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Research Paper

DESIGN OPTIMIZATION OF THE TUBING ASSEMBLY STRUCTURE FOR SEISMIC CONDITIONS

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In this paper, desired data from the modal analysis will be obtained from ANSYS using tubing assembly structure model. The FRS data is obtained from the geographical region where this structure will be mounted. Those data will be used for performing response spectrum analysis, which is essential data for designing a structure. Therefore, it was possible to determine whether the structure is safe through. In my current project the scope of work includes, Creating 3d model of the tubing assembly structure. Modal analysis to study the fundamental frequencies of the structure Dynamic analysis: To evaluate seismic response of the system under Operation Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE). The response spectra used for SSE in X, Y, Z directions are given as input. Calculation of stresses in the beam elements as per ASME section, sub-section NF for the above load cases are done, also Verification of adequacy of welded/nut bolt joints are done. In this project “g” values at five locations where maximum accelerations occur are computed. Design optimization of the structure was done based on the results obtained.

Keywords: Tubing assembly, Seismic conditions, FRS data, ANSYS

INTROUCTION

Even if the ground peak acceleration is a small fraction of gravity (e.g., 0.2 g) the effects of earthquakes on tubing assembly are significant and have to be carefully taken into account in its design. A seismic event is in fact, in many cases, the most demanding loading condition, in particular for the interface structures (e.g., supports) which must be sized for high strength, and often also for high stiffness.

The two main reasons why these events are of so much importance are as follows.

1. Seismic motion has a relatively broadband spectral content which encompasses the typical natural frequencies of structures (e.g., 1 to 33 Hz) with therefore spectral

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amplifications likely to take place. Spectral amplification factors are a function of both damping and natural frequency of the structures and are established by enveloping charts, called design response spectra. The typical value of acceleration amplification factors (for structures with natural frequency between 1 and 33 Hz) is about 3.

2. Structures are usually weaker when loaded by horizontal inertial loads, even when these are a small fraction of gravity.

The tubing assembly is a mounting structure used to mount 25 numbers of transmitters for control systems in nuclear plants. In this paper, the tubing assembly structure is designed to with stand seismic vibrations.

METHODOLOGY

A detailed Finite Element model was built with shell, beam and mass elements to idealize all the components of the tubing assembly. Modal analysis was carried to capture the natural frequencies and their mass participations.

A Response Spectrum Analysis (RSA) was simulated to evaluate seismic response of the system under OBE and SSE conditions obtained from the geographical data along horizontal X, Y and vertical Z direction that is 2/3rd of horizontal and the Square Root of the Sum of the Squares (SRSS) method was used to combine the total response in each direction. The stresses in the structural members were calculated and compared against the allowable stresses as per ASME section, sub-section NF for the following load cases:

- Level A condition: dead weight
- Level B condition: dead weight + OBE
- Level C condition: dead weight + SSE

Finite element analysis was carried in the following steps:

- Static (dead weight) analysis of tubing assembly for the original model.
- Modal analysis for natural frequencies and mass participation for the original model.
- Response spectrum analysis for original model under given OBE and SSE condition.
- Static analysis (dead weight) of tubing assembly for modified model.
- Modal analysis for natural frequencies and mass participation for the modified model.
- Response spectrum analysis for modified model under OBE and SSE condition.

Material Properties:

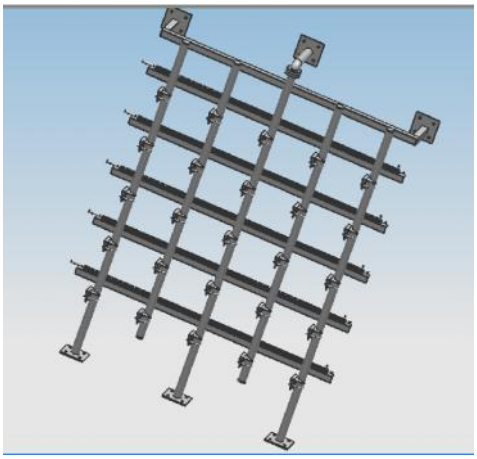
All the components of the tubing Assembly are made using steel. All the components of the tubing Assembly are assigned as per the below material properties. The total weight of the tubing Assembly for Finite Element simulation is 350 Kgs.

