SEISMIC ANALYSIS OF A POST-TENSIONED PRECAST CONCRETE FRAME

Masahiro SUGATA[1], John F STANTON[2] And Gregory A MACRAE[3]

SUMMARY

Post-tensioned, precast concrete frames have recently been proposed for use in seismic regions. The columns are cast as multi-story pieces, the beams are each one bay long, and they are post-tensioned against the columns by tendons that run the length of the building. The tendons are unbonded, so that during seismic motion they remain elastic and provide a restoring force that re-centers the structure. Behavior can thus be classified as nonlinear elastic. The consequent lack of residual drift minimizes the need for post-earthquake repair.

Cyclic tests have been conducted on such a system at the University of California at San Diego. A system that is similar, except that the beam column connections also contain conventional reinforcing bars grouted in ducts, has been tested at NIST. The advantage of the reinforcing bars is that they provide some energy dissipation. The post-tensioning and reinforcing are designed so that the recentering feature is retained. Behavior under test was very good in both cases. High drifts were achieved, the system recentered and damage was minimal.

The system is being used in the building to be tested at UC San Diego under Phase III of the PRESSS program. Its behavior is being studied as part of the building design, which is being conducted at the University of Washington. The design involves many other issues, but this paper only addresses the post-tensioned precast frame. The frame behavior includes several unusual features, so a sophisticated nonlinear model has been developed in order to evaluate its dynamic response. The model includes contact elements at each column faces that permit the top or bottom of the beam to lift off temporarily from the column. This paper describes the model and the predicted behavior of the post-tensioned frame.

The nonlinear model was first subjected to push-pull imposed displacements. This response was need both to verify that it replicated experimental results and to establish the damping, by evaluating the hysteretic energy dissipated in each cycle at a given drift ratio. The effective stiffness and damping were used to create a simple, equivalent linear, viscously damped model, which was itself then used to conduct Displacement-Based Design (DBD) of the whole structure. DBD has been adopted as the basis for designing the test structure, and, in general allows the elements to be designed for smaller forces than if Force-Based Design were used. The predicted displacements show that the beams lengthen due to the gaps that open up at the column faces, and that the lengthening imposes a pattern of member forces and displacements that must be superimposed on those expected from the conventional sway response. Beam growth also occurs to some extent in cast-in-place concrete frames, but is seldom measured in tests and never taken into account in analysis, largely because doing so is difficult and requires a more sophisticated analytical model than is generally used.

The model was then subjected to dynamic input. The results show a pattern of overall displacements that a similar to those predicted from the DBD analyses, although the beam lengthening causes some differences. However, the contact elements give rise to some high-frequency, local accelerations that in turn cause high local forces. These features do not appear in a comparable analysis that excludes the contact elements. The predicted response has some features of chaotic motion, as might be expected in a system that contains a large number of contact elements that open and shut during the motion. The local forces are being investigated to determine whether they will occur in the prototype building or whether they are a property of the analytical model alone.

[1] *Department of Civil Engineering, University of Washington. E-mail: sugata@u.washington.edu*
[2] *Department of Civil Engineering, University of Washington. E-mail: stanton@u.washington.edu*
[3] *Department of Civil Engineering, University of Washington. E-mail: macrae@u.washington.edu*