the contribution from all possible collapse mechanisms of a frame. Although the collapse probability associated with a given mechanism may be small, the overall collapse probability, which considers the contribution from each collapse mechanism, may become significant (23). The calculation of the overall collapse probability, however, requires an analysis of correlations between mechanisms. With this regard, the solution model proposed by Ang and Ma (23) may be used.

Load Distribution.—The probabilities obtained for the first yield, formation of plastic hinge, and collapse mechanism in the example problems are extremely small. With such small values, the results may become sensitive to the type of probability distribution used in the problem (22). Since the applied loads are the only random variables in the model, the results may be sensitive to the load distributions. More investigations along this line will, perhaps, clarify the role of load distribution in the failure probability of a framed system.

Appendix.—References

22. Ang, A. H.-S., "Structural Risk Analysis and Reliability-Based Design," *Journal of Structural Engineering*, ASCE, Vol. 109, No. ST9, Sept., 1983, pp. 1891–1910.
23. Ang, A. H.-S., and Ma, H.-F., "On the Reliability Analysis of Framed Structures," *Proceedings, Probabilistic Mechanics and Structural Reliability*, A. H.-S., Ang and M. Shinozuka, eds., Jan., 1979.

Closure by Tai-Yan Kam,[6] Ross B. Corotis,[7] M. ASCE and Edwin C. Rossow,[8] M. ASCE

The writers would like to thank Mohammadi and Longinow for their discussion, which pointed out some of the general areas in which the original paper could be extended. In fact, these extensions have been carried out and were presented at the ASCE Specialty Conference on Probabilistic Mechanics and Structural Reliability (24) and have been further developed in a paper currently under review.

The discussers mention the necessity of including resistance variability in the formulation. This is indeed a point well-taken, and their Eqs. 13–15 are the accepted form that is generally used. Unfortunately, there are two problems with entering the resistance variables as basic quantities directly in the limit state function. One is that for structures of reasonable complexity, the dimension of the resistance space becomes very large, thus rendering the problem intractable unless a practical search technique is adopted for identifying dominant modes. The second problem is that for intermediate limit states (e.g., serviceability) and nonlinear structural behavior, the limit state functions are most conveniently found from an incremental loading of a trial structure, which might be thought of as a single realization of a random structure. The generalization of

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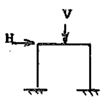
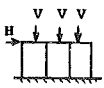
TABLE 2.—Sample Results

Structure (1)	Status (2)	Member resistance correlation ρ_M (3)	Coefficient of variation V_L (V_M) (4)	H and V Normal 0.1 (5)	H and V Normal 0.3 (6)	H and V Lognormal 0.1 (7)	H and V Lognormal 0.3 (8)
	Deterministic			1.8×10^{-26}	2.96×10^{-4}	8.0×10^{-14}	5.6×10^{-3}
	Random	0	0.05 (0.1)	6.4×10^{-7}	4.82×10^{-4} 15.6×10^{-4}	9.0×10^{-7}	6.1×10^{-3} 8.0×10^{-3}
		1	0.05 (0.1)	3.7×10^{-5}	7.1×10^{-4} 37.9×10^{-4}	1.9×10^{-6}	6.6×10^{-3} 10.0×10^{-3}
	Deterministic			1.5×10^{-18}	1.97×10^{-3}	9.3×10^{-11}	1.16×10^{-2}
	Random	0	0.05 (0.1)	2.66×10^{-6}	2.62×10^{-3} 5.27×10^{-3}	5.1×10^{-6}	1.2×10^{-2} 1.5×10^{-2}
		1	0.05 (0.1)	7.85×10^{-5}	3.23×10^{-3} 8.92×10^{-3}	1.4×10^{-5}	1.3×10^{-2} 1.8×10^{-2}

the result to full distributions of random resistances is not straightforward except by Monte Carlo techniques, which are limited in usefulness due to the dimensions of the problem. A new approach has been developed in which a reduced resistance variable unique to each load path in load space is utilized to represent structural system resistance variability. The statistics of the reduced variables are assessed from a utilization matrix relating load to successive component strengths. The method has been seen to agree well with Monte Carlo simulation, and sample results are presented in Table 2. Expanded details of these and other examples are included in the paper currently under review.

The discussers mention identification of collapse modes, and this is a critical problem in all reliability approaches based on failure mode formulation. One of the principal advantages of the writers' method is that it obviates the necessity of identifying distinct collapse modes.

The discussers also point out the sensitivity of the computed reliability to the assumed probability distribution of load. This is a valid concern, and one with which the reliability community will always be faced. It may be seen from Table 2 that the use of realistic resistance variance increases the failure probability significantly, and does decrease somewhat the sensitivity to the extreme tail of the load distribution. The writers would also like to note that an advantage of their approach is that due to the insensitivity of the limit state to load path for first crossing (24), all structural analyses in their method are independent of load distribution. Thus, different assumed load distributions can be tried and different load combinations can be evaluated in an efficient and inexpensive manner.

APPENDIX.—REFERENCE

24. Lin, T. S., and Corotis, R. B., "Limit State Reliabilities of Structural Systems," Proceedings of the ASCE Specialty Conference on Probabilistic Mechanics and Structural Reliability, held at Berkeley, Calif., Jan., 1984, pp. 53–56.

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