Discussion: Pure creep, maturity and MP-creep in concrete in terms of an exo-process

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Contribution by J. R. Martí-Vargas

The paper under discussion (Blechman, 2014) contains an interesting study on concrete creep and maturity. Several equations are obtained to compute pure creep, both elastic and strength maturity, and MP-creep. The author should be complimented for producing this detailed paper, which was of interest to the discussor, who would like to offer some comments for consideration and response.

The author states that, for structural concrete, the potential of relaxation (λ), exponent (N) and time of complete relaxation (t_f) are 0.42, 4 and 50 d, respectively. These parameters are used in Equations 3 and 4, which allow the operator of relaxation (R_t) and the time-operator (B_t), respectively. Therefore, it seems that the aforementioned λ , N and t_f values are the same, regardless of the main variables such as loading stress level or concrete type and strength. The author also indicates that, for a given concrete, the λ parameter and the operator of total pure creep (C_f) are constant. However, the author states that the λ parameter (and consequently C_f , R_t and other parameters) depends on concrete parameters such as cement content, water/cement ratio and so on. In order to offer a better understanding, can the author provide some details regarding how the implied basic parameters (λ , N , t_f) account for the different characteristics and properties of concrete?

The author defines a half-creep factor of pure creep (h_c^*) to reflect the time needed for half the total pure creep realisation. Then Equation 20 involves a B_h parameter defined as the time-operator of exo-process for half its duration, and a half-relaxation factor (h^*) is given through Equation 25 by using a 0.5 time rate (time under load in relation to complete relaxation time). Therefore, it seems that there is an inconsistency between Equation 19 and Equations 20 and 25: the former considers that half-creep realisation equals half its final value, whereas the latter consider half time intervals, which may not correspond to the periods with a half development of the associated phenomena.

Different values are obtained for the M exponent involved in the time-operator maturity (B_m , also M_t according to the

notation) established in Equation 27. The author concludes that, for structural concrete, the exponent is 4.2–4.8 (4.2–4.6 according to the section on parameters of maturity) for elastic maturity and 3.8–4.2 for strength maturity, depending on the kind and content of cement. The discussor believes that the information included in the section on parameters of maturity does not suffice to clarify whether the detailed ranges cover all the cases or only exposed examples. It is noteworthy that the concrete strength considered at 180 d seems to be 75% of its strength at 28 d.

The discussor notes that Equation 6 should be defined in terms of strains rather than stresses; that is, $\varepsilon_{\text{tot}} = \varepsilon_{\text{load}}/R_t$ instead of $\sigma_{\text{tot}} = \sigma_{\text{load}}/R_t$, and perhaps the $1/N$ exponent in Equation 25 should affect all the terms and not only the second term. Finally, the discussor encourages the author to conduct further studies on creep in terms of an exo-process in the prestress losses context (Caro *et al.*, 2013), and by considering the influence of specimen size on the elastic modulus of concrete (Martí-Vargas *et al.*, 2014a). The 'Ecada' test method (Martí-Vargas *et al.*, 2014b) may be useful for experimental comparisons.

Author's reply

The author would like to thank the discussor for these valuable comments. The answers are given below.

- Investigations about relaxation are very rare. In the frame of the published data on structural concrete, its potential of relaxation was found to be 0.42; however, owing to the great variability of concrete, this factor must be investigated separately for its different types.
- The half-relaxation and half-creep factors are defined as dimensionless time (in the interval $0 \div 1$), where the half of the pliancy in question is achieved.

The proof of Equation 25 is as follows: as the value of half-pliancy h^* is independent of σ_{in} and λ , it can be written as

$$48. \quad B_h = 0.5$$

where

$$49. \quad B_h = [1 - (1 - h^*)^N]^{1/N}$$

Using Equations (48) with (49), the following equations are obtained

$$50. \quad 0.5^N = 1 - (1 - h^*)^N$$

and

$$51. \quad (1 - h^*)^N = 1 - 0.5^N$$

from which the Equation 25 is obtained as

$$52. \quad h^* = 1 - (1 - 0.5^N)^{1/N}$$

- As for the first comment, only further investigations will provide a sound value for the exponent in the equation of maturity.

- Equation 6 is transformed into Equations 7–9 owing to the constancy of the elastic modulus in the relaxation and creep processes, when maturity is not in effect.

The propositions of the discussor correspond with the author's own scientific interest.

REFERENCES

- Blechman I (2014) Pure creep, maturity and MP-creep in concrete in terms of an exo-process. *Magazine of Concrete Research* **66(10)**: 505–513, <http://dx.doi.org/10.1680/mac.12.00065>.
- Caro LA, Martí-Vargas JR and Serna P (2013) Prestress losses evaluation in prestressed concrete prismatic specimens. *Engineering Structures* **48**: 704–715.
- Martí-Vargas JR, Caro LA and Serna-Ros P (2014a) Size effect on strand bond and concrete strains at prestress transfer. *ACI Structural Journal* **111(2)**: 419–429.
- Martí-Vargas JR, García-Taengua E, Caro LA and Serna P (2014b) Measuring specific parameters in pretensioned concrete members using a single testing technique. *Measurement* **49**: 421–432.