

B

Structural Design

General Structural Issues

The Manufactured Housing Research Alliance (MHRA) retained Anderson-Peyton Structural Engineering Consultants to provide a state of the art prototype structural design using cold-formed steel framing as an alternative to the traditional timber framing materials. This appendix documents their work including drawings and specifications based on a single story double section unit. The double section design is by far the most typical manufactured home configuration accounting for about three-quarters of all new shipments (2001). Double sections are sold in a narrow range of widths from 24 feet to 32 feet and in varying lengths with most homes falling between 40-feet and 70-feet. The 28 foot by 60 foot footprint of the prototype is a standard plan used by most manufacturers.

Homes built under the HUD standards¹ are subject to reviews by two agencies: the Design Approval Plan Inspection Agency (DAPIA) and In-plant Inspection Agency (IPIA). The design and supporting calculations are reviewed by the plant's DAPIA. For the steel frame design, the DAPIA was RADCO. RADCO was selected based on their prior experience with steel framing design. Over the course of nearly 12 months, Anderson-Peyton worked closely with RADCO through an iterative process with the goal of providing sufficient documentation and engineering analysis to qualify the cold-formed steel design under the HUD standards. The final DAPIA approved version of the design is described in this appendix. The DAPIA letter attesting to its conformance to the HUD standards is provided in Appendix A.

In developing the prototype design, the consultant conducted a study of the plant manufacturing process with a goal of using as much of the current timber manufacturing process as possible while substituting cold-formed steel framing materials. The engineers were directed to confine design proposals to those that could be realized within the confines of current plant manufacturing operations and production flows, and without changes to materials that attach to the frame of the home. Within these parameters, they were encouraged to take advantage of efficiencies afforded by cold formed steel framing techniques. The major changes involved steel for wood substitutions for the roof, wall, and floor framing assemblies. (All stud material used in the design was per the SSMA ICBO ER 4943P. For stud designators and nomenclature refer to that ICBO report and Figure B-0.)

Although improvements in the manufacturing process were not considered, this is an area ripe for future investigation. For example, the steel industry has developed methods for fabricating components such as studs at relatively low cost using small extruders that can be located in the home manufacturing plant. Such technologies can reduce the number of SKUs and the space in the plant dedicated to materials storage; changes that potentially reduce production costs and increase efficiency.

As noted above, the prototype was developed for an industry standard double section home measuring a nominal 28 x 60 ft. Elevations and a floor plan for this representative design are provided in Figure B-0 through Figure B-0.

¹ Federal Manufactured Housing Construction and Safety Standards, Part 3280

Figure B-0 Universal stud designator

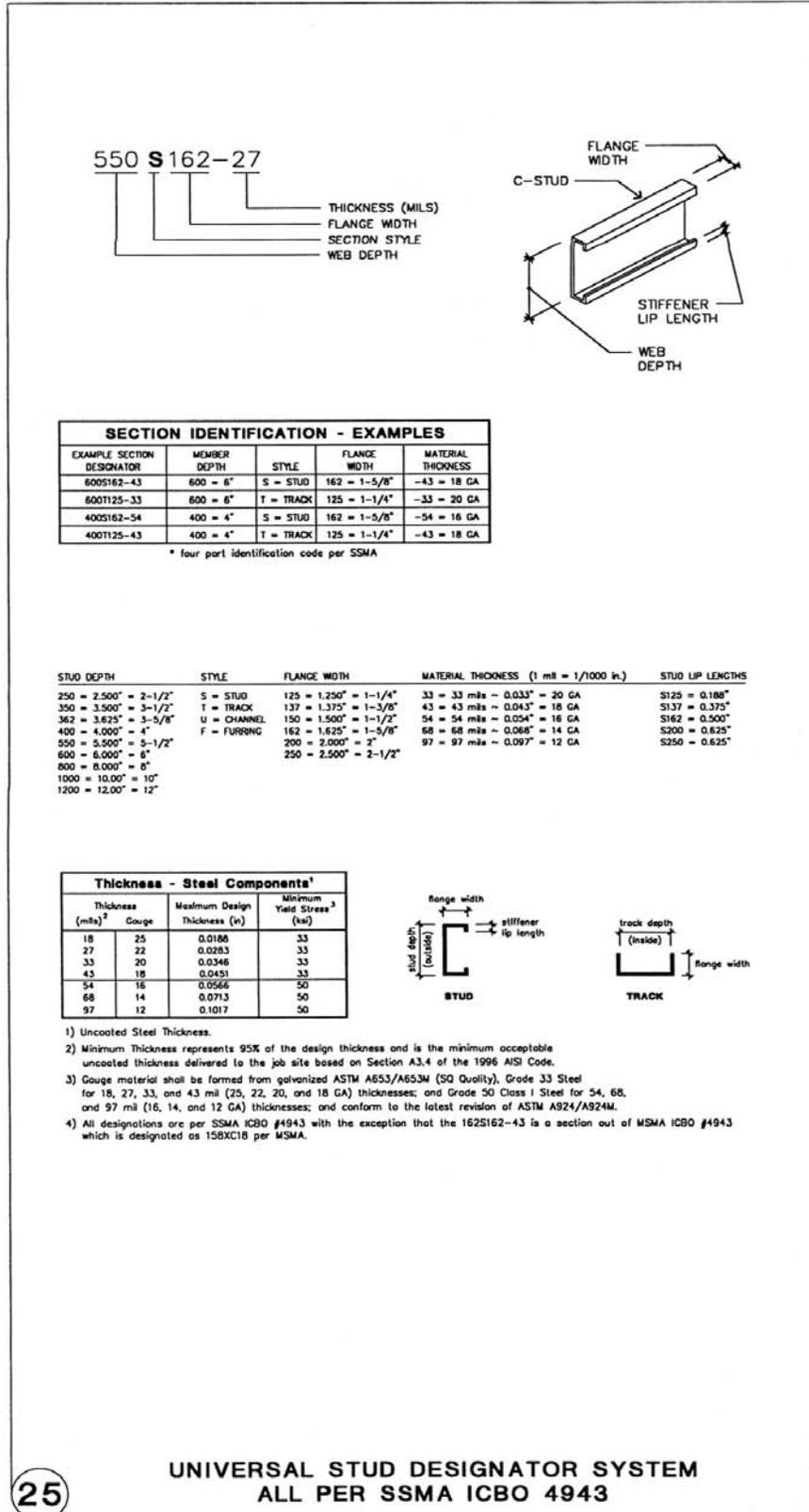
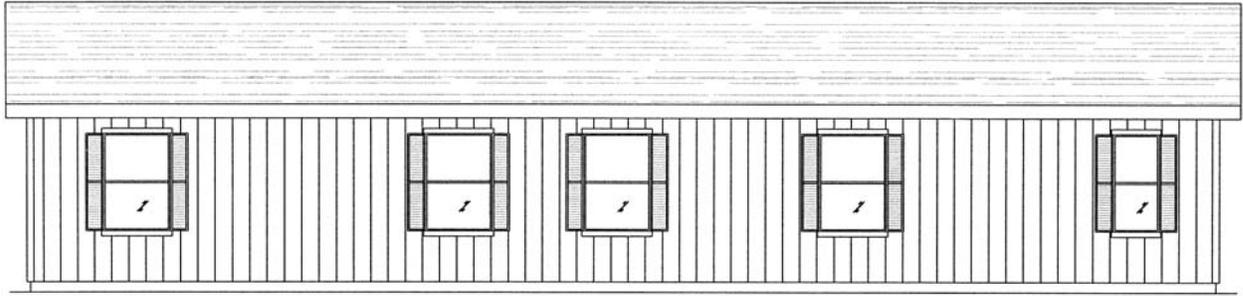


