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ANALYSIS OF LOAD-BEARING STRUCTURE OF MULTI-STORY BUILDINGS BY MEANS OF CONCENTRATED DEFORMATION METHOD

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ABSTRACT

The paper deals with analysis of the segments of reinforced concrete of framed structures and flatworks of the load bearing structures of multistory buildings based on the concentrated deformation method and development of discrete analytical models for reinforced concrete framed structures and flatworks of the load bearing structures of multistory buildings, compilation of algorithms and programs with the use of computer machines and obtaining the construction solutions thereupon, which are characterized by economic efficiency and engineering simplicity. Besides, a concentrated deformation method has been developed for the analysis of reinforced concrete framed structures and flatworks of load bearing structures of multistory buildings, taking into account the actual nonlinear deformation curves of concrete and steel with different load duration and is caused by discrete nonlinear analytical models and algorithms, providing the cost-effective design solutions for framed structures and flatworks of the load bearing structures of multistory buildings.

Keywords: concentrated deformation method, discrete analytical models,rigidity matrix, concrete,load duration, thrust effect.

INTRODUCTION

The construction practice and analyzes show that the concentration of population around metropolitan cities is a logical, objective and global process related to population growth and development of the productive forces.

It is clear that in the context of natural scarcities of land and its increasing value the cities cannot spread outwards infinitely; they become higher and higher by increasing the number of storeys of residential, civil and public buildings.

With the increasing number of storeys, the buildings become more complex and critical structures. Their criticality is evidenced by the fact that there are thousands of people in the office or residential high-rise buildings, and their life and well-being are directly dependent on the knowledge and skills of designers and builders implementing these structures.

The load bearing structures of the modern reinforced concrete multistory buildings are formed from framed structures and plane elements, the total number of which may be many hundreds or thousands. Fault-free performance of individual elements and their set must be supported by the analysis [1-12] for all the loads and effects at the stages of manufacture, erection and operation.

The most critical stage in this analysis consists in the development of analytical models for individual elements of the load bearing structures in general. Analytical models must meet two dialectically conflicting requirements: on the one hand, analytical model should reflect the characteristics of the simulated element of the load bearing structure more adequately; on the other hand, it should be simple and easy to implement with the use of computer aids [18- 22].

Researchers in this field can offer a variety of mathematical models to describe the same system, and we cannot specify a simple and clear criterion for their discretization. Only those models that resonate with intuitive notions about the nature of the system under consideration are well accepted.

Two types of analytical models are most commonly used for the concrete structures of frame constructions of multistory buildings at present: discrete-continuum and discrete models.

The trends of follow-on development of the concrete structures of frame constructions of multistory buildings require the combination of the theory of nonlinear deformation of reinforced concrete with methods of structural mechanics and computer machines in analytical models for obtaining comprehensive and reliable information about stress and strain state in elements and connections, load bearing structures in general.

Based on the above, cost-efficient and reliable construction solutions for the concrete structures of frame constructions of multistory buildings can be designed and implemented in practice.

This paper is aimed at development and elaboration of discrete analytical models for the analysis of the load bearing structures of multistory buildings erected with the use of reinforced concrete, on the basis of it; compilation of algorithms and software for computer machines; carrying out experimental studies on segments from the full-scale reinforced concrete elements to solve the solution of the reliability of the obtained results of analysis judging from the proposed methods of analysis.

Academic novelty consists in:

- development of the concentrated deformation method for analysis of framed structures, plain stress and flexural reinforced concrete structures of load bearing structures of multistory buildings, taking into account the actual nonlinear deformation curves of concrete and steel with different load duration;

- methods for obtaining the rigidity matrices for reinforced concrete structures for different types of stress and strain state and load duration, providing research and methodology complex in solving the calculation tasks of various types;

- the findings of experimental studies of segments of precast concrete floor slabs from the full-scale elements in terms of vertical and horizontal effects, reflecting the actual operation conditions of constructions in the system of multistory buildings;

- new analytical data with the use of computer machines, taking into account the actual nonlinear deformation curves of concrete and steel of various elements of the load bearing structures according to the concentrated deformation method and the results of their comparison with the data of full-scale experiments and other calculation methods;

- new analytical model, taking into account the impact of ductility of connection between the individual precast reinforced concrete elements on the total stress and strain state of the system in general, and giving them the actual picture at any load level.

The developed discrete nonlinear analytical models, algorithms and guidelines for test methods of segments of precast concrete floor slabs from the full-scale elements produce cost-effective design solutions for framed structures and flatworks of the load bearing structures of multistory buildings. The results of these studies have been applied in the design and research work and are used in the teaching and learning activities in the training of specialists with a specialization in industrial and civil construction.

The following regulatory documents have been produced according to the research results: “Recommendations for the design of precast concrete floor slabs in buildings with cast-in-situ walls” (agreed on 02.03.07 under No. ОЮ/04-747 by the State Committee for Architecture and Construction of Uzbekistan, Tashkent, 2007) and the “Application guideline for DIRAR software for nonlinear analysis of reinforced concrete structures by means of concentrated deformation method”, (Bishkek, 07.03.07, order No. 14-ПР (ОН)) [16, 17].

Application of recommendations for the design of precast concrete floor slabs in buildings with cast-in-situ walls with the use of standard reinforcement steel and high-tensile reinforcement steel in them allows us to reduce the consumption of metal by up to 30% per unit of prefabricated reinforced concrete.

The main provisions of calculation procedure of reinforced concrete framed structures and flatworks according to the concentrated deformation method are based on experimental data on full-scale specimens; deformation and strength properties of materials of constructions and their joint connections. Most analyses are implemented in numerical examples, and the results of calculations have been extensively compared with the data obtained by experiment or other calculation methods.

