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RADVA Insulated Structural Wall System

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[STRUCTURAL DESIGN VALUES]

[This report provides the structural engineer with load tables for axial compression and transverse loading. Tables provide the engineer values for 3.5” and 5.5” thick insulated structural composite wall panels. These wall systems are manufactured with embedded galvanized steel studs that are spaced 16 inches or 24 inches on center. Values are available for 24, 20, 18 and 16 gauge thicknesses. Gauge and spacing are chosen based on the loads. Provisions are made to assist the engineer choose when the panel is subjected to both axial compression and transverse pressure. When panels are subjected to transverse loading, deflection can be a factor. Thus, tables are provided for deflection limits of L/180 to L/960. Racking shear is beyond the scope of this report and is not included.]

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DESCRIPTION

General

The RADVA Insulated Structural Wall Building systems are manufactured structural panels used in wall, roof and floor applications. This building system utilizes the latest in green technology and is marketed under the trade name RADVA TG Panel.

RADVA panels are manufactured with expandable polystyrene and galvanized steel to create a structural composite sandwich panel. Steel load carrying members are located flush with each face of the panel and separated by polystyrene. The polystyrene is fully bonded to the steel as this is part of the manufacturing process. This composite is created in a low-pressure molding process to form structural panels. The lightest panel manufactured consists of No. 24 gauge galvanized steel channels each face separated by insulation between. This approach provides the owner with a thermal break between each face of the panel. If it is needed, panels may be manufactured using 20, 18 or 16 gauge members. A typical application is illustrated in Figure 1.

Consider a panel for a vertical application. For this condition, the wall panel steel members now act as steel studs. The stud spacing in this system is either 16 inches or 24 inches (406 mm or 610 mm). If the panel is placed horizontal, steel members now act as beams. Typically, each panel is manufactured in 48 inch (1219 mm) widths and lengths of 8 ft (2438 mm), 9 ft (2743 mm), 10 ft (3048 mm), and 12 ft (3658 mm). There are two panel thicknesses available. These are 3 ½ inches (89 mm) and 5 ½ inches (140 mm). Each of these panels are installed with a unique tongue and groove fastening system, see Figure 2. Corners are joined in accordance with the details shown in Figure 3.

Expanded polystyrene panels or boards are manufactured in accordance with ASTM C 578, having a nominal density of 1.3 pounds per cubic foot (20.8 grams/liter) a flame-spread rating of 25 or less and a smoke-density rating of less than 450 when tested in accordance with ASTM E 84. The expanded polystyrene (EPS) density of 3.5" panels will be 1.5 pcf plus or minus 0.2 pcf. The EPS density for the thicker panels, 5.5" and 7.5", will be 1.1 pcf plus or minus 0.2 pcf. The embedded steel members are typically No. 24 gauge [0.0239 inch (0.61 mm)] complying with ASTM A 653 SS, Grade 37, with G-60 galvanizing. All thicknesses of steel noted in this evaluation report refer to minimum uncoated base-metal thickness. The steel noted in this report is coated with G-60 galvanizing complying with ASTM A924. A thermosetting adhesive is used to coat the steel prior to molding the panel. This is part of the panel manufacturing process as described in the approved quality control manual.

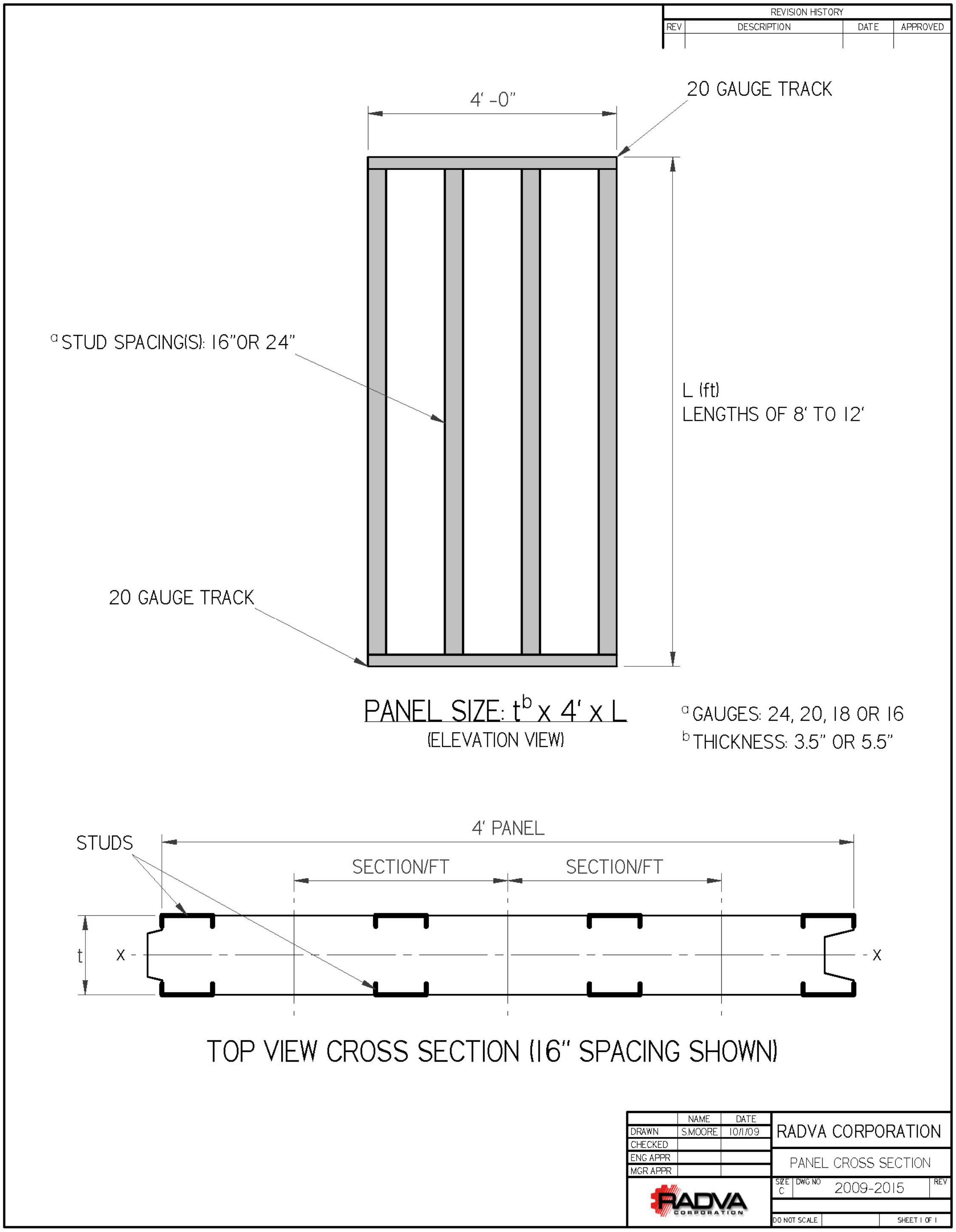

Figure 1. Typical RADVA Insulated wall panel without siding or sheet rock

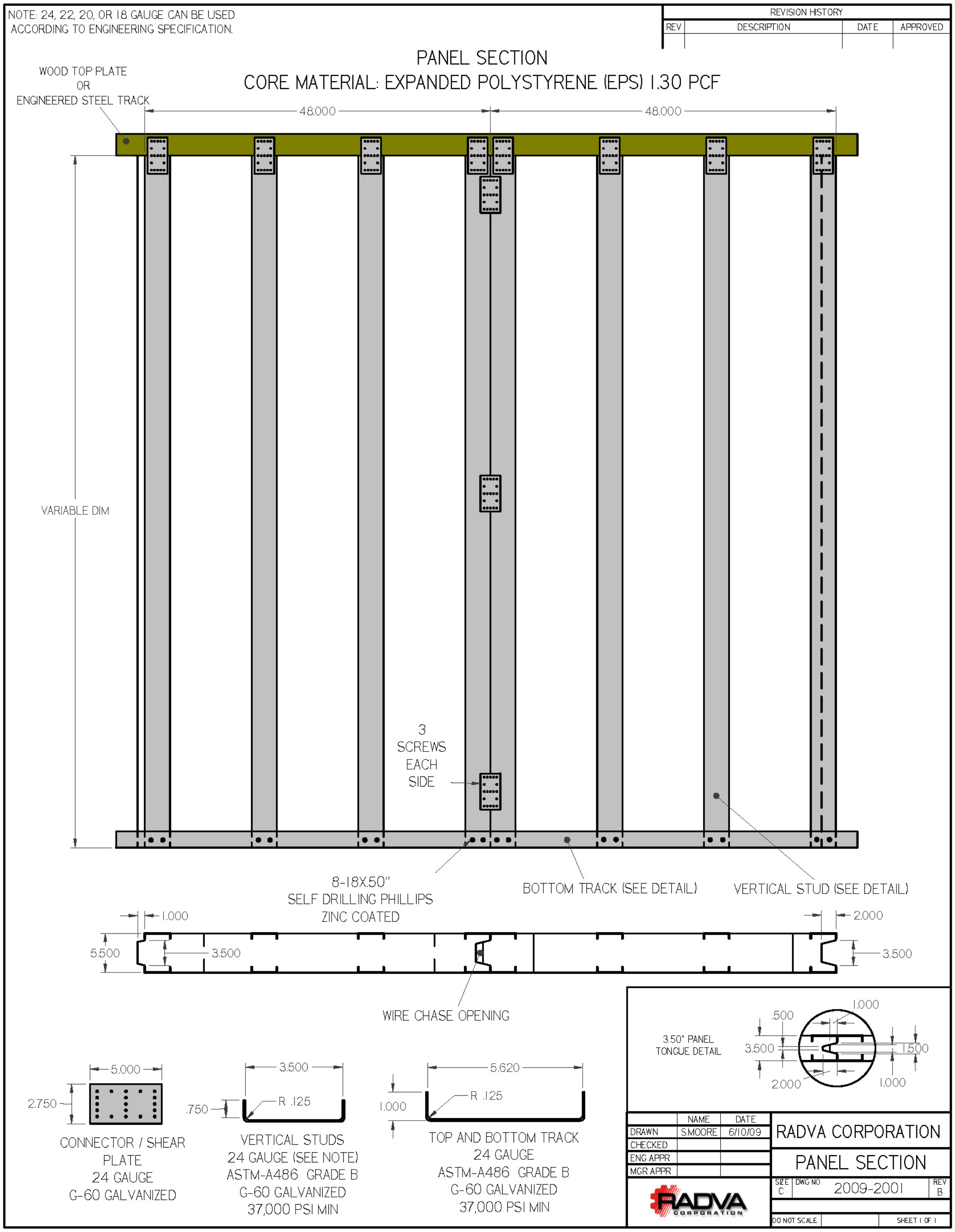

Figure 2 RADVA Insulated TG Structural Composite Panel (Fastening for 2 wall panels)

Expanded polystyrene panels or boards are either manufactured in accordance with ASTM C 578, having a nominal density of 1.3 pounds per cubic foot (20.8 grams/liter) a flame-spread rating of 25 or less and a smoke-density rating of less than 450 when tested in accordance with ASTM E 84. The steel is typically No. 24 gauge [0.0239 inch (0.61 mm)] complying with ASTM A 653 SS, Grade 37, with G-60 galvanizing. All thicknesses of steel noted in this evaluation report refer to minimum uncoated base-metal thickness. All steel noted in this report is coated with G-60 galvanizing complying with ASTM A924. The thermosetting adhesive used to coat the steel are during panel manufacture are described in the approved quality control manual.

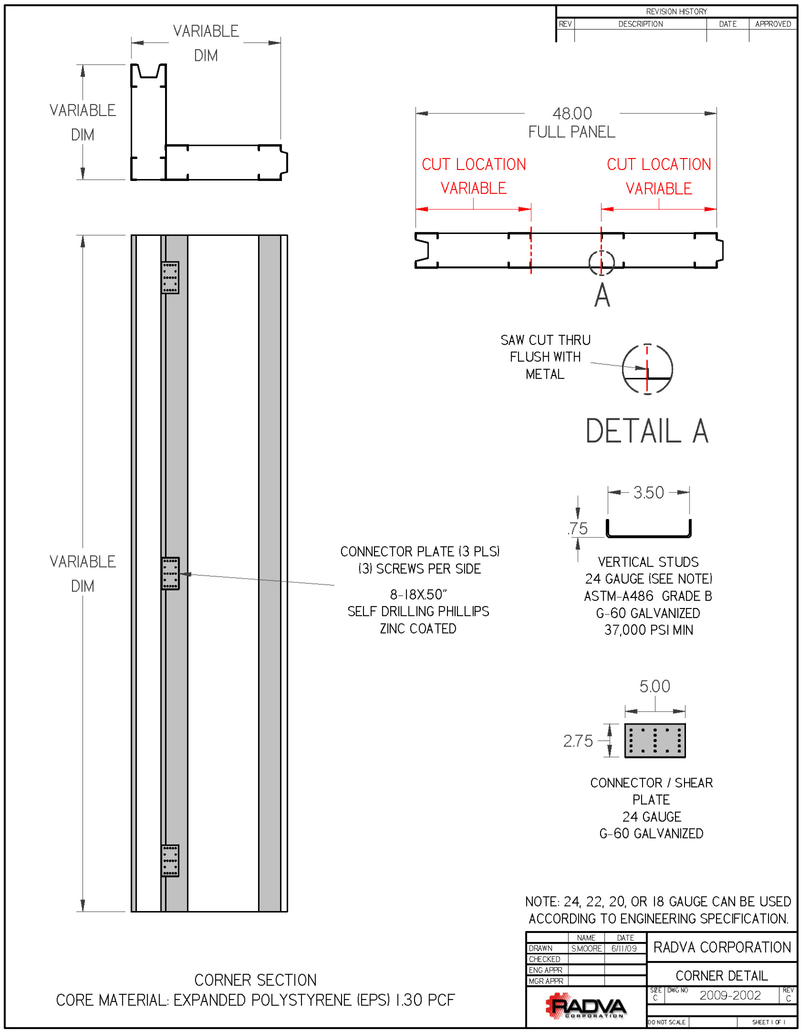

Figure 3 RADVA TG Insulated Structural Composite Sandwich Panel – Corner Fastening Details

DESIGN CONSIDERATIONS

Each structure using the RADVA TG system shall meet current building codes with adopted addenda and ordinances resulting from location dependent conditions. The panels shall be sized to meet the ASCE 7-05 - Minimum Design Loads for Buildings and Other Structures. Panel selection load tables are provided in this document for use by the Architect or Engineer. The calculations used to determine the load design values are consistent with American Iron and Steel Institute AISI 2007 North American Standard Specification for the Design of Cold Formed Steel Structural Members and the International Building Code 2006.

