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IDENTIFICATION OF DYNAMIC PARAMETERS OF A CONSTRUCTION MODELLING THE BEHAVIOUR OF A STRUCTURE WITH DISENGAGING BRACES

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ABSTRACT

Using the adaptive seismic protection systems is one of the approaches to ensuring earthquake resistance of structures through the seismic load reduction. One of the ways to reduce the seismic load is decreasing strength of certain elements of construction. Now we use such kind elements as the special disengaging braces and investigate the oscillating process in the structure when the braces are disengaged under dynamic actions. We took under consideration the oscillating process excited by harmonic influence only. To investigate the behaviour of structure with disengaging braces the small laboratory model which displayed the process of disengaging of the braces was made. The dynamic parameters of this model were not constant during the vibration. Identification of its dynamic parameters had given us a possibility to obtain a calculated response that was very similar to the test response.

KEYWORDS

Adaptive seismic protection system; identification; dynamic parameters; disengaging braces.

ASEISMIC STRUCTURE: IDENTIFICATION PARAMETERS

Twenty five years ago a Program of seismoisolation development and application was started in Russia, Moscow Research Institute of Building Structures. The Program's main goal was to develop seismoisolation for ordinary housing, multi-storey buildings and other usual structures. One way to build a seismic resistant structure - to increase strength of the elements of construction. Another way is using specific seismic isolation systems such as sliding belts, rocking supports and others. One of them are adaptive systems of seismic isolation (Eisenberg J.M. 1976). For example the systems with disengaging braces.

The problem of identification of dynamic parameters of aseismic structure has been under consideration of number of authors such as Eisenberg J.M., Denisov B.E. (TsNIISK,Moscow), A.O.Cifuentes (California Institute of Technology, 1984). Udwadia F.E. and Marmarelis P.Z. investigated a question of the identification of building structural systems, Beck J.L., McVerry G.H. and Jennings P.C. showed the possibilities of application of system identification techniques to recorded earthquake response and others. In general the problem of identification of the structure of dynamic system is known and was investigated in different fields of engineering (Arbachauskene N. Vilnius,1974; Deitch P.M. Moscow,1979).

Structure with Disengaging Braces

The application of seismic protection in the form of disengaging braces, located in the additional framed ground floor, gives the possibilities to decrease the seismic loads on the building as a whole. The decreasing of the seismic force is due to the natural period of the structure change and dissipation during the disengaging of the braces.

The subject of observation was full-scale panel house with flexible frame ground- floor. There were a few special shear-walls with disengaging braces their. Shear-walls consist of lower part with disengaging braces and upper part as shown in Fig. 1. Disengaging braces were installed in the joint connection of upper and lower portions of diaphragms. The panel part of the house was a standard 5-storey panel building.

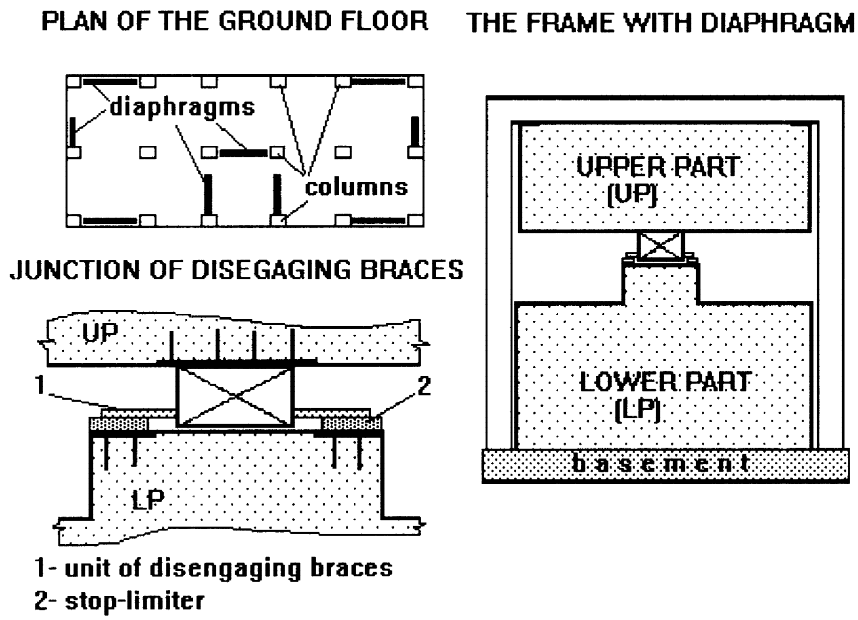

Fig. 1. The location of shear-walls with disengaging braces in the first ground floor.

