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Research Paper

Terms in the Application of Stress-strain Relations for Concrete Creep (Version 2)

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ABSTRACT: *The application of concrete creep and shrinkage coefficients should facilitate and eliminate the dilemmas that are now present in the practice and theory of [2]RC, [3]PC and Composite structures. The first part of the paper points out the possible difficulties that arise in obtaining experimental data and the exact definition of the creep coefficient and the function of measure concrete creep. The largest part of this paper deal with how to get the expression and value of creep coefficients and measures of creep and shrinkage of concrete. The paper is intended for researchers in laboratories for testing the behavior of concrete under long - term loads. The work can be usefully informative for designers and builders. In the new version 2 of the paper, typing errors and other observed differences were eliminated for the previous version.*
KEYWORDS*: Concrete, rheological data, creep (viscosity), experiments*

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I. INTRODUCTION

The intention of this paper is to point out the importance of the concepts of creep and shrinkage of concrete in order to increase the accuracy of the data obtained by experiments for the service loads. Although some parts of national regulations are simple enough to use, work remains unfinished on discussions of definitions of several terms, due to different formulations of terms in the period before 1970 and more recently. Also, the importance of proper processing of measurement data on concrete samples in laboratories and in the application of expressions for certain functions of creep measures is insufficiently emphasized.

Until now, a large number of creep functions have been proposed based on the testing of a large number of concrete samples in devices, which are able to activate a constant compressive force or a variable force over time. The degree of coincidence of previous experimental results and theoretical values is often unacceptable for application in practice.

So far, measurements of due to shrinkage and creep of concrete samples have been performed in laboratory climate chambers at a constant temperature, which is usually $T = 20^0C$ and relative humidity HP = 40% or 70%. Measurements are also performed on construction sites in environmental conditions. Coverage of changing climatic conditions of the environment does not yet have completely acceptable and explained forms. Therefore, greater caution is required in the measurements that are sometimes performed on the structure itself. Based on the measurements, occasionally the necessary interventions are performed on the structures in order to obtain the desired state of deformations.

II. IMPORTANCE OF THE TERMS END NOTATIONS

2.1 Creep coefficients

For several significant structures, measurements of concrete characteristic at long observation time for different environmental conditions were performed at the IMS Institute in Belgrade. The structures are listed now again: Hangar 2 of Belgrade Airport, Railway Bridge over the Sava in Belgrade, Prefabricated concrete girders of the company ‘Gradis’ from Maribor in order to point our experience in this field [13].

An overview of the concrete strains, is given in the manner often shown in the books for this area (Fig. 1), but here is shown on a more complete insight into the types and forms of concrete deformations.There are indicated measured values of strains with the big difference in the interpretation works in relation to the types of curves when unloading of samples is done, for time $\geq t_1$, which shows in a new way the behavior of concrete sanmples in accordance with the proposed modified rheological models[21].

[2]RC - Reinforced Concrete , [3]PC – Prestressed Concrete

A review for test of samples in Fig. 1 will be further basic for the description and idealized explanation of the presented creep and shrinkage curves of concrete.