Table 1: Material Properties

Material Properties				
Material Specification	Young's Modulus (N/mm2)	Poission's ratio	Density (N-Sec2/mm4)	Yeild stress (N/mm2)
steel	1.93e5-2e5	0.3	8.00E-09	215

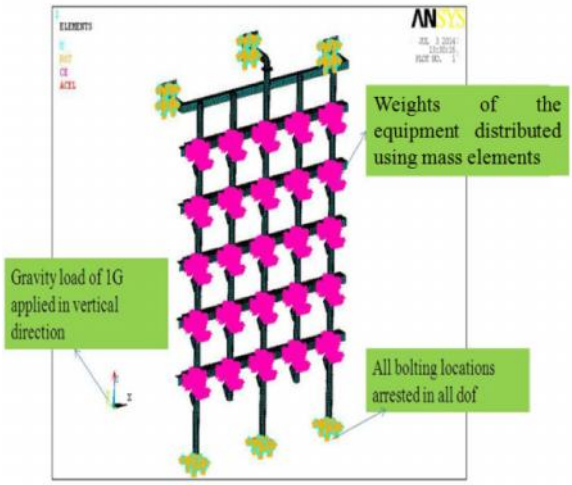
3D MODELING OF TUBINGASSEMBLY

Figure 1: 3D Model of Tubing Assembly Used for Analysis



STATIC ANALYSIS OF ORIGINAL MODEL (DEAD WEIGHT)

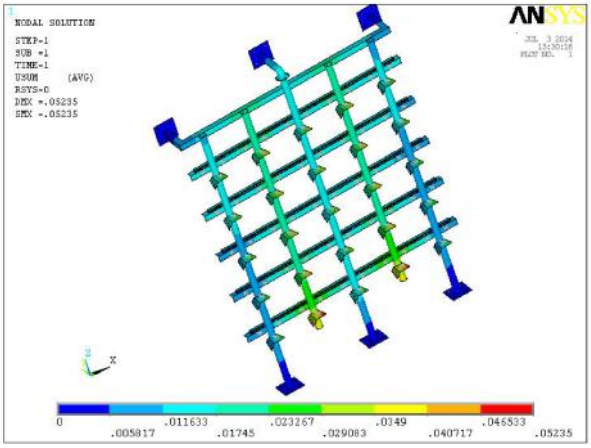
Figure 2: Boundary Conditions Applied on the Tubing Assembly for Static Analysis



RESULTS

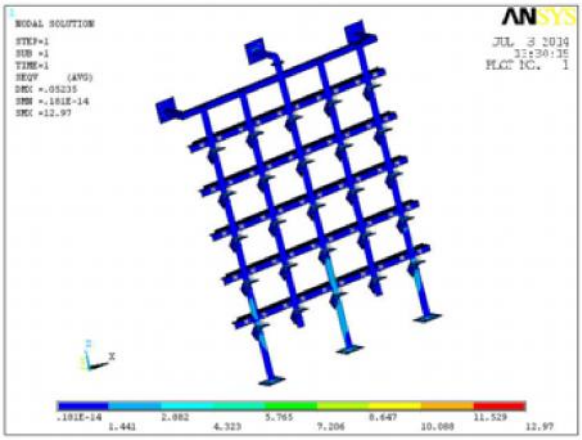
From the above analysis the deflections and stress results are plotted. Maximum deflection of 0.05 mm is observed.

Figure 3: Total Deflection Plot of the Tubing Assembly for Level A Condition



Maximum Von Mises stress of 12.97 MPa was observed as shown in the below figure.

