# Parametric Study On Dynamic Response Of Silo

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## Abstract

*Structural response to earthquakes is a dynamic phenomenon that depends on dynamic characteristics of structures and the intensity, duration and frequency content of the exciting ground motion. Dynamic analysis procedures are categorized as either linear dynamic analysis or nonlinear time history analysis. In the present work, dynamic analysis of a typical steel silo is done by using Equivalent Static Analysis and Response Spectrum method for earthquake zone II to Zone V as per Indian code. Two distinct analyses are carried out namely, Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA) using STAAD.Pro V8i software. The Load combinations are considered as per Indian code. The results in terms of Fundamental natural period, Design Base shear, lateral Displacements, Axial forces in columns are compared for the different silo models considered in the present study.*

***Keywords—****Silo, Plates, Surface, Natural Frequency and STAAD. ProV8i.*

## 1. Introduction

In any industrial structures for the storage of bulk solids are important. These containers are usually called bins, bunkers, silos or tanks. There is no generally accepted definition for each of these terms. The essential difference between bunkers and silos lies in the ratio of their dimensions. Silos are in general structures whose height is large compared to the lateral dimensions. Materials like grains and cement are usually stored in silos. In cement factories as well as in large construction projects, cement is stored in large silos. The plane of rupture for this type of structures cuts the opposite sides. Therefore, only a small portion of the vertical weight of the stored material is supported by the hopper bottom and large amount of vertical weight is supported by the side walls and the stored material. The necessity to store and contain materials like coke, coal, ores etc. in the various steel plants and other industrial establishments cannot be over emphasized. In cement factories as well as in construction projects, cement is stored in large silos. Steel plate shear walls have been used more and more in the steel structures to resist earthquake and wind forces.

This system offers several advantages as compared to the other usual lateral load resisting systems. Steel saving, speed of erection, reduced foundation cost, and increased usable space in structures are some apparent advantages of the steel plate shear walls. Steel plate shear walls also provide major stiffness against structure drift for the hi-rise structures. The hysteretic characteristic, ductility and the energy absorption capacity make this system suitable to be used as seismic resistant element in the steel structures.



## 2. Details of the Structure

### *A. Modelling and Analysis*

The main objective of the analysis is to study the different forces acting on a structure. The analysis is carried out in STAAD Pro V8i software. Results of plate elements and surface elements are discussed below. The typical Silo is modelled and analyzed for the different combinations for Dynamic loading. The comparison is made between the plate and surface element for seismic zone II to zone V.

### *B. Assumptions*

The following are the assumptions made:

The structure considered for the study contains eight silo arranged in such a way that there are four silos in row. Each silo is having a cross section of 3m×3m. The opening of the hopper bottom is having a cross section of 0.6m×0.6m. The height of the vertical wall of the silo is 6.5m. The structure is supported on concrete pedestal. The walls of the steel silo are modelled as plates of thickness 12mm and surface element thickness of 12m. Shear wall openings provided about 25%.

### *C. Group Properties*

The different components of Silo are as follows.
Columns of the structure is ISWB 600
Beam of the structure is ISMB600
Walls thickness(Plates/Surface) is 10mm.
Size of Concrete pedestal is 600mmX600mm
Material properties : $M_{25}$

