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Qualification of Structural Support System for Various Spectral Accelerations Due to Base Excitation

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***Abstract*: As the structural component performance is an important criteria in analyzing structure life. In this project the support structure is of Steel Structural construction and consists of Column Rack, Bracket and fixed to wall. This design basis report covers the Static, Modular & Response spectrum analysis for qualification of the cable carrier Steel support system for Externally induced forces such as Aircraft crash, Air shock wave, Explosive blast, short circuit and other forces which are having same effects withstand ability using FEA techniques. For many engineers that use finite element analysis or FEA, it is very important to know how to properly model and obtain accurate solutions for complicated loading conditions such as shock loading. Transient acceleration loads, such as shocks, are not as common as static loads.**

***Keywords*: Equivalent section, Rack, Response spectrum, Spectral loads.**

1. Introduction

The project includes installation of cable carrier support system and design basis report covers the Static, Modular & Response spectrum analysis for qualification of the cable carrier Steel support system for Externally induced forces such as Aircraft crash, Air shock wave, Explosive blast, short circuit and other forces which are having same effects withstand ability using FEA techniques.

The support structure is of Steel Structural construction and consists of Column Rack, Bracket and rack is fixed to wall. The horizontal cantilever member called bracket and is attached to rack. Static Load and Spectral loads are acting directly on bracket. If required numbers of bracket are more in Support system, then increase in the height of the rack can be carried.

This report includes analysis and design of Cable rack assembly with 2 brackets to 16 brackets.

A. Base excitation and response spectrum analysis

Base excitation models the behavior of a vibration isolation system. The base of the spring is given a prescribed motion; causing mass to vibrate. This system can be used to model a vehicle suspension system, or the earthquake response of a structure. With the same concept as of Base excitation that cause only mass to react for forces acting on it, in this project response spectrum analysis is carried out for externally influenced forces.

For high-rise buildings under wind loads and for nuclear plant designs under Seismic loads most used analysis is Response spectrum analysis. Based on the Response spectrum input maximum response can be calculated for given Base excitation and the method used to combine the modal responses. The combination methods available are: The Square Root of the Sum of the Squares (SRSS), the Complete Quadratic Combination (CQC).

B. Analysis

Analysis is carried in ANSYS workbench software. Static analysis, modal analysis and response spectrum analysis are done with use of software. Input data of Acceleration, Velocity and Displacement units included in response spectrum. This spectrum is applied as an excitation. Each frequency will be there for each spectrum value. The excitation must be applied at fixed degrees of freedom. Because a new solve is required for each requested output, for example, displacement, velocity and acceleration, the content of Commands objects inserted in a response spectrum analysis is limited to SOLUTION commands.

2. Methodology

A. System Description

The support structure is of Steel Structural construction and consists of Column Rack, Bracket and rack is fixed to wall. Brackets are connected to Rack by bolts at regular vertical distance and Rack is supported by wall at fixing locations. Cable tray carry cable through it and load due to cable is transfer to bracket. Number of Bracket is increased as increase in height of Rack. This project analysis and design is carried for Cable rack assembly with 2 brackets to Cable rack assembly 16 brackets. Length of Bracket is 630mm is constant as required.

The vertical distance of first bracket from bottom of rack will be 100 mm and then for successive bracket distance with each will be 200 mm. The maximum unsupported length that is distance between the fixed conditions is considered 600 mm.

the vertical distance between the brackets from top of rack is kept as 300 mm.

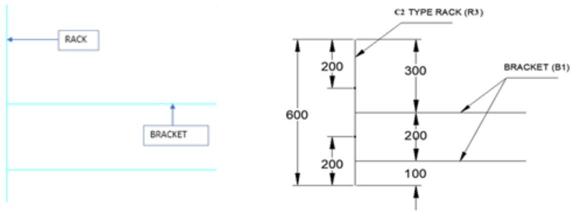

Fig. 1. Model and Details of cable rack assembly in mm

B. Codes used

- ASME SEC III SUB SEC NF: 2017- BPVC division 1 sub section NF for supports.
- IS 2062: 2011- Hot rolled medium and high tensile structural steel
- IS 1079: 2009- Hot rolled carbon Steel sheet and strip specification
- IS-801: 1975 -Code of practice for use of cold – formed light gauge steel structured members in general building construction
- ASCE 4-98: 2008 -Seismic analysis of safety related nuclear structures and commentary.

