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INFLUENCE OF THE ACCEPTED CONCRETE DEFORMATION DIAGRAMS ON THE RESULTS OF CALCULATING BENDING REINFORCED CONCRETE ELEMENTS

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The article describes the influence of various types of concrete deformation diagrams on the accuracy of the deformational analysis of a bending concrete element. By analyzing different forms of diagrams, we get results with the help of the software "Beta 4.2 (5.0)". After getting the results, conclusions are drawn, according to particular qualities concerning the investigated element.

The strength and deformability of concrete in a reinforced concrete structure depends on the structure of the already hardened concrete, which includes pores and micro-cracks. As numerous experiments have shown, the smaller the number of defects in concrete, the more durable it is. The strength of concrete increases by improving its composition, technology of production and subsequent concreting of structures. Due to the fact that the strength of concrete depends on many factors, the calculation of structures is based on the deformation diagrams of concrete, which are essentially the generalized characteristics of the mechanical properties of concrete. The deformation diagrams are completely different under certain conditions, considering the action of the loads on the specimen: two-axial, three-axial compression/tension, tension - compression; short-term/long-term and others [1].

In this paper, we will consider the basic characteristics of concrete, obtained as a result of an axial short-term compression and tension. The diagram shows the relationship between stresses σ and longitudinal relative deformations ε of compressed (tensioned) concrete. To describe the deformation diagrams, we will use two values of relative deformations: - ε_{cl} relative deformations, corresponding to the peak stresses in the diagram; - ε_{cu} limit relative deformations of concrete under compression.

Introduction. To evaluate the stress-strain state of reinforced concrete elements at different stages of their loading, currently, the most promising is the nonlinear deformation model, since it is more accurate. The choice of one or another form of the diagram and its influence on the calculation results, will be considered in this paper by using the software "Beta 4.2 (5.0)".

Task formulation. Calculation of a beam having a rectangular cross-section concerning its strength, using the deformation method for different options of the concrete deformation diagrams.

Given:

b = 300 mm

h = 800 mm

c = 70 mm

$l_{eff} = 4500$ mm

Concrete class C20/25 ($f_{ck} = 20\text{MPa}; f_{cd} = 13.4\text{MPa}; E = 27000\text{ MPa.}$)

Tensioned reinforcing bar of class S500 ($f_{yk} = 500\text{MPa}; f_{yd} = 450\text{MPa}; E_s = 20 \cdot 10^4\text{MPa.}$) $A_{st} = 1963\text{ мм}^2$(4Ø25 S500).

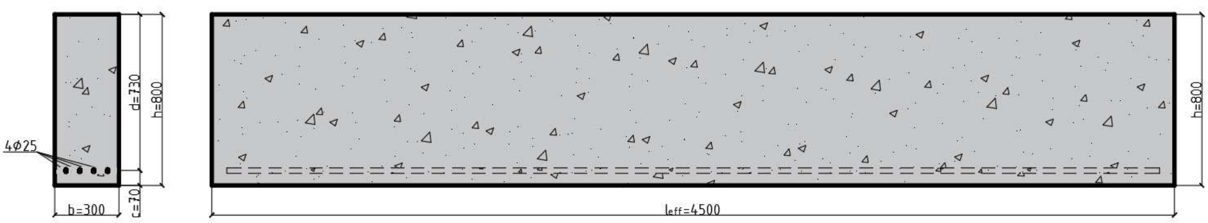


Figure 1. – General view of the beam

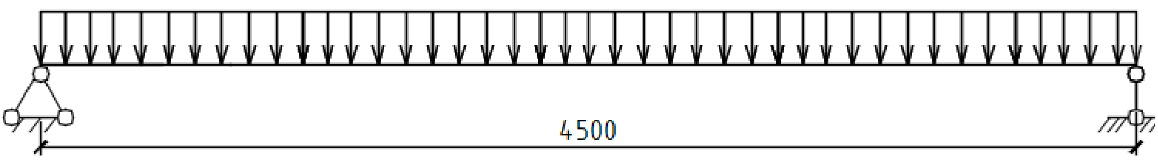


Figure 2. – Beam's design scheme

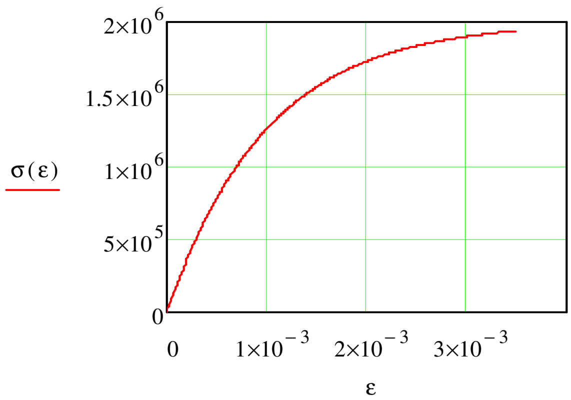
Table 1

Sample	Design value, M_{Rd}, кН×м							
	Limit state method ($M_{Rd(1)}$)	Simplified defor-mation method ($M_{Rd(2)}$)	General defor-mation method ([9]) ($M_{Rd(3)}$)	Simplified defor-mation method ([8]) ($M_{Rd(4)}$)	General defor-mation method (diagram 1) ($M_{Rd(5)}$)	General defor-mation method (diagram 2) ($M_{Rd(6)}$)	General defor-mation method (diagram3) ($M_{Rd(7)}$)	General defor-mation method (diagram 4) ($M_{Rd(8)}$)
	531.96	515.72	543.1	542.5	539.3	540.9	545.8	547.2

Diagram 1. Based on the formula of Yashchuk V.E. [2]. It is used to determine the stresses in elasto-plastic materials:

$$\sigma(\varepsilon) := R_1 \cdot \left(1 - e^{-E \cdot \frac{\varepsilon}{R_1}}\right)$$

where E_0 – initial modulus of elasticity; R_1 – final strength of a concrete sample.

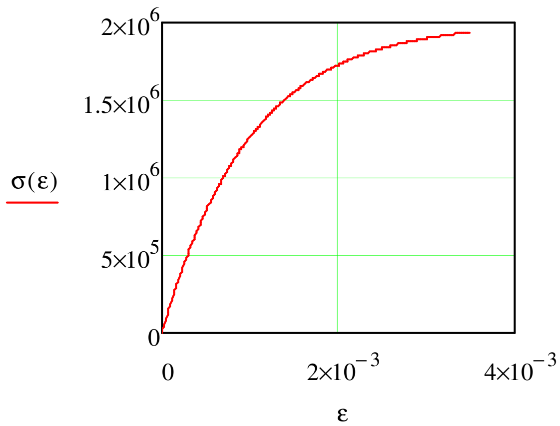


Graph 1. – First deformation diagram (by Yashchuk V.E.)

Diagram 2. Based on the formula of Murashkin G.V. and Murashkin V.G. [3, 4]. The advantage of this formula is that it combines both experimental data (coefficients) and theoretical specifications:

$$\sigma(\varepsilon) := \alpha \cdot \varepsilon^{b} \cdot \exp\left(b \cdot \frac{\varepsilon}{p}\right)$$

where α, b, p – coefficients, determined from the calculated assumptions incorporated in [5].

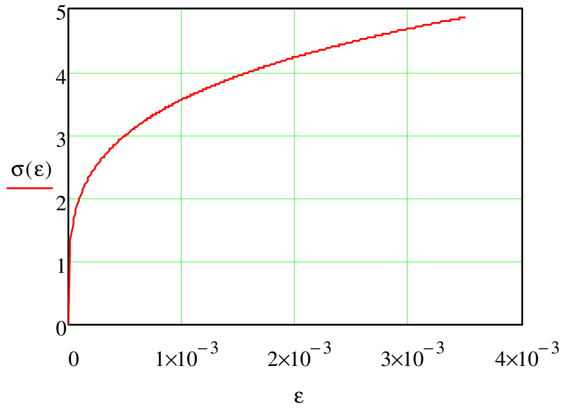


Graph 2. – Second deformation diagram (by Murashkin G.V. and Murashkin V.G)

Diagram 3. Based on the formula of Sheykin A.E. [6]. Here, it is taken into account that the creep deformations of concrete are directly proportional to the magnitude of the stresses in it and the time of the load:

$$\sigma(\varepsilon) := \frac{\varepsilon}{E_0} + \alpha \cdot \varepsilon^2$$

where E_0 – initial modulus of elasticity; α – coefficient of proportionality in accordance with [5].

