Applied Mechanics and Materials *Online: 2012-12-13*
ISSN: 1662-7482, Vols. 256-259, pp 2091-2095
doi:10.4028/www.scientific.net/AMM.256-259.2091

Seismic Response Analysis of Containment with Hemisphere Dome for Advanced Nuclear Power Station

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Keywords: containment; MIDAS/Gen; spectrum analysis; time history analysis; seismic response

Abstract. Nuclear Power Station is the last bulwark of the nuclear reactors, and the seriousness of the consequences due to the damage and the enormous impact of human psychology, the seismic response analysis of nuclear power plants is essential. MIDAS/Gen finite element model of the structure of the space, for example, a nuclear power plant, the power of the research containment structure under horizontal seismic response characteristics and undermine the law, the natural frequency of the structure, shapes characteristics, structure the displacement distribution parameters, provides a basis for the design of the structure and to provide a reference for similar studies.

Introduction

The nuclear power plant containment envelope structure of the nuclear reactor, the last line of defense as a nuclear fuel leak following the cladding of the nuclear burning the pressure shell after the third safety barrier. Containment of a nuclear power plant as the research object, the application of the finite element software MIDAS/Gen establish the finite element model of the containment, the main consideration of the containment under horizontal seismic action, application of the finite element software containment static analysis, modal analysis, response spectrum analysis and time history analysis, dynamic response of the containment structure under horizontal seismic characteristics and undermine the law, the natural frequency of the structure, modal characteristics, structural displacement distribution parameters. This analysis is based on the hemispherical security shell model.

Containment Static Analysis

This paper studies the containment structure is made of reinforced concrete, mainly of reinforced concrete from the top of the hemispherical dome, the vertical cylindrical reinforced concrete casing and reinforced concrete pad at the bottom of three parts. Cylindrical shell inside diameter of 40m, wall thickness of 1m, high 35m; dome hemispherical shell diameter 40m, wall thickness 1m; bottom of the reinforced concrete pad diameter of 50m, thickness of 4m. MIDAS/Gen software analysis, containment backplane board unit established model, cylindrical shell and dome hemisphere shell element modeling. C50 grade concrete containment material parameters: elastic modulus E=3.4554×104MPa, Poisson's ratio μ=0.2, bulk density 25KN/m3, mass density 2.549KN/m^3/g; simplify the calculation, according to the containment structure size, does not consider the anchoring device in the wall of the containment and buttresses factors openings, etc., within the elastic range of the analysis of safety shell. The modeling assumes that the concrete elastic material, the bottom of the foundation of the impact is negligible, all solid support at the bottom of the structure, a finite element model.

The bottom surface of the containment floor all boundary constraints, static and finite element model of the containment strive solution. Static analysis of the stress distribution obtained in the Z direction, as shown in Figure 1.

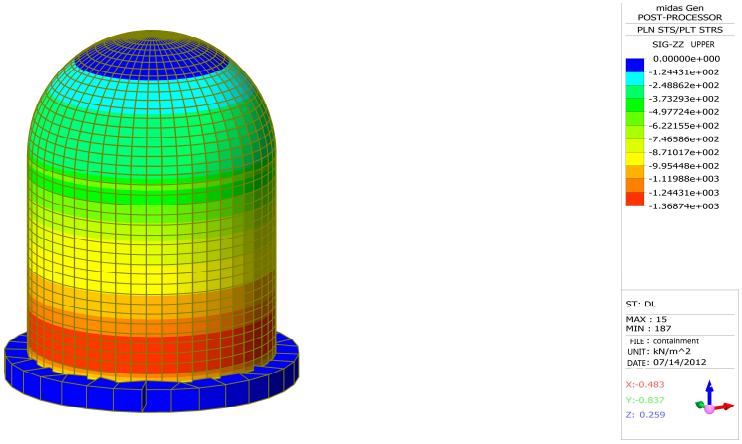

Fig.1 Z - Component stress contour under gravity

The containment under its own weight, the containment is basically in the pressure on the state of the whole cross-section. There was a start 297.099KPa decreased by 271.152KPa then increased reached 513.106KPa after changing area to reduce further increased, and the remaining portion of gradually increasing compressive stress from top to bottom in the hemispherical shell and a cylindrical shell junction compressive stress, the maximum value of the compressive stress in the safety shell vertical cylindrical housing and the bottom plate of the connection site reaches its maximum value of 1368.742kPa, and the maximum value of the compressive stress is much less than the compressive strength of the C50 concrete.

Containment Modal Analysis

This paper modal analysis of a nuclear power plant containment Lanczos method can guarantee the accuracy of calculation and do not affect the calculation speed. Through eigenvalue analysis, extraction of the first 20 cycle and frequency of vibration mode, as shown in Table 1;12th order vibration and extract diagram, shown in Figure 2.

