



Earthquake house

- Key Topics:
- earthquake [2]
  - engineering [3]
  - mitigation [4]


Cost-effective mitigation strategy for building related earthquake risk [5]  
Research was undertaken to understand the seismic vulnerabilities of existing unreinforced masonry and limited ductile reinforced concrete buildings and methods to address them seismic retrofit; assess the risk of building stock through the development of an economic loss model with trial evaluation; and advance an end-use focused research utilisation project in the area of community risk reduction – York, Western Australia.

Project: detail Notabs


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## Description

This research developed an evidence base to inform decision making on the mitigation of the seismic risk posed by the most vulnerable Australian buildings subject to earthquakes. Without this evidence base, it is impossible to make cost-effective and economically justifiable decisions by building owners and government officials on all matters concerning seismic strengthening of existing and design of new buildings. While the focus of this project was on buildings, many of the project outputs are also relevant for other Australian infrastructure such as bridges, roads and ports, while at the same time complementing other CRC project proposals for severe wind and flood.

In order to achieve the overall project aim, work was undertaken on three complementary fronts to:

1. understand the seismic vulnerabilities of existing unreinforced masonry (URM) and limited ductile reinforced concrete (LDRC) buildings and methods to address them through seismic retrofit
2. risk assessment of the building stock through development of an economic loss model with trial evaluations for a regional town (York, WA) and a metropolitan area (Melbourne)
3. advance an end-user focused research utilisation project in the area of community risk reduction. This is done through an Earthquake Mitigation Case Study for the historic town of York in Western Australia.

[Read the final report here.](#) [38]

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Survey to protect historic WA town from earthquake  
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25 JAN 2016

Earthquake and wind testing in Adelaide  
CYCLONE, EARTHQUAKE

[67]

Publications

Year	Type	Citation
2022	Conference Paper	Tsang, H. - H. [16], Pitilakis, K. [68], Li, S. [69] & Hung, W. - Y. [70] <b>Geotechnical seismic isolation system based on rubber-soil mixtures: analytical modelling, experimental testing and field me</b>
2021	Journal Article	Mehdipanah, A. [76], Lumantarna, E. [12] & Lam, N. [24] <b>Shear Wall and Frame Dual Systems Featuring Discontinuous Load Paths in Frame Elements in Low-to-Moderate Seismic Regions</b> [77].
2021	Journal Article	Hu, Y. [82], Lam, N. [24], Menegon, S. [83] & Wilson, J. [19] <b>The Selection and Scaling of Ground Motion Accelerograms for Use in Stable Continental Regions</b> [84]. <i>Journal of Earthquake Engine</i>
2021	Report	Ryu, H. [17] <i>et al.</i> <b>Cost-effective mitigation strategy development for building related earthquake risk – Melbourne case study</b> [89]. (Bushfire and Natural Hazards CRC, 2021). Google Scholar [9
2021	Report	Griffith, M. [6] <b>Cost-effective mitigation strategy development for building related earthquake risk - final project report</b> [38]. (Bushfire and Natural Hazards CRC, 2021). Google Scholar [93] BibTe
2020	Journal Article	Howlader, M. [96], Masia, M. [97] & Griffith, M. [6] <b>In-plane response of perforated unreinforced masonry walls under cyclic loading</b> [98]. <i>Journal of Structural Engineering</i> <b>146</b> , (2020). DOI [99] Gc
2020	Journal Article	Derakhshan, H. [14], Nakamura, Y. [103], Griffith, M. [6] & Ingham, J. [104] <b>Suitability of Height Amplification Factors for Seismic Assessment of Existing Unreinforced Masonry Components</b> [1
2020	Journal Article	Tsang, H. - H. [16], Tran, D. - P. [110], Hung, W. - Y. [70], Pitilakis, K. [68] & Gad, E. F. [10] <b>Performance of geotechnical seismic isolation system using rubber soil mixtures in centrifuge testing</b>
2020	Journal Article	Amirsardari, A. [35], Lumantarna, E. [12], Rajeev, P. [116] & Goldsworthy, H. M. [15] <b>Seismic Fragility Assessment of Non-ductile Reinforced Concrete Buildings in Australia</b> [117]. <i>Journal of Eart</i>
2020	Journal Article	Tsang, H. - H. [16], Wilson, J. [19] & Gad, E. F. [10] <b>Collapse probability of soft-storey building in Australia and implications for risk-based seismic design</b> [122]. <i>Australian Journal of Structural I</i>
2020	Journal Article	Tiwari, R. [127], Lam, N. [24] & Lumantarna, E. [12] <b>Modeling of Seismic Actions on Earth Retaining Structures</b> [128]. <i>Recent Advances in Computational Mechanics and Simulations</i> <b>103</b> , 247-256 (
2020	Journal Article	Tang, Y. [133], Lam, N. [24] & Tsang, H. - H. [16] <b>A Computational Tool for Ground Motion Simulations Incorporating Regional Crustal Conditions</b> [134]. <i>Seismological Research Letters</i> (2020). c
2020	Journal Article	Derakhshan, H. [14], Nakamura, Y. [103], Griffith, M. [6] & Dhanasekar, M. [139] <b>Simplified calculation of roof accelerations in existing low-rise symmetric unreinforced masonry buildings with f</b>

