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GROUND MOTION SITE EFFECTS TEST AREA NEAR PARKFIELD, CALIFORNIA

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SUMMARY

A test area has been established at Turkey Flat, near Parkfield, California, to test and systematically compare methods of estimating the effect of local surface geology on strong ground motion during earthquakes. High quality ground motion and geotechnical data are being collected on and beneath the ground surface at several sites across the valley, and distributed to ground-motion modelers around the world who will make estimates of the effect of site conditions on ground motion. The results from each method will be compared with actual observations and with one another to determine which are the most cost effective and reliable.

INTRODUCTION

At the 1985 meeting of the International Association of Seismology and Physics of the Earth's Interior (IASPEI), held jointly with the International Association of Earthquake Engineering (IAEE) in Tokyo, Japan, a resolution was passed forming the IASPEI/IAEE Joint Working Group on The Effects of Local Geology on Seismic Motion. The purpose of this group is to coordinate the establishment of an international series of test areas designed to provide a data base for comparing and testing contemporary methods, and developing new methods, to predict the effects of local geology on ground motion caused by earthquakes. The 1985 Mexico earthquake is only the most recent reminder that local ground conditions can have a major influence on where damage will occur in major earthquakes. Although methods for assessing site effects are being used to construct critical facilities around the world, the reliability of these methods has not been rigorously tested. A primary goal of this international program is to fulfill this serious need. An international program provides a forum for experts around the world to exchange ideas, and significantly increases the prospects of acquiring data from a broad suite of geologic site conditions soon.

Responding to similar needs, the California Department of Conservation's Division of Mines and Geology has established a prototype test area in Turkey Flat, near Parkfield, California. Because our general perceptions and experiment objectives echo those of IASPEI/IAEE's Joint Working Group, during their first workshop, held during the XIX Assembly of the International Union of Geodesy and Geophysics in Vancouver, British Columbia, Canada in August of

1987, a resolution was passed incorporating the experiment at Turkey Flat into the international program. This paper describes the goals, objectives, and accomplishments of the Turkey Flat test area.

TURKEY FLAT TEST AREA

The principal objectives of the Turkey Flat Experiment are to systematically test and compare all methods of estimating the influence of shallow stiff-soil site conditions on ground motion during earthquakes, in order to determine the reliability and cost effectiveness of each. Secondary objectives are to generate a data base for the improvement of these methods, or the development of new methods, and to address the long standing debate on the linearity of site response. The approach is to collect high quality weak and strong ground motion data, and geotechnical data, and carry out a series of "blind predictions". Experts from around the world will be invited to use their preferred method and the acquired data to predict ground motion at a location where the actual response will be known but held in confidence until all predictions have been submitted.

<u>Organization</u> The experiment is being conducted in several phases (figure 1), and oversight committees are being formed to provide input from government and industry that will supplement advice received from the IASPEI/IAEE Joint Working Group. A Geotechnical Planning Committee has already been formed, and is composed of representatives from the geotechnical industry in the U.S. and Japan. The purpose of this committee is to plan, help organize, and assist in carrying out the site characterization program which has recently been completed. A second oversight committee is now under formation, and will address both the weak and strong motion prediction phases of the experiment.

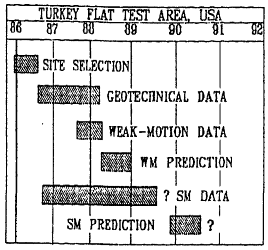

Figure 1. Project Schedule.

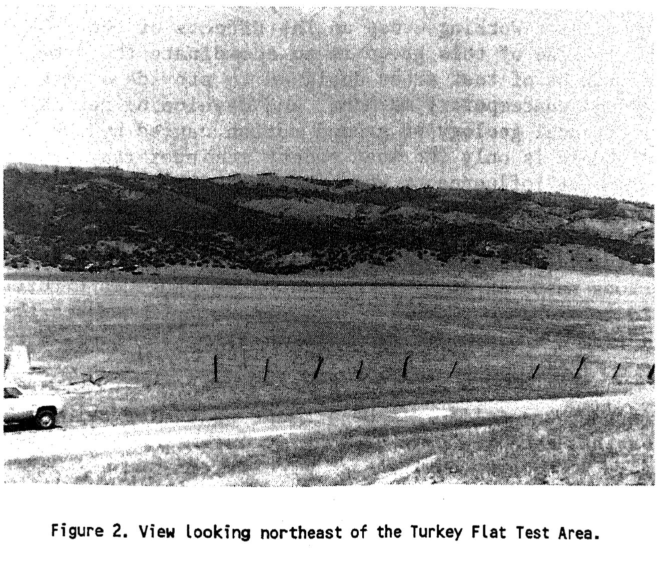

Figure 2. View looking northeast of the Turkey Flat Test Area.

