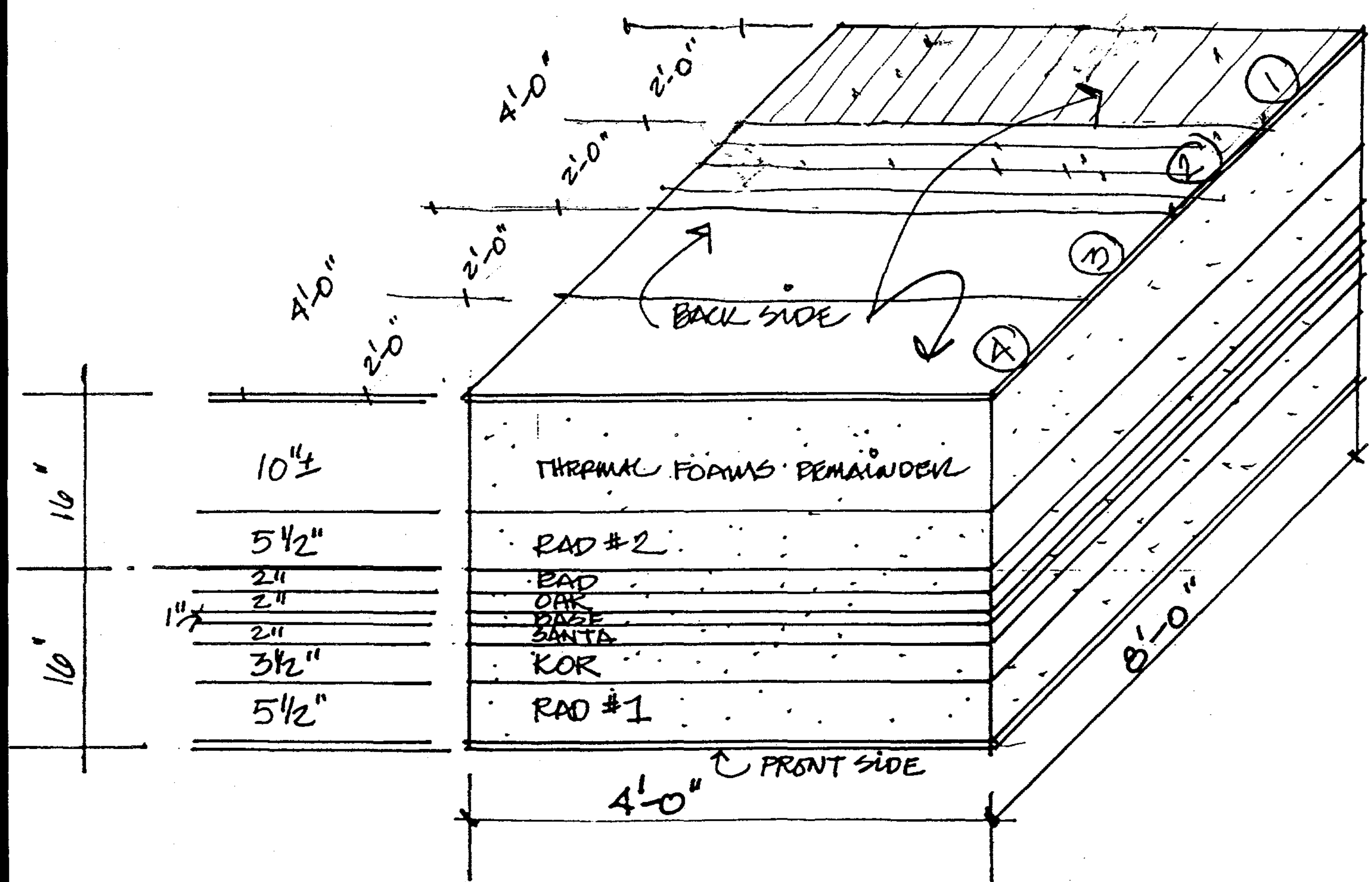
PANELS FROM KORWALL
Labels from Korwall

ASTM C-297 TENSILE TEST RESULTS

SAMPLE	%SCALE	%FF	%WF	%SF	PSI
20A-1	64.0	100	0	100	24.0
20A-2	53.5	100	0	100	20.1
20A-3	77.0	100	0	100	28.9
20A-4	64.0	100	0	100	24.0
20A-5	40.0	0	100	100	15.0
20A-6	74.0	100	0	100	27.8
20A-7	77.0	100	0	100	28.9
20A-8	52.0	100	0	100	19.5
20A-9	68.0	100	0	100	25.5
20A-10	42.5	100	0	100	15.9
20A-11	65.5	100	0	100	24.6
20A-12	48.0	100	0	100	18.0
20A-13	22.0	0	100	100	8.3
20A-14	42.5	100	0	100	15.9
20A-15	72.0	100	0	100	27.0
20A-16	59.5	100	0	100	22.3
20A-17	69.5	100	0	100	26.1
20A-18	68.0	100	0	100	25.5
20A-19	57.0	100	0	100	21.4
20A-20	70.0	100	0	100	26.3
25A-1	62.5	100	0	100	23.4
25A-2	45.0	100	0	100	16.9
25A-3	56.0	100	0	100	21.0
25A-4	55.0	100	0	100	20.6
25A-5	62.0	100	0	100	23.3
25A-6	46.0	100	0	100	17.3
25A-7	67.5	100	0	100	25.3
25A-8	42.5	100	0	100	15.9
25A-9	65.0	100	0	100	24.4
25A-10	60.5	100	0	100	22.7
25A-11	63.5	100	0	100	23.8
25A-12	NA	0	100	100	#VALUE!
25A-13	57.5	100	0	100	21.6
25A-14	62.0	100	0	100	23.3
25A-15	51.0	100	0	100	19.1
25A-16	NA	0	100	100	#VALUE!
25A-17	62.5	100	0	100	23.4
25A-18	35.0	100	0	100	13.1
25A-19	58.5	100	0	100	21.9
25A-20	49.0	100	0	100	18.4

PANELS FROM KORWALL
Labels from Korwall

APPENDIX D: Cutting Pattern of EPS Block into Slabs for SIP Cores and Test Samples



SECTION BLOCK (A)

NOTE: BLOCK B SIMILAR EXCEPT THAT BLOCK IS "FLIPPED" AND BACK AND FRONT SIDES ARE REVERSED