C. Parameters Adopted in the Analysis

- Grade of Steel for Rack and Bracket: FE410
- Modulus of Elasticity of Steel: 20000 N/mm^2
- Poisson's ratio: 0.33
- Yield Strength of Steel: 410 N/mm^2
- Ultimate Tensile Strength of Steel: 540 N/mm^2

D. Modelling

1) General

The support structure modelling consists of bracket and rack in 3-D by using software ANSYS (version 18.0). As the rack is supported with wall fixed depends on its height. From equivalent sections structure geometry is considered. The vertical rack is fixed to the wall at various supports and constrained in all the 3 translation directions. Isometric views of FE model are given in figure below which also indicate the co-ordinate system. The masses applied at each bracket as distributed mass. Static analysis has done under self-weight then proceeds with modal, spectrum analysis. The Response Spectrum for all Level is applied in the all the three directions & directional combination are done by SRSS method.

2) Geometry

A 3-D modeling of support structure is of line frame consisting rack and brackets as shown in fig. 2 and 3. By the meshing of solid model, finite model is developed Vertical column having channel section of length is 600mm fixed to the wall by 2 points in translation directions.

Horizontal bracket having channel section of length is 630mm fixed to the column as cantilever. The sectional dimensions used to execute structure will have the slots also brackets are tapered along its length which is not modelled in ANSYS, so these dimensions are calculated from the equivalent sections.

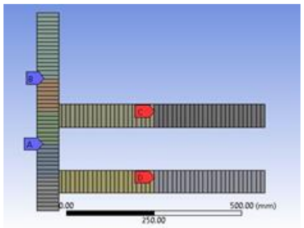

Fig. 2. Solid model of Cable rack assembly

Once the geometry is created as per specifications it is imported into ANSYS workbench for Discretization. The finite element model is prepared by meshing it with appropriate by linear quadrilateral elements.

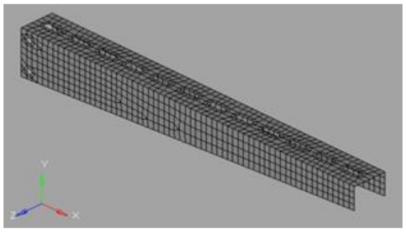
Fig. 3. Meshing model of bracket

Loads and boundary conditions were applied on the FE Model as follows,

1. Moment of inertia about Z-axis

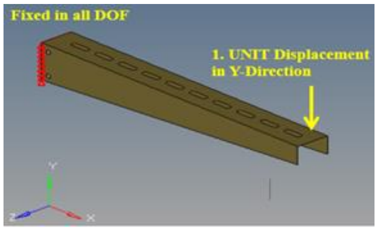

Fig. 4. Bracket with boundary conditions-1

As shown in the Figure above, one end of the bracket nodes is fixed in all degrees of freedom and other one extreme end nodes are applied by unit displacement in Y-Direction. The Reaction forces will be calculated at the fixed nodes is called as ‘W’.

W= 1269.4 N (Total force causes to unit deformation, Data from FEM Results)

Stiffness (K) is technically defined as Force per unit deformation. So, Stiffness of the bracket is will be arrived by equation.