Year	Type	Author	Citation
2020	Journal Article	Howlader, M. [96], Masia, M. [97] & Griffith, M. [6]	<b>Numerical analysis and parametric study of unreinforced masonry walls with arch openings under lateral in-plane loading</b> [145]. <i>Engineering Structures</i> <b>202</b> , (2020).DOI [146] Google Scholar [147]
2020	Journal Article	Tang, Y. [133], Lam, N. [24], Tsang, H. - H. [16] & Lumantarna, E. [12]	<b>An Adaptive Ground Motion Prediction Equation for Use in Low-to-Moderate Seismicity Regions</b> [150]. <i>Journal of Earthquake Engineering</i> <b>23</b> , (2020).DOI [151] Google Scholar [152]
2020	Journal Article	Howlader, M. [96], Masia, M. [97] & Griffith, M. [6]	<b>In-plane shear testing of unreinforced masonry walls and comparison with FEA and NZSEE predictions</b> [155]. <i>5</i> , (2020).DOI [156] Google Scholar [157]
2020	Journal Article	Raza, S. [160], Menegon, S. [83], Tsang, H. - H. [16] & Wilson, J. [19]	<b>Axial Load Variation of Columns in Symmetrical RC Buildings Subject to Bidirectional Lateral Actions in Regions of Low to Moderate Seismicity</b> [161]. <i>Australian Journal of Structural Engineering</i> <b>18</b> , (2017).DOI [162] Google Scholar [163]
2020	Report	Mohanty, I. [166], Edwards, M. [20], Ryu, H. [17] & Wehner, M. [23]	<b>Cost-effective mitigation strategy development for building related earthquake risk</b> [167]. (Bushfire and Natural Hazards CRC, 2020).Google Scholar [168] BibTeX [169] EndNote XML [170]
2020	Report	Griffith, M. [6]	<b>Cost-effective mitigation strategy development for building related earthquake risk: annual report 2019-2020</b> [171]. (Bushfire and Natural Hazards CRC, 2020).Google Scholar [172] BibTeX [173] EndNote XML [174]
2020	Report	Wehner, M. [23] <i>et al.</i>	<b>Earthquake mitigation of WA regional towns: York case study - final report</b> [175]. (Bushfire and Natural Hazards CRC, 2020).Google Scholar [176] BibTeX [177] EndNote XML [178]
2020	Report	Ryu, H. [17], Wehner, M. [23], Edwards, M. [20] & Mohanty, I. [166]	<b>Progress report on case study CBD precinct</b> [179]. (Bushfire and Natural Hazards CRC, 2020).Google Scholar [180] BibTeX [181] EndNote XML [182]
2020	Report	Lumantarna, E. [12], Lam, N. [24], Tsang, H. - H. [16], Gad, E. F. [10] & Wilson, J. [19]	<b>Final report on vulnerability of as-built and retrofitted LDRC buildings</b> [183]. (Bushfire and Natural Hazards CRC, 2020).Google Scholar [184] BibTeX [185] EndNote XML [186]
2019	Conference Paper	Vaculik, J. [187] & Griffith, M. [6]	<b>Out-of-plane fragility of URM parts and components based on time-history analysis-comparison to simplified force-based approaches</b> [188]. <i>Australian Earthquake Engineering Society 2019 Conference</i> (2019).at <https://aees.org.au/wp-content/uploads/2019/08/Out-of-plane-fragility-of-URM-parts-and-components-based-on-time-history-analysis-comparison-to-simplified-force-based-approaches.pdf>
