Pacific Earthquake Engineering Research Center (PEER)
NGA-West 2
Project
Proposal Form

Topic Number:	**NGA-West2: Site Factors**

Topic Name:	NGA-West 2 Project

Project Title:	Further Development of Site Response in NGA Models

PI/ Co-PI Information			
PI Name:	Jonathan P. Stewart	Institution Address:	UCLA Civil & Environ. Eng.
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Co-PI #1		Institution	
Co-PI #2		Institution	

Project Description

Enter appropriate information beneath each of the following headings (2 pages maximum):

1. Goals/ Objectives:

The site factor terms in the NGA ground motion prediction equations (GMPEs) express the effect of shallow site conditions on various ground motion intensity measures (IMs) as a function of V_{s30}. Site factors in the NEHRP *Provisions*, which are used in building codes throughout the US and much of the world, are based on site categories derived from V_{s30}.

The NGA site factors are based on a combination of numerical simulations and empirical constraint on site amplification, with the empirical data derived from the large NGA database (Chiou et al., 2008). In contrast, the NEHRP site factors are based on a very small database of recordings in the San Francisco Bay Area from the 1989 Loma Prieta earthquake, which establishes relatively weak motion amplification empirically, in combination with nonlinear effects established from numerical simulations (Dobry et al., 2000). Not surprisingly, experience in practice and from some preliminary research (Huang et al. 2010) indicates that the NGA and NEHRP site factors have some discrepancies. The principal objective of this project is to identify those discrepancies for the IMs of interest in the NGA-West2 project and propose new site factors for application in NEHRP that will resolve the differences.

Additional, related objectives concern enhancing the site database developed in the original NGA project to incorporate the results of additional site characterization efforts, and to check the performance of the existing NGA site factors through analyses of residuals. Those residuals analysis efforts will emphasize, but not be limited to, data collected since the original NGA project (approximately 1500 recordings).

2. Milestones and Deliverables:

Milestones: (i) direct comparison of NEHRP factors and NGA site factors; (ii) enhancement of site database; (iii) analysis of residuals; (iv) development of recommended new site factors for NEHRP application and potential recommended modifications to NGA site terms.

Deliverables: Recommended revisions to NEHRP Site Factors. Report and papers presenting results of work; suitable conference presentations.

3. Scope and Project Plan: This project involves the work of the PI and a graduate student working in coordination with an Advisory Panel of practicing engineers and researchers with expertise in site response. Some members of the Advisory Panel are also very experienced in the process of revising the NEHRP *Provisions* and *Commentary*. We envision the scope to involve the four tasks described below, although the details may change over time as a result of input received from the Advisory Panel.

Task 1: Direct Site Factors Comparisons. Our first task will involve comparisons of the NEHRP site factors with NGA site factors derived from the four NGA GMPEs having site terms. Those comparisons will be targeted to evaluate differences in median amplification levels at various levels of rock ground motion as well as possible differences in the nonlinearity of site amplification. Preliminary results of such a comparison are shown in Figure 1. The different slopes of the NEHRP factors and the NGA factors for the F_v parameter indicate different levels of nonlinearity. Bias in the weak motion amplification is also evident for F_v.

