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# System Identification of structures in the Laboratory and in the Field

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**System identification of a scale structure in the laboratory preceded full scale studies of the Four Seasons office building under forced vibrations and the Louis Factor building under earthquake and ambient vibrations.**




### Scale Structure (Lab)

- 4-story ~1/6 scale aluminum structure with steel masses and fiberglass floors
- Attached at the base to the mass of a ***linear hydraulic shaker*** at the UCLA C&EE structures laboratory




### Four Seasons Office Building (Sherman Oaks, CA)

- 4-story reinforced concrete structure with lateral moment resisting frames (***LMRF***) along the perimeter and post-tensioned slabs and columns form the interior gravity frame
- Damaged in the 1994 Northridge earthquake: ***slab punching*** and ***joint cracks***
- UCLA NEES pilot project (4/04 to 8/04) in which mass shakers attached to the roof vibrated the building while data was recorded using ***UCLA NEES data acquisition equipment*** (i.e. mobile command center, Q330's, episensors)



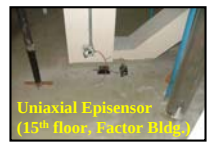




### Louis Factor Building (UCLA)

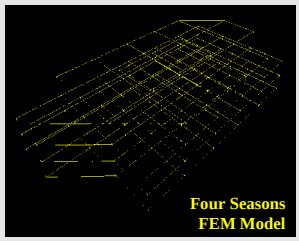
- 15 story steel frame structure with LMRF
- After the 1994 Northridge earthquake, USGS & CENS instrumented the building with ***72 uniaxial accelerometers*** wired into central recording system sampling at 100 & 500 samples per second
- It is now the most densely instrumented structure in North America
- Continuously recording ***ambient*** and ***earthquake*** vibration data including recent events (Parkfield)



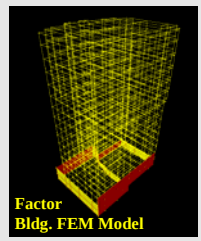




**System Identification involves determining the dynamic properties of a system by using the measured response of the system to a known or unknown excitation.**

Of many existing system identification algorithms, one advanced method is ***N4SID*** (**N**umerical **S**ubspace **S**tate **S**pace **S**ystem **I**dentification). This algorithm identifies system matrices in the state space from which modal properties (***frequencies, damping ratios, and mode shapes***) can be extracted. This algorithm can be applied to systems subjected to known or unknown excitation.




Each structure has been analyzed using a ***finite element*** computer program (SAP2000) to obtain system properties for purposes of comparison. Assumptions made were appropriately verified, e.g. material properties, ***diaphragm and joint rigidity***.

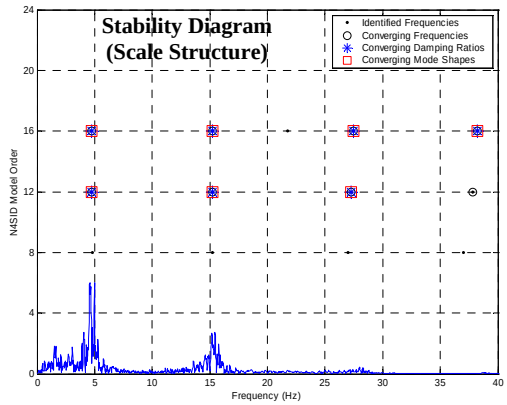



**Results and Conclusions (Results in the North-South Direction are shown in tables and plots below).**

## Scale Structure in the Laboratory

Due to sensor noise and measurement error, the ***N4SID model order*** required for accurate results is greater than 2*DOF (degree of freedom) which leads to 'extraneous' or non-physical modes. To determine and extract real structural modes, the ***stability diagram*** is employed.

| | Identified | | Analyzed |
|---|---|---|---|
| Mode | $f$ (Hz) | $\zeta$ (%) | $f$ (Hz) |
| 1 | 4.77 | 4.9 | 4.66 |
| 2 | 15.22 | 2.0 | 14.98 |
| 3 | 27.45 | 1.3 | 27.52 |
| 4 | 38.21 | 2.2 | 39.90 |




## Four Seasons Building

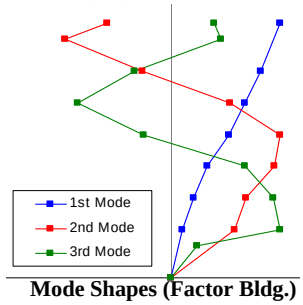
Preliminary identified modal properties from the linear shaker tests compare well with analytical model properties. Data from the eccentric mass shakers are currently being processed. Additional tests performed to investigate ***damage detection***.

| | Identified | | Analyzed |
|---|---|---|---|
| Mode | $f$ (Hz) | $\zeta$ (%) | $f$ (Hz) |
| 1 | 1.10 | 4.9 | 1.24 |
| 2 | 3.17 | 6.1 | 3.50 |
| 3 | 6.04 | 6.4 | 6.37 |
| 4 | 9.60 | 5.8 | 10.00 |

## Louis Factor Building

Identified modal frequencies from the ***ambient vibrations*** are slightly higher than those identified from data during the ***2002 Yorba Linda earthquake***. This could be due to the decrease of lateral stiffness contribution associated with non-structural elements (e.g. partitions, gravity frame) under larger vibrations. Data from recent earthquakes (6/04 San Deigo, 9/04 Parkfield) are currently being processed.

| | Identified - Ambient | | Identified - Earthquake | | Analyzed |
|---|---|---|---|---|---|
| Mode | $f$ (Hz) | $\zeta$ (%) | $f$ (Hz) | $\zeta$ (%) | $f$ (Hz) |
| 1 | 0.58 | 2.0 - 3.0 | 0.55 | 2.0 - 2.5 | 0.51 |
| 2 | 1.80 | 2.0 - 3.0 | 1.70 | 1.8 - 3.0 | 1.46 |
| 3 | 3.03 | 2.5 - 3.5 | 2.74 | 2.2 - 4.0 | 2.46 |




Mode Shapes (Factor Bldg.)