Figure 4: Von Mises Stress Plot for Level A Condition



MODAL ANALYSIS OF TUBING

Table 2: Frequencies and Mass Participation

MODE	FREQUENCY	EFFECTIVE MASS		
		X Dir	Y Dir	Z Dir
1	16.18	2.13E-05	0.2925	1.17E-07
2	19.41	1.75E-02	4.91E-04	4.16E-06
3	28.6	0.307	8.70E-07	6.86E-05

Mode Shapes

Figure 5: Mode1 @ 16 Hz

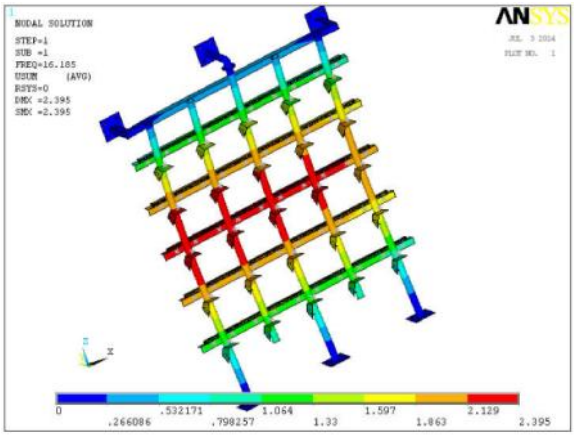


Figure 6: Mode2 @ 19 Hz

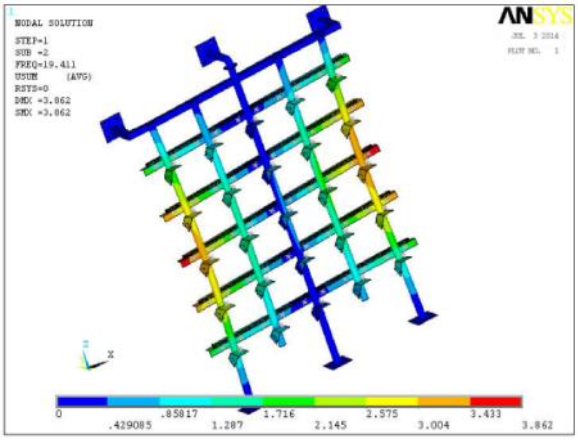
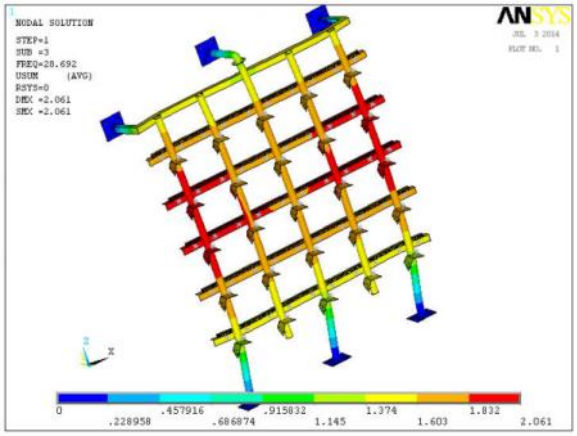


