

# **CBD Building Performance at Liquefied Sites in Christchurch**

**Jonathan Bray & Misko Cubrinovski**

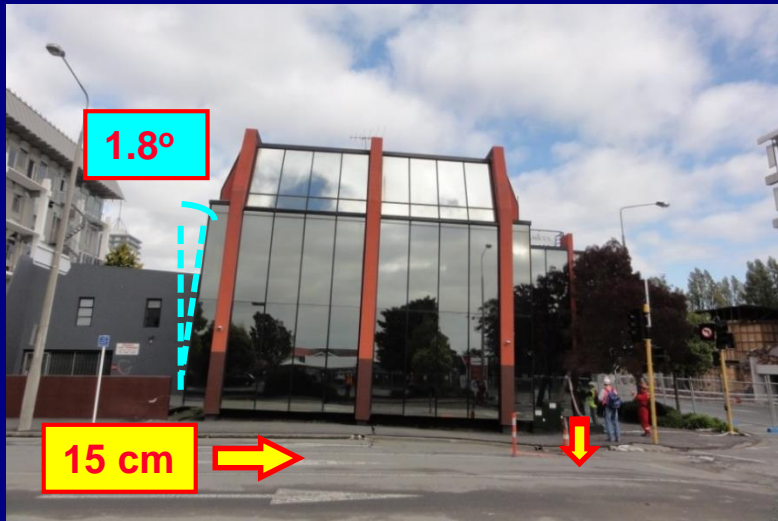
*Univ. of California, Berkeley & Univ. of Canterbury*

**Part of a Collaborative Study With:**

**C. Markham, C. Beyzaei, R. Luque, M. Riemer, J. Zupan, M. Stringer, M. Taylor, T. O'Rourke, S. van Ballegooy, M. Jacka, R. Wentz, B. Bradley, L. Wotherspoon, R. Green, K. Stokoe, B. Cox, etc.**

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# Liquefaction Effects on Structures



Tilting and Sliding of Buildings



Settlement of Ground next to Piled Bldg.



