Risk Profile – Chile 2010 earthquake

1. **A reanalysis of the Chile 2010 earthquake, the fifth biggest instrumentally recorded earthquake in the World, puts losses in the housing sector at around $6.8 billion (upwards of 3.8% of capital stock).**
2. **The exposure analysis shows a value of $177 billion which is in between estimates from other sources (GAR, GEM).**
3. **The estimation of housing sector losses post-2010 in Chile requires more information, given that the reported losses appear to only include a portion of the full housing sector.**

Why are we looking at Chile?

- The Chile 2010 earthquake was a large subduction event which can be expected in the order of every 25-40 years along the South American (Nazca plate) subduction zone. By thoroughly reviewing the effects of such an event, better planning can be made for next time. In addition improved loss statistics can be created.
- The Chile 2010 event had a very wide area of damage with damage extending over 5 regions, where 75% of Chileans live. By knowing the breakdown of building types and the influence on the damage, this may inform future decisions for reconstruction, or at least retrofit programs.

Why is this useful to the TTL?

The Chile scenario is useful to inform the GFDRR and TTLs of the potential reoccurrence of such an event as well as giving some background as to the potential losses in the residential sector. It also provides lessons as to the collection within a PDNA of quality of housing information seeing the large difference in this case.

Why are we doing the disaster scenario?

The "Disaster Scenarios" Chile earthquake model can be applied to a country-level probabilistic or deterministic modelling effort in the future. The building of this model allows for future events to be quickly analysed and losses to be determined more easily in the residential sector. By reviewing the loss differences today vs. at the time of the event, a full suite of scientific studies, knowledge and expertise has become possible to be analysed, which benefits the production of exposure, hazard and vulnerability models for earthquake anywhere around the world.

Background

The February 28, 2010 Mw8.8 Maule, Chile earthquake was the largest earthquake to occur in Chile since 1960 causing a devastating tsunami and extensive damage due to ground shaking, claiming 550 lives and $30 billion in associated loss effects. In addition, focussing on the residential damage 370,000 houses were either damaged or destroyed amounting to 6.5% of Chile's housing stock.

Disaster Type	Earthquake	**Casualties**	550
Magnitude and Location	Mw8.8 (Maule)	**Homeless**	1,150,000
Date	27/02/2010	**Houses existing at time**	5,669,900
Country Population at Time	16,953,000	**People in dam./destr. houses**	862,609
Capital Stock at Time (Res.) $USDbn	132,227	**Houses destroyed**	81,444
Capital Stock at Time (Non-Res.) $USDbn	n/a	**Houses damaged**	288,607

How did we remodel the scenario?

The Global Earthquake Model's (GEM) Chile exposure database created in the framework of the South America Risk Assessment (SARA) project funded by Swiss Re was evaluated and used. This exposure model gives a good basis for the residential building-vulnerability typologies existing in Chile. However, when focussing on the value of these assets, it was judged to be significantly underestimated compared to gross capital stock and replacement costs.

The ground motion was based on the USGS Shakemap which had very good resolution given that 36 strong motions stations had recorded this great earthquake. This meant that all the main urban exposure was resolved to within 10km of a strong motion recording station, meaning that the derived ground motion map was reasonable for use within the reanalysis.