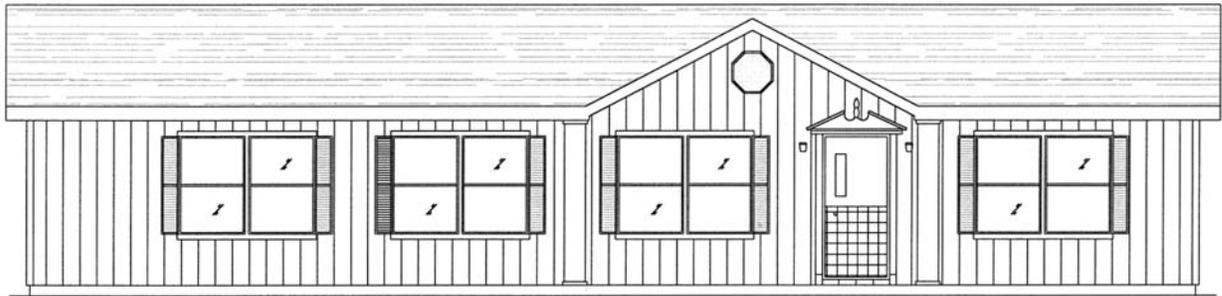
Figure B-0 Typical front and rear elevations of a multisection manufactured home.



ELEVATION - 28x60 - (BOM-1681)

SCALE: 1/4"=1'-0"

1,493 Sq. Ft. THREE BEDROOM, TWO BATH

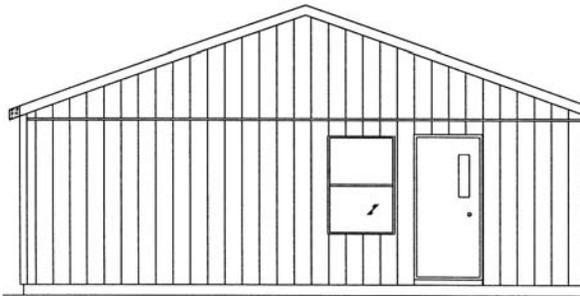


ELEVATION - 28x60 - (BOM-1681)

SCALE: 1/4"=1'-0"

1,493 Sq. Ft. THREE BEDROOM, TWO BATH

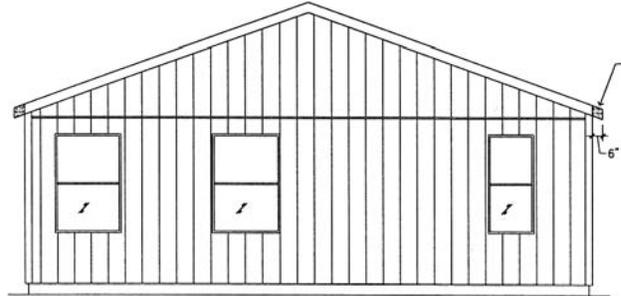
Figure B-0 Typical side elevations of a multisection manufactured home.



