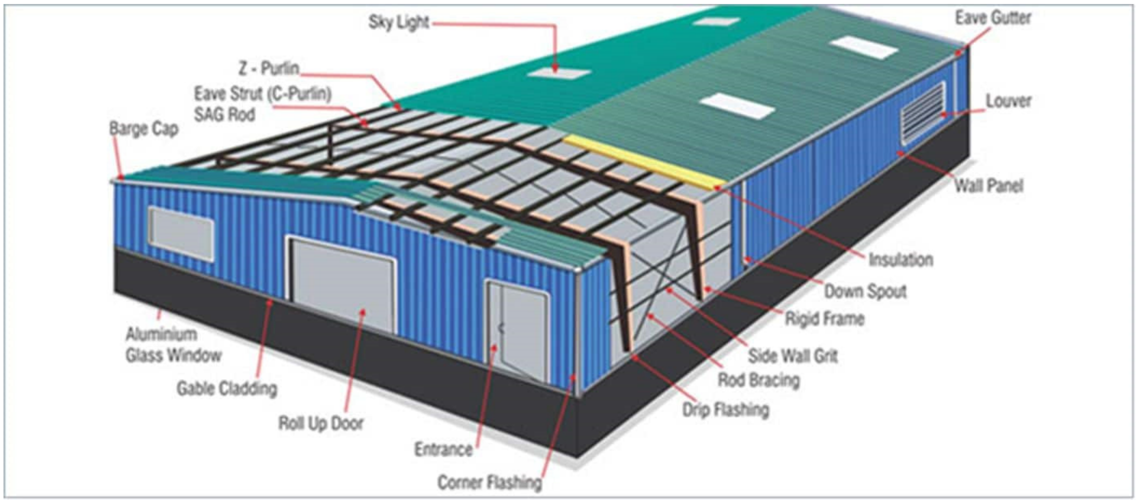
DESIGN OF PRE-ENGINEERED BUILDING

CE 332 Group Project



Course Instructor

Prof. Siddhartha Ghosh

Indian Institute of Technology Bombay

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By Group 2

Aditi Gupta	Aman Jain	Ankita
Arnaov Jamini	Chetan Kumar	Gaurvansh Yadav
Harshvardhan Siddharth	Kapil Singh	Md. Anish
Kushal Choudhary	Vaibhav Besekar	Yashwanth Gaddipati
Vandana Chandu	Dipender Mina	

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Introduction

Pre-Engineered Buildings (PEB) are the buildings which are engineered at a factory and assembled at site. Usually, PEBs are steel structures. Built-up sections are fabricated at the factory to exact size, transported to site and assembled at site with bolted connections. This type of Structural Concept is generally used to build Industrial Buildings, Metro Stations, Warehouses etc.

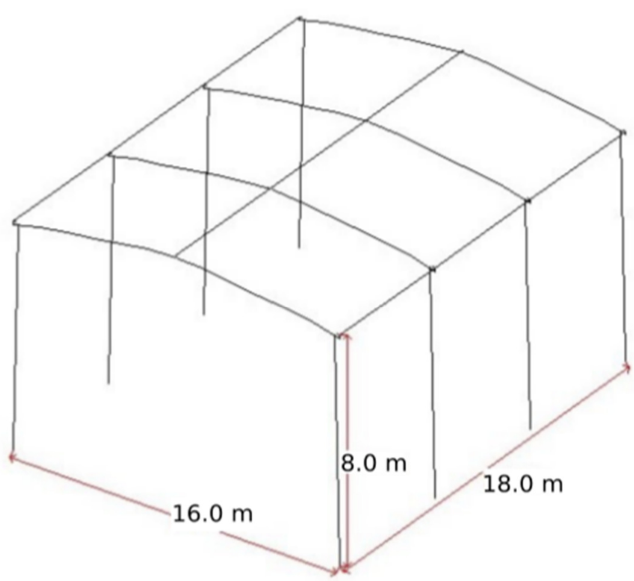
A pre-engineered building is a system utilizing three distinct product categories:

- Built-up “I” to shape primary structural framing members (columns and rafters)
- Cold-formed “Z” and “C” to shape secondary structural members (roof purlins, wall girts, and eave struts)
- Roll-formed sheeting profiles (roof and wall cladding).

The adoptability of PEB in the place of Conventional Steel Building design concept resulted in many advantages, including economy & easier fabrication. This type of building structure can be finished internally to serve any functions that is actually helpful in low rise building design.

General Arrangement

- The plan dimension of the PEB: 16m (width) X 18m (length)
- Eaves height of the structure: 8m
- Slope of roof: 1 in 7.5
- Support at base: Hinged
- Longitudinal Bracing between frames along one span
- Side sheeting along the length (18 m span) and roof should be considered c during loading



Load Summary

Dead Load

Weight of Roof and Side Sheeting

$$Mass\ per\ unit\ area = 4kg/m^2$$

$$Area = Area\ of\ roof + Area\ of\ side\ sheeting$$

$$Area = 2 \times 18 \times \sqrt{7.5^2 + 1^2} \times \frac{8}{7.5} + 2 \times 18 \times 8 = 578.54\ m^2$$

$$Mass = Mass\ per\ unit\ area \times Area = 2314.19\ kg$$

Weight of Structural Members

Material Properties

- Material Used: E 250 (Fe 410W) A
- Density: 7550 kN/m^3 (weight), 7700 kg/m^3 (mass)
- Ultimate tensile stress (min): 410 MPa

Live Load

Roof Live Load

Code: IS 875 Part-II

$$Uniformly\ Distributed\ Imposed\ Load\ on\ Plan\ Area = 0.75\ kN/m^2$$

$$Plan\ Area = 16 \times 18 = 288\ m^2$$

$$Load = UDL \times Area = 216\ kN$$

Wind Load

Site Conditions

- Site is at location in industrial areas.
- The topography of the site is such that the upwind slope is less than 3 deg.
- Site is at non cyclonic region in Mumbai.