Figure 7: Mode3 @ 28 Hz



RESPONSE SPECTRUM ANALYSIS OF TUBINGASSEMBLY

Level B: Dead Weight + OBE

Figure 8: Total Deflection Plot of the Tubing Assembly for Level B Condition

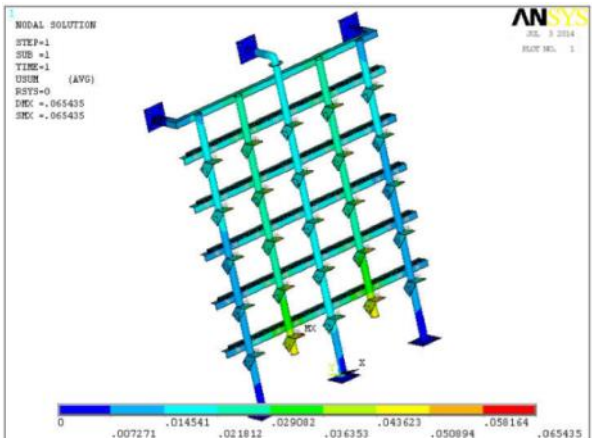
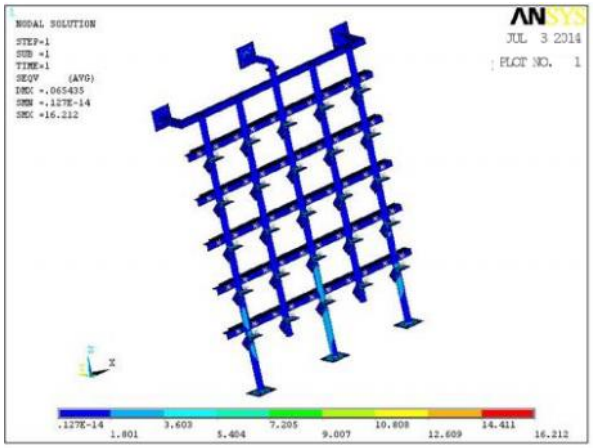


Figure 9: Von Mises Stress Plot of the Tubing Assembly for Level B Condition



Level C: Dead Weight + SSE

Maximum deflection of 0.4 mm is observed.

Maximum Von Mises stress of 20.03 MPa was observed as shown in the below figure.

Foundation Bolt Calculation

The reactions at the anchoring locations:

Figure 10: Total Deflection Plot of the Tubing Assembly for Level C Condition

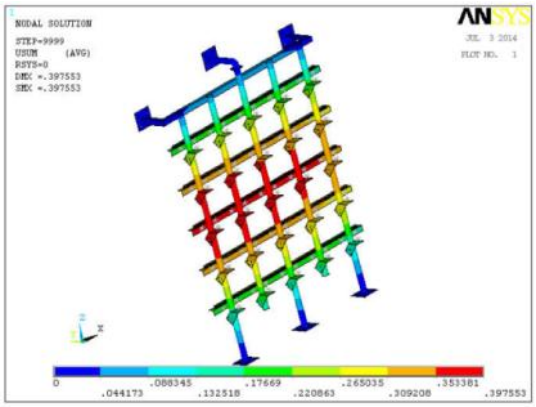


Figure 11: Von Mises Stress Plot of the Tubing Assembly for Level C Condition

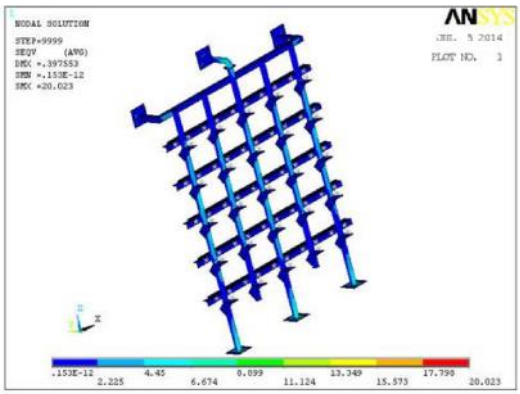


Figure 12: Reactions at Anchoring Locations

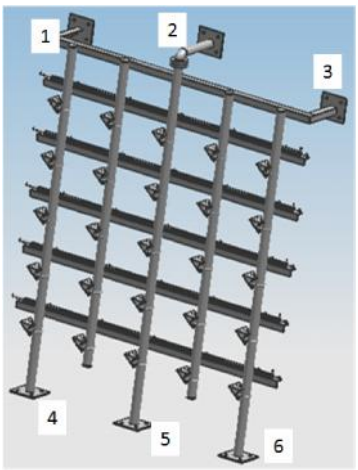


Table 3: Reaction Forces at Anchoring Locations

Forces/Moments	Anchor 1	Anchor 2	Anchor 3	Anchor 4	Anchor 5	Anchor 6
Fx	76.63	50.75	66.15	97.93	114.51	88.73
Fy	262.63	436.08	226.42	161.61	198.84	148.99
Fz	34.70	182.34	30.89	3084.60	3384.70	2759.40

