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ASSESSMENT OF THE BEARING CAPACITY OF ELEMENTS OF REINFORCED CONCRETE FLOORS WITH REGARD TO ADAPTATION TO SPECIAL EFFECTS

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The paper discusses the features of the calculation of reinforced concrete bar structures during possible emergencies. A modified deformation model is used to calculate the bearing capacity of a bendable reinforced concrete element. Specific calculations can be performed at different levels: an element cross-section, an individual element, a structural system.

Key words: *special effects, progressive collapse, super-critical stages of deformation, transformation of the design scheme*

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The design-based analysis of buildings made of ferro-concrete at random emergency effects is widely used in construction due to a reasonable probability of man-caused threats: accidents of municipal life support systems, fires, explosions, as well as effects of nature (natural disasters) [1, 2]. The intensity of emergency loads associated with the operation of facilities has a tendency to increase. The importance of the calculations of various structural systems for the progressive collapse is confirmed by the development of the regulatory framework, in particular, the regulatory documents of the Russian Federation: SP 296.1325800.2017 [3] , SP 385.1235800.2018 [4]. As for similar documents from other countries, UCF 4-023-03 should be mentioned [5].

Calculation of progressive collapse fully implements the nonlinear approach in the calculation of reinforced concrete structures. The specifics of calculations are manifested at different levels: a system, a system element (bar), an element cross-section. One of the most common emergency scenarios is when an inner column in a multi-storey multi-span frame fails (Fig. 1). When assessing the bearing capacity of a slab element located directly in the area of the destroyed support, the following effects occur.

The structural system level. *A sudden method of external load application (impulse action), increase in span, presence of elastic support in the middle of the span.*

The element level. *Deformation with expansion force, presence of discrete cracks along the element. Transformation of the design scheme of the floor element (bendable element - rigid thread). Change of loading mode — from soft mode (torque load) to hard mode (curvature load).*

The element cross-section level. *Modal section loading, super-critical section work, deplanation of the cross section.*

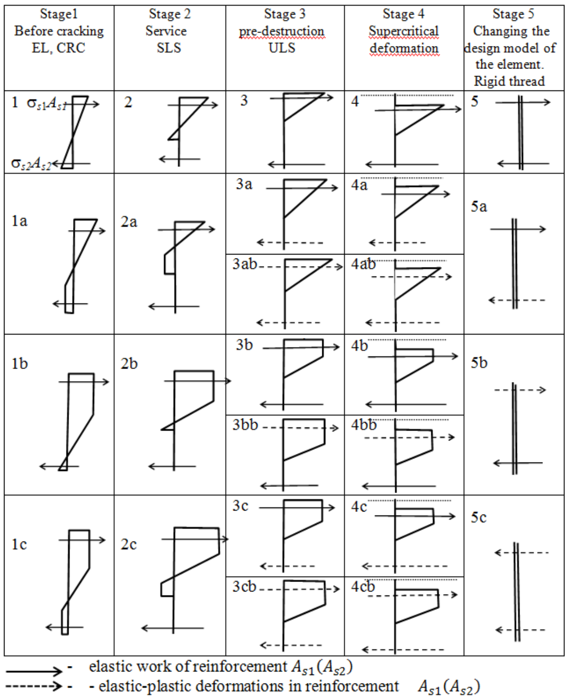
A modified deformation model is used to calculate the bearing capacity of a bendable reinforced concrete element. Adaptation of the deformation model is performed to obtain the crack formation process in the form of a system of discrete cracks, as well as to account for deplanation of concrete.

During the life cycle, the stress-strain state (SSS) of a bendable reinforced concrete element is usually transformed by continuous force deformation. Qualitative and quantitative changes of the parameters of an SSS element are determined in the specific stages (Table 1).

If the internal support suddenly fails, the dynamic effects of loading are manifested. Dynamic load factork_{din} is related to the plasticity factork_{pl}, which allows to use a quasi-static calculation instead of a dynamic one. For the quantitative estimation of the coefficients k_{pl} and k_{din} the calculation of the boundary curvature values is performed.

According to the calculation data, the maximum value k_{pl}=12,83 is obtained at symmetrical reinforcement and taking into account the work of stretched reinforcement bar A_{s2} according to the strengthening scheme. For the case of unilateral reinforcement, the properties of which are described in the Prandtl diagram, k_{pl} = 4,26. The corresponding dynamic coefficient values are k_{din} = 1,04 and k_{din} = 1,13. It is to be expected that, taking into account the clutch resilience, the values k_{pl} will increase slightly, which is optimal for improving the safety of the slab elements, as the effect of dynamic load application is minimized.

