

## Natural vibration characteristics analysis of single-layer valley type latticed intersected cylindrical shell

Xiaoyang Lu<sup>1, a</sup>, Xiong Jiang<sup>2, b</sup>, Shaobo Lu<sup>3, c</sup>, Haoxin Fu<sup>2, b</sup>, Tao Li<sup>1, a</sup>,  
Lulu Wang<sup>1, a</sup>

<sup>1</sup>Research Institute of Engineering Mechanics, Shandong Jianzhu University, Jinan 250101, China

<sup>2</sup>Civil Engineering School, Shandong Jianzhu University, Jinan 250101, China

<sup>3</sup>Shandong Tongyuan Design Group Co. Ltd. ,Jinan 250101, China

<sup>a</sup>luxy5504@163.com., <sup>b</sup>821985898@qq.com, <sup>c</sup>946761893@qq.com

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**Abstract.** Using ANSYS and subspace iteration method to analyze natural vibration frequencies of Three-directional grid LICS, Fred Boolean type LICS, Single-diagonal LICS, Double-diagonal LICS. The figures of natural frequencies and corresponding shapes are obtained. Macro parameters include span  $S$ , rise  $f$ , valley number  $Kn$ , radial node number  $Nx$  on natural vibration frequencies are analyzed under 52 working conditions. The results show that natural vibration characteristics of Three-grid LICS is the best and Fred Boolean type LICS, Single-diagonal LICS and Double-diagonal LICS' are close. It provides reference for practical engineering design.

### Introduction

The strong ground motion makes reticulated shells vibrate when earthquake happens. For vibrated reticulated shells, the effect of inertia is not negligible in general. The inertia effect caused by seismic makes reticulated shells produce a great deal of seismic internal force and displacement, which is likely to cause the destruction or collapse for reticulated shells[1]. Therefore, it is very important to analyze the seismic response of reticulated shells in seismic precautionary zone[2]. The frequency of natural vibration which is the inherent property of reticulated shells directly influences dynamic characteristics under earthquake. It is necessary to study characteristics of reticulated shells' natural vibration in seismic response analysis. This paper studies modal analysis of Three-directional grid LICS, Fred Boolean type LICS, Single-diagonal LICS, Double-diagonal LICS by using ANSYS. The influence of span( $S$ ), rise( $f$ ), valley number( $Kn$ ) and radial node number( $Nx$ ) on LICS's frequency is studied on the base of natural frequencies and shapes are obtained.

### Basic structural information

The Q235 hot rolled seamless bars are used in the structure. The modulus of elasticity is  $2.06 \times 10^5$  MPa. The Poisson ratio is 0.3. The element of beam188[3] of ANSYS is used in the modeling. The hinged supports are used in the structure which has 235 MPa of yield strength. The average roof's loads are  $2.35 \text{ kN/m}^2$ [4] which divided by  $g$  to be applied on the corresponding joints. The bars' cross section of different parts of the single LICS are different[[5,6]. The hot rolled seamless bars with  $351 \times 16$  mm are selected on the valley line and the outermost hoop and the others is  $299 \times 16$  mm.

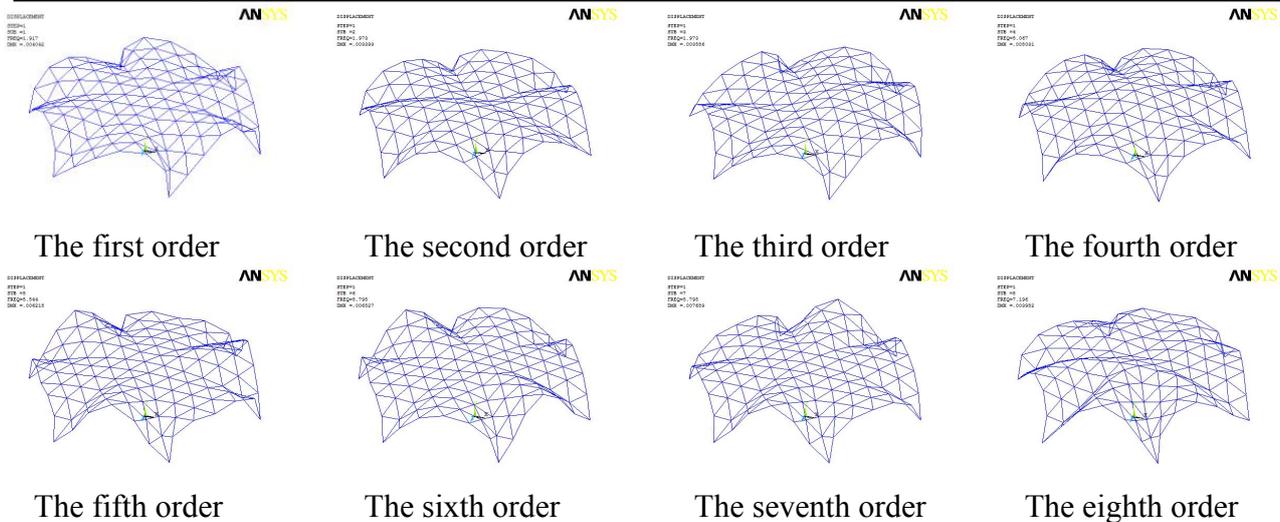
### Structural natural vibration characteristics

