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SOCIETAL REALITIES OF EARTHQUAKES AND PROSPECTS OF LOW-DAMAGE STRUCTURES

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Abstract: Building and infrastructure have been traditionally designed to ensure life safety and to protect people from serious injuries. Minor to moderate damage to the structures after a major event such as an earthquake is expected as an acceptable compromise. But a new level of realization has evolved in recent years in the wake of a number of earthquakes; the economic consequences of even a moderate event can be very severe even without any loss of life and catastrophic collapse of structures. The money and time required to repair damaged structures is unacceptable in many cases, particularly when the facility is out of service for a long period of time. There is increasing demand on the engineering community to find better solutions that avoid this type of scenario. The "Low-damage" concept has been proposed by researchers in New Zealand to eliminate the cause of such problems through solutions that provide building design concepts that result in minimum damage, can be repaired easily and quickly, and without significant cost. The realities and prospects are investigated for societies in developed and developing environments to awareness and avoid potential similar scenarios.

1 INTRODUCTION

Recent earthquakes in New Zealand, Chile and the United States have shown that despite low numbers of human casualties the economic effects of a major earthquake can be significant even for a developed economy. The additional social and emotional consequences due to the inconveniences can also be very troublesome for the community. While traditional ductile design philosophy generally helps to provide life safety it does not necessarily limit damage to structures or downtime for its owners and occupants. Fortunately, new technology has been developed over the last three decades that can help prevent such calamities. First developed for precast concrete structures the self-centering jointed ductile concept has emerged as the "low-damage" concept for a range of materials in various arrangements. The necessity and applicability of the concept has been justified by the aftermath of recent earthquakes, in particular the series of events around Christchurch in 2010-2011. Since then it has gain increased acceptance and the growing list of structures with concrete, steel and timber underlines society's demand of superior level of performance of the built environment.

2 LESSONS FROM CHRISTCHURCH EARTHQUAKES

The series of earthquakes in the Canterbury region of New Zealand included two major events of magnitude 7.1 and 6.3 on 4 September 2010 and 22 February 2011 respectively. There were 185 casualties in the second event but no lives were lost in the first. Despite that there was wide-spread damage to Christchurch Central Business District (CBD) with thousands of buildings damaged to various levels (Kam et al 2011, Elwood et al 2013). In the following months it became evident that a large number of buildings were in such conditions that it was technically possible to repair and re-occupy them but the cost of repair was too high to be justified. Eventually it was decided for over 1500 buildings that they would be demolished and re-built at later stages which is yet to be completed after more than six years. Figure 1 explains the situation: the red, yellow and green tags indicate demolition, repair and safe states for buildings, respectively.

Figure 1: Distribution of building designations in Christchurch CBD after the earthquakes in 2010-2011 (Kam et al 2011, left) and aerial view of the CBD with empty lots after demotion (Pampanin 2012b)

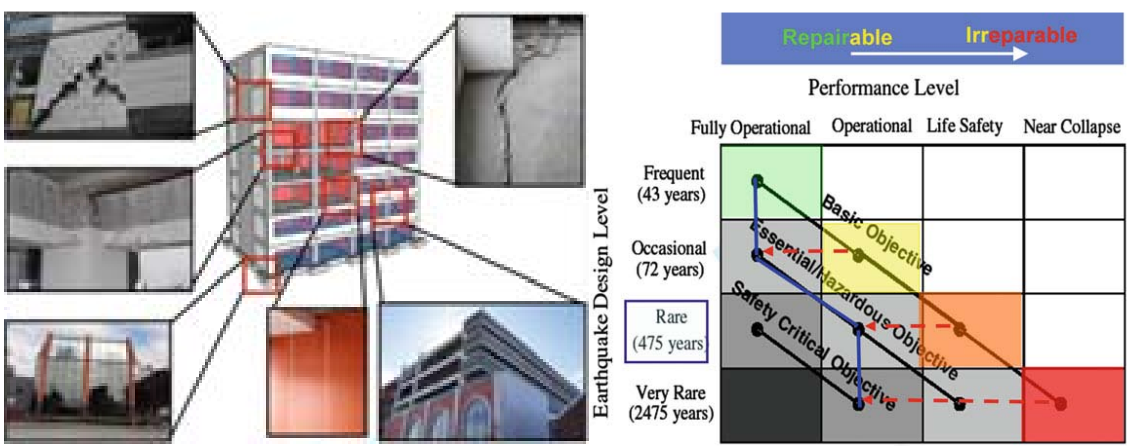

Figure 2: Damages in a building: structural (wall, frame system, floor), non-structural (partition, façade) and foundation (Pampanin 2015, left) and seismic performance objective matrix with proposed modifications and the basic objective curve (blue line) following low-damage approach (after Pampanin 2015, right)

