Proceedings of the 9th U.S. National and 10th Canadian Conference on Earthquake Engineering
Compte Rendu de la 9ième Conférence Nationale Américaine et
10ième Conférence Canadienne de Génie Parasismique
July 25-29, 2010, Toronto, Ontario, Canada • Paper No 795

SEAOC'S EARTHQUAKE PERFORMANCE EVALUATION PROGRAM

Fred Turner, SE[1], Anthony Court, SE[2], David McCormick, SE[3], and Joseph Valancius, SE[4]

ABSTRACT

The Structural Engineers Association of California's (SEAOC's) Existing Buildings Committee (EBC) launched a new initiative now called the Earthquake Performance Evaluation Program in 2007 to systematically gather useful building performance data after earthquakes, including the performance of structural and non-structural systems.

Introduction

For decades, surveys of the performance of buildings have been performed by various groups and individuals following significant earthquakes around the world. While these efforts have been useful for raising the awareness about the potential for damage to certain vulnerable building types, U.S. efforts typically have not gathered sufficiently detailed engineering performance data correlated with ground motions to support useful analytical or statistical studies. Furthermore, U.S. efforts have generally not attempted to record performance data for buildings that perform well, instead focusing on those that perform poorly. For some damaged buildings, many of the surveys were initiated too long after the event to capture much of the ephemeral damage data. Also, these studies have not focused on the performance of previously retrofitted buildings, a topic of particular interest to the Existing Building Committee (EBC).

Many structural engineers and researchers in the U.S. have been aware and frustrated by these "lost opportunities" and have called for more systematic efforts to gather post-earthquake performance data. SEAOC's *Vision 2000* (SEAOC 1995), EERI's *Collection and Management of Earthquake Data* (EERI 2002), as well as the National Institute of Standards and Technology have each recommended or taken steps toward enhancing performance data collection efforts. NIST recently found that a "lack of research and performance data will limit the scope of Performance Based Seismic Design and, potentially, its accuracy and usefulness" (NIST 2009). The Federal Government is now partially funding a new Post-Earthquake Information Management System (PIMS 2008).

In response to this identified need for better data collection, the SEAOC EBC proposed to develop a program for sending trained Structural Engineers to the field to systematically gather detailed building performance data regarding both damaged and undamaged conditions

[1] Staff Structural Engineer, Alquist California Seismic Safety Commission, Sacramento, CA
[2] President, A. B. Court & Associates, San Diego CA
[3] Principal, Simpson Gumpertz & Heger, Inc., San Francisco, CA
[4] Principal, Wiss Janney Elstner Associates, Inc., Burbank CA

after significant seismic events. The EBC proposal was approved by the SEAOC Board of Directors in 2006. The EBC formed the Post-Disaster Performance Observation Committee (PDPOC) as a program management subcommittee, and began to develop the Earthquake Performance Evaluation Program (EPEP) in 2007.

Figure 1. A SEAOC-EPEP volunteer observing performance of a damaged building in Pomona, California in March 2009.

The purpose of SEAOC's Earthquake Performance Evaluation Program (EPEP) is to:

> Provide consistent and detailed efforts to collect and archive observations of the behavior of building structural and nonstructural systems, as well as the effects on occupants and contents, to accurately record variations in performance in relation to variations in ground shaking intensity and to help SEAOC and the engineering and academic communities analyze and explain, through accurate science and engineering, these seismic performance variations. (Derived from ATC 73 2007)(PDPOC-AAR 2008).

The near term goal of the EPEP program is to develop data collection procedures and to train evaluators so that SEAOC can deploy teams to the field promptly after significant earthquakes to collect data from buildings located around strong motion sensors.

The EPEP initially developed a three-phase approach to the collection and evaluation of performance observations: "Phase I is proposed to span from the onset of an earthquake to several days, with the duration varying depending on the size of the earthquake and the opportunities to collect initial observations in the field. Phase II will extend from the end of Phase I to 1 month or more after the disaster. Phase III will extend from month(s) to years following the earthquake. A fourth phase has been added for SEAOC-PDPOC activities that take place between events" (Turner & McCormick 2007).

