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CREEP OF CONCRETE – THE SHORT STUDY CONDUCTED AT THE NEW LABORATORY AT THE UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN

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Abstract

In order to launch the newly bought creep testing machine, concrete creep was studied. The creep coefficients were calculated and the results were compared to results reached based on Eurocode 2 regulations. The results were compatible.

Introduction

The phenomenon of creep is the tendency of a solid material to deform permanently under the influence of load over a period of time. Creep must be taken into account in the design of prestressed concrete structures and significantly influences internal forces in RC elements in compression as well as deflections resulting from bending. It also influences to a lesser degree (which is nonetheless present in the codes) the width of cracks. In prestressed structures, creep and shrinkage lead to a loss of prestressing force. Creep increases deflections of slender beams. In columns creep decreases concrete stresses but increases reinforcement stresses. Reinforcement with time takes over the part of load that was initially carried by concrete. This is why in order to study the reinforced concrete structures influenced by long term loads it is necessary to be able to calculate the creep of concrete.

The newly opened UWM laboratory for technical control of structures, built within the framework of the Regional Operational Programme Warmia

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and Mazury for the years 2007–2013, has been equipped with creep testing machine (Fig. 1) Type HKB-1000 kN (and its software), which has been placed in an air-conditioned chamber.

Fig. 1. Concrete creep testing machine Type HKB-1000 kN manufactured by walter+bai ag

Creep Testing Machine Series HKB specially designed for long term creep tests on concrete specimens up to ϕ 160 or cubes 150 mm by means of a pressure exerted load. Tests can be carried out either on a single sample or on several specimens in series. The load cylinder is put under pressure by a hand pump. The force can be read of the pressure gauge or electric read out and is kept constant by a compressed gas storage system. Main technical data: max. compression force 1000 kN, machine grad (from 100 to 1000 kN) – Grade 1, max. distance between compression platen 1250 mm, min. distance 290 mm, piston stroke 20 mm, lower and upper compression platen ϕ 200 mm. The launch process of the new equipment involved the study described later in the paper.

Creep study

The study of creep was carried out using cylinder specimens d = 150 mm and the height h = 300 mm, according to ITB instructions, number 194 and the fast-setting cement CEM II/A-V 42,5 R. The specimens after twenty-four hours were placed in an air-conditioned chamber at the temperature of 20°C and relative humidity over 90% for seven days. Next, the specimens were placed in an air-conditioned chamber with 50% relative humidity and a temperature of 20°C and stored there until the time of the experiment. Since it is necessary to decrease the deformations resulting from creep by shrinkage, another load-free specimen was prepared to measure shrinkage. All the specimens prepared for measuring creep and other accompanying parameters were stored in the same conditions. An extensometer was used with the resolution of 1/100 mm and the measuring base of 250 mm (Fig. 2) The benchmarks were installed alongside three lines evenly placed on the side of the cylinder (every 120 degrees). The analysis started at an concrete age of 14 days. First, the compressive strength of concrete was determined ($f_c(14)$ = 30,5 MPa), whose value became the base for calculating the level of long-term loads in the study of creep. After placing the sample in the creep testing machine, it was left without any load for an hour. Then, the initial measurement was taken, then the sample was loaded. The load was continually increased until the stress reached $\sigma = 0{,}4f_c$ (the measurements were also taken at the levels of 0,5σ, 2/3σ, σ). The full load was reached within ten minutes.

The first measurement was taken after 5 minutes, and the result was defined as temporary deflection. The next measurements were taken for 253 days, in the first week every day, during the next three months, once a week, and then only once a month.

The creep measurements were accompanied by shrinkage measurements. The load-free sample was placed in the same position and the same air-conditioned chamber as the loaded sample. Based on the results, the creep curve was determined (Fig. 3).

Fig. 2. Deformation measurement with the use of the extensometer

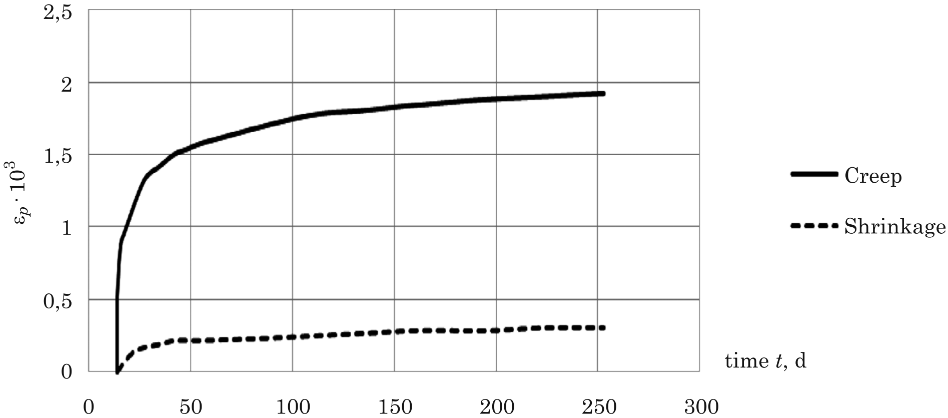

Fig. 3. Creep curve for axial compression (t_0 = 14d, $f_c(14)$ = 30,5 MPa), the stress equals $0{,}4f_c(14)$

