New Zealand Base Isolation Design Guideline & Properties of LRB`s Under Tension Loads

Umit Ozkan – Robinson SL
Structural Engineer, PhD candidate
Who am I?

- Alan R.L Park – CEO Robinson Seismic Ltd
- University of Canterbury, Masters of Engineering.
- Base Isolation/Low Damage Design specialist.

- First worked in construction side of the building industry 1996 following graduation – some 20 years ago.

- Started as a technical adviser and unit designer for Robinson
- I have consulted, designed, tested, supervised, installed, quality checked, reviewed many isolated buildings (over 100)
- Have since brought the company (part owner)
- Formally an owner and shareholder of Holmes Consulting. Have been a designer/consultant.
Is Base isolation new technology?

- Lead rubber Bearing Invented in 1978 by William (Bill) Robinson.
- Founder of Robinson Seismic Limited
- We proudly carry Bill's legacy in our company name, being the original inventor and creator of the Lead Rubber Bearing (LRB), which has been adopted globally to create the base isolation market that we have today.
- In excess of 10,000 buildings isolated globally.
- Globally accepted design and installation techniques
- Everything is verified by testing – full scale.
- There are other forms of Base Isolation, and seismic energy dissipation available
- First building isolated – William Clayton building – 1978
Project Experience
New Zealand

William Clayton Building | Wellington
79 – 600 sq LRB
Project Experience
New Zealand

MPI | National Biocontainment Laboratory | Wellington
10-1370mm ø LRB | 20 - Pot Sliders

Spark | Data Centre | Auckland
60-530mm ø LRB

Ministry of Health Acute Services Building | Christchurch
12-1120mm ø LRB | 67-1020mm ø LRB | 49 - Pot Sliders

Ministry of Justice | Supreme Court | Wellington
69-770mm ø LRB | 64 - Pot Sliders
Project Experience
New Zealand

20 Customhouse Quay | Wellington
17-1020mm ø LRB | 8-220mm ø LRB | 46-Pot Sliders

Ministry of Justice | CJESP | Christchurch
50-1020mm ø LRB | 83-Pot Sliders

Wellington Town Hall | Wellington
18-820mm ø LRB | 100-770 ø LRB | 66-Pot Sliders

Old Bank Arcade | Wellington
109-560mm ø LRB | 12-Pot Sliders
Project Experience
New Zealand

Wellington Hospital | Wellington
52-620mm o LRB | 20-Pot Sliders

National Museum of New Zealand | Wellington
74-1075mm Sq LRB | 59-975mm Sq LRB | 121-Pot Sliders
Project Experience
Turkey

Manisa City PPP Hospital | Manisa
544 - 770mm ø LRB | 119 - 870mm ø LRB
71 - 970mm ø LRB

Anlalya Muratpasa Hospital | Antalya
160 - 700mm ø LRB | 223 - 770mm ø LRB
60 - 870mm ø LRB

Gebze İzmir Highway Project | Gebze
2296 - 650mm ø LRB

Corum Hospital | Corum
256 - 820mm ø LRB | 233 - 970mm ø LRB
212 - 1020mm ø LRB | 40 - 1120mm ø LRB
Project Experience
Turkey

Bursa Gemlik Hospital | Bursa
26 - 870mm ø LRB | 210 - 970mm ø LRB
24 - Pot Sliders

Erdine Kesan Hospital | Erdine
180 - 770mm ø LRB | 12 - Pot Sliders

Mecidyeckoy Viaduct | Istanbul
60-1000mm Sq. LRB

Engineering Department ITU | Istanbul
27-550mm ø LRB
Project Experience
China | Taiwan

Zhejiang Zhoushan LNG Tanks
638-770mm φ LRB

NZ Embassy | Beijing
33-670mm φ LRB | 18-Pot Sliders

LNG tanks | Guandong
1080 - 700mm φ HDRB

C601 Bridge | Wufeng | Taiwan
82-920mm Sq. LRB | 64-Pot Sliders
Project Experience
Taiwan

Great Apartment | Taipei
38-1120mm φ LRB

C608 Bridge | Pull | Taiwan
22-950mm φ LRB
Project Experience

Iran

Qazvin Rasht Rail Bridge | Manjil
16 - 650mm 6 LRB | 32 - 800mm Sq LRB

Rudshur Rail Bridge | Tehran
26 - 670mm Sq LRB

Traffic Building | Tehran
40 - Isolators | 8 Viscous Dampers

Violet Garden Apartments | Golastan
84 - 970mm 6 LRB
Others...

