NOTICE

Empirical Analysis of Horizontal Ground Displacement Generated by Liquefaction-Induced Lateral Spreads

by

S.F. Bartlett and T.L. Youd

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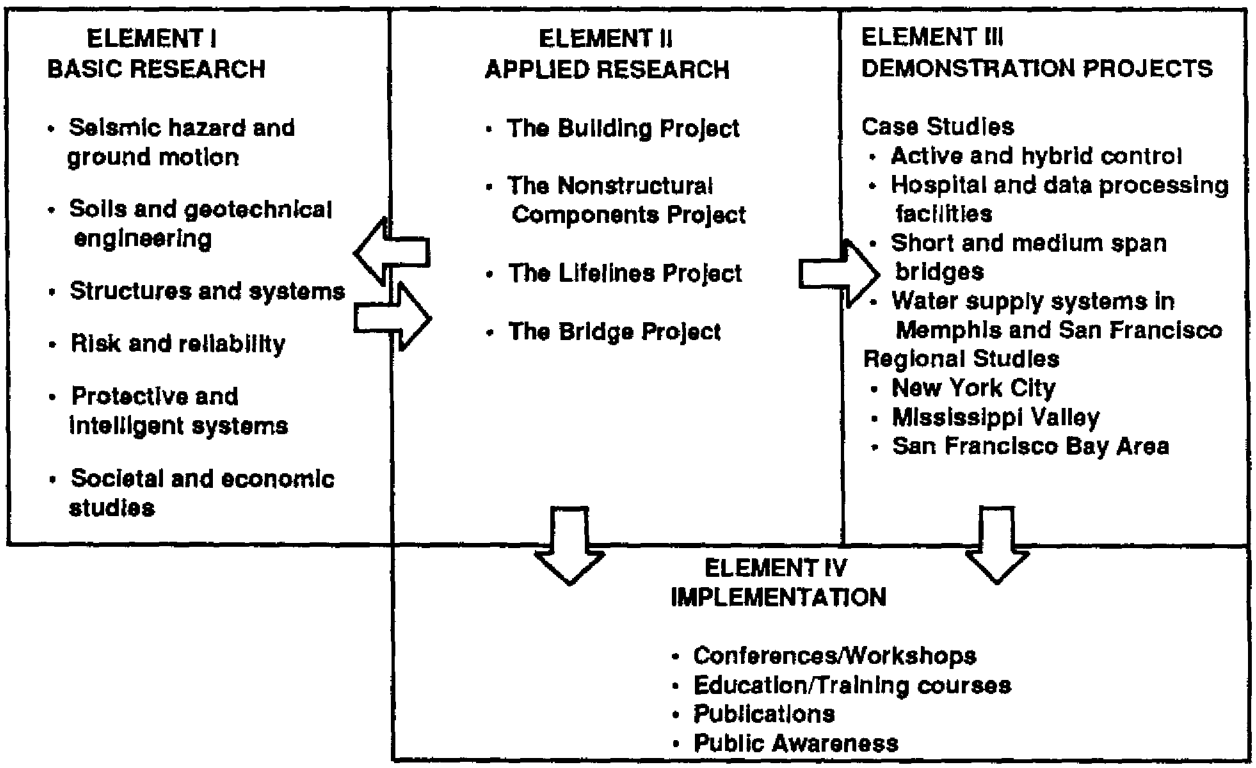
1 Research Assistant, Civil Engineering Department, Brigham Young University
2 Professor, Civil Engineering Department, Brigham Young University

NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH
State University of New York at Buffalo
Red Jacket Quadrangle, Buffalo, NY 14261

PREFACE

The National Center for Earthquake Engineering Research (NCEER) was established to expand and disseminate knowledge about earthquakes, improve earthquake-resistant design, and implement seismic hazard mitigation procedures to minimize loss of lives and property. The emphasis is on structures in the eastern and central United States and lifelines throughout the country that are found in zones of low, moderate, and high seismicity.