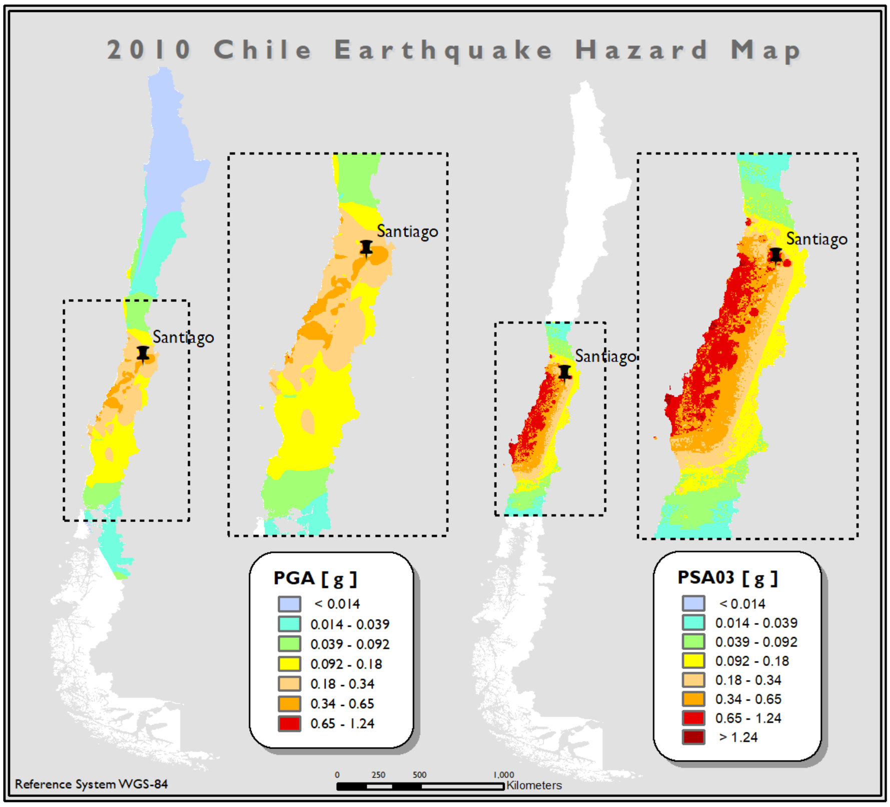
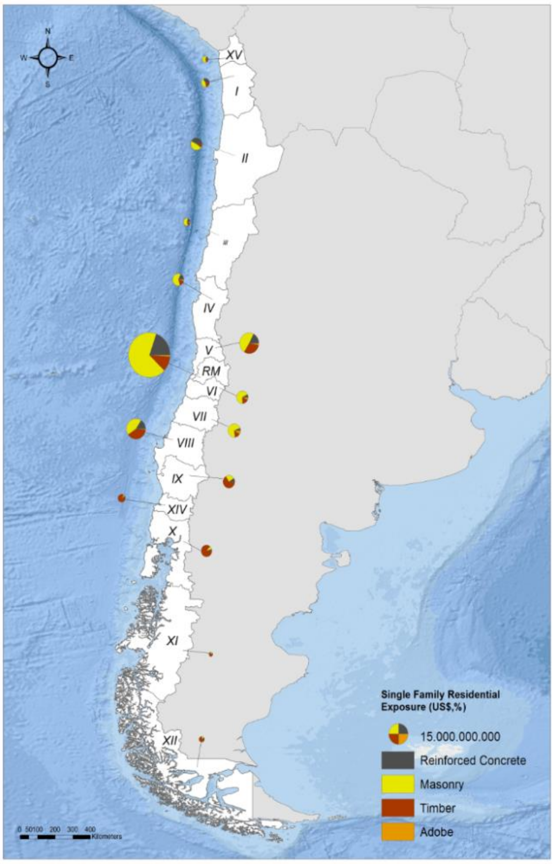


Figure 1: Peak ground acceleration – Peak ground acceleration (PGA) and peak spectral acceleration at period of 0.3 sec – PSA03 hazard maps for the Chile 2010 earthquake reanalysis.

Given the large number of high-rise buildings in Santiago, Valparaiso, Vina del Mar and Concepcion, accurate characterisation of the spectra as well as the exposure was required in order to resolve the losses.

