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Accuracy of estimating long-term strains in concrete*

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The work undertaken by Dr Brooks in this investigation is indeed welcome, as there is a clear need for more research in this area, especially as it sheds new light on the estimation of long-term creep from short-term data. In this discussion, special attention is given to the comparison of experimental creep test results with predicted creep values by applying standard methods. Such comparisons have been presented in several previous investigations[1–3] and new results are presented by Dr Brooks which are discussed here.

Dr Brooks gives the uncertainty of the method of prediction applied by an average standard error, M, determined from the differences between measured and calculated creep values. This standard error coefficient describes the deviation of the predicted creep formula from the test data, but is not informative in the case when one would like to decide whether or how the applied method overestimates or underestimates the measured values. The model uncertainty implied in the several creep formulae can be estimated more precisely by evaluating the average mean value m (bias) and the corresponding coefficient of variation v of the ratio between measured and calculated creep values[3]. The uncertainty in each prediction method can be then accounted for by a random variable J with log-normal distribution and sample statistics m and v.

When the standard errors obtained from different investigations are compared, remarkable discrepancies can be observed. This may be ascribed partly to the consideration of different test results and partly to the use of the well-known hyperbolic creep–time expression. The comparison presented and discussed by Dr Brooks shows that, if known moduli of elasticity are used, the CEB 70 method is more accurate than the CEB 78 formula when, for example, total creep is predicted. It is felt that this conclusion is only valid for test results which give special consideration to the varying concrete composition. The most important varying parameter influencing the creep of the test specimens described by Dr Brooks is the water/cement ratio. The CEB 70 method implies an independent coefficient to describe the effect of the concrete mix—and especially the influence of the water/cement ratio—upon concrete creep, whereas the CEB 78 method suggests a 25% reduction or increase of the basic creep coefficient according to the concrete composition (wet or dry concrete). The CEB 70 prediction formula covers the influence of the varying concrete composition upon creep better than CEB 78, but involves a number of several other shortcomings, which are reviewed and commented on by Rüsch *et al.*[4] An improvement of the CEB 78 formula can be achieved by providing analytical expressions for the basic creep coefficient[3].

For general conclusions concerning the accuracy of several prediction methods, a large sample of test

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specimens should be chosen, in which the influence of several parameters such as environmental humidity, random temperature, member size, concrete composition, concrete age etc. is treated. Of course, this was not the objective of Dr Brooks's analysis, since only few ten-year data are available to provide relationships for long-term creep from estimated short-term values.

Further, it should be noted that the standard error between measured and calculated creep depends also upon the variability of the laboratory conditions, which are not negligible in this case with a varying air humidity of $60 \pm 10\%$. Owing to the variability of the creep strains in the laboratory, the estimated error coefficients can be slightly reduced. But, also in that case, the model uncertainties of the several prediction methods remain large and therefore I fully agree with Dr Brooks that, for improved accuracy, short-term data are necessary.

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Reply by the author

I should like to thank Dr Diamantidis for his comments on my paper and to offer the following remarks.

I agree that the error coefficient alone is not informative when one is trying to decide whether a particular method of prediction over-estimates or underestimates the measured values. This is why I included Figure 7 to show that the majority of my results were underestimated by all methods. Where the trend is less clear, of course, it would be more appropriate to use more sophistication as suggested by Dr Diamantidis.

With regard to his comment on the improved accuracy of the CEB 70 method in comparison with the CEB 78 method when the moduli of elasticity are used to estimate creep, I agree that this is valid only for my tests in which the water/cement ratio and aggregate type varied. None of the methods really accounts for the effect of the type of aggregate upon creep whilst, as Dr Diamantidis states, the CEB 78 method of allowing for water/cement ratio is inferior to that of the CEB 70 method. With the former method, the adjustment of the flow coefficient requires an engineer to guess what is low- or high-consistency fresh concrete before making a 25% decrease or increase as appropriate. Surely this is too imprecise?

Although it is desirable to assess the accuracy of methods of prediction by a long-term programme of tests involving the influence of all the pertinent factors, this is not feasible in any one laboratory. At best, we can only attempt to assess methods on the basis of each set of data as it becomes available. Therefore, when the effect of only one parameter upon a long-term prediction method is assessed, the findings should supplement those of previous investigators so that an over-all assessment of methods can be made. Moreover, when designing for long-term movements, an engineer is interested in the accuracy of prediction when only one or two parameters are changed, and not necessarily in the general accuracy as assessed from changing all the influencing factors.