

## Lessons for Insurance: Risk Management and Engineering in the major Earthquakes of 2010-2011

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### ► Lessons and Opportunities for Insurers and Insureds

*This paper is a brief summary of the primary lessons for insureds and the insurance industry to be learned from the five major earthquakes of 2010-2011. The insurance industry can draw important lessons from these events because they occurred in three of the most advanced countries, and one of the least advanced countries, for the practice of earthquake engineering. The lessons have implications for earthquake engineering, but also for non-structural loss prevention and business continuity. These earthquakes included two of the largest and potentially most destructive earthquakes to occur in the modern era of engineering and insurance – the Magnitude (M) 8.8 Chile and the M 9.0 Great East Japan (Tohoku, Sendai) EQ. The other three earthquakes occurred in areas without recent histories of strong earthquakes – Christchurch, New Zealand with M of 7.1 and 6.3 and Haiti with M of 6.9 – even though both countries are in two of the most active earthquake regions in the world.*

**The primary lessons for the insurance industry are summarized below and expanded upon in the following sections:**

1. All five earthquakes (and one tsunami) exposed insureds and insurers to much higher risks than they had calculated. Seismologists, engineers, and insurers did not adequately understand the potential strength of the shaking, and the earthquakes dramatically exceeded the requirements of the local building codes. Consequently, damage was much worse than generally expected. Future insurance underwriting and loss control must reflect this in order for insurers to understand their true exposure.
2. There is a major difference between the *expectations* of insurers and insureds regarding earthquake damage and the *intent* (or expectations) of building codes. Most businesses generally do not understand that earthquake codes in the most advanced countries protect primarily against injuries and building collapse and not against financial or property loss. Further, fundamentally there is minimal, if any, mandated protection against business interruption. The earthquakes of 2010-2011 demonstrated this dramatically.
3. Most of the financial loss in Chile stemmed from easily preventable non-structural and equipment damage. The same occurred in Japan in areas not affected by the tsunami. To reduce these easily preventable losses, insurers and insureds can adopt risk improvement and loss control standards for earthquakes that are similar in structure and execution to those for fire protection engineering and underwriting.
4. Preventing non-structural and equipment damage through risk improvement and loss control is critical for (1) reducing business interruption (including suppliers), (2) emergency planning and business continuity planning, (3) reducing employee injuries, and (4) reducing insured losses. Annualized loss control is the best solution.
5. Catastrophe modelling as practiced by the insurance industry is grossly inadequate for individual risks, for facultative risks, and for any significant industrial risks. In these cases, insurers and insureds must have a detailed understanding of the engineering aspects of the systems involved, and of the specific potential for business interruption. The insurance industry needs to understand the implications and to demand loss control and engineering-based modelling specific to individual sites or portfolios.
6. Business interruption modelling can give insurers and insureds false confidence if it does not include detailed risk improvement and loss control measures. Understanding and improving interruption scenarios, as well as modelling specific critical systems and their financial implications, are also necessary.
7. On the positive side, the good performance in Chile of a certain low-cost earthquake resistant structural system, called *confined masonry*, demonstrated that disasters like Port-au-Prince in Haiti can be avoided in areas with minimal earthquake standards and building practices.
8. Both the Chile and the Japan earthquakes demonstrated that certain types of modern buildings perform very well, even in M 9.0 earthquakes. Insurers, insureds, and other stakeholders could benefit by carefully examining the reasons for this good performance and adapting their practices to reflect the lessons they have learnt. This is particularly true in the US (especially California and the Pacific Northwest), Canada (British Columbia), as well as many countries in Latin America, Southern Europe and Asia.

## ► The five major Earthquakes of 2010-2011: An Overview

The countries most advanced in the practice of earthquake engineering, in no particular order, are California, Japan, Chile and New Zealand. In the span of a little over one year, all but California were affected by significant earthquakes – often the largest earthquakes to strike the respective regions since the advent of modern earthquake engineering.

The **M8.8 Central Chile 2010 earthquake** was, from an engineering and insurance perspective, the most important earthquake in modern earthquake history. It was the first mega-earthquake, with a magnitude near 9, to strike modern (and insured) cities with state-of-the-art structures, industries, and infrastructure. Chile has excellent structural and earthquake engineering. It has a modern building code that is comparable to and often exceeds the requirements of the codes of California and Japan. Intense ground shaking that lasted about 120 seconds and a major tsunami tested all this and affected 82% of the country's population over an area roughly equal to half of California.

