165 ft ROUND PRE-ENGINEERED BUILDING

STRUCTURAL DESIGN SPECIFICATION — ANSI/AISC 360-22

Client / Owner: Fusion Developers

Project: 165 ft Diameter Round PEB (Conical Roof)

Governing Code: ANSI/AISC 360-22, *Specification for Structural Steel Buildings* (15th Ed. AISC Steel Construction Manual)

Fabrication Standard: AISC 303-22, *Code of Standard Practice for Steel Buildings and Bridges*

Design Method: LRFD (Load and Resistance Factor Design)

Status: PRELIMINARY — FOR REVIEW ONLY

Document No.: FD-165RPEB-STR-SPEC-001 · Rev 0

1. DESIGN BASIS

Item	Value / Reference
Specification	ANSI/AISC 360-22 (2022)
Manual	AISC Steel Construction Manual, 15th Edition
Method	LRFD
ϕ — Flexure	0.90 (AISC 360-22 §F1)
ϕ — Axial Compression	0.90 (§E1)
ϕ — Shear	0.75 (§G1, for I-shapes not meeting §G2.1(a))
ϕ — Tension Rupture / Bolts	0.75 (§D2, §J3)
Modulus of Elasticity, E	200,000 MPa (29,000 ksi)
Shear Modulus, G	77,200 MPa
Steel — ACTIVE scheme	ASTM A36/A36M: Fy = 250 MPa, Fu = 400 MPa
Steel — Comparison scheme	ASTM A572 Gr.50: Fy = 345 MPa, Fu = 450 MPa
Purlin steel	Galvanized cold-formed, Fy = 345 MPa (AISI S100 governs purlin design)
Bolts	ASTM F3125 Gr. A325 (structural); ASTM F1554 Gr.105 (anchor rods)
Welds	AWS D1.1, E70XX electrodes (Fexx = 480 MPa)

Note on code vintage: *Results per AISC 360-22 fall within ~1–2 % of the earlier AISC 360-16 screen for all members checked. The* ***governing member is unchanged*** *(long rafter in flexure). Chapter and equation references below are to the 2022 edition.*

2. CONFIRMED GEOMETRY

Parameter	Value
Building diameter	165 ft (50.292 m)
Radius, R	82.5 ft (25.146 m)
Eave height	18 ft (5.486 m)
Apex height	26.25 ft (8.001 m)
Roof slope	1:10 conical (5.71°)
Perimeter columns	20 nos., equally spaced (18°), h = 18 ft
Internal columns	4 nos. @ r = 41.25 ft (half radius), 90° apart, h = 22.125 ft (6.748 m)
Long rafters	20 nos., eave → internal column ring, L = 41.46 ft (12.637 m)
Short rafters	4 nos., internal column → apex ring, L = 37.48 ft (11.424 m)
Apex ring	8 ft dia. circular ring, CHS 406.4 × 12.5
Inner ring beam	**NONE** — no square inner ring beam in this scheme
Purlins	Z 200 × 75 × 1.6 GI @ 1.5 m c/c — 199 purlin lines

3. SECTION PROPERTIES

Property	ISMB 600	ISMB 450	CHS 406.4×12.5
Usage	Columns + A36 rafters	A572 rafters (alt.)	Apex ring
Depth, d (mm)	600	450	406.4 (OD)
Flange width, bf (mm)	210	170	—
Web thickness, tw (mm)	11.8	9.5	12.5 (wall)
Flange thickness, tf (mm)	23.6	17.4	—
Clear web depth, h (mm)	552.8	415.2	—
Gross area, Ag (mm²)	18,750	13,100	15,460
Plastic modulus, Zx (cm³)	2,820	1,690	1,572 (approx.)
rx (mm)	245	185	139.4
ry (mm)	60	30.1	139.4
Mass (kg/m)	133	85.4	122

4. SIXTEEN-PARAMETER DESIGN SCHEDULE (A36 — ACTIVE SCHEME)

#	Parameter	A36 Value	AISC 360-22 Reference	Limit / Result
1	**Member depth, d**	ISMB 600 = 600 mm (cols + rafters); ISMB 450 = 450 mm (alt.); CHS OD = 406.4 mm	§B4.1, Table B4.1a/b	Depth adequate for span/depth ≈ L/21 (12.637 m / 0.6 m) — acceptable for PEB rafters
2	**Flange width, bf**	ISMB 600 = 210 mm; ISMB 450 = 170 mm	Table B4.1b Case 10	b/t = bf/2tf = 4.45 ≤ λp = 10.75 → **COMPACT FLANGE**
3	**Clear web depth, h**	ISMB 600 = 552.8 mm; ISMB 450 = 415.2 mm	Table B4.1a Case 5 / B4.1b Case 15	h/tw = 46.8 — see items 12 below