In Phase 1, the EPEP volunteers will attempt to gather data from buildings, damaged and undamaged, within 500 feet of selected Strong Motion Instrumentation Program (SMIP) and U.S. Geological Survey (USGS) stations. At the same time, volunteers will attempt to identify candidate buildings for further investigation in Phases 2 and 3. The EPEP will also coordinate during Phase 1 with other organizations such as EERI and governmental agencies as much as possible, to assist them and share information through post-earthquake information clearinghouses.

Phase 1 focuses on the collection of general and ephemeral performance data, in order to facilitate statistical studies of building performance and to help make decisions about whether a building is a candidate for Phase 2. Post-event efforts will continue through a follow-up Phase 2 with more detailed data gathering for selected buildings and then a Phase 3 in which the SEAOC EBC will either perform its own studies or advocate for research using the information obtained in Phases 1 and 2. The overall goal of the EPEP is to contribute to the development of improved, performance-based seismic design and retrofit codes, standards, and guidelines for buildings and building-like structures.

Refinements to the EPEP Operations Manual

Since the initial startup and program definition phase in 2007, much of the focus by the PDPOC has been on the EPEP's fourth phase, making refinements to Phase 1 operation protocols, developing data collection forms and holding exercises described in later sections of this paper. A Preliminary Operations Manual for the Earthquake Performance Evaluation Program (PDPOC-OPS 2009) is now available for review and comment.

EPEP is initially targeting groups or "pods" of buildings located within 500 to 1000 feet radii of strong motion recordings for collecting ephemeral performance observations based on ATC 38 (ATC 2000). See Fig. 2.

Figure 2. A pod of buildings within 500 feet of a strong motion recording station.

PDPOC has set as a high priority observations of the performance of CSMIP- and USGS-instrumented buildings following earthquakes. These buildings, as well as free-field instruments, and their recorded levels of shaking can begin to be identified at www.strongmotioncenter.org within short periods of time following earthquakes.

PDPOC currently expects to deploy SEAOC volunteers when future ground motions exceed thresholds of both 0.20g peak ground acceleration (PGA) and 20 cm/sec peak ground velocity (PGV). These levels roughly correspond to orange and red regions on ShakeMaps www.cisn.org (ATC 54, 2006) and instrument location maps at www.strongmotioncenter.org

PDPOC defined minimum team requirements for Phase 1 of at least two members with at least one EPEP-trained and credentialed Structural Engineer on each team. Teams will typically spend one to two hours per building collecting performance observations and completing forms. However, some larger and/or instrumented buildings may warrant longer time commitments for more in-depth observations.

Performance Observations

EPEP observations will include sketches of overall building plans, geo-locations of buildings and digital imagery, descriptions of structural and nonstructural systems, damage details, casualties, disruptions to building functions as well as descriptions of systems and subsystems that were undamaged and functions that were not disrupted.

One of the goals of the collection effort is to provide data that can be used to assist in the development of ATC 58 fragility relationships. EPEP uses ATC-38 damage classifications that are based on reparability thresholds (NIMH – none, incidental, moderate, and heavy). NIMH has not really provided enough specificity for actual use in generating fragility relationships, but could be useful for sorting and retrieving more detailed data later. EPEP has also added a damage classification for minor damage to its observation forms (NIMMH) based on experience gained during training exercises.

Teams will typically access the exterior of all buildings from public sidewalks and rights-of-way. Access to the interiors of buildings will be determined on a case-by-case basis. Where interior access is available, full advantage will be taken to gather as much interior performance information as practical, provided the building is deemed safe to enter and occupants or owners are cooperative.

EPEP will function separately from CalEMA’s Safety Assessment Program. SEAOC volunteers responding to government requests for safety assessments will take priority over EPEP deployments. The intent is not to interfere with the safety assessment efforts being performed by the CalEMA’s Safety Assessment Program (CalEMA-SAP 2009) (ATC 20 1995). EPEP activities are expected to be coordinated by PDPOC members with one or more volunteers assigned to help orchestrate the deployment of volunteers, as well as to help collect and review data, and identify priorities for additional evaluations and data gathering.

