Review of Differences of Steel related Properties between Proposals of European Structural Codes

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Introduction

This report contains a letter to the main committee CEN/TC250 organizing the structural CEN codes on behalf of the project team CEN/TC250/SC2/PT10 writing the fire chapter of the concrete code.

The letter indicates that properties of steel were not the same in the proposals for the concrete code and the steel code.

One consequence of the letter was that full stress-strain curves were introduced in the structural codes.

However, in 2004, the parameters to be used for the curves are still misleading, because a stress parameter indicated by the index “y” is not a yield stress or 0.2% strength, but a stress, which can only be found for a large strain of 2.0%, and this stress is the one, which is tabulated in the code text.

It has been experienced that most engineers misunderstand this and uses the tabulated stress marked “y” in their structural calculations, instead of making the troublesome derivation of the 0.2% stress from the tabulated values and the complicated expressions for the full stress-strain curve.

Although this letter is from 1993 it serves as documentation for what has happened and explains why the 0.2% stress should be applied instead of the tabulated values found in the codes.

The technical content of the letter is therefore still of interest and the present report is made in order to make it accessible for the public.

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1993-04-29
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Dr.-Ing. E.H. Günter Breitschaft
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Dear Sirs,

In the present proposals for design of constructions for fire resistance differences occur for the physical properties and safety coefficients of steel and steel constructions. A closer analysis of background documents and a more detailed analysis of the consequences show that logic as well as physics seems to be violated in some codes in favour of steel as a structural material. It seems that the present proposals contain misleading information which will cause a distortion of the competition between steel and other structural materials.

The project team writing the proposal of a fire design chapter for the concrete code finds that steel properties should be in accordance with physics and logic and has therefore decided to present such data even when they are in conflict with data presented in the proposal for the steel code.

The enclosed review of the problem is made in order to draw the attention of CEN/TC250 to it and to explain why steel data of the present proposal for fire design of EC3 do not correspond with the data of the same steel in the proposal of EC2.

yours sincerely

Kristian Hertz

cf: SC1, SC2, SC3, SC4, Horizontal Group.

REVIEW OF DIFFERENCES OF STEEL RELATED PROPERTIES BETWEEN PROPOSALS OF EUROPEAN STRUCTURAL CODES

1) SAFETY COEFFICIENTS

In EC3 2.3(2) a partial safety factor of $\gamma_{MF} = 0.9$ is introduced for the strength. It seems that the application of this value is not reasonable. If it is argued that the basic fractile should be increased, the characteristic strength applied for fire design should be increased instead of decreasing the partial safety factor. But also this seems to be unreasonable because the fractile takes the uncertainty of the data into account, and this consideration is not altered in case of fire. The value $\gamma_{MF} = 1.0$ is therefore used in EC2.

In EC3 2.4.2(4) the degree of loading during fire is where it is $\eta_F = 0.6$, where it is 0.7 in EC2 corresponding to approximately 50 % imposed load. The value 0.6 corresponds to a load reduction, for which it is difficult to find a valid argument.

2) ASSUMED STEEL STRAIN

In the proposed parts of fire design of the European structural codes a steel stress is often used which can only be reached if the strain in the steel is at least 2.0 %.

It is therefore assumed that the steel has a strain of 2.0 % or more.

For reinforcement in **concrete columns and compression zones** it is obvious that a precondition of a compressive strain larger than the strain at which the concrete brakes can not be allowed. For most fire exposed constructions this maximum strain of a compression zone will be between 0.35 % and 1.0 %.

For reinforcement in **concrete beams and tension zones** a precondition of a certain tensile strain can be accepted if it can be shown that the compression zone does not break before the tensile strain has been reached.

The proposal for EC2 takes these considerations into account and offers data for 2.0 % strain as well as 0.2 % strain.

It must be a precondition that a verification based on calculation must not lead to a larger standard fire resistance than a verification based on a test. A fire test should be made in accordance with the standard CEN/TC127 which gives two criteria for failure: deflection and deflection velocity.

These criteria are made in order to describe the limit at which the construction no more can be considered to fulfil its purpose.

The deflection criterion is $L^2/400h$ where L is the beam length and h is the beam height. From this it is easily shown that the strain on the edge of a symmetrical cross section of a steel beam must not exceed 1.2 % and this corresponds to about 1.0 % strain for a plastic consideration.

The deflection velocity criterion can be shown to be violated for most steel beams as soon as the limit for its use is passed. This limit, which is a deflection of L/30, is therefore identical to the deflection velocity criterion for steel beams. The steel strain of an ordinary beam of L/h = 24 is 0.67 % at this limit.

This means that for symmetrical **steel beams** a precondition of a strain of more than approximately 0.5 % for' the reduction of the decisive steel stress can not be allowed because it would lead to a larcrer fire resistance by a simplified calculation than can be obtained by test, where the test criterion describes the limit at which the construction does not anv more fulfil its purpose. This is in conflict with the present proposal of EC3.

In EC3 clause 4.2.2.3. (4.5) the load bearing capacity of a steel column is reduced due to the influence of fire by a factor equal to the reduction of the steel stress at 2.0 % strain: $R_{d,F(t)} = k_{y(\theta)}R_d/1.2$. This simplified procedure leads to a larger loadbearing capacity than a more correct calculation of the column based on the reduced stress strain curve given in the same code draft. For example is $k_{y(\theta)} = 1.0$ at $\theta = 400$ºC assuming a steel strain of 2.0 %, but the reduction of the modulus of elasticity of the same steel is 0.70 (Background document 10.1 for EC3 of 1992-05-11), where 1.0/1. 2 = 0. 83. It cannot be allowed that a simplified procedure leads to a more unsafe construction than a more correct procedure. It can be shown that the two methods represent the same safety level if the reduction of the steel stress refers to an assumed steel strain of 0.5 % in stead of 2.0 %.

This means that it is only valid to reduce the loadbearing capacity of a fire exposed steel column by a stress reduction if this stress reduction is based on a steel strain of no more than approximately 0.5 %. This is therefore in conflict with the present proposal of EC3.

Since the calculation methods of the draft of a European code for **composite constructions** cannot immediately be verified, no further considerations have been made for these constructions.

However, the general limitations for the application of the material properties of steel and concrete are also valid for composite constructions.

3)METHODS OF ASSESSMENT

In EC3 4.2.2.2 the fire resistance of beams under a non-uniform temperature distribution is related to that under a uniform distribution by the expression $R_{d,F(t)} = R_{d,F(\theta)}/\kappa$, where κ is an **"adaptation factor"** < 1.0. The values of the adaptation factors seems to be totally undocumented and the argument for them is a veiled mixture of support conditions, fire exposure and a correction for the difference between average values and characteristic values, which has already been made once in the doubtful γ_{MF} factor mentioned above.

4) MATERIAL DATA

In the draft of EC1 10.5.2.1 the **emissivity** of steel is given as 0.62, where 0.7 is a more reasonable value. This means that fire exposed steel constructions are heated relatively less than constructions of other materials.

The **stress-strain data** used in the draft of EC3 are determined in the background document 10.2 "Stress-strain relationship...” of 1992-05-18, where some available test data are divided into two clusters. The most unsafe values are chosen partly by the argument that they have been used in the drafted UK standard. This seems not to be an acceptable procedure.