SEISMIC INSTRUMENTATION OF FEDERAL BUILDINGS

A PROPOSAL DOCUMENT FOR CONSIDERATION BY FEDERAL AGENCIES

By

Mehmet Çelebi[1]

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Open-File Report 98-117

(This replaces and supersedes OFR 97-452 titled 'Seismic Instrumentation of Federal Buildings: Strawman Document for Consideration by Federal Agencies' by M. Çelebi and S. Nishenko)

March 1998

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards (or with the North American Stratigraphic Code). Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U. S. Government

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CONTENTS

SYNOPSIS AND EVOLUTION

The following is an expanded version of presentations "Instrumentation of Federal Buildings" made by the senior author during:

1. the theme session on "How to Comply: The Halfway Point" organized by Subcommittee on Buildings of the Interagency Committee on Seismic Safety in Construction (ICSSC) held at National Institute of Standards and Technology (NIST) on January 15, 1997, and
2. the Full Committee Meeting of ICSSC held in Dallas, Texas on January 28, 1997.

Later, an earlier version of this open file report was prepared for distribution, discussion and consideration at the National Earthquake Loss Reduction Program (NEP) of the National Earthquake Hazard Reduction Program (NEHRP) Agencies Meeting held at the FEMA Building (Washington, D.C.) on July 8, 1997 (Çelebi and Nishenko, 1997). During this meeting, an ad-hoc committee comprising the authors of this report was formed. The report was forwarded to the representatives of several committees of ICSSC for evaluation and discussion. Ensuing were the following endorsements and/or presentations:

1. Based on input from various committees of ICSSC, on October 3, 1997, the Steering Committee of ICSSC endorsed the plan and provided comments summarized in Appendix B.
2. Following a presentation on October 18, 1997 by the senior author at the meeting of the Committee for the Advancement of Strong Motion Programs in the United States (CASMP [now reformed as COSMOS - - Consortium of Organizations for Strong Motion Observation Systems]), the plan was endorsed by the committee with comments provided in Appendix B.
3. A short presentation was made during the Earthquake Engineering Research Institute (EERI) workshop on "Seismic Rehabilitation of Buildings – Strategic Plans 2005 – the Second Decade" held in Reno, Nevada on August 12-13, 1997. Following the meeting, the Applied Technology Council endorsed the plan (letter included in Appendix B).
4. Full Committee Meeting of ICSSC held in Washington, D.C. on October 29, 1997 voted to endorse the plan.

This revised open-file report documents the endorsements and comments provided by different committees and organizations (Appendix B). Also included in this report is a summary of how data from instrumented structures is used with sample references (Appendix A). Finally, the ultimate purpose of the document is to further advance the consideration of this proposal (to instrument federally owned/leased buildings) by the National Earthquake Hazards Reduction Program (NEHRP) agencies and adopted by all federal agencies.

1.0 GENERAL BACKGROUND INFORMATION

There are two main approaches to evaluating seismic behavior and performance of structural systems. One requires a laboratory in which subsystems, components, or (if the facility is large enough) prototypes or large, scaled models of complete systems are tested under static, quasi-static, or dynamic loading. This approach does not necessarily demand a time-dependent testing scheme, such as a shaking table or an hydraulically powered and electronically controlled loading system; however, testing of structural systems under controlled simulated environments is desirable. Since the early 1950's such laboratory research has increased both in quantity and quality, with engineering colleges in the United States and private and governmental laboratories in Japan playing a key role. Laboratory testing has also contributed substantially to our understanding of dynamic soil properties and the interaction phenomenon between the soil and structure (Çelebi and others, 1987).

The second approach to evaluate behavior and performance of structural systems is to use the natural laboratory of the Earth, by recording structural motions on scale, and by observing and studying the behavior and damage, if any, to structures from earthquakes. By determining why specific designs lack earthquake resistance, and then by using extensive laboratory testing of modified designs, significant progress in improved designs can be achieved.

For such design studies a natural laboratory would be a seismically prone area that offers a variety of structural systems. In optimum test areas, strong ground motions as well as moderate-level motions would be experienced frequently. Integral to the "natural laboratory" compared to "controlled laboratory " approach is the advanced instrumentation of selected structures so that their responses can be recorded during future earthquakes. Thus, it is essential that integrated arrays of instrumentation be planned and installed to assess thoroughly the relation of ground motion that starts at a source and is transmitted through various soils to a substructure and finally to a superstructure. The direction for seismologists and engineers working together is clear: to develop integrated networks which measure the seismic source, the transmittal of ground motion, and the structural response processes.

1.1 General Objective

The main objective of the seismic instrumentation program for structural systems is to improve our understanding of the behavior and potential for damage of structures under the dynamic loads of earthquakes. This will be achieved through the development of an integrated network that measures the earthquake source, transmitted ground motions, and structural response. These measurements will be correlated with observations of structural performance to evaluate current design and construction practices in order to minimize damage to buildings during future earthquakes. In accordance with Executive Orders 12941 [Seismic Safety of Existing Buildings] signed in December 1, 1994 and Executive Order 12699 [Seismic Safety of New Buildings] signed on January 5, 1990, this program will initially concentrate on instrumenting federally owned and leased buildings.

1.2 Prior Recommendations

Although not directly targeted to federal buildings, several workshops and meetings in the past referred to importance of seismic instrumentation. For example, the following quotes are from "Earthquake Prediction and Hazard Mitigation Options for USGS and NSF Programs" published in 1976 by NSF and USGS:

> Page 51: Under Activities for Sub-element b: Acquisition of Strong-Motion Data:
> 1. *Improve the national-strong-motion instrumentation network by:*
>   (a) *Replacing obsolete instruments,*

(b) *Installing adequate instrumentation arrays in all seismic regions,*
(c) *Developing arrays to measure the two and three dimensional distribution of ground motion.*
(d) ***Instrumenting representative types of structures, particularly in the more active parts of the country.***

The following quotes are from " ***Recommendations for the Strong-Motion Program in the United States***" published in 1987 by Committee on Earthquake Engineering of the National Research Council":

> Page 50: " ***Plans for deployment of strong-motion instruments requires decisions as to whether they should be located in structures or in the free-field. Both kinds of data are needed by engineers, whereas seismologists prefer free-field data***."

> Page 49: *"**An effective national strong-motion program must be concerned with all phases of activities, including strong-motion instrument development, deployment and operation of instruments, processing, archiving and dissemination of data, the uses of data, strong-motion research, strong-motion applications, integration of activities of various governmental agencies, universities and corporations taking part in strong-motion activities, and identification of the amount of funding required for such a national effort and the source of funding.**"*

Many other reports published between 1976-1997 refer to the above recommendations.

1.3 Requisites of an Instrumentation Program

The instrumentation of a structure should provide an optimal number of sensors to allow reconstruction of the response of the structure in sufficient detail to compare with the response predicted by mathematical models -- the goal being to improve the models. In addition, the data should make it possible to explain the reasons for any damage to the structure. ***The nearby free-field and ground-level time history should be known*** in order to quantify the interaction of soil and structure. More specifically, a well-instrumented structure for which a complete set of recordings has been obtained should provide useful information to:

(1) check the appropriateness of the dynamic model (both lumped-mass and finite element) in the elastic range,
(2) determine the importance of nonlinear behavior on the overall and local response of the structure,
(3) follow the spreading nonlinear behavior throughout the structure as the response increases, and determine the effect of this nonlinear behavior on the frequency and damping,
(4) correlate the damage with inelastic behavior models,
(5) determine the ground-motion parameters that correlate well with building response and/or damage, and
(6) make recommendations to improve seismic codes.

1.4 Code Recommendations for Instrumentation and Deficiencies

Various codes in effect in the United States recommend different types and schemes of instrumentation depending upon their purposes. For example, the Uniform Building Code (UBC) of 1976 (and those that followed, including the recent 1997 issue), recommended that, for seismic zones 3 and 4, a minimum of three accelerographs be placed in every building over six stories with an aggregate floor areas of 60,000 square feet or more, and in every building over ten stories regardless of the floor area. The purpose of this requirement by the UBC was to monitor rather than to analyze structural response. In 1976 the City of Los Angeles adopted the UBC's recommendation but in 1983 revised this requirement to require only one accelerograph (to be deployed at the roof of the building). Recently, there has been a movement in Los Angeles to go back to the original UBC recommendation. The code instrumentation recommendation is illustrated in Figure 1a.