Structural design tables are provided in this document for axial compression and flexure. These tables provided design loads for panels manufactured with galvanized steel in 24 gauge, 20 gauge, 18 gauge and 16 gauge. Choices are provided for 16 inch or 24 inch stud spacing and panel lengths of 96 inches (2,438 mm) to 144 inches (3,658 mm).

The structural engineer has the choice of using either the LRFD method or the ASD method. When using the LRFD method, floor and roof panels should be selected to meet the desired serviceability requirements. For example, the panel may be strong enough but too flexible. So, service load displacement choices are provided.

In each case the structural engineer should design these panels like any other structure. The panel should be selected to be within acceptable limits for each load combination. This means mean that exterior wall panels should be selected to accommodate both moment and axial load.

INSTALLATION

Wall Panels

Exterior Wall Panels- The exterior wall panel shall be attached to the floor and roof or ceiling system with No. 20 gauge [0.0359 inch (0.91 mm)], 3-inch-by-5-inch (76 mm-by127 mm) steel shear plates that connect the panel to the wall top and bottom plates. These shear plates shall be located at each vertical steel metal stud and shall be attached with three No. 8 by $^{1}/_{2}$-inch-long (12.7 mm), self-tapping screws into the panel and the metal or timber bottom plate. Shear plates shall be attached to both sides of the wall at each stud. The connection is the same at the top and bottom of the wall. A top plate may be either steel or timber and the connection is a shear plate at each stud with three No. 8 self-tapping screws per shear plate.

The exterior wall panel may be placed in a No. 16 [0.0598 inch (1.5 mm)] or No. 18 [0.0478 inch (1.21 mm)] gauge steel channel attached to the floor system with anchor bolts at 4 feet on center (1219 mm) as specified in Section 2308.3 under the section sill anchorage in the 2006 International Building Code (IBC 2006) or as specified by the Professional engineer. Each wall panel has a steel channel along the vertical edges of the outside and inside facings which butts to the edge of the next panel. A minimum of 3 shear plates should used and equally spaced at the connection of both the outside and inside faces No. 8 by ½-inch (12.7 mm), self-tapping screws.

After the exterior wall panels are erected, the contactor or builder shall install single or double metal top plates to these wall panels. These plates shall be connected to the studs with a minimum of three No. 8 by ½-inch long (12.7 mm) self-tapping screws. Alternatively, a single or double timber top plate that is a 2-by-4 (3 ½" thick panel) or 2 by 6 (5 ½" thick panel) may be used. The top plate is attached with shear plates in the same manner as a wood sill plate. Other attachment methods are acceptable, provided it is specified by a professional engineer and submitted to the building official for each project. Either the LRFD or ASD methods for sizing the carrying capacity of these panels is acceptable and should be consistent with Tables 6-10. The connection of the wall panel to top and bottom plates must be designed to the satisfaction of the building official.

All windows, doors and other openings are to be framed to meet the design loads. Window and door openings may be framed with panels, AISI light gauge metal, or conventional wood framing. The framing shall be designed by a professional engineer and approved by the local building official. The framing around openings shall be designed in accordance with the provisions listed in Chapter 22 of the IBC 2006. If the frames around window and door openings are wood, the design shall meet the provisions listed in Chapter 23 of IBC 2006. Exposed edges and openings in the foam plastic around hose bibs, electrical panels or any holes in the substrate surface shall be caulked with DAP Acrylic Latex No. 11465 or an approved equal.

Interior Wall Panels- The interior wall panels are attached in the same manner as described for the exterior wall panel connections.

Roof Panels- The roof panels are set and attached together to bear on roof beams, trusses and exterior or interior bearing wall plates. All panels shall have conventional roof sheathing installed on the top face. All roof panels shall have horizontal reinforcement field-installed across the width of the panel for attachment to wall panels. This attachment shall be designed by the structural engineer and submitted for review by the building official. A roof covering, underlayment and flashing complying with Chapter 15 of the IBC 2006 are applied over the panels.

Floor Panels- The floor panels are set and attached together to bear on foundations, beams, and exterior or interior wall plates. All panels may have conventional wood floor sheathing on the top face.

CLADDING ATTACHMENT

Walls

Exterior - Conventional claddings such as hardboard siding, stucco, plywood, and aluminum siding are to be attached to the vertical metal studs (c channels or modified steel studs) with fasteners of sufficient length to penetrate and protrude through the metal at least $^1/_4$ inch (6.4 mm), as set forth in the cladding manufacturer's instructions. This is the same technology that is used for conventional steel or timber stud walls. The only difference is, the insulation is an integral part of the wall. Therefore, cladding is attached to the steel studs in the same manner as conventional construction.

For full-size panel claddings such as plywood, fasteners shall be spaced at 6 inches (152 mm) on center along the edges. Otherwise, use a spacing of 12 inches (305 mm) on center. In addition edge nailing or screws is required within 2 feet (610 mm) of wall corners.

Interior- Interior claddings, such as $^1/_2$-inch (12.7 mm) gypsum wallboard, are attached to the panel with 1-inch long (25.4 mm), Type S, bugle head drywall screws complying with ASTM C 1002 spaced at 12 inches (305 mm) on center on all vertical steel studs, 1 inch (25.4 mm) from panel edges on perimeter metal channels and centered on interior metal studs.

Roofs

Exterior- For roof sheathing, fasteners are spaced at 6 inches (152 mm) on center for edges and 12 inches (305 mm) in the field. The edges are defined as the area of the roof within a distance from ridges, eaves, hips or gables of 10 feet (3,048 mm) or 0.1 times the least width of the structure, whichever is smaller.

Interior- The attachment of cladding is as specified for interior wall applications.

Party Wall

The Party Wall consists of a panel, 4 feet (1219 mm) wide by 8 feet (2,438 mm) in height, with a laminate of one $^{5}/_{8}$-inch-thick (15.9 mm), Type X Fire Code gypsum wallboard and one $^{1}/_{2}$-inch-thick (12.7 mm), regular gypsum wallboard fastened on each side. The $^{5}/_{8}$-inch-thick (15.9 mm), Type X wallboard is fastened to the vertical panel members with $1^{1}/_{4}$-inch-long (32 mm) drywall screws at 8 inches (203 mm) on center, except at the resilient furring channels where it is fastened at 12 inches (305 mm) on center. Hat channels 2 1/2, inches (54 mm) deep and 2 inches (50.8 mm) wide are then attached to the vertical reinforcement members through the $^{5}/_{8}$-inch-thick gypsum wallboard with $1^{1}/_{2}$-inch-long (38.1 mm) drywall screws at 12 inches (305 mm) on center, offset 6 inches (152 mm) from the previous screws. The $^{1}/_{2}$-inch-thick (12.7 mm) regular gypsum wallboard is then attached to the hat channels with 1-inch-long (25.4 mm) drywall screws. The Party Wall has a minimum STC rating of 50 when tested in accordance with ASTM E 90 and E 413.

Fire-resistive Construction

One-hour Fire-resistive Nonload-bearing Wall Construction- This system may be obtained by the use of 5/8" type X or other equivalent fire rated gypsum board applied to both faces.

Two-hour Fire-resistive Nonload-bearing Wall Construction-The construction consists of a panel with two layers of $^{1}/_{2}$-inch-thick (12.7 mm) Type X gypsum wallboard complying with ASTM C 36 on each side. A No. 20 gauge, $3^{5}/_{6}$-inch-by-1-inch (92 mm by 25.4 mm) steel channel is fitted to both top and bottom ends of the panel, and the panels are then connected to the top and bottom plates by toe-nailing both sides with six 16-penny common nails per 4- foot (1,219 mm) panel. The panels are attached to each other with $^{3}/_{4}$-inch-long (19 mm) sheet metal screws at 12 inches (305 mm) on center along the shiplap edges. The base layer of $^{1}/_{2}$-inch-thick (12.7 mm), Type X gypsum wallboard is vertically applied to both sides and secured using 1-inch-long (25.4 mm) drywall screws 24 inches (610 mm) on center with each vertical member and 12 inches (305 mm) on center to top and bottom channels. The face layer of $^{1}/_{2}$-inch-thick (12.7 mm), Type X gypsum wallboard is then applied horizontally to both sides and secured using $1^{5}/_{c}$inch-long (41.3 mm) drywall screws at 12 inches (305 mm) on center in top, bottom and field. The screw locations and the vertical joints are staggered from the layer. The joints are taped and coated with joint compound. Screw heads are also coated with joint compound.

FINDINGS

The RADVA TG Manufactured Panel Building System described in this report complies with the 2006 International Building Code (IBC) but subject to the following conditions. Structural analysis of the panels, panel connections and supporting structure must be submitted to the building official for review. Either the LRFD method or ASD method is considered an acceptable choice provided the appropriate load tables in this document are used.

The panels are recognized for Type V construction only; see Chapter 6, IBC 2006.

The panels must be separated from the building interior by a thermal barrier complying with Section 2603.4 of the IBC 2006. A minimum of ½-inch thick (12.7 mm) gypsum wallboard attached in accordance with this report is an acceptable thermal barrier. Panels shall be fabricated, identified and installed in accordance with this report and the manufacturer's instructions. Panels are manufactured Alabama in accordance with the IAPMO quality control program.

Lateral load design, including details for resistance to racking shear, need to be submitted to the building official for approval. Racking shear values are not included in this report. Shear walls shall be designed in accordance with the design standards provided in Chapter 23 section 2305 of the IBC 2006.

Material Properties

Table 1 Light Gauge Metal thickness Reference Guide

	Uncoated			Coated (Galvanized)	
Gauge	Minimum	Nominal	AISI Design	Abs min	Nominal
24	0.0209	0.0239	0.0220	0.0236	0.0276
22	0.0269	0.0299	0.0283	0.0296	0.0336
20	0.0329	0.0359	0.0346	0.0356	0.0396
18	0.0428	0.0478	0.0451	0.0466	0.0516
16	0.0538	0.0598	0.0566	0.0575	0.0635

Table 2 Material Properties for EPS (Alliance of Foam Packing Recyclers)

Density (pcf)	Stress @ 10% Compression (psi)	Flexural Strength (psi)	Tensile Strength (psi)	Shear Strength (psi)
1.0	13	29	31	31
1.5	24	43	51	53
2.0	30	58	62	70
2.5	42	75	74	92
3.0	64	88	88	118
3.3	67	105	98	140
4.0	80	125	108	175

Panel Section Properties

The section properties for these wall panels were approximated by treating the assembly as a fully bonded structural composite. The EPS carries a small portion of the load and it provides confinement around the steel studs (wall panels) or stringers (floor or roof panels). The EPS seems to be particularly beneficial in resisting local or lateral buckling of the steel members. It appears to be an extremely effective damper and provides impressive ductility when loaded to failure. Section properties for C shaped members are provided in Table 3; see Figure 4 for the section width. Flange and bend radius for RADVA C (track) shapes are shown in Figure 5.

Table 3. Section properties per C-section

Panel Thickness (t) (in)	Stud thickness Gauge	Area (A) (sq in)	Moment of Inertia (I_{xx}) (in^4)	Section Modulus(S_{xx}) (cu in)	Radius of gyration (in)
3.5	24	0.2186	0.5868	0.3353	1.6382
	20	0.3430	0.9097	0.5198	1.6328
	18	0.4429	1.1719	0.6696	1.6267
	16	0.5532	1.4533	0.8305	1.6208
5.5	24	0.2198	1.5206	0.5530	2.6301
	20	0.3430	2.3636	0.8595	2.6251
	18	0.4429	3.0494	1.1089	2.6241
	16	0.5532	3.7936	1.3795	2.6187

