25 Design Solutions and Seismic Requirements for GRC Projects in New Zealand

Michael Newby
Holmes Consulting Group, New Zealand

Introduction

New Zealand is a relatively young country located in a highly seismic region of the South Pacific with most of the building stock constructed in the last 100 years. As a result of these factors, there is an absence of any strong historical building styles that allows building designers and the construction industry to continually innovate with new ideas, methodologies and construction materials.

This paper presents the design philosophies of the GRC industry in NZ as we have adapted overseas experience and applied this to our design solutions to local architectural and seismic requirements. The paper specifically demonstrates the principles of seismic design, movement requirements and the advantages of light weight GRC panels systems have over precast concrete.

Background

New Zealand is located on the intersection between the Pacific and Australian Tectonic Plates, which places NZ up there with Japan in terms of high seismicity. As a rule of thumb, NZ experiences destructive magnitude 7 earthquakes in cities or built-up areas on average every 25 years.

GRC2011 Istanbul

Figure 1. Map of New Zealand Tectonic Plates

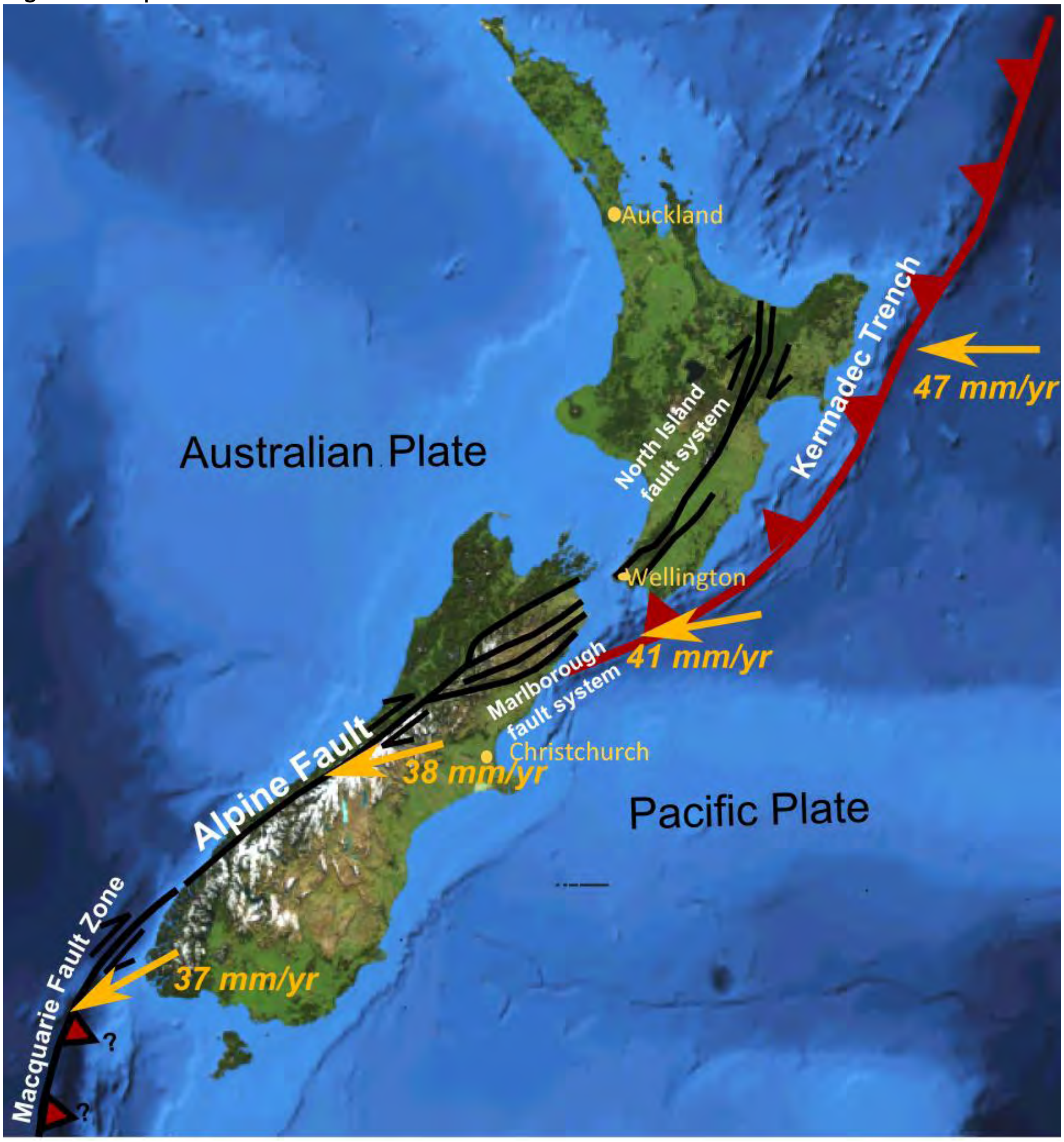


Figure 2. Auckland

Figure 3. Wellington

Figure 4. Christchurch

Figure 5. Christchurch Earthquake 2011 – 7 seconds of Destruction

To put some perspective to the magnitude of this earthquake, the epicentre was very shallow at 10km and located almost directly under the city of Christchurch. The horizontal ground accelerations of 0.8g were twice the level required by the building code and the vertical accelerations were. These are the highest known horizontal accelerations ever recorded in a built-up area.

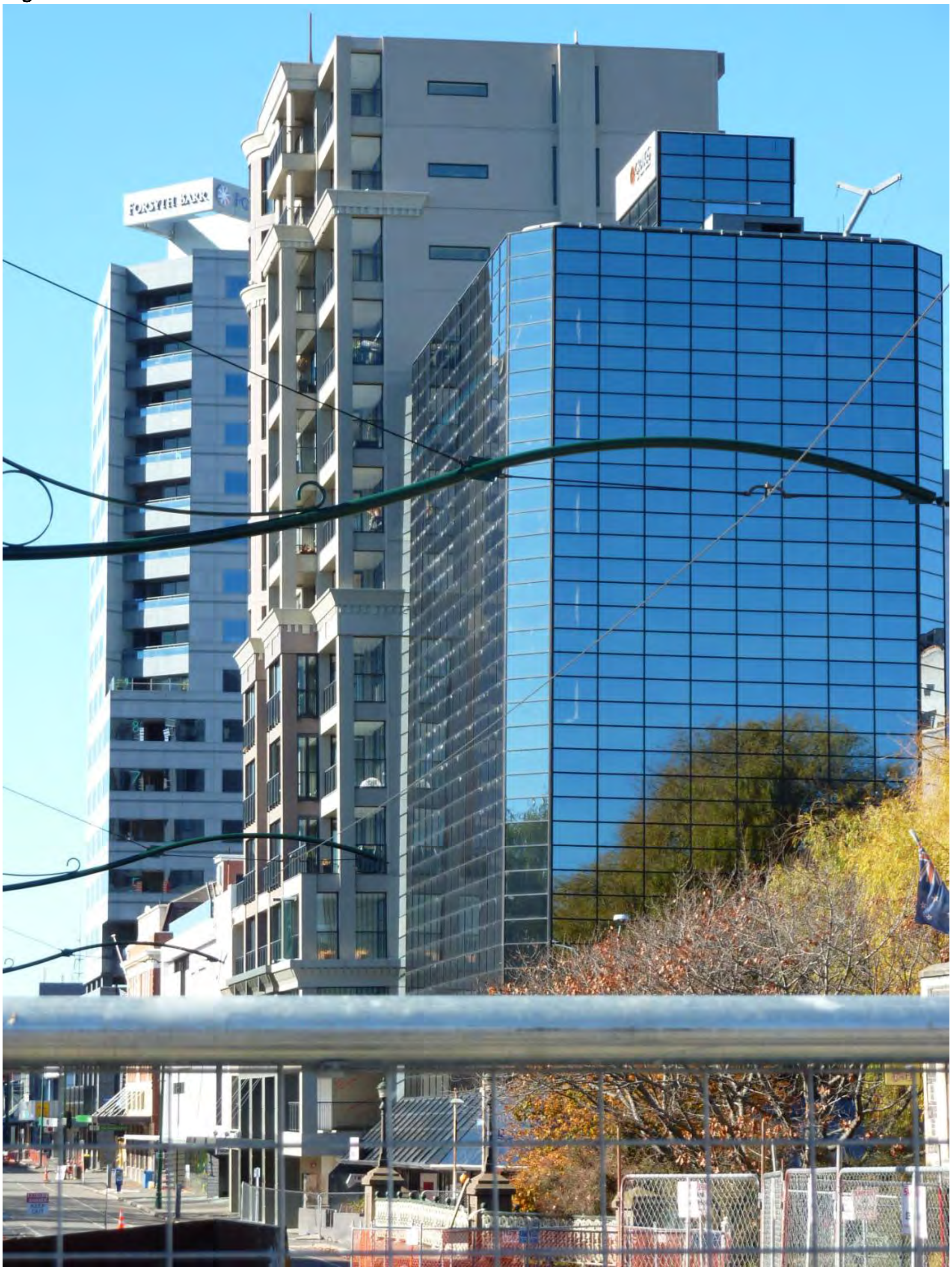
Principles of Seismic Design of Building Structures