The bolt with maximum reaction forces is checked for strength. The bolts are checked for tension and shear as per ASME section III, NF 3324. In the present case M8 bolts are used. The maximum reaction force obtained from the analysis in the tensile direction (vertical) is used to find out tensile stress on the bolt and the resultant of shear forces in other two directions for shear stress calculation.

$$Ft = \frac{Tensile\ force\ (N)}{Area\ of\ foundation\ bolt\ (mm^2)} = 16.84\ N/mm^2$$

Resultant shear force = Frs = Sqrt (Fx2 + Fy2)

$$Fs = \frac{Resultant\ Shear\ force}{Area\ of\ foundation\ bolt\ (mm^2)} = 2.24\ N/mm^2$$

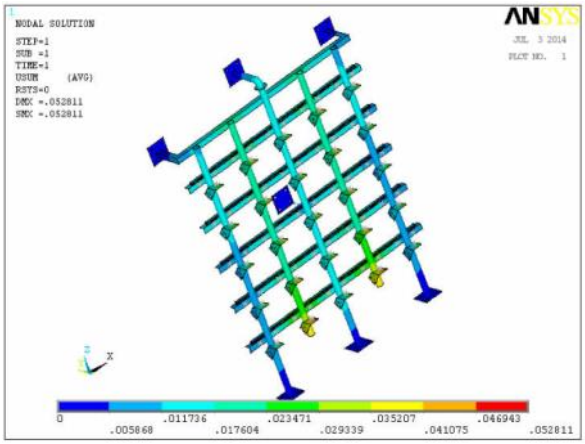
From the above results, it is observed that the stresses are within the allowable limits; however it is observed that the bending of the structure is dominant in the first and third vibration modes (Table 1). From the Table1 it is observed that 83% of mass participation exists at the frequency of 16.1 Hz in Y-dir and 87% of mass participation exists at the frequency of 28.6 Hz in X-dir. Design changes are incorporated to shift the dominant bending modes (1 and 3) by adding structural member at the centre.

Results of Modified Tubing Assembly

From the above analysis the deflections and stress results are plotted for the modified

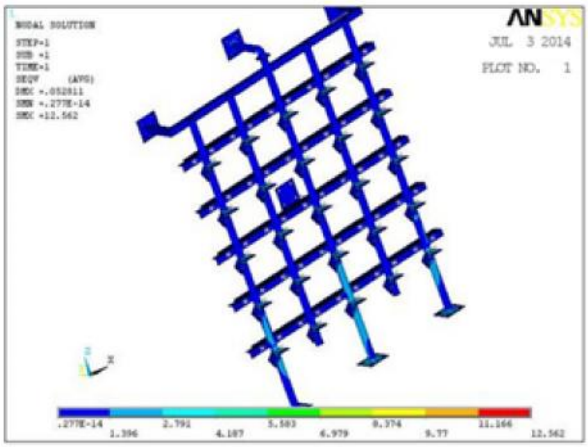
tubing assembly. Maximum deflection of 0.052 mm is observed for level A condition.

Figure 13: Total Deflection for Level A Condition



Maximum Von Mises stress of 12.5 MPa was observed as shown in the below figure.

Figure 14: Von Mises Stress for Level A Condition



MODAL ANALYSIS OF MODIFIED TUBINGASSEMBLY

Modal analysis was carried out to determine the natural frequencies and mode shapes of a structure in the frequency range of 0-33 Hz. Eigen values and their mass participations in all the three directions up to 30 modes are listed in the Table.