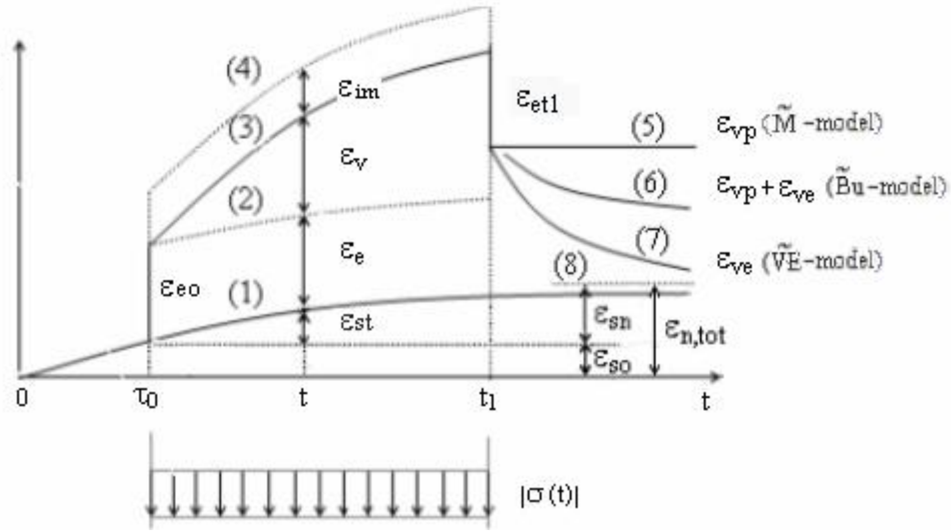

Fig. 1 Strain curves of concrete samples as a function of time (idealized [6])

There are four types of strains for concrete samples depending on the cause of their occurence in Fig.1:

1**)** Under loading (Force on the sample is $P_0 = const$)

ε_{e0} -initial elastic strain in time $t = \tau_0$ due the force P_0 of concrete samples at $\sigma_0 < 0.3fc'$

The elastic strain curve (2) is plotted parallel to curve (1) for shrinkage of concrete (idealized).

ε_v -viscous strain due to stress σ_0 in the time (t) are shown by curve (3), which are measured in relation to curve (2).

2) Under unloading (Force on the samples is $P_0 = 0$)

ε_{et1} - elastic strain of concrete samples in time (t_1) (elastic reversibile - returned)

ε_{vp} - viscoplastic strain of concrete samples (irreversible curve (5))

ε_{ve} - viscoelastic strain in concrete samples (reversible curve (7))

$\varepsilon_{vp} + \varepsilon_{ve}$ - sum of viscoplastic end viscoelastic strains (curve (6))

3) Concrete shrinkage (P_0=0)

ε_{s0} -strains due the shrinkage samples of concrete in the point (τ_0). The effects of concrete shrinkage in a time interval (0, τ_0) is most often considered independently in the calculatons.

ε_{st} - strain of the shrinkage samples of concrete between (τ_0) and (t) shown by curve (1).

ε_{sn} - the final measure of shrinkage of concrete samples for the time interval (τ_0 , t_n).

$\varepsilon_{sn,\ tot}$ - the final measure of shrinkage in concrete samples which is valid for time interval (0, t_n).

Asymptote for the curve (1) is the line (8).

4) Effects of imposed deformations (P_0=0)

ε_{im} -imposed, independent and known change of strains shown in concrete samples by the curve (4)

For example: due to temperature change T^0 or due displacement of structural supports.

The creep coefficient is the introductory and first characteristic of concrete creep, the application of which has been very successful on a large number of structures for service loads. Its net experimental value is defined by the ratio of the measured viscous strain (creep) at discrete observation times ($\tau_0, t_1, \ldots, t_n$) and the measured elastic strain, which is validity only for $\tau_0 = const$ (Fig.2):

$$\varphi(t_i)_{exp} = \frac{\varepsilon_v(t_i)}{\varepsilon_e} \qquad (1)$$

wherein

φ (t_i) - experimental net value of creep coefficient

$\varepsilon_v(t_i)$ - viscous strain of concrete in time(t_i) (calculated value)

ε_e - initial elastic strain in loading time τ_0 =const for only one series of concrete samples (see: Fig.2)

Measurements of total strains of concrete together include strains of viscous creep of concrete, shrinkage of concrete due to ambient changes temperature and humidity. The creep coefficient at the observation time (t_i) shows how many times is viscous strain greater (or less) then the elastic one at the initial time (τ_0).
Therefore it can be written:

$$\varepsilon_{v,red} = \varepsilon_{tot} - \varepsilon_e - \varepsilon_{st} - \varepsilon_T \qquad (2)$$

wherein (see: Fig. 1):

$\varepsilon_{v,\ red}$ - reduced value of viscous strain of concrete in time (t_i) (calculated value)

ε_{tot} - total value of concrete strain in time (t_i) (measured value)

ε_e - elastic strain value (measured value)

ε_{st} - strain value of concrete shrinkage in observation time (t) for initial time $t_0 = \tau_0$ (measured value)

$\varepsilon_{T\ (t_i)}$ - strain value of concrete caused by a change of temperature in relation to the mean value (T^om): $\Delta T_i = T_i - T^om$ (usually is $T^om = 20^oC$ for climatic environment of Serbia). Here is given new proposal for calculation of strains. Also it would be useful to see: [2]).

