MATEC Web of Conferences **73**, 04014 (2016) DOI: 10.1051/matecconf/20167304014
TPACEE-2016

Influence of Kinetics Concrete Hardening on Strength of Constructions

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Annotation. In this article the question of the influence of the kinetics of hardening concrete on its strength in building structures through the stress function. Determined a direct correlation between the optimal structure of concrete and a guarantee of high strength and durability of building structures that ensured a coincidence given the amounts and extreme properties. A method for predicting the elastic properties of concrete based on known theory of strength of concrete model. It is shown by way of example, that in certain specific strength characteristics of concrete, properties of its components (cement stone and aggregates), the maximum value of the short-term strain, creep deformation and modulus of elasticity of concrete depends on its strength at the time of loading. The proposed method is the most convenient for practical approximation to obtain the equations of mechanical state to determine the total deformation of concrete.In this article the approach to determine the strength of concrete in building structures through the stress function under load. It is shown by way of example, that the results obtained by experiment and the proposed article approach to the assessment of the strength to coincide with high accuracy.

1 Introduction

Deformation properties of concrete depends on its structural characteristics, resulting dosage and quality components, but the intensity of deformations in concrete constructions can not be reliably predicted depends only on the strength of the composite, while retaining all other conditions equal to [4, 6]. In practice, this implies that the findings on the relationship between deformation and concrete strength to do is useless, if not provided in advance some of the boundary conditions and additional factors characterizing features of the concrete structure, which vary (or remain constant) simultaneously with the change in strength. This fact is proved by the authors [1, 2] under different operating conditions and loadings [3, 5].

Under the long-term strength (durability) understand the stress that causes the destruction of the material in a given time. Obtaining high quality concrete in advanced technology conglomerate materials today becomes a major factor both in science and in practice, the production of artificial materials and products. It is known that the favorable construction and performance of the concrete consist of: the largest - the strength and

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elasticity; least - creep, porosity and defects in the structure. According to the law "alignment" I.A.Rybev, which reflects a high quality performance products, provided that the specific values of the properties are at specified values, you must use the following principle: a comparison of materials in the research and practical developments are not as often made - equal to or under the same conditions (which can result in large errors) but only when the respective conditions, i.e. under optimal - similar to each other, structures.

2 Method

This assumption establishes a direct connection between the properties and the optimal structure parameters. In other words, the guarantee of high (if not higher) quality products to accepted technology of its production is given a coincidence and extreme properties of the amounts, which is possible only when the optimal structure.

In particular, to improve the reliability of the valuation of deformation characteristics of concrete, along with the strength necessary for the long-term deformation (creep and shrinkage) to take into account the specific (by volume) amount of water in the mixing of concrete, which is closely correlated with the initial moisture content of the concrete; for short-term deformation (initial elastic modulus and ultimate strains) to take into account the specific (by weight) of cement paste content in the concrete mix, which determines the ratio of cement paste and aggregate in the hardened concrete.

Prediction of the elastic properties of concrete can be made using methods known in the theory of strength of concrete models:

linear -

$$\frac{1}{E_b(\tau)} = b_0 + b_1 P_z + b_2 \frac{P_z}{R_b(\tau)} + b_3 \frac{1-P_z}{E_a} \tag{1}$$

and nonlinear –

$$\frac{1}{E_b(\tau)} = b_0 + b_1 P_z + b_2 \frac{P_z^{\varphi}}{[R_b(\tau)]^{\psi}} + b_3 \frac{1-P_z}{E_a} \tag{2}$$

Where $R_b(\tau)$- the strength of concrete loaded at a time τ , $E_b(\tau)$ - initial modulus of elasticity of concrete loaded on the age τ ; P_z - Specific (by weight) content of cement paste in compacted concrete mix; E_a - modulus of elasticity of the filler; b_0, b_1, b_2 and b_3 - deformability parameters taken from experimental data.

