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STATES OF STRENGTH AND DEFORMATION OF REINFORCED CONCRETE ELEMENTS IN BENDING

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Abstract
This article describes the work done to determine the deformations of composite reinforced flexible beams in concrete and reinforcement, measuring the slope of the beam, the location and width of cracks formed in the beam.

Keywords: stress, deformation, deformation state, strength and deformation indicators, elongation and compression reinforcement, deformation of concrete compression and elongation areas.

The theory of calculating the load-bearing capacity of reinforced concrete elements has gone through three main periods in its development and improvement. In the first - initial period, the theory of "Calculation by fixed stresses" was used in the calculation of reinforced concrete elements. This theory was based on formulas in the science of material resistance. The second period of development begins with the important conclusions obtained from the scientific works of A.F. Loleyt and A.A. Gvozdev. Based on these conclusions, a method of calculating the "Deterioration stage" was created. The norms and technical conditions for calculating reinforced concrete constructions according to this method were in use from 1938 to 1955. In the third period of development, a new method - "Boundary states" calculation method - was created. This method is still being improved every year.

The relationship between stress and strain in concrete is not linear. Even if reinforcement is added to the concrete, this connection remains nonlinear. At the same time, the influence of concrete and reinforced concrete on resistance, penetration, heat, and the cracks formed in the stretching zone strongly affect the stress-deformation state of reinforced concrete.

In addition, if it is taken into account that these properties depend on the mesh of concrete and reinforcement, the duration of the load, it becomes more clear how difficult it is to create a perfect theory of reinforced concrete resistance.

From the experiments, it was found that the non-linear deformation of concrete and the presence of cracks in the tensile part of reinforced concrete structures have a great influence on the stress-strain state.

In many cases, the formulas of resistance of elastic materials lead to confusion in the calculation of reinforced concrete structures, it is necessary to see the theory of resistance of reinforced concrete based on experimental data.

Observations carried out in various reinforced concrete structures showed that as a result of the increase of the externally acting load, the stress-deformation state occurs in three stages. Cross sections of reinforced concrete beams can have different shapes. Among them, the most common ones are right quadrangular, with the shelf located above, tavr and koshtavr shaped sections.

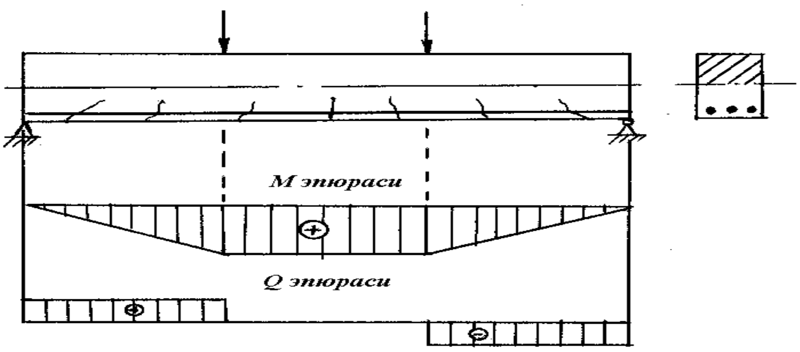

Figure 1. Placement of reinforcement in a bending element and its operation under load.

Along with these, the lower shelf, square, trapezoidal, hollow and other shaped sections are also used. Torn cross-sections are found both in individual beams and in monolithic beams with ribs. The height of cross-sections is usually 1/10-1/20 of the length of the beam, and the width is 1/2-1/4 of the height. In order to make the cross-sectional dimensions uniform, the height of the beam (if h < 500 mm) is multiplied by 50 mm and (if h > 500 mm) by 100 mm; the width of the beam is 100, 120, 150, 180, 200, 250 mm, the length is a multiple of 50 mm.