$E_c = 5000\sqrt{f_{ck}}$

Es=200kN/m$^2$

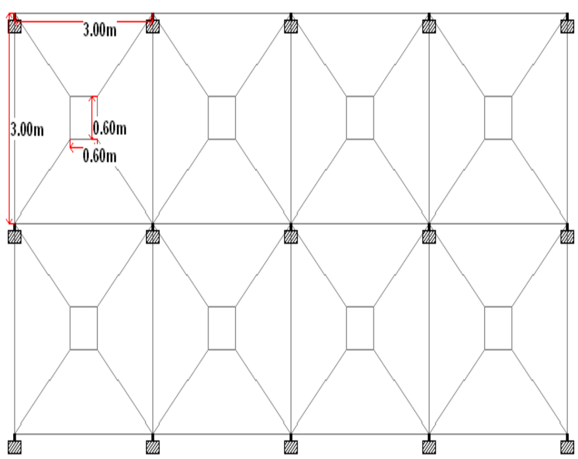


**Figure 2.1** Plan of Silo

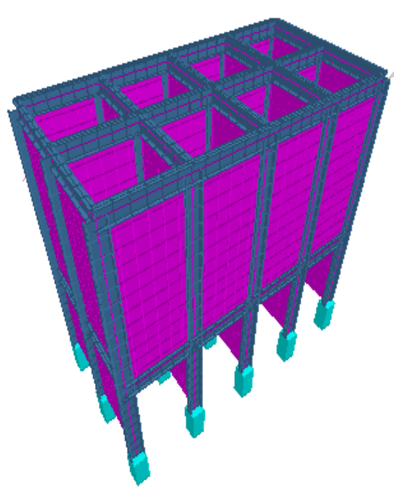

**Figure 2.2** Model of Silo with Plates

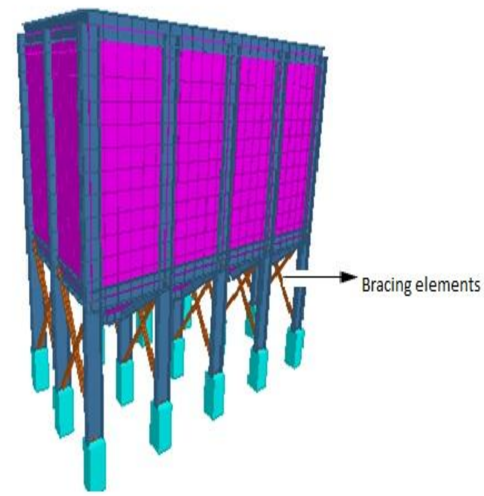


**Figure 2.3** Model of Silo with Bracing Element

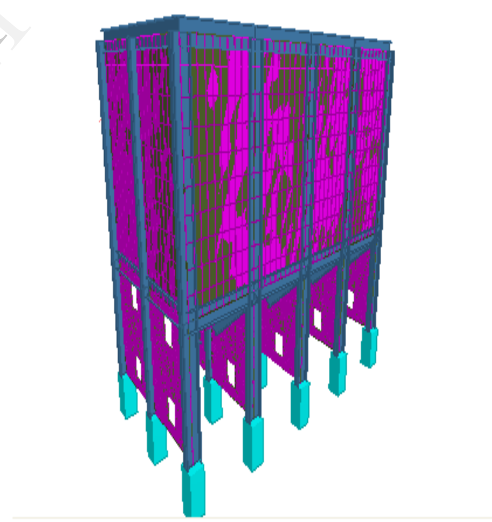

**Figure 2.4** Model of Silo with openings in Surface

## 3. Description for Loading

The loading on the structure is considered as per following calculations

Density of Cement taken as 16kN/m$^3$.

| Location | Contributing Weight | Volume($m^3$) | Weight(kN) | Load Per Node(kN) |
|---|---|---|---|---|
| Top of the vertical wall | Upper half of the rectangular portion | 29.25 | 468 | 117 |
| Bottom of the vertical wall | Lower half of the rectangular portion | 29.25 | 468 | 117 |
| | Upper half of the hopper bottom | 2.1 | 33.65 | 8.5 |
| Lower end of hopper bottom | Lower half of the hopper bottom | 2.1 | 33.65 | 8.5 |

*Earthquake Forces Data*

Earthquake load for the structure has been calculated as per IS-1893-2002:

i. Zone (Z) = II to V
ii. Response Reduction Factor ( RF ) = 3
iii. Importance Factor ( I ) = 1.5
iv. Rock and soil site factor (SS) = 1
v. Type of Structures = 1
vi. Damping Ratio (DM) = 0.02

## 4. Results and Discussions

Dynamic analysis for different types of steel silo is done by using Response Spectrum method for earthquake zone II to zone V as per Indian Standard code. During the dynamic analysis, the effect of shear wall (Plates/Surface) and openings in shear wall is evaluated. In the present work, significant change in the seismic parameters such as Fundamental Natural Period, Design Base Shear, Displacement of the structure is noticed. Permissible displacement of structure is 45mm.