3 Results

Summarizing, we can write:

$$\frac{1}{E_b(\tau)} = a + \frac{b}{R_b(\tau)^m} = \frac{1}{R_b(\tau)^m}\left[aR_b(\tau)^m + b\right] \tag{3}$$

where $a = a(P_z, E_a); b = b(P_z)$; $m = 1$ and or 0.75.

Maximum short-term strain on the concrete « $\sigma - \varepsilon$ » curve:

$$\varepsilon_R = \frac{R_b(\tau)}{E_b(\tau)} + 274\times10^{-8} P_z \frac{0.3+1.8\bar{e}_0}{0.3+\bar{e}_0}\frac{E_b(\tau)}{R_b(\tau)} \tag{4}$$

where $\bar{e}_0 = {}^{e}\!/\!_{h}$ - relative eccentricity of load application.

Limit specific concrete creep deformation, constant load loaded at a time determined by the formulas:

$$C(\infty,\tau) = k_c \frac{W}{R_b(\tau)} \tag{5}$$

or

$$C(\infty,\tau) = k_c \frac{W}{R_m + \Delta} \tag{6}$$

here R_m - the strength characteristics of cement paste at the start of loading, W - the quantitative value of the aqueous component in the concrete mix, k_c - individual constant coefficient of concrete.

When the strength of concrete in the $\tau = 28 days.$ concrete creep age defined by the formula (5), where $k_c W = C(\infty,28)R_b(28)$.

Assume the notation

$$a_n = C(\infty,28)R_b(28) \tag{7}$$

and substituting (7) the expression (6), we obtain $C(\infty,\tau) = \frac{a_n}{R_b(\tau)}$, and taking into account the duration of the stress full expression to creep measures will be:

$$C(t,\tau) = \frac{1}{R_b(\tau)} a_n f(t-\tau) \tag{8}$$

Equation (6) differs from (8) by the presence of the parameter $\Delta \neq 0$, and is used instead of the matrix R_m strength concrete strength in the record $R_b(\tau)$ that is most convenient for practice approximations.

If we assume that the initial relative level of stress

$$\eta(\tau) = {}^{\sigma(\tau)}\!/\!_{R_b(\tau)} \tag{9}$$

and specific to them creep

$$\bar{S}_r(\tau) = \eta(\tau)\left[1 + V_r \eta(\tau)^m\right] \tag{10}$$

it can be written for each particular strain stress function:

$$S_r(\tau)=R_b(\tau)\bar{S}_r(\tau) \tag{11}$$

If $T(\tau)=20^o C$, $W(\tau)=50\%$ and $S(\tau)=const$, taking into account the record (3) and $m=1$ obtain the record:

$$\varepsilon^{эт}(t,t_0)=\bar{S}_k\left[aR_b(t_0)+b\right]+\bar{S}_c(t_0)a_n f(t-t_0) \tag{12}$$

or

$$\begin{gathered}\varepsilon^{эт}(t,t_0)=\frac{R_b(t_0)}{R_b(t)}\bar{S}_k(t_0)\left[aR_b(t_0)+b\right]+\\+\bar{S}_c(t_0)\left[a_n f(t-t_0)+b\left(1-\frac{R_b(t_0)}{R_b(t)}\right)\right]\end{gathered} \tag{13}$$

$$d\varepsilon^{эт}(t,\tau)=\delta_k(\tau)\frac{\partial}{\partial\tau}\bar{S}_k(\tau)d\tau+a_n f(t-\tau)\frac{\partial}{\partial\tau}\bar{S}_c(\tau)d\tau \tag{14}$$

where,

$$\delta_k(\tau)=aR_b(\tau)+b \tag{15}$$

a and b take the same meanings as in the formula (3), as a_n calculated from (7).