Observation Forms and Supporting Documents

Forms to help SEAOC-EPEP volunteers systematically record observations of performance for all building types are now available. See Fig. 3 for an excerpt.

Information Below For Entire Building: ❑Y ❑N For Only Floor/Roof Level: ____________ Bldg. ID: ____________________
Page No. ____________________

Nonstructural Subsystems - Descriptions & Response

Exterior Cladding/Glazing Type(s): ____________________
Partitions Type(s): ____________________
Ceiling System Type(s): ____________________
Roofing System Type(s): ____________________
Other Systems: ____________________

Overall Nonstructural Damage Classification: ❑None ❑Insignificant ❑Minor ❑Moderate ❑Heavy ❑UNK
Nonstructural Response: ____________________

Exterior:	Cladding Separation or Damage:	❑None	❑Insignificant	❑Minor	❑Moderate	❑Heavy	❑UNK	❑NA
	Roofing System Damage:	❑None	❑Insignificant	❑Minor	❑Moderate	❑Heavy	❑UNK	❑NA
	Window System Damage:	❑None	❑Insignificant	❑Minor	❑Moderate	❑Heavy	❑UNK	❑NA
	Chimney Damage:	❑None	❑Insignificant	❑Minor	❑Moderate	❑Heavy	❑UNK	❑NA
Interior:	Lights and Ceiling System Damage:	❑None	❑Insignificant	❑Minor	❑Moderate	❑Heavy	❑UNK	❑NA
	Partition Damage:	❑None	❑Insignificant	❑Minor	❑Moderate	❑Heavy	❑UNK	❑NA
	Water, Sprinkler Lines Damage:	❑None	❑Insignificant	❑Minor	❑Moderate	❑Heavy	❑UNK	❑NA
	Gas System Damage:	❑None	❑Insignificant	❑Minor	❑Moderate	❑Heavy	❑UNK	❑NA
	HVAC Duct Damage:	❑None	❑Insignificant	❑Minor	❑Moderate	❑Heavy	❑UNK	❑NA

Equipment – Descriptions & Response

Description: ____________________

Overall Equipment Damage Classification: ❑None ❑Insignificant ❑Minor ❑Moderate ❑Heavy ❑UNK

Equipment Response: ____________________

Damage to Boilers, Chillers, Fans, Pumps, etc.:	❑None	❑Insig	❑Minor	❑Mod	❑Heavy	❑UNK	❑NA
Damage to Tanks	❑None	❑Insig	❑Minor	❑Mod	❑Heavy	❑UNK	❑NA
Elevator Eqt. Damage (Car & Counterweight Rails, Cars, Penthouse Eqt.):	❑None	❑Insig	❑Minor	❑Mod	❑Heavy	❑UNK	❑NA
Electrical Equipment Damage Including Backup Generators:	❑None	❑Insig	❑Minor	❑Mod	❑Heavy	❑UNK	❑NA
Other: ____________________	❑None	❑Insig	❑Minor	❑Mod	❑Heavy	❑UNK	❑NA

Contents – Descriptions & Response

Description: ____________________

Overall Contents Damage Classification: ❑Insignificant ❑Minor ❑Moderate ❑Heavy ❑UNK
Response: ____________________

Hazardous Materials: ❑Y ❑N ❑UNK

Casualties

No. of Minor Injuries: ___ ❑UNK No. of Major Injuries: ___ ❑UNK No. of Fatalities: ___ ❑UNK

Functions

Percent Usable Space Immediately: ___% ❑UNK Percent Usable Space in 1-3 Days: ___% ❑UNK
Percent Usable Space within 1 Week: ___% Time Until Full Occupancy: __________ ❑UNK ❑NA
Utilities Function During Visit: ____________________

Shoring, Temporary Bracing, Barricading, Post-EQ Repairs – Observations Only: ________________

Figure 3. An excerpt from the SEAOC Earthquake Performance Evaluation Program form.