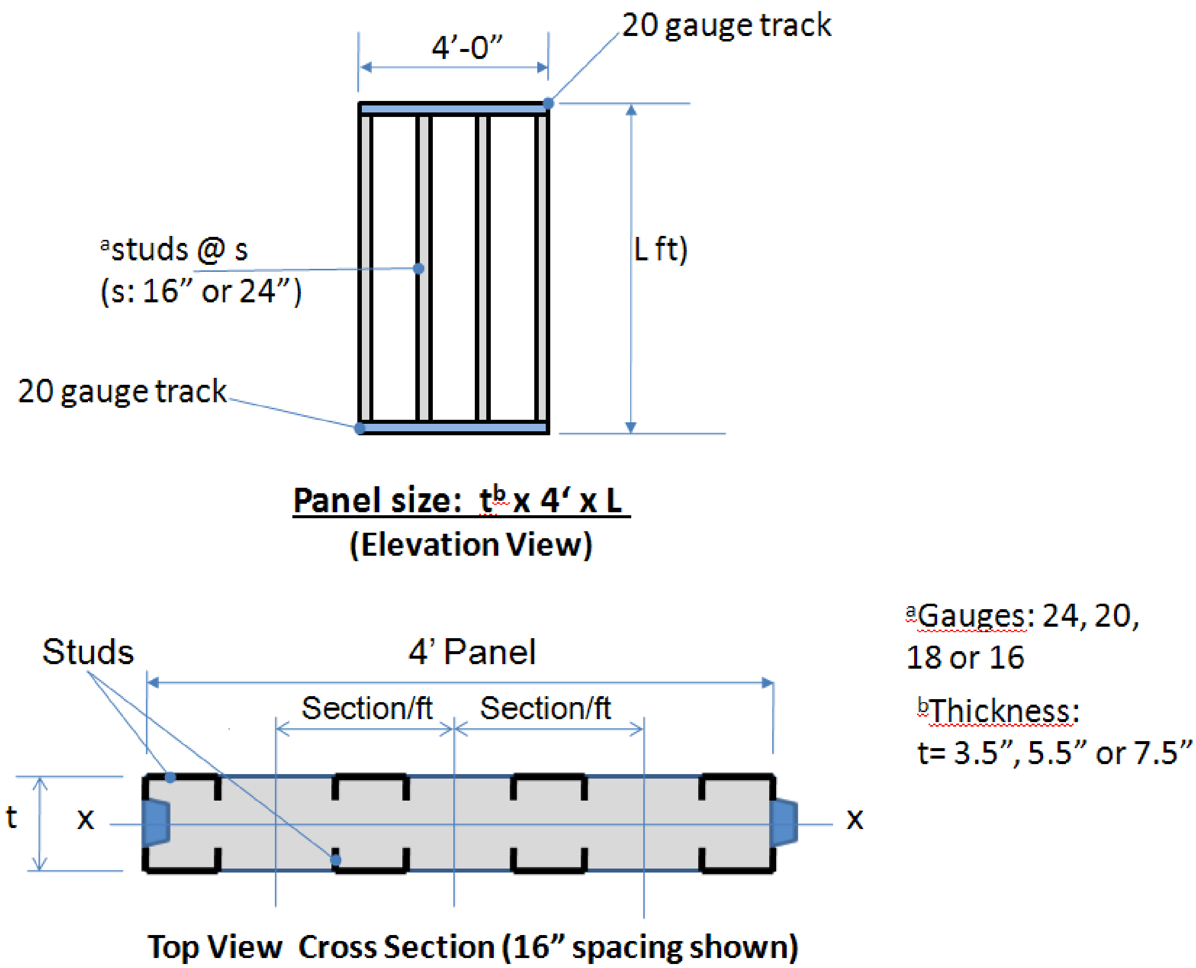

Figure 4 Wall Panel Cross-section (1-C shape stud on each face)

Panel Section Properties per ft

Except for concentrated loads at or near the roof trusses, load is typically expressed on a wall panel in lbs/ft. When these panels are used to carry floor loads or roof loads, the loads are typically expressed in pounds per square foot. Therefore, it is helpful to have panel section properties expressed per foot. Table 4 provides section properties for this purpose.

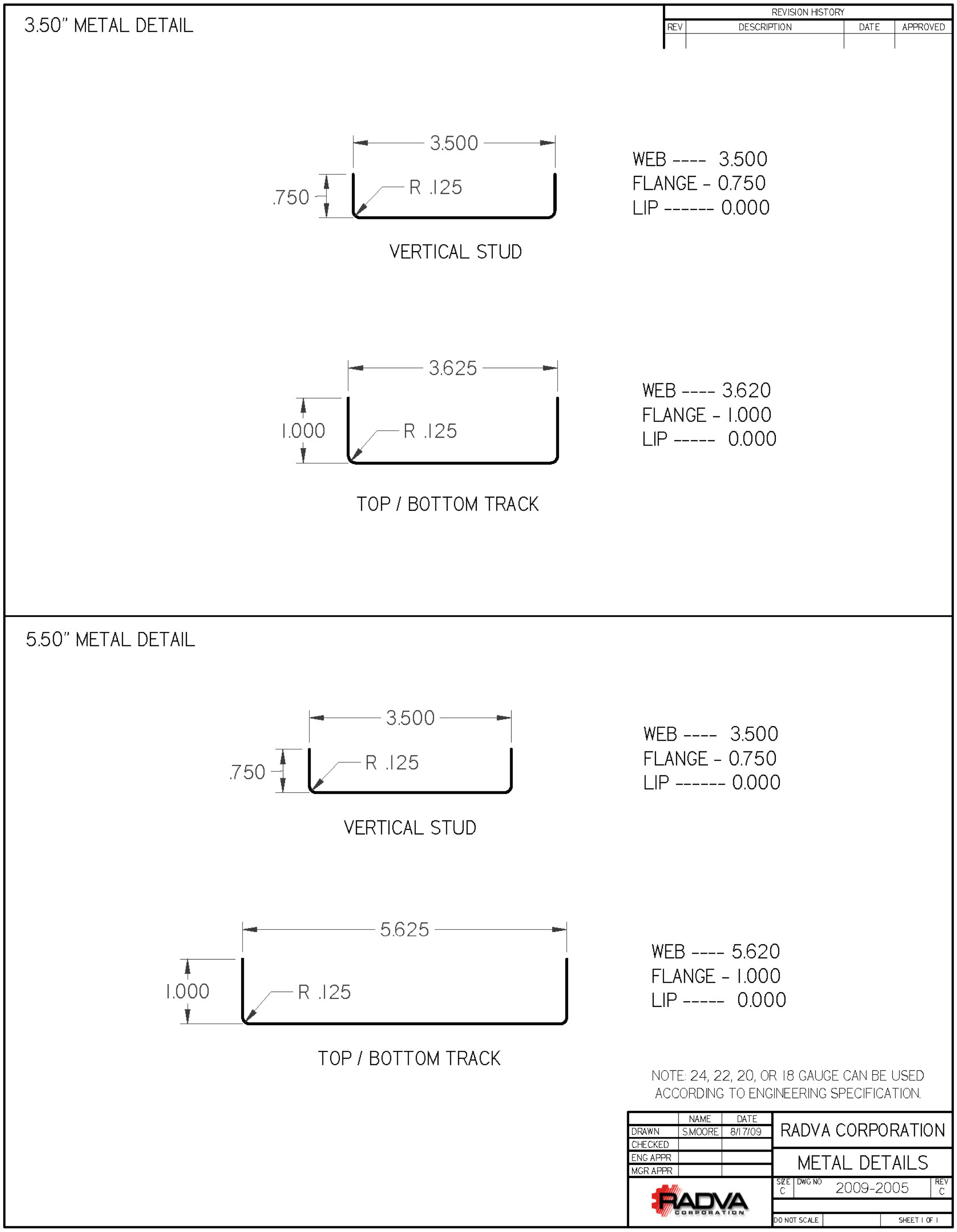

Figure 5 C Shapes: Flange, Web and Bend Details

Table 4. Panel Section Properties per ft

Panel Thickness (t) (in)	Stud thickness Gauge	Area (A) (sq in)	Moment of Inertia (I_{xx}) (in^4)	Section Modulus(S_{xx}) (cu in)	Shear Stiffness (K) (lb/ft)	Radius of gyration (in)
1. Studs 16" on center						
3.5	24	0.1640	0.4401	0.2515	187,385	1.2286
	20	0.2559	0.6817	0.3896	187,385	1.2241
	18	0.3321	0.8783	0.5019	187,385	1.2196
	16	0.4149	1.0894	0.6225	187,385	1.2153
5.5	24	0.1649	1.1405	0.4147	220,846	1.9726
	20	0.2572	1.7721	0.6444	220,846	1.9685
	18	0.3321	2.2865	0.8315	220,846	1.9678
	16	0.4149	2.8446	1.0344	220,846	1.9638
2. Studs 24" on center						
3.5	24	0.1093	0.2934	0.1676	187,385	0.8191
	20	0.1706	0.4545	0.2597	187,385	0.8161
	18	0.2214	0.5856	0.3346	187,385	0.8131
	16	0.2766	0.7263	0.4150	187,385	0.8102
5.5	24	0.1099	0.7603	0.2765	220,846	1.3150
	20	0.1715	1.1814	0.4296	220,846	1.3124
	18	0.2214	1.5243	0.5543	220,846	1.3119
	16	0.2766	1.8964	0.6896	220,846	1.3092

STRUCTURAL LOADS

The symbols used to describe different types of loads and their combinations are listed below

D = dead load
E = earthquake load
F = load due to fluids with well-defined water pressure, or pressure of bulk materials
H = load due to lateral earth pressure, ground water pressure, or pressure of bulk materials
L = live load
L_r. = roof live load
S = snow load
T = self-straining force, and
W = wind load.

Allowable Stress Design (ASD)

In the allowable stress design method, each member shall be checked for the worst load case determined from the following eight combinations (ASCE 7-05). This method is based on the idea that each member is allowed to reach a fraction of yield or strength. The eight load combinations are given by:

1. D + F
2. D + H + F + L + T
3. D + H + F + (L_r or DS or R)
4. D + H + F + 0.75(L + T) + 0.75(L_r or S or R) (1)
5. D + H + F + (W or 0.7E)
6. D + H + F + 0.75(W or 0.7E) + 0.75L + 0.75(L_r or S or R)
7. 0.6D + W + H
8. 0.6D + 0.7E + H

Load Resistance Factor Design (LRFD)

In the Load Resistance Factor Design method, each member is sized to fail when the worst factored load combination is acting on the member. Seven factored load combinations listed by the Minimum Design Loads for Buildings and Other Structures (ASCE 7-05) are used to check the member strength. When you size members by LRFD you insure it is sufficiently strong (this is a strength check). In this method, you must also check in-service member deflections (this is a flexibility check). The seven factored load combinations are:

1. 1.4(D + F)
2. 1.2(D + F + T) + 1.6(L+ H) + 0.5(L_r or S or R)
3. 1.2D + 1.6(L_r or S or R) + (L or 0.8W)
4. 1.2D + 1.6W + L + 0.5(L_r or S or R) (2)
5. 1.2D + 1.0E + L + 0.2S
6. 0.9D + 1.6W + 1.6H
7. 0.9D + 1.0E + 1.6H

STRUCTURAL DESIGN

Axial Compression Design Loads

Acceptable axial compression design loads for the RADVA insulated structural composite wall panel were based on calculations and experimental data that was determined by testing 4-ft wide panels in load frame. Each panel is manufactured with EPS bonded to a light gauge modified steel stud (galvanized light gauge metal track; this is a hybrid stud). Studs were evaluated to resist yielding, local buckling and lateral buckling. The galvanized light gauge steel elements were evaluated for consistency with the 2007 AISI Standard "North American Specification for the Design of Cold-Formed Steel Structural Members".

The strength of each panel was evaluated by calculations and where experimental data were available, compared with the wall panel test data. Structural design values for these wall panels were evaluated to resist local buckling, lateral buckling and yielding (AISI Commentary, 2007), Galambos, 1998) (Timoshenko and Gere, 1961), (Pokharel and Mahendran, 2008). The EPS within each panel provides a significant amount restraint to the structural steel column members. Subsequently, this enables the hybrid light gauge steel studs to be structurally more effective in carrying axial load.

Design Values- Four wall heights are typically available and others can be custom formed. Wall heights are 8-ft, 9-ft, 10-ft and 12-ft in 3.5" and 5.5" wall thicknesses. Design values provided in this report are for structural insulated composite wall panels without contributions from siding, shear panels (OSB or Plywood) or sheetrock. These attachments will contribute or increase the carrying capacity of the panel. The axial compressive strength for 3.5" wall panels with steel studs spaced at 16" on center is provided in Figures A1 to A4 in Appendix A. The compressive strength values for axially loaded 5.5" wall panels are shown in Figures A5 to A6 in Appendix A.

The design guidelines for both the Allowable stress method (ASD) and the Load Resistance Factored Design Method (LRFD) are given in Tables 6 to 7. If the panel is subjected to a distributed axial load and no transverse loads (0 psf), than Tables 6 to 7 are valid. Figure 6 shows a wall panel that is subjected to distributed axial compression loads. A wall panel that is subjected to concentrated loads and no transverse loads (0 psf), than use Table 8, see Figure 7.

ASD Method- If you use Allowable Stress Design, determine the largest service load that is expected to act on the wall. This service load is calculated in accordance with IBC 2006 and the ASCE Minimum Design Loads for Buildings and Other structures (ASCE 7-05). If this service loads is less than the allowable shown in the allowable load tables, you have a panel that is satisfactory?