2019	Conference Paper	Ryu, H. [17] <i>et al.</i>	<b>Earthquake Management Logistics for York, WA, Pre and Post Mitigation</b> [193]. <i>Australian Earthquake Engineering Society 2019 Conference</i> (2019).at <https://aees.org.au/wp-content/uploads/2019/08/Earthquake-Management-Logistics-for-York-WA-Pre-and-Post-Mitigation.pdf>
2019	Conference Paper	Xing, B. [198], Lumantarna, E. [12], Lam, N. [24] & Menegon, S. [83]	<b>Prioritisation strategy for seismic retrofitting of reinforced concrete buildings in Australia</b> [199]. <i>Australian Earthquake Engineering Society 2019 Conference</i> (2019).at <https://aees.org.au/wp-content/uploads/2019/08/Prioritisation-strategy-for-seismic-retrofitting-of-reinforced-concrete-buildings-in-Australia.pdf>
2019	Conference Paper	Edwards, M. [20], Wehner, M. [23], Ryu, H. [17], Griffith, M. [6] & Vaculik, J. [187]	<b>Modelling the vulnerability of old URM buildings and the benefit of retrofit</b> [204]. <i>Australian Earthquake Engineering Society 2019 Conference</i> (2019).at <https://aees.org.au/wp-content/uploads/2019/08/Modelling-the-vulnerability-of-old-URM-buildings-and-the-benefit-of-retrofit.pdf>
2019	Conference Paper	Alazem, R. [209], Lumantarna, E. [12], Lam, N. [24] & Menegon, S. [83]	<b>Development of Cost-effective Mitigation Strategy for Limited Ductile Reinforced Concrete Buildings</b> [210]. <i>Australian Earthquake Engineering Society 2019 Conference</i> (2019).at <https://aees.org.au/wp-content/uploads/2019/08/Development-of-Cost-effective-Mitigation-Strategy-for-Limited-Ductile-Reinforced-Concrete-Buildings.pdf>
2019	Conference Paper	Tsang, H. - H. [16], Daniell, J. [215], Wenzel, F. [216] & Wilson, J. [19]	<b>How Safe is Safe Enough? Melbourne Case Study</b> [217]. <i>Australian Earthquake Engineering Society 2019 Conference</i> (2019).at <https://aees.org.au/wp-content/uploads/2019/08/How-Safe-is-Safe-Enough-Melbourne-Case-Study.pdf>
2019	Conference Paper	Edwards, M. [20] <i>et al.</i>	<b>Mitigating earthquake risk in Australia</b> [222]. <i>2019 Pacific Conference on Earthquake Engineering and Annual NZSEE Conference</i> (2019).at <http://db.nzsee.org.nz/2019/Oral-Session-1/Abstracts/Abstract-222.pdf>
2019	Conference Paper	Lumantarna, E. [12], Lam, N. [24] & Wilson, J. [19]	<b>Predicting Maximum Displacement Demand of Asymmetric Reinforced Concrete Buildings</b> [227]. <i>Australian Earthquake Engineering Society 2019 Conference</i> (2019).at <https://aees.org.au/wp-content/uploads/2019/08/Predicting-Maximum-Displacement-Demand-of-Asymmetric-Reinforced-Concrete-Buildings.pdf>
2019	Journal Article	Hoult, R. D. [37], Goldsworthy, H. M. [15] & Lumantarna, E. [12]	<b>Vulnerability Functions for RC Shear Wall Buildings in Australia</b> [232]. <i>Earthquake Spectra</i> <b>35</b> , 27 (2019).DOI [233] Google Scholar [234] BibTeX [235] EndNote XML [236]
2019	Journal Article	Tsang, H. - H. [16]	<b>Innovative Upscaling of Architectural Elements for Strengthening Building Structures</b> [237]. <i>Sustainability</i> <b>11</b> , 2636 (2019).DOI [238] Google Scholar [239] BibTeX [240] EndNote XML [241]
