# Damage Investigation of the 2010 Chile Earthquake and Tsunami - Consideration to the Damage of a Structure subjected to a Seismic Excitation and a Following Tsunami Wave Load -

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We show the investigation results on the tsunami-induced damage of houses and infrastructures after subjected to a seismic excitation in the 2010 Chile earthquake and tsunami, from the field survey from 26 April to 3 May, 2010 for the affected areas.

***Key Words :*** *2010 Chile earthquake and tsunami, damage of houses and infrastructures, combination of seismic and tsunami wave loads*

## 1. INTRODUCTION

The tsunami-induced damage of houses and infrastructures after subjected to a seismic excitation is observed in affected areas by the 2010 Chile earthquake and tsunami. Reports on the related damage have not been shown sufficiently enough for previous earthquake and tsunami disasters, although we can guess easily that there existed many houses and infrastructures suffered by combination of seismic and tsunami wave loads. From the reason above we focused on field survey to investigate the tsunami-induced damage of houses and infrastructures after subjected to a seismic excitation in the 2010 Chile earthquake and tsunami. This investigation was carried out based on the framework of research project on “Enhancement of earthquake and tsunami disaster mitigation technology in Peru” sponsored by the JST- JICA SATREPS project (leader, Professor F. Yamazaki at Chiba University) [1)].

## 2. DAMAGE OF HOUSES AND INFRASTRUCTURES

### (1) Survey areas

The following tsunami-induced damage of houses and infrastructures after subjected to a seismic excitation is observed obviously in two areas: first area is the east part of Talcahuano and second one is Coliumu which is located at the opposite shore of Dichato (**Fig. 1**). In the former area the damage of a bridge, sewerage pipelines and houses is shown and in the latter area the damage of houses is shown (**Fig. 2**).

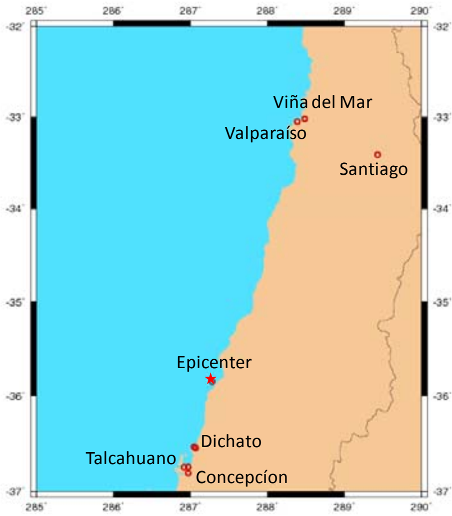


**Fig.1** Subject areas in the related regions with the 2010 Chile earthquake.


**Fig.2** Locations of the occurrence of the damage (left figure shows the locations at the east part of Talcahuano and right one at Coliumu).

**(2) Damage of a bridge**

**Figure 3** show the damage of a bridge at the east part of Talcahuano. The bridge is located at the river mouth and it is a six-spanned bridge with prestressed concrete girders. The span length is about 10m long and the total width of a deck is about 20m long. Significant liquefaction occurs along both riversides in the direction from the location of the bridge to the 30m - 50m upstream. Consequently, subsidence of both abutments and these backfill occurs although we can not observe significant physical damage of bridge girders and piers. We guess that severer subsidence of the abutment at the left bank of the river by scouring of the backfill subjected to tsunami compression and tensile waves, follows the subsidence by the liquefaction subjected to ground motions, than that at the right bank.

**Fig.3** Damage of a bridge

**Fig.4** Damage of sewerage systems

**(3) Damage of sewerage pipelines**

**Figure 4** show the damage of sewerage systems buried in adjacent road with the river at the east part of Talcahuano. Manholes of the systems are uplifted about 15cm to 25cm high from the road surface, and subsidence of buried pipelines and gaps between those spans occur at the side of the road in front of houses. It is inferred from the damage above that liquefaction of the ground with sewerage systems subjected to a ground shaking is a dominant influence factor of the damage. In addition to this, the tsunami-induced flow runs extensively into the suffered sewerage pipelines by the liquefaction, and causes the interruption of flowing of wastewater through the pipelines.