Wall panel thickness, wall height, stud thickness (gauge), and stud spacing affect the allowable load in lbs/ft. This should be equal or greater than the acting service load. Check to see if the acting service load is less than the allowable load. This is given by

$$p \le p_a \qquad (2a)$$

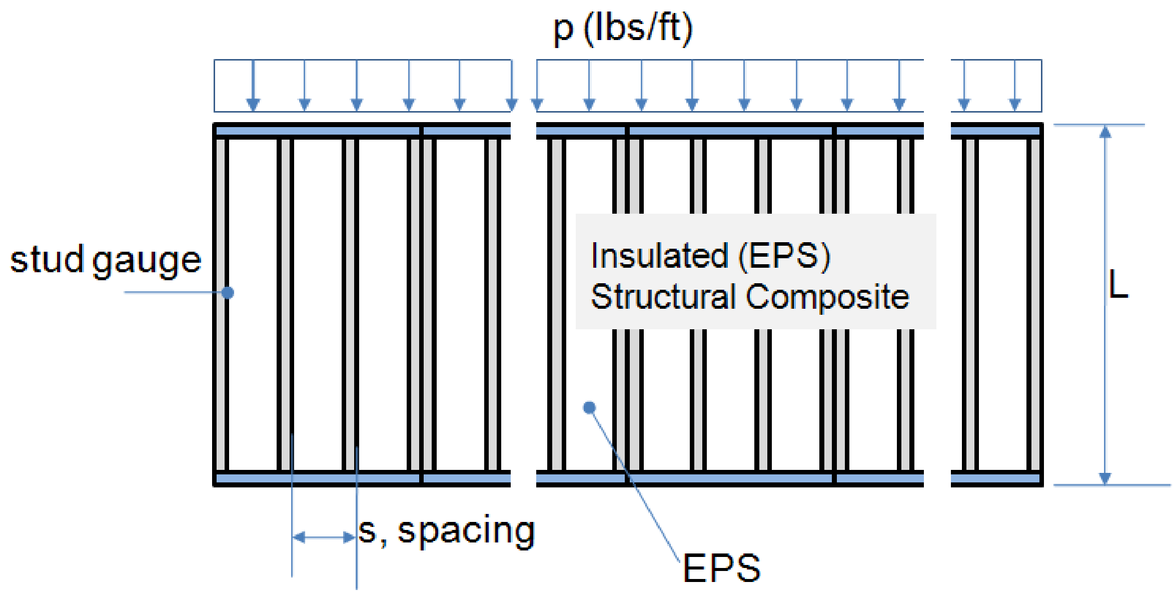

Figure 6 Axially Loaded Walls with a Distributed Load, p (lbs/ft)

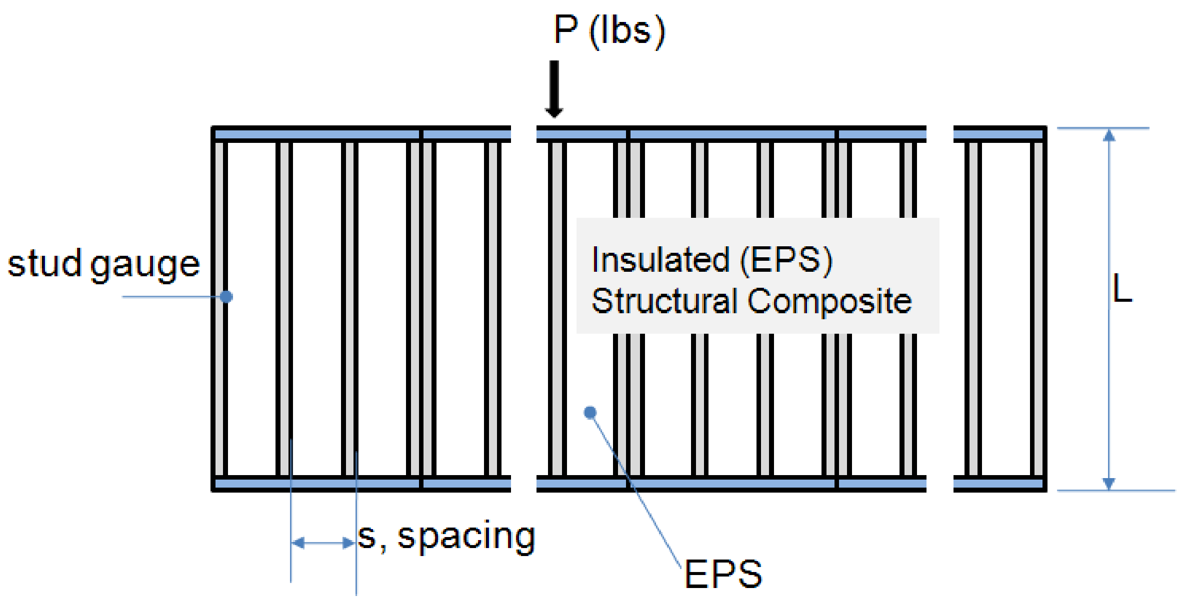

Figure 7 Concentrated Axial Compression Service Loads

In which p is the axial distributed service load acting on the wall panel in plf. The allowable axial distributed load, $p_{a,}$ (plf) on a given wall panel is provided in the Design Load Tables (Tables 6 to 7). Both allowable loads and the nominal panel strength are provided in Appendix C. In the case of a concentrated load, the wall panel should be checked to meet the following requirement.

$$P \leq P_a \qquad (2b)$$

In which P is a concentrated load in lbs and P_a is the allowable concentrated load in lbs. The allowable concentrated axial compression load is given in Tables 8 to 9.

LRFD Method- If you use the Load Resistance Factor Design Method, you will first determine the factored load acting on the member. The worst load combination is determined in accordance with IBC 2006 and ASCE Minimum Design Loads for Buildings and Other structures (ASCE 7-05). This is the required axial compression load, R_u. The calculated strength given in Tables 6 to 7 is the probable design strength, φR_n. The probability that the panel is equal or stronger than 75% of the test value is expressed as a resistance factor, φ. The panel design strength must be equal or greater than the failure load and this is given by

$$\varphi R_n \geq R_u \tag{3}$$

In which R_u is the required strength, R_n is the nominal strength, φ is the resistance factor and φR_n is the factored resistance or design strength. The panel is sized by calculating the required strength, R_u , which is the sum of the factored load (force or moment) effects. Load tables provide panel design strength and this shall be equal or larger than the required strength.

Transverse Loads

The panels may be designed to meet either LRFD or ASD. The attached Table illustrates the values that may be used to meet these criteria. In using LRFD, the structural engineer shall design the panels to meet design load combinations in accordance with the Minimum Design Loads for Buildings and Other Structures by the 2007 edition of ASCE 7-05 and IBC 2006 Chapter 16.

Factors of Safety

ASD Method- If you use the ASD method, the allowable load tables were prepared for a factor of safety (Ω) of 2. Allowables were determined from calculated (theoretical predicted failure loads). A comparison between theory and experimental shows that the theoretical typically under predicts the the experimental load capicity. That is the axial compression uniform loads are

$$p_a = \frac{p_u}{\Omega} = \frac{p_u}{2} \tag{4}$$

In which p_u (lbs/ft) is the calculated distributed load that will cause failure, Ω is the factor of safety and p_a (lbs/ft) is the allowable load. In the case of axial compression concentrated loads, the allowable load tables are based on

$$P_a = \frac{P_u}{\Omega} = \frac{P_u}{2} \tag{5}$$

In which P_u (lbs) is the acting concentrated load acting on the panel at failure; Ω is the factor of safety and P_a (lbs) is the allowable concentrated load. If these concentrated loads are not directly over a stud, the structural engineer must design a stiff top plate to transfer the load to the embedded structural steel column members. Remember, EPS provides confinment, load re-distribution, ductility and based on limited experimental studies by the author, rebound to the original geometry after being subjected to the load limit.

Consider a panel that is subjected to a distributed transverse pressure. In this case, the allowable load tables are based on a factor of safety of 2. This is expressed in Equation 6.

$$w_a = \frac{w_u}{\Omega} = \frac{w_u}{2} \tag{6}$$

In which w_u (psf) is the transverse pressure load at failure, Ω is the factor of safety and w_a (psf) is the allowable pressure load. In the case of floors and roofs, it is important to check the panel for deflection. Typically, the minimum allowable live load deflection for simple spans is L/360 where the L is the span length. The allowable load tables provide limiting allowable live load pressures for L/180 to L/960. The tables were developed to provide engineering alternatives.

LRFD Method- The design load tables provided in this report represent nominal calculated values for failure. The probability of panels to reach the test load at failure will be addressed by a resistance factor; φ . So, for the purpose of this document, the author compared results between the LRFD method and values if you use the allowable stress method, ASD.

So, consider the most probable axial load case; that is when both dead (D) and live (L) loads act on the panel. The factored load is given by Equation 7. This is in accordance with ASCE 7-05 Minimum Design Loads.

$$R_u = 1.2D + 1.6L \tag{7}$$

So, the service load is

$$P = D + L \tag{8}$$

Consider the service load, P, given in Equation 8. The percent dead load, D, is f_D and the percent live load is f_L. The probability that experimental or calculated values will be equal or larger than expected the true failure load is accounted for by a resistance factor, φ. Subsquently, the probable factored resistance or design strength is expressed by φR_n. The term R_n is the nonimal resistance of the panel. If design strength is equated to the factored load at failure and we substiturte Equation 8 into Equation 7 , we get

$$\varphi R_n \geq R_u = \{1.2(f_D P) + 1.6(f_L P)\} \tag{9}$$

A comparison between the two methods for Load Case 2 acting on an axial compression member is given by Table 5. Experimental data were nearly the same as theoretical. The resistance factor, φ , was taken as 0.75 for axial compression members and 0.8 for transverse loading. Thus, the relationship between failure load and the allowable load at an acceptable stress state is given by

$$\frac{R_n}{\Omega} \geq R_a \tag{10}$$

In which the Ω is the factor of safety, R_n is the nominal strength (same as for LRFD), R_n / Ω is the allowable strength, and R_a is required strength (sum of service load effects from ASCE 7-05). This provides a factor of safety in relation to tested nominal strength values

$$\Omega = \frac{(1.2 f_D + 1.6 f_L)}{\varphi} \tag{11}$$

So, for the purpose of this report, LRFD values in the table are considered to be the probable design strength, φR_n, and they shall be used as follows. First use IBC 2006 or the ASCE 7-05 method to calculate the appropriate factored applied load, R_u. Than, find the appropriate panel that will provide the needed strength from the table. Listed strength values would be compared to the required from Equation 12.

$$\varphi R_n \geq (R_u) \tag{12}$$

Table 5. Comparision of Factor's of Safety by LRFD vs. ASD

Load Resistance Factor Design Method, (LRFD)					Factor of Safety	
Percent Dead	Percent Live	Factored Loads			LRFD	ASD
f_D	f_L	Dead/P $1.2 f_D P$	Live/P $1.6 f_L$	Total, R_u $1.2D + 1.6L = fP$	$\Omega = \frac{fP}{\varphi P} = \frac{f}{\varphi}$	$\Omega = 2$
0.2	0.8	0.24	1.28	1.52	2.03	2
0.333	0.667	0.3996	1.0672	1.4668	1.96	2
0.4	0.6	0.48	0.96	1.44	1.92	2
0.5	0.5	0.6	0.8	1.4	1.87	2
0.6	0.4	0.72	0.64	1.36	1.81	2
0.75	0.25	0.9	0.4	1.3	1.73	2
0.8	0.2	0.96	0.32	1.28	1.71	2
1	0	1.2	0	1.2	1.60	2

ASD and LRFD methods were equated for a service load where L = 4D; $\phi = 0.75$.

Biaxial (axial Loads Plus Transverse Loads)

It is common to expect that walls are required to carry both axial compression loads and transverse pressure loads such as wind. In the case where the panel is subjected to both axial compression and bending, the engineer must account for both. This may be done in the same manner as other strucutral systems which is given by

$$\frac{P_r}{P_c} + \frac{M_r}{M_c} \leq 1 \quad (13)$$

In which P_r is the required axial strength (sum of load effects using ASCE 7-05), P_c is the available axial strength (provided in the design tables), M_r is the required moment strength, and M_c is the available moment strength. Consider that the panel moment for simple supports is given by

$$M = \frac{wL^2}{8} \quad (14)$$

In which w is the transverse pressure acting on a unit width of panel and L is the panel length. Therefore, if substitute subscripts into Equation 13 and combine it with Equation 14, we get

$$\frac{P_r}{P_c} + \frac{w_r}{w_c} \leq 1 \quad (16)$$

Where, axial contributions are determined by the first part of the equation and this is given by

P_r = Required axial strength

= P_u for LRFD (sum of the factored loads from ASCE 7-05)

= P for ASD (sum of the load effects from ASCE 7-05)

P_c = Available axial strength

= φP_n for LRFD (see the Design Tables)

= P_n/Ω for ASD (see the Design Tables)

Transverse contributions from Equation 15 are determined by

w_r = Required axial strength

= w_u for LRFD (sum of the ASCE 7-05 factored loads)

= w_n for ASD (sum of the ASCE 7-05 loads)

w_c = Available axial strength

= φw_n for LRFD

= w_n/Ω for ASD

LOAD DESIGN TABLES

Axial compression

Design selection tables for 3.5" and 5.5" thick panels without gypsum or siding are provided herein. Design values for either the Allowable stress method or the LRFD method are provided in Tables 6 and 7 for distributed loads in lbs/ft are listed below.

Table 6. 3.5" Thick Panel with track type studs; no gypsum and no siding; (plf)

Length (ft)	Stud spacing @ 16" on center				Stud spacing @ 24" on center			
	Strength			Allowable	Strength			Allowable
	Nominal (p_n)	Tests Avg.	LRFD (φp_n)	ASD (p_a)	Nominal (p_n)	Tests Avg.	LRFD (φp_n)	ASD (p_a)
24 gauge								
8	3,069	3,005	2,302	1,535	2,046		1,535	1,023
9	3,069		2,302	1,535	2,046		1,535	1,023
10	3,069	2,960	2,302	1,535	2,046		1,535	1,023
12	3,069	2,875	2,302	1,535	2,046		1,535	1,023
20 gauge								
8	5,850		4,388	2,925	3,900		2,925	1,950
9	5,850		4,388	2,925	3,900		2,925	1,950
10	5,850		4,388	2,925	3,900		2,925	1,950
12	5,850		4,388	2,925	3,900		2,925	1,950
18 gauge								
8	10,177		7,633	5,089	6,785		5,089	3,392
9	9,680		7,260	4,840	6,453		4,840	3,227
10	9,153		6,865	4,577	6,102		4,577	3,051
12	8,040		6,030	4,020	5,360		4,020	2,680
16 gauge								
8	12,696		9,522	6,348	8,464		6,348	4,232
9	12,071		9,053	6,036	8,047		6,036	4,024
10	11,409		8,557	5,705	7,606		5,705	3,803
12	10,013		7,510	5,006	6,675		5,006	3,338

It can be seen that the resistance factor, $\varphi = 0.75$, provides conservative strength values as compared to numerous failure tests, see both Tables 6 and 7. The calculated values are based on applying a uniform axial load to the top of a 4-ft wide test panel. Those listed in the table are just a sample of the test data available.