For one series of samples (most often $m \geq 3$) it is always τo = const, so it can be argued that the function of creep coefficients depends of one argument, i.e. $\varphi_t = \varphi(t)$. In Fig.2 it can be seen that τo = const holds along the whole curve between $to = \tau o = 0$ and t_n for theory of aging, and also same is valid for theory of heritage if it is given $t_\infty = t_n$.

If a series of measurements of these strains in time (t0, t1...tn) is performed and the corresponding individual values are calculated ($\varphi_0, \varphi_1, ..., \varphi_n$), an experimental polygonal curve for concrete creep are is shown obtained in the paper [21])

In Ulickij's book [6], many more points were taken than in the author's work [21], i.e., a much smaller number of characteristic points of time observation of creep and shrinkage for concrete was selected, due to greater clarity and easier explanation of work procedures. at the end of each month from measurement start. In the first month of concrete hardening, there are major changes in the deformation of concrete, so you should take a total of at least three measuring points

Creep function is idealized by a series of points calculated by mean exponential values for curves which are shown in folowing Fig. 2:

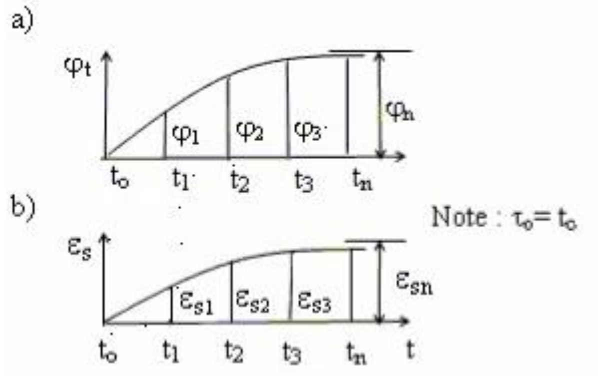

Fig. 2 a) Creep coefficient function (φ_t) of concrete (by theory of aging)[6]
b) Shrinkage strain function (ε_{st}) of concrete [6]

The theoretical creep coefficient curve passes through points that must fulfill the geometric conditions of the experimental curves, but also the conditions of rheological models and mathematical conditions which are considered in [20] [21]. The creep curve allows, also to find creep coefficients at points (t) of axes in which measurements were not made ($t \neq ti$).

Until the 1970th, it was adopted that the creep coefficient function $\varphi = \varphi(t)$, which will now be discussed in more detail, have been represented on the described way by the most famous researchers Volterra, Dischiger, Ulicki, Aleksandrovskij, Sattler, Djurić and many others (see: [1],[5], [6][7]).

However, somewhat later it was broadly accepted that it was valid $\varphi = \varphi(t, \tau_0)$, i.e. as function of two arguments, although this is contrary to the definition in expression (1) for $\varphi(t)$ and for expression (2) (see: [11],[9], [18], [2], [3]).

This statement can also be found in the paper of Illston-Jordan (1972), which is cited in [11]. However, later (1984.) a probabilistic approach for determining creep coefficients is proposed in paper[14][1]. It seems that the name of function for creep coefficients $\varphi = \varphi(t)$ and the term to function of creep measures (viscous) of concrete $\delta_V = \delta_V(t, \tau_0)$ have been mixed, which will now be treated in more detail.

