საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 6, №2, 2012
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 6, no. 2, 2012

Structural Mechanics

One Mathematical Model and Algorithm of the Microtremor Use for Structure Real Seismic Resource Assessment

Guram Gabrichidze

Academy Member, K. Zavriev Structural Mechanics, Earthquake Resistance and Engineering Examination Center, Tbilisi

ABSTRACT. Study of the structure behavior under microtremors to assess its real operating condition or to ascertain its dynamic characteristics is a widespread method in the world. It is distinguished for its cheapness, mobility, though it has also certain limitations. It is that transition process from microtremor to real is not univocal and relies on certain assumptions. Therefore, when we use this approach in practice, we are offered different algorithms and technologies of material processing obtained as the result of the experimental observation of the structure under microtremor, which creates probability of structure operational condition, particularly, its earthquake resistance distinctive assessment. Mathematical model and algorithm constructed on its basis, which univocally ascertains how to process displacements recorded under microtremors that to speak substantially about structure behavior when real seismic wave (seismogram) passes its foundation are suggested in the present article. *© 2012 Bull. Georg. Natl. Acad. Sci.*

Key words: *microtremors, seismic resistance of structures, earthquake.*

At present the acute problem of the whole world is seismic resistance assessment of structures located in seismically active regions. Complexity of this problem solution is determined by the fact that enormous number of structures are subject to such assessment,not only those that are built without observing antiseismic design standards, but also those that are built considering the requirements of these standards. This is due to the fact that standards of earthquake resistance design periodically change and structures, built “yesterday”, do not correspond to today’s beliefs.

In practice very often it is necessary to examine a great number of structures in a short term in an operational situation. Such necessity often arises after a strong earthquake, or in the cases when the existing view concerning real seismic danger assessment changes and seismic danger assessment of a large populated region is required.

In such cases it is very difficult, or even impossible to carry out detailed inspection of the structures operational condition, following the recommendations of the corresponding normative documents, and incomplete examination of buildings in many cases is

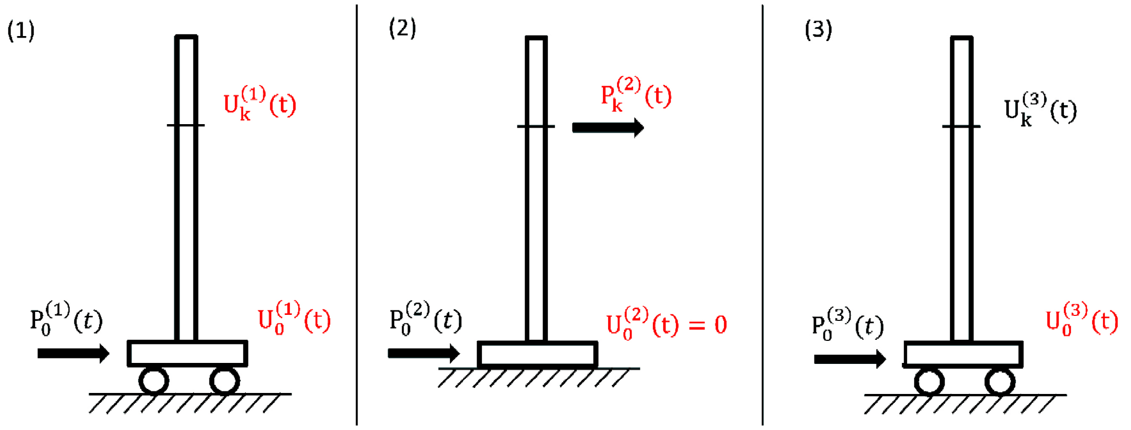

Fig. Dynamic states of structures.

unreliable or even dangerous.

In practice often an experimental method is used for structures behavior assessment under earthquake, connected with carrying out full-scale dynamic tests. In such cases structural elements of the structure reveal their real physical-mechanical properties and define the structure behavior as a whole.

Carrying out of full-scale dynamic tests of structures is an expensive and laborious process and cannot be used as an express-method. It should be mentioned also that as a result of full-scale dynamic tests basic dynamic parameters of the structure are defined, such as vibrations frequencies and forms, damping factor and so on. To ascertain structure behavior under earthquake it is also required to construct a mathematical model according to the results obtained experimentally and to carry out special calculations that are associated with certain conditionality.

In the engineering practice a number of simplified methods of structures seismic resource definition by full-scale dynamic tests are developed and applied. Some of them are characterized by refusal to apply complex, expensive means of excitation of strong vibrations of the structure and study structure behavior under microtremors or even ambient noise of the earth's surface. On the basis of the obtained data structure behavior under stronger excitations, particularly earthquakes, is assessed.

Transition from structure behavior under microtremor to behavior under strong influence is not univocal process and relies on certain assumptions that make possible to develop different algorithms and, hence, different assessments of the seismic resource of the structure under test [1-4].

A mathematical model is suggested in the present article and on its basis an algorithm is constructed, which defines univocally how to process experimental information, obtained from structure under microtremor, to speak substantially about structure behavior under real, stronger and other kind of influence, in particular, under seismic waves passage.

Let us consider a structure (Fig.) in the foundation of which (at point 0) and at some level (at point K) seismographs are placed and displacements of these points synchronously caused by microtremor in the foundation of the structure are recorded.

This dynamic state of the structure, acting forces in the foundation and generated displacements conditionally are shown in the first column of the Fig. All the parameters of this dynamic state are marked by (1).

In the second column of the Fig. the second dynamic state of the structure is shown. It is imaginary and actually is not realized. The structure is rigidly fastened in the foundation and arbitrary force $P_k^2(t)$ is applied at the point **K**. All the parameters of this dynamic state are marked by (2).