In Chile the last available census is from 2002, as the 2012 Population and Housing census was declared invalid. For the development of the exposure we used the exposure model developed by CIGIDEN in the framework of GEM's SARA project. This model uses three sources to estimate the exposure: a) the 2002 census (for houses existing in Chile in Apr. 2002 at census block level); b) unique edification statistics form (UESF) for buildings and houses getting a build permit in Jan. 2002 - Sept. 2014 aggregated at commune level and c) the 2012 census for emergency and informal houses only. The UESF dataset provides crucial information about the height of the buildings, which is not available through the census. The model contains 16 structural classes (ten types of masonry; four types of reinforced concrete (RC); adobe; timber). The height classes for reinforced concrete (RC) buildings are 3-9; 10-24; 25+ floors (influenced by 2010 earthquake damage experience and related statistics). It was not possible to differentiate RC by earthquake code period (early guidelines for pre-1973 buildings; first recent code in 1973-1996; modern code for buildings constructed post-1996). The conversion of the seven outer wall classes of the 2002 census to the 16 structural classes was done using the 2002-14 UESF data, which leads to an overestimation of dwellings in multi-story buildings e.g. the model results in circa 10% of the dwellings being in 10+ story buildings which coupled with higher vulnerability for these structures during subduction events can lead to risk overestimation. The model is for the year 2014 and at census block resolution. Average dwelling unit size is circa 75 square meters but significant differences apply depending on structure type and location (region, commune). Construction costs range from 93 USD/m^2 for adobe to 545 USD/m^2 for good quality RC. Location and quality cost modifiers are then introduced at the commune level for each of the 16 structure types. Overall residential exposure for ca 5.3 million houses is estimated at 177.4 billion USD (68% of the 2014 GDP). The costs of construction have been modified so that they would better correlate to the Chile Gross Capital Stock in 2014. Fig. 2 (Left) shows the exposure in single-family houses by region, aggregated into four broad typologies (masonry, reinforced concrete, timber and adobe). Fig. 2 (Right) shows the equivalent exposure for houses in apartment buildings (multi-family).



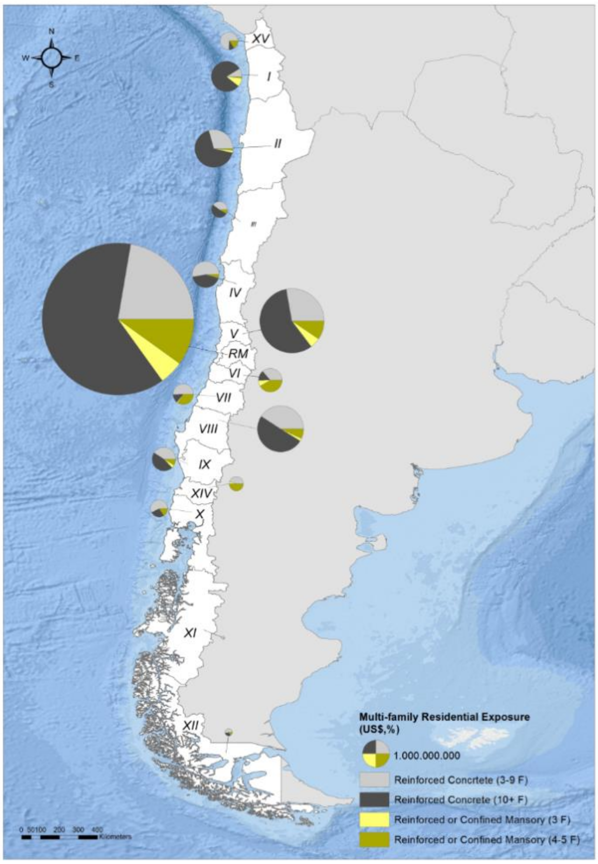


Figure 2 Left: Single-family residential exposure in Chile (2014). The map shows the size of the exposure in USD (scaled pie charts) and its breakdown into four broad structural classes in Chile's 15 regions (I to XIV and Region Metropolitana - RM); Right: Multi-family residential exposure in Chile (2014). The map shows the size of the exposure in USD (scaled pie charts) and its breakdown into two broad structural classes and four height classes in Chile's 15 regions.

