Jonathan D. Bray, Ph.D., P.E.
J D Bray Consultants, LLC
285 Pickering Place
Walnut Creek, CA 94598
United States of America

October 18, 2011

Canterbury Earthquakes Royal Commission
Department of Internal Affairs
PO Box 805
Wellington 6140
New Zealand

ATTN: Justine Gilliland, Executive Director

RE: Review of the August 2011 Report by M. Cubrinovski & I. McCahon titled: "Foundations on Deep Alluvial Soils," a Technical Report Prepared for Canterbury Earthquake Royal Commission

Introduction

Through this letter report I am providing my review comments regarding the August 2011 report by M. Cubrinovski & I. McCahon titled: "Foundations on Deep Alluvial Soils," a Technical Report Prepared for Canterbury Earthquake Royal Commission. I was engaged as an independent expert through a contract with the Canterbury Earthquake Royal Commission (CERC). The directive was to review the report titled "Foundations on Deep Alluvial Soils" by Professor Misko Cubrinovski and his co-author "*to ensure that the findings will sit well with accepted international best practice, and that the thinking in New Zealand is not for any reason unsound.*"

The August 2011 Cubrinovski and McCahon report is reviewed according to this directive. My overall assessment of the report is provided first. Primary review comments are then addressed. Several relevant opinions are shared, followed by secondary (minor) review comments.

Overall Assessment

The geotechnical earthquake engineering characterizations, analyses, and findings presented in the Cubrinovski & McCahon report titled "Foundations on Deep Alluvial Soil" reflect the "state-of-the-practice" internationally. This report conforms to "accepted international best practice," and its reasoning is sound. It presents the key issues on seismic site response, soil liquefaction, and foundation performance in an excellent manner. The report is well organized. The provided information is insightful. The findings are supported by reasonable interpretations of existing information. The recommendations are sound. Overall, the report is well done.

Specifically, there are several excellent points made in the report. The depositional history of the soils of Christchurch is explained well. The primary characteristics of the critical soil strata are described including the age of the soils, which are generally less than 4000 years old in the upper 10 m. The maps depicting the observations of liquefaction made following the 4 September 2010 and 22 February 2011 earthquakes identify the areas of the Central Business District (CBD) that are most vulnerable to liquefaction in future events. The levels of earthquake ground shaking during these two events, one of which exceeded the 475-year return period design level of earthquake shaking, are described well. The documented performance of buildings with different foundation types provides great insight. The assessment of the likely effects of a large earthquake on the distant Alpine fault is reasonable, although as noted in the report, this assessment is preliminary because it involves a significant level of uncertainty. Thus, additional work in this area is warranted. The recommendations made in the report regarding the importance of proper geotechnical investigations and robust foundations are well supported. The conclusions of the report summarize the key issues and provide useful strategies for moving forward after the series of damaging earthquakes.

Primary Review Comments

Although the report is sound, there are a few potentially important issues for which I would like to provide review comments for your consideration. They are:

1. The relative advantages of the cone penetration test (CPT) in subsurface characterization are emphasized in the report. The CPT can provide nearly continuous profiling of ground conditions in a standardized, efficient manner at relatively low cost. Representative CPT profiles should be shown in Figure 7 along with the traditional soil boring logs with standard penetration test (SPT) N values to further emphasize the relative benefits of the CPT. Moreover, the CPT profiles would better show the variability of soil conditions with depth in Christchurch by showing a nearly continuous record of penetration resistance with depth. The SPT N values are often spaced meters apart, and the connection of SPT N values with straight lines oversimplifies the true variability of the soil deposits with depth.

2. In Section 7, several statements are made "for important structures." The definition of an "important structure" is not clear, and it is not clear what an "unimportant structure" is. This should be clarified. It is my opinion that most structures within the CBD are important in terms of the ensuring satisfactory seismic resilience of the City of Christchurch.

Relevant Opinions

In addition to the sound findings and excellent recommendations made by the authors of the report, I would like to provide some opinions that are relevant to the overall issue of seismic resilience of a city. They are:

A. The CBD with its buildings, roads, utilities, and other infrastructure components is a system that requires a comprehensive, integrated systems perspective. This report addresses "Foundations on Deep Alluvial Soils." It discusses geotechnical earthquake engineering phenomena and their resulting impact on building foundations. It is unclear to me at this point how the CERC intended this particular report to fit into its overall assessment of the City of Christchurch. I would like to ensure that someone is addressing the potential issues regarding the seismic performance of utilities and other lifelines. Geotechnical phenomena such as soil liquefaction can impact greatly the performance of utilities and lifelines. Buildings with well-designed foundations may not provide adequate resilience if they are not connected with robust utilities and lifelines. Moreover, disrupted utilities can initiate fire and hamper firefighting efforts. Thus, the CBD seismic resilience should be assessed both at the building component level and the city system level.