The **M9.0 Tohoku (Sendai), Japan earthquake** was similar in size to the Chile earthquake and affected a comparable region of Japan, a little less than half of the Island of Honshu, the largest island of Japan. It was the second mega-earthquake, after Chile, to strike well-designed modern cities. It was also the first mega-earthquake in an advanced economy to cause tsunami damage that far exceeded the damage caused by the earthquake shaking itself. The earthquake also demonstrated the reactive nature of the building codes and regulations, and of the insurance industry. The nuclear

industry of Japan had failed to keep up with modern tsunami research and knowledge; consequently, the industry had not increased requirements for protection against tsunamis at nuclear power plants. This failure to increase regulatory (code) requirements led to the largest single financial loss from an earthquake ever – the loss of several units at the Fukushima Nuclear Power Plant and the extended closure of many other nuclear power plants, most of which were unaffected or likely undamaged, and the associated losses of revenue.

In New Zealand, the earthquake code effectively has three levels of zonation (and thus three levels of design and three zones for earthquake insurance) based on the history of New Zealand earthquakes and extensive state-of-the-art seismology and geology studies. These design zones are (A) High-risk earthquake areas, (B) Moderate-risk earthquake areas, and (C) Low-risk earthquake areas. Christchurch and the surrounding Canterbury region are far removed from the largest and most feared fault system in the country – the Alpine Fault (which is comparable to and very similar to California's San Andreas Fault) and thus are in a low-risk zone. The **M7.1 Christchurch earthquake of September 4, 2010** occurred on a previously unknown fault; fortunately, the epicenter of this major earthquake was far enough from Christchurch so as not to cause major damage to newer structures.

However, the **M6.3 Christchurch earthquake of February 22, 2011**, (an aftershock of the 2010 earthquake) was centred almost directly underneath the center of Christchurch, even though

Christchurch is located on the boundary of the Moderate and Low earthquake code zones. Consequently, buildings there were designed and also retrofitted to relatively low standards. The earthquake caused short but extremely strong ground motions, greatly exceeding the design requirements of a "low-risk" area; effectively none of the buildings in the city were designed for such ground motions. Most of the older buildings in Central Christchurch were damaged severely; many collapsed. Several large, modern, occupied buildings collapsed. Many new buildings, including most high-rise buildings, suffered severe damage. In less than 15 seconds, Christchurch, the country's second largest city, became a ghost town for months to come. The financial and economic consequences were severe and are still ongoing.

In complete contrast to the above four earthquakes, the **M7.0 Haiti (Port-au-Prince) earthquake of 2010** occurred in an area where most buildings were not designed to be earthquake resistant. From engineering, humanitarian, and insurance perspectives, this earthquake presents a worst-case scenario for a densely populated city with little or no earthquake design in a known earthquake region without many high-rise and large commercial and residential buildings. In terms of loss of life and property, the Haiti disaster will likely only be exceeded by strong earthquakes centred on some of the world's largest cities, which often have inadequate construction and engineering practices but contain many high-rises and other large buildings. These include Manila, Teheran, Istanbul, Beijing and many other large cities in China and India, Indonesia, South and Central America, and elsewhere.

## ► Main lessons for Insurers and Insureds from the Earthquakes of 2010-2011

### 1. All five earthquakes (and one tsunami) exposed insureds and insurers to much higher risks than they had calculated.

In all five earthquakes, the strength of the shaking greatly exceeded the expectations of insurers, seismologists, and engineers. This points to a possible generic lack of conservatism in the codes around the world, including the codes of the best prepared countries such as Chile, Japan, and New Zealand. What about other earthquake prone countries such as those in Central and South America and the Caribbean, North America, Southern and Southeastern Europe, parts of the Middle East and Central Asia, all of South and East Asia and China?

