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Nepalese School Building Stock and Implications on Seismic Vulnerability Assessment

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Abstract

The last catastrophic seismic events in Nepal have shown that the Nepalese school building stock is characterized by a high level of vulnerability with respect to seismic actions. According to different post-event reconnaissance reports, thousands of schools have been destroyed by the 2015 earthquakes, depriving the country of a fundamental social and economic asset. Within the SAFER (Seismic Safety and Resilience of Schools in Nepal) project, a specific working task is dedicated to the assessment of school structures in terms of probabilistic fragility functions. These curves will be included in a comprehensive seismic risk management framework for the Nepalese community. However, the derivation of fragilities has to be preceded by: (i) a meaningful subdivision of the total building inventory in different structural typologies, (ii) a detailed investigation about the recurrent seismic damage and failure modes of Nepalese constructions. These two aspects and their implications on the selection of proper structural assessment methodologies are carefully discussed and mapped in the present paper.

Keywords: *Nepalese school building; Earthquake damages; Structural typology; Vulnerability assessment.*

1. Introduction

It is nowadays common knowledge that the Nepalese school building stock is characterized by a high level of vulnerability. According to a 2014 Asian Development Bank report (ADB 2014), 18% of the nation's schools require rebuild while 43% need major retrofitting interventions. The last catastrophic 2015 seismic event has unfortunately worsened this situation. Different post-event reconnaissance reports (Aon Benfield, 2015; Build Change, 2015; EERI Earthquake Engineering Research Institute, 2016; Government of Nepal, 2015; Paci-Green *et al.*, 2015) estimate that about 6,000-8,200 schools have been destroyed by the 2015 earthquakes. Post-earthquake surveys carried out adopting the inspection form from the National Society of Earthquake Technology (NSET) resulted in 6,000 school buildings tagged with a damage grade (DG) 4 corresponding to "very heavy damage" or DG5 (collapse) and 11,000 tagged with damage score DG2 or DG3 corresponding to moderate and heavy damage, respectively. In terms of classrooms, 47,557 suffered structural damage. In details, 9.1% of country`s classrooms experienced collapse, while 5.1% and 7.8% of the classrooms experienced heavy and moderate damage respectively (Aon Benfield, 2015). In the areas close to the earthquake epicentre, the consequences on school buildings were even more catastrophic. For instance, in the Sindhupalchowk district, 99% of the classrooms suffered seismic damage while, in Gorkha district, 85% of the classrooms were destroyed by the earthquake event. The Government of Nepal have estimated about $300-400M in damage and losses in the education sector (Government of Nepal, 2015; Paci-Green *et al.*, 2015).

In order to reduce these dramatic consequences in case of future earthquakes, it is of paramount importance to adequately estimate the seismic risk exposure of the school building stock. One of the

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main aspects of the risk assessment is the estimation of the structural vulnerability, which is usually carried out through vulnerability or fragility functions (e.g., Rossetto *et al.*, 2013; Pitilakis *et al.*, 2014). As underlined by Porter *et al.* (2007) the evaluation of these curves can be performed using three main approaches: (i) statistical processing of post-quake observational data, the so called "empirical fragilities"; (ii) analytical/numerical simulations, the so called "analytical fragilities"; (iii) expert opinions, the so called "expert elicitation-based fragilities". Excluding the last methodology, which can lack of scientific robustness (e.g., Aspinall, 2010), the first two techniques have been already adopted in the Nepalese context. For instance, Gautam *et al.* (2018) developed observational fragility functions for three classes of Nepali residential buildings (namely reinforced concrete, brick masonry and stone masonry) using survey data from 1934 Bihar-Nepal earthquake, 1980 Chainpur earthquake, 1988 Eastern Nepal earthquake, 2011 Eastern Nepal earthquake and 2015 Gorkha earthquake. Furthermore, Chaulagain *et al.*, (2016) derived fragility functions for reinforced concrete buildings by adopting a numerical approach based on finite element modelling. In order to have a more comprehensive representation of the probabilistic seismic vulnerability of the school buildings in Nepal, more systematic studies are required. These studies could be used to inform a new damage surveying method, tailored to the Nepalese school building typologies, and meeting the needs of disaster response and planning agencies. Starting from the various post-2015-earthquakes survey reports available in literature, the present paper summarizes: (i) the taxonomy of the Nepalese school building stock resulting from previous projects (e.g., ARUP, 2015); (ii) the recurrent seismic damage observed for any structural typology; (iii) the most suitable analytical methodology to be used for the vulnerability assessment.