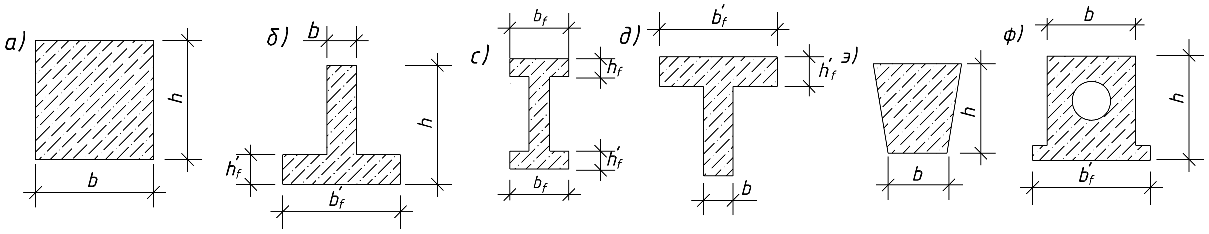

Figure 2. Cross-sectional surfaces of reinforced concrete beams.

Longitudinal working reinforcement is placed in the tensile zone of the beam, leaving a small protective layer. In order to increase the resistance in inclined sections, transverse reinforcements are installed. In addition, mounting reinforcement is placed in the compression zone of the beam to fix the transverse reinforcement and create a space frame. The number of flat welding webs in the cross-section of the beam can be different. If the width of the cross section of the beam is 100-150 mm - one, if the width is greater - two or more meshes are installed. In order to save steel, a part of the working longitudinal reinforcements can be disconnected in the middle without being delivered to the supports. This work is done based on accounts. However (if the width of the beam is 150 mm and more) at least two masts must be continued to the support. Separate flat meshes are joined together on the ground of the struts to form a spatial frame. When the beams are reinforced with fabric frames, clamps are installed to receive transverse forces. If the longitudinal struts in the compression zone do not exceed two - an open clamp, if they exceed two and reinforcement should be placed in the compression zone according to the calculation - a closed clamp is placed. If the width of the beam is greater than 350 mm, it is recommended to put a four-wire clamp; such a clamp consists of two two-wire clamps. The number of flat weld webs in the cross-section of the beam can be different. If the width of the cross section of the beam is 100-150 mm - one, if the width is greater - two or more meshes are installed. In order to save steel, a part of the working longitudinal reinforcements can be disconnected in the middle without being delivered to the supports. This work is done based on accounts. However (if the width of the beam is 150 mm and more) at least two masts must be continued to the support. Separate flat meshes are joined together on the ground of the struts to form a spatial frame.

In order to speed up the production of reinforced concrete structures, reinforcements in the form of welded wire mesh and frames are used. The working rod is placed in one or two rows along its length. It is technologically more convenient to one-way weld longitudinally placed rods with transversely placed rods.

Flat frames are sometimes called nets. After the flat frames are installed on the formwork, tie rods are usually used to connect them together to maintain their design positions, resulting in a space frame.

When designing welding frames, it is necessary to take into account the conditions of welding technology in order not to burn small-diameter rods, for this, $d_w > 0.25 \cdot d$, d_w -where dw is the diameter of transverse rods, and d is the diameter of longitudinal rods. Welded frames are used for reinforcing long elements (beam, column, etc.), and welded meshes are mainly used for reinforcing plate structures. Depending on the direction of the working rods:

a) Longitudinal working fittings;

b) Transverse working armature;

c) Is divided into two types of working fittings located in both directions.

Nets are available in coil and flat form. Working reinforcements placed lengthwise in winding nets are made of reinforcements with a diameter of no more than 5 mm. If the diameter is more than 5 mm, the working reinforcement is made of rolled mesh or flat frames. The maximum diameter of crossbars in winding nets does not exceed 8 mm.

Rolled and flat nets are made of B-1, B_p-1, *A*-I, *A*-II, *A*-III class fittings.

Woven mesh and frames are used in complex looking forms and monolithic structures, as well as in structures that work under the influence of dynamic and repetitive loads. Fabric mesh and frames are connected with a soft (d =0.8...1 mm) wire at the point where the rods cross each other.

Three series of beams were prepared and tested to investigate the pure bending work of the bending elements on normal sections.

The length of the beams is 260 cm, taking into account the loading of two symmetrically located loads with different cross-section intervals (from 1.5 ho to 4 ho). The cross-section of the beams is 30 cm high, 16 cm wide, and the calculated length is 220 cm. Working fittings are different in each series.