Insurers can most easily address this issue in the underwriting domain, where (1) future underwriting can be more conservative, and (2) additional loss control can be required, just like it is in fire loss control and underwriting. The insurance industry uses earthquake hazard maps that are not conservative enough, and may even be wrong, based on the earthquakes of the last two years. The sophisticated probabilistic CAT models used by the industry generally failed in Japan and New Zealand. In Chile, the overall numbers for reinsurance were reasonable but the details were inaccurate. That might have been acceptable from a reinsurance perspective, but not from that of an insurer or an insured.

In Chile, shaking "beyond code" caused extensive damage to new tall (high-rise) buildings that were designed to the latest standards, including more flexible structural systems. In Concepción, for example, 10% to 20% of tall buildings suffered severe structural damage and will be torn down and replaced at great cost. In Japan,



the strength of the shaking and its duration also exceeded the requirements of the codes, as exemplified by the design criteria exceedance at several nuclear power plants (which also occurred in the 2007 M6.8 Kashiwazaki, Niigata earthquake). Numerous tsunami walls were overtopped along Japan's northeast coast, as happened in the 1993 M7.8 Nansei-oki, Hokkaido, Japan earthquake. In that earthquake, a 10-meter tsunami overwhelmed the 5-meter high tsunami wall surrounding the lower part of the town of Aonae on the Island of Okushiri. These should not have been lessons learned following an earthquake because the technology to predict these earthquake and tsunami characteristics exists in both Japan and Chile.

As discussed above, the same earthquake effects (excluding tsunami) happened in New Zealand – but to a greater extent because of the erroneous zonation of the region coupled with very poor soils. Many, if not most, of the tall buildings in Christchurch, all of which are relatively new, will be torn down. The cost of replacing them is in the order of three times the original cost (original cost, tear-down cost plus effect on surrounding buildings, plus replacement cost). This does not include the cost of business interruptions.

## 2. There is a major difference between the expectations of Insurers and Insureds regarding earthquake damage and the intent (or expectations) of building codes.

The public and insureds generally do not understand that earthquake codes in the most advanced countries protect primarily against injuries and building collapse, not against financial or property loss. They typically expect near total protection from buildings “built to code” because they have not been involved in the development of earthquake code requirements. The public, long-term owners, insurers, and diverse public interests should all be involved, not only the professions and a few public officials. The five earthquakes point out clearly that a wider public involvement is necessary in the development of earthquake codes, particularly by the insurance industry. Again, the development of risk improvement and loss control for fire protection, with broad insurance industry support over many years, is a good example to emulate.

In California, for example, the code states that moderate structural damage is acceptable in moderate earthquakes and severe structural damage is acceptable in the largest earthquakes, so long as the damage does not cause injury or death. This does not preclude general building collapse, however, as the codes are reactive to earthquake lessons and are not generally proactive. The codes

do not reflect the latest developments in design and construction, some of which can be dangerous. There is minimal, if any, protection mandated in the codes against business interruption. The earthquake requirements for fire protection systems go a little further, but generally smaller diameter fire lines are not adequately braced for earthquakes. The only exceptions to functionality and business interruption are schools, hospitals, nuclear power plants, and certain government buildings and infrastructure, where specific and separate codes and/or requirements govern the earthquake resistance. That resistance is set at a much higher level than for ordinary commercial and industrial structures and buildings.

The earthquakes of 2010-2011 dramatically demonstrated the rift between the public's expectations and the intent of the building codes. Numerous new high-rise buildings, both commercial and residential, were fatally damaged during the earthquake in Chile (in Concepción, Viña del Mar, Santiago, etc.) and were left leaning a few degrees, often surrounded by other tall and occupied buildings in the middle of cities. The buildings, with a few exceptions, did not collapse and cause casualties but were total losses, much to the surprise of their owners and to public officials.

Insurers can improve underwriting practices through deeper reliance on engineering and loss control and less on portfolio modelling. The Christchurch earthquake is the best example for this need, as most of the earthquake losses were covered by insurance, leading to large losses. These “surprising” losses should not have happened in one of the most earthquake active countries in the world, where good engineering and construction practices prevail. The Christchurch earthquake insurance scenario is reminiscent of the 1994 M6.6 Northridge, Los Angeles Area, California earthquake. There, the 20th Century Insurance Company, which was headquartered in the epicentral area of the earthquake on an unknown fault, which happened to occur in the heart of its property portfolio.