Building Settlement



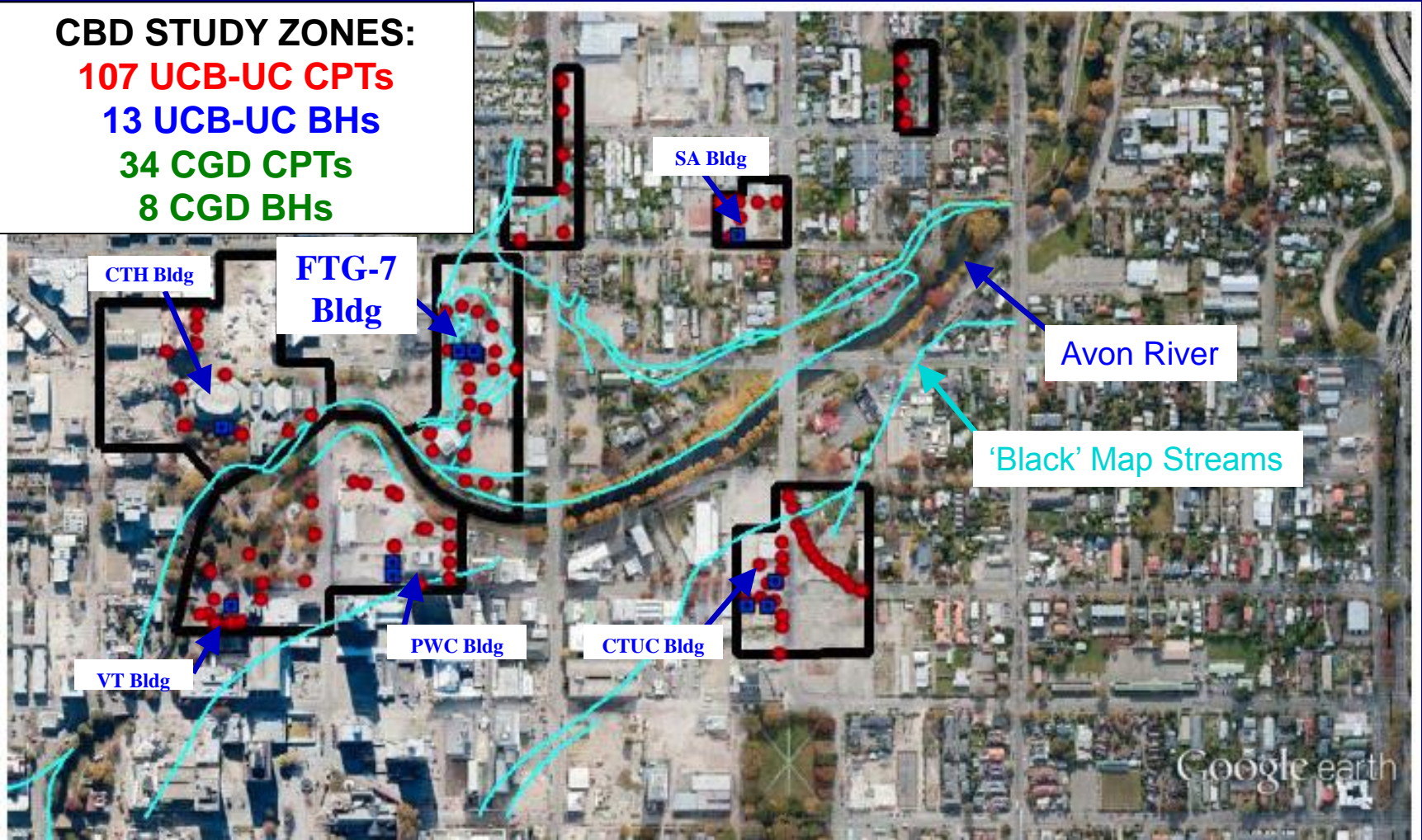
Tilt of Tall Buildings



# Central Business District of Christchurch

## CBD STUDY ZONES:

- 107 UCB-UC CPTs