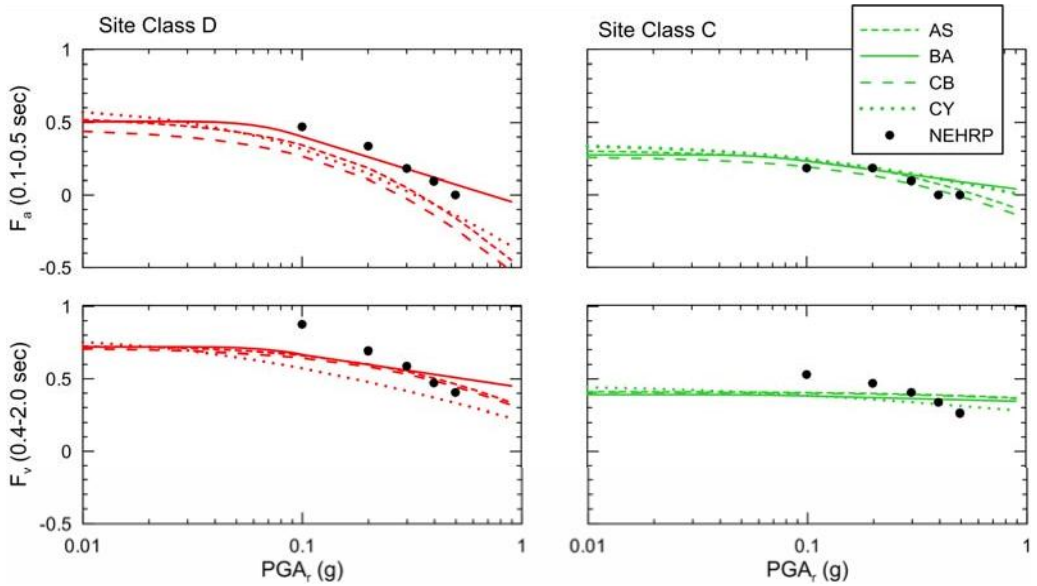

Figure 1. Comparison of NEHRP site factors to site factors from NGA relationships averaged across corresponding period ranges (0.1-0.5 sec for F_a; 0.4-2.0 sec for F_v). The V_{s30} values used for the NGA relations are averages within the C and D category for sites in the NGA database (275 and 425 m/s).

Task 2: Database Development. The database work will involve working with Pacific Engineering and Analysis to ensure that recently collected geophysical data from various regions contributing data to the NGA database is reflected in the site database. In particular, we will work with Alan Yong of USGS in Pasadena to ensure that his data collection efforts are incorporated. We will also check California sites without data against the Virtual Geotechnical Data center to see if there may be data that can be utilized for this purpose.

Task 3: Residuals Analysis. After receiving the revised NGA database in late summer 2010, we will begin residuals analyses. Those analyses will include the following steps:

a. Calculation of data residuals relative to NGA GMPE median predictions for a V_{s30}=760 m/s site condition. This will be done both for the full NGA database (following summer 2010 updates) and for the data available in the original NGA model development. These analyses will be useful to check the site amplification implied by the median of residuals with the NEHRP factors and the NGA site terms. Analysis with the two data sets will enable us to evaluate the influence, if any, of the new data.
b. Repeat (a) but now with the model used for residual analysis being the NGA GMPE median for V_{s30}=760 m/s modified by the NEHRP factors. Non-zero medians in these residuals will indicate a bias in the NEHRP site factors.

Task 4: Develop Recommendations. Based on the results of Tasks 1 and 3, we will propose modifications to the NEHRP factors to bring the factors into compliance with the levels of amplification and nonlinearity implied by the NGA dataset. Some checks on these factors will be made by comparing ground motion hazard curves derived from PSHA with the NGA GMPEs and hybrid hazard curves developed from rock PSHA modified by the proposed modified NEHRP site factors and the existing NEHRP site factors (e.g., Goulet and Stewart, 2009).

The research work in this project will be performed in a consensus-building process in cooperation with our Advisory Panel. This will ensure that the research results are sufficiently robust and comprehensive to support modification of the NEHRP site factors in the next round of *Provisions* updates.

4. Other similar work outside PEER, and differentiation of this work: Work by Alan Yong and Robert Kayen of the USGS, among others, is providing data on site characterization that will be useful in this project.

5. Interaction of this work to other related PEER work, if any: Additional work on site classification for use in V_{s30} estimation is being performed (or planned) as part of the NGA East and GEM projects. Additional work on the development of site factors is underway as part of the NGA East project.

6. Potential Impact of Project on Practice: If the project is successful in modifying the NEHRP site factors, it will have substantial and far-reaching impact on seismic design for buildings, bridge, and other structures.

References:

Chiou, B. S.-J., Darragh, R., Dregor, D., and Silva, W. J. (2008). NGA project strong-motion database, *Earthquake Spectra*, 24 (1), 23–44.

Dobry, R., Borcherdt, R.D., Crouse, C.B., Idriss, I.M., Joyner, W.B., Martin, G.R., Power, M.S., Rinne, E.E., and Seed, R.B. (2000). "New site coefficients and site classification system used in recent building seismic code provisions," *Earthquake Spectra*, 16 (1), 41-67.