The recommendations for instrumentation according to the UBC provisions does not allow complete analyses of a building. For example, a single triaxial accelerograph deployed at a floor (Figure 1a) does not allow the evaluation of torsional behavior of a building. Furthermore, only one vertical component at the ground or basement level does not allow evaluation of rocking motions of a building, if any. This type of instrumentation was prevalent particularly prior to the 1971 San Fernando earthquake.

Since the 1971 San Fernando earthquake, extensive instrumentation of building structures has been used as demonstrated in Figure 1b. Such a scheme involves distribution of triaxial channels as uniaxial channels on different floors of a building such that both translational and torsional motions of the structural system can be recorded. Also, additional vertical sensors on the ground floor or basement facilitates the evaluation of rocking motions. Furthermore, whenever physically possible, a free-field triaxial accelerograph is deployed in the vicinity of the building to facilitate additional studies related to soil-structure interaction and correlation studies of possible damage with free-field ground motions. Figures 1c and d illustrate special cases of instrumentation for diaphragm effect and base-isolated buildings.

1.5 Specific Issues Related to Seismic Instrumentation of Structures

- Instrumentation of structures requires multiple single-channels rather than a tri-axial unit used for free-field deployment. There are hardware costs involved as presented later in this document.

- Instrumentation of structures needs interconnection of cables between the accelerometers and recorders for common-time recording. Until such time when wireless/remote motion detection/recording is feasible, reliable, and readily available, cables will have to be used to achieve common-time recording. Furthermore, recent digital systems with GPS options require additional cable connection between the GPS unit (which has to be placed at the roof or appropriate location so that the GPS unit can see the sky) and the recording unit.

- There are installation costs. In some cases, this can be minimal and in other cases it can be substantial. The installation costs include conduits, pulling cables and electrical wiring.

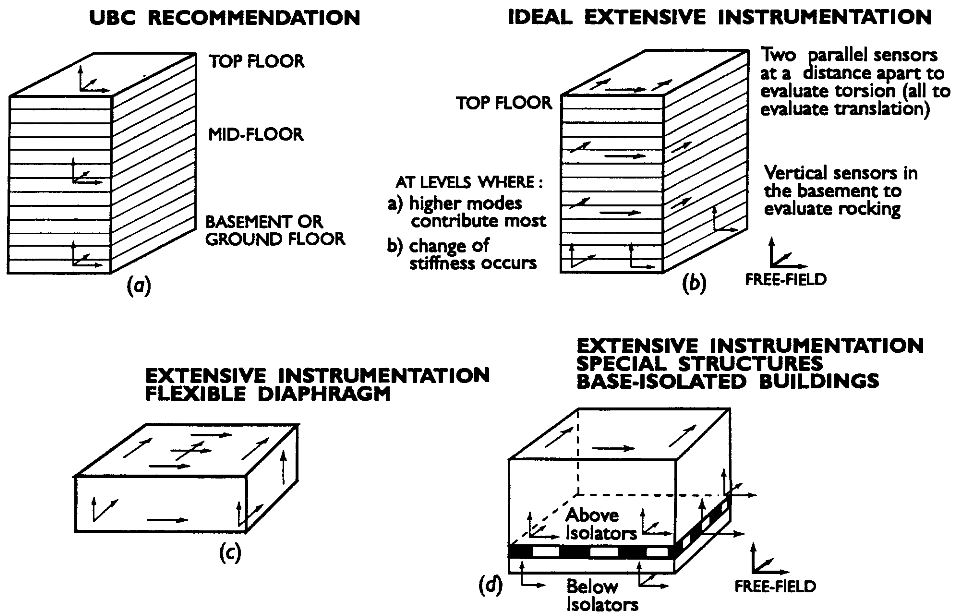

Figure 1. Instrumentation Schemes

- Finally, there is the maintenance, data retrieval, processing and dissemination issue. In the past, with analog instruments, this was a major problem. However with recent advances and improvements on digital accelerograph systems, the cost to maintain, retrieve, process and disseminate data from such systems will be lower.

1.6 Data Utilization

Often, there are questions raised related to how data is utilized. In Appendix A, sample applications with references are provided. The list of references in Appendix A are by no means complete. However, it will provide sufficient leads and significant answers as to how data from instrumented structures are utilized.

2.0 WHY INSTRUMENT FEDERALLY OWNED BUILDINGS?

- In general, it is very difficult to pursuade private property owners to instrument their buildings. In most cases, it is not possible to get private property owners to allow federal or state (public) agencies to deploy seismic instruments or conduct comprehensive damage surveys. Part of the problem for building owners is the concern for possible future litigation. *This problem can be circumvented by instrumenting federally owned/leased structures.* **Federally owned/leased buildings will not require permits to deploy instruments by a federal agency** nor will they be closed to federal inspection teams following a damaging earthquake. *Making the connection between recording strong ground motions and documenting building performance is essential to a national earthquake engineering* *program.* [For example, very few (only 2) steel buildings that were damaged during the Northridge earthquake were instrumented (only minimally). Approximately 800 steel buildings that are being investigated for possible damage did not have any instruments in them. Currently, USGS is having trouble in obtaining permission from one of the owners of a (Northridge earthquake) damaged/retrofitted (SAC)[9] steel building to deploy a seismic monitoring system (even at no cost to the owner)].

- Instrumentation of federally owned and leased buildings supports the aims of the 1977 National Earthquake Hazards Reduction Act which refers to priorities such as:
  - Assist in developing improved building codes
  - Assess earthquake hazards in federal facilities.
- Instrumentation of federally owned and leased buildings is compatible with the spirit of the Public Law 101-614 NEHRP Reauthorization Act. Section 8(a)(1) of this law states: " The president shall adopt, not later than December 1, 1994, standards for assessing and enhancing the seismic safety of existing buildings constructed for or leased by the Federal Government...."
- Instrumentation of new and existing federal buildings is particularly important in light of Executive Orders 12941 [Seismic Safety of Existing Buildings] signed in December 1, 1994 and Executive Order 12699 [Seismic Safety of New Buildings] signed on January 5, 1990. These two executive orders demonstrate both the concern and the need for safety of both the personnel that work within the buildings and the public that use the buildings. Public safety will be enhanced by seismic instrumentation because seismic instrumentation will provide important data to:
  - Assess the causes of damage, if any.
  - Develop the best methods to repair damaged structures.
  - Assess the vulnerability of the buildings
  - Evaluate the dynamic characteristics of the buildings for planning for and selection of the best methods to strengthen and retrofit structures, if necessary.
- ***There are approximately 84,000 federally owned and 5000 federally leased buildings in Seismic Areas 3 and 4*** (as defined in the Seismic Zone Map of the United States in the Uniform Building Code [UBC 1997]). ***The acquisition value of these buildings is $16 billion (does not include contents).*** Therefore, protection of property is also an issue. The distribution of federally owned/leased properties are illustrated in Table 1 and Figure 2 (both from GAO/GGD 92-62 Quake Threatened Buildings, 1992). Instrumentation of federal buildings therefore will lead to improvements in the seismic performance of the buildings, thus resulting in safety to employees and the public, and to protection of public property.

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[9] *SAC buildings are those steel buildings damaged during the Northridge earthquake and studied by a consortium consisting of Structural Engineers Association of California (SEAOC), Applied Technology Council (ATC) nd California Universities for Research in earrthquake Engineering (CUREe).*

- Federal agencies should set an example by instrumenting federally owned/leased buildings.

