Modal analysis of support structure of cylindrical container

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Abstract. The paper deals with dynamic analysis of a container. The analyzed structure consists of a steel support structure and a cylindrical container. The container is used for storage of road salt and other spreading materials during winter road maintenance. Three variants of support system of a structure have been analyzed. These have been introduced into the model as different boundary conditions. The modal analysis was performed, whose results are eigenfrequencies and eigenshapes of the structure. In the final part, the results obtained from the seismic analysis of the structure (displacements and internal forces) have been presented.

1 Introduction

Structures for storage of various materials represent an important part of any manufacturing process. Material storage requires additional costs without increasing the value of the stored material. The basic requirement for storage tanks is to preserve the properties of stored materials and to prevent their deterioration.

The topic of this paper is modeling of three alternatives of bearing structures and their consecutive modal and spectral analysis. The characteristics of container, being designed by a specialized company, were used as input data, i.e.: its shape and dimensions, and specification of a stored material. Results have been presented in a form of a comparison of structural variants from various viewpoints.

1.1 General description of cylindrical containers

Structures serving for storage of different types of media can be categorized as:

- containers for storage of loose bulk materials,
- tanks for storage of liquid materials,
- gasholders for storage of gaseous materials.

The container consists of a silo and a hopper. For purposes of large storage capacities, containers might be combined in groups. The most frequently used materials for production of containers are steel and concrete. The top-loaded containers have been filled

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mechanically, by means of belt conveyors; or pneumatically by means of a discharge pipe. They dealt with a similar problem [1], [3]

1.1.1 Containers of a circular cross-section

In the common practice, circular containers have been used most frequently. They offer a benefit of optimal distribution of loads to the container walls, which implies they provide more space for the stored material. A cone-shaped hopper with its circular bottom hole enables smooth and perfect emptying. Compared to square or rectangular containers, there is a drawback in a smaller effectiveness of utilizing of the occupied built area.

2 Structure of a cylindrical container

The container is composed of a cylindrical silo with height 5.8 m, a cone-shaped hopper with height 1.7 m, an emptying hole with diameter 300 mm, and a roof with height 1.5 m. Overall container height including the hopper and the roof is 9.0 m. The loading from the silo to the bearing structure has been transferred via 10 columns. A corrugated steel sheet with reinforcing elements forms the silo cladding.

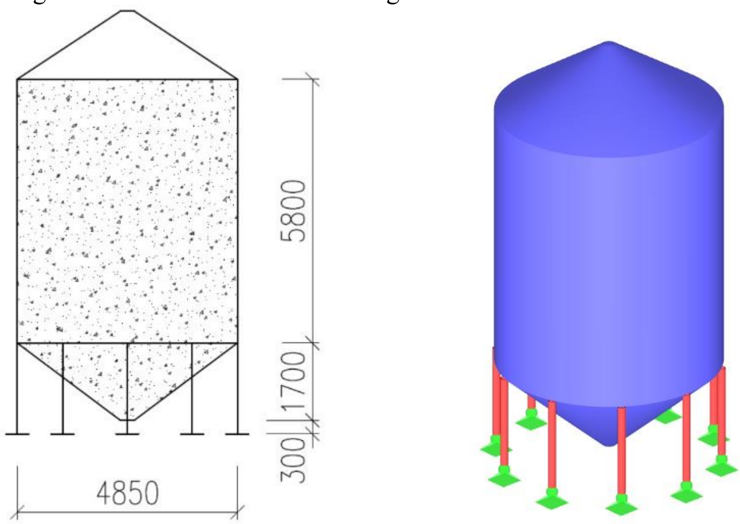


Fig. 1. Scheme of media size and volume in the cylindrical container.

2.1 Description of structure

The designed structure must meet the functional requirements, primarily the driving profile of a lorry. The position of horizontal beams of a bearing structure is limited by geometry of the silo columns. Axial distance of vertical bearing elements of a transversal bond is 8.48 m while in the direction perpendicular to the transversal bond it is 2.305 m. With respect to the height of a lorry, the underpass height must not be smaller than 4.0 m.

2.1.1 Model 1

The first alternative of a container bearing structure consists of stiff beams interconnected by frames, and rods loaded by axial forces. Columns are made of steel rolled profiles HEB 360 and are hinged to the foundation structures. A transverse wall is of a HEA 360 profile. Stiffening elements have a circular cross-section RO 168x6.3. All structural elements are made of steel S235 [2], [4].

