# طرح نگهداشت و افزایش تولید 27 مخزن

# CALCULATION NOTE FOR UTILITY SHELTER

## نگهداشت و افزایش تولید میدان نفتی بینک

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
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**Status:**

**IDC: Inter-Discipline Check**
**IFC: Issued For Comment**
**IFA: Issued For Approval**
**AFD: Approved For Design**
**AFC: Approved For Construction**
**AFP: Approved For Purchase**
**AFQ:** Approved For Quotation
**IFI: Issued For Information**
**AB-R: As-Built for CLIENT Review**
**AB-A: As-Built –Approved**

## REVISION RECORD SHEET

| PAGE | D00 | D01 | D02 | D03 | D04 |
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## CONTENTS

## 1.0 INTRODUCTION

Binak oilfield in Bushehr province is a part of the southern oilfields of Iran, is located 20 km northwest of Genaveh city.

With the aim of increasing production of oil from Binak oilfield, an EPC/EPD Project has been defined by NIOC/NISOC and awarded to Petro Iran Development Company (PEDCO). Also PEDCO (as General Contractor) has assigned the EPC-packages of the Project to "Hirgan Energy - Design and Inspection" JV.

## 2.0 SCOPE

This report covers the structure & foundation calculation report of the “Utility Shelter ”. The structure modelled by “SAP” software & the foundation modelled by “SAFE” software.

## 3.0 NORMATIVE REFERENCE

### 3.1 Local Codes and Standards

- INBC Part 6 “Iranian National Building Code
- INBC Part 7 “Iranian National Building Code
- INBC Part 9 “Iranian National Building Code
- INBC Part 10 “Iranian National Building Code
- Iranian Seismic Design Code for Petroleum Facilities(3rd edition)

### 3.2 International Codes and Standards

- ASCE 7-10 “Minimum Design Loads and Associated Criteria for Buildings and Other Structures-American Society of Civil Engineers”.
- ACI 318. “Building Code Requirements for Reinforced Concrete”, American Concrete Institute.
- AISC 358 “Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications.” American Institute of Steel Construction, Inc.
- AISC 360 - “Specification for Structural Steel Buildings”. American Institute of Steel Construction, Inc.

### 3.3 The Project Documents

- BK-GNRAL-PEDCO-000-ST-SP-0001 SPECIFICATION FOR CONCRETE WORK
- BK-GCS-PEDCO-120-ST-DW-0068 STRUCTURAL DRAWING FOR UTILITY SHELTER
- BK-GNRAL-PEDCO-000-ST-SP-0006 SPECIFICATION FOR FIREPROOFING

## 4.0 MATERIAL PROPERTIES

Material properties are delivered in the following table.

TABLE 1 -MATERIAL PROPERTIES

| Foundation Concrete | F'c = 30 Mpa(28- day cylindrical sample) |
|---|---|
| Long. reinforcement bar | Fy = 400 Mpa(AIII) |
| Trans. reinforcement bar | Fy = 400 Mpa(AIII) |
| Bolt Type | HV 8.8 |
| Electrode Type | E 70 |

## 5.0 STRUCTURE ‘S SYSTEMS

The Structure’s System is OMF in X direction and OCBF system in Y direction. Seismic Parameters according to Iranian Code of Practice for Seismic Resistant Design of Building Standard No. 038 ($3^{th}$ Edition) listed at below table.

TABLE 2 - DESIGN COEFFICIENTS AND FACTORS FOR SEISMIC FORCE-RESISTING SYSTEMS

| | Structure System | R | Ω | Cd |
|---|---|---|---|---|
| X Dir | OMF | 3.5 | 3 | 3 |
| Y Dir | OCBF | 3.25 | 2 | 3.25 |

# 6.0 DESIGN LOAD

## 6.1 Dead load

Dead loads include the self-weight of the structure and all the permanent equipment which are supported by the structures

Corrugated sheet : $8\ \mathrm{kg/m^2}$

Z Purlin : $8\ \mathrm{kg/m^2}$

Insulation : $10\ \mathrm{kg/m^2}$

$$\sum \mathrm{sum} = 26\ \mathrm{kg/m^2}$$

According to NISOC comment Roof weight is assigned in software 50kg/m2.

- At ended frame : $50 \times 2 = 100\ kg/m$
- At middle frame : $50 \times 5 = 250\ kg/m$

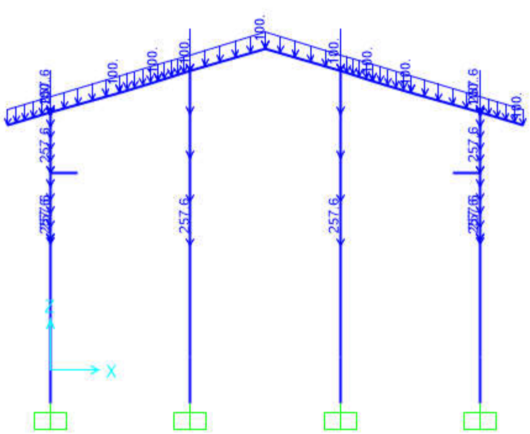


**Figure 1-**Applied Dead load on ended axe(1&4) (kg/m)

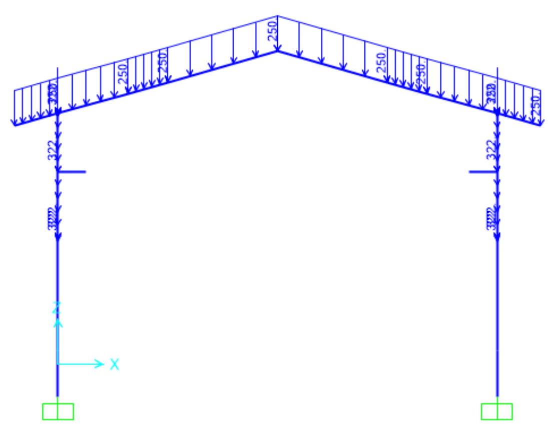


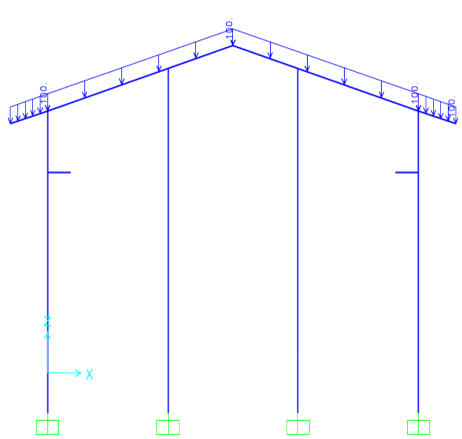
**Figure 2-**Applied Dead load on middle axe 2(kg/m)

## 6.2 LIVE LOADS

The design live load on an area shall be defined as the weight of all movable loads, including personnel, tools, and parts of dismantled equipment, cranes, hoist, and temporarily stored materials.

According to Iranian National Building Code No.6 Live load in light slop roof is 50kg/m2 and has been applied at frame.

- At ended frame : $50 \times 2 = 100\ kg/m$
- At middle frame : $50 \times 5 = 250\ kg/m$



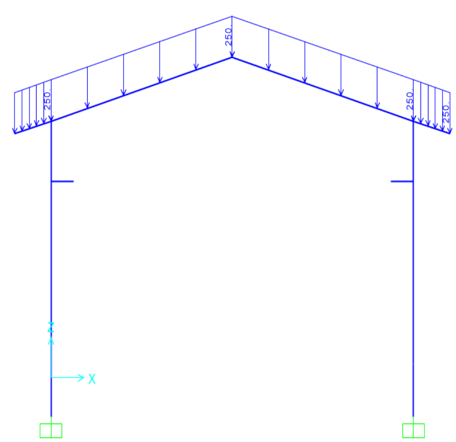




**Figure 3-** Applied Live load on ended axes 1&4 (kg/m) **Figure 4-** Applied Live load on middle axes 2&3 (kg/m)

## 6.3 SNOW LOADS

Snow load of this structure is calculated in accordance with Iranian National Building Code No.6 Latest edition. Parameters which are used in calculation of snow force is presented in below:

$P_r = P_s C_n C_h I_s C_s$

Ps=25 kg/m2 , Is=1

Cs= 0.91 (slope 11.31º)=1-$\frac{\alpha-\alpha_0}{70-\alpha_0} = 1 - \frac{11-5}{70-5} = 0.902$

Ch=1

Cn=0.8

$P_r = P_s C_n C_h I_s C_s = 18.06 \frac{kg}{m2}$

- At ended frame: $18.06 \times 2 = 36.12\ kg/m$
- At middle frame: $18.06 \times 5 = 90.3\ \ kg/m$

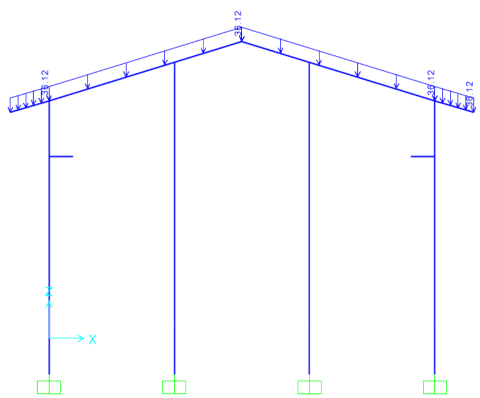


**Figure 5-**Applied Snow load on ended axes 1&4 (kg/m)

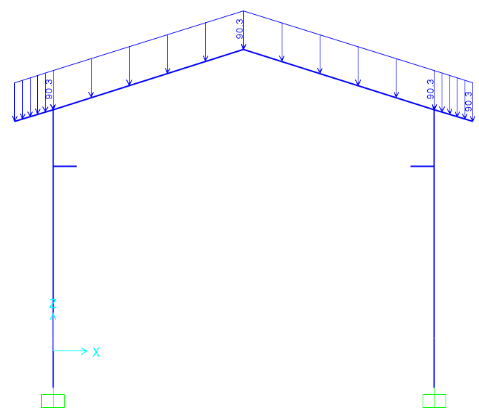


**Figure 6-**Applied Snow load on middle axes 2&3 (kg/m)

## 6.4 SEISMIC LOADS

All structures are in area with high-risk zone of seismic and until finalizing of “Geotechnical Final Report” soil type consider is type II. Equivalent static method is used for calculation of seismic loads. Parameters which are used in calculation of earthquake force and seismic coefficient is presented in below.

According to Iranian Code of Practice for Seismic Resistant Design of Building Standard No. 038 (3th Edition)

| Parameter | Y-Direction | X-Direction |
|---|---|---|
| Importance factor, $I_e$ | 1.25 | 1.25 |
| Structural system | OCBF | OMF |
| R | 3.25 | 3.5 |
| Ω | 2 | 3 |
| Cd | 3.25 | 3 |
| A | 0.3 | 0.3 |
| Soil Type | II | |
| T0(s) | 0.10 | 0.10 |
| Ts(s) | 0.5 | 0.5 |
| Ta = Calculated Period | $=0.05*(8.5)^{0.75} = 0.248$ | $=0.072*(8.5)^{0.8} = 0.398$ |
| Tm = Analytical Period | 0.158(Mode 13) | 0.829 (Mode 1) |

| | | |
|---|---|---|
| Ta=min(1.4Ta$_{\text{(Calculated Period)}}$ ، Ta$_{\text{(Analytical Period)}}$) | 0.158 | 0.5572 |
| k | 1.00 | 1.03 |
| $C_{s_{min}} = 0.12AI$ | 0.045 | 0.045 |
| SD1 | 0.375 | 0.375 |
| SDs | 0.75 | 0.75 |
| Sa | 0.75 | 0.673 |
| $C_s = \frac{Sa.I}{R}$ | 0.288 | 0.2403 |

- According to Iranian seismic Design code for Petroleum facilities code 038 $\rho$ in X directions assumed 1.3.

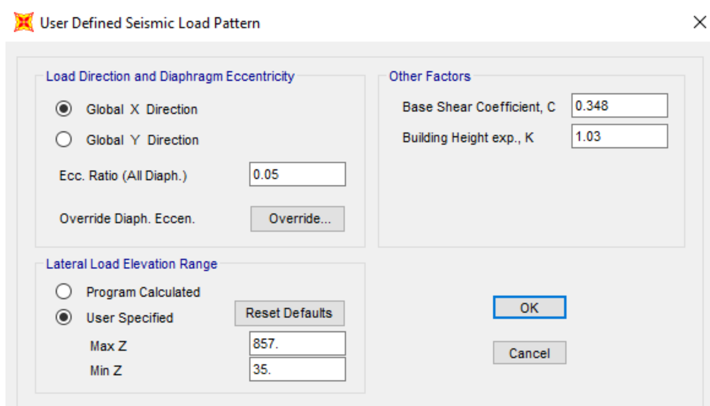



Fig 7- X Direction Seismic Load

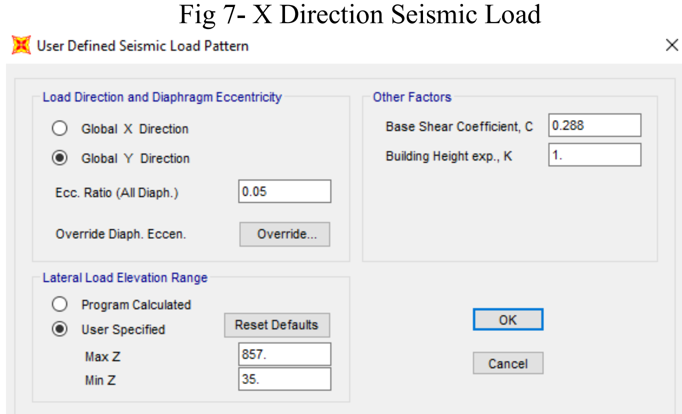



Fig 8- Y Direction Seismic Load

## 6.5 CRANE LOAD

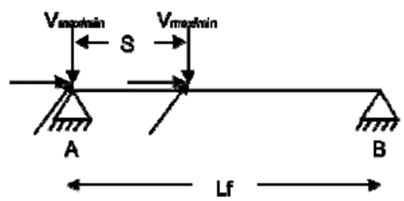
Distribution of crane load is as below:

- **CRO** is the operating load of crane which shall be defined as the Crane Dead Load plus the crane capacity with considering the vertical, lateral and longitudinal Impact factor.

| Input Data | | |
|---|---|---|
| Lifted Crane Load = LCL | 2 | ton |
| Crane Weight = CW | 0.117 | ton/m |
| Trolley and Hoist Weight = THW | 2 | ton |
| Crane Approach = CAD | 0.75 | m |
| Shelter Width | 12 | m |
| The Maximum Load Factor for this span based on the side approach is | 0.9375 | - |
| The Minimum Load Factor for this span based on the side approach is | 0.0625 | - |
| **There are 2 wheels per truck and 2 trucks per crane for a total of 4 wheels for this crane.** | | |
| Wheels per Truck = TrW | 2 | - |
| Total number of Wheels = TTrW | 4 | - |
| Maximum Wheel Load | 2.226 | ton |
| Minimum Wheel Load | 0.476 | ton |
| The sum of all wheel loads | 5.404 | ton |
| Check the sum of the lifted load + the crane, trolley and hoist weight | 5.404 | **Ok** |
| The distance between frames is the bay size (Lf) | 6 | m |
| The Wheel Spacing (s) | 2 | m |
| **Impact factor** | | |
| Vertical Impact factor (Kv) | 1.25 | - |
| Horizontal Impact factor (kh) | 0.2 | - |
| Longitudinal Impact factor (kl) | 0.1 | - |
| **Vertical Frame Load:** | | |
| Maximum Live Load | 2.7825 | ton |
| Minimum Live Load | 0.595 | ton |

Frame Analysis Data:

| CRO | | |
|---|---|---|
| Left | | |
| RAv (max) | 4.6375 | ton |
| RAh (max) | 0.742 | ton |
| RAl (max) | 0.2226 | ton |
| RBv (min) | 0.9275 | ton |
| RBh (min) | 0.1484 | ton |
| RBl (min) | 0.2226 | ton |
| Right | | |
| RAv (max) | 0.991666667 | ton |
| RAh (max) | 0.158666667 | ton |
| Ral (max) | 0.0476 | ton |
| RBv (min) | 0.198333333 | ton |
| RBh (min) | 0.031733333 | ton |
| RBl (min) | 0.0476 | ton |



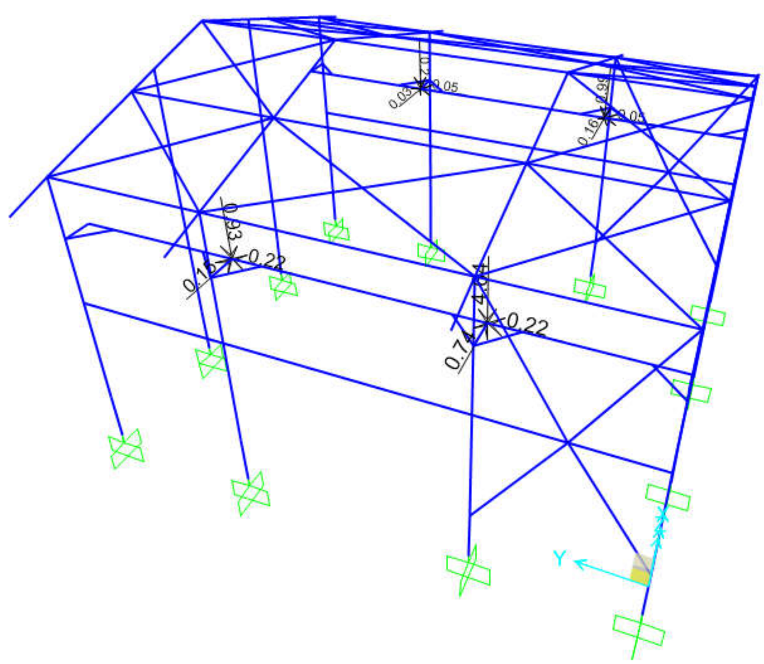




**Figure 9-**Applied Crane Operating load (CRO1) on Structure (ton)

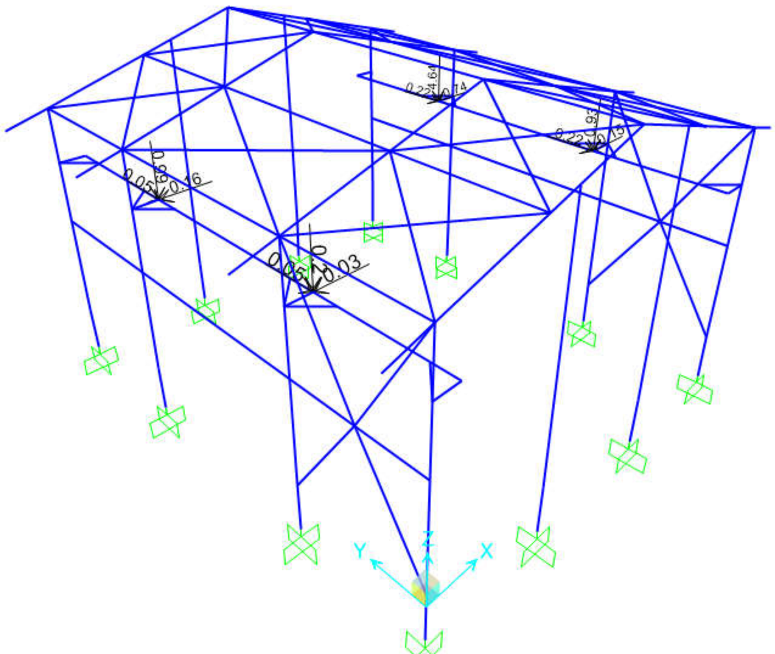



**Figure 10-**Applied Crane Operating load (CRO2) on Structure (ton)

- **CRD (Crane Dead Load)** Crd is the weight of Crane Bridge plus crab and trolley weight which is as follow:

| CRD | | |
|---|---|---|
| Vmax | 1.2885 | ton |
| Vmin | 0.4135 | ton |
| **Left** | | |
| RAv (max) | 2.1475 | ton |
| RBv (min) | 0.4295 | ton |
| **Right** | | |
| RAv (max) | 0.689167 | ton |
| RBv (min) | 0.137833 | ton |

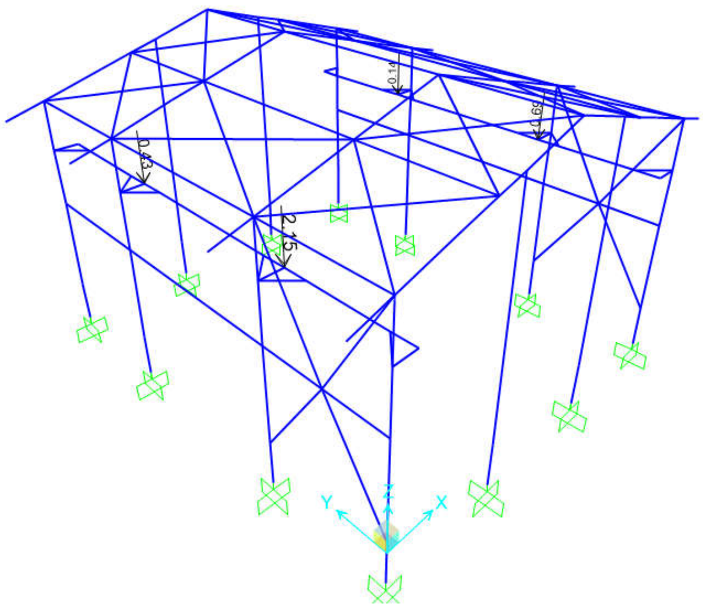


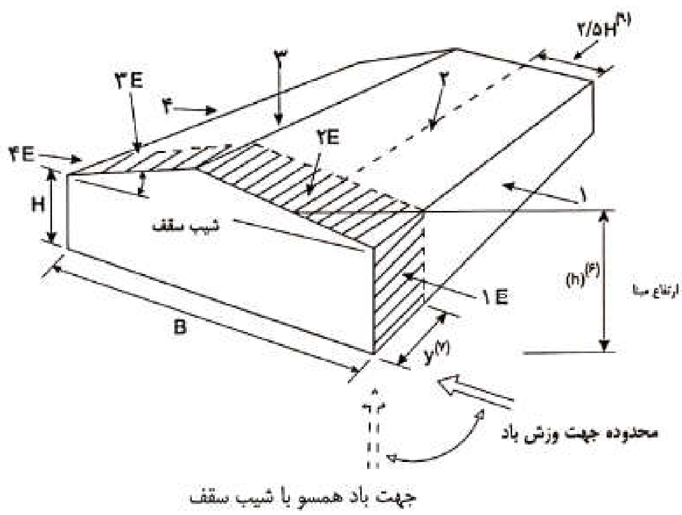

**Figure 11-**Applied Crane Dead load (CRD) on Structure (ton)

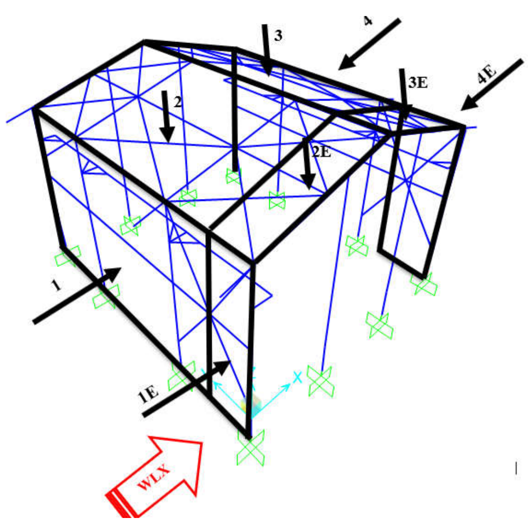
## 6.6 WIND LOADS

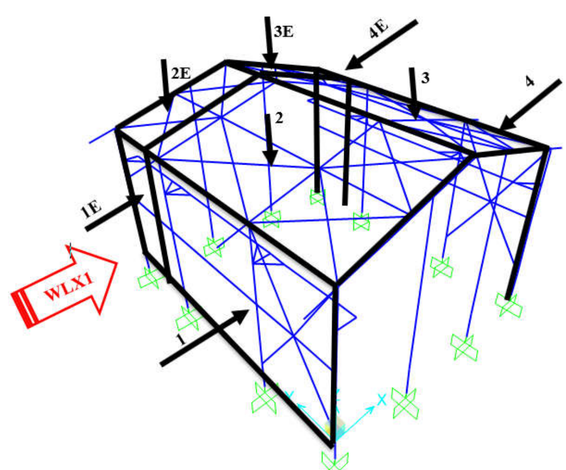
Wind loads are calculated for shelter building (according to Iranian National Building Code No.6 last edition) and applied at model as below:

| | | |
|---|---|---|
| سرعت باد (Km/h) | 120 | Km/h |
| فشار مبنای باد(q) | 0.681 | kPa |
| ضریب اهمیت(I) | 1 | جدول 6-1-2 |
| ارتفاع متوسط بام (کمتر از 6m نباشد) (H) | 7.4 | m |
| ارتفاع بازشو از سطح زمین | 3 | m |
| عرض سوله (کمترین بعد افقی در پلان) | 12 | m |
| نوع زمین | باز | بند 6-10-6-1 |
| Ce | 0.941556409 | - |
| Cgi | 2 | بند 6-10-8-1 |
| Cpi (گروه 1، 2، یا 3) | 3 | بند 6-10-11 |
| Cpi (positive) | 0.7 | بند 6-10-11 |
| Cpi (Negative) | -0.7 | بند 6-10-11 |
| شیب بام | 11 | درجه |
| y (فاصله قابها) | 4 | صفحه 87 مبحث ششم (m) |
| z | 1.2 | صفحه 87 مبحث ششم (m) |
| Cd | 0.85 | بند 6-10-12 |
| Ct | 1 | بند 6-10-7 |

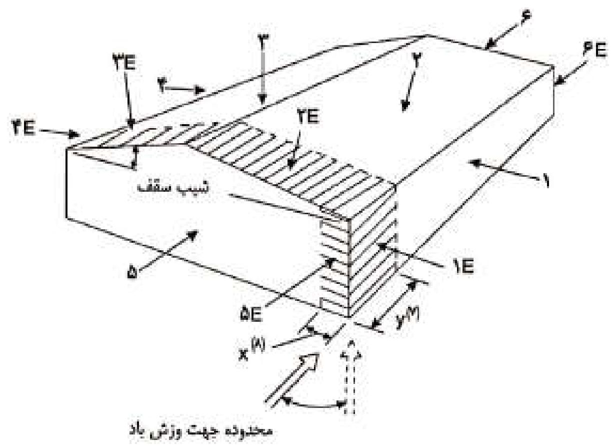
| | 1 | 1E | 2 | 2E | 3 | 3E | 4 | 4E |
|---|---|---|---|---|---|---|---|---|
| شکل الف-CgCp | 0.85 | 1.29 | -1.3 | -2 | -0.78 | -1.12 | -0.65 | -0.96 |
| P=I*q*Ct*Ce*CgCp*Cd(kPa) | 0.463 | 0.703 | -0.708 | -1.090 | -0.425 | -0.610 | -0.354 | -0.523 |
| Pi (kPa) | 0.763 | 0.763 | -0.763 | -0.763 | -0.763 | -0.763 | -0.763 | -0.763 |
| P+Pi (kPa) | 1.226 | 1.466 | -1.471 | -1.853 | -1.188 | -1.373 | -1.117 | -1.286 |
| **WLX & WLX1 (kg/m2)** | **122.63** | **146.61** | **-147.16** | **-185.31** | **-118.81** | **-137.35** | **-111.73** | **-128.62** |



