Submission to the Canterbury Earthquake Royal Commission On the Paper "Design of Conventional Structural Systems Following The Canterbury Earthquakes"

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Foreword

Capacity Design is a "Fool's errand". No important document such as this should even be contemplated without covering the alternative of base isolation.

It is vitally important that Base Isolation be included in this document. This document is likely to become a foundation document for the redevelopment of Christchurch. As the document stands, it totally ignores the very best solution available.

The title "Design of Conventional Structural Systems Following the Canterbury Earthquake" needs to be changed. It is far too confining and restrictive and likely to become enshrined in the thinking of those responsible for taking matters forward in rebuilding Christchurch.

Fallacy No1 – Base Isolation is Too Expensive

This generally held belief "that base Isolation is expensive" could not be further from the truth. A properly designed building with Base Isolation should be targeted to cost 5 to 10% less than a "Conventional" building, because although the lead rubber bearings or alternative methods are expensive, to withstand a similar earthquake the structure can afford to be lighter and the window and cladding details are simpler and cheaper, resulting in the overall cost of the building being less.

Cost effectiveness applies to existing base isolation methodologies in use now. Union House designed by Peter Boardman on the Auckland waterfront built in 1983, by using seismic isolation produced an estimated cost saving of nearly 7% in total construction costs including a construction time saving of 3 months. [1]

C. W. Ashby is currently developing a Base Isolation system which should prove very economic and simple enough for use in domestic houses construction, with potential scalability. While this technology is at present before it's time, it is anticipated that it will be available within 12 months subject to commitments and funding.

The plea is that Base Isolation should not be set aside on the false premise of "Cost".

Fallacy No2 – Engineers Know all about Base Isolation

The unfortunate truth is that most engineers understand the basic concept of base isolation but have a tendency to put it in the 'too hard' basket and write it off as being too costly. Expertise in this field in New Zealand is limited with those formally at the forefront getting older, retiring or dying. There is a need for a renaissance.

A renaissance will not happen if this vital methodology is left out of the very paper intended to solve the woes of Christchurch.

The Word 'Conventional"

The word "Conventional" should be struck from the title, why repeat the disasters of the past. Capacity design is a disaster.

Base Isolation is the way forward and needs to be grasped with both hands by the Engineering Community.

Base isolation as witnessed by the Christchurch Woman's Hospital, is already a tried and proven technology that fulfils the desired result of being able to;

- Emerge virtually unscathed after a catastrophic event that has turned the adjoining City using "Conventional Structural Systems" into dust and rubble.
- protect its occupants
- protect its contents
- Remain fully functional after the event
- Remain structurally sound without the need for subsequent demolition.

Such technology should not be held back by conventional conservative thinking. The question really should be: "Why would anyone use anything else but base isolation?"

If Base Isolation in New Zealand (the country of its development) is not as well accepted as it is overseas, we need to do something about it. This is the opportunity to arise from the ashes and dust of Christchurch and make a positive contribution to Earthquake Engineering, and the betterment of our fellow man.

Recommendations

It is recommended that;

- it be explicitly brought home to the Engineering Community that Base Isolation is cost efficient.
- Engineers be positively encouraged to become involved in a 'Renaissance' of the Art of Base Isolation.
- The word "Conventional" be struck from the title of the paper.
- a section on Base Isolation be added to the paper . (I humbly suggest that in the absence of a more worthy presentation, the attached section on Base Isolation be used).
- a further section be added summarising other developing technologies.

There is a need for a change in mindset, a quantum leap in thinking.

BASE ISOLATION

Introduction

Base or Seismic Isolation has been around since the days of the Ancient Greeks who built the Temples of Segesta, and the Parthenon erected between 447 and 438 B.C.
Emerson once wrote; “Earth proudly wears the Parthenon as the best gem upon her zone”. [3]

This building constructed of Unreinforced Masonry (UM) with unreinforced masonry columns over 10m high, survived in a region of active seismic activity for over 2,000 years and nature and earthquakes did not destroy it. The central part was destroyed in 1687 when a Venetian shell exploded a Turkish powder magazine located in it.

In December 1967 Dr William (Bill) Robinson (deceased) the former Founder and Chief Engineer of Robinson Seismic Ltd, of Wellington NZ, joined the Department of Scientific and Industrial Research (DSIR) and his interest in seismic isolation lead to the development of the lead-rubber bearing as well as other isolating systems. When the DSIR was later disbanded he formed Robinson Seismic Ltd. As a result of his work and the work of his associates, a large number of bridges throughout New Zealand have been fitted with Base Isolation, as well as a number of buildings in New Zealand. [1]

It is in the writer’s view that unfortunately some of the early projects such as the retrofitting of Parliament Buildings were such horrendously challenging and costly “no expense spared” projects, that in New Zealand at least, Base Isolation has been tarnished with the false belief that it is expensive, which it is not.

As a result, Dr Robinson’s technology has tended to have been more widely accepted overseas where it has proved highly successful in large earthquakes in Japan and California.