2. School Building Typologies

Nepal is among the poorest economies in the world (Muzzini *et al.*, 2013) and one of the less urbanized nations in South Asia with 80.3% of the population living in rural areas (United Nations 2018). For these reasons, despite the large number of projects carried out on school buildings in Nepal by international agencies and NGOs, an official and detailed database on structural typology distribution over the country is still lacking. A recent study from the Asian Development Bank (ABD 2014) gives a rough indication of the building construction types in different areas of the nation. In the Kathmandu valley 30% of the schools have a reinforced concrete (RC) frame bearing system while 65% have brick unreinforced masonry (URM) supporting walls. In the plain area (*Terai*), the RC framed structures are just 10% in favour of a more consistent presence of brick masonry (85%). These percentage distributions consistently change in the hilly and mountain regions where most of the buildings (respectively 87% and 97%) are recognized as "other type" i.e., stone masonry, adobe, wooden or mixed-system structures. Similar data are reported in post-2015-earthquake survey reports. According to Paci-Green *et al.* (2015), most of the school buildings in Nepal, i.e. 89%, are constituted by unreinforced masonry (URM) material. Moreover, in mountain areas, because of the lack of construction materials (such as fired bricks, cement and steel), 50% of these constructions are made of dry/mud-mortar rubble-stone masonry. Contrariwise, thanks to the vicinity to industrial activities, the distribution of school structural typologies in the Kathmandu Valley is slightly different from the rest of the country.

A more detailed reconnaissance of the school structural taxonomy and distribution in Nepal dates back to 2000 and was prepared by the Nepalese National Society for Earthquake Technology (NSET) and GeoHazards International (NSET 2000). In this report, the vulnerability of public schools in the Kathmandu Valley is analysed. Particularly, the work gives an indication of the construction techniques present in the region starting from a survey-based catalogue of 909 school buildings. According to the study, at the time of the survey there were 643 public schools in Bhaktapur, Lalitpur and Kathmandu districts with approximately 1 to 9 buildings for each institute. Table 1 reports the number of school buildings subdivided by structural typology and the corresponding percentage with respect to the total available data. For comparison purposes, in the same table, the general building typology distribution of the Kathmandu Valley (i.e. Bhaktapur Municipality, Lalitpur Sub-Metropolitan City and Kathmandu Metropolitan City) in 2011 is reported (Chaulagain *et al.*, 2016). It can be observed that according to NSET (2000), 68.1% of the school buildings were constituted by adobe/masonry material, split in 16.7% of adobe/stone assemblage and 51.4% of regular bricks. The second most recurrent school building type was the one-story metallic structure (also called earthquake block). These schools were constructed under the World Bank - Earthquake Affected Areas Reconstruction and Rehabilitation Project (EAARRP) in the period 1992-1997. According to NSET (2000), this typology represented 22.2% of the total school building stock. Lastly the RC accounted for 8.1% of the school catalogue.

Table 1. School typology distribution in the Kathmandu valley in 2000 (NSET 2000) and comparison with respect to the 2011 general building distribution reported by Chaulagain *et al.* (2016).

Acronym*	School building types in 2000			Building types in 2011		
	Typology	Number of buildings [-]	Percentage [%]	Percentage BMC** [%]	Percentage LSMC** [%]	Percentage KMC** [%]
A	Adobe	34	3.7	3.0	3.0	2.0
URM-SM	Stone-mud masonry	114	12.5	31.0	27.0	26.0
URM-BM	Brick-mud masonry	281	30.9			
URM-SC	Stone-cement masonry	5	0.5	27.0	30.0	33.0
URM-BC	Brick-cement masonry	187	20.5			
RC	Reinforced concrete	74	8.1	39.0	40	39
S	Metallic (EAARRP)	202	22.2	-	-	-
	Other	15	1.6	-	-	-
TOTAL		909	100	100	100	100