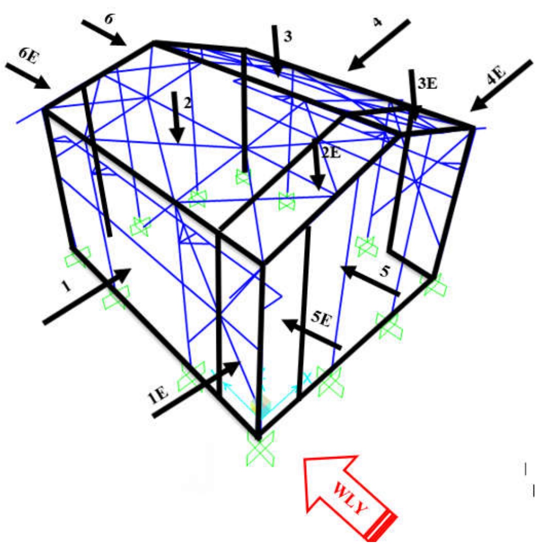



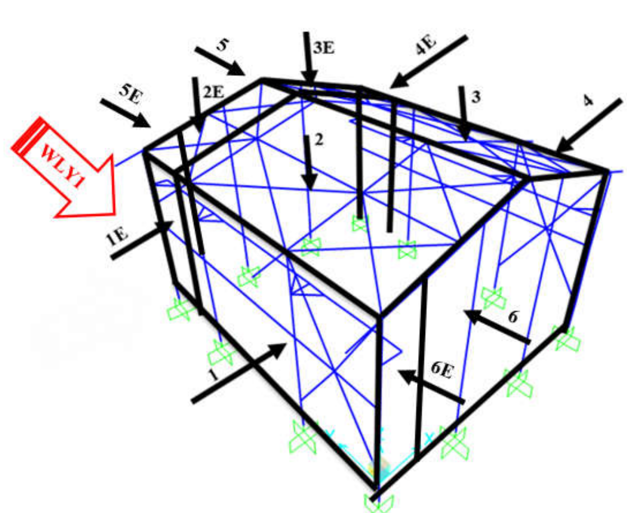



| | 1 | 1E | 2 | 2E | 3 | 3E | 4 | 4E | 5 | 5E | 6 | 6E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CgCp-شکل ب | -0.85 | -0.9 | -1.3 | -2 | -0.7 | -1 | -0.85 | -0.9 | 0.75 | 1.15 | -0.55 | -0.8 |
| P=I*q*Ct*Ce*CgCp*Cd (kPa) | -0.463 | -0.490 | -0.708 | -1.090 | -0.381 | -0.545 | -0.463 | -0.490 | 0.408 | 0.626 | -0.299 | -0.436 |
| Pi (kPa) | -0.763 | -0.763 | -0.763 | -0.763 | -0.763 | -0.763 | -0.763 | -0.763 | 0.763 | 0.763 | -0.763 | -0.763 |
| P+Pi (kPa) | -1.226 | -1.253 | -1.471 | -1.853 | -1.144 | -1.308 | -1.2267 | -1.253 | 1.171 | 1.389 | -1.062 | -1.199 |
| **WLY & WLY1 (kg/m2)** | **-122.63** | **-125.35** | **-147.16** | **-185.31** | **-114.45** | **-130.80** | **-122.63** | **-125.35** | **117.18** | **138.98** | **-106.28** | **-119.90** |

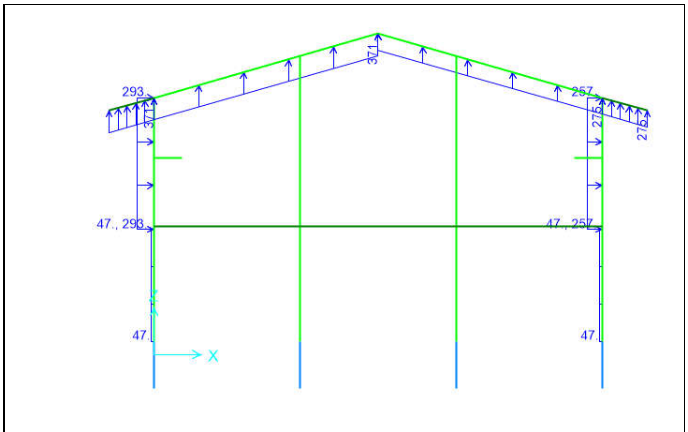



جهت باد عمود بر شیب سقف

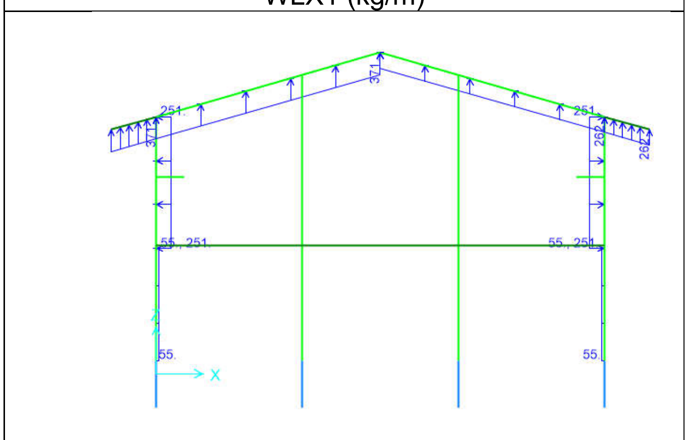


### 6.6.1. Wind loading on Frame “1,4”:

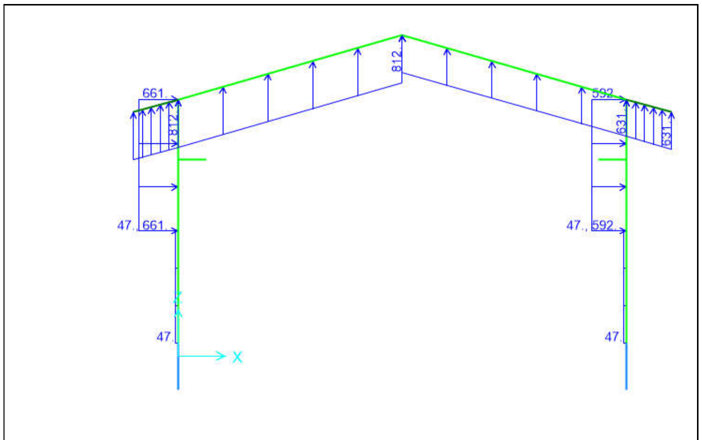



WLX1 (kg/m)

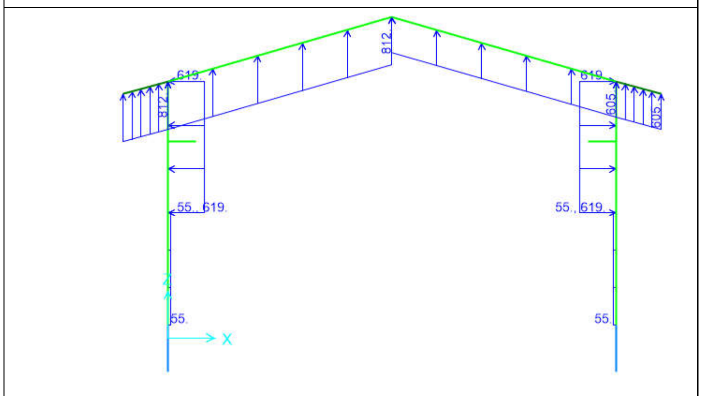



WLY1 (kg/m)

### 6.6.2. Wind loading on Frame "2,3":




WLX1 (kg/m)




WLY1 (kg/m)

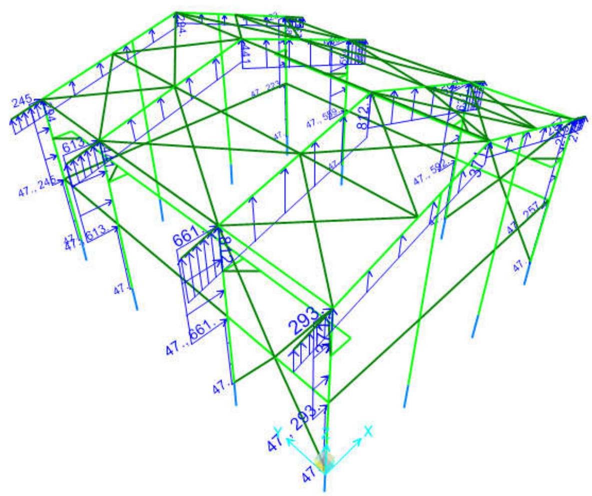



**Figure 12-**Applied Wind load (WLX1) on Structure (kg/m)

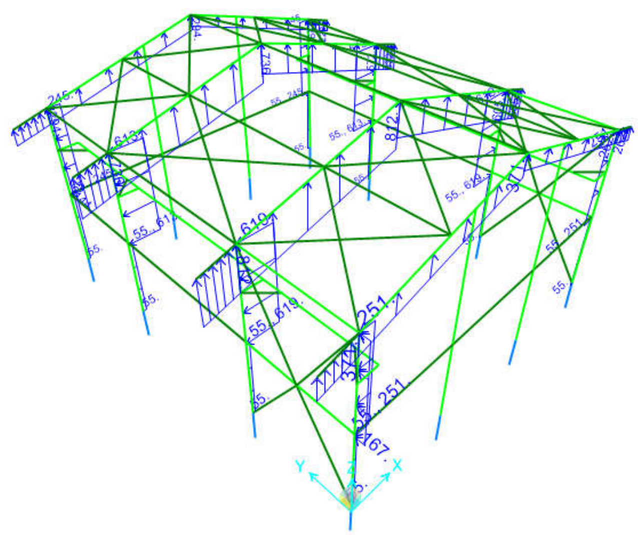
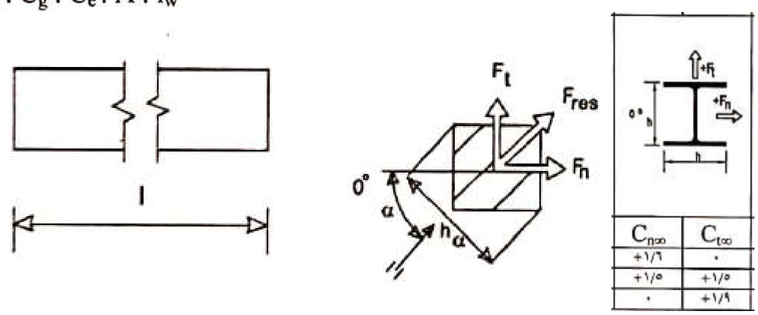



**Figure 14-**Applied Wind load (WLY1) on Structure (kg/m)

- For columns wind load applied as below (according to INBC no.6)

$F_n = K \cdot C_{n\infty} \cdot q \cdot C_g \cdot C_e \cdot A \cdot l_w$

$F_t = K \cdot C_{t\infty} \cdot q \cdot C_g \cdot C_e \cdot A \cdot l_w$




$\alpha = 0 \quad C_{n\infty} = 1.6$

$\alpha = 90 \quad C_{t\infty} = 1.9$

$F_n = F_x = K.C_{n\infty}.q.Cq.Ce.A.Iw$

$F_t = F_x = K.C_{t\infty}.q.Cq.Ce.A.Iw$

$F_n = F_x = 0.75 \times 1.6 \times 0.681 \times 2 \times 0.941 \times 0.3 \times 1 = 0.4613KN = 46.13\ \ kg$

$Wx_n = F_x = 46.13\ \ kg/m$
$Wyn = F_y = 0.75 \times 1.9 \times 0.681 \times 2 \times 0.941 \times 0.3 \times 1 = 0.5479\ kN/m = 54.79kg/m$

## 6.7. Thermal Load:

Thermal loads are those forces caused by a change in temperature. for this area assumed 28℃.

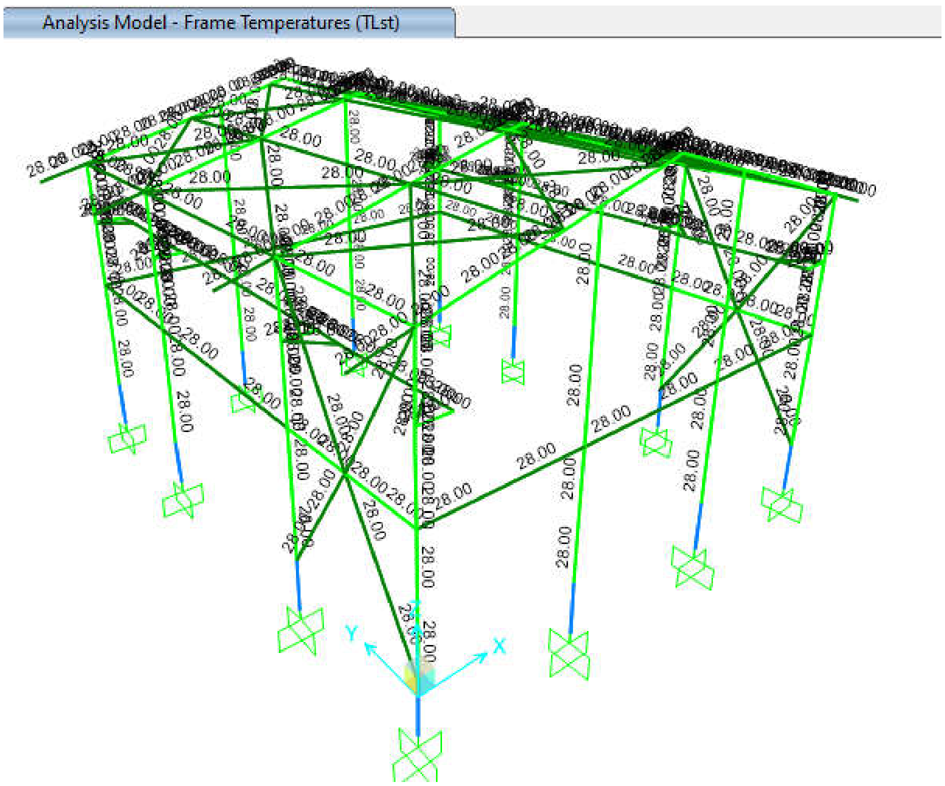



**Figure 16-**Applied Thermal Load (TLst) on Structure

## 7.0 SAP2000 Load Pattern

| TABLE: | |
|---|---|
| **LoadPat** | **Notes** |
| DEAD | Dead Load |
| Live | Live Load |
| S | Snow Load |
| EQX | Seismic Load in Dir X |
| EQY | Seismic Load in Dir Y |
| WLX1 | Wind Load in in Dir X (senario 1) |
| WLY1 | Wind Load in in Dir Y (senario 1) |
| WLX2 | Wind Load in in Dir X (senario 2) |
| WLY2 | Wind Load in in Dir Y (senario 2) |
| CRD | Crane Dead Load |
| CRO1 | Crane Operation Load (Senario 1) |
| TLst | Temperature Load |
| NotionalX(DL) | Notional Dead Load in Dir X |
| NotionalY(DL) | Notional Dead Load in Dir Y |
| NotionalX(LL) | Notional Live Load in Dir X |
| NotionalY(LL) | Notional Live Load in Dir Y |
| CRO2 | Crane Operation Load (Senario 2) |
| Soil | Soil Load |
| Ev | Vertical Sesimic Load |
| NotionalX(CRO1) | Notional CRO1 Load in Dir X |
| NotionalY(CRO1) | Notional CRO1 Load in Dir Y |
| NotionalX(CRO2) | Notional CRO2 Load in Dir X |
| NotionalY(CRO2) | Notional CRO2 Load in Dir Y |
| NotionalX(CRD) | Notional CRD Load in Dir X |
| NotionalY(CRD) | Notional CRD Load in Dir Y |

## 8.0 Load combinations

According to code INBC No.6 structures, components, and foundations shall be designed, so that their design strength equals or exceeds that effect of factored loads in the following combination:

- *1.4(D)*
- *(1.2D) +1.6(L)+0.5(Lr/S/R)*
- *1.2D+1.6(Lr/S/R) + (L/0.5W)*
- *1.2D+1.0(W) + L+.5(Lr/S)*
- *1.2D+1.0E+L+0.2S*
- *0.9D+1.0W*
- *0.9D+1.0E*

Load listed herein shall be considered to act in the following combinations; whichever produces the most unfavourable effect considering soil reactions.

- *D*
- *D+L*
- *D+(Lr/S/R)*
- *D+0.75(L)+0.75(Lr/R/S)*
- *D+(0.6W or 0.7E)*
- *D+0.75L+0.75(0.6W)+0.75(Lr/S/R)*
- *D+0.75L+0.75(0.7E)+0.75S*
- *0.6D+0.6W*
- *0.6D+0.7E*

# 9.0 STRUCTURE ANALYSIS AND DESIGN

## 9.1 ANALYSIS

Structural analysis is done by SAP2000 software. In model loads are applied, some graphical outputs from model are shown as follows.

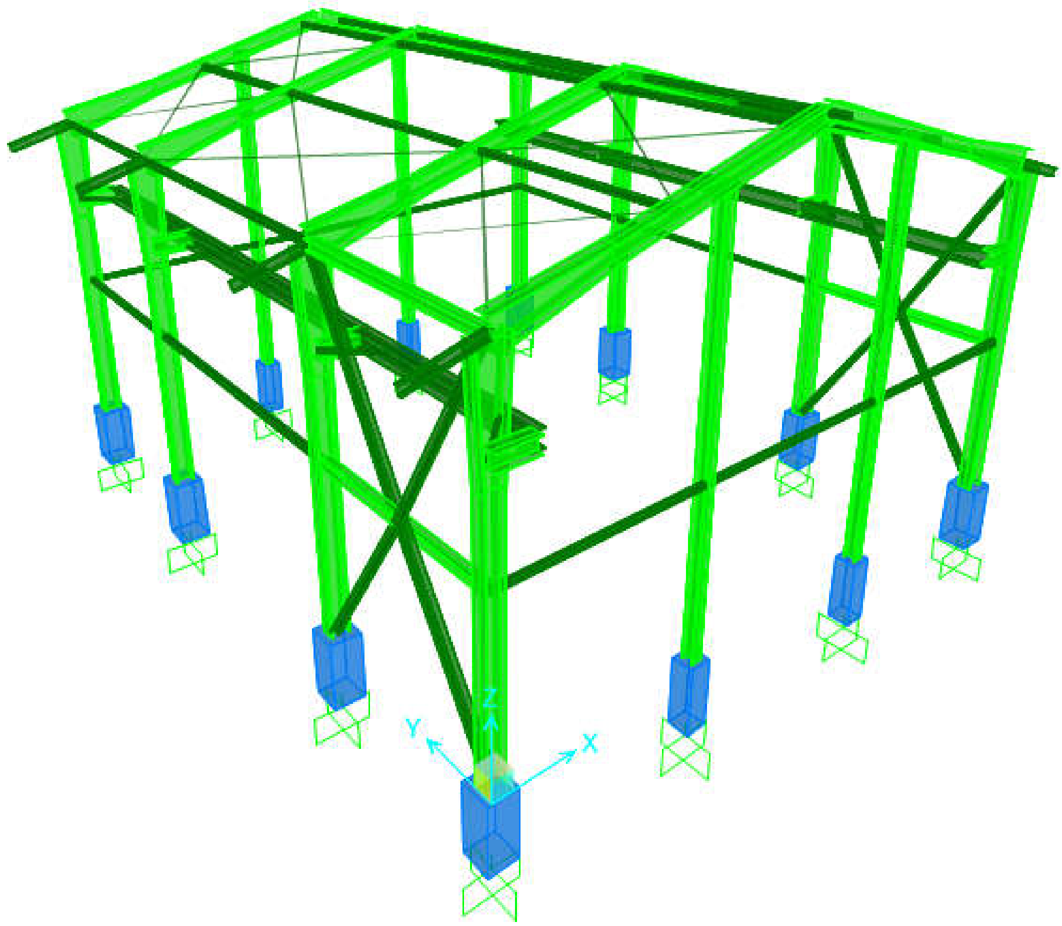



**Figure 12-3D VIEW OF SAP MODEL**

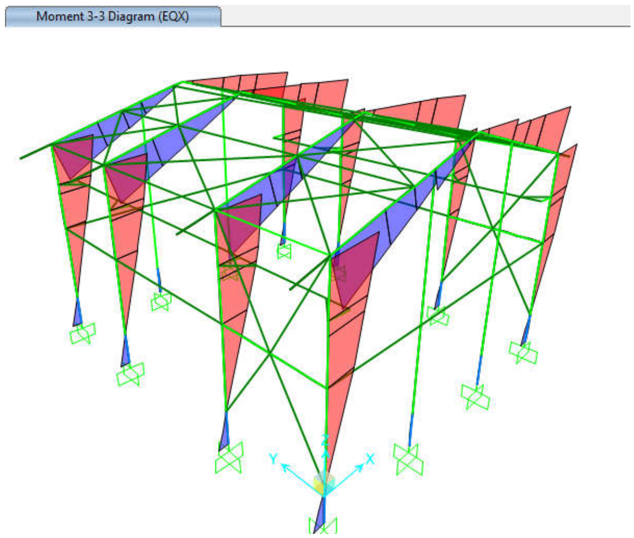



Figure 13: MOMENT 3-3 UNDER EQX LOAD

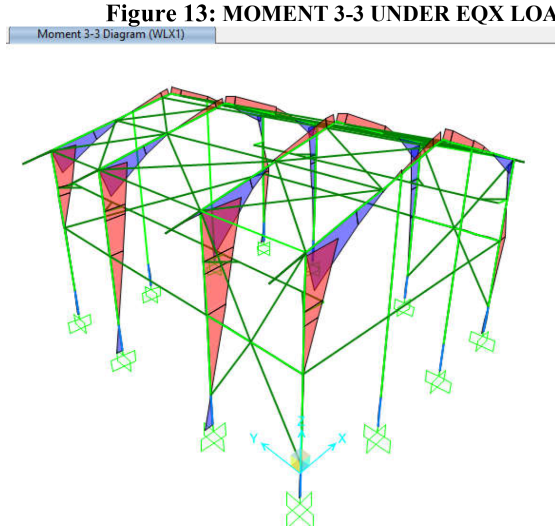



Figure 14: MOMENT 3-3 WLX1 LOAD

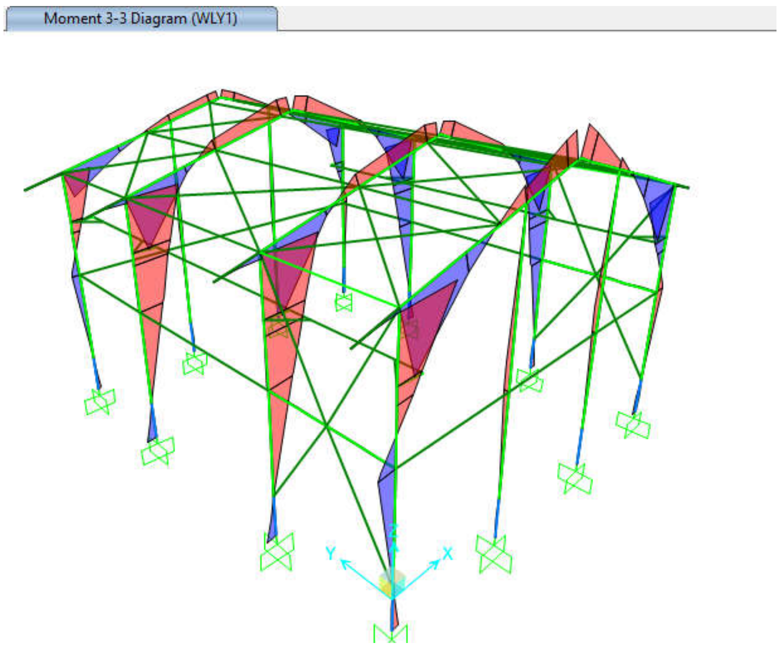



**Figure 15: MOMENT 3-3  WLY1 LOAD**

## 9.2 DRIFT CONTROL:

According to “Civil & Structural Design Criteria”, horizontal displacements for shelter shall not exceed H/200.

$$allowable\ drift\ is\ \frac{h}{200} = \frac{686}{200} = 3.43cm$$

The maximum displacement is less than H/200, so the displacement values are acceptable

| TABLE: Joint Displacements | | | | | | |
|---|---|---|---|---|---|---|
| **Joint** | **OutputCase** | **CaseType** | **StepType** | **U1** | **U2** | **U3** |
| Text | Text | Text | Text | cm | cm | cm |
| 17 | ENV-A | Combination | Max | 2.899 | 0.045 | 0.225 |
| 17 | ENV-A | Combination | Min | -3.286 | -0.172 | 0.119 |
| 18 | ENV-A | Combination | Max | 3.428 | 0.038 | 0.225 |
| 18 | ENV-A | Combination | Min | -2.790 | -0.167 | 0.123 |
| 38 | ENV-A | Combination | Max | 2.910 | 0.191 | 0.219 |
| 38 | ENV-A | Combination | Min | -3.355 | -0.039 | 0.109 |
| 39 | ENV-A | Combination | Max | 3.401 | 0.184 | 0.220 |
| 39 | ENV-A | Combination | Min | -2.805 | -0.035 | 0.114 |
| 43 | ENV-A | Combination | Max | 2.846 | 0.429 | 0.218 |
| 43 | ENV-A | Combination | Min | -3.314 | 0.119 | 0.107 |
| 44 | ENV-A | Combination | Max | 3.402 | 0.421 | 0.214 |
| 44 | ENV-A | Combination | Min | -2.765 | 0.126 | 0.111 |
| 48 | ENV-A | Combination | Max | 2.846 | 0.568 | 0.217 |
| 48 | ENV-A | Combination | Min | -3.248 | 0.195 | 0.114 |
| 49 | ENV-A | Combination | Max | 3.376 | 0.559 | 0.213 |
| 49 | ENV-A | Combination | Min | -2.746 | 0.211 | 0.119 |
| | | | MAX | 3.4276 | | |