2019	Journal Article	Menegon, S. [83] <i>et al.</i>	<b>Framework for seismic vulnerability assessment of reinforced concrete buildings in Australia</b> [242]. <i>Australian Journal of Structural Engineering</i> <b>20</b> , 143-158 (2019).DOI [243] Google Scholar [244] BibTeX [245] EndNote XML [246]
2019	Journal Article	Derakhshan, H. [14], Walsh, K. [247], Ingham, J. [104], Griffith, M. [6] & Thambiratnam, D. [248]	<b>Seismic fragility assessment of nonstructural components in unreinforced clay brick masonry buildings</b> [249]. <i>Journal of Earthquake Engineering</i> <b>22</b> , 115-130 (2019).DOI [250] Google Scholar [251] BibTeX [252] EndNote XML [253]
2019	Journal Article	Tsang, H. - H. [16], Daniell, J. [215], Wenzel, F. [216] & Wilson, J. [19]	<b>A universal approach for evaluating earthquake safety level based on societal fatality risk</b> [254]. <i>Bulletin of Earthquake Engineering</i> <b>17</b> , 115-130 (2019).DOI [255] Google Scholar [256] BibTeX [257] EndNote XML [258]
2019	Journal Article	Tang, Y. [133], Lam, N. [24], Tsang, H. - H. [16] & Lumantarna, E. [12]	<b>Use of Macroseismic Intensity Data to Validate a Regionally Adjustable Ground Motion Prediction Model</b> [259]. <i>Geosciences</i> <b>9</b> , 100 (2019).DOI [260] Google Scholar [261] BibTeX [262] EndNote XML [263]
2019	Report	Lumantarna, E. [12], Lam, N. [24], Tsang, H. - H. [16], Gad, E. F. [10] & Wilson, J. [19]	<b>Progress report on costing of limited ductile reinforced concrete buildings</b> [264]. (Bushfire and Natural Hazards CRC, 2019).Google Scholar [265] BibTeX [266] EndNote XML [267]
2019	Report	Vaculik, J. [187] & Griffith, M. [6]	<b>Final report on vulnerability of as-built and retrofitted URM buildings</b> [268]. (Bushfire and Natural Hazards CRC, 2019).Google Scholar [269] BibTeX [270] EndNote XML [271]
2019	Report	Mohanty, I. [166], Edwards, M. [20], Ryu, H. [17] & Wehner, M. [23]	<b>Cost-effective mitigation strategy development for building related earthquake risk: progress report on economic loss modelling</b> [272]. (Bushfire and Natural Hazards CRC, 2019).Google Scholar [273] BibTeX [274] EndNote XML [275]
2019	Report	Griffith, M. [6] <i>et al.</i>	<b>Cost-Effective Mitigation Strategy Development for Building Related Earthquake Risk Annual Report 2017-2018</b> [276]. (Bushfire and Natural Hazards CRC, 2019).Google Scholar [277] BibTeX [278] EndNote XML [279]
2019	Report	Griffith, M. [6]	<b>Cost-effective mitigation strategy for building related earthquake risk - annual report 2018-2019</b> [280]. (Bushfire and Natural Hazards CRC, 2019).Google Scholar [281] BibTeX [282] EndNote XML [283]
2018	Journal Article	Derakhshan, H. [14], Lucas, W. [284], Visintin, P. [285] & Griffith, M. [6]	<b>Out-of-plane strength of existing two-way spanning solid and cavity unreinforced masonry walls</b> [286]. <i>Structures</i> <b>13</b> , 88-100 (2018).DOI [287] Google Scholar [288] BibTeX [289] EndNote XML [290]
