Dynamic Analysis of Cylindrical Steel Silo Structure with the Effect of Shear Wall

Raj Kumar Janghel[1], R. C. Singh[2]

Department of Civil Engineering, RSR Rungta College of Engineering and Technology, Bhilai, INDIA.

ABSTRACT

Shells of various shapes were investigated such as elliptical hemispherical, conical and cylindrical shells. These structures are mostly failing by bucking under external pressure. Cylindrical steel silos are big lean structures used for storing materials like cement, grains, fly ash, carbon black, coal saw dust etc. They are special structures subjected to many different unconventional loading conditions, ranging from few tones to hundreds to thousands of tones which results in unusual failure modes. In this work considered the steel silo structure as per literature data and apply the different shear wall curvature. The method has been applying in this work is response spectrum analysis, which are robust dynamic analysis tool in STAAD.Pro. The present work investigates and compared the lateral analysis of steel silo structure with different model types and provide the best as compared to specified structure type and literature basic structure. From in this work it has been observed that the steel silo structure with shear wall-A type are more useful than the others. The deformation structure and stress in plate are obtained to be critical more in literature, shear wall-B, shear wall-C and shear wall-D as compared to shear wall-A. The work is also representing the behaviour of steel silo structure with varying the plate thickness and kept constant the other silo parameters.

Keywords: Silo Steel Structure, RCC Shear wall, Seismic analysis, Response spectrum analysis.

I. INTRODUCTION

Steel silos differ principally from their concrete counterparts in that they are much lighter structures, quick to erect and dismantle, carrying their loads by different structural mechanisms, deforming readily and reversibly when subject to unsymmetrical loads, and placing smaller loads on their foundations. Thus, steel silos are widely used for short and long-term storage of large quantities of bulk solids and have been built increasingly in recent years in many industries including mining, chemical, electric power generation, agriculture and food processing.

A few representative silos that were damaged or collapsed during recent earthquakes around the world. Earthquakes frequently cause damage and/or collapse in silos resulting in not only significant financial loss but also loss of life. An earthquake ground motion has three components resulting in structural loads in the vertical and two horizontal directions. The effect of vertical seismic loads on the relatively heavy silo structures is usually small, whereas the effect of lateral loads can be significant especially on the taller silos containing heavier material. The magnitude of the horizontal seismic load is directly proportional to the weight of the silo. As the silo height increases the height of the center of mass of the silo structure also increases.

II. PROBLEM IDENTIFICATION

Silos have been used since a very long time for storage of various materials such as wheat, rice husk, cement and fly ash. They have been proved to be very effective in the process of storing materials and hence grew in demand as the industry progressed. But one of the major constraints faced by storage structures all throughout the world, is its increased rate of failures. This has been accounted to various reasons such as wrong computations of the analytical pressures acting on the walls of the silo and the effect of the entire pressure of the stored material on the base or hopper region of the silo. To counter this, certain inclusions were made to the structure, namely multi compartments and a central cone.

III. METHODOLOGY

From the study of all literatures it is observed that, structural performance of silo depends some many factors which includes, material stored, wind interaction, type of supports, wall flexibility, staging height, stiffeners etc. In this chapter will discussed about the mathematical and software evaluation in the field of silo structure analysis.

Table 1. Details of steel silo structure [28]

Details	Description
Cement Steel Silo Structure Capacity	100 tonne
No. of Supports (Steel pipe is fixed to the foundation)	4
Support Connected up to Height or Level (entire silo volume together with the conical hopper supporting the material)	2.2m Level
Steel Silo Wall Thickness	10mm-40mm
Total Height of Steel Silo	11.5m
Silo Cylinder Diameter	1.6m
Behaviour of Material	Isotropic and Elastic
Young's Modulus	21000 MPa
Poisson's ratio	0.3
mass density	7.8 E-09 t/mm^3
The loading on the structure is considered as per following calculations	
Unit weight of Iron ores	37.0 kN /m^3
Diameter (d) of circular silo	7.00 m
Height (h_1) of cylindrical portion of circular silo	8.05 m
Height (h_2) of Hopper portion	3.50 m
Weight of Roof	18.5 kN
Size of column diameter	500mm
Stiffeners of Size ISA 70 x 70 x 8mm	0.083kN/m
Spacing of Horizontal stiffener	1.10m
Spacing of vertical stiffener are staggered with spacing	0.88m
Size of opening	500mm diameter
Weight of lining (assumed)	0.25 kN/m^2
Weight of top cover with gritting	4kN/m^2
Equipment load (assumed)	15 kN
Chute load (under choked condition)	10 kN
Conveyor load	5 kN
Unit weight of plate	0.628 kN/ m^2
Earthquake load for the structure has been calculated as perIS-1893(Part 1) 2002	
Zone (Z)	II
Response Reduction Factor (RF) For Braced Frame	4
Importance Factor (I)	1.5
Soil condition	Medium
Zone factor	0.10
Damping Ratio (DM)	0.02
Wind load for the structure has been calculated as per IS 875 (part-3)	
Wind speed	39 m/s
Terrain category	2