Code: IS 875 Part-III

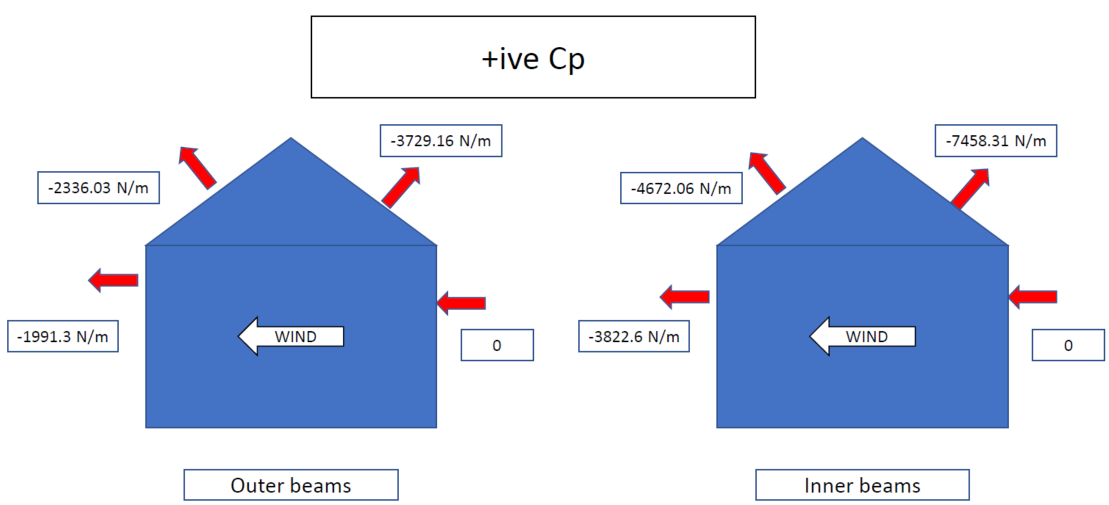
Parameters

- k_1 = 1 (Probability coefficient for general buildings and structure)
- k_2 = 0.8 (terrain roughness and height factor for terrain category 4)
- k_3 = 1 (Topography factor for upwind slope is less than 3°)
- k_4 = 1.15 (Importance factor for cyclonic region for industrial areas)
- V_b = 44 m/s (Basic wind speed for Mumbai region)
- V_z = 40.48 m/s (Design wind speed (Vz=Vb*k1*k2*k3*k4))
- p_z = 983.18 N/m^2 (Wind pressure at any height above the mean ground ($p_z = 0.6*V_z^2$))
- k_d = 0.9 (Wind Directionality factor for prismatic buildings)
- k_a = 0.8 (Area averaging factor for tributary area greater than 100 m^2)

- k_c = 1 (Combination factor - given)
- $p_d = p_z{*}k_d{*}k_a{*}k_c$ = 707.89 N/m^2
- Wind Direction to be considered - 0° and 180°
- C_{pe} for wall (External Pressure Coefficient of walls)
    - Windward = 0.7
    - Leeward = -0.2
- C_{pe} for roof (External Pressure Coefficient of roof)
    - Windward = -1.056
    - Leeward = -0.4
- C_{pi} = ±0.7 (Internal Pressure Coefficient)

Results

- For Positive C_{pi}
    - UDL acting on the walls
        - Windward = 0
        - Leeward = -637.10 N/m^2
    - UDL acting on the roof
        - Windward = -1243.05 N/m^2
        - Leeward = -778.68 N/m^2
- For Negative C_{pi}
    - UDL acting on the walls
        - Windward = 991.04 N/m^2
        - Leeward = 353.94 N/m^2
    - UDL acting on the roof
        - Windward = -252.01 N/m^2
        - Leeward = 212.37 N/m^2



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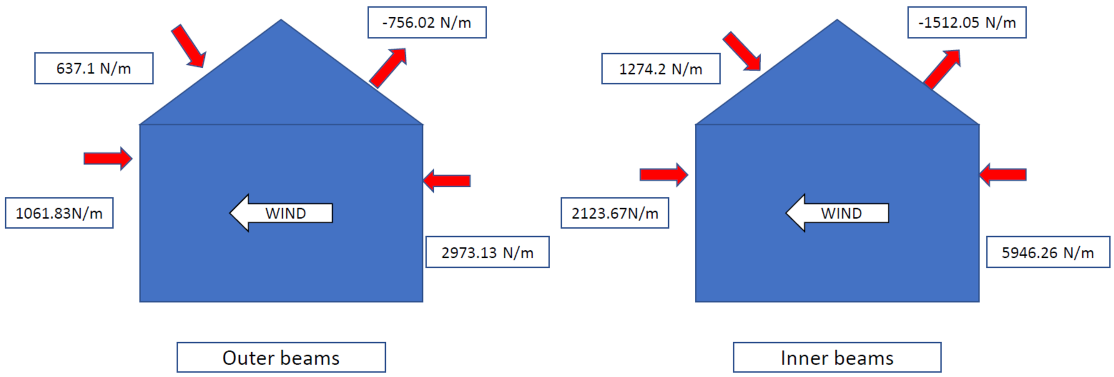

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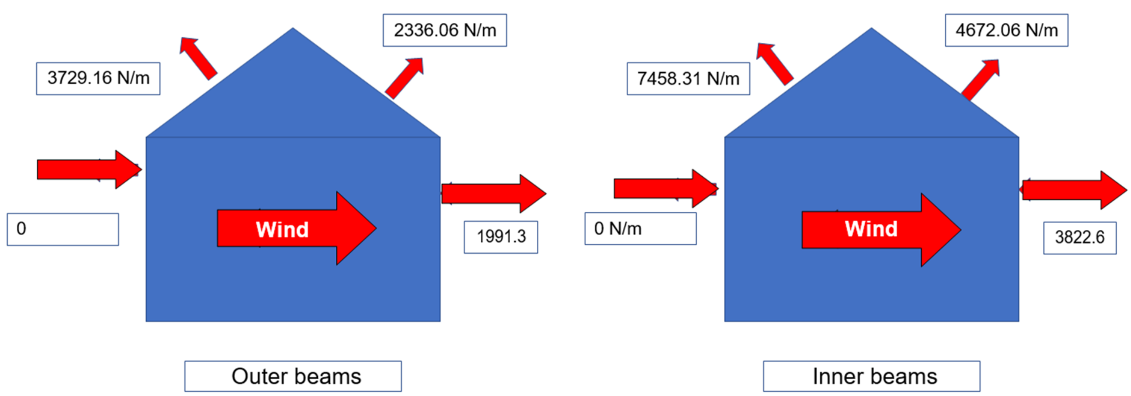

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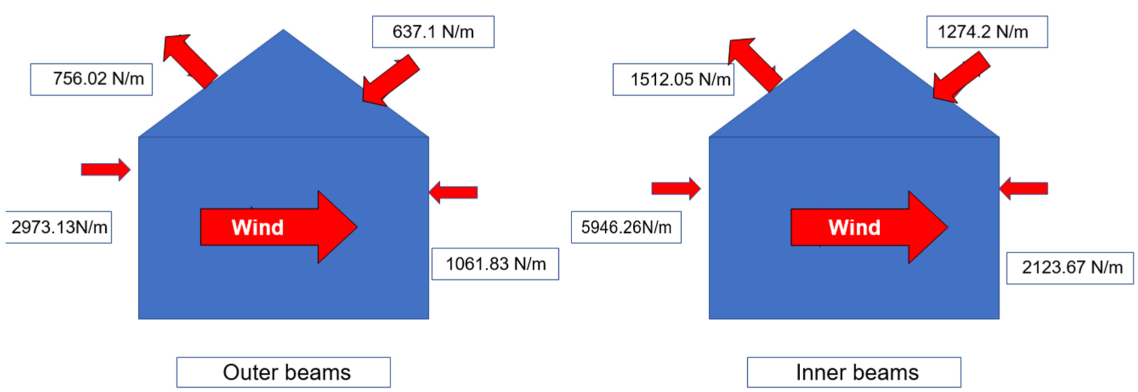


Load Combinations

- Limit State of Strength
  - 1.2 DL + 1.2 LL
  - 1.2 DL + 1.2 LL + 1.2 WL
- Limit State of Serviceability
  - 1 DL + 1 LL