$$K = \frac{W}{\text{Unit deformation}} \text{ N/mm}$$

$$K = \frac{626.862}{1} \text{ N/mm}$$

K = 1269.4 N/mm

The Stiffness formula used for cantilever beam with point load at the end is given $K = \frac{3EI_{ZZ}}{L^3}$

$$1269.4 = \frac{3 \text{ x } 2e5 \text{ x } I_{ZZ}}{630^3}$$

$I_{ZZ} = 0.5290143 \text{ x } 10^6 \text{ mm}^4$

Where, E is Young's Modulus

I_{ZZ} is Moment of Inertia about Z-axis

2. Moment of inertia about Y-axis

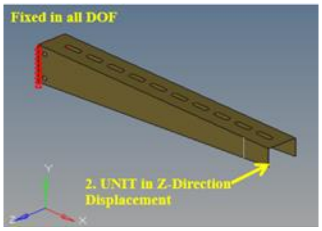

Fig. 5. Bracket with boundary conditions-2

As shown in the Figure, one end of the bracket nodes is fixed in all degrees of freedom and other extreme end nodes are applied by unit displacement in Z-Direction. The Reaction forces will be calculated at the fixed nodes is called as 'W'.

W= 1100.508 N (Data from FEM Results)

Stiffness (K) is technically defined as Force per unit deformation. So, Stiffness of the bracket is will be arrived by the below equation.

$$K = \frac{W}{\text{Unit deformation}} \text{ N/mm}$$

$$K = \frac{1100.508}{1} \text{ N/mm} \qquad K = 1100.508 \text{ N/mm}$$

The Stiffness formula used for cantilever beam with point load at the end is given $K = \frac{3EI_{yy}}{L^3}$

$$1100.508 = \frac{3 \text{ x } 2e5 \text{ x } I_{YY}}{630^3}$$

$I_{YY} = 0.4586314 \text{ x } 10^6 \text{ mm}^4$

Equivalent sections are found out based moment of inertia in ANSYS.

Table 1
Moment of inertia of Bracket comparison

Moment of Inertia From Calculations	$I_{ZZ} = 0.53012426 \text{ x } 10^6 \text{ mm}^4$
	$I_{YY} = 0.45940981 \text{ x } 10^6 \text{ mm}^4$
Moment of Inertia From Equivalent Sections	$I_{ZZ} = 0.5290143 \text{ x } 10^6 \text{ mm}^4$
	$I_{YY} = 0.458614 \text{ x } 10^6 \text{ mm}^4$

Similarly, as of Bracket Moment of Inertia for Rack is calculated by applying load at top and bottom of rack is fixed.

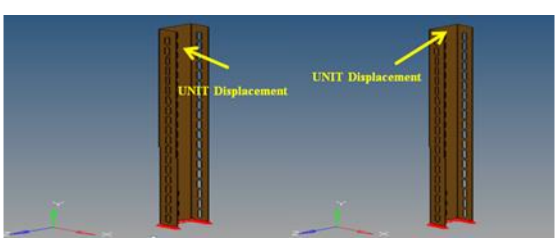

Fig. 6. Rack with boundary conditions-1 and 2

Equivalent Section Validation:

- Beam element modelled of 630 mm length and assigned equivalent section properties.
- One is fixed in all DOF and other end is applied by total reaction forces of 641.548N in Z- direction
- Displacement in Z-direction is 1mm and hence equivalent section is validated.

Table 2
Moment of inertia of Rack comparison

Moment of Inertia From Calculations	$I_{ZZ} = 0.35016516 \text{ x } 10^6 \text{ mm}^4$
	$I_{YY} = 0.56444193 \text{ x } 10^6 \text{ mm}^4$
Moment of Inertia From Equivalent Sections	$I_{ZZ} = 0.349409 \text{ x } 10^6 \text{ mm}^4$
	$I_{YY} = 0.5643212 \text{ x } 10^6 \text{ mm}^4$

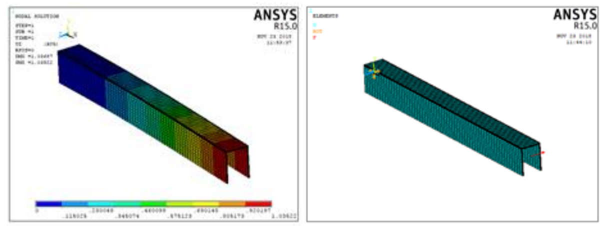

Fig. 7. Equivalent section validation

3) Support Condition

Following to the Geometry modelling support condition applied. As support structure is wall mounted fixed support is considered at various interval depends on height. Maximum distance between two consecutive supports should not more than the 600mm. Finite model is developed by meshing the solid model. Load is applied directly on each Bracket as Distributed mass.

