Theoretical and Experimental Research of the Complete Shearing Stress-Strain Diagram

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The descending branch of the shearing stress-strain diagram τ-γ has been obtained for the concrete in pure torsion in the course of the tests of the concrete cylinders under laboratory conditions. Analysis of its comparison with the theoretical one testifies both to quality and exactness of the theoretical methodology and reliability of the worked out setting, experiment's cleanness and authenticity of the obtained data.

Key words – torsional stiffness, plastic deformation, stress-strain diagram for the concrete in pure torsion, the diagram's descending branch, pure torsion.

I. Problem description

Modern researchers of reinforced concrete pay much attention to the bending stiffness' studies and mechanical strength characteristics' investigation, work out different patterns of the concrete behaviour under compression-tension. However torsional effect on the work of the reinforced concrete constructions should be studied not less because of their constant necessity to resist the effect of not only bending and compressing forces but of the torsional ones (for example, in any asymmetrical loading of the spatial structures' elements like bridge superstructures, overlap constructions, as the influence of the forces redistribution on the side beams causes torsion etc.). In the software packages the bending stiffness' changes at all the steps of the concrete work is taking into account unlike the torsional stiffness' reduction.

The purpose of the work is to research the shear modulus G_c taking into consideration nonlinear properties of concrete and to examine the full shearing stress-strain diagram which was obtained as the result of the theoretical analysis and confirmed in the experimental tests.

The shearing stress-strain diagram should be used as the generalized characteristic of mechanical properties of concrete (fig.1), similar to the compression stress-strain diagram. Modern building standards provide structure's calculation by the elastic stiffness characteristics, however reinforced concrete elements are not solid elastic bodies, because of what this calculation doesn't correspond to the real picture of the element's work and requires research of the shear modulus at all the phases of the concrete work, taking into account plastic deformations, cracks influens and introduction of results.

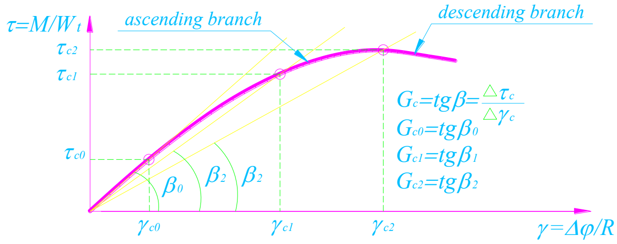

Fig. 1. General view of the concrete deformation under the influence of the pure short duration torsion

By the theoretical methodology [2] angular deformations depend on tangent tensions as

$$\tau_c = G_c \gamma_c = \frac{E_c^0 \vartheta_c}{2(1+\mu_c)} \gamma_c ,$$

where τ_c is a tangent tension; γ_c is an angular deformation; G_c is the shear modulus; E_c^0 is an initial modulus of elasticity of concrete; ϑ_c is a coefficient of the secant shear modulus' change, it is determined by [4]; μ_c is a Poisson's ratio for the concrete.

II.Summary of the major research materials

The essence of the method of obtaining the shearing stress-strain diagram for concrete is in the use of traverse for a supervised efforts' transfer on a concrete model (fig.2). The principle of shear and compression stress-strain diagram for the concrete is common. The difficulty is in the experimental definition of the descending branch's parametric points by usage of the traditional experimental settings because of the sudden element's destruction as a result of the ultimate potential deformation energy immediately realizes to the impact energy.

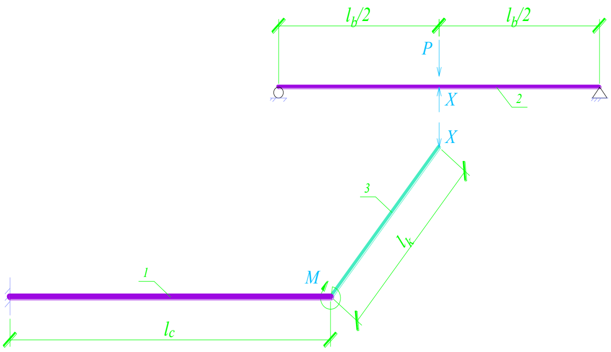

Fig. 2. Forses' scheme in the statically indeterminate system «the beam – the model to tested for torsion»

Notation conventions:

1 – the concrete model;

2 – traverse (cross-beam) to control the forces on the cylinder;

3 – lever to create the required torque at the concrete element;

P – the force applied to the beam;

X – the force, which is passed on concrete cylinder by way of the lever 3;

M – the torque, perceived by the investigated sample.

The advantages of this method of obtaining parametric points shearing stress-strain diagram is provided by the common deformation of the model with the cross-beam from the very beginning of the loading untill its complete destruction and lack of necessity to interference in a testing process that provides obtaining of the clear charts' M_t-τ values, respectively avoiding mistakes of the system «researcher-explored model".

It should also be noted that designing the installation using two cross-traverse of metal, plastic, etc. is useful for the convenience and security of the members in any kind of relationship of their deformability and strength.

To compare theoretical research with the experimental ones the dependence of the shear angle on the tangent strains has been calculated by the the above technique. The main physical and mechanical concrete characteristics by the experiments' results, which are f_{ck}=15.3236MPa, f_{ctk}=1.3328MPa, E_{ck}=2275.961MPa, correspond the class of concrete C16/20, which properties by DBN are f_{ck}=15MPa, f_{ctk}=1.3MPa, E_{ck}=2200MPa (elasticity modulus is taken for the fine-grained concrete which was used in the experimental trials)**.**

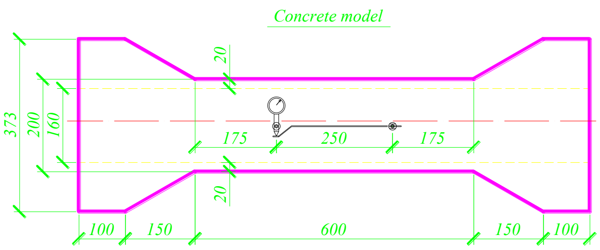

Fig. 3 Geometric data of the concrete model

The obtained results can be reduced to the M_t-φ and τ-γ diagrams. We investigate the diagram τ-γ (fig.3) because it characterizes not only the current concrete and elements' characteristics, but is the fundamental one and is substantially important for the deflection mode's research of reinforced concrete.

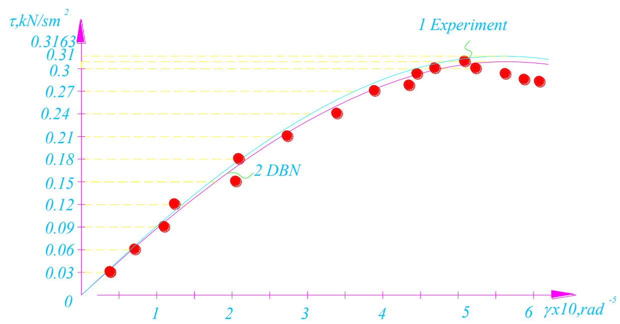

Fig. 4 The comparison of the theoretical shearing stress-strain diagrams with the experimental one

The analysis of diagram allows to make a conclusion that tangent tensions diminish on 9% on the descending branch, the shear angle increases on 26% comparatively with the ultimate point of the diagram. It is evidence of that one should use the theoretical data [4] quite carefully, as the descending branch of the shear stress-strain diagram is short enough, and the length of the descending branch should be limited. Probably, it is the consequence of that we deal with tension (by the main areas), similar to that the complete concrete compression (tension) stress-strain diagram also has long enough descending branch in the compressed zone, and short one in the stretched part.

The degree of the curves', which were build by the theoretical and experimental data, accordance obtained for the tangent tensions by the numerical interpolation can be defined by the **correlation ratio** η. The meaning η=0,984 testifies the high probability level of approaching the value γ, which was approximated by the experimental data, and theoretical value defined by the methodology [2], and also tells about sufficient exactness' degree both of the developed theoretical methodology of the complete shearing stress-strain diagram's calculation and effectiveness of the experimental mount offered by the authors.

Conclusions and Prospects of Researches

1. The importance of the conducted researches is substantiated by the fact that direct influence of the shear modulus of the concrete with consideration the plastic deformations on the torsional stiffness of the constructions at the different stages of their work take place, howehever it is not taken into account by the modern calculation methodologies and software packages.
2. The proposed method for the experimental obtaining of the complete shearing stress-strain diagram differs in reliability of the parametric points' determination, absence of the difficult mounts' constructions' necessity and risk of human factor's influence.
3. As the result of the concrete models' experimental research the shearing stress-strain diagram has been built by the parametrical points obtained in the laboratory terms.
4. The degree of the experimental graph with the theoretical dependence's nonlinear connection's accordance is determined by the correlation ratio. The defined correlation ratio η=0,984 testifies both to the experiment's cleanness and correctness and about the reliable and well-grounded theoretical methodology.

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