The subject matter of this paper is described in monographs and textbooks and published in more than 100 publications.

In this paper, we formulate the main lines of research and their methodological assumptions; construction solutions of the load bearing structures of multistory buildings and methods of their analysis, as well as “stress and strain” ratio for concrete and steel with different load duration are analyzed; as a result, basic research tasks are formulated. Currently, the following classification of analytical models for the load bearing structures of multistory buildings has been established in the literature: continuum, discrete-continuum and discrete models [2-12, 24].

Continuous models in which the building is represented as a solid multistage (multiconnected) prismatic shell, didn't obtain a wide circulation due to specific features of the simulated load bearing structures of multistory buildings. The multistory buildings represent the complex of discretely located elements, joined by ductile connections and jagged by window apertures and doorways. In this model, we have to make a double transition, as first we continualize discrete signs of the load bearing structure, and then we resample the obtained results.

Thus, discrete-continuum analytical model proved to be quite viable, productive and advanced; its potentialities seem to be developed in the future. At the same time, it can be assumed that discrete-continuum analytical models will be, to the extent of development of computer technology, increasingly frequently replaced by discrete analytical models as a result of greater generality, universality and good mathematical supportability.

Concentrated deformation method (CDM) is one of numerous methods of analysis of statically undeterminable framed structures and flatworks [18, 19, 25]. The idea of the concentrated deformation method is initially disclosed on the elastic bar elements with constant normal cross-sections with plane of mirror symmetry, in which the vectors of external forces are active. Solid support and end support conditions in the concentrated deformation method may be arbitrary, including ductile with known stiffness properties of the bearing assemblies.

The essence of the concentrated deformation method lies in the fact that the initial bar is divided into elements where the deformations of adjoining elements are concentrated along their division planes. We can put it differently: the initial corrugated bar is divided into elements which are transformed into rigid elements and connected between each other by ductile connections, ductility (stiffness) properties of which must preserve the properties of the initial bar.

The main advantage of the concentrated deformation method is the simplicity of formation of rigidity matrices of cross sections, elements, and framed structures made of them; in which case, the elements of rigidity matrices are stiffness properties of the beam slabs (flexural, axial, etc.).

The second advantage of the concentrated deformation method is distinct division of the complex stress and strain state into elementary components (flexure, tension and compression, etc.).

The third advantage of the concentrated deformation method consists in a simple consideration of ductility of connections between the elements or in the bearing assemblies, it matters in the analysis of cast-in-place and precast construction or composite constructions.

The fourth advantage of the concentrated deformation method within the prospect under development consists in the wide use of plane-sections hypothesis. This fact allows us to dramatically reduce the number of elements of the concentrated deformation method compared with conventional numbers from the finite-element method with no loss of accuracy in the description of the stress and strain state in the areas of considerable length.

However, concentrated deformation method is mainly oriented to the analysis of elements taking into account the actual nonlinear deformation curves of concrete with different duration of the impact of external load; in this case, the bars should be divided the same way as in conventional finite-element method in order to take into account the stiffness which varies over the length; that's why in this case the concentrated deformation method and conventional finite-element method are relatively equal in the sense of necessary degree of discretization. At the same time, if we take into account the nonlinearity of reinforced-concrete bars in the conventional finite-element method, it is necessary to search for the elements of the rigidity matrix in centroidal principal axes which change their position depending on the stress level and strain state and duration of the impact of external load.

Rigidity matrices of the elements in the concentrated deformation method are constructed directly on the basis of rigidity matrices of cross sections in the same axes without transition to the central axes of cross sections. This circumstance suggests significant advantage of the concentrated deformation method [13-15].

This study of the bar elements and framed structures has several abovementioned features and is based on the following assumptions:

longitudinal strains of concrete and steel in standard cross-sections are developed according to the law of plane deformation (plane-sections hypothesis) at all levels from the impact of external load;

longitudinal strains and the corresponding normal forces in concrete and steel are taken as “averaged”;

complete diagrams “σ – ε” are introduced in the analysis for concrete and steel, including the descending arms obtained during their unaxial impact on the reference samples with different duration of the impact of external load;

normal cross-sections may have any shape (rectangle, T piece, circle, thick-walled ring, double tee, U-section, etc.);

the standard cross-sections in the analysis are designated in digital form by the complex of elementary sections of concrete Abn and steel Ask, the shape and dimensions of which depend on specific situation;

the stresses in concrete σbn and steel σsk are evenly distributed in the corresponding elementary areas;
the reinforcing steel of different grades - both standard steel and prestressed steel (combined reinforcement), as well as concretes of different grades (sandwich constructions) provided that they ensure reliable combined action, can be positioned in standard cross-sections;

equations of equilibrium are written in a consistent form, regardless of the nature of external forces in the cross section, the shape of its stress level and strain state.

The degree of discretization presents an important question: it must be optimal to preserve all dimensional characteristics of the simulated initial cross section within the required accuracy of analysis and at the same time with few elementary areas opportunities to reduce the amount of calculation.

Then polydimensional deformation reinforced-concrete structures in the load bearing structures of multistory buildings are examined. The flexural stress state in reinforced-concrete elements of flatworks of the load bearing structures per se virtually cannot be found; usually it is accompanied by the components of plane stress state.

The components of plane stress state in flexural slabs are developed not only as a result of application of load in plane of slabs, but also due to inhibition of deformations under the conditions of fixing on the supports in confined spaces (thrust effect) and development of geometrical and physical nonlinearity [18-22, 23].

First we'll analyze a uniform-thickness flexural slab, isotropic in elastic stage of behaviour without actual seams. Initial flexural reinforced-concrete solid cross-section floor slab develops in concentrated deformation planes into rectangular (square) elements with dimensions of ak•bk.