3 ALTERNATIVE SOLUTIONS WITH LOW-DAMAGE STRUCTURES

As part of a major research project on precast concrete structural systems for seismic regions Stanton (1997) developed the “Hybrid” concept (Figure 3) that combining post-tensioning with energy dissipating elements. The rocking connections exhibit self-centering and significant energy dissipation during ground shaking with almost no structural damage or residual deformations. The concept was promoted as “Damage Avoidance Design (DAD) by Mander (2004) and subsequently adopted to steel (Chancellor et al 2014, MacRae and Clifton 2013) and timber (Buchanan et al 2012) as well as coined “Low-Damage”.

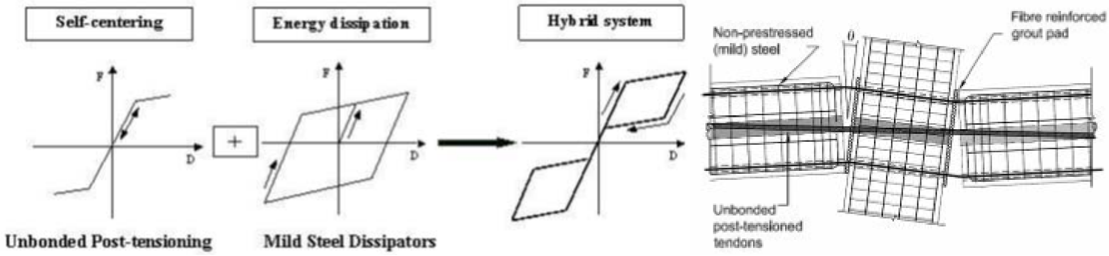

Figure 3: Components of self-centering jointed ductile (Hybrid) system (after Stanton et al. 1997, left) and a practical arrangement for precast concrete hybrid beam-column joint (right)

The consequences of the Christchurch earthquakes brought renewed focus on the approach (Pampanin 2012a,b, 2015) both in terms of further research and developments as well as applications. It was identified as a viable alternative to traditional construction for improved performance (Royal Commission 2012). Practitioners also took interest and a number of structures utilizing the technology have already been designed built with concrete, steel and timber (Figures 4 -6) within New Zealand (Brown et al 2014, Latham et al. 2013, Pampanin et al. 2012a,b). Further work is continued for an Integrated Low-Damage System intended for holistic improvement of building performance with carefully designed multiple details with a single structure (Pampanin 2015).

Figure 4: Example applications of Hybrid concept in practical concrete structures (Pampanin et al. 2012a)