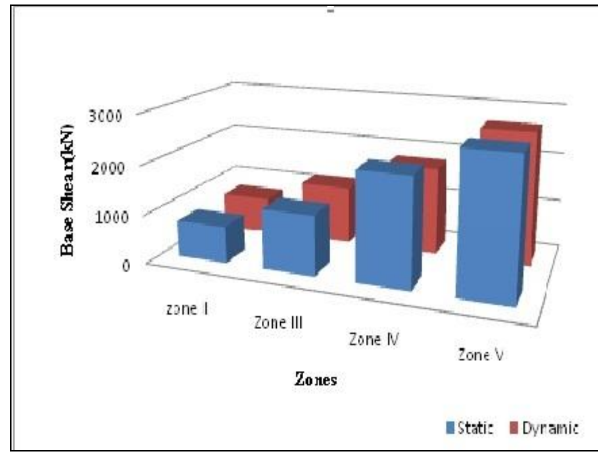


**Figure 4.1** Design base shear (kN) of Silo with Plate element for Zone II to V

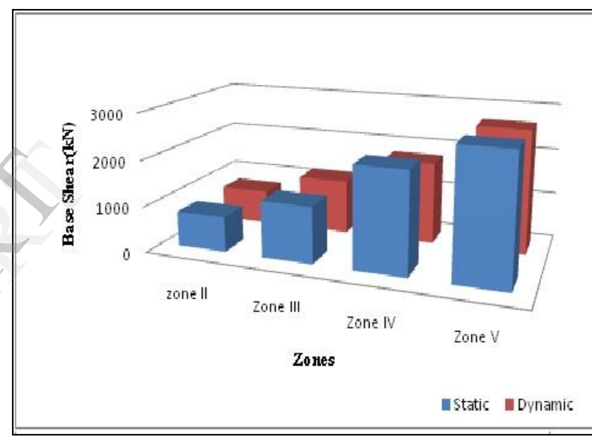


**Figure 4.2** Design Base shear (kN) of Silo with Openings in Plate element between supporting columns for Zone II to V

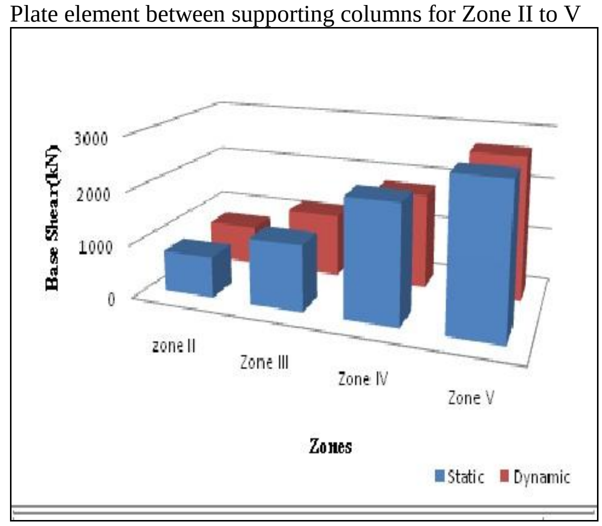


**Figure 4.3** Design Base shear (kN) of Silo with Bracing element between supporting columns for Zone II to V

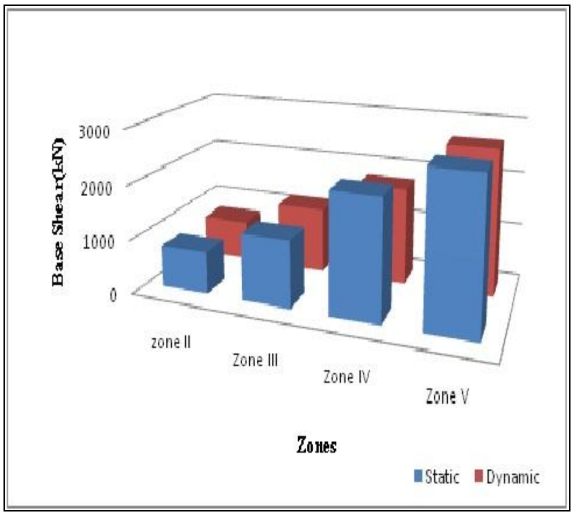


