

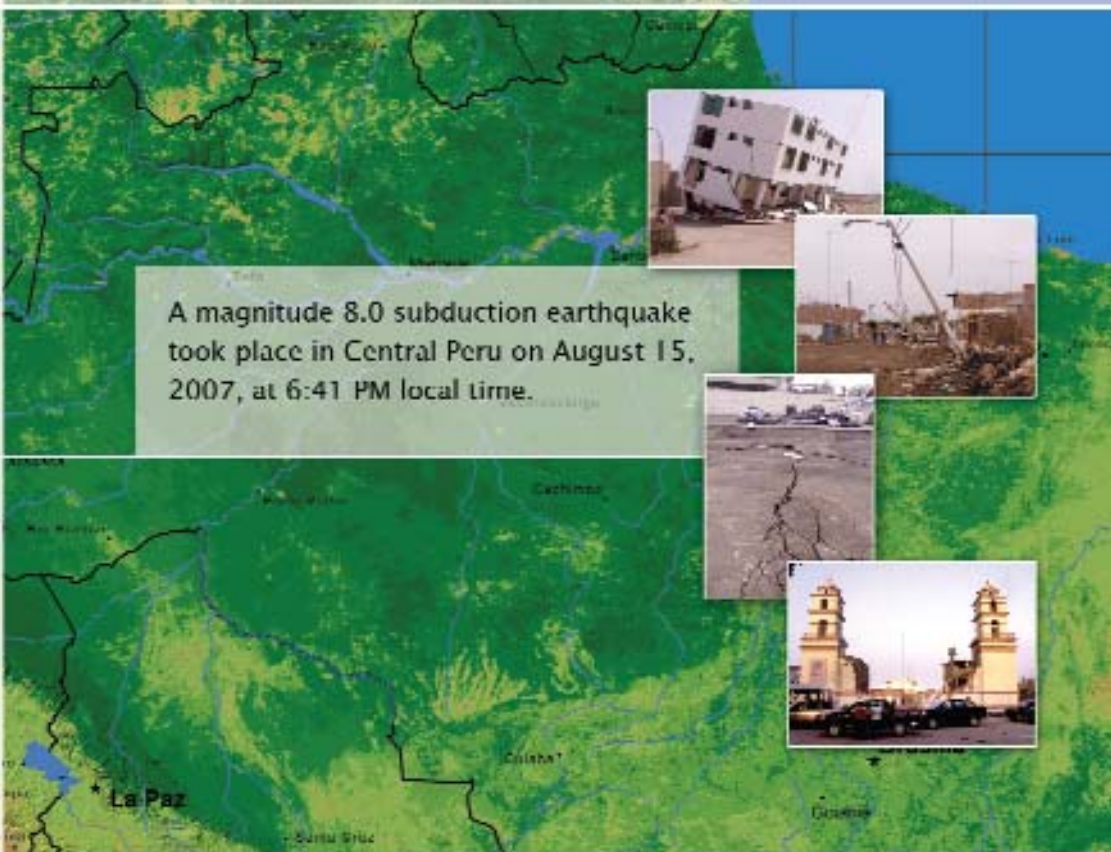
REPORT

of the

Magnitude 8.0

Pisco Peru Earthquake

August 15, 2007



A magnitude 8.0 subduction earthquake took place in Central Peru on August 15, 2007, at 6:41 PM local time.

INTRODUCTION

A magnitude 8.0 subduction earthquake shook Central Peru on August 15, 2007, at 6:41 PM local time. The epicenter was located offshore, 30 miles west of Chincha Alta, about 95 miles south of Lima, at a depth of 24 miles. Approximately 600 people were killed, primarily due to the collapse of adobe structures. Approximately 50% of the fatalities occurred in two different churches in Pisco and Ica, where Wednesday evening services were underway.



GEOTECHNICAL

Seismology and Ground Motions

The Nazca Plate converges with the South American Plate at a rate of over three inches per year, making it one of the most active seismic zones in the world. The rupture area reported by the Geophysical Institute of Peru was approximately 120 miles long by 70 miles wide. The USGS reported that the August 15 event occurred among three historic events on the same fault boundary, the 1974 magnitude 8.1 earthquake to the north, and the 1942 and 1996 magnitude 7.7 events to the south. A magnitude 9 event in 1868, which was 400 miles south of the August 15 event, produced a tsunami that killed several thousand people.

