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USE OF THE DESIGN REINFORCED CONCRETE STRENGTH IN SOLVING PRACTICAL STRENGTH PROBLEMS

***Abstract.** The paper presents a generalized deformation model for the calculation of reinforced concrete structures, which is considered as composite material formed of reinforcement and concrete. On this basis, it is proposed to use the concept of the design strength of reinforced concrete into solving practical strength problems. This allows us to reduce the structural analysis of reinforced concrete members to the methodology of calculations introduced in the classical strength of materials, which contributes to a significant simplification and acceleration of the design process of both single members and structures in general.*
***Keywords**: concrete, reinforcement, strength, analysis.*

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ВИКОРИСТАННЯ РОЗРАХУНКОВОЇ МІЦНОСТІ ЗАЛІЗОБЕТОНУ ПРИ РОЗВ'ЯЗАННІ ПРАКТИЧНИХ ЗАДАЧ МІЦНОСТІ

***Анотація.** У роботі представлена узагальнена деформаційна модель для розрахунку залізобетонних конструкцій, в якій залізобетон розглядається як композиційний матеріал, утворений з арматури та бетону. На цій основі пропонується використовувати при розв'язанні практичних задач міцності поняття розрахункової міцності залізобетону. Це дозволяє звести розрахунок залізобетонних елементів до методики розрахунків, запровадженої в класичному опорі матеріалів, що сприяє значному спрощенню та прискоренню процесу проектування як окремих елементів, так і конструкцій в цілому.*
***Ключові слова**: бетон, арматура, міцність, аналіз.*

The first methods of flexural reinforced concrete members' strength determination were based on the method of structural analysis. This method was used for members of elastic materials. The first mention of reinforced concrete occurs in the middle of the eighteenth century. The main prerequisites of the method included the following: the validity of Hooke's law for materials and the hypothesis of plane sections, the cross-section was reduced to a conditional homogeneous, the ratio of elasticity modules was assumed constant [1]. The essence of the method was to determine the stresses in structures caused by the action of external loads and compare them with allowable stresses for the structure material.

Modern methods of reinforced concrete member's structural analysis [2 – 4] provide using of nonlinear stress-strain diagrams for materials subject to validity of the linearity of longitudinal strains in the section of the members. This leads to necessity of iterative methods introduction for designing structures using computational techniques.

Problem statement. The main ideal of the presented method is to improve and simplify the structural analysis of reinforced concrete members by introducing the synthesized concept of the design reinforced concrete strength, taking into account the strength characteristics of concrete and reinforcement, the reinforcement ratio and the location of reinforcement in the cross-section.

Basic material and results. The following prerequisites for structural analysis are accepted [2]:

1) Concrete stress-strain diagram $\sigma_c = f(\varepsilon_c)$ is used in the form of nonlinear dependencies that conformed by generally accepted deformation criteria.

2) Reinforcing steel stress-strain diagram $\sigma_s = f(\varepsilon_s)$ is described by bi-linear Prandtl diagram with corresponding values of the limiting points.

3) Hypothesis of plane cross sections is used.

4) The tensile strength of concrete is ignored.

As destruction criteria for nonlinear stress-strain diagrams of materials, the following are accepted:

1) The ultimate concrete compressive strains ε_{cu} and the yield strength of the tensile reinforcement in the absence of the extremum of the load-bearing capacity are achieved in the cross-section.

2) The tensile reinforcement strains reach ε_{ud}.

In order to use the concept of reinforced concrete strength in calculations of reinforced concrete members bearing capacity, tables of its values are compiled depending on the reinforcement ratio, concrete and reinforcement classes [Tables 1, 2]. In calculating these values, the rectangular stress distribution in the compressed concrete area was adopted.

The general condition of flexural reinforced concrete members bearing capacity has the form

$$f_{zM} \geq \frac{M_{Ed}}{W}, \tag{1}$$

where $f_{zM} = f(C, \rho_l, f_{yd})$ – the design value of reinforced concrete strength in flexural members, is taken in table 1; W – elastic moment of resistance of the effective concrete section.