- Manisa City Hospital | Turkey
- Balikesir Hospital | Turkey
- Kuzey Marmara Highway Viaducts
- Wellington Control tower | Wellington
- Transmission Gully | Wellington
- Site 10 | Wellington
- Bhurach Apartments | India
- + many more....
New Zealand Seismic Isolation Guide

- Chapter 1: Introduction
- Chapter 2: Isolated design system and building philosophy
- Chapter 3: Building performance
- Chapter 4: Seismic hazard spectra and ground motions
- Chapter 5: Analysis requirements
- Chapter 6: Design
- Chapter 7: Detailing at the isolation plane
- Chapter 8: Specification for procurement of isolation systems and isolators
- Chapter 9: Inspection and maintenance
New Zealand Seismic Isolation Guide

• Sets out the approach for establishing EQ design actions to be used in the limit state of structures incorporating seismic isolation in accordance with NZS 1170.5:2004

• Applicable to
  • NRB
  • LRB
  • HDR
  • Pot Sliders in conjunction with elastomeric isolators
  • Curved Surface Sliders (Friction Pendulums)
  • Viscous Dampers only in conjunction with elastomeric isolators.
4 Types of buildings

- **Type 1: (Simple)** Low-rise regular structures, where the superstructure is designed and detailed for nominal ductility.

- **Type 2: (Normal)** Other structural systems not meeting Type 1 criteria, where the superstructure is designed and detailed for nominal ductility.

- **Type 3: (Ductile)** Superstructures designed for ductility (not exceeding $\mu = 2.0$) where the total displacement demands are met by displacement in both the isolation system and superstructure. Full capacity design of the superstructure is required.

- **Type 4: (Brittle)** Structures where the superstructure has no ductility capacity (i.e. is brittle).

Criteria's are set for each type of building to decide design philosophy and analysis types.
<table>
<thead>
<tr>
<th>Earthquake severity</th>
<th>Performance dimension</th>
<th>Performance description</th>
<th>Tolerable impact description</th>
<th>NZBC requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor</td>
<td>Return period</td>
<td>Limit state</td>
<td>SLS</td>
<td>0.5 Star</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Star (****)</td>
<td>No entrapment</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Star (*****</td>
<td>No entrapment</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate</td>
<td>No damage</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mild</td>
<td>No damage</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>negligible</td>
<td>No damage</td>
<td>-</td>
</tr>
<tr>
<td>Moderate</td>
<td>Return period</td>
<td>Limit state</td>
<td>ULS</td>
<td>1 Star (****)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Star (****)</td>
<td>Residual bearing displacement possible, No damage to frame spaces</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Star (*****</td>
<td>Residual bearing displacement possible, No damage to frame spaces</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate</td>
<td>Check access over exit spaces</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mild</td>
<td>Check access over exit spaces</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>negligible</td>
<td>Check access over exit spaces</td>
<td>None</td>
</tr>
<tr>
<td>Large</td>
<td>Return period</td>
<td>Limit state</td>
<td>CALS</td>
<td>2 Star (****)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Star (****)</td>
<td>Safety</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Star (*****</td>
<td>Safety</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate</td>
<td>Damage</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mild</td>
<td>Damage</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>negligible</td>
<td>Damage</td>
<td>-</td>
</tr>
<tr>
<td>Rare</td>
<td>Return period</td>
<td>Limit state</td>
<td>SLS</td>
<td>3 Star (*****</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Star (****)</td>
<td>Safety</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Star (*****</td>
<td>Safety</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate</td>
<td>Damage</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mild</td>
<td>Damage</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>negligible</td>
<td>Damage</td>
<td>-</td>
</tr>
<tr>
<td></td>
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<td>-</td>
</tr>
</tbody>
</table>

Service Limit State SLS
Ultimate Limit State ULS
Collapse Avoidance Limit State CALS
New Zealand Seismic Isolation Guide – Non Structural Performance Objectives

