# Structural Glued Laminated Timber Pitched and Tapered Curved Beams of Southern Pine

*Hannahville School Gymnasium, Wilson, MI.*

**AMERICAN INSTITUTE OF TIMBER CONSTRUCTION**

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# Advantages

Pitched and tapered curved beams are manufactured using a renewable, sustainable natural resource—wood. The inherent aesthetic appeal, strength and economy of wood have made glued laminated timber the preference of engineers, architects and designers for more than one-half century.

Pitched and tapered curved (PTC) glued laminated beams are the logical choice for many roof designs. PTC beams provide a traditional roof pitch, desirable clear spans and a feeling of extra spaciousness while maintaining conventional wall heights.

# Design

The optimum geometry of PTC beams is influenced by centerline deflections, bending stress at the tangent points (PT), the maximum stress in the tapered rafters, shear parallel to grain at the supports and radial tension in the curved portion.

The tangent point for the soffit curve is determined by the radius selected and the shape of the beam toward the support points. The bottom surface of the beam can be parallel to the roof pitch but the cross-section is usually tapered along the rafter length.

The radius should be selected to permit a balance between a maximum lamination thickness and the least volume of wood in the curved cross section. Short radii require thinner laminations, and thus added cost for wood and adhesive. Longer radii increase the volume of wood through the curve and the centerline depth, which may increase cost and adversely affect appearance. A curved segment that equals 1/4 the length of the span will yield a slightly different solution for the volume of wood than a design using the shortest curve length.

Begin by selecting the span, the top edge (roof) slope and the applied loads. Centerline depth is determined by choosing an end depth, bottom edge slope and a radius. Bending stresses are checked at mid span, the points of tangency of the curve and at several locations along the tapered sections.

When subjected to a bending moment, radial stresses develop in a direction parallel to the radius of curvature. Radial tension stress, a combination of shear parallel-to-grain and tension perpendicular-to-grain, is limited to 1/3 the allowable shear parallel to grain design value for Southern Pine for all load conditions.

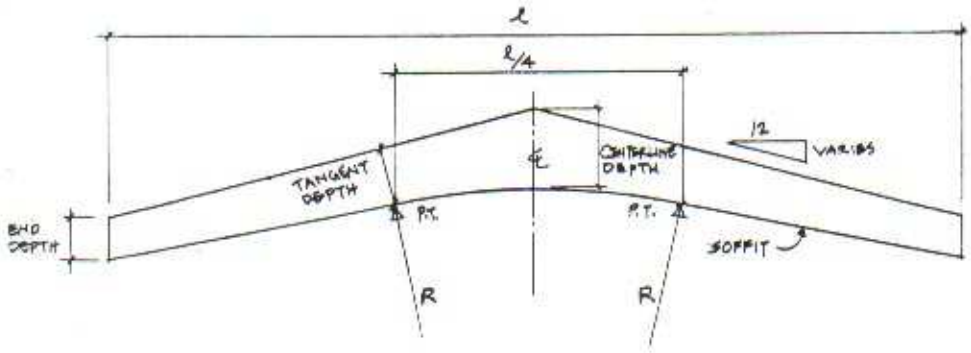
*Shelter Building, Michigan State University, East Lansing, MI.*

PITCHED & TAPERED CURVED BEAMS
(CURVE LENGTH = 1/4 SPAN)