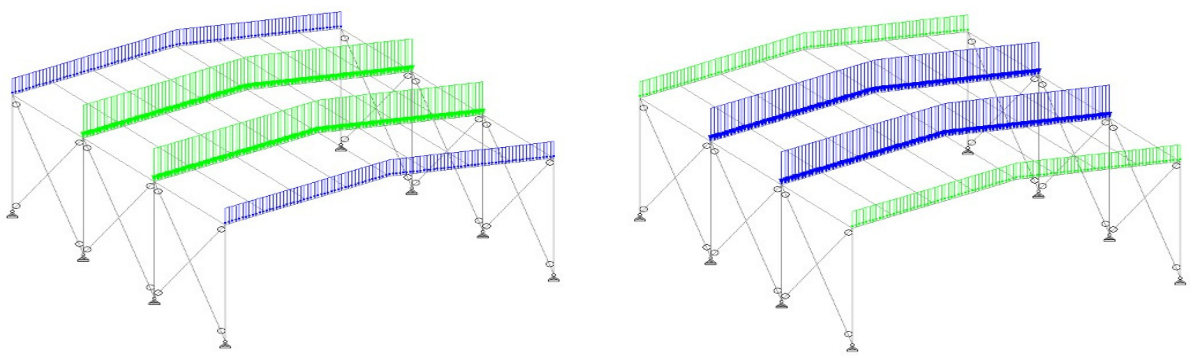
Sectional Properties

- Rafters - WB 450 to WB 300 (taper)
- Columns - WB 450 to WB 300 (taper)
- Ridge Board – LB 300
- Purlin – LB 300
- Bracings – ISA 50x50x5

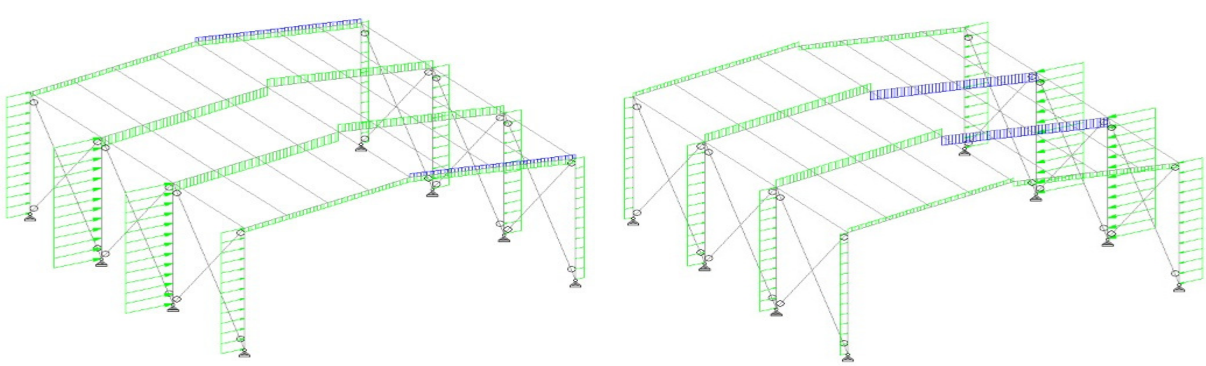
Analysis and Design

The above section properties were used to make the structure. Material used is structural steel. For the supports Mx, My, Mz were kept free. Bracings were taken as axial members.

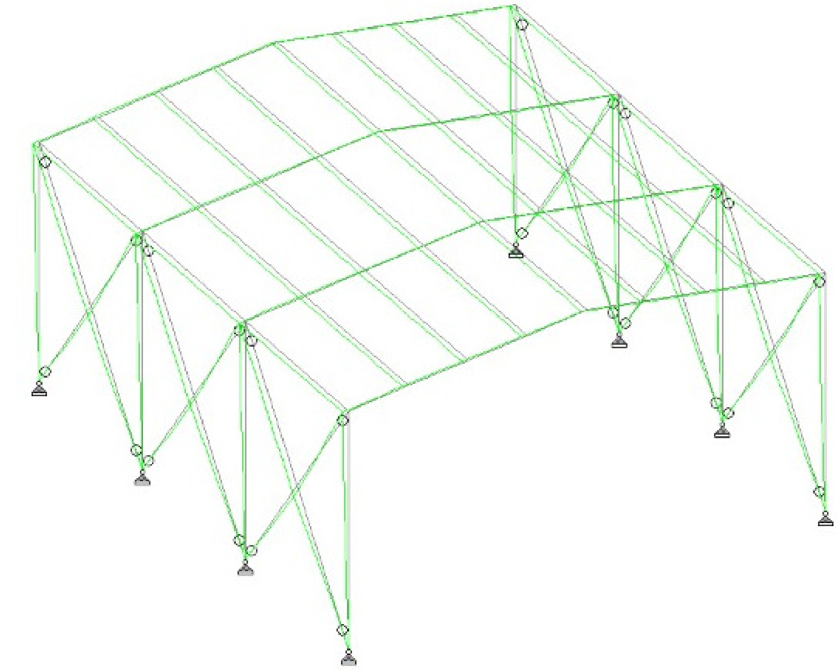
STAAD Analysis



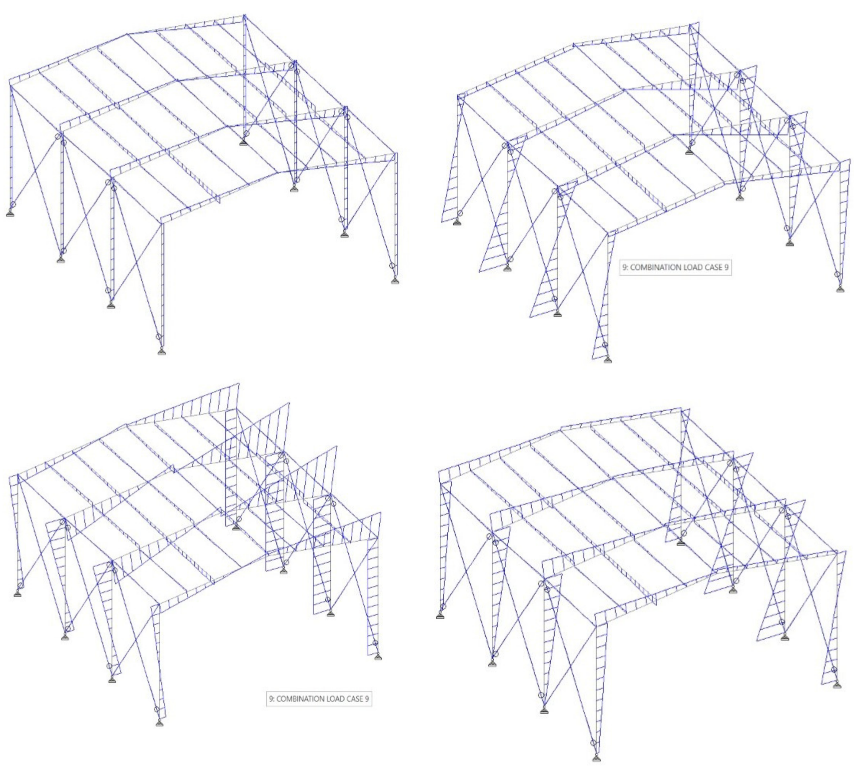
Live Load and Dead Load applied respectively