* Readapted from ARUP classification (ARUP 2015)
** BMC = Bhaktapur Municipality, LSMC = Lalitpur Sub-Metropolitan City, KMC = Kathmandu Metropolitan City

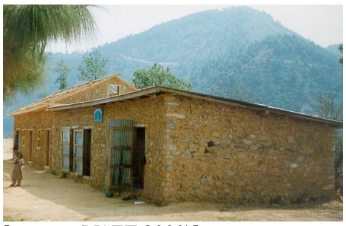
It is worth highlighting that in 2000 most of the URM school constructions were constituted by low-quality mud-mortar (43.4% mud-mortar versus 21% cement-mortar) while, looking at the data reported in Chaulagain *et al.* (2016), it can be noticed that in the last decade the cement-mortar URM increased, at least at global building inventory level. The same conclusion can be drawn for RC constructions: in 2000 they accounted for 8.1% of the Kathmandu Valley school building inventory while in 2011 they were 40% of the total building stock. Given the increasing urbanization of the country (Ishtiaque *et al.*, 2017), it is reasonable to assume that this construction trend is also affecting the school building stock. Lastly, as a consequence of the ongoing post-2015-earthquake reconstruction phase, it is likely that the percentage of metallic buildings will increase in future years since this structural typology is among the structural designs approved by the Department of Education of Nepal (DOE, 2016).

In Table 2, the main school building typologies are described starting from the classification provided by ARUP (2015), NSET (2000) and considering the work by Gautam *et al.* (2018), Chaulagain *et al.* (2016) and Adhikari *et al.* (2018). In this regard, it should be acknowledged that often in Nepal schools are built incrementally (according to increases in demand and availability of funding). Construction materials are readily changed between different increments, leading to buildings that do not always fit neatly into typologies.

3. Recurrent Damage

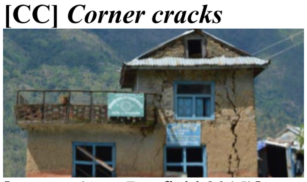
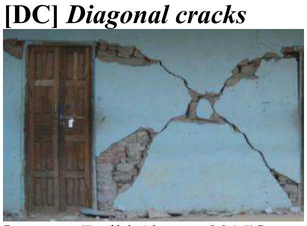
Several post-quake assessment reports have discussed the typical damage of the Nepalese buildings after the 2015 earthquakes (e.g., Brando e*t al.,* 2017; Paci-Green *et al.*, 2015; Sharma *et al.*, 2016; EERI 2016; Build Change 2015; Gautam & Chaulagain, 2016; Chiaro *et al.*, 2015). This information is of fundamental interest for the seismic vulnerability phase since the damage evidence suggests which assessment procedure should be used and under which precautions. Table 3 attempt to summarize the main outcomes from the damage evidence provided in literature.

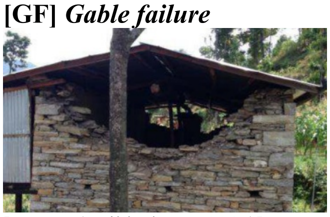
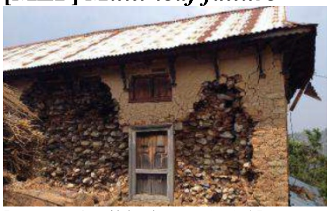
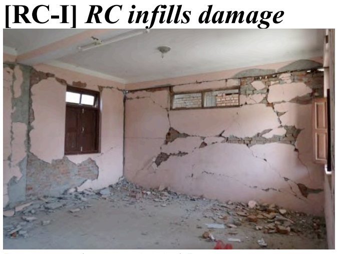
Table 2. Nepalese school structural typologies adapted from ARUP (2015) and NSET (2000).