The **vulnerability** of the built structures was characterised within the GEM-SARA project with vulnerability functions for the 16 typologies being given based on 3 levels of spectra (0, 0.3, 1.0 sec). Substantial checks of the Chile modelling of the GEM-SARA project were undertaken and these functions were updated in line with the losses seen in past events (Fig. 3).

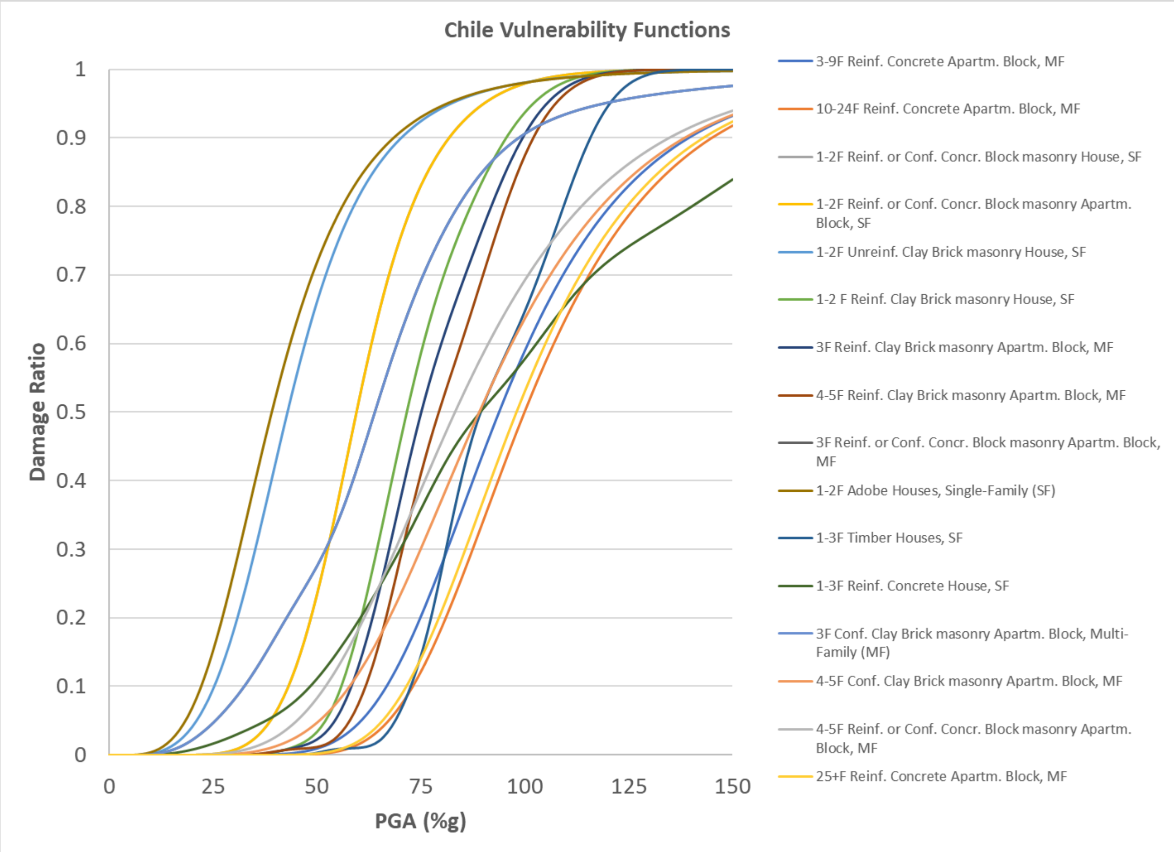


Figure 3: PGA vulnerability curves for the Chile 2010 Reanalysis.

What are the potential losses in Chile?

