EXPERIMENTAL STUDIES OF EARTHQUAKE RESISTANCE OF A SYSTEM WITH DISENGAGING TIES

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SYNOPSIS

The experimental investigations on a physical model as a system with disengaging ties have been carried out. Three models mounted on a shaking table were simultaneously subjected to high amplitudes vibration in horizontal direction: a) a model of a flexible structure; b) a model of a rigid structure; c) a disengaging ties structure model. The diversity of possible predominant frequencies of earthquakes ground motion was modelled by slow changing the shaking table frequency of vibration. The frequency band of the shaking table vibration covered the entire interval of natural frequencies of the flexible and rigid models. The rigid and flexible models collapsed. The ties of the third model switched off and the model survived.

INTRODUCTION

As the results of earthquakes show, some constructions resist much greater seismic loads than their design values, One of the reasons, that can explain such a "liveability" of constructions, is that in the process of development of local damages (cracks, etc.) the rigidity and natural frequencies decrease and the construction, so to say, "leaves" the zone of dangerous frequencies and accomodates itself to the seismic effect. The facts of significant decrease of natural frequencies of buildings in the process of accumulation of damages are established by many recent investigations, in particular, by the authors' investigations /I/.

As is known, vibrations of the ground during different earthquakes differ in their spectral density, dominant frequencies and other parameters. There is yet no data on the parameters of seismic vibrations, representative of various sites. Furthermore, at one and the same site earthquakes are sometimes recorded which differ significantly in dominant periods and other characteristics depended of the natu-

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re and location of the epicenter.

The idea of adaptation of the construction to the seismic effect indicated by the nature itself of the phenomenon served as a basis of constructive solutions of special economical earthquake resistant structures with disengaging ties (SVS), developed recently at the Central Research Institute for Building Structures (TsNIISK). Methods of optimum designing of such systems with variable parameters have been developed by J.M.Eisenberg.

A set of non-stationary random processes is therefore taken as a mathematical model of the seismic effect. The maxima of the spectral densities of these processes cover a certain range of frequencies known from experience. There was studied a minimax problem of finding out the parameter of the SVS, minimizing the maximum load out of all possible seismic loads satisfying the elements of the design set, i.e. the specific problem of the optimum design. The number of optimizing parameters includes initial and limit frequencies of natural vibrations of the SVS and the level of displacements which being exceeded, causes the disengagement of ties and change-over of the inner structure of the system. The practical advantage of the SVS is that the disengaging ties which ensure the automatic change of the dynamic structure of the system during the earthquake are located at those points of the structure which are planned beforehand by the designer.

Their restoration after the earthquake presents no difficulty. They are therefore much more economical than ordinary structures, damages in which occur in a random unforseen manner. Besides, their design is safer as the design models are clearer and more definite. It will be understood that the realization of the idea needs to be verified experimentally. Here a number of specific problems is encountered, in particular, the problem of the effect of additional stresses during the transient regime set up by an abrupt drop of the rigidity and the restoring force.

The experiment, the results of which are given in the paper, presents one of the stages of the research programme on such systems.

EXPERIMENTAL RESULTS

The constructive realization of the SVS may vary. The filling of the framework, partitions and special members may serve as switching off braces. One of the simple but effective ways of constructive realization of the SVS is the usage of buildings with frame ground floor the panels of which or some special elements can serve as disengaging ties being adequately designed. A similar building was taken as a

prototype of the model of the SVS tested in this work (Model M-2).

To compare the performance of structures of various types under different effects, three models differing in the constructive solution and dynamic characteristics were tested at a time: M-I a model of the framed carcass. M-2 a model of a carcass building with disengaging ties and M-3 - a model of a rigid building (Fig. I). The models were made out of concrete Grade M-200, E = 200000 kg/sq.cm.

Model M-I was a three-dimensional structure with four columns and a floor. Columns of the cross-section 7 x 7 cm were provided with metall caps at the head and bottom to fasten them to the base and floor by electric welding. Model M-2 was a structure of two diaphragms, connected by a floor. The diaphragm consisted of two columns and a panel with an opening which was fastened only to the base and floor by metal backing details and had no direct connection with the column. Columns were 7 x 7 cm in the cross-section, panels were 2.2 cm deep, the interfenestrations were 9 cm wide.

Model M-3 was a three-dimensional structure of two transverse walls with two openings connected by a floor. The walls were 3.8 cm deep, the interfenestrations were 7 cm wide. All the models were I00 cm high and 60 x I30 cm in plan. The weight of loading together with the floor for all models was 450 kg. Before the test was started, frequencies of natural vibrations of the models were measured. Vibrations were excited by striking lightly the floor. The following values of frequencies of natural vibrations were obtained: for Model M-I - 4,6 hz, M-2 - I3,5 hz, M-3 - I8 hz (Fig. 3a).