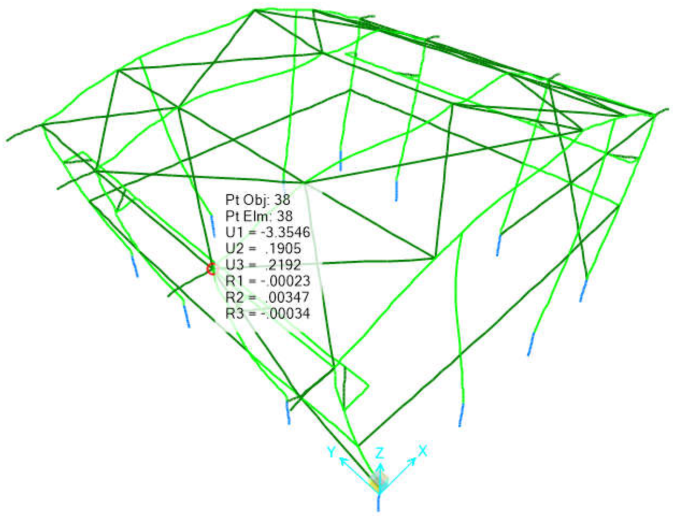



**Figure 16: Maximum displacement (Envelope Allowable)**

## 10. Structural Design Results

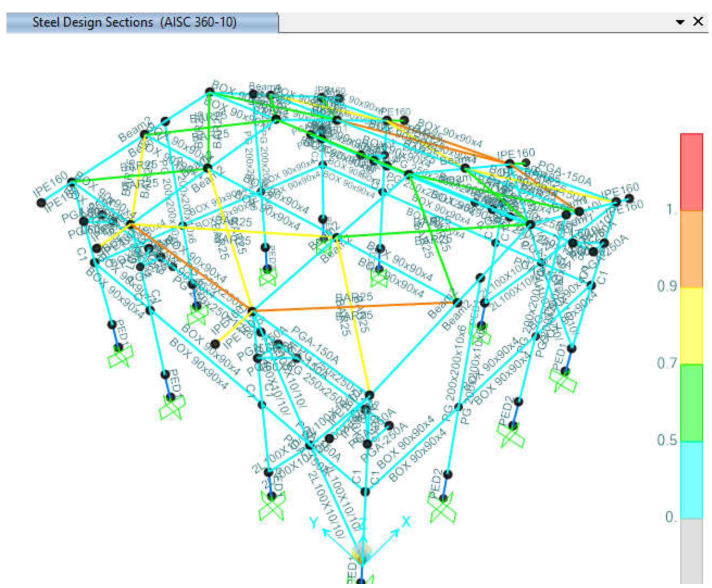
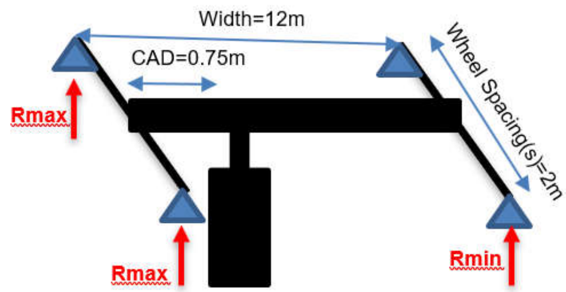


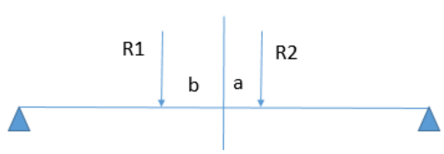

**Figure 17: M-P interaction Ratio of Shelter Elements**

## 11. FLEXTURAL DESIGN OF CRANE BEAM




| | | |
|---|---|---|
| Lifted Crane Load = LCL | 2 | ton |
| Crane Weight = CW | 0.117 | ton/m |
| Trolley and Hoist Weight = THW | 2 | ton |
| Crane Approach = CAD | 0.75 | m |
| Shelter Width | 12 | m |
| The Maximum Load Factor for this span based on the side approach is | 0.9375 | - |
| The Minimum Load Factor for this span based on the side approach is | 0.0625 | - |
| **There are 2 wheels per truck and 2 trucks per crane for a total of 4 wheels for this crane.** | | |
| Wheels per Truck = TrW | 2 | - |
| Total number of Wheels = TTrW | 4 | - |
| Maximum Wheel Load (Rmax) | 2.226 | ton |
| Minimum Wheel Load (Rmin) | 0.476 | ton |

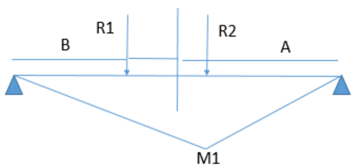
$(R1, R2)max$=(2.226,2.226)=4.452ton




$$b = \frac{2.226 \times (a+b) + 2.226 \times 0}{4.452 \times 1.25} = \frac{2.226 \times (2) + 2.226 \times 0}{4.452 \times 1.25} = 0.8m$$

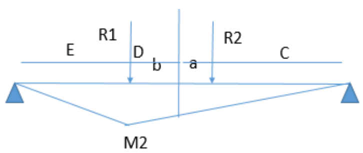
b = 2 - 0.8 = 1.2m

According to below moment diagram under R2 load calculation is:




$$M1 = \frac{P1AB}{L} = \frac{2.226 \times 2.4 \times 3.6}{6} = 3.205\ ton.m$$

According to below moment diagram under R2 load calculation is:




$$M2 = \frac{C}{C+D}\frac{P2.E.(D+C)}{L} = \frac{2.4}{4.4} \times \frac{2.226 \times 0.6 \times 4.4}{6} = 0.534\ ton.m$$

$$Mu = 3.205 + 0.534 = 3.739\ ton.m$$

$$f = 0.6Fy = \frac{M}{S} \qquad Sreq = \frac{3.739 \times 1000 \times 100}{0.6 \times 2400} = 259.652\ cm^3$$

According to above calculation crane support beam needs 259.652 $cm^3$ modulus.

$\underline{Sused = 1035.51cm^3\ \ OK}$

$Wgt = 2.226 \times 1.25 = 2.7825\ ton$

$Ft(transverse\ direction) = 0.2 \times 2.7825 = 0.5565\ ton$

$FL(longitudinal\ direction) = 0.1 \times 2.7825 = 0.278\ ton$

$Wgt = 2.226 \times 1.25 = 2.7825\ ton$

$Ft(transverse\ direction) = 0.2 \times 2.7825 = 0.5565\ ton$

$FL(longitudinal\ direction) = 0.1 \times 2.7825 = 0.278\ ton$

### 11.1. Deflection control

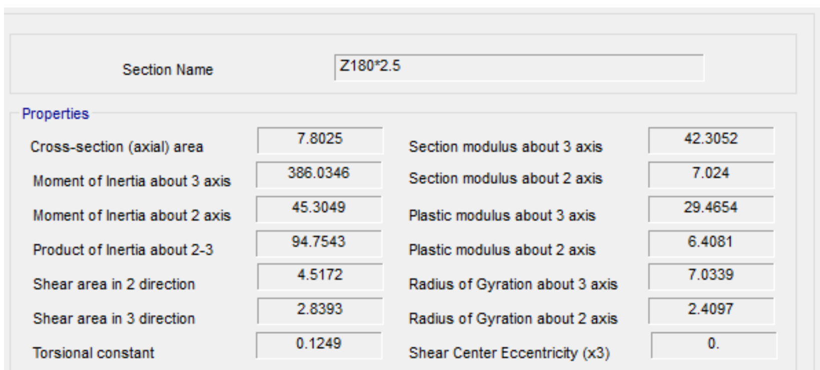
Maximum beam deflection under crane live load on shelter is:

$$\delta_{max} = \frac{PL^3}{48EI} = \frac{4.452 \times 1000 \times 600^3}{48 \times 2.1 \times 10^6 \times 17085} = 0.55\ cm$$

$$\delta_{all} = \frac{L}{1000} = \frac{600}{1000} = 0.6\ cm > 0.55\ cm\ \ ok$$

## 12. PURLIN DESIGN

### 12.1. PROPERTY OF PURLIN(Z180X2.5)



Section Name: Z180*2.5

Properties

| | | | |
|---|---|---|---|
| Cross-section (axial) area | 7.8025 | Section modulus about 3 axis | 42.3052 |
| Moment of Inertia about 3 axis | 386.0346 | Section modulus about 2 axis | 7.024 |
| Moment of Inertia about 2 axis | 45.3049 | Plastic modulus about 3 axis | 29.4654 |
| Product of Inertia about 2-3 | 94.7543 | Plastic modulus about 2 axis | 6.4081 |
| Shear area in 2 direction | 4.5172 | Radius of Gyration about 3 axis | 7.0339 |
| Shear area in 3 direction | 2.8393 | Radius of Gyration about 2 axis | 2.4097 |
| Torsional constant | 0.1249 | Shear Center Eccentricity (x3) | 0. |

**FIGURE 18-**Section Property Of Purlin

According to above table :

$A = 7.80\ cm2$

$J = 0.12\ cm4$

$Ix = 386.06\ cm4$

$Iy = 45.304\ cm4$

$rx = 7.033\ cm$

$ry = 2.41\ cm$

$ho = 18\ cm$

$SY = 42.305\ cm3$

$SX = 7.024\ cm3$

<u>FOR Z 180 :</u>

$\mathrm{D + L = 26 + 50 = 76\ kg/m^2}$

$\mathrm{P_y = 76.\cos 11 = 74.6\ \ kg/m^2}$

$\mathrm{P_x = 76.\sin 11 = 14.5\ \ kg/m^2}$

$$\text{middle of span}:\ M_y = \frac{w.L^2}{8} = \frac{74.6 \times 1.0 \times 6^2}{8} = 335.7\ \text{kg.m}$$

$$\text{middle of span}:\ M_x = \frac{w.L^2}{360} = \frac{14.5 \times 1 \times 6^2}{360} = 1.45\ \text{kg.m}$$

$$f_b = \frac{M_y}{s_y} + 2\frac{M_x}{s_x} = \frac{335.7 \times 100}{42.305} + 2\frac{1.45 \times 100}{7.024} = 793.52 + 41.28 = 834.8 < 1440\ \text{ok}$$

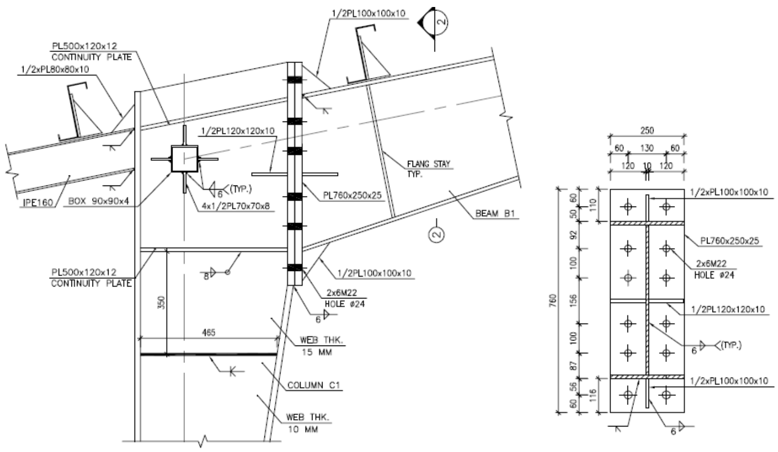
$$\text{moment on sagrod support}:\ M_y = \frac{w.L^2}{9} = \frac{74.6 \times 1.0 \times 6^2}{9} = 298.4\ \text{kg.m}$$

$$\text{moment on sagrod support}:\ M_x = \frac{w.L^2}{90} = \frac{14.5 \times 1.0 \times 6^2}{90} = 5.8\ \text{kg.m}$$

$$f_b = \frac{M_y}{s_y} + 2\frac{M_x}{s_x} = \frac{298.4 \times 100}{42.305} + 2\frac{5.8 \times 100}{7.024} = 705.35 + 165.14 = 870.49 < \ 1440 \quad \text{ok}$$

## 13. STRUCTURE CONNECTIONS

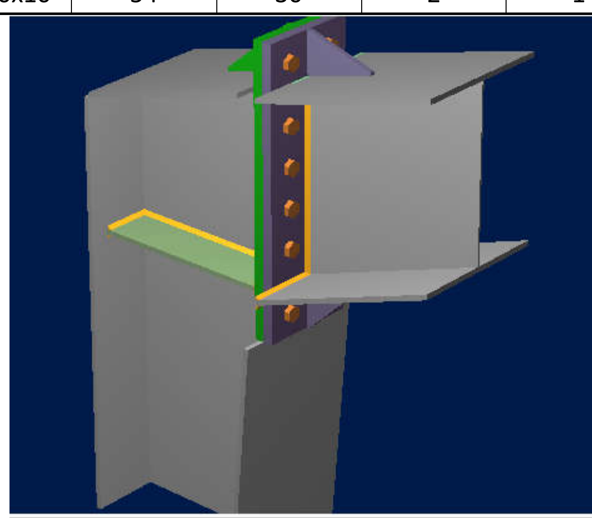
### 13.1. Beam To Column




**Input Data:**

Connection Type: Moment End Plate of PG 550x250x20x8 (Rigid Connection)

| Member | Section Name | d | Bf | tf | tw | Area | Z33 |
|---|---|---|---|---|---|---|---|
| | | cm | cm | cm | cm | cm2 | cm3 |
| Beam | PG 500x300x12x8 | 52.4 | 30 | 1.2 | 1 | 122 | 2468.2 |
| Column | PG 500x300x20x10 | 54 | 30 | 2 | 1 | 170 | 3745 |



Design Load: (Based on Capacity of Member)
According to AISC360-16:

$$M_{pr} = Z_{3-3}F_y = 2468 * 2400 = 5923200\ kgf - cm \qquad \text{(F2-1)}$$
$$M_u = 1.1RyMpr = 1.1 * 1.15 * 5923200 = 7492848\ kgf - cm$$
$$V_u = \frac{2M_u}{L_B} = \frac{2 * 7492848}{600} = 24976\ \ kgf$$

| Load | Vu | Mu |
|---|---|---|
| Unit(Ton, m) | 21.42 | 64.25 |

RAM® Connection
CONNECT Edition

**Current Date:** 10/16/2023 10:47 AM
**Units system:** SI

# Steel connections

**Results**

---

**Connection name : MEP_KNEE_BCF_VERTICAL_EU_1/4_PL_2B_1B1/2**
**Connection ID : 1**

---

Family: Beam - Column flange (BCF)
Type: Knee moment end plate
Design code: AISC 360-16 LRFD

**DEMANDS**

| Description | Beam Ru [kN] | Beam Pu [kN] | Beam Mu [kN*m] | Right beam PufTop [kN] | Right beam PufBot [kN] | Left beam PufTop [kN] | Left beam PufBot [kN] | Column Pu [kN] | Panel Vu [kN] | Load type |
|---|---|---|---|---|---|---|---|---|---|---|
| DL | 105.13 | 20.44 | 321.25 | -648.46 | 668.89 | 0.00 | 0.00 | 0.00 | 668.89 | Design |

**GEOMETRIC CONSIDERATIONS**

| Dimensions | Unit | Value | Min. value | Max. value | Sta. | References |
|---|---|---|---|---|---|---|
| Extended end plate | | | | | | |
| End plate stiffener thickness | [mm] | 12.00 | 8.00 | -- | ✔ | DG4 Eq. 3.15, AISC 358-10 Eq. 6.10-9, Eq. 6.10-10 |
| Vertical edge distance | [mm] | 60.00 | 29.94 | 152.40 | ✔ | Sec. J3.5 |
| Horizontal edge distance | [mm] | 60.00 | 29.94 | 152.40 | ✔ | Sec. J3.5 |
| Vertical bolt spacing (external flange) | [mm] | 100.00 | 58.67 | -- | ✔ | Sec. J3.3 |
| Vertical bolt spacing (internal flange) | [mm] | 100.00 | 58.67 | -- | ✔ | Sec. J3.3 |
| Horizontal center-to-center spacing (gage) | [mm] | 130.00 | 58.67 | 250.00 | ✔ | Sec. J3.3, |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | DG4 Sec. 2.4, DG4 Sec. 2.1, 2.4, DG16 Sec. 2.5 |
| Outer bolt distance (external flange) | [mm] | 50.00 | 34.70 | -- | ✔ | DG4 Sec. 2.1 |
| Inner bolt distance (external flange) | [mm] | 87.00 | 34.70 | -- | ✔ | DG4 Sec. 2.1 |
| Outer bolt distance (internal flange) | [mm] | 60.00 | 34.70 | -- | ✔ | DG4 Sec. 2.1 |
| Inner bolt distance (internal flange) | [mm] | 87.00 | 34.70 | -- | ✔ | DG4 Sec. 2.1 |
| Bolt diameter | [mm] | 22.00 | -- | 38.10 | ✔ | DG4 Sec. 1.1 |
| - Use CJP weld for the end plate stiffener | | | | | | |
| Beam | | | | | | |
| Weld size (internal flange) | [1/16in] | 6 | 3 | -- | ✔ | table J2.4 |
| Web | [1/16in] | 6 | 3 | -- | ✔ | table J2.4 |
| Support | | | | | | |
| Horizontal edge distance | [mm] | 60.00 | 28.35 | 152.40 | ✔ | Sec. J3.5 |

**PLATE / COLUMN BEHAVIOR**

End plate behaviour (external flange)
Thin plate behavior controlled by bolt rupture with prying action

End plate behaviour (internal flange)
Thin plate behavior controlled by bolt rupture with prying action

Connection plate behavior (external flange)
Thick plate behavior controlled by no prying bolt rupture

Connection plate behavior (internal flange)
Thick plate behavior controlled by no prying bolt rupture

**DESIGN CHECK**

| Verification | Unit | Capacity | Demand | Ctrl EQ | Ratio | References |
|---|---|---|---|---|---|---|
| Moment end plate (external flange) | | | | | | |
| Flexural yielding | [KN*m] | 544.80 | 0.00 | DL | 0.00 | DG16 Sec 2.5 |
| No prying bolt moment strength | [KN*m] | 436.28 | 0.00 | DL | 0.00 | DG16 Sec 2.5 |
| Bolt rupture with prying moment strength | [KN*m] | 345.01 | 0.00 | DL | 0.00 | DG16 Sec 2.5 |
| Bolts shear | [KN] | 608.57 | 105.13 | DL | 0.17 | Tables (7-1..14) |
| Bolt bearing under shear load | [KN] | 2375.37 | 0.00 | DL | 0.00 | Eq. J3-6 |
| Shear yielding | [KN] | 837.71 | 324.23 | DL | 0.39 | DG4 Eq. 3.12 |
| Shear rupture | [KN] | 869.62 | 324.23 | DL | 0.37 | DG4 Eq 3.14, AISC 358 Eq. 6.9-12, DG4 Eq. 3.13 |
| Moment end plate (internal flange) | | | | | | |
| Flexural yielding | [KN*m] | 515.61 | 326.23 | DL | 0.63 | DG16 Sec 2.5 |
| No prying bolt moment strength | [KN*m] | 439.80 | 326.23 | DL | 0.74 | DG16 Sec 2.5 |
| Bolt rupture with prying moment strength | [KN*m] | 346.91 | 326.23 | DL | 0.94 | DG16 Sec 2.5 |
| Bolts shear | [KN] | 608.57 | 0.00 | DL | 0.00 | Tables (7-1..14) |
| Bolt bearing under shear load | [KN] | 2375.37 | 105.13 | DL | 0.04 | Eq. J3-6 |
| Shear yielding | [KN] | 837.71 | 334.45 | DL | 0.40 | DG4 Eq. 3.12 |
| Shear rupture | [KN] | 869.62 | 334.45 | DL | 0.38 | DG4 Eq 3.14, AISC 358 Eq. 6.9-12, DG4 Eq. 3.13 |
| Beam | | | | | | |
| Web weld shear strength | [KN] | 709.31 | 105.13 | DL | 0.15 | Eq. J2-4 |
| Web weld strength to reach yield stress | [KN/m] | 4348.20 | 1787.11 | DL | 0.41 | Eq. J2-4, Eq. J4-1 |
| Shear yielding | [KN] | 595.70 | 105.13 | DL | 0.18 | Eq. J4-3 |
| Flange weld capacity (internal flange) | [KN] | 1079.53 | 668.89 | DL | 0.62 | Eq. J2-4 |
| Support | | | | | | |
| Flexural yielding (external flange) | [KN*m] | 834.58 | 0.00 | DL | 0.00 | DG4 Eq. 3.20, Sec. 2.2.3, DG4 Eq. 3.21 |
| Support bolt bearing (external flange) | [KN] | 2662.05 | 0.00 | DL | 0.00 | Eq. J3-6 |
| Flexural yielding (internal flange) | [KN*m] | 1129.30 | 326.23 | DL | 0.29 | DG4 Eq. 3.20, |

| | | | | | | |
|---|---|---|---|---|---|---|
| Support bolt bearing (internal flange) | [KN] | 2662.05 | 105.13 | DL | 0.04 | Sec. 2.2.3, DG4 Eq. 3.21 Eq. J3-6 |
| Support - right side | | | | | | |
| Local web yielding | [KN] | 1012.87 | 668.89 | DL | 0.66 | DG4 eq. 3.24, DG13 Eq. 4.3-1, Sec. J10 |
| Transverse stiffeners - bottom | | | | | | |
| Yielding strength due to axial load | [KN] | 664.81 | 320.83 | DL | 0.48 | Eq. J4-1 |
| Compression | [KN] | 447.36 | 0.00 | DL | 0.00 | Sec. J4.4 |
| Flange weld capacity | [KN] | 983.81 | 320.83 | DL | 0.33 | Eq. J2-4 |
| Web weld capacity | [KN] | 2509.83 | 320.83 | DL | 0.13 | Eq. J2-4 |
| **Global critical strength ratio** | **1.90** | | | | | |

RAM Connection
CONNECT Edition

**Current Date:** 10/16/2023 10:47 AM
**Units system:** SI

# Steel connections

## Results

**Connection name : MEP_KNEE_BCF_VERTICAL_EU_1/4_PL_2B_1B1/2**
**Connection ID : 1**

Family: Beam - Column flange (BCF)
Type: Knee moment end plate
Design code: AISC 360-16 LRFD

**DEMANDS**

| Description | Beam Ru [kN] | Beam Pu [kN] | Beam Mu [kN*m] | Right beam PufTop [kN] | Right beam PufBot [kN] | Left beam PufTop [kN] | Left beam PufBot [kN] | Column Pu [kN] | Panel Vu [kN] | Load type |
|---|---|---|---|---|---|---|---|---|---|---|
| DL | 105.13 | 20.44 | 321.25 | -648.46 | 668.89 | 0.00 | 0.00 | 0.00 | 668.89 | Design |

**GEOMETRIC CONSIDERATIONS**

| Dimensions | Unit | Value | Min. value | Max. value | Sta. | References |
|---|---|---|---|---|---|---|
| Extended end plate | | | | | | |
| End plate stiffener thickness | [mm] | 12.00 | 8.00 | -- | ✔ | DG4 Eq. 3.15, AISC 358-10 Eq. 6.10-9, Eq. 6.10-10 |

$t_{smin} = \max(t_{wb}*(F_{yb}/F_{ys}), (h_{st}/0.56)*(F_{ys}/E)^{1/2})$
$= \max(8[mm]*(248.21[N/mm2]/248.21[N/mm2]), (110[mm]/0.56)*(248.21[N/mm2]/2.00E+05[N/mm2])^{1/2})$
$= \mathbf{8}[mm]$

DG4 Eq. 3.15, AISC 358-10 Eq. 6.10-9, Eq. 6.10-10

| | | | | | | |
|---|---|---|---|---|---|---|
| Vertical edge distance | [mm] | 60.00 | 29.94 | 152.40 | ✔ | Sec. J3.5 |

$L_{emin} = e_{dmin} + C_2$
= 28.35[mm] + 1.588[mm]
= **29.938**[mm] — Tables J3.4, J3.5

$L_{emax}$ = min(12*$t_p$, 6 [in])
= min(12*25[mm], 6 [in])
= **152.4**[mm] — Sec. J3.5

| Check | Unit | Value | Min | Max | Status | Reference |
|---|---|---|---|---|---|---|
| Horizontal edge distance | [mm] | 60.00 | 29.94 | 152.40 | ✔ | Sec. J3.5 |

$L_{emin} = e_{dmin} + C_2$
= 28.35[mm] + 1.588[mm]
= **29.938**[mm] — Tables J3.4, J3.5

$L_{emax}$ = min(12*$t_p$, 6 [in])
= min(12*25[mm], 6 [in])
= **152.4**[mm] — Sec. J3.5

| Check | Unit | Value | Min | Max | Status | Reference |
|---|---|---|---|---|---|---|
| Vertical bolt spacing (external flange) | [mm] | 100.00 | 58.67 | -- | ✔ | Sec. J3.3 |

$s_{min}$ = 8/3*d
= 8/3*22[mm]
= **58.667**[mm] — Sec. J3.3

| Check | Unit | Value | Min | Max | Status | Reference |
|---|---|---|---|---|---|---|
| Vertical bolt spacing (internal flange) | [mm] | 100.00 | 58.67 | -- | ✔ | Sec. J3.3 |

$s_{min}$ = 8/3*d
= 8/3*22[mm]
= **58.667**[mm] — Sec. J3.3

| Check | Unit | Value | Min | Max | Status | Reference |
|---|---|---|---|---|---|---|
| Horizontal center-to-center spacing (gage) | [mm] | 130.00 | 58.67 | 250.00 | ✔ | Sec. J3.3, DG4 Sec. 2.4, DG4 Sec. 2.1, 2.4, DG16 Sec. 2.5 |

$g_{min}$ = Max(8/3*d, 2*$k_{1c}$ + 2*d, $t_{wb}$ + 2*w + $d_h$)
= Max(8/3*22[mm], 2*2.381[mm] + 2*22[mm], 8[mm] + 2*9.525[mm] + 26.763[mm])
= **58.667**[mm] — Sec. J3.3, DG4 Sec. 2.4

$g_{max}$ = $b_{fb}$
= **250**[mm] — DG4 Sec. 2.1, 2.4, DG16 Sec. 2.5

| Check | Unit | Value | Min | Max | Status | Reference |
|---|---|---|---|---|---|---|
| Outer bolt distance (external flange) | [mm] | 50.00 | 34.70 | -- | ✔ | DG4 Sec. 2.1 |

d< = 1 [in] → 22[mm]<
= 1 [in] → **True**

$p_{fmin}$ = d + 1/2 [in]
= 22[mm] + 1/2 [in]
= **34.7**[mm] — DG4 Sec. 2.1

| Check | Unit | Value | Min | Max | Status | Reference |
|---|---|---|---|---|---|---|
| Inner bolt distance (external flange) | [mm] | 87.00 | 34.70 | -- | ✔ | DG4 Sec. 2.1 |

d< = 1 [in] → 22[mm]<
= 1 [in] → **True**

| | | | | | | |
|---|---|---|---|---|---|---|
| $p_{fmin}$ = d + 1/2 [in] | | | | | | |
| = 22[mm] + 1/2 [in] | | | | | | |
| = **34.7**[mm] | | | | | | DG4 Sec. 2.1 |
| Outer bolt distance (internal flange) | [mm] | 60.00 | 34.70 | -- | ✔ | DG4 Sec. 2.1 |
| d< = 1 [in] → 22[mm]< | | | | | | |
| = 1 [in] → **True** | | | | | | |
| $p_{fmin}$ = d + 1/2 [in] | | | | | | |
| = 22[mm] + 1/2 [in] | | | | | | |
| = **34.7**[mm] | | | | | | DG4 Sec. 2.1 |
| Inner bolt distance (internal flange) | [mm] | 87.00 | 34.70 | -- | ✔ | DG4 Sec. 2.1 |
| d< = 1 [in] → 22[mm]< | | | | | | |
| = 1 [in] → **True** | | | | | | |
| $p_{fmin}$ = d + 1/2 [in] | | | | | | |
| = 22[mm] + 1/2 [in] | | | | | | |
| = **34.7**[mm] | | | | | | DG4 Sec. 2.1 |
| Bolt diameter | [mm] | 22.00 | -- | 38.10 | ✔ | DG4 Sec. 1.1 |
| $d_{bmax}$ = 1.5 [in] | | | | | | DG4 Sec. 1.1 |
| - Use CJP weld for the end plate stiffener | | | | | | |
| <u>Beam</u> | | | | | | |
| Weld size (internal flange) | [1/16in] | 6 | 3 | -- | ✔ | table J2.4 |
| $w_{min}$ = $w_{min}$ | | | | | | |
| = **0.004763** | | | | | | table J2.4 |
| Web | [1/16in] | 6 | 3 | -- | ✔ | table J2.4 |
| $w_{min}$ = $w_{min}$ | | | | | | |
| = **0.004763** | | | | | | table J2.4 |
| <u>Support</u> | | | | | | |
| Horizontal edge distance | [mm] | 60.00 | 28.35 | 152.40 | ✔ | Sec. J3.5 |
| $L_{emin}$ = $e_{dmin}$ + $C_2$ | | | | | | |
| = 28.35[mm] + 0[mm] | | | | | | |
| = **28.35**[mm] | | | | | | Tables J3.4, J3.5 |
| $L_{emax}$ = min(12*$t_p$, 6 [in]) | | | | | | |
| = min(12*25[mm], 6 [in]) | | | | | | |
| = **152.4**[mm] | | | | | | Sec. J3.5 |
| <u>Transverse stiffeners</u> | | | | | | |
| Length | [mm] | 462.30 | 225.00 | 450.00 | ✘ | Sec. J10.8 |
| $l_{smin}$ = ($d_c$ - 2*$t_{cf}$)/2 | | | | | | |
| = (500[mm] - 2*25[mm])/2 | | | | | | |
| = **225**[mm] | | | | | | Sec. J10.8 |
| $l_{smax}$ = $d_c$ - 2*$t_{cf}$ | | | | | | |
| = 500[mm] - 2*25[mm] | | | | | | |
| = **450**[mm] | | | | | | Sec. J10.8 |
| Width | [mm] | 125.00 | 80.95 | -- | ✔ | Sec. J10.8 |
| $b_{smin}$ = b/3 - $t_w$/2 | | | | | | |