## 3. Most of the financial loss in Chile stemmed from easily preventable non-structural and equipment damage.

Easily preventable non-structural and equipment damage, and resulting business interruptions, caused most of the financial loss in the very large earthquake in Chile. The same happened in Japan in the areas outside the reach of the tsunami. Considering that the content of buildings is frequently more valuable than the structures themselves, a large portion of insurers' and insureds' potential losses is not addressed at all in building codes.

This is a relatively new and an interesting development in earthquake engineering. Figure 1 below shows the relative investment costs in the Western United States of the structural part of a building vs. the non-structural parts (suspended ceilings, finishes, equipment, tenant improvements) and the physical contents of buildings. The graph shows office buildings, hotels, and hospitals (which have expensive equipment and contents). The structural costs of a modern building are typically between about 8% and 15% of the total value. The rest is made up of finishes and contents. Again, the codes require earthquake protection for the structures and minimal protection for the non-structural portion, which makes up 50% to 70% of the value of the building. Effectively, today's earthquake insurance is covering the finishes of a building.

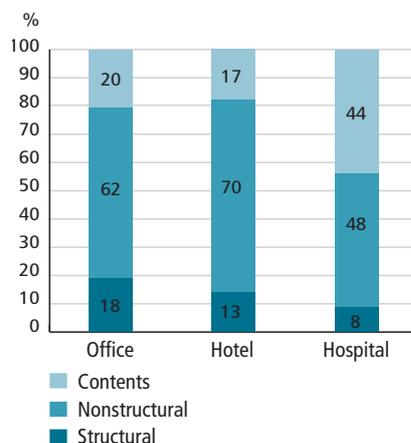


Figure 1. Relative investment costs for new buildings - comparison of structural, non-structural, and content costs for typical classes of buildings. (Federal Emergency Management Agency, 2011).

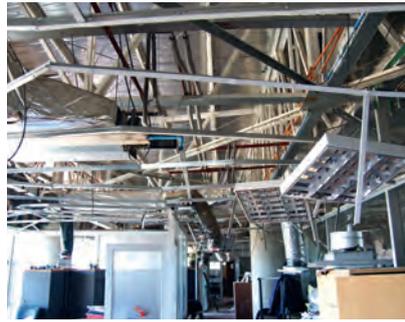
The Chile and Japan earthquakes extensively damaged the interior non-structural and architectural features and the mechanical and electrical systems of new commercial and other buildings, including hospitals and other critical structures. Similar, but more limited, damage has been repeatedly observed in earthquakes in California, for example, but these earthquakes were much smaller and of shorter durations.

Figure 2 below shows a typical example from Santiago, Chile. The five story office building (upper left) is surrounded by many other new buildings and buildings under construction in a new business park. The building was structurally undamaged but the interior was essentially destroyed. The loss is in the order of 50% or more, without structural damage.



**Figure 2.** Structurally undamaged new concrete building in Santiago (upper left). Note the undamaged windows in the lobby and the water damage from broken water pipes in higher floors in the photograph on the upper right. The lower two photographs show interior damage to inadequately braced office partitions, suspended lights and other fixtures, suspended ceilings, suspended heating, air-conditioning and ventilating equipment, computers, etc.

The damage was typical throughout Chile, New Zealand, and Japan, as also shown in Figures 3 and 4 below. The damage shut down for extensive periods structurally undamaged office and retail buildings, hospitals, industrial buildings and complexes, airports, computer and control centers, etc.



**Figure 3.** Damage to a transportation computer center inside an undamaged building in Concepción, Chile. Note the undamaged glass facade of the building. The third photograph shows a server room with inadequately braced/anchored and now destroyed servers, IT equipment cabinets, and other related equipment.



**Figure 4.** Christchurch, New Zealand. The damage to the facade of this shopping mall building was caused by the sliding (movement) and collapse of rooftop-mounted air handling equipment that was not anchored properly. A remaining air-handling unit can be seen in the upper right. The interior non-structural elements of the building were also damaged extensively.