Table 7. 5.5" Thick Panel with track type studs; no gypsum and no siding; (plf)

Length (ft)	Stud spacing @ 16" on center				Stud spacing @ 24" on center			
	Strength			Allowable	Strength			Allowable
	Nominal (p_n)	Tests Avg.	LRFD (φp_n)	ASD (p_a)	Nominal (p_n)	Tests Avg.	LRFD (φp_n)	ASD (p_a)
24 gauge								
8	3,431	4,115	2,574	1,716	2,288	3,165	1,716	1,144
9	3,431		2,574	1,716	2,288		1,716	1,144
10	3,431	3,915	2,574	1,716	2,288	2,775	1,716	1,144
12	3,431	3,925	2,574	1,716	2,288	2,875	1,716	1,144
20 gauge								
8	7,176	7,609	5,382	3,588	4,784		3,588	2,392
9	7,176		5,382	3,588	4,784		3,588	2,392
10	7,176	7,363	5,382	3,588	4,784		3,588	2,392
12	7,176	7,120	5,382	3,588	4,784		3,588	2,392
18 gauge								
8	11,431	14,730	8,573	5,715	7,620		5,715	3,810
9	11,213		8,410	5,606	7,475		5,606	3,738
10	10,974	14,230	8,231	5,487	7,316		5,487	3,658
12	10,441	13,994	7,831	5,221	6,961		5,221	3,480
16 gauge								
8	14,274		10,706	7,137	9,516		7,137	4,758
9	14,001		10,501	7,000	9,334		7,000	4,667
10	13,702		10,276	6,851	9,135		6,851	4,567
12	13,034		9,775	6,517	8,689		6,517	4,345

In the case where truss or concentrated loads act on the panel, the axial compression design loads for the 3.5" and 5.5" panels that may be applied to these panels are given in Tables 8 and 9. The structural Engineer shall size the top plates to carry concentrated axial compression loads that are carried by the panel.

Table 8. 3.5" Panel, track type studs; no gypsum, no siding; Concentrated Load

		Strength (lbs)		Allowable (lbs)
Length (ft)	gauge	Nominal (P_n)	LRFD (φP_n)	ASD (P_a)
8	24	3,221	2,415	1,610
9	24	3,221	2,415	1,610
10	24	3,221	2,415	1,610
12	24	3,221	2,415	1,610
8	20	6,092	4,569	3,046
9	20	6,092	4,569	3,046
10	20	6,092	4,569	3,046
12	20	6,092	4,569	3,046
8	18	13,433	10,075	6,717
9	18	12,907	9,680	6,453
10	18	12,204	9,153	6,102
12	18	10,720	8,040	5,360
8	16	16,928	12,696	8,464
9	16	16,095	12,071	8,047
10	16	15,212	11,409	7,606
12	16	13,350	10,013	6,675

Table 9. 5.5" Panel, track type studs; no gypsum, no siding; Concentrated Load

		Strength (lbs)		Allowable (lbs)
Length (ft)	gauge	Nominal (P_n)	LRFD (φP_n)	ASD (P_a)
8	24	3,431	2,574	1,716
9	24	3,431	2,574	1,716
10	24	3,431	2,574	1,716
12	24	3,431	2,574	1,716
8	20	9,567	7,176	4,784
9	20	9,567	7,176	4,784
10	20	9,567	7,176	4,784
12	20	9,567	7,176	4,784
8	18	15,241	11,431	7,620
9	18	14,950	11,213	7,475
10	18	14,632	10,974	7,316
12	18	13,922	10,441	6,961
8	16	19,032	14,274	9,516
9	16	18,668	14,001	9,334
10	16	18,269	13,702	9,135
12	16	17,378	13,034	8,689

Transverse Loads

Panels subjected to transverse loads shall be sized for both strength and serviceability. Tables 10 and 11 provide the structural engineer with bending strength for the 3.5" and 5.5" panels.

Deflections shall be checked using Tables 12 to 13. In these tables, the engineer may choose the appropriate panel stiffness for the application. For example, a floor should be sized to provide a stiffness of L/360 to L/960. If you want to use panels for a roof or where deflection is not a concern, defection limits based on L/180 to L/240 are provided for guidance in your choice.

Table 10. Transverse Loads; 3.5" Panel, track type studs; no gypsum, no siding; (psf)

	Stud spacing @ 16" on center				Stud spacing @ 24" on center			
	Strength Requirements				Strength Requirements			
Length (ft)	Nominal w_n	Tests Avg.	LRFD φw_n	ASD (Allowable) $w_a = w_n / \Omega$	Nominal w_n	Tests Avg.	LRFD φw_n	ASD (Allowable) $w_a = w_n / \Omega$
24 gauge								
8	70	81	56	35	47	60	37	23
9	55		44	28	37		30	18
10	45	50	36	22	30	34	24	15
12	31	34	25	16	21	23	17	10
20 gauge								
8	150		120	75	100		80	50
9	119		95	59	79		63	40
10	96		77	48	64		51	32
12	67		53	33	45		36	22
18 gauge								
8	194		155	97	129		103	65
9	153		122	76	102		82	51
10	124		99	62	83		66	41
12	86		69	43	57		46	29
16 gauge								
8	240		192	120	160		128	80
9	190		152	95	126		101	63
10	154		123	77	102		82	51
12	107		85	53	71		57	36

Table 11. Transverse Loads; 5.5" Panel, track type studs; no gypsum, no siding; (psf)

	Stud spacing @ 16" on center				Stud spacing @ 24" on center			
	Strength Requirements				Strength Requirements			
	Nominal	Test s	LRFD	ASD (Allowable)	Nominal	Tests	LRFD	ASD (Allowable)
Length (ft)	w_n	Avg.	φw_n	$w_a = w_n / \Omega$	w_n	Avg.	φw_n	$w_a = w_n / \Omega$
24 gauge								
8	87	125	69	43	58	82	46	29
9	68		55	34	46		36	23
10	55	66	44	28	37	56	30	18
12	38	50	31	19	26	37	21	13
20 gauge								
8	248		199	124	166		133	83
9	196		157	98	131		105	65
10	159		127	80	106		85	53
12	110		88	55	74		59	37
18 gauge								
8	321		256	160	214		171	107
9	253		203	127	169		135	84
10	205		164	103	137		109	68
12	142		114	71	95		76	47
16 gauge								
8	399		319	199	266		213	133
9	315		252	158	210		168	105
10	255		204	128	170		136	85
12	177		142	89	118		95	59

Table 12 Deflection Limits for Transverse Loads, 3.5" panel with track type studs; no gypsum or siding.

		Stud spacing @ 16" on center					Stud spacing @ 24" on center				
Gauge	Ht (ft)	L/180	L/240	L/360	L/480	L/960	L/180	L/240	L/360	L/480	L/960
24	8	47	35	24	18	9	36	27	18	13	7
24	9	36	28	18	13	7	27	20	13	10	5
24	10	28	21	14	10	5	20	15	109	8	4
24	12	17	13	9	7	3	12	9	6	5	2
20	8	61	46	30	23	11	48	36	24	18	9
20	9	47	36	24	18	9	37	27	18	14	7
20	10	38	28	19	14	7	28	21	14	11	5
20	12	24	18	12	9	5	18	13	9	7	3
18	8	69	52	35	26	13	56	42	28	21	11
18	9	55	36	24	18	9	43	27	18	14	7
18	10	44	33	22	16	8	34	25	17	13	6
18	12	29	22	15	11	5	22	16	11	8	4
16	8	76	57	38	29	14	63	47	31	24	12
16	9	61	46	30	23	11	49	37	25	18	9
16	10	49	37	25	18	9	39	29	20	15	7
16	12	33	25	17	13	6	26	19	13	10	5

Table 13 Deflection Limits, 5.5" panel with track type studs; no gypsum or siding.

		Stud spacing @ 16" on center					Stud spacing @ 24" on center				
Gauge	Ht (ft)	L/180	L/240	L/360	L/480	L/960	L/180	L/240	L/360	L/480	L/960
24	8	85	64	43	32	16	70	52	35	26	13
24	9	68	51	34	25	13	54	41	27	20	10
24	10	54	41	27	20	10	43	32	21	16	8
24	12	36	27	18	14	7	28	21	14	10	5
20	8	101	76	51	38	19	86	65	43	32	16
20	9	82	62	41	31	15	69	52	34	26	13
20	10	68	51	34	25	13	56	42	28	21	10
20	12	47	36	24	18	9	37	28	19	14	7
18	8	110	82	55	41	21	96	72	48	36	18
18	9	91	62	41	31	15	78	52	34	26	13
18	10	76	57	38	28	14	63	48	32	24	12
18	12	54	40	27	20	10	44	33	22	16	8
16	8	116	87	58	44	22	104	78	52	39	19
16	9	97	73	48	36	18	85	64	42	32	16
16	10	82	61	41	31	15	70	52	35	26	13
16	12	59	45	30	22	11	49	37	25	18	9

TEST DATA

Some of the panel test results for axial compression and transverse loading are provided for review and consideration in Appendix D. Each test is listed by panel size and the Professional Engineer who supervised the tests and certified the results. These data were used to verify the author's theory. At present, the author developed a conservative design procedure. At present, the design loads do not account for contributions by the sheet rock or siding. In some cases, the siding such as plywood or OSB should contribute significantly to the load carrying capacity of these panels. If local buckling is prevented, we can expect shear diaphragms (plywood and OSB) to be effective in stiffening and assisting the panels carry load.

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APPENDIX A
CALCULATED AXIAL COMPRESSION FAILURE LOADS

(RADVA INSULATED STRUCTURAL COMPOSITE WALL PANELS)

The following axial compression loads were calculated for 3.5" and 5.5" wall panels. The stud spacing's provided in this Appendix are limited to 16" on center. The stud configuration is a galvanized steel track configuration in gauges of 24, 20, 18 and 16. The yield stress for these panels is 37 ksi and the expanded polystyrene is fully bonded to the steel. The 3.5" panels are manufactured with a foam density of 1.3 pcf to 1.7 pcf. The 5.5" panels are manufactured with a foam density of 0.9 pcf to 1.3 pcf. Sectional properties for each panel per ft of wall width are shown in Table A1 and Figure A1.

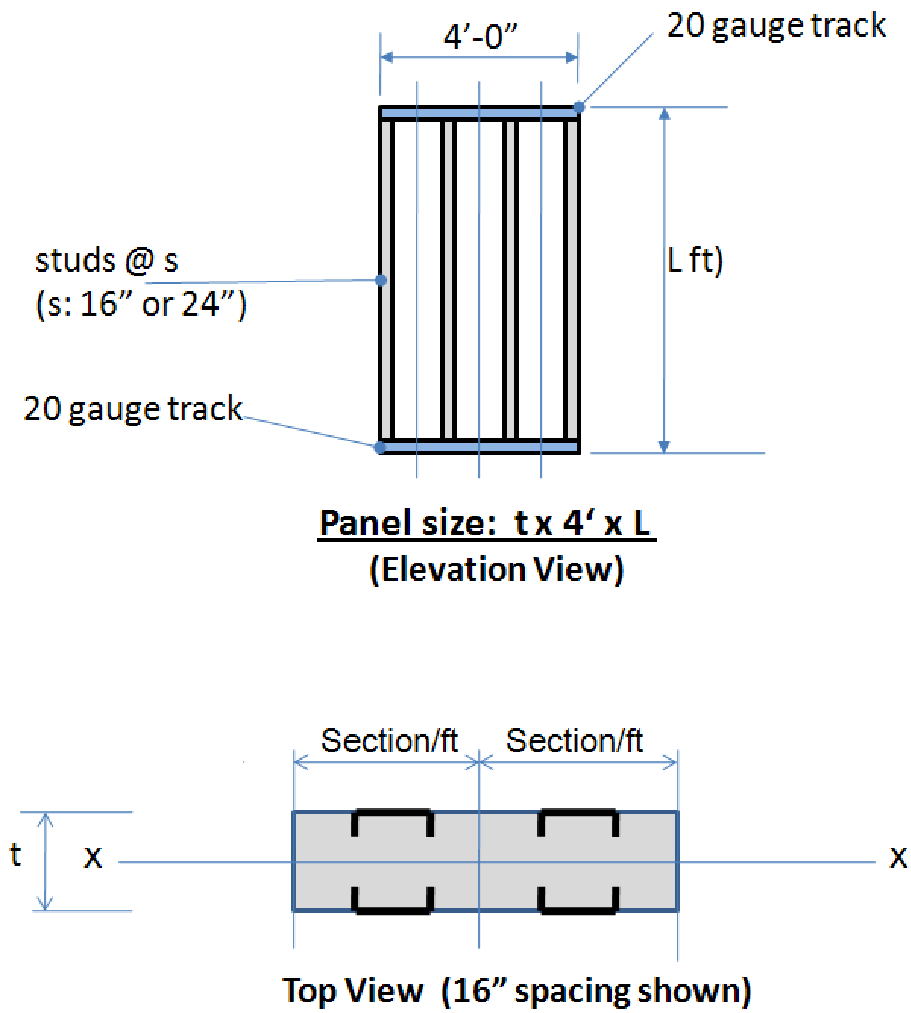

Figure A1 Section Properties for a typical wall panel

The calculated axial strength for the RADVA TG wall panels was determined by evaluating failure modes in local buckling, inelastic lateral buckling, elastic lateral buckling and yielding. The calculated results are presented in Figures A2 to A5 for 3.5" wall panels with studs spaced at 16-inches on center. Similarly, the axial compression load at failure for 5.5" thick wall panels with studs spaced at 16-inches on center is presented in Figures A6 to A9. Panel axial compression values were calculated assuming only studs resist axial load. Remember, the steel is fully bonded to the EPS. A fully bonded EPS was found to restrain the steel against in-plane lateral buckling and local buckling of the member elements (flanges and webs). Where experimental data were available, the calculated failure loads compared favorably with the calculated values.

The wall panel section properties per unit width of wall are provided in Table A1.

Local Buckling-. The critical buckling stress necessary to locally buckle a light gauge metal member is given in AISI as Equation CB2-1. It is

$$f_{cr} = \frac{k\pi^2 E}{12(1-\mu^2)(w/t)^2} \qquad \text{(A1)}$$

In which,

k = the Von Karman factor plate buckling coefficient and for the studs, the value is 6.97

E = the modulus of Elasticity of the steel

μ = the Poisson's ratio and this value are typically 0.3 for steel in the elastic range

W = the flat width of the compression element

t = the thickness of the compression element.