= 250[mm]/3 - 4.762[mm]/2
= **80.952**[mm] — Sec. J10.8

Weld size — [1/16in] — 6 — 4 — -- — ✔ — DG 13 Eq. 4.3-6
$w_{min} = (0.943*F_{ys}*t_p)/F_{EXX}$
= (0.943*248.21[N/mm2]*12[mm])/482.631[N/mm2]
= **5.82**[mm] — DG 13 Eq. 4.3-6

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**PLATE / COLUMN BEHAVIOR**

End plate behaviour (external flange)
Thin plate behavior controlled by bolt rupture with prying action
End plate behaviour (internal flange)
Thin plate behavior controlled by bolt rupture with prying action
Connection plate behavior (external flange)
Thick plate behavior controlled by no prying bolt rupture
Connection plate behavior (internal flange)
Thick plate behavior controlled by no prying bolt rupture

**DESIGN CHECK**

| Verification | Unit | Capacity | Demand | Ctrl EQ | Ratio | References |
|---|---|---|---|---|---|---|

Moment end plate (external flange)

| Flexural yielding | [KN*m] | 544.80 | 0.00 | DL | 0.00 | DG16 Sec 2.5 |
|---|---|---|---|---|---|---|

$s = 0.5*(b_p*g)^{1/2}$
$= 0.5*(250[mm]*130[mm])^{1/2}$
= **90.139**[mm] — DG16 Table 3-2

$p_{fi} = min(p_{fi}, s)$
= min(87[mm], 90.139[mm])
= **87**[mm] — DG16 Table 4-2

$Y_p = b_p/2*(h_1*(1/p_{fi}) + h_2*(1/s) + h_0*(1/p_{f0}) - 1/2) + 2/g*(h_1*(p_{fi} + 0.75*p_b) + h_2*(s + 0.25*p_b)) + g/2$
= 250[mm]/2*(400.775[mm]*(1/87[mm]) + 300.775[mm]*(1/90.139[mm]) + 550[mm]*(1/50[mm]) - 1/2) + 2/130[mm]*(400.775[mm]*(87[mm] + 0.75*100[mm]) + 300.775[mm]*(90.139[mm] + 0.25*100[mm])) + 130[mm]/2
= **3902.07**[mm] — DG16 Table 4-4

$M_{pl} = F_{yp}*t_p^2*Y_p$
$= 248.21[N/mm2]*25[mm]^2*3902.07[mm]$
= **605.332**[kN*m] — DG16 Sec 2.5

IsFlushConnection → **False**

$\gamma_r = 1$ — DG16 Sec 2.5

$\phi M_n = \phi_b*M_{pl}/\gamma_r$
= 0.9*605.332[kN*m]/1
= **544.799**[kN*m] — DG16 Sec 2.5

| No prying bolt moment strength | [KN*m] | 436.28 | 0.00 | DL | 0.00 | DG16 Sec 2.5 |
|---|---|---|---|---|---|---|

$P_t = A_b*F_{nt}$
= 380.133[mm2]*620.528[N/mm2]
= **235.883**[kN] — DG16 Sec 2.5

$M_{np} = 2*P_t*(\Sigma d_n)$
= 2*235.883[kN]*(1233.05[mm])
= **581.713**[kN*m] — DG16 Sec 2.5

$\phi M_n = \phi*M_{np}$

= 0.75*581.713[kN*m]
= **436.285**[kN*m] DG16 Sec 2.5

Bolt rupture with prying moment strength [KN*m] 345.01 0.00 DL 0.00 DG16 Sec 2.5

$P_t = A_b*F_{nt}$
= 380.133[mm2]*620.528[N/mm2]
= **235.883**[kN] DG16 Sec 2.5

$w' = b_p/2 - (d + 1/16$ [in])
= 250[mm]/2 - (22[mm] + 1/16 [in])
= **101.413**[mm] DG16 Sec 2.5

$a_i = 3.682*(t_p/d)^3$ [in] - 0.085 [in]
= $3.682*(25[mm]/22[mm])^3$ [in] - 0.085 [in]
= **135.077**[mm] DG16 Sec 2.5

$F_i' = (t_p^2*F_{yp}*(0.85*b_p/2 + 0.80*w') + \pi*d^3*F_{nt}/8)/(4*p_{fi})$
= $(25[mm]^2*248.21[N/mm2]*(0.85*250[mm]/2 + 0.80*101.413[mm]) + \pi*22[mm]^3*620.528[N/mm2]/8)/(4*87[mm])$
= **90.986**[kN] DG16 Sec 2.5

$discr = F_{yp}^2 - 3*(F_i'/(w'*t_p))^2$
= $248.21[N/mm2]^2 - 3*(90.986[kN]/(101.413[mm]*25[mm]))^2$
= **5.77E+10**[kN] DG16 Sec 2.5

$Q_{maxi} = (w'*t_p^2)/(4*a_i)*(F_{yp}^2 - 3*(F_i'/(w'*t_p))^2)^{1/2}$
= $(101.413[mm]*25[mm]^2)/(4*135.077[mm])*(248.21[N/mm2]^2 - 3*(90.986[kN]/(101.413[mm]*25[mm]))^2)^{1/2}$
= **28.189**[kN] DG16 Sec 2.5

$w' = b_p/2 - (d + 1/16$ [in])
= 250[mm]/2 - (22[mm] + 1/16 [in])
= **101.413**[mm] DG16 Sec 2.5

$F_o' = (t_p^2*F_{yp}*(0.85*b_p/2 + 0.80*w') + \pi*d^3*F_{nt}/8)/(4*p_{f0})$
= $(25[mm]^2*248.21[N/mm2]*(0.85*250[mm]/2 + 0.80*101.413[mm]) + \pi*22[mm]^3*620.528[N/mm2]/8)/(4*50[mm])$
= **158.316**[kN] DG16 Sec 2.5

$discr = F_{yp}^2 - 3*(F_o'/(w'*t_p))^2$
= $248.21[N/mm2]^2 - 3*(158.316[kN]/(101.413[mm]*25[mm]))^2$
= **4.99E+10**[kN] DG16 Sec 2.5

$a_o = min(3.682*(t_p/d)^3$ [in] - 0.085 [in], $p_{ext} - p_{f0})$
= $min(3.682*(25[mm]/22[mm])^3$ [in] - 0.085 [in], 110[mm] - 50[mm])
= **60**[mm] DG16 Sec 2.5

$Q_{maxo} = (w'*t_p^2)/(4*a_o)*(F_{yp}^2 - 3*(F_o'/(w'*t_p))^2)^{1/2}$
= $(101.413[mm]*25[mm]^2)/(4*60[mm])*(248.21[N/mm2]^2 - 3*(158.316[kN]/(101.413[mm]*25[mm]))^2)^{1/2}$
= **59**[kN] DG16 Sec 2.5

$M_q = Max(2*(P_t - Q_{maxo})*d_0 + 2*(P_t - Q_{maxi})*(d_1 + d_3) + 2*T_b*d_2, 2*(P_t - Q_{maxo})*d_0 + 2*T_b*(d_1 + d_2 + d_3), 2*(P_t - Q_{maxi})*(d_1 + d_3) + 2*T_b*(d_0 + d_2), 2*T_b*(d_0 + d_1 + d_2 + d_3))$
= Max(2*(235.883[kN] - 59[kN])*543.834[mm] + 2*(235.883[kN] - 28.189[kN])*(394.609[mm] + 0[mm]) + 2*176[kN]*294.609[mm], 2*(235.883[kN] - 59[kN])*543.834[mm] + 2*176[kN]*(394.609[mm] + 294.609[mm] + 0[mm]), 2*(235.883[kN] - 28.189[kN])*(394.609[mm] + 0[mm]) + 2*176[kN]*(543.834[mm] + 294.609[mm]), 2*176[kN]*(543.834[mm] + 394.609[mm] + 294.609[mm] + 0[mm]))
= **460.008**[kN*m] DG16 Sec 2.5

$\phi M_n = \phi*M_q$
= 0.75*460.008[kN*m]

= **345.006**[kN*m] DG16 Sec 2.5

| | | | | | | |
|---|---|---|---|---|---|---|
| Bolts shear | [KN] | 608.57 | 105.13 | DL | 0.17 | Tables (7-1..14) |

$k_{sc}$ = max(1 - $T_u$/(ϕ*$D_u$*$T_b$*$N_b$), 0.0)
= max(1 - 0[kN]/(1*1.13*176[kN]*12), 0.0)
= **1** Eq. J3-5

ϕ$R_n$ = ϕ*μ*$D_u$*$h_f$*$T_b$*$n_s$*$k_{sc}$
= 0.85*0.3*1.13*1*176[kN]*1*1
= **50.714**[kN] Eq. J3-4

ϕ$R_n$ = C*ϕ$R_n$
= 12*50.714[kN]
= **608.573**[kN] Tables (7-1..14)

| | | | | | | |
|---|---|---|---|---|---|---|
| Bolt bearing under shear load | [KN] | 2375.37 | 0.00 | DL | 0.00 | Eq. J3-6 |

$L_{c\text{-}end}$ = Max(0.0, $L_e$ - $d_h$/2)
= Max(0.0, 60[mm] - 26.763[mm]/2)
= **46.619**[mm] Sec. J3.10

$L_{c\text{-}spa}$ = Max(0.0, s - $d_h$)
= Max(0.0, 100[mm] - 26.763[mm])
= **73.238**[mm] Sec. J3.10

ϕ$R_n$ = ϕ*(min($k_1$*$L_{c\text{-}end}$, $k_2$*d) + min($k_1$*$L_{c\text{-}spa}$, $k_2$*d)*(n - 1))*$t_p$*$F_u$*$n_c$
= 0.75*(min(1.2*46.619[mm], 2.4*22[mm]) + min(1.2*73.238[mm], 2.4*22[mm])*(3 - 1))*25[mm]*399.894[N/mm2]*2
= **2375.37**[kN] Eq. J3-6

| | | | | | | |
|---|---|---|---|---|---|---|
| Shear yielding | [KN] | 837.71 | 324.23 | DL | 0.39 | DG4 Eq. 3.12 |

ϕ$R_n$ = ϕ*0.6*$F_{yp}$*$b_p$*$t_p$
= 0.9*0.6*248.21[N/mm2]*250[mm]*25[mm]
= **837.709**[kN] DG4 Eq. 3.12

| | | | | | | |
|---|---|---|---|---|---|---|
| Shear rupture | [KN] | 869.62 | 324.23 | DL | 0.37 | DG4 Eq 3.14, AISC 358 Eq. 6.9-12, DG4 Eq. 3.13 |

$L_h$ = $d_h$ + 1/16 [in]
= 26.763[mm] + 1/16 [in]
= **28.35**[mm] Sec. D3-2

$A_n$ = ($b_p$ - 2*$L_h$)*$t_p$
= (250[mm] - 2*28.35[mm])*25[mm]
= **4832.5**[mm2] DG4 Eq 3.14, AISC 358 Eq. 6.9-12

ϕ$R_n$ = ϕ*0.6*$F_{up}$*$A_n$
= 0.75*0.6*399.894[N/mm2]*4832.5[mm2]
= **869.619**[kN] DG4 Eq. 3.13

<u>Moment end plate (internal flange)</u>

| | | | | | | |
|---|---|---|---|---|---|---|
| Flexural yielding | [KN*m] | 515.61 | 326.23 | DL | 0.63 | DG16 Sec 2.5 |

s = 0.5*($b_p$*g)$^{1/2}$
= 0.5*(250[mm]*130[mm])$^{1/2}$
= **90.139**[mm] DG16 Table 3-2

$p_{fi}$ = min($p_{fi}$, s)
= min(87[mm], 90.139[mm])
= **87**[mm] DG16 Table 4-2

$Y_p = b_p/2*(h_1*(1/p_{fi}) + h_2*(1/s) + h_0*(1/p_{f0}) - 1/2) + 2/g*(h_1*(p_{fi} + 0.75*p_b) + h_2*(s + 0.25*p_b)) + g/2$
$= 250\text{[mm]}/2*(400.668\text{[mm]}*(1/87\text{[mm]}) + 300.668\text{[mm]}*(1/90.139\text{[mm]}) + 560\text{[mm]}*(1/60\text{[mm]}) - 1/2) + 2/130\text{[mm]}*(400.668\text{[mm]}*(87\text{[mm]} + 0.75*100\text{[mm]}) + 300.668\text{[mm]}*(90.139\text{[mm]} + 0.25*100\text{[mm]})) + 130\text{[mm]}/2$
$= \mathbf{3692.97}\text{[mm]}$ DG16 Table 4-4

$M_{pl} = F_{yp}*t_p^2*Y_p$
$= 248.21\text{[N/mm2]}*25\text{[mm]}^2*3692.97\text{[mm]}$
$= \mathbf{572.895}\text{[kN*m]}$ DG16 Sec 2.5

IsFlushConnection → **False**

$\gamma_r = 1$ DG16 Sec 2.5

$\phi M_n = \phi_b*M_{pl}/\gamma_r$
$= 0.9*572.895\text{[kN*m]}/1$
$= \mathbf{515.606}\text{[kN*m]}$ DG16 Sec 2.5

| | | | | | | |
|---|---|---|---|---|---|---|
| No prying bolt moment strength | [KN*m] | 439.80 | 326.23 | DL | 0.74 | DG16 Sec 2.5 |

$P_t = A_b*F_{nt}$
$= 380.133\text{[mm2]}*620.528\text{[N/mm2]}$
$= \mathbf{235.883}\text{[kN]}$ DG16 Sec 2.5

$M_{np} = 2*P_t*(\Sigma d_n)$
$= 2*235.883\text{[kN]}*(1243\text{[mm]})$
$= \mathbf{586.405}\text{[kN*m]}$ DG16 Sec 2.5

$\phi M_n = \phi*M_{np}$
$= 0.75*586.405\text{[kN*m]}$
$= \mathbf{439.804}\text{[kN*m]}$ DG16 Sec 2.5

| | | | | | | |
|---|---|---|---|---|---|---|
| Bolt rupture with prying moment strength | [KN*m] | 346.91 | 326.23 | DL | 0.94 | DG16 Sec 2.5 |

$P_t = A_b*F_{nt}$
$= 380.133\text{[mm2]}*620.528\text{[N/mm2]}$
$= \mathbf{235.883}\text{[kN]}$ DG16 Sec 2.5

$w' = b_p/2 - (d + 1/16\ \text{[in]})$
$= 250\text{[mm]}/2 - (22\text{[mm]} + 1/16\ \text{[in]})$
$= \mathbf{101.413}\text{[mm]}$ DG16 Sec 2.5

$a_i = 3.682*(t_p/d)^3\ \text{[in]} - 0.085\ \text{[in]}$
$= 3.682*(25\text{[mm]}/22\text{[mm]})^3\ \text{[in]} - 0.085\ \text{[in]}$
$= \mathbf{135.077}\text{[mm]}$ DG16 Sec 2.5

$F_i' = (t_p^2*F_{yp}*(0.85*b_p/2 + 0.80*w') + \pi*d^3*F_{nt}/8)/(4*p_{fi})$
$= (25\text{[mm]}^2*248.21\text{[N/mm2]}*(0.85*250\text{[mm]}/2 + 0.80*101.413\text{[mm]}) + \pi*22\text{[mm]}^3*620.528\text{[N/mm2]}/8)/(4*87\text{[mm]})$
$= \mathbf{90.986}\text{[kN]}$ DG16 Sec 2.5

$discr = F_{yp}^2 - 3*(F_i'/(w'*t_p))^2$
$= 248.21\text{[N/mm2]}^2 - 3*(90.986\text{[kN]}/(101.413\text{[mm]}*25\text{[mm]}))^2$
$= \mathbf{5.77E+10}\text{[kN]}$ DG16 Sec 2.5

$Q_{maxi} = (w'*t_p^2)/(4*a_i)*(F_{yp}^2 - 3*(F_i'/(w'*t_p))^2)^{1/2}$
$= (101.413\text{[mm]}*25\text{[mm]}^2)/(4*135.077\text{[mm]})*(248.21\text{[N/mm2]}^2 - 3*(90.986\text{[kN]}/(101.413\text{[mm]}*25\text{[mm]}))^2)^{1/2}$
$= \mathbf{28.189}\text{[kN]}$ DG16 Sec 2.5

$w' = b_p/2 - (d + 1/16\ \text{[in]})$
$= 250\text{[mm]}/2 - (22\text{[mm]} + 1/16\ \text{[in]})$
$= \mathbf{101.413}\text{[mm]}$ DG16 Sec 2.5

$F_o' = (t_p^2*F_{yp}*(0.85*b_p/2 + 0.80*w') + \pi*d^3*F_{nt}/8)/(4*p_{f0})$
= (25[mm]$^2$*248.21[N/mm2]*(0.85*250[mm]/2 + 0.80*101.413[mm]) + π*22[mm]$^3$*620.528[N/mm2]/8)/(4*60[mm])
= **131.93**[kN] DG16 Sec 2.5

$discr = F_{yp}^2 - 3*(F_o'/(w'*t_p))^2$
= 248.21[N/mm2]$^2$ - 3*(131.93[kN]/(101.413[mm]*25[mm]))$^2$
= **5.35E+10**[kN] DG16 Sec 2.5

$a_o = \min(3.682*(t_p/d)^3$ [in] - 0.085 [in], $p_{ext} - p_{f0})$
= min(3.682*(25[mm]/22[mm])$^3$ [in] - 0.085 [in], 120[mm] - 60[mm])
= **60**[mm] DG16 Sec 2.5

$Q_{maxo} = (w'*t_p^2)/(4*a_o)*(F_{yp}^2 - 3*(F_o'/(w'*t_p))^2)^{1/2}$
= (101.413[mm]*25[mm]$^2$)/(4*60[mm])*(248.21[N/mm2]$^2$ - 3*(131.93[kN]/(101.413[mm]*25[mm]))$^2$)$^{1/2}$
= **61.077**[kN] DG16 Sec 2.5

$M_q = Max(2*(P_t - Q_{maxo})*d_0 + 2*(P_t - Q_{maxi})*(d_1 + d_3) + 2*T_b*d_2, 2*(P_t - Q_{maxo})*d_0 + 2*T_b*(d_1 + d_2 + d_3), 2*(P_t - Q_{maxi})*(d_1 + d_3) + 2*T_b*(d_0 + d_2), 2*T_b*(d_0 + d_1 + d_2 + d_3))$
= Max(2*(235.883[kN] - 61.077[kN])*553.888[mm] + 2*(235.883[kN] - 28.189[kN])*(394.556[mm] + 0[mm]) + 2*176[kN]*294.556[mm], 2*(235.883[kN] - 61.077[kN])*553.888[mm] + 2*176[kN]*(394.556[mm] + 294.556[mm] + 0[mm]), 2*(235.883[kN] - 28.189[kN])*(394.556[mm] + 0[mm]) + 2*176[kN]*(553.888[mm] + 294.556[mm]), 2*176[kN]*(553.888[mm] + 394.556[mm] + 294.556[mm] + 0[mm]))
= **462.546**[kN*m] DG16 Sec 2.5

$\phi M_n = \phi*M_q$
= 0.75*462.546[kN*m]
= **346.909**[kN*m] DG16 Sec 2.5

Bolts shear [KN] 608.57 0.00 DL **0.00** Tables (7-1..14)

$k_{sc} = \max(1 - T_u/(\phi*D_u*T_b*N_b), 0.0)$
= max(1 - 0[kN]/(1*1.13*176[kN]*12), 0.0)
= **1** Eq. J3-5

$\phi R_n = \phi*\mu*D_u*h_f*T_b*n_s*k_{sc}$
= 0.85*0.3*1.13*1*176[kN]*1*1
= **50.714**[kN] Eq. J3-4

$\phi R_n = C*\phi R_n$
= 12*50.714[kN]
= **608.573**[kN] Tables (7-1..14)

Bolt bearing under shear load [KN] 2375.37 105.13 DL **0.04** Eq. J3-6

$L_{c\text{-}end} = Max(0.0, L_e - d_h/2)$
= Max(0.0, 60[mm] - 26.763[mm]/2)
= **46.619**[mm] Sec. J3.10

$L_{c\text{-}spa} = Max(0.0, s - d_h)$
= Max(0.0, 100[mm] - 26.763[mm])
= **73.238**[mm] Sec. J3.10

$\phi R_n = \phi*(\min(k_1*L_{c\text{-}end}, k_2*d) + \min(k_1*L_{c\text{-}spa}, k_2*d)*(n - 1))*t_p*F_u*n_c$
= 0.75*(min(1.2*46.619[mm], 2.4*22[mm]) + min(1.2*73.238[mm], 2.4*22[mm])*(3 - 1))*25[mm]*399.894[N/mm2]*2
= **2375.37**[kN] Eq. J3-6

Shear yielding [KN] 837.71 334.45 DL **0.40** DG4 Eq. 3.12

$\phi R_n = \phi*0.6*F_{yp}*b_p*t_p$
= 0.9*0.6*248.21[N/mm2]*250[mm]*25[mm]

= **837.709**[kN] DG4 Eq. 3.12

$\phi R_n = \phi*0.6*F_{yp}*b_p*t_p$
= 0.9*0.6*248.21[N/mm2]*250[mm]*25[mm]
= **837.709**[kN] DG4 Eq. 3.12

Shear rupture [KN] 869.62 334.45 DL **0.38** DG4 Eq 3.14, AISC 358 Eq. 6.9-12, DG4 Eq. 3.13

$L_h = d_h + 1/16$ [in]
= 26.763[mm] + 1/16 [in]
= **28.35**[mm] Sec. D3-2

$A_n = (b_p - 2*L_h)*t_p$
= (250[mm] - 2*28.35[mm])*25[mm]
= **4832.5**[mm2] DG4 Eq 3.14, AISC 358 Eq. 6.9-12

$\phi R_n = \phi*0.6*F_{up}*A_n$
= 0.75*0.6*399.894[N/mm2]*4832.5[mm2]
= **869.619**[kN] DG4 Eq. 3.13

Beam

Web weld shear strength [KN] 709.31 105.13 DL **0.15** Eq. J2-4

$F_w = 0.6*F_{EXX}$
= 0.6*482.631[N/mm2]
= **289.578**[N/mm2] Sec. J2.4

$A_w = (2)^{1/2}/2*D/16$ [in]$*L$
= $(2)^{1/2}/2*6/16$ [in]*242.455[mm]
= **1632.98**[mm2] Sec. J2.4

$\phi R_n = 2 * (\phi*F_w*A_w)$
= 2 * (0.75*289.578[N/mm2]*1632.98[mm2])
= **709.313**[kN] Eq. J2-4

Web weld strength to reach yield stress [KN/m] 4348.20 1787.11 DL **0.41** Eq. J2-4, Eq. J4-1

LoadAngleFactor = $1 + 0.5*(\sin(\theta))^{1.5}$
= $1 + 0.5*(\sin(1.379))^{1.5}$
= **1.486** p. 8-9

$F_w = 0.6*F_{EXX}*\text{LoadAngleFactor}$
= 0.6*482.631[N/mm2]*1.486
= **430.396**[N/mm2] Sec. J2.5

$\phi R_w = 2 * (\phi*F_w*(2)^{1/2}/2*D/16$ [in])
= 2 * (0.75*430.396[N/mm2]*$(2)^{1/2}/2*6/16$ [in])
= **4.348**[kN/mm] Eq. J2-4

$\phi R_n = \phi*F_y*t_w$
= 0.9*248.21[N/mm2]*8[mm]
= **1.787**[kN/mm] Eq. J4-1

Shear yielding [KN] 595.70 105.13 DL **0.18** Eq. J4-3

$A_g = L_p*t_p$
= 500[mm]*8[mm]
= **4000**[mm2] Sec. D3-1

$\phi R_n = \phi * 0.60 * F_y * A_g$
= 1*0.60*248.21[N/mm2]*4000[mm2]
= **595.704**[kN] — Eq. J4-3

| | | | | | | |
|---|---|---|---|---|---|---|
| Flange weld capacity (internal flange) | [KN] | 1079.53 | 668.89 | DL | 0.62 | Eq. J2-4 |

LoadAngleFactor = 1 + 0.5*(sin(θ))$^{1.5}$
= 1 + 0.5*(sin(1.571))$^{1.5}$
= **1.5** — p. 8-9

$F_w = 0.6 * F_{EXX}$*LoadAngleFactor
= 0.6*482.631[N/mm2]*1.5
= **434.367**[N/mm2] — Sec. J2.5

$A_w = (2)^{1/2}/2*D/16$ [in]*L
= $(2)^{1/2}$/2*6/16 [in]*492[mm]
= **3313.71**[mm2] — Sec. J2.4

$\phi R_n = \phi * F_w * A_w$
= 0.75*434.367[N/mm2]*3313.71[mm2]
= **1079.53**[kN] — Eq. J2-4

<u>Support</u>

| | | | | | | |
|---|---|---|---|---|---|---|
| Flexural yielding (external flange) | [KN*m] | 834.58 | 0.00 | DL | 0.00 | DG4 Eq. 3.20, Sec. 2.2.3, DG4 Eq. 3.21 |

$c = p_{f0} + p_{fi} + t_{bf}$
= 50[mm] + 87[mm] + 12.225[mm]
= **149.225**[mm] — DG4 Table 3.4, AISC 358 Table 6.5

$s = 0.5*(b_p*g)^{1/2}$
= 0.5*(250[mm]*130[mm])$^{1/2}$
= **90.139**[mm] — DG16 Table 3-2

$Y_c = b_{cf}/2*(h_0*(1/s) + h_2*(1/s)) + 2/g*(h_0*(s + c) + h_1*(p_b) + h_2*(s)) + g/2$
= 250[mm]/2*(550[mm]*(1/90.139[mm]) + 300.775[mm]*(1/90.139[mm])) + 2/130[mm]*(550[mm]*(90.139[mm] + 149.225[mm]) + 400.775[mm]*(100[mm]) + 300.775[mm]*(90.139[mm])) + 130[mm]/2
= **4303.87**[mm] — Yield line Meth.