In the third column of the Fig. the structure is shown, in the foundation of which seismic wave (seismogram) of the real earthquake spreads. All the parameters of this dynamic state are marked by (3).

To simplify the perception of the further lay-outs in Fig. and in the obtained expressions, given (known) functions are represented in red color.

Let us apply to the known principle of the works reciprocity $A^{(i)(k)}(t) = A^{(k)(i)}(t)$ which states that the work of the forces of **i** dynamic state on the displacements of the **k** dynamic state is equal to the work of the forces of **k** state on the displacements of the **i** state.

Let us apply this principle to the dynamic states (1) and (2):

Considering the directions of the Fig. we write:

$$A^{(1)(2)}(t) = \int_0^t P_0^{(1)}(t-\tau)\times U_0^{(2)}(\tau)d\tau = 0\,.$$

Hence, the principle of the work reciprocity $A^{(1)(2)}(t) = A^{(2)(1)}(t)$, will take the form $A^{(2)(1)}(t) = 0$ and will be written as an integral equation:

$$\int_0^t P_0^{(2)}(t-\tau)\times U_0^{(1)}(\tau)d\tau +$$

$$+\int_0^t P_k^{(2)}(t-\tau)\times U_k^{(1)}(\tau)d\tau = 0. \qquad \text{(a)}$$

Solving the equation (a) we define the function $P_0^{(2)}(t)$.

Let us apply the principle of the work reciprocity to the dynamic systems (2) and (3). Let us remember that we have already defined function $P_0^{(2)}(t)$ and it is known (it is red). Considering the mentioned and directions of the Fig. we write:

$$A^{(3)(2)}(t) = \int_0^t P_0^{(3)}(t-\tau)\times U_0^{(2)}(\tau)d\tau = 0.$$

Hence, the principle of the work reciprocity $A^{(2)(3)}(t) = A^{(3)(2)}(t)$ will take the form

$A^{(2)(3)}(t) = 0$ and will be written as an integral equation:

$$\int_0^t P_0^{(2)}(t-\tau)\times U_0^{(3)}(\tau)d\tau +$$

$$+\int_0^t P_k^{(2)}(t-\tau)\times U_k^{(3)}(\tau)d\tau = 0. \qquad \text{(b)}$$

Solving the integral equation (b) we define $U_k^3(t)$, displacement of the point K under real seismic wave passage in the foundation of the structure.

Such method allows possible to define displacements of any point and hence, behavior of the entire structure, all of its structural and non-structural elements and components under real earthquake. Modern possibilities of measuring technology, existence of wireless sensory nets and telecommunication systems open wide possibilities for the solution of various problems, using the suggested method.

სამშენებლო მექანიკა

ნაგებობის რეალური სეისმური რესურსის შესაფასებლად სუსტი რყევების გამოყენების ერთი მათემატიკური მოდელი და ალგორითმი

გ. გაბრიჩიძე

აკადემიის წევრი, კ.ზავრიევის სამშენებლო მექანიკის, სეისმომედეგობის და საინჟინრო ექსპერტიზის ცენტრი, თბილისი

სუსტი რყევებისას ნაგებობის ქცევის შესწავლა მისი რეალური ტექნიკური მდგომარეობის შესაფასებლად, ან მისი დინამიკური მახასიათებლების დასადგენად, ფართოდ გავრცელებული მეთოდია მთელს მსოფლიოში. იგი გამოირჩევა თავისი სიიაფით, მობილურობით, თუმცა გააჩნია გარკვეული შეზღუდვებიც. საქმე იმაშია, რომ სუსტიდან რეალურზე გადასვლის პროცედურა არ არის ცალსახად განპირობებული და გარკვეულ დაშვებებს ემყარება. ამის გამოა, რომ პრაქტიკაში ამ მიდგომის გამოყენებისას, სუსტი რყევებისას ნაგებობაზე ექსპერიმენტული დაკვირვებისას მოპოვებული მასალის გადამუშავებისას სხვადასხვა ალგორითმებსა და ტექნოლოგიებს გვთავაზობენ, რაც ნაგებობათა ტექნიკური მდგომარეობის, კერძოდ, მისი სეისმომედეგობის განსხვავებული შეფასების ალბათობას ქმნის. წარმოდგენილ სტატიაში შემოთავაზებულია მათემატიკური მოდელი და მის საფუძველზე ჩამოყალიბებული ალგორითმი, რომელიც ცალსახად განსაზღვრავს, თუ როგორ უნდა გადამუშავდეს სუსტი ზემოქმედებისას ჩაწერილი გადაადგილებები, რომ დასაბუთებულად ვიმსჯელოთ შენობის ქცევაზე მის ფუძეში რეალური სეისმური ტალღის (სეისმოგრამის) გავლისას.

REFERENCES

1. *Yutaka Nakamura, E.Dilek Gurler, Jun Saita* (1999), Dynamic Characteristics of Leaning Tower of Piza Using Microtremor-Preliminary Results. 25th Japan Congress on Earthquake Engineering. Tokyo. 7: 29-31.
2. *Yutaka Nakamura* (2001), Inventory Development for Natural and Built Environments: Use of Seismic Motion and Microtremor for Vulnerability Assessment. 4th EQTAP Workshop in Kamakura, December. 6p.
3. *Jun Saita, Yutaka Nakamura* (2010), Vulnerability Assessment for Ground and Structures Using Ambient Noise. System and Data Research, Co., Ltd., 3-25-3 Fujimidai, Kunitachi, Tokyo, 186-0003, Japan. 2p.
4. *G. Gabrichidze* (2005), Proceedings of the Institute of Structural Mechanics and Earthquake Engineering, 5: 31-35, Tbilisi.

Received May, 2012