- Evolution of new technologies in earthquake resistant design, construction and retrofit practices requires systematic and efficient verification of the performance of structures built with the new technologies or retrofitted with new methods. Such verification can only be accomplished by strategically deploying seismic sensors in such structures to record their performances during future events. Several federal buildings in seismic areas are being retrofitted by such emerging technologies (e.g. VA Hospital in Long Beach, Court of Appeals Building in San Francisco [both buildings using base-isolation], a Navy Building in San Diego [using viscous-elastic dampers]).

Table 1. Statistical Distribution of Federally Owned/Leased Buildings and Employees in Seismic Risk Zones Nationwide (from GAO/GGD -92-62: Quake Threatened Buildings)

Level of Seismic Risk	Level of Expected Damage	Number of Owned Buildings	Number of Leased Space Locations	Number of Employees
VERY HIGH	Most Buildings	32,000	2,000	215,000
HIGH	Many Buildings	52,000	3,000	224,000
MODERATE	Some Buildings	99,000	22,000	668,000
LOW	No Buildings	234,000	41,000	1,759,000

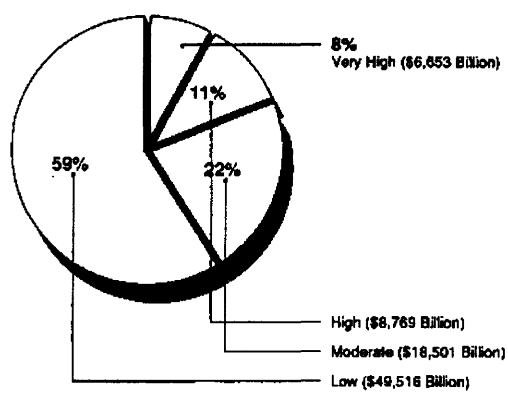

Figure 2. Distribution of Federally Owned Buildings and Acquisition Values (from GAO/GGD -92-62: Quake Threatened Buildings)

- The severity of damages to numerous steel structures during the January 17, 1994 Northridge earthquake (M_s=6.7) and Kobe (Japan) earthquake of January 17, 1995 (M_s=6.8) is a perfect example that points to the need for instrumentation of both the new generation design of mid-rise to high-rise steel buildings but also those that were repaired and/or retrofitted by methods developed for the particular damage problem. It is therefore essential to obtain data during future events for response studies to assess the effectiveness and revise and/or improve the new methods of design, construction and retrofitting.

- Federal building inventory should be compatible with at least the recommendations of Uniform Building Code.

- Within the United States, there are large inventories of buildings within 10 km of major faults capable of generating M>7 earthquakes. This is particularly important now because, very recently, the Structural Engineers Association of California (SEAOC) issued the 1996 edition of the ***Recommended Lateral Force Requirements and Commentary*** which has provisions for increasing the design base shear of such structures by up to 100 % depending on the distance of a building from the fault. It is now also reflected in the 1997 issue of the Uniform Building Code. This implies that forecasting of the performance of buildings within 10 km of major faults, where they are subjected to higher levels of motions, must be done more informatively. This requisite information can only be acquired by studying response data from buildings during earthquakes.

- Recent developments on "Performance Based Design" requires response data from all types of structures. Such data will help improve future design procedures based on this concept.

3.0 SUGGESTED ACTIONS:

(a) Instrumentation of federally owned and leased buildings should be confined only to Seismic Areas 3 and 4 according to the Seismic Zone Map of the United States in the Uniform Building Code [UBC 1997] and on ***a selective basis*** that reflects the objectives of the strong-motion instrumentation of structures program. Alternatively, the areas for instrumentation can be identified by the recent seismic hazard maps of conterminous United States that indicate the highest risk or highest PGA with 10 % probability of exceedance (Frankel and others, 1997a and 1997b).

(b) As an initial target, 0.1 % of the buildings can be feasibly instrumented. The number would reach approximately 90 (of the approximately 84,000 federally owned and 5000 federally leased buildings in areas 3 and 4) based on the current information and data base of inventory and geographical distribution of federally owned/leased structures within the seismic areas of the United States). ***This will create a visible program and set an example to other institutions, state agencies, and private owners***.

(c) Funding for this effort should be provided by:
  - Individual agencies,
  - Federal Emergency Management Agency (FEMA),
  - General Services Administration (GSA),
  - Department of Defense
  - Tie into EO 12941 and 12699
  - A new Executive Order
  - Other sources [*e.g.* special add-on to budget, NSF, etc.].

(d) USGS should provide expertise and guidance in deployment and continuous monitoring on a reimbursable basis, as well as in management and dissemination of acquired data. **<u>USGS should have umbrella agreements with FEMA, GSA and all other federal agencies.</u>** [USGS currently cooperates with the Veterans Administration, and to a lesser extent with GSA, to instrument, monitor, retrieve and disseminate data].

(e) Seismic instrumentation of federally owned/leased buildings should be included in the revisions of TR 4 & TR 5 prepared by ICSSC.

(f) Final selection of buildings to be instrumented should be made according to a protocol to be developed by an interagency committee drawn from members of the ICSSC. Some of the issues that would be addressed by this protocol include:

- **<u>Selection Criteria</u>**

  <u>Building Types</u>
  - Which of the 15 model building types [*e.g.* FEMA 178] do we instrument?
  - Additional priorities based on occupancy class, usage [re ICSSC TR-17]
  - Are there specific lessons or experiments that we need to conduct/learn for a specific building type?
  - Do we want to develop "Demonstration" Experiments? [*e.g.* similar structures in close proximity, with and without retrofit/rehabilitation or built to different codes [pre- and post- ICSSC benchmarks]

  <u>Building Locations</u>
  - Selection with respect to ground conditions (*e.g.* "hard rock" vs. "soft rock")
  - Selection with respect to geologic considerations[*e.g.* distance from a specific earthquake source -- strike slip, normal, thrust faults)
  - Selection with respect to geographic considerations[*e.g.* California, Seattle, Utah, Central US]
  - "Demonstration" Experiments [*e.g.* Two similar structures in close proximity, built on different types of ground]

  - Site Surveys for Geologic Conditions (all sites of instrumented buildings should be included in a separate or ongoing site characterization efforts). Some possible considerations for site surveys are:
    - Development of a standardized approach [adopt ATC-26-1 standards for all sites?]
    - Surface geology, Borehole logs [Lithology, Shear wave velocities, other geotechnical parameters]
    - Consideration of 3-D Sedimentary Basin structure, Wave Focusing and Defocusing Effects

  - **Instrumentation**
    - Hardware
    - Deployment

Within the building(s), development of standardized deployment for specific structure classes, and designs
Outside the building(s), development of 'rule of thumb' for distance from structure to record true 'free field' measurements [re. soil-structure interaction].

(g) Schedule

- Develop funding base for initiative and/or partnership agreements
- Set up ICSSC Sub-Committee for Instrumentation Issues to deal with :
  (a) development of selection criteria of structures for instrumentation,
  (b) preliminary selection of specific structures,
  (c) strong motion experiments as necessary and feasible,
  (d) instrumentation,
  (e) data archiving & distribution,
  (f) organization of workshops as necessary
- Meeting to finalize building selection and strong motion experiments.
- Deployment

4.0 COST/BUDGET ISSUES:

- The cost of hardware and installation for each building can vary between $30-60 K based on the number of channels involved. It seems feasible to provide a standardized 12-18 channel instrumentation scheme that follows in general the illustration shown in Figure 1b. Therefore on the average $ 50 K per building is the current average expenditure for a building. This normally will include a triaxial free-field station in the immediate vicinity of the building, if physically possible. Therefore, notwithstanding special cases discussed below, hardware and installation costs for 90 federally/owned and leased buildings will be $4.5 M. This amount is for a duration of 5 years based on a calculation that approximately 18 buildings/per year can be instrumented. Instrumentation costs of $50 K for **a building and its contents** is a small investment when compared with the actual worth of a building (and its contents).

