Impact Factor Value 5.856 **e-ISSN: 2456-3463**
International Journal of Innovations in Engineering and Science, Vol 5, No.7, 2020
www.ijies.net

Design of Foundation of Steel Structure for Fractionation Plant

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DOI: 10.46335/IJIES.2020.5.7.1

Abstract *– In Oil & Gas, Refinery & Power Plants different types of Equipment's plays a major role for process requirements. Majority of equipment are categorized into Horizontal Vessels, Vertical vessels, Exchangers, Storage tanks. These are further divided into Static equipment and Dynamic equipment based on rotations and vibration. Equipment Foundations design is major challenge for Structural Engineers to withstand process loads and Environmental loads for different load combination in terms of safety and economy. Most of the Vertical equipment Foundation are Octagonal in shape for Constructability point of view and economy point of view. In the present project Equipment Foundation has been analyzed by using Staad Software and designed by using International codes as per American code of institute.*

Keywords *- Horizontal Vessels, Vertical vessels, Foundation.*

1- INTRODUCTION

1.1 General: Foundations are substructures that are constructed below the ground level which support the superstructures above the ground level. The main function of the footing or foundation is to

- Transmit the load safely and effectively coming on to it to the underlying soil without exceeding the "Safe bearing capacity of the soil".
- Ensuring that the settlements of the structure are within the permissible limits.
- In addition to that, the foundation should provide adequate safety against possible instability due to overturning, sliding and uplift.
- The design is carefully done so that foundation has to provide adequate steel to resist tensile forces and at the same time it should be verified that more steel than required should not be placed as it gives brittle failure.

1.2 Types Of Equipment Foundations:

- Vertical Vessel Foundation
- Horizontal Vessel Foundation

1.2.1 Vertical Vessel Foundation:

Vertical vessels are process equipment placed vertically on either foundation at grade either in a concrete or steel structure. Vertical vessels are cylindrical in shape with each end capped by a domed cover called a head. The length to diameter ratio of a vertical vessel is typically 3:1. Vertical vessels are usually supported by legs, lugs and skirts. They can be Short and stubby or tall and slim.

1.2.2 Horizontal Vessel Foundation:

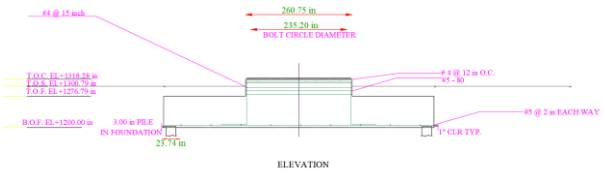
Horizontal vessels are relatively large diameter cylindrical pressure vessel used for variety of pressure functions. The height above grade is usually determined by NPSH requirements of pumps in the liquid outlet line or gravity flow requirement to other equipment. Foudation type is similar to both of them. Horizontal vessels are usually supported on fixed end saddle and sliding end saddle.

II- METHOLOGY

2.1 Vertical Vessel:

2.1.1 Vessel 1:

Table 1	Operating	Empty
Live load	1 kN/m^2	1 kN/m^2
Dead load	10488.834 kN	6307.464 kN
Shear	324.739 kN	119.884 kN
Moment	10827.890 kNm	6511.38 kNm



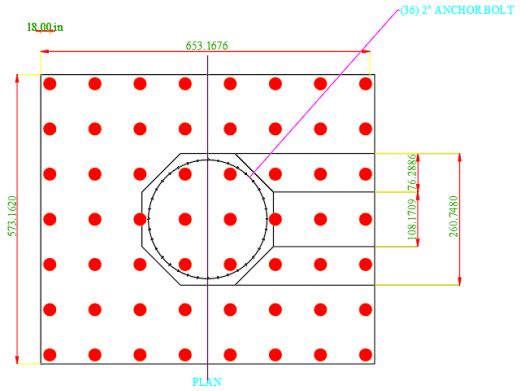


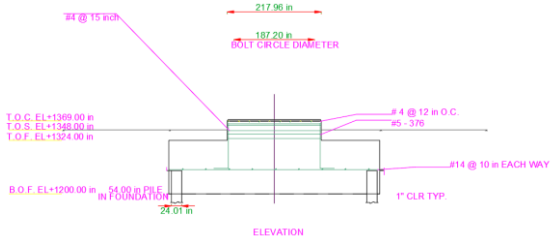
Fig. 1, 2 - fig shows the STAAD Foundation output

Table 2: Anchor Bolt	
Grade	F1554 Grade 36
Tensile strength	399895.5 kN/m^2
Yield strength	248211 kN/m^2
Diameter	0.069 m

Table 3: Pedestal:	
Geometry	Octagonal
Length of each side	2.747 m
Height of pedestal	1.053 m
Area	36.188 m^2