Table 1 Cycle and frequency of the first 20th-order modal shape

Modal	Frequency/Hz	Cycle/s	Modal	Frequency/Hz	Cycle/s
1	5.8131	0.1720	10	11.2445	0.0889
2	5.8131	0.1720	11	12.1385	0.0824
3	8.0000	0.1250	12	15.2998	0.0654
4	8.0000	0.1250	13	15.2998	0.0654
5	8.5655	0.1167	14	15.4157	0.0649
6	8.5655	0.1167	15	15.6050	0.0641
7	9.8289	0.1017	16	15.6050	0.0641
8	9.8289	0.1017	17	16.6477	0.0601
9	11.2445	0.0889	18	16.6477	0.0601
10	11.2445	0.0889	19	16.7082	0.0599
11	12.1385	0.0824	20	16.7082	0.0599

Due to the containment of the nuclear power plant is a symmetrical structure, the structure vibration mode has obvious symmetry. The difference is small for the frequency value the two groups shapes deformation in the modal chart on the performance of a certain symmetry and similarity. As can be seen from the modal diagram: the first mode-based X parallel to the direction,

and the second-order vibration mode Y parallel to the direction of moving the main third-order modes shrinkage deformation mainly in the X direction, the additional Y direction prominent deformation; fourth vibration mode mainly contraction deformation mainly in the Y direction, an additional X-direction projecting deformation; fifth vibration mode to the X, Y direction is the main shrinkage deformation; sixth order vibration mode of the X, Y direction protruding deformation . The eleventh order modes appear obvious torsional deformation.

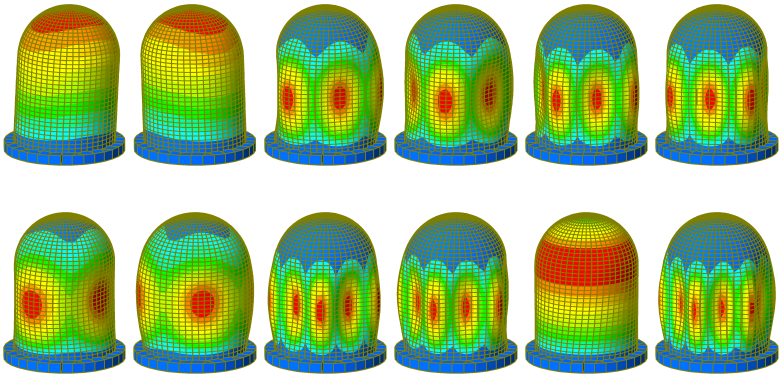

Fig.2 The first 12th-order modal shape

Base frequency is relatively high, and its value 5.8131Hz, described the overall structural rigidity of the safety shell relatively large.

Assumes that the bottom of the safety shell are fully constrained, secure shell, the two vibration type offset with increases away from the bottom of the distance becomes large; third, fourth, fifth, sixth vibration mode in a secure The deformation of the shell cylinder central offset to maximum. Without considering the finite element containment divided the bottom concrete support in the form as well as the semi-basement of the containment structure, there are some differences in the specific circumstances.

Containment Response Spectrum Analysis

The existing seismic fortification intensity considering a nuclear power plant site 7 degrees basic design earthquake acceleration value of 0.10 g, site class for Class II design earthquake packet to the second group. According to GB 50267-97 " Code for seismic design of nuclear power plants " and GB50011-2010 " Code for seismic design of buildings " provisions, through the look-up table to determine the nuclear power plant is the first class buildings once fortified improve the seismic fortification intensity 8 degrees; the engineering basic seismic acceleration value of 0.20 g, the characteristic period Tg=0.40s, horizontal seismic influence coefficient αmax=0.16, the containment structure damping ratio $\zeta = 0.05$. Based on the above parameters and reference seismic influence coefficient curve, the use of vibration response spectrum method for seismic analysis.

In response spectrum analysis, consider the containment in effect under the joint action, and the first 20 modes contribution to its own weight and level of response spectra. Define the X direction to the horizontal direction of the finite element model input earthquake response spectra, using the SRSS combination resulting from the earthquake response of the structure along the X direction. Response spectrum analysis of the containment structure deformation maps; containment maximum horizontal displacement from the bottom to the top, as shown in Table 2;

The Response Spectrum Analysis Results

The structure lateral displacement substantially uniformly along the height changes, the description of the structure of the layers change in stiffness is uniform, and the maximum horizontal displacement of the bottom-up is gradually increased, the maximum value is located in the top of

the safety shell, multi case of seismic the maximum value is 1.5273mm, the maximum under rare earthquake 8.5913mm, both maximum appear in the 1144 node in the top of the containment, the smaller displacement values reflects the structural stiffness.