If we regard these “elements of the CDM” as rigid in flexure, torsion and shear (cut), out of their plane and in their plane, we shall introduce the conditioned (fictitious) connections between them which are able to resist flexure, torsion, shear and compression-tension; stiffness properties of the elements of these connections should be preset to be such as to make the initial slab and its module of concentrated deformation method equivalent.

During this action, the loads produced the same deflections, deflection angles; values of the moments of flection and torque moments, as well as transverse (shear) forces in the cross sections of interest [13-15].

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Stress and strain state of reinforced concrete slabs is revealed from the system of algebraic linear equations of deflection method in general form

$$[R]\cdot\{V\} = \{P\} \quad (1)$$

where:

[R] is the extrinsic rigidity matrix for the whole analyzed structure;

its elements $R_{i,j}$ represent the reaction in i-connection of deflection method from the shift of j connection per unit;

{V}is the vector of required deflection; its elements are the deflections of elements of the concentrated deformation method (two angular deflections and one linear deflection for each);

{P}- is the load vector, its elements are concentrated forces and moments of flection which act in the attachment points of elements of the concentrated deformation method.

The inner forces are determined by the deflections based on the common dependences

$$\{F\} = [Э]\cdot\{\lambda\} \quad (2)$$

where:

{F}- is the vector of inner forces, the elements of which are the inner forces along the concentrated deformation planes, moment of flection M, torque moment H and transverse force Q on each of four sides of element of the concentrated deformation method;

[Э]is the intrinsic rigidity matrix of the structure, where its elements are the inner forces along the concentrated deformation planes from the unit mutual displacement of adjacent elements of the concentrated deformation method;

{λ}is the concentrated deformation vector (mutual displacements and deflections of elements of the concentrated deformation method).

Plane-sections hypothesis is adopted for all cross-sections of elements of the concentrated deformation method along the concentrated deformation planes. The system of algebraic equations (1) is solved with respect to deflection vector {V}. Extrinsic rigidity matrix [R] and nodal forces vector {P} must be known for this purpose.

When we have an analytical model, we can easily compose a vector of external forces {P}. The main difficulty lies in the formation of the extrinsic rigidity matrix of structure [R].

We can apply the method of unit deflections of elements of the concentrated deformation method in the direction of the superimposed connections in order to form this matrix.

However, experience has shown that it is more convenient to use formula

$$[R] = [A]\cdot[K]\cdot[A]^{т} \quad (3)$$

where:

[A]is the matrix of coefficients of equations of equilibrium of the elements of the concentrated deformation method;

$[A]^{т}$ is the matrix which has been transposed with the matrix of coefficients of equations of equilibrium [A];

[K] is the matrix of intrinsic rigidity of the cross sections.

According to formula (2), we'll write down the connection between the inner forces along the concentrated deformation planes and the corresponding deformations for a standard k-element of the concentrated deformation method in matrix view

$$\{F\}_k=[Э]_k\cdot\{\lambda\}_k \quad (4)$$

where:

{F}k is the vector of inner forces along the side planes of k-element along the concentrated deformation planes;

$[Э]_k$is the rigidity matrix of the cross sections for k-element along the same side planes;

$\{\lambda\}_k$ is the vector of the corresponding deformations.

In case of precast and monolithic reinforced concrete slab structures which operate under the conditions of action of thrust forces (Figure-1), the situation is complicated by the fact that the cross sections along the concentrated deformation planes are complex (include concrete, steel and real connections).

Furthermore, it is known that concrete and steel usually do not show elastic behaviour even at relatively low and short-term external loads. This study deals with behaviour of reinforced concrete beam slab which was in the conditions of stress and strain state caused by the presence of thrust forces. Based on the concentrated deformation method, strength and deflection of precast concrete floor slabs have been determined, taking into account the specifics of their behaviour in the multistory buildings and structures; the algorithm of DIRAR software for the analysis with the use of computer machines has been developed and implemented [13, 18]. Technique and algorithm of the software allow performing analysis of deflections of precast concrete floor slabs under various boundary conditions of fixing.

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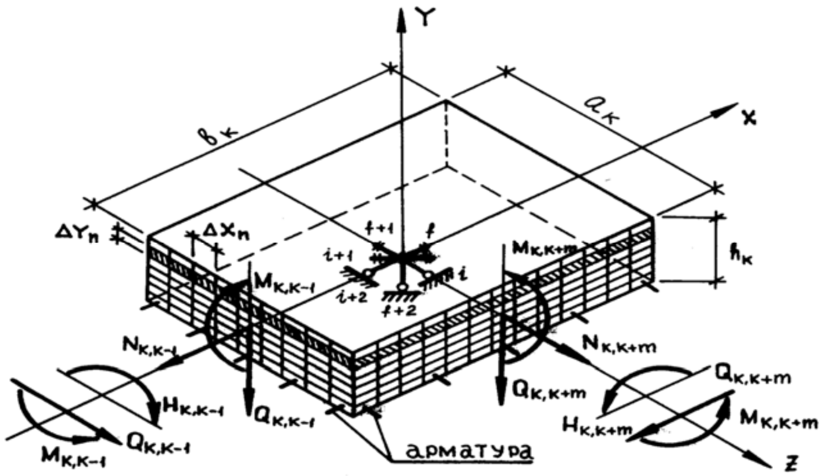

Figure-1. Analytic model based on the concentrated deformation method for reinforced concrete slabs.

Specific features of calculation procedure and the algorithm for the program lie in the fact that besides nonlinear properties of precast concrete floor slabs, they allow taking into account the impact of behaviour of normal forces throughout the height of the cross section of precast concrete floor slabs.