In many papers, the creep coefficient is defined by the ratio $\delta_V(t, \tau)/ \delta_e(\tau_0)$,which is wrong, because the value of the creep coefficient function with two variables is obtained. For easier analysis, you should see Example1 and papers EC2 [2] and many others[1].

2.2 Creep measures of concrete

a) The case E_0 = const and σ_0 =const in the time interval (τ_0, t1) (see: Fig, 1)

a1. Application of creep coefficient functions

The curves of the creep coefficients of concrete are used to form curves by which theirs measures of (viscous) creep are sought. The creep measure of concrete $\delta_v(t_1,\tau_0)$ is function of specific values of creep strains in time (t_1) due to unit stress in time (τ_0). Therefore, it depends of the observation time (t_1) and of the time of initial loading of concrete samples (τ_0).

The expression for the function creep measure of concrete can be obtained using the expressions already found for the functions of the creep coefficients $\varphi = \varphi(t)$, for two theories of concrete based on the properties of aging and the heritage of concrete, which will be described below.

If the experimental values of φ (t) are available for all curves of creep measures in the time interval (τ_{0i}, t1), they can be applied, but it is more difficult to estimate the calculation errors because such a procedure corresponds to the average characteristics of concrete for (τ_{0m}).

Creep curves can be used to determine the kernel in σ-ε relation for concrete. The following (Fig.3) shows the functions of the creep measures of a concrete samples in the interval $\tau_0 \leq \tau_1 \leq t_1$ according to the theory of aging and the theory of heritage.

The expression for the function creep measure of concrete can be obtained using the expressions already found for the functions of the creep coefficients $\varphi = \varphi(t)$, for two theories of concrete based on the properties of aging and the heritage of concrete, which will be described below.

Values of φ (t) are available for all curves of creep measures in the time interval (τ_{0i}, t_1), they can be applied, but it is more difficult to estimate the calculation errors because such a procedure corresponds to the average characteristics of concrete for (τ_{0m}).

For the theory of aging, any curve (2) for $\delta_v(t_1,\tau_1)$ can be obtained on the basis of the curve(1) in Fig. 3 for$\delta_v(t_1,\tau_0)$, because they are considered to be formed by displacement the initial curve in the direction of the ordinates, i.e. is valid:

$$\delta_V(t_1,\tau_1) = \delta_V(t_1,\tau_0) - \delta_V(\tau_1,\tau_0) \quad . \qquad (3)$$

This translation reduces the ordinates of the curve (2), i.e. the creep measures $\delta_V(t_1,\tau_1)$[6].

Also, it is true for the theory of heritage, that it can be obtained on the basis of curve (3) any curve (4), because it is considered that it is obtained by translational displacement of the initial curve in the direction of the abscissa.

This translation increases the ordinate of the curve (3) in Fig.3b.

When is valid $\tau_1 - \tau_0 = t_1 - \tau_1$, then follows on next page exsspesion which is valid for theory of heritage .

[1] CEB Design Manual (1984)

$$\delta_v (t_1 -\tau_1) = \delta_v (\tau_1-\tau_0) \qquad (4)$$

Time(τ_1) is any time (τ) that satisfies the condition: $\tau_0 \leq \tau_1 \leq t_1$ in Fig.3.

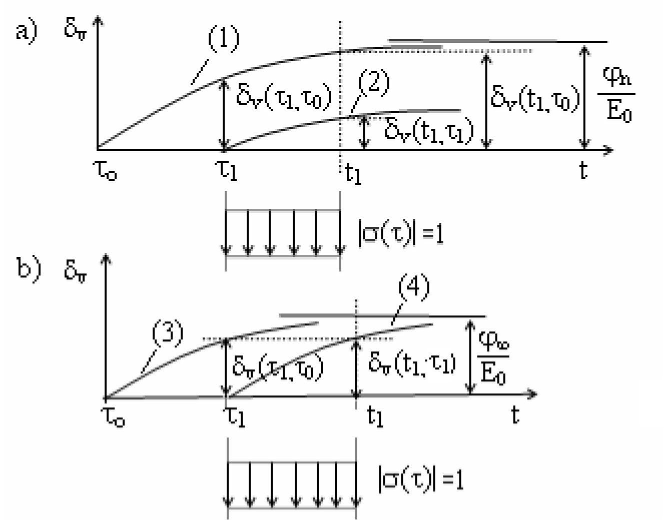

Fig. 3 Function creep measures (specific values of strains) of concrete samples for two theories: a) Theory of aging b)Theory of heritage

