

SECTION 6 CONCLUSION

6.1 General

The experimental data generated by this project provides a well-documented base of shake table tests of a SDOF system subjected to earthquakes of progressively increasing intensity up to collapse due to instability. This data will be useful for, and shared with, other researchers who may wish to validate or develop algorithms capable of modeling inelastic behavior of steel frame structures up to and including collapse. The data presented here will also be located on the world-wide-web (with all intermediate data files) for immediate access by those other researchers.

The sizes of the specimens were chosen to allow testing to full collapse on a small-scale shake table. The size made the fabrication and erection of each of the test structures a delicate procedure. Once these procedures were standardized, tests could be performed in rapid succession while ensuring the safety of those performing the tests, as well as of the instruments recording data. Unscaled ground motions were used as the specimens were designed to fit actual parameters of interest, and not intended to be scaled models of actual structures.

Fabrication quality, as in every structure, varied for the various columns tested here, even among those making up the same specimen. Imperfections were therefore measured in a number of ways to allow for their proper consideration in subsequent analytical modeling. A procedure was also developed to correct the displacement time histories accounting for angle changes at large displacements.

Note that the damping of the specimens tested was measured to be non-linear. As a general trend, during free vibration testing, the damping ratio was observed to increase as the free vibration response amplitude decreased. This caused some modeling difficulties, when a simplified SDOF analysis program that only accounts for constant damping was used in an attempt to replicate the test results, even though this program was only used to illustrate how data generated by this research can be used.

The research presented here demonstrated a number of important points that must be considered in the design of slender steel structures. The stability coefficient, θ , has the most significant effect on the behavior of the structure. As θ increases, the maximum attainable ductility, sustainable drift, and spectral acceleration, which can be resisted before collapse, all decrease. When this factor is larger than 0.1, the ultimate values of the maximum spectral acceleration, displacement ductility, and drift reached before collapse are all grouped below values of 0.75 g, 5, and 20%, respectively. Stability coefficient values less than 0.1 tend to increase each of those response values significantly.

All specimens exceeded the strength dictated by inelastic moment amplification factors. In addition, some specimens actually exceeded the calculated strength based on first order effects. Specimen 1, having the lowest value of the stability factor of all specimens, exceeded all calculated strengths. Considering the base shear coefficient without P- Δ effects, C_{so}^* , all of the specimens for which this value exceeds S_{a-max} have $\theta < 0.4$, though not all specimens in this range of the stability factor reached this state. In addition, Specimens 6 and 12 each reached a value of the base shear coefficient with P- Δ effects, C_s^* , larger than that of maximum calculated spectral acceleration.

6.2 Recommendations for Further Research

A larger range of specimens should be tested under various conditions to further quantify the nonlinear inelastic behavior of columns under dynamic P- Δ effects. Parameters that should be considered are:

1. The stability coefficient, θ : This appears to be the most significant parameter affecting behavior, as illustrated in this study. However, more tests should be performed to more accurately quantify the impact of this factor over various ranges, and in combination with other parameters.
2. The frequency content of the ground motion with respect to the specimen being tested. The 1940 El Centro ground motion was utilized for all specimens in this study. A ground motion, measured or synthesized, with a more uniform response spectrum over the entire frequency range may be more desirable in removing the impact of ground motion as a

variable affecting the behavior of the specimens. Alternatively, the effects of large pulses (near-fault effects) versus more regular cyclical excitations could be considered.

3. The specimen setup: The specimens were fabricated in a way that made minimization of imperfections difficult. The size at which the specimens were fabricated increases the likelihood of them being affected by the heat imparted when welding the pieces together. A different method of fabrication, possibly one in which the specimen is clamped into the base plate rather than welded to it, may be a more effective solution.
4. The characterization of inherent damping in a highly non-linear system. This remains an important problem that deserves further investigation.