The algorithm of DIRAR software for the analysis with the use of computer machines uses the following basic data for precast concrete floor slabs of multistory buildings and structures:

- number of discrete elements of concentrated deformation method for precast concrete floor slabs along the centre lines X and Y;
- geometrical dimensions of discrete elements of concentrated deformation method for precast concrete floor slabs along the centre lines X and Z;
- physical characteristics and dimensional characteristics of materials (concrete and steel) for precast concrete floor slabs;
- conditions of fixing on the supports of precast concrete floor slabs and action of the normal forces throughout the height of the cross section for precast concrete floor slabs;
- the maximum number of iterative processes for computation;
- the accuracy of the convergence of the iterative resolution process;
- incremental step from the action of external loads.

The algorithm for the program prints out the results of the computations, namely, deflections, vertical and horizontal stresses, axial deformations, inner forces (moments of flection in plane and out of plane, torque moments, transverse forces in plane X and plane Y, as well as normal forces) in the tabular form.

The algorithm of DIRAR software is built according to the following diagram (Figure-2).

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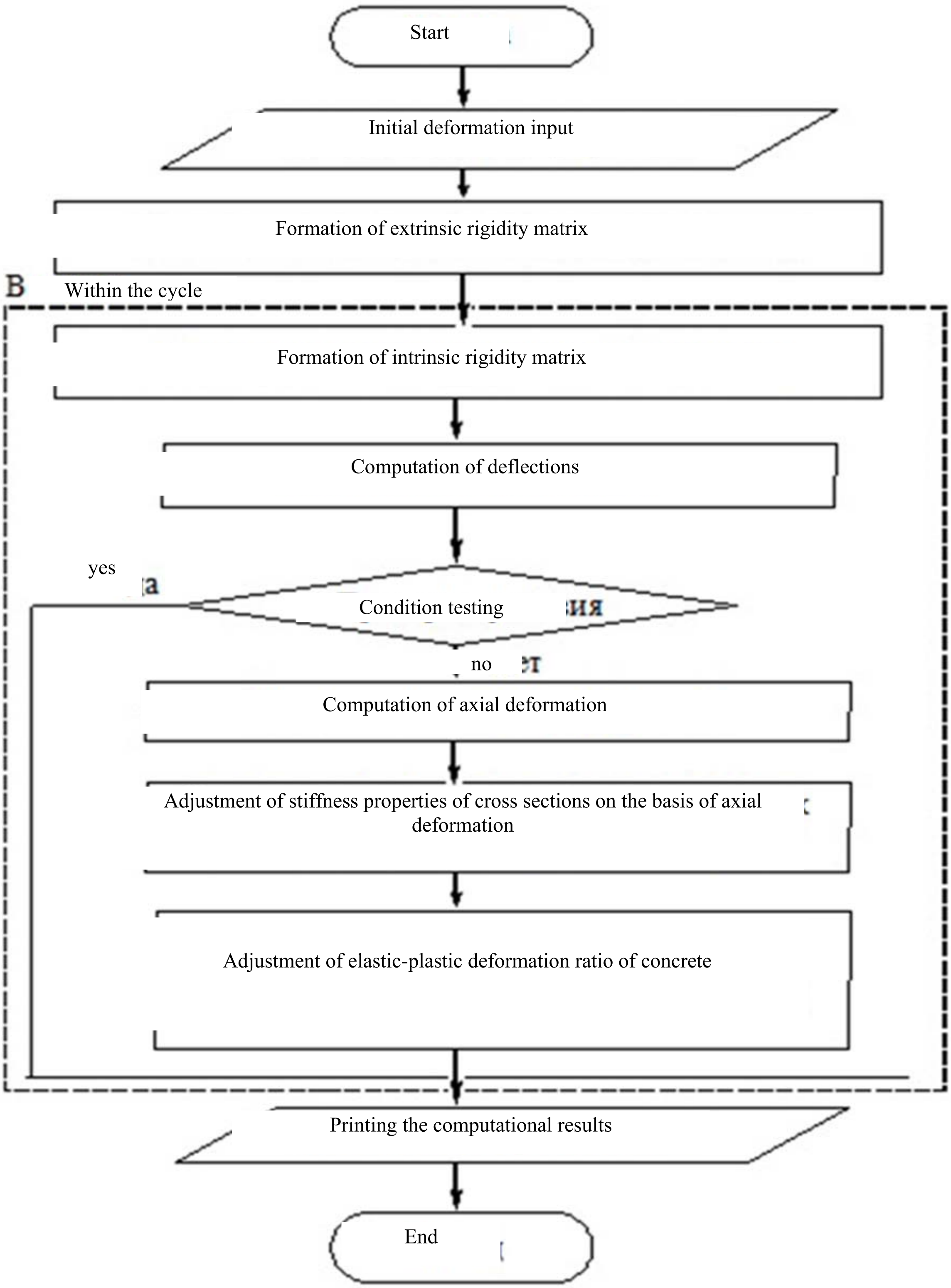

Figure-2. Flow diagram of DIRAR software.

Therefore, experimental test procedure has been developed, providing for testing of reinforced concrete simply supported slabs and beam slabs to the action of vertical loads, where the bearing members of slabs were fixed to prevent horizontal displacements, as well as for

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testing the precast solid flat slabs, simply supported along four sides.

Based on the experimental studies, the amount of deflection and thrust in the beam slabs which were fixed to prevent horizontal displacements, was measured at all levels from the impact of external load, which gave an option of analyzing the following:

- measurement of the thrust forces, i.e. the thrust effect;
- impact of the thrust forces on strength, stiffness and first-cracking strength.

In addition, the resulting force of the thrust forces H was determined according to the measurements of deformations of dynamometers by means of the calibration curves.

According to the analysis of the calibration curves it has been found that thrust forces act within h/4 throughout the height of the cross section of the beam slabs.