This part of the paper can be summarized: expressions for creep measure functions δv(t1,τ1) can be obtained using already found expressions for creep coefficient functions $\varphi = \varphi(t)$ for two basic concrete theories [6].

a.2 Application Voltaire's integral equation

Another way to obtain the creep measure function is by using second form of Volterra's equation, which is here:

$$\varepsilon(t) = \frac{\sigma(t)}{E(t)} + \frac{1}{E(t)} \int_{\tau_0}^{t} \sigma(\tau) K(t,\tau) d\tau + \varepsilon_{st} \qquad (5a)$$

, from it follows :

$$\varepsilon = \varepsilon_e + \varepsilon_v + \varepsilon_{st} \qquad (5b)$$

This well-known integral equation (5a) is also presented in [20], which contains the sum of three terms. If E (t) = E_0 and $\tau_0 \leq \tau_1 \leq t_1$, its closed analytic solutions are found in [12]. Also, its numerical solutions are possible because the expressions for the kernels of integral equations for the four relations σ - ε are proposed.

The first term of expression (5a) represents elastic strain (εe), the second viscous strain of concrete (ε_v), and the third strain of concrete shrinkage (ε_{st}). The kernel K (t,τ)/E_0 is equal to the derivative of the function of creep measure with a negative sign [15] [20]:

$$K(t, \tau) = E_0 \frac{\partial}{\partial \tau} [-\delta(t,\tau)] \qquad (6)$$

If are entered reltion (6) in (5a), then E_0 =const. $\sigma_0 =1$, $\tau = \tau_1$ and $t = t_1$, it follows directly, comparing expressions (5a) and (6), that is (See denotes in Fig.3):

$$\delta (t_1 ,\tau_1) = \frac{1}{E_0} + \delta_v (t_1 ,\tau_1) \qquad (7)$$

The first member of this expression is specific elastic strain, so it can be denoted with :

$$\delta_e = \frac{1}{E_0} \tag{8}$$

Expression (8) is valid only for τ_0 =const.

The second member of expression (7) is the function of the Creep measure of specific concrete strain expressed over the kernel of the integral (for $\sigma(\tau)$ =1) :

$$\delta_v(t_1,\tau_0) = \frac{1}{E_0}\int_{\tau_1}^{t_1} \sigma(\tau)\,K(t,\tau)\,d\tau \tag{9}$$

If we keep in mind that the kernel K (t,τ) has two variables, it follows that δ_V (t,τ) is also a function of two arguments. Herein it is entered in expression (5a) value (t1) instead (t) and (τ_1) instead (τ). In this expression, t = t_1 and is now a possible and certain value. The creep coefficients are dimensionless, and the creep measure has the dimension [$\%_o \cdot 1$ / kN / cm^2]. The measure of creep is easily obtained from expression (9) for basic theories of concrete because the expressions for their kernel K (t, τ) are known. (see. [20]). In many papers, expression (7) is called the 'creep function', although it contains the first term that constitutes a specific elastic strain (see: EC2 [2], CEB [11], etc.). The shown expressions will be given in comparative way within the broader overview of selected creep measure functions in the next paper.

Ulickij denote the creep measure with δ_v (t,τ) or C(t,τ), then Aleksandrovski has used both denotes, which are correct, and now the more common denotes with total δ (t,τ) (i.e. ϕ (t,τ) or φ (t,τ) are used by EC2, by Trost, and in [2],[7],[8]).

a. 3 Superposition of load with the same direction

In the previous presentation, the importance of the creep measure for concrete samples loaded with only one specific load was shown.