To improve the design model of a structure with disengaging braces the vibration full-scale tests were carried out. The vibration force was generated by the powerful exciter located on the roof of building. Test data obtained were used as a basis for the design of a laboratory model which displayed the qualitative work of the seismic protection system with disengaging braces. The purpose of the investigation was to obtain the oscillating process which occurred in the structure when the braces were disengaging under dynamic actions. So the development of a model was done with preserving the stiffness relations expressed as the relation between the frequencies of the standard and framed parts of the actual building and the laboratory model. We ignored some points of the similarity theory because the main idea of investigation was the discussion of behaviour of structure with changeable period of vibration. The calculation of the model design was carried out by the finite element method. The model had a rigid upper part and the flexible frame at the lower part. The junction of two parts of modelling shear-walls was the aluminium rivet. The experimental equipment was used for testing this model. The procedure of laboratory tests included both static and vibration-resonance loading. The vibration loading unit was the shaking table. The vibrational load had been changed by increasing the frequency of vibration of the shaking table. The frequency of vibration unit had been increased until the resonance. The vibrational load had been mounting to maximum value during the resonance. Disengaging braces had been switching off during the resonance.

Identification of Structure

To find the mathematical expression to describe the system behaviour the method of identification was used. This method consist in using the vibrational influence and response records for creation the mathematical model. The engineering task may be represented as "black box" - dynamic system with certain influence and response and unknown mathematical expression of dynamic system as shown in Fig. 2.

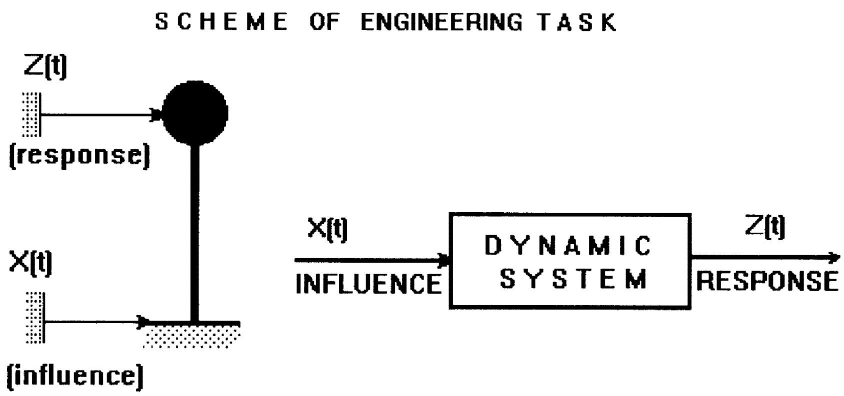

Fig. 2. Scheme of engineering task for identification of structure.

There are two variants of identification: one is with well-known and another - with unknown structure of mathematical model. The mathematical model is expressed as transfer function. The process of identification may be shown as equation **Z(t)=A∗X(t).** Where A is the transfer function between **X(t)** as influence and **Z(t)** as response of dynamic system. If the structure of transfer function is known we have to find such mathematical parameters of the function those give us an opportunity to get calculated response as more closely as possible to tested response. The scheme of process identification is shown in Fig. 3.

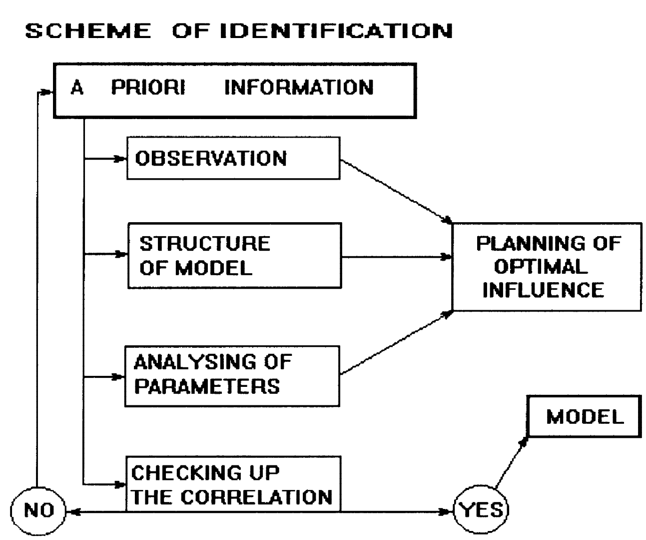

Fig. 3. Scheme of identification structure of model.