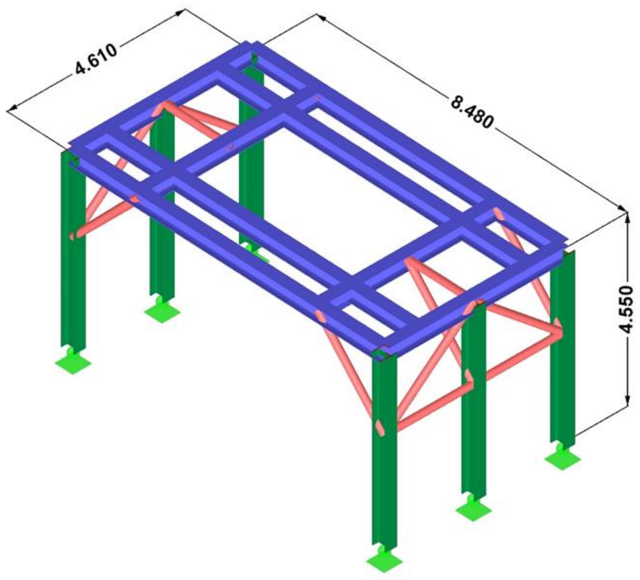


Fig. 2. Model 1.

2.1.2 Model 2

A second alternative is a combined structure, composed of a reinforced concrete wall 400 mm thick and of horizontal girders made from steel profiles HEA 450, hinged to the wall. The wall is clamped into the foundation structure. Structural elements have been manufactured from concrete C30/37 and steel S235 [2], [4].

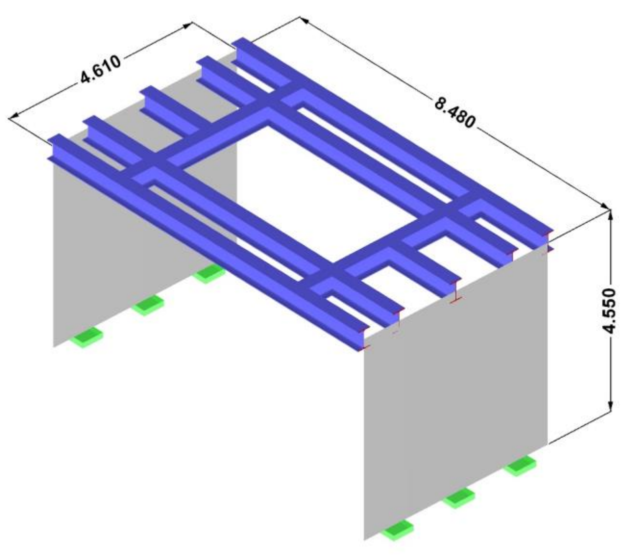


Fig. 3. Model 2.

2.1.3 Model 3

The third alternative of a container's bearing structure consists of columns and a lattice structure. Columns are composed of steel rolled profiles HEB 300 and they are hinged to the foundations. Upper stripe of a lattice structure is of a cross-section HEA 300. Diagonals, verticals and lower stripes are of a circular cross section RO 168x6.3. Columns and upper stripes of a lattice structure together create stiff frames to which the additional elements are hinged. The material used is steel S235 [2], [4].

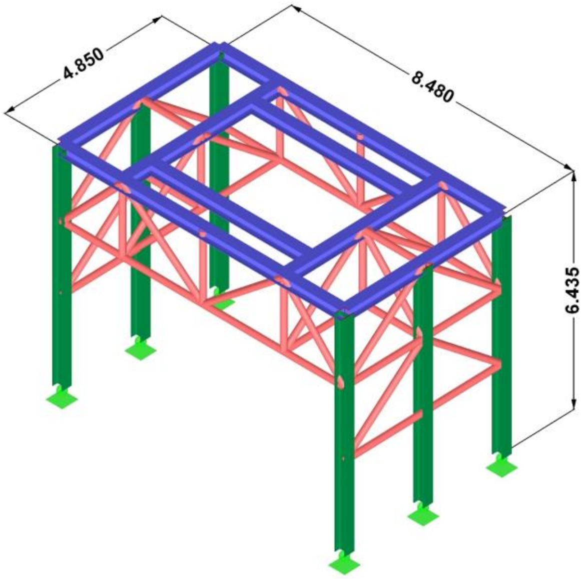
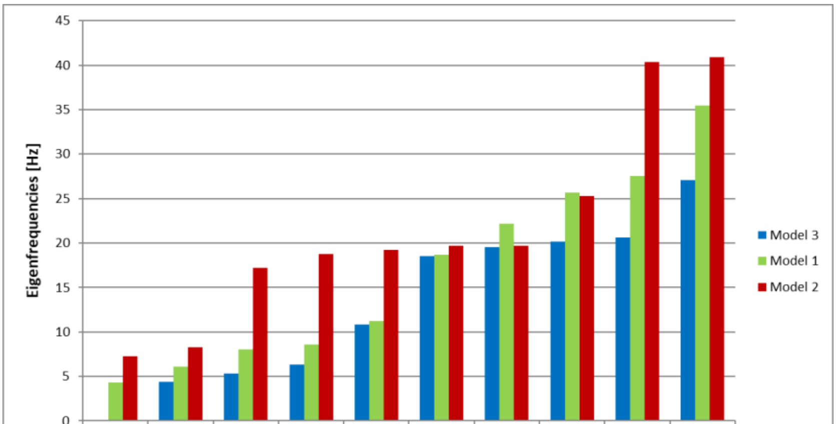


Fig. 4. Model 3.