Of particular interest in New Zealand a number of buildings using seismic isolation have been constructed including; William Clayton Building, Wellington (4 storeys). Union House Auckland (12 storeys). Wellington Central Police Station (10 storeys). Retrofit of Parliament House (5 Stories). Retrofit of Parliament Library (5 Stories). Te Papa Museum, the Supreme Court, the new Wellington Hospital, parts of the Hutt Hospital (including the new emergency department and operating theatre block now under construction).

In Christchurch the only building with base isolation, the Christchurch Women's Hospital, remained fully operational following both the September and February earthquakes.

Dr Robinson before his death believed that seismic isolation devices save lives and "must" become a key part of protecting buildings when Christchurch is rebuilt. *"Christchurch residents may feel reluctant to live or work in multi-level buildings now. It is crucial that devices such as lead-rubber bearings are used in the reconstruction of the Christchurch CBD so that Cantabrians can go to their places of work and study with the confidence that they are* *as safe as possible. Base isolation is the technology that can help provide that greater level of safety and peace of mind."* [4]

In Christchurch a lot of buildings strengthened with traditional methods did not collapse but are now unusable. The strengthening allowed people to escape but the buildings were so badly damaged they have to be demolished. The Christchurch Women's Hospital behaved exactly as it was designed to. The bearings moved and took the force of the shake but the building was not damaged internally. In contrast, buildings around it were damaged and in some cases could not be used afterwards.

There's no excuse for this technology not to be put to more extensive use in New Zealand. Base isolation is the most effective way to protect critical structures, for every dollar spent before a disaster saves four to eight dollars in response and recovery costs. [4]

We need to not only ask whether we can afford not to base isolate apartments, hospitals and public buildings, but whether even more cost effective Base Isolation solutions can be developed which would protect family homes and light commercial and industrial buildings.

Seismic Isolation in Context

Although still thought of as a relatively recent technology, seismic isolation has been well evaluated and reviewed and has been the subject of international workshops [1] and has already proved highly successful in large earthquakes in Japan and California, and more recently Christchurch.

Seismic isolation has been used in the Wellington Central Police Station which has a critical Civil Defence role in the event of a very severe earthquake to ensure it is immediately ready for action after such an event as low levels of structural and non-structural damage may be achieved as a result of base isolation. [1]

In the wake of the Canterbury Earthquakes, it is evident that as a nation we cannot afford to “write off” entire cities following an earthquake. It is highly desirable that buildings remain standing and not only safe to evacuate, but remain functional with structural and non-structural damage minimalised and easily repaired. Therefore the same parameters and methods which were applicable to the design of the Christchurch Women’s Hospital, the Wellington Central Police station and others are highly desirable in rebuilding Christchurch and base isolation must be at the forefront.

Base Isolation may often reduce the cost of providing a given level of earthquake resistance - a typical target being 5% of the structural costs. Reduced costs arise from reduced ductility demand, the consequent simplification of load-resisting members and from lower structural deformations. This can be accommodated with lower cost detailing of the external cladding and glazing.[1]

With seismic isolation, provision must be made for a seismic gap to be maintained around the building. The general consensus has been 50mm to 400mm, and possibly up to twice that amount if “extreme” earthquake motions are considered [1]. It has been noted that in the 22 February 2011 event, horizontal spectral displacements of between 650mm and 750mm (or 325 to 375mm in each direction) at a period of 3.5 seconds were recorded across the central city [2]. It was not until a period of 5 seconds that the bulk of recordings dropped below a 450mm total displacement. It is therefore imperative that the seismic gaps be large and be maintained and that the period of the building be attuned to be as long as possible.

A number of factors should be considered by an engineer, architect or client in deciding whether or not to incorporate base isolation in a structure. [1]

1. Seismic hazard, which depends on local geology, proximity to faults, soil substructure, etc.
2. Recorded history of earthquakes in the region.
3. Any known factors about the probable characteristics of an earthquake (severity, period, etc)
4. Based on the above a variety of design options can be considered, some containing base isolation and some not. The probable level of seismic damage can then be evaluated and a cost/ benefit analysis carried out inclusive of the "Value" of having the building and its contents in good condition after the event, as well as considering the implications with respect to insurance, loss of amenity and income to occupants, etc.

In the current situation in Christchurch there is;

- known and ongoing seismic hazard with many relatively shallow violent earthquakes
- accumulative effects on plastic hinging of more conventional structures
- likely to be ongoing social disruption,
- likely to be ongoing damage to buildings
- likely to be ongoing damage to contents.
- Increased risk of injury or Death.
- nervous insurers and non availability of insurance in some quarters.

Even if Base isolation were not potentially 5 to 10% cheaper from the construction perspective, it is a certainty that in the present situation a "Benefit/Cost" analysis when the "intangibles" are taken into account would make its use imperative.

It is therefore a "No Brainer" that Seismic Isolation should be used in Christchurch.

Flexibility, Damping and Period Shift

Historically, design earthquake motions have been taken as being similar to the 1940 El Cetro, California earthquake with large accelerations at periods of 0.1 to 1.0 seconds with maximum severity considered to be in the range 0.2 to 0.6 seconds.