ELEVATION - 28x60 - (BOM-1681)

SCALE: 1/4"=1'-0"

1,493 Sq. Ft. THREE BEDROOM, TWO BATH



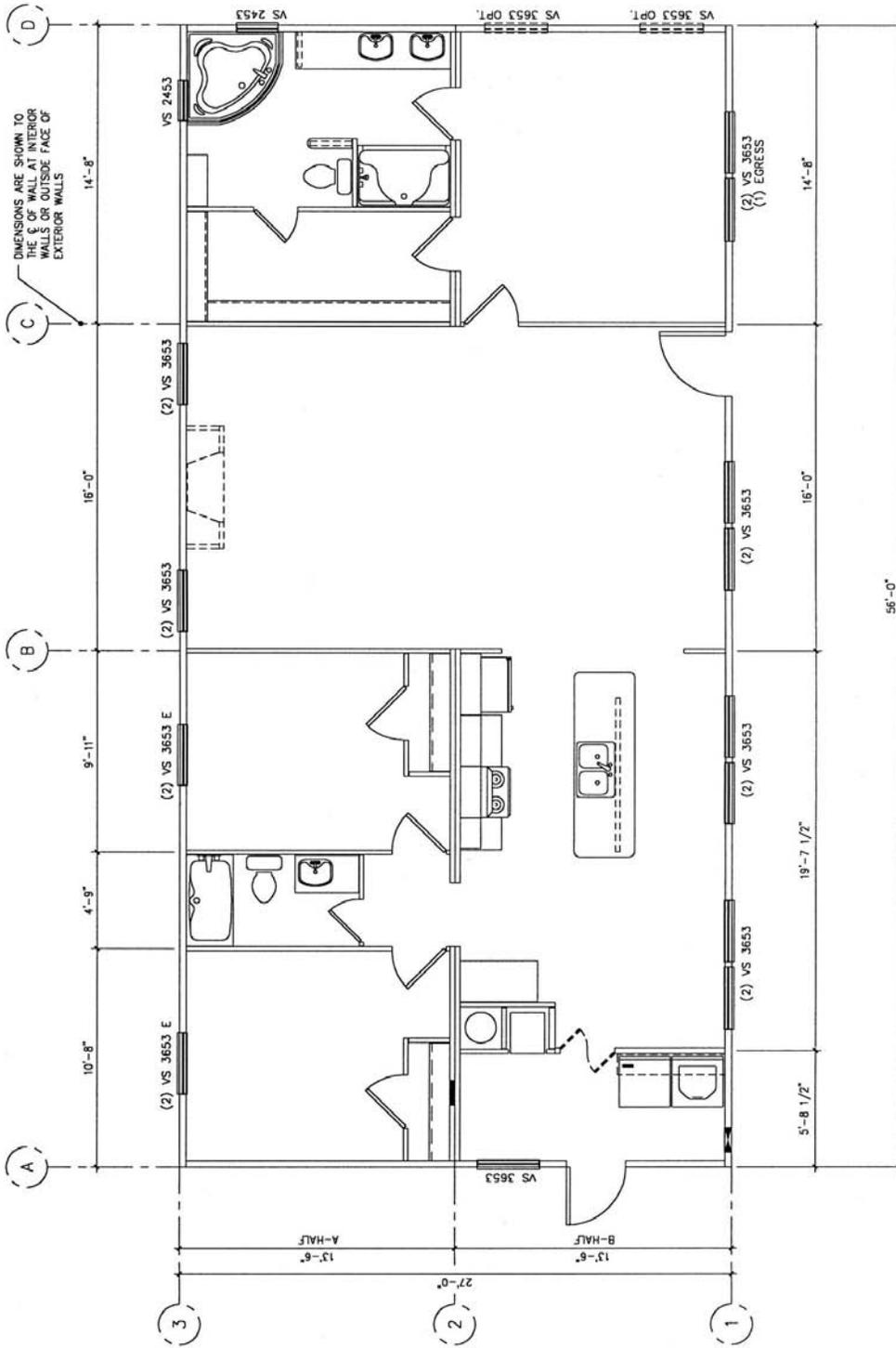
SHADED PORTION INDICATES
EAVE. SEE DET. 10/S6 FOR
EAVE OPTION

ELEVATION - 28x60 - (BOM-1681)

SCALE: 1/4"=1'-0"

1,493 Sq. Ft. THREE BEDROOM, TWO BATH

Figure B-0 Typical floor plan layout of a multifunction manufactured home



FLOOR PLAN - 28x60 - (BOM-1681)

SCALE: 1/4"=1'-0" 1,483 Sq. Ft. THREE BEDROOM, TWO BATH

The pages that follow provide a discussion of approach to structural design for each of the major structural components followed by accompanying graphic illustrations. The following drawings are provided:

