

**SEISMIC VULNERABILITY ASSESSMENT OF MASONRY  
INFILLED REINFORCED CONCRETE SCHOOL  
BUILDING FRAMES IN SRI LANKA**

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Degree of Master of Science

Department of Civil Engineering

University of Moratuwa  
Sri Lanka

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## DECLARATION

“I declare that this my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by other person except where the acknowledgement is made in the text.

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## ABSTRACT

Sri Lanka is considered as an aseismic country, hence the seismic risk is not explicitly considered in the planning and designing of critical structures. However, current studies indicate that the seismic risk cannot be completely omitted when designing buildings in Sri Lanka, particularly post-disaster structures like schools and hospitals that should be designed to withstand any potential seismic action. Meanwhile, assessing the seismic risk of all the critical structures in depth across Sri Lanka might not be an easy task, and therefore, the creation of a rapid assessment method would help to effectively screen the buildings which are seismically vulnerable.

Therefore, in this study, an attempt was made to assess the seismic vulnerability of school buildings in Sri Lanka in detail by incorporating possible variations and proposing an alternate Rapid Visual Screening method (RVS) for Sri Lankan conditions by incorporating FEMA P-154 guidance.

In order to study the existing school building typologies, detailed structural surveys were carried out across Sri Lanka in selected school buildings. The survey revealed that school buildings in Sri Lanka can be characterised as reinforced concrete (RC) frames, infilled with unreinforced masonry walls (MI). Based on the structural configurations, mainly two building typologies were found as (1) Type 01 and (2) Type 02. Nonetheless, in terms of MI arrangements, it was observed that significant variations exist among the school buildings. Therefore, those variabilities were explicitly taken to assess the seismic performance of MI-RC school buildings.

The seismic performance of the school buildings was analysed using the OpenSees (OS) finite element programme. The torsional effects and post-processing as shear capacity and stochastic material properties (concrete, steel, and masonry) from Monte-Carlo simulation were incorporated in this study. The modal analysis and non-linear static pushover analysis were carried out, in which a total of 640 building cases were analysed.

The analyses of pushover (PO) and seismic fragility revealed that the Type 02 buildings exhibit significantly better performance than the Type 01 buildings. Also, the variation in MI arrangements significantly influences the seismic resistance of the buildings. In addition, the application of the proposed RVS method is effective to carry out the seismic screening method of school buildings in Sri Lanka.

**Keywords:**

School buildings, Non-linear static pushover, Seismic performance assessment, Seismic Fragility assessment and Rapid visual screening method

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## LIST OF ABBREVIATIONS

<i>ADRS</i>	-	Acceleration Displacement Response Spectrum
<i>ATC</i>	-	Applied Technology Council
<i>CC</i>	-	Capacity Curve
<i>CDS</i>	-	Capacity Demand Spectrum method
<i>CF</i>	-	Collapse Factors
<i>CW</i>	-	Central Window
<i>d</i>	-	Displacement
<i>Du</i>	-	Ultimate displacement
<i>DW/SW</i>	-	Doubly or Single thickness masonry wall
<i>Dy</i>	-	Yield displacement
<i>FEMA</i>	-	Federal Emergency Management Agency
<i>FGS</i>	-	Fully closed Ground Storey
<i>HAZUS</i>	-	Hazard in United States
<i>HO</i>	-	Half Opening wall
<i>IEP</i>	-	Initial Evaluation Procedure
<i>ISA</i>	-	Initial Seismic Assessment
<i>JBDPA</i>	-	Japan Building Disaster Prevention Association
<i>MCS</i>	-	Monte-Carlo Simulation
<i>METU</i>	-	Metropolitan Municipality of Istanbul
<i>MI</i>	-	Masonry Infills
<i>NBS%</i>	-	New Building Standard percentage
<i>NLSPA</i>	-	Non-Linear Static Pushover Analysis
<i>NRCC</i>	-	National Building Council of Canada
<i>NSI</i>	-	Non-Structural Index
<i>OGS</i>	-	Open Ground Storey
<i>OS</i>	-	OpenSees
<i>PC</i>	-	Precast Concrete
<i>PO</i>	-	Pushover
<i>QO</i>	-	Quarter Opening wall
<i>RC</i>	-	Reinforced Concrete
<i>RC-MI</i>	-	Masonry Infilled Reinforced Concrete
<i>RM</i>	-	Reinforced Masonry
<i>RVS</i>	-	Rapid Visual Screening
<i>S02/S03</i>	-	Three or Two Storey
<i>Sa</i>	-	Spectral Acceleration
<i>Sd</i>	-	Spectral Displacement
<i>SI</i>	-	Structural Index
<i>T01/T02</i>	-	Type-01 or Type-02 buildings
<i>TO</i>	-	Three-quarter Opening wall
<i>URM</i>	-	Unreinforced Masonry
<i>V</i>	-	Base Shear