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Some model tests on multi-storey rigid steel frames

by

Murray William Low, B.E., Grad.I.C.E.

Discussion

Professor W. Merchant (Professor of Structural Engineering, University of Manchester) observed that the results given by Mr Low formed a useful addition to those available on model tests of rectangular frame instability. A series of tests on single-storey portals with wedged joints had been made by Bolton¹ and an extensive series of tests on one-, two-, three- and four-storey single-bay frames by Salem². Salem's test models had tubular members and brazed joints. The present series differed in that they were largely tests under zero or small lateral loads.

44. The results had been presented in such a way as not to bring out fully the instability effect. The Author reported that in all but two test frames (Nos 24 and 37) the beam mechanism had given a lower collapse load than the sway mechanism in the rigid-plastic theory, and it was therefore presumed that he used the beam mechanism load in the generalized Rankine formula.

45. The sequence of events could be followed from Fig. 12. The sway collapse load was dependent on the sway deflexion, while the beam mechanism was relatively independent. As the sway deflexion increased, the sway mechanism crossed the beam mechanism, and in the Author's tests all the frames had failed by sway. The interaction between plasticity and stability was due to the effect of the sway deflexion on the sway collapse mechanism, and it was the corresponding rigid-plastic collapse load which should appear in the generalized Rankine formula. The beam mechanism did not interact with the sway critical load and should be considered separately.

46. Test frames 16, 17, 18, 19, and 20 had the same nominal dimensions, and were tested with increasing lateral loads and therefore, naturally, had diminishing failure loads in the same order. If the value of W_L used was that for the sway mechanism, this would also diminish and the points might not appear in the same sequence in Figs 8 and 9. There was, in fact, less variation due to inaccuracies of manufacture when there were considerable lateral loads, and the generalized Rankine formula became a more reliable prediction. It had not been claimed that the Rankine formula was much on the safe side and in Salem's tests, the lowest experimental result had been 8% below the Rankine prediction. In an accompanying theoretical investigation^{2, 3} a large number of idealized frames had been calculated and cases found down to 4% less than the Rankine value.

The Author, in reply, suggested that the test results had been presented with a different objective to that envisaged by Professor Merchant. While the Author fully agreed with the form of Fig. 12, he did not consider that it was much help to the designer. The immediate question arose as to the magnitude of the sway deflexion to be assumed. The simple rigid-plastic theory postulated that elastic deflexions were negligible, and it followed from the principles of *simple* plastic analysis that the calculated collapse load was independent of the sway deflexion.

† Proc. Instn civ. Engrs, vol. 13, p. 287 (July 1959).

48. While it might be held that such an approach could not be used to provide a theoretical explanation of the actual collapse load of a given laboratory model tested in the past and fully instrumented, it remained the only practical means for the designer to estimate a plastic collapse load for a frame as yet unbuilt. With this in mind, the W_L values quoted in the Paper had been the lowest simple plastic collapse loads calculated for the frames in question, i.e. geometry changes were neglected. That these values had usually corresponded to the beam mechanism while failure had been in a sway mode might seem unusual at first glance, but it was a "safe" procedure using the simple plastic theory.

49. Concerning the apparent inconsistency, the Author emphasized the essential difference between "failure by sway" and "failure in a sway mode". He was not prepared to accept the assumption that a frame which collapsed sideways in a dead-load test had failed by sway, and that the sway mechanism was therefore appropriate for the W_L calculation. Wood¹¹ had clearly shown that a set of beam hinges could lead to elastic instability, and this form of failure was very marked in some of the tests reported. In such cases, was not the beam mechanism appropriate?

50. Typical values of sway deflexion observed in the Author's tests were of interest (Table 2), and would indicate the order of importance of this quantity. The figures indicated the maximum deflexions observed immediately before collapse of various types of frame. In most (but not all) cases these were deflexions of the top of the frame.

TABLE 2

	Sway deflexion just before collapse			
	Frames without side loading		Frames with side loading	
	Max. value: inches	Min. value: inches	Max. value: inches	Min. value: inches
3 storey . . .	0.373	0.051	0.974	0.412
5 storey . . .	0.173	0.045	1.033	0.314
7 storey . . .	0.268	0.046	0.828	—

REFERENCES

1. A. Bolton. Ph.D. Thesis, Manchester University, 1957.
2. A. Salem. Ph.D. Thesis, Manchester University, 1958.
3. W. Merchant, C. A. Rashid, A. Bolton, and A. Salem, "The behaviour of unclad frames". Fiftieth Anniversary Conference, Instn Struct. Engrs (October 1958).