#	Parameter	A36 Value	AISC 360-22 Reference	Limit / Result
4	**Unsupported length, Lu**	Rafters Lb = 1.5 m (purlin spacing); Perimeter columns Ly = 5.486 m; Internal columns Ly = 6.748 m; Apex ring = continuously curved/braced	§F2.2, §E3	Rafter Lb = 1.5 m < Lp = 2.99 m → plastic range (no LTB). Columns KL/ry = 91.4 / 112.5 ≤ 200 ✔
5	**Purlin spacing**	1.5 m c/c, Z 200×75×1.6 GI, 199 lines	§F1 User Note / AISI S100	Provides discrete top-flange bracing to rafters at 1.5 m — governs Lb (item 4)
6	**Bracing system**	Perimeter X-bracing in wall bays (wind/stability); sag rods at each purlin line; rafter top-flange lateral restraint at every purlin; rigid roof diaphragm (screwed sheeting) + apex compression ring	App. 6 §6.2 (Point bracing), §6.3	Required brace strength Pbr = 0.02·Mr·Cd/ho; stiffness βbr = 10Mr·Cd/(Lb·ho·ϕ). Satisfied by purlin + sag-rod system
7	**Steel yield strength, Fy**	A36: Fy = 250 MPa, Fu = 400 MPa (**ACTIVE**)	§A3.1, Table 2-4 (Manual)	A572 Gr.50 (Fy = 345, Fu = 450) evaluated as comparison — see §8
8	**Axial compression, Pu**	Perimeter col Pu = 307 kN; Internal col Pu = 384 kN	Ch. E, Eq. E3-1/E3-2/E3-3; E7 for slender web	Perimeter: KL/ry = 91.4, Fe = 236 MPa, Fcr ≈ 152 MPa, ϕPn ≈ 2,570 kN → **util 11.9 % PASS**. Internal: KL/ry = 112.5, Fe = 156 MPa, Fcr ≈ 121 MPa, ϕPn ≈ 2,040 kN → **util 18.8 % PASS**
9	**Bending moment, Mu**	Long rafter Mu = 473 kN·m (w = 23.7 kN/m); Short rafter Mu = 386 kN·m	Ch. F, §F2.1, Eq. F2-1 (Mn = Mp = Fy·Zx)	ϕMn = 0.90 × 250 × 2,820×10^3 = **634.5 kN·m**. Long rafter util = **74.5 % — GOVERNS (PASS)**. Short rafter util = 60.8 % PASS
10	**Shear, Vu**	Long rafter Vu = 150 kN; Short rafter Vu = 135 kN	Ch. G, §G2.1, Eq. G2-1 (Vn = 0.6·Fy·Aw·Cv1)	Aw = d·tw = 600 × 11.8 = 7,080 mm² (conservatively taken as 450×11.8 = 5,310 mm² for the effective panel) → ϕVn = 0.75 × 0.6 × 250 × 5,310 = **597 kN**. Util = **25.1 % PASS**
11	**Wind uplift**	qz ≈ 26 psf (1.27 kPa); roof suction Cp = –0.9 → uplift ≈ 23 psf (1.10 kPa)	ASCE 7-22 Ch. 27/28 (loads); AISC 360-22 §D2, §J3 (resistance)	Net DL+LL = 63 psf downward > 23 psf uplift → **net load remains DOWNWARD (~40 psf)**. Uplift therefore does **NOT** govern member gravity design; it **GOVERNS ANCHOR-ROD TENSION and connection design** (item 14)
12	**Local buckling**	Flange λ = bf/2tf = 210/47.2 = **4.45**; Web λ = h/tw = 552.8/11.8 = **46.8**	§B4.1, Table B4.1a (compression) & B4.1b (flexure)	**Flexure:** λp,f = 0.38√(E/Fy) = 10.75 → flange COMPACT; λp,w = 3.76√(E/Fy) = 106.3 → web COMPACT. **Section is COMPACT in flexure — full Mp available. Pure compression:** λr,w = 1.49√(E/Fy) = 42.1 < 46.8 → web is **SLENDER (non-compact) in uniform compression** → §E7 effective-area reduction applies; reduction is minor (Ae/Ag ≈ 0.97) and columns run at only 12–19 % utilization → **PASS with margin**
13	**Lateral-torsional buckling (LTB)**	Lb = 1.5 m; Lp = 1.76·ry·√(E/Fy) = 1.76 × 60 × 28.28 = **2,987 mm** ≈ **2.99 m**	§F2.2, Eq. F2-5 (Lp); Eq. F2-2/F2-3	**Lb (1.5 m) < Lp (2.99 m) → NO LTB. Yielding limit state controls; full plastic modulus Zx is usable (Mn = Mp).** This is a key design requirement: **purlin spacing must not exceed 2.99 m anywhere.** 1.5 m provides a 2× margin
14	**Connection forces**	Eave gusset: Vu = 150 kN shear + horizontal thrust; anchor rods: uplift tension per perimeter column ≈ (23 psf × trib. 213 ft²) ≈ 4,900 lbf ≈ **21.8 kN** gross uplift, offset by 0.9·DL → net anchor tension small but rods sized for min. 4 × M25 F1554 Gr.105	Ch. J: §J3.6 (bolt shear/tension), §J3.7 (combined), §J4 (affected elements), §J10 (web local); §D5 (pin/anchor)	M25 A325-N: ϕRn,shear = 0.75 × 0.450 × 491 = 166 kN/bolt (single shear). 4-bolt eave group: ϕRn = 663 kN ■ 150 kN ✔. M25 F1554 Gr.105: ϕRn,tension = 0.75 × 0.75 × 725 × 491 = 200 kN/rod ■ demand ✔. **FLAG: full connection design (gusset plate, base plate bending, weld sizing, prying, concrete breakout per ACI 318 Ch.17) to be completed in the detailed design phase.**
15	**Fabrication tolerances**	Member straightness ≤ L/1000, max 6 mm; camber ±L/1000; bolt hole dia = d + 1.5 mm (+1.5/–0); fit-up gap ≤ 3 mm; splice mismatch ≤ t/4; column plumb ≤ H/500; base plate elevation ±3 mm	AISC 303-22 *Code of Standard Practice*, §6 (Fabrication) & §7 (Erection); AISC 360-22 §M2, §M4	Compliance mandatory; mill tolerances per ASTM A6/A6M. Erection out-of-plumb limit 1:500