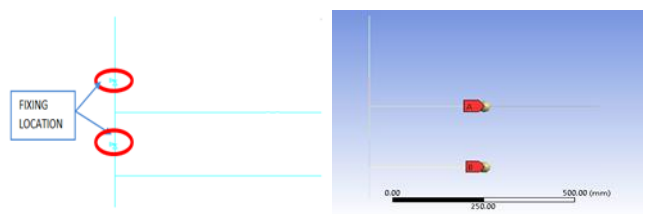

Fig. 8. FE model of Bracket Rack assembly with Boundary condition and mass applied

4) Static Analysis

The self-load of 2200 N has been applied by 3D distribution mass element for Static analysis. Acceleration due to gravity is applied on Centroid of Bracket Rack assembly in vertical downward direction.

5) Modal Analysis

Modal analysis is Prerequisite for Response spectrum analysis as both analysis share model data and geometry. The self-load of 1100 N has been applied by 3D distribution mass element for Modal analysis. Acceleration due to gravity is not applied on Centroid of Bracket Rack assembly. Number of modes shapes to be entered to achieve 90% of mode distribution.

6) Response Spectrum Analysis

Case 1: The spectrum is applied as base excitation. The Response Spectrum for CASE1 level is applied in each

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individual direction as per Spectral inputs.

- SPECTRA IN X-DIRECTION: The spectrum for CASE1 level with peak acceleration of 18 m/s^2 in X-direction
- SPECTRA IN Y-DIRECTION: The spectrum for CASE1 level with peak acceleration of 18 m/s^2 in Y-direction.
- SPECTRA IN Z-DIRECTION: The spectrum for CASE1 level with peak acceleration of 18 m/s^2 in Z-direction is as given in table below.

Damping Factor of Steel for CASE is 10%

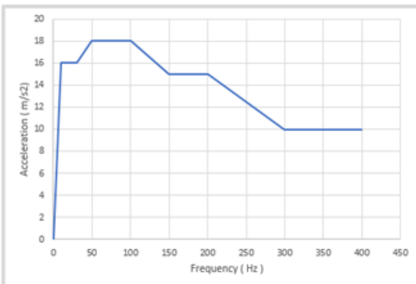

Fig. 9. Graphical representation of Spectral input data for Case-1

Case 2: The spectrum is applied as base excitation. The Response Spectrum for CASE2 level is applied in each individual direction.

- SPECTRA IN X-DIRECTION: The spectrum for CASE2 with peak acceleration of 60 m/s^2 in X direction
- SPECTRA IN Y-DIRECTION: The spectrum for CASE2 with peak acceleration of 60 m/s^2 in Y direction
- SPECTRA IN Z-DIRECTION: The spectrum for CASE2 with peak acceleration of 60 m/s^2 in Z direction is given table below.

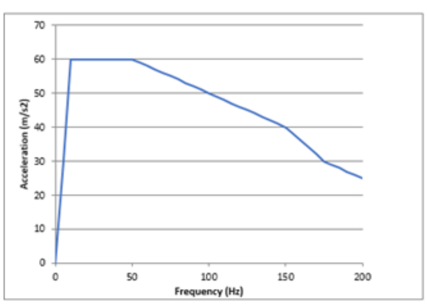

Fig. 10. Graphical representation of Spectral input data for Case-2

3. Analysis Results and Design

A. Analysis Results

Results from analysis of bracket rack assembly in ANSYS workbench are obtained in SOLUTION. Importing parameters required to Design structure from SOLUTION and are noted.

Forces and moments in Rack and Bracket with 2 Bracket is given in Table 3 and Table 4 respectively.