**Figure 4.4** Design Base shear (kN) of Silo with Stiffener for Zone II to V

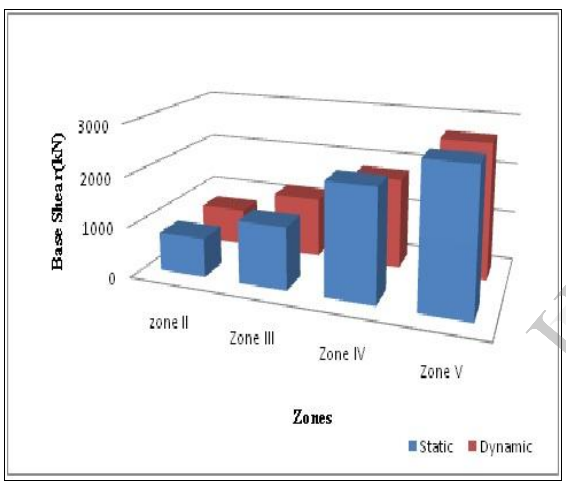


**Figure 4.5** Design Base shear (kN) of Silo with Surface element for Zone II to V

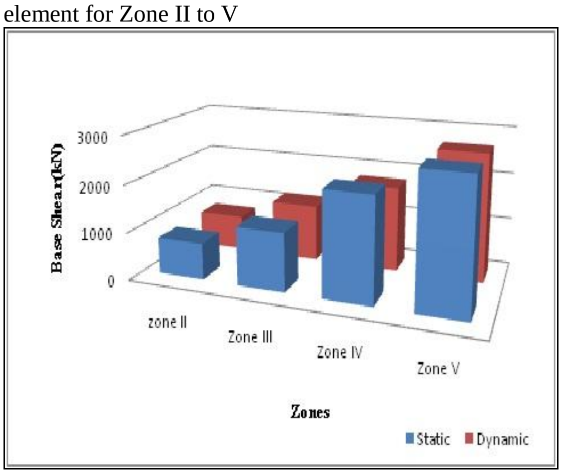


**Figure 4.6** Design Base shear (kN) of Silo with Openings in Surface element between supporting columns for Zone II to V

