Chile Earthquake and Tsunami of 2010

Performance of Coastal Infrastructure

COPRI Chile Earthquake Investigation Team

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Initially, Jaime Serrano was making arrangements and providing supporting information to the Team. However, after his successful efforts in the field and supporting this document with innumerable requests for information, the Team confirmed him as a member of the COPRI Chile Investigation Team.

Chapter 1

Introduction

On February 27, 2010 a magnitude (Mw) 8.8 earthquake struck off the coast of South-Central Chile, resulting in significant loss of life and property. The Coasts Oceans Ports and Rivers Institute (COPRI) of the American Society of Civil Engineers (ASCE) deployed a team including coastal, structural and geotechnical engineers to investigate the coastal impacts of the earthquake and tsunami. The first objective of the Team's reconnaissance was to identify infrastructure that performed poorly as well as that which performed as intended. The second objective was to compare the performance of older systems that were not designed using current methods with systems that were designed with Chile's modern codes. This report is intended for the practicing engineer to use in better understanding the requirements of designing, constructing and maintaining marine facilities.

1.1 Description of Earthquake

The February 27, 2010 earthquake epicenter was located about 35 km out to sea from Maule, Chile (at latitude 35.909S, longitude 72.733W), which is nearly 105 km north of the population center of Concepción and about half way between Concepción and Constitución. Santiago, Chile's capitol and largest city, is approximately 330 km northeast of the epicenter. The earthquake was immediately to the north of the rupture zone of the Mw 9.5 Chilean earthquake of 1960 (the largest earthquake recorded to date at Valdivia). It had a plate rupture estimated to be about 550 km long by 150 km wide. It was felt over the entire country, affecting nearly 80 percent of Chile's population. Numerous, significant (Mw 6 or higher) aftershocks occurred over the following weeks.

The earthquake created intense shaking for a period as long as three minutes and a tsunami was generated and spread across the Pacific Ocean. This tsunami (and follow-on waves) generated by the earthquake created a run-up of approximately 10m within a 200 km radius of the epicenter. It was reported by other teams that a tsunami run-up of 30m was measured in Tirua, approximately 350 km south of the epicenter. This tsunami produced extensive damage to coastal communities and facilities.

The 2010 earthquake is the fifth largest ever recorded to date. Although this event was much stronger than the 2010 Haiti earthquake with an Mw 7.0, it caused substantially less damage due to the more earthquake-resistant infrastructure and lower population density of the affected area. Due to the extreme magnitude of the Chile event, significant damage to ports, buildings, roads, bridges and other modern lifeline facilities were reported throughout central Chile. An example of significant damage to the waterfront observed in Talcahuano is shown in Figure 1.1.

According to the United States Geological Survey (USGS, 2010), at least 521 people were killed, with 56 missing, and about 12,000 injured during the earthquake or tsunami. In addition, it was noted that about 800,000 people were displaced and at least 370,000 houses, 4,013 schools, 79 hospitals and 4,200 boats were damaged or destroyed by the earthquake and tsunami in the Valparaiso-Concepción-Temuco area.

