EARTHQUAKE
SPECTRA
The Professional Journal of the Earthquake Engineering Research Institute

SUPPLEMENT A TO VOLUME 18

Bhuj, India Earthquake of January 26, 2001 Reconnaissance Report

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RECONNAISSANCE INVESTIGATION AND REPORT

The Earthquake Engineering Research Institute (EERI), as part of its ongoing Learning From Earthquakes program (supported by the National Science Foundation, Washington D.C.), dispatched a 15-member reconnaissance team to document the effects of the M_w 7.7 earthquake— the seismotectonic setting; local geological and geotechnical effects; performance of buildings, lifelines and other structures and facilities; and social and governmental response to the earthquake.

Because of the widespread damage to modern engineered structures and the unique seismotectonic setting of the earthquake, several teams of investigators were dispatched to the impacted area from the United States and other countries. The EERI Reconnaissance Team was among the first to reach the area and collaborated with other teams in organizing investigations. Members of other research teams and individuals provided important observations and contributions to this reconnaissance report.

COMBINED EERI-NSF RECONNAISSANCE EFFORTS

The EERI Reconnaissance Team was led jointly by Professor Sudhir K. Jain (Specialization: Structural Engineering) of the Indian Institute of Technology Kanpur, India, and Dr. William R. Lettis (Specialization: Seismotectonics) of William Lettis & Associates, Inc., Walnut Creek, USA. Members of the EERI Reconnaissance Team included:

- Jaswant N. Arlekar, Indian Institute of Technology Kanpur, Kanpur, India
- Donald Ballantyne, EQE International, Seattle, Washington, USA
- Sailender K. Chaubey, Indian Institute of Technology Kanpur, Kanpur, India
- Umesh Dayal, Indian Institute of Technology Kanpur, Kanpur, India
- Rakesh K. Goel, California Polytechnic State University, San Luis Obispo, California, USA
- Alok Goyal, Indian Institute of Technology Bombay, Mumbai, India
- James Hengesh, William Lettis & Associates, San Rafael, California, USA
- Sudhir K. Jain, Indian Institute of Technology Kanpur, Kanpur, India
- William R. Lettis, William Lettis & Associates, Inc., Walnut Creek, CA, USA
- Praveen K. Malhotra, Factory Mutual Research Corporation, Norwood, Massachusetts, USA
- C.V.R. Murty, Indian Institute of Technology Kanpur, Kanpur, India
- P.L. Narula, Consulting Geologist, Faridabad, India
- Chandan K. Saikia, URS Corporation, Pasadena, California, USA
- Mahendra P. Singh, Virginia Polytechnic and State University, Blacksburg, Virginia, USA
- Krishna Vatsa, George Washington University, Washington, D.C., USA

The National Science Foundation (NSF), under the Siting and Geotechnical Systems Program, supported a geotechnical engineering team headed by Jean-Pierre Bardet (a co-editor of this

volume) of the University of Southern California, Los Angeles, California, and Raymond B. Seed of the University of California, Berkeley, California. The NSF geotechnical team included:

- Jean-Pierre Bardet, University of Southern California, Los Angeles, California, USA
- Bijan Khaleghi, Washington State Department of Transportation, Olympia, Washington, USA
- Robert E.S. Moss, University of California, Berkeley, California, USA
- Garry Norris, University of Nevada at Reno, Reno, Nevada, USA
- Uday Patil, Globus Engineering, San Pedro, California, USA
- Ellen M. Rathje, University of Texas, Austin, Texas, USA
- Raymond B. Seed, University of California, Berkeley, California, USA
- J.P. Singh, J.P. Singh and Associates, El Sobrante, California, USA
- Jonathon Stewart, University of California, Los Angeles, California, USA
- Sendhil V. Vandhana, University of California, Los Angeles, California, USA
- R. H. Wright Geomatrix Consultants, Inc. Oakland, California, USA

The NSF team also included three members of the Mid-America Earthquake (MAE) center:

- J. David Frost, Georgia Institute of Technology, Atlanta, Georgia, USA
- Scott L. Deaton, Georgia Institute of Technology, Atlanta, Georgia, USA
- P. Goel**,** Georgia Institute of Technology, Atlanta, Georgia, USA

This NSF geotechnical team closely collaborated with the EERI Reconnaissance Team and performed many follow-up investigations after the EERI Team departed. This volume is a joint report from the combined EERI-NSF team.

Several follow up visits to the region were made by Indian investigators to collect more information and insights. A grant from the Department of Science and Technology, Government of India, to the Indian Institute of Technology Kanpur supported a part of the first reconnaissance visit of participants from India, subsequent visits, and the preparation of this report.

Research and reconnaissance teams were deployed in groups of one, two, or three, with local support, to recon an area that covered a 400 kilometer radius from the epicenter. Reconnaissance teams evaluated the performance of lifelines, masonry construction, heritage monuments, modern urban buildings and infrastructure, port facilities, and small to moderate size embankment dams throughout the region, in addition to response of the government in postearthquake disaster management. Geosciences information was collected to document the presence or absence of permanent ground deformation, including surface fault rupture, liquefaction and landslides, and the impact of ground deformation to the built environment.

ACKNOWLEDGMENTS

The observations presented in this special volume of *Earthquake Spectra* on the effects of the January 26, 2001 Bhuj earthquake are largely the result of a cooperative effort among engineers and scientists dispatched by the Earthquake Engineering Research Institute, members of the National Science Foundation Earthquake Engineering Reconnaissance Team, and numerous Indian engineers, scientists, and government officials. The enormous outpouring of support, in particular, from Indian collaborators and interested citizens, greatly enhanced the success of this reconnaissance. Local agencies and private citizens provided access to remote areas, offering vehicular support, food, water, and shelter. This cooperation and support made this reconnaissance effort possible and is gratefully acknowledged by all reconnaissance team members.

Financial support for the NSF geotechnical reconnaissance effort was provided by the National Science Foundation (grant #CMS-0119344) under the Siting and Geotechnical Systems Program (C. Astill). The Mid-America Earthquake Center (D. Abrams) provided financial support for their three team members.

A grant from the Department of Science and Technology, Government of India to the Indian Institute of Technology Kanpur enabled partial support for the first recon trip by team members from India, all their subsequent visits to the area, and their efforts in preparing this report.

Countless other individuals with related reconnaissance teams sponsored by U.S., Indian, and other international organizations openly shared their observations and data. This report benefits greatly from the input of all these individuals and organizations. In particular, Steve Wesnousky (University of Nevada, Reno), Tom Rockwell (San Diego State University), and Leonardo Seeber (Lamont-Doherty Earth Observatory) shared observations on the presence or absence of permanent fault rupture. Arch Johnston (University of Memphis) provided preliminary data and observations on aftershock seismicity and the depth and geometry of the fault rupture. The Indian National Trust for Art and Cultural Heritage (INTACH) carried out an extensive survey of damage to heritage buildings, and Divay Gupta of INTACH shared their findings for Chapter 12, Heritage Structures.

In addition to technical contributions to the EERI Reconnaissance Team, many individuals provided logistical support in the field. In particular, Sanjay Barot and Jitendra S. Mehta provided enormous assistance with vehicles, food, water, and shelter for the team, and accompanied various team members throughout the investigation. Nishith S. Desai and K.K. Parikh helped organize the logistics and local contacts in Ahmedabad, and M.M.S. Bhandari helped provide food and shelter in Bhuj in the days immediately after the earthquake. Colonel Herbaz Singh was of great assistance to the geotechnical teams with lodging and navigation in unmapped terrain.

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