The models were tested at resonant frequencies as follows. At low amplitudes the bases were subjected to frequencies in the range of I to 20 hz in order to determine resonant frequencies which were found to be equal to the earlier obtained date.

Then by changing slowly frequencies of vibrations from I to 5 hz the resonance was reached on Model M-I, and the tests were continued at slowly increasing amplitudes till through cracks appeared at the bottom of columns. Fig. 3b shows the record of vibrations of the models at one of the intermediate stages when the resonant frequency of Model M-I dropped to the value of 3.3 hz. Unsteadiness of the resonant regime, seen in the drop of amplitudes, is attributed to the fall of natural frequencies of the model.

Further at low amplitudes frequencies of vibrations of bases were increased and Models M-2 and M-3 were put into resonance. At the frequency close to the resonant frequenci-

es of the models the amplitude was increased and the performance of the models was observed. Cracks started occuring at the bottom and head of the interfenestrations of panels of Models M-2 and M-3. The development of through crackes brought about reduction in resonant frequencies of both models and the falling out of interfenestrations in panels. The resonant frequency of vibrations of Model M-2 when the filling had been damaged was about 5 hz (Fig. 3d), i.e. it became close to the initial frequency of the flexible Model M-I. Fig. 3c illustrates the recording of vibrations of the models at one of the stages of that phase. Just before the collapse the resonant frequency of Model M-3 reduced to 2-3 hz.

CONCLUSION

Models M-I and M-3 collapsed, and in Model M-2 the panels of the filling only failed: the presence of disengaging ties permitted the model "to withstand" at all the regimes of testing including the transient regimes after the braces had disengaged.

REFERENCES

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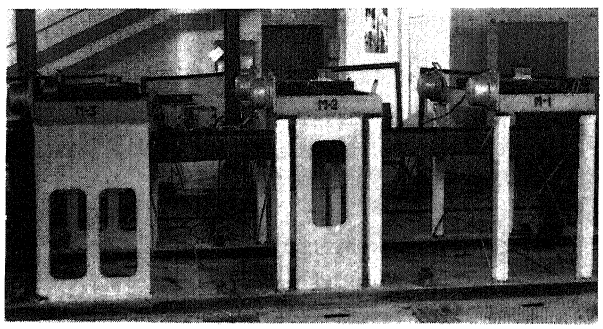

Fig. 1.

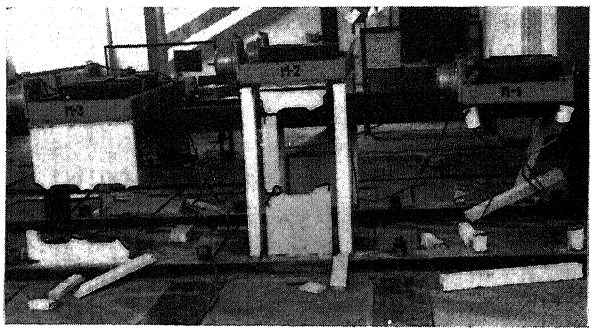

Fig. 2.

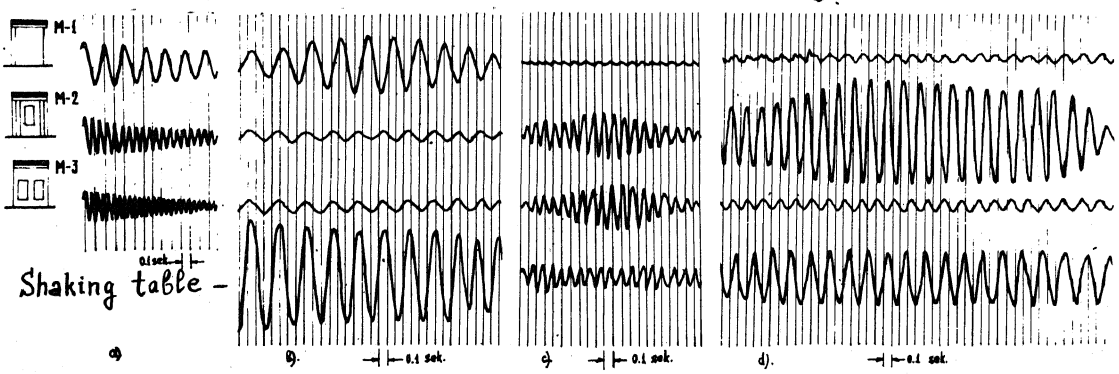

Fig. 3.