Type	Description
[A] *Adobe*  [source: (NSET 2000)]	- *Location:* plain area (*terai*). - *Typical N. of stories:* 1. - *Story height:* 1.8–2.4 m. - *Wall thickness:* 45–60 cm. - *Wall characteristics:* sun-dried bricks in mud mortar; absence of wall-to-wall connections (external walls are usually constructed before the internal ones); lack of wall-to-floor connections (absence of anchor ties). - *Floors typology:* mud layer on wooden planks and timber/bamboo joists. - *Roof typology:* corrugated iron (CGI) sheets on timber joists (duo-pitch).
[URM-SM] *Stone-mud URM*  [source: (NSET 2000)]	- *Location:* hills and mountain area. - *Typical N. of stories:* 1. - *Story height:* 1.8–2.4 m. - *Wall thickness:* 45–60 cm. - *Wall characteristics:* the cross-section of the wall is usually composed by two external wythes and an internal rubble core (no through-stones); absence of wall-to-wall connections; lack of wall-to-floor connections. - *Floors typology:* mud layer on wooden planks and timber/bamboo joists; in some cases, traditional floors are replaced with RC slabs. - *Roof typology:* CGI sheets on timber joists.
[URM-BM] *Brick-mud URM*  [source: (NSET 2000)]	- *Location:* rural areas and old cities. - *Typical N. of stories:* 2. - *Story height:* 2.7 m. - *Wall thickness:* 35–45 cm. - *Wall characteristics:* lack of wall-to-wall connection; lack of wall-to-floor connections, lack of through-stones. - *Floors typology:* mud layer on wooden planks and timber/bamboo joists; RC brick-concrete floors or concrete slabs. - *Roof typology:* cast-in-situ RC roof; CGI sheets on timber joists.
[URM-SC] *Stone-cement URM*  [source: (NSET 2000)]	- *Location:* hills and mountain area. - *Typical N. of stories:* 2. - *Story height:* 2.4–2.7 m. - *Wall thickness:* 45 cm. - *Wall characteristics:* lack wall-to-wall connection; lack of wall-to-floor connections; significant number of openings. - *Floors typology:* cast-in-situ RC. - *Roof typology:* cast-in-situ RC roof is usually more common than CGI sheets on timber joists roof.
[URM-BC] *Brick-cement URM*  [source: (NSET 2000)]	- *Location:* urban areas (recent constructions). - *Typical N. of stories:* 2-3. - *Story height:* 2.7 m. - *Wall thickness:* 20–23 cm (one brick thick). - *Wall characteristics:* absence of vertical/horizontal bands; absence of ring beams; large openings; lack or wall-to-wall and wall-to-floor connections; usually do not respect building code regulations. - *Floors typology:* cast-in-place RC brick-concrete floors or RC slabs. - *Foundations typology:* strip foundation made of brick-cement masonry.
[RC-N] *RC non-engineered*  [source: Andreas Stavridis]	- *Location:* urban areas. - *Typical N. of stories:* 1-5. - *Story height:* 2.7–3.0 m. - *RC Frame characteristics:* regular in plan; columns dimension 23 x 23 cm; beams dimension 23 x 32.5 cm; column spacing between 3 and 5 m; inadequate load path (beams do not properly frame into columns); lack of reinforcement detailing; low redundancy; quality of concrete is not assured. - *Partition wall thickness:* 23 cm (one brick thick). - *Floors typology:* cast-in-place RC slabs (7-10 cm thick). - *Roof typology:* CGI Roof supported by steel structure or RC. - *Foundations typology:* strip foundation made of brick-cement masonry

[RC-E] ***RC engineered***  [source: http://www.gems.edu.np/]	- *Location:* urban areas (new structures). - *Typical N. of stories:* 1-5. - *Story height:* 2.7–3.0 m - *RC Frame characteristics:* regular in plan; columns dimension 30 x 30 cm; redundancy and detailing according to IS 13920. - *Partition wall thickness:* 23 cm (one brick thick). - *Floors typology:* cast-in-place RC slabs (7-10 cm thick). - *Roof typology:* CGI Roof supported by steel structure or RC.
[S] ***Metallic (EAARRP)***  [source: (NSET 2000)]	- *Location:* rural areas (realized between 1992 and 1997 under the World Bank - Earthquake Affected Area Reconstruction and Rehabilitation Project). - *Typical N. of stories:* 1. - *Story height:* 2.4 m (minimum). - *Structure characteristics:* light-gauge steel frame regular in plan; the perimetric walls are realized with stone/brick mud/cement mortar depending on the local availability of the materials; lintel bands for the walls-roof connection are usually absent. - *Partition wall typology:* variable (filed-stones/bricks in cement-mud mortar depending on the availability); walls are not connected to the steel frame - *Roof typology:* CGI Roof supported by steel structure

Table 3. Damage types description of Nepalese buildings.

