Final Project Summary— PEER Lifelines Program

Project Title—**ID Number**	*Equipment Overturning*—**409**		
Start/End Dates	5/1/00 – 9/30/01	Budget/ Funding Source	$65,000 / PG&E/CEC
Project Leader (boldface) and Other Team Members	**Makris (UCB)**		

1. Project goals and objectives

This study concentrates on the rocking response of rigid equipment, such as electrical equipment in substation, supported on a foundation base when subjected to earthquake ground motions.

2. Benefits of the results of this project to develop technologies and protocols to mitigate the vulnerability of electric systems and other lifelines to damage directly and indirectly caused by earthquakes. Also, benefits to develop assessment techniques to evaluate damage to electric systems caused by earthquakes and to assess fiscal impacts due to the loss of electric service to the community.

The study shows that for specific equipment/base configurations the high-strength restrainers used by PG&E are sufficient to engage the foundation base in rocking motion for a wide family of recorded earthquake motions. It was shown that the minimum strength capacity of the restrainer needed to avoid fracture is closely related to peak ground acceleration and that only the Cape Mendocino record is capable of fracturing the high-strength restrainers.

3. Brief description of the accomplishments of the project

It was found that the strength capacity of the restrainer should be as high the weight of equipment as to engage the base foundation in rocking motion. The study reveals that for earthquakes with long distinguishable pulses, the margin between exceeding the serviceability level of uplift and achieving overturning is minimal. Nevertheless, none of the strong motions used in this study is capable of overturning the freestanding configurations examined. Two

4. Describe any instances where you are aware that your results have been used in industry

The results of this study are directly applicable for utilities such as PG&E.

5. Methodology employed

In the event that the strength of the restrainers is sufficiently large and the ground acceleration is sufficiently strong, the equipment will engage its foundation in rocking motion. On the other hand, if the restrainers are too fragile they will fracture and eventually the equipment will rock atop its foundation base. Accordingly, equipment anchored to a base foundation exhibits two distinct rocking capacities: (a) the equipment engages the base foundation in rocking motion and (b) the restrainers fracture and the equipment subsequently rocks as a freestanding block atop its foundation base. The aim of this study is to compare these two capacities for practical values of the foundation footprint and the restrainer strength. The study examines intensity levels of ground shaking that will exceed serviceability levels (6 in. uplift at edge), and intensity levels that will result in overturning.

6. Other related work conducted within and/or outside PEER

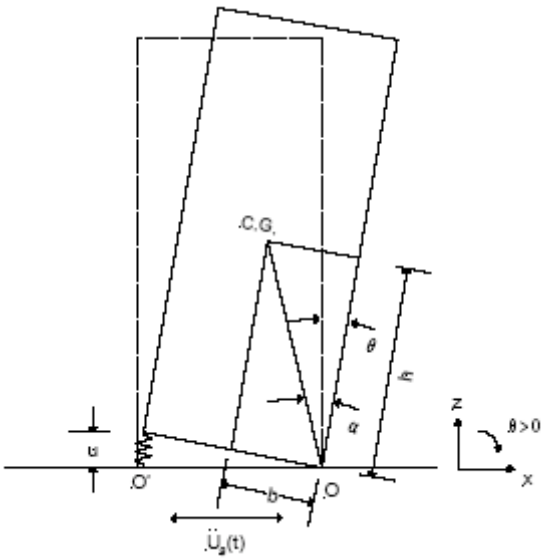
A previous related work by the same PI was conducted in 1999: PEER Report 1999/06, "Rocking Response and Overturning of Anchored Equipment under Seismic Excitations **by** N. Makris and J. Zhang

7. Recommendations for the future work: what do you think should be done next?

8. <u>Author(s), Title, and Date</u> for the final report for this project

N. Makris and C. Black, "Rocking Response of Equipment Anchored to a Base Foundation**,"** PEER Report 2001/14, 2001.

Figure 1.1. Overturned electrical equipment at Sylmar Converter Station damaged during the 1971 San Fernando earthquake (top), and a detail showing the failed back-left restrainer (bottom). Photos taken from the Steinbrugge collection, NISEE, University of California, Berkeley.



Schematic of an anchored block in rocking motion.