NCEER's research and implementation plan in years six through ten (1991-1996) comprises four interlocked elements, as shown in the figure below. Element I, Basic Research, is carried out to support projects in the Applied Research area. Element II, Applied Research, is the major focus of work for years six through ten. Element III, Demonstration Projects, have been planned to support Applied Research projects, and will be either case studies or regional studies. Element IV, Implementation, will result from activity in the four Applied Research projects, and from Demonstration Projects.



Tasks in Element I, **Basic Research,** include research in seismic hazard and ground motion; soils and geotechnical engineering; structures and systems; risk and reliability; protective and intelligent systems; and societal and economic impact.

The **soils and geotechnical engineering program** constitutes one of the important areas of research in Element I, **Basic Research.** Major tasks are described as follows:

1. Perform site response studies for code development.
2. Develop a better understanding of large lateral and vertical permanent ground deformations associated with liquefaction, and develop corresponding simplified engineering methods.
3. Continue U.S. - Japan cooperative research in liquefaction, large ground deformation, and effects on buried pipelines.
4. Perform soil-structure interaction studies on soil-pile-structure interaction and bridge foundations and abutments, with the main focus on large deformations and the effect of ground failure on structures.
5. Study small earth dams and embankments.

This report describes an empirical model for estimating the horizontal ground displacement caused by liquefaction-induced lateral spreads. The model was developed from multiple linear regression analyses of data pertaining to earthquake, topographical, and geological variables for Japanese and U.S. earthquakes. Two types of lateral spreads are distinguished in the model: lateral spread toward a free face; and lateral spread down gentle ground slopes. Horizontal movement associated with free face lateral spreads was found to correlate with the logarithm of the free face ratio, which is the height of the free face divided by horizontal distance from the free face. In contrast, displacement associated with ground slope failure is strongly correlated with the steepness of the ground slope. The model is expressed as a multiple linear regression equation linking lateral movement with moment magnitude of the earthquake, distance from the seismic source, free face ratio, ground slope, thickness of saturated granular soil with a modified standard penetration value $[(N_1)_{60}]$ *less than or equal to 15,* $(N_1)_{60}$ *of the soil with lowest factor of safety against liquefaction, and depth to the soil with lowest safety factor against liquefaction. Because the model was developed for a wider range of seismic and site conditions than utilized in previously proposed empirical models, it is more general and will result in better estimates. The model appears to give the best predictions for earthquakes with moment magnitudes of 6.5 to 8.0 at sites underlain by sands and silty sand layers with* $(N_1)_{60} \leq 15$ *and thickness greater than 0.3 m at depths less than 15 m. The model does not appear to work well for gravels with mean grain sizes greater than 2 mm. Because the model was primarily developed from western U.S. and Japanese data, it is best suited to regions that have high to moderate ground motion attenuation.*

ABSTRACT

Liquefaction-induced ground failure is responsible for considerable damage to engineered structures during major earthquakes. Presently, few empirical techniques exist for estimating the amount of horizontal ground displacement resulting from liquefaction-induced lateral spread. None of these techniques fully addresses all the earthquake and site conditions known to influence ground displacement.

This study compiles earthquake, geological, topographical, and soil factors that affect ground displacement and develops empirical models from these factors. Case histories of lateral spread are gathered from the 1906 San Francisco, 1964 Alaska, 1964 Niigata, 1971 San Fernando, 1979 Imperial Valley, 1983 Nihonkai-Chubu, 1983 Borah Peak, Idaho, and 1987 Superstition Hills earthquakes. Multiple linear regression (MLR) is used to develop empirical models from the compiled data. Two general models are derived herein, one for free face failures and one for ground slope failures. The predictive performance of the proposed empirical models is determined by comparing predicted displacements with those actually measured at the case history sites.

ACKNOWLEDGEMENTS

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