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance level</td>
<td>Damage control limit state</td>
</tr>
<tr>
<td>Return period</td>
<td>250 years or 500 years</td>
</tr>
<tr>
<td>Secondary structure</td>
<td>Secondary structure retains its strength and stiffness. Minor non-structural partition damage. Facade water tightness maintained. All building services remain operational with only minor repairs required. All fire and emergency systems operational.</td>
</tr>
<tr>
<td>Ceilings</td>
<td>Ceiling systems remain intact. Minor damage related to movement. No dislodgement.</td>
</tr>
<tr>
<td>Cladding</td>
<td>Cladding undamaged; movement; joints may have minor damage.</td>
</tr>
<tr>
<td>Lifts</td>
<td>Lifts operational, but may have minor damage.</td>
</tr>
<tr>
<td>Stairs</td>
<td>Stairs remain fully functional; Undamaged.</td>
</tr>
<tr>
<td>HVAC</td>
<td>Units are secure and operational.</td>
</tr>
<tr>
<td>Services ducts</td>
<td>Minor movement at joints, but remain serviceable.</td>
</tr>
<tr>
<td>Services pipework</td>
<td>Serviceable; No leaks.</td>
</tr>
<tr>
<td>Fire sprinkler system</td>
<td>Sprinkler system operational; No leaks.</td>
</tr>
<tr>
<td>Fire alarm system</td>
<td>Alarm system operational.</td>
</tr>
<tr>
<td>Fireproof cladding</td>
<td>Fire proofing intact; No damage.</td>
</tr>
<tr>
<td>Emergency lighting</td>
<td>Operational.</td>
</tr>
<tr>
<td>Electrical systems</td>
<td>Units are secure and operational; Minor damage to some parts of the lighting.</td>
</tr>
<tr>
<td>Shelving</td>
<td>Unrestrained shelving remains upright; hooks may fall off.</td>
</tr>
</tbody>
</table>
Earthquake damage results from drift and floor accelerations. Generally, structural and non-structural elements such as cladding and glazing are damaged by inter-storey drifts. Plant and equipment usually suffer more damage resulting from local accelerations at each floor, which are a function of a building’s response to earthquake shaking. Seismic isolation is able to significantly reduce both inter-storey drifts and floor accelerations.

The Low Damage Design Code of Practice currently being developed by MBIE considers the following criteria:

- structural damage mitigation effectiveness
- reparable
- residual drift
- floor acceleration
- self-centering ability
- durability and maintenance
- ULS and CALS performance
- Development and testing of a LDD system
- Non-structural damage
- Contents damage or disruption
- Cost.
New Zealand Seismic Isolation Guide – Design Procedures Summary

• Tells what to do
• Explains iterative design procedure
• Defines ADRS
• Calculates base shear (SDOF)
• Calculates displacement (SDOF)
• Equivalent static analysis
• Nonlinear time history analysis
• Gives flowcharts for each type of analysis methods
• Allows uplift
Properties of LRB`s under tension

Tension Stiffness
Depends on size of unit
Core diameter

Compression = Tension

???
## Properties of LRB`s under tension

### Tension Stiffness

<table>
<thead>
<tr>
<th>Unit</th>
<th>Bearing Diam.</th>
<th>Plug Diam.</th>
<th>Rubber Area (A_r)</th>
<th>G</th>
<th>Rubber height</th>
<th>(1G \times A_r)</th>
<th># Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>mm</td>
<td>mm</td>
<td>mm(^2)</td>
<td>MPa</td>
<td>mm</td>
<td>kN</td>
<td>-</td>
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<tr>
<td>770LRB120</td>
<td>770</td>
<td>120</td>
<td>454353</td>
<td>0.45</td>
<td>220</td>
<td>204</td>
<td>44</td>
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<tr>
<td>820LRB100</td>
<td>820</td>
<td>100</td>
<td>520248</td>
<td>0.55</td>
<td>280</td>
<td>286</td>
<td>44</td>
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<td>870LRB155</td>
<td>870</td>
<td>155</td>
<td>575599</td>
<td>0.55</td>
<td>220</td>
<td>317</td>
<td>19</td>
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<tr>
<td>970LRB155</td>
<td>970</td>
<td>155</td>
<td>720112</td>
<td>0.55</td>
<td>280</td>
<td>396</td>
<td>48</td>
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<tr>
<td>1020LRB190</td>
<td>1020</td>
<td>190</td>
<td>788775</td>
<td>0.55</td>
<td>280</td>
<td>434</td>
<td>25</td>
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<tr>
<td>1120LRB190</td>
<td>1120</td>
<td>190</td>
<td>956851</td>
<td>0.55</td>
<td>280</td>
<td>526</td>
<td>7</td>
</tr>
</tbody>
</table>
Properties of LRB`s under tension

Tension Stiffness
Properties of LRB's under tension

**Tension Stiffness**

- 770LRB120
- 820LRB100
- 870LRB155
- 970LRB155
Properties of LRB`s under tension

Tension Stiffness
Properties of LRB’s under tension

Tension Stiffness / Compression Stiffness
Questions?

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