The ground motion record at Parcona Station (near Ica) showed a peak horizontal ground acceleration of 0.5g and a peak vertical ground acceleration of 0.3g. A record in Lima, 95 miles to the north, had a peak ground acceleration of 0.6g. USGS ground motion mapping, however, shows peak ground accelerations along the coast as large as 0.3g. This is consistent with observations on the ground where most engineered structures performed well.

Tsunami

A tsunami, two to three feet in height, was reported along the coast although there was no report of catastrophic damage. Evidence of the tsunami in the form of deposited debris was observed in Paracas, Pisco and Tambo de Mora. Offices in a fish processing facility in Tambo de Mora were flooded. Adobe structures were also damaged in Tambo de Mora due to the tsunami.



Tambo de Mora street with extensive liquefaction.



Tambo de Mora house settled four feet.

Liquefaction

Extreme liquefaction was observed in Tambo de Mora, on the coast west of Chincha Baja, in Paracas, and at Port San Martin. In Tambo de Mora, adobe, brick and concrete block houses settled into the liquefied soil as much as four feet.



Chincha prison door/wall settled four feet.



Chincha prison wall and power poles tipped.



East edge of lateral spread Tambo de Mora.



Scarp on east edge of lateral spread.

At a regional prison near Tambo de Mora, walls toppled and/or sank into the ground as much as four feet. Power poles and light poles toppled. Approximately one km east of the prison, a scarp formed along the eastern edge of a large block of soil hundreds of meters in each dimension indicating lateral movement.

INFRASTRUCTURE

At the time this report was written, the extent of the overall damage to the infrastructure was unknown. The following relays observed post-earthquake damage, but actual loss is neither calculated nor cited in this report.

Buildings

A high percentage of housing was constructed of adobe, which performed poorly. Most of the fatalities resulted from the collapse of adobe structures. Most multistory structures, as high as five stories, consisted of a reinforced concrete frame with infill comprised of hollow tile or brick. The damage mechanism for these types of structures was that the infill falls out when subjected to out-of-plane loading. Once the infill masonry is gone, the concrete frame has little lateral load resisting strength, and collapses. Some of these structures performed well while others collapsed. The specific design and detailing influenced their performance. In several cases, soft stories (buildings with limited lateral support on the first floor) collapsed.



Building collapsed due to soft story.

Industrial Facilities

There are many industrial facilities along the coast including steel plants, fertilizer/fish processing plants, an air separation plant and oil storage and refining facilities. From afar, there did not appear to be any significant damage to these engineered facilities. Information from a few engineers who had access to the plants indicated that there was minimal or no damage.

Highways & Bridges

The Pan American Highway from Lima to Pisco and Ica was closed immediately following the earthquake due to a rockslide just north of Chincha. Slides also occurred in roads leading to the Andes.



Rock fall on road east of Indenpencia.



PanAm highway bridge over Rio Pisco.

Six days after the earthquake, the highway was open in one direction, but was closed again several days later. Just downstream of the bridge, a concrete panel lining the river dike/bank had slumped down the bank. Other bridges in the impact area were observed, but only very slight damage was found.

Other sections of the highway suffered from liquefaction/cracking, but probably remained passable immediately following the event. The only damaged bridge that was identified was on the Pan Am Highway crossing the Rio Pisco, just south of San Clemente.



Liquefaction/lateral spread behind warehouse.



Ground cracking around pipeline/manhole.



3 - 4' settlement behind sea wall.



Loading emergency supplies/settlement.

Ports

Small piers were slightly to moderately damaged in Pisco and Paracas. Most of the significant damage was at the Port of San Martin. It has a wharf about 3,000 feet long.

The front (water side) 60 feet is pile supported. Fill behind a sea wall settled about three feet, and pushed the wall towards the piles, slightly bending them. A warehouse just behind the sea wall had pile-supported walls. The floor and surrounding area settled about two feet, with extensive evidence of liquefaction. The port personnel were unloading coal and emergency supplies while the reconnaissance team was in the area.



Emergency water supplies.

Gas/Liquid Fuels

There is no gas distribution system as gas is distributed in bottles. A gas line travels down from the Andes, and the gas is liquefied at a facility in Pisco and then loaded onto ships at an offshore facility. No damage was reported at any of these facilities. On August 21, one gas station just north of the Pisco turn-off on the Pan American Highway was running a generator to pump gas. An oil tank farm (private facility) was observed in Tambo de Mora where liquefaction had occurred under some of the tanks causing settlement.



