Damage to School Buildings During the 2015 Nepal Earthquake and Reconstruction Strategy

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Abstract

The 2015 Nepal Earthquake (Mw7.8) affected more than 9,000 schools in the country. Damage distribution in the 14 most-affected administrative districts shows that the construction practices were an important determent for the level of damage extended. Use of improper construction materials, lack of construction supervision, and non-compliance with the existing building codes during design and construction probably contributed to the severe damage of most of the school buildings. Preliminary damage assessment results show that in the most-affected districts, about 86% schools were affected by the earthquake and about one million students were out of their schools for a long time. The damage survey data indicate that about 30% classrooms collapsed, about 13% classrooms sustained major damage, and about 17% classrooms sustained minor damage within the 14 districts. Such evidence of loss and damage in the earthquake disasters provides an opportunity to learn lessons for the future preparedness and to encounter the disaster challenges. Based on the damage analysis data and experience of reconstruction process after the 2015 Nepal Earthquake, this paper highlights the steps to be considered during reconstruction strategy planning for school buildings after an earthquake disaster.

1 Introduction

The 2015 Nepal Earthquake (Mw7.8), with its epicenter about 80 km northwest of the capital Kathmandu produced strong shakings in the central part of the country and caused massive damages. Out of the total 75 administrative districts in the country, 14 (as indicated by ‘Severely hit’ and ‘Crisis hit’ in Figure 1) were heavily affected. The quake killed about 9,000 people and destroyed about 600,000 houses and about 9,000 school buildings (MoHA 2015). The total economic loss in the education sector including the school infrastructures and physical assets was estimated at NPR 31.3 billion (PDNA 2015), which is equivalent to about 300 million US dollars. More than 80% of this loss in education sector, particularly in damage to public-school buildings occurred in the 14 most-affected districts towards east of the epicenter (refer to Figure 1).

The public-school buildings in Nepal are particularly susceptible to seismic damage because of poor construction materials and method. A study conducted in 1998 by National Society for Earthquake Technology (NSET) revealed that one third of the schools in the Kathmandu valley were structurally dilapidated and needed demolition and rebuilding (NSET 2000). Moreover, as high as 60% of the public-school buildings in the valley were found to be vulnerable to seismic damage under normal operating conditions (Dixit et al. 2014). The NSET (2000) study also highlighted a compelling need of developing and implementing an effective, integrated, and ground-real strategy for radically improving the seismic safety of schools all over the country. Moreover, despite higher risk of earthquake disasters in Nepal (Paudyal et al. 2012a; 2012b; 2013), school building construction practice has largely ignored the issues of structural safety, especially in terms of structural design and construction. High vulnerability level of school buildings was well evidenced in the 2015 earthquake, which destroyed thirty-six thousand classrooms in total, but fortunately during the off-school hours. This extent of damage to the schools virtually affected about one million children, who were not able to properly attend their schools for several months (PDNA 2015).

According to National Reconstruction Authority (NRA 2021), which was constituted by the Government of Nepal after the earthquake to look after and implement all recovery and reconstruction work strategy, the total number of schools to be reconstructed was more than 7,500 in 32 of the 53 affected districts. The school reconstruction strategy mainly involved the School Management Committee (SMC) through government funding, which took over nearly 80% of the total reconstruction work. Of the rest 20% rebuilding work, International Non-government Organizations (INGOs) and Non-governmental Organizations (NGOs) took over 10%, and the development partners took over 10% work directly through the contractors (Figure 2-a). The status of the progress made in the school reconstruction strategy as of August 2021 is shown in Figure 2-b: 88% of the damaged schools have already been reconstructed while 12% are still under construction.

Not only the school reconstruction strategy, but the whole earthquake reconstruction program is also expected to be completed within a year or so. The reconstruction strategy and experience, especially in rebuilding the schools in this paper’s context may be an important reference for any future earthquake school reconstruction programs in other parts of the country as well as in similar other earthquake-prone countries. So, the objectives of this damage data analysis-based study are: 1) spatial interpretation of the school building damage distribution, 2) building material-based damage extent analysis, and 3) damage scenario-based reconstruction experience sharing as a guideline to preparing for any future earthquake disasters in the country, as introduced in the following section, as well as in the similar high seismic risk areas of the world.