Table 4: Frequencies and Mass Participation

MODE	FREQUENCY	PARTICIPATION FACTOR			CUMULATIVE MASS FRACTION		
		X Dir	Y Dir	Z Dir	X Dir	Y Dir	Z Dir
1	20.38	-1.98E-01	2.91E-02	2.10E-03	3.91E-02	8.49E-04	4.43E-06
2	27.57	2.69E-02	4.41E-01	-4.09E-04	7.26E-04	1.95E-01	1.67E-07
3	39.48	5.27E-01	-1.19E-02	-1.63E-02	2.78E-01	1.41E-04	2.67E-04

RSA OF MODIFIED MODEL

Level B Condition - Dead Weight + OBE

Figure 15: Total Deflection Plot Level B Condition

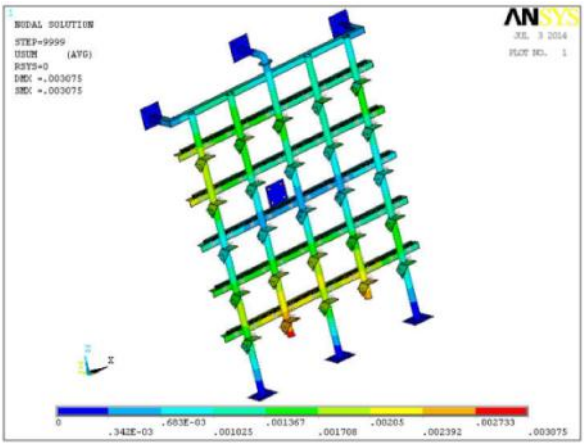
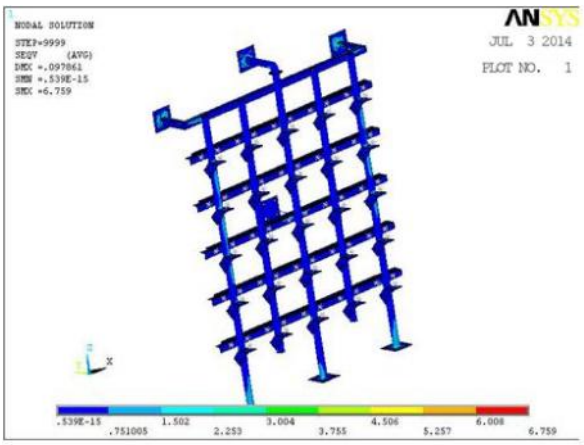


Figure 16: Von Mises Stress for Level B Condition



The maximum stresses in the Modified Tubing Assembly for level C are compared against allowable stresses as per ASME section, sub-section NF. Maximum VonMises stress of 6.75 MPa was observed

Level C Condition - Dead Weight + SSE

The maximum stresses in the Modified Tubing Assembly for level C are compared against allowable stresses as per ASME section, sub-section NF. Maximum Von Mises stress of 17.32 MPa was observed.

Figure 17: Total Deflection Plot Level C Condition

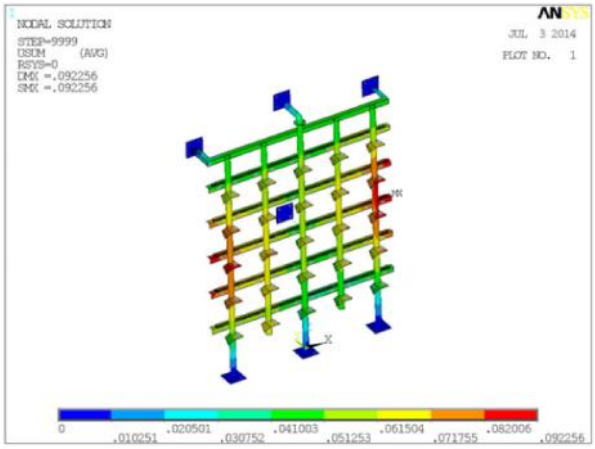
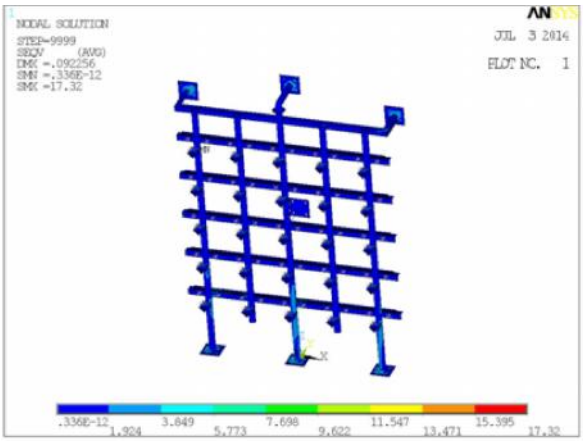