B. The information in this report should motivate the city officials and its developers to engage geotechnical engineers in the future so that adequate subsurface characterizations can be performed that will provide sufficient information to develop robust foundation designs that are appropriate for the ground conditions and the potential levels of earthquake shaking in Christchurch. The variability of the soils in Christchurch is not unknowable or unexplainable. The observed significant variability of these soils is due to the fluvial nature of the soil deposits as described in the report. Good site investigations can discern the underlying patterns in the soils of Christchurch. Site-specific investigations and designs can develop resilient buildings and supporting utilities and lifelines. However, the common desire to control up-front costs in construction often limits the amount that one invests in characterizing the ground conditions beneath a proposed building. When faced with these same competing interests in California, we often found that investments were not made in conducting comprehensive geotechnical site investigations. Liquefaction and landslides damaged many structures in the 1989 Northern California (Loma Prieta) earthquake. These outcomes provided sufficient political willpower to enact the 1990 Seismic Hazards Mapping Act. This Act led to the development of zones that require geotechnical earthquake engineering studies to evaluate these hazards. Importantly, the Act requires peer review of the studies to elevate the standard of practice. A similar approach may be necessary in New Zealand so that a satisfactory level of geotechnical earthquake engineering is required for all projects in potentially hazardous zones.

C. The geotechnical earthquake engineering profession has developed to the point wherein well-calibrated simplified procedures exist for evaluating the liquefaction hazard. With adequate site investigations through the use of the CPT complemented with some drilling and sampling for testing soils in the laboratory, these simplified liquefaction evaluation procedures can be employed with confidence. Much of what was observed in Christchurch as a result of the 22 February 2011 earthquake can be explained using these simplified liquefaction evaluation procedures. Thus, every effort should be made to collect the data required to employ these procedures to affect foundation design for future projects.

Secondary Review Comments

Several minor comments are provided for completeness in this review. These comments do not affect the validity of the interpretations and findings in the report. These secondary review comments are:

a) Although as suggested on page 3 of the text that “significant softening of the soils due to liquefaction causes filtering out (removal) of the high frequencies,” liquefied soil may undergo moments of dilation during cyclic loading which may lead to high frequency acceleration spikes. This phenomenon is illustrated in Figure 13 of the report which shows some significant high frequency spikes in the acceleration-time history after the initiation of liquefaction. Soil liquefaction can lead to ground motions that have damaging spikes in acceleration.

b) At the start of Section 2.2 on page 3, it is stated that liquefaction occurs in granular soils, such as non-plastic silts. At the end of Section 2.2 on page 4, the authors state that “plastic soils … are considered non-liquefiable.” Soil liquefaction/softening can also occur in slightly plastic silts and clayey silts. There is debate in the profession regarding the location of the division between soils that liquefy and soils that undergo cyclic failure. However, as noted by the authors later in the report, low plasticity silts or clayey silts should be considered potentially liquefiable. They can be assessed conservatively with traditional penetration tests such as the CPT or SPT.

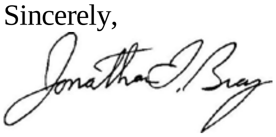
c) In Step 1 of Section 2.3 on page 4, the authors should remind the reader that soils that are classified as “non-liquefiable” must be evaluated in terms of their potential for severe strength loss. In U.S. practice, some engineers focus solely on soils that are potentially liquefiable. However, “non-liquefiable” sensitive soils, for example, can undergo severe strength loss that can lead to significant damage as well.

d) In Step 3 of Section 2.3 on page 5, also cite updated approaches such as Zhang et al. (2002).
e) The Magnitude Scaling Factor (MSF) is used to compare seismic demands from five significant earthquakes from 4 September 2010 to 13 June 2011 (see Table 1 in the report). Although there is debate in the profession about this issue, I (as well as several liquefaction experts) limit the MSF to a maximum value of about 1.8. However, in these cases the impact of not employing a cap on MSF is minor, so the resulting findings are unaffected by this issue. Additionally, the MSF relationship labeled as “Expression 3” in Table 3 is less reliable than those relationships labeled as “Expression 1” and “Expression 2,” so this should be noted in the report.
f) Consider showing the location of the Riccarton station (RHSC), which is referred to on page 20 and in Figure 14, on one of the preceding figures (e.g., Fig 9), so the reader can see its location relative to the CBD. It would also be useful to show the spectra of another strong motion station on non-liquefiable ground that is outside of the CBC as an additional point of comparison in Figure 14.
g) In Section 5.2 on page 23, the SLS and ULS earthquake shaking levels are referred to as a particular earthquake. The seismic hazard is defined by a level of earthquake shaking and not by an earthquake. Thus, for example, it would be preferable to use the term “SLS earthquake shaking level” as opposed to “SLS earthquake” and to use “475 year return period earthquake shaking level” as opposed to “475 year return period earthquake.”
h) It would be insightful to show the inelastic spectra of the recorded earthquake ground motions based on several representative elasto-plastic structural models of the CBD buildings. However, this information may be contained in another report, so it may not be necessary in this report.
i) It would be useful to show photographs that illustrated the statements made in the “Effects of Pronounced Ground Weakness” section on page 27 of the report.

Closure

Thank you for providing this opportunity to review this important report. Hopefully, my review comments and opinions prove to be useful as you move forward. Please contact me at 001-925-212-7842 or at bray@ce.berkeley.edu if you have questions.

Sincerely,



Jonathan D. Bray, Ph.D., P.E.