Comparison of deflection curve shows that deflections in slabs without regard to thrust exceed the deflections in slabs with account of thrust by 1.75 - 2.5 times.

It follows that the thrust significantly increases the stiffness of structure. Consequently, the following conclusions can be drawn based on the results of experimental studies: the lower is the coefficient of reinforcement; the higher is the impact of thrust on the load-bearing capacity of the structure (Figure-3).

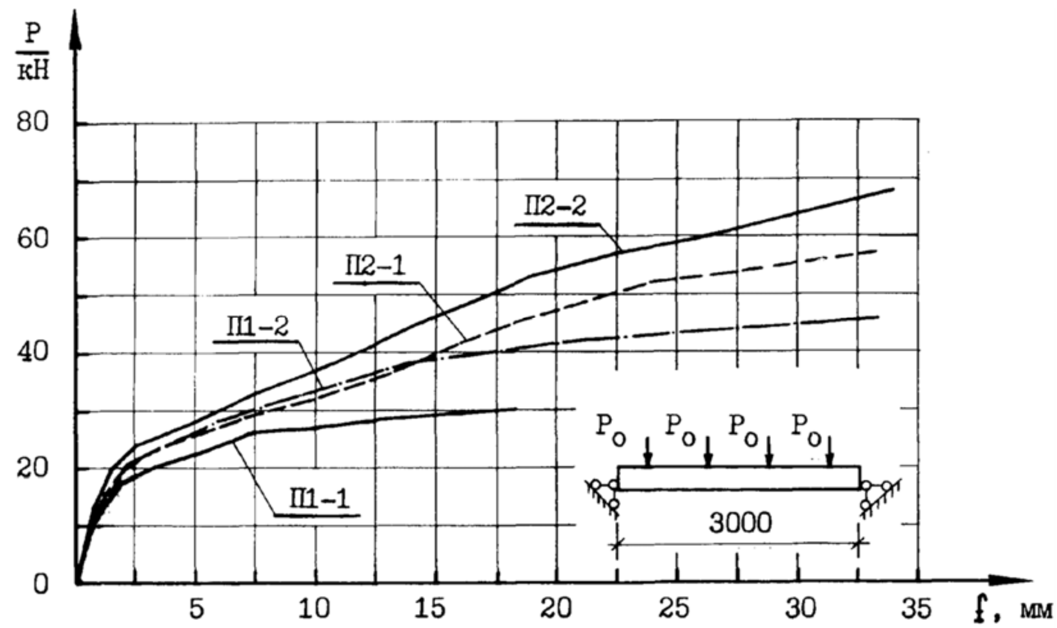

Figure-3. Deflections of beam slabs in the midspan.

Based on the foregoing, we can recommend using the slab, supported along four sides, with a minimum ratio of reinforcement, in the solid cross-section structures.

In addition, the tests of precast reinforced concrete slabs for the monolithic multistory buildings were carried out at the precast concrete factory in Novocheboksarsk. The main objective of the test was to assess its strength, stiffness and first-cracking strength, in the improvement of construction solutions and verification of manufacturability of precast flat floor slabs.

On completion of testing of precast flat floor slabs it has been found out that their actual strength and stiffness are much higher than control values in terms of strength and stiffness. This phenomenon is caused by the presence of thrust forces which are effective along their outline. If we take into account the thrust effect in the design process, it will reduce consumption of working reinforcement.

In order to determine the load-bearing capacity, deflections and first-cracking strength of concrete floor slabs, supported along four sides, taking into account the specifics of their behaviour as part of the load-bearing elements of the monolithic multistory building, a special software for the analysis with the use of computer machines has been developed, which makes it possible to perform analysis of the concrete floor slabs, supported along four sides, under any boundary conditions.

We have obtained the deflections, inner forces for each element of the concentrated deformation method and deformation of elementary strips into which the cross section is divided throughout the height and width, and which are compared with experimental data as the results of analysis of reinforced concrete floor slabs.

It appears from the diagram that good ratio between experimental data and calculation data has been achieved in deflections (Figures 4, 5 and 6) of beam slabs in the midspan. This ratio is equal to 5.0 - 23.6 %.

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Besides, we have made a comparison of the moments of flection in the cross-sections of beam slabs and concrete floor slabs, supported along four sides, determined by the rules of structural mechanics, reliability handbook, and concentrated deformation method; the values of thrust forces, obtained during the testing and based on the results of machine computation, were put in correspondence (Figures 4 and 5).

The obtained deflections according to the concentrated deformation method were compared with the result of the experiment and result of analysis according to the elasticity theory. Given the load on the point P_o = 2.0 kN, which corresponded to the elastic stage of behaviour of beam slabs with account of thrust, deflection according to the concentrated deformation method was $f_{мсд}$ = 0.271 mm, and according to the theory of elasticity - $f_{см}$ = 0.294 mm.

Moreover, it should be noted that the diagrams of the impact of external load had certain discrepancies in terms of concentrated deformation method; analysis was performed for the impact of four concentrated forces, and uniformly distributed load on the structure was assumed based on the theory of elasticity.