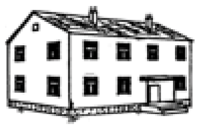
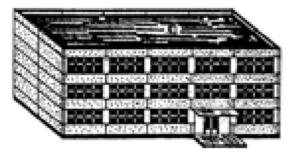
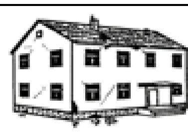
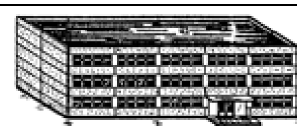
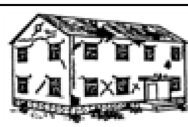
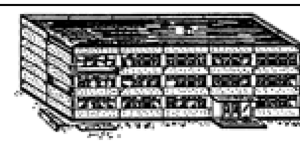
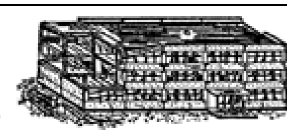
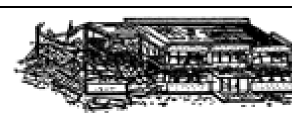
2 Method

2.1 Damage survey and data collection

The school damage-related data in the 53 affected districts were collected through the district-level offices of the Department of Education of the Government of Nepal. The damage data were recorded on a rapid damage assessment form (Figure 3), which was developed after wide consultations with different stakeholders including the Department of Education (DOE), the Department of Urban Development and Building Construction (DUDBC), The United Nations Children's Fund (UNICEF), Save the Children (SC), and so on with the support of engineers, sub-engineers, resource persons, school supervisors and school teachers. Also, during the damage survey, the Educational Management Information System (EMIS) code of each school was extracted from the Flash Report 2015 of the Department of Education, and it was used as an identification number for analyzing the data (DOE 2015). School buildings were classified according to the material and structure types used in construction, such as reinforced cement concrete (RCC), steel frame, adobe, bamboo, stone masonry in mud mortar, stone masonry in cement-sand mortar, brick masonry in mud mortar, brick masonry in cement-sand mortar, and so on.

For estimating the building damage grade as well as classroom damage level, the European Macroseismic Scale 1998, Vol. 15 (EMS 1998), as presented in Table 1, was referred to. Based on the collected data, the damage grades were judged in terms of collapse (i.e., Grade 5), major damage (Grade 2, Grade 3, and Grade 4), minor damage (Grade 1), and no damage. Some typical damage types of the school buildings in the survey area are shown in photographs of Figure 4. These damage types also indicate that most school buildings either suffered total collapse or partial damage due to brick or stone masonry wall collapse.

Table 1 Damage grade based on the European Macroseimic Scale 1998 (EMS-98)

Damage grade	Load bearing masonry buildings	Reinforced cement concrecte buildings
Grade 1 (G-1)	• Negligible to slight damage (no structural damage, slight non-structural damage) • Hair-line cracks in very few walls  • Fall of small pieces of plaster only • Fall of loose stones from upper parts of buildings in very few cases	• Negligible to slight damage (no structural damage, slight non-structural damage)  • Hair-line cracks in plaster over frame members or in walls at the base • Fine cracks in partitions and infills
Grade 2 (G-2)	• Moderate damage (slight structural damage, moderate non-structural damage) • Cracks in many walls • Fall of fairly large pieces of plaster  • Partial collapse of chimneys	• Moderate damage (slight structural damage, moderate non-structural damage) • Cracks in columns and beams of frames and in structural walls  • Cracks in partition and infill walls • Fall of brittle cladding and plaster • Falling mortar from the joints of wall panels
Grade 3 (G-3)	• Substantial to heavy damage (moderate structural damage, heavy non-structural damage) • Large and extensive cracks in most walls  • Roof tiles detach Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls)	• Substantial to heavy damage (moderate structural damage, heavy non-structural damage)  • Cracks in columns and beam column joints of frames at the base and at joints of coupled walls. