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Study of Steel Silo Used for Material Storage

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Abstract

A silo of 40 ton capacity is designed, analyzed, fabricated and tested. The silo is designed based on ASME Sec VIII Div I, using PV elite software. The material used is SA 36 for fabrication of the silo. According to the design calculation required thickness of shell is 7mm, cone is 8mm, and top head is 8.8mm. The thickness of the material used is 10mm for shell, 12mm for cone and top head. Maximum allowable working pressure and Maximum Allowable Pressure (New and Cold) are calculated for the given thickness and are seen to be less than the working pressure. Actual stress at given pressure and thickness is also calculated with corrosion rate of 1.5.

INTRODUCTION

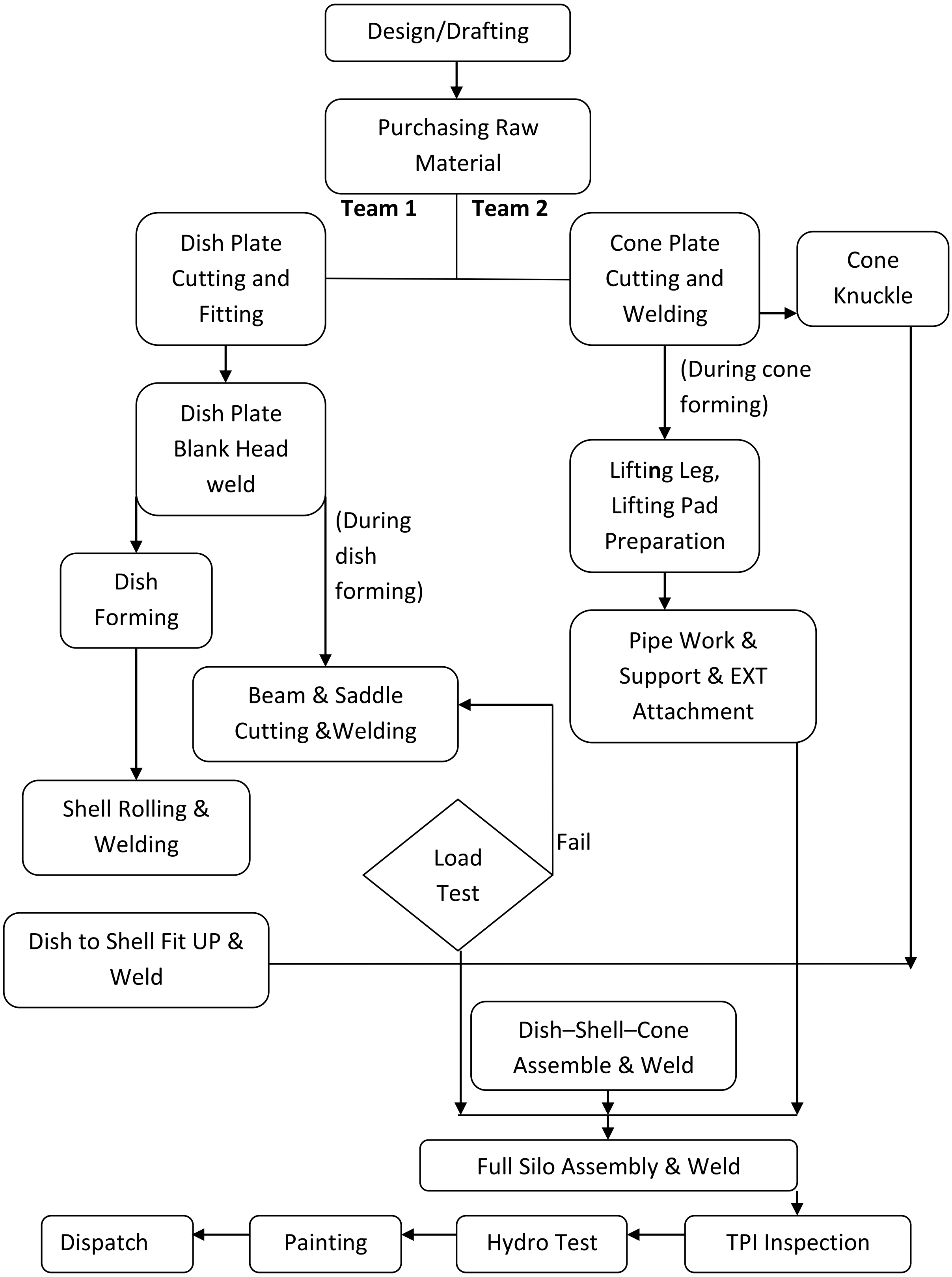
Silo is cylindrical shape, in the bottom of the silo, there are four supporting legs. Silo was initially used in farms for storage of agriculture produce such as rice, millets, etc. It is a tall structure which can be constructed using concrete or steel. Silos now are being used in marine operations, for off shore productions. Silos have evolved from stones, concrete to steel. Steel Silos are fabricated and shipped to the required destination. Silo which is used for cement storage is a part of any concrete production. It is cylindrical shape, in the bottom of the silo, there are four supporting legs.

For the design of the silo, references is based on an international code of ASME Boiler and Pressure vessel code, ASME SEC VIII DIV -1, 2015 code. This gives the rules for construction of pressure vessels. AutoCAD is the primary software used for drafting in this project. PV Elite is a complete solution for vessel and heat exchanger design, analysis and evaluation**.** STAAD is a structural analysis and design computer program. Spot Radiography test and Visual and dimension inspections. Pneumatic test is done for 4.5 bars. Capacity of each silo is 40 ton of cement. Size of the silo is Length 3250mm x Width 3250mm x Height 5157mm. Weight of silo is 7.2 Ton approx. External Blasting to S.A. 2.5 and 3 coat painting of each coat 250 μg.

The silo is fabricated based on the design calculations. After the fabrication of silo, two test are conducted – load and pneumatic test. In load test the silo is loaded with a 2 ton plate and the silo is lifted above the ground at one meter and held for 2 and deflection is seen to be less than 1 cm which passes the test. In pneumatic test the pressure inside is raised to 4.5 bars. It is held at 4.5 bars for 30 minutes, than the joints are tested with soap water for leaks. If no leaks the test is passed. Therefore, as there were no leaks the silo passed the pneumatic test. AutoCAD has been used for drafting and Staad Pro has been used for lifting analysis.

Figure 1: Silos after fabrication and painting

FABRICATION PROCUDURE



LIFTING SYSTEM

Design Of Lifting Lug is as the calculation done below. The Lifting lug is shown in Figure 2 for the specified nomenclature. Total number of lift lugs is 4

Material of construction is SA 36. Yield Stress of SA 36, Fy = 229.6 MPa. Load to be lifted/ Weight of vessel, P = 55250 N

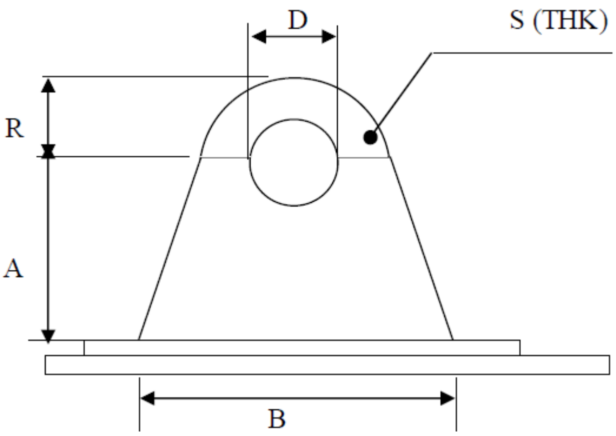


Figure 2: Lifting Lug

Hole provided in Lug, D = 50 mm, Thickness of Lug, S = 25 mm, Width of the Lug, B= 200 mm, Distance from bottom of lug to centre line of lug pin, A = 130 mm, Distance from top point to the centre of hole, R = 100 mm. Pad Size: Length of pad, ap =260 mm, Width of pad, bp = 120 mm, Pad Thickness = 12 mm. Weld Size: Size of fillet for lug = 12mm, Size of fillet for pad plate = 10 mm. Impact factor, I = 1.5 N
Design load = P * SF = 82875N
Load per Lifting Lug = Pd/N = 20718.75N
Diameter of Pin for lifting lug, d
Allowable shear stress, Fs = 0.4*Fy = 91.84Mpa
Pdl = (2* π * D² * Fs)/4

Therefore, d = $\sqrt{\frac{Pdl*4}{2*\pi*Fs}}$ = 379.07mm, taking d =394mm

Thickness of lifting lugs:

