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EARTHQUAKE-RESISTANT BUILDINGS AND STUDIES OF ELASTIC-PLASTIC SYSTEMS AND STRUCTURES

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Annotation

When designing newly constructed earthquake-resistant structures, there is a need to solve the optimization problem associated with the creation of economical buildings, the construction and operation costs of which should be the lowest over the service life. There is a need to evaluate the work and establish the parameters of the limiting states of elastic-plastic systems with different degrees of initial antiseismic amplifications (different bearing capacity).

Keywords: design, reinforced concrete structures, load-bearing, monolithic, earthquakes, columns, crossbars, nodes, deformations, reinforcement.

Introduction

Currently, the theory and practice of earthquake-resistant construction have reached a high level of development, as evidenced by the results of engineering analysis of the consequences of many earthquakes, in which buildings and structures built in accordance with the current standards for earthquake-resistant construction, satisfactorily tolerate seismic impacts. At the same time, the catastrophic consequences of the earthquake in Armenia on 07.12.1988 in which massive collapses of modern buildings were observed, a number of problems were identified that require more detailed study and urgent solution [1].

The main part. One of the most important issues in the study of building structures in the conditions of real earthquakes is the question of the external impact itself. Since, as a rule, accelerograms of real earthquakes are taken as the law of motion of the foundation, the question arises about those parameters of accelerograms that are of paramount importance and should be taken into account when studying and calculating earthquake-resistant objects.

Particular attention should be paid to the characteristics of seismic impacts when analyzing inelastic systems, when a complex, random process, such as any earthquake, affects a system whose properties depend on its intensity of engineering seismology and earthquake-resistant construction have caused quite a lot of work to appear recently devoted to the study of seismic movements of the ground, including the main parameters of accelerograms used in the calculations of buildings and structures [2,3,4].

The calculation of seismic loads, when accelerograms of past earthquakes are set as an external influence, is carried out, as a rule, according to a variety of implementations. At the same time, V.T. Rasskazovsky's technique can be used to exclude random factors [4], according to which accelerograms of various frequency composition should be in the calculated sample. Comparability of accelerograms is achieved by their normalization according to the calculated standard σp. This procedure can also be carried out on the basis of comparing the maximum accelerations of Amax, the maximum values of the standard in the transient mode σmax, the root-mean-square accelerations at the end of the processing interval σo. However, it should be borne in mind that such a technique is fully justified in calculations in the elastic stage. The behavior of elastic-plastic systems depends not only on the intensity of the earthquake, but is largely determined by its duration, since the consumption of the load-bearing capacity of inelastic systems is greater the longer the impact. Thus, for the analysis of elastic-plastic structures, in addition to the intensity and spectral composition, it is necessary to have estimates of the duration of the seismic process.

According to the current situation in Japan, it is impossible to design buildings with a height of more than 31 m from reinforced concrete structures without special permission. Usually load-bearing structures are solved either from reinforced concrete in combination with steel, or from steel structures [5]. Purely reinforced concrete structures are allowed for use in buildings up to seven floors. Despite this, based on the analysis of the behavior of structures during the Tokashi-Oki earthquake, 1968, and special studies that showed that with appropriate placement of longitudinal and transverse reinforcement in the structure, brittle destruction can be prevented and the necessary malleability achieved, it was decided to build a 20-storey residential frame building. Its load-bearing structures are designed in monolithic reinforced concrete.

The building is 59 m high . (Fig.1.a) with a plan size of 24x13.5 m with a column pitch of 3 and 4.5 m, respectively, in the longitudinal and transverse directions. shown in (Fig.1.a). A feature of the columns with a cross section of 60x60 cm . is the simultaneous use of square and spiral clamps. The amount of longitudinal reinforcement does not exceed 1.2%.

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Monolithic crossbars have a height of 60 cm and a width of 35, 40 and 45 cm. Two methods are accepted (Fig. 1. d, e) for anchoring crossbars in the reinforcement column: conventional and in the form of U-shaped loops (continuous anchoring).