Table—B-1 Index of structural drawings

Fig. No.	Drawing title	Page No.
Roof truss		
B-5	Roof framing plan	B-8
B-6	Building section	B-9
B-7	Truss details	B-10
B-8	Truss bridging at interior mating wall	B-11
B-9	Alternative truss bearing at interior mating wall	B-11
B-10	Typical screw attachment	B-12
B-11	Typical truss and joist to stud alignment	B-12
B-12	Screw attached gypsum ceiling	B-13
B-13	Field connection—roof strap across end walls at mating wall	B-13
B-14	Typical roof over framing	B-13
Walls		
B-15	Mating wall connection to floor joist	B-15
B-16	Truss bearing on exterior wall	B-15
B-17	Alternate distributor plate at top of wall for trusses bearing at 24 in. on center with studs at 16 in. on center	B-16
B-18	End wall section	B-16
B-19	Wall bracing options	B-17
B-20	Wall intersection details	B-17
B-21	Typical wall top track splice options	B-18
B-22	Truss roof assembly to wall assembly	B-18
Ridge beams and headers		
B-23	Ridge beam splice	B-19
B-24	Isometric L-header at single and double window opening at side wall locations	B-20
B-25	Double L-header beams	B-21
Shearwalls		
B-26	Typical wall to floor strap (non hold down locations)	B-23
B-27	Shearwall component table	B-23
Floor joist and chassis systems		
B-28	Floor framing plan	B-25
B-29	Isometric floor to wall connection	B-26
B-30	Additional joist at window jamb studs and additional blocking at outrigger	B-26
B-31	Exterior wall to floor joist connection	B-27
B-32	Floor joist strap and blocking to main rail beam	B-27
Miscellaneous construction information		
B-33	General construction notes	B-28
B-34	Roof, floor and wall assembly fastener types	B-29
B-35	Allowable field penetrations	B-29

Roof Truss Design

General Description: Truss requirements are minimal given they need only span approximately 13'-5 in., the 24 in. on center spacing, and carry a load of only 20 psf. A 3:12 slope is used on the top chord with a lesser cathedral slope on bottom chord (ceiling). See Figure B-0, Figure B-0 and Figure B-0 for a roof framing plan and a full truss profile including specific panel point details.

Many plants obtain their trusses pre-assembled while a few choose to assemble the trusses in their plants. The most common assembly currently used by the industry is a timber truss, which utilizes nominal 2 x 2 in. elements for the diagonal webs as well as the top and bottom chords. Connections are made with gang nail plates. This truss assembly is very economical for the current plant assembly process. The steel prototype uses a 250S162-27 (33 ksi material) for top, bottom, and web chords. This is a 2½ in. deep by 1⅝ in. wide by 22 gauge (27 mil) “C” stud. Although it was recognized that the wood truss would be difficult to compete with using steel, it was found that the cost comparison (see Chapter 4) yielded only a 3 percent more expensive steel truss. This slightly more expensive truss was based on currently available steel sections without the benefit of economizing research. Details on the marriage wall to roof connection are provided in Figure B-0 and Figure B-0.

It should be noted that the prototype truss could be economized with additional truss testing as will be indicated below. During the truss design three areas of economy were investigated:

1. Section geometry
2. Steel material strength
3. Joint fasteners

Section Geometry: With cold-formed steel virtually any section shape is possible to roll-form. Since the section shape defines the strength of the element then there is room to experiment with preferred shapes to minimize both the material used and ease of construction. Ease of construction means that certain shapes may be easier to handle than others during in-plant assembly.

Alternate section geometry may be pursued to develop the most cost effective section for the specific short span truss configuration. A hemmed angle section shape was investigated but would need to be tested, as the current code does not provide a design methodology to analyze the design capacity. It is possible that a 20 gauge 2 x 2 in. angle with ½ in. hems might be an effective section for testing. In addition, hat-shaped trusses may be a more economical but would require some research. There are proprietary shaped trusses such as Alpine, Studco, or Mitek that, given a sufficient volume of sales, could prove to make a cost competitive shape specifically for the manufactured housing industry.

Steel Material Strength: The cold-formed material strengths most commonly used in the US are 50 ksi for 16 gauge (54 mil) and thicker, and 33 ksi for 18 gauge (43 mil) and thinner. This is not to say that other steel strengths are not available in differing thicknesses. The designers reviewed standard shapes available but with non-standard steel strengths. It was found that 250S162-27 using 33 ksi steel was an economical section using standard shapes. Since a 2½ in. “C” shape worked at 33 ksi then the next smaller standard size (1⅝ in.) was checked at a higher 50 ksi but found to be 25 percent overstressed. Defaulting back to the 250S162-27 it was noted that 85 percent of the section strength is to be used. This leaves room to expect that an alternate non-standard section somewhere between a 2.5 in. and 1.625 in. web depth using 50 ksi may provide more economy.

Fasteners: Potential fastening of the joints could be made with screws, welds, integral clinching, pneumatic pins, adhesives, or combinations of these techniques. It was determined that connections for the prototype would be most economically made with #8 screws per detail shown in Figure B-0.

There are (18) member connections involved for the 13'-5" truss span. One connection joint requires (12) screws each end, another requires (7), another (5) and the rest only (2) screws. Note that the thinner 22 gauge (27 mil) material requires more fasteners than thicker materials. Some investigation was made into using adhesives combined with a mechanical pneumatic fastener by Aerosmith, Inc. (see Appendix E for supplier contact information). Preliminary tests indicated high strength for the adhesive but set times and fire ratings were unknown at the time of this study.