Structure class	B
Risk coefficient (k_1 factor)	1
Topography (k_3 factor)	1
Temperature forces data	
Coefficient of thermal expansion α in °K of steel	12 X 10^{-6}
Temperature difference taken	20° C

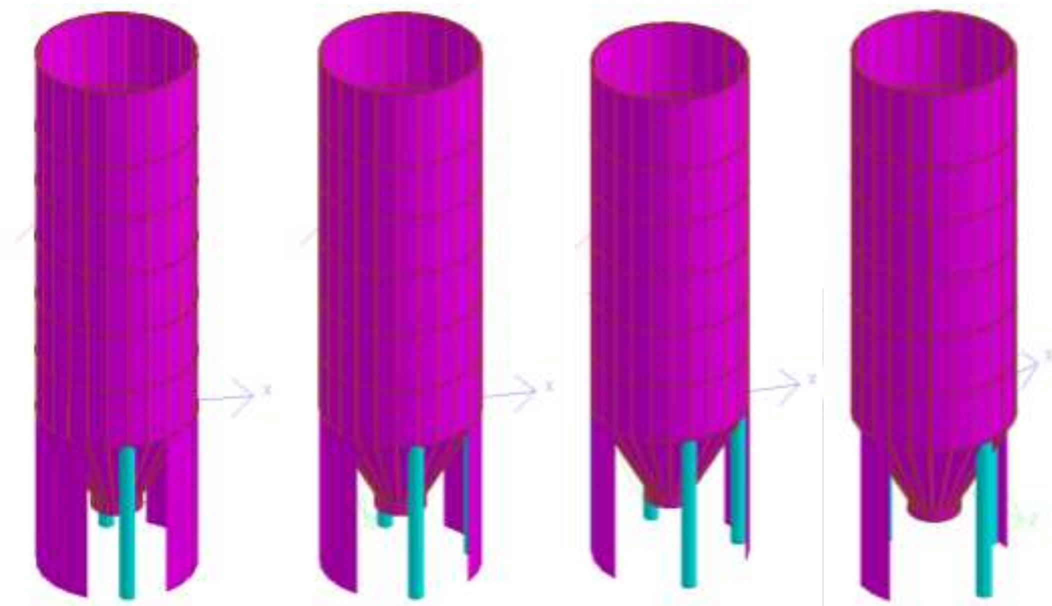

Figure 1. Steel silo structure with RCC shear wall (Shear Wall-A, B C and D types)

Different structural loads that the building typically must carry are:

- Dead load
- Live load
- Equipment load
- Wind load
- Seismic load

Forces that act vertically are gravity loads like dead load, live load, Equipment load. Forces that act horizontally, such as wind and seismic events require lateral load resisting systems to be built into structures. As lateral loads are applied to a structure, horizontal diaphragms (floors and roofs) transfer the load to the lateral load resisting system.

IV. RESULT AND DISCUSSIONS

In steel silo structure with maximum displacement and von mises stress in steel plate were calculated with varying the steel plate thickness 10mm to 40mm as per literature [28]. The thickness of shear wall remains constant for all structure types and carried out the effect of all types of structure i.e. Shear wall-A, Shear wall-B, Shear wall-C and Shear wall-D. In this work, obtained results were compared to the literature [28].

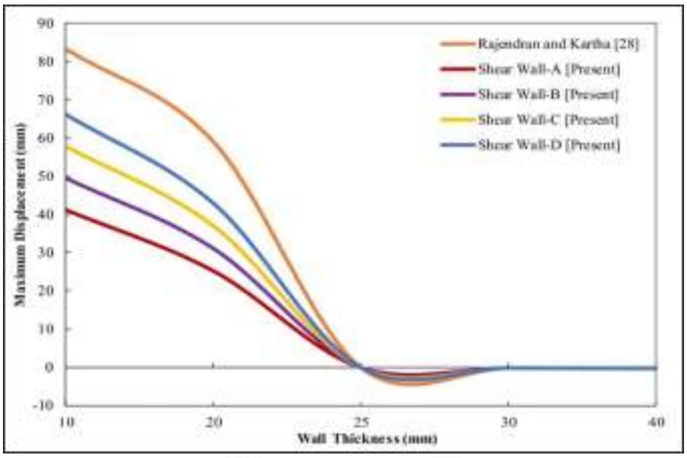

Figure 2. Graphical representation of maximum displacement and wall thickness of steel silo wall plate