Now, solutions should be generalized in the case of multiple loads applied at a time t = $\tau_0,\tau_1,... \tau_n$, Slightly more complex derivation of these expressions can be found in [1] and [6], but now will be expected, probably with more clear notations and descriptions.

A new example of two loads action with same direction in the interval (τ0, τ1) will be considered.

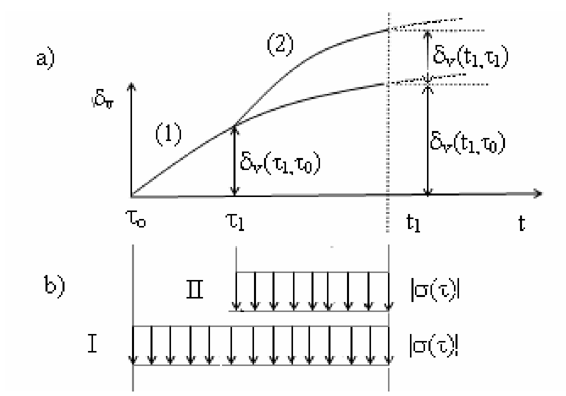

Fig. 4 a) Courves for Creep measures of concrete b) Load I and II

Expressions are given on basis of principle superposition of loads and definition of creep measured for concrete, when follows:

- For strain due to I^{ts} load : $\varepsilon^I(t_1)=\sigma^I(t_1)\ \delta_v{}^I(t_1,\tau_0)$
- For strain due to II^{nd} load : $\varepsilon^{II}(t_1)=\sigma^{II}(t_1)\ \delta_v{}^{II}(t_1,\tau_1)$ (10)
- And for both strain : $\varepsilon(t_1) = \varepsilon^I(t_1) + \varepsilon^{II}(t_1)$.

Analogy expressions would be obtained in the case of a larger number of loads.

a. 4 Superposition of the loads with opposite direction

A more complex example of the action of a load in the interval (τ0, τ1) will be considered. In Fig. 5 it is shown that this load is reduced to the difference of the selected loads: PA = PI - PII. The denote P = const indicates the concentrated pressure force on the concrete samples.

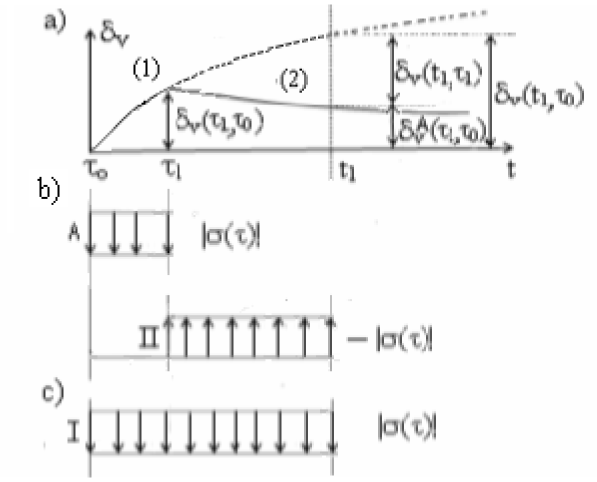

Fig. 5 a) Courves for creep measures for load I –II ; b) Load A is known c) Load A is equivalent to load (I - II)

Similar results are obtained in [1] and [6] , but with different explanations.
Creep measure of load A is shown in expression (11) on the top of next page.

$$\delta_v^{A}(t_1,\tau_0) = \delta_v^{I}(t_1,\tau_0) - \delta_v^{II}(t_1, \tau_1). \qquad (11)$$

Multiplying expression (11) by abs (σ),for load A the strain of the concrete sample follows:

$$\varepsilon^{A}(t_1) = \varepsilon^{I}(t_1) - \varepsilon^{II}(t_1) \qquad (12)$$

The example shown in Fig. 5 can be considered as a case of unloading concrete samples, which is very usefull for laboratories.