Damage types	Description
[CC] ***Corner cracks***  [source: (Aon Benfield 2015)]	Corner cracks are more likely to develop when: (i) the masonry assemblage is characterized by low-quality mortar and vertical alignments of the head joints; (ii) there is a lack of connection with the horizontal structures. The development of these cracks negatively affects the dynamic response of the building and may lead to local collapse mechanisms.
[DC] ***Diagonal cracks***  [source: (Build Change 2015)]	Diagonal cracks usually affect masonry piers subjected to severe in-plane horizontal loads. Particularly, when the stiffness/strength of the units is considerably higher than the corresponding mortar's values, shear actions activate inclined diagonal cracks which follow bed/head mortar joints. On the contrary, when blocks and mortar have comparable mechanical characteristics, the inclined cracks follow the principal stress directions through joints and units.
[OOP] ***Out-of-plane failure***  [source: Rama Mohan Pokhrel]	The out-of-plane failure is the most common type of damage for URM structures in Nepal. As a matter of fact, most of the buildings lack of seismic detailing (such as anchors, ties, ring beams) and out-of-pane displacements are not restrained. The out-of-plane is more frequent for the non-loadbearing walls which: (i) are intrinsically more vulnerable because of the absence of stabilizing loads; (ii) do not benefit from the retaining effect of the beams.
[TSC] ***Top-story collapse***  [source: (Build Change 2015)]	The upper floor walls are generally subjected to larger horizontal accelerations due to the filtering effect of the supporting structure (e.g., Lagomarsino 2015). Accordingly, in the post-earthquake phase, it has been observed that the walls located at the last floor of adobe/URM buildings have been more severely affected by in-plane and out-of-plane damage. The combination of these failure modes has eventually led to the complete collapse of the top-story. The presence of light roofs (e.g. Corrugated Galvanised Iron (CGI)) not adequately connected to the walls has also intensified this damage pattern.

Damage types	Description
[GF] ***Gable failure***  [source: (Build Change 2015)]	Gable walls are extremely vulnerable to seismic actions especially when they are not connected to the roofing structural system (Gautam et al. 2016). This damage type is essentially out-of-plane and usually affects even a portion of the perimetric wall below the gable. As for the top-story collapse [TSC], the amplification of the horizontal accelerations negatively affects the stability of the gable.
[MLF] ***Multi-leaf failure***  [source: (Build Change 2015)]	When the structural walls are characterized by significant thickness (i.e., more than 40 cm), they are usually constituted by multi-leaf masonry. It has been observed that, in most cases, the layers are not connected with through-stones and include an internal incoherent core. Structures of this kind are usually characterized by the delamination and out-of-plane failure of the external layer. The phenomenon is more accentuated when the mechanical properties of the mortar are low (i.e., mud mortar).
[RC-J] ***RC joint damage***  [source: (EERI 2016)]	RC beam-column joints of Nepalese building have been interested by severe damage. The main reasons of their weakness are: (i) the limited confinement of the joint due to the lack of stirrups; (ii) the absence of seismic detailing, (iii) the limited amount of longitudinal reinforcement in the columns; (iv) the presence of surfaces of discontinuity due to consecutive concrete castings (EERI 2016).
[RC-I] ***RC infills damage***  [source: (EERI 2016)]	According to Gautam et al. (2016) the most recurrent damage observed for the infill panels was related to in-plane diagonal cracks. The absence of adequate connections between the panels and the RC structure have also provoked a consistent number of out-of-plane collapse. Lastly, masonry panels with high thickness were also responsible of damage to the reinforced concrete columns due to local interaction (e.g., Verderame et al. 2011).
[SSC] ***Soft-story collapse***  [source: (Gautam et al. 2016)]	Several reconnaissance surveys have pointed out that the soft-story collapse is one of the most recurrent damage of RC buildings in Nepal. As reported by Gautam et al. (2016) three are the main causes of this damage: (i) presence of large openings at the ground level while the upper floors are characterized by thick masonry infills (23 cm); (ii) non-fulfilment of the “strong column-weak beam” capacity design criterium (e.g., Verderame et al. 2011); discontinuity of the framing system (i.e. presence of floating columns) which generates additional bending moment at the ground level columns and, eventually, provokes buckling failures (Gautam et al. 2016).