In 1976 NZ published the first capacity seismic design code for reinforced concrete structures. This design philosophy recognises the magnitude of the loads resulting from code level earthquakes are so large, that it is uneconomic to design multi storey buildings to resist these forces and for their materials to remain within their elastic range of stresses.

Either we had to accept solid walls without windows, or we had to limit the forces that would be generated within the building structural elements. Capacity design allows for a strong column / weak beam mechanism to allow load limiting points or hinges, to form in the beams to prevent the columns from being overstressed. It is the avoidance of column failure that ensures building collapse does not occur and the building remains safe.

Engineering success is defined as prevention of building collapse, emergency egress elements such as stairs remain functional, and the avoidance of failure of wall claddings and glazing systems onto the streets below. However significant damage is unavoidable and this is accepted in code level earthquakes, but the building may need to be demolished after it has done its work.

Figure 6.



The building on the left is still plumb and straight, the building in the middle is clad with GRC panels and is leaning forward 450mm to the left, and the glass clad building on the right is leaning about the same degree backwards to the right. The jury is still out whether the middle and right hand buildings can be straightened, or if they will be demolished. The performance of these GRC and glass cladding systems is testament to the good engineering design of the fixings and provision for significant building deflections under an extreme earthquake.

Design Codes

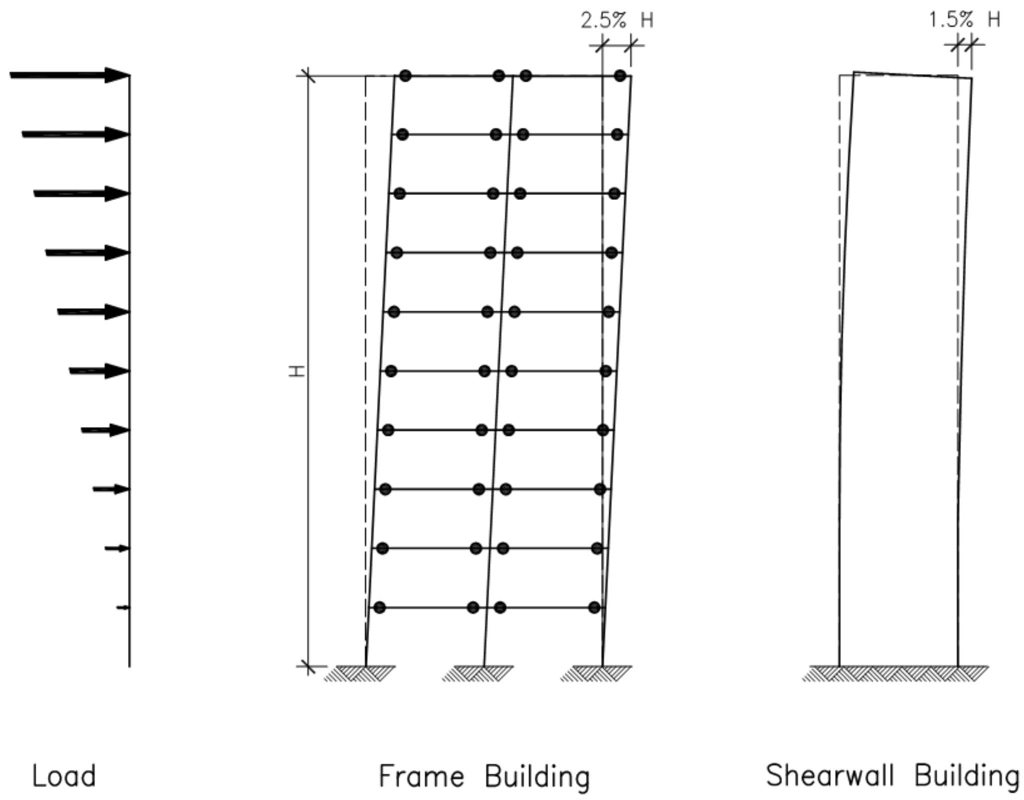
NZ has two levels of seismic design compliance:

SLS – Service Limit State – the level of forces and deflections that the building and its elements must be able to sustain without damage under service loads.

ULS – Ultimate Limit State – the ultimate level of forces and deflections that the building and elements must survive without collapse or loss of live.

In simple terms, the SLS is similar to design levels in most other Country codes for typical loads such as dead, live, wind and seismic loads if any. The ULS level for seismic loads is 4 times the SLS level. As a result of these large loads demands, buildings have correspondingly very large interstorey deflections that need to designed and accommodated in the fixings and detailing of the cladding systems.

Figure 7. Load Distribution and Building Deflections



Typically the interstorey deflections for frame buildings are higher than shearwall buildings, these relative deformations can be up to 20mm SLS and 80mm ULS between floors.

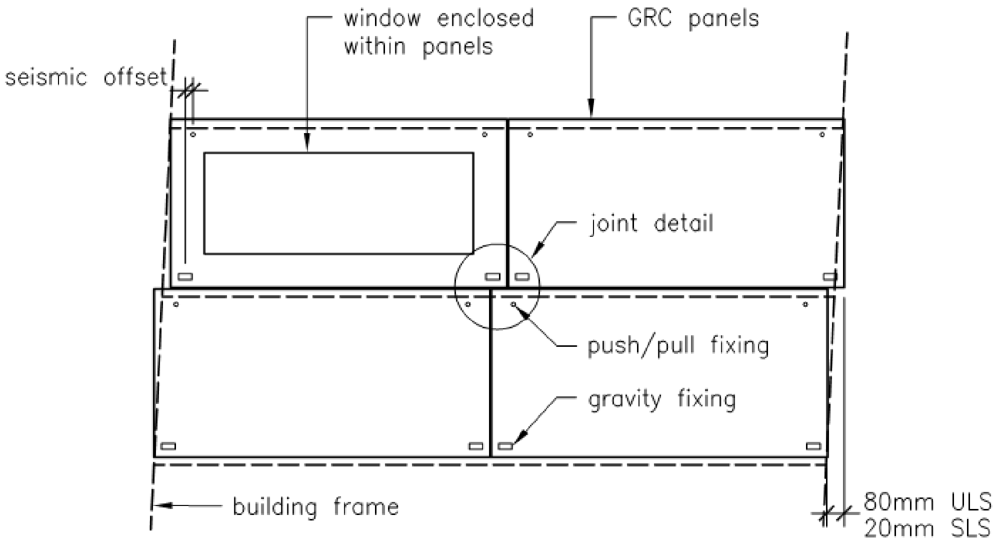
Seismic Design for GRC Cladding Panels

This is where the advantages of lightweight steel stud GRC panels become superior to precast concrete systems.

Essentially seismic forces are proportional to the mass of the building or the individual elements for local effects. GRC panels are approx 15% of the mass of precast concrete panels which has very significant benefits for the fixings. Fixings under capacity design are designed for over-strength, ie the fixings of cladding components must have an over-strength factor of at least 2 to prevent a progressive collapse of the cladding system.

A typical GRC gravity fixing will support a load of 250 to 500kg, an equivalent precast fixing will support 1.5T to 3T. This advantage for GRC fixings dramatically increases further when the over-strength factor of 2, allowance for construction tolerance, and the eccentricities of loads from inter-storey deflections of up to 80mm, are compounded and applied to the required fixing capacities.