Additional documents are under development. For example, Performance Observation and Evaluation Guidance Documents for three building types, with supplemental forms, now exist in draft form. A detailed document based on performance evaluations after the 2003 San Simeon Earthquake was developed for unreinforced masonry buildings in 2004. Draft documents were developed in 2009 for concrete frames with unreinforced masonry infill as well as tilt-up buildings.

The intent is that these guidance documents can be used before earthquakes for training as well after earthquakes when data are summarized. It is intended that these guidance documents be developed by specialists with significant, practical experience in designing and evaluating the performance of specific building types. Major headings in the draft unreinforced masonry guidance document include:

1. Building Type, including descriptions of common system variants and typical subsystems
2. Where to Look for Indications of Earthquake Performance
3. Common Modes of Response or Fragility Specifications (Ranked in Order of Prevalence)
4. Design Conditions that can Effect Performance
5. Construction Conditions that can Effect Performance
6. Material Deterioration that can Effect Performance
7. Advice for Documenting Building Performance
8. Bibliography, Past Earthquake Performance Documentation
9. Contact Information for Building Type Specialists

A second document of use to volunteers is a draft Commentary on the practice of data collection and the development of other guidance documents. Currently, it has four general sections:

1. Commentary on the use of the general EPEP form
2. Commentary on a flyer that can be given to building owners to explain the purpose of EPEP assessments
3. Guidance on photo documentation
4. Suggestions for developing other guidance documents

Additional information about EPEP is available in a paper titled *SEAOC's Earthquake Performance Evaluation Program: An Update* (Turner et al 2009). It includes copies of observation forms, recommendations for digital imagery, and a comparison of California's SAP and EPEP programs with similar efforts in Japan, Italy, Greece, and other countries in the European Union.

Chino Hills Earthquake Deployment and Lessons Learned

The Magnitude 5.4 Chino Hills Earthquake on July 29, 2008 was, for the PDPOC, a fortunate and meaningful educational opportunity. The earthquake was large enough to trigger a response by the EPEP but was small enough that a comprehensive response was not required since the earthquake did not result in widespread damage. The earthquake also coincidentally occurred several hours before a previously scheduled PDPOC conference call.

CSMIP instrumentation at a fire station in the city of Walnut, CA registered a peak acceleration of 0.44g and a peak velocity of 39 cm/sec. See Fig. 4. Both the acceleration and velocity exceeded the response triggers in the EPEP Operations Manual. The PDPOC's experience in responding to this event and some of the lessons from the response are described in this section. The event was relatively small in magnitude and there were few, if any, early reports of significant damage. Only four CSMIP stations (Walnut, West Covina, Fullerton, and Anaheim) registered peak accelerations and velocities high enough to trigger an EPEP response. See Fig. 4.

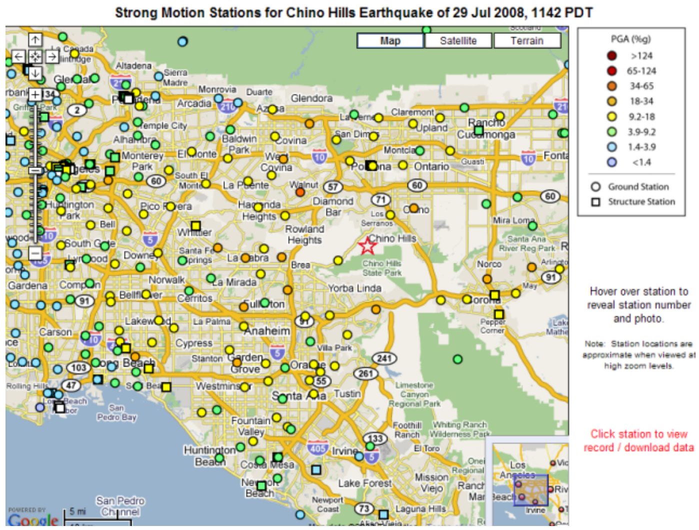

Figure 4. Chino Hills Earthquake Recordings Map from www.strongmotioncenter.org

One lesson from this event was that the PDPOC needed to revise its deployment trigger acceleration and velocity thresholds, and to consider requiring a minimum number of stations in a local area registering above the response threshold levels before the EPEP is deployed. Revising the triggers can help limit the EPEP's involvement to events that will provide more meaningful information worth collecting.