4. Recommendation for the Seismic Assessment

From Tables 2 and 3 the following assessment suggestions for the different structural typologies are outlined:

- [A]: Given the low-mechanical performance of adobe material (Tarque *et al.,* 2014), the most recurrent damage for this category involve corner cracks, walls delamination, detachment of portions of the walls and consequent out-of-plane failure. The numerical assessment of these type of structures is, in general, a challenging task and could require complex finite element models (e.g. Illampas *et al.*, 2014). More recently adobe structures have been also analysed with the discrete element technique (Mendes *et al.*, 2018). Obviously, the aforementioned techniques require a high implementation effort and computational cost. For this reason, they are more suitable for the seismic analysis of specific case-studies rather than used for regional-scale building stock assessments. On the other side, adequately simple techniques for the assessment of adobe structures are usually based on the analysis of constituting walls through methodologies based on the rigid-body theory (e.g., Doherty *et al.*, 2002; Ferreira *et al.*, 2015). It is worth mentioning that some studies (Lagomarsino, 2015) suggest a reduction of the wall nominal thickness to consider possible non-monolithic response.

- [URM-SM], [URM-BM]: As for adobe constructions, stone-mud and brick-mud structures are largely affected by out-of-plane failure. This damage mode mostly involves non-loadbearing walls and gable walls. The assessment considerations outlined for adobe apply to these building categories as well.
- [URM-SC], [URM-BC]: The presence of rigid cast-in-place concrete floors usually increases the dynamic box-behaviour of the structure and could lead to better wall-to-wall and wall-to-floor connections. Under these conditions, URM walls are mostly affected by in-plane damage (diagonal cracks, bed joint sliding or in-plane rocking). In terms of assessment, the equivalent frame methodology (e.g. Roca *et al.*, 2005) is the commonly-adopted technique for the assessment of this building typology, but, once again, it appears more suitable for the analysis of single buildings. Nevertheless, simplified techniques for the vulnerability assessment of masonry at territorial scale have been proposed in the literature and are essentially based on a simplified evaluation of the lateral capacity of the first storey of the building (e.g., Lagomarsino & Giovinazzi, 2006).
- [RC-N]: The assessment of these structures can be approached numerically, using nonlinear beam elements for the frame and multiple equivalent struts for masonry infills. Both lumped plasticity or smeared fibre discretization can be employed (e.g., De Luca & Verderame, 2015). For non-engineered structures, lumped plasticity is generally more suitable since it allows including brittle behaviour of RC structural elements and local interaction with masonry infills (e.g., Blasi *et al.*, 2018). Simplified spectral-based methods, more suitable for a regional-scale vulnerability assessment, are also available in the literature (e.g., De Luca *et al.*, 2015). They are essentially based on a soft-storey collapse mechanism assumption and account for infills stiffness and strength contribution. Nevertheless, proper calibration of the model parameters is required to account for the typical material properties of the Nepalese building stock.
- [RC-E]: The same assessment approach of RC-N can be considered for this category of buildings. It has to be specified that Nepali engineered RC structures generally do not fulfil the same ductility and high-specification requirements of advanced seismic code such as the Eurocode 8 (CEN 2004). Additionally, also in this case, masonry infill contribution can still play an important role in the overall building capacity and lead to brittle failures for flexural-shear interaction (e.g., De Luca & Verderame, 2015). As per RC-N, even if ductile behaviour is more likely to happen in the majority of the structural elements, a lumped plasticity model could be more informative with respect to fibre modelling. In terms of simplified methods for rapid large-scale assessments, the spectral-based approaches mentioned for RC-N remain a valid option adapting the analytical formulation to estimate the capacity curve to the improved design criteria (e.g., higher seismic design coefficient).
- [S]: Thanks to their limited weight, single-story metallic structures are generally not affected by severe damage. However, several cases of out-of-plane damage of the perimeter walls have been observed during post-earthquake surveys. Therefore, the vulnerability assessment of these school structures should include: (i) the analysis of the steel frame which can be executed with standard linear response spectrum analysis or, given their structural regularity, with the lateral load method (CEN, 2004); (ii) the out-of-plane assessment of the perimeter masonry walls as for A, URM-SM and URM-BM.

