

Comparison between equivalent spring element method and additional mass method in nuclear power structure

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Keywords: Equivalent spring element method; Additional mass method; Dynamic characteristics

Abstract. In order to study the effect of fluid on the structural dynamic characteristics, in this paper, a three-dimensional spring element was applied to the dynamic analysis of the fluid. Based on the simplified model of nuclear power structure, the upper water tank of concrete containment was analyzed in different water level by equivalent spring element method and additional mass method. The theory of three-dimensional equivalent spring element was put forward, and then the numerical simulation of different water tank was carried out. The computational results of the two methods showed that the equivalent spring element method and the additional mass method have the similar accuracy.

Introduction

For the third generation of nuclear power structure, the test or numerical simulation of nuclear power structure can almost not be found from the literature, as the third generation of reactor type at the top of the fluid solid coupling of the storage tank, how to simulate the analysis is less. Yu Xiaoyu^[1] and Dang Junjie^[2] used additional mass method in analysis of nuclear power containment cooling water storage tank structure, through experiments and other numerical examples demonstrate the feasibility and effectiveness of additional mass method. Ying Xiumei^[3] applied the simplified theory of the rigid body spring element to the double layer graphite granular structure, and gave the theoretical basis of the stiffness and damping equivalent of spring element. The spring element was proposed by Professor Kawai^[4] in Japan firstly. The traditional finite element method can handle the continuous medium. This paper compared the equivalent spring element method with the additional mass method and the feasibility of the spring element method for the numerical simulation of nuclear power structure was studied.

Formula derivation of spring element

The three prism of any cross section can be equivalent to a three-dimensional spring element model. In Fig. 1, the three section length prism are a, b, c, the height is h. The formula for calculating the equivalent spring element is as follows: The cross bar area formula:

$$A_{1-2} = A_{4-5} = \frac{A}{6} \cdot \frac{b}{gh} \quad (1) \quad A_{2-3} = A_{5-6} = \frac{A}{6} \cdot \frac{c}{gh} \quad (2) \quad A_{1-3} = A_{4-6} = \frac{A}{6} \cdot \frac{a}{gh} \quad (3)$$

The Oblique bar area formula:

$$A_{1-5} = A_{2-4} = \frac{A}{6} \cdot \frac{b^2 + h^2}{(h^2 - gb^2)} \cdot \frac{\sqrt{b^2 + h^2}}{h} \quad (4)$$

$$A_{3-5} = A_{2-6} = \frac{A}{6} \cdot \frac{c^2 + h^2}{(h^2 - gc^2)} \cdot \frac{\sqrt{c^2 + h^2}}{h} \quad (5)$$

$$A_{1-6} = A_{3-4} = \frac{A}{6} \cdot \frac{a^2 + h^2}{(h^2 - ga^2)} \cdot \frac{\sqrt{a^2 + h^2}}{h} \quad (6)$$

The spring rigidity formula:

$$K = \frac{EA}{L} \quad (7)$$

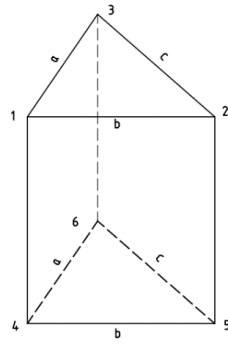


Fig.1 Solid model

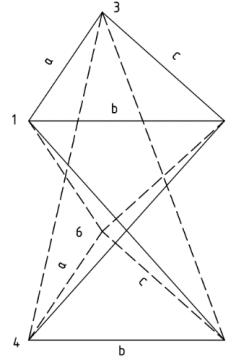


Fig.2 Equivalent spring element model

The illustration of nuclear power structure

The size of nuclear power structure

The inner diameter of the shell is 48.57 m, the thickness of concrete is 1.1m, the outer diameter of the water tank is 29.22 m, the inner diameter is 9.76 m, the water tank is 0.5 m, the material is the same as the concrete shell.

The material parameters of nuclear power structure

Because there are not detailed parameters in the nuclear power structure, the concrete C30 is chosen as the material of the concrete shell. The bulk modulus of the water is $2.2e9 \text{ Pa}^{[5]}$.

