Sensitivity: General

Seismic Design Manual for Bridges in Papua New Guinea- an update 40 years in the making

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Abstract: Papua New Guinea is located on the 'Pacific Ring of Fire', situated at the convergence of three major tectonic plates, and consequently a highly seismic region. Significant earthquakes including the 1971 Madang, 1985 Bialla, and 2018 Southern Highlands earthquakes caused major damage particularly to bridges and their approaches. Mitigating for the effects of earthquakes as part of engineering design of bridges and major infrastructure is a crucial priority for civil and structural engineers in Papua New Guinea (PNG). The PNG Department of Works and Highways has undertaken a significant revision of the design manual, entitled: "Seismic Design Manual for Bridges in Papua New Guinea: 2025 Revision". The original document was developed by Beca Carter Hollings and Ferner in the mid-1970s and was last updated in 1985. The 2025 update aims to reflect current international standards and engineering practice, incorporate updated seismic hazard information for PNG prepared by Geoscience Australia, while maintaining the pragmatic focus of the original document, aimed at informing engineering practitioners on good engineering design principles for the practical design of routine bridge typologies adopted in PNG. The update scope has drawn on a review of modern design practice as provided for example in the NZTA Bridge Manual and NZGS/MBIE Earthquake Geotechnical Engineering Guidelines, with amendments made to seismic design provisions and informative appendices on structural and geotechnical design aspects.

The existing manual (Dept. Works, 1985) was aligned with the PNG building code seismic provisions of the time (Jury et al. 1982). It contained introductory earthquake engineering design principles applied to bridges, and examples of failures during past earthquakes. Geotechnical information and guidance covered site investigations, geotechnical hazards, and seismic design of foundations and retaining walls. Seismic design recommendations specific to common PNG bridge typologies was provided as well as unique challenges associated with bridge abutments. It provided broad practical guidance aimed at PNG practitioners to achieve international 'best practice' at the time. Forty years on, the manual it was in urgent need of revision to reflect modern design methods, new knowledge on design seismic hazard, and changes in the materials and methods of construction.

Our understanding of earthquakes, the tectonic sources, frequency of occurrence in different parts of PNG, and the severity of shaking that may result has evolved significantly over the past 40 years. A recent collaboration between the PNG Port Moresby Geophysical Observatory (PMGO) and Geoscience Australia developed a new seismic hazard model and completed a Probabilistic Seismic Hazard Analysis (PSHA) (Ghasemi et al. 2020). Comparisons to the PNG Building code showed significant anomalies resulting in new bridges being either under- or over-designed. Workshops with PNG Stakeholders in 2024 identified instances where design loads may be half what was needed, and in other locations, eight times greater than necessary. The same workshop also identified that PNG engineers used AS5100 (Standards Australia, 2017) for most aspects of PNG bridge design, however geotechnical and structural design for earthquake was primarily based on the current Manual. In combination with the need for updating the seismic provisions, it was agreed to update the manual for the seismic structural and geotechnical design content, and to be aligned with current Australian standards and New Zealand design manuals.

The development of the updated seismic provisions (spectra, Peak Ground Acceleration) in a codified form familiar to NZS1170.5 (i.e., Z, Ch(T), Ru factors) are documented by Edwards et al. (2021) and in an accompanying guideline to the new Manual. For undertaking liquefaction assessment, representative mean magnitudes were also required. These were developed based on seismic hazard disaggregation across 230 gridded locations for two return periods and then contoured in the new Manual.

The geotechnical content of the original manual was generally excellent and practical and held up well today, however it received a general update for modern investigation and testing practice, notably the Cone Penetration Test (CPT), and pile load testing with reference to the Piling Standard AS2159 (Standards Australia 2009) among other details. Seismic slope stability assessment was updated – notably for modern software approaches and rock mass strength characterisation. Soil Liquefaction assessment received a major update with reference made to the NZGS/MBIE (2021) guidelines and the recommended approaches therein for undertaking liquefaction triggering and cyclic softening assessments as well as the resulting impacts and effects requiring mitigation through design. Dynamic earth pressures on retaining walls were also updated reflecting current practice.

The core principles of seismic design, including capacity design and good detailing were well covered in original manual, with the manual encouraging designers to follow specific bridge typologies with guidance to ensure a robust structural form was chosen. These important considerations in the original manual were retained, and the structural updates focused on updating key procedures for force-based design. Updates included; providing the new method for determining seismic design forces using the new hazard model, revised material properties consistent with current Australian and New Zealand standards, improved guidance on modelling assumptions for structural analysis. The new Manual provided a broader range of ductility classifications, with provisions for including damping, to better reflect contemporary understanding of bridge response under strong ground shaking. A significant advancement in the new Manual is the introduction of modern methods for assessing member deformation capacity, particularly providing the method for determining plastic hinge rotation demands and

capacities to confirm that the structure can provide the assumed structural ductility in the force-based design method.

Conclusion

The 2025 revision of the *Seismic Design Manual for Bridges in Papua New Guinea* represents a substantial and necessary update of a document that has served the country well for more than four decades. By integrating updated seismic hazard information, aligning with current Australian and New Zealand design standards, and retaining the practical approach of the original manual, the updated document provides PNG engineers with an improved framework for the seismic design of bridges.

The updated provisions enhance the reliability of bridge performance during major earthquakes, contributing to safer, more resilient national transport connectivity.

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