In the I-Series, 2 Ø12 class A-III fittings are used.

II-Series uses 2 Ø14 class A-III fittings.

In the III-Series, 2 Ø16 class A-III fittings are used.

The number of longitudinal reinforcements was determined based on the recommendations adopted in QMQ 2.03.01-96 for calculating the strength of normal sections.

Transverse reinforcement in beams of the first and second series was 0.26%, and in beams of the third series 0.26%. In this case, 5 x 15 cm thick wire ropes made of V-I class wires with a diameter of 5 mm were placed on both sides, and 3 x 30 cm in the middle. Experience in the reinforcement of beams.

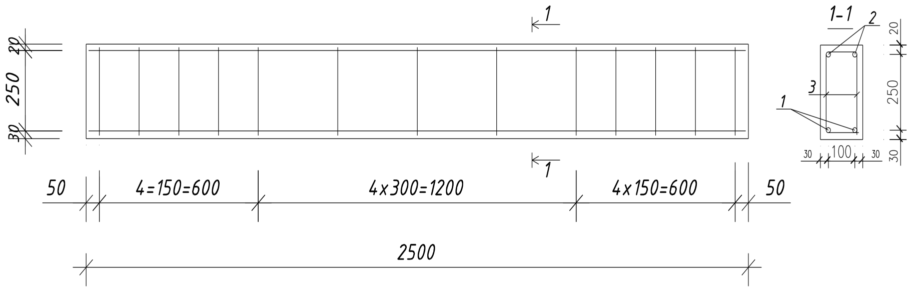

Figure 3. Anchorage of tensile longitudinal reinforcement when bending elements are freely supported.

1) fittings with 2 diameters of 12, 14, 16 class A-III;

2) fittings with 2 diameters of 8 classes A-I;

3) clamps made of wires of class V-I with a diameter of 5 mm are placed every 15 cm;

A total of 6 beams were made. In beam marking, letters B1 B2 or B3 indicate a group of numbers, that is, the number of transverse reinforcements (I-0; II-0, 0.26%), the last number indicates the number of the beam according to the loading scheme in this group. For example, in the beam of the B3 brand, quartz sand was taken as concrete fillers, reinforced with clamps at every 10 cm step, the cross section is equal to 4 ho.

Beams are made in a rectangular cross-section, to compare the results, the dimensions are the same as the previous beams - the cross-section of the beams is 30 cm high, 16 cm wide, and the calculated length is 220 cm. Woven mesh and frames are used in complex looking forms and monolithic structures, as well as in structures that operate under dynamic and repetitive loads. Fabric mesh and frames are connected with a soft (d =0.8...1 mm) wire at the point where the rods cross each other.

Three series of beams were prepared and tested to investigate the pure bending work of the bending members on normal sections.

Concreting of test beams.

To study the properties of concrete under investigation, control samples at the same time as experimental beams - cubes (15x15x15 cm) for determining the cube strength, prisms for determining the coefficient of prism strength and compressive stress ratio (15x15x60 cm), prisms for studying the shrinkage and yielding of concrete (10x10x40 cm)), cylinders (diameter 11 cm, height 40 cm) and prisms (15x15x10 cm) were prepared to determine the axial tensile strength of concrete and to study the connection of reinforcement with concrete.

2 tables. Composition of concrete

T/r	Concrete strength, MPa	1 м^3 бетонга материаллар сарфи						Dry in the case concrete volumeмассаси, kg/m^3
		Big filler		Ash	Kvars sand, kg	cement, kg	Water, liter	
		5-10	10-20					
I	37,6	330	700	-	300	530	2	1800
П	23,1	230	800	450		340	240	1600
Ш	34	400	560	250		530	230	1750
IV	28,2	313	627	259		419	247	1600
V	34,8	320	640	-	371	376	215	1750

Before testing the beams, their geometric dimensions were measured and control samples were tested, and the main characteristics of concrete and reinforcement were determined based on their results.