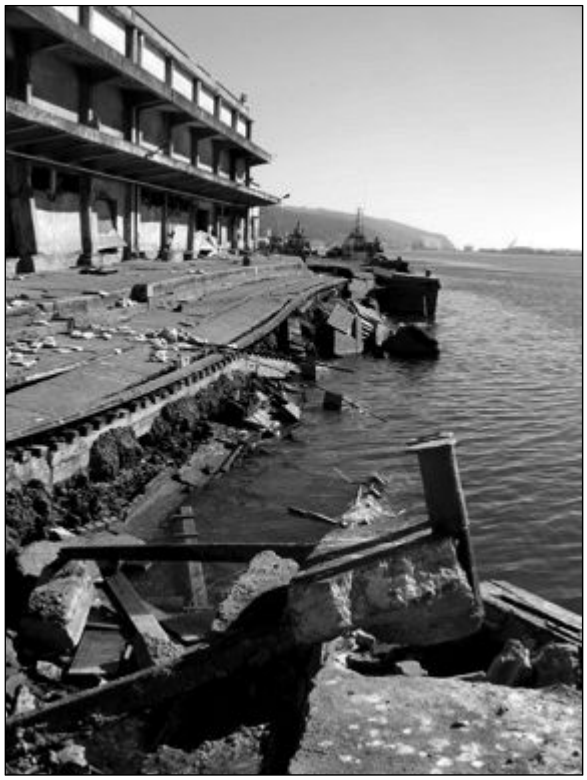

Figure 1.1 Damage to the Waterfront Observed in Talcahuano

The total economic loss in Chile was estimated by Chilean President Sebastian Pinera at 30 billion U.S. dollars immediately after assuming office (BBC, 2010). In many areas the electricity, telecommunications and water supplies were disrupted and the airports at Concepción and Santiago had minor damage. The tsunami damaged or destroyed many buildings and roads at coastal towns such as Dichato, Talcahuano, Constitución, Concepción and Pichilemu. It also created damage as far away as San Diego, California and created a small seiche in Lake Pontchartrain, Louisiana. A maximum Peak Ground Acceleration (PGA) of 0.65g was recorded at Concepción (USGS, 2010); and readings closer to the epicenter suggest PGA over 1g (Boroschek, 2010).

There was also damage to port and harbor infrastructure in several locations. Some of the ports were able to return to full operations within days while others had not returned to full operations at the time of the COPRI Team visit. Port damage included subsidence, container crane failure, foundation damage, and a multitude of other modes of failure. Several early field investigations with documented water levels from the tsunami were published by GEER (2010) and JRC (2010) of the European Commission.

1.2 Objectives of this Study

COPRI of ASCE deployed a team including coastal, structural and geotechnical engineers to assess and learn from the effects of the February 27, 2010 earthquake and subsequent tsunami which struck off the coast of South-Central Chile. ASCE and COPRI have been very active over the past ten years investigating damage to coastal and port infrastructure associated with earthquakes, tsunamis, hurricanes (typhoons) and other natural disasters. A parallel investigation by Technical Council on Lifelines and Earthquake Engineering (TCLEE) of ASCE investigated damages to primary infrastructure, including support facilities for major ports (TCLEE, 2010).

The primary purpose of this COPRI Investigation was to assess and learn from the performance of port infrastructure including waterfront, storage and protective structures, handling equipment, foundations and utilities. It is important for COPRI to learn from the performance of these systems, provide recommendations, and, based on these findings, reassess the effectiveness of design guidelines and repair recommendations in both Chile and the U.S. In addition, the Team investigated the tsunami-impacted areas to assess the run-up heights, performance of coastal structures, and scour and deposition of sediments. Before, during and after the visit by the COPRI Team to the sites, there were as many as thirty other investigation teams working. Therefore, the confined focus of this study remained on harbor structures affected by the earthquake and related tsunami impacts. It is COPRI and ASCE's intent that by performing this assessment and working with pertinent organizations in both countries, a significant reduction in future loss of lives and lifeline services may be possible.

1.3 Site Investigation

There are 37 commercial ports in Chile, with the largest facilities supporting mining in the north and container import and export at major population centers. A summary of foreign cargo passing through visited ports is included in Table 1-1.

Table 1-1. Total Cargo in Foreign Trade Passing through Ports Visited by Team

Port	Total Cargo (MT)*	Percent of National
Talcahuano	283,880	0.4
Terminal Gasero ABAS	95,713	0.1
Lirquen	4,010,319	5.1
Coronel	3,343,591	4.2
Valparaiso	6,342,893	8.0
San Antonio	8,970,758	11.3
National Total	79,154,264	41.3%

**Note: the cargo at Terminal Gasero ABAS is liquefied gas and the use of metric tons (MT) can be misleading.*

Source: Data from Camara Maritima y Portuaria de Chile A.G.