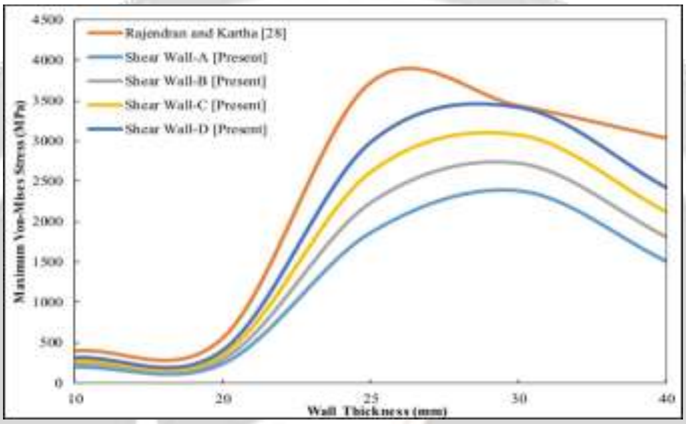

Figure 3. Graphical representation of maximum von-mises stress and wall thickness of steel silo wall plate

Table 2. Percentage variation of maximum displacement in plate between literature [28] and present work (Shear Wall-A)

Thickness of Plate (mm)	Rajendran and Kartha [28]	Shear Wall-A [Present]	% Variation
10	83.4418	41.3037	51%
20	59.1418	25.3038	57%
25	0.0248	0.0124	50%
30	-0.1105	-0.0768	31%
40	-0.2157	-0.1074	50%

Table 3. Percentage variation of maximum von-mises stress in plate between literature [28] and present work (Shear Wall-A)

Thickness of Plate (mm)	Rajendran and Kartha [28]	Shear Wall-A [Present]	% Variation
10	394.17	195.1142	52%
20	557.508	238.5298	56%
25	3721.359	1866.4848	49%
30	3431.359	2384.7945	30%
40	3029.917	1508.5957	51%

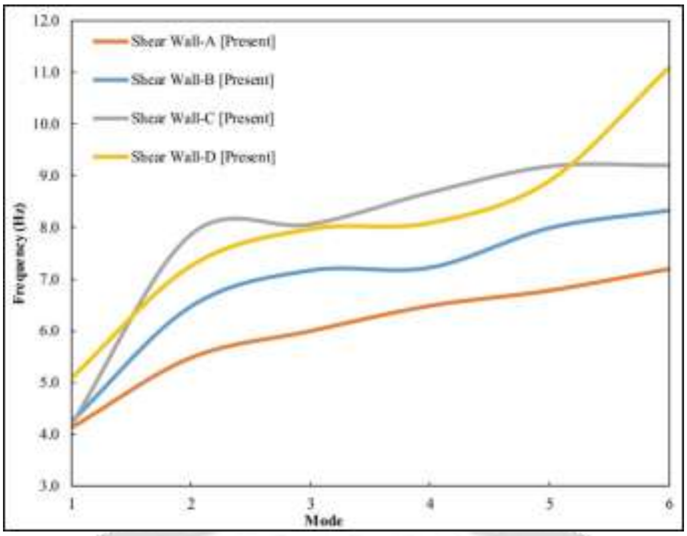

Figure 4. Graphical plot of frequency generated in different types of structure model with respect to six modes

V. CONCLUSIONS

From the analysis of the all types of structure and discussing the all results, the following conclusion have been drawn which are presenting in below:

- It is concluded that the, by collecting information of several literatures it is clear that there is a possibility to enhance the quality of structure with the help of shear wall.
- From this present work there is a good agreement found between Response spectrum analysis which was carried out to provides effect of shear wall at locations on seismic behaviour of building and find the behaviour of structure.
- It is also concluded that the for-steel silo structure, while increasing thickness of plate is decreased the displacement as well von-mises also be decreases of all types of structure considered in this work, but as per economically point of view, increase of plate thickness increases the cost.
- In this present work is has been also found that the frequency generation in the structures are less in shear wall-A types with respect to different six modes.
- In steel silo structure with 100tonne of capacity, 10mm wall thickness and 3mm ring stiffeners, the considered structure significantly increases the stability of structure, but the shear wall-A provide more reliable as compared to specified types and literature [8].
- The main advantage of the steel silo structure as compared to concreate silo, if due to any types of the failure occurring in the structure, the steel silo can be reinstalled with less time and cost as compared to concreate silo structure because of steel silo is cheaper as compare to concreate silo structure.

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