The limited field observations also provided useful information, in that some building owners and tenants often have reluctance to allow volunteers to walk around and photograph their buildings. This confirmed the need for an informational flyer that EPEP volunteers can hand out to the inquiring public. EPEP activities can be expected to draw the attention of the public.

Although the event was relatively small, many local engineers, including PDPOC members, started receiving calls and assignments to observe buildings for owners or management companies. This is a competing priority for local engineering firms that have on-call contracts with national and international corporations. Many of these clients will expect local Structural Engineers to respond to their building(s), even if they are undamaged. What PDPOC concluded from this small earthquake is that in the event of a larger earthquake, it will likely prove difficult for Structural Engineers with offices near the event to volunteer significant time to EPEP efforts, especially in the hours and days immediately following the earthquake. The PDPOC intends to address this issue by seeking assistance from Structural Engineers outside of the affected area after larger earthquakes. This, however, raises a potential issue with funding required for travel and accommodations.

In summary, the EPEP response to the Chino Hills Earthquake provided a number of valuable lessons:

1. The need for EPEP observers to have a structural engineering background and structural engineering experience
2. The need for field training
3. The need to develop and continue to revise data forms specific to the EPEP's needs
4. The likely need to deploy EPEP observers from outside of the affected area, in the event of a strong or major earthquake
5. The need to have a funding mechanism in place to fund travel and accommodations
6. The need to revise response triggers, so that the EPEP response is limited to truly meaningful events that will provide useful data
7. The need to develop an informational letter to explain to tenants and owners the purpose of the EPEP. Volunteers must also endeavor to respect the confidentiality of the owners and occupants. (PDPOC – AAR – 8-12-08)

Training Exercises and Resulting Refinements

Since the Chino Hills Earthquake, the PDPOC has undertaken training exercises in San Diego and Pomona. These exercises were valuable in demonstrating the need for field observation forms tailored to the EPEP's priorities. The training exercises also brought to light several biases of observers based on their own personal experiences and backgrounds. Variations in how volunteers fill out forms must be anticipated, so steps need to be taken to minimize those variations. Periodic training can reduce misinterpretations and variations in the completed forms. Exercises and future earthquakes will also provide new opportunities for further refinements to the evaluation procedures to improve the EPEP.

On August 12, 2008, the EPEP held its first exercise in downtown San Diego inviting five guests in addition to five PDPOC members. Prior to the exercise, a host committee of three members scouted out buildings within a 500 feet radius of a SMIP station and generated scenarios with written and visual descriptions of mock damage for several of the buildings. After a pre-briefing describing a hypothetical earthquake and the data collection process, the exercise participants were given a mock scenario describing the performance of the first building. Then they walked around the building, taking images and filling out ATC 38 forms. Discussions and comparisons of observations were encouraged. Participants then formed teams of two and dispersed to survey other buildings in the pod. Average observation times were between 30 minutes and one hour per building.

On March 26, 2009, a second exercise with twelve participants was held in Pomona. Half of the day focused on a six-story instrumented concrete frame with unreinforced masonry (URM) infill walls damaged in the Chino Hills earthquake. A nearby one-story URM bearing wall building was also surveyed since it too was partially damaged in that earthquake. Observation teams could have spent more time in addition to the two hours in the first building, since it was relatively large and access to each floor and roof was granted by the owners. Recorded PGA was 0.15 g and PGV was 13 cm per sec at the building's basement (www.strongmotioncenter.org), well below the EPEP's deployment threshold and yet damage was significant, suggesting that thresholds may warrant future adjustments depending on the vulnerabilities of building types.