- In special cases, the geotechnical , geological and topographical environment of a building could provide opportunities to deploy additional hardware in the vicinity of the building to assess the performance of building structures in relation to those environs. I suggest consideration of $0.5 M/yr for such special cases, again for the 5 year duration. For example,

  - One important aspect of structural response is the soil-structure interaction. In many cases, under a specific geotechnical environment, certain structures will respond differently than if that structure were built as a fixed based structure on a very stiff (e.g rock) site condition. This alteration of vibrational characteristics of structures due to soil-structure interaction can be either beneficial or detrimental to their performances. To date, the engineering community is not clear about the pros and cons of SSI. In Mexico City, during the Michoacan earthquake of Sept. 19, 1985, many structures were negatively affected due to SSI because the lengthening of their fundamental periods placed them in a resonating environment close to the approximately 2-second resonant period of Mexico City lakebed. On the other hand, under different circumstances, SSI may be beneficial because it produces an environment whereby the structure escapes the severity of the response spectra due to shifting of its fundamental frequency. Certainly, in a basin such as that of Los Angeles area, SSI may cause both beneficial and detrimental effects in the response of structures. The identification of the circumstances and the parameters for which SSI is beneficial or detrimental is a necessity. **In some cases; therefore, we may wish to deploy additional hardware (e.g. free-field accelerographs on the surface and in boreholes [downhole accelerographs].**

- There are many urban areas in the United States where structures are built on hills. There is now sufficient evidence to consider a phenomenon known as the topographical effect – amplification of ground motions due to the geological and geometrical characteristics of the topography of the site of a building. Thus, in some cases, we could deploy additional free-field accelerograph to assess whether the motions at the site of the building are amplified due to topographical effects.

- *The total budget envisioned for the 5 year duration of this effort will be $5 M. or $1M /year.*

- **Other costs such as maintenance costs should be arranged by an umbrella agreement between USGS and the agencies involved.**

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APPENDIX A

SAMPLE PAPER SUMMARIZING UTILIZATION OF DATA FROM INSTRUMENTED STRUCTURES AND NEW TRENDS

CURRENT AND NEW TRENDS IN UTILIZATION OF DATA FROM INSTRUMENTED STRUCTURES

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ABSTRACT

The many uses of seismic response data include assessment of design and analysis procedures, improvement of code provisions, and correlation of system response with damage. A preliminary list of applications of response data with sample references is provided. An example of different analyses performed on data recorded from a 30-story building during the 1989 Loma Prieta earthquake is used to illustrate uses of response data. A recent seismic monitoring method being developed using GPS technology is introduced. GPS technology provides a potential new tool for monitoring tall buildings as well as other long-period structures.

INTRODUCTION

Seismic monitoring of structural systems constitutes an integral part of the National Earthquake Hazard Reduction Program in the United States and similar programs in other countries. Recordings of the acceleration response of structures have served the scientific and engineering community well and have been useful in assessing design/analysis procedures, improving code provisions and in correlating the system response with damage. Table A.1 summarizes some of the uses for the data from instrumented structures. Unfortunately, only a few damaged structures have been instrumented in advance to perform studies of the initiation and progression of damage during strong shaking (e.g. Imperial County Services Building during the 1979 Imperial Valley earthquake, [Rojahn and Mork, 1981]). In the future, instrumentation programs should consider this deficiency. Jennings (1997) summarizes this view as follows: "As more records become available and understood, it seems inevitable that the process of earthquake resistant design will be increasingly, and quite appropriately, based more and more upon records and measured properties of materials, and less and less upon empiricism and qualitative assessments of earthquake performance. This process is well along now in the design of special structures".

The methods used in studying structural response records are quite diverse:

(a) mathematical modeling (finite element models varying from crude to very detailed, subjected to time-history, response spectrum or modal analyses). The procedure requires the blueprints of the structures which may not be readily accessible;
(b) system identification techniques: single input/single output or multi input/multi output. In these procedures, the parameters of a model are adjusted for consistency with input and output data (Ljung, 1987);
(c) spectral analyses: response spectra, Fourier amplitude spectra, autospectra, S_x or S_y, cross-spectral amplitudes S_{xy}, and coherence functions (γ) [using the equation : $\gamma^2_{xy}(f) = S^2_{xy}(f) / S_x(f) S_y(f)$] and associated phase angles (Bendat and Piersol, 1980); and

(d) simple procedures based on principles of structural dynamics (*e.g.* recently Jennings (1997) analyzed data from two buildings within close proximity (<20 km) to the Northridge epicenter, calculated the base shear from the records as 8 and 17 % of the weights of the buildings, drift ratios as 0.8 and 1.6 % (exceeding code limitations). Jennings (1997) states: "A difference between code design values and measured earthquake responses of this magnitude – approaching a factor of ten – is not a tenable situation."

Table A.1. A Preliminary List of Data Utilization & Sample References

GENERIC UTILIZATION
Verification of mathematical models (usually routinely performed) (*e.g.*Boroschek et al, 1990)
Comparison of design criteria vs. actual response (usually routinely performed)
Verification of new guidelines and code provisions (*e.g.*Hamburger, 1997)
Identification of structural characteristics (Period. Damping, Mode Shapes)[Goel and Chopra, 1997, Mulhern and Maley, 1973, ATC3-06, 1978), NEHRP (1994), Marshall et. al., 1992, Çelebi, 1996]
Verification of maximum drift ratio (*e.g.* Astaneh, 1991, Çelebi, 1993)
Torsional response/Accidental torsional response (*e.g.* Chopra, 1991, DeLalera, 1995)
Identification of repair & retrofit needs & techniques (Crosby, 1994)
SPECIFIC UTILIZATION
Identification of damage and/or inelastic behavior (*e.g.* Rojahn & Mork, 1981)
Soil-Structure Interaction Including Rocking and Radiation Damping (Stewart, 1996, Çelebi, 1996, 1997, Todorovska, 1992, Lin and Papageorgiou, 1989)
Response of Unsymmetric Structures to Directivity of Ground Motions (*e.g.* Porter, 1996)
Responses of Structures with Emerging Technologies (base-isolation, visco-elastic dampers, and combination (Kelly and Aiken, 1991, Kelly, 1993, Çelebi, 1995)
Structure specific behavior (*e.g.* diaphragm effects, Çelebi et al, 1989, ATC3-08, 1978, Boroschek and Mahin,1991, Çelebi, 1994)
Development of new methods of instrumentation/hardware (Çelebi, 1997, Straser, 1997)
Improvement of site-specific design response spectra
Associated free-field records(if available) to assess site amplification, SSI and attenuation curves
Verification of Repair/Retrofit Methods (Crosby et al, 1994, Çelebi and Liu, 1997)
Serviceability Requirements (Uang & Maarouf, 1991)
Identification of Site Frequency from Building Records (more work needed)
RECENT TRENDS TO ADVANCE UTILIZATION
Studies of response of structures to long period motions (e.g. Hall et al, 1996)
Need for new techniques to acquire/disseminate data (Straser, 1997, Çelebi, 1997, 1998)
Verification of Performance Based Design Criteria (future essential instrumentation work)
Near Fault Factor (more free-field stations associated with structures needed)
Comparison of strong vs weak response (Marshall, Long and Çelebi, 1992)
Functionality (Needs additional specific instrumentation planning)
Health Monitoring and other Special Purpose Verification (Heo et al, 1997)

Until recently, in general, only accelerometers (single, biaxial or triaxial) were used to instrument structures. However, observations of damages during the 1994 Northridge and 1995 Kobe earthquakes, have forced engineers and scientists to focus on performance based seismic design methods and to find new techniques to control drift and displacements. To verify these developments, sensors directly measuring displacements or relative displacements (transducers, laser devices and GPS units) are now being considered. A recent development in this direction is presented later in this paper.

In general, accelerometer deployments, as depicted in Figure 1 (of the main text), fall into three categories:

(a) minimal [a triaxial accelerograph only at the roof of a building or three triaxial accelerographs deployed at the roof, mid-floor and gound (or basement) levels – the later better known as the UBC recommended instrumentation];
(b) extensive [combinations of uniaxial, biaxial and triaxial accelerometers to record translational, torsional and rocking motions];
(c) special cases [additional accelerometers to detect deformations of in-plane motions of flexible diaphragms];
(d) special cases [additional accelerometers to detect relative vertical displacements of isolators of a base-isolated structure].