- 13 UCB-UC BHs
- 34 CGD CPTs
- 8 CGD BHs



Google earth

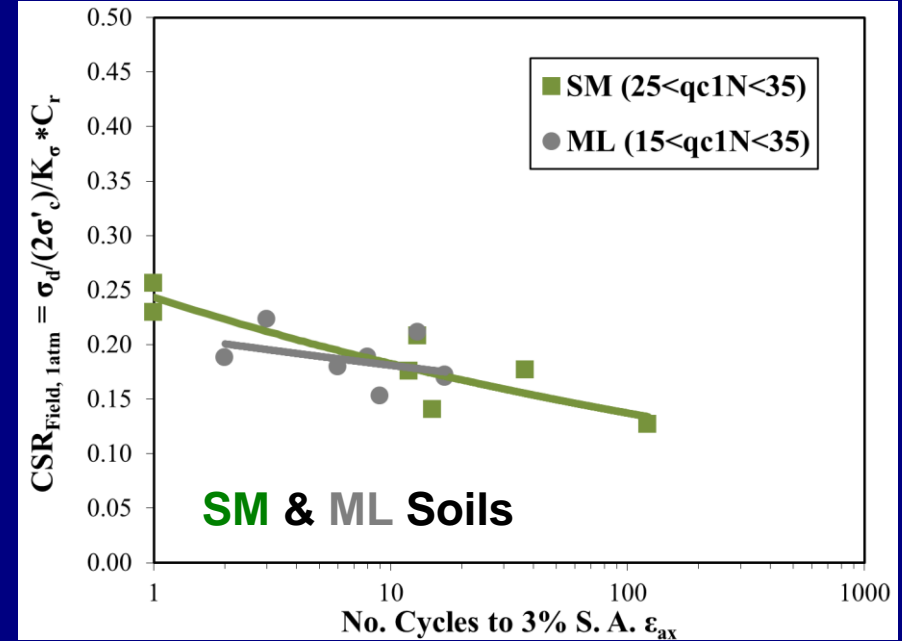
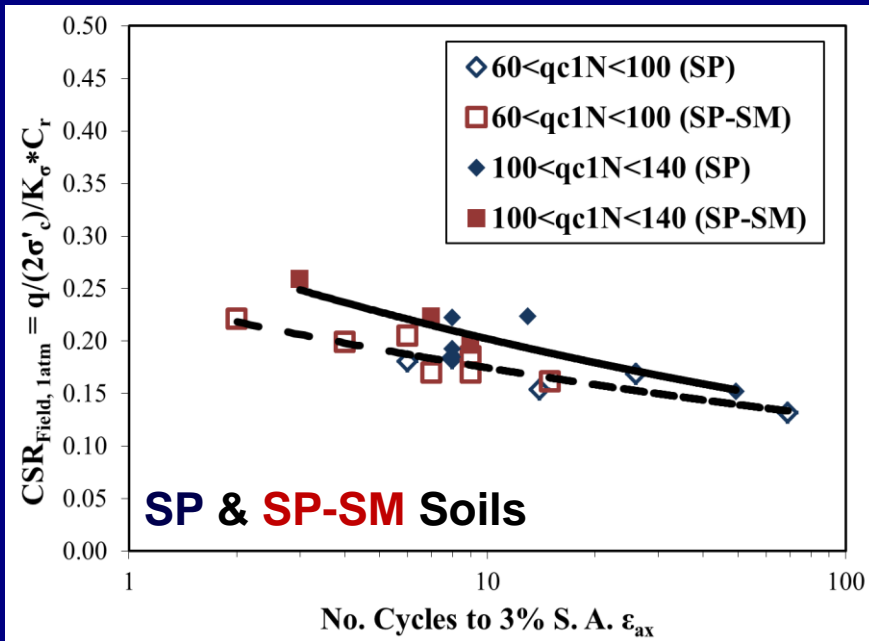
feet  
meters