Table 3
Forces and moments in RACK with 2 Brackets

Description	Static 220Kg	Static 110Kg	Case 1	Case 2	Units
MAX Tensile Force F_T	2203.1	1124.3	1350.7	4806.2	N
MAX. Compressive Force Fc	1101.5	562.17	0	0	N
Max. Bending moment Myy	0	0	35065	117720	N-mm
Max. Bending moment Mzz	690270	350470	5615140	2082700	N-mm
Max Torsional moment Mt	0	0	0	0	N-mm
Max Shear Force in Y-Dir FY	3117.6	1582.9	2476.1	9025.4	N
Max Shear Force in Z-Dir FZ	0	0	349.21	1171.1	N

Table 4
Forces and moments in BRACKET with 2 Brackets

Description	Static 220Kg	Static 110Kg	Case 1	Case 2	Units
MAX Tensile Force F_T	0	0	1302.3	2679.6	N
MAX. Compressive Force Fc	0	0	0	0	N
Max. Bending moment Myy	0	0	152890	503580	N-mm
Max. Bending moment Mzz	690270	350470	544970	2036200	N-mm
Max Torsional moment Mt	0	0	0	0	N-mm
Max Shear Force in Y-Dir FY	2056.5	1045.2	1340.7	4781.3	N
Max Shear Force in Z-Dir FZ	0	0	424.87	1445.1	N

B. Design procedure

Material data:

Grade of steel E410

Young's modulus E = $2X10^5$ N/mm^2

Yield strength S_y = 410 N/mm^2

Ultimate tensile strength = 540 N/mm^2

Effective length factor K = 1.2

Considering the analysis results for design by assuming,

Static 220 kg as Design Static

Static 110 kg + Case 1 as Design Case 1

Static 110 kg + Case 2 as Design Case 2

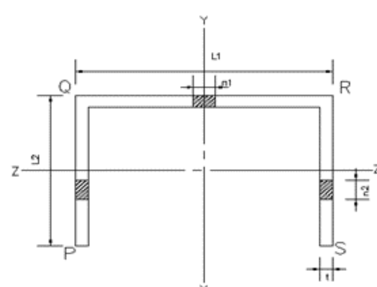

Fig. 11. Cross Section of Rack

Dimensions:
QR = 69mm, PQ = 68mm
t = 4mm
Slot Dia. n1 = 10.2mm
Slot Width n2 = 34mm
Unsupported length = 200mm
Net area= $[(69 - 10.2) \times 4 + (68 - 4) \times 4] - [2 \times 10.2 \times 4] = 665.6$ mm^2
Gross area, A = $(69 \times 4) + [(68 - 4) \times 4 \times 2] = 788$ mm2
Laterally unsupported length:
Unsupported length of compression flange

$$\leq \frac{200 b_f}{\sqrt{Sy}} = \frac{200\times 68}{\sqrt{410}} = 671.66 \text{ mm}$$

and also $\leq \frac{138000}{\left(\frac{d}{A_f}\right)Sy} = \frac{138000}{\left(\frac{69}{4\times 68}\right)\times 410} = 1326.89$ mm
(From ASME BPVC SECTION 3322.1(d) (1), eq. 11)
∴ 200 < 671.66 and also 200 < 1326.89
Hence ok
i) Ratio of slenderness for Compression members

$$\frac{KL}{r} < 200 = 10.46 < 200 \text{ mm}$$

(from ASME BPVC SECTION 3322.2(c), (1))
ii) Ratio of slenderness for Tension members
$\frac{L}{r} < 240 = \frac{200}{22.94} = 8.72 < 240$ mm
(from ASME BPVC SECTION 3322.2(c), (2))
iii) Ratio of slenderness for Lateral bracing members

$$\frac{L}{r} < 300 = 8.72 < 300 \text{ mm}$$

(from ASME BPVC SSECTION 3322.2(c), (2)),
Hence ok
Allowable stresses:
i) Allowable bending stress:
$\frac{PQ}{t} = \frac{68}{4} = 17$ mm, $\frac{QR}{t} = \frac{69}{4} = 17.25$ mm
Actual width to thickness ratio $\frac{b}{t_f} = 17.25$ mm
Actual width to twice thickness ratio $\frac{b}{2t_f} = 8.625$ mm
Allowable width to thickness ratio $\frac{170}{\sqrt{Sy}} = 8.40$ mm
Allowable width to thickness ratio $\frac{250}{\sqrt{\frac{Sy}{Kc}}} = 12.35$ mm
Allowable width to thickness ratio $\frac{510}{\sqrt{\frac{Sy}{Kc}}} = 25.19$ mm