**4. Preventing non-structural and equipment damage through risk improvement and loss control is critical for (1) reducing business interruption (including suppliers), (2) emergency planning and business continuity planning, (3) reducing employee injuries, and (4) reducing insured losses. Annualized loss control is the best solution.**

The solution to this problem is relatively easy and has already been applied to some classes of buildings in California, for example. These include schools, hospitals and critical government buildings. The requirements include better bracing and anchoring of equipment and other non-structural features that can cause business interruptions.

Most of the necessary risk improvements are inexpensive, including retrofits, through loss control programs. To reduce these easily preventable losses, insurers and insureds need to adopt risk improvement and loss control standards for earthquakes that are similar in their structure and execution to those for fire protection engineering and underwriting.

Further, any non-structural and equipment risk improvement and loss control program needs to be maintained over time, otherwise it loses its resilience. That is the case for fire protection and it is also the case for maintaining earthquake resistance to non-structural systems and critical equipment. Good examples are computer centers, where equipment is regularly changed and moved and must be continuously anchored or re-anchored.



**Figure 5.** Unanchored and tipped-over electrical equipment in the 1999 M7.6 Central Taiwan earthquake. The solution (anchor bolts) is shown on the right of the right photograph. That particular IT rack is standing next to another one that is not anchored and that will fall over in a strong earthquake. The racks are part of the control system for a major Metro system in the U.S.

### 5. Catastrophe modelling as practiced generally by the insurance industry is grossly inadequate for individual risks, for facultative risks, and for any significant industrial risks.

For individual risks, facultative risks, and any significant industrial risks, insurers and insureds must have a detailed understanding of the engineering aspects of the systems involved, as well as the specific potential causes of business interruption. By understanding the implications and demanding loss control and engineering-based modelling specific to individual sites or portfolios, insurers can better predict losses of all types.

The following example of business interruption is taken almost verbatim from one of the authors' publications following the M6.8 2007 Niigata (Chuetsu Oki) Japan earthquake. The earthquake caused limited but concentrated damage in the vicinity of Kashiwazaki, just south of the City of Niigata. A few large industrial and commercial facilities were affected. They present ideal case studies for earthquake risk management. The name of one of the companies that is discussed below, although well known, is not important for the purposes of this paper. Most large companies and organizations around the world would have done no better, as was clearly shown following the much larger earthquake in Japan four years later.

Japan's largest manufacturer of piston rings and other parts used in cars and trucks was located in a single facility in the Town of Kashiwazaki in 2007. Following the earthquake the business media reported that the plant manufactured about 40% of all piston rings for the Japanese automobile industry. The plant is a sprawling, mostly

older manufacturing facility, with dozens of buildings and mostly relatively low-tech manufacturing operations. For the most part, the structures performed adequately (Figure 6) and did not contribute significantly to the roughly 10 days of loss of operations. That business interruption was caused almost entirely by damage to equipment. The primary cause of damage was the inadequate or non-existent anchorage of equipment. 1,240 out of 1,840 of heavy machinery (70%) slid or toppled during the earthquake. All of this damage could have been



**Figure 6.** Some of the structures that were undamaged or lightly damaged at the piston ring manufacturing plant.

prevented with simple equipment anchorages and braces through a risk improvement and loss control program.

The company's management described the earthquake motion as a series of strong lateral shocks, three or four of which knocked down or pushed sideways the unanchored equipment. The duration of the earthquake shaking was in the order of 15 seconds; the duration of the much larger 2011 earthquake was about 120 seconds. As the equipment slid or fell over it also damaged attached piping, ducting, electrical conduits, etc. Equipment that was bolted down to its foundations, such as heavy rotating machinery that must be anchored in order to operate properly, was not damaged.

The shutdown of production widely affected most of Japan's auto industry. Most of Japan's major auto manufacturers, all of whom use just-in-time supply chains, could not manufacture cars without parts from their main supplier. The auto manufacturers, who are not located in Kashiwazaki and were not directly affected by the earthquake, sent large teams of their own engineers and machinists to assist their supplier in Kashiwazaki with engineering and repair, allowing the supplier to restart operations more quickly. Nevertheless, the overall result was a loss of production of a reported 120,000 vehicles. That loss was greater than the direct damage to the plant and its manufacturing equipment.