Alternate material strengths (such as, 50 ksi instead of 33 ksi) were investigated. Although a higher ksi yield strength would decrease the required section thickness, the cost of the panel point connections was increased due to additional fastener requirement in the thinner material

Additional Roof Assembly Notes: A rafter solution was briefly investigated but was dropped as the design criteria required trusses to be capable of accommodating heat ducting through the open web truss spaces.

Details of other roof truss connections are shown in Figure B-0 through Figure B-0.

Figure B-0 Roof framing plan

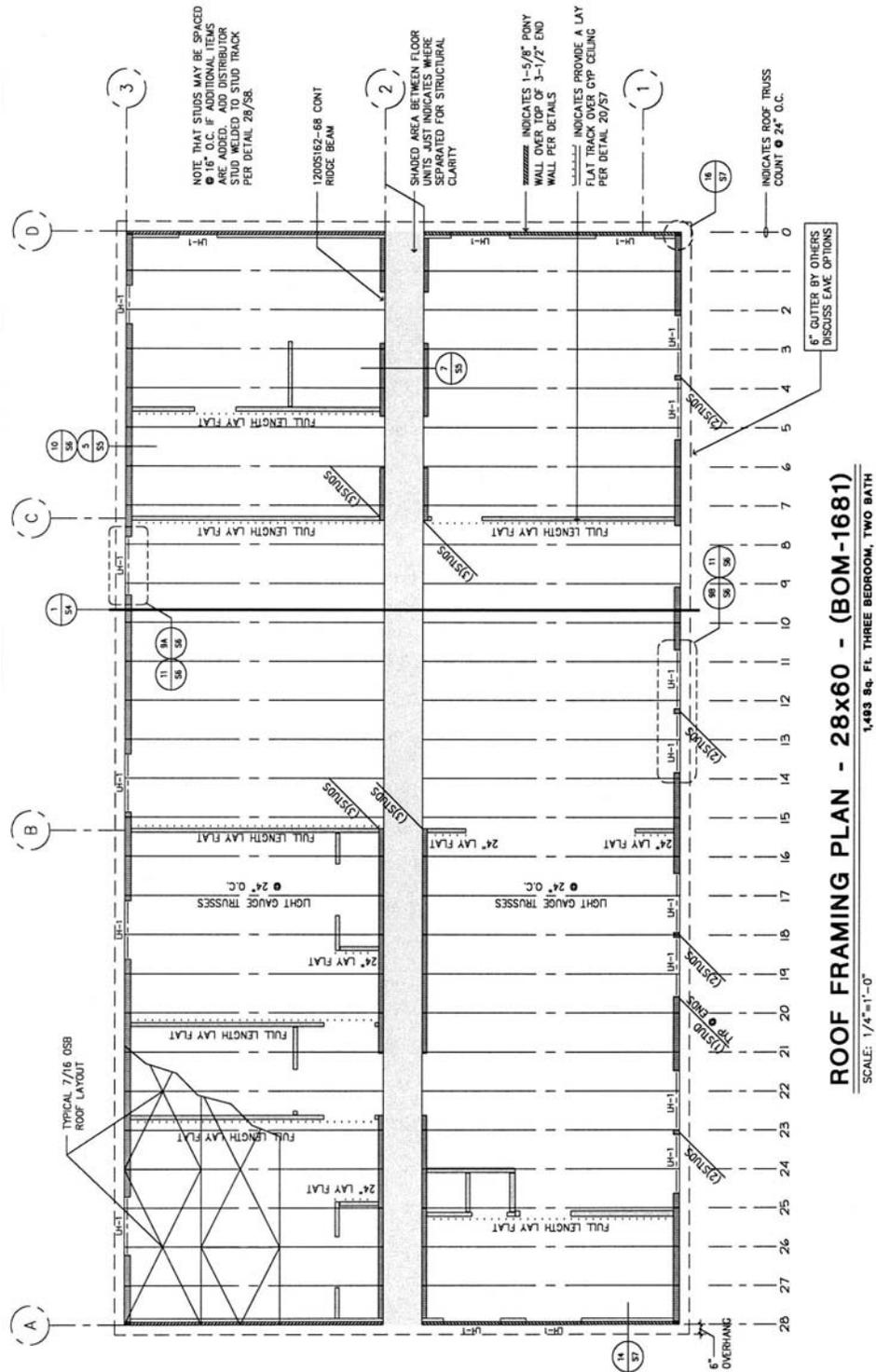


Figure B-0 Truss details

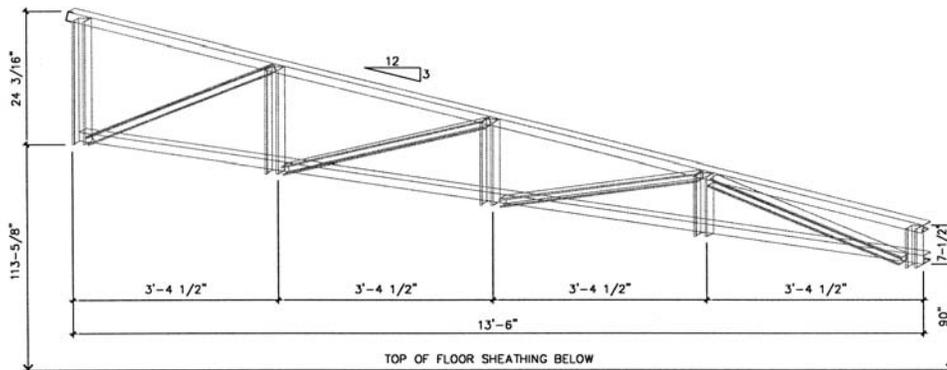
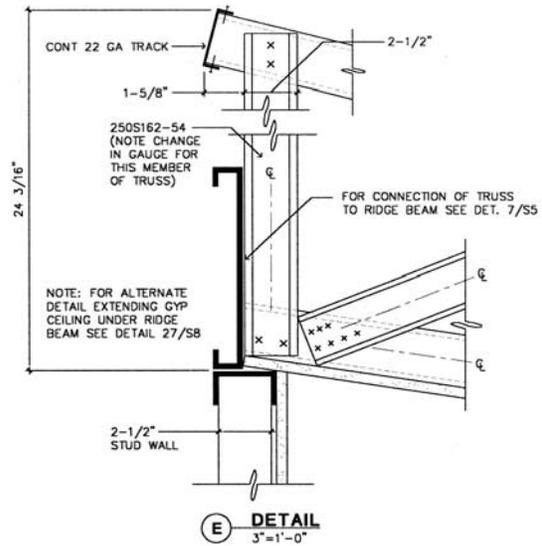
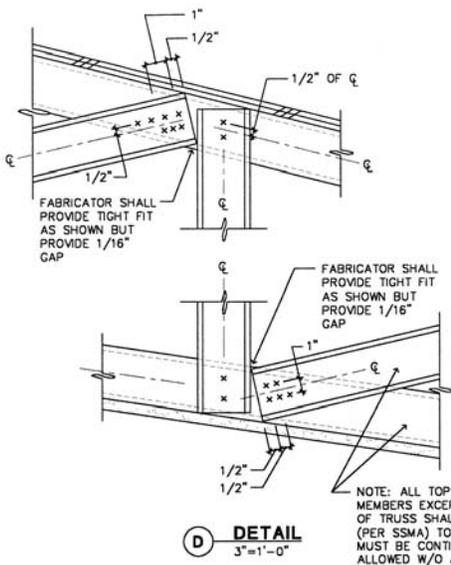
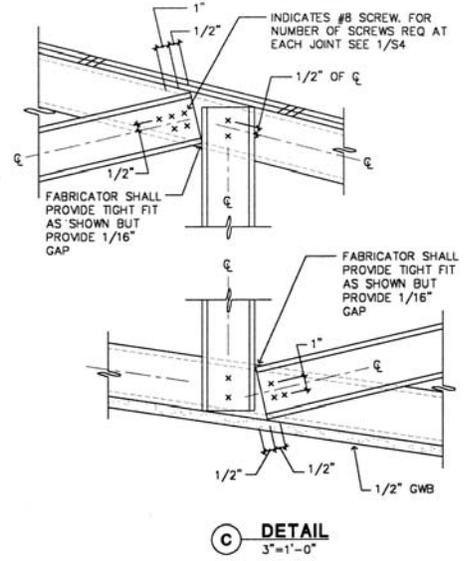
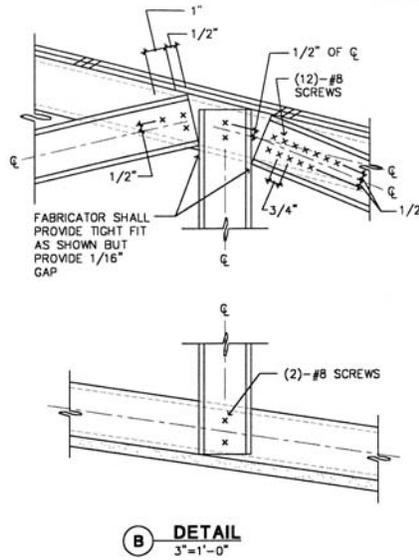
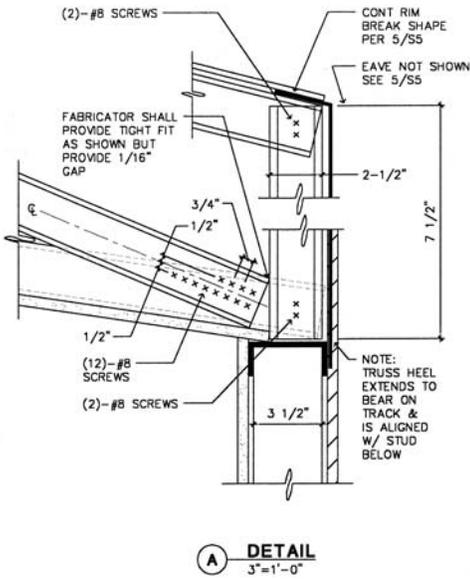