2.1.2 Vessel 2:

Table 4	Operating	Empty
Live load	1 kN/m^2	1 kN/m^2
Dead load	10562.98 kN	5744.472 kN
Shear	328.129 kN	40.085 kN
Moment	15612.58 kNm	8483.188 kNm



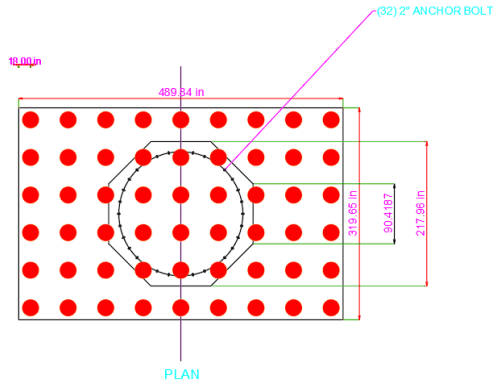


Fig. 3, 4: fig shows the STAAD Foundation output

Table5: Anchor Bolt	
Grade	F1554 Grade 36
Tensile strength	399895.5 kN/m^2
Yield strength	248211 kN/m^2
Diameter	0.074 m

Table 6: Pedestal	
Geometry	Octagonal
Length of each side	2.514 m
Height of pedestal	1.143 m
Area	30.53 m^2

2.1.3 Vessel 3:

Table 7	Operating	Empty
Live load	1 kN/m^2	1 kN/m^2
Dead load	6848.7 kN	2759.016 kN
Shear	212.694 kN	85.681 kN
Moment	11787.795 kNm	4748.594 kNm

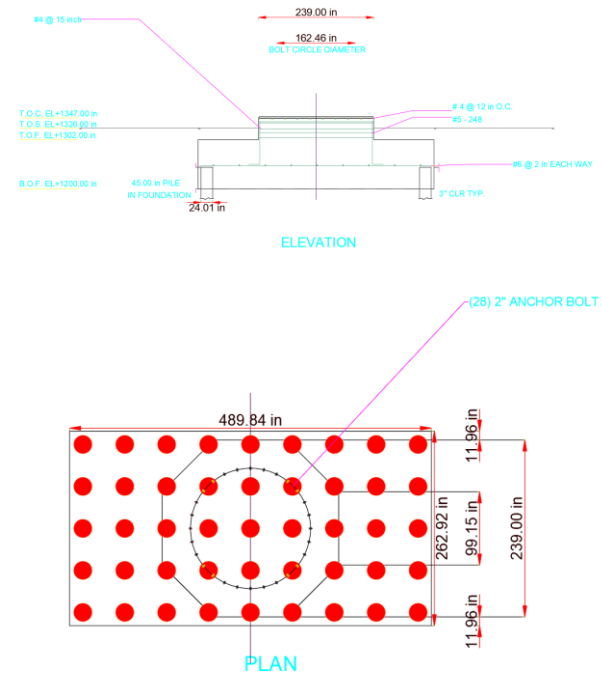


Fig. 5, 6: fig shows the STAAD Foundation output

Table 8: Anchor Bolt	
Grade	F1554 Grade 36
Tensile strength	399895.5 kN/m^2
Yield strength	248211 kN/m^2
Diameter	0.069 m

Table 9: Pedestal	
Geometry	Octagonal
Length of each side	2.514 m
Height of pedestal	1.143 m
Area	30.53 m^2

2.2 Horizontal Vessel:

2.2.1 Vessel 1:

Seismic in transverse direction (for sliding):

Table 10	Operating	Empty
Shear	32.6 kN	20.514 kN
Moment	146.453 kN.m	90.201 kN.m

Seismic in longitudinal direction (for sliding):

Table 11	Operating	Empty
Shear	24.241 kN	15.247 kN
Vertical load	9.924 kN.m	6.242 kN.m

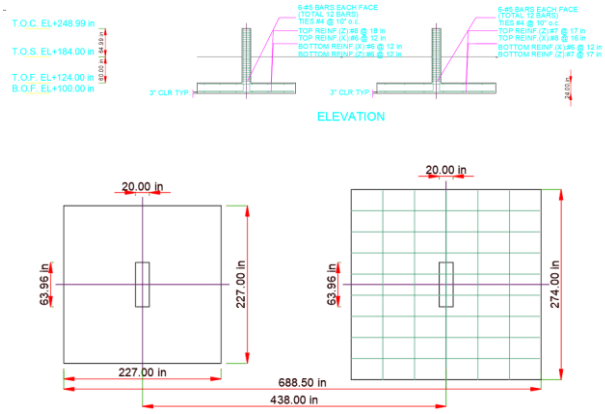


Fig 7,8- shows the STAAD Foundation output

Seismic in transverse direction (for fixed):

Table 12	Operating	Empty
Shear	48.127 kN	30.304 kN
Moment	216.399 kN.m	136.141 kN.m

Seismic in longitudinal direction (for fixed):

Table 13	Operating	Empty
Shear	56.574 kN	35.539 kN
Vertical load	9.924 kN.m	6.242 kN.