A SAMPLE CASE: Pacific Park Plaza (Emeryville)

The set of records from the 30-story Pacific Park Plaza (PPP) building is possibly the most studied building response data recorded during the M_s=7.1 Loma Prieta earthquake of October 17, 1989. The building is an equally spaced three-winged, cast-in-place, ductile, moment-resistant framed structure. Constructed in 1983 and instrumented in 1985, it is the tallest reinforced concrete building in northern California. A general view, a plan view, a three-dimensional schematic, and its instrumentation is shown in Figure A.1 (Çelebi, 1992, 1996). Twenty-one channels of synchronized uniaxial accelerometers are deployed throughout this structure. Three channels of accelerometers are located at the north free-field outside the building. All are connected to central recording systems. In addition, a triaxial strong-motion accelerograph is deployed at a free-field site on the south side of the building (SFF or EMV[10,11]).

The foundation of PPP is a 5-foot-thick concrete mat supported by 828 (14-inch-square) prestressed concrete friction piles, each 20-25 m in length, in a primarily soft-soil environment, with an average shear-wave velocity between 250 and 300 m/s and a depth of approximately 150 m to harder soil. The building, at 100 km from the epicenter of the earthquake, had considerably amplified input motions but was not damaged during the earthquake. The east-west components of acceleration recorded at the roof and the ground floor of the structure, at the associated free-field station (SFF in Figure A.2) and, for comparison, the motion at Yerba Buena Island (YBI), the

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[10] In most studies, the site of south free-field (SFF) is referred to as the Emeryville site (EMV).
[10] In 1997, the analog recording instruments at Emeryville were upgrade to digital. A downhole accelerograph was installed at the same location as the surface free-field station, SFF.

closest rock site with a peak acceleration of 0.06 *g*, are shown in Figure A.2. The response spectra also shown in Figure A.2 clearly demonstrate that the motions at EMV were amplified by as much as five times when compared with YBI. Amplification is also indicated by the amplitude of the peak accelerations (0.26 *g* for EMV and 0.06 *g* for YBI). The differences in peak acceleration at the free-field station (0.26 *g*) and at the ground floor of the building (0.21 *g*) (Figure A.2a) suggest that there was soil-structure interaction (SSI).

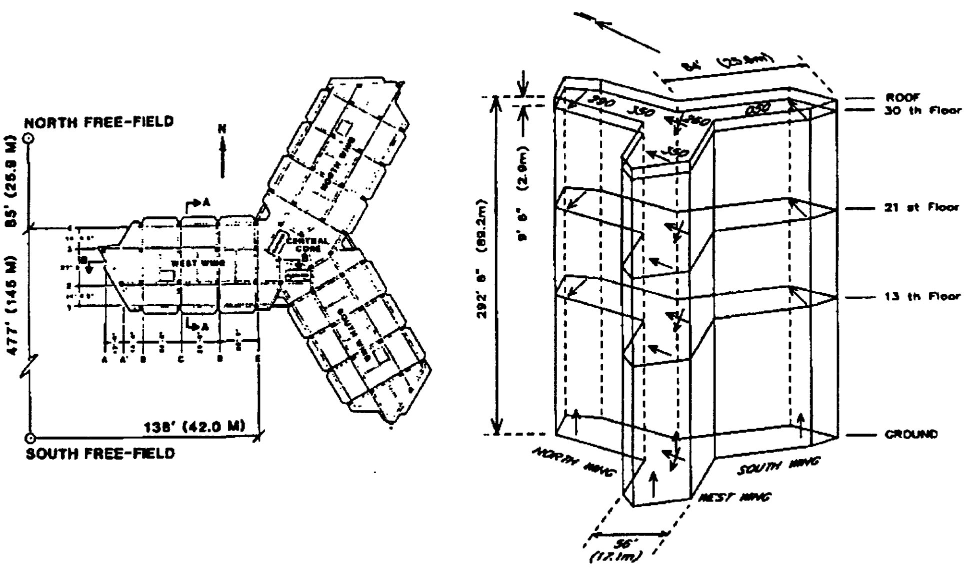

Figure A.1. Plan layout and three-dimensional schematic and instrumentation scheme of Pacific Park Plaza (PPP), Emeryville, Ca.

In the design of the building, site-specific design response spectra (based on three probabilistic earthquakes based on expected levels of performance) were used: (a) the maximum probable earthquake (50 % probability of being exceeded in 50 years with 5 % damping) anchored at zero period acceleration (ZPA) of 0.32g., and two maximum credible earthquakes both with 10 % damping but 10 % probability of being exceeded in (b) 50 years [ZPA of 0.53 g] and (c) 100 years [ZPA of 0.63 g]. The design response spectra and the spectrum of the EW component of recorded motion at the SFF is shown in Figure A.3. The ZPA of the recorded EW acceleration at SFF (0.26 g) (at 100 km from the epicenter) is close to that of the postulated maximum probable earthquake (0.32 g). Furthermore, the spectral accelerations of the EW component of SFF is considerably higher than the maximum probable earthquake for periods >0.6 seconds – that is, practically for the first three modes of the building. Therefore, one important conclusion derived from the records is that improvements are necessary in establishing site-specific design response spectra to account for realistic shaking at a specific site taking into account expected future closer earthquakes likely to produce larger peak accelerations.

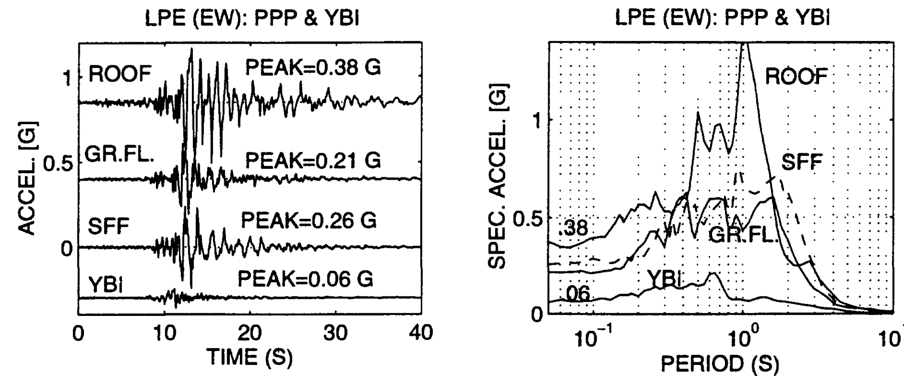

Figure A.2. Recorded (EW components) of accelerations and corresponding response spectra at the free-field, ground floor and roof of Pacific Park Plaza (PPP), and at Yerba Buena Island (YBI), at approximately the same distance as PPP, depict the level of amplification.

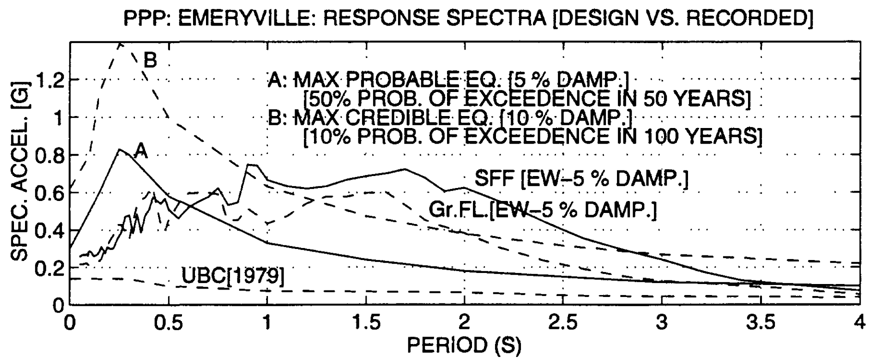

Figure A.3. Design response spectra and response spectra of recorded motions at the ground floor and SFF of Pacific Park Plaza. Also shown is the 1979 UBC response spectrum for comparison.