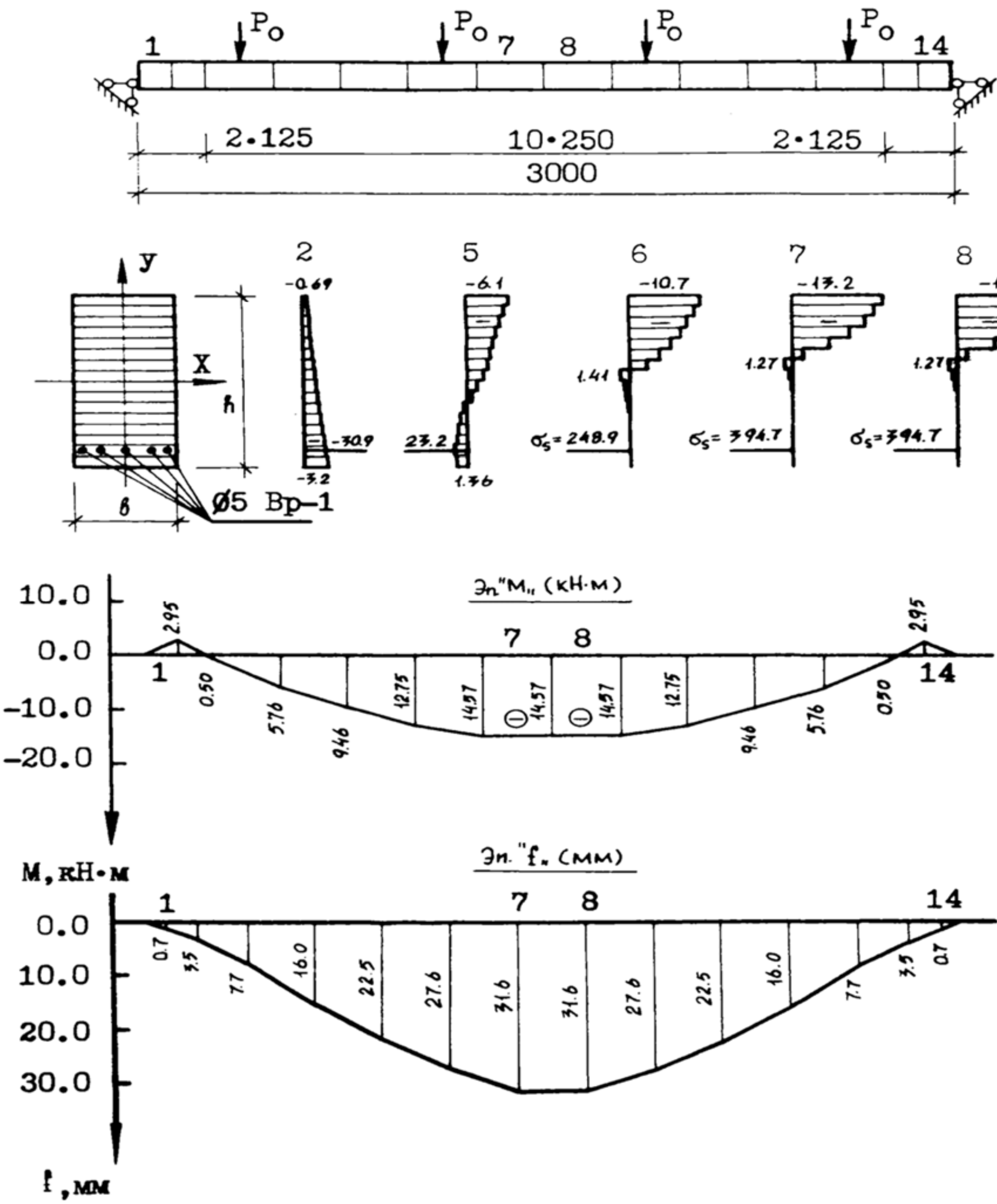

Figure-4. Distribution diagrams of stresses, moments and deflections of beam slabs(e = –h/4 and P_0 =16.0 kN).

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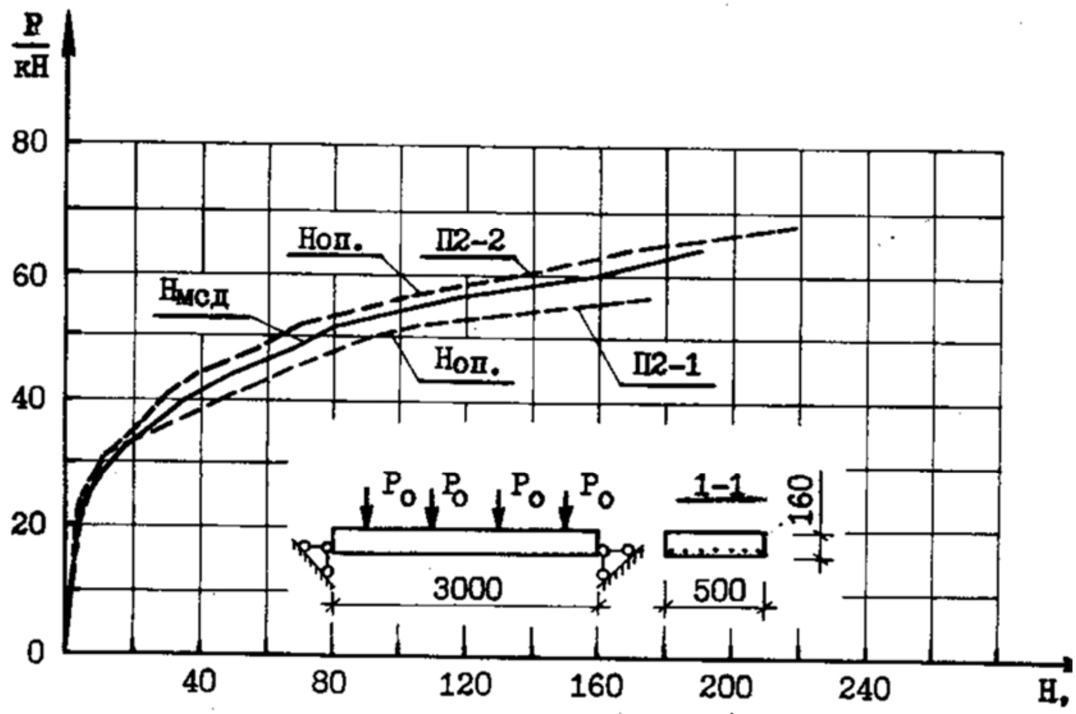

Figure-5. Variation in thrust forces of beam slabs.

