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Gravelly soils that liquefied during 2008 Wenchuan, China earthquake, M_s=8.0

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ABSTRACT

Field investigations following the 2008 Wenchuan earthquake (M_s=8.0) identified 118 liquefaction sites nearly all of which are underlain by gravelly sediment in the Chengdu Plain and adjacent Mianyang area. Field studies, including core drilling, dynamic penetration tests (DPT), and multiple channel analysis of surface wave velocity tests (MASW) for measurement of shear wave velocities, reveal the following: (1) Sand boils and ground fissures, indicative of liquefaction, occurred across hundreds of square kilometers affecting 120 villages, 8 schools and 5 factories. (2) The Chengdu plain is underlain by sandy gravels ranging in thickness up to 540 m; loose upper layers within the gravels beds liquefied. (3) Mean grain sizes for gravelly layers that liquefied range from 1 mm to more than 30 mm. (4) Shear wave velocities in gravels that liquefied range up to 250 m/s. (5) A 50% probability curve, developed from logistic procedures, correctly bounds all but four data points for the 47 compiled V_s data.

1. Introduction

On May 12, 2008 a devastating earthquake (M_s=8.0, M_w=7.9), with an epicenter in Wenchuan County, struck Sichuan Province, in southwestern China, killing more than 100,000 people. The earthquake was the largest and most destructive to strike China since the 1976 Tangshan earthquake (M_s=7.8, M_w=7.6), which killed more than 240,000 people [1]. Shortly after the Wenchuan earthquake, a team of geotechnical specialists, organized by the Institute of Engineering Mechanics (IEM), China Earthquake Administration (CEA) traveled to the affected area to investigate occurrences of liquefaction and consequent damage. Through months of detailed field investigations, 118 liquefaction sites were identified, effects documented, and many sites drilled and tested. Most of these sites are located on the Chengdu plain or in the Mianyang area to the northeast. Nearly all of the investigated liquefaction sites are underlain by loose gravels at shallow depth.

The senior author was a member of the IEM team and spent five months conducting post-earthquake investigations. The first two weeks were spent aiding emergency response by assessing the safety of damaged buildings. The next two months were spent with the liquefaction team identifying, mapping and documenting surface effects (primarily sand boils and ground fissures). The last two and one-half months were spent (1) drilling liquefaction sites to log bore holes and extract core samples; (2) conducting dynamic penetration tests (DPT); and (3) measuring shear wave velocities and compiling velocity cross sections using multiple channel analysis of surface wave velocities (MASW) procedures. Results from these investigations and tests will be published in two papers in English. This paper documents the distribution and character of gravelly soils that liquefied, derives probabilistic shear-wave correlations for predicting liquefaction resistance of gravels, provides a case history database for future research, and provides comparisons of results from the Wenchuan investigation with those of previous earthquakes. The second paper will present and analyze results from Chinese dynamic penetration tests (DPT) and develop predictive correlations.

In the past, gravelly soils were commonly regarded as non-liquefiable because of large grain sizes and generally high permeabilities that allow rapid dissipation of pore pressure. This hypothesis has been revised as case histories of liquefaction of gravels have been reported from past earthquakes (Table 2): 1976 Tangshan [2], 1976 north-eastern Italy [3], 1983 Borah Peak [4,5], 1988 Armenia [6], 1995 Hyogo-ken Nanbu [7], and 1999 Chi-Chi [8].

Cyclically loaded laboratory tests have added understanding of liquefaction mechanisms for gravelly soils. Large diameter cyclic triaxial tests were conducted by Evans et al. [9], Suzuki et al. [10], Hatanaka et al. [11], and Evans et al. [12]. Harder [13] and Sy et al. [14] used Becker penetration tests (BPT) to develop predictive procedures for gravelly soils by correlating BPT and standard penetration (SPT) resistances. However, fully reliable methods for evaluating liquefaction resistance of gravelly soils have not been developed, largely because of a lack of adequately documented field case histories.

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