2018	Journal Article	Raza, S. [160], Tsang, H. - H. [16] & Wilson, J. [19]	<b>Unified models for post-peak failure drifts of normal- and high-strength RC columns</b> [291]. <i>Magazine of Concrete Research</i> <b>70</b> , 1101 (2018).DOI [292] Google Scholar [293] BibTeX [294] EndNote XML [295]
2018	Journal Article	Derakhshan, H. [14], Lucas, W. [284], Visintin, P. [285] & Griffith, M. [6]	<b>Laboratory testing of strengthened cavity unreinforced masonry walls</b> [296]. <i>Journal of Structural Engineering</i> <b>144</b> , (2018).DOI [297] Google Scholar [298] BibTeX [299] EndNote XML [300]
2018	Journal Article	Wilson, J. [19], Tsang, H. - H. [16] & Liu, X. [301]	<b>Seismic retrofit of precast soft-storey building using diagonal steel-shape memory alloy bracing device: Numerical investigation</b> [302]. <i>Advanced Steel Construction</i> <b>5</b> , 1-12 (2018).DOI [303] Google Scholar [304] BibTeX [305] EndNote XML [306]
2018	Journal Article	Vaculik, J. [187], Visintin, P. [285], Griffith, M. [6], .G.Burton, N. [307] & .Seracino, R. [308]	<b>State-of-the-art review and future research directions for FRP-to-masonry bond research: Test methods and design</b> [309]. <i>Journal of Bridge Engineering</i> <b>23</b> , 04018001 (2018).DOI [310] Google Scholar [311] BibTeX [312] EndNote XML [313]
2018	Journal Article	Zabihi, A. [36], Tsang, H. - H. [16], Gad, E. F. [10] & Wilson, J. [19]	<b>Seismic retrofit of exterior RC beam-column joint using diagonal haunch</b> [314]. <i>Engineering Structures</i> <b>174</b> , (2018).DOI [315] Google Scholar [316] BibTeX [317] EndNote XML [318]
2018	Report	Vaculik, J. [187] & Griffith, M. [6]	<b>Final report on fragility curves for retrofitted URM buildings in Australia</b> [319]. (Bushfire and Natural Hazards CRC, 2018).Google Scholar [320] BibTeX [321] EndNote XML [322]
2018	Report	Griffith, M. [6] & Vaculik, J. [187]	<b>Retrofitting costs for URM buildings</b> [323]. (Bushfire and Natural Hazards CRC, 2018).Google Scholar [324] BibTeX [325] EndNote XML [326]
2018	Report	Mohanty, I. [166], Edwards, M. [20], Ryu, H. [17] & Wehner, M. [23]	<b>Cost-effective mitigation strategy development for building related earthquake risk: reporting on economic loss models</b> [327]. (Bushfire and Natural Hazards CRC, 2018).Google Scholar [328] BibTeX [329] EndNote XML [330]
2018	Report	Lumantarna, E. [12] <i>et al.</i>	<b>Report on fragility curves for limited ductile reinforced concrete buildings</b> [331]. (Bushfire and Natural Hazards CRC, 2018).Google Scholar [332] BibTeX [333] EndNote XML [334]
2018	Report	Derakhshan, H. [14] & Griffith, M. [6]	<b>Final report on pushover analysis of classes of URM buildings to characterise drift ratios for different damage levels</b> [335]. (Bushfire and Natural Hazards CRC, 2018).Google Scholar [336] BibTeX [337] EndNote XML [338]