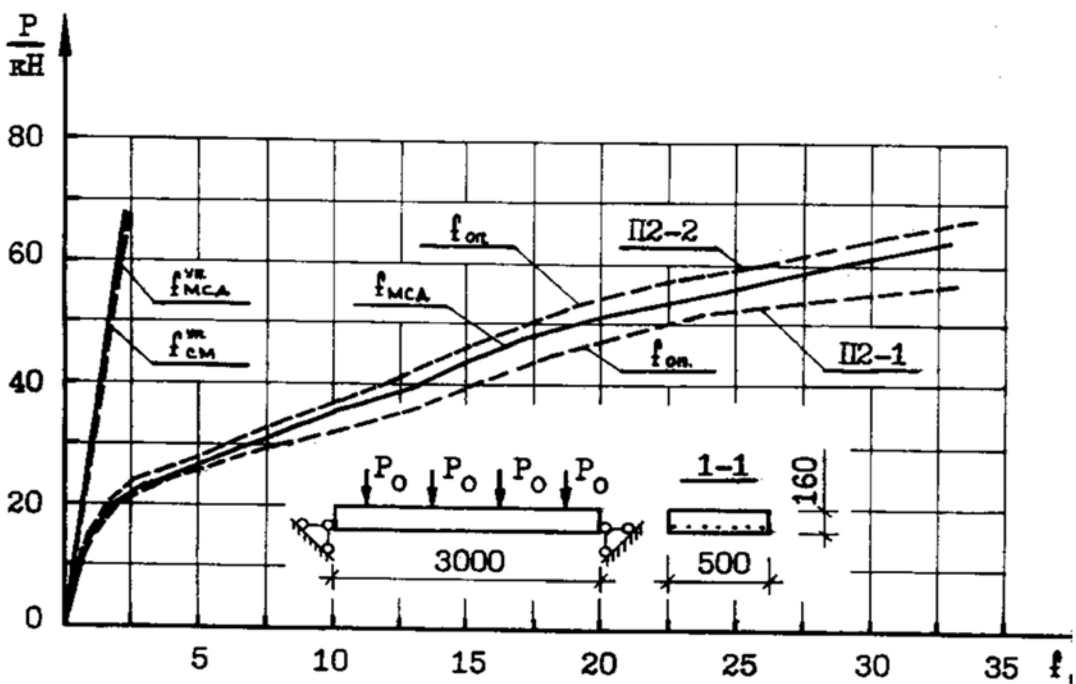

Figure-6. Deflections in the midspan of beam slabs.

In light of the foregoing, good agreement of the obtained deflections should be noted, as the divergence is about 7.8 %. For this level, experimental deflection from the impact of external load is equal to $f_{оп}$ = 0.28 mm, which is equal to 3.3 % in relation to $f_{мсд}$ and is equal to 5.0 % in relation to $f_{см}$.

The section below describes the analytical model of concentrated deformation method for the interflooring of multistory buildings, erected from full-scale precast

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reinforced concrete elements, in terms of vertical and horizontal effects, taking into account the actual nonlinear deformation curves of concrete and steel with different duration of the impact of external load; the main principles of their analysis using the mentioned method are described.

The results of analysis of the experimental segment of interflooring under the influence of vertical and horizontal effects have been obtained on the basis of the proposed methods and algorithms for the developed programs.

In addition, the calculation procedure can be implemented by means of DIRAR software presented above. The deflections that were obtained according to the concentrated deformation method are well supported by experimental data presented in Figure-7.

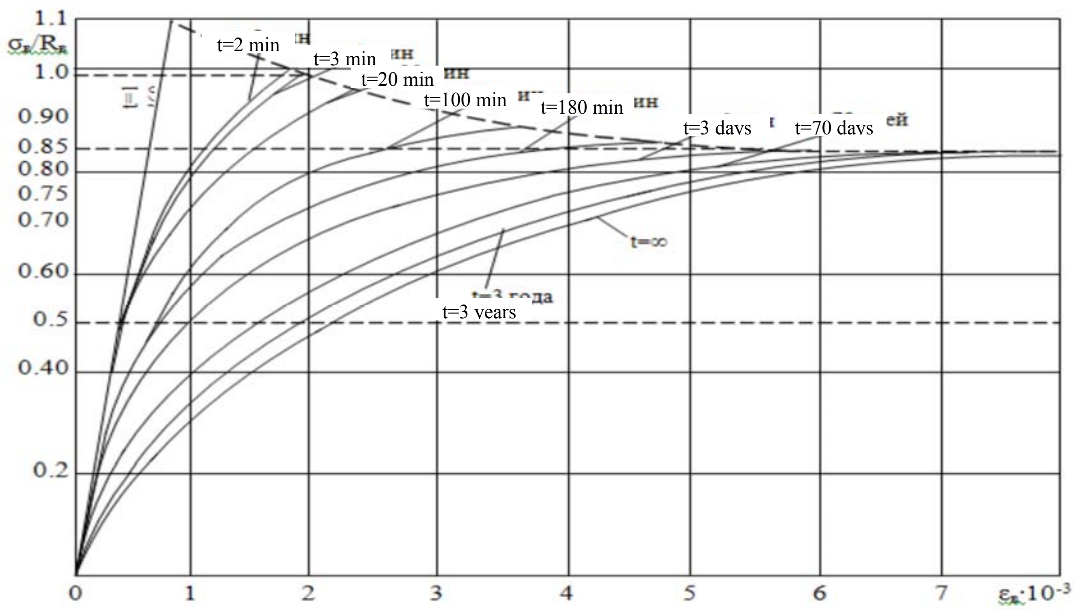

Figure-7. "Stress and strain" dependence diagrams.