The two exercises had major differences. The first focused on buildings with hypothetical damage developed by a host committee and evaluations relied on the ATC 38 form. The second exercise evaluated buildings with actual earthquake damage and used revised forms including supplemental forms developed for concrete infills and URM bearing wall buildings. After both exercises, participants uploaded digital imagery and geotagged them with captions on EERI's Clearinghouse website. In addition, After Action Reports were completed based on surveys filled out by the participants. The following recommendations were developed in After Action Reports by the participants:

1. Develop more detailed hypothetical damage scenarios for future exercises.
2. Increase classroom time during future exercises and provide examples of observations in the classroom to allow participants to get more familiar with the forms and the data collection procedures.
3. Provide certification and identification cards for participants that complete training.
4. Improve the digital image archiving, captioning, geotagging process.
5. Make improvements to the observation forms as described elsewhere in this paper.
6. Establish minimum qualifications for observation team members.
7. Refine the Operations Manual and the description of the purpose of the Program.
8. Provide an on-line file sharing site for use by the EPEP exercise participants.
9. Increase the size of the exercise host committee.
10. Reconsider the responsibilities of the Data Chief.
11. Reduce the inconsistencies in the exercise participants' abilities to distinguish variations in performance classifications of damage.
12. Make further improvements in training, commentaries, and other guidance to reduce the variability in the interpretation and categorization of damage.
13. Anticipate more time for collecting performance information in large buildings, particularly instrumented buildings. (PDPOC–AAR8-12-08)(PDPOC–AAR3-26-09)

Conclusion

The authors are very hopeful that the new Earthquake Performance Evaluation Program will become a welcomed activity for SEAOC volunteers as well as Structural Engineers in other regions of the U.S. and Canada, to provide practical seismic performance information for use in research and standards development and to help improve performance-based design of buildings.

Acknowledgements

Participants in the Post-Disaster Performance Observation Committee in 2008-09 have included Joseph Valancius from Southern California, Anthony Court and Travis Sanders from San Diego, Brian McDonald and David McCormick from Northern California, and Ken Luttrell and Fred Turner from Central California. The authors would also like to thank EERI's Learning from Earthquakes Program for its cooperation and sharing of EERI's image uploading and

geocoding capabilities.

References

ATC 20, 1995. Post-*Earthquake Safety Evaluation of Buildings*, Applied Technology Council.

ATC 38, 2000. *Database on the Performance of Structures Near Strong-Motion Recordings: 1994 Northridge, California Earthquake,* Applied Technology Council, TH1095 D27 2000ENGI.

ATC 54, 2006. *Guidelines for Using Strong-Motion Data and ShakeMaps in Post-earthquake Response*.

ATC 58, 2009. *Development of Next-Generation Performance-Based Seismic Design Procedures for New and Existing Buildings*, Applied Technology Council, Ongoing Draft.

ATC 73, 2007. *Prioritized Research for Reducing the Seismic Hazards of Existing Buildings*, Page 7.

CalEMA – SAP, 2009. *Safety Assessment Program*, California Emergency Management Agency, www.calema.ca.gov.

EERI, 2002. *Collection and Management of Earthquake Data*, Workshop Proceedings.

NIST, 2009. *Research Required to Support Full Implementation of Performance-Based Seismic Design*, National Institute of Standards and Technology, GCR 09-917-2, April.

PDPOC- AAR 8-12-08, 2008. *After Action Report for the SEAOC Earthquake Performance Evaluation Program Exercise in San Diego*, December 8 Available upon request by contacting the PDPOC Chairman.

PDPOC- AAR 3-26-09, 2009. *After Action Report for the SEAOC Earthquake Performance Evaluation Program Exercise in Pomona*, May 12 Available upon request by contacting the PDPOC Chairman.

PDPOC-OPS, 2009. *Preliminary Operations Manual: Earthquake Performance Evaluation Program,* Available upon request by contacting the PDPOC Chairman, March Draft Version.

PIMS, 2008. *Post-Earthquake Information Management System Scoping Study,* PIMS Project Team University of Illinois, FEMA, NIBS, September.

SEAOC, 1995. *Vision 2000*, Structural Engineers Association of California.

Turner, Fred, and McCormick, David, 2007. SEAOC's New Post-Disaster Performance Observation Committee, *SEAOC Convention Proceedings*.

Turner, Fred, Court, Anthony, McCormick, David, and Valancius, Joseph, 2009. SEAOC's Earthquake Performance Evaluation Program: An Update, *SEAOC Convention Proceedings.*