60KV transformer moved on rail breaking insulators.

Electric Power

Electricity is produced by hydro power. High voltage lines (appeared to be 230 KV) transmit the power from the Andes to a substation in Independencia, about 12 miles inland. There was no apparent damage to this substation. Power is then distributed at 60 KV from this substation through multiple circuits serving Pisco, Ica, and Paracas. On the circuit serving Paracas/San Andreas, three line supports failed. Two transformers at this substation (60 KV-10 KV) rolled on the support track, breaking insulators where the wire connections were fixed.



Broken insulators.

The building housing the substation, which is a reinforced concrete frame with infill masonry, had only slight structural damage. The transformer at this substation leaked oil, causing it to fail. Power company personnel indicated that substations were operational within one day. However, there were many damaged poles, in addition to poles that had toppled in liquefiable soil. Service drops were cut when buildings collapsed (particularly in Pisco). Workers indicated that it would take two weeks to restore power completely.

Communication

The hardwired system failed. Cell systems were functional by August 21. Portable call centers were set up in the square in Pisco.

Water Supply

Pisco gets water from a infiltration gallery 18 miles east of town. Pipeline damage along the transmission line into the town reduced the flow from 4700 GPM to 2700 GPM. The chlorine disinfection system at the operations center in Pisco was damaged from ground motion.



Emergency water distribution in Tambo de Mora.



Chlorine room under elevated tank.

Bottled water was shipped in through the Port of San Martin. Much of their system is PVC piping, with only moderate amounts of CIP and AC. Evaluation of the distribution system had not taken place at the time of inspection.



Emergency water tank delivery Tambo de Mora.



Emergency water supplies.



Elevated tank/emergency water distribution.

The Pisco system had one 370,000-gallon concrete elevated tank (where their operations center is located) and one 1.2-million gallon ground-level tank. The elevated tank support structure had spalling at the joints. The ground level tank appeared undamaged. Many concrete elevated tanks throughout the region appeared to be undamaged.

Guadalupe has several wells. It was reported that the water was turbid for 30 minutes following the event, but then cleared. Tambo de Mora receives water from Chincha Baja. The transmission line connecting the two was broken, so Tambo de Mora had no water as of August 23. In Tambo de Mora in the area of extreme liquefaction, hydrants were located along the road. Pipeline damage in this area was expected to be severe.

Wastewater

There is a wastewater system in Pisco. It was reported that the collection system was heavily damaged, and would probably have to be replaced entirely. The wastewater treatment plant was not damaged, however due to damaged transmission lines the plant was not in operation.

SIGNIFICANCE TO THE AMERICAS

The characteristic which makes this earthquake of particular interest relevant is its duration—nearly three minutes of shaking. Though this event occurred in South America, it could expect a similar duration in a comparable North American event. The long duration results in extensive liquefaction and severe damage to non-ductile structures at large distances from the fault rupture even though they may encounter only moderate shaking intensities. Liquefaction occurred in Lima, along with some structural damage, 95 miles away.

This subduction event occurred at the interface between the Nazca Plate and the South American Plate, similar to the tectonic structure that occurs in North America. In the Pacific Northwest, the Juan de Fuca Plate is subducting below the North American Plate running 1,100 miles from Vancouver Island southward to Eureka, California.

In addition to the significance of the event itself are the after-effects of an extreme event. Following an earthquake or any other natural peril, success of recovery is highly dependent upon how well the population has prepared for and planned to handle the event and its aftermath. A lesson to be learned from any natural disaster is it to have in place a thorough business continuity planning process to identify and quantify the possible business disruption and to minimize the interruption as much as practically possible.

CONCLUSIONS

- The earthquake had shaking intensity that lasted for nearly three minutes.
- The long duration of shaking caused extensive damage to brittle structures such as adobe buildings and some reinforced concrete frame buildings with masonry infill.
- The long duration of shaking exacerbated liquefaction and lateral spreading that impacted housing and one major port.
- Rigid structures, including adobe and concrete frame with infill masonry, performed poorly. Their collapse caused in most of the casualties.
- Engineered structures performed well.
- Power system transformer insulator failures caused short-term power outage. Pole breakage and toppling due to liquefaction caused outages expected for several weeks.
- Pipeline damage caused disruption in the water supply.