DEVELOPMENT OF A HYBRID SUBSTRUCTURED LOADING SYSTEM FOR EARTHQUAKE RESPONSE

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Introduction Because of its economy and versatility as an investigative tool, isolated-beam specimens remain the most often-used experimental models to study general seismic behavior. However, interpretation and comparison of data accumulated over years of testing isolated-beam specimens have been made extremely difficult by differences in defining realistic loading programs among various research groups. Furthermore, results obtained by subjecting test specimens to arbitrarily-prescribed loading histories might not correlate well with members of a complete structure undergoing inelastic deformations, in which extensive redistribution of stresses takes place among members. It has been noted that magnitude of tip displacements imposed during inelastic cyclic tests should be dependent not only on building drifts, but should also be some function of the location of the prototype beam in a complete structure.

Substructure-Based Definition of Realistic Loading Criteria for Experimental Testing of Isolated Beam-Specimens Under the proposed substructure-based on-line hybrid system, loading program for beam specimens does not have to be prescribed in terms of arbitrarily-defined deformation histories. Instead, seismic behavior of a member being studied is simulated by imposing on a cantilever model the local deformation level that a member sustains as part of a complete structural system loaded by earthquake forces. These local deformations, transformed from generalized displacements corresponding to the test specimen, results from a step-by-step inelastic seismic structural analysis. Restoring forces developed on the loaded specimen are measured and transformed into generalized forces.

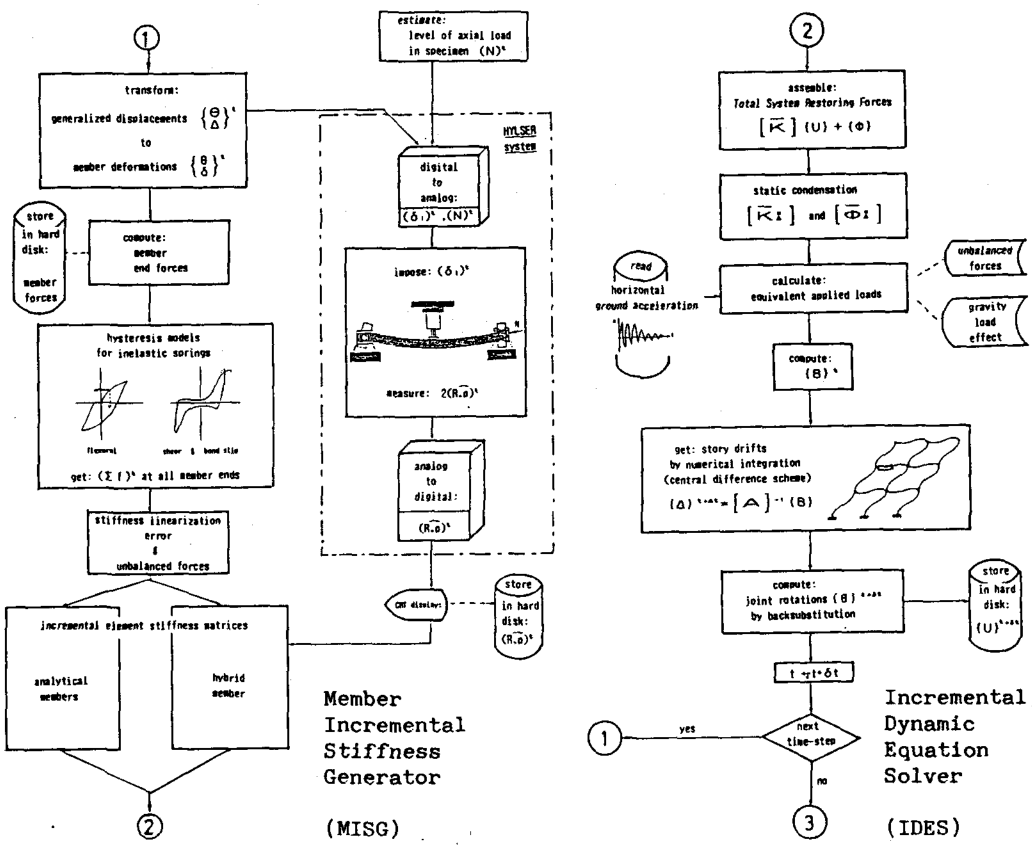
transform generalized displacements ---> impose member deformations ---> measure restoring forces ---> transform to generalized forces

These generalized experimental restoring forces are then assembled to those of the analytical members, whose properties are defined by mathematical constitutive laws. Equations of motion are set up and condensed to a form similar to static force-displacement relationship.

$$\left[A \right] \left\{ \Delta \right\}^{t+\delta t} = \left\{ B \right\}$$

where the A-coefficient matrix contains constants related to both mass and damping matrices; and the B-vector is updated incrementally for changes in applied earthquake loads, analytical stiffness matrix, and experimental restoring-force vector. Lateral drifts for the next time step are explicitly determined based entirely on displacement vectors of the previous two steps. From there, step-by-step solution proceeds recursively to get the next displacement vector.

As an investigative tool for studying general seismic behavior of frame structures, deformation (axial, lateral, rotational) histories need not be imposed in the exact manner outlined above. Great simplification is achieved by pinpointing the inflection on the frame member where a critical section is to be studied. Presumably, if the inflection point does not shift appreciably during dynamic motion, inelastic property of a frame member in focus could be modeled by forcing the tip displacements of an analytical cantilever sub-element and an experimental cantilever sub-element to deform so that these equal the lateral deformation of the simulated frame member at the inflection point. Flow diagrams describing the two main routines of a substructure-based on-line experimental testing of isolated-beam specimens are charted in the accompanying figures.



Member Incremental Stiffness Generator

(MISG)

Incremental Dynamic Equation Solver

(IDES)

Concluding Remarks An experimental program could be devised to test isolated-beam specimens under a better-defined realistic loading criteria. Since a specimen is tested as part of a complete structural system, interaction features among members could be accounted for. In terms of equipment needs, the proposed experimental system does not entail anything more than those configured for an automated structural testing system.