Stress reduction factor $Q_s = 1.293 - 0.00118 \times \frac{b}{t_f} \times \sqrt{\frac{S_y}{Kc}}$
(From ASME BPVC SECTION 3322.2 Eq 29)
$Q_s = 1.293 - 0.00118 \times 17.25 \times 20.248$
$Q_s = 0.8808$
Since, $\frac{510}{\sqrt{\frac{Sy}{Kc}}} > \frac{b}{t_f} > \frac{250}{\sqrt{\frac{Sy}{Kc}}}$
Therefore, Allowable bending stress $F_b = Q_s \times 0.66 \times S_y$
= 0.8808 × 0.66 × 410
= 238.36 N/mm^2 (Design Static)
= 357.53 N/mm^2 (Design case1)
= 357.53 N/mm^2 (Design case2)

ii) Allowable compressive stress:

Radius of gyration about Y axis $r_{yy} = \sqrt{\frac{I_{YY}}{A}} = \sqrt{\frac{564441.93}{665.6}}$
=29.12 mm

Radius of gyration about Z axis $r_{zz} = \sqrt{\frac{I_{ZZ}}{A}} = \sqrt{\frac{350165.16}{665.6}}$
= 22.94 mm
∴ r_{max} = 29.12 mm (max. of above)
Effective Slenderness ratio = $\frac{KL}{r_{max}} = \frac{1.2\times 200}{22.94} = 10.46$ mm

$$c_c = \sqrt{2\times\pi^2\times\frac{E}{Qs_y}} = \sqrt{\frac{2\times\pi^2\times 2\times 10^5}{0.8808\times 410}} = 104.55$$

∴ Allowable compressive strength F_a ,

$$F_a = \frac{QsQa\left[1-\frac{\left(\frac{KL}{r}\right)^2}{2c_c{}^2}\right]S_y}{\frac{5}{3}+\frac{3\left(\frac{KL}{r}\right)}{8(c_c)^3}-\frac{\left(\frac{KL}{r}\right)^3}{8(c_c)^3}}$$

(from ASME BPVC SECTION 3322.2 eq.35)

$$F_a = \frac{0.8808\times 1\left[1-\frac{10.46^2}{2\times 104.55^2}\right]\times 410}{\frac{5}{3}+\frac{3\times 10.46}{8\times 104.55}-\frac{10.46^3}{8\times 104.55^3}}$$

F_a= 210.87 N/mm^2 (Design Static)
= 316.30 N/mm^2 (Design case1)
= 316.30 N/mm^2 (Design case2)

iii) Allowable tensile stress $F_t = 0.45 \times Sy$
(From ASME BPVC SECTION 3322.1(a)eq 2)
= 0.45 × 410
= 184.5 N/mm^2 (Design Static)
= 276.75 N/mm^2 (Design case1)
= 276.75 N/mm^2 (Design case2)

iv) Allowable shear stress $F_v = 0.4 \times Sy$
(From ASME BPVC SECTION 3322.1(b) eq3)
= 0.4×410
= 164 N/mm^2 (Design Static)
= 246 N/mm^2 (Design case 1)
= 246 N/mm^2 (Design case 2)

Actual stress for Design Static condition:
i) Actual bending stress:

Table 5
Maximum Bending Stress Design Static condition

Bending stress	Neutral axis depth from bottom	Neutral axis depth from top
Due to M_{yy} is $\sigma_y = \frac{M_{yy}}{Z_{yy}}$	$\frac{0}{16360.47} = 0$	$\frac{0}{16360.47} = 0$
Due to M_{zz} is $\sigma_z = \frac{M_{zz}}{Z_{zz}}$	$\frac{690270}{7967.35} = 86.64$	$\frac{690270}{14559.88} = 47.40$
Total Bending Stress, $\sigma_y + \sigma_z$	86.64	47.40