1. For bearing
   D * S * Fb = Pdl
   Fb = 0.9*Fy = 206.64Mpa
   Smaller permissible diameter of pin = 54mm
   Required thickness, t = Pdl/(d*Fb) = 0.25 mm,
   Provided thickness of Lug = 25mm
   Provided thickness is greater than required thickness. Hence, design is Safe.
2. For Shear
   Actual edge distance available, K= R-D/2 =75mm
   Thickness of Lug = Pdl/(Fs*2K) = 1.5 mm
   Provided thickness is greater than required thickness. Hence, design is Safe.
3. Design of weld joint between Lug and Pad
   Length of weld Joint = (2*a)+(2*b). Where, a is width of lug= 200mm, b is the thickness of lug =25mm
   Throat Dimension = 0.707 X Sf =8.48mm
   Weld Area (Aw) =Throat Dimension*Length of weld (Lw) =3817.8 mm²
   Stress = Pdl/Aw= 5.43MPa
   Allowable stress (weld joint) = 0.4*Fy = 91.84 MPa
   Since allowable stress 91.84 MPa > stress 5.43MPa
   Actual Stress is less than allowable stress. Hence, Design is Safe
4. Design of weld joint between Pad and Shell
   Length of weld (Lw2) = (2*ap)+(2*bp)= 760mm
   Throat Dimension = 0.707 X Sf =7.07 mm
   Weld area (Aw2) = Throat Dimension*Length of weld(Lw2)=5373.20 mm²
   Stress =Pdl/Aw2= 3.86 Mpa.
   Allowable Stress = 91.84 Mpa
   Actual stress is less than allowable stress. Hence, Design is Safe

5. Check for bending of Lugs
   Angle of bent rope & Vertical, θ = 60°
   Pull in Ropes = Pdl/cosθ = 41437.50
   Distance from bottom of lug to centre line of lug pin = 130mm
   Pull in rope X distance from bottom of lug to centre line of lug pin =5386875 N-mm
   Section modulus z = (S*B²)/6 = 166666.667 mm³
   Maximum bending stress = M/Z = 32.32MPa
   Allowable bending stress =0.66 * Fy = 151.54 MPa
   Actual bending stress is less than allowable bending stress. Hence, Design is Safe

Basic checks such as shear stress and flexural strength check has been done for the pad. Load on the pad is considered as 12.5 tones. The typical details of a pad eye considered at the base frame as shown in Figure 3

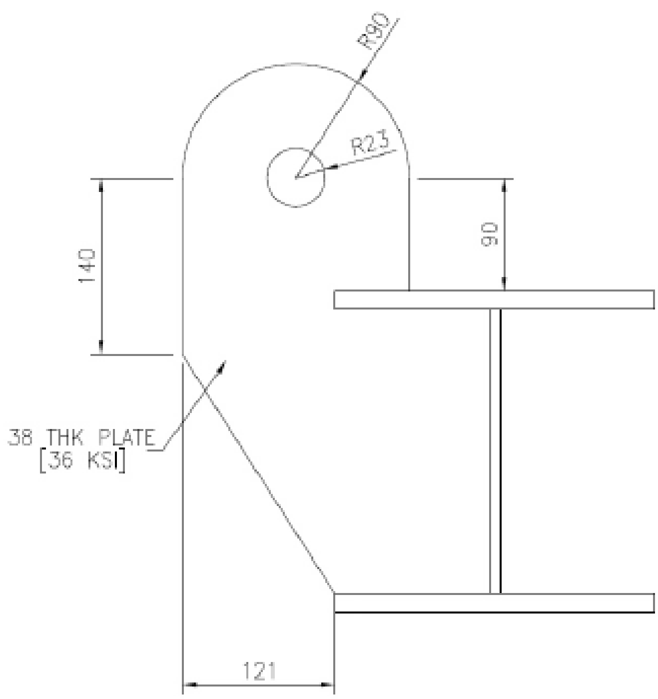


Figure 3: Pad eye

1. Check for Shear
   Considering depth of critical area of shear as 67mm.
   No. of shear plane is 2.
   Yield strength of plate Fy = 250MPa (A36 grade)
   Allowable shear strength = 0.4Fy = 100 MPa
   Thickness of plate t = 38mm
   Area of shear = 38 X 67 X 2= 5092 mm²
   Shear stress = (125 x 1000)/5092 = 24.55 MPa
   < 100 MPa which is allowable.
2. Check for flexure
   Flexural strength of plate = 0.6 Fy = 0.6 X 250 = 150MPa
   Moment developed = 125 X eccentric moment 0.90 = 11.25 KNm
   Depth of the plate section resisting moment d = 225mm
   Section modulus of the section under flexure = td²/6 = 38 X 225² /6= 320325 mm³
   Bending stress = 11.25 X10^6/320625 = 35.08 MPa <150 MPa, which is allowable