Figure 8. Interstory Deflections of Wall Cladding Panels

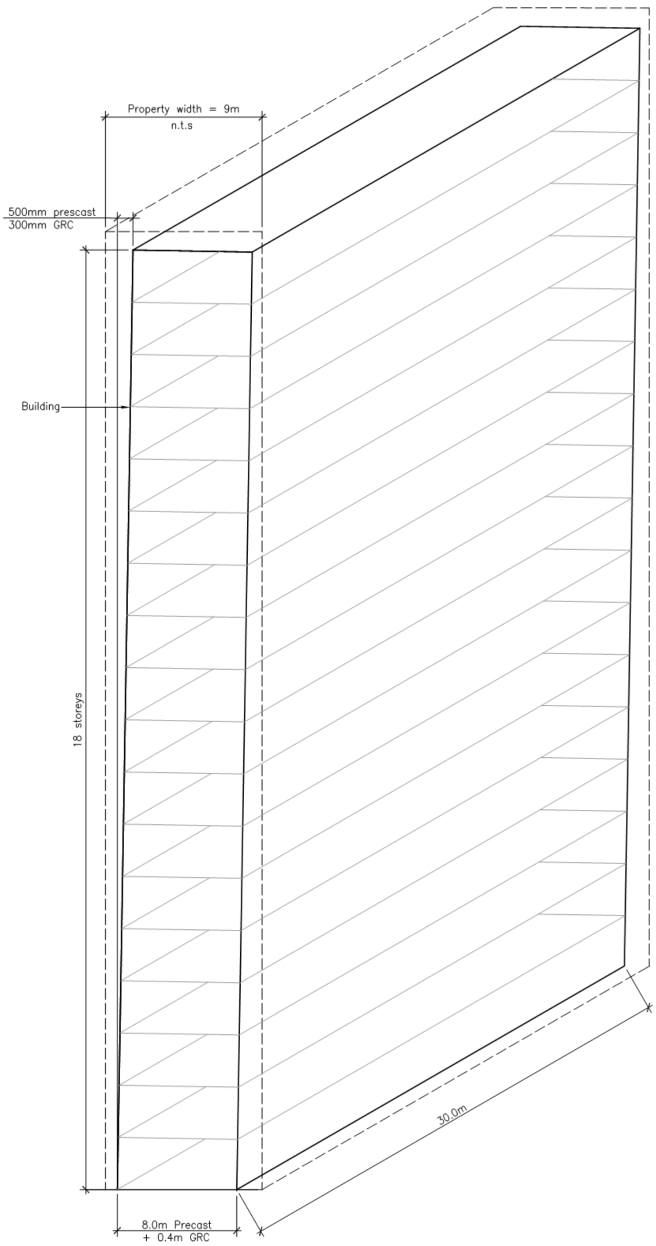


We are all familiar with the magnitude and detailing for GRC movement from everyday actions such as shrinkage, live loads and wind loads. The above diagram shows the added effects of inter-storey drifts on the movement requirements of the fixing and joint details.

Another significant benefit of the GRC steel stud system is the flex anchors provide an isolating spring system between the rigid GRC skins and the stud frame. This isolation serves to protect the cladding from adversely attempting to restraint the building sway through strut action between the exterior GRC panels, which may overload the panel fixings and cause failure.

Benefit of Lightweight GRC Panels

Figure 9. Increase in Building Width due to lightweight GRC wall cladding



The Johnson St Apartment building in Wellington originally was designed to have precast concrete panels on the side walls. However there is a building code requirement in NZ, that buildings under seismic swaying must stay within their legal property boundaries to avoid building clash.

Due to the tall slenderness ratio of this building, the calculated sway of the building under ULS conditions was +/- 500mm, resulting in a maximum building width of 8.0m within a property width of 9.0m. A GRC cladding system was substituted prior to construction with a 600T saving in mass and a reduction in the building sway of +/- 200mm. This allowed the building width to be increased by 400mm. The increase in rentable floor area of 400mm over 18 storeys by 30m depth, exceeded the total cost of the GRC contract.

Conclusions

The requirements of seismic design for multi storey buildings are very onerous in terms of load capacity and deflection capability. GRC is less affected by these requirements by its lightweight nature and the inherent flexibility of the stud frame system that these become a significant competitive advantage against precast concrete systems in high seismic areas.

References:

Figure 1. Photo by Mike Norton
Figure 2. Photo by Terry Fong
Figure 3. Photo by Mandy Simpson
Figure 4. Photo by Andrew Cooper
Figure 5. Photo by Gillian Needham