EFFECTS OF RESIDUAL STRESSES IN WELDED STRUCTURES

Discussion by A. W. Huber and L. S. Beedle

It is the purpose of this discussion to comment on the influence of residual stresses on members loaded in compression. The author refers only briefly to the influence of residual stresses on instability. Recently much new information has been added to the subject.\textsuperscript{1-4} Theory and tests on both axially and eccentrically loaded rolled steel columns of ordinary wide-flange shape clearly indicate a pronounced influence of residual stress upon the ultimate strength.

It is true that there is no influence of residual stresses on "slender" axially loaded steel columns in the Euler buckling range provided the sum of the applied stress and residual stress does not exceed the proportional limit. Therefore it is more appropriate to speak of inelastic instability or elastic-plastic instability. The bending stiffness, $EI$, in the Euler buckling formula is modified to the bending stiffness, $EI_e$, of the unyielded part of the cross section (see References 2 and 4).

The influence of residual stress in the case of axially loaded steel columns is clearly demonstrated in the accompanying figure. The results of annealed and as-delivered columns, free to bend in the weak direction, are compared on a nondimensional basis. Theoretical solutions are also shown which agree very well with tests. The residual stresses, in this case, are those formed due to cooling after rolling. The solid test points represent members which were annealed and thus nearly free from all residuals. As a result they are closer to the horizontal dashed line that represents the strength of an ideal column free from residual stresses.

Residual tension stresses in welds can amount to as high a value as the yield point but are rather localized in the neighborhood of the weld (see author's Fig. 1). It would be expected that the compressive stresses, generally, would be low in magnitude. Thus, in the case of welded columns, built up from plates, a smaller reduction in column strength is possible.

The author refers to the tests made at the University of Illinois\textsuperscript{5} on welded built-up columns. These columns had an effective slenderness ratio, $KL/r$, between 35 and 41 since they were tested in flat-ended conditions ($K \approx 0.55$). Actually they were short and not slender columns. As has been shown\textsuperscript{4} the effect of residual stresses is greatest for intermediate columns of an effective slenderness ratio between 50 and 110.

Residual stresses were undoubtedly present in the material used to make the built-up columns in the University of Illinois tests. Further, tests of the un-reinforced columns inherently included the effects of residual stresses. The addition of cover plates by welding probably did not result in an unfavorable change in residual stress distribution as can be deduced from the remarks made earlier. This and the low effective slenderness of the columns seem to be the reason that the reinforcement...
plates appeared to be 100% effective in increasing the load-carrying capacity over unreinforced columns. However, it would be erroneous to conclude from these tests that generally residual stresses have no detrimental effect upon column strength.

As was shown in Reference 4, even though the presence of residual stresses reduces column strength, this does not mean that structures are unsafe that were designed according to formulas neglecting the effect of residuals. Current specifications are conservative, in this regard, since they are based, in part, on tests. Of course, the test members contained residual stresses.

Through the sponsorship of Column Research Council, Pennsylvania Department of Highways, Bureau of Public Roads, and National Science Foundation, work is continuing at Lehigh University on a project to determine the basic compressive strength of steel columns, including the effect of residual stresses. The studies include not only rolled shapes, but also columns built up of plates and shapes. One of the eventual objectives is to suggest a column strength formula that will include the effect of residual stresses.

References


The influence of residual stress on column strength as indicated by theory and tests

\[ \lambda = \frac{1}{\pi} \sqrt{\frac{\sigma_y}{E}} \frac{L}{r} \]