Computerized Methods of Structural Limit State Design of Prefabricated Public Buildings

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KEYWORDS

Frame-and-panel buildings, structural limit state, non-linear design methods, full strain diagrams, computer application.

ABSTRACT

In connection with extensive application of frame-and-panel structural systems for mass-scale construction of public buildings the integrated studies aimed at developing limit state design methods for the braced frame buildings were conducted.The methods of designing the bearing systems and structural elements consider non-linear and non-elastic properties of reinforced concrete and joints on the basis of strain diagrams.The two versions of efficient algorithms for non-linear design and the computer programs have been developed allowing to automate the most labor-intensive stages of engineering designs.

Methodes de conoeption assictèe par ordinateur salon des etats limites des structures des batiments publics en elements prafabriques.

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MOTS-CLEFS:

Batiments a ossature et panneaux, etats limites des structures, methodes de calcul non-lineaire, diagramme complet de deformation, emploi ordinateurs.

RESUME:

En vue de large emploi des structures a ossature et panneaux dans la construction de masse des batiments publics, on a effectue des recherches complexes visant a la creation des methodes de conseption des batiments avec l'ossature aux contreventements selon des etats limites. En elaborant les procedes de calcul systemes portants et des elements structuraux, on a pris en consideration des proprietes elastiques et non-elastiques du beton arme ainsi que des joints obtenues a partir des diagrammes de deformation. On a effectue deux variantes des algorithmes efficaces pour la realisation des calculs non-lineaires et du programme pour l'ordinateur permettant l'automatisation des etapes les plus difficiles des calculs techniques.

The basis of prefabrication of public buildings for various purposes in the USSR is at present a braced frame-and-panel structural system. The joints between cross-bars and columns in the braced frame are close to the hinge ones, as a result all horizontal leads, or to be more precise, all loads trying to induce horizontal displacements of a building, are taken by special structural elements - stuffening diaphragms. The latter are integrated that consist of the frame columns and wall panels filled in between; they are connected with welds ensuring combined behaviour of columns and wall panels under vertical and horizontal loads.
Due to mass-scale application of the braced structural system in civil engineering the studies aimed at developing the limit state design method for bearing systems of braced frame buildings saquire special urgency: the most essential element of the method being the building design algorithm taking into account non-linear and non-elastic properties of reinforced concrete structures and their joints at all stages of structural behaviour. The basis for the analysis of the actual structural behaviour is a full non-linear strain diagram expressing a functional link between the values of generalized force F in an element or a joint and corresponding displacement Y. For the practical analysis of frame-and-panel buildings designed with the use of type precast concrete elements the two verions of an algorithm has been developed talking into account the full structural strain diagram having a descending branch. The first algorithm version - the method of elastic solutions - envisages sequential refinement of correspondence between the calculated values of forces and displacements and the strain diagram. The assigned loading history is presented in the form of a sequence of steps characterized by the values of full loads at the step end. The analysis is performed by an interation method.For each interation a linear problem is solved where stiffness characteristics are assumed to be aqual to the slopes of secants drawn from the origin of coordinates to that point in the diagram the abscissa of which corresponds to the element strain defined as a result of the previous interation.The criterion of the interation process is the condition.

$$F_{ik}(P_j;\ D_{i,\ k-1}) - F_{id}(Y_{ik}) < e \qquad (1)$$

where i - No.of a structural element or a joint
k - No.of interation; J - No. of a loading step
P - load; F_{ik}, Y_{ik} - values of the internal force in the element and the corresponding displacement defined as a result of static design of the bearing system; F_{id} - ordinate of the design strain diagram;
$D_{i,\ k-1}$ - secant stiffness of an element; e- assigned design accurasy.

The second algorithm version is constructed as a modification of the step-by-step loading method with due account of featuresensuing from piece-linear presentation of strain diagrams. A system of loads acting on a building is considered with increase in all its components proportional to one parameter. Basing on the prerequisite that the piece-linear strain diagram is available for all elements, the loading history is divided into a sequence of stages, each having a certain value depending on paraments of the structural strain diagram.
At each stage the increments of internal forces in elements and corresponding displacements with regard to the load increments are determined. With this approach the relationship between the forces and displacements for elements is discribed by secant characteristics of their regidities being constant values in the finite ranges determining the magnitude of the loading stages due to the prerequisite about the piece-linear strain law. Within the stage limits proportionality between the force increments and displacements increments is retained, and consequently, the regularities and methods of linear mechanics of elastic systems are valid for these values. The beginning and the end of the next in turn stage can be determined from a condition of concidence of forces or strains (or several al once) elements of the design model with coordinates of one or another point of the piece-linear strain diagram break. The fundamental feature of this approach is definiteness of the load value at each stage, therefore the algorithm is not an interation process, and the solution can be obtained as a result of a finite number of design cycles.

Let us consider the procedure of the load increment determination corresponding to a stage with k number. In the beginning of the stage the system's stress-strained state is characterized by a set of force values in elements $F_{i,\ k-1}$, while the load - by a force system depanding on parameter P_{k-1}. In accordance with internal force values $F_{i,\ k-1}$ for each element one determines sections of strain plots to which these forces belong, and the corresponding values of tangential stiffness characteristics determining the element deformability at the given stage are assigned. The parameter determining the loading level is assigned with unity increment $P_i=1$, then analysis of the action of the corresponding force is performed, and the 2 "unity"increments of internal forces F_{ui} are determined. The load increments at this stage are equal to the minimum one out of P_k values calculated for each element according to formula

$$P_k = (F_{csi} - F_{i,\ k-1}) / F_{ui} \quad (i=1,2,\ldots,n) \qquad (2)$$

Where F - coordinate of the next point of the i-th element strain diagram break; n - number of elements in the bearing system. By the defined increment of parameter P_k the values of internal forces, strains and loads at the stage and are determined.

Realisation of the above algorithms in the design process is ensured by the elaborated recommendations on buildings design as well as strain diagrams of structural elements and joints. A set of applied computer programs allows to automate both individual stages of design and integrated testing of safety of the building's spatoal bearing system over all limit state groups.

Computerization of Engineering Calculations in Studying Structures

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ABSTRACT

The examination of qualitative characteristics of building structures dictates a certain mathematical formalization of their physical and engineering properties. The formalization is generally described by boundary problems for diffrential equations in partial derivatives. Conditions imposed upon the solution of the problem are formalized as equalities and inequalities. The resultant relationships do not always correspond to the "typical" problems realized in software, e.g., on the basis of the finite element method.

On the other hand, the experience of numerical solution of boundary problems allows the most suitable form to be chosen for their description - variational expression realizing a concrete physical or mathematical concept.

In this case, problem formulation is reduced to putting down an integrand and additional conditions imposed upon the solution of the problem. It is, therefore, reasonable to develop a universal algorithm for computer-aided study of building structures wherein mathematical formulation as well as geometrical cinditions and engineering requirements are set forth at the level of formal parameters. Software developed on the basis of such algorithms make it possible to obtain numerical results in solving non-standard boundary problems of structural mechanics in a short period of time. It is very important, e.g., in studying new structures at the development stage or in investigating into a prompt engineering intervention into operating conditions of existing structures.

A number of variants of such an approach the the computer-aided design of structures have been developed in the USSR.