Goulet, C.A. and Stewart, J.P. (2009). Pitfalls of deterministic application of nonlinear site factors in probabilistic assessment of ground motions. *Earthquake Spectra,* 25 (3), 541-555.

Huang, Y.-N., Whittaker, A.S., and Luco, N. (2010). NEHRP Site Amplification Factors and the NGA Relationships. *Earthquake Spectra,* 26 (2), 583-593.

Biographical Sketch of Principal Investigator

(2 pages maximum):

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PROFESSIONAL PREPARATION

University of California, Berkeley, Ph.D., 1996, Civil Engineering
University of California, Berkeley, M.S., 1992, Civil Engineering
University of California, Berkeley, B.S., 1990, Civil Engineering (with honors)

APPOINTMENTS

Vice Chairman for Graduate Studies: Civil & Environmental Engineering Department, University of California, Los Angeles, July 2007 – present (Undergraduate Vice Chair July 2005 – June 2007).

Professor of Civil Engineering: University of California, Los Angeles, July 2007 – present. (Associate Professor, July 2003 – June 2007; Assistant Professor Jan. 1997 – June 2003)

Lecturer: European School for Advanced Studies in Reduction of Seismic Risk (ROSE), Pavia, Italy, Nov 2005 – present. First course taught April-May 2008.

Visiting Professor: Università di Roma La Sapienza, Dipartimento di Ingegneria Strutturale e Geotecnica, Rome, Italy, January 2005 – June 2005.

Staff Engineer: Alan Kropp and Associates, Berkeley, California, May 1989 – June 1993

PUBLICATIONS

5 Most Related Publications

Goulet, C. and Stewart, J.P. (2009). "Pitfalls of deterministic application of nonlinear site factors in probabilistic assessment of ground motions," *Earthquake Spectra*, 25 (3), 541-555.

Kwok, A.O., Stewart, J.P., Hashash, Y.M.A., Matasovic, N., Pyke, R., Wang, Z., and Yang, Z. (2007). "Use of exact solutions of wave propagation problems to guide implementation of nonlinear seismic ground response analysis procedures," *J. Geotech. & Geoenv. Engrg.*, ASCE, 133 (11), 1385-1398.

Kwok, A.O. and Stewart, J.P. (2006). "Application of theoretical 1D amplification factors for evaluation of seismic site effects," *Bull. Seism. Soc. Am.*, 96 (4a), 1422-1436.

Choi, Y. and Stewart, J.P. (2005). "Nonlinear site amplification as function of 30 m shear wave velocity," *Earthquake Spectra*, 21 (1), 1-30.

Stewart, J.P., Liu, A.H., and Choi, Y. (2003). "Amplification factors for spectral acceleration in tectonically active regions," *Bull. Seism. Soc. Am.*, 93 (1), 332-352.

5 Other Significant Publications

Stewart, J.P., Abrahamson, N.A., Atkinson, G.M., Baker, J.W., Boore, D.M., Bozorgnia, Y., Campbell, K.W., Comartin, C.D., Idriss, I.M., Lew, M., Mehrain, M., Moehle, J.P., Naeim, F., and Sabol, T.A. (accepted – June 2010). "Representation of bi-directional ground motions for design spectra in building codes," *Earthquake Spectra*.

Lemnitzer, A., Ahlberg, E.R., Nigbor, R.L., Shamsabadi, A., Wallace, J.W., and Stewart, J.P. (2009). "Lateral performance of full-scale bridge abutment wall with granular backfill," *J. Geotech. & Geoenv. Engrg.*, ASCE, 135 (4), 506-514.

Goulet, C.A., Haselton, C.B., Mitrani-Reiser, J., Beck, J.L., Deierlein, G.G., Porter, K.A., and Stewart, J.P. (2007). "Evaluation of the seismic performance of a code-conforming reinforced-concrete frame building - from seismic hazard to collapse safety and economic losses," *Earthquake Engineering and Structural Dynamics*, 36 (13), 1973-1997.

Choi, Y., Stewart, J.P., and Graves, R.W. (2005). "Empirical model for basin effects that accounts for basin depth and source location," *Bull. Seism. Soc. Am.*, 95 (4), 1412-1427.

Kim, S. and Stewart, J.P. (2003). "Kinematic soil-structure interaction from strong motion recordings," *J. Geotech.. & Geoenv. Engrg.*, ASCE, 129 (4), 323-335.