| | | SPAN = 20 ft. | | | | | SPAN = 30 ft. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Loading plf | Roof Pitch | Width, in. | End depth (plumb) in. | CL depth, in. | Depth at Tangent in. | Radius, ft. | Width, in. | End depth (plumb) in. | CL depth, in. | Depth at Tangent in. | Radius, ft. |
| 200 | 2/12 | 3.00 | 6.0 | 14.0 | 10.0 | 24.0 | 3.00 | 10.0 | 21.0 | 16.0 | 24.0 |
| | 3/12 | 3.00 | 6.0 | 17.0 | 12.0 | 24.0 | 3.00 | 10.0 | 26.0 | 17.0 | 24.0 |
| | 4/12 | 3.00 | 6.0 | 21.0 | 13.0 | 24.0 | 3.00 | 10.0 | 31.0 | 17.0 | 24.0 |
| 400 | 2/12 | 3.00 | 8.5 | 18.0 | 14.1 | 26.5 | 3.00 | 12.5 | 26.5 | 23.1 | 23.0 |
| | | | | | | | 5.00 | 10.0 | 23.5 | 19.6 | 26.3 |
| | 3/12 | 3.00 | 8.5 | 20.0 | 12.0 | 21.8 | 5.00 | 10.0 | 25.5 | 17.5 | 21.4 |
| | 4/12 | 3.00 | 8.5 | 24.0 | 12.0 | 24.0 | 5.00 | 10.0 | 31.0 | 17.0 | 24.0 |
| 600 | 2/12 | 3.00 | 12.0 | 19.5 | 15.7 | 23.3 | 5.00 | 11.0 | 26.5 | 22.1 | 32.0 |
| | | 5.00 | 10.0 | 16.5 | 13.0 | 21.1 | 6.75 | 13.5 | 22.5 | 17.6 | 29.0 |
| | 3/12 | 3.00 | 12.0 | 24.0 | 15.0 | 24.0 | 5.00 | 11.0 | 28.5 | 20.3 | 22.5 |
| | | | | | | | 6.75 | 13.5 | 24.5 | 15.7 | 22.8 |
| | 4/12 | 3.00 | 12.0 | 29.0 | 14.0 | 24.0 | 5.00 | 11.0 | 32.5 | 18.1 | 21.7 |