$M_n = F_{yc} * Y_c * t_{cf}^2$
= 344.736[N/mm2]*4303.87[mm]*25[mm]$^2$
= **927.313**[kN*m] — DG4 Eq. 3.20, Sec. 2.2.3

$\phi M_n = \phi * M_n$
= 0.9*927.313[kN*m]
= **834.582**[kN*m] — DG4 Eq. 3.21

| | | | | | | |
|---|---|---|---|---|---|---|
| Support bolt bearing (external flange) | [KN] | 2662.05 | 0.00 | DL | 0.00 | Eq. J3-6 |

$L_{c\text{-}end} = Max(0.0, L_e - d_h/2)$
= Max(0.0, 100[mm] - 23.588[mm]/2)
= **88.206**[mm] — Sec. J3.10

$L_{c\text{-}spa} = Max(0.0, s - d_h)$
= Max(0.0, 100[mm] - 23.588[mm])
= **76.413**[mm] — Sec. J3.10

$\phi R_n = \phi*(min(k_1*L_{c\text{-}end}, k_2*d) + min(k_1*L_{c\text{-}spa}, k_2*d)*(n - 1))*t_p*F_u*n_c$

= 0.75*(min(1.2*88.206[mm], 2.4*22[mm]) + min(1.2*76.413[mm], 2.4*22[mm])*(3 - 1))*25[mm]*448.157[N/mm2]*2
= **2662.05**[kN] Eq. J3-6

Flexural yielding (internal flange) [KN*m] 1129.30 326.23 DL **0.29** DG4 Eq. 3.20, Sec. 2.2.3, DG4 Eq. 3.21

$p_{si} = p_{fi} + t_{fb}/2 - t_s/2$
= 87[mm] + 12.332[mm]/2 - 12[mm]/2
= **87.166**[mm] DG4 Table 3.4

$p_{s0} = p_{f0} + t_{fb}/2 - t_s/2$
= 60[mm] + 12.332[mm]/2 - 12[mm]/2
= **60.166**[mm] DG4 Table 3.4

$c = p_{f0} + p_{fi} + t_{bf}$
= 60[mm] + 87[mm] + 12.332[mm]
= **159.332**[mm] DG4 Table 3.4, AISC 358 Table 6.5

$s = 0.5*(b_p*g)^{1/2}$
= $0.5*(250[mm]*130[mm])^{1/2}$
= **90.139**[mm] DG16 Table 3-2

$Y_c = b_{cf}/2*(h_1*(1/p_{si}) + h_2*(1/s) + h_0*(1/p_{s0} + 1/s)) + 2/g*(h_1*(p_{si} + 3*p_b/4) + h_2*(s + p_b/4) + h_0*(s + p_{s0})) + g/2$
= 250[mm]/2*(400.668[mm]*(1/87.166[mm]) + 300.668[mm]*(1/90.139[mm]) + 560[mm]*(1/60.166[mm] + 1/90.139[mm])) + 2/130[mm]*(400.668[mm]*(87.166[mm] + 3*100[mm]/4) + 300.668[mm]*(90.139[mm] + 100[mm]/4) + 560[mm]*(90.139[mm] + 60.166[mm])) + 130[mm]/2
= **5823.69**[mm] Yield line Meth.

$M_n = F_{yc}*Y_c*t_{cf}^2$
= $344.736[N/mm2]*5823.69[mm]*25[mm]^2$
= **1254.77**[kN*m] DG4 Eq. 3.20, Sec. 2.2.3

$\phi M_n = \phi*M_n$
= 0.9*1254.77[kN*m]
= **1129.3**[kN*m] DG4 Eq. 3.21

Support bolt bearing (internal flange) [KN] 2662.05 105.13 DL **0.04** Eq. J3-6

$L_{c\text{-}end} = Max(0.0, L_e - d_h/2)$
= Max(0.0, 100[mm] - 23.588[mm]/2)
= **88.206**[mm] Sec. J3.10

$L_{c\text{-}spa} = Max(0.0, s - d_h)$
= Max(0.0, 100[mm] - 23.588[mm])
= **76.413**[mm] Sec. J3.10

$\phi R_n = \phi*(min(k_1*L_{c\text{-}end}, k_2*d) + min(k_1*L_{c\text{-}spa}, k_2*d)*(n - 1))*t_p*F_u*n_c$
= 0.75*(min(1.2*88.206[mm], 2.4*22[mm]) + min(1.2*76.413[mm], 2.4*22[mm])*(3 - 1))*25[mm]*448.157[N/mm2]*2
= **2662.05**[kN] Eq. J3-6

Panel web shear [KN] 352.23 668.89 DL **1.90** Sec. G1

$kvLimit = (a_v/h>3.0) \text{ or } (a_v/h>(260.0/(h/t_w))^{2.0})$
= $(500[mm]/500[mm]>3.0) \text{ or } (500[mm]/500[mm]>(260.0/(500[mm]/4.762[mm]))^{2.0})$
= **False** Sec. G2.1

$k_v = 5.0 + 5.0/(a_v/h)^{2.0}$
= $5.0 + 5.0/(500[mm]/500[mm])^{2.0}$

= **10** Sec. G2.1

CvLimit = $h/t_w<1.10*(k_v*E/F_y)^{1/2}$
= 500[mm]/4.762[mm]<1.10*(10*2.00E+05[N/mm2]/344.736[N/mm2])$^{1/2}$
= **False** Sec. G2.1

CvLimit = $(h/t_w>1.10*(k_v*E/F_y)^{1/2})$ and $(h/t_w<=1.37*(k_v*E/F_y)^{1/2})$
= (500[mm]/4.762[mm]>1.10*(10*2.00E+05[N/mm2]/344.736[N/mm2])$^{1/2}$) and (500[mm]/4.762[mm]<
= 1.37*(10*2.00E+05[N/mm2]/344.736[N/mm2])$^{1/2}$)
= **False** Sec. G2.1

CvLimit = $h/t_w>1.37*(k_v*E/F_y)^{1/2}$
= 500[mm]/4.762[mm]>1.37*(10*2.00E+05[N/mm2]/344.736[N/mm2])$^{1/2}$
= **True** Sec. G2.1

$C_v = 1.51*E*k_v/((h/t_w)^2*F_y)$
= 1.51*2.00E+05[N/mm2]*10/((500[mm]/4.762[mm])$^2$*344.736[N/mm2])
= **0.795** Sec. G2.1

kvLimit = $(a_v/h>3.0)$ or $(a_v/h>(260.0/(h/t_w))^{2.0})$
= (500[mm]/500[mm]>3.0) or (500[mm]/500[mm]>(260.0/(500[mm]/4.762[mm]))$^{2.0}$)
= **False** Sec. G2.1

$k_v = 5.0 + 5.0/(a_v/h)^{2.0}$
= 5.0 + 5.0/(500[mm]/500[mm])$^{2.0}$
= **10** Sec. G2.1

$h/t_w< = 1.10*(k_v*E/F_y)^{1/2}$ → 500[mm]/4.762[mm]<
= 1.10*(10*2.00E+05[N/mm2]/344.736[N/mm2])$^{1/2}$ → **False**

$V_n = 0.6*a_v*t_w*F_y*C_v$
= 0.6*500[mm]*4.762[mm]*344.736[N/mm2]*0.795
= **391.361**[kN] Sec. G2.1

$\phi V_n = \phi*V_n$
= 0.9*391.361[kN]
= **352.225**[kN] Sec. G1

Support - right side

| | | | | | | |
|---|---|---|---|---|---|---|
| Local web yielding | [KN] | 1012.87 | 668.89 | DL | 0.66 | DG4 eq. 3.24, DG13 Eq. 4.3-1, Sec. J10 |

IsBeamReaction → **False**

$l_b$ = N
= **12**[mm] Sec. J10-2

IsMemberEnd → **False**

$\phi R_n = \phi*(1*(6*k + 2*t_p) + N)*F_{yw}*t_w$
= 1*(1*(6*25[mm] + 2*25[mm]) + 12[mm])*344.736[N/mm2]*4.762[mm]
= **348.063**[kN] DG4 eq. 3.24

$A_{st} = t_p*(b_s - clip)$
= 12[mm]*(125[mm] - 1[mm])
= **1488**[mm2] DG13 Sec. 4.3

$\phi R_{nts} = 2 * (\phi*F_y*A_{st})$

= 2 * (0.9*248.21[N/mm2]*1488[mm2])
= **664.806**[kN] — DG13 Eq. 4.3-1

$\phi R_n = \phi R_n + \phi R_{nts}$
= 348.063[kN] + 664.806[kN]
= **1012.87**[kN] — Sec. J10

Transverse stiffeners - bottom

| | | | | | | |
|---|---|---|---|---|---|---|
| Yielding strength due to axial load | [KN] | 664.81 | 320.83 | DL | 0.48 | Eq. J4-1 |

$A_g = 2 * ((b_s - clip)*t_p)$
= 2 * ((125[mm] - 1[mm])*12[mm])
= **2976**[mm2] — Sec. D3.1

$\phi R_n = \phi*F_y*A_g$
= 0.9*248.21[N/mm2]*2976[mm2]
= **664.806**[kN] — Eq. J4-1

| | | | | | | |
|---|---|---|---|---|---|---|
| Compression | [KN] | 447.36 | 0.00 | DL | 0.00 | Sec. J4.4 |

$r = t_p/(12)^{1/2}$
= 12[mm]/(12)$^{1/2}$
= **3.464**[mm] — Sec. E2

$A_g = L_p*t_p$
= 124[mm]*12[mm]
= **1488**[mm2] — Sec. D3-1

K*L/r>25 → 0.65*462.3[mm]/3.464[mm]>25 → **True**

$F_e = \pi^2*E/(K*L/r)^2$
= $\pi^2$*2.00E+05[N/mm2]/(0.65*462.3[mm]/3.464[mm])$^2$
= **262.253**[N/mm2] — Eq. E3-4

$F_e$> = 0.44*Q*$F_y$ → 262.253[N/mm2]>
= 0.44*1*248.21[N/mm2] → **True**

$F_{cr} = 0.658^{(Q*Fy/Fe)}*F_y$
= $0.658^{(1*248.21[N/mm2]/262.253[N/mm2])}$*248.21[N/mm2]
= **167.024**[N/mm2] — Eq. E7-2

$\phi P_n = 2 * (\phi*F_{cr}*A_g)$
= 2 * (0.9*167.024[N/mm2]*1488[mm2])
= **447.357**[kN] — Sec. J4.4

| | | | | | | |
|---|---|---|---|---|---|---|
| Flange weld capacity | [KN] | 983.81 | 320.83 | DL | 0.33 | Eq. J2-4 |

$L = b_{st} - clip - w$
= 122.619[mm] - 1[mm] - 9.525[mm]
= **112.094**[mm] — Comm. J10.8

LoadAngleFactor = 1 + 0.5*(sin($\theta$))$^{1.5}$
= 1 + 0.5*(sin(1.571))$^{1.5}$
= **1.5** — p. 8-9

$F_w = 0.6*F_{EXX}$*LoadAngleFactor
= 0.6*482.631[N/mm2]*1.5
= **434.367**[N/mm2] — Sec. J2.5

$A_w = (2)^{1/2}/2*D/16$ [in]*L
= $(2)^{1/2}$/2*6/16 [in]*112.094[mm]

= **754.973**[mm2] Sec. J2.4

$\phi R_n$ = 4 * ($\phi$*$F_w$*$A_w$)
= 4 * (0.75*434.367[N/mm2]*754.973[mm2])
= **983.807**[kN] Eq. J2-4

| | | | | | | |
|---|---|---|---|---|---|---|
| Web weld capacity | [KN] | 2509.83 | 320.83 | DL | 0.13 | Eq. J2-4 |

L = l - 2.0*clip - 2.0*w
= 450[mm] - 2.0*1[mm] - 2.0*9.525[mm]
= **428.95**[mm] Comm. J10.8

$F_w$ = 0.6*$F_{EXX}$
= 0.6*482.631[N/mm2]
= **289.578**[N/mm2] Sec. J2.4

$A_w$ = $(2)^{1/2}$/2*D/16 [in]*L
= $(2)^{1/2}$/2*6/16 [in]*428.95[mm]
= **2889.06**[mm2] Sec. J2.4

$\phi R_n$ = 4 * ($\phi$*$F_w$*$A_w$)
= 4 * (0.75*289.578[N/mm2]*2889.06[mm2])
= **2509.83**[kN] Eq. J2-4

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**Global critical strength ratio** **1.90**

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**NOTATION**

$A_b$: Nominal bolt area
$A_g$: Gross area
$a_i$: Distance from the interior bolt centerline to the prying force
$A_n$: Net area
$a_o$: Distance from the outer bolt centerline to the prying force
$A_{st}$: Transverse stiffener cross-sectional area
$a_v$: Clear distance between transverse stiffeners
$A_w$: Effective area of the weld
b: Plate, connector or member width
$b_{cf}$: Width of column flange
$b_{fb}$: Beam flange breadth
$b_p$: Plate width
$b_s$: Transverse stiffener width
$b_{smin}$: Minimum transverse stiffener width
$b_{st}$: Contact length between transverse stiffener and support flange
N: Bearing length
C: Bolt group coefficient
$C_2$: Edge distance increment
c: Vertical bolt spacing
$C_v$: Web shear coefficient
clip: Transverse stiffener corner clip dimension
CvLimit: Limit for the calculation of the web shear coefficient
d: Nominal bolt diameter
$d_0$: Distance from the center of the beam compression flange to the outer bolt centerline in extended end-plate configurations
$d_1$: Distance from the center of the beam compression flange to the farthest inner load-carrying bolt centerline
$d_2$: Distance from the center of the beam compression flange to the second farthest inner load-carrying bolt centerline
$d_3$: Distance from the center of the beam compression flange to the third farthest inner load-carrying bolt centerline
$d_{bmax}$: Maximum bolt diameter
$d_h$: Nominal hole dimension
$D_u$: Bolt pretension ratio
d: Beam depth
$d_c$: Column depth
discr: Discriminant under the root sign for the calculation of Qmaxi, Qmaxo
D: Number of sixteenths of an inch in the weld size
E: Elastic modulus
$F_{cr}$: Critical stress, flexural stress buckling

$F_e$: Elastic critical buckling stress
$F_{EXX}$: Electrode classification number
$F_{nt}$: Nominal tensile stress
$F_i'$: Flange force per bolt at the thin plate limit when calculating Qmaxi for end-plate configurations with large inner pitch distances
$F_o'$: Flange force per bolt at the thin plate limit when calculating Qmaxo for end-plate configurations with large inner pitch distances
$F_u$: Specified minimum tensile strength
$F_{up}$: Specified minimum tensile strength of the plate
$F_w$: Nominal strength of the weld metal per unit area
$F_y$: Specified minimum yield stress
$F_{yb}$: Specified minimum yield stress of beam, plate or branch material
$F_{yc}$: Specified minimum yield stress of column material
$F_{yp}$: Specified minimum yield stress of plate
$F_{ys}$: Specified minimum yield stress of stiffener material
$F_{yw}$: Specified minimum yield stress of web
g: Transversal gage between bolts
$g_{max}$: Maximum bolt gage
$g_{min}$: Minimum bolt gage
$\gamma_r$: Load factor to limit connection rotation at ultimate moment to 10% of simple span rotation
h: Clear distance between flanges
$h_0$: Distance from the compression side of the beam to the outer bolt centerline in extended end-plate configurations
$h_1$: Distance from the compression side of the beam to the farthest inner load-carrying bolt line
$h_2$: Distance from the compression side of the beam to the second farthest inner load-carrying bolt line
$h_f$: Factor for fillers
$h_{st}$: Stiffener height
IsBeamReaction: Is beam reaction
IsFlushConnection: Is flush connection
IsMemberEnd: Is member end
K: Effective length factor
$k_1$: Bearing factor
$k_{1c}$: Distance from column web centerline to flange toe of fillet
$k_2$: Bearing factor
k: Outside corner radius
$k_{sc}$: Slip resistance factor
$k_v$: Web plate buckling coefficient
kvLimit: Limit of the clear distance between stiffeners to clear distance between flanges ratio
l: Length
L: Length
$l_b$: Bearing length
$L_{c\text{-}end}$: Clear distance
$L_e$: Edge distance
$L_{emax}$: Maximum edge distance
$L_{emin}$: Minimum edge distance
$L_h$: Hole dimension for tension and shear net area
$L_p$: Plate length
$l_{smin}$: Stiffener minimum length
L: Length of weld
LoadAngleFactor: Load angle factor
$M_n$: Nominal moment
$M_{np}$: No prying moment
$M_{pl}$: End plate or column flange flexural strength
$M_q$: Connection strength for the limit state of bolt fracture with prying action
$e_{dmin}$: Minimum edge distance
$\mu$: Mean slip coefficient
n: Bolts rows number
N: Bearing length
$N_b$: Number of bolts carrying the applied tension
$n_c$: Number of bolt columns
$n_s$: Number of slip planes
$p_b$: Pitch between the inner and the outer row of bolts
$p_{ext}$: End-plate extension beyond the exterior face of the beam tension flange
$p_{f0}$: Distance from the inside of a beam tension flange to the nearest outside bolt row
$p_{fi}$: Distance from the inside of a beam tension flange to the nearest inside bolt row
$p_{fmin}$: Minimum distance from the inside of a beam tension flange to the nearest inside bolt row
$p_{s0}$: Distance from the outside face of column stiffener to the nearest outside bolt row
$p_{si}$: Distance from the inside face of column stiffener to the nearest inside bolt row
$P_t$: Bolt tensile strength

$\phi$: Design factors

$\phi_b$: Design factor for bending

$\phi M_n$: Design or allowable strength

$\phi P_n$: Design or allowable strength

$\phi R_n$: Design or allowable strength

$\phi R_n$: Design or allowable strength per unit length

$\phi R_{nts}$: Transverse stiffener design or allowable strength

$\phi R_w$: Fillet weld capacity per unit length

$\phi V_n$: Design or allowable shear strength

Q: Prying action coefficient

$Q_f$: Chord stress interaction parameter

$Q_{maxi}$: Maximum possible prying force for interior bolts

$Q_{maxo}$: Maximum possible prying force for outer bolts

r: Radius of gyration

s: Distance from the most inside or outside tension bolt row to the edge of a yield line

$s_{min}$: Minimum spacing

s: Longitudinal bolt spacing

$L_{c-spa}$: Distance between adjacent holes edges

$\Sigma d_n$: Sum of all distances from centerline of compression flange to the nth bolt row

$t_p$: Thickness of the connected material

$T_b$: Minimum fastener pretension

$t_{bf}$: Thickness of the flange

$t_{cf}$: Thickness of the column flange

$t_f$: Thickness of the loaded flange

$t_{fb}$: Beam flange thickness

$t_p$: Plate thickness

$t_s$: Column stiffener thickness

$t_{smin}$: Minimum plate stiffener thickness

$T_u$: Tension force

$t_w$: Web thickness

$t_{wb}$: Thickness of beam web

$\theta$: Load angle

ThickPlateSmallerBoltsBehaviorApply: Thick plate behavior controled by bolt rupturwe without prying action apply

ThinPlateYieldingApply: Thin plate behavior controlled by end-plate yielding apply

$V_n$: Nominal shear strength

$w_{min}$: Minimum weld size required

$w_{min}$: Minimum weld size required

w': Width of end-plate per bolt minus the bolt hole diameter

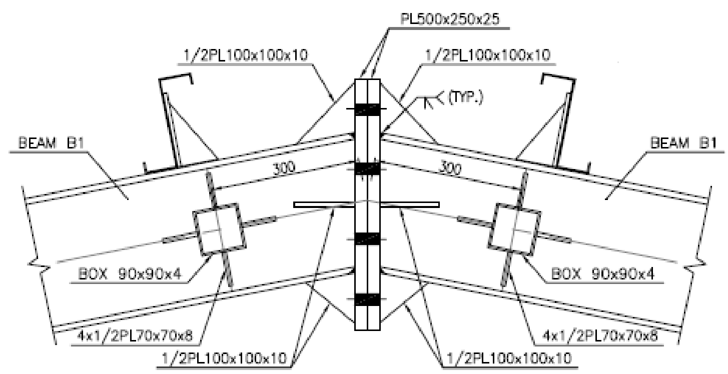
w: Weld size

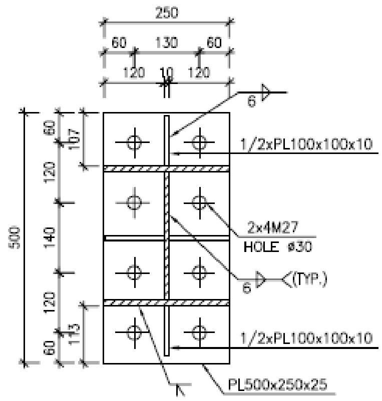
$Y_c$: Column yield line mechanism parameter

$Y_p$: Yield line mechanism parameter

$l_{smax}$: Stiffener maximum length

## 13.2. Beam to Beam:

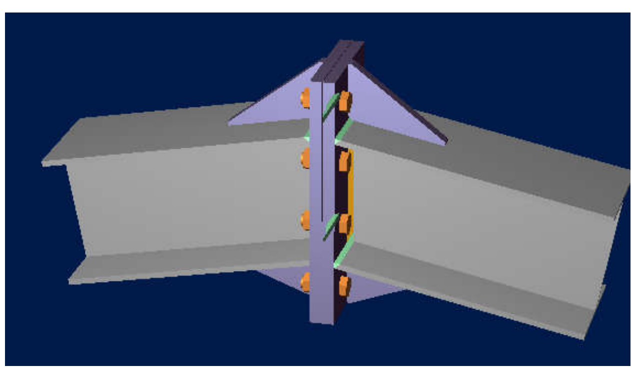



**Input Data:**

Connection Type: Moment End Plate of PG 250x250x20x8 ( Rigid  Connection )

| Member | Section Name | d | Bf | tf | tw | Area | Z33 |
|---|---|---|---|---|---|---|---|
| | | cm | cm | cm | cm | cm2 | cm3 |
| Beam | PG 250x250x12x8 | 27.4 | 25 | 1.2 | 0.8 | 84.48 | 1141.272 |
| Beam | PG 250x250x12x8 | 27.4 | 25 | 1.2 | 0.8 | 84.48 | 1141.272 |



Design Load: (Based on Capacity of Member)
According to AISC360-16:

$M_{pr} = Z_{3-3}F_y = 1141.272 * 2400 = 2739053kgf - cm$ (F2-1)

$M_u = 1.1RyMpr = 1.1 * 1.15 * 2739053 = 3464902\ kgf - cm$

$$V_u = \frac{2M_u}{L_B} = \frac{2 * 3464902}{600} = 11549.67.75kgf$$

| Load | Vu | Mu |
|---|---|---|
| Unit(Ton, m) | 5.774 | 17.324 |

RAM® Connection
CONNECT Edition

**Current Date:** 10/16/2023 11:32 AM
**Units system:** SI
**File name:** C:\Users\n.razani\Desktop\RAM CON\RAFTER TO COL.rcnx

# Steel connections

**Results**

---

**Connection name : MEP_BS_APEX_EU_3/8_PL_2B_1B1/2**
**Connection ID : 2**

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Family: Beam splice (BS)
Type: Moment end plate
Design code: AISC 360-16 LRFD

**DEMANDS**

| Description | Ru [kN] | Pu [kN] | Mu [kN*m] | PufTop [kN] | PufBot [kN] | Load type |
|---|---|---|---|---|---|---|
| DL | 56.68 | -11.02 | 173.24 | -654.58 | 643.56 | Design |

**GEOMETRIC CONSIDERATIONS**

| Dimensions | Unit | Value | Min. value | Max. value | Sta. | References |
|---|---|---|---|---|---|---|
| Extended end plate | | | | | | |
| End plate stiffener thickness | [mm] | 25.00 | 8.00 | -- | ✔ | DG4 Eq. 3.15, AISC 358-10 Eq. 6.10-9, Eq. 6.10-10 |

$t_{smin} = \max(t_{wb}*(F_{yb}/F_{ys}), (h_{st}/0.56)*(F_{ys}/E)^{1/2})$
$= \max(8[mm]*(248.21[N/mm2]/248.21[N/mm2]), (117[mm]/0.56)*(248.21[N/mm2]/2.00E+05[N/mm2])^{1/2})$
$= \mathbf{8}[mm]$ — DG4 Eq. 3.15, AISC 358-10 Eq. 6.10-9, Eq. 6.10-10

| Dimensions | Unit | Value | Min. value | Max. value | Sta. | References |
|---|---|---|---|---|---|---|
| Vertical edge distance | [mm] | 60.00 | 30.35 | 152.40 | ✔ | Sec. J3.5 |

$L_{emin} = e_{dmin} + C_2$
$= 30.35[mm] + 0[mm]$
$= \mathbf{30.35}[mm]$ — Tables J3.4, J3.5

$L_{emax} = \min(12*t_p, 6\ [in])$
$= \min(12*25[mm], 6\ [in])$

= **152.4**[mm] Sec. J3.5

| | | | | | | |
|---|---|---|---|---|---|---|
| Horizontal edge distance | [mm] | 60.00 | 30.35 | 152.40 | ✔ | Sec. J3.5 |

$L_{emin} = e_{dmin} + C_2$
= 30.35[mm] + 0[mm]
= **30.35**[mm] Tables J3.4, J3.5

$L_{emax}$ = min(12*$t_p$, 6 [in])
= min(12*25[mm], 6 [in])
= **152.4**[mm] Sec. J3.5

| | | | | | | |
|---|---|---|---|---|---|---|
| Vertical bolt spacing (external flange) | [mm] | 129.22 | 64.00 | -- | ✔ | Sec. J3.3 |

$s_{min}$ = 8/3*d
= 8/3*24[mm]
= **64**[mm] Sec. J3.3

| | | | | | | |
|---|---|---|---|---|---|---|
| Vertical bolt spacing (internal flange) | [mm] | 137.22 | 64.00 | -- | ✔ | Sec. J3.3 |

$s_{min}$ = 8/3*d
= 8/3*24[mm]
= **64**[mm] Sec. J3.3

| | | | | | | |
|---|---|---|---|---|---|---|
| Horizontal center-to-center spacing (gage) | [mm] | 130.00 | 64.00 | 250.00 | ✔ | Sec. J3.3, DG4 Sec. 2.4, DG4 Sec. 2.1, 2.4, DG16 Sec. 2.5 |

$g_{min}$ = Max(8/3*d, 2*$k_{1c}$ + 2*d, $t_{wb}$ + 2*w + $d_h$)
= Max(8/3*24[mm], 2*0[mm] + 2*24[mm], 8[mm] + 2*9.525[mm] + 27.175[mm])
= **64**[mm] Sec. J3.3, DG4 Sec. 2.4