<u>Siting</u> The principal criteria used to select the location of the test area were 1) a site likely to experience strong-motion (>.25 g) in the next few years, 2) a site where ground motion is expected to be affected by the local geology to such a degree that it is measurable, and 3) a site not too unlike that commonly used for urban and industrial development. The Parkfield, California region was immediately chosen because it lies along that segment of the San Andreas fault

where the only officially recognized U.S. earthquake prediction is pending (Bakun and McEvilly, 1984). This 30 km segment, known as the Parkfield segment, ruptured in a moderate size earthquake (M5-6) in 1966, producing a record acceleration of 1/2 g. This event is expected to repeat by 1992 with a 90% confidence.

The selected test area lies in Turkey Flat, a shallow northwest trending elongated valley located about 5 kilometers east of the San Andreas fault and eight kilometers southeast of the town of Parkfield (figures 2 and 3). The valley is approximately 6.5 kilometers long and 1.6 kilometers wide and is bounded on the north and east by the steep west flank of Table Mountain, part of the southern Diablo Range, and on the south and west by a gentle topographic high. The Turkey Flat site lies close enough to the San Andreas fault (5 km) to expect strong motion from a moderate earthquake, but not so close as to be dominated by source effects that might over shadow any local site effects. A series of reconnaissance seismic refraction profiles across the valley indicated a thin wedge of sediment having a maximum thickness of about 25 meters and a velocity contrast of about three with the underlying bedrock.

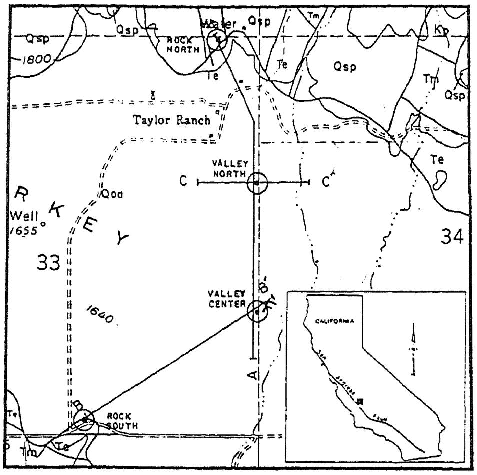

Figure 3. Map of Turkey Flat Test Area showing four test sites and three lines of profile.

Table 1. Geotechnical field tests.

FIELD TESTS	CDMG	HLA	LCA	QEST	WCC	PDC	OYO	KC
DRILLING AND SAMPLING	■		■		■	■	■	
STANDARD PENETRATION TEST	■		■		■	■		
WATER TABLE DEPTH	■							
CALIPER		■					■	
BOREHOLE DEVIATION	■							
ELECTRICAL							■	
DENSITY (GAMMA-GAMMA)		■						
NATURAL GAMMA		■						
BOREHOLE LATERAL LOAD TEST							■	
DOWNHOLE VP/VS	■		■	■	■		■	
CROSSHOLE VP/VS		■						
SUSPENSION VP/VS							■	
DOWNHOLE Q (P&S)	■			■			■	■
VERTICAL SEISMIC PROFILING							■	
SEISMIC REFLECTION (P&S)							■	
SEISMIC REFRACTION (P&S)	■						■	

CDMG - Calif. Dept. of Conservation Division of Mines and Geology
HLA - Harding Lawson Associates
KC - Kajima Corporation
LCA - LeRoy Crandall and Associates
OYO - OYO Corporation
PDC - Pitcher Drilling Co.
QEST - QEST Consultants
WCC - Woodward-Clyde Consultants

Site Characterization

A site characterization program was conducted in order to produce a geotechnical model of the test area to provide the input parameters necessary to estimate the seismic response of the valley, and permit execution of the prediction phase of the experiment. This program consisted of site drilling and sampling, laboratory measurements, *in situ* measurements using geophysical field surveys, and subsequent data reduction and interpretation. The principal parameters sought are P- and S-wave velocities, modulus reduction curves, density, and damping as a function of depth at each site where ground motion observations/predictions will be made. For those participants that might consider 2- or 3-dimensional models, it is desirable to obtain some knowledge of the spatial variability of parameters. More than one method of measuring a particular parameter was used as a means of cross-checking reliability, particularly for new techniques. Even in the case where standard procedures were used, such as for downhole velocity measurements, several surveys were repeated by different investigators as a means of obtaining the best possible data, and for estimating uncertainties. The various field surveys and laboratory tests made by each participant are shown in tables 1 and 2 respectively.

Table 2. Geotechnical Laboratory Tests

LABORATORY TESTS	D&M	LCA	OYO
SOIL CHARACTERISTICS*	■	■	■
CONSOLIDATION TEST		■	
DIRECT SHEAR TEST		■	
DYNAMIC TRIAXIAL TEST	■		
RESONANCE COLUMN TEST			■
DYNAMIC TORSION TEST			■
TRIAXIAL ULTRASONIC WAVE VELOCITY			■

* Grain size, specific gravity, moisture content, unit weight, liquid limit, and plastic limit.