Using different methods, the building has been studied in detail by Anderson and Bertero (1994), Anderson and others (1991), Kagawa and others (1993), Kagawa and Al-Khatib (1993), Aktan and others (1992), Kambhatla and others (1992) and Çelebi and Safak (1992). All investigators agree that the predominant three response modes of the building and the associated frequencies (periods) are 0.38 Hz (2.63 s), 0.95 Hz (1.05 s), and 1.95 Hz (0.51 s). These three modes of the building are torsionally-translationally coupled (Çelebi, 1996) and are depicted in the cross-spectra (S_{xy}) of the orthogonal records obtained from the roof, ground floor and SFF (the south free-field site) (Figure A.4) and the normalized cross-spectra of the orthogonal records (bottom right in Figure A.4). The frequency at 0.7 Hz (1.43 s) observed in the spectra is this site frequency (Çelebi, 1996).

System identification techniques, when applied to the records of this building, yielded unusually large damping ratios corresponding to the 0.38-Hz first-mode frequency [11.6 % (NS) and 15.5 % (EW)] [Table A.2] (Çelebi, 1996a). Such unusually high damping ratios attributed to a conventionally designed/constructed building with its large mat foundation in a relatively soft geotechnical environment is due to radiation (or foundation) or material damping. This is one of two cases where large damping percentages implied by the recorded responses of buildings have been attributed to radiation damping; the other case is from the Olive View Hospital in Sylmar, Ca. – data from the Northridge earthquake (Çelebi, 1997).

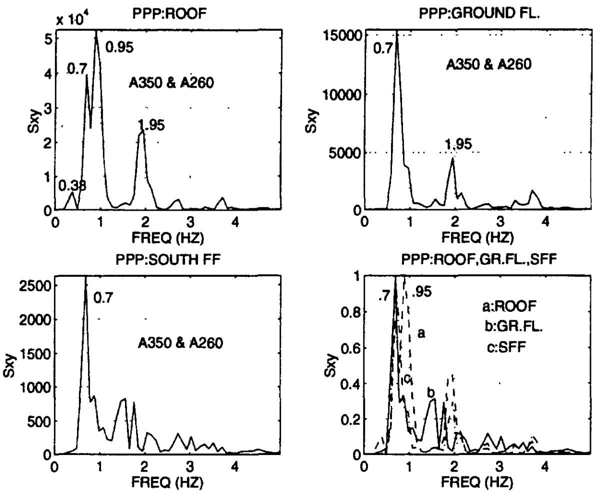

Figure A.4. Cross-spectra of orthogonal accelerations (A350 & A260) at the roof, ground floor, free-field of PPP. Also shown (bottom right) is the normalized cross-spectrum depicting structural and site frequency peaks. (350 & 260 depict degrees clockwise from true north).

Table A.2. Summary of dynamic characteristics for Pacific Park Plaza

	Frequencies (Hz)			Damping (%)		
	Mode			Mode		
	1	2	3	1	2	3
1989 (LPE) STRONG-MOTION DATA (from Çelebi, 1996)						
N-S	0.38	0.95	1.95	11.6		
E-W	0.38	0.95	1.95	15.5		
MODAL ANALYSES (from Stephen and others, 1985)						
N-S	0.60	1.67	3.10			
E-W	0.60	1.67	3.10			
TORSION	0.57	1.70	3.25			

The dynamic characteristics determined from Loma Prieta response records of Pacific Park Plaza as well as those determined from modal analyses (Stephen and others, 1985) are summarized in Table A.2. Also, it is noted in Table A.2 that although flexibility of the foundation was considered in the 1985 analyses, the structural frequency remained the same as the frequency determined with fixed base assumption. Clearly, the mathematical models developed at that time needed improvements. This conclusion could only be reached because we have recorded on scale motions. Most recent studies indicate that the frequencies from recorded motions can be matched when soil-structure interaction (SSI) is incorporated into the mathematical models (Kagawa and others, 1993; Aktan and others, 1992; Kambhatla and others, 1992). Furthermore, a study of the building for dynamic-pile-group interaction by (Kagawa and Al-Khatib, 1993; Kagawa and others, 1993) indicates that there is significant interaction. Their studies show that computed responses of the building using state-of-the-art techniques for dynamic-pile-group interaction compares well with the recorded responses. On the other hand, Anderson and others (1991) and Anderson and Bertero (1994) concluded that soil-structure interaction was insignificant for Pacific Park Plaza during the earthquake. They compared the design criteria, code requirements, and the elastic and nonlinear dynamic response of this building due to the earthquake using both simplified and detailed analytical models.

DEVELOPMENT OF GPS BASED DISPLACEMENT MONITORING

Recording displacements at higher sampling rates than before (*e.g.* 10 Hz) using GPS technology is now possible. This provides a great opportunity to reliably monitor tall buildings, perhaps buildings that are 20-40 stories or more. The majority of such buildings are flexible steel framed structures whose period can be estimated with the empirical formula: $T = 0.1\,N$, where N is the number of stories of the buildings. The frequencies corresponding to the fundamental periods of most tall buildings over 20 stories are 10-20 times the Nyquist frequency of the sampling, which is sufficient to accurately assess its average drift ratio and therefore the damageability of a building. During extreme motions caused by earthquakes and strong winds, data recorded from tall buildings monitored with GPS units can be used by building managers/engineers to assess the performance of building performance, which is accomplished by establishing different threshold displacements or drift ratios and identifying changing dynamic characteristics. Such information can then be used to secure public safety and/or take steps to improve the performance of an individual building. On the other hand, while displacements, relative displacements or average drift ratios can be measured directly using the GPS technology, a double-integration process, not normally automated, is required to calculated the same.

To investigate the feasibility of using GPS technology to monitor tall buildings, a rectangular, fixed-based, steel bar (H [height]=6', B [width]=2", t (thickness]=1/8") was used to simulate an approximately 40 story flexible building (Figure A.5). With a 10 Hz sampling GPS unit attached at its tip, the bar was set to free vibration. Figure A.5 also shows a sample displacement plot and amplitude spectra indicating the fundamental frequency (period) to be 0.245 Hz (4.08 s) and yielding a damping percentage of approximately 2 %. This simple test shows that with GPS, sampling at 10 Hz, a clear and accurate response history (displacements, drift ratios and dynamic characteristics)can be obtained (Çelebi *et al*, 1997a). A project is underway to deploy permanent GPS units on the roof of a tall building already instrumented with accelerometers. This will facilitate comparison of roof displacements recorded with the GPS unit and those derived by double-integration of the acceleration recordings from the same location. Possible steps in use of the GPS based data are:

(1) A building equipped with GPS units on its roof can be configured to provide real-time or near real-time data to indicate its real-time average drift ratio and changes in dynamic characteristics after it has exceeded predetermined thresholds (*e.g.* A, B and C as shown in Figure A.6). When warranted, according to pre-established procedures, this information can be made available to building managers (or interested parties) in real-time or near real-time for additional assessment and action. If a situation is serious, the management may make decisions to inspect/vacate the building and to secure safety of the occupants.

(2) The collected information on the response of the building during strong motion events can be used to make decisions for further evaluation of the damageability of the building, and to develop future repair/retrofit schemes.
(3) The recorded data can be used to analyze the performance of the building, and the results can be used to improve future analyses/design procedures.