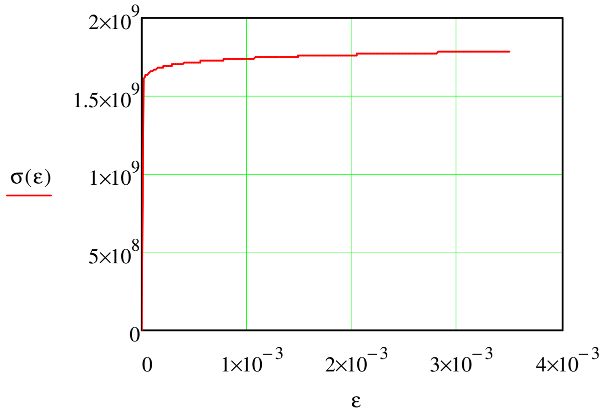


Graph 3. – Third deformation diagram (by Sheykin A.E.)

Diagram 4. Based on the very first formula (after Hooke's law), proposed in 1729 by Bülfinger G.B., later written down as [7]

$$\sigma(\varepsilon) := A \cdot \varepsilon^k$$

where A – a constant, having the unit of stresses; к – degree index (unitless dimension); from a material with an arbitrary value of k, you can automatically obtain a solution for linear-elastic and rigid-plastic structures.



Graph 4. – Fourth deformation diagram (by Bülfinger G.B)

Diagram 5. Based on the formula of M.Sargin, recommended by the Euro-International Committee for Concrete (CEN)[8]:

$$\sigma(\varepsilon 1) := \frac{k \cdot \frac{\varepsilon 1}{\varepsilon 10} - \left(\frac{\varepsilon 1}{\varepsilon 10}\right)^2}{1 + (k-2) \cdot \frac{\varepsilon 1}{\varepsilon 10}} \cdot f$$

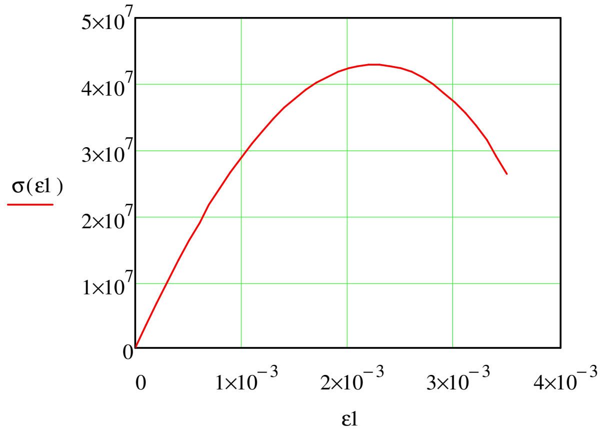
where f – average strength (28 days), table.3.1 [8];

ε_1 – relative deformation;

ε_{10} – relative deformation at the maximum (peak) stress value in accordance with table 3.1 [9].

$$\eta = \frac{\varepsilon_1}{\varepsilon_{10}}$$

$$\kappa = \frac{1{,}05 \cdot E \cdot |\varepsilon_{10}|}{f}$$



Graph 5. – Fifth deformation diagram (by EN 1992-1-1-2009)

Conclusion. Based on the obtained data, it can be concluded that the choice of a particular concrete deformation diagram will not actually affect the calculation results, since there is no significant difference in the results.

Hence, the concrete did not show us all the tensile stresses because of the analyzing of the limit values of the reinforcing bars.

Analyzing in more detail, it is obvious that the most deviated from the average value of the result, was by the simplified deformation method. This is explained by the fact that the calculation is carried out using tables (approximations), therefore this method is the most inaccurate and the calculation is carried out in the safety margin.

Despite of the fact that the limit state method is one of the most common methods, it also gave an inaccurate result due to the calculation using empirical formulas and taking into consideration the engineering errors of calculation.

The general deformation method gave almost identical results, the error between the most deviated values is Δ = 1,44%. The small divergence between the results is due to the fact that the exhaustion of the structural strength occurs as a result of reaching the limit values of either the compressed concrete's zone or the tensioned reinforcing bars. In this case, the destruction occurs in the tensioned reinforcement after reaching the yield strength.

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