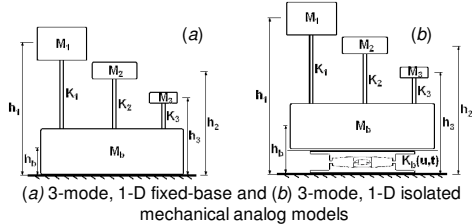


# SHAKING TABLE TESTING OF FIXED-BASE AND SEISMICALLY ISOLATED LIQUID STORAGE TANKS

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## Introduction

- No prior multi-component shaking table tests of liquid storage tanks
- No prior shaking table tests of tanks isolated with Triple Pendulum™ bearings
- No prior experimental validation of isolated numerical mechanical analog tank model used worldwide for design



Fully instrumented test specimen on the shaking table.

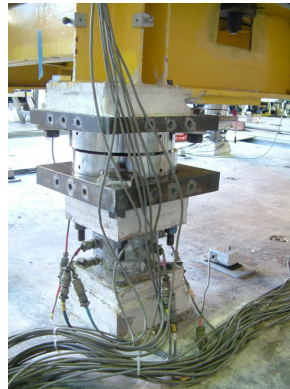
## Instrumentation



Parallel wire gauges and HD cameras used to monitor water surface dynamics. DCDT's used to measure tank deformation



Accelerometers, DCDT's, linpots, and wire pots used to measure tank dynamics



5-component load cells are positioned between the bearings and the shaking table

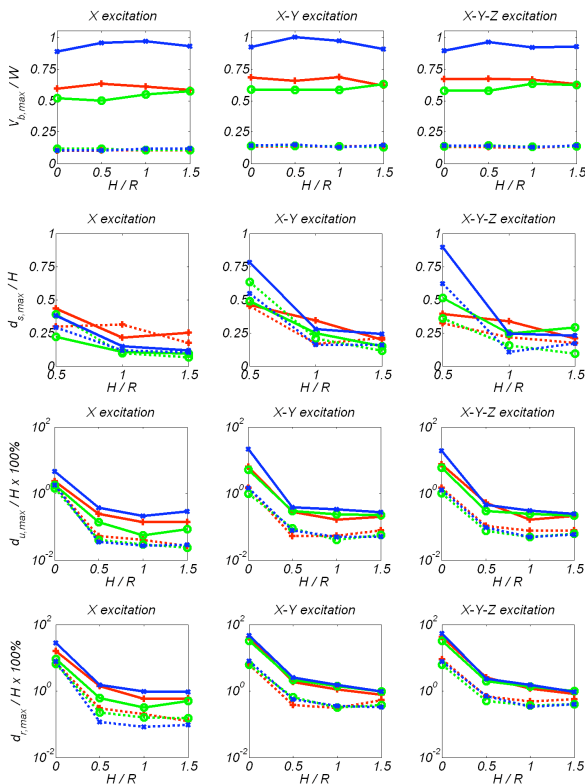
## Experimental Program

- Ground Motions
  - Loma Prieta LGP (CA, 1989)
  - Kobe TAK (Japan, 1995)
  - Chi-Chi 028 (Taiwan, 1999)
- Trigonometric Pulses
- Length Scales 1/5 to 1/2
- Magnitude Scales 1/4 to 1
- Water Levels  $H/R = 0$  (empty) to 1.5 (54in)
- Isolated vs. Fixed-Base
- A total of 264 tests conducted

## Conclusions

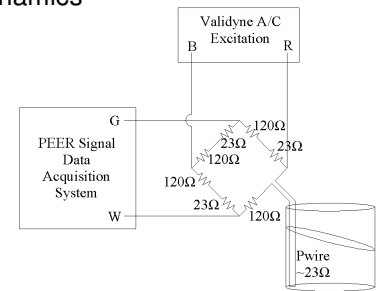
- Seismic isolation is effective in reducing base shear, tank deformation, and tank uplift
- A simple 1-dof Housner model provides a good estimate of base shear for both fixed-base and isolated liquid storage tanks
- Higher sloshing modes important for sloshing dynamics, but not for base shear and tank stresses
- SRSS combination of individual 1D simulation responses provides a good estimate of 2D excitation response
- Code provisions for maximum sloshing for fixed-base tanks also valid for isolated tanks
- 2- and 3- component ground motions significantly affect liquid sloshing dynamics

## Shaking Table Test Results



These results are for length scale 4 and magnitude scale 1/2 tests. The benefits of seismic isolation for base shear ( $V_b$ ), tank uplift ( $d_u$ ) and deformation ( $d_s$ ) responses are evident. Note that isolation benefits for water sloshing ( $d_s$ ) are not as uniform.

- ◆ Loma Prieta, Isolated
- ◆ Loma Prieta, Fixed-Base
- ◆ Kobe, Isolated
- ◆ Kobe, Fixed-Base
- ◆ Chi-Chi, Isolated
- ◆ Chi-Chi, Fixed-Base



Schematic representation of the parallel wire depth gauge used to measure water surface dynamics

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