Table 1 The parameters of each material

material	density (kg/m^3)	Elastic(Pa)	Poisson's ratio
concrete	2400	$3e10$	0.2
water	1000	$2.2e9$	0.5

Comparison between three kinds of quality method and spring element method

The total water level in the tank is 6.088m. Calculate the height of the water level is 4m, 5m, 6m.

Additional mass method

In this paper, the density of the total mass of the water and the water tank in the water tank and the ratio of the volume of the water to the area are given to the water tank in the region to achieve the additional mass method. Such as the water in level 4m.

Table 2 Volume density in level 4m

	Volume (m^3)	density (kg/m^3)
water	2109.532	1000
concrete	908.200	2400

$$\text{Equivalent density } r = 2400 + \frac{2109.532 \times 1000}{908.1997} = 4722.762 \text{ kg/m}^3$$

Spring element method

The arrangement of the spring element is shown in Fig. 3. The two particles are arranged along the vertical direction, and each layer has three concentric circles of 14.01m, 9.67m and 5.33m, respectively, along the circumferential direction of the 24 particles.

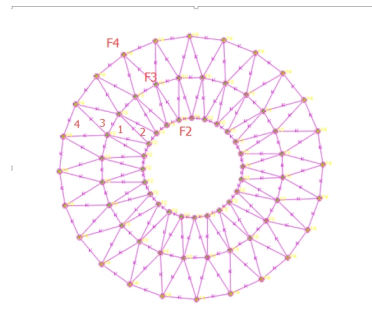


Fig.3 Spring element layout

The comparison of first thirty order frequency

The first 30 thirty order frequency of the two methods are as follows.

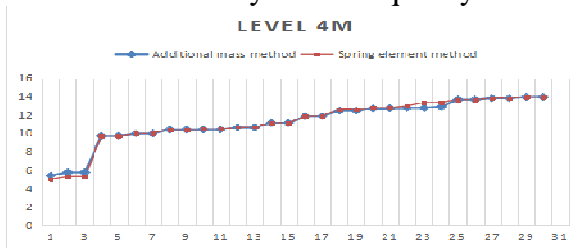


Fig.4 the frequency in level 4m

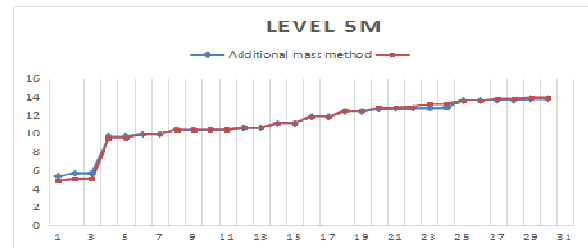


Fig.5 the frequency in level 5m

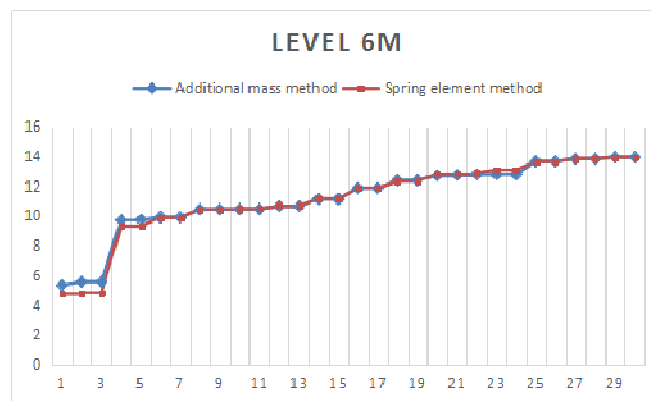


Fig.6 the frequency in level 6m

Conclusion

This paper compares the different level, using added mass method and spring element method nuclear power structure concrete containment of the modal analysis results. A comparison of the two analysis method to obtain the order of formation and frequency is basically the same, both calculated formation diagram similar. In the engineering application, we found that the spring element can be used to simplify the fluid.

Acknowledgements:

Project supported by the National Natural Science Foundation of China (Nos. 11272340), the Chinese Academy Of Agricultural Engineering (Nos. 201401).

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