$g_{max} = b_{fb}$
= **250**[mm] DG4 Sec. 2.1, 2.4, DG16 Sec. 2.5

| | | | | | | |
|---|---|---|---|---|---|---|
| Outer bolt distance (external flange) | [mm] | 57.00 | 36.70 | -- | ✔ | DG4 Sec. 2.1 |

d< = 1 [in] → 24[mm]<
= 1 [in] → **True**

$p_{fmin}$ = d + 1/2 [in]
= 24[mm] + 1/2 [in]
= **36.7**[mm] DG4 Sec. 2.1

| | | | | | | |
|---|---|---|---|---|---|---|
| Inner bolt distance (external flange) | [mm] | 60.00 | 36.70 | -- | ✔ | DG4 Sec. 2.1 |

d< = 1 [in] → 24[mm]<
= 1 [in] → **True**

$p_{fmin}$ = d + 1/2 [in]
= 24[mm] + 1/2 [in]
= **36.7**[mm] DG4 Sec. 2.1

| | | | | | | |
|---|---|---|---|---|---|---|
| Outer bolt distance (internal flange) | [mm] | 65.00 | 36.70 | -- | ✔ | DG4 Sec. 2.1 |

d< = 1 [in] → 24[mm]<
= 1 [in] → **True**

$p_{fmin}$ = d + 1/2 [in]

= 24[mm] + 1/2 [in]
= **36.7**[mm] — DG4 Sec. 2.1

Inner bolt distance (internal flange) — [mm] — 60.00 — 36.70 — -- — ✔ — DG4 Sec. 2.1
$d<$ = 1 [in] → 24[mm]<
= 1 [in] → **True**

$p_{fmin}$ = d + 1/2 [in]
= 24[mm] + 1/2 [in]
= **36.7**[mm] — DG4 Sec. 2.1

Bolt diameter — [mm] — 24.00 — -- — 38.10 — ✔ — DG4 Sec. 1.1
$d_{bmax}$ = 1.5 [in] — DG4 Sec. 1.1

- Use CJP weld for the end plate stiffener

Beam
Web — [1/16in] — 6 — 3 — -- — ✔ — table J2.4
$w_{min} = w_{min}$
= **0.004763** — table J2.4

---

**DESIGN CHECK**

| Verification | Unit | Capacity | Demand | Ctrl EQ | Ratio | References |
|---|---|---|---|---|---|---|
| Moment end plate (external flange) | | | | | | |
| Flexural yielding | [KN*m] | 386.90 | 0.00 | DL | 0.00 | DG16 Sec 2.5 |

$s = 0.5*(b_p*g)^{1/2}$
= 0.5*(250[mm]*130[mm])$^{1/2}$
= **90.139**[mm] — DG16 Table 3-2

$p_{fi} = \min(p_{fi}, s)$
= min(60[mm], 90.139[mm])
= **60**[mm] — DG16 Table 4-2

$s> = d_e$ → 90.139[mm]>
= 60[mm] → **True**

$Y_p = b_p/2*(h_1*(1/p_{fi} + 1/s) + h_0*(1/p_{f0} + 1/(2*s))) + 2/g*(h_1*(p_{fi} + s) + h_0*(d_e + p_{f0}))$
= 250[mm]/2*(206.904[mm]*(1/60[mm] + 1/90.139[mm]) + 336.128[mm]*(1/57[mm] + 1/(2*90.139[mm]))) + 2/130[mm]*(206.904[mm]*(60[mm] + 90.139[mm]) + 336.128[mm]*(60[mm] + 57[mm]))
= **2771.1**[mm] — DG16 Table 4-3

$M_{pl} = F_{yp}*t_p^2*Y_p$
= 248.21[N/mm2]*25[mm]$^2$*2771.1[mm]
= **429.885**[kN*m] — DG16 Sec 2.5

IsFlushConnection → **False**

$\gamma_r = 1$ — DG16 Sec 2.5

$\phi M_n = \phi_b*M_{pl}/\gamma_r$
= 0.9*429.885[kN*m]/1
= **386.896**[kN*m] — DG16 Sec 2.5

| Verification | Unit | Capacity | Demand | Ctrl EQ | Ratio | References |
|---|---|---|---|---|---|---|
| No prying bolt moment strength | [KN*m] | 223.51 | 0.00 | DL | 0.00 | DG16 Sec 2.5 |

$P_t = A_b*F_{nt}$
= 452.389[mm2]*620.528[N/mm2]

= **280.72**[kN] — DG16 Sec 2.5

$M_{np} = 2*P_t*(\Sigma d_n)$
= 2*280.72[kN]*(530.808[mm])
= **298.017**[kN*m] — DG16 Sec 2.5

$\phi M_n = \phi * M_{np}$
= 0.75*298.017[kN*m]
= **223.513**[kN*m] — DG16 Sec 2.5

Bolts shear [KN] 505.30 56.68 DL **0.11** Tables (7-1..14)
$\phi R_n = \phi * F_{nv} * A_b$
= 0.75*372.317[N/mm2]*452.389[mm2]
= **126.324**[kN] — Eq. J3-1

$\phi R_n = C * \phi R_n$
= 4*126.324[kN]
= **505.296**[kN] — Tables (7-1..14)

Bolt bearing under shear load [KN] 1698.97 0.00 DL **0.00** Eq. J3-6
$L_{c\text{-}end} = Max(0.0, L_e - d_h/2)$
= Max(0.0, 60[mm] - 27.175[mm]/2)
= **46.413**[mm] — Sec. J3.10

$L_{c\text{-}spa} = Max(0.0, s - d_h)$
= Max(0.0, 129.225[mm] - 27.175[mm])
= **102.05**[mm] — Sec. J3.10

$\phi R_n = \phi*(min(k_1*L_{c\text{-}end}, k_2*d) + min(k_1*L_{c\text{-}spa}, k_2*d)*(n - 1))*t_p*F_u*n_c$
= 0.75*(min(1.2*46.413[mm], 2.4*24[mm]) + min(1.2*102.05[mm], 2.4*24[mm])*(2 - 1))*25[mm]*399.894[N/mm2]*2
= **1698.97**[kN] — Eq. J3-6

Shear yielding [KN] 837.71 327.29 DL **0.39** DG4 Eq. 3.12
$\phi R_n = \phi*0.6*F_{yp}*b_p*t_p$
= 0.9*0.6*248.21[N/mm2]*250[mm]*25[mm]
= **837.709**[kN] — DG4 Eq. 3.12

Shear rupture [KN] 865.91 327.29 DL **0.38** DG4 Eq 3.14, AISC 358 Eq. 6.9-12, DG4 Eq. 3.13

$L_h = d_h + 1/16$ [in]
= 27.175[mm] + 1/16 [in]
= **28.763**[mm] — Sec. D3-2

$A_n = (b_p - 2*L_h)*t_p$
= (250[mm] - 2*28.763[mm])*25[mm]
= **4811.88**[mm2] — DG4 Eq 3.14, AISC 358 Eq. 6.9-12

$\phi R_n = \phi*0.6*F_{up}*A_n$
= 0.75*0.6*399.894[N/mm2]*4811.88[mm2]
= **865.908**[kN] — DG4 Eq. 3.13

<u>Moment end plate (internal flange)</u>
Flexural yielding [KN*m] 385.08 171.77 DL **0.45** DG16 Sec 2.5
$s = 0.5*(b_p*g)^{1/2}$
= $0.5*(250[mm]*130[mm])^{1/2}$
= **90.139**[mm] — DG16 Table 3-2

$p_{fi} = min(p_{fi}, s)$
= min(60[mm], 90.139[mm])
= **60**[mm] — DG16 Table 4-2

s> = $d_e$ → 90.139[mm]>
= 60[mm] → **True**

$Y_p = b_p/2*(h_1*(1/p_{fi} + 1/s) + h_0*(1/p_{f0} + 1/(2*s))) + 2/g*(h_1*(p_{fi} + s) + h_0*(d_e + p_{f0}))$
= 250[mm]/2*(206.904[mm]*(1/60[mm] + 1/90.139[mm]) + 344.128[mm]*(1/65[mm] + 1/(2*90.139[mm]))) + 2/130[mm]*(206.904[mm]*(60[mm] + 90.139[mm]) + 344.128[mm]*(60[mm] + 65[mm]))
= **2758.07**[mm] — DG16 Table 4-3

$M_{pl} = F_{yp}*t_p^2*Y_p$
= 248.21[N/mm2]*25[mm]²*2758.07[mm]
= **427.862**[kN*m] — DG16 Sec 2.5

IsFlushConnection → **False**

$\gamma_r = 1$ — DG16 Sec 2.5

$\phi M_n = \phi_b*M_{pl}/\gamma_r$
= 0.9*427.862[kN*m]/1
= **385.076**[kN*m] — DG16 Sec 2.5

| | | | | | | |
|---|---|---|---|---|---|---|
| No prying bolt moment strength | [KN*m] | 226.88 | 171.77 | DL | 0.76 | DG16 Sec 2.5 |

$P_t = A_b*F_{nt}$
= 452.389[mm2]*620.528[N/mm2]
= **280.72**[kN] — DG16 Sec 2.5

$M_{np} = 2*P_t*(\Sigma d_n)$
= 2*280.72[kN]*(538.808[mm])
= **302.508**[kN*m] — DG16 Sec 2.5

$\phi M_n = \phi*M_{np}$
= 0.75*302.508[kN*m]
= **226.881**[kN*m] — DG16 Sec 2.5

| | | | | | | |
|---|---|---|---|---|---|---|
| Bolts shear | [KN] | 505.30 | 0.00 | DL | 0.00 | Tables (7-1..14) |

$\phi R_n = \phi*F_{nv}*A_b$
= 0.75*372.317[N/mm2]*452.389[mm2]
= **126.324**[kN] — Eq. J3-1

$\phi R_n = C*\phi R_n$
= 4*126.324[kN]
= **505.296**[kN] — Tables (7-1..14)

| | | | | | | |
|---|---|---|---|---|---|---|
| Bolt bearing under shear load | [KN] | 1698.97 | 56.68 | DL | 0.03 | Eq. J3-6 |

$L_{c-end} = Max(0.0, L_e - d_h/2)$
= Max(0.0, 60[mm] - 27.175[mm]/2)
= **46.413**[mm] — Sec. J3.10

$L_{c-spa} = Max(0.0, s - d_h)$
= Max(0.0, 137.225[mm] - 27.175[mm])
= **110.05**[mm] — Sec. J3.10

$\phi R_n = \phi*(min(k_1*L_{c-end}, k_2*d) + min(k_1*L_{c-spa}, k_2*d)*(n - 1))*t_p*F_u*n_c$

= 0.75*(min(1.2*46.413[mm], 2.4*24[mm]) + min(1.2*110.05[mm], 2.4*24[mm])*(2 - 1))*25[mm]*399.894[N/mm2]*2
= **1698.97**[kN] — Eq. J3-6

Shear yielding — [KN] — 837.71 — 321.78 — DL — **0.38** — DG4 Eq. 3.12

$\phi R_n = \phi*0.6*F_{yp}*b_p*t_p$
= 0.9*0.6*248.21[N/mm2]*250[mm]*25[mm]
= **837.709**[kN] — DG4 Eq. 3.12

$\phi R_n = \phi*0.6*F_{yp}*b_p*t_p$
= 0.9*0.6*248.21[N/mm2]*250[mm]*25[mm]
= **837.709**[kN] — DG4 Eq. 3.12

Shear rupture — [KN] — 865.91 — 321.78 — DL — **0.37** — DG4 Eq 3.14, AISC 358 Eq. 6.9-12, DG4 Eq. 3.13

$L_h = d_h + 1/16$ [in]
= 27.175[mm] + 1/16 [in]
= **28.763**[mm] — Sec. D3-2

$A_n = (b_p - 2*L_h)*t_p$
= (250[mm] - 2*28.763[mm])*25[mm]
= **4811.88**[mm2] — DG4 Eq 3.14, AISC 358 Eq. 6.9-12

$\phi R_n = \phi*0.6*F_{up}*A_n$
= 0.75*0.6*399.894[N/mm2]*4811.88[mm2]
= **865.908**[kN] — DG4 Eq. 3.13

Beam

Web weld shear strength — [KN] — 372.54 — 56.68 — DL — **0.15** — Eq. J2-4

$F_w = 0.6*F_{EXX}$
= 0.6*482.631[N/mm2]
= **289.578**[N/mm2] — Sec. J2.4

$A_w = (2)^{1/2}/2*D/16$ [in]*L
= $(2)^{1/2}/2*6/16$ [in]*127.34[mm]
= **857.657**[mm2] — Sec. J2.4

$\phi R_n = 2 * (\phi*F_w*A_w)$
= 2 * (0.75*289.578[N/mm2]*857.657[mm2])
= **372.538**[kN] — Eq. J2-4

Web weld strength to reach yield stress — [KN/m] — 4348.20 — 1787.11 — DL — **0.41** — Eq. J2-4, Eq. J4-1

$LoadAngleFactor = 1 + 0.5*(\sin(\theta))^{1.5}$
= $1 + 0.5*(\sin(1.763))^{1.5}$
= **1.486** — p. 8-9

$F_w = 0.6*F_{EXX}*LoadAngleFactor$
= 0.6*482.631[N/mm2]*1.486
= **430.396**[N/mm2] — Sec. J2.5

$\phi R_w = 2 * (\phi*F_w*(2)^{1/2}/2*D/16$ [in])
= 2 * (0.75*430.396[N/mm2]*$(2)^{1/2}/2*6/16$ [in])
= **4.348**[kN/mm] — Eq. J2-4

$\phi R_n = \phi*F_y*t_w$
= 0.9*248.21[N/mm2]*8[mm]

= **1.787**[kN/mm] Eq. J4-1

| | | | | | | |
|---|---|---|---|---|---|---|
| Shear yielding | [KN] | 326.45 | 56.68 | DL | 0.17 | Eq. J4-3 |

$A_g = L_p*t_p$
= 274[mm]*8[mm]
= **2192**[mm2] Sec. D3-1

$\phi R_n = \phi*0.60*F_y*A_g$
= 1*0.60*248.21[N/mm2]*2192[mm2]
= **326.446**[kN] Eq. J4-3

---

**Global critical strength ratio** **0.76**

---

**NOTATION**

$A_b$: Nominal bolt area
$A_g$: Gross area
$a_i$: Distance from the interior bolt centerline to the prying force
$A_n$: Net area
$a_o$: Distance from the outer bolt centerline to the prying force
$A_w$: Effective area of the weld
$b_{fb}$: Beam flange breadth
$b_p$: Plate width
C: Bolt group coefficient
$C_2$: Edge distance increment
d: Nominal bolt diameter
$d_0$: Distance from the center of the beam compression flange to the outer bolt centerline in extended end-plate configurations
$d_1$: Distance from the center of the beam compression flange to the farthest inner load-carrying bolt centerline
$d_2$: Distance from the center of the beam compression flange to the second farthest inner load-carrying bolt centerline
$d_3$: Distance from the center of the beam compression flange to the third farthest inner load-carrying bolt centerline
$d_{bmax}$: Maximum bolt diameter
$d_e$: Distance from the first bolt row to the top plate edge
$d_h$: Nominal hole dimension
discr: Discriminant under the root sign for the calculation of Qmaxi, Qmaxo
D: Number of sixteenths of an inch in the weld size
E: Elastic modulus
$F_{EXX}$: Electrode classification number
$F_{nt}$: Nominal tensile stress
$F_{nv}$: Nominal shear stress
$F_i'$: Flange force per bolt at the thin plate limit when calculating Qmaxi for end-plate configurations with large inner pitch distances
$F_o'$: Flange force per bolt at the thin plate limit when calculating Qmaxo for end-plate configurations with large inner pitch distances
$F_u$: Specified minimum tensile strength
$F_{up}$: Specified minimum tensile strength of the plate
$F_w$: Nominal strength of the weld metal per unit area
$F_y$: Specified minimum yield stress
$F_{yb}$: Specified minimum yield stress of beam, plate or branch material
$F_{yp}$: Specified minimum yield stress of plate
$F_{ys}$: Specified minimum yield stress of stiffener material
g: Transversal gage between bolts
$g_{max}$: Maximum bolt gage
$g_{min}$: Minimum bolt gage
$\gamma_r$: Load factor to limit connection rotation at ultimate moment to 10% of simple span rotation
$h_0$: Distance from the compression side of the beam to the outer bolt centerline in extended end-plate configurations
$h_1$: Distance from the compression side of the beam to the farthest inner load-carrying bolt line
$h_{st}$: Stiffener height
IsFlushConnection: Is flush connection
$k_1$: Bearing factor
$k_{1c}$: Distance from column web centerline to flange toe of fillet
$k_2$: Bearing factor
$L_{c-end}$: Clear distance
$L_e$: Edge distance
$L_{emax}$: Maximum edge distance
$L_{emin}$: Minimum edge distance
$L_h$: Hole dimension for tension and shear net area
$L_p$: Plate length

L: Length of weld
LoadAngleFactor: Load angle factor
$M_{np}$: No prying moment
$M_{pl}$: End plate or column flange flexural strength
$M_q$: Connection strength for the limit state of bolt fracture with prying action
$e_{dmin}$: Minimum edge distance
n: Bolts rows number
$n_c$: Number of bolt columns
$p_{ext}$: End-plate extension beyond the exterior face of the beam tension flange
$p_{f0}$: Distance from the inside of a beam tension flange to the nearest outside bolt row
$p_{fi}$: Distance from the inside of a beam tension flange to the nearest inside bolt row
$p_{fmin}$: Minimum distance from the inside of a beam tension flange to the nearest inside bolt row
$P_t$: Bolt tensile strength
$\phi$: Design factors
$\phi_b$: Design factor for bending
$\phi M_n$: Design or allowable strength
$\phi R_n$: Design or allowable strength
$\phi R_n$: Design or allowable strength per unit length
$\phi R_w$: Fillet weld capacity per unit length
$Q_{maxi}$: Maximum possible prying force for interior bolts
$Q_{maxo}$: Maximum possible prying force for outer bolts
s: Distance from the most inside or outside tension bolt row to the edge of a yield line
$s_{min}$: Minimum spacing
s: Longitudinal bolt spacing
$L_{c\text{-}spa}$: Distance between adjacent holes edges
$\Sigma d_n$: Sum of all distances from centerline of compression flange to the nth bolt row
$t_p$: Thickness of the connected material
$T_b$: Minimum fastener pretension
$t_p$: Plate thickness
$t_{smin}$: Minimum plate stiffener thickness
$t_w$: Web thickness
$t_{wb}$: Thickness of beam web
$\theta$: Load angle
ThickPlateSmallerBoltsBehaviorApply: Thick plate behavior controled by bolt rupturwe without prying action apply
$w_{min}$: Minimum weld size required
w': Width of end-plate per bolt minus the bolt hole diameter
w: Weld size
$Y_p$: Yield line mechanism parameter

## 13.3. PURLIN DESIGN

### 13.4 PROPERTY OF PURLIN(Z180X2.5)

Section Name: Z180*2.5

Properties

| | | | |
|---|---|---|---|
| Cross-section (axial) area | 7.8025 | Section modulus about 3 axis | 42.3052 |
| Moment of Inertia about 3 axis | 386.0346 | Section modulus about 2 axis | 7.024 |
| Moment of Inertia about 2 axis | 45.3049 | Plastic modulus about 3 axis | 29.4654 |
| Product of Inertia about 2-3 | 94.7543 | Plastic modulus about 2 axis | 6.4081 |
| Shear area in 2 direction | 4.5172 | Radius of Gyration about 3 axis | 7.0339 |
| Shear area in 3 direction | 2.8393 | Radius of Gyration about 2 axis | 2.4097 |
| Torsional constant | 0.1249 | Shear Center Eccentricity (x3) | 0. |

**FIGURE 19-**Section Property Of Purlin

According to above table :

$$A = 7.80\ cm2$$

$$J = 0.12\ cm4$$

$$Ix = 386.06\ cm4$$

$$Iy = 45.304\ cm4$$

$$rx = 7.033\ cm$$

$$ry = 2.41\ cm$$

$$ho = 18\ cm$$

$$SY = 42.305\ cm3$$

$$SX = 7.024\ cm3$$

FOR Z 180 :

$$\mathrm{D + L = 26 + 50 = 76\ kg/m^2}$$

$$\mathrm{P_y = 76.\cos 11 = 74.6\ \ kg/m^2}$$

$$\mathrm{P_x = 76.\sin 11 = 14.5\ \ kg/m^2}$$

$$\text{middle of span}:\ \mathrm{M_y = \frac{w.L^2}{8} = \frac{76 \times 1.0 \times 5^2}{8} = 237.5\ kg.m}$$

$$\text{middle of span}:\ \mathrm{M_x = \frac{w.L^2}{360} = \frac{14.5 \times 1 \times 5^2}{360} = 1.00kg.m}$$

$$\mathrm{f_b = \frac{M_y}{s_y} + 2\frac{M_x}{s_x} = \frac{237.5 \times 100}{42.305} + 2\frac{1.00 \times 100}{7.024} = 561.39 + 28.47 = 589.86 < 1440\ ok}$$

$$\text{moment on sagrod support}:\ \mathrm{M_y = \frac{w.L^2}{9} = \frac{76 \times 1.0 \times 5^2}{9} = 211.11\ kg.m}$$

moment on sagrod support : $M_x = \frac{w.L^2}{90} = \frac{14.5 \times 1.0 \times 5^2}{90} = 4.02\ kg.m$

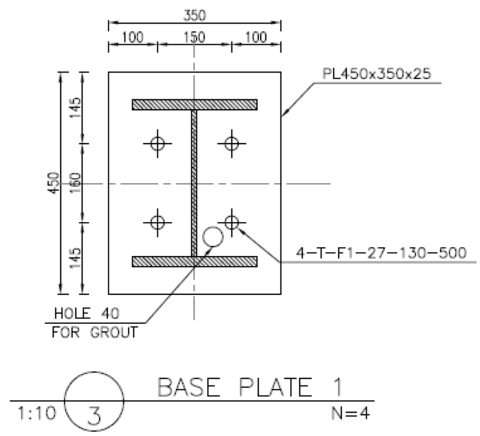
$f_b = \frac{M_y}{s_y} + 2\frac{M_x}{s_x} = \frac{211.11 \times 100}{42.305} + 2\frac{4.02 \times 100}{7.024} = 498.99 + 114.46 = 613.45 < \ 1440 \quad ok$

**13.4.1 .UNDEFORMED SHAPE CONTROL:**

dead + live loads : $\Delta = \frac{5 \times q \times L^4}{384 \times E \times I} = \frac{5 \times 0.76 \times 1.0 \times 600^4}{384 \times 2.04 \times 10^6 \times 1350} = 0.46cm \ < \ \frac{L}{240} = 2.0cm$

for live loads : $\Delta = \frac{5 \times q \times L^4}{384 \times E \times I} = \frac{5 \times 0.5 \times 1.0 \times 600^4}{384 \times 2.04 \times 10^6 \times 1350} = 0.3cm \ < \ \frac{L}{360} = 1.3\ cm$

## 13.5. Base Plate:




Design Code: AISC-360-16 LRFD

Connection Type: Base plate of column PG 300x250x20x8 (Simple Connection)

| Member | Section Name | d | Bf | tf | tw | h | Area | Z33 | Z22 | $r_{min}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | cm | cm | cm | cm | cm | cm2 | cm3 | cm3 | cm |
| Column | PG 300x250x20x10 | 34 | 25 | 2 | 1 | 30 | 130 | 1825 | 632.5 | 6.33 |

Design Load:

$$\frac{kL_c}{r_{min}} = \frac{1*360}{6.33} = 56.87 \le 4.71\sqrt{\frac{2*10^6}{2400}} = 135.9 \quad ok$$

$$F_e = \frac{\pi^2 E}{(\frac{kL_c}{r_{min}})^2} = 6401.489\ kgf$$

$$F_{cr} = \left[0.658^{\frac{F_y}{F_e}}\right] F_y = 2051.43$$

$$P_u = \varphi F_{cr} A_g = 0.9 * 2051.43 * 130 = 240017.3\ kgf$$

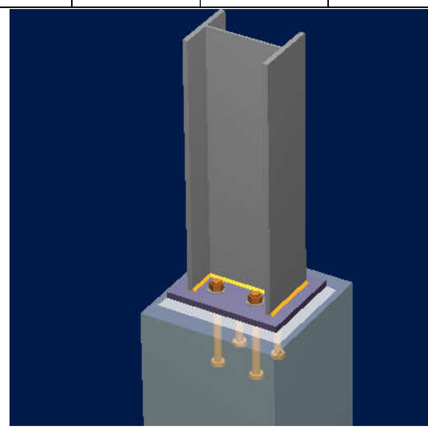
$$M_{p3-3} = Z_{3-3} F_y = 1825 * 2400 = 4380000\ kgf - cm$$

$$M_{p2-2} = Z_{2-2} F_y = 632.5 * 2400 = 1518000\ kgf - cm$$

$$V_{2-2} = \frac{M_{p3-3}}{L_c} = \frac{4380000}{650} = 6738.46\ kgf$$

$$V_{3-3} = \frac{M_{p2-2}}{L_c} = \frac{1518000}{650} = 2335.385 kgf$$

| Section | P (Ton) | V2 (Ton) | V3 (Ton) | M2 (Ton-m) | M3 (Ton-m) |
|---|---|---|---|---|---|
| PG 300x250X20X10 | 240.017 | 6.74 | 2.335 | ------ | ----- |



RAM® Connection
CONNECT Edition

# Steel connections

**Results**

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**Connection name : Pinned BP - HSS Member**
**Connection ID : 101**

---

Family: Column - Base (CB)
Type: Base plate
Description: BS1-PG 300X300X20x10
Design code: AISC 360-16 LRFD, ACI 318-11

**DEMANDS**

| Description | Pu [T] | Mu22 [T*m] | Mu33 [T*m] | Vu2 [T] | Vu3 [T] | Load type |
|---|---|---|---|---|---|---|
| BS1 | -240 | 0.00 | 0.00 | 6.7 | 2.335 | Design |
| BS2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Design |
| BS3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Design |
| BS4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Design |
| BS5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Design |

## Design for major axis
## Base plate (AISC 360-16 LRFD)

**GEOMETRIC CONSIDERATIONS**

| Dimensions | Unit | Value | Min. value | Max. value | Sta. | References |
|---|---|---|---|---|---|---|
| Base plate | | | | | | |
| Distance from anchor to edge | [cm] | 11.00 | 0.64 | -- | ✓ | |
| Weld size | [1/16in] | 8 | 3 | -- | ✓ | table J2.4 |
| $w_{min} = w_{min}$ | | | | | | |
| = **0.004763** | | | | | | table J2.4 |

**DESIGN CHECK**

| Verification | Unit | Capacity | Demand | Ctrl EQ | Ratio | References |
|---|---|---|---|---|---|---|
| Pedestal | | | | | | |
| Axial bearing | [Ton/cm2] | 0.17 | 0.17 | BS1 | 1.00 | DG1 3.1.1; |

$f_{p,\,max} = \phi*\min(0.85*f'_c*(A_2/A_1)^{1/2}, 1.7*f'_c)$
= 0.65*min(0.85*300[kg/cm2]*(1)$^{1/2}$, 1.7*300[kg/cm2])
= **165.75**[kg/cm2] — DG1 3.1.1