Figure B-0 Alternate truss bearing at interior mating wall

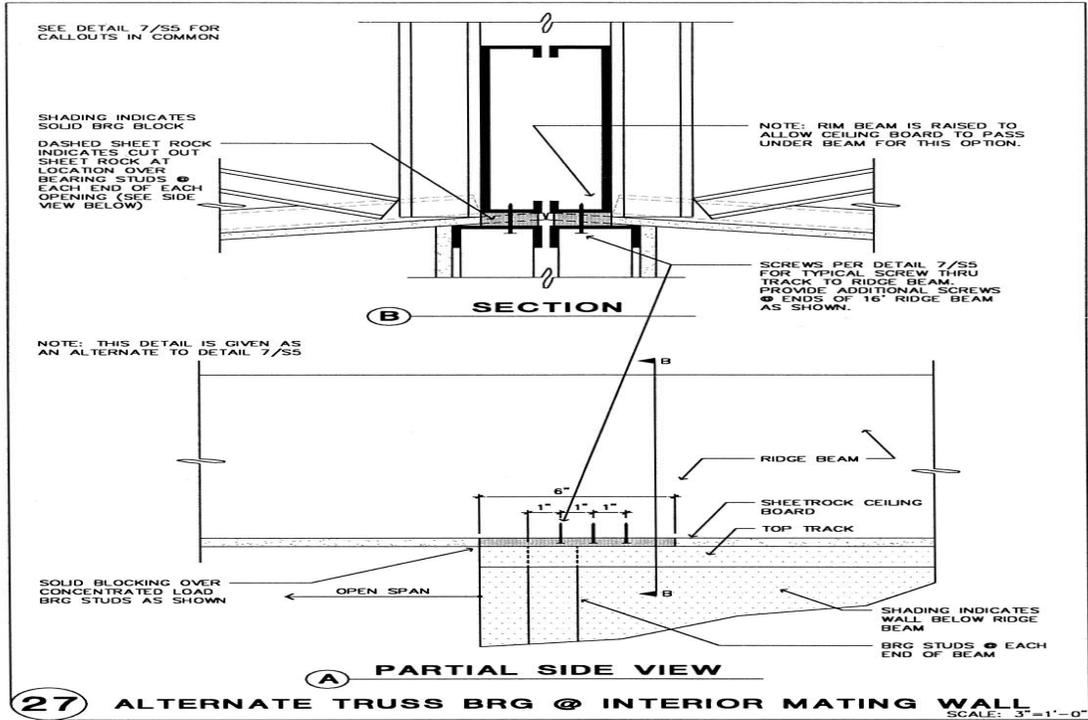


Figure B-0 Truss bearing at interior mating wall

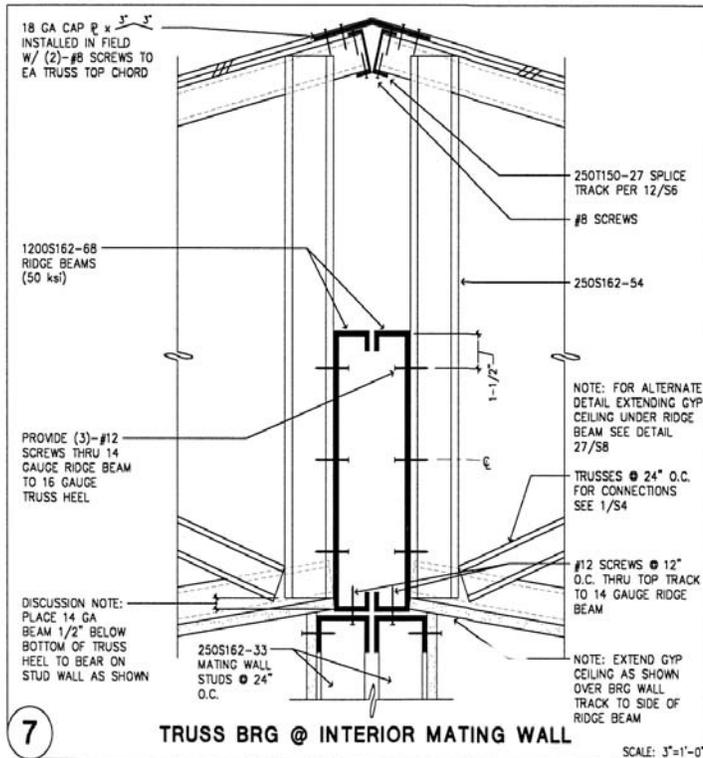


Figure B-0 Typical screw attachment

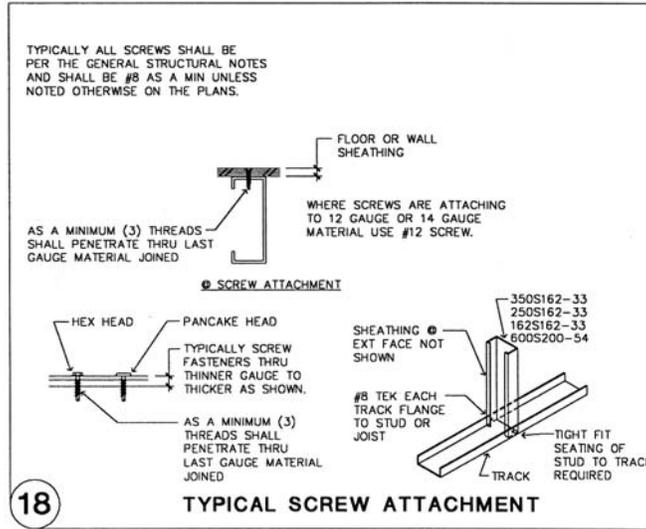