AISI provided the equation for the effective width over which $f_{\max}$ acts is given by AISI Equation CB2.1-3 and is expressed by

$$b = 1.9t\sqrt{\frac{E}{f_{\max}}}\left[1-0.4151\left(\frac{t}{w}\right)\sqrt{\frac{E}{f_{\max}}}\right] \qquad \text{(A2)}$$

In which,

$f_{\max}$ = a uniform state of stress over an effective width of the element. If the plate is likely to locally buckle, the effective width will be less than full width.

b = effective width of the compression element over which the uniform state of stress is used as to approximate the internal resistance.

Alternatively, the effective width may be found by AISI Equation CB2.1-4 and is expressed as

$$b = w\sqrt{\frac{f_{cr}}{f_{\max}}}\left[1 - 0.22\sqrt{\frac{f_{cr}}{f_{\max}}}\right] \qquad \text{(A3)}$$

Yielding and Lateral Buckling- Consider an axially loaded column. If member plate elements (flanges and webs) are sufficiently stiff the column will either yield or laterally buckle. If between these two extremes, the member will experience some inelastic behavior. That is, it can laterally buckle but before that occurs; some of the fibers were yielded. If the height of the wall panel between supports is sufficiently long, it may laterally buckle before any of the steel reaches yield. In order to approximate the buckling strength, we will use the term KL to describe the height or length of the wall panel. The following expression will be used to determine if the wall panel studs are inelastic or elastic for a given buckling strength.

$$\lambda_c = \frac{KL}{r\pi}\sqrt{\frac{F_y}{E}} \qquad \text{(A4)}$$

In which,

KL = the effective length of the wall panel, inches
r = radius of gyration of the wall panel, inches

F_y = the yield stress of the steel studs

E = modulus of the steel studs.

If $\lambda_c \leq 1.5$

The member will experience inelastic lateral buckling and the critical state of stress in the steel studs may be approximated by

$$(F_{cr})_{inel} = \left[0.658^{\lambda_c^2}\right] F_y \qquad \text{(A5a)}$$

In which F_{cr} is the critical state of stress in the studs when the wall panel is likely to laterally buckle.

If $\lambda_c \geq 1.5$

The wall panel will laterally buckle before any of the studs reach yield stress in the outer fibers. This is called elastic buckling and the following equation was introduced by Euler and was shown to provide accurate and reliable values for long columns (tall wall panels).

$$\sigma_{cr} = \frac{\pi^2 E}{(KL/r)^2} \qquad \text{(A5b)}$$

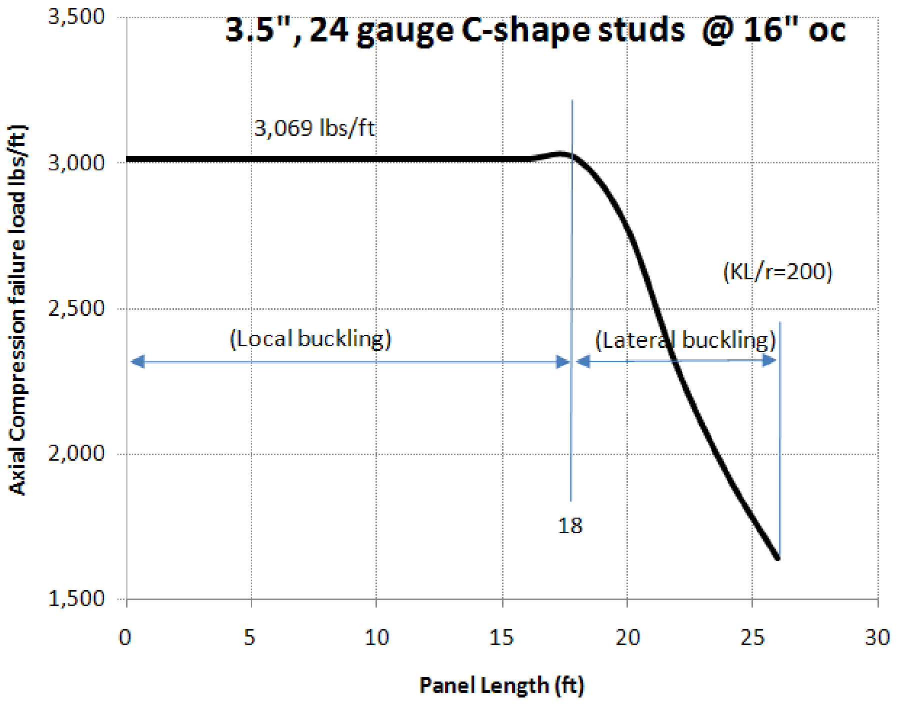

Figure A2 Axial Compression Strength for 3.5" Wall Panel; 24 gauge studs @ 16" oc

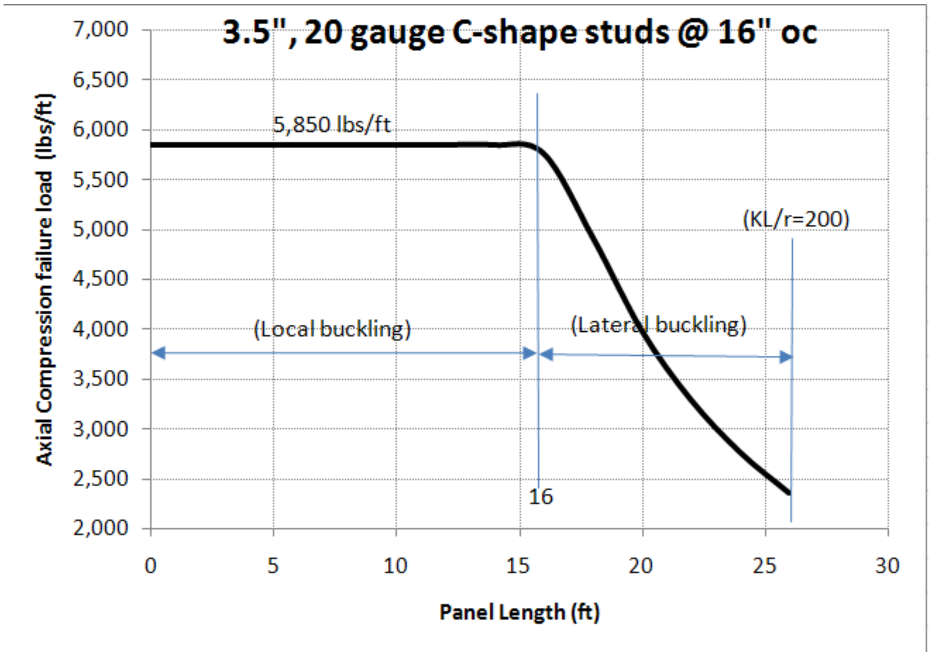

Figure A3 Axial Compression Strength for 3.5" Wall Panel; 20 gauge studs @ 16" oc

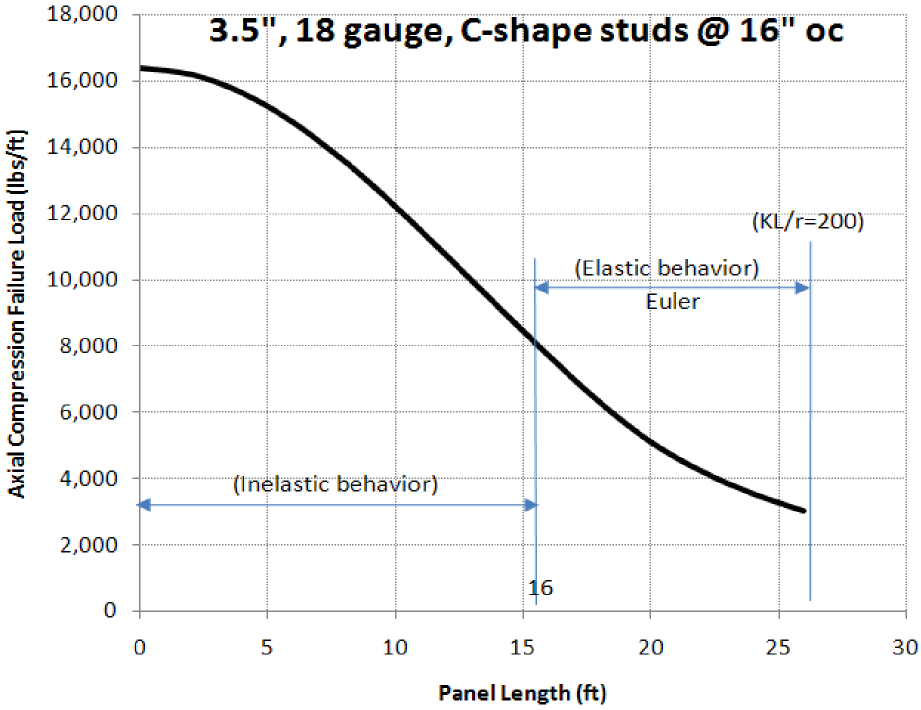

Figure A4 Axial Compression Strength for 3.5" Wall Panel; 18 gauge studs @ 16" oc

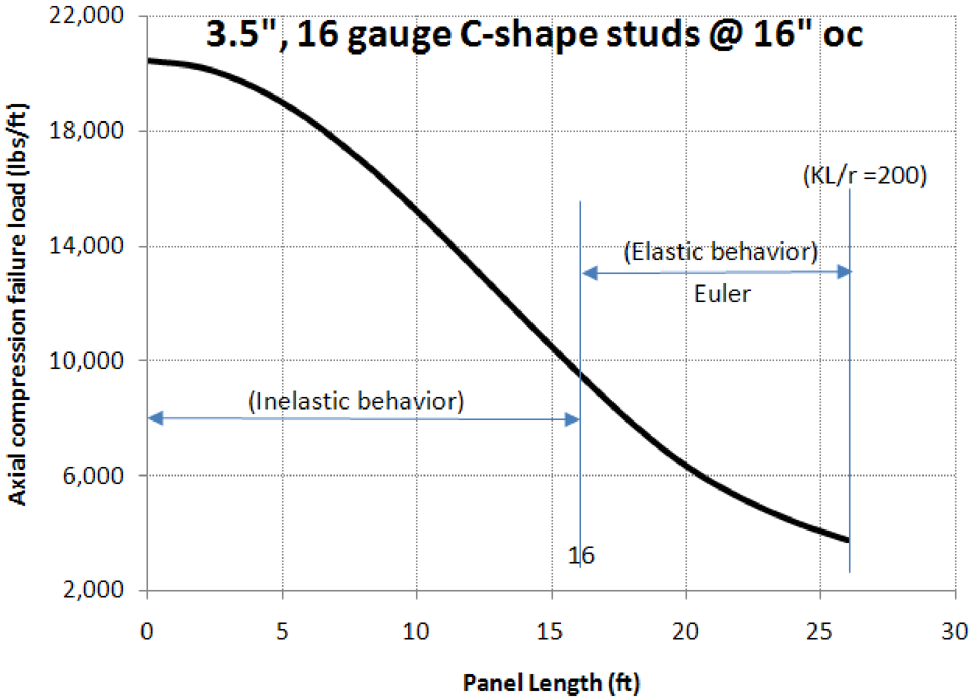

Figure A5 Axial Compression Strength for 3.5" Wall Panel; 16 gauge studs @ 16" oc

APPENDIX B
TRANSVERSE DESIGN LOADS FOR WALL, FLOOR AND ROOF PANELS

(RADVA INSULATED STRUCTURAL COMPOSITE PANELS)

Consider an insulated panel that is subjected to a uniform distributed transverse load, w (lbs/ft), see Figure B1. The panel should be sized for strength and checked to meet an allowable mid-span deflection (this is a flexibility requirement).

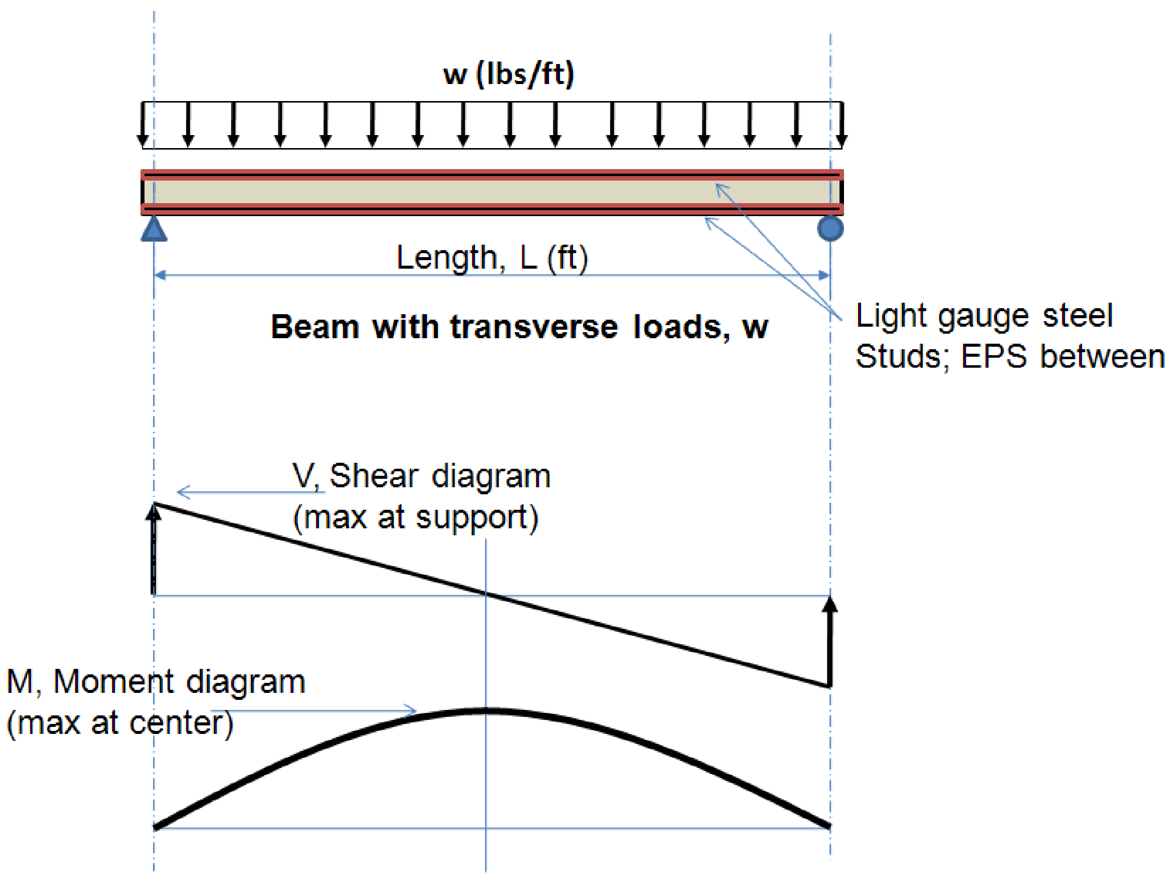

Figure B1. Insulated structural panel subjected to a uniform transverse load.