Table 1 – Design strength values of reinforced concrete f_{zM1} for flexural members with single reinforcement, MPa

Strength classes for concrete	Longitudinal reinforcement ratio ρ_l							
	0.05	0.5	1	1.25	1.75	2	2.5	3
	f_{yd} = 364 MPa (A400C)							
C8/10	1.075	9.263	15.215	16.948	17.29	17.29	17.29	17.29
C12/15	1.080	9.750	17.163	19.993	23.898	24.49	24.49	24.49
C16/20	1.083	10.055	18.385	21.899	27.634	29.854	33.13	33.13
C20/25	1.085	10.234	19.098	23.016	29.824	32.714	37.466	40.848
C25/30	1.086	10.335	19.501	23.646	31.059	34.327	39.986	44.476
C30/35	1.086	10.410	19.801	24.115	31.977	35.526	41.86	47.174
C32/40	1.087	10.468	20.033	24.476	32.686	36.452	43.307	49.259
C35/45	1.088	10.522	20.250	24.815	33.350	37.320	44.662	51.210
C40/50	1.088	10.558	20.394	25.041	33.793	37.898	45.566	52.511
C45/55	1.088	10.588	20.515	25.229	34.162	38.380	46.319	53.595
C50/60	1.088	10.618	20.635	25.417	34.531	38.861	47.071	54.679

Table 2 – Design strength values of reinforced concrete f_{zM1} for flexural members with single reinforcement, MPa

Strength classes for concrete	Longitudinal reinforcement ratio ρ_l							
	0.05	0.5	1	1.25	1.75	2	2.5	3
	f_{yd} = 435 MPa (A500C)							
C8/10	1.281	10.684	16.638	17.841	17.28	17.28	17.28	17.28
C12/15	1.288	11.380	19.421	22.189	24.49	24.49	24.49	24.49
C16/20	1.292	11.815	21.163	24.912	30.557	32.454	33.13	33.13
C20/25	1.295	12.071	22.185	26.507	33.685	36.54	40.781	43.065
C25/30	1.296	12.215	22.760	27.407	35.448	38.842	44.379	48.246
C30/35	1.297	12.322	23.188	28.076	36.759	40.555	47.055	52.099
C32/40	1.298	12.404	23.519	28.593	37.772	41.878	49.122	55.076
C35/45	1.299	12.482	23.829	29.077	38.720	43.117	51.058	57.863
C40/50	1.299	12.533	24.035	29.399	39.353	43.942	52.348	59.721
C45/55	1.300	12.576	24.207	29.668	39.879	44.631	53.423	61.269
C50/60	1.300	12.619	24.379	29.937	40.406	45.319	54.498	62.817

Condition (1) allows solving all problems of designing reinforced concrete members: check and determine the strength of the cross-section, calculate the reinforcement area. This method permits to reduce the calculation of reinforced concrete members to the method of classical strength of materials, but taking into account nonlinear deformation of materials. The proposed method of calculation is not simplified. After all, at the values of the corresponding reinforcement ratios given in the table, the cross section strength calculated by (3) completely coincides with the strength defined by Eurocode 2 in the software complexes.

Conclusions.

The strength characteristic of reinforced concrete is used, which using substantially simplifies the practical method of structural analysis of flexural reinforced concrete members based on the deformation model. Using the developed method, the tables have been constructed for easily and quickly performing the calculation of the bearing capacity of reinforced concrete beams according to the non-linear analysis method without the use of computer programs. Similar tables are developed for the calculation of reinforced concrete members in other deformation modes. In order to simplify the work of designers, engineers and students of Civil Engineering specialties it is expedient to include tables into the reinforced concrete members design rules. The proposed method gives the opportunity to teach it in the Strength of Materials base course for the calculation of reinforced concrete members.

References

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