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DYNAMIC BEHAVIOR OF SPATIAL TRUSS STRUCTURES SUBJECTED TO EARTHQUAKE MOTIONS

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ABSTRACT

An earthquake proof design of ordinary buildings is carried out using the seismic load and distribution according to the standard seismic design code of each country. It is difficult for structural engineers to determine the loads and distributions applied on spatial and shell structures, which have a unique structural configuration.

Seismic design coefficients

Seismic design coefficients of the domes are neccesary to calucalate the design seismic load applied on roof type domes for their safety verification against earthquake motions.

As shown in Fig.1, the roof type dome is induced by ground motion with amplification characteristics of the surface layer (B) in relation to predominant periods of the layer. The input ground motion (C) for the design is to be defined for the engineering bedrock (the layer A), with the shear wave velocity being about 400 m/sec or more.

The inertia force F_H must be set up considering the most important factors as follows:

$$F_H=K_H \cdot W \tag{1}$$

$$K_H=Z \cdot k_H \cdot K_0 \tag{2}$$

Where K_H is the seismic design coefficient, W is the weight of the dome, Z is the seismic hazard zoning coefficient, k_H is the seismic design coefficient determined by the structural amplification ratio, and K_0 is the standard seismic design coefficient.

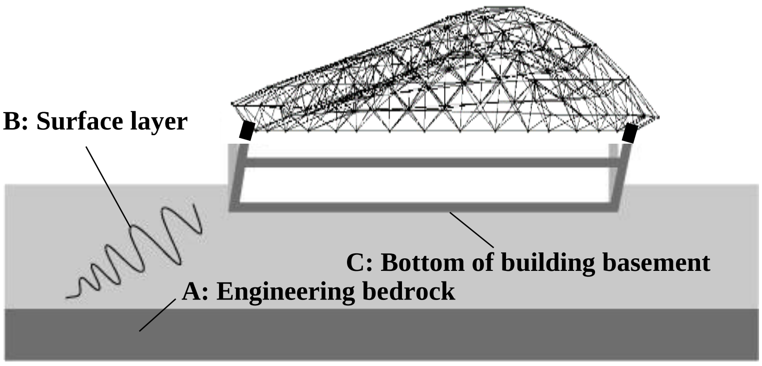
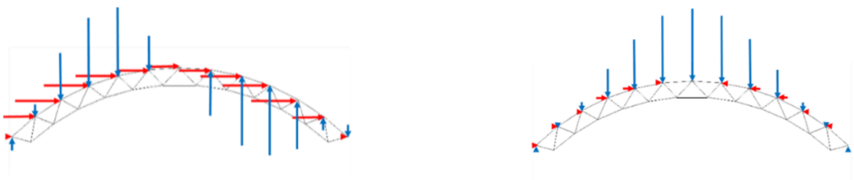


Figure 1. Earthquake response of a structure with a double layer truss dome

Distributions of Static Equivalent Seismic Loads

The static equivalent seismic load is derived by using the participation vectors and the acceleration response spectrum. The static seismic load distributions are shown in Fig. 2. It is seen that the horizontal and vertical distributions of the dome show asymmetry and symmetry shape, respectively.



(a) Asymmetry shape (b) Symmetry shape

Figure 2. Distributions of static equivalent seismic load distribution (θ=30°)

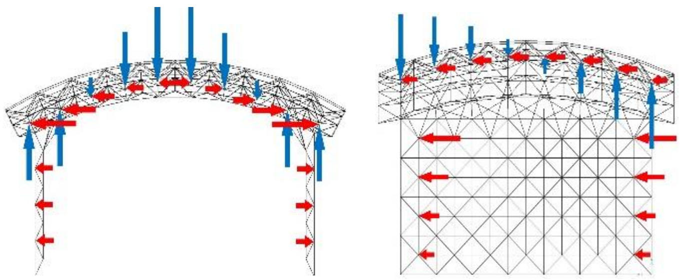
The natural periods and the vibration modes of the dome are obtained by means of the eigenvalue analysis. The first and the third natural periods such as T_1 and T_3 are shown in Figs.3, respectively. The corresponding vibration mode shapes are also shown in Figs.3, respectively. It is seen that the vertical vibration mode shapes such as the third mode of θ=30°in Fig.3.

