RESEARCH ON SEISMIC RESISTANCE OF LARGE-PANEL APARTMENT BUILDINGS

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SYNOPSIS

The work is devoted to the questions of improvement the research and design methods of built-up buildings of large panels assigned for construction in seismic regions.

The large-panel building is investigated, the design scheme of which is presented as the three-dimensional system of panels. The design analysis is carried out on the basis of finite elements method. Structural elements of the building are taken as the finite elements (inside and outside wall panels and floor slabs). The elements of panels stiffness matrices of different types are defined experimentally. Seismic forces are taken in accordance with dynamic parameters of the research building and the design codes operating in the USSR. The interaction forces between the panels, caused by the vertical loads and seismic forces are defined analytically.

One of the most actual problems of civil engineering for all the regions including the seismic is the problem of economical dwelling houses construction satisfying the modern requirements, presented to the comfortability of dwelling and technological production. At most the large-panel dwelling houses construction meets these requirements. The wall panels and floor slabs production as well as the production of other elements of such buildings is concentrated at the specialized mills and their mounting is carried out on the building ground. Such construction requires the considerable primary investments however, they are worth while owing to the comparatively small cost of these buildings.

Working out the architectural-planning decisions of the economical large-panel dwelling-houses first of all one must proceed from their functional fixing, for that the predominants of the design process become the problems of elements technological production and their mounting.

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Large-panel buildings are characterized by the structural definition,uniform distribution of load-bearing elements and joints between them along the building volume. The structure consists of many identical elements. The number of elements of different types is reduced to minimum. The division of buildings by elements,the dimensions of which correspond to the dimensions of rooms is widely practised. Connection between the elements is carried out at the transition joint between the panels by the reinforcement outlets welding or the metal parts anchored in the panel. The joints and the welds between the panels are monolithed with concrete.

The structural decisions of the large-panel dwelling houses,mainly,based on technological requirements meets the principles of buildings design in seismic regions. However,it should be mentioned,that the history of large-panel buildings construction is comparatively small.and the experience of their behaviour during the earthquakes is insignficant. When the large-panel buildings construction volume in seismic regions is steadily increasing, the abovementioned fact requires the most thorough theoretical and experimental substantiation of their seismic stability and the strength reserves investigation(I).

The inspection of destructive earthquakes results occured in the Caucasus and in the Middle Asia has shown that the large-panel buildings structures are one of the most seismic resistant. As the result of one of the inspections,it was set that while the majority of brick buildings has failed and has got hard damages,and in many frameworks the filling has got considerable damages, in most of the large-panel buildings(about)forty) only the cracks along the panels contour were observed. This inspection showed that the most vulnerable were the joints between the panels. Significant deformations have developed in some joints and local damages occured in separate joints. The analysis of these deformations and damages has shown that they were the results of unsatisfactory structural decision of joints between the panels and the quality of their monolithing with concrete during the mounting of building.

If estimate the large-panel buildings damages from the view point of expenditure for their reconstruction,here the advantages of the large-panel buildings to the buildings of other types are more evident.Indeed,even in stable,but in flexible buildings,the plaster pieces dropped,the significant damages in filling elements and in partitions took place.Generally,in the large-panel buildings the plaster is absent and the secondary elements have the less rigidity and follow the deformations of the axial elements without damages.

When solving the problem of seismic protection degree of the building system in seismic regions,it's not enough to proceed from the requirements of the separate buildings stability at the design seismic influence,it's neccessary also to consider the degree of the different type buildings damages during the earthquakes of the lower intensity,which can occur at the given point of construction during the exploitation of the building. This problem is reduced to a minimum of the expenditure for the initial earthquake-proof measures and the following reconstruction works when restricting the degree of damages in the conditions of the design seismic influence. For the correct solve of this problem the clear definition of the influence design models and the structures themselves is neccessary. Further we shall consider that part of the abovementioned problem which concerns the structures design models with reference to the large-panel buildings.

Three-dimensional stability of the large-panel buildings is provided by the system of interperpendicular plane elements of wall panels and floor slabs. The building rigidity is mainly determined by the rigidity of these elements in their plane and by the rigidity of the continious joints between them. The continuity of joints between the elements is reached by the monolithing of the connecting elements with concrete along the perimeter of joints. The interaction forces between the structural elements are distributed along the contact surfaces. However, in the conditions of intensive seismic influence,in consequence of joints local damages,the interaction forces are localized in the structural joints. In this conditions, the strength and the stability of large-panel buildings form provides the strength and rigidity of the structural elements and joints. Hence,it's clear that the static design scheme of the large-panel building is described by the design scheme of the finite elements method,where the load-bearing elements of the building (wall panels and floor slabs) are adopted as the finite elements. Design dynamic scheme of the building is obtained by adding its static scheme,describing the inertia properties of the system, by means of determining the load masses values concentrating in the system joints. Inspite of mentioned successful qualitative character of design scheme correspondence to the subject of research,such design scheme has some indeterminacy caused by insufficient investigation of deformation properties of large-panel buildings and their nodes.