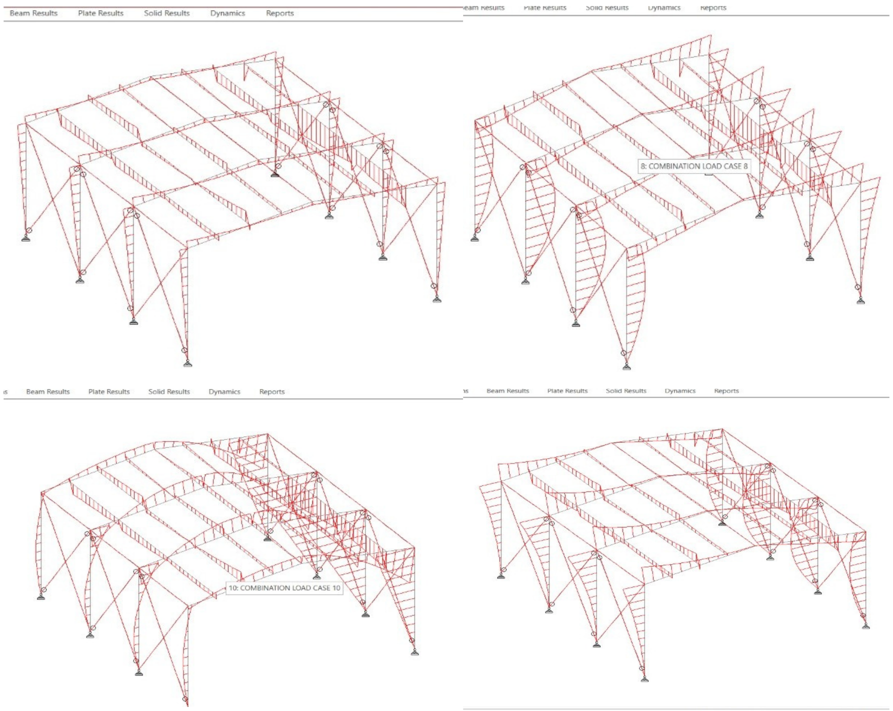
Wind Load applied on structure



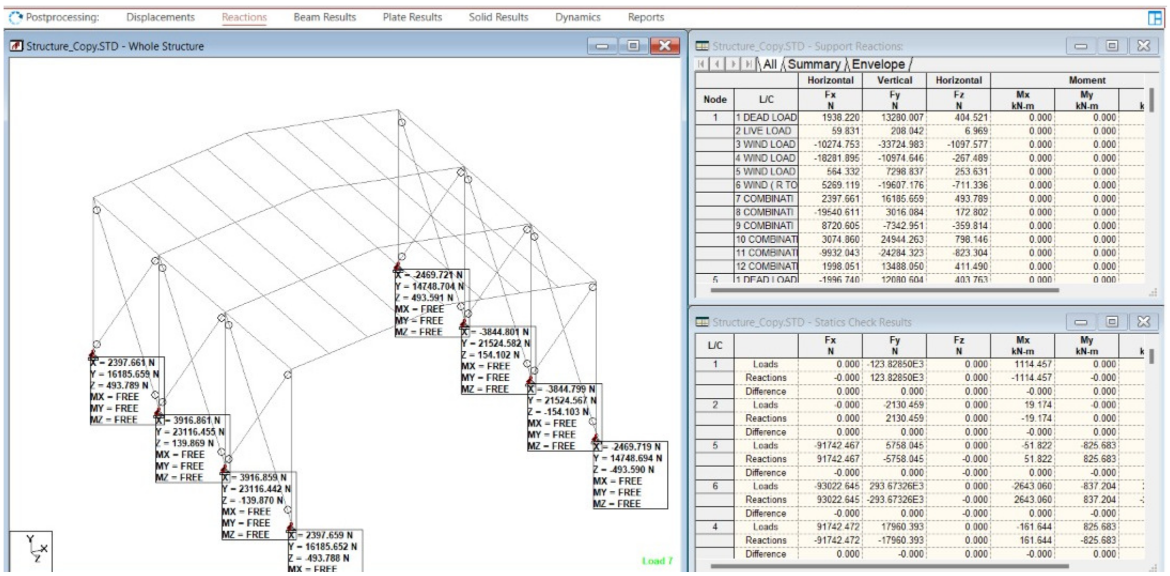
Displacements for one of the load combinations



Shear Force (F_y) for various load combinations



Bending Moment along Z (Mz) for various load combinations

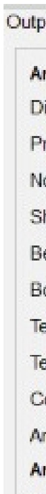


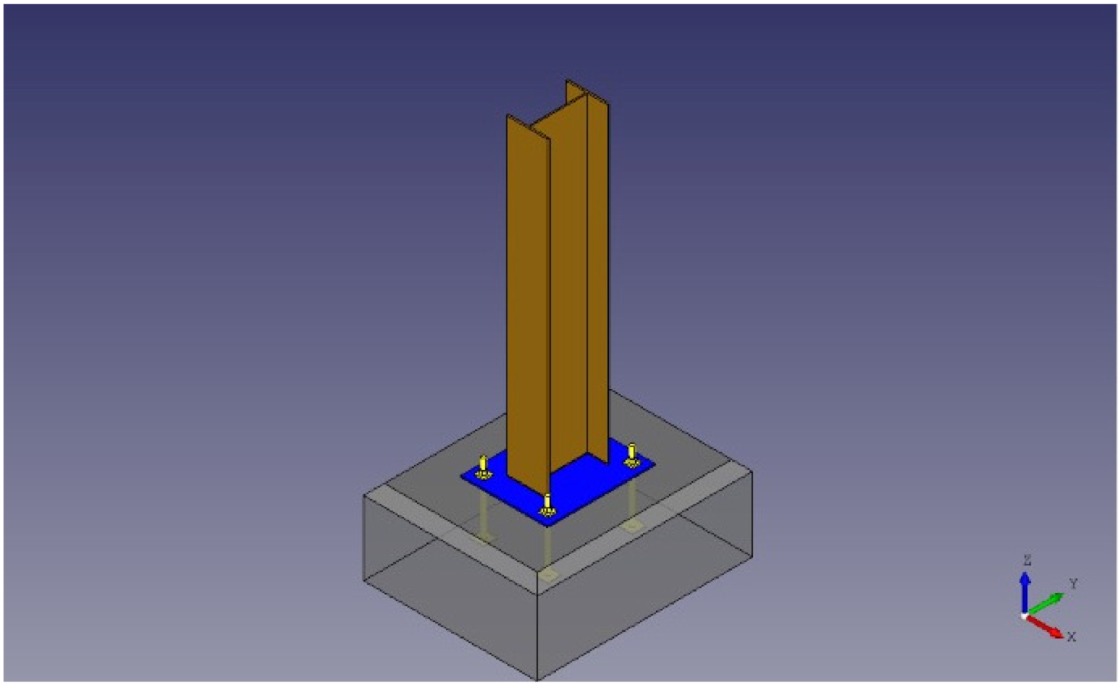
Support Reactions for various load combinations

Connection Design

Baseplate Connection

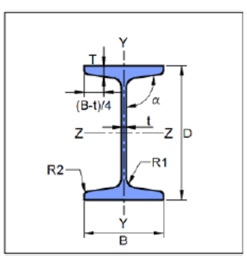
The Column Base Plate connection is a rectangular steel plate welded to the bottom of a steel column. The steel plate sits on the top of a concrete support (with or without a grout pad between). The plate is bolted to the concrete with headed bolts that are embedded in the concrete.