*Prairie Island Community Center, Welch, MN*

# Symmetrical PTC Beams




## PITCHED & TAPERED CURVED BEAMS (CURVE LENGTH = 1/4 SPAN)

| Total Loading, psf | Roof Pitch | SPAN = 40 ft | | | | | SPAN = 50 ft | | | | | SPAN = 60 ft | | | | | SPAN = 70 ft | | | | | SPAN = 80 ft | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Width, in. | End Depth (plumb), in. | CL Depth, in. | Depth at Tangent, in. | Radius, ft. | Width, in. | End Depth (plumb), in. | CL Depth, in. | Depth at Tangent, in. | Radius, ft. | Width, in. | End Depth (plumb), in. | CL Depth, in. | Depth at Tangent, in. | Radius, ft. | Width, in. | End Depth (plumb), in. | CL Depth, in. | Depth at Tangent, in. | Radius, ft. | Width, in. | End Depth (plumb), in. | CL Depth, in. | Depth at Tangent, in. | Radius, ft. |
| TL = 400 | 2/12 | 5.00 | 10.0 | 33.0 | 28.8 | 33.3 | 5.00 | 12.5 | 41.5 | 33.0 | 68.6 | 6.75 | 13.5 | 45.5 | 39.5 | 45.1 | 6.75 | 13.5 | 55.0 | 44.1 | 90.5 | 6.75 | 15.5 | 63.0 | 51.4 | 96.2 |
| | | 6.75 | 13.5 | 27.5 | 23.9 | 22.0 | 6.75 | 13.5 | 37.0 | 29.1 | 54.4 | 8.50 | 17.0 | 40.0 | 34.6 | 34.1 | 8.50 | 17.0 | 49.5 | 38.2 | 77.8 | 8.50 | 17.0 | 58.0 | 48.0 | 73.1 |
| | 3/12 | 5.00 | 10.0 | 35.5 | 26.8 | 24.7 | 5.00 | 12.5 | 44.0 | 34.5 | 28.7 | 6.75 | 13.5 | 48.5 | 40.2 | 22.0 | 6.75 | 13.5 | 59.0 | 46.0 | 37.1 | 6.75 | 16.0 | 67.5 | 51.9 | 44.6 |
| | | 6.75 | 13.5 | 30.0 | 21.0 | 23.4 | 6.75 | 13.5 | 39.5 | 29.4 | 27.1 | 8.50 | 17.0 | 43.0 | 32.2 | 26.0 | 8.50 | 17.0 | 52.5 | 42.0 | 27.5 | 8.50 | 17.0 | 62.5 | 48.6 | 37.8 |
| | 4/12 | 5.00 | 10.0 | 39.0 | 24.8 | 21.4 | 5.00 | 12.5 | 48.0 | 32.8 | 22.5 | 6.75 | 13.5 | 53.0 | 37.7 | 22.1 | 6.75 | 13.5 | 63.5 | 47.8 | 22.5 | 6.75 | 16.0 | 72.5 | 54.5 | 25.7 |
| | | 6.75 | 13.5 | 33.5 | 18.5 | 21.8 | 6.75 | 13.5 | 43.0 | 28.1 | 21.5 | 8.50 | 17.0 | 47.0 | 30.2 | 23.9 | 8.50 | 17.0 | 57.0 | 40.7 | 22.9 | 8.50 | 17.0 | 67.5 | 49.6 | 25.2 |
| TL = 600 | 2/12 | 5.00 | 15.0 | 38.0 | 29.3 | 40.7 | 6.75 | 14.0 | 42.0 | 34.0 | 62.1 | 6.75 | 17.0 | 50.0 | 42.9 | 54.2 | 6.75 | 20.0 | 58.5 | 49.7 | 67.7 | 8.50 | 19.0 | 65.0 | 52.4 | 100.7 |
| | | 6.75 | 13.5 | 32.0 | 28.2 | 25.8 | 8.50 | 17.0 | 37.0 | 30.5 | 41.8 | 8.50 | 17.0 | 46.5 | 39.7 | 48.1 | 8.50 | 17.0 | 56.5 | 45.5 | 86.6 | 10.50 | 21.0 | 60.0 | 47.5 | 88.2 |
| | 3/12 | 5.00 | 15.0 | 38.0 | 26.0 | 32.9 | 6.75 | 14.0 | 44.5 | 35.4 | 25.2 | 6.75 | 17.0 | 53.0 | 44.0 | 24.3 | 6.75 | 20.0 | 62.5 | 48.6 | 38.5 | 8.50 | 19.0 | 69.5 | 55.0 | 40.6 |
| | | 6.75 | 13.5 | 34.5 | 25.6 | 23.7 | 8.50 | 17.0 | 39.5 | 29.1 | 27.0 | 8.50 | 17.0 | 49.5 | 39.6 | 26.2 | 8.50 | 17.0 | 60.5 | 46.1 | 40.4 | 10.50 | 21.0 | 64.0 | 49.9 | 37.8 |
