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Strain measurements on reinforced concrete columns*

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Mr Ashworth's paper on strain measurements on reinforced columns is most interesting and should lead to some anxiety on the part of designers of point blocks where the cross-sectional area of columns is sacrificed to letting area. This leads to the use of rich or very rich mixes, so that a high working stress may be applied to the concrete in the column. Since mixes of the 1:1½:3 type tend to develop relatively high temperature in the early stages of hardening, it is evident that the concrete will expand during this period. The greatest expansion will take place while the shuttering is in place because this is when the highest rate of chemical reaction between the cement and water occurs. It is also apparent that the total movement of the concrete is chiefly restricted to the vertical direction by the restraining influence of the formwork at this time.

Now whilst it may be correct to assume that, in the hardened state, the coefficient of expansion of the concrete is equal to that of the steel, it is certainly not so during the very early stages of hardening. It is probable, therefore, that the concrete tends to slip over the steel in expanding which must tend to break the bond with the steel originally established during placing.

The next phase in the mechanical performance of the steel and concrete will start when the column shutters are removed and cooling and moisture loss intervene in the relation between these two structural elements.

At this time the hardening of the concrete has advanced sufficiently to make its resistance to compression and tension significant. It may be presumed that, as the earlier relative motion between steel and concrete has reduced the bond between the two, the initial increments in the shrinkage phase would not immediately transmit load to the steel. However,

mechanical jamming must eventually take place between the bars and their surrounding concrete and load will be transferred, this load being entirely due to thermal and moisture loss shrinkage. Calculation shows that the level of stress reached by the steel can be as large as one-third of the permissible design stress. This could account for the excessive stress values mentioned in the author's paper and the abnormally low concrete compressive stresses.

Reply by the author

I should like to thank Mr Stewart for his contribution, which I have read with interest.

Any difference in the coefficients of thermal expansion of the concrete and the steel would certainly result in stresses being produced in both materials as a result of a change of temperature, provided that a bond had been established between them. The magnitude of these stresses would depend, amongst other things, on the temperature at which this bond became effective in relation to average room temperature, since this is the equilibrium temperature of the columns once hydration has ceased.

No measurements were taken of the temperatures produced in the columns as a result of the hydration process but, by assuming a temperature rise as high as 20°F before the bond developed and taking the coefficients of thermal expansion as 7.3×10^{-6} per °F for concrete made with gravel aggregate⁽¹⁾, and 6.1×10^{-6} per °F for steel, then the differential strain is only 24×10^{-6} . This is less than 5% of the estimated drying shrinkage of the concrete, and therefore it would seem unlikely that more than a small fraction of the high steel stresses can be attributed to thermal strain although it may rightly be considered a contributing factor.

Mr Stewart's statement in his closing paragraph that calculations show steel stresses due to thermal and moisture loss shrinkage may be as large as one-third

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of the permissible design stress is most interesting. More recent work carried out by the author on an isolated column of the same dimensions as those described in the paper has indicated compressive stresses in the steel of 6,000 lb/in² on the day following casting. These shrinkage stresses increased gradually over the following 15 months and were of the order of 10,000 lb/in² by the end of that time.

REFERENCE

1. BONNELL, D. G. R. and HARPER, F. C. *The thermal expansion of concrete*. London, H.M.S.O., 1951. National Building Studies Technical Paper No. 7.