April 16, 2016 Ecuador Earthquake
EERI Learning from Earthquakes Briefing Webinar

GEOTECHNICAL OBSERVATIONS
GEER-ATC Reconnaissance Mission

Sissy Nikolaou
WSP | Parsons Brinckerhoff
GEER-ATC TEAM

Geotechnical Extreme Events Reconnaissance

Turning Disaster into Knowledge
Sponsored by the National Science Foundation
With support from the Applied Technology Council

S. Nikolaou
WSP|PB
Leader (USA)

X. Vera
U. Guayaquil
Leader (EC)

R. Gilsanz*
GMS
(ATC)

D. Alzamora
FHWA

V. Diaz*
GMS/ATC

G. Diaz-Fanas
WSP|PB

G. Lyvers
Army Corps

K. Rollins
Bring. Young U.

C. Wood
U. Arkansas

A. Zekkos
U. Michigan

Ecuadorian Collaborators:
EC Government EC Army, Geodynamics Institute,
T. Toulkeridis, A. Alvarado, A. Caicedo, C. Luque,
W. Mera, G. Ponce, F. Ripalda, C. Salcedo, G. Vela,
J. Vera-Grunauer, F. Yepes

R. Luque
UC Berkeley

E. Miranda
Stanford
PEER

E. Morales
U. Buffalo
Ecuadorian Army

MINISTERIO DE DESARROLLO URBANO Y VIVIENDA

Ecuadorian Ministry of Housing
GEOTECHNICAL HIGHLIGHTS

● **Ground motions** were extreme, often exceeding design

● **Site conditions are generally Class “F”**
  ○ Deep, soft, plastic clay deposits, or
  ○ Liquefiable man-made fills

● **Site effects were evident**
  ○ Large soil amplification (> 10 times the rock motions)
  ○ Extensive liquefaction
  ○ Landslides and slope instabilities
  ○ Infrastructure – bridge embankments, dams
RECONNAISSANCE

Helicopter Flyovers
Security Cameras
Drones
3-D Lidar, Imaging from Drones
Vs In-situ Measurements
Conventional Technology on Ground
TECTONICS

Subduction
Crustal earthquakes
Volcanism

Ref: Prof. Th. Toulkeridis
Escuela Politecnica del Ejercito
Military Academy, Quito
HISTORIC SEISMICITY

Mega-thrust subduction events

1906 $M_w$ 8.8 Esmeraldas
1942 $M_w$ 7.8 Jama
1958 $M_w$ 7.8 Esmeraldas
1979 $M_w$ 8.2 Colombia
1998 $M_w$ 7.2 Bahia
2016 $M_w$ 7.8 Muisne

modified from Collot et al. (2004)

Slide: PEER Presentation, Miranda et al. (2016)
HISTORIC SEISMICITY

Preconception: “... The 1942, 1958, 1979 ruptures cover the 1906 rupture area, so there is no seismic gap.”

Chlieh et al. (2014): “Reconsider: asperity between 1942--1958 ruptures ... remains unbroken since 1906. A M_w >7.5 event with tsunami in next decades should be considered....”
Ground Motion Observations

Courtesy of IG-EPN

90 records
30 stations
3 components
3 networks
(RENAC, OPC, IRD)

Processing using PEER standard
(Ancheta et al., 2014)

Largest recorded PGA in Pedernales (APED)
EW: 1.4 g
TIME HISTORIES E-W DIRECTION

Slide: R. Luque, GEER

GEER-ATC Geotechnical Observations
EERI LFE Briefing for the April 16, 2016 Ecuador Earthquake
APED STATION 1.4g (Pedernales)

Slide: R. Luque, GEER
SOIL CONDITIONS - GUAYAQUIL

Downtown subsoil profile (ref: Geostudios)

R = 290 km
SOIL CONDITIONS - GUAYAQUIL

Depth: m

<table>
<thead>
<tr>
<th>Depth</th>
<th>Soil Type</th>
<th>Vs₃₀</th>
<th>Site Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Young estuarine deltaic</td>
<td></td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>Fine-grained soils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Dense Sand</td>
<td>100</td>
<td>B+</td>
</tr>
<tr>
<td>15</td>
<td>Hard Clay (q_c&gt;0.5MPa)</td>
<td>1070</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Very Dense Sand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Hard Clay (q_c&gt;0.5MPa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Soft Claystone</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Vs₃₀ = 100 m/s
Site Type F
DEEP SOFT SOILS
Station AGYE2

Vs₃₀ = 1070 m/s
Site Type B+
Hard ROCK
Station AGYE

Vs₃₀ = 100 m/s
Site Type F
DEEP SOFT SOILS
Station AGYE2

Vs₃₀ = 1070 m/s
Site Type B+
Hard ROCK
Station AGYE

T_soil ~ 1.5 s

Period T : s

SA : g

x10 larger
BRIDGE EMBANKMENTS

RIO CHICO BRIDGE EMBANKMENT

30 to 60 cm of settlement relative to bridge

MEJIA BRIDGE

Rotation of Sign

Lateral displacement of toe of slope

Failure planes

Displacement 5 cm to 2 m

Crest of slope plunging

Sliding and rotating block away from embankment

MEJIA BRIDGE
DAMS

ATC Geotechnical Observations
January for the April 16, 2016 Ecuador Earthquake
LANDSLIDES
ROCK FALLS

GEER-ATC Geotechnical Observations
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LIQUEFACTION: MANTA PORT
Extensive sand boils. Lateral/vertical movement/cracks at south parking lot. GEER measured shear wave velocity $V_s$ and cross-sections of displacements.
LIQUEFACTION: MANTA PORT

Extensive sand boils.
Lateral/vertical movement/cracks at south parking lot.
LIQUEFACTION : MANTA PORT

Damage to reverse and forward batter piles

Damage to reverse batter piles

Battered piles with no damage

Vertical Displacement

Horizontal Displacement
LIQUEFACTION : MANTA PORT

- Battered piles with no damage
- Damage to reverse and forward batter piles
- Damage to reverse batter piles

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LIQUEFACTION : MANTA PORT

Mw = 7.8, PGA = 0.45 g, Boulanger & Idriss (14) 50% P_L curve

Soil Description: SAND, SP-SM, FC = 3 – 11%

SPT data from Geoestudios, CPT from Subterra and Vs measurements from GEER (Clinton Wood, U. Arkansas). Analysis by R. Luque
Thank You!

......more GEER-ATC Ecuador Report
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