Experimental Investigations of Seismic Stability of Cross-Stranded Spatial Structures on Small-Scale Models

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ABSTRACT

The article provides a methodology for the experimental investigation of small-scale cross-stranded spatial structure (CSSS) models under dynamic loads such as seismic. Determination of the frequency and corresponding free and forced oscillations of the CSSS for different types of support and design schemes.

KEYWORDS: *model, static, dynamic, seismic, horizontal, spatial, amplitude, vibration, vibration sensors.*

Introduction

The main focus of the development of building structures is the further industrialization, unification and standardization of structural elements, ensuring serial and mass production, reducing the weight of structures, the time required for their installation and the overall cost of construction. These requirements are fully met in earthquake engineering by cross-stranded spatial structures (CSSS).

Due to the spatial nature of their work, CSSS have high stiffness, are capable of redistributing forces in the structure and can withstand concentrated forces and mobile crane loads, as well as dynamic and seismic forces up to and including the 9-point limit.

In order to determine the actual performance of a mass-produced structure, field tests are usually carried out on real structures. [1].

However, it is very common in design practice to have individual CSSS. In order to obtain an accurate solution, in-situ testing of such structures is extremely impractical due to the high labor and cost involved. In this case, calculation methods using small-scale models can be helpful.

The purpose of the work was to investigate the stress-strain state of metallic cross-stranded spatial structures from dynamic influences of seismic type in order to clarify calculation methods and to establish laws of applicability of the results obtained during the model test to calculations of full-scale structures.

Methods and materials.

The models were made to a scale of 1/10th the actual size of the structures. The models are 3.0 m x 3.0 m and 3.6 m x 3.6 m in plan, 300 x 300 mm meshes, with a structural height of 150 mm. The core elements of the models are made of aluminium alloy tubular profiles.

In a small-scale model, complete similarity between the wall thickness and the diameter of the tube profiles of the model and the full-scale structure cannot be obtained, as in this case the wall thickness becomes so small that it deforms (gets dented) from contact [2].

For this reason, a wall thickness of 1mm was adopted for all elements of the tubular section model, and a stiffness similarity with the real structure was achieved by using 6; 8 and 12 mm tubular sections [3], [4].

The dynamic testing of the structure was preceded by a series of static and dynamic compression and tensile tests on the individual rod elements and lattice pyramids, as well as static tests on the model. These tests made it possible to establish a gradation of the experimental load steps and to establish the relationship between the load and the deformation of the bars under both static and dynamic load conditions.

The static loading was carried out with cast-iron weights placed on square plywood boards fixed in the nodes of the upper chord so that no bending moments could build up in the chords or struts, and so that the upper chord rods could deform freely and all nodes could move freely in the three directions.

Each load step was assumed to be equal to 20% of the design value.

The vertical movements of the lower chord assemblies were measured with clock type masses mounted below the assemblies on a special beam that moved along the structure on the frame of the stand.(fig.1)

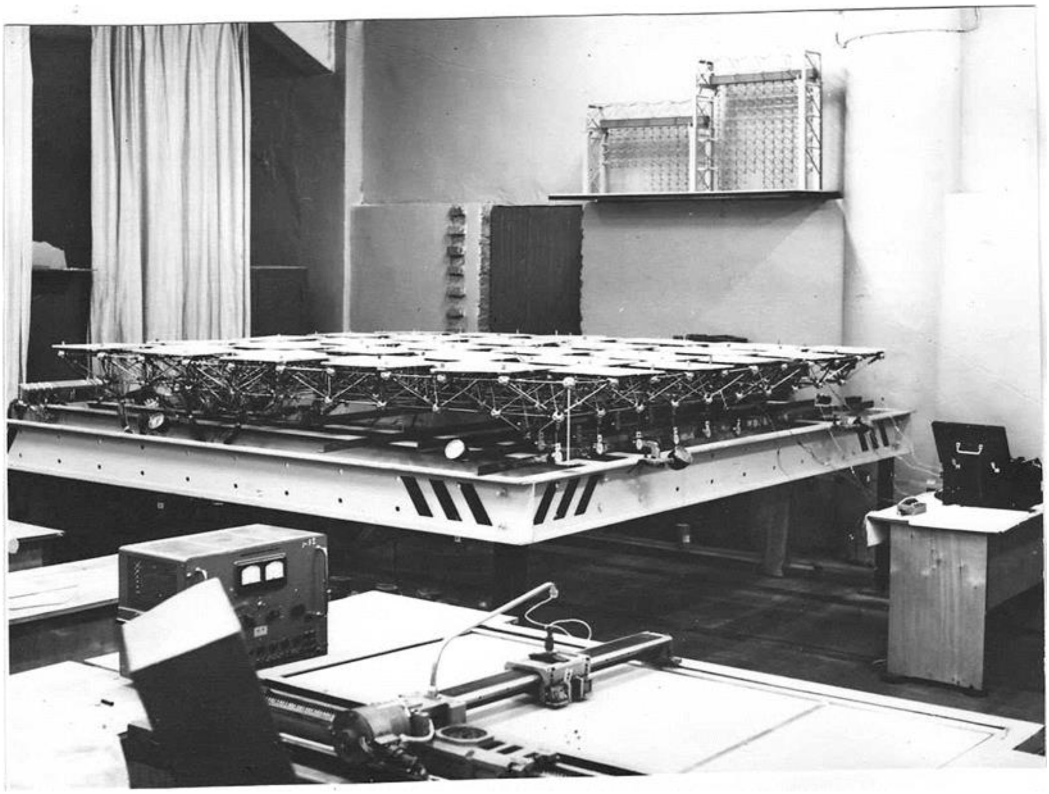

Fig.1. General view of the experimental set-up with design model.