If the overall record of the equation of the mechanical condition of the concrete substitute (12 and 14), we obtain a record of private strain

$$\varepsilon(t,t_0)=\varepsilon^{эт}(t,t_0)+\int_{t_0}^{t}d\varepsilon^{эт}(t,\tau) \tag{16}$$

spending is not complicated iteration write

$$\begin{gathered}\varepsilon(t,t_0)=\delta_k(t)\bar{S}_k(t)+a_n f(0)\bar{S}_c(t)-\int_{t_o}^{t}\bar{S}_k(\tau)\frac{\partial}{\partial\tau}\delta_k(\tau)d\tau-\\-\int_{t_0}^{\tau}a_n\bar{S}_c(\tau)\frac{\partial}{\partial\tau}f(t-\tau)d\tau.\end{gathered} \tag{17}$$

We use the expression (13) for recording the total relative deformations

$$d\varepsilon^{эт}(t,\tau)=\frac{1}{E_b(\tau)}\frac{\partial}{\partial\tau}\sigma_k(\tau)d\tau+C^*(t,\tau)\frac{\partial}{\partial\tau}\sigma_c(\tau)d\tau \tag{18}$$

Further, by rewriting the expression (18) together with (13) we obtain

$$d\varepsilon^{эт}(t,\tau)=\delta_k(t,\tau)\frac{\partial}{\partial\tau}\overline{S}_k(\tau)d\tau+\delta_c(t,\tau)\frac{\partial}{\partial\tau}\overline{S}_c(\tau)d\tau, \tag{19}$$

where

$$\delta_k(t,\tau)=R_b(\tau)\left[a+{b}/{R_b(t)}\right] \tag{20}$$

and

$$\delta_k(t,\tau)=a_n f(t-\tau)+b\left[1-{R_b(\tau)}/{R_b(t)}\right] \tag{21}$$

Here,

$$\delta_k(t,t)=\delta_k(t)=aR_b(t)+b \tag{22}$$

and

$$\delta_k(t,t)=a_n f(0)=const. \tag{23}$$

After further changes, substituting (13 and 19) to (16), we obtain the equation for determining the mechanical condition of the total strain

$$\varepsilon(t,t_0)=\delta_k(t)\overline{S}_k(t)+a_n f(0)\overline{S}_c(t)-\int_{t_o}^{t}\overline{S}_k(\tau)\frac{\partial}{\partial\tau}\delta_k(t,\tau)d\tau-$$
$$-\int_{t_0}^{t}\overline{S}_c(\tau)\frac{\partial}{\partial\tau}\delta_c(t,\tau)d\tau. \tag{24}$$

From the foregoing, it is evident that under certain specific strength characteristics of concrete, properties of its components (cement stone and aggregates), the maximum value of the short-term strain, creep deformation and modulus of elasticity of concrete depends on its strength at the time of loading.

It is known that concrete creep deformation are separate relative to the initial level of stress in the structure $S(t,\tau)=\dfrac{\varepsilon_c(t,\tau)}{\beta(\tau)}$, where $\beta(\tau)=\dfrac{\sigma(\tau)}{R_b(\tau)}$, where t - time of the beginning of loading, τ - the current time of observation.

Creep practically do not depend on the age of the concrete and are the property of invariance with respect to the loading.

The relationship between stress $\sigma(\tau)$ and specific creep, ascribed to stresses $S(t,\tau)$, is given.

$$S(t,\tau)=C(t,\tau)R_b(\tau) \tag{25}$$

If creep measures in the form of Mack Henry and S.V.Aleksandrovskiy can accept an expression

$C(t,\tau)=C(\infty,28)\Omega(\tau)f(t-\tau)$, (25) can be rewritten as

$$S(t,\tau)=C(\infty,28)\Omega(\tau)R_b(\tau)f(t-\tau) \quad (26)$$

Concrete creep deformation $S(t,\tau)$ depends on the duration of loading and $(t-\tau)$ is not dependent on age concrete τ . In this case, the condition must be satisfied

$$\Omega(\tau)R_b(\tau)=k \quad (27)$$

where k - is a constant of the material.