Bending stress concentration factor K_b= 1 (Hand book: Petersons stress cont. factor)
Maximum Bending Stress S_b = 86.64 N/mm^2
Actual Net Bending stress = S_b x K_b
= 86.64 x 1

= 86.64 N/mm^2

∴ Allowable bending stress > Actual bending stress

238.36 > 86.64

ii) Calculated stress in compression:

Stress in compression $f_a = \frac{F_c}{A} = \frac{1101.5}{788} = 1.397$ N/mm^2

∴ Allowable Compressive stress > Actual Compressive stress

210.87 > 1.397

iii) Calculated stress in Tension:

Stress concentration Kc= 1 (Hand book: Petersons stress concentration factor)

Actual Tensile stress $= \frac{F_t}{Net\ area} = \frac{2203.1}{665.6} = 3.31$ N/mm^2

∴ Allowable Tensile stress > Actual Tensile stress

184.5 > 3.31

iv) Calculated stress in shear

Area for shear stress A1 = $L_1 \times t = 69 \times 4 = 276$ mm^2

Area for shear stress A2 = $L_2 \times t \times 2 = 68 \times 4 \times 2 = 544$ mm^2

Shear stress due to Maximum Shear force in Y direction, $\sigma_{s1} = \frac{F_y}{A2} = \frac{0}{544} = 0$ N/mm^2

Shear stress due to Max Shear force in Z direction, $\sigma_{s2} = \frac{F_z}{A1} = \frac{3117.6}{276} = 11.3$ N/mm^2

Shear stress due to Torsional moment M_t,

$\sigma_{st} = \frac{M_t}{A} = \frac{0}{788} = 0$ N/mm^2

Actual Net Shear stress $= \sqrt{\sigma_{s1}^2 + \sigma_{s2}^2 + \sigma_{st}^2}$

$= \sqrt{0^2 + 11.30^2 + 0^2}$

$= 11.3$ N/mm^2

Table 6
Maximum Bending Stress Design Case1 condition

Bending stress	Neutral axis depth from bottom	Neutral axis depth from top
Due to M_{yy} is $\sigma_y = \frac{M_{yy}}{Z_{yy}}$	$\frac{35065}{16360.47} = 2.14$	$\frac{35065}{16360.47} = 2.14$
Due to M_{zz} is $\sigma_z = \frac{M_{zz}}{Z_{zz}}$	$\frac{912010}{7967.35} = 114.46$	$\frac{912010}{14559.88} = 62.63$
Total Bending Stress, $\sigma_y + \sigma_z$	116.6	64.77

∴ Allowable Shear stress > Actual Shear stress

164 > 11.3 Hence ok

Actual stress for Design Case1 condition:

i) Actual bending stress:

Bending stress concentration factor K_b= 1 (Hand book: Petersons stress cont. factor)

Maximum Bending Stress S_b = 116.6 N/mm^2

Actual Net Bending stress = S_b x K_b

= 116.6 x 1

= 116.6 N/mm^2

∴ Allowable bending stress > Actual bending stress

357.53 > 116.6

ii) Calculated stress in compression:

Stress in compression $f_a = \frac{F_c}{A} = \frac{0}{788} = 0$ N/mm^2

Allowable Compressive stress > Actual Compressive stress

316.30 > 0

iii) Calculated stress in Tension:

Stress concentration Kc= 1 (Hand book: Petersons stress concentration factor)

Actual Tensile stress $= \frac{F_t}{Net\ area} = \frac{1350.7}{665.6} = 2.03$ N/mm^2

∴ Allowable Tensile stress > Actual Tensile stress

276.75 > 2.03

iv) Calculated stress in shear:

Area for shear stress A1 = $L_1 \times t = 69 \times 4 = 276$ mm^2

Area for shear stress A2 = $L_2 \times t \times 2 = 68 \times 4 \times 2 = 544$ mm^2