Figure B-0 Typical truss and joist to stud alignment

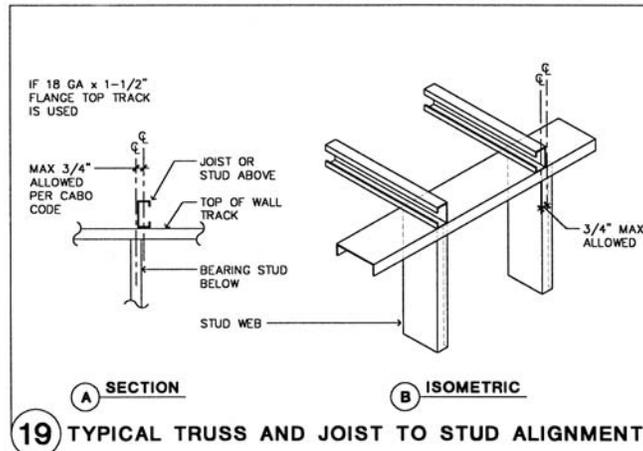


Figure B-0 Screw attached gypsum ceiling

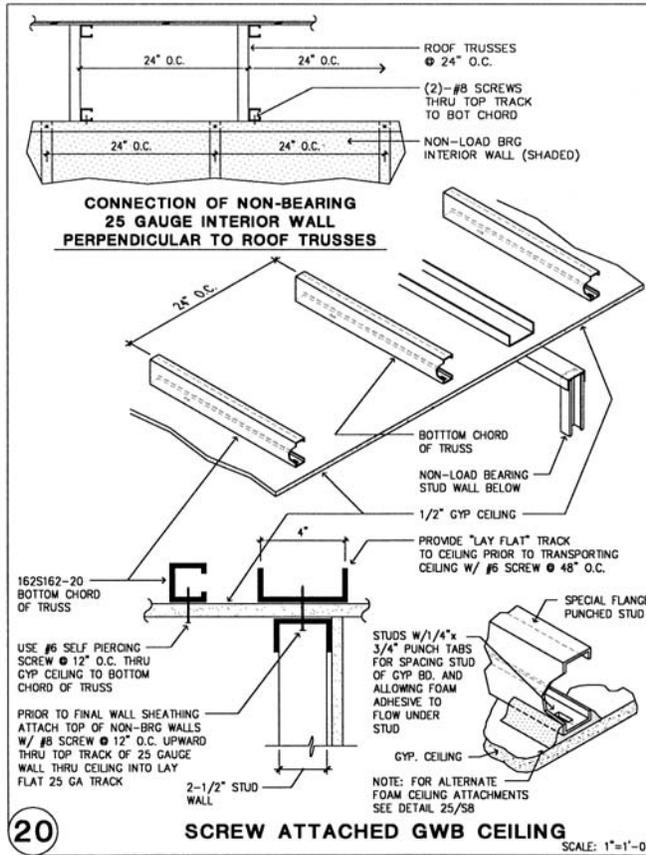


Figure B-0 Roof strap across mating line

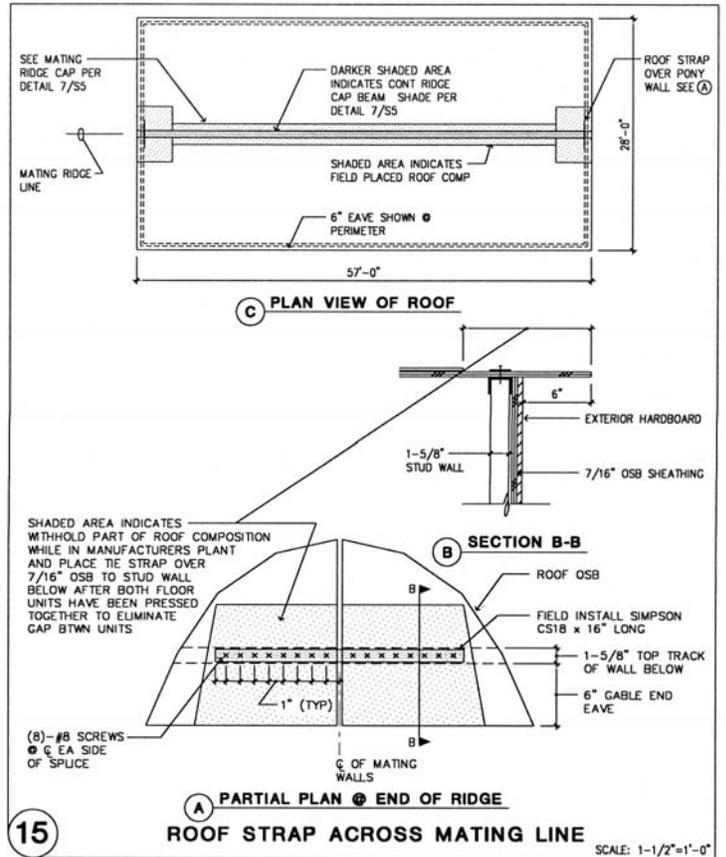


Figure B-0 Typical roof over framing