First mode: T_1=0.162(s) Third mode: T_3=0.131(s)

Figure 3. The first and third vibration mode shapes and natural periods T_1 and T_3

Seismic force distribution and deformation property

Fig. 4 shows the static seismic force using the 6th-order mode (natural period T_6=0.146s) of the analysis model without eccentricity. For the acceleration response spectrum, the observed wave phase of El-Centro 1940 and the announced spectrum were set as the target spectra. The reason for adopting the 6th-order mode is that the effective mass ratio is 0.95, which is the largest value in the direction along the wall. The mode shape appears a shear deformation type of the wall.

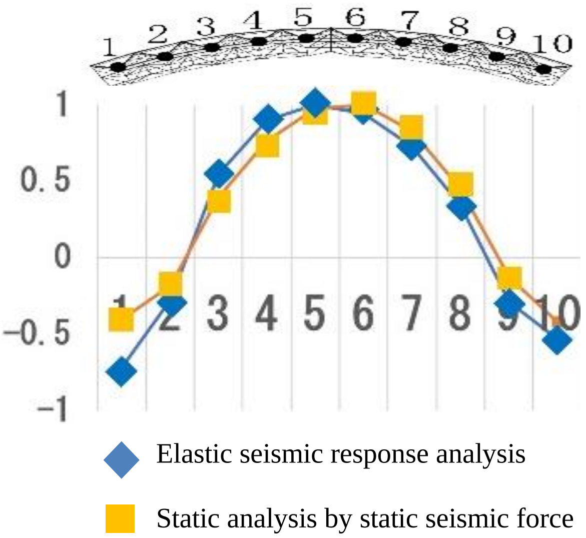


(a) Seismic force distribution (x-y plane) (b) Seismic force distribution (y-z plane)

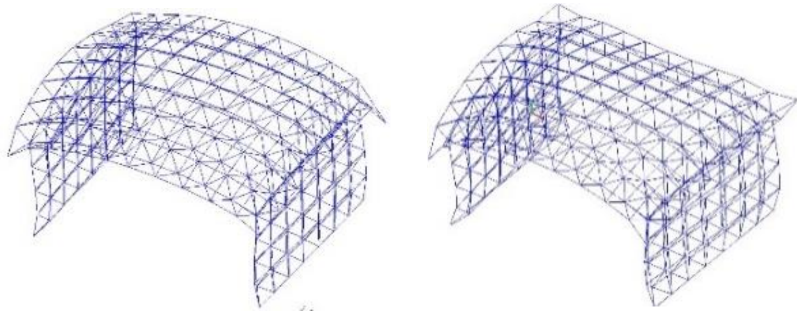
Figure 4. Distribution map of static seismic force

The following seismic force distribution is recognized from this figure. That is, in the distribution (y-z plane), the roof response acceleration applies the seismic force in the vertical direction in a symmetrical distribution, and the walls response acceleration applies the seismic force in the out-of-plane direction due to the thrust from the roof. In the distribution (x-y plane), the roof receives a vertical seismic force in inverse symmetry, and the walls response acceleration applies a horizontal seismic force with an inverted triangular distribution. Regarding the seismic force acting on the roof cross section in the direction from the center point of the wall in the girder direction, the seismic response analysis and static seismic force are normalized and shown in Fig. 5 (a). The seismic force obtained by seismic response analysis was calculated as follows. That is, at the time when the maximum response acceleration in the girder direction of the center point of the upper surface of the dome became maximum, the response accelerations of all the nodes were obtained from the time history response analysis. Next, the seismic force is calculated by multiplying the mass of each node by the response acceleration. It can be seen that the seismic response analysis and static analysis have relatively close distributions from Fig. 5 (a).

Deformation properties in Fig. 5 (b) show the deformation diagram by the seismic response analysis, and Fig. 5 (c) shows a deformation diagram of static analysis by applying static seismic force. From this, the following can be confirmed for the roof structure. That is, in static analysis, it floats forward in the distribution (y-z plane). On the other hand, a deformation that sinks behind the girder appears. In the seismic response analysis, the same deformation is seen, but compared to the static analysis, the roof plate is smoothly deformed into a rigid body. The following was confirmed for the wall structure. This means that the outside of the wall surface is deformed due to the thrust from the roof structure in the girder direction. On the other hand, it was confirmed that the shear deformation property was shown in the wall direction.



(a) Normalized seismic force distribution



(b) Seismic response analysis (c) Static analysis by static seismic force

Figure 5. Comparison of seismic force distribution acting on the roof and deformation

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