	Historic	Modelled
Residential Damage (mn USD)	3943	6819
Residential Stock (mn USD)	132226	177402
Exposed Stock over MMI6 (mn USD)		117204
Residential Loss Ratio	2.98%	3.84%

When comparing the losses versus the historical event losses, it can be seen that the absolute values today are higher than in 2010. Since 2010 there has been a 34% increase in exposure meaning a total of $177 billion is now exposed as compared to $132 billion at the time of the event. **When reanalysing the historical Chilean losses, it has been found that the residential portion seems to be underestimated with respect to the total damage via the event.**

The Chile government carried out a disaster needs assessment soon after the event in mid-March 2010 which was further elaborated within the general Reconstruction Plan of August 2010. For the Housing sector the early damage estimate of the Ministry of Housing (MINVU) was used. As the event had caused damage due to tsunami and ground motion in an area of more than 700 km from North to South and time was of the essence this early assessment was carried-out on the basis of cadastral surveys produced by the regional services, communal reports of ONEMI (National Office of Emergency of the Interior Ministry), data from the 2002 census and their growth extrapolations, information from the socio-economic survey CASEN 2006 and cartographic information with housing densities in coastal areas affected by the tsunami. The results were reviewed by the Ministry of

Finance and later a second more accurate analysis was provided by MINVU (the first analysis estimated 256,000 affected housing units of which 72,230 were destroyed, and the second estimated 370,000 affected housing units of which 81,495 were destroyed) using more up-to-date ONEMI situation reports. Affected households had to register for government financial assistance and at the end of the process 240,658 households were eligible for subsidies, of which around 5.2% were rejected by the households themselves. In addition home owner's earthquake insurance had significant penetration in the affected region reported to be around 28%. The insurance sector has reported separately that 189,451 residential insurance claims had also been submitted. This suggests that just over 430,000 housing units have been affected (7.6% of Chile's housing stock).

