TEST ON PRE-STRESSED REINFORCED CONCRETE BRIDGE BEAMS

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The results of test on bridge 27 m long prestressed reinforced concrete beams have been presented. Operational fitness of beams has been estimated according to the second limited state, in particular, by comparison of the received values of diflection with theoretically calculated ones. All tested beams satisfy the project specifications.

Loading redistribution diagrams in tested beams have been presented. It has been stated that before operational loading in beam stretched zone the concrete is gradually liberated from prestressing and it doesn't participate in beam working. Outside loading is completely balanced by prestressed reinforcement.

Both bridges consist of sectional pre-stressed concrete beams with span L=27,0 m and supports of one and the same type, in particular, of pile foundation and pile grating, columns and cross-bars.

The Lekhura Bridge consists of 3 spans, length 108 m and width 13,7 m.

The maximum height of the support columns is 10,8 m (See photo 1), and the length of the Igoeti Bridge is 175 m, maximum height of the support columns is 18,9 m.

Foto 1. Lekhura Bridge

The work of pre-stressed reinforced concrete beams is evaluated by comparing three experimental data obtained as test results, with normative requirements of the limit condition.

A Structure cannot be considered as suitable for use and does not pass the test, if the breaking force or deformation (deflection) and the width of the crack exceed corresponding values presented in norms and technical conditions:

- **For example, maximum deflections in reinforced concrete beams must not exceed 1/500 ÷1/600 of the value of the span, and a width of crack opening of 0,1mm for** elements working on central stretch, or non central stretch, when the total section is stretched;

- 0,2 mm deflection, for non-centrally compressed or stretched elements, and
- 0,3 mm for all other elements.

The evaluation of the structure is made

- first according to the limit strength conditions,
- second – stiffness (movements, deformations) and
- third – crack resistance.

The most reliable test is to bring the structure to the breaking condition; according to these results judgment can be made about the condition of the structure at every stage of the load and finally the reserve coefficient of the strength can be defined. However this type of test besides technical difficulties, is also expensive (unrealistic), because the structure becomes useless for further use.

Thus, generally the evaluation of structures is made based on the second limit condition, in particular based on stiffness (rigidity).

Pre-cast and pre-stressed reinforced concrete beams of two Highway Bridges were tested. The Length of beam L=27,0m and T-shaped (see Drawing 1). In the stretching zone, 20 steel tendons (7 wires each) are located, with a total area of 139,0mm^2, a strength of R=1905 N/mm^2 and a yield rate of R = 1625 N/mm^2. For pre-stressing the beam, each tendon is stretched with 195,4kN force, thus creating 1406 N/mm^2 stress in each tendon.

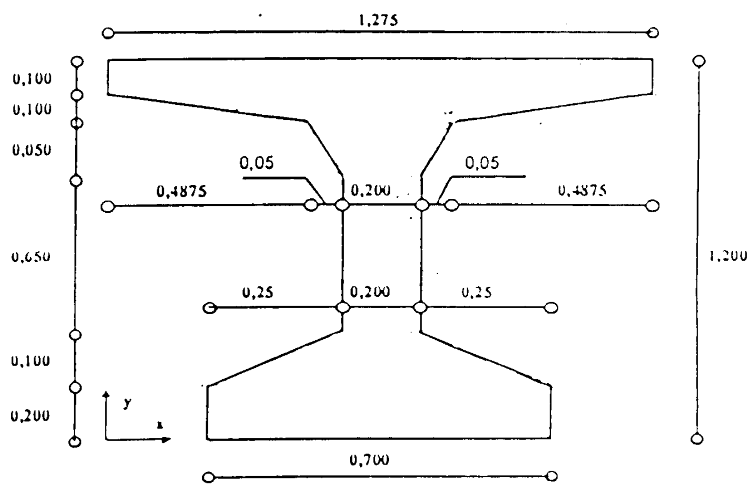

Fig. 1. Cross section of the beam

Information about beams and test results are presented in the following table.

The stiffness of the beam is calculated by comparing the measured f_m with the Standard f_{th}=0,049m.

f_m - is the deflection, which arises on the structure by control loading, and

f_{th} - is the theoretical calculated deflection, obtained during brief control loading (2P=479kN).

Beam No.	Age at Test, days	Concrete Compressive Strength, N/mm^2		Maximum Deflection, cm		
		At cutting tendons	At 28 days	At the moment of strength application	After 30 minutes under load	After unloading
1	32	48,5	69,2	3,50	3,56	0,19
2	89	41,9	57,2	1,97	2,10	0,13
3	119	43,3	54,7	3,16	3,33	0,22
4	157	39,7	64,0	2,30	2,36	0,20

The testing scheme presents the beam with *L= 26,7m,* placed on two supports with the concentrated load at 1/3 rd of the span (see foto).

The size of the deflection was measured by Maximov's type deflectometer, with 0,01mm per unit. The stiffness of the structure was evaluated based on the deflection of the middle part and settlement of the supports. The actual deflection was defined as the difference between deflections measured in the middle part of the beam and half-sum of the support settling.

Before the test, the beam was visually inspected to fixate cracks and other defects. As a result of inspection no defects could be observed on the beam.

Foto 2. General view of the beam test

The load was applied step by step. The weight of devices creating the loading scheme was considered as the first stage, which equals to 40kN. The loading of stage II equaled 184kN, stage III- 280kN, stage IV-280kN and stage V – the control load – 496kN.

For achievement of control loading, the load was maintained for 30 minutes. During this period thorough inspection of the beam surface was carried out to reveal appearance of any strain cracks. This process was carried out with a magnifying lens X 8, Proceq, Switzerland, with 0.01 mm per unit. After inspection no appearance of cracks could be observed.

After this, unloading of the beam took place and the residual deformation was measured.

Fig. 2 shows the scheme of interdependence of the beam loading P and the deflection f. As it can be observed from the scheme, this interdependence is rectilinear and the maximum value f_{max} was reached during the control loading. After 30 minutes delay, the deflection increased insignificantly (see Table). All of this shows that the beam remained in the elastic stage and there were no cracks formed.

We have defined the distribution of forces in the tested beam, which is based on the method developed by Prof. V. Mikhalkov for centrally stretched pre-stressed reinforced concrete elements. This picture is presented in a form of O_pABC curve (see Fig. 3).