Table 2 Layers of maximum horizontal displacement response spectrum

Elevation(mm)	Frequent earthquake(mm)	Rare Earthquake(mm)
55500.00	1.5273	8.5913
54496.66	1.5121	8.5057
53265.63	1.4893	8.3773
49495.69	1.4092	7.9270
41334.85	1.2093	6.8022
35000.00	1.0311	5.8001
28000.00	0.8137	4.5773
21000.00	0.5901	3.3190
14000.00	0.3712	2.0879
7000.00	0.1687	0.9489
0	0	0

Containment Time History Analysis

MIDAS/Gen mode superposition analysis. For comparative analysis of selected two natural seismic record analysis and calculation: the 1940 famous El Centro 270 Deg, record time 30s, 1952 Taft of Lincoln School, 69 Deg record. Determine the duration of the project's principle is: the most intense part of the seismic records should be included in the selected duration. Analytical procedures, mode superposition transient structural analysis.Three load cases are: TH1, X to enter the El Centro wave; TH2, X-directional input Taft wave; TH3, X to the input X to enter El Centro wave Y to enter the Taft wave.

Time History Analysis Results

From the layer displacement (Figure 3), the two seismic waves and the response spectrum method analysis results are generally consistent time history analysis from the floors of the maximum displacement is greater than the results of the spectral analysis. Two seismic waves, the El Centro wave structure seismic reaction force large than Taft wave.

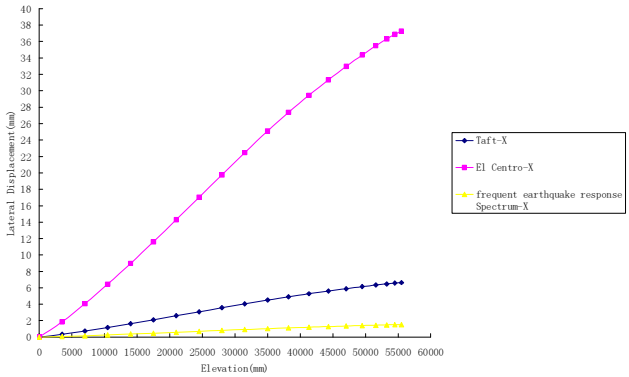

Fig.3 Layer displacement

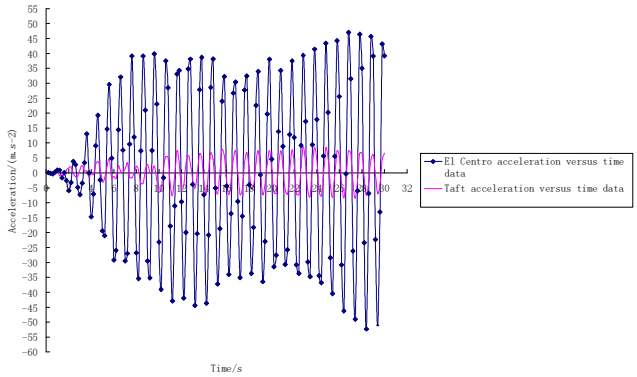

Fig.4 Acceleration versus time data

The dynamic characteristics of the containment seismic response and the structure itself, the spectral characteristics of the seismic waves and earthquake intensity has a relationship, the seismic response of the structure in the excitation of two different seismic waves showed a significant difference, as shown in Figure 4.

By comparison, the response spectrum method is unsafe, mainly due to the vibration response spectrum method to obtain the number of less than normal, increase the number of modal lesson and improving the accuracy results compared with the time-history method is still biased unsafe.

Conclusions

Application of MIDAS finite element analysis software, the computer simulation model to establish a secure shell analysis the following conclusions:

Response spectrum analysis the earthquake horizontal structure layer sway along basic uniform height changes, the floor uniform change in stiffness, gradually increasing the maximum horizontal displacement of the bottom-up, the maximum value is located in the top of the containment, maximum of 1.6318 mm, and containment fundamental frequency is relatively high, it is 5.8131Hz, stiffness of the containment structure is relatively large earthquake load. Horizontal earthquake action, the containment structure of the maximum bending moment occurs in reinforced concrete pad at the intersection with the vertical cylindrical reinforced concrete shell that is there for the weakest structure, may be appropriate to increase the construction at the intersection reinforcement, thereby enhancing the stability of the containment structure.

The dynamic characteristics of the containment seismic response and the structure itself, the spectral characteristics of the seismic waves and earthquake intensity has a relationship, the seismic response of the structure in the excitation of two different seismic waves showed a significant difference. By comparison, the response spectrum method is unsafe, mainly due to the vibration response spectrum method to obtain the number of less than normal, to increase the number of mode shapes lesson and improving the accuracy of the results compared with the time-history method is still unsafe , the response spectrum method is recommended in the reference design.

Because they do not consider the containment wall of the anchoring device and the buttress, the bottom of the opening and the underlying impact is ignored excluding such factors, and the actual values there is a certain deviation.

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