b) Case E (t) =E_0 and $\sigma(\tau) \neq$ const in a time interval (τ_0, t_1)

If the expression (5a) includes E (t) = E_0, its new shape is obtained, which can be solved for the basic theories of concrete in the following ways:

- Using analytical procedure for the main monotone changes σ(τ) in the interval (τ0, t) [12]. Solutions have closed form and explicit expressions for many tasks in RC, PC and in composite structures (several types) [15]
- Using numerical procedure for applying algebraic relations for stress-strain relations (see examples: [23]). An application program has been created, that numerically successfully solves the already mention structural tasks.

c) Examples for application of creep coefficients and creep measures

Example1. Theoretical values of creep coefficients

Data: $\varphi_n = 2.5$; βn =0.0401 [1/days]; $\tau_0 = 7$ [days]; φ(7)=0 .

Find: φ_1 (t)=? za $t_1 = 90$ [days] and $t_2 = 150$ [days].

Results: $\varphi_1(t_1) = \varphi_n(1 - e^{-\beta_n t_1}) = 2.43$ [-]; $\varphi_2(t_2) = 2.49$ [-]

(Data values are taken based on experiments or regulations [21].)

Example2. Theoretical values of concrete creep measure (According to the theory of aging)

Data: φ_n =2.25; β_n =0.0243 [1/days]; τ_1 = 7 [days]; $\varphi(\tau_1)$ =0;
E_0= 3250 [kN/cm^2]; σ_0 = 1 [kN/cm^2]

Find: $\delta_v(t_1,\tau_1)$ =? for t1 = 90 [days]. See: Fig. 3

Result: $E_0 \cdot \delta_v(t_1,\tau_1) = \varphi_n(1- e^{-\beta_n t_1}) - \varphi_n(1- e^{-\beta_n \tau_1})$=2.100 -0.924= 1.076 [-].

Follows: $\delta v(t_1,\tau_1)$ = 1.076 / 3250 = 0.308 [%o 1 / kN/cm^2].

Example3. Theoretical values of concrete creep measure (According. to the heritage theory)

Data: φ_∞ = 1.02; $\beta\infty$ =0.013 [1/days]; τ_0 = 10 [days]; $\varphi(t_0-\tau_0)$ = 0.
E_0= 3750 [kN/cm2]; σ_0 = 1 [kN/cm^2];

Find: $\delta v(t_1,\tau_1)$ =? for t_1 = 90 and t_2 = 180 [days]. See data shown in Fig 3.

Results: They are given in Table 1.

Table1. Creep coefficients and creep measures for heitage theory

(i)	t (days)	$t-\tau_0$ (days)	$\varphi(t-\tau_0)$ (-)	$\delta_v(t-\tau_0)$ (%o·1/ kN/cm^2)
1	10	0	0.000	0.000
2	100	90	0.702	0.187
3	190	180	0.922	0.245

(see: example in [20])

The table1 shows the values $\varphi(t-\tau_0)$ calculated using the formulas:

$$\varphi(t-\tau_0)= \varphi_\infty(1- e^{-\beta_\infty(t-\tau_0)}) \quad ; \quad E_0\, \delta_v(t-\tau_0) = \varphi(t-\tau_0)$$

Table2. Cofficients of 'fluidity'for two basic theories

τ_0 (days)	β_n (1/day)	β_∞ (1/day)
3 - 10	0.04	0.01
11 - 20	0.03	0.01
>20	0.02	0.01

Note: If experimental data are not available, the 'fluidity' coefficients βn and $\beta\infty$ can be taken from Table 2 (for details see: [20]).

III. CONCLUSIONS

Based on the presented topic, the following conclusions can be formed:

1. Definitions of creep coefficients and creep of concrete are now analyzed in accordance with measurement procedures, and can therefore be considered to be of a more complete and clear form.
2. From the comparative presentation of the calculated values of the creep coefficients and the creep measures, the true meaning of both quantities can be seen (see: Example 2. and 3.).
3. Examples of stress superposition are suitable for tasks in laboratories (3 variants).
4. Table of 'fluidity' coefficients for aging theory and heredity theory it should be useful in practice, also when there are no experimental results.