Shear stress due to Max Shear force in Y direction,

$\sigma_{s1} = \frac{F_y}{A2} = \frac{349.24}{544} = 0.64$ N/mm^2

Shear stress due to Max Shear force in Z direction,

$\sigma_{s2} = \frac{F_z}{A1} = \frac{2476.1}{276} = 8.97$ N/mm^2

Shear stress due to Torsional moment M_t,

$\sigma_{st} = \frac{M_t}{A} = \frac{0}{788} = 0$ N/mm^2

Actual Net Shear stress $= \sqrt{\sigma_{s1}^2 + \sigma_{s2}^2 + \sigma_{st}^2}$

$= \sqrt{0.64^2 + 8.97^2 + 0^2}$

$= 8.99$ N/mm^2

∴ Allowable Shear stress > Actual Shear stress

246 > 8.99 Hence ok

Actual stress for Design Case 2 condition:

i) Actual bending stress:

Bending stress concentration factor K_b= 1 (Hand book: Petersons stress cont. factor)

Maximum Bending Stress S_b = 312.58 N/mm^2

Actual Net Bending stress = S_b x K_b

= 312.58 x 1

= 312.58 N/mm^2

∴ Allowable bending stress > Actual bending stress

357.53 > 312.58

Table 7
Maximum Bending Stress Design Case2 condition

Bending stress	Neutral axis depth from bottom	Neutral axis depth from top
Due to M_{yy} is $\sigma_y = \frac{M_{yy}}{Z_{yy}}$	$\frac{117720}{16360.47} = 7.19$	$\frac{117720}{16360.47} = 7.19$
Due to M_{zz} is $\sigma_z = \frac{M_{zz}}{Z_{zz}}$	$\frac{2433170}{7967.35} = 305.39$	$\frac{2433170}{14559.88} = 167.11$
Total Bending Stress, $\sigma_y + \sigma_z$	312.58	174.304

ii) Calculated stress in compression:

Stress in compression $f_a = \frac{F_c}{A} = \frac{0}{788} = 0$ N/mm^2

∴ Allowable Compressive stress > Actual Compressive stress

316.30 > 0

iii) Calculated stress in Tension:

Stress concentration Kc= 1 (Hand book: Petersons stress concentration factor)

Actual Tensile stress $= \frac{F_t}{Net\ area} = \frac{4806.2}{665.6} = 7.22$ N/mm^2

∴ Allowable Tensile stress > Actual Tensile stress

276.75 > 7.22

iv) Calculated stress in shear:

Area for shear stress A1 = $L_1 \times t = 69 \times 4 = 276$ mm^2

Area for shear stress A2 = $L_2 \times t \times 2 = 68 \times 4 \times 2 = 544$ mm^2

Shear stress due to Max Shear force in Y direction,

$\sigma_{s1} = \frac{F_y}{A2} = \frac{1171.1}{544} = 2.15$ N/mm^2

Shear stress due to Max Shear force in Z direction,

$\sigma_{s2} = \frac{F_z}{A1} = \frac{9025.4}{276} = 32.70$ N/mm^2

Shear stress due to Torsional moment M_t,

$\sigma_{st} = \frac{M_t}{A} = \frac{0}{788} = 0$ N/mm^2

Actual Net Shear stress $= \sqrt{\sigma_{s1}^2 + \sigma_{s2}^2 + \sigma_{st}^2}$

$= \sqrt{2.15^2 + 32.70^2 + 0^2}$

$= 32.77$ N/mm^2

∴ Allowable Shear stress > Actual Shear stress

246 > 32.77 Hence ok

4. Conclusions

- This project includes installation of cable carrier Structural steel support system and design basis report covers the Static, Modular & Response spectrum analysis for qualification of the cable carrier Steel support system.
- The support structure is consists of Column Rack, horizontal cantilever Bracket and rack is fixed to wall.
- Feasibility to confirm that the support system as outlined in this report can be practically manufactured from sheet steel and wires using general industry practices.
- Analysis is carried in ANSYS workbench software (version 18.0). Static analysis, modal analysis and response spectrum analysis are done with use of software.
- And development of design, qualification for static load and seismic, aircraft crash and air shock wave, load requirements, preparation of drawings for the complete cable carrier system including all supports and accessories, preparation of detailed specifications for procurement and installation of support system as brought out in specification.

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