In a traditional beam problem (flexural problem), the member is sized to resist a mid-span bending moment. The maximum moment (located at mid-span) for a simply supported beam that is subjected to a uniform distributed load is given by

$$M_{\max} = \frac{wL^2}{8} \tag{B1a}$$

Or,

$$w = \frac{8M_{\max}}{L^2} \tag{B1b}$$

In which w is the applied uniform load expressed in lbs/ft; L is the span length, ft; and M_{max} is the maximum moment at mid-span (ft-lbs). In the case of the structural insulated composite wall panel, the uniform load and moment in Equation B1 are based on stud (stringer) spacing, s.

Allowable Stress Design (ASD)

In the allowable stress design method, the allowable state of stress in the stringers is set to prevent yielding and local buckling of the flanges and web of these galvanized embedded hybrid light gauge steel members. Maximum moment is given by

$$M_{\max} = F_b S_x \tag{B2}$$

In which F_b is the allowable bending stress, psi, and S_x is the section modulus for the spacing width. The resulting allowable distributed uniform transverse load that will be within allowable bending stress, F_b, is given by

$$p_a = \left(\frac{8F_b S_x}{L^2}\right) / s; psf \tag{B3}$$

In which p_a is the allowable uniform load, psf. This insures that the panel will not be overstressed. It does not check to see if deflection will be within limits. This must also be checked; see flexibility for an explanation of how this is done.

Load Resistance Factor Design Method (LRFD)

In this method, the panel is sized to fail at IBC 2006factored transverse load. Failure will either occur by the light gauge steel members yielding or local buckling. The steel stringers are embedded and bonded in EPS which eliminates lateral torsional buckling as one of the modes of failure. The Maximum moment or ultimate moment is given by

$$M_u = \varphi F_{bcr} S_x \tag{B4}$$

In which F_{bcr} is the critical bending stress at failure, psi, and S_x is the section modulus for the spacing width. The ultimate distributed uniform transverse load that meets the expected factored uniform load is given by

$$p_u = \left(\frac{8\varphi F_{bcr} S_x}{L^2} \right) / s; psf \tag{B5}$$

In which p_u is the ultimate distributed uniform load, psf, which will cause the panel to fail in bending. Remember, the factors are 1.2 for dead load and 1.6 for live load. This means that the panel will have a factor of safety between1.2 to 1.6. If it is 50% dead load and 50% live load, the factor of safety to prevent a bending failure is 1.5. This does not check insure that the panel deflection is satisfactory. Like the ASD method, deflection must also be checked; see flexibility for an explanation of how this is done.

Flexibility

Consider a typical roof or floor panel. The amount of displacement that we will allow is a function of the usage. Typically, in roofs, we allow simple span service live load deflections to be L/180 or

L/240. This depends on what is attached to the underside of the panel. If it is a brittle material like plaster, these values may not be restrictive enough. In floors, it is common to limit the live load deflections to L/360. If we want a stiffer floor, values of L/480 or L/960 are not uncommon. In residential construction, to achieve a three star rating, use a deflection limit of L/480. If you want to achieve a four star rating, use a deflection limit of L/960.

Panel displacements in a simply supported beam, see Figure B1, are maximum at mid-span. These displacements are a combination of bending deflections and shear deflections. Center span deflection caused by bending for a uniform distributed load are given by

$$\Delta_b = \left(\frac{5wL^4}{384EI}\right) \tag{B6}$$

In which E is the modulus for the steel stringers; I is the moment of inertia for a section of panel with a stud spacing width, w is the uniform load in lbs/ft acting on the spacing width. In addition to bending deformations, the panel also experiences deflection caused by shear of the EPS core. This results in a deflection of

$$\Delta_s = \left(\frac{wL^2}{K}\right) \tag{B7}$$

The panel deflection is the sum of the contributions from bending and shear. Thus, combining Equations B6 and B7 gives

$$\Delta = \left(\frac{5wL^4}{384EI}\right) + \left(\frac{wL^2}{K}\right) \tag{B8}$$

Service Loads were evaluated in accordance with the following

$$w_a = \frac{\Delta_a}{(a_1 + a_2)} \quad \text{(B9)}$$

Where,

Δ_a = the limiting live load deflection such as L/360;

w_a = the allowable uniform live load in psf;

$a_1 = \frac{5L^4}{384EI}$; and

$a_2 = \frac{L^2}{K}$

Theoretical vs Experimental

3.5" Thick Panels- A comparison between theoretical and experimental values for both strength and deflection are presented herein. The theoretical calculations were developed by the author. The calculated uniform panel load at failure for 3.5" thick 24 gauge studs at 16" compare favorably with experimental, see Figure B2. Theoretical displacements for 3.5" thick 24 gauge studs at 16" are slightly larger than measured values, see Figures B3 and B4.

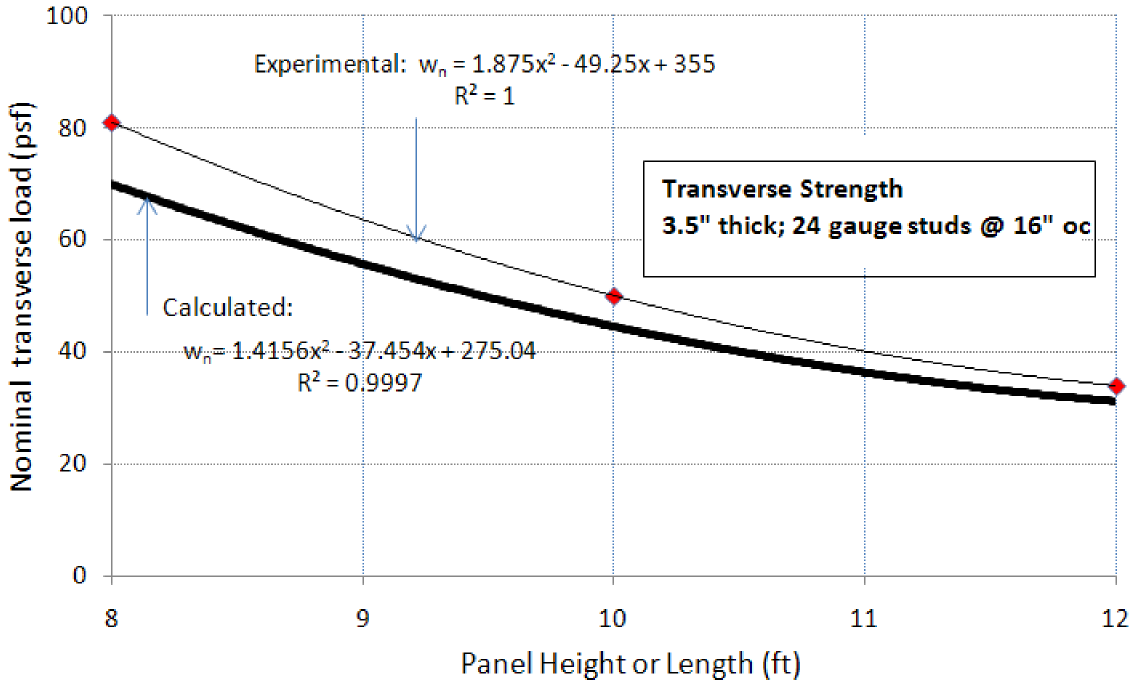

Figure B2 Distributed Uniform Load at Failure (Strength Test)

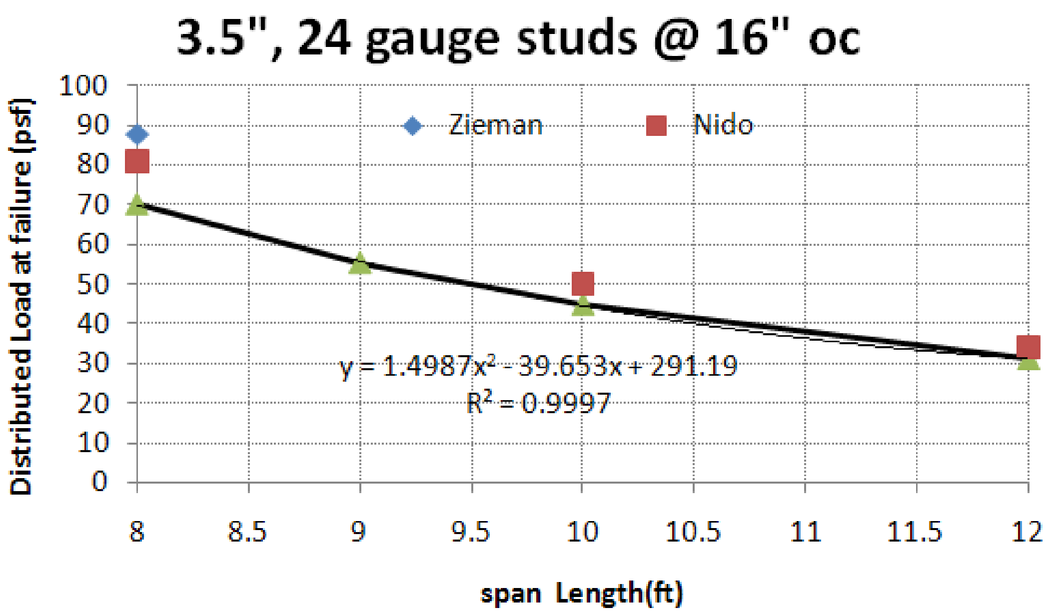

Figure B3. Theoretical Uniform Distributed Failure Load for an 8ft panel

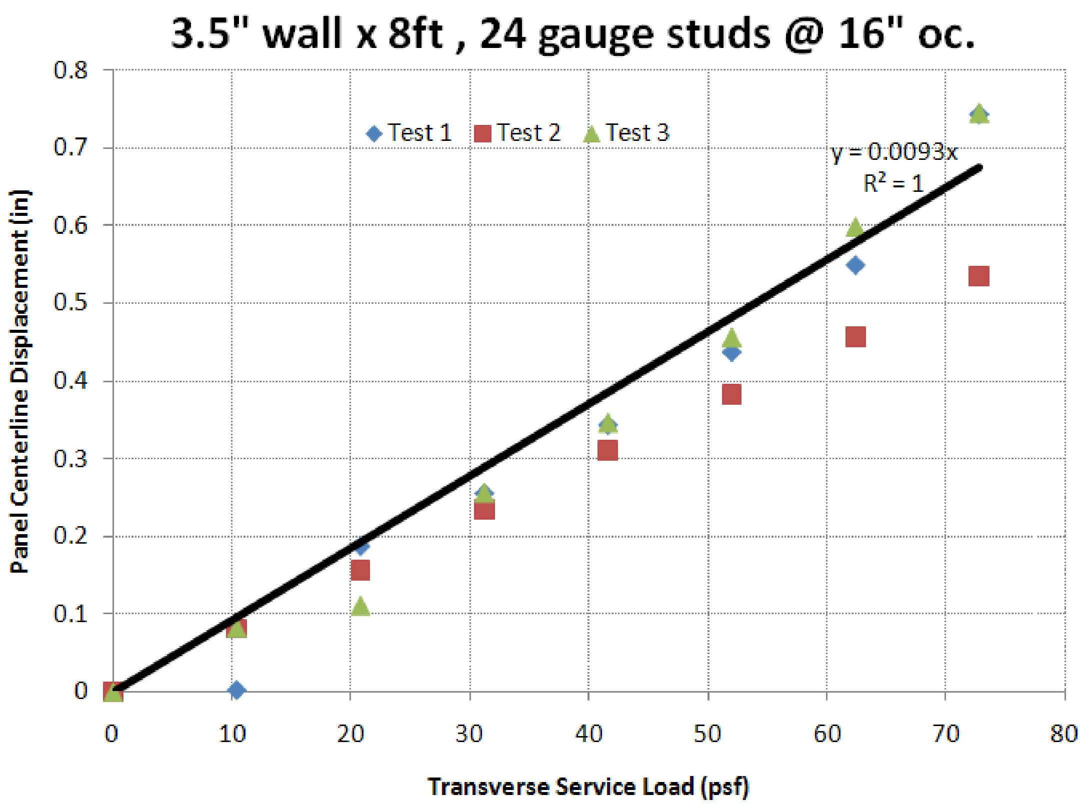

Figure B4. Mid-span Displacements for a Uniform Distributed Load; Theoretical vs. Test Results

5.5" Thick Panels- A comparison between theoretical and experimental values for both strength and deflection are presented. The calculated uniform panel load at failure for 5.5" thick 24 gauge studs at 16" compare favorably with experimental, see Figure B5. Theoretical displacements for 5.5" thick 24 gauge studs at 16" are nearly the same as measured values, see Figures B6.