1 Input Parameters

Main Module	Moment Connection
Module	Base Plate Connection
Connectivity	Welded Column Base
End Condition	Pinned
Axial Compression (kN)	33.22
Axial Tension/Uplift (kN)	0.0
Shear Force (kN)	
- Along major axis (z-z)	0.67
- Along minor axis (y-y)	34.02
Bending Moment (kNm)	
- Major axis (M_{z-z})	0.0
- Minor axis (M_{y-y})	0.0

Column Section - Mechanical Properties				
	Column Section		WB 300	
	Material		E 250 (Fe 410 W)A	
	Ultimate Strength, F_u (MPa)		410.0	
	Yield Strength, F_y (MPa)		250.0	
	Mass, m (kg/m)	48.1	I_z (cm^4)	9820.0
	Area, A (cm^2)	61.3	I_y(cm^4)	990.0
	None	None	r_z (cm)	12.7
	D (mm)	300.0	r_y (cm)	4.02
	B (mm)	200.0	Z_z (cm^3)	655.0
	T (mm)	10	Z_y (cm^3)	99.0
	t (mm)	7.4	Z_{pz} (cm^3)	628.39
	Flange Slope	96	Z_{py} (cm^3)	1551.3
	R_1 (mm)	11.0		
	R_2 (mm)	5.5		

Base Plate - Design Preference	
Material	E 250 (Fe 410 W)A
Ultimate Strength, F_u (MPa)	410
Yield Strength, F_y (MPa)	250

Stiffener/Shear Key - Design Preference	
Material	E 250 (Fe 410 W)A
Anchor Bolt Outside Column Flange - Input and Design Preference	
Diameter (mm)	['M20', 'M24', 'M30', 'M36', 'M42', 'M48', 'M56', 'M64', 'M72']
Property Class	['3.6', '4.6', '4.8', '5.6', '5.8', '6.8', '8.8', '9.8', '10.9', '12.9']
Anchor Bolt Type	End Plate Type
Anchor Bolt Galvanized?	Yes
Designation	M20X344.5 IS5624 GALV
Hole Type	Over-sized
Total Length (mm)	344.5
Material Grade, F_u (MPa)	1220.0
Anchor Bolt Inside Column Flange - Input and Design Prefereself.anchor_grade_list_outnce	
Diameter (mm)	N/A
Property Class	N/A
Anchor Bolt Type	N/A
Anchor Bolt Galvanized?	N/A
Designation	N/A
Hole Type	N/A
Total Length (mm)	N/A
Material Grade, F_u (MPa)	N/A
Friction Coefficient (between concrete and anchor bolt)	0.3
Weld - Design Preference	
Type of Weld Fabrication	Shop Weld
Material Grade Overwrite, F_u (MPa)	410.0
Detailing - Design Preference	
Edge Preparation Method	a - Sheared or hand flame cut
Are the Members Exposed to Corrosive Influences?	Yes
Design - Design Preference	
Design Method	Limit State Design
Base Plate Analysis	Effective Area Method

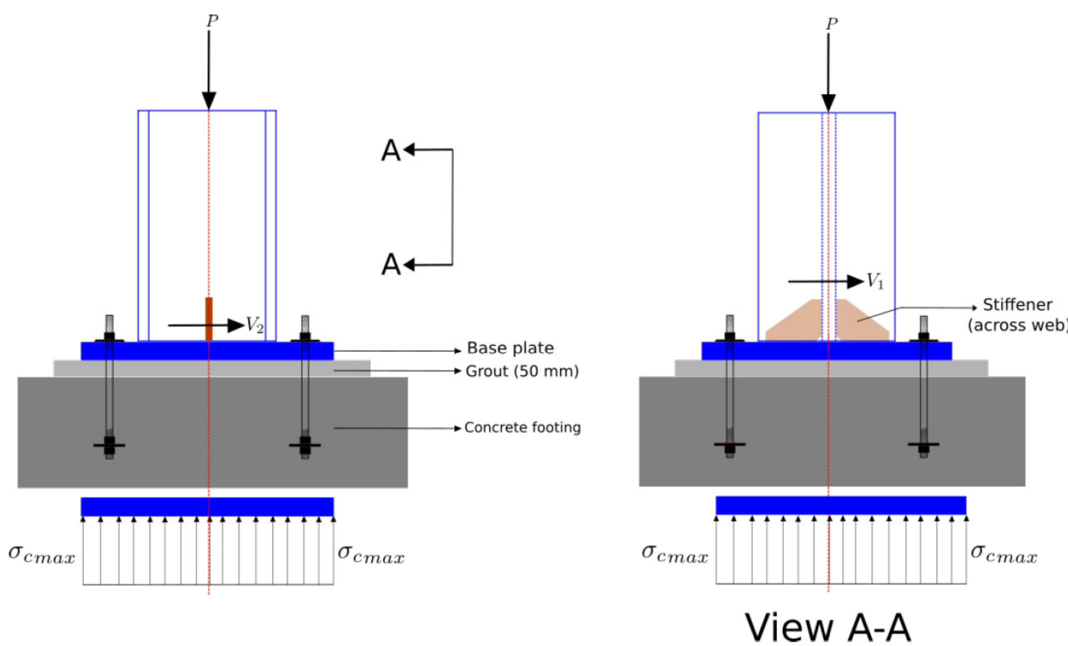


Figure 1: Typical Base Plate Details

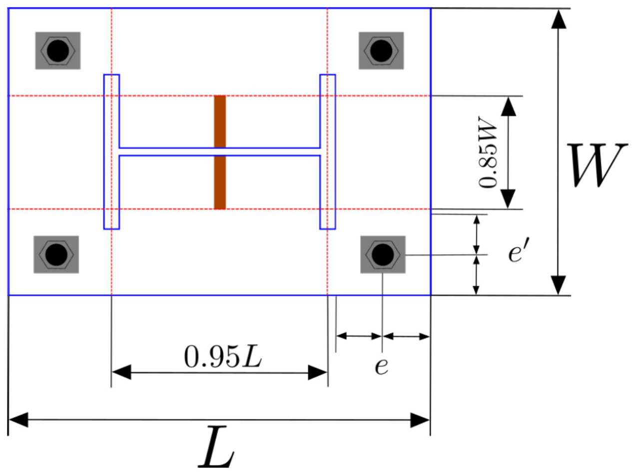


Figure 2: Typical Base Plate Detailing

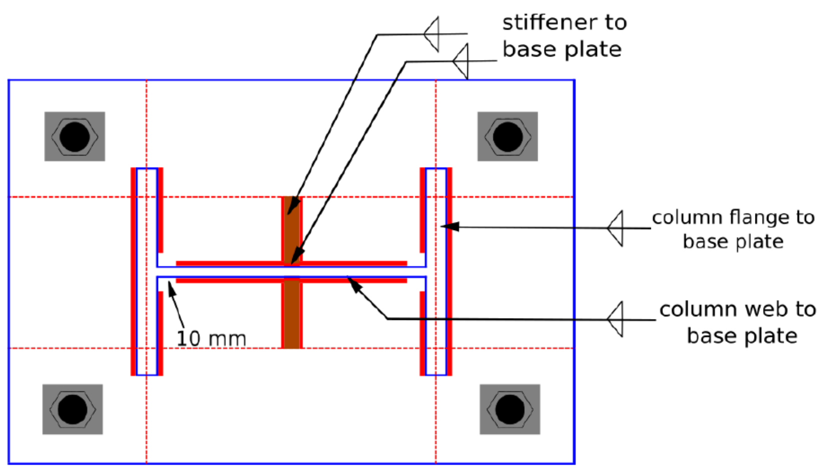
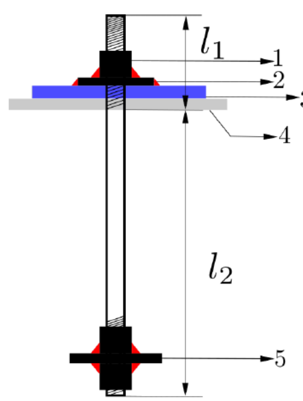