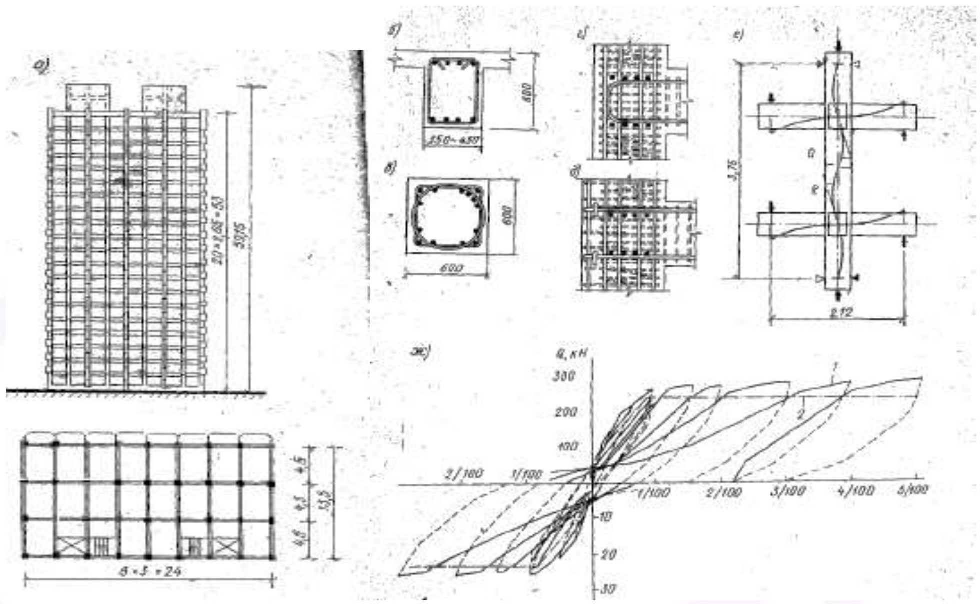


Fig. 1. a-facade and building plan; b, c-crossbar and column; d, d-continuous and bull reinforcement of the intersection points of the crossbar with the column; e, g-experimental fragment, its loading scheme and load-deflection dependence; 1-experimental curves; 2- trilinear dependence accepted for calculation.

The design of the building is based on the results of studies of the main load-bearing structures. The influence of alternating loading on the load-bearing capacity and compliance of the junction of columns and crossbars was studied. The anchoring of the working armature of the crossbars in the node area was considered. The experiments were carried out on models of spatial fragments of a column with two intersection nodes with crossbars. The scale of the models is 1/2; the compressive strength of concrete on a light aggregate did not exceed 30 MPa.

According to the scheme (Fig. 1.e), at first 10 cycles of alternating loads were carried out with the value of the angular deformations of the fragment 1/100. No more than 15% reduction in load-bearing capacity was obtained. At the load level calculated by the maximum bending moment in the beam, the stresses in the shear-sensing armature reached half the yield strength. Loading with an increased angular deformation of 5/100 resulted in a sufficiently high malleability, although no structural damage was observed. In the experiments, no significant differences were obtained between the accepted methods of reinforcement under loads with an angular displacement of up to 5/100. The sealing was provided reliably, the fluidity of the reinforcement in the anchoring zone developed more slowly compared to the fluidity in the stretched zone.

On the basis of experimental load-deflection curves, the authors proposed a trilinear deformation curve of longitudinal and transverse frame structures, which was then used in building calculations (Fig. 1.g).

A cantilever system with concentrated masses was taken as the design model of the building; the operation of the model was considered taking into account shear and bending.

To analyze the degree of earthquake resistance of buildings, the following classification of earthquakes is proposed: class I. Earthquake of average strength (≈0.1g) - no damage; class II. Strong earthquake (≈0.3g) - the stress in the reinforcement of structural elements does not reach the yield strength; class III. Destructive earthquake (≈0.5g) - slight deformation of structural elements is possible, destruction of structures is not allowed.

It is established that during a Class I earthquake, cracks can occur only in the crossbars of the 15th floor, and the maximum displacement of the floor is approximately 2/1000 rad.

A Class II earthquake can cause cracks in the columns of the 7th and 13th floors and a floor shift of no more than 1/1000 rad.

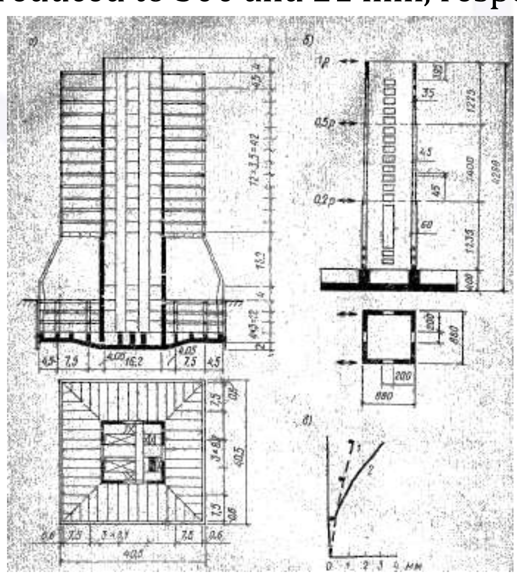
For both classes of earthquake, it is characteristic that the structure completely returns to its original position when the load is removed. The most dangerous buildings of the type under consideration are class III earthquakes. They will cause a residual deflection of 0.7 cm in the level of the 12th floor and the fluidity of reinforcement in the beams of the 6th-14th floors. The maximum floor shift compared to the first two classes will increase to 3.01 cm. The authors consider the described type of building to be very promising.