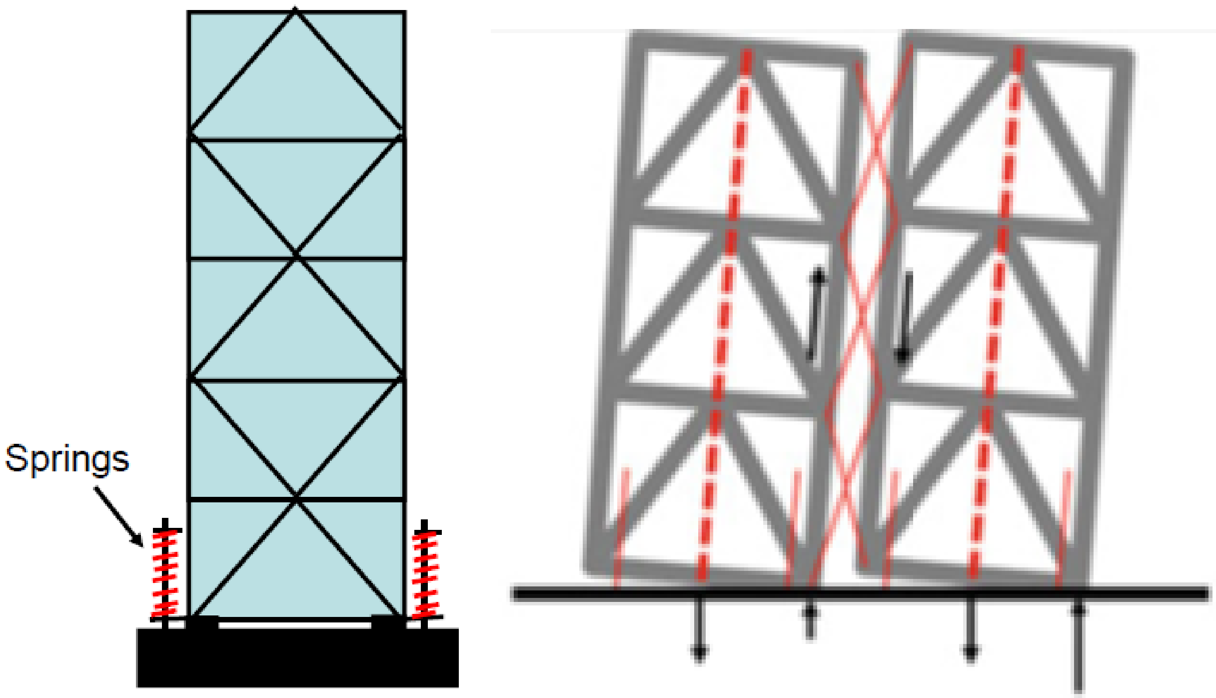

Figure 5: Example applications of Hybrid concept in steel structures (Latham et al. 2013)

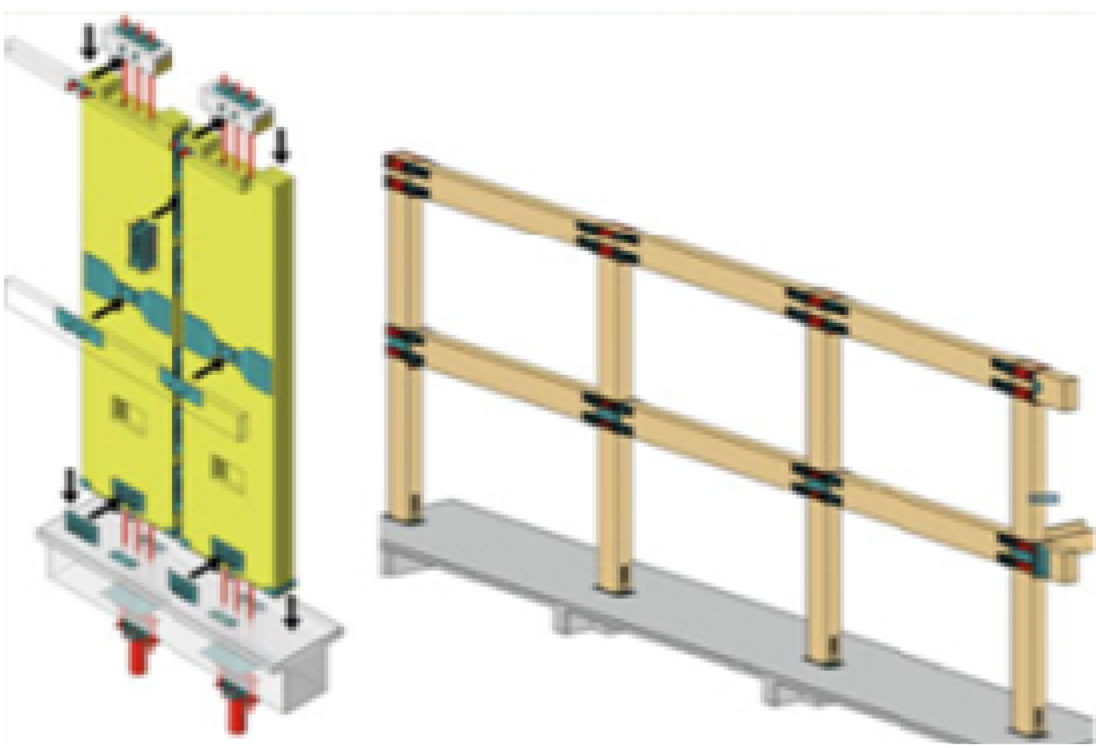

Figure 6: Example applications of Hybrid concept in practical timber structure (Brown et al. 2014)

4 CONCLUSIONS

Observations of building performance and damage in recent earthquakes have shown that the traditional ductile design philosophy is generally the best strategy for life safety but that is no longer sufficient to avoid wide-spread damage and loss of properties. The financial consequences and practical inopportuneness to a significant population after a major earthquake is simply unacceptable and that realization is leading to growing demand for better solutions that can minimize damage and downtime as well as providing life safety. Low-damage design approach promises to achieve that. Professionals and the community in general need to be made aware of the potential opportunities and accompanying benefits of the new technology.

Acknowledgements

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