Figure 18: Von Mises Stress for Level C Condition



The Reactions at the Bolting Locations

Figure 19: Reactions at Anchoring Locations for the Modified Model

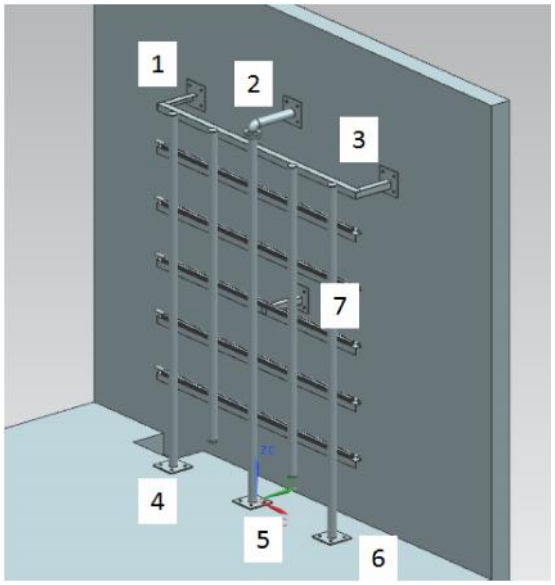


Table 5: Forces at Anchoring Locations

Forces/Moments	Anchor 1	Anchor 2	Anchor 3	Anchor 4	Anchor 5	Anchor 6
Fx	53.97	52.82	48.12	61.70	67.50	59.28
Fy	295.43	323.55	269.51	51.64	48.39	47.59
Fz	30.44	32.38	28.19	852.69	518.98	778.38

The bolt with maximum reaction forces is checked for strength. The bolts are checked for tension and shear as per ASME section, NF 3324. In the present case M8 bolts are used.

The maximum reaction force obtained from the analysis in the tensile direction (vertical) is used to find out tensile stress on the bolt and the resultant of shear forces in other two directions for shear stress calculation.

$$Ft = \frac{Tensile\ force\ (N)}{Area\ of\ foundation\ bolt\ (mm^2)} = 4.24\ N/mm^2$$

Resultant shear force = Frs = Sqrt (Fx2 + Fy2)

$$Fs = \frac{Resultant\ Shear\ force}{Area\ of\ foundation\ bolt\ (mm^2)} = 1.93\ N/mm^2$$

Tensile stress of 4.24 N/mm^2 and Shear stress of 1.93 N/mm^2 observed in the bolts.

RESULTS AND DISCUSSION

Seismic analysis of the Tubing Assembly for Level A, level B and level C condition was performed. The original model was studied for response spectrum for the given X, Y and Z directions. The stresses and deflections were observed to be below the allowable limits. However it was observed that dominant bending modes were existing within the 0-33 Hz. A design change was incorporated by adding a structural member to shift the bending modes. The maximum stresses in the Original and Modified Tubing Assembly for Level A, Level B and level C are compared against allowable stresses as per ASME section, sub-section NF.