Problems of this work are a whole with the previous two papers of the author [20], [21].

REFERENCES

[1]. Đurić M.: "The theory of composite and prestressed structures",(in Serbian) , SANU, Bgd , 1963.
[2]. EUROCOD-EC2, "Design of Concrete structures", (in Serbian), Belgrade, Faculty of Civil Engineering, 1994.
[3]. PBAB 1987- P'87, (in Serbian), Official Journal of Yu-Code, Belgrade, 1987.
[4]. Rüsh H.,Jungwirth D.,"Berückichtingung der Einflüusse von Kriechen und Schwinden auf dasVerhaltender Tragwerke",Werner Verlag, Düssldorf, 1976.
[5]. Rzanicin A., "The theory of materials creep", (in Serbian), Gadjev.kniga, Belgrade, 1974.
[6]. Ulickij I.,"Theory and design of AB line stuctures with the effects of long - term processes", (in Russion), Budveljnik, Kiev, 1967.

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[7]. Sattler K., "Theorie der Verbundkonstruktionen", Wilhelm Ernst und Sohn, Berlin.
[8]. Trost H.," Auswir des Superpostionsprinczips auf Kriech - und Relaxationsprobleme bei Beton und Spannbeton", BETON-UND STAHLBETONBAU 10,230-238, 1967.
[9]. Bazant Z.," Prediction of Concrete Creep Effects Using Age-Adjusted Effective Modulus Method", ACI Journal, pp 212-217, 1972.
[10]. Mihailović V., "Rheological model for concrete according to the theory of aging", Simp. SJL, (in Serbian), Ohrid, II-16, 1975.
[11]. Ivković M., Prašćević Ž, "A review of some recent proposals of the relationship between stresses end deformations of Concrete, (in Serbian), (GRADJEVINAR),9-14, Zagreb, 1977.
[12]. VMihailović V. A general procedure for analysis of composite and prestressed structures, (in Serbian),GF Belgrade (Diss.)., 1978.
[13]. Mihailović V., Krstić G."Test results of modulus of elasticity, shrinkage and creep of concrete", pp123-133, (Professional seminar: Hangar 2-JAT at Belgrade Airport, SGITJ), Belgrade, 1986.
[14]. Jordaan I., "Models for creep of concrete, with special emphasis on probabilistic aspects", Materiaux et constructionns, Vol.13-No 73, Calgary, 1980.
[15]. Mihailović V.." Composite and prestressed structures (in Serbian)", 'Scientific books', Belgrade, GF Subotica,1989.
[16]. Mihailović V., Kukaras D.,"Problems of calculation stresses and deformations of composite structures (in Serbian), Confer. Of Modern Building Practice '99, Novi Sad, 1999
[17]. Mihailović V., Landović A., "The relationship between the properties of concrete and its characteristics in the rheological models", (in Serbian), Zb.Rad.. GFS '10, p.10, Subotica, 2010.
[18]. Rilem colloquium (Creep and shrinkage), Leeds, 1978.
[19]. Aleksandrovski S. ," Calculation of RC structures on creep effects", Strojizdat, Moskva, (In Russion), 1973
[20]. Mihailovic V., "A gener.of stress– strains relations for concrete", Internacional Conf.'19 , GFS, Sumpp.9,Subotica, Serbia, 2019.
[21]. Mihailovic V. "A.Rheol. charach. of models in applic. of concrete creep theories", Rad Zb GFS '35, Spp.8 , Sub.,2020.
[22]. Rilem-ACI colloquium (Long-term observation of concrete structures), Budapest, Hungary, 1984.
[23]. Program ConstructSections, 'Site' GFS, http://www.gf.uns.ac.rs, Subotica, Serbia (2010).