This case occurred during a moderate earthquake in one of the world's most sophisticated economies. What if the earthquake had had a much larger magnitude, 7.5 instead of 6.8? Building damage would have been extensive and equipment damage much worse. The business

interruption could have lasted months instead of days. Because of inadequate earthquake risk management at just one company, Japan's automobile industry would have faced a huge financial loss. Of course, all of that happened in March 2011 in a M9.0 earthquake centered near Sendai, to the northeast of Kashiwazaki. As of late August 2011, one of the world's biggest auto manufactures is still unable to ship some of its best selling cars around the world because of damage to a supplier.

**6. Business interruption modelling can give Insurers and Insureds false confidence if it does not include detailed risk improvement and loss control measures. Understanding and improving interruption scenarios, as well as modelling specific critical systems and their financial implications, are also necessary.**

Since the 1995 Northridge earthquake in the Los Angeles area, insurers and reinsurers have relied heavily on the modelling of insurance portfolios. The senior author of this paper has been involved in probabilistic, computer-driven modelling since he co-founded EQECAT Inc., one of the three main modelling companies. Some of the main drawbacks and weaknesses of modelling have become obvious to us after years of running models and investigating the effects of over 100 earthquakes around the world. Many of these earthquakes are part of the modelling software available to the industry today. The five earthquakes of 2010-2011 reinforce some of these observations.

The modelling of business interruption using generic software and generic damage functions is not possible except in the simplest cases, and even then it requires some engineering studies to understand the specifics of the systems that would be damaged and/or interrupted. Accurate modelling of business interruption for the business park illustrated in Figure 2, for example, is impossible without having detailed engineering data on the buildings and their non-structural characteristics. Knowing whether the building has a steel-frame or a reinforced-concrete frame and whether the soils are soft or not is not nearly enough. Figure 7 illustrates the problem. The building in Figure 7 is a few hundred feet from the building in Figure 2. Both structures are undamaged. Their glass facades are intact; there is absolutely no facade damage in Figure 7. The interior of the building in Figure 2, however, has extreme damage. The interior of the building in Figure 7 has absolutely no damage. The soils are the same – relatively soft. The details of the non-structural aspects of the buildings are very similar. The one difference

is that the building in Figure 7 is very stiff whereas the building in Figure 2 is relatively flexible (it is typical of similar buildings in California). Both buildings housed computer centers. Business interruption lasted many months for Figure 2 and just a few weeks for Figure 7. Damage to the overall business park, the unavailability of labor, and damage to the utilities serving the business park caused the business interruption for the building in Figure 7. All of these variables can only be predicted through engineering loss control assessments, which can then be included in the models.



Figure 7.

The failure of battery racks required to run emergency systems represents some of the most extreme cases of easily controllable business interruption. For example, if a power plant is operating when a strong earthquake occurs and its emergency batteries are damaged, which is a very common occurrence, the small lubricating oil pumps pumping lubricant to the bearings of the turbines stop. That damages severely the bearings and the very complex turbines themselves. A detail worth a few hundred dollars causes business interruptions worth tens or hundreds of millions of dollars. This type of damage and extreme business interruption has been repeated in almost all strong earthquakes affecting power generation plants. Again, an engineering inspection is key for accurately modelling power facilities. The situation is comparable to modelling a fire protection system on the basis of the age of the building that houses it.

**7. On the positive side, the good performance in Chile of a certain low-cost earthquake resistant structural system, called confined masonry, demonstrated that disasters like Port-au-Prince in Haiti can be avoided in areas with minimal earthquake standards and building practices.**

In areas with generally low-quality construction, such as rural areas in South America, insurers can inexpensively increase safety and minimize losses by promoting confined-masonry construction. Engineered Confined-Masonry Buildings are masonry buildings (typically un-reinforced brick or concrete block) built with reinforced concrete frames that are poured in-between the bricks, thus providing interlocking and some continuity in the structures. This is by far the most inexpensive type of earthquake resistant construction that has performed well in strong earthquakes. When properly designed and built, one and two story buildings of this type performed very well in the 2010 M8.8 Chile earthquake, even in areas that experienced very strong and long shaking. This type of buildings has been popular in Chile since the late 1930s and has repeatedly performed well.

Figure 8 below shows a side of a typical confined masonry building that survived the 2010 Chile earthquake with no significant structural damage. A new, multi-story hotel adjacent to the building suffered extensive damage.