| | 4/12 | 5.00 | 15.0 | 41.5 | 26.8 | 21.5 | 6.75 | 14.0 | 48.5 | 32.9 | 22.9 | 6.75 | 17.0 | 57.5 | 41.1 | 23.6 | 6.75 | 20.0 | 66.5 | 50.6 | 22.2 | 8.50 | 19.0 | 74.5 | 55.8 | 26.6 |
| | | 6.75 | 13.5 | 36.0 | 23.3 | 21.4 | 8.50 | 17.0 | 43.0 | 27.5 | 22.1 | 8.50 | 17.0 | 53.5 | 38.2 | 21.7 | 8.50 | 17.0 | 64.5 | 49.0 | 21.6 | 10.50 | 21.0 | 66.5 | 51.0 | 24.1 |
| TL = 800 | 2/12 | 5.00 | 19.5 | 36.0 | 31.4 | 29.0 | 6.75 | 18.5 | 43.5 | 36.7 | 48.4 | 6.75 | 22.0 | 52.5 | 44.0 | 61.4 | 6.75 | 26.0 | 61.0 | 52.5 | 60.6 | 8.50 | 24.5 | 68.0 | 56.1 | 90.3 |
| | | 6.75 | 14.5 | 35.0 | 29.9 | 36.6 | 8.50 | 17.0 | 41.0 | 35.1 | 41.2 | 8.50 | 18.0 | 51.0 | 41.5 | 72.7 | 8.50 | 21.5 | 59.5 | 47.4 | 91.5 | 10.50 | 21.0 | 65.5 | 55.3 | 79.0 |
| | 3/12 | 5.00 | 19.5 | 42.0 | 26.5 | 36.4 | 6.75 | 18.5 | 47.0 | 33.3 | 37.6 | 6.75 | 22.0 | 56.5 | 41.1 | 42.2 | 6.75 | 26.0 | 66.5 | 49.3 | 47.0 | 8.50 | 25.0 | 71.5 | 58.9 | 33.7 |
| | | 6.75 | 14.5 | 38.0 | 26.5 | 31.9 | 8.50 | 17.0 | 43.5 | 34.3 | 24.4 | 8.50 | 18.0 | 53.5 | 44.8 | 23.1 | 8.50 | 21.5 | 63.0 | 49.6 | 36.7 | 10.50 | 21.0 | 70.0 | 55.9 | 38.9 |
| | 4/12 | 5.00 | 19.5 | 48.0 | 28.0 | 29.7 | 6.75 | 18.5 | 50.0 | 34.1 | 22.8 | 6.75 | 22.0 | 59.5 | 42.4 | 24.3 | 6.75 | 26.0 | 68.5 | 52.3 | 22.1 | 8.50 | 25.0 | 76.5 | 57.6 | 26.2 |
| | | 6.75 | 14.5 | 41.5 | 25.6 | 23.5 | 8.50 | 17.0 | 47.5 | 31.5 | 23.1 | 8.50 | 18.0 | 56.0 | 42.4 | 22.2 | 8.50 | 21.5 | 67.0 | 50.7 | 22.6 | 10.50 | 21.0 | 75.0 | 56.5 | 26.0 |
| TL = 1000 | 2/12 | 5.00 | 23.5 | 40.0 | 33.5 | 41.6 | 6.75 | 22.5 | 45.0 | 37.8 | 47.8 | 6.75 | 27.5 | 53.5 | 47.5 | 36.6 | 6.75 | 32.0 | 64.0 | 56.3 | 51.6 | 8.50 | 30.5 | 69.5 | 61.2 | 57.4 |
| | | 6.75 | 18.0 | 36.0 | 30.5 | 36.7 | 8.50 | 18.5 | 43.5 | 37.0 | 45.9 | 8.50 | 22.5 | 52.0 | 45.6 | 44.9 | 8.50 | 26.5 | 61.0 | 51.8 | 84.8 | 10.50 | 25.5 | 68.0 | 57.0 | 82.1 |
| | 3/12 | 5.00 | 26.0 | 45.5 | 31.6 | 36.0 | 6.75 | 22.5 | 51.0 | 35.9 | 41.0 | 6.75 | 27.5 | 62.0 | 43.8 | 49.4 | 6.75 | 32.0 | 73.0 | 52.8 | 55.1 | 8.50 | 30.5 | 77.0 | 56.9 | 54.9 |
| | | 6.75 | 18.0 | 40.5 | 28.0 | 33.9 | 8.50 | 18.5 | 47.0 | 33.7 | 36.4 | 8.50 | 22.5 | 56.5 | 40.9 | 42.6 | 8.50 | 26.5 | 66.5 | 48.9 | 47.9 | 10.50 | 25.5 | 72.0 | 57.6 | 38.8 |
| | 4/12 | 5.00 | 29.5 | 50.0 | 35.6 | 24.0 | 6.75 | 22.5 | 54.5 | 39.4 | 21.2 | 6.75 | 27.5 | 64.0 | 46.7 | 24.1 | 6.75 | 32.0 | 75.5 | 55.6 | 27.7 | 8.50 | 30.5 | 78.0 | 60.1 | 24.1 |
| | | 6.75 | 18.0 | 48.0 | 31.6 | 21.0 | 8.50 | 18.5 | 50.0 | 34.1 | 22.8 | 8.50 | 22.5 | 59.0 | 42.7 | 22.9 | 8.50 | 26.5 | 68.5 | 51.2 | 23.8 | 10.50 | 25.5 | 76.5 | 58.5 | 24.6 |