To facilitate the visual control of the appearance and development of cracks, the sides of the beams are plastered with mortar, and the contours of the reinforcement frames are drawn on it.

The beams were tested on the stand. The stand consists of lifting and straxovka supports, a power frame, a hydraulic jack, a pumping station and a dividing beam.

The load-carrying capacity of the beam was created using a hydro-jack with 250 and 500 kN. The hydraulic jack works using a manual pump station of the brand NSR-400M. The hydrojack support is mounted in the center of the distribution crossbar, and the spherical support rests on the power frame. The load from the distribution crossbar is applied to the two sections of the tested element through the support on the metal plates with dimensions 10x17 mm and thickness 20 mm. The same plates are also installed on the supports supporting the beams, which are loaded through a 50 mm diameter cylinder.

Beams of the I, II and III series were tested with the same loads, the distance between the supports is 1.5; It was 2.25, 3 and 4 ho. Loads were applied to the beams step by step with a force of about 1/20 of the estimated breaking load, holding each step for 10...15 min. At this time, all measuring instrument readings were recorded, the appearance of new cracks and the development of existing cracks were recorded, and the width of the opening was determined. At the level of longitudinal reinforcement - normal; in the center of the weight of the load and in the largest opening places - oblique; in the beam with transverse reinforcement - it was determined at the intersections of the clamps with oblique cracks. The loading step was reduced twice before the expected cracks appeared, as well as before failure.

As a result of testing the beams of the I, II and III series, the following was determined:

-loads of occurrence of normal and oblique cracks in the pre-support sections of the beams and in the middle part of the span;

- character of distribution and spread of normal and oblique cracks and their opening width;

-destructive loadings and the character of failure of experimental beams;

-deformation of longitudinal and transverse reinforcements;

- displacement of the longitudinal reinforcement in the cross section of the beams.

These data were used to analyze the experimental results and compare them with theoretical data and results obtained by other authors.

In order to determine the stress-deformation state of concrete, electrodes with a base of 50 mm were attached to one of the cross-section steps of the side of the beams. Similar sensors were attached along the upper edge of the beam to the loading area in a chain pattern to measure the concrete deformation along the compression zone of the beam at that step of the cross-section. The stresses in the longitudinal reinforcement and clamps were measured using strain gauges on a 20 mm base attached to them according to the scheme shown in Figure 2.3.

Beam deflections were determined using Maximov system progibometers with a scale of 0.01 mm. They are mounted on pins (to prevent the bases from sinking) at the level of the neutral axis in the base sections of the frames. Deflections were determined in the center of the beams and in sections under load.

Cracks were measured using portable microscopes (scale unit 0.05 mm) with a magnification of 24 times the opening width.

The analysis of the average deformation of the longitudinal reinforcement measured with the help of electro-strain gauges shows that the leveling of deformation and stresses at the boundaries of the shear range occurs after the formation of normal cracks.

To a greater extent, this flattening occurs as a result of the formation and development of oblique faults. As a result of the development of oblique cracks, an intensive increase in deformation and stress is observed at the intersections of transverse reinforcement and cracks, and the difference between deformation and stress along the length of the longitudinal reinforcement decreases at the limits of the projection of oblique cracks. But the full alignment of deformation and stresses does not occur, especially in hammers with a collar, the alignment is less pronounced than in hammers without a collar.

According to the results of the conducted experiments, the differences of the deformations and stresses in the transverse reinforcement between the starting and ending intervals of the oblique section were 10....12% in the beams without the clamp, and 22...23% in the beams with the clamp.

Conclusion

According to the measurement results of the deformation and stress in the transverse reinforcement, the deformation and stress in the clamps are not very large until the oblique cracks are formed, and they are evenly distributed along the length. When oblique cracks are formed, an intensive growth of deformation is observed at the intersection of the clamps with oblique cracks. Strains and stresses are not uniformly distributed along the length of the boom. Deformation and stress decreased as the clamps moved away from the intersection with oblique cracks. Deformations in the clamps along the length of the horizontal projection of oblique cracks are unevenly distributed. The largest increase in deformation and stress in clamps is observed in the middle part of oblique cracks, and the least - at the ends.

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