Design & construction of the first building worldwide with a low-cost PVC-sand seismic isolation system

Fact sheet

Location

- Kathmandu, Nepal

Partner Institutions

- University of Bristol (UK)
- National Society for Earthquake Technology – Nepal (NSET)

Research and Design Team

- Anastasios G. Sextos, Nicholas A. Alexander (University of Bristol)
- Vibek Manandhar, Sangib Shrestha, Rabin Chaulagain, Narayan P. Marasini, Ramesh Guragain (NSET)

Partner School

- Shree Adarsha Secondary School, Kageshwori Manohara Municipality, Kathmandu, Nepal

Completion date

- August 2023

Construction / Seismic isolation cost

- £57,500 / £11,500 (20% of total)

Concept

Low-cost, PVC-sand seismic isolation

PVC-s is a novel, low-cost, easy-to-implement, friction-based seismic-isolation system which encapsulates locally resourced sand grains between two sheets of polyvinyl chloride (PVC) covering the area underneath the raft foundation. This "hybrid" system requires that the superstructure is designed according to local seismic code, with the interface acting as a "fuse" that promotes sliding once the friction force is exceeded. The main advantage is that, particularly in regions where implementation of capacity design cannot be guaranteed, the maximum seismic energy that is transferred to the superstructure is well kept under control. The system has been qualified by large scale testing at the 3m x 3m shaking table of UoB, while extensive sand samples sourced from Nepal were tested to assess the statistical properties of the kinetic friction coefficient for different vertical stress, sand density and degree of saturation.

Structural system

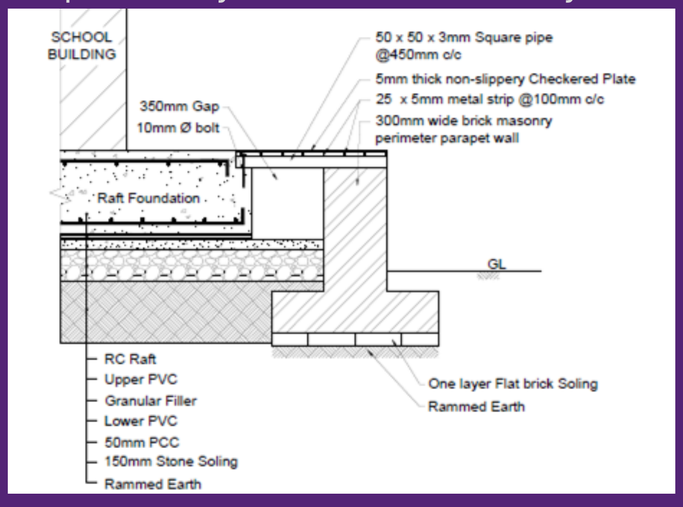
The building is a reinforced concrete structure resting on a raft foundation that is seismically isolated using the low-cost PVC-sand-PVC (PVC-s) system. The PVC sheets have a thickness of 2mm and the encapsulated sand interface is single grain with density of 2kg/m^2. The friction coefficient is experimentally assessed with a mean value of 0.21 and a C.O.V. equal to 0.25, for vertical stress varying between 10-32 kPa for the seismic combination. Given that the PVC-s acts as an additional level of safety the above uncertainty is deemed tolerable. The system is designed to be triggered when the spectral acceleration exceeds the friction force at the PVC-s surface, with the target activation threshold set between 0.20g and 0.25g, i.e., at a level that aligns with the design acceleration of the specific region. The foundation and the PVC-s are built above ground to facilitate sliding. A sacrificial brick parapet is built around a gap of 35cm that is numerically derived to correspond to 1% probability of exceedance in 50 years.

Architectural features

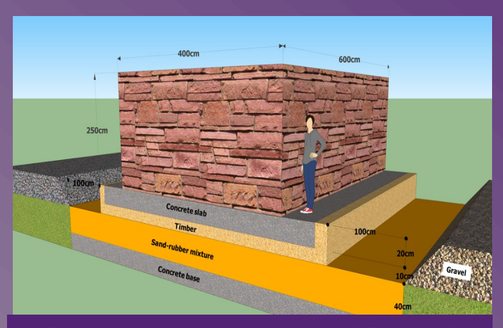
The project exhibits a low-cost base isolation technology on a four classroom, two - storey RC school building located at the north-east part of the Kathmandu Valley. The rectangularly shaped rectangular buildings has a footprint of 44 sqm. The structural and architectural design of the building is based on official type design published by the Government of Nepal and updated to comply with the latest seismic design code in Nepal. The building has a simple architectural layout with a central staircase separating the two classrooms and a staircase cover on the top storey.

Performance & Cost

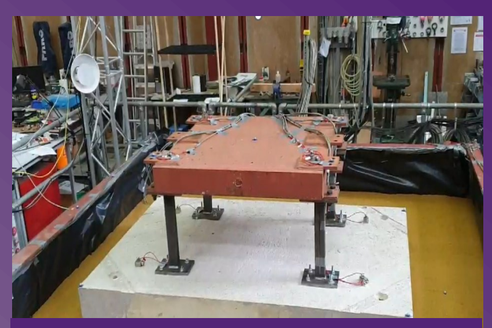
The adoption of the PVC-s base isolation system resulted in a cost increment of 20 % compared to constructing a similar building without isolation. The benefits of this low-cost isolation system can be considered to outweigh the additional expense, as it significantly reduces the seismic forces, directly enhancing the overall seismic performance and minimizing life-cycle earthquake-induced damage. This is of paramount importance for building seismic capacity and resilience of underprivileged communities worldwide.



Sextos, A.G., Zhang, Z. and N.A. Alexander (2022) "Large-scale testing for enhancing the resilience of schools in seismic regions: challenges and cost-efficient solutions", Invited Lecture. Progresses in European Earthquake Engineering and Seismology. ECEES, Springer Proceedings in Earth and Environmental Sciences, pp. 433–448. Springer. https://doi.org/10.1007/978-3-031-15104-0_26.



Conceptual design of PVC-S


Large-scale shaking table tests

Nepal sand sampling


Kinetic friction testing


Parapet construction


Preparation of the base


Spreading of the sand


Laying of Upper PVC layer


Mat reinforcement


Mat foundation

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Column concreting


Brickwork completion


Operational building