Figure 8. A lightly damaged confined masonry building in Talca, one of the most damaged cities of Chile in 2010.

Confined-masonry could be a good solution for inexpensive residential and small commercial buildings in the less developed earthquake areas throughout the world,

including the Caribbean, Central and South America. A little structural engineering and a little more reinforcing steel in the right places of the concrete frame, such as can be seen

in **Figure 9**, made the difference between the successful buildings in Chile and the devastation of otherwise-similar buildings in Port-au-Prince, Haiti in 2010.



**Figure 9.** The new terminals at Santiago's International Airport (left) and Sendai's Airport (right). Both structures had light structural damage but extensive non-structural damage (and long business interruptions). Note the undamaged glass facades in both buildings. The lack of damage to the glass indicates that the structural design was excellent. The Sendai terminal suffered extensive tsunami damage to its first floor (the damage in the lower foreground).

**8. Both the Chile and the Japan earthquakes demonstrated that certain types of modern buildings perform very well, even in M 9.0 earthquakes. Insurers and Insureds can benefit from this lesson.**

The five earthquakes of 2010-2011 demonstrated that certain types of modern buildings perform very well in earthquakes. What is new is that those buildings performed well even in M8.8 and M9.0

earthquakes. This knowledge needs to be transferred to the insurance industry – into the modelling software which is currently too dependent on classes and ages of buildings and into underwriting practices which must rely more on engineering and accurate modelling data collected through field inspections. These are critical lessons because they expand our understanding of the performance of modern structures to mega earthquakes. This knowledge did not exist before the 2010 Chile earthquake.

It was strengthened by the observations from the 2011 M9.0 Japan earthquake.

**Figures 9 and 10** (opposite) summarize the lessons to be learned. Modern buildings can perform well, or they can collapse. In Chile older modern buildings often performed better than new buildings. The difference in performance was due to the earthquake engineering details and systems built into the structures.



**Figure 10.** Three adjacent structures in Concepción, Chile are shown in the top photograph after the 2010 earthquake. The collapsed steel silos in the foreground of the first photograph are much newer than the much less damaged and much older steel silos in the back. The lightly damaged building in the left of the first photograph is shown in the middle photograph. It is much older than the collapse new tall apartment building in the third photograph. The collapsed building was new.

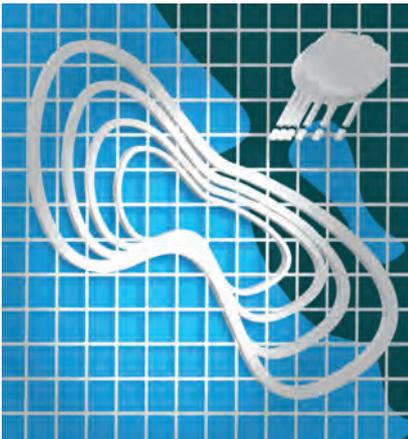
## ➤ Conclusion

While seismology, earthquake engineering and catastrophe modelling are ever evolving sciences, when insureds, insurers and reinsurers work with specialists, it is possible to minimize the loss of life, as well as the financial impact insured and non-insured

that earthquakes can cause. SCOR continually invests in helping our clients and our industry better understand and prepare for such events. Through the SCOR Global Risk Center, we aim to gather and analyse the most interesting resources about risks

and related subjects concerning insurance and reinsurance, based both on data and resources produced by SCOR itself, and on all other resources available.

**Jean-Paul Conoscente**  
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*Peter Yanev, of Yanev Associates, LLC, is one of the world's leading authorities in earthquake engineering and risk management. Yanev Associates specializes in cost-effective earthquake risk mitigation, with an emphasis on minimizing business interruption following earthquakes. Peter Yanev founded EQE International & EQECAT in San Francisco in 1981 and 1994, respectively, and has worked in earthquake risk management since 1970. Currently he is the senior consultant to the World Bank for earthquake projects. He sits on academic boards at University of California Berkeley and the Massachusetts Institute of Technology, where he earned degrees in structural engineering. Peter Yanev, who authored the best-selling earthquake preparedness guide "Peace of Mind in Earthquake Country", has lead field investigations to over 100 earthquakes worldwide since 1971.*

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