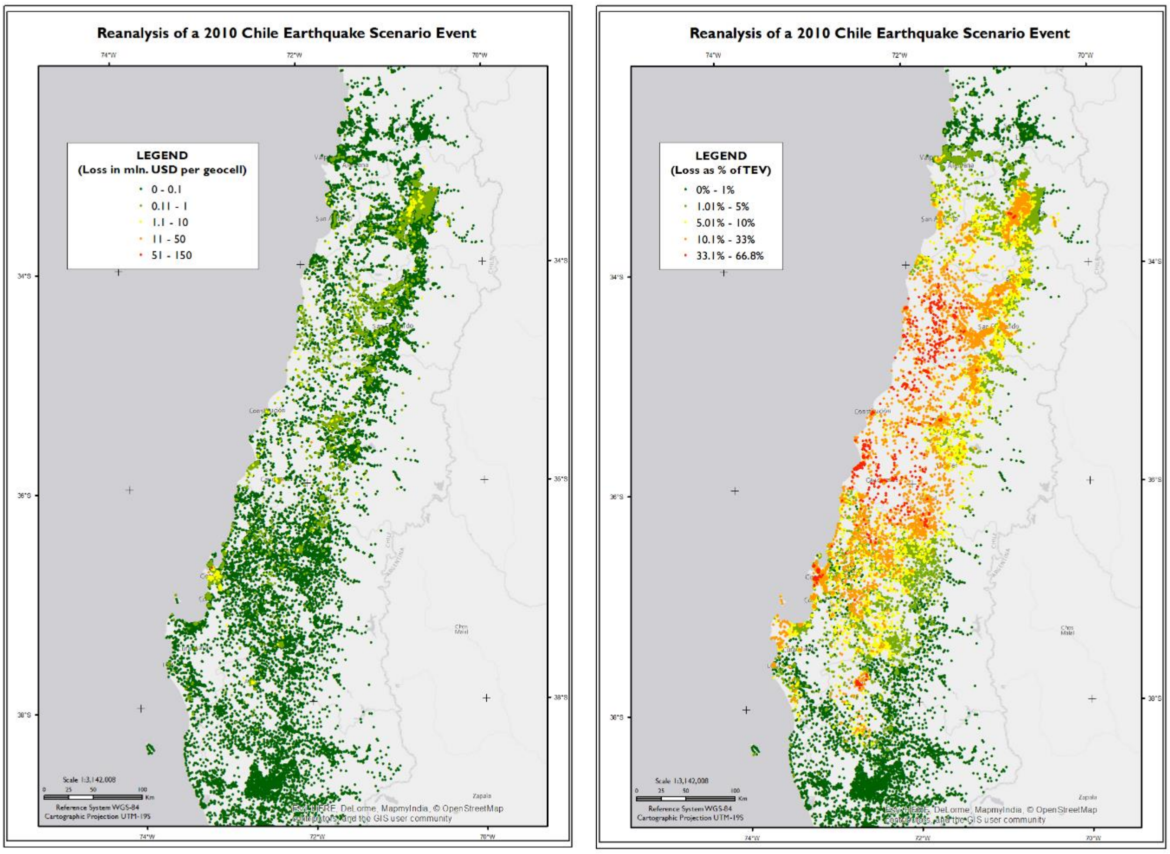


Figure 4: Left: absolute losses per geocell in million USD; Right: the absolute losses normalised by exposed capital to give a loss ratio.

Table: Provincial losses and exposure for the Chile 2010 reanalysis

Province	Exposure ($USDm)	Loss ($USDm)	Loss Ratio (%)
Maule	7986.1	869.3	10.9%
Bio-Bio	18574.9	1822.7	9.8%
O'Higgins	6921	400.4	5.8%
Santiago	87015.5	3373.3	3.9%
Araucania	7575.6	113.2	1.5%
Valparaiso	18561.2	239.8	1.3%