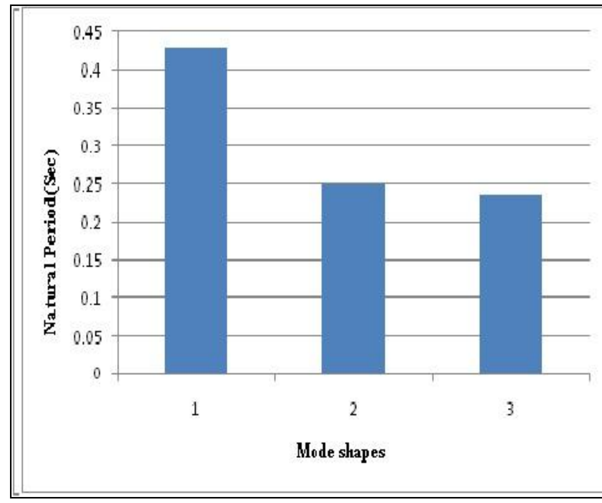


**Figure 4.7** Fundamental natural period (Sec) of Silo with Plate element

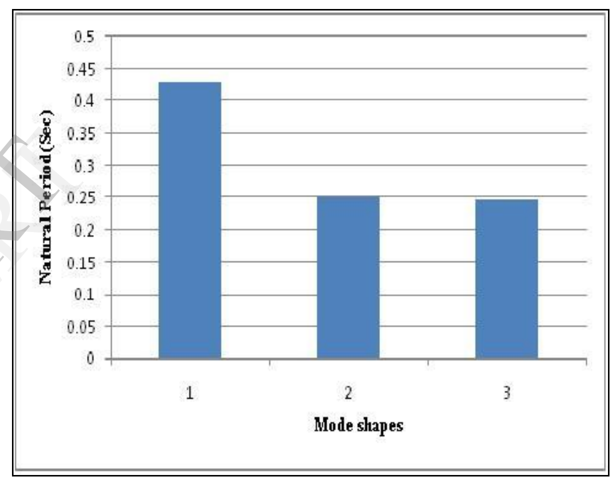


**Figure 4.8** Fundamental natural period (Sec) of Silo with Openings in plate element between supporting columns

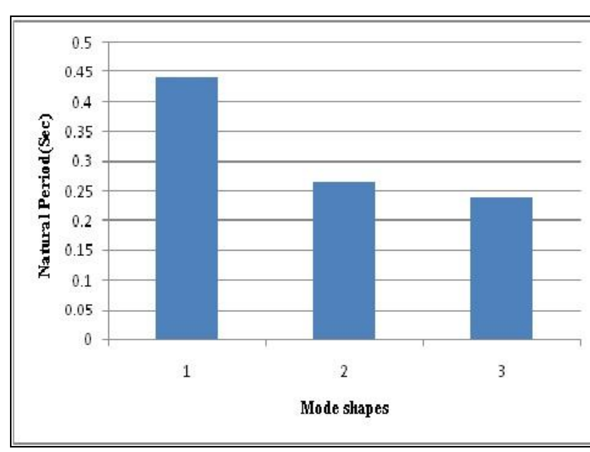


**Figure 4.9** Fundamental natural period (Sec) of Silo with Bracing element between supporting columns

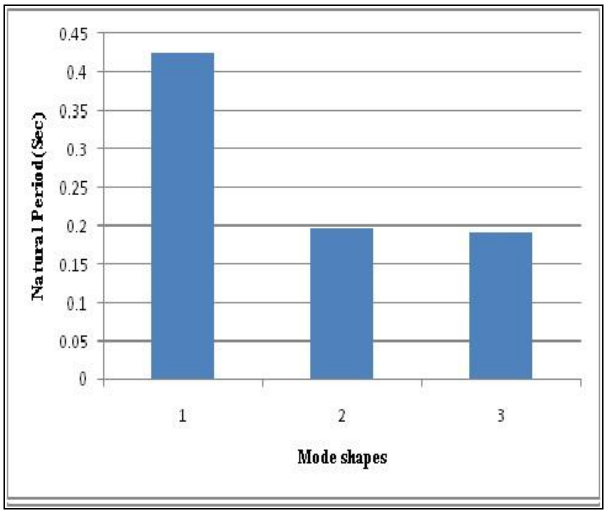


**Figure 4.10** Fundamental natural period (Sec) of Silo with Stiffener at intermediate levels

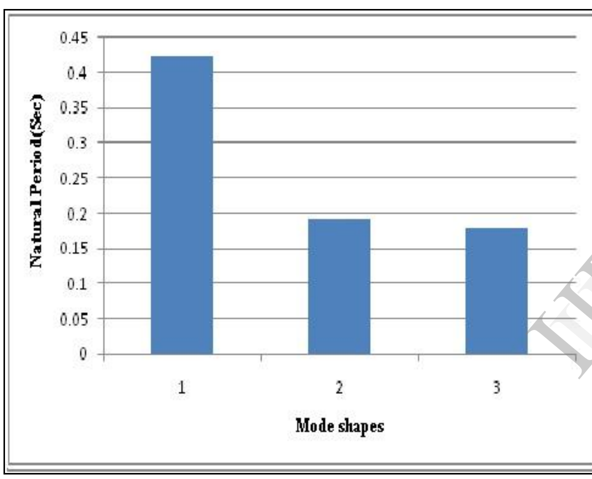


