Consideration of Transient Creep in the Eurocode Constitutive Model for Concrete in the Fire situation

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EUROCODE EXPLICIT TRANSIENT CREEP (EETC) MODEL

Strain Components

Implicit (EC2) model $\varepsilon_{tot} = \varepsilon_{th} + \varepsilon_{m}$

Explicit (EETC) model $\varepsilon_{tot} = \varepsilon_{th} + \varepsilon_{\sigma} + \varepsilon_{tr}$

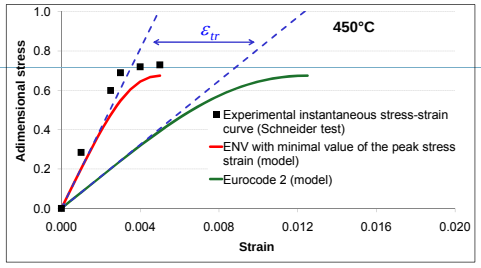
Limitations of the Implicit Model

•No distinction between heating under stress and loading at elevated T
•Transient creep treated as elastic strain (recovered during unloading)

Distinction Apparent VS Actual Modulus

Apparent Modulus (EC2): initial tangent to the constitutive curve $(\varepsilon_m ; \sigma)$

Actual Modulus (EETC): initial tangent to the constitutive curve $(\varepsilon_\sigma ; \sigma)$

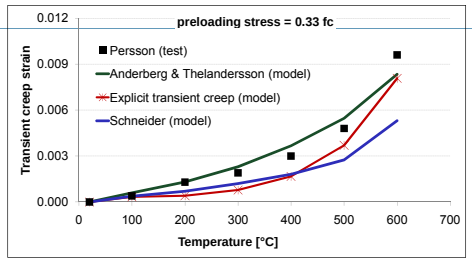


Characteristics of the EETC model

▪ Calibrated to yield the same mechanical strain as the EC2 model for first-time heating under constant stress
▪ Young modulus of ENV with minimum value of the peak stress strain
▪Transient creep proportional to the applied stress

Transient Creep

$$\varepsilon_{tr}(T) = \varepsilon_m - \varepsilon_\sigma = \phi'(T)\frac{\sigma}{f_c} \quad with \quad \phi'(T) = \frac{2}{3}\left(\varepsilon_{c1,EC2} - \varepsilon_{c1,\min}\right)$$



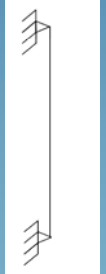
Instantaneous Stress-Strain Relationship

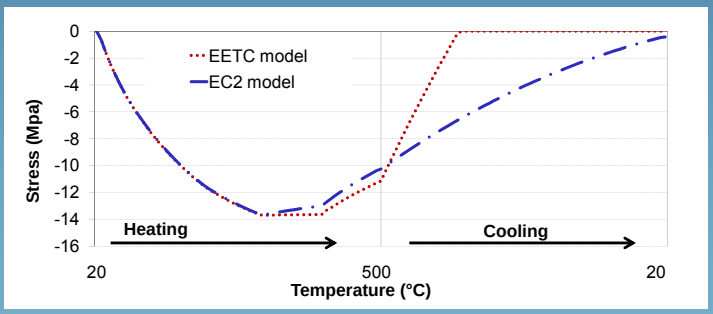
In the EETC model, the constitutive relationship is expressed in terms of the instantaneous stress-related strain, in order to treat the transient creep effects separately from the elastic and plastic effects:

$$\frac{\sigma}{f_c(T)} = \frac{3\left[\varepsilon_\sigma + \phi'(T_{\max})\left(\sigma / f_c\right)\right]}{\varepsilon_{c1,EC2}(T)\left(2 + \left(\frac{\varepsilon_\sigma + \phi'(T_{\max})\left(\sigma / f_c\right)}{\varepsilon_{c1,EC2}(T)}\right)^3\right)}$$

RESTRAINED ELEMENT SUBMITTED TO HEATING-COOLING SEQUENCE

▪Simulation with the FE software SAFIR of an axially restrained concrete cylinder heated uniformly to 500°C and then cooled down to 20°C
▪This numerical calculation highlights the importance of considering the actual elastic modulus, i.e. not treating the transient creep strain as reversible
▪The influence of the explicit consideration of transient creep strain is particularly visible during the cooling phase: the strains are mostly permanent so the stresses rapidly decrease when the element is cooled down

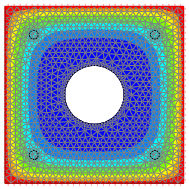




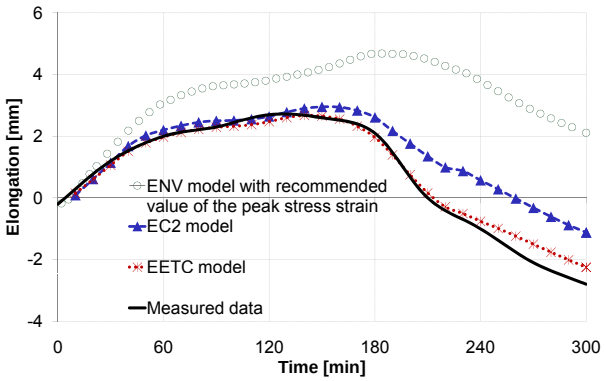
COMPARISON WITH EXPERIMENTAL DATA

▪Simulation with the FE software SAFIR of an experimental fire test on centrally loaded concrete column
▪Beyond 140 minutes, the effect of the explicit consideration of transient creep on the structural behavior becomes notable. The EETC matches better than the EC2 model the actual behavior of the structure.
▪The difference is very significant during the cooling phase. The final shortening of the column is explained by the decrease of thermal strain coupled with a very limited recovery of mechanical strain. The EC2 model significantly underestimated this shortening because the transient creep was implicitly recovered .

•Section 300x300 mm² with centre hole Φ100mm
•4 Φ16 cover 40 mm



•Concrete 55 MPa
•Load 677 kN
•Japanese standard fire during 180 minutes



CONCLUSIONS

The implicit consideration of transient creep in the current model of the Eurocode leads to some approximations in the representation of the transient creep strain, especially when modeling the behavior of concrete structures during the cooling phase of a fire. A new formulation of the generic Eurocode 2 concrete model that contains an explicit term for consideration of the transient creep (EETC) has been presented. The simplicity and generic characteristics of the Eurocode model are preserved and the new explicit formulation is calibrated to give the same results as the implicit formulation that is proposed in the Eurocode when the material is heated under constant load. However, the improvements allow taking into account with more accuracy the phenomenon of transient creep in concrete under more complex situations. Particularly, the EETC model takes into account the irreversibility of transient creep. The model implementation in finite-element software can be performed by an adaptation of the current EC2 model. The differences between the two formulations have been highlighted for a simple structure. The improvement is significant as it has been showed by modeling an experimental test.