Table 1. Possible stress-strain state stages during deformation of a bendable reinforced concrete bar element



Values of bending moments in the cross-sections of a slab element at the operation stage (M_{ser}) and after the failure of the internal column (M_{fr}) are shown in Table 2.

Table 2. Values of bending moments in cross-sections of a crossbar

Powerfactor	Cross-sections		
	1-1	2-2	3-3
m_{ser}	-0,77	0,095	-0,152
m_{fr}	-0,173	0,146	0,280
m_{fr}/m_{ser}	2,250	1,540	1,850
$(m_{fr}/m_{ser})k_{dim}$	2,340	1,600	1,920

$$m_{ser} = \frac{M_{ser}}{WR_{bn}},\ m_{fr} = \frac{M_{fr}}{WR_{bn}}, W = bh^2/6, k_{din} = 1,04.$$

The modal loading of ferro-concrete elements was most fully considered in the works of N.I. Karpenko and his followers [2]. In the zone of the failed support (section 3-3, Fig. 1), the influence of changes in the original design scheme is shown: the designed span increases twice in the presence of elastic suspension in the form of a column of the second floor.

The work of section 3-3 is accompanied by initially forced unloading, then the process of deformation continues when the bending moment sign changes. This process should be interpreted as "hard mode" of loading – curvature loading.

Taking into account the effect of expansion is one of the additional reserves when assessing the bearing capacity for bendable elements of monolithic reinforced concrete structures at $h/L \geq 30$ (Fig. 2).

In the process of calculation, the deformed scheme of the reinforced concrete element is considered with regard to the scheme of discrete cracks location (future stationary plastic joints).

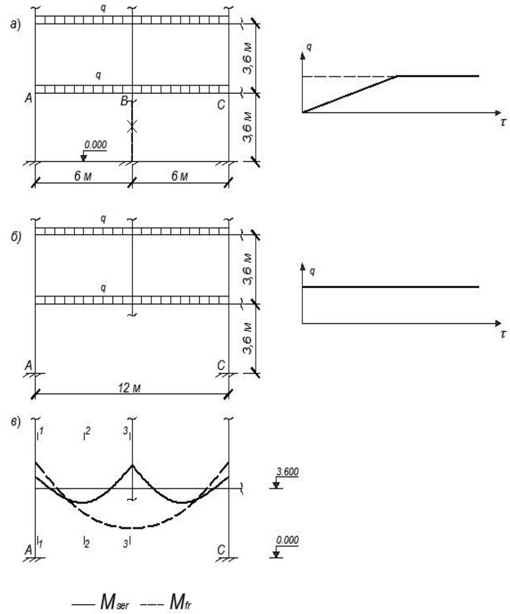


Fig. 1. Design scheme of a slab element in case of failure of the internal column of the ground floor

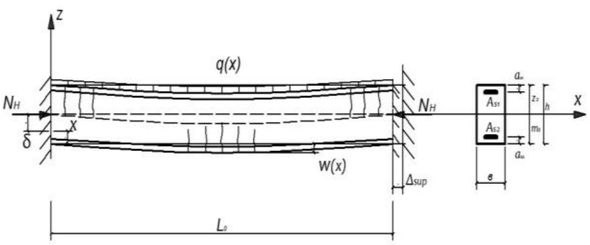


Fig. 2. Design scheme of a reinforced concrete element working with a split

After the relative deformations in one of the sections of the element in the extreme compressible concrete fibers have reached their ultimate compressibility: $\varepsilon_{bc}(z)|_{z=x}\varepsilon_{bcu}$, the critical deformation stage is realized. This stage is realized only in the "hard mode" of loading. In the critical stage, the bendable bar element under the transverse load and longitudinal force is transformed into a rigid thread.

Discrete cracks – the curvature concentrators – determine the places of fracture of the axis of the bar and lead to the development of deplanation of the cross-sections of the concrete branch. Therefore, after the cracks are formed, the Bernoulli's hypothesis can be used to model the process of force resistance of a bendable reinforced concrete element to a limited extent. The V.Z. Vlasov's bimoment theory approach was used to account for deplanations in the concrete branch. This theory was designed for continuous cross-section bars.

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