3 Modal and spectral analysis

Graph in Fig. 5 shows the comparison of ten eigenfrequencies.



	1	2	3	4	5	6	7	8	9	10
Model 3	0	4.36	5.307	6.362	10.872	18.515	19.568	20.126	20.613	27.083
Model 1	4.337	6.128	8.039	8.602	11.197	18.704	22.212	25.684	27.514	35.438
Model 2	7.236	8.303	17.214	18.722	19.208	19.702	19.717	25.259	40.336	40.901

Fig. 5. Eigenfrequencies of Models 1, 2, 3.

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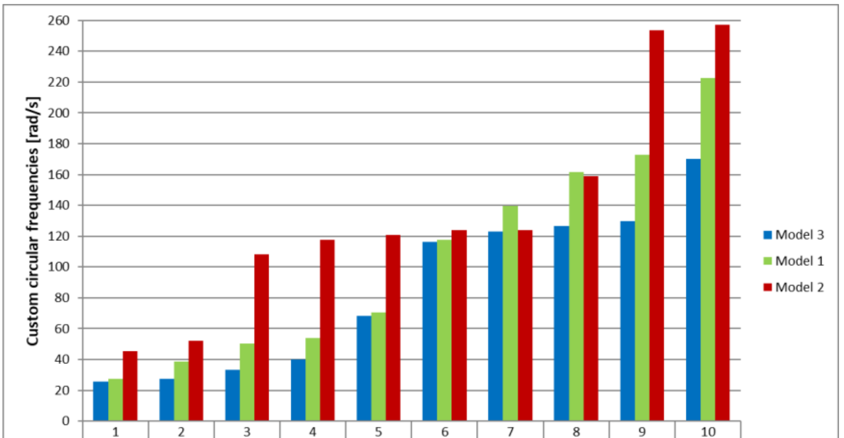
Graph in Fig. 6 shows the comparison of ten circular eigenfrequencies.



	1	2	3	4	5	6	7	8	9	10
Model 3	25.408	27.397	33.343	39.971	68.312	116.332	122.951	126.457	129.513	170.167
Model 1	27.248	38.505	50.51	54.046	70.35	117.521	139.564	161.379	172.879	222.666
Model 2	45.466	52.169	108.159	117.632	120.685	123.794	123.884	158.71	253.441	256.991

Fig. 6. Circular eigenfrequencies of Models 1, 2, 3.

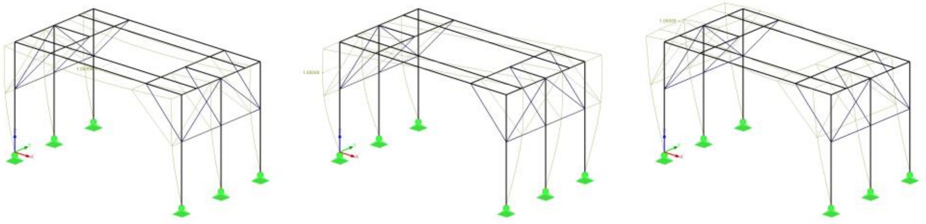


Fig. 7. Model 1 – first three eigenshapes.

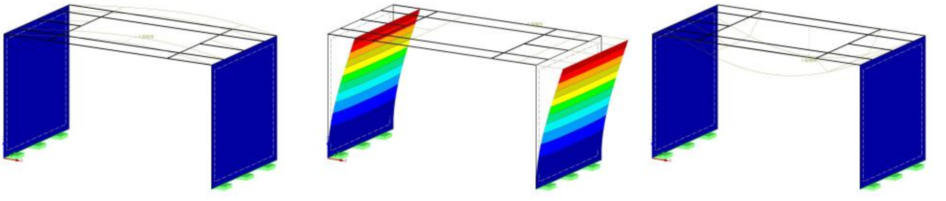


Fig. 8. Model 2 – first three eigenshapes.

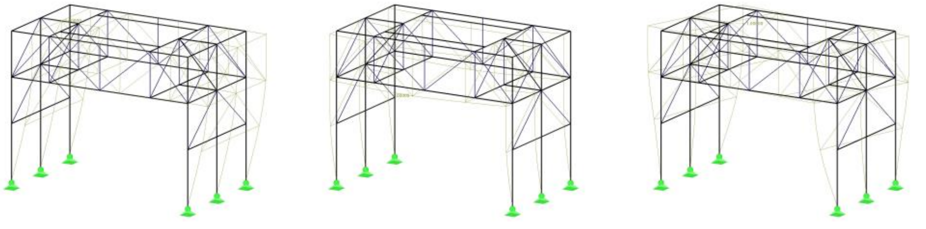


Fig. 9. Model 3 – first three eigenshapes.

4 Conclusion

Modal analysis has confirmed the dependence between eigenfrequencies and the stiffness of the structure. These results are documented in the graphs in Figs. 5 and 6. The following Figures (7-9) show the courses of the first three eigenshapes of vibration. The results obtained from the modal analysis serve as the basis for the following spectral analysis.

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