DISCUSSION OF PAPER:
'Comparison of Recent New Zealand and United States Seismic Design Provisions for Reinforced Concrete Beam–Column Joints and Test Results for Four Units Designed According to the New Zealand Code' by R.Park and J.R. Milburn.

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Discussion by R.C. Fenwick.

The New Zealand Loading Code Commentary (NZS 4203) requirement for ductile members that they resist 4 complete loading cycles of ± 4D, where D = first yield displacement (equivalent to 32D accumulated ductility, according to the authors) with less than a specified strength loss. This is not equivalent to the test methods of two cycles of ± 2D plus two cycles of ± 4D plus one cycle of ±6D, (equivalent to 36D accumulated ductility) as this ends at a greater final displacement than 4D. In the final half cycle the extra deflection of 4D to 6D increases the load sustained. A more logical comparison point would be at the 4D point on the last half cycle of the 6D cycle. However, even this load is likely to be higher than the 4 x ± 4D cycle due to the large movement + 6D to - 4D which is 2D greater than the + 4D to - 4D movement. If unit one is checked at the 4D point on the last 6D half cycle (at 34D accumulated ductility) its performance would not be as good as suggested.

Authors' reply:

The criterion in the Commentary of the N.Z. Loadings Code for "adequate ductility", namely that the structure should be capable of deflecting laterally through at least four cycles to a displacement ductility μ of 4 without more than a specified allowable reduction in strength, is a very simple rule. For example, the criterion does not account for other important features, such as the shape of the hysteresis loop and the area within it, which have a major effect on the energy dissipation.

In tests at the University of Canterbury it has been preferred to apply the displacement cycles with a progressively increasing displacement ductility factor (e.g. two cycles to $\mu = \pm 6$) in order to observe performance first at low levels of ductility demand and then at larger levels of ductility demand. It is debatable how this Canterbury test loading should be interpreted with regard to the criterion of the N.Z. Loadings Code Commentary, as Dr Fenwick has pointed out. However it could be argued that the smaller damage caused during the two cycles to $\mu = \pm 2$ means that after the next two cycles to $\mu = \pm 4$ the test structure should be loaded to $\mu = \pm 6$. Dr Fenwick is quite correct in that using the cummulative displacement ductility factor rather than specified displacement ductility cycles will lead to anomalies in structural systems in which the stiffness reduces but which continue to have an increasing load capacity with deflection.

Discussion by D.C. Hopkins:

The Capacity design concept is intended to deal with very severe energy inputs into buildings, i.e. far in excess of design levels. Does the transfer of damage, admittedly at high levels of ductility, from the intended plastic hinge region to the joint region imply any partial failure to achieve the full intent of capacity design?

Authors' Reply:

In the "relocated plastic hinge" design the beam is detailed so that the required beam strength is achieved with the critical section of the plastic hinge in the beam located at distance not less than the beam depth or 500 mm away from the column face. This requires the longitudinal reinforcement to be detailed so that the ideal flexural strength of the beam at the column face is not reached unless the moment at the critical section of the plastic hinge reaches its overstrength value.

The use of an overstrength factor of 1.25 for Grade 275 reinforcement at a relocated plastic hinge, when determining the longitudinal steel area required in the beam at the column face to suppress yield there, should lead to satisfactory performance within the definition of "capacity design". Although yield at the column face and in the joint core may not be entirely prevented at high displacement ductility factors, the plastic hinging will continue to occur mainly in the relocated hinge region. It should be noted that the overstrength factor used in the design of the interior beam-column joint unit 2 was 1.16 and for the exterior beam-column joint unit 4 was 1.20. In both of these units during the tests, strain-hardening of the longitudinal reinforcing at the relocated plastic hinge raised the flexural capacity there sufficiently to cause yield of longitudinal steel to spread along the beam to the column face and to penetrate into the joint core, leading eventually to yield of the joint core hoops. Hence use of an overstrength factor of less than 1.25 for Grade 275 reinforcement would be inadvisable.

GENERAL INFORMATION:

CONFERENCES:

FIP/CPCI Symposia, Calgary, Alberta, Canada - August 25-31, 1984.

Conference on 'Concrete Pressure and Storage Vessels', 'Sea Structures in Arctic Regions' and 'Prefabrication'. This Symposia will be of interest to professionals interested in all aspects of prestressed concrete construction. In addition to the technical programme other activities include a Poster Display, Technical Films, a Trade Exhibition and various technical and recreational tours in the Calgary, Bauff and Alberta