*Discussion on Paper No. 6577**

The design of frame structures considering strength, stability and deflexions

by

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Dr D. S. Mansell (Lecturer, University of Melbourne) commented that the Author, in Part I of his paper, expressed interest in the effect of additional material on the strength of an elasto-plastic structure. There was no doubt that intuition, which was frequently a designer's guide, suggested that additional material could not cause a loss of load capacity when its dead weight effect was negligible. The fact that for two limiting types of failure, viz. elastic instability and plastic collapse, theorems could be advanced to show that this was true, lent some analytical weight to this intuitive conclusion. Therefore the Author was to be congratulated on the caution of his statement in § 24 that it was reasonable to conclude that the load carrying capacity of an elasto-plastic structure was unlikely to be reduced by the addition of material.

68. The Author and the reader might therefore be interested in a series of tests on elementary trusses carried out by Dr Mansell at the University College of Swansea, in which the hinge at joint B, shown in Fig. 13, was replaced by a fixity in half of the trusses tested. This corresponded with an increase in the stiffness of restraint from the viewpoint of elastic stability, and an increase in the fully plastic moment from the viewpoint of plastic collapse, and was tantamount to an addition of material.

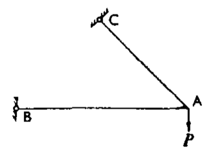

FIG. 13

Yet the truss was so designed that this change alone effected a *reduction* in the collapse load from $0{\cdot}89P_s$ to $0{\cdot}77\ P_s$ where $P_s = A\sigma_y$ was the squash load of the strut AB. These figures were each the average of five independent truss tests. The scatter of results was such that the lowest load capacity of the pinned truss was $0{\cdot}84\ P_s$ and the highest load capacity of the fixed truss was $0{\cdot}83\ P_s$.

69. These experiments were undertaken to justify this result which had been obtained analytically, and the work had been accepted for publication.[8]

70. In that paper would be found a rigorous mathematical proof, based on the principle of minimum potential energy, of the proposition which the Author had discussed in § 28.

71. It was therefore possible to state categorically that the addition of material *could* weaken a structure which failed by elasto-plastic stability. However, it should be pointed out that the large experimental effect reported above was obtained by designing the truss to have proportions which emphasized the effect originally noticed in analysis. It might yet be proved that in normal frames and trusses any loss of load capacity occasioned by additional material or restraint would be negligibly small.

The Author, in reply, thanked Dr Mansell for his contribution drawing attention to the more recent work of Professor Neal and himself on the question of whether

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* *Proc. Instn civ. Engrs,* vol. 23, November 1962, pp. 337–360.

adding material could weaken an elasto-plastic structure. In their paper it was also interesting to see the proof, covered in §§ 26–28 of the Author's Paper, that adding material could not reduce the load at which an ideally elastic structure became unstable, as developed in rigorous mathematical form using the energy argument.

73. Regarding Dr Mansell's experiments on elementary trusses, they showed that increased restraint by causing changes in secondary stresses involving plastic strain could result in a deterioration of stability and lowering of the failure load. This concept was not, of course, limited to trusses and applied to any structure in which the members were subject to a combination of bending and axial force, i.e. tall frames. It was, in fact, this identical point which concerned the Author in § 62 but it was decided that it was unlikely to be serious for the specific case under consideration on the grounds of the argument of § 63.

74. Another rather obvious case of increased restraint lowering the failure load had since occurred to the Author. Consider, for example, a no-sway frame in which the beams were pinned to the columns and designed as simply supported, the columns being designed primarily for axial load. Welding up the beam to stanchion connexions would undoubtedly induce considerable bending in the columns. Previous work on the elasto-plastic behaviour of stanchions, supported by experiments on which the Author was currently engaged, indicated that, despite negative stiffness considerations, i.e. ultimately the beams restraining the columns, bending actions from the beams could often reduce the ultimate axial load carrying capacity of the columns. Hence the overall strength of the structure could be reduced.

75. This rather obvious case indicated that the work of Professor Neal and Dr Mansell might be relevant to a wider range of structures and put in question the widely-held belief that increased continuity was invariably beneficial.

Reference

8. B. G. Neal *and* D. S. Mansell. Effect of restraint upon the collapse load of mild steel trusses. *Int. J. mech. Sci.*, vol. 5, 1963, pp. 87–97.