These tables contain selected spans, roof pitches and loadings. They provide configurations and dimensions for PTC beams that are symmetrical about the centerline.

$F_b$ = 2400 psi  $F_{tt}$ = 67 psi
$F_v$ = 200 psi  E = 1,700,000 psi
$C_D$=1.15 (load duration factor for snow loads)
Lamination thickness = 1-3/8 in.
Minimum radius 21 ft.
Deflection limit = (ℓ/180) for Total Load
Total load includes the weight of the beam.

Length of curve = 1/4 span length.
Span (ℓ) = distance from centerline to centerline of bearings.

Beam width and depth is in inches (in.). Radius is in feet (ft.)
Depth/Width ratio is approximately 9 to 1 at centerline and 6 to 1 at tangent points.

When horizontal cuts are used to provide end bearings, the end depth is measured from the inside of the cut and perpendicular to the roof pitch.

A roof pitch of 5 in 12 is not shown, but may be considered for all but the longer spans where shipping height can be a controlling factor.

An 18 ft. radius is frequently a minimum for PTC beams, with little change in dimensions from a 21 ft. radius. Shorter radii are possible when nominal 1-inch laminations are used.

Optional outlookers or overhangs can be provided by additional beam length beyond the supports. Do not cut across laminations on the bottom surface of the beam in the span between the supports.

Pitched and tapered curved beams must have proper continuous lateral support along the compression side, and be held in line at the end bearing supports.

Permissible horizontal deflection depends on end support conditions and possible beam contact with adjacent framing members or systems.

*Luther Manor, Marinette, WI*

*West Virginia University Natatorium, Morgantown, WV.*

This data is subject to specific design requirements of local building codes or special conditions, and is for preliminary design only. The designs are based on the most accurate and reliable technical data available. They should not be used or relied upon for any general or specific application without competent professional review as to accuracy, suitability or applicability by a licensed professional engineer, designer or architect.

The AITC *Timber Construction Manual*, Fourth Edition 1994, and AITC 104, *Typical Construction Details*, should be referenced for additional information.

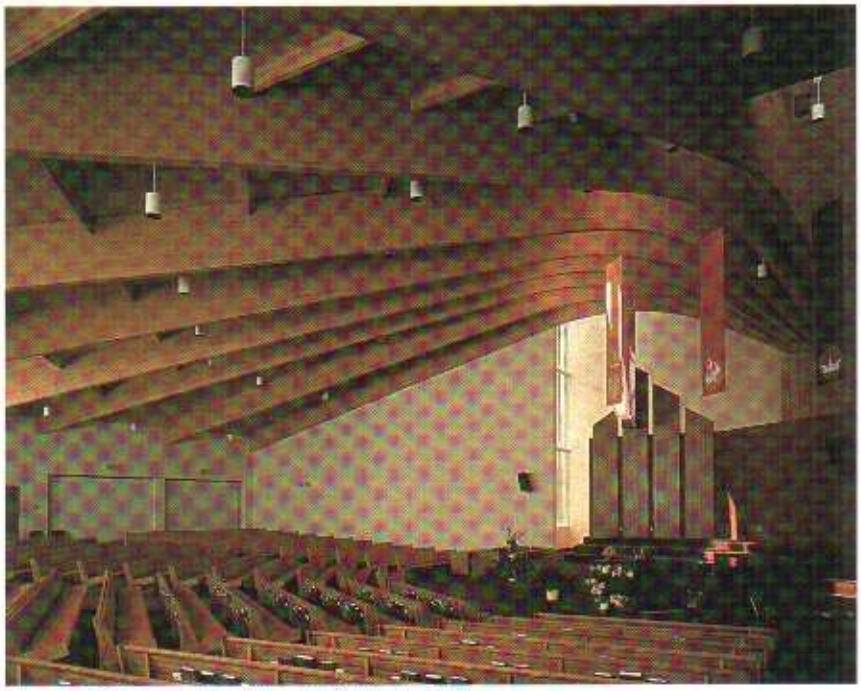
*William Tell Inn Banquet Room, Countryside, LaGrange, IL.*

