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CALCULATION OF REINFORCED CONCRETE STRUCTURES TAKING INTO ACCOUNT THE INELASTIC PROPERTIES OF MATERIALS

B. Sulaymanov

Senior Lecturer, Fergana Polytechnic Institute, Fergana, Uzbekistan

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Annotation

The article provides a general description of the methods for calculating statically indeterminate reinforced concrete structures and the influence of complex design solutions, especially from monolithic reinforced concrete, which are widely used in modern construction. The conditions for the application of limit equilibrium methods for calculating the bearing capacity of structures, taking into account the increase in plastic deformations, are analyzed, and the rules that must be observed when designing reinforced concrete structures by the limit equilibrium method are proposed.

Introduction

Statically indeterminate reinforced concrete structures and complex structural solutions, especially from monolithic reinforced concrete, are widely used in modern construction. Among such design solutions are spatial multi-span frames of buildings with a regular and irregular grid of columns and walls, monolithically connected with floor slabs, transition slabs and structurally heterogeneous foundation slabs, frames of high-rise buildings with heavily loaded massive columns, walls and stiffeners, etc. However, methods calculation and design of such structures are practically not reflected in KMK 2.03. 01-96 “Concrete and reinforced concrete structures. Basic Provisions” [1-12], which mainly provides instructions on the calculation of the simplest reinforced concrete structures (planar structures such as beam-walls, floor slabs) taking into account the inelastic properties of concrete and reinforcement.

In design practice, as is known, for the calculation of statically indeterminate structures, he uses the structural mechanics of elastic systems. However, for a correct assessment of the bearing capacity, it is necessary to take into account the inelastic properties of materials.

Calculation of structures by the method of limit equilibrium.

One of the methods for taking into account the inelastic properties of materials is the method of limit equilibrium (MPR).

The application of the limit equilibrium method provides for the following prerequisites:

Deformations of the structure before the exhaustion of its bearing capacity must be small so that changes in the geometric quantities included in the equilibrium conditions can be neglected;

The forces in the structural elements, especially those determining its actual bearing capacity, must be limited by the limiting conditions, upon reaching which the deformations of these elements can increase indefinitely.

It is possible to check by two methods of MPR: static and kinematic.

In the static MPR method, if both prerequisites are met, the load corresponding to the limit of the bearing capacity of the structures will be the largest at which it is still possible to simultaneously comply with both the equilibrium conditions and the limiting conditions for all elements of the system. In the kinematic method of MPR, the load value is equal to the smallest of the values determined by the equality of the work of external forces and the limiting internal forces on any possible displacements. The possible displacement leading to this smallest value determines the structure fracture pattern when its load-bearing capacity is exhausted.

Depending on the type of structure, both static and kinematic methods can be applied. If the latter, with known fracture patterns, gives simpler expressions for the bearing capacity, then the static method does not require knowledge of the fracture patterns, since they are obtained as a result of calculation mainly using a computer.

Limiting conditions for strength are called inequalities that determine the limiting limit for efforts. When such an inequality turns into equality, the structural element to which the force in question relates enters a new stage of work.

A necessary condition for applying the limit equilibrium method for calculating the bearing capacity of structures is a sufficiently significant increase in deformations in sections where the forces have reached the limit conditions.

A sufficient increase in deformations in sections or in zones should be considered values or a set of values that ensure the growth of deformations in the structure after reaching the limit load, when the structure turns into a kinematically variable system. The accumulation of deformations in the zones of their insignificant development occurs mainly due to:

- rotation of a normal or inclined section from the action of a bending moment (plastic hinge);
- shortening or elongation in normal sections from the action of longitudinal forces (plastic shortening or elongation);
- Shear deformations along inclined sections from the action of transverse forces (plastic shear).

A combination of the main types of deformations in the state of ultimate equilibrium of structures along normal or inclined sections is allowed.

To ensure conditions that meet the second premise of the limit equilibrium method, i.e. the possibility of developing sufficient local deformations, when the forces in the structural elements reach the limiting conditions, the following rules must be observed:

1) design structures in such a way that the cause of destruction could not be the destruction of the concrete of the compressed zone before the reinforcement begins to flow;
2) to use for reinforcing steel structures that allow sufficiently large deformations. This condition is met by reinforcement of class AII, AIII, BpI with a two-line diagram, as well as reinforcement with a conditional yield strength of classes AIV - AVI, Bp II and a three-line diagram;
3) not to allow the use in statically indeterminate structures calculated by the limit equilibrium method

of ordinary and prestressed reinforcement that does not have adhesion to concrete (bundles, strands, rods and ropes in channels without mortar injection, trussed structures, drawn rods, etc. .

4) select the main design sections, as well as the places of reinforcement breakage in elements operating on a transverse load (beams, decks, racks, compressed with a large eccentricity), so that the relative height of the compressed zone in strength is less than the boundary, determined in accordance with paragraph 1. 3.7 [1-17].

This limitation does not apply to posts that do not carry crane or other cantilever loads and are compressed with a slight eccentricity. It is justified in such a way that in the risers, with their sufficient length and no loads on the consoles, the transverse forces are small, and therefore the bending moments change slowly in height. In this regard, if the limiting condition in the most dangerous section turns into equality, then very noticeable local deformations will occur on a rather large area of the adjacent section.

Accumulating over a relatively large length, these deformations will provide a sufficient angle of rotation between the sections that limit the region of large deformations on the rack. On the contrary, in elements working on a transverse load or on a load applied to the consoles, significant transverse forces often act in places of maximum moments.

When the first prerequisite of the limit equilibrium method is met, the structures must be sufficiently rigid; however, the sign of sufficiency is not the operational requirements, but the degree of change in the equilibrium conditions due to the resulting deformations.

After the implementation of zones of concentrated deformations and fracture lines in the system, the system becomes kinematically variable at the limit load determined by the limit equilibrium method, there corresponds a set of states for various displacements of the system. Of this set, the method for determining the displacement is the only one that corresponds to the achievement in the last plastic connection of the limiting value of deformation (angle of rotation, shortening, elongation or shear), after which the system becomes kinematically variable.

If it is necessary to take into account the deformations of the structure that develop before the exhaustion of the bearing capacity, then these deformations should be determined by calculation and to assess the strength of the structures, the limit equilibrium method should be applied to the deformed (with changed geometry) system. In other words, one should consider the limit equilibrium not of the original (before the application of the load) structure, but the limit equilibrium of a new structure, the geometric characteristics of which have changed as a result of the manifested deformation.

Conclusion.

When calculating by the method of limit equilibrium of structures reinforcing and relying on bulk materials, it is allowed to take the simultaneous achievement of limiting conditions in reinforced concrete and in bulk material (reaching limit shear stresses in the soil along slip lines).

At present, in all guidelines for the calculation and design of reinforced concrete structures, to a greater or lesser extent, it is allowed to take into account the phenomena of the redistribution of forces. The expansion of the application of new methods is facilitated by the fact that existing regulatory documents recommend taking into account the change in the distribution of forces caused by the occurrence of cracks and the plastic properties of structures [2].

Despite the studies of reinforced concrete elements and structures performed in world practice, the issue of redistribution of efforts remains relevant at present. In this regard, and the use of new high-strength reinforcing steels [3-34], it becomes necessary to clarify the established basic conditions and restrictions imposed on reinforced concrete structures during their design, taking into account nonlinear work.

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