D&M - Dames & Moore
LCA - LeRoy Crandall and Associates
OYO - OYO Corporation

The final task of the site characterization program was to derive a "consensus" model of the test area to serve as a standard against which all ground motion site effect estimation methods can be compared. The standard model was derived by a systematic procedure of data acquisition, analysis, and interpretation involving eight U.S. and two Japanese geotechnical firms and the California state government. Results of the extensive field and laboratory tests were evaluated by members of an oversight committee of experts, leading to an average model of the test area that was reached by a consensus. The standard model is shown in figures 3 and 4.

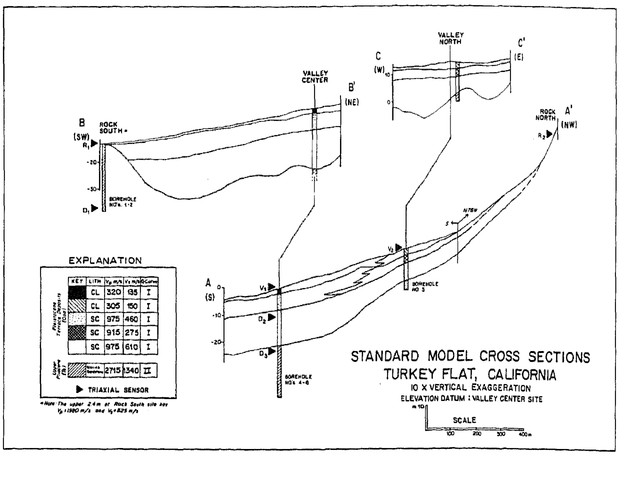

Figure 4. Three profile views of Turkey Flat Test Area.

Ground Motion Predictions The seismic response of the test area is being monitored at four locations: on rock, along the northern and southern flanks of the valley, and on sediments at the valley center and about midway to the northern valley edge (figure 3). Triaxial accelerometers and velocity transducers have been deployed at the locations shown by black triangles in figure 4. All signals are recorded digitally on cassette tape. The accelerometer array is installed and operated by the California Strong Motion Instrumentation Program.

Two sets of ground motion predictions will be made: one for strong motion and one for weak motion. Each set will include predictions at all remaining sensor locations given actual records of different events recorded in bedrock along the valley margin and beneath the valley sediments (sensor locations R_1 and D_3 of figure 4). A third set of predictions will be made as an initial benchmark test using an arbitrary ground motion record. Classes of site effect estimation methods that might be tested include physical models (e.g. foam rubber and centrifuge models), computer models (e.g. one, two, and three dimensional mathematical descriptions of the test area using experimentally determined properties of the sub stratum), and seismic (e.g. measurements of the response of the test sites to microtremors, small earthquakes, and man-made explosions). While participants may choose to use their own "preferred" model derived from the basic geotechnical data, all participants will be asked to make a full set of predictions using the "standard" model. After all site response predictions have been submitted, they will be compared with one another and with actual recordings at each site to determine the accuracy and reliability of each.

CONCLUSIONS

A project is underway near Parkfield, California to test and compare the reliability and cost of various methods used to estimate the effects of local soil conditions on earthquake ground motion. A systematic study of this kind is needed before methods can be used routinely to assess an area's potential for strong ground shaking and to incorporate the results into land use, design, and construction decisions on a regular basis. While the shallow stiff-soil conditions present in the test area are common in other urban areas throughout the world, there are many other different site conditions that underlay urban areas that are equally common. Whatever conclusions are drawn from this experiment will be applicable only to a subset of all site conditions. Methods that work well at the Turkey Flat Test Site might not work well at other sites; methods that fail at Turkey Flat might be adequate elsewhere. These limitations underscore the need to establish other test areas in California and elsewhere in the world, in places where other site conditions are present. The international program will help fill this need.

ACKNOWLEDGMENTS

We are grateful for endorsement by the IASPEI/IAEE Joint Working Group on Ground Motion Site Effects. We also wish to express sincere appreciation to the following organizations for their advice and assistance in characterizing the site conditions at the test site: LeRoy Crandall Associates, Dames & Moore, Geomatrix Consultants, Harding Lawson Associates, Kajima Corporation, Lawrence Livermore National Laboratory, Pitcher Drilling Company, Qest Consultants, and Woodward-Clyde Consultants. We are especially indebted to OYO Corporation of Japan, who traveled great distances at great expense to contribute to the site characterization effort and share their technologies. We also wish to thank the California Department of Transportation for their assistance in field operations, the Bay Area Regional Earthquake Preparedness Project for assistance in preparing the geologic map of the test area, and the California Strong Motion Instrumentation Program for installation and maintenance of the accelerograph array, and planned processing of strong-motion data.

Most of all, we are grateful for the generosity and kindness of the land owners, Donald and Nila McCornack, and adjacent residents Melvin and Ruth Taylor, who have made the land available for this experiment, and who have persevered weeks of having the solitude of their setting disrupted. Their sincere interest in the future of mankind has made this important experiment possible.