SYNERGISTIC ACTIVITIES (selected)

Editor Emeritus, *J. Geotechnical & Geoenvironmental Engineering*, ASCE, 4/2010-present (Editor-in-Chief, 1/2007-3/2010; Editor 6/2004 – 12/2006; Editorial Board Member, 7/2002 – 6/2004).
Editorial Board Member, *Earthquake Spectra*, 1/2004 – present.
Guest Editor, Special issue of *Earthquake Spectra* on NGA project, February 2008 issue
Member, *BSSC NEHRP Provisions Update Committee*, 1/2005 – present.
Member, *BSSC NEHRP Foundations and Geotechnical Subcommittee TS-3*, 6/2001 – present (corresponding member 9/1998-6/2009).
Member, *Implementation Committee, 1990 California Seismic Hazards Mapping Act, Landslide Hazards*, ASCE and Southern California Earthquake Center, 8/98 – 6/2002.

COLLABORATORS

Recent Collaborators and Co-Editors (non-students):

Boulanger, RW (UC Davis), Brandenberg, SJ (UCLA), Graves, RW (URS), Hashash, YMA (U. Illinois), Hutchinson, TC (UC San Diego), Kayen, RE (USGS), Kramer, SL (U. Washington), Kutter, BL (UC Davis), Lanzo, G (U. Rome), Mylonakis, G (U. Patras), Naeim, F (JAMA), O'Rourke, TD (Cornell), Taciroglu, E (UCLA), Youd, TL (BYU-retired), Wallace, JW (UCLA),

Graduate Advisors: Fenves, GL, Johnson, L, and Seed, RB (UC Berkeley).

Graduate Students Advised:

Ahlberg, ER (Ph.D., 2008); Ancheta, TD (Ph.D., 2010); Baturay, MB (Ph.D., 2002); Bro, A (M.S., 2007); Choi, Y (Ph.D., 2004); Chu, D (Ph.D., 2006); Duku, PM (Ph.D., 2007); Givens, M (Ph.D., current); Goulet, CA (Ph.D., 2008); Hilson, C (Ph.D., current); Janoyan, KD (Ph.D., 2001); Kempton, JJ (M.S., 2004); Kim, S (Ph.D., 2001); Kwak, DY (Ph.D., current); Kwok, AO (Ph.D. 2007); Lemnitzer, A (Ph.D., 2009); Liu, A (M.S., 2001); Moyneur, M(M.S., 2004); Scasserra, G (Ph.D., 2008), Seyhan, E (Ph.D., current); Sholtis, S (M.S., 2000); Smith, PM (Ph.D., 2002); Star, LM (Ph.D., current); Tileylioglu, S (Ph.D., 2008); Whang, DH (Ph.D., 2001), Yee, E (Ph.D., current). All students affiliated with UCLA except Scasserra (U. Rome). Thesis graduate students as major advisor=26 (20 graduated).

Visiting scholars: Lin, P-S (N. Chung-Hsing Univ., Taiwan, 2003); Kwon, OY (Konkuk University, S. Korea, 2004-2005); Mikami, A (Univ. of Tokushima, Japan, 2005-2006), Kojobaev, K (Kyrgyz-Turkish Univ., 10/2009-present); Feng, S (Tongji Univ., China, 1/2010-present), Mylonakis, G (Univ Patras, Greece, 3/2010-present).

AWARDS AND HONORS (selected)

2009	Elected Fellow, ASCE
2008	Walter A. Huber Civil Engineering Research Prize, ASCE
2007	Outstanding Paper Award, Vol. 21 (2005), Earthquake Spectra
2006	Shamsher Prakash Research Award, Shamsher Prakash Foundation
2005	Fulbright Scholarship, Senior Lecturer in Italy, United States Department of State
2003	Northrop Grumman Excellence in Teaching Award, UCLA HSSEAS
2001	Arthur Casagrande Professional Development Award, ASCE
1998	Faculty Early Career Development Award, NSF
1995	Graduate Student Fellowship in Earthquake Hazard Reduction, EERI/FEMA

PROFESSIONAL QUALIFICATIONS

Registered Professional Engineer in California, #51189, since June, 1993
Fellow: ASCE.
Member: EERI, SSA, NEES Inc.