For the clearing up of this indeterminacy the experimental-analytical modification of the finite elements method was offered. The essence of this modification of method consists in fact that the pliancy matrices or the rigidity matrices of the finite elements are determined experimentally and the further course of the problem solve is carried out analytically. Such approach is particularly expedient,in case,when proceeding from the given problem the design must be carried out considering the release of separate connections out of work and developing the sufficient plastic deformations. For the nodes pliancy consideration,which depend on their structural realization mostly,one can act in two ways. Firstly the welds between the structural elements,can be considered having the finite geometrical dimensions and to include them in the design scheme as the finite elements. Further their rigidity (pliancy)at the different influence levels is determined experimentally. Secondly,the rigidity(Pliancy) matrices of the structural elements considering the joints deformatibility may be experimentally determined.

All the finite elements of the large-panel building design scheme are presented as the rectangular plane elements working omly in their plane. Each element,having four nodes in which the joints are concentrated,has eight degrees of freedom from which five are linearly independent. Proceeding from the errors analysis during the experimental research and orientating on the application of structural design programme by the finite elements method using the rigidity matrices of the eighth order,the sequence of their calculation is determined as follows. The pliancy matrix of fifth order for the k-th element fastened in the joints by three connections $[\delta^{K}]_{5\times5}$ is determined experimentally. Then the invariant rigidity matrix of this element is determined $[\tau^{K}]_{5\times5} = [\delta^{K}]^{-1}_{5\times5}$ Using the rectangular matrices of the displacement transformation $[\alpha^{K}]_{5\times8}$, $[\alpha^{K}]^{T}_{8\times5}$ we determine the element rigidity matrix of the eighth order as follows:

$$[\tau^{K}]_{8\times8} = [\alpha^{K}]^{T}_{8\times5} \times [\tau^{K}]_{5\times5} \times [\alpha^{K}]_{5\times8}$$

The description of the course of building design on seismic forces,in its nonlinear propounding of the problem when using the finite elements method and the step method of the motion equations integration is given in (2), Here we shall note the following. If the nonlinear dependence of the connections reactions of the displacements vector values and the parameters vectors characterising the history of the elements deformation R_i is known,the solution of the nonlinear problem is reduced to the consequent solution of the linear equations system regarding to the unknown increments of the displacement vector components:

$$\sum_{j=1}^{n} \frac{\partial R_i}{\partial x_j}\bigg|_{y=y_t} \times \Delta x_j = \Delta P_t^{i} \qquad i = 1, 2, 3 \ldots, n$$

where $$\frac{\partial R_i}{\partial x_j}\bigg|_{y=y_t} = \sum_{K} \frac{\partial \tau_i^{K}}{\partial x_j}\bigg|_{y=y_t}$$

here $\frac{\partial \tau_i^{K}}{\partial x_j}\big|_{y=y_t}$ - are the elements of rigidity matrix of the k-th finite element,determined at the loading level,defining by the parameter point $y=y_t$.(Summation in the last term is distributed on all the elements having the connection i).

ΔP_t^{i} - increment of influence at the time moment t.

It follows from this term that when we determine the rigidity matrix of elements experimentally and first of all the elements modeling the connections it's neccessary to define their values at different influence levels. The analysis of the earthquake results and carried out experiments has shown that these levels is convenient to connect with following typical damages: the cracks appearance along the contour of monolithing joints, concrete crushing of joints and reinforcement bending,break away of the panels concrete at reinforcement anchoring places, plastic flow of the reinforcement and crushing of concrete.

After analytical design, the additional experimental research of the more stressed elements for the clearing up of stress distribution in them, actual safety factors and precision of structural solutions is carried out. Approximate design of the nine-storey large-panel building, carried out according the Codes operating in the USSR showed that the largest shear forces of seismic influence take place in the panels of the longitudinal walls of the second floor in the central part of the building. The largest vertical forces in these panels arise at the level of the first floor at the face planes of the building. As for the forces from the vertical load, they are distributed rather uniformly along the building plan and mainly are perceived by the heavy reinforced concrete panels of the inner walls.

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