2.2.2 Vessel 2:

Seismic in transverse direction (for sliding):

Table 14:	Operating	Empty
Shear	27.755 kN	13.415 kN
Moment	136.352 kN.m	65.891 kN.m

Seismic in transverse direction (for fixed):

Table 15	Operating	Empty
Shear	38.564 kN	18.628 kN
Moment	189.635 kN.m	91.504 kN.m

Seismic in longitudinal direction (for sliding):

Table 16	Operating	Empty
Shear	19.922 kN	9.612 kN
Vertical load	8.46 kN.m	4.083 kN.m

Seismic in longitudinal direction (for fixed):

Table 17	Operating	Empty
Shear	46.486 kN	22.435 kN
Vertical load	8.46 kN.m	4.083 kN.m

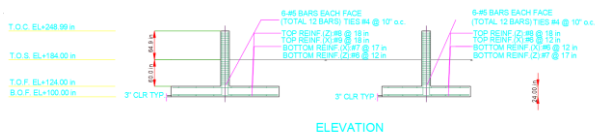


Fig. 9: fig shows the STAAD Foundation output

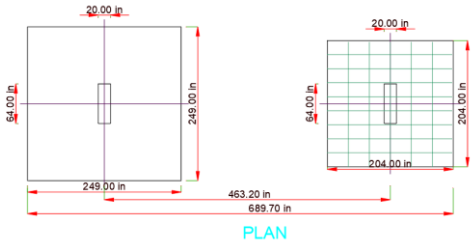


Fig. 10: fig shows the STAAD Foundation output

III- CONCLUSIONS:

The conclusions as per the result obtain from the STAAD foundation:

We came into conclusion that:

1. **For vertical vessel 1**: the value calculated for the overturning moment is slightly increased. The manually calculated value was **18612.956 kip-ft** while STAAD calculated the value was **164002.586 kip-ft.** due to which there is change in no. of dowels. Through manual calculation it was **50 Nos**. and the STAAD result was **80 Nos**. also STAAD foundation has calculated checks for one way shear which found out to be safe.

2. **For vertical vessel 2**: the value calculated for the overturning moment is slightly increased. The manually calculated value was **32040.971 kip-ft** while STAAD calculated the value was **442375.553 kip-ft.** due to which there is change in no. of dowels. Through manual calculation it was **50 Nos**. and the STAAD result was **376 Nos**. also STAAD foundation has calculated checks for one way shear which found out to be safe.

3. **For vertical vessel 3 :** the value calculated for the overturning moment is slightly increased. The manually calculated value was **18353.735kip-ft** while STAAD calculated the value was **290123.983 kip-ft**. due to which there is change in no. of dowels. Through manual calculation it was **50 Nos**. and the STAAD result was **248 Nos**. The tensile force also changes. while STAAD value was **16.706 kip-ft**. also STAAD foundation has calculated checks for one way shear which found out to be safe.

4. **For horizontal vessel 1:** the footing geometry provided for fixed and sliding saddle was identical. The minimum length provided was **15 ft** and maximum was **25 ft**. but the final length

and width of vessel adopted was **18.91 ft.** with depth same as provided **2ft**.if we provide load combination in STAAD Foundation as per PIP we can see that the Foundation is failing in bearing check as well as the footing size is inadequate so to avoid such errors we will provide the load combination as per ASCE 7-05.

5. **For horizontal vessel 2:** the footing geometry provided for fixed and sliding saddle was identical. The minimum length provided was **15 ft** and maximum was **25 ft**. but the final length and width of vessel adopted was **20.75 ft**. with depth same as provided **2ft**.if we provide load combination in STAAD Foundation as per PIP we can see that the Foundation is failing in bearing check as well as the footing size is inadequate so to avoid such errors we will provide the load combination as per ASCE 7-05.

REFERENCES

[1] *Finite Element Analysis Software – STAAD Foundation, STAAD Pro, AutoCAD Naviswork.*

[2] *ACI (American concrete institute)-Concrete code – ACI – 318-11*

[3] *ASCE (American society of civil engineer)-Loading code- ASCE-SEI-7-10*

[4] *PIP (Process industry practices)-Structural code-STE05121-STE03360*

[5] *Structural magazine - Burns & McDonnell performed an Engineer, Procure, Construct contract for a new NGL Fractionation Plant for ONEOK Hydrocarbon, L.P. located in Mont Belvieu, TX.*

[6] *Tutorial links*

a. *https://www.youtube.com./watch?v=G2elijkignZ8&t=226s – Horizontal Vessel Foundation Isolated design*
b. *https://www.youtube.com./watch?v=hZ_5G6qdzMU&t=1550s – For loading criteria*