Using subspace iteration method[7] to analyze natural frequencies and corresponding patterns which are obtained by modal analysis of ANSYS[8] of Three-directional grid LICS, Fred Boolean type LICS, Single-diagonal LICS, Double-diagonal LICS. Characteristics of natural vibration of Three-directional grid LICS, Fred Boolean type LICS, Single-diagonal LICS and Double-diagonal LICS are analyzed in the paper.

Forty orders of frequencies are get in ANSYS[9] when LICS have specifical spans(55m),rises(10m),different valley numbers(6) and node numbers(6). The roof's even loads which are 2.35 kN/m<sup>2</sup> divided by g are applied on the corresponding joints[10]. The model uses mass21 of ANSYS.Forty orders of frequencies of natural vibration of Three-directional grid LICS,Fred Boolean type LICS,Single-diagonal LICS,Double-diagonal LICS in table 1.Three-directional grid LICS's graph of eight orders of mode shape are in Fig.1.

**Table1 Forty orders of frequencies of natural vibration of LICS (Hz)**

Type	Order	1	2	3	4	5	6	7	8	9	10
Three-directional grid LICS	1-10	1.917	1.973	1.974	5.067	5.544	5.795	5.795	7.196	7.196	7.879
	11-20	7.879	10.562	10.562	10.760	10.760	10.782	10.782	10.963	11.743	12.842
	21-30	13.169	15.499	15.593	15.593	15.951	15.994	15.998	17.236	18.149	18.149
	31-40	19.357	20.815	20.815	21.048	22.454	22.639	22.639	22.661	22.661	23.335
Fred Boolean type LICS	1-10	1.534	1.629	1.630	3.977	4.157	4.244	4.245	5.446	5.446	6.902
	11-20	6.902	7.765	7.765	8.309	8.310	8.391	8.776	8.920	9.090	9.090
	21-30	11.066	11.067	11.074	11.194	12.321	12.323	12.602	13.902	14.050	14.457
	31-40	14.458	16.145	16.432	16.442	16.499	16.989	16.990	17.114	17.114	18.027
Single-diagonal LICS	1-10	1.438	1.615	1.616	3.945	4.052	4.120	4.120	5.031	5.031	6.828
	11-20	6.829	7.396	7.396	7.699	7.700	8.083	8.116	8.724	9.201	9.202
	21-30	10.701	10.701	11.032	11.227	12.343	12.343	12.858	13.943	14.094	14.255
	31-40	14.255	16.149	16.153	16.245	16.259	16.894	16.894	16.929	16.929	17.866
Double-diagonal LICS	1-10	1.492	1.612	1.612	3.771	4.051	4.052	4.091	5.462	5.462	6.655
	11-20	6.655	7.505	7.505	7.995	8.234	8.234	8.584	8.824	8.995	8.996
	21-30	10.702	10.702	11.012	11.931	12.445	12.448	12.589	13.864	13.864	14.287
	31-40	14.578	15.444	15.820	15.821	17.128	17.353	17.356	17.622	17.622	18.823



**Fig.1 Three-directional grid LICS's graph of eight orders of mode shape**

The following conclusions can be drawn from table 1 and Fig.1 under working conditions.

The vibration patterns of Three-directional grid LICS,Fred Boolean type LICS,Single-diagonal LICS and Double-diagonal LICS are characterized by the horizontal vibration patterns, the vertical

vibration patterns, combinations of horizontal and vertical vibration patterns. So it is necessary to input the horizontal and vertical seismic wave in earthquake response analysis.

Three-directional grid LICS's frequencies of natural vibration are greater than Fred Boolean type LICS, Single-diagonal LICS and Double-diagonal LICS' in the same order, so is the rigidity. The frequencies of natural vibration of Fred Boolean type LICS, Single-diagonal LICS and Double-diagonal LICS' are close because their bars' connections are roughly the same. Three-directional grid LICS, Fred Boolean type LICS, Single-diagonal LICS and Double-diagonal LICS' frequencies of natural vibration are discrete and some of them are equal because single-layer valley type LICS have multiple symmetry axes.

The first order and the third order patterns of vibration of Three-directional grid LICS are horizontal vibration in the direction of approximately 45 and 60 degrees with the XZ plane. However, the second and the fourth are the vertical vibration along the Z axis. It is shown that the combinations of horizontal and vertical vibration patterns from the beginning of the fifth order. The surfaces of vibration of the first four orders are simple, the following orders are complicated.