This expression is determined by a function of aging concrete in building structures on the creep properties

$$\Omega(\tau)=\frac{k}{R_b(\tau)} \quad (28)$$

or prism strength of concrete.

$$R_b(\tau)=\frac{k}{\Omega(\tau)} \quad (29)$$

Then take concrete function of aging at the age of 28 days: $\Omega(\tau)=\Omega(28)=1$,

further in accordance with the condition (27) at obtain $k=R_b(28)$

$$R_b(\tau)=R_b(28)\Omega(\tau)^{-1} \quad (30)$$

Concrete strength depends on its age: $R_b(t)=0.7R_b(28)\lg t$,

aging function $\Omega(t)=0.5+0.7e^{-2\gamma t}$ for $\gamma=0.006$.

When loading at a time $t=100 days$, depending on the concrete age, account for the strength of the prism will have the form $R_b(100)=0.7R_b(28)\lg 100=1.4R_b(28)$:

and a function of aging $\Omega(100)=0.5+0.7e^{-2\times 0,006\times 100}=0.71$.

According to the formula (30)

$$R_b(100)=R_b(28)\Omega(100)^{-1}=R_b(28)\frac{1}{0,71}=1.4R_b(28).$$

For concrete example, the age t = 1000days:

$$R_b(1000)=0.7R_b(28)\lg 1000=2.1R_b(28),$$

$$\Omega(1000)=0.5+0.7e^{-2\times 0,006\times 1000}\approx 0.5$$

and formula (30) $R_b(1000)=R_b(28)\dfrac{1}{0,5}=2R_b(28)$.

As seen from the above examples, the results obtained by experiment and by the same formula (30) with high accuracy.

Continuing iterations, multiply the right and left sides in (30) a setting deformation nonlinearity $\frac{1+V_k}{E_b(\tau)}$, we obtain $\frac{R_b(\tau)(1+V_k)}{E_b(\tau)}=\frac{R_b(28)(1+V_k)}{E_b(\tau)}\Omega(\tau)^{-1}$.

Limit the relative shortening of the instantaneous static sense uploading reflects left-hand side of this expression.

Then we get from where $\varepsilon_{k,R}(\tau)=\frac{R_b(28)(1+V_k)}{E_b(\tau)}\Omega(\tau)^{-1}$,

$$E_b(\tau)=\frac{R_b(28)(1+V_k)}{E_{k,R}(\tau)}\Omega(\tau)^{-1} \tag{31}$$

at $\tau=28$ $\Omega(\tau)=1$ and

$$E_b(28)=\frac{R_b(28)(1+V_k)}{E_{k,R}(28)} \tag{32}$$

Further, substituting (32) (31), we get

$$E_b(28)=\frac{R_b(28)(1+V_k)}{E_{k,R}(28)} \tag{33}$$

If we neglect the change in the limit of deformability of concrete under short-time loading, depending on the age, we get.

$$E(\tau)=E_b(28)\Omega(\tau)^{-1} \tag{34}$$

Experiments known scientists show that the age of the concrete limit deformability depends weakly, and its variations are within the experimental error. However, current regulations limit deformability take concrete constant.

4 Discussion

Our results give reason to assume that in this case, three mechanical characteristics of concrete: strength measure $\frac{1}{R_b(\tau)}$, elastic-instantaneous deformation $\frac{1}{E_b(\tau)}$ and creep C (t,τ) are proportional to the value of one common aging function expressing $\Omega(\tau)$, the changes considered indicators for any concrete age in relation to the reference age $\tau_1 = 28$ days.

Unique, besides a strong link between deformability and strength of concrete properties exists for the particular concrete with a fixed number of components of the composition and other indicators.

This fact is consistent with the "physical" theory O.Ya. Berg strength, as the process of changing these values is the result of a single cause: the hardening of concrete. From this it follows that to improve the reliability of deformation characteristics of concrete standardization must be considered, along with the strength of the influence of material characteristics, namely: the standardization of long deformations (creep and shrinkage) - specific (by volume) amount of mixing water in the concrete mix, which is closely correlated with an initial moisture content of the concrete; when standardization of short-term deformation (initial elastic modulus and ultimate strains) - specific (by weight) of cement paste content in the concrete mix, which determines the ratio of cement paste and aggregate in the hardened concrete.

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