In [6], the reactions of a tall building to seismic impacts are analyzed using the finite element method. The overall rigidity of such buildings depends on the structural solution of the stiffness elements. Usually they are vertical diaphragms without openings and with openings. As a rule, the second type (double diaphragms) is the most common. The stiffness of the twin diaphragms is greater than the stiffness of the connecting beams-jumpers, therefore, when horizontal loads act on the diaphragm, stresses are redistributed between these structures, as a result of which the flow of reinforcement in the beams may begin.

Paying tribute to the role of diaphragms, they are examined in order to study the stress-strain state and establish the bearing capacity. Most often, studies are carried out under the action of static loads, considering the diaphragms as consoles with a seal in the base. The height of the diaphragm may have unequal thickness, differences in the location and size of openings, in the strength and deformative properties of materials. If we also take into account the dynamic nature of real impacts, then, according to the authors [6], the analysis of the dynamic reaction of the structure using the finite element method (FEM) is the most effective. Its advantages are as follows: the structure can be considered as continuous; it is possible to take into account the differences in the height of the properties of the structure under study; the influence on the stress state of the diaphragms of elements of the perpendicular direction can be taken into account; the method is applicable not only to analyze the behavior of the structure in the elastic, but also in the elastic-plastic stage.

The FEM was used [7] to calculate the diaphragms that formed the core of the rigidity of a real building with 15 aboveground and three underground floors. The building is 68 m high, with a square plan with dimensions in the high-rise part of 40.5 x 40.5 m, and at the base of 48.3 x 48.3 m. It rests on a monolithic reinforced concrete ribbed slab (Fig. 2.a). A rigid element (core) of double diaphragms with a plan size of 16.2x16.2 m. is located in the center. The thickness of the walls varied from 1.25 m at the base to 0.6 m at the top.

Columns made by centrifugation with a diameter of 750 mm at the base and a wall thickness of 67 mm are installed at the four corners of the core. In the upper part, these dimensions were reduced to 300 and 21 mm, respectively.



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The central interior of the building was considered on a 1/20 life-size model. The model with a height of 4.26 m. was loaded with alternating horizontal forces in the levels of change in the cross-section of the walls, in height (Fig. 2.b). The horizontal load was assigned in fractions of the magnitude of the seismic reaction of the design model. In dynamic analysis, the building was represented as a system with concentrated masses with 25 degrees of freedom.

The horizontal stiffness of the double vertical diaphragms of the building was calculated according to the FEM (Fig. 2.d). From (Fig. 2.d) it can be seen that the data obtained correspond well with the experimental ones. The usual method, representing the design in the form of a console, gives significantly worse results.

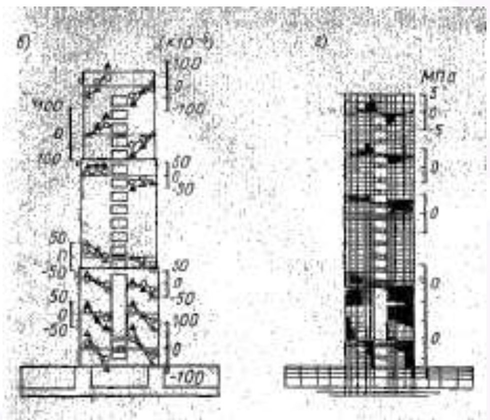

Fig. 2. To the design of a building using the finite element method. a-a vertical section and a plan of a 15-storey building; b-a model of the stiffness core and a load application scheme; c-deformations of the model; d-stress plots calculated according to the FEM; d-displacement of the model. O-6000 N (1 p); °-10,000 N (1 p); °-experimental values; 1-according to FEM; 2-calculation as a cantilever rod

Main Conclusions

1. Since the actual external load is dynamic in nature, shear reactions should be determined from dynamic analysis.
2. Connecting beams should be designed capable of absorbing vibration energy, provided that the required bearing capacity of the vertical diaphragms as a whole is guaranteed.

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