2017	Conference Paper	Lumantarna, E. [12], Mehdipanah, A. [76], Lam, N. [24] & Wilson, J. [19]	<b>Methods of structural analysis of buildings in regions of low to moderate seismicity</b> [339]. <i>2017 World Congress on Advanced Structural and Architectural Engineering</i> (2017).at <https://www.asce.org/conferences-and-symposia/2017-world-congress-on-advanced-structural-and-architectural-engineering>
2017	Journal Article	Tsang, H. - H. [16], Wilson, J. [19] & Lam, N. [24]	<b>A refined design spectrum model for regions of lower seismicity</b> [343]. <i>Australian Journal of Structural Engineering</i> <b>18</b> , (2017).DOI [344] Google Scholar [345] BibTeX [346] EndNote XML [347]
2017	Journal Article	Mehdipanah, A. [76], Lumantarna, E. [12] & Lam, N. [24]	<b>Methods of Structural Analysis of Buildings Incorporating Higher Modes Effects</b> [348]. <i>Australian Earthquake Engineering Society</i> <b>10</b> (2017).DOI [349] Google Scholar [350] BibTeX [351] EndNote XML [352]
2017	Journal Article	Tsang, H. - H. [16], Wilson, J. [19], Lam, N. [24] & Su, R. Kai Leng [353].	<b>A design spectrum model for flexible soil sites in regions of low-to-moderate seismicity</b> [354]. <i>Soil Dynamics and Earthquake Engineering</i> <b>95</b> , (2017).DOI [355] Google Scholar [356] BibTeX [357] EndNote XML [358]
2017	Journal Article	Vaculik, J. [187], Sturm, A. B. [359], Visintin, P. [285] & Griffith, M. [6]	<b>Modelling FRP-to-substrate joints using the bilinear bond-slip rule with allowance for friction - Full-range analytical solution</b> [360]. <i>Journal of Bridge Engineering</i> <b>22</b> , 04017011 (2017).DOI [361] Google Scholar [362] BibTeX [363] EndNote XML [364]
2017	Journal Article	Yacoubian, M. [365], Lam, N. [24], Lumantarna, E. [12] & Wilson, J. [19]	<b>Analytical modelling of podium interference on tower walls in buildings</b> [366]. <i>Australian Journal of Structural Engineering</i> <b>18</b> , (2017).DOI [367] Google Scholar [368] BibTeX [369] EndNote XML [370]
2017	Journal Article	Hashemi, M. [371], Tsang, H. - H. [16], Al-Ogaiddi, Y. [372], Wilson, J. [19] & Al-Mahaidi, R. [373]	<b>Collapse assessment of reinforced concrete building columns through multi-axis hybrid simulation</b> [374]. <i>Journal of Earthquake Engineering</i> <b>20</b> , 115-130 (2017).DOI [375] Google Scholar [376] BibTeX [377] EndNote XML [378]
2017	Journal Article	Yacoubian, M. [365], Lam, N. [24], Lumantarna, E. [12] & Wilson, J. [19]	<b>Effects of podium interference on shear force distributions in tower walls supporting tall buildings</b> [378]. <i>Engineering Structures</i> <b>143</b> , 115-130 (2017).DOI [379] Google Scholar [380] BibTeX [381] EndNote XML [382]
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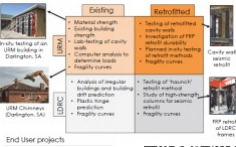


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Cost-effective mitigation strategy for building related earthquake risk

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Enhancing resilience of critical road infrastructure

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