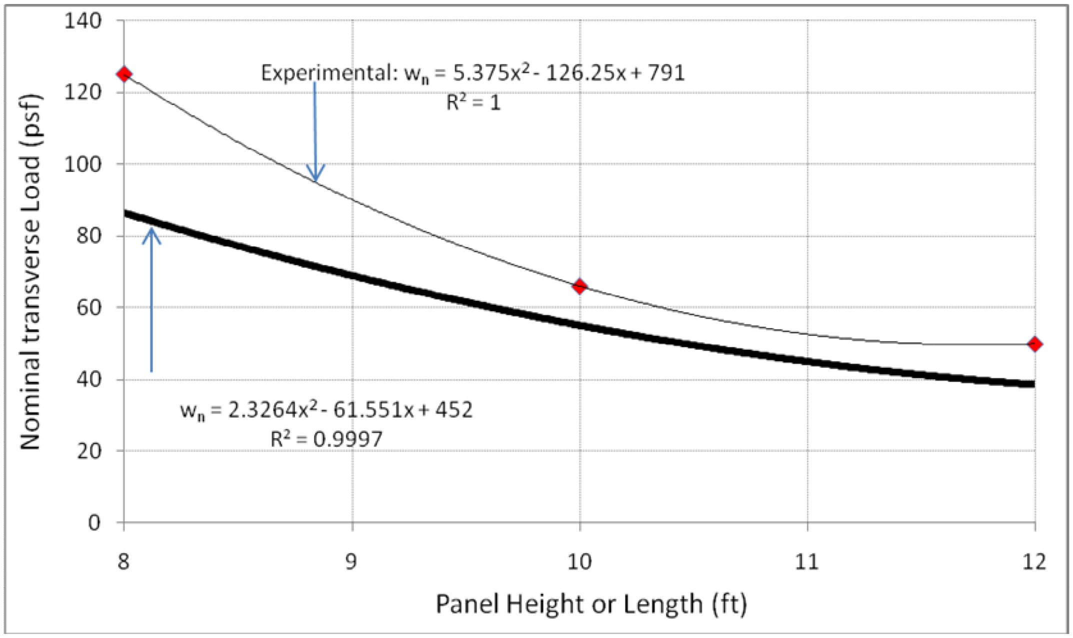

Figure B5. Uniform Distributed Transverse Failure Load (psf)

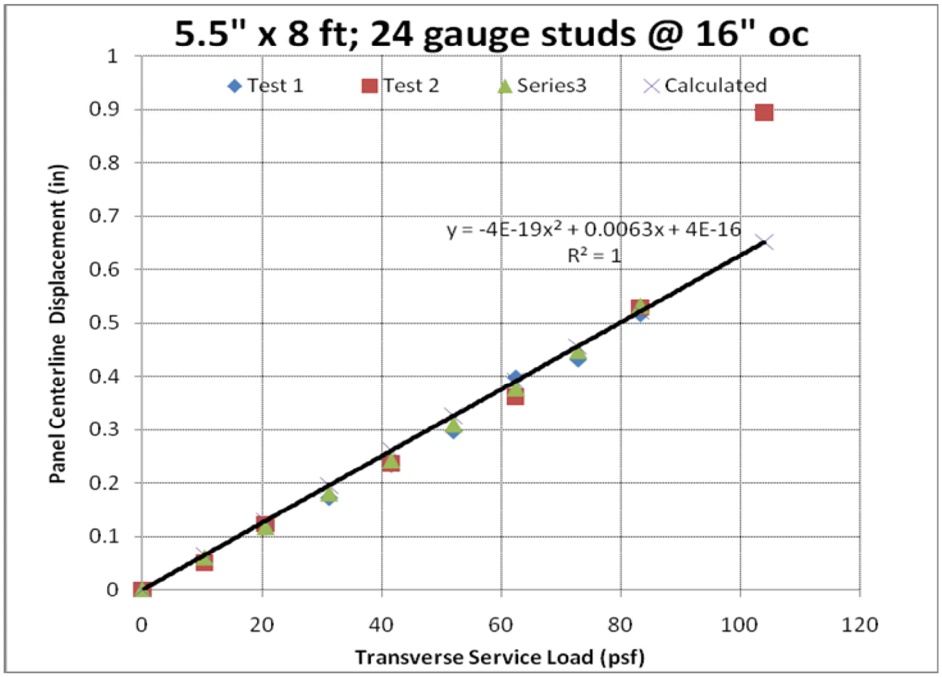

Figure B6. Center Displacements for a Uniform Distributed Load

APPENDIX C
CALCULATED PANEL DISTRIBUTED FAILURE & DISPLACEMENT LOADS

(RADVA INSULATED STRUCTURAL COMPOSITE WALL PANELS)

This Appendix provides the engineer with another presentation of the load capacity of the RADVA panels in axial compression and bending. Depending on the engineer, these tables may be more useful than those presented in the text.

Table C1. 3.5" thick panel with track type studs at 16" o.c.; no gypsum or siding.

		Axial compression (lbs/ft)[a]				Transverse Loads (psf)[b]						
		Tested		Calculated		Strength		Calculated Service loads				
Gauge	Ht (ft)	EPS density (pcf)	Failure	Failure (Nominal)	Allowable (ASD)	Tested	Calculated (Nominal)	Allowable (ASD)	L/180	L/240	L/360	L/480	L/960
24	8		3005	3,069	1,535	81	70	35	50	37	25	19	9
24	9			3,069	1,535		55	28	38	28	19	14	7
24	10		2960	3,069	1,535	50	45	22	29	22	15	11	6
24	12		2,875	3,069	1,535	34	31	16	19	14	9	7	3
20	8			5,850	2,925		150	75	61	46	30	23	11
20	9			5,850	2,925		119	59	47	36	24	18	9
20	10			5,850	2,925		96	48	38	28	19	14	7
20	12			5,850	2,925		67	33	24	18	12	9	5
18	8			10,177	5,089		193	97	69	52	35	26	13
18	9			9,680	4,840		153	76	55	36	24	18	9
18	10			9,153	4,577		124	62	44	33	22	16	8
18	12			8,040	4,020		86	43	29	22	15	11	5
16	8			12,696	6,348		240	120	76	57	38	29	14
16	9			12,071	6,036		190	95	61	46	30	23	11
16	10			11,409	5,705		154	77	49	37	25	18	9
16	12			10,013	5,006		107	53	33	25	17	13	6

(a) The panel was tested to failure. Calculations meet 2007 AISI and IBC 2009. Allowable loads are based on a factor of safety of 2.
Calculated values meet the 2007 AISI specifications; the IBC 2009. The values account for local buckling, yielding and lateral buckling.

(b) Panels were tested to failure and the type of failure was observed and recorded.
Allowable loads are based a factor of safety for flexure of 2. This accounts for local buckling, lateral torsional buckling, or yielding.

Ref 1: Viccars, C.L., PE; Coake, E.R.; "Test Report ASTM D-1183", April 1984.: 24 gauge; 8-ft, axial compression failure: 3,600 lbs/ft

Table C2. 3.5" thick panel with track type studs at 24" o.c.; no gypsum or siding.

		Axial compression (lbs/ft)[(a)]				Transverse Loads (psf)[b]							
		Tested		Calculated		Strength		Calculated Service loads					
Gauge	Ht (ft)	EPS density (pcf)	Failure	Failure (Nominal)	Allowable (ASD)	Tested	Calculated (Nominal)	Allowable (ASD)	L/180	L/240	L/360	L/480	L/960
24	8			2,046	1,023	60	47	23	38	28	19	14	7
24	9			2,046	1,023		37	18	28	21	14	11	5
24	10			2,046	1,023	34	30	15	22	16	11	8	4
24	12			2,046	1,023	23	21	10	13	10	7	5	3
20	8			3,900	1,950		100	50	48	36	24	18	9
20	9			3,900	1,950		79	40	37	27	18	14	7
20	10			3,900	1,950		64	32	28	21	14	11	5
20	12			3,900	1,950		44	22	18	13	9	7	3
18	8			6,785	3,392		129	64	56	42	28	21	11
18	9			6,453	3,227		102	51	43	27	18	14	7
18	10			6,102	3,051		83	41	34	25	17	13	6
18	12			5,360	2,680		57	29	22	16	11	8	4
16	8			8,464	4,232		160	80	63	47	31	24	12
16	9			8,047	4,024		126	63	49	37	25	18	9
16	10			7,606	3,803		102	51	39	29	20	15	7
16	12			6,675	3,338		71	36	26	19	13	10	5

(a) The panel was tested to failure. Calculations meet 2007 AISI and IBC 2009. Allowable loads are based on a factor of safety of 2.
Calculated values meet the 2007 AISI specifications; the IBC 2009. The values account for local buckling, yielding and lateral buckling.

(b) Panels were tested to failure and the type of failure was observed and recorded.
Allowable loads are based a factor of safety for flexure of 2. This accounts for local buckling, lateral torsional buckling, or yielding.

Table C3. 5.5" thick panel with track type studs at 16" o.c.; no gypsum or siding.

		Axial compression (lbs/ft)[a]				Transverse Loads (psf)[b]								
		Tested		Calculated		Strength		Calculated Service loads						
Gauge	Ht (ft)	EPS density (pcf)	Failure	Failure (Nominal)	Allowable (ASD)	Tested	Calculated (Nominal)	Allowable (ASD)	L/180	L/240	L/360	L/480	L/960
24	8		4,115	3,431	1,716	125	87	43	88	66	44	33	17
24	9			3,431	1,716		68	34	70	53	35	26	13
24	10		3,915	3,431	1,716	66	55	28	57	43	28	21	11
24	12		3,925	3,431	1,716	50	38	19	38	29	19	14	7
20	8		7,609	7,176	3,588		248	124	101	76	51	38	19
20	9			7,176	3,588		196	98	82	62	41	31	15
20	10		7,363	7,176	3,588		159	79	68	51	34	25	13
20	12		7,120	7,176	3,588		110	55	47	36	24	18	9
18	8		14,730	11,431	5,715		320	160	110	82	55	41	21
18	9			11,213	5,606		253	127	91	62	41	31	15
18	10		14,230	10,974	5,487		205	103	76	57	38	28	14
18	12		13,994	10,441	5,221		142	71	54	40	27	20	10
16	8			14,274	7,137		399	199	116	87	58	44	22
16	9			14,001	7,000		315	158	97	73	48	36	18
16	10			13,702	6,851		255	128	82	61	41	31	15
16	12			13,034	6,517		177	89	59	45	30	22	11

(a) The panel was tested to failure. Calculations meet 2007 AISI and IBC 2009. Allowable loads are based on a factor of safety of 2.
Calculated values meet the 2007 AISI specifications; the IBC 2006. The values account for local buckling, yielding and lateral buckling.
(b) Panels were tested to failure and the type of failure was observed and recorded.
Allowable loads are based a factor of safety for flexure of 2. This accounts for local buckling, lateral torsional buckling, or yielding.

Table C4. 5.5" thick panel with studs at 24" o.c.; no gypsum or siding.

		Axial compression (lbs/ft)[(a)]				Transverse Loads (psf)[b]							
		Tested		Calculated		Strength		Calculated Service loads					
Gauge	Ht (ft)	EPS density (pcf)	Failure	Failure (Nominal)	Allowable (ASD)	Tested	Calculated (Nominal)	Allowable (ASD)	L/180	L/240	L/360	L/480	L/960
24	8		3,165	2,288	1,144	82	58	29	73	55	36	27	14
24	9			2,288	1,144		46	23	57	43	28	21	11
24	10		2,775	2,288	1,144	56	37	18	45	34	22	17	8
24	12		2,875	2,288	1,144	37	26	13	29	22	15	11	5
20	8			4,784	2,392		166	83	86	65	43	32	16
20	9			4,784	2,392		131	65	69	52	34	26	13
20	10			4,784	2,392		106	53	56	42	28	21	10
20	12			4,784	2,392		74	37	37	28	19	14	7
18	8			7,620	3,810		214	107	96	72	48	36	18
18	9			7,475	3,738		169	84	78	52	34	26	13
18	10			7,316	3,658		137	68	63	48	32	24	12
18	12			6,961	3,480		95	47	44	33	22	16	8
16	8			9,516	4,758		266	133	104	78	52	39	19
16	9			9,334	4,667		210	105	85	64	42	32	16
16	10			9,135	4,567		170	85	70	52	35	26	13
16	12			8,689	4,345		118	59	49	37	25	18	9

(a) The panel was tested to failure. Calculations meet 2007 AISI and IBC 2009. Allowable loads are based on a factor of safety of 2.
Calculated values meet the 2007 AISI specifications; the IBC 2009. The values account for local buckling, yielding and lateral buckling.
(b) Panels were tested to failure and the type of failure was observed and recorded.
Allowable loads are based a factor of safety for flexure of 2. This accounts for local buckling, lateral torsional buckling, or yielding.

APPENDIX D

CERTIFIED PANEL TESTS DOCUMENTATION FOR AXIAL COMPRESSION & TRANSVERSE PRESSURE

(RADVA Insulated Structural Composite Wall Panels

Table D1. Panels Tested and Certified by a Professional Engineer

wall Panels			3.5" thick wall panel						5.5" thick wall panel					
Stud spacing			16			24			16			24		
Wall panel height (ft)			8	10	12	8	10	12	8	10	12	8	10	12
Description	Type of test	EPS Density (pcf)												
1. Transverse (psf)														
24 gauge studs														
Douglas J. Nido, PE			81	50	34	60	34	23	125	66	50	82	56	37
Michael L. Zieman, PE; April 2002		1.5	88						122					
2. Axial Comp. (plf)														
24 gauge studs														
Douglas J. Nido, PE (Pennsylvania, 1997)			3,005	2,960	2,875	2,530	2,160	2,215	4,115	3,915	3,925	3,165	2,775	2,875
James H. Moore, PE (RADVA, Virgina, 1994)		1.383	4,183											
		1.336				3,460								
		1.223	3,615											
		1.239				2,043								
		1.222				2,163								
C. Leon Vicars, PE (Virginia, 1984)	Moisture exposure tests		3,608											
	Moisture exposure tests		3,592											
20 gauge studs														
Thomas E. Scott, PE (Virginia, 12/3/2001)									7,609	7,363	7,120			
18 gauge studs														
Thomas E. Scott, PE (Virginia, 12/3/2001)									14,730	14,230	13,994			