### Influence of span on frequency of natural vibration

The influence of span on frequency of natural vibration of four different kinds of single-layer valley style LICS which have specific spans (50, 55 and 60m), rises (10m), different valley numbers (6) and node numbers (6) are analyzed. The roof's even loads which are  $2.35 \text{ kN/m}^2$  divided by  $g$  are applied on the corresponding joints. The model uses mass21 of ANSYS. The results are drawn in Fig.2.

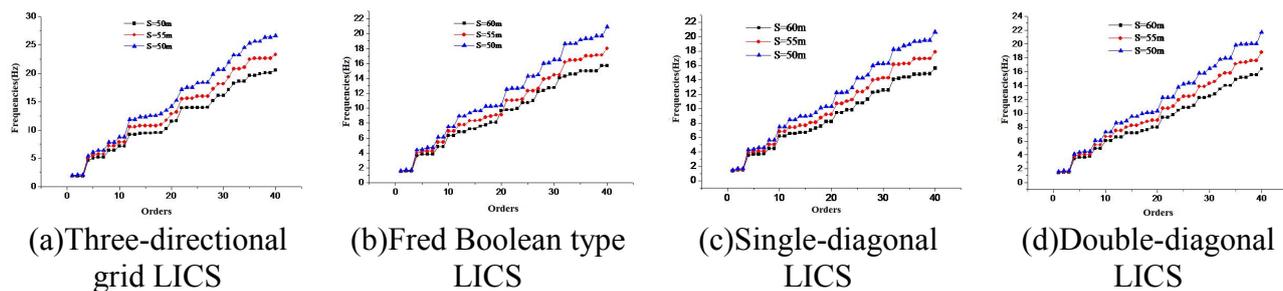


Fig.2 The curve of influence of span on frequency

Under 12 working conditions, we know that Three-directional grid LICS, Fred Boolean type LICS, Single-diagonal LICS and Double-diagonal LICS' frequencies of natural vibration which are discrete decrease with span increased, so is the rigidity. At the moment, more energies are absorbed by the structure and the ability to resist deformation is weaker when the earthquake happens.

### Influence of rise on frequency of natural vibration

The influence of rise on frequency of natural vibration of four different kinds of single-layer valley style LICS which have specific spans (55m), rises (6, 8 and 10m), different valley numbers (6) and node numbers (6) are analyzed. The roof's even loads which are  $2.35 \text{ kN/m}^2$  divided by  $g$  are applied on the corresponding joints. The model uses mass21 of ANSYS. The results are drawn in Fig.3.

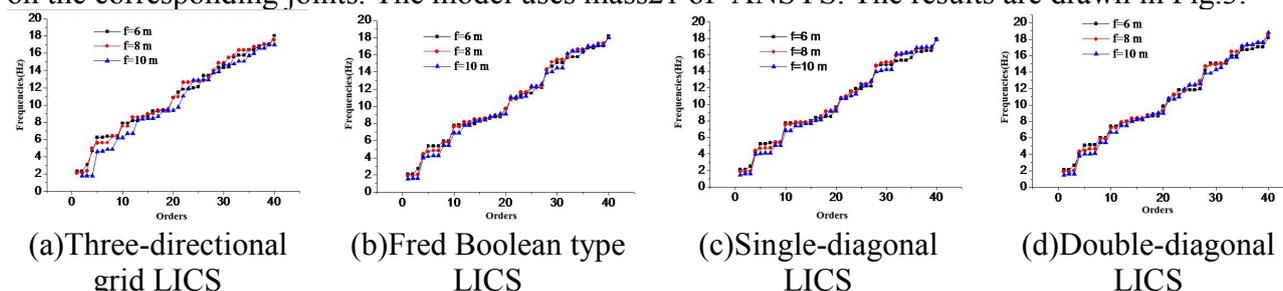


Fig.3 The curve of influence of rise on frequency

Under 12 working conditions, we know that Three-directional grid LICS, Fred Boolean type LICS, Single-diagonal LICS and Double-diagonal LICS' the first ten orders' frequencies of natural vibration decrease with rise increased, so is the rigidity. At the moment, more energies are absorbed by the structure and the ability to resist deformation is weaker when the earthquake happens. Eleven to thirty orders' frequencies of natural vibration are complicated with rise increased.

### Influence of $Kn$ on frequency of natural vibration

The influence of  $Kn$  on frequency of natural vibration of four different kinds of single-layer valley style LICS which have specific spans(55m), rises(10m), different valley numbers(4,5 and 6) and node numbers(6) are analyzed. The roof's even loads which are  $2.35 \text{ kN/m}^2$  divided by  $g$  are applied on the corresponding joints. The model uses mass21 of ANSYS. The results are drawn in Fig.4.