For the estimation of the structural integrity of the Tubing assembly, the allowable stresses are applied as follows

Allowable Stress (*Ft*: tensile, *Fv*: shear, *Fa*: compression, *Fb*: bending)

$Ft = 0.6Sy$ ...(1)

$Fv = 0.4Sy$ ...(2)

$Fa = Sy\ (0.47 - kl/r/444),\ kl/r < 120$ ...(3)

$Fb, major = Fb, minor = 0.66Sy$ ...(4)

Combined stress ratio ...(5)

$(fa/Fa) + (fbx/Fbx) + (fby/Fby) < 1.0,\ fa/Fa < 0.15,$

Figure 20: Comparison of Level A Stresses for Original and Modified Model

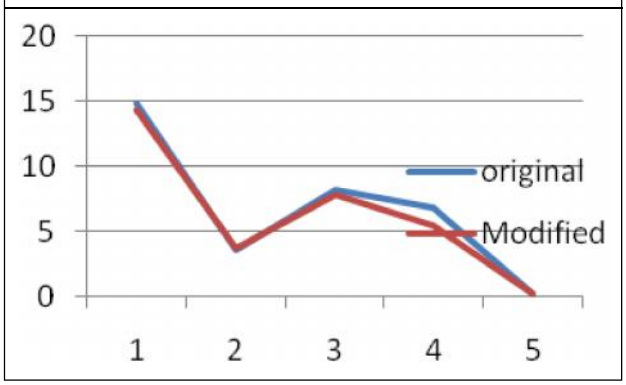


Figure 21: Comparison of Level B Stresses for Original and Modified Model

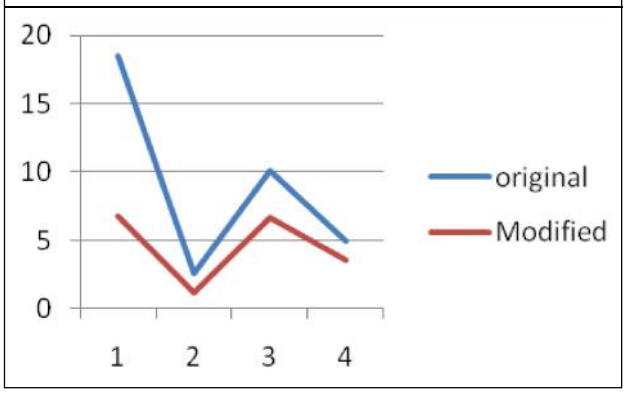
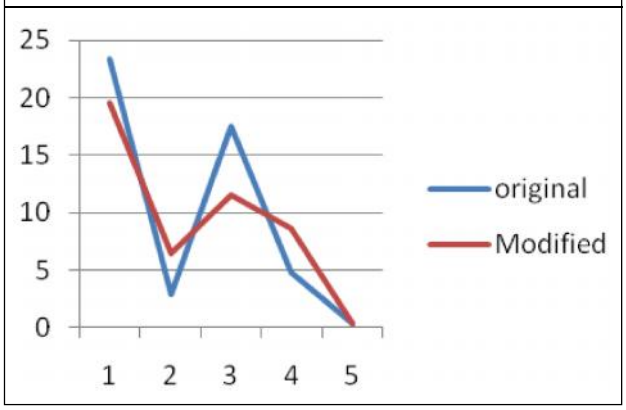


Figure 22: Comparison of Level C Stresses for Original and Modified Model



CONCLUSION

The original model was studied for response spectrum for the given X, Y and Z directions. The stresses and deflections were observed

to be below the allowable limits. However it was observed that dominant bending modes were existing within the 0-33 Hz. A design change was incorporated by adding a structural member to shift the bending modes. The maximum stress and translations are well within the acceptable limits of the material. The analysis ensures that the Modified tubing assembly and foundation bolts are safe under specified seismic load prevailing at site.

The Modified tubing assembly is thoroughly checked under prevailing loads including seismic acceleration forces and moments on the flanges etc and is found safe from the point of structural integrity and operability during a seismic event. The modified Tubing assembly with all the structural members was found to be adequately safe for the critical loading conditions. M8 Bolt sizing are found more than adequate, safe at most critical loading conditions and meeting all seismic requirements. The modified tubing assembly is SAFE.

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