Figure 3: Typical Weld Details



l_1 = length above footing
l_2 = length below footing
1 = t_n, nut thickness
2 = t_w, washer thickness
3 = t_p, plate thickness
4 = t_g, grout thickness
5 = end plate thickness

Figure 4: Typical Anchor Bolt Details

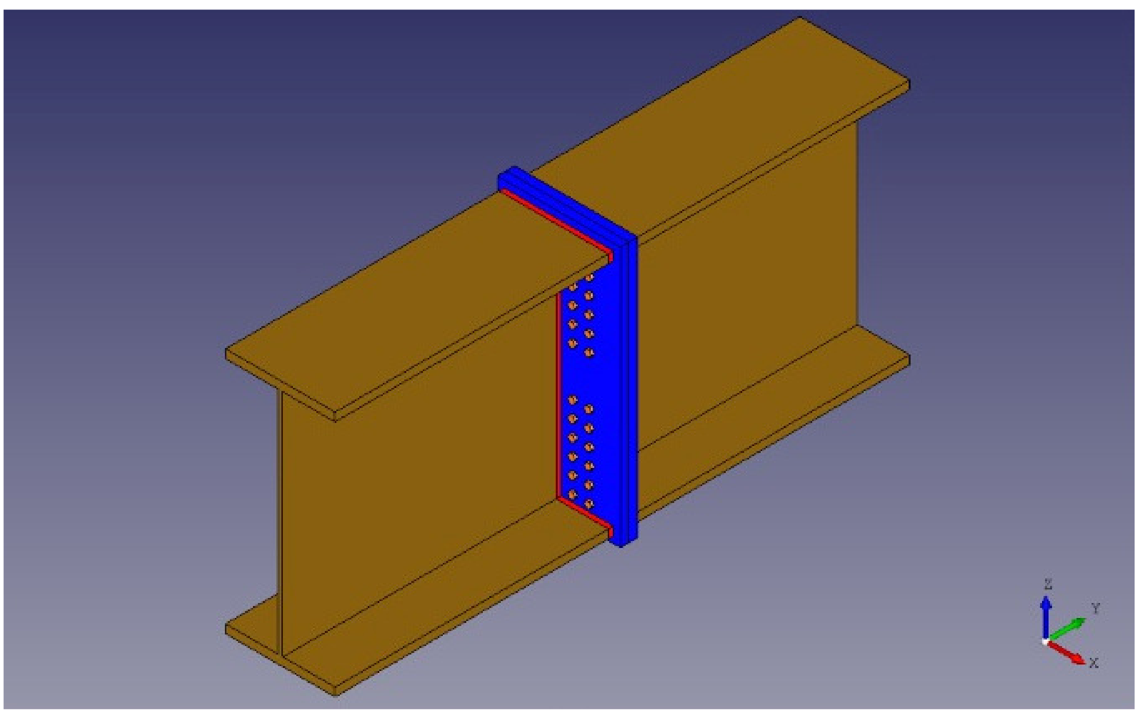
Beam-to-Beam End Plate Connection

A flexible end plate connection consists of a plate fastened to both sides of the web in metal beam structures by fillet welds. The connection should transmit vertical shear and allow beam end rotations to occur without the development of significant moments. They provide moment-resistant connections between beams and columns at the corner of frames or a moment resistant connection to elongate beams.

Typical flexible end plate connections may be partial depth or full-depth and are welded to the supported metal beam structures. The beam then bolts to the supporting beam or column on site.

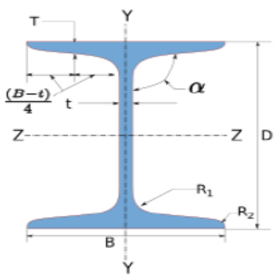
This type of connection is relatively low-priced but has the disadvantage of little opportunity for site adjustment. The overall beam lengths need steel fabrication within tight limits, although packs are used to compensate for fabrication tolerances and erection tolerances.

End plates are used with skewed beams and tolerate moderate offsets in a beam to column joints. The end plate is connected to the metal beam structures through weld because its capacity and size are managed by the sheer magnitude of the beam adjoining the weld. The stress applied to the connection at the end of the member does not have eccentricities. There are various types of end plate connections including a flexible, semi-rigid, and rigid end plate connections.



1 Input Parameters

Main Module	Moment Connection
Module	Beam-to-Beam End Plate Connection
Connectivity	Coplanar Tension-Compression Flange
End Plate Type	Flushed - Reversible Moment
Bending Moment (kNm)	15.506
Shear Force (kN)	0.0
Axial Force (kN)	12.634761
Beam Section - Mechanical Properties	



Beam Section	WB 450		
Material	E 250 (Fe 410 W)A		
Ultimate Strength, F_u (MPa)	410		
Yield Strength, F_y (MPa)	250		
Mass, m (kg/m)	79.52	I_z (cm^4)	35100.0
Area, A (cm^2)	10100.0	I_y(cm^4)	1700.0
D (mm)	450.0	r_z (cm)	18.6
B (mm)	200.0	r_y (cm)	4.1
t (mm)	9.2	Z_z (cm^3)	1560.0
T (mm)	15.4	Z_y (cm^3)	170.0
Flange Slope	96	Z_{pz} (cm^3)	1760.0
R_1 (mm)	15.0	Z_{py} (cm^3)	284.0
R_2 (mm)	7.0		

Plate Details - Input and Design Preference	
Thickness (mm)	[8, 10, 12, 14, 16, 18, 20, 22, 25, 28, 32, 36, 40, 45, 50, 56, 63, 75, 80, 90, 100, 110, 120]
Material	E 250 (Fe 410 W)A
Ultimate Strength, F_u (MPa)	410
Yield Strength, F_y (MPa)	250
Bolt Details - Input and Design Preference	
Diameter (mm)	[8, 10, 12, 14, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 42, 45, 48, 52, 56, 60, 64]
Property Class	[3.6, 4.6, 4.8, 5.6, 5.8, 6.8, 8.8, 9.8, 10.9, 12.9]
Type	Bearing Bolt

Bolt Tension	Non pre-tensioned
Hole Type	Standard
Slip Factor, (μ_f)	0.3
Weld Details - Input and Design Preference	
Type of Weld Fabrication	Shop Weld
Material Grade Overwrite, F_u (MPa)	410.0
Beam Flange to End Plate	Groove Weld
Beam Web to End Plate	Fillet Weld
Stiffener	Fillet Weld
Detailing - Design Preference	
Edge Preparation Method	Sheared or hand flame cut
Gap Between Beams (mm)	0.0
Are the Members Exposed to Corrosive Influences?	False