It contains the a priory information that allows to chose the structure of mathematical transfer function as the structure of model, observation, analyse of parameters, checking up the correlation between calculated and experimental data, planning of optimal influence. The most important problem is modelling of the system transfer from the initial state (with the braces) to the final state (after the disengaging of the braces). The variant with well-known structure of transfer function was used here. The transfer function between the displacement of the top point of structure and the lower point acceleration was represented as single-degree of freedom oscillator. As the result of laboratory tests time-story of vibration records were obtained. The experimental data was filtered in the frequency band from 5 to 30 Hz. For the further investigations of time-story of vibration the differential equation of motion of order II was used:

$$\ddot{Y}(t) + 2 * \varepsilon * \omega * \dot{Y}(t) + \omega^2 * Y(t) = -\ddot{X}(t) \tag{1}$$

Where Y(t), Y(t) and Y(t) were the relative acceleration, vibration rate and the displacement of the model. **X(t)** was the absolute acceleration of influence.

The records of experimental data were not synchronised due to the synchronisation of recording instruments and as a consequence of the digitisation process. The synchronisation of the records of relative displacement of the roof of model with respect to the vibration table was made. To synchronise the experimental data we checked up the direction of the hysteresis loops. And if the direction was negative we exchanged the shift of one record with respect to the other. To form the hysteresis loops the next differential equation was used:

$$M * \ddot{Y} + F(Y; \dot{Y}) = -M * \ddot{X} \tag{2}$$

M was the mass of the construction. Y(t), Y(t) and Y(t) were the relative acceleration, vibration rate and the displacement of the model. **X(t)** was the absolute acceleration of influence. **F(Y,Y)** - restoring force related to a mass unit can be written as acceleration. Restoring force per unit of mass depends on the relative displacement - Y and the relative vibration rate -Y. That expressed as:

$$\frac{F(Y; \dot{Y})}{M} = \ddot{Z} \tag{3}$$

Where **Z** is the absolute acceleration of the top point of model. Using this expression the diagram of restoring force as hysteresis loops was made.

After the synchronisation and filtering of experimental data the identification of model was began. The main idea of construction a piecewise-linear model consisted in using the well-known differential equation of motion of order II for two random moments of vibration time.

$$\begin{aligned} \ddot{Y}_1 + 2 * \varepsilon * \omega * \dot{Y}_1 + \omega * Y_1 &= -\ddot{X}_1 \\ \ddot{Y}_2 + 2 * \varepsilon * \omega * \dot{Y}_2 + \omega * Y_2 &= -\ddot{X}_2 \end{aligned} \tag{4}$$

We regarded the damping - ε and the frequency - ω as inconstant values. But our assumption was that these coefficients were constant within vibration intervals of constant intensity. To solve this system of equations (4) with two unknown quantities we have to substitute these as follow:

$$2 * \varepsilon * \omega = r ; \omega^2 = q \tag{5}$$

Then solution may be written as:

$$r = \frac{Y_1 * (\ddot{X}_2 + \ddot{Y}_2) - Y_2 * (\ddot{X}_1 + \ddot{Y}_1)}{\dot{Y}_1 * Y_2 - \dot{Y}_2 * Y_1}$$

$$q = \frac{\dot{Y}_2 * (\ddot{X}_1 + \ddot{Y}_1) - \dot{Y}_1 * (\ddot{X}_2 + \ddot{Y}_2)}{\dot{Y}_1 * Y_2 - \dot{Y}_2 * Y_1} \tag{6}$$

We may write it in short form:

$$P_1 = Y_1 * (\ddot{X}_2 + \ddot{Y}_2) - Y_2 * (\ddot{X}_1 + \ddot{Y}_1)$$
$$P_2 = \dot{Y}_2 * (\ddot{X}_1 + \ddot{Y}_1) - \dot{Y}_1 * (\ddot{X}_2 + \ddot{Y}_2) \tag{7}$$
$$P_3 = \dot{Y}_1 * Y_2 - \dot{Y}_2 * Y_1$$

And then we get

$$r = 2 * \varepsilon * \omega = \frac{P_1}{P_3}; \quad q = \omega^2 = \frac{P_2}{P_3} \tag{8}$$