**Figure 4.11** Fundamental natural period (Sec) of Silo with Surface elements

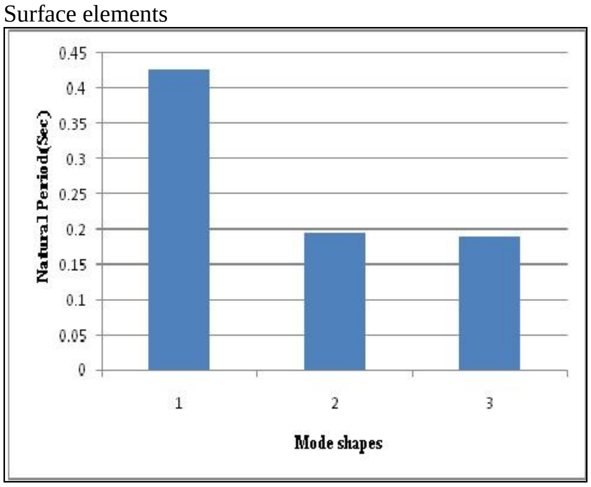


**Figure 4.12** Fundamental natural period (Sec) of Silo with Openings in Surface element between supporting columns

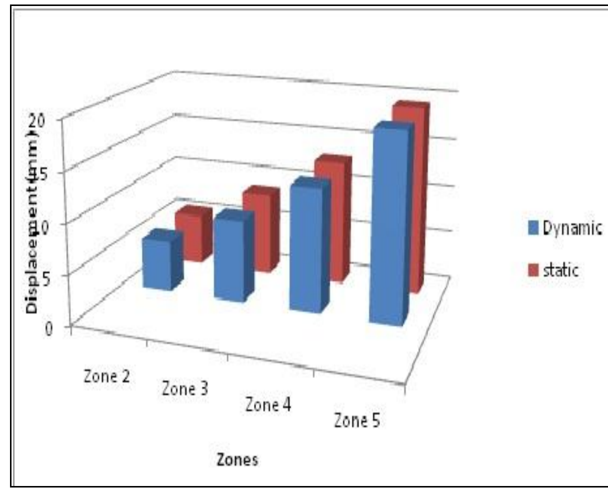


**Figure 4.13** Maximum Displacements (mm) of Silo with Plate element for Zone II to V

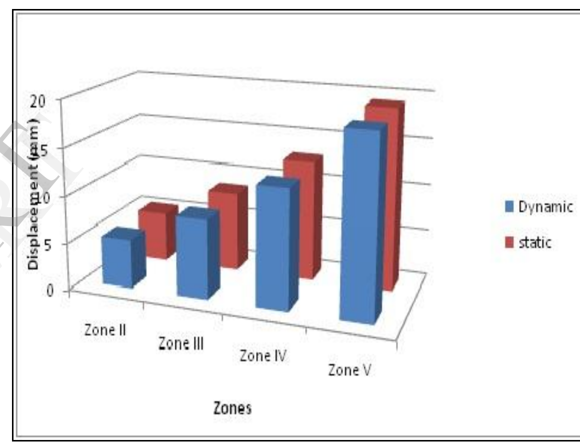


**Figure 4.14** Maximum Displacements (mm) of Silo with openings in Plate element between supporting columns for Zone II to V