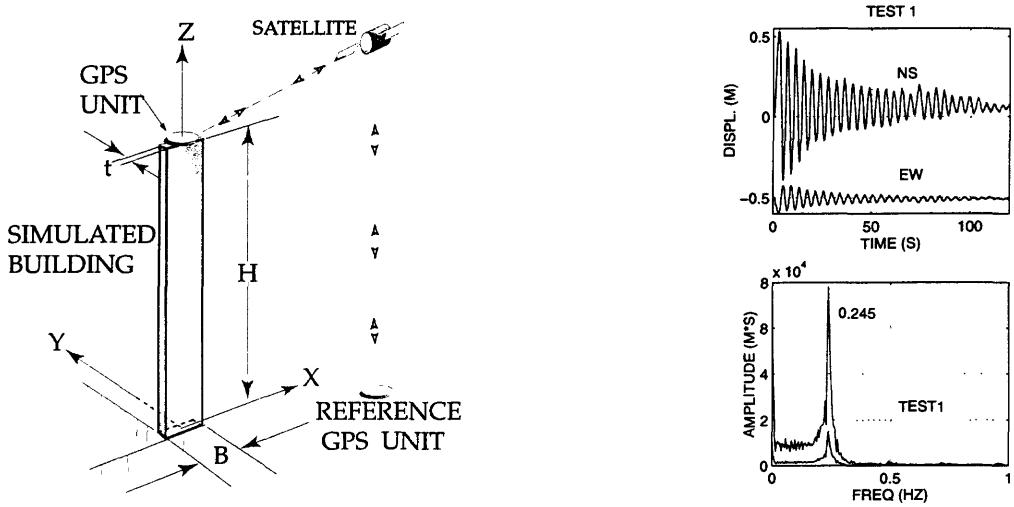

Figure A.5. Simulated tall building with GPS antenna, displacement response and amplitude spectra.

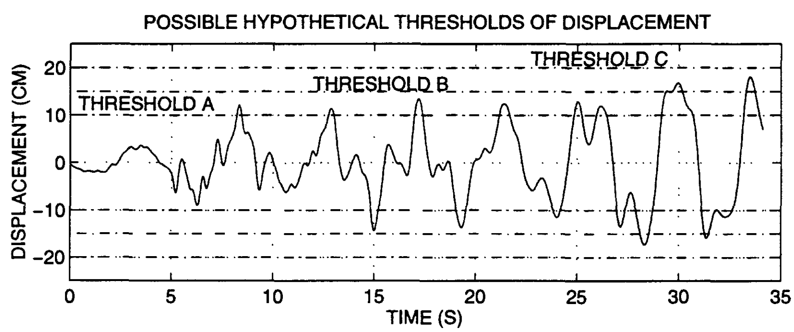

Figure A.6. Hypothetical thresholds for measured displacement of a structure.

CONCLUSIONS

In this paper, various uses of data from instrumented structures are summarized. A preliminary listing and classification of the different uses of data is provided with some sample references. A data set from an instrumented building is used to demonstrate extraction of dynamic characteristics (modal frequencies) and other features (radiation damping). It is shown for this case that during future earthquakes that are closer to the building, the design response spectra will be significantly exceeded. On a generic note, it is noted that development of design response spectra particularly for longer periods should be improved and soil-structure interaction should be considered in design/analyses procedures. Furthermore, a recent method being developed for monitoring structures using GPS technology is introduced.

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APPENDIX B

LETTERS, ENDORSEMENTS, AND COMMENTS

ICSSC Steering Committee Meeting

Meeting Summary

Date: Friday, October 3, 1997
Time: 9:00 a.m. to noon
Place: Department of Commerce
14th and Construction Avenue

Attendees: Richard Wright, Chair
Charles Gutberlet, Walt Hays
H. S. Lew, UgoMorelli
Riley Chung

Summary Prepared by: Riley Chung

Distributed to: ICSSC Full Committee Members

SUMMARY

2. **ICSSC Comments on Seismic Instrumentation for NEP**

Riley presented a two-page compilation of the comments received from ICSSC members in their review of the proposal. In addition to the points in the summary, Ugo mentioned that the former Soviet Union should also have data related to SSI (soil-structure interaction) and suggested to contact Keith Nakanishi at LLNL on this topic.

It was suggested that Riley consolidate these comments and present the revised summary at the October 29 Full Committee meeting. (Attachment 1)

Meanwhile, it is agreed that ICSSC should inform NEP that "ICSSC endorses the proposal for consideration as part of the NEP Strategic Planning process, with the clarification of some of the comments given by the ICSSC members." (This message was passed along to Bob Volland at the NEP's October 7 meeting).

October 20, 1997

Attachment 1
to ICSSC SC 10/3/97
meeting summary

Summary of Comments on
Draft Seismic Instrumentation of Federal Buildings

Comments by seven (7) ICSSC members from six (6) agencies were received and they are summarized below. By and large, the members expressed their support to this proposed effort.

Supporting statement:

- Add to Section 2.0: One additional benefit would be the ability to use the strong motion data for determining the level of post seismic assessment of the building after an earthquake. As an example, if the building felt low g-levels and there is no visual damage the assessment would be minimal. If the building felt high g-levels and there is still no visual damage, a more detailed assessment, such as opening a few walls for internal inspection of critical components, should be performed.

Issues to be resolved

- Proposed program versus the CDMG program
  - The proposal does not discuss similarities or differences with the California Strong Motion Instrumentation Program (CSMIP). "Lessons learned" from the implementation of CSMIP should be beneficial to this effort and factored into the planning.

- Cost
  - The proposal lacks an estimation of cost associated with the development of the mathematical building models and supportive pre-and post-earthquake analyses. Section 1.3 states "The instrumentation of a structure should provide an optimal number of sensors to allow reconstruction of the response of the structure in sufficient detail to compare with the response predicted by mathematical models - the goal being to improve the models."
  - The proposal should give a rough idea of the level of maintenance cost that USGS would assess the agencies who own the instrumented buildings.

- Soil-structure Interaction (SSI)
  - Data on soil-structure interaction (SSI) are undoubtedly very significant in the design of complex buildings and structures, and appropriately instrumented and located buildings are a good source of such data. With so many competing

demands on a budget that shows no growth signs, however, I believe that the ICSSC should ask NEP to examine two questions pertinent to this proposal:

- How successful have been the efforts to date to mathematically model SSI) Is the degree of approximation heretofore achieved by modeling adequate for design purposes?
- How does the proposed building instrumentation program compare in terms of need, urgency, and probability of success to the other major ongoing and new programs competing for available funds?

These questions should be examined against the realization that data from a building instrumentation program would yield useful results only in the very long term, hence the program should be initiated, if at all, only if it can be assured of continuing support over many years. The NEP Strategic Plan now in preparation appears to be the proper vehicle for this analysis.

- There are many references describing SSI. The selection of the reference list is too narrow. Why not delete the list?

Specific Suggestions

- Change the wording on the objective to "The main objective of the seismic instrumentation program for buildings and structures is to improve our understanding of their behavior and their potential for damage under earthquake loading."

- We could delete Section 1.2, Prior Recommendations since the connection of that section and what this proposal wants to accomplish is very weak.

- Section 3.0: As much as possible in the selection process, use the EO12941 inventory data base due in December 1998, rather than casting out another data call for agencies to respond to. Maybe it should be the other way around, the Committee selects buildings from the EO12041 inventory, and then proposes that selection to agencies. How would selection work under EO12699 for new construction? Note that where EO12699 is cited it doesn't mean the Federally assisted and regulated aspects of that EO.

Questions

- Section 2.0: Does instrumenting Federally owned/leased buildings mean leased buildings and not space (portions of buildings)? Wouldn't owners of leased buildings have the same "litigation concerns" as other private property owners?
- The statement on p. 9, "Federal building inventory should be compatible with at least the recommendations of UBC," is not clear as to its intent under Section 2. Does it mean to state, "therefore representing the state of the practices in seismic design"?

CASMP

J. S. Committee for Advancement
of Strong Motion Programs ______ Leadership for Earthquake Saftey

November 6, 1997

Mr. Robert H. Volland
Director, National Earthquake Loss
Reduction Program Office
Federal Emergency Management Agency
500 C Street, S. W., Room 416
Washington, DC 20472

Dear Mr. Volland:

Subject: Seismic Instrumentation of Federal Buildings

By this letter I am providing comments of the U. S. Committee for Advancement of Strong Motion Programs on the Draft Document: "Seismic Instrumentation of Federal Buildings", prepared by Mehmet Celebi and Stuart Nishenko, USGS Open-File Report 97-452, July 1997. The Committee particularly appreciated the review of this document provided by Dr. Celebi at its meeting on October 18, 1997. The comments contained in this letter are a result of Dr. Celebi's very valuable presentation.