#	Parameter	A36 Value	AISC 360-22 Reference	Limit / Result
16	**Corrosion allowance**	**No sacrificial steel thickness added.** Protection by coating system: main frame — abrasive blast SSPC-SP6/SP10 + zinc-rich epoxy primer + polyurethane topcoat, **DFT 75–125 µm** (SSPC-PA 2 / IS 12744); **OR** hot-dip galvanized to **ASTM A123** / IS 4759 Pt.3, min **85** µ**m** for steel > 6 mm. Purlins/girts: pre-galvanized Z-section (Z275 coating)	§A3.1; §M3 (Shop Painting); AISC 303-22 §6.5	Typical Pakistan practice: painted main frame + galvanized secondaries. Galvanizing recommended for the apex ring and all roof-level members due to access difficulty. Anchor rods hot-dip galvanized

5. DEMAND / CAPACITY SUMMARY (A36, LRFD)

Member	Section	Action	Demand	ϕ·Capacity	Utilization	Result
Perimeter column	ISMB 600	Axial (Ch. E)	Pu = 307 kN	ϕPn ≈ 2,570 kN	11.9 %	PASS
Internal column	ISMB 600	Axial (Ch. E)	Pu = 384 kN	ϕPn ≈ 2,040 kN	18.8 %	PASS
Long rafter	**ISMB 600**	**Flexure (Ch. F)**	**Mu = 473 kN·m**	ϕ**Mn = 634.5 kN·m**	**74.5 %**	**PASS — GOVERNS**
Long rafter	ISMB 600	Shear (Ch. G)	Vu = 150 kN	ϕVn = 597 kN	25.1 %	PASS
Short rafter	ISMB 600	Flexure (Ch. F)	Mu = 386 kN·m	ϕMn = 634.5 kN·m	60.8 %	PASS
Short rafter	ISMB 600	Shear (Ch. G)	Vu = 135 kN	ϕVn = 597 kN	22.6 %	PASS
Apex ring	CHS 406.4×12.5	Hoop compression	≈ 1,500 kN (distributed thrust)	ϕPn ≈ 3,100 kN (short, braced)	≈ 48 %	PASS — **FLAGGED** for 3D verification

PEAK A36 UTILIZATION = 74.5 % — Long rafter, ISMB 600, flexure (AISC 360-22 §F2.1).

Combined axial + flexure interaction (§H1.1, Eq. H1-1a/H1-1b) for columns: $P_r/P_c = 0.19 < 0.2 \rightarrow$ Eq. H1-1b applies; $P_r/(2P_c) + M_r/M_c \approx 0.09 + 0.30 = 0.39 < 1.0$ ✔.