During dynamic tests, the vibrations of the experimental model in the vertical and horizontal directions were excited by momentary removal of suspended loads, by pulling the head of the column with a calculated static load followed by its momentary release, by dropping loads, by a vibrating machine with continuously variable speed and frequency control of the generated vibrations. The maximum speed of the vibrating machine was 1,800 rpm, which gives a forced oscillation of up to 30 Hz. The vibration sensors were installed along the axes of the quarters and the vibration machine in the centre and quarters of the model span.

Results and discussion.

The results of the seismic-type vertical load tests have shown that the CSSS model, when the frequency of the forced vertical oscillations decreases smoothly, records three resonance zones in the oscillogram. As the external uniformly distributed load and dynamic loads increase, the natural frequencies of the vertical vibrations and the dynamic stiffness of the CSSS decrease while the shape of the CSSS remains constant. (fig.2).

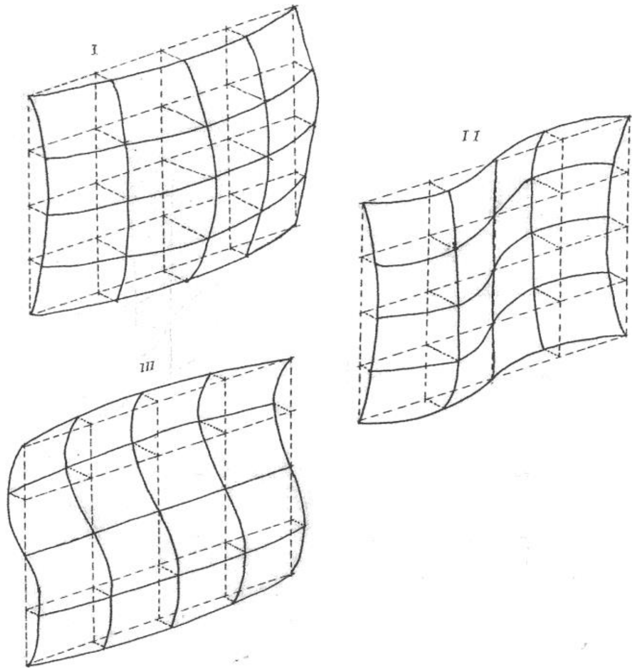

Fig 2. The shapes of the natural oscillations.

Experiments have also shown that the periods of natural vertical vibrations of the experimental models are in the range 0.06 - 0.207 s, depending on the type of model and the supporting conditions. The amplitude variation pattern of the oscillations of the individual points of the CSSS, gradually decaying in time, and the logarithmic decrements of the vertical oscillations, whose value is not less than 0.09, have been identified.

The results of the experimental models showed that under the action of horizontal load, the CSSS together with the columns can be considered as a system with one degree of freedom in the first approximation or as a system with an infinite number of degrees of freedom.

The horizontal self-oscillation periods of the CSSS ranged from 0.03 - 0.147 s and the logarithmic decrements of the oscillations did not exceed 0.04. From the evenly distributed load across the entire pavement, the struts in the support area of the structure were the most heavily stressed.

The increase in force on the rods, when the vertical seismic loading is taken into account, is a maximum of 18% for the 3.0 x 3.0 metre model and 14% for the 3.6 x 3.6 metre model. The elements of the experimental models operated in the elastic stage at all stages of loading.

The deflection pattern of the model corresponded to its stress state. The highest deflection under normal symmetrical loading was recorded in the middle of the model and was equal to 5.23 mm, which was 1/425 of the span and indicated sufficient stiffness of the structural model.

Conclusion

Comparison of the experimental data with the results of displacement calculations using finite elements showed a fairly good agreement. The experimental data exceeded the calculated data by only 7-15%.

If CSSSs consist of homogeneous or similar material with physico-mechanical properties, the stress-strain state of such repeatedly static undefined systems under static and dynamic loads can be determined by experimental testing on small-scale models. The model, in addition to satisfying the requirements for similarity of linear dimensions, must also satisfy the requirements for ratios, stiffness and equality of the logarithmic decrement of vibration.

Tests on the small-scale CSSS model to the inertial forces induced by harmonic vibrations showed that the distribution of forces between the bars corresponds to the theoretical distribution determined from the calculation of the structure for seismic loads. The resulting forces in the model rods under inertial action are in good agreement with the forces in the rods of the full-scale structure in terms of their distribution.

The tests showed that the structure has sufficient strength, stability, stiffness and earthquake resistance.

Based on the results, recommendations are made for their use in the design and construction of full-scale structures made of different metal profiles [5].

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