Comparison of experimental creep coefficients with values calculated according Eurocode 2

Later in the paper, the coefficients obtained in the study and by following Eurocode 2 regulations were compared. The values of coefficients in the study were obtained from the following relation:

$$\varphi(t,t_0) = \frac{\varepsilon_p(t,t_0)}{\varepsilon_d(t_0)} = \frac{\varepsilon_c(t,t_0) - \varepsilon_{cs}(t,t_0) - \varepsilon_d(t_0)}{\varepsilon_d(t_0)} \tag{1}$$

where:
$\varepsilon_p(t,t_0)$ – is creep strain after t time of the specimen loaded in t_0 time,
$\varepsilon_c(t,t_0)$ – is total strain in t time,
$\varepsilon_{cs}(t,t_0)$ – shrinkage in t time,
$\varepsilon_d(t_0)$ – is instantaneous strain after 5 minutes of loading.

According to Eurocode 2 creep coefficients can be obtained from the formula:

$$\varphi(t,t_0) = \varphi_0\beta_c(t,t_0) \tag{2}$$

where:
φ_0 – the basic creep coefficient, and function $\beta_c(t,t_0)$ shows the progress of creep in time depending on $(t - t_0)$, (RH), h_0 and f_{cm}.

These values were obtained based on Eurocode 2, Annex B. For calculations it was assumed that the relative humidity was RH = 50%, the notional size of the cross section was h_0 = 75 mm and the average strength of concrete aged 28 days was f_{cm} = 34,33 MPa. An adjusted age of concrete was taken into account and was defined by coefficient $\alpha = 1$ for class R cement. The results were presented in Table 1. In bold are the values of creep coefficients obtained through the study. They are higher than the ones obtained according to Eurocode 2.

Table 1

Comparison of experimental creep coefficients and coefficients according to Eurocode 2

t_0 [d]	t [d]	$\varphi_1 = \varphi(t,t_0)$ according to the study	$\varphi_2 = \varphi(t,t_0)$ according to Eurocode 2	$\frac{\lvert\varphi_2 - \varphi_1\rvert}{\varphi_1}$ 100%
14	15	0.47	0.56	19.15
	16	0.68	0.69	1.47
	17	0.72	0.78	8.33
	18	0.76	0.85	11.84
	19	0.81	0.91	12.34
	20	0.85	0.96	12.94
	21	0.91	1.00	9.89
	22	0.95	1.04	9.47
	23	1.05	1.08	2.86
	28	**1.29**	1.23	4.65
	35	**1.41**	1.38	2.12
	42	**1.52**	1.50	1.31
	49	1.59	1.59	0.00
	56	1.67	1.67	0.00
	105	1.97	2.03	3.04
	133	2.01	2.17	7.96
	161	2.05	2.27	10.73
	197	2.13	2.37	11.27
	225	2.14	2.44	14.02
	253	2.16	2.50	15.74

Conclusions

The new creep testing machine was put to use. For elements loaded in the age of fourteen days to a stress of $0{,}4f_c(t_0)$ coefficients of concrete creep were determined after t time in which measurements were taken. The results of the study were compared with the results calculated according to Eurocode 2. They were fairly compatible. The differences between the results are not greater than 20%. For the most part of the analysis, the values obtained through calculations turned out to be greater than the ones obtained experimentally. In opposite cases, the differences are insignificant.

References

PN-EN 1992-1-1: 2004. Eurokod 2. *Projektowanie konstrukcji z betonu*. Część 1–1: *Reguły ogólne i reguły dla budynków*.

Instrukcja ITB nr 194. 1998. *Badania cech mechanicznych betonu na próbkach wykonanych w formach*. Wyd ITB, Warszawa.

KNAUFF M. 2012. *Obliczanie konstrukcji żelbetowych według Eurokodu 2*. Wyd Naukowe PWN, Warszawa.

MITZEL A. 1972. *Reologia betonu*. Arkady, Warszawa.

NAGRODZKA-GODYCKA K. 1999. *Badanie właściwości betonu i żelbetu w warunkach laboratoryjnych*. Arkady, Warszawa.

NEVILLE A.M., DILGER W.H., BROOKS J.J. 1983. *Creep of plain and structural concrete*. Construction Press, London and New York.

ULICKII I.I. 1967. *Teoria i rasczot żeliezobietonnych stierzniewych konstrukcji s uczotom dlitielnnych prociesow*. Izdatielstwo Budiwielnik, Kijew.