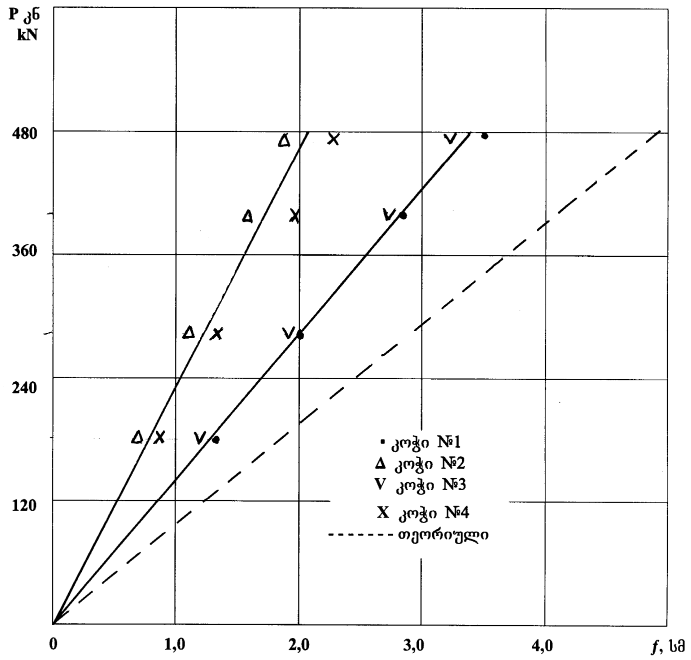

Fig. 2. Scheme of deflection and load interdependence

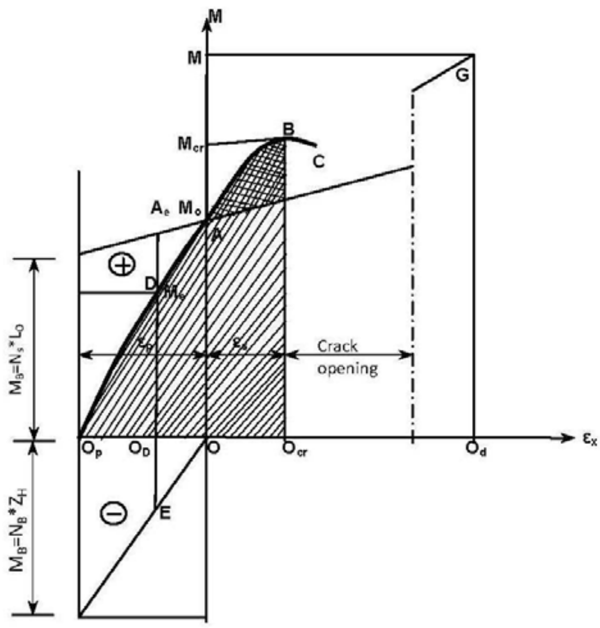

Fig. 3. Distribution of forces in the pre-stressed reinforced concrete elements

At the starting moment, when external forces do not impact the element yet, its materials (concrete and reinforcement) are already in the stressed condition, generated by the influence from pre-stressing of the structure. This influence is balanced and the initial deformed condition is maintained by the compressing force M_B in the concrete and M_s in the reinforcement, at this time $M_B = M_S$.

It is advisable to consider as initial condition, such stressed condition, when forces are exhausted in the lower edge of the concrete structure from the working load. This condition on the diagram is reflected with the OM line, on which the vertical coordination axis is applied.

In O_pO, the total load of each stage until work load is totally balanced by the beam reinforcement. In any D point, which causes O_p O_D deformation, external force M_e is balanced by the strain created in the reinforcement

$$M_e=(O_D D+ DA_e)-O_DE$$

Due to the fact, that the compressive force in the concrete and the tension in the reinforcement are equal, we get:

$$DA_e=O_DE$$

And, accordingly

$$M_e= O_DD$$

Or whatever the value of the force is when gradually releasing the beam concrete from pre-stressing, the external force is totally assimilated with the pre-stressed reinforcement. In this case, the concrete compressive force and the pre-stressed part of the beam reinforcement will always exist, as shown on the diagram (+) and (-). Considering these forces, as internal mutually balancing, and which are not linked with the outside forces, we define that these forces in the O_pO range will be directly balanced by means of the stretched beam reinforcement. But the variation of the balance, or in other works, outside the bearing capacity O_p from the deformation point to point A, significantly differs E_a= $(1,8\div2,2)X10^5$ according to the steel elasticity module. On the diagram the O_pA line is significantly curved for the ε_p deformation, and only slightly curved for the AG line for the ε_a deformation.

The tangent of angle of the bending of the straight line O_pA is called load module, or conditional module, which is geometrically calculated from the diagram and it is considered, that E_{con}= $22E_s$ [1] that pre-stressed reinforced bar during the exploitation on the action section accumulates such load capacities, which corresponds with elasticity of steel, E_s= E_{con}, this means, that the steel is working with ten times decreased elasticity.

After the O_pO deformation, which means above M_O, the reinforcement and the concrete participate in taking up the forces. In this case the receiving of load by reinforcement is carried out according to the AG line and in case of concrete according to ABC curve, or it is acting similarly as in the case of reinforced concrete.

The pre-stressed force of the test beams is N_O =20*195,4 = 3908kN. Preliminary losses for reinforcement are 15 % of pre-stressing, N_{O2} = 0,85*3908 = 3322kN.

Forces in the concrete, on the level of reinforcement load centre will be:

$$\sigma_b = \frac{N_{02}}{A_b} + \frac{N_{02} \cdot e_p^2}{\Im_{xB}} = \frac{3222}{0{,}53375} + \frac{3322 \cdot 0{,}563^2}{0{,}101675} = 16580 \text{ kN/m}^2 \approx 16{,}6 \text{ MPa.}$$

In case of concrete strength R=60 Mpa, the E-module will be equal to E_b=39000 MPa, according to the norms, then the compression deformation from pre-stressing on the outer layer of the beam will be:

$$OO_p = \varepsilon = \frac{\sigma_b}{E} = \frac{16{,}92}{39000} = 43{,}4 \cdot 10^{-5}$$

The Compression force in the outer layer will be

σ_b= 16918 = 16,92 Mpa.

The Bending moment caused by the maximum load (2P=479kN) during the test is

$$M_d = 2155{,}5 \text{ kN/m}$$

This force corresponds to the following stress

$$\sigma_b = \frac{M}{W} = \frac{2155{,}5}{0{,}15576} = 13839 \text{ kN/m}^2 \approx 13{,}84 \text{ Mpa.}$$

As long as the outside stress (13,84 Mpa) is less than the forces caused from compression forces (16,6 Mpa) in the outside layers of the beam, the compression force caused from pre-stressing, still acts. All of the above mentioned, gives us the possibility to conclude, that under the test load the beam worked in the elasticity stage, in the stretched zone, without any cracks. It is also shown in the linear relation between load and movement deformation.

R E F E R E N C E S

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