### (4) Damage of houses at the east part of Talcahuano

**Figure 5** show the damage of houses at the east part of Talcahuano, which are RC masonry ones.

The house in the upper part of **Fig. 5** seems to be suffered by about 1m inundation after the occurrence of subsidence and declination equivalent to about 40cm to 50cm height of the house due to ground motions. The subsidence and declination cause dominant shear crack between bricks and motor in the sidewall of the house. We can measure the inundation height at the site by the inundation horizontal marks remained in the 1st floor of the house.

Similarly, the house in the lower part of **Fig. 5** seems to be suffered by about 20cm subsidence of the ground, which is due to the liquefaction of surrounding soil subjected to ground motions. Consequently, it causes that the RC-framed beam is pulled down locally about 40cm at the joint corner between a column and a beam. The failure of the upper beam causes the failure of the sidewall in the house. These structural damage of the house is due to the forced displacement due to the liquefaction.

It is inferred that the houses in the areas are subjected more dominantly to the forced displacement due to the liquefaction, than to the inundation after the tsunami run-up along the river.

**Fig.5** Damage of houses at the east part of Talcahuano

### (5) Damage of houses at Coliumu

The houses in the areas at Coliumu, which is located at the opposite shore of Dichato, seem to be suffered by combination of forced vibration due to ground motions and direct tsunami wave pressure due to tsunami wave propagation. The structural type of houses suffered by the combination loads is a RC masonry one.

**Figure 6** show the damage of the house by the combination loads. The minor horizontal cracks in the sidewall of the house occur at the height from the bottom of the wall to about 1m high, and furthermore the major one crack occurs in the diagonal direction from the joint corner between upper beam and a column. The former cracks seem to be due to the forced vibration of the house subjected to ground motions and the latter crack seems to be due to the tsunami wave pressure, which is modeled as a triangle load to a wall located in parallel with the direction of tsunami wave propagation [2), 3)]. Based on the results by previous research [2),3)], the occurrence of above diagonal major crack in the wall can be explained by the loading to a wall of tsunami wave pressure with a 3m - 4m inundation height.

**Figure 7** show the damage of the house, which is suffered by no damage by ground motions, however is suffered by minor functional damage by tsunami inundation. Functional damage means that the residents can not use their own house for dairy life due to the inundation although the house is not suffered by the physical damage due to the combination of seismic and tsunami loads. One of residents says that the inundation reaches the height of the upper beam at the second floor of the house. It is inferred from his evidence that the inundation height at the house is about 7m - 8m from the ground level, which can be interpreted as very high inundation height to a house. The guideline on the tsunami-proof design for a building offered by Japanese Cabinet Office [4] describes how to design a building resisting the tsunami wave load of about 8m inundation height. The damage of this house should be further analyzed based on the evaluation framework of a tsunami wave load to a structural component by the guideline.

**Fig.6** Damage of a house by combination of seismic and tsunami wave loads at Coliumu

**Fig.7** Minor functional damage of a house by combination of seismic and tsunami wave loads at Coliumu

## 3. CONCLUDING REMARKS

We focused on field survey to investigate the tsunami-induced damage of houses and infrastructures after subjected to a seismic excitation in the 2010 Chile earthquake and tsunami. The following tsunami-induced damage of houses and infrastructures after subjected to ground motions is observed obviously in two areas: first area is the east part of Talcahuano and second one is Coliumu which is located at the opposite shore of Dichato. In the former area the damage of a bridge, sewerage pipelines and houses is shown and in the latter area the damage of houses is shown. The former damage of a bridge, sewerage pipelines and houses in the areas seems to be subjected more dominantly to the forced displacement due to the liquefaction by ground motions, than to the tsunami inundation after the tsunami run-up along the river. The latter damage of houses seems to be subjected to combination of forced vibration due to ground motions and direct tsunami wave pressure due to tsunami wave propagation.

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