2000

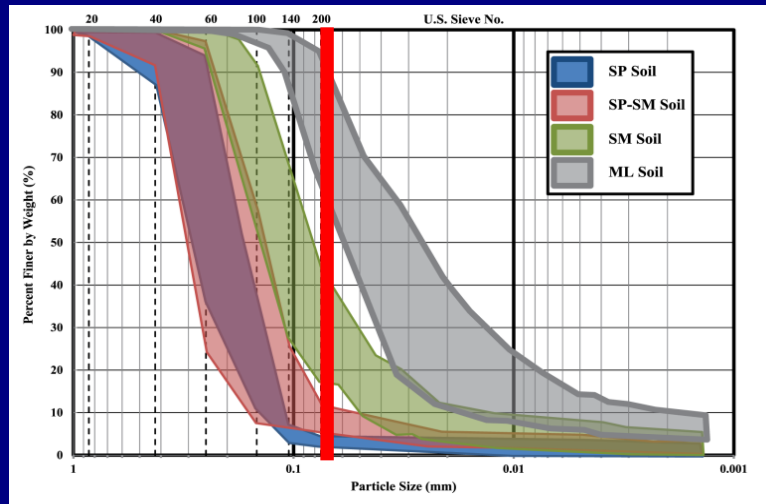
700



# CBD Shallow SOILS: Cyclic Resistance



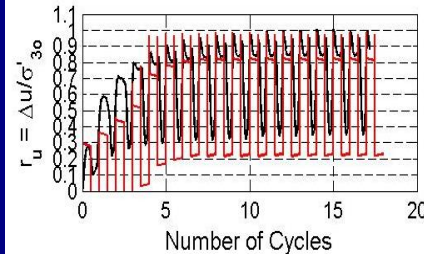
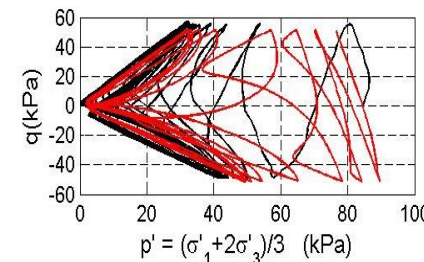
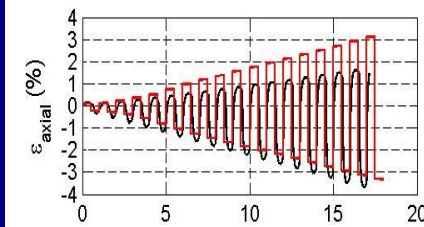
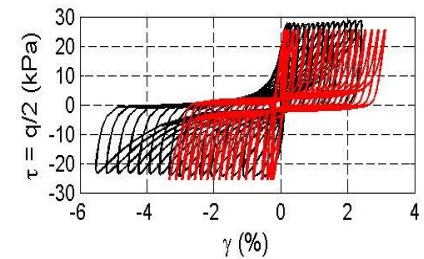
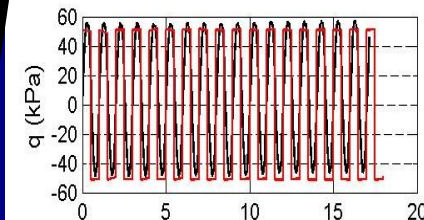
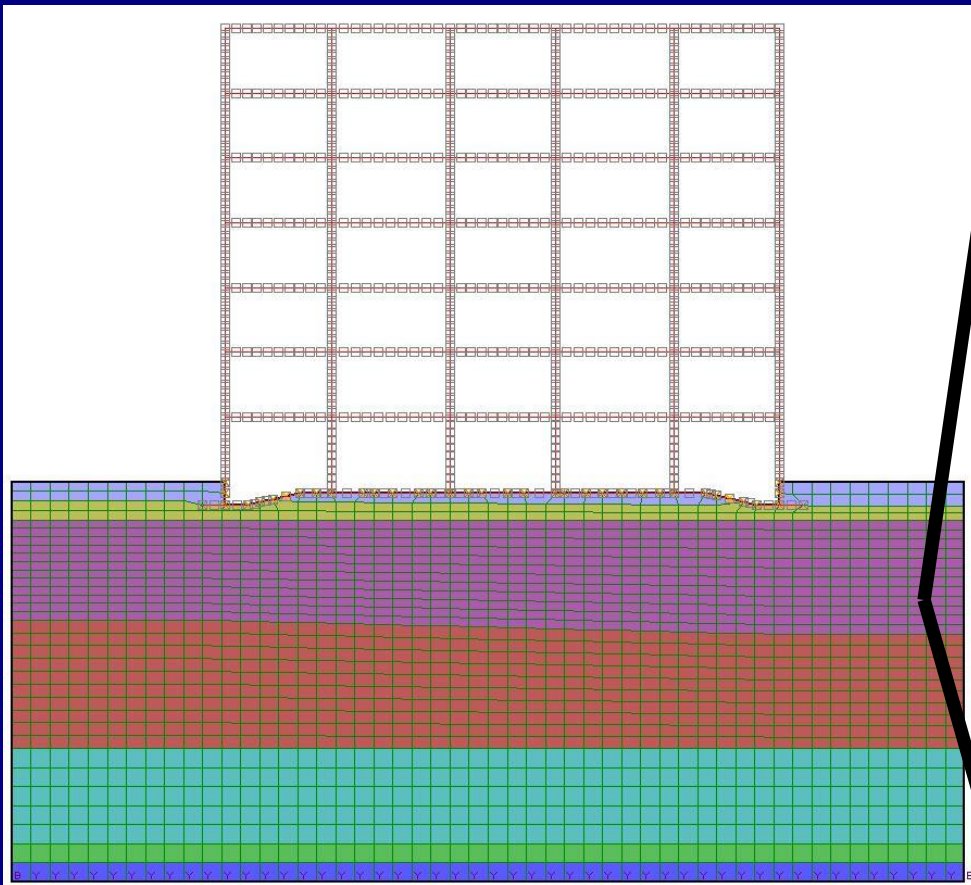
**SP**       $1.7 < I_c < 2.1$   
**SP-SM**    $1.7 < I_c < 2.2$   
  