A practical technique is provided in this paper for taking into account the long-lasting action of load during the analysis of flexural reinforced concrete slabs according to the service limit state by the deflections and crack growth.

The main point of this paper consists in the determination of value of elastic-plastic deformation ratio of concrete ν depending on the stress level in concrete $\sigma_в/R_в$, grade of concrete and load duration according to average diagrams "$\sigma_в$ - $\varepsilon_в$".

The analytic expression for the elastic-plastic deformation ratio of concrete ν can be presented in the form of the following equation:

$$\nu = (\varepsilon_в)/\{\varepsilon_в+\varepsilon_{pc}\cdot[t\cdot(\sigma_в/R_в)]\} \quad (5)$$

where:

$\varepsilon_в$ is the value of completely recoverable deformation of concrete;

ε_{pc} is the value of plastic strain of concrete;

$\sigma_в/R_в$ is the stress level in concrete;

t is the load duration.

In case of short-term and long-term action of constant and permanently acting loads νassumes the value equal to (0.1-0.15), depending on the application conditions, and does not depend on the duration of the continuous load portion, stress level $\sigma_в/R_{в,}$ that does not correspond to the experimental data either.

The above discrepancies between the recommendations of SNiP 2.03.01-84* [26] and the experimental data can be eliminated if we use averaged experimental diagrams "$\sigma_в$ - $\varepsilon_в$" with different duration of the impact of external load from the concrete [27, 28], presented in Figure-8. In case of the long-term impact of external load, according to data presented in Fig. 7, the value of elastic-plastic deformation ratio ν varies within 0.43 to 0,1 and depends both from the load duration and from the stress level in concrete.

At the same time, codes of structural design SNiP 2.03.01-84*, the value ν is recommended to be taken equal to (0.1 - 0.15) in case of continuous action of constant and permanently acting loads regardless of load duration and stress level in concrete.

MAIN CONCLUSIONS

- as a result of the analysis, patent search and generalization of experience, the problem of further improvement and development of design shapes and methods of analysis of concrete structures of frame constructions of multistory buildings has been theoretically substantiated and solved. The prospects for their elements consist in the developed analytical models of the concentrated deformation method, based on the current concept of nonlinear deformation of reinforced concrete elements with the use of computer machines.

- based on developed discrete analytical models of the concentrated deformation method for the reinforced concrete cross sections, bars, bar systems, plain stress and flexural slabby structures in the load bearing structures of multistory buildings, specific features of behaviour of reinforced concrete structures have been found with account of duration of the impact of external loads which cause nonlinearity and elasto-plastic behaviour of connections between the precast reinforced concrete elements.

- based on the results of experimental and theoretical research with account of the previously existing theoretical positions, the concentrated deformation method has been developed, referring to the category of discrete methods and close to the finite-element method, characterized by the simplicity of formation of resolving equations in case of implementation with the use of computer machines.

- the dependences for the elements of the extrinsic rigidity matrix of framed structures and flatworks have been obtained in the process of analysis of concrete structures of frame constructions of multistory buildings, which excludes the multiplication operators for matrices. It is highly expedient in case of nonlinear analyses related to repeated updating of rigidity matrices caused by iterative processes.

- with account of deformation of the analytic model during the analysis of elements of load bearing structures of multistory buildings, a method to correct the vector of external forces has been proposed, which consists in the addition of the node point moments thereto. It is a good practice to correct the vector of external forces within a single cycle along with updating of extrinsic rigidity matrices without changing the structure of resolving equations.

- in order to determine the strength of standard cross-sections of statically determinate reinforced concrete of bar elements in nonlinear setting for any sectional shapes and the diagrams of application of external forces it is expedient to use the suggested uniaxial deformation curves of concrete and steel with different load duration, including the descending arms. The strength of standard cross-sections can be verified immediately by the known (predetermined) vector of external forces, bypassing its gradual increase.

- it has been found that plane stress reinforced concrete elements of load bearing structures of multistory buildings with account of nonlinear behaviour of concrete and steel in structures, as well as connections between the precast elements can be simply and securely analyzed according to the concentrated deformation method. Adoption of plane-sections hypothesis within each element and the possibility of change of the stiffness properties of materials of the concentrated deformation method allow adopting these elements on a significantly larger scale than in the finite-element method.

- in the analysis of reinforced concrete elements of interflooring for the external action, the bending state and planar stressed state should be taken into account at the same time, for which the six-degree elements have been developed based on the concentrated deformation method. The developed analytic models for flexural reinforced concrete elements of interflooring can be considered as the most common of them; we can obtain solutions both for framed structures and plain stress elements of the load bearing structures as special cases.

- the developed and proposed technique and algorithm of analysis allow using the actual deformation curves of materials, take into account the nonlinearity and nonuniformity of development of normal forces and shear stress along the depth of a cross section of elements, caused by the conditions of fixing on the supports in confined spaces, i.e. the presence of the thrust effect.

- analytical model of concentrated deformation method takes into account the influence of factor of long action of external load on the spatial behaviour of segments of interflooring, erected from standard elements of framed multistory buildings and allows to appraise their stress and strain state at any level from the impact of external load.

- analysis of the results of theoretical and experimental studies of spatial behaviour of precast concrete floor slabs, supported along four sides, in monolithic buildings and segments of the precast concrete floor slab, erected from standard elements of framed multistory buildings, shows that these constructions have significant reserves in terms of the load-bearing capacity and serviceability.

- the economic effectiveness of results has been investigated, is obvious, and has been confirmed through the implementation of produced regulatory documents contributing to reduction of costs and terms for the design and construction of buildings by 30%.

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