A schematic flow-chart of the possible methodologies for detailed assessment (building scale) and simplified assessment (regional scale) is reported in Fig. 1.

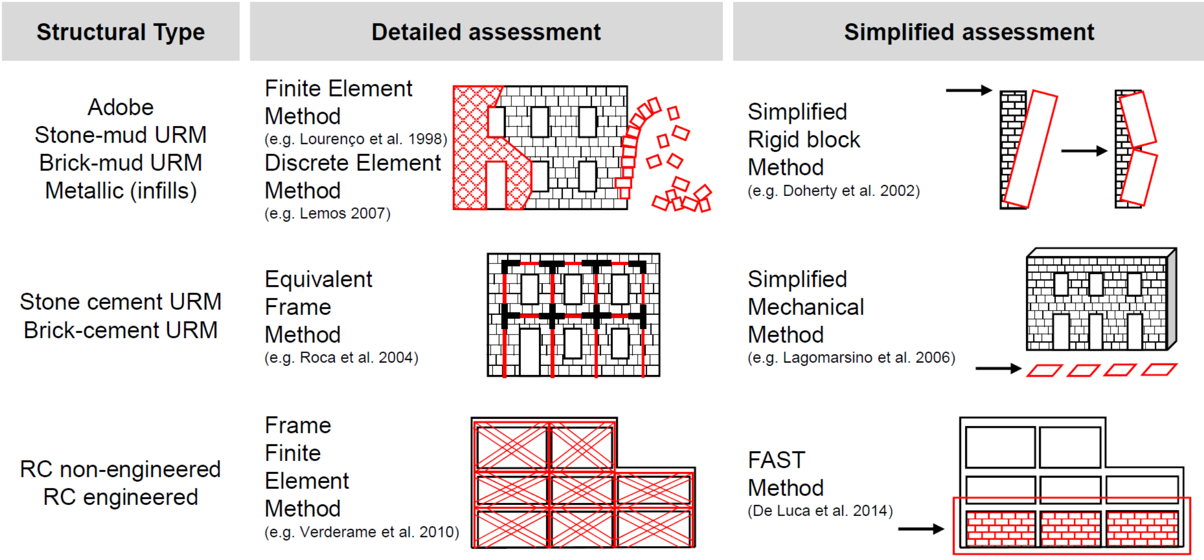


Fig. 1. Flow-chart of detailed (single building) and simplified (portfolio) assessment for Nepalese school building stock.

5. Conclusion

An overview of the Nepalese school structural typologies and a summary of the recurrent damage observed after the 2015 seismic events have been presented. This information has been combined to outline some useful indications for the vulnerability assessment stage. Looking at the available data on building type distribution over the country it is clear how URM structures play an important role in the overall seismic resilience of the school building stock. For traditional mud mortar URM, the out-of-plane failure seems the most critical type of damage: generally, is preceded by corner cracks and involves non-loadbearing walls, gable walls or the external wythe of thick masonry panels. In absence of specific post-quake damage data, the derivation of fragility curves with simplified rigid-body methods seem a reasonable compromise between assessment accuracy and computational cost. Additionally, it is pointed out that the poor construction quality of the walls can be accounted through specific cross-section thickness penalizing factors. Similar conclusions are valid for adobe structures that, anyhow, represent only a slight portion of the total school building stock. Cement mortar URM can be instead estimated by accounting the in-plane capacity of the different walls of the building through equivalent frame discretization or simplified mechanical-based formulations. For metallic structures, a part of conventional linear elastic analysis for the frame (damage to the steel frames were very rarely observed during recent 2015 seismic events), simplified out-of-plane vulnerability assessment of the perimeter walls is still suggested for regional-scale applications. For what regards RC structures, the typical analytical detailed FE lumped plasticity models are perfectly fitted as long as the global and local interaction with masonry infills can be captured by the model. On the other hand, also in this case, a rapid spectral-based methodology, accounting for contribution of masonry infills to the seismic structural behaviour can work efficiently as long as it can be calibrated for the context of Nepalese construction materials and building practices.

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