$A_{1\,(req)} = P/f_{p,\,max}$
= 220.4[T]/165.75[kg/cm2]
= **1329.71**[cm2] — DG1 Sec 3.1.1

$\Delta = (0.95*d_c - 0.8*b_c)/2$
= (0.95*34[cm] - 0.8*30[cm])/2
= **4.15**[cm] — DG1 Sec 3.1.4

$N_{eff1} = (A_{1\,(req)})^{1/2} + \Delta$
= (1329.71[cm2])$^{1/2}$ + 4.15[cm]
= **40.615**[cm] — DG1 Sec 3.1.4

$B_{eff1} = A_{1\,(req)}/N_{eff}$
= 1329.71[cm2]/40.615[cm]
= **32.739**[cm] — DG1 Sec 3.1.4

$N_{eff2} = (d_c*b_c)^{1/2} + \Delta$
= (34[cm]*30[cm])$^{1/2}$ + 4.15[cm]
= **36.087**[cm]

$B_{eff2} = b_c$
= **30**[cm]

$N_{eff3} = d_c$
= **34**[cm]

$B_{eff3} = (d_c - \Delta)^2/d_c$
= (34[cm] - 4.15[cm])$^2$/34[cm]
= **26.207**[cm]

$N = \min(N_{eff}, N_{dim})$
= min(40.615[cm], 50[cm])
= **40.615**[cm]

$B = \min(B_{eff}, B_{dim})$
= min(32.739[cm], 42[cm])
= **32.739**[cm]

| Verification | Unit | Capacity | Demand | Ctrl EQ | Ratio | References |
|---|---|---|---|---|---|---|
| Base plate | | | | | | |
| Flexural yielding (bearing interface) | [Ton*m/m] | 6.62 | 5.28 | BS1 | 0.80 | DG1 Sec 3.1.2 |

$\phi M_n = \phi*F_y*t_p^2/4$
= 0.9*2400[kg/cm2]*3.5[cm]$^2$/4
= **6.615**[T*m/m] — DG1 Eq. 3.3.13

$m = (N - 0.95*d_c)/2$
= (40.615[cm] - 0.95*34[cm])/2
= **4.158**[cm] — DG1 Sec 3.1.2

$n = (B - 0.8*b_c)/2$
$= (32.739[cm] - 0.8*30[cm])/2$
$= \mathbf{4.37}[cm]$ DG1 Sec 3.1.2

$P_p = 0.85*f'_c*A_1$
$= 0.85*300[kg/cm2]*1329.71[cm2]$
$= \mathbf{339.077}[T]$ Eq. J8-1

$X = (4*d_c*b_c/(d_c + b_c)^2)*P/(\phi*P_p)$
$= (4*34[cm]*30[cm]/(34[cm] + 30[cm])^2)*220.4[T]/(0.65*339.077[T])$
$= \mathbf{0.996}$ DG1 Sec 3.1.2

$\lambda = \min(2*(X)^{1/2}/(1 + (1 - X)^{1/2}), 1.0)$
$= \min(2*(0.996)^{1/2}/(1 + (1 - 0.996)^{1/2}), 1.0)$
$= \mathbf{1}$ DG1 Sec 3.1.2

$n' = \lambda*(d_c*b_c)^{1/2}/4$
$= 1*(34[cm]*30[cm])^{1/2}/4$
$= \mathbf{7.984}[cm]$ DG1 Sec 3.1.2

$l = \max(m, n, n')$
$= \max(4.158[cm], 4.37[cm], 7.984[cm])$
$= \mathbf{7.984}[cm]$ DG1 Sec 3.1.2

$f_p = P/(B*N)$
$= 220.4[T]/(32.739[cm]*40.615[cm])$
$= \mathbf{165.75}[kg/cm2]$ DG1 Sec 3.1.2

$M_{pl} = f_p*(l^2/2)$
$= 165.75[kg/cm2]*(7.984[cm]^2/2)$
$= \mathbf{5.283}[T*m/m]$ DG1 Sec 3.1.2

Flexural yielding (tension interface) [Ton*m/m] 6.62 0.00 BS1 **0.00** DG1 Eq. 3.3.13

$\phi M_n = \phi*F_y*t_p^2/4$
$= 0.9*2400[kg/cm2]*3.5[cm]^2/4$
$= \mathbf{6.615}[T*m/m]$ DG1 Eq. 3.3.13

$M_{pT} = M_{strip}/B_{eff}$
$= 0[T*m]/16[cm]$
$= \mathbf{0}[T*m/m]$

Friction shear capacity [Ton] 79.78 7.75 BS1 **0.10** DG1 Sec 3.5.1

$\phi V_{fn} = \min(\phi*mu*P_u, 0.2*f'_c*A_c)$
$= \min(0.75*0.55*220.4[T], 0.2*300[kg/cm2]*1329.71[cm2])$
$= \mathbf{79.783}[T]$ DG1 Sec 3.5.1

Column

Weld capacity [Ton/m] 298.32 0.00 BS1 **0.00** p. 8-9, Sec. J2.5, Sec. J2.4

$LoadAngleFactor = 1 + 0.5*(\sin(\theta))^{1.5}$
$= 1 + 0.5*(\sin(1.571))^{1.5}$
$= \mathbf{1.5}$ p. 8-9

$F_w = 0.6*F_{EXX}*LoadAngleFactor$
$= 0.6*4921.46[kg/cm2]*1.5$
$= \mathbf{4429.32}[kg/cm2]$ Sec. J2.5

$A_w = (2)^{1/2}/2*D/16$ [in]*L
= $(2)^{1/2}/2*8/16$ [in]*100[cm]
= **89.803**[cm2] Sec. J2.4

$\phi R_w = \phi*F_w*A_w/L$
= 0.75*4429.32[kg/cm2]*89.803[cm2]/100[cm]
= **2.983**[T/cm]

| | | | | | | |
|---|---|---|---|---|---|---|
| Elastic method weld shear capacity | [Ton/m] | 198.88 | 12.92 | BS1 | 0.06 | p. 8-9, Sec. J2.5, Sec. J2.4 |

LoadAngleFactor = $1 + 0.5*(\sin(\theta))^{1.5}$
= $1 + 0.5*(\sin(0))^{1.5}$
= **1** p. 8-9

$F_w = 0.6*F_{EXX}$*LoadAngleFactor
= 0.6*4921.46[kg/cm2]*1
= **2952.88**[kg/cm2] Sec. J2.5

$A_w = (2)^{1/2}/2*D/16$ [in]*L
= $(2)^{1/2}/2*8/16$ [in]*100[cm]
= **89.803**[cm2] Sec. J2.4

$\phi R_w = \phi*F_w*A_w/L$
= 0.75*2952.88[kg/cm2]*89.803[cm2]/100[cm]
= **1.989**[T/cm]

$f_v = V/L_{shear}$
= 7.753[T]/60[cm]
= **0.129**[T/cm]

| | | | | | | |
|---|---|---|---|---|---|---|
| Elastic method weld axial capacity | [Ton/m] | 298.32 | 0.00 | BS1 | 0.00 | p. 8-9, Sec. J2.5, Sec. J2.4 |

LoadAngleFactor = $1 + 0.5*(\sin(\theta))^{1.5}$
= $1 + 0.5*(\sin(1.571))^{1.5}$
= **1.5** p. 8-9

$F_w = 0.6*F_{EXX}$*LoadAngleFactor
= 0.6*4921.46[kg/cm2]*1.5
= **4429.32**[kg/cm2] Sec. J2.5

$A_w = (2)^{1/2}/2*D/16$ [in]*L
= $(2)^{1/2}/2*8/16$ [in]*100[cm]
= **89.803**[cm2] Sec. J2.4

$\phi R_w = \phi*F_w*A_w/L$
= 0.75*4429.32[kg/cm2]*89.803[cm2]/100[cm]
= **2.983**[T/cm]

$f_a = P/L$
= -220.4[T]/118.4[cm]
= **-1.861**[T/cm]

$f_b = M*c/I$
= 0[T*m]*17[cm]/34980[cm3]
= **0**[T/cm]

$f = max(f_b + f_a, 0.0)$
= max(0[T/cm] + -1.861[T/cm], 0.0)
= **0**[T/cm]

| Ratio | 1.00 |
|---|---|

## Major axis
## Anchors

**GEOMETRIC CONSIDERATIONS**

| Dimensions | Unit | Value | Min. value | Max. value | Sta. | References |
|---|---|---|---|---|---|---|
| <u>Anchors</u> | | | | | | |
| Anchor spacing | [cm] | 14.00 | 8.00 | -- | ✔ | Sec. D.8.1 |
| $s_{min} = 4*d_a$ <br> = 4*2[cm] <br> = **8**[cm] | | | | | | Sec. D.8.1 |
| Concrete cover | [cm] | 20.00 | 5.08 | -- | ✔ | Sec. 7.7.1 |
| IsConcreteCastAgainstEarth → **False** | | | | | | |
| Cover = 2 [in] | | | | | | Sec. 7.7.1 |
| Effective length | [cm] | 51.30 | -- | 123.70 | ✔ | |

**DESIGN CHECK**

| Verification | Unit | Capacity | Demand | Ctrl EQ | Ratio | References |
|---|---|---|---|---|---|---|
| Anchor tension | [Ton] | 7.49 | 0.00 | BS1 | 0.00 | Eq. D-2 |
| $A_{se} = \pi/4.0*(d_a - 0.9743 [in]/n_t)^2$ <br> = π/4.0*(2[cm] - 0.9743 [in]/10.58)² <br> = **2.45**[cm2] | | | | | | Sec. D.5.1.1, D.6.1.2 |
| $f_{uta} = min(f_{uta}, 1.9*f_{ya}, 125 [ksi])$ <br> = min(4077.78[kg/cm2], 1.9*2531.04[kg/cm2], 125 [ksi]) <br> = **4077.78**[kg/cm2] | | | | | | Sec. D.5.1.2 |
| $\phi N_{sa} = \phi*A_{se,N}*f_{uta}$ <br> = 0.75*2.45[cm2]*4077.78[kg/cm2] <br> = **7.492**[T] | | | | | | Eq. D-2 |
| Breakout of anchor in tension | [Ton] | 11.13 | 0.00 | BS1 | 0.00 | Eq. D-3, Sec. D.3.3.4.4 |
| $c_{a1Left}<1.5*h_{ef}$ → 21[cm]<1.5*50[cm] → **True** | | | | | | |
| $c_{a1Left} = c_{a1Left}$ <br> = **21**[cm] | | | | | | Sec. D.5.2.1 |
| $c_{a1Right}<1.5*h_{ef}$ → 39[cm]<1.5*50[cm] → **True** | | | | | | |
| $c_{a1Right} = c_{a1Right}$ <br> = **39**[cm] | | | | | | Sec. D.5.2.1 |
| $c_{a2Top}<1.5*h_{ef}$ → 37[cm]<1.5*50[cm] → **True** | | | | | | |
| $c_{a2Top} = c_{a2Top}$ | | | | | | |

= **37**[cm] Sec. D.5.2.1

$c_{a2Bot}$<1.5*$h_{ef}$ → 23[cm]<1.5*50[cm] → **True**

$c_{a2Bot}$ = $c_{a2Bot}$
= **23**[cm] Sec. D.5.2.1

IsCloseToThreeEdges → **True**

$h_{ef}$ = $c_{amax}$/1.5
= 39[cm]/1.5
= **26**[cm] Sec. D.5.2.3

$c_{a1Left}$<1.5*$h_{ef}$ → 21[cm]<1.5*26[cm] → **True**

$c_{a1Left}$ = $c_{a1Left}$
= **21**[cm] Sec. D.5.2.1

$c_{a1Right}$<1.5*$h_{ef}$ → 39[cm]<1.5*26[cm] → **False**

$c_{a1Right}$ = 1.5*$h_{ef}$
= 1.5*26[cm]
= **39**[cm] Sec. D.5.2.1

$c_{a2Top}$<1.5*$h_{ef}$ → 37[cm]<1.5*26[cm] → **True**

$c_{a2Top}$ = $c_{a2Top}$
= **37**[cm] Sec. D.5.2.1

$c_{a2Bot}$<1.5*$h_{ef}$ → 23[cm]<1.5*26[cm] → **True**

$c_{a2Bot}$ = $c_{a2Bot}$
= **23**[cm] Sec. D.5.2.1

$A_{Nc}$ = ($c_{a1Left}$ + $c_{a1Right}$)*($c_{a2Top}$ + $c_{a2Bot}$)
= (21[cm] + 39[cm])*(37[cm] + 23[cm])
= **3600**[cm2] Sec. RD.5.2.1

$A_{Nco}$ = 9*$h_{ef}^2$
= 9*26[cm]$^2$
= **6084**[cm2] Eq. D-5

$c_{a,min}$<1.5*$h_{ef}$ → 21[cm]<1.5*26[cm] → **True**

$\psi_{ed,N}$ = 0.7 + 0.3*$c_{a,min}$/(1.5*$h_{ef}$)
= 0.7 + 0.3*21[cm]/(1.5*26[cm])
= **0.862** Eq. D-10

CrackedConcrete → **False**

$\psi_{c,N}$ = 1.25 Sec. D.5.2.6

IsCastInPlaceAnchor → **True**

$\psi_{cp,N}$ = 1 Sec. D.5.2.7

IsCastInPlaceAnchor → **True**

$k_c$ = 24 Sec. D.5.2.2

(IsCastInPlaceAnchor) and (IsHeadedBolt) and ($h_{ef}$>=11 [in]) and ($h_{ef}$<=25 [in]) → (True) and (True) and (26[cm]> = 11 [in]) and (26[cm]<
= 25 [in]) → **False**

$N_b = k_c*\lambda_a*(f_c/(1\ [psi]))^{1/2}*(h_{ef}/(1\ [in]))^{1.5}$ [lb]
= $24*1*(300[kg/cm2]/(1\ [psi]))^{1/2}*(26[cm]/(1\ [in]))^{1.5}$ [lb]
= **23.289**[T] Eq. D-6

$N_{cb} = (A_{Nc}/A_{Nco})*\psi_{ed,N}*\psi_{c,N}*\psi_{cp,N}*N_b$
= (3600[cm2]/6084[cm2])*0.862*1.25*1*23.289[T]
= **14.84**[T] Eq. D-3

HighSeismicDesignCategory → **False**

$\phi N_{cb} = \phi*N_{cb}$
= 0.75*14.84[T]
= **11.13**[T] Sec. D.3.3.4.4

| Pullout of anchor in tension | [Ton] | 10.95 | 0.00 | BS1 | 0.00 | Sec. D.3.3.4.4 |
|---|---|---|---|---|---|---|

$A_{brg} = 0.866025*F^2 - A_g$
= 0.866025*3[cm]$^2$ - 3.14[cm2]
= **4.654**[cm2]

IsHeadedBolt → **True**

$N_p = 8*A_{brg}*f_c$
= 8*4.654[cm2]*300[kg/cm2]
= **11.17**[T] Eq. D-14

CrackedConcrete → **False**

$\psi_{c,P}$ = 1.4 Sec. D.5.3.6

$N_{pn} = \psi_{c,P}*N_p$
= 1.4*11.17[T]
= **15.638**[T] Eq. D-13

HighSeismicDesignCategory → **False**

$\phi N_{pn} = \phi*N_{pn}$
= 0.7*15.638[T]
= **10.947**[T] Sec. D.3.3.4.4

| Anchor shear | [Ton] | 3.12 | 0.00 | BS1 | 0.00 | Eq. D-29, Sec. D.6.1.3 |
|---|---|---|---|---|---|---|

$A_{se} = \pi/4.0*(d_a - 0.9743\ [in]/n_t)^2$
= $\pi/4.0*(2[cm] - 0.9743\ [in]/10.58)^2$
= **2.45**[cm2] Sec. D.5.1.1, D.6.1.2

$f_{uta} = \min(f_{uta}, 1.9*f_{ya}, 125\ [ksi])$
= min(4077.78[kg/cm2], 1.9*2531.04[kg/cm2], 125 [ksi])
= **4077.78**[kg/cm2] Sec. D.5.1.2

HasGroutPad → **True**

$\phi V_{sa} = 0.8*\phi*0.6*n*A_{se,V}*f_{uta}$
= 0.8*0.65*0.6*1*2.45[cm2]*4077.78[kg/cm2]
= **3.117**[T] — Eq. D-29, Sec. D.6.1.3

Breakout of anchor in shear | [Ton] | 5.42 | 0.00 | BS1 | 0.00 | Table D.4.1.1, Sec. D.4.3

$c_{a2Left}<1.5*c_{a1}$ → 21[cm]<1.5*23[cm] → **True**

$c_{a2Left} = c_{a2Left}$
= **21**[cm] — Sec. D.6.2.1

$c_{a2Right}<1.5*c_{a1}$ → 39[cm]<1.5*23[cm] → **False**

$c_{a2Right} = 1.5*c_{a1}$
= 1.5*23[cm]
= **34.5**[cm] — Sec. D.5.2.1

$h_a<1.5*c_{a1}$ → 125[cm]<1.5*23[cm] → **False**

$h_a = 1.5*c_{a1}$
= 1.5*23[cm]
= **34.5**[cm] — Sec. D.5.2.1

IsCloseToThreeEdges → **False**

$c_{a1} = c_{a1}$
= **23**[cm] — Sec. D.6.2.4

$L_{Vc} = c_{a2Left} + c_{a2Right}$
= 21[cm] + 34.5[cm]
= **55.5**[cm] — Sec. RD.6.2.1

$A_{Vc} = L_{Vc}*\min(h_a, 1.5*c_{a1})$
= 55.5[cm]*min(125[cm], 1.5*23[cm])
= **1914.75**[cm2] — Sec. RD.6.2.1

$A_{Vco} = 4.5*c_{a1}^2$
= 4.5*23[cm]$^2$
= **2380.5**[cm2] — Eq. D-32

$c_{a2}<1.5*c_{a1}$ → 21[cm]<1.5*23[cm] → **True**

$\psi_{ed,V} = 0.7 + 0.3*(c_{a2}/(1.5*c_{a1}))$
= 0.7 + 0.3*(21[cm]/(1.5*23[cm]))
= **0.883** — Eq. D-28

CrackedConcrete → **False**

$\psi_{c,V} = 1.4$ — Sec. D.6.2.7

$h_a<1.5*c_{a1}$ → 125[cm]<1.5*23[cm] → **False**

$\psi_{h,V} = 1$ — Sec. D.6.2.8

$l_e = \min(h_{ef}, 8*d_a)$
= min(50[cm], 8*2[cm])

= **16**[cm] — Sec. D.6.2.2

$V_b$ = min((7*($l_e$/$d_a$)$^{0.2}$*($d_a$/(1 [in]))$^{1/2}$)*$\lambda_a$*($f_c$/(1 [psi]))$^{1/2}$*($c_{a1}$/(1 [in]))$^{1.5}$ [lb], 9*$\lambda_a$*($f_c$/(1 [psi]))$^{1/2}$*($c_{a1}$/(1 [in]))$^{1.5}$ [lb])
= min((7*(16[cm]/2[cm])$^{0.2}$*(2[cm]/(1 [in]))$^{1/2}$)*1*(300[kg/cm2]/(1 [psi]))$^{1/2}$*(23[cm]/
(1 [in]))$^{1.5}$ [lb], 9*1*(300[kg/cm2]/(1 [psi]))$^{1/2}$*(23[cm]/
(1 [in]))$^{1.5}$ [lb])
= **7.266**[T] — Eq. D-33, D-34

$V_{cb}$ = ($A_{Vc}$/$A_{Vco}$)*$\psi_{ed,V}$*$\psi_{c,V}$*$\psi_{h,V}$*$V_b$
= (1914.75[cm2]/2380.5[cm2])*0.883*1.4*1*7.266[T]
= **7.222**[T] — Eq. D-30

$\phi V_{cb}$ = $\phi$*$V_{cb}$
= 0.75*7.222[T]
= **5.416**[T] — Table D.4.1.1, Sec. D.4.3

| Pryout of anchor in shear | [Ton] | 20.78 | 0.00 | BS1 | 0.00 | Eq. D-3, Table D.4.1.1, Sec. D.4.3 |
|---|---|---|---|---|---|---|

$h_{ef}$<2.5 [in] → 50[cm]<2.5 [in] → **False**

$k_{cp}$ = 2 — Sec. D.6.3.1

$c_{a1Left}$<1.5*$h_{ef}$ → 21[cm]<1.5*50[cm] → **True**

$c_{a1Left}$ = $c_{a1Left}$
= **21**[cm] — Sec. D.5.2.1

$c_{a1Right}$<1.5*$h_{ef}$ → 39[cm]<1.5*50[cm] → **True**

$c_{a1Right}$ = $c_{a1Right}$
= **39**[cm] — Sec. D.5.2.1

$c_{a2Top}$<1.5*$h_{ef}$ → 37[cm]<1.5*50[cm] → **True**

$c_{a2Top}$ = $c_{a2Top}$
= **37**[cm] — Sec. D.5.2.1

$c_{a2Bot}$<1.5*$h_{ef}$ → 23[cm]<1.5*50[cm] → **True**

$c_{a2Bot}$ = $c_{a2Bot}$
= **23**[cm] — Sec. D.5.2.1

IsCloseToThreeEdges → **True**

$h_{ef}$ = $c_{amax}$/1.5
= 39[cm]/1.5
= **26**[cm] — Sec. D.5.2.3

$c_{a1Left}$<1.5*$h_{ef}$ → 21[cm]<1.5*26[cm] → **True**

$c_{a1Left}$ = $c_{a1Left}$
= **21**[cm] — Sec. D.5.2.1

$c_{a1Right}$<1.5*$h_{ef}$ → 39[cm]<1.5*26[cm] → **False**

$c_{a1Right}$ = 1.5*$h_{ef}$

= 1.5*26[cm]
= **39**[cm] Sec. D.5.2.1

$c_{a2Top}$<1.5*$h_{ef}$ → 37[cm]<1.5*26[cm] → **True**

$c_{a2Top}$ = $c_{a2Top}$
= **37**[cm] Sec. D.5.2.1

$c_{a2Bot}$<1.5*$h_{ef}$ → 23[cm]<1.5*26[cm] → **True**

$c_{a2Bot}$ = $c_{a2Bot}$
= **23**[cm] Sec. D.5.2.1

$A_{Nc}$ = ($c_{a1Left}$ + $c_{a1Right}$)*($c_{a2Top}$ + $c_{a2Bot}$)
= (21[cm] + 39[cm])*(37[cm] + 23[cm])
= **3600**[cm2] Sec. RD.5.2.1

$A_{Nco}$ = 9*$h_{ef}^2$
= 9*26[cm]$^2$
= **6084**[cm2] Eq. D-5

$c_{a,min}$<1.5*$h_{ef}$ → 21[cm]<1.5*26[cm] → **True**

$\psi_{ed,N}$ = 0.7 + 0.3*$c_{a,min}$/(1.5*$h_{ef}$)
= 0.7 + 0.3*21[cm]/(1.5*26[cm])
= **0.862** Eq. D-10

CrackedConcrete → **False**

$\psi_{c,N}$ = 1.25 Sec. D.5.2.6

IsCastInPlaceAnchor → **True**

$\psi_{cp,N}$ = 1 Sec. D.5.2.7

IsCastInPlaceAnchor → **True**

$k_c$ = 24 Sec. D.5.2.2

(IsCastInPlaceAnchor) and (IsHeadedBolt) and ($h_{ef}$>=11 [in]) and ($h_{ef}$<=25 [in]) → (True) and (True) and (26[cm]> = 11 [in]) and (26[cm]<
= 25 [in]) → **False**

$N_b$ = $k_c$*$\lambda_a$*($f_c$/(1 [psi]))$^{1/2}$*($h_{ef}$/(1 [in]))$^{1.5}$ [lb]
= 24*1*(300[kg/cm2]/(1 [psi]))$^{1/2}$*(26[cm]/(1 [in]))$^{1.5}$ [lb]
= **23.289**[T] Eq. D-6

$N_{cb}$ = ($A_{Nc}$/$A_{Nco}$)*$\psi_{ed,N}$*$\psi_{c,N}$*$\psi_{cp,N}$*$N_b$
= (3600[cm2]/6084[cm2])*0.862*1.25*1*23.289[T]
= **14.84**[T] Eq. D-3

$V_{cp}$ = $k_{cp}$*$N_{cb}$
= 2*14.84[T]
= **29.681**[T] Eq. D-40

$\phi V_{cp}$ = $\phi$*$V_{cp}$
= 0.7*29.681[T]

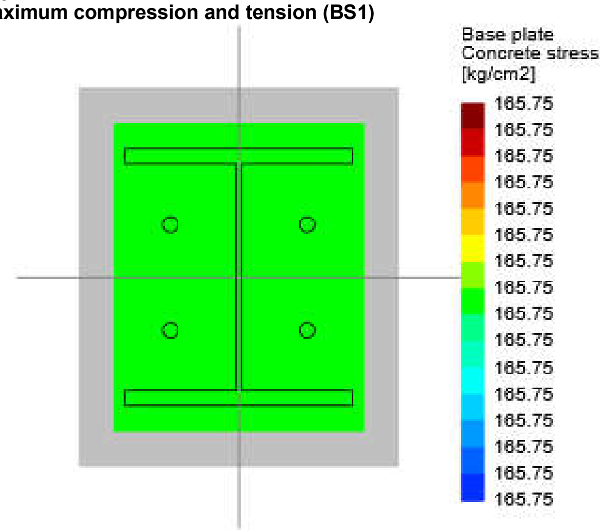
= **20.777**[T]

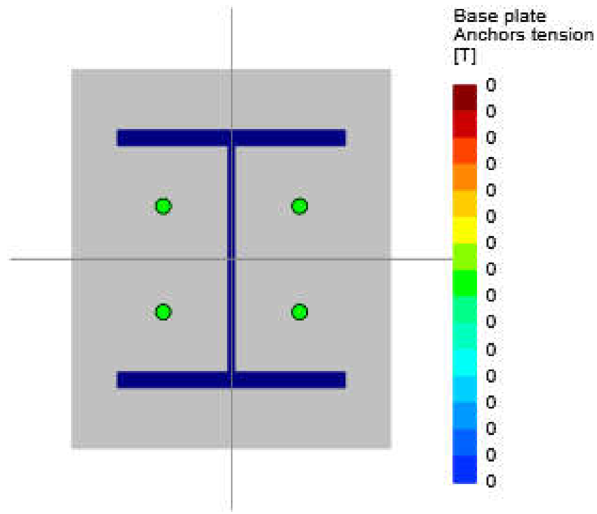
Table D.4.1.1, Sec. D.4.3

---

| | |
|---|---|
| **Ratio** | **0.00** |
| **Global critical strength ratio** | **1.00** |

**Major axis**
**Maximum compression and tension (BS1)**




| | | |
|---|---|---|
| Maximum bearing pressure | 165.75 | [kg/cm2] |
| Minimum bearing pressure | 165.75 | [kg/cm2] |
| Maximum anchor tension | 0.00 | [T] |
| Minimum anchor tension | 0.00 | [T] |
| Neutral axis angle | 0.00 | [deg] |
| Bearing length | 1E32 | [cm] |

**Anchors tensions**

| **Anchor** | **Transverse** [cm] | **Longitudinal** [cm] | **Shear** [T] | **Tension** [T] |
|---|---|---|---|---|
| 1 | -9.00 | -7.00 | 1.94 | 0.00 |
| 2 | -9.00 | 7.00 | 1.94 | 0.00 |
| 3 | 9.00 | 7.00 | 1.94 | 0.00 |
| 4 | 9.00 | -7.00 | 1.94 | 0.00 |