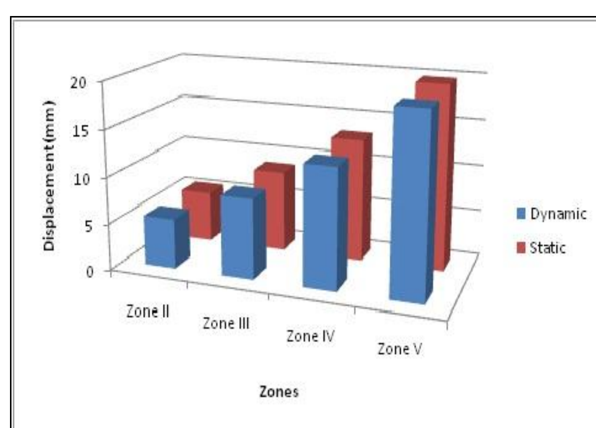


**Figure 4.15** Maximum Displacements (mm) of Silo with Bracing element between supporting columns for Zone II to V

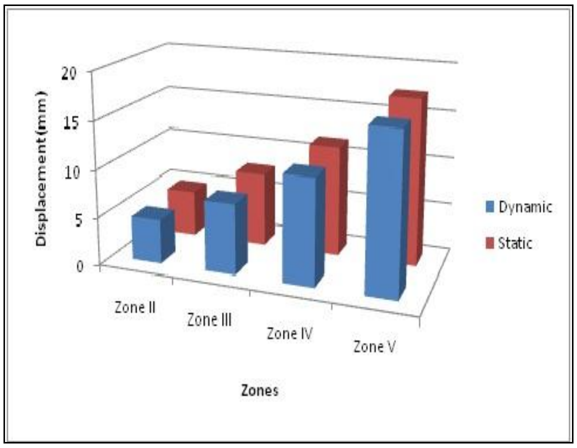


**Figure 4.16** Maximum Displacements (mm) of Silo with Stiffener at intermediate levels for Zone II to V

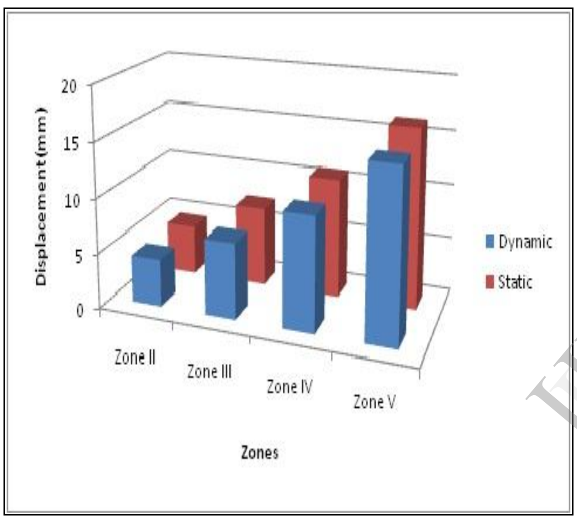


**Figure 4.17** Maximum Displacements (mm) of Silo with Surface element for Zones II to V

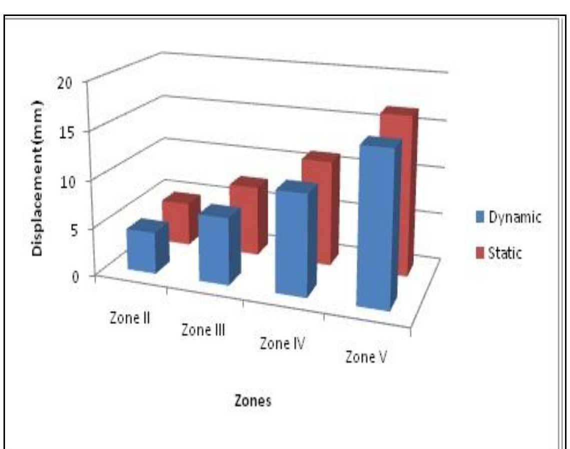


**Figure 4.18** Maximum Displacements (mm) of Silo with Openings in Surface elements between supporting columns for Zones II to V

## 5. Conclusions

On the basis of the present study, following conclusions are made:

1. The frequency of the silo is increased providing surface element. This increase accounts for about 15%. Thus providing surface element increases the stability of the structure, especially in earth quake prone areas or under dynamic loading.
2. The displacement of Silo with Plate element, Bracing element and Surface element are well within the permissible limits. The displacement increases as zone increases.
3. The displacement of the structure is generally found to be reduced from about 20% on providing surface element.
4. The Surface element as shear wall gives the economical results compared to bracing element.

## 6. References

[1] Sivabala. P , Elangovan. G , Kameshwari. B, “Effect of shear wall panels on the dynamic response of a silo”International Journal of Civil and Structural Engineering Volume 1, No 4, 2011.

[2] Jaspal Singh V.R.Sharma N.K. Khullar “Analysis of Hopper Bottom Cylindrical Silos Subjected to Earthquakes” The 12th International Conference of International Association for Computer Methods and Advances in Geo mechanics (IACMAG) 1-6 October, 2008 Goa, India

[3] R.S. Londhe, A.P. Chavan, “Behaviour of Building Frames With Steel Plate Shear Walls” Asian Journal Of Civil Engineering Vol. 11, No. 1 (2010) Pages 95-102.

[4] V.K.Sehgal and Kadam S.S. “A study of openings in shear walls” Proc of The Icfai University Journal of Structural Engineering, Vol. III No.1, 2010, pp28-41.

[5] Mohammed Abbas Husain “Analysis of shear walls with opening using brick element” Proc of European Journal of Scienti_c Research, ISSN 1450-216X,Vol.51 No.3 (2011), pp359-371.

[6] J. Mark F. G. Holst, Jin Y. Ooi, J. Michael Rotter, And Graham H. Rong, “Numerical Modeling Of Silo Filling. I:Continuum Analyses” Journal Of Engineering Mechanics / January 1999 125:94-103.

[7] F. Nateghi and M. Yakhchalian, “Seismic Behavior of Silos With Different Height to Diameter Ratios Considering Granular Material structure Interaction” Structural Engineering Research Center, International Institute of Earthquake Engineering and Seismology, Tehran, Iran December 15, 2011