The Committee considers recordings of earthquake generated strong motions in and near important classes of buildings to be an essential need to improve earthquake safety. This need was strongly emphasized by participants in the recent workshop held by the CASMP: "Vision 2005: An Action Plan for Strong Motion Programs to Mitigate Earthquake Losses in Urbanized Areas", April 2-4, 1997. The proposed initiative described in Open-File Report 97-452, to instrument certain classes of federal buildings exposed to high earthquake ground shaking hazard is a significant initial step toward monitoring the safety performance of structures in densely populated urban areas during future earthquakes. The potential benefits are significant. Critical needs following every strong earthquake affecting a densely populated area are to rapidly determine the damage impact for implementation of emergency response and recovery actions and to return facilities to full operation. The proposed instrumentation of federal buildings could contribute to these critical needs for post earthquake information by aiding in the early assessment of buildings safety and functionality for continued use. The Committee recognizes that use of strong motion recordings to rapidly determine a building's damage state is in development. With near real-time monitoring capability however, post earthquake response and recovery and the developing potential for rapid determination of structural performance could be greatly facilitated.

The Committee notes that the proposed instrumentation initiative contributes to several goals established in NEP Strategic Plan: "Strategy for National Earthquake Loss Reduction", April 1996. In particular, it contributes to Goal 1: Provide Leadership and Coordination for Federal Earthquake Research; Goal 3: Improve Engineering of the Built Environment; Goal 4: Improve Data for Construction Standards and Codes; Goal 5: Continue Development of Seismic Hazard and Risk Assessment Tools; and Goal 9: Continue Documentation of Earthquakes and their Effects. There is broad consensus that there will not be significant improvement in earthquake engineering technology until we have numerous records from buildings experiencing different levels of damage in strong ground shaking.

The Committee notes also that the proposed instrumentation initiative is consistent with the framework for achieving seismic safety in federal buildings expressed in Executive Order 12941: "Seismic Safety of Existing Buildings", December 1, 1994, and Executive Order 12699: Seismic Safety of New Buildings, January 5, 1990. While strong motion instrumentation is not specifically mandated by these Executive Orders, such instrumentation is critically important for determining the safety performance of structures following strong earthquake shaking. Seismic instrumentation could therefore, be considered an important element of the implementation of the Executive Orders. The Committee considers coordinated Federal leadership in the spirit of these Executive Orders and the NEP Strategic Plan to be vitally important for achieving national safety goals in earthquakes.

Coordination with other seismic monitoring initiatives is considered to be highly important to achieve economy and effectiveness in meeting national earthquake hazard mitigation goals. Specifically, the Committee considers close coordination between the proposed initiative for Seismic Instrumentation of Federal Buildings and the FY 1999 Initiative: Real-Time Hazards Warnings, put forward by the USGS, July 1997 which includes seismic together with other natural hazards monitoring, to have significant value in advancing national preparedness to respond to earthquakes in densely urbanized areas.

The Committee considers the proposed initiative for Seismic Instrumentation of Federal Buildings to be a needed, important action to advance safety in earthquakes and strongly supports its implementation.

Sincerely,

J. Carl Stepp
Chairman

c: William A. Anderson (NSF)
John Filson (USGS)
Richard N. Wright (NIST/ICSSC)

CASMP

U. S. Committee for Advancement
of Strong Motion Programs_______________________________*Leadership for Earthquake Safety*

November 11, 1997

Dr. Mehmet Celebi
U. S. Geological Survey
MS 977
345 Middlefield Road
Menlo Park, CA 94025

Dear Mehmet:

By this letter I want to thank you for attending the CASMP meeting on October 18 and for your very valuable discussion of the initiative for instrumentation of certain classes of federal buildings in high seismic hazard zones: SEISMIC INSTRUMENTATION OF FEDERAL BUILDINGS, by Mehmet Celebi and Stuart Nishenko, USGS OFR 97-452. The Committee considers recordings of earthquake generated strong motions in and near important classes of buildings to be an essential need to improve earthquake safety.

During the discussion following your presentation the Committee made several suggestions and observations. I am passing them on to you for consideration as you move forward with further development of this initiative.

- A stated objective of the initiative is to instrument each building sufficiently to record free-field motions and to determine the translational, tortional and rotational responses of the building. It was noted that the scope of seismic instrumentation needs may vary among classes of structures. It would be desirable to develop specific seismic monitoring objectives and needs for different classes of buildings to optimize the effectiveness of the initiative for the investment. The function of a building and possibly, other use considerations could be an important. A useful initial action might be to convene a small group of knowledgeable engineers to develop criteria for selecting buildings to be instrumented.

- The seismic instrumentation may be able to contribute to rapid determination following potentially damaging shaking, of the instrumented buildings' structural health and fitness to return to service. This potential function should be considered in determining the scope and layout of the seismic sensors.

- It is considered highly important that the selection of buildings to be instrumented under this initiative should be coordinated with other activities aimed at installing seismic instrumentation in structures located in densely urbanized areas. Specifically, the Committee considers close coordination between the proposed initiative and the FY 1999 Initiative, Real-Time Hazards Warnings, put forward by the USGS in July 1997 as well as with existing strong motion programs to have significant value in advancing national preparedness to respond to earthquakes in densely urbanized areas.

- An important need as part of the initiative is to provide for long term maintenance of the instrumentation and develop a plan for processing and disseminating the data following an earthquake.

There is broad consensus that there will not be significant improvement in earthquake engineering technology until we have numerous records from buildings experiencing different levels of damage in strong ground shaking. Considering this recognized need, the Committee considers the proposed initiative to seismically instrument federal buildings, though modest, to be highly important and offers its continued support as you move forward with its implementation.

Sincerely,

J. Carl Stepp
Chairman

c: Robert H. Volland, FEMA/NEP

Applied Technology Council
A Nonprofit Corporation
Advancing Engineering Applications for Natural Hazard Mitigation

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ATC

November 10, 1997

Mr. Robert Volland
Federal Emergency Management Agency
500 C Street, S. W.,
Washington, DC 20472

Dear Bob:

SUBJECT: SEISMIC INSTRUMENTATION OF FEDERAL BUILDINGS

At the FEMA-funded EERI Workshop on "Seismic Rehabilitation of Buildings—Strategic Plan 2005—The Second Decade" held in Reno, Nevada, on August 12-13, 1997, I learned of a plan from the U.S. Geological Survey (USGS) for "Seismic Instrumentation of Federal Buildings". The plan is described in detail in USGS Open-File Report 97-452, authored by Mehmet Celebi and Stuart Nishenko (see attached), and proposes that state-of-the-art instruments be installed in approximately 90 federally owned or leased buildings over the next five years at a capitalization cost of approximation $ 4.5 million.

The purpose of this letter is endorse the proposed plan and to encourage that steps be taken to fund the proposed program in full. ATC experience on the FEMA-funded SAC Program for Reducing Seismic Hazards of Steel Moment Frame Buildings, the U. S. Postal Service Seismic Program (ATC-26 project), and several USGS-funded projects (e.g., ATC-10, ATC-10-1, and ATC-35) has clearly indicated that strong-motion instrumentation of federally owned and leased buildings is highly desirable for several fundamentally important reasons: (1) the Federal inventory is representative of the at-large inventory of commercial buildings in the United States and includes excellent examples of all types of standard "model" building types in all seismic regions; (2) restrictions cannot be placed on the use of data acquired from such structures (as is potentially possible for virtually all instrumented private-sector buildings); and (3) strong-motion data from severely shaken and damaged buildings are the most important source of data for development of new knowledge on building seismic performance and the improvement of codes and standards for seismic design. In fact, it can be argued that, given the high cost of instrumentation, installation of such equipment in privately owned buildings is conceptually flawed.

Applied Technology Council strongly endorses the concepts outlined in USGS Open-File Report 97-452. If we can be of further assistance in advancing the program, please advise. Thank you.

Sincerely,

Christopher Rojahn
Executive Director

cc: Robert Page
bcc: Mehmet Celebi