**NOTATION**

$A_1$: Base plate area
$A_{1\,(req)}$: Base plate required area
$A_w$: Effective area of the weld
$A_2/A_1$: Ratio between the concrete support area and the base plate area
B: Base plate design width
$B_{dim}$: Base plate width perpendicular to moment design direction
$B_{eff}$: Effective bearing width
$b_c$: Width of column section
$B_{eff}$: Controlling effective width
$B_{eff1}$: Base plate effective bearing width
$B_{eff2}$: Base plate effective bearing width due column rigid width
$B_{eff3}$: Base plate effective bearing width due column rigid depth
c: Distance to weld group

$\Delta$: Auxiliary variable to optimize the plate dimension
$d_c$: Column depth
D: Number of sixteenths of an inch in the weld size
$f_a$: Axial stress on welds
$f_b$: Bending stress on welds
$f'_c$: Specified compressive strength of concrete
f: Combined stress on welds
$F_{EXX}$: Electrode classification number
$f_p$: Uniformly bearing stress under base plate
$f_{p, max}$: Maximum uniformly bearing stress under base plate
$f_v$: Vertical shear force on weld
$F_w$: Nominal strength of the weld metal per unit area
$F_y$: Specified minimum yield stress
I: Inertia of weld group
l: Critical base plate cantilever dimension
L: Length of weld
$L_{shear}$: Length of weld receiving shear
$\lambda$: Auxiliary variable to calculate the critical base plate cantilever dimension
LoadAngleFactor: Load angle factor
M: Bending required
m: Base plate bearing interface cantilever direction parallel to moment direction
$M_{pl}$: Plate bending moment per unit width
$M_{pT}$: Plate bending moment per unit width at tension unstiffened strip interface
$M_{strip}$: Maximum bending moment at the strip
N: Base plate design length
$N_{dim}$: Base plate length parallel to design moment direction
n: Base plate bearing interface cantilever direction perpendicular to moment direction
n': Yield line theory cantilever distance from column web or column flange
$N_{eff}$: Effective bearing length
$N_{eff1}$: Base plate effective bearing length
$N_{eff2}$: Base plate effective bearing length due column rigid width
$N_{eff3}$: Base plate effective bearing length due column rigid depth
P: Required axial force
$P_p$: Nominal bearing stress
$\phi$: Design factors
$\phi M_n$: Design or allowable strength per unit length
$\phi R_w$: Fillet weld capacity per unit length
$t_p$: Plate thickness
$\theta$: Load angle
V: Shear load
$w_{min}$: Minimum weld size required
X: Auxiliary variable to calculate the critical base plate cantilever dimension
$A_{brg}$: Net bearing area of the head of stud or anchor bolt
$A_g$: Gross area of anchor
$A_c$: Area of concrete section resisting shear transfer
$A_{Nc}$: Projected concrete failure area of a single anchor or group of anchors, for calculation of strength in tension
$A_{Nco}$: Projected concrete failure area of a single anchor, for calculation of strength in tension if not limited by edge distance or spacing
$A_{se}$: Effective cross-sectional area of anchor
$A_{se,N}$: Effective cross-sectional area of anchor in tension
$A_{se,V}$: Effective cross-sectional area of anchor in shear
$A_{Vc}$: Projected concrete failure area of a single anchor or group of anchors , for calculation of strength in shear
$A_{Vco}$: Projected concrete failure area of a single anchor, for calculation of strength in shear, if not limited by corner influences, spacing, or member thickness
$c_{a1}$: Distance from the anchor center to the concrete edge
$c_{a1Left}$: Distance from the anchor center to the left edge of the concrete base
$c_{a1Right}$: Distance from the anchor center to the right edge of the concrete base
$c_{a2}$: Distance from the anchor center to the concrete edge in perpendicular direction
$c_{a2Bot}$: Distance from the anchor center to the bottom edge of the concrete base
$c_{a2Left}$: Distance from the anchor center to the left edge of the concrete base
$c_{a2Right}$: Distance from the anchor center to the right edge of the concrete base
$c_{a2Top}$: Distance from the anchor center to the top edge of the concrete base
$c_{amax}$: Maximum distance from center of an anchor shaft to the edge of concrete
$c_{a,min}$: Minimum distance from center of an anchor shaft to the edge of concrete
Cover: Concrete cover
CrackedConcrete: Cracked concrete at service loads

$d_a$: Outside diameter of anchor or shaft diameter of headed stud, headed bolt, or hooked bolt
F: Distance between head flat sides
$f_c$: Specified compressive strength of concrete
$f_{uta}$: Specified tensile strength of anchor steel
$f_{ya}$: Specified yield strength of anchor steel
$f'_c$: Specified compressive strength of concrete
$h_a$: Thickness of member in which an anchor is located, measured parallel to anchor axis
$h_{ef}$: Effective embedment depth of anchor
HasGroutPad: Has grout pad
HighSeismicDesignCategory: High seismic design category (i.e. C, D, E or F)
IsCastInPlaceAnchor: Is cast in place anchor
IsCloseToThreeEdges: Anchor is close to three or more edges
IsConcreteCastAgainstEarth: Is concrete cast against and permanently exposed to earth
IsHeadedBolt: Is anchor headed stud
$k_c$: Coefficient for concrete pry out basic strength
$k_{cp}$: Coefficient for pry out strength
$l_e$: Load-bearing length of the anchor for shear
$L_{Vc}$: Projected concrete failure length of a single anchor or group of anchors , for calculation of strength in shear
$\lambda_a$: Lightweight concrete modification factor
mu: Friction coefficient
n: Number of anchors in the group
$N_b$: Basic concrete breakout strength in tension of a single anchor in cracked concrete
$N_{cb}$: Nominal concrete breakout strength in tension of a single anchor
$N_p$: Pullout strength in tension of a single anchor in cracked concrete
$N_{pn}$: Nominal pullout strength of a single anchor in tension
$n_t$: Number of threads per inch
$P_u$: Factored compressive load
$\phi$: Strength reduction factor
$\phi N_{cb}$: Concrete breakout strength in tension of a single anchor
$\phi N_{pn}$: Pullout strength in tension of a single anchor
$\phi N_{sa}$: Strength of a single anchor or group of anchors in tension
$\phi V_{cb}$: Concrete breakout strength in shear of a single anchor
$\phi V_{cp}$: Concrete pryout strength of a single anchor
$\phi V_{fn}$: Shear strength due to friction
$\phi V_{sa}$: Strength in shear of a single anchor or group of anchors as governed by the steel strength
$\psi_{c,N}$: Factor used to modify tensile strength of anchors based on presence or absence of cracks in concrete
$\psi_{c,P}$: Factor used to modify pullout strength of anchors based on presence or absence of cracks in concrete
$\psi_{cp,N}$: Factor used to modify tensile strength of postinstalled anchors intended for use in uncracked concrete without supplementary reinforcement
$\psi_{c,V}$: Factor used to modify shear strength of anchors based on presence or absence of cracks in concrete and presence or absence of supplementary reinforcement
$\psi_{ed,N}$: Factor used to modify tensile strength of anchors based on proximity to edges of concrete member
$\psi_{ed,V}$: Factor used to modify shear strength of anchors based on proximity to edges of concrete member
$\psi_{h,V}$: Factor used to modify shear strength of anchors located in concrete members with ha < 1.5ca1
$s_{min}$: Center-to-center anchor minimum spacing
SideFaceBlowoutApply: Side-face blowout apply
$V_b$: Basic concrete breakout strength in shear of a single anchor in cracked concrete
$V_{cb}$: Concrete nominal breakout strength in shear of a single anchor
$V_{cp}$: Nominal pryout strength of a anchor in shear

# 14. FOUNDATION DESIGN

## 14.1. Soil pressure and settlement

Until finalize of geotechnical report for this area we consider (page 41 section 6 of geotechnical report) => qa= 2kg/cm2

Based on Bowels experimental formula for subgrade modulus (Based on geotechnical report as follow) => Ks = 1.69 qall

Loading used for foundation design, have been received from SAP analysis.

| *B(m)* | مدول عکس‌العمل بستر پی سطحی *(kg/cm3)* | | | |
|---|---|---|---|---|
| | *L/B=1* | *L/B=2* | *L/B=5* | *L/B=10* |
| *1.0* | *1.69* | *1.33* | *1.14* | *1.09* |
| *2.0* | *1.00* | *0.85* | *0.78* | *0.77* |
| *3.0* | *0.78* | *0.69* | *0.65* | *0.64* |
| *4.0* | *0.68* | *0.60* | *0.57* | *0.57* |
| *5.0* | *0.61* | *0.55* | *0.53* | *0.53* |

## 14.2. DESIGN

Concrete Foundation are designed according to ACI 318-14. Required loads are derived from SAP data, and design process will be done according to ACI code based on ultimate strength procedure.

$f'_c = 30\text{Mpa}$ $\qquad$ $f_y = 400\text{Ma}$

## 14.3. FOUNDATION DESIGN CONTROL

### 14.3.1 CHECK OF STRESS FOR FOUNDATION

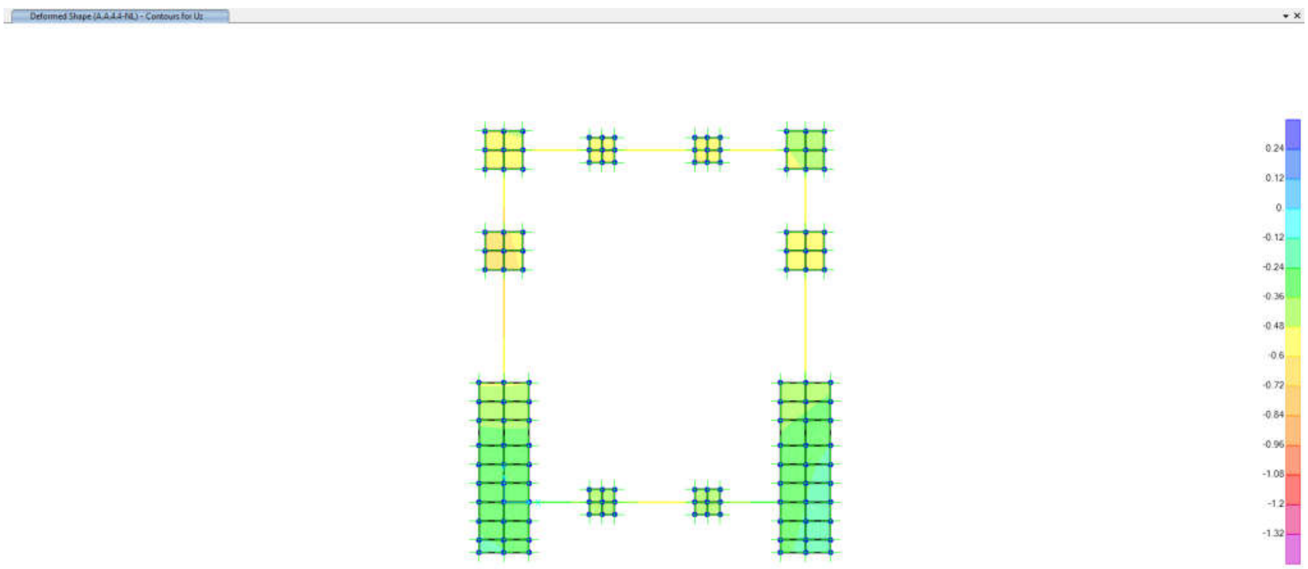


**FIGURE 20 -** Check of Displacement for Foundation (cm)

| TABLE: Joint Displacements | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Joint | OutputCase | CaseType | StepType | U3 | ks | Q | Q all | Control |
| Text | Text | Text | Text | cm | kg/cm3 | kg/cm2 | kg/cm2 | |
| … | … | … | … | … | … | … | … | … |
| 121 | A.D.3.1-NL | NonStatic | Min | -0.31975 | 1.69 | -0.54037 | -2 | Ok |
| 121 | A.D.3.2-NL | NonStatic | Min | -0.29259 | 1.69 | -0.49448 | -2 | Ok |
| 121 | A.D.3.3-NL | NonStatic | Min | -0.31548 | 1.69 | -0.53316 | -2 | Ok |
| 121 | A.D.3.4-NL | NonStatic | Min | -0.28815 | 1.69 | -0.48697 | -2 | Ok |
| 121 | A.D.3.5-NL | NonStatic | Min | -0.35003 | 1.69 | -0.59155 | -2 | Ok |
| 121 | A.D.3.6-NL | NonStatic | Min | -0.34882 | 1.69 | -0.5895 | -2 | Ok |
| 121 | A.D.3.7-NL | NonStatic | Min | -0.25932 | 1.69 | -0.43825 | -2 | Ok |
| 121 | A.D.3.8-NL | NonStatic | Min | -0.25798 | 1.69 | -0.43598 | -2 | Ok |
| 122 | A.A.1.1-NL | NonStatic | Min | -0.46004 | 1.69 | -0.77746 | -2 | Ok |
| 122 | A.A.2.1-NL | NonStatic | Min | -0.53147 | 1.69 | -0.89818 | -2 | Ok |
| 122 | A.A.2.2-NL | NonStatic | Min | -0.52839 | 1.69 | -0.89298 | -2 | Ok |
| 122 | A.A.3.1-NL | NonStatic | Min | -0.52426 | 1.69 | -0.886 | -2 | Ok |
| 122 | A.A.3.2-NL | NonStatic | Min | -0.52196 | 1.69 | -0.88212 | -2 | Ok |

| TABLE: Joint Displacements | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Joint | OutputCase | CaseType | StepType | U3 | ks | Q | Q all | Control |
| Text | Text | Text | Text | cm | kg/cm3 | kg/cm2 | kg/cm2 | |
| 122 | A.A.4.1-NL | NonStatic | Min | -0.27108 | 1.69 | -0.45813 | -2 | Ok |
| 122 | A.A.4.2-NL | NonStatic | Min | -0.65062 | 1.69 | -1.09954 | -2 | Ok |
| 122 | A.A.4.3-NL | NonStatic | Min | -0.21987 | 1.69 | -0.37158 | -2 | Ok |
| 122 | A.A.4.4-NL | NonStatic | Min | -0.70106 | 1.69 | -1.18479 | -2 | **Ok** |
| 122 | A.A.4.5-NL | NonStatic | Min | -0.3855 | 1.69 | -0.65149 | -2 | Ok |
| 122 | A.A.4.6-NL | NonStatic | Min | -0.53295 | 1.69 | -0.90068 | -2 | Ok |
| 122 | A.A.4.7-NL | NonStatic | Min | -0.23827 | 1.69 | -0.40268 | -2 | Ok |
| 122 | A.A.4.8-NL | NonStatic | Min | -0.68187 | 1.69 | -1.15235 | -2 | Ok |
| 122 | A.A.5.1-NL | NonStatic | Min | -0.35963 | 1.69 | -0.60778 | -2 | Ok |
| … | … | … | … | … | … | … | … | … |

According to SAFE report, Max soil pressure under the foundation is:

$q_n = 1.18 kg/cm^2 \ < \ 2 \ \ kg/cm^2 \ \ ok$

### 14.4 REINFORCING CONTROL

Foundation Reinforcement in “*ENV-S*” (Critical) Load Combination have been reported in the following figure:

$$A_{s\,used=}\ \emptyset 16@200 = \frac{2.01\ cm2}{20\ cm} = 0.1005\ \frac{cm^2}{cm}$$

$$According\ to\ analysis;\ A_{s,required} = 0.07\ \frac{cm^2}{cm}$$

$$\text{OK} A_{s\,used} > A_{s,required}$$

As noted before, both foundation and structure is modeled in a single model in sap2000. T16@200mm at each side of section is adequate.

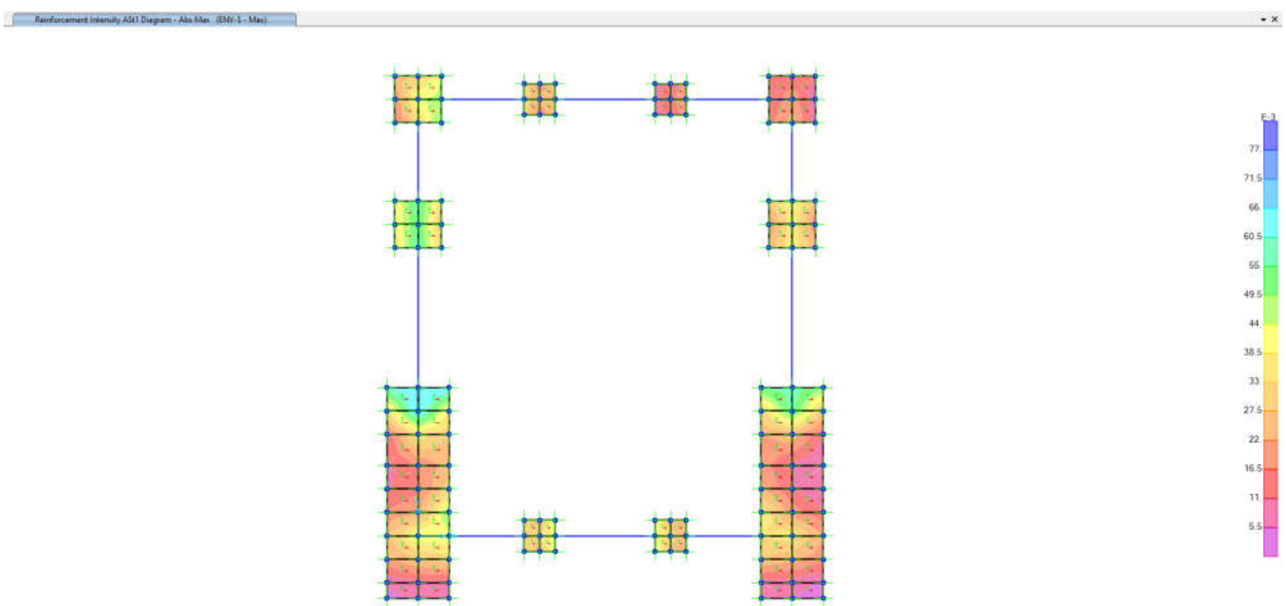



**Figure 21:** Foundation Reinforcement Intensity Ast1 (Unit: $\frac{cm2}{cm}$)

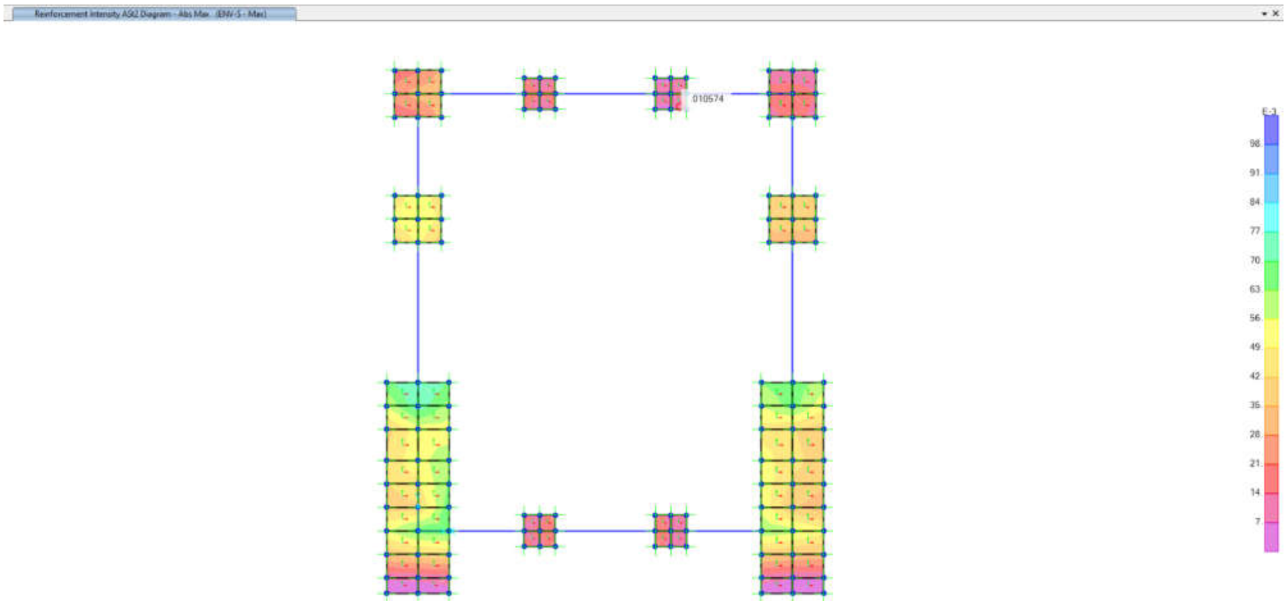



**Figure 22:** Foundation Reinforcement Intensity Ast2 (Unit: $\frac{cm2}{cm}$)

## 14.5 PUNCHING SHEAR CONTROL

### Shear Control:

### “PED1”:

| TABLE: Element Forces - Frames | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Frame | Station | OutputCase | CaseType | StepType | P | V2 | V3 | T | M2 | M3 |
| Text | cm | Text | Text | Text | Kgf | Kgf | Kgf | Kgf-cm | Kgf-cm | Kgf-cm |
| 1 | 0 | ENV-S | Combination | Max | 514.26 | 1948.33 | 331.8 | 128.3 | 41352.74 | 243402.2 |
| 1 | 0 | ENV-S | Combination | Min | -10343.9 | -1012.06 | 132.65 | -59.45 | 16422.62 | -126641 |
| 2 | 0 | ENV-S | Combination | Max | 2411.46 | 2205.95 | 245.43 | 93.81 | 30555.11 | 275599.4 |
| 2 | 0 | ENV-S | Combination | Min | -16734.2 | -684.25 | 37.05 | -58.68 | 4471.08 | -85670.4 |
| 3 | 0 | ENV-S | Combination | Max | 18064.78 | 2073.63 | 6973.04 | 144.56 | 872102.4 | 259061.8 |
| 3 | 0 | ENV-S | Combination | Min | -33419.3 | -520.6 | -3859.01 | -150.79 | -482299 | -65198.6 |
| 4 | 0 | ENV-S | Combination | Max | 16695.42 | 1861.11 | 3823.86 | 183.77 | 477678.7 | 232501.1 |
| 4 | 0 | ENV-S | Combination | Min | -27124.9 | -925.73 | -7640.09 | -259.05 | -955735 | -115849 |
| 5 | 0 | ENV-S | Combination | Max | 2952.45 | 3066.75 | 351.03 | 110.88 | 43754.87 | 383192.9 |
| 5 | 0 | ENV-S | Combination | Min | -12668 | -3938.76 | 108.47 | -197.57 | 13399.16 | -492639 |
| 6 | 0 | ENV-S | Combination | Max | 5581.68 | 4127.8 | 229.22 | 95.11 | 28527.6 | 515784.4 |
| 6 | 0 | ENV-S | Combination | Min | -19611.8 | -5494.7 | 48.1 | -145.3 | 5852.68 | -687288 |
| 7 | 0 | ENV-S | Combination | Max | 20188.06 | 3990 | 7964.94 | 172.38 | 996288.6 | 498578.7 |
| 7 | 0 | ENV-S | Combination | Min | -38328 | -5682.12 | -4801.37 | -158.56 | -600018 | -710770 |
| 8 | 0 | ENV-S | Combination | Max | 19542.04 | 3104.89 | 4722.73 | 237.14 | 589957.9 | 387964.2 |
| 8 | 0 | ENV-S | Combination | Min | -29887.7 | -3960.04 | -8651.1 | -156.69 | -1082251 | -495300 |
| | | | | | **-38328** | **-5682.12** | **-8651.1** | **-259.05** | **-1082251** | **-710770** |

### One-way Shear Control:

$V_u \leq \emptyset V_n$

$V_n = V_c + V_s$

$V_c = \left(0.17\lambda\sqrt{f_c'}\right)b_w d$

Axes X:

$V_c = \left(0.17 * 1 * \sqrt{300}\right)145 * 42.5 = 18.145ton$

$V_{ux} = 5.68\text{ton}$

$V_{ux} \leq \emptyset V_n \rightarrow 5.68 \leq 0.75 * 18.145 = 13.6 \quad ok$

Axes Y:

$$V_c = \left(0.17 * 1 * \sqrt{300}\right)145 * 42.5 = 18.145\ ton$$

$$V_{uy} = 8.65 \text{ ton}$$

$$V_{uy} \leq \emptyset V_n \rightarrow 8.65 \leq 0.75 * 18.145 = 13.6 \quad ok$$

**Two-way Shear Control:**

$$V_u \leq \emptyset V_n$$

$$V_n = V_c + V_s$$

$$V_c = min\begin{cases} 0.33\lambda_s\lambda\sqrt{f_c'} = 0.33 * 1 * 1 * \sqrt{300} = 5.71 \\ 0.17\left(1+\dfrac{2}{\beta}\right)\lambda_s\lambda\sqrt{f_c'} = 0.17 * \left(1+\dfrac{2}{1.3}\right) * 1 * 1 * \sqrt{300} = 7.47 \\ 0.083\left(2+\dfrac{\alpha_s d}{b_0}\right)\lambda_s\lambda\sqrt{f_c'} = 0.083 * \left(2+\dfrac{40 * 42.5}{290}\right) * 1 * 1 * \sqrt{300} = 11.3 \end{cases}$$

$$V_c = 0.33\lambda_s\lambda\sqrt{f_c'}bd = 0.33 * 1 * 1 * \sqrt{300}(290 * 42.5) = 70.375\ ton$$

$$v_u = \frac{V_u}{A_c} \pm \frac{M_{uv,x}C_y}{J_{cx}} \pm \frac{M_{uv,y}C_x}{J_{cy}}$$

$$V_u = 8651.1\ kgf$$

$$M_{ux} = 1082251\ \ kgf - cm$$

$$M_{uy} = 710770\ \ kgf - cm$$

$$\gamma_v = 1 - \gamma_f = 1 - \frac{1}{1+\frac{2}{3}\sqrt{\frac{b_1}{b_2}}} = 0.39$$

$$M_{uv,x} = \gamma_v M_{ux} = 0.39 * 1082251 = 422{,}077.89\ kgf - cm$$

$$M_{uv,y} = \gamma_v M_{uy} = 0.39 * 710770 = 277{,}200.3\ \ kgf - cm$$

$$\frac{J_{cx}}{C_y} = \frac{1}{3}\left[b_1 d(b_1 + 3b_2) + d^3\right] = \frac{1}{3}\left[145 * 42.5(145 + 3 * 145) + 42.5^3\right] = 1{,}217{,}005.2$$

$$\frac{J_{cy}}{C_x} = \frac{1}{3}\left[b_2 d(b_2 + 3b_1) + d^3\right] = \frac{1}{3}\left[145 * 42.5(145 + 3 * 145) + 42.5^3\right] = 1{,}217{,}005.2$$

$$v_u = \frac{8651.1}{290 * 42.5} + \frac{422,077.89}{1,217,005.2} + \frac{277,200.3}{1,217,005.2} = 0.7 + 0.34 + 0.34 = 1.38$$

Shear Ratio= $\frac{v_u}{\emptyset v_c} = \frac{1.38}{0.75*5.71} = 0.322\ ok$