DRAFT OF SILO

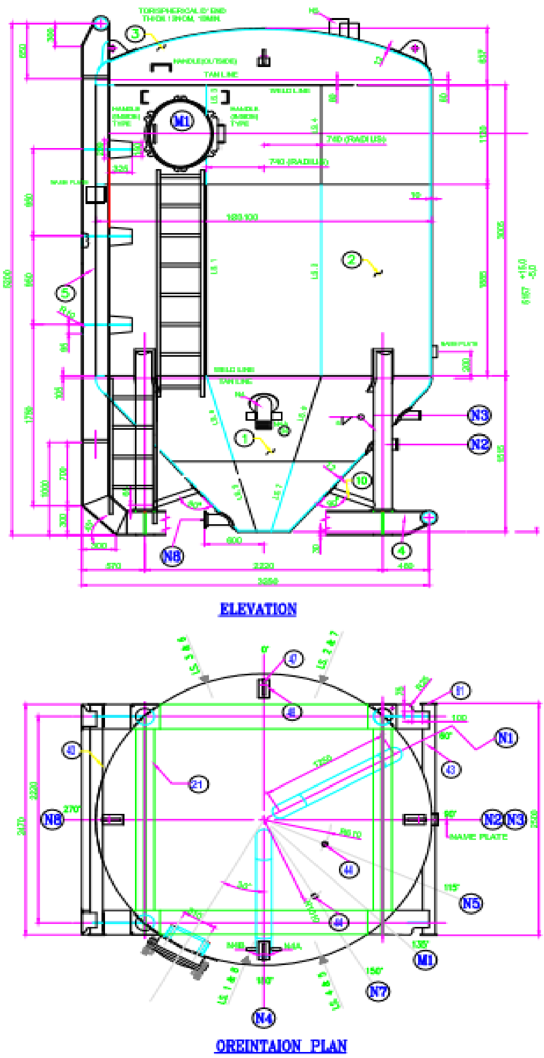


Figure 3: Drafting of Silo

The figure 3 shows elevation and orientation plan of the silo. The dimensions of the various parts are as specified: Tori conical head :OD 3120 X OD 500 X LG1400 X 12THK, Shell Courses :OD 3120 X L3200 X 10THK,Tori spherical head: OD 3120 X 12THK, Base Frame Beam :250 X 250 X LG3150, Side Frame Beam :250 X 250 X LG4985

CONCLUSIONS

The design calculations suggest that the silo is safe for the capacity of 40 ton. The designs where based on the specific gravity of cement as 1.65 g/cc Actual stress at internal pressure 3.442 bars and thickness 14.5mm $= 88.202\ N/mm^2$.Actual stress of cone at 3.461 bars pressure and 10 mm thickness, corroded= $78.594\ N/mm^2$.Actual stress of shell at 3.442 bars pressure and 8.5 thickness, Corroded= $74.157\ N/mm^2$.Actual stress of top head at 3 bars pressure and 8.5mm thickness, corroded $= 99.129\frac{N}{mm^2}$. The required thickness of lifting lug is 1.5 mm and provides is 25mm. Therefore, the given thickness is safe for shear stress. The required thickness of lifting lug is 2.5 mm and provides is 25mm. Therefore, the given thickness is safe for bearing. The actual stress of weld joint between Lug and Pad is 5.43 MPa and allowable is 91.84 MPa, making the design safe. The actual stress of weld joint between Pad and Shell is 3.86 MPa and allowable is 91.84 MPa, making the design safe. The lifting analysis shows the utilization ratios of spreader frame is seen to be 0.518. Actual deflection is less than 1cm and average of deflection is seen to be 8.66. The ratio between the analyzed deflection and Actual deflection is 0.863. During Pneumatic test, the silo's pressure was raised to 4.5 and held for 30 minutes. After the test, no leaks where found.

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