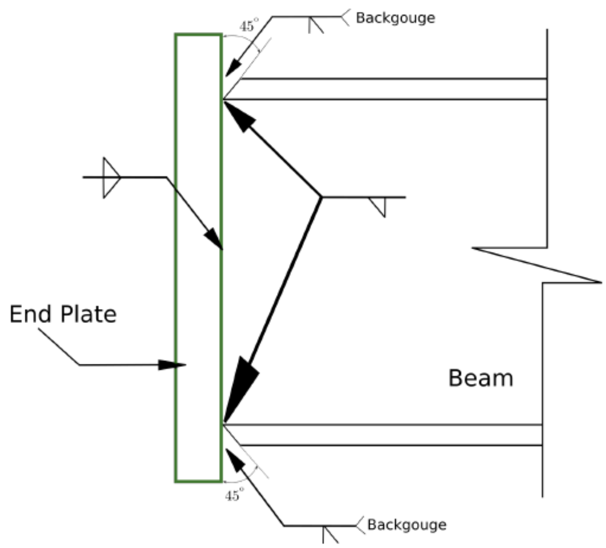


Figure 1: Typical Weld Details -- Beam to End Plate Connection

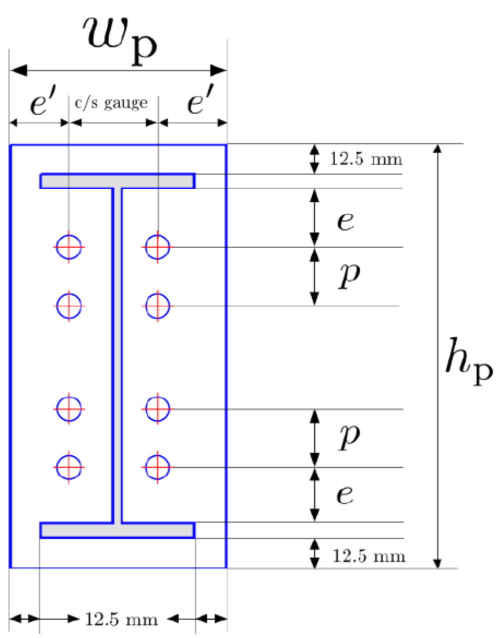


Figure 2: Typical Detailing

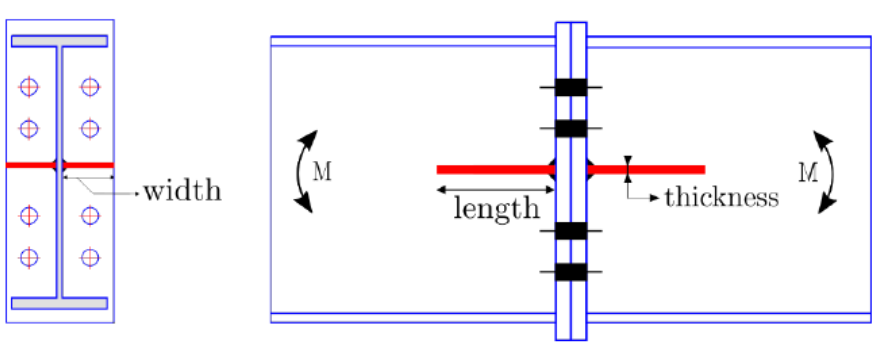
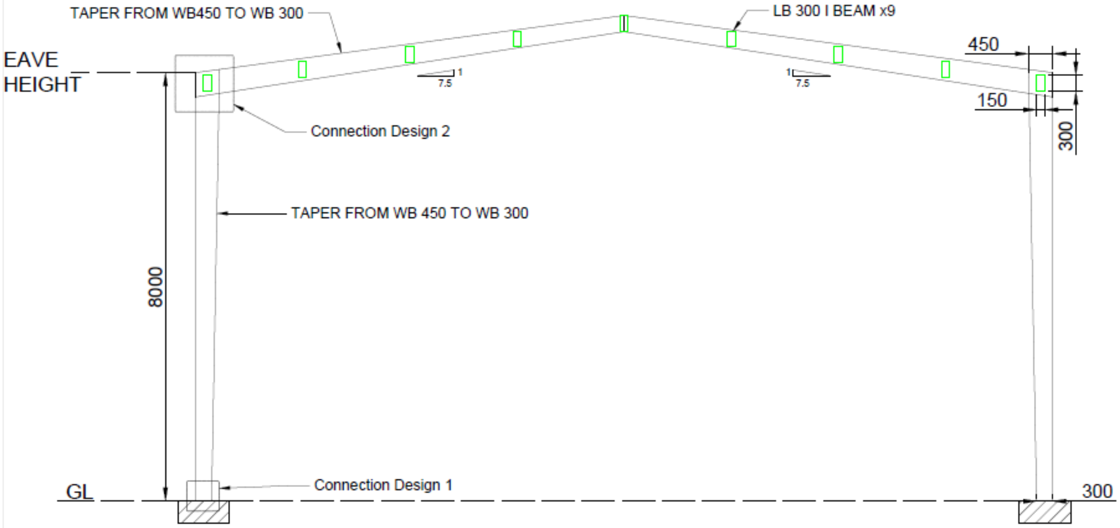