6. WIND UPLIFT — ASSUMPTIONS & CONCLUSION

Assumptions (state explicitly, PRELIMINARY):

- Basic wind speed V = 110 mph (3-s gust), Risk Category II
- Exposure Category C; $K_z \approx 1.0$ at 18 ft eave; $K_{zt} = 1.0$ (flat terrain); $K_d = 0.85$; $K_e = 1.0$
- $q_z = 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot K_e \cdot V^2 = 0.00256 \times 1.0 \times 1.0 \times 0.85 \times 110^2 \approx$ **26 psf (1.27 kPa)**
- Conical/dome roof external pressure coefficient $C_p \approx$ –**0.9** (suction), $GC_{pi} = \pm 0.18$
- Net uplift ≈ 0.9 × 26 ≈ **23 psf (1.10 kPa)**

Conclusion: Gravity DL + LL = **63 psf** downward. Under 0.9D + 1.0W the net roof pressure remains **downward at approximately 40 psf**. Therefore wind uplift **does not reverse rafter moments** and does not govern member sizing. It **does govern**:

- Anchor-rod tension and base-plate design at perimeter columns
- Purlin-to-rafter clip fastener pull-out
- Sheeting-to-purlin screw pull-over (edge/corner zones with higher local GCp)
- Perimeter X-bracing lateral load path

Zone-specific higher local coefficients (edge/corner, GCp up to –1.8) must be applied to cladding and fasteners in detailed design.

7. LOCAL BUCKLING & LTB — DESIGN NOTES

7.1 Local buckling (§B4.1)

- λp(flange, flexure) = 0.38√(200000/250) = **10.75**; actual = 4.45 → **compact**
- λp(web, flexure) = 3.76√(200000/250) = **106.3**; actual = 46.8 → **compact**
- ⇒ ISMB 600 is a **compact section in flexure**; Mn = Mp = Fy·Zx with no reduction (§F2.1).
- λr(web, uniform compression) = 1.49√(200000/250) = **42.1**; actual = 46.8 → **slender element in pure compression**. §E7 requires an effective-area reduction; Ae/Ag ≈ 0.97. Column utilizations (12–19 %) absorb this with large margin.

7.2 Lateral-torsional buckling (§F2.2)

- Lp = 1.76 · ry · √(E/Fy) = 1.76 × 60 × √(200000/250) = **2,987 mm (2.99 m)**
- Provided Lb = **1.5 m** (purlin spacing) < Lp ⇒ **limit state of LTB does not apply**; yielding governs.
- **DESIGN MANDATE:** purlin spacing shall not exceed 2.99 m at any location, including at rafter ends, splices, and near the apex ring. Missing or omitted purlin lines during erection invalidate this check.
- Cb may conservatively be taken as 1.0; no benefit claimed.

8. A36 vs A572 Gr.50 — COMPARISON NOTE

Scheme	Rafter Section	ϕMn	Peak Util	Mass/rafter (long)	Remark
A36 (ACTIVE)	ISMB 600	634.5 kN·m	74.5 %	133 kg/m × 12.637 = 1,681 kg	Heavier section, widely available locally, lower unit rate
A572 Gr.50 (alt.)	ISMB 450	0.9 × 345 × 1,690×10³ = **524.8 kN·m**	473/524.8 = **90.1 %**	85.4 kg/m × 12.637 = 1,079 kg	~36 % lighter, but 90 % utilization leaves little reserve; also Lp = 1.76 × 30.1 × 24.08 = 1.276 m **< Lb = 1.5 m** ⇒ **LTB APPLIES**, reducing ϕMn below 524.8 kN·m → **would require purlins at ≤1.25 m c/c**. **NOT RECOMMENDED without re-spacing purlins.**

Recommendation: Retain **A36 / ISMB 600** as the active scheme. It is compact, LTB-free at 1.5 m purlin spacing, and carries a healthy 25 % reserve.

9. PRELIMINARY CAVEAT

This document is a **PRELIMINARY design specification**. The following remain outstanding and may alter member sizes:

• **Full 3D finite-element analysis** of the radial frame + apex compression ring (ring hoop force of ~1,500 kN is a hand-estimate from roof thrust and must be verified; ring buckling and radial deflection compatibility not yet checked).

• **Wind load interaction / directional analysis** per ASCE 7-22 including torsional load cases, internal pressure, and zone-specific GCp for a circular plan — circular buildings are not explicitly covered by standard rectangular-building coefficients; **wind-tunnel data or CFD is recommended**.

• **Complete connection design** — eave gusset, rafter-to-internal-column moment/pin joint, apex ring splices, base plates, anchor-rod concrete breakout (ACI 318-19 Ch. 17).

• **Seismic design** per ASCE 7-22 / AISC 341 if the site seismic demand exceeds the wind case.

• **Serviceability** — rafter deflection limits (L/240 live, L/180 total) and ponding check (§ Appendix 2) not yet reported.

• **Foundation design** — not in scope of this specification.

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Specification: ANSI/AISC 360-22 · AISC 303-22 · ASCE 7-22 (loads)

Revision: 0 — PRELIMINARY