As the experimental data had the mistakes of measurement we changed the system of two equations (4) to the system of two inequalities for two random moments of vibration time of close intensity. The time-story of vibration was divided into several intervals of intensity. Solution of such kind of system of inequalities was done for each of them. The values of ε and ω were in certain limits:

$$\sqrt{\min \frac{P_2}{P_3}} \leqslant \omega \leqslant \sqrt{\max \frac{P_2}{P_3}} \tag{9}$$

$$\frac{\min P_1/P_3}{2 * \sqrt{\max \frac{P_2}{P_3}}} \leqslant \varepsilon \leqslant \frac{\max P_1/P_3}{2 * \sqrt{\min \frac{P_2}{P_3}}}$$

As the result of solving these systems histograms of more probable values of frequency and coefficient of damping in every interval of intensity of vibration were obtained.
The final design model was prepared after few cycles of identification and checking up the correlation between model and experimental data. And as the result the experimental response and the response calculated on the base of the design model are very closely (Fig. 4).

RESULTS AND CONCLUSION

A small-scale model developed on the principle of preserving the stiffness relation represents adequately the qualitative behaviour of a construction with disengaging braces;

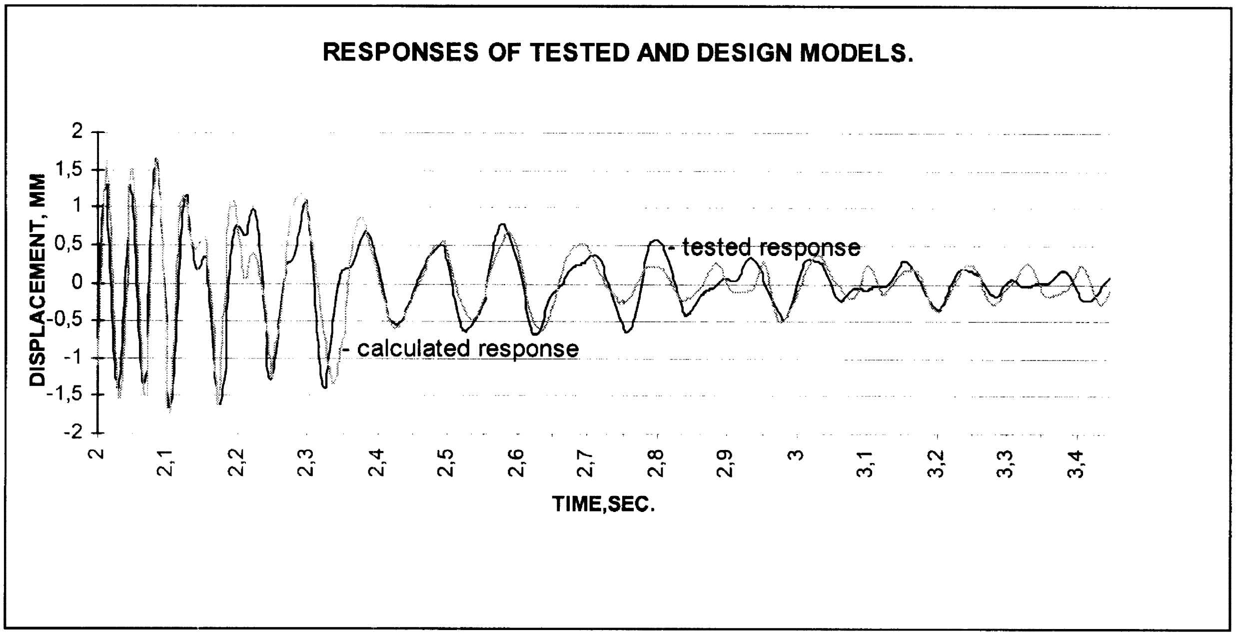

Fig. 4. Responses of tested and design models.

The sharp changes of damping coefficient values in the process of disengaging of the braces were observed. They were result from the failure of disengaging braces;

The natural period variability of structure and the relationship between the period and intensity of vibrations of the construction at the time of disengaging of the braces has been revealed;

The solution of inequalities systems for two random moments of time of vibration of close intensity makes it possible to construct a piecewise-linear dynamic design model which gives a good agreement between the design model response and the response obtained by tests;

The method used for processing the test records enabled to obtain dynamic diagrams of deforming the construction as hysteresis loops.

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