**SM**       $2.2 < I_c < 2.4$   
  
**ML**       $2.2 < I_c < 2.6$   
 ( $0 \leq PI \leq 5$ )



Also, Sandy  
 Gravel with:  
 50-60%  
 gravel, 30-  
 40% sand, &  
 10% Fines

# Performance Based Earthquake Engineering

- Requires Advanced Analyses
- Advanced Analyses Require Calibration Data



**ICU Static TX Comp. Data vs PM4SAND**

Site:	151 Kil St	$\rho_{sat}$ (kg/m <sup>3</sup> ):	1758
Borehole:	DM BH2	$D_r$ (%):	47
Sample No.:	4U	$G_s$ :	392
Nearest CPT:	Z1-B3	$h_v$ :	3.25
Spec. Depth (m):	5.88	$e_{min}$ :	0.93
Gs:	2.7	$e_{max}$ :	0.59
$e_v$ :	0.77	$\eta_v$ :	0.5
$\sigma'_{30}$ (kPa):	84.7	$\eta_{30}$ :	2
PI (%):	--	$A_{30}$ :	3.1812
USCS:	--	$Z_{min}$ :	4.386
FC (%):	12	$C_c$ :	250
$N_{30,EA}$ (Lab):	14	$C_u$ :	1.8
$N_{30,EA}$ (Flac):	16.5	$e_{cr}$ :	33
$N_{30,DA}$ (Lab):	16.5	$\omega$ :	0.3
$N_{30,DA}$ (Flac):	14	$Q_c$ :	9.5
		$R$ :	1

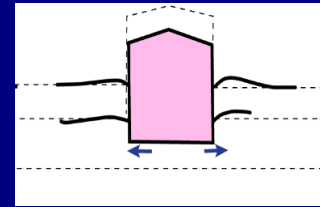
Ph.D. Students: C. Markham & R. Luque

FTG-7 Building (Luque & Bray 2015)

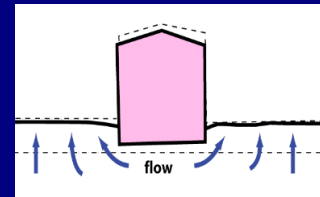
# DISPLACEMENT MECHANISMS (Bray & Dashti 2010)

## 1. Volumetric Deformations

Partial Drainage ( $\epsilon_{p-DR}$ )



Sedimentation ( $\epsilon_{p-SED}$ )

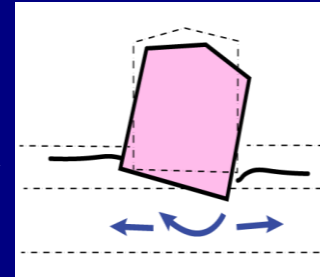


Consolidation ( $\epsilon_{p-CON}$ )

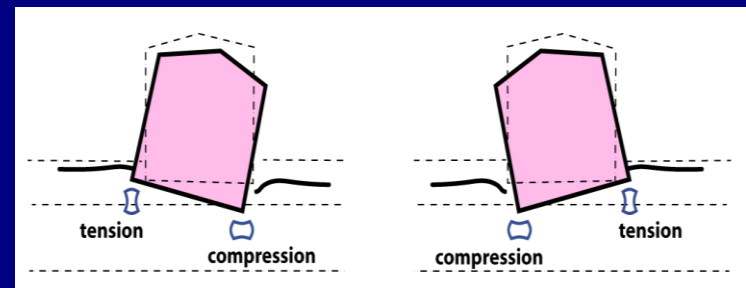


## 2. Shear-Induced Deformations

Bearing Capacity Failure ( $\epsilon_{q-BC}$ )



SSI-Induced Ratcheting ( $\epsilon_{q-SSI}$ )



## 3. Ground Loss due to Ejecta