# Unsymmetrical PTC Beams

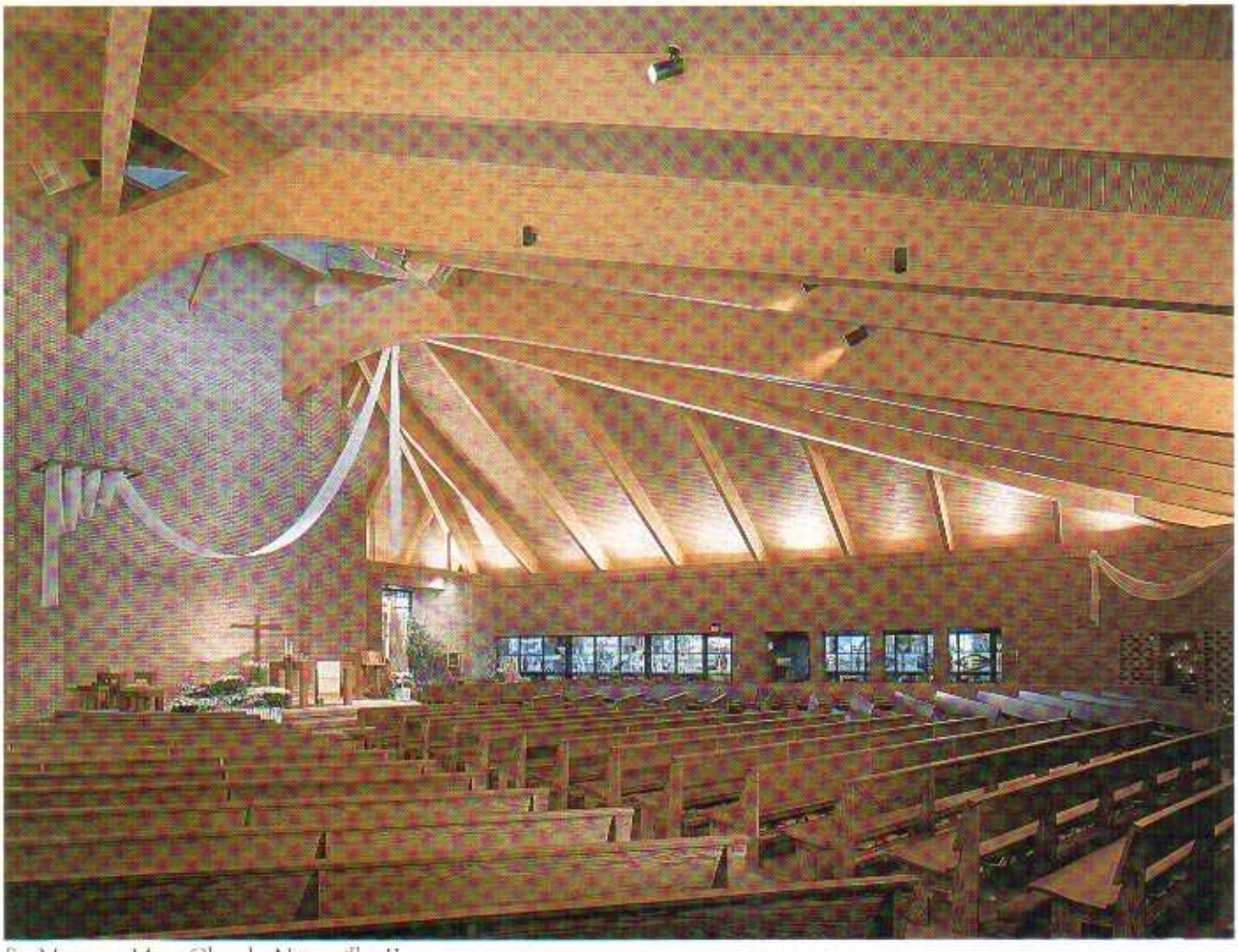
Pitched and tapered curved beams unsymmetrical about the centerline may be the proper solution for roof framing systems with different roof pitches on opposite sides of the centerline, half spans of unequal lengths and opposite end supports at different elevations. Unsymmetrical PTC beams are the ideal choice for the roof framing over a fan-shaped seating arrangement in a church building. Unequal loadings must be considered for beams with different spacing on opposite half spans.

The effect of unequal halfspans, different roof pitches and opposite end supports at different elevations must be considered in the selection of radii that meet radial tension design requirements.

PTC beams, parallel to one another and unsymmetrical about the centerline, may be the framing selection when using a clerestory or other accent point in relation to the floor plan beneath the beams.



*New Life Community Church, Oshkosh, WI.*



*St. Margaret Mary Church, Naperville, IL.*