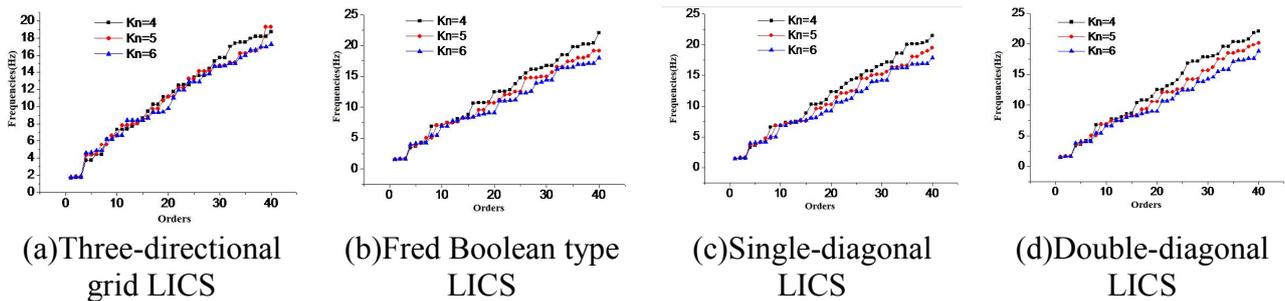


Fig.4 The curve of influence of  $Kn$  on frequency

Under 12 working conditions, we know that Three-directional grid LICS, Fred Boolean type LICS, Single-diagonal LICS and Double-diagonal LICS' frequencies of natural vibration which are discrete decrease with  $Kn$  increased, so is the rigidity. At the moment, more energies are absorbed by the structure and the ability to resist deformation is weaker when the earthquake happens.

### Influence of $Nx$ on frequency of natural vibration

The influence of  $Nx$  on frequency of natural vibration of four different kinds of single-layer valley style LICS which have specific spans(40m), rises(10m), different valley numbers(6) and node numbers(6,11 and 16) are analyzed. The roof's even loads which are  $2.35 \text{ kN/m}^2$  divided by  $g$  are applied on the corresponding joints. The model uses mass21 of ANSYS. The results are drawn in Fig.5.

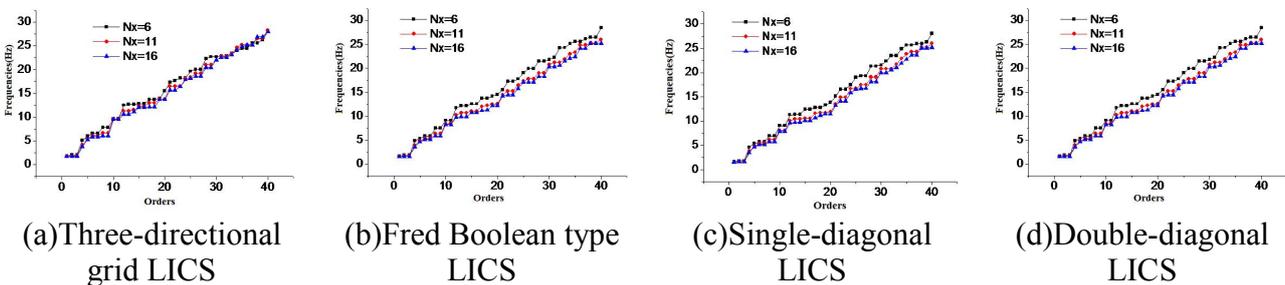


Fig.5 The curve of influence of  $Nx$  on frequency

Under 12 working conditions, we know that Three-directional grid LICS, Fred Boolean type LICS, Single-diagonal LICS and Double-diagonal LICS' frequencies of natural vibration which are discrete decrease with  $Nx$  increased, so is the rigidity. At the moment, more energies are absorbed by the structure and the ability to resist deformation is weaker when the earthquake happens.

## Conclusions

This paper analyzes four influence factors and 52 working conditions on natural vibration frequency of four different kinds of single-layer valley style latticed intersected cylindrical shell. The results are as follows.

The vibration patterns of single-layer valley style latticed intersected cylindrical shell are characterized by the horizontal vibration patterns, the vertical vibration patterns, combinations of horizontal and vertical vibration patterns. Three-directional grid LICS's frequencies of natural vibration are greater than Fred Boolean type LICS, Single-diagonal LICS and Double-diagonal LICS' in the same order. The frequencies are discrete and some of them are equal.

The natural vibration frequencies of Three-directional grid LICS, Fred Boolean type LICS, Single-diagonal LICS and Double-diagonal LICS decrease with span, rise, valley number and radial node number increased. Rise has little influence on natural vibration frequency.

It is suggested that Three-directional grid LICS should be first considered in practical engineering design.

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