Structures with a natural period of vibration of between 0.1 and 1.0 seconds are therefore normally considered particularly vulnerable to seismic attack because they may resonate. The most important feature of seismic isolation is that its increased flexibility increases the natural period of the building. Because the period is increased beyond that of the earthquake, resonance and near resonance are avoided and the seismic acceleration response is reduced. [1]

However the Christchurch earthquakes with near-source and deep soft underlying soils give a different signature, extending the amplification of low frequency periods and the severity.

From the wealth of data recorded from the earthquakes [2] which have occurred recently in the area, the spectra of the accelerogram is pretty well known with, for the main part, deep soft soils amplifying low frequency earthquake motions extending the range of large accelerations at periods of 0.1 to as much as 3.5 seconds.

With this type of motion, flexible mountings with moderate damping may increase rather than reduce the structural response. [1]

This does present a challenge for base isolation under such conditions. A building period of 5 seconds or more would be desirable judging from the Christchurch accelerograms.

To achieve such a long period, a large displacement and a good damping system is required.

Base isolation, if appropriately designed, will reduce earthquake induced shear forces within the structure and will reduce structural damage to the point of being non-existent. The supported structure and components will remain within elastic limits.

Comparison of Conventional & Seismic Isolation Approaches

Conventional buildings are designed considering “capacity design” to absorb extreme seismic energy through the failure mode-controlled approach whereby beam/column joints etc are designed to yield. The only problem with this approach is that at the end of the event, while the building has not collapsed, critical components have yielded, the building is severely damaged and the remaining life of the components is unknown and they are difficult or impossible to replace with elongation of members also affecting secondary components such as floors. Often the only solution is to demolish the building and rebuild, which can be a very expensive exercise, particularly as there are likely to be multiple buildings affected at the same time, combined with damaged infrastructure, thus stretching resources and increasing construction costs.

In the conventional approach, it is accepted that considerable earthquake forces and energy will be transmitted to the structure from the ground. The design problem is to provide a structure with the capacity to withstand these substantial forces [1]. However, strength often equates to making things bigger and heavier, which in the case of earthquakes attracts more force and energy.

In seismic isolation, the fundamental aim is to reduce substantially the transmission of earthquake forces and energy to the structure from the ground [1]. This is achieved by mounting the building on an isolating layer allowing the ground to shake and displace under the building while the inertia of the building itself holds the building in a relatively static state with only moderate motions induced into the structure itself.

However there is often a trade off between the extent of force, isolation, acceptable maximum relative displacement of the building and the capacity of present isolating systems to cope with the eccentricities of loading when such displacements occur. (However a system currently under development by C.W. Ashby would allow significant displacements without introducing isolator eccentricity problems).

Isolation increases displacement (x) but decreases acceleration (a). Damping decreases displacement. By increasing displacement, acceleration and hence as “F= Ma” Force drops. As force drops the structural frame does not need to be as strong to resist it. As strength normally correlates to mass, less mass is needed in a base isolated building which in turn attracts less destructive seismic forces, which require less strength which requires less mass which attracts less seismic force, etc, etc.

Wind load also needs to be considered as if the base isolator is too effective the structure could move about on a windy day. While this is currently catered for by the stiffness of lead-rubber bearings under non-seismic conditions, an alternative may be “frangible” connections which may suit structures allowing greater deflection under severe seismic load.

Perhaps a frangible connection similar to the “V” notched base plate and bolting layout at the base of cold formed steel highway lighting poles designed to withstand wind load but release upon impact from a vehicle. Another alternative may be glass shear pins or timber dowels, able to withstand a buffeting wind load but designed to shatter under the hammer blow impact of a sizable earthquake. Such would thereby decouple the building from the ground and enabling, via inertia, the building to stand relatively still while the ground shakes under it. However, frangible connections would need to be replaced or reset after each major event and be checked regularly by someone who knows what they are doing. Any system dependent on human maintenance is at risk of neglect, however further thought is warranted.

Conclusion

This Section can only afford to be a brief overview and introduction on Base Isolation and in particular its applicability to Christchurch. For more in depth study the book “Seismic Isolation for Designers and Structural Engineers” co-authored by Trevor E. Kelly, R. Ivan Skinner and Bill (W.H.) Robinson is highly recommended reading.

It is apparent that base isolation will produce the desired results of minimising damage and protecting lives and delivering a fully functional facility after a major earthquake at possible 5 to 10% less cost that the “conventional” Capacity Design Structure.

It is time in New Zealand for a Renaissance in the Art of Seismic Isolation.

References;
[1] “Seismic Isolation for Designers and Structural Engineers”-T.E.Kelly, R.I.Skinner, W.H.Robinson.
[2]NZSEE Vol.44,No 4 Dec2011,”Near-Source Strong Ground Motions..” –B.A.Bradley, M. Cubrinovski
[3] http://www.portergaud.edu/academic/faculty/cmcarver/part.html
[4] http://www.stuff.co.nz/dominion-post/news/local-papers/hutt-news/4927103/Quakes-wake-up-building-owners-to-Robinsons-bearings-technology

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