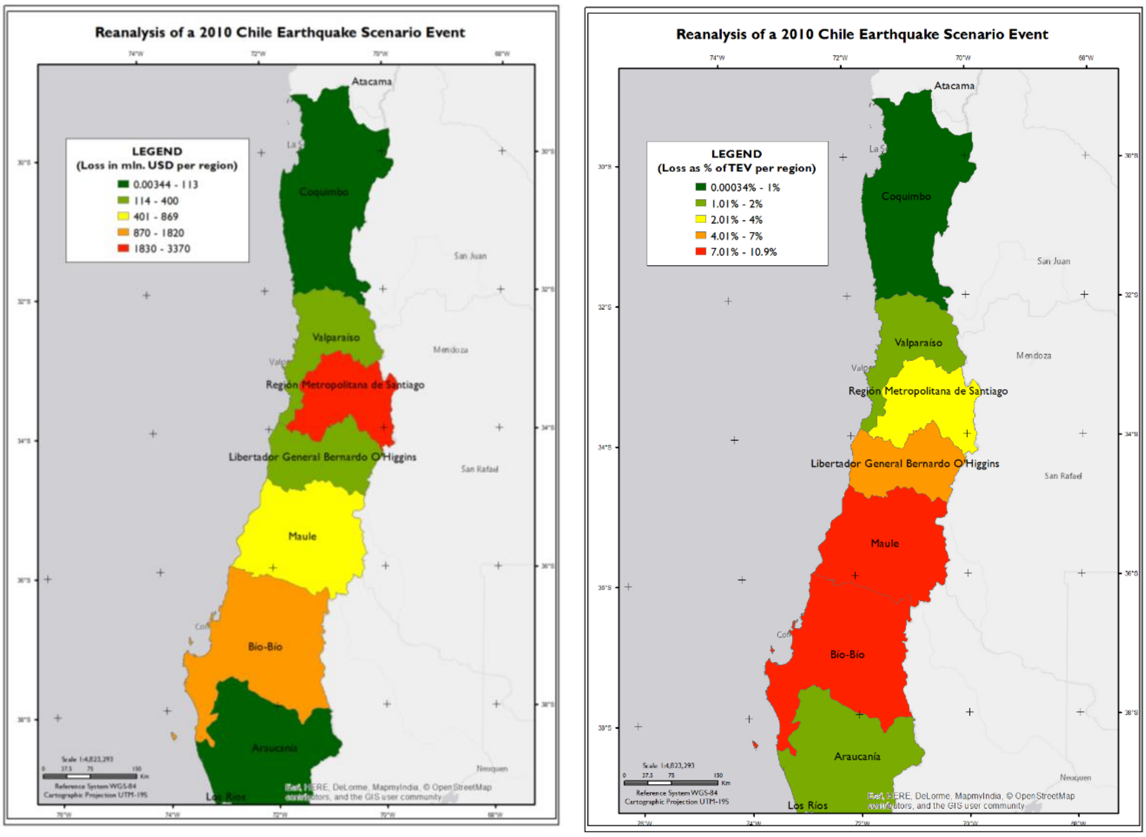


Figure 5: Left: absolute and Right: relative losses on an administrative level 1 unit (regions)

The large magnitude of the event, associated with and extensive fault rupture zone culminated in large numbers of damaged and destroyed houses, with 85.6% of the residential capital stock of the country being exposed to a peak ground acceleration greater than 2% g (properly felt). Losses were highest in the unreinforced building stock such as adobe housing or unreinforced clay brick portion of the residential stock.

Typology	All Exposure (USD mill.)	Exp. PGA > 0.02g (USD mill.)	Loss (USD mill.)	Loss Ratio (%)
1-2F Adobe Houses, Single-Family (SF)	2,528	2,256	757.5	29.97%
1-2F Unreinf. Clay Brick masonry House, SF	9,764	9,229	2,772.3	28.39%
3F Conf. or Unreinf. Clay Brick masonry Apartm. Block, Multi-Family (MF)	454	447	126.6	27.91%
3F Reinf. or Conf. Concr. Block masonry Apartm. Block, MF	1,777	1,623	167.2	9.40%
1-2F Reinf. or Conf. Concr. Block masonry Apartm. Block, SF	19,219	18,241	1,605.0	8.35%
1-3F Reinf. Concrete House, SF	20,212	16,078	751.0	3.72%
1-2F Reinf. or Conf. Concr. Block masonry House, SF	6,252	3,692	191.7	3.07%
4-5F Reinf. or Conf. Concr. Block masonry Apartm. Block, MF	246	218	6.0	2.44%
4-5F Conf. Clay Brick masonry Apartm. Block, MF	2,165	2,104	24.4	1.13%
1-2 F Reinf. Clay Brick masonry House, SF	30,485	26,675	306.9	1.01%
4-5F Reinf. Clay Brick masonry Apartm. Block, MF	3,225	3,038	19.6	0.61%
3-9F Reinf. Concrete Apartm. Block, MF	15,115	12,978	45.7	0.30%
3F Reinf. Clay Brick masonry Apartm. Block, MF	426	402	0.6	0.14%
1-3F Timber Houses, SF	32,115	25,247	28.3	0.09%
10-24F Reinf. Concrete Apartm. Block, MF	26,561	23,878	15.1	0.06%
25+F Reinf. Concrete Apartm. Block, MF	6,858	5,901	1.2	0.02%

What is the return period of such an event?

Using the GAR2015 and scaling the residential portion, this would represent a 215 year event, which seems high considering that a number of events have struck Chile with higher economic loss ratios historically. However, given the amount of exposed stock and the spectral response, this event is likely in the order of a 100 year event plus. The uncertainties on loss estimates from historic events means the 1906 Valparaiso (23.8%); 1939 Chillan/Concepcion earthquakes (9.5%); 1960 Concepcion earthquakes (5.4%) and the 1985 Valparaiso earthquake (1.5%) are difficult to place, however the large impact on Santiago in the 2010 event, and the change in vulnerability as a result of code enforcement mean that the historic loss ratios are much higher than they would potentially be today.

Why was it important to collate the data?

The 2010 Chile event was an event where there was a significant amount of information and many studies undertaken post-disaster. However, this also meant that there were many conflicting numbers post-disaster.

With a 4 times difference in residential exposure between the GAR2015 and GEM-SARA project exposure estimates, it was decided that the Gunasekera et al. (2015) approach of top-down capital stock and bottom-up unit price estimates would be undertaken to resolve the difference.