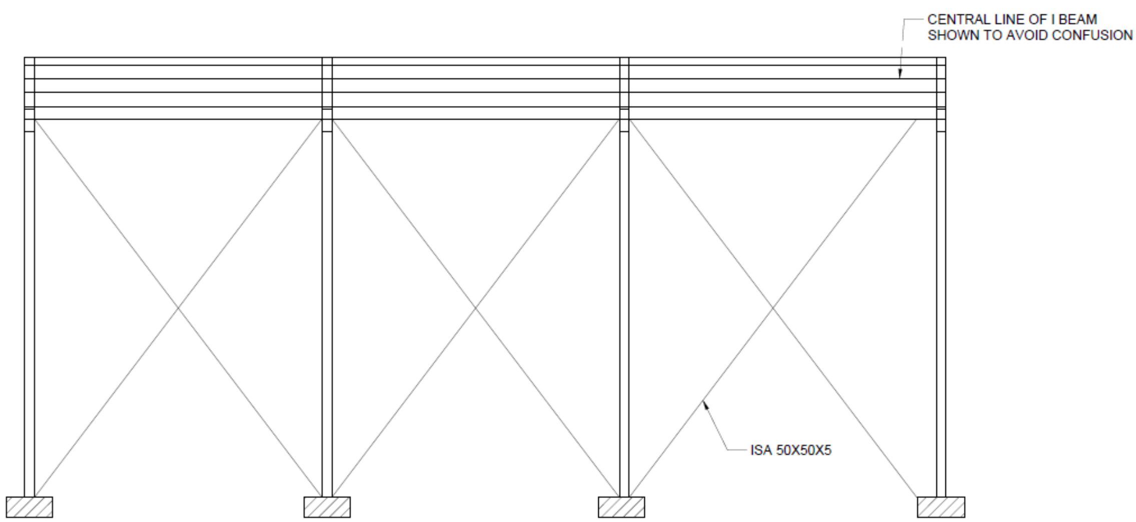
Figure 3: Typical Stiffener Details

Autocad Drawings

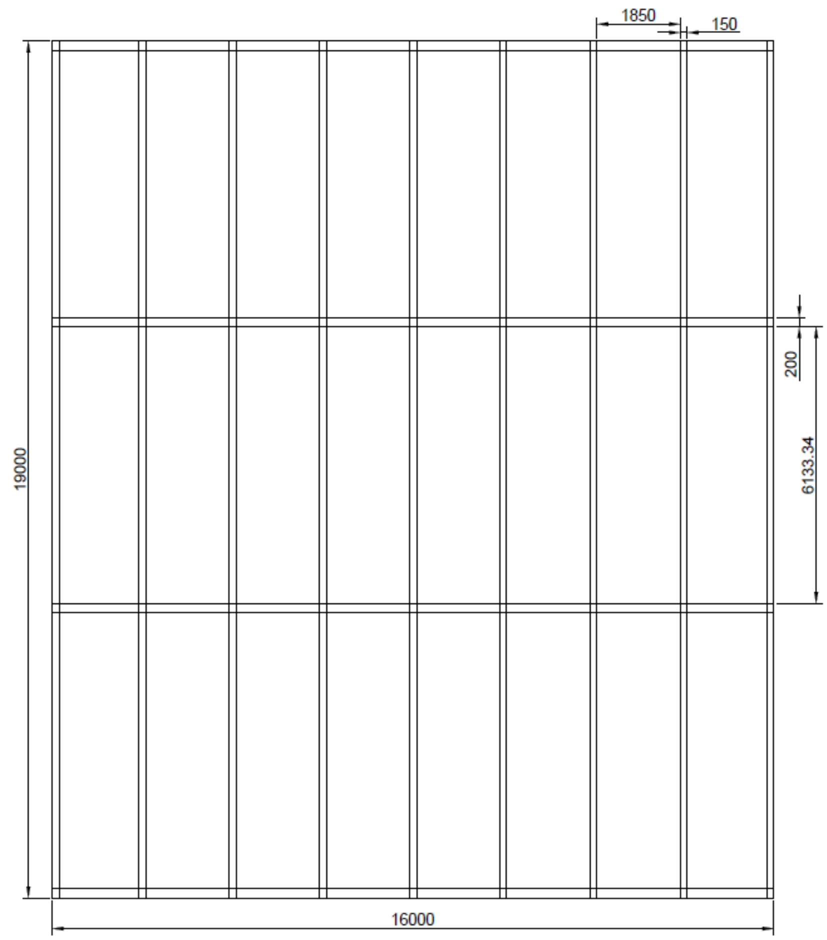
Structural Drawings



Front View

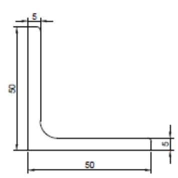


Side View

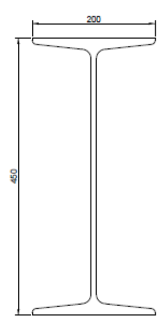


Top View
SCALE 1:50

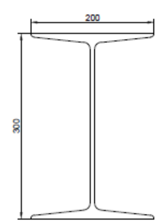
Sectional Drawings



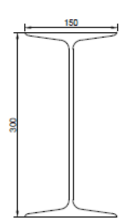
ISA 50x50x5



WB 450



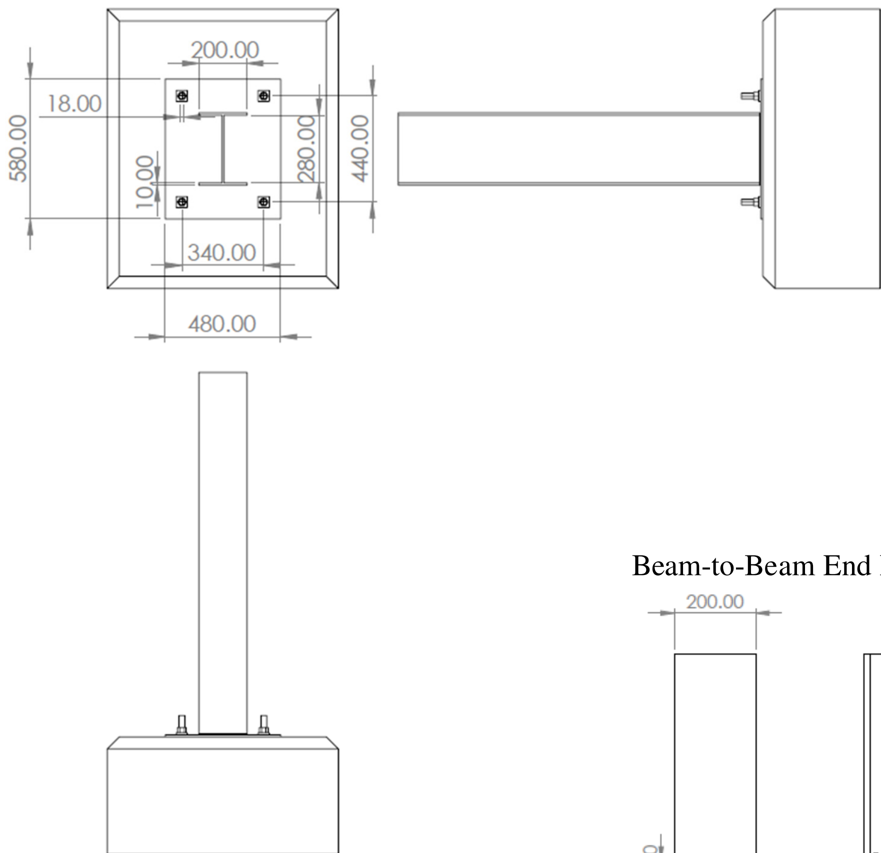
WB 300



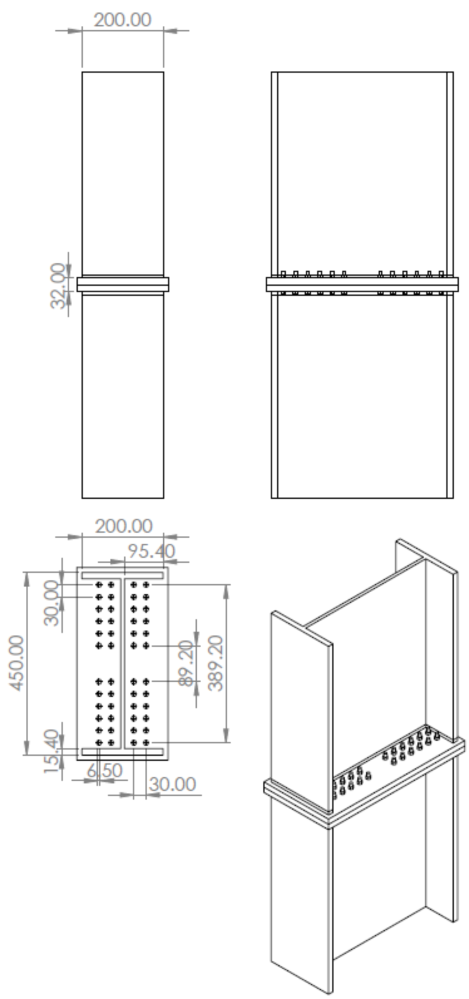
LB 300

Connection drawings

Baseplate Connection



Beam-to-Beam End Plate Connection



Bill of Quantities

Serial Number	Particulars of Item/Work	Length (m)	Weight (N)	Weight (Kg)	Rate	Unit	Cost (Rs.)
1	Structural Steel						
	Sections						
a	Columns - Tapered I Beam WB 450 to WB 300	64.28	41160.503	4197.13649	50	Rs. per kg	209856.8245
b	Rafters - Tapered I Beam WB 450 to WB 300	64.28	38205.077	3895.7717			194788.5851
c	Purlins - LB 300	162	58540.34	5969.35847			298467.9235
d	Bracings - ISA 50x50x5	120	4415.569	450.255571			22512.77855
	Total		142321.49	14512.5222			725626.1117
2	Additional Cost						
a	Connection Cost				10%	% of Cost of Structural Steel	72562.61117
b	Labour Cost				5%		36281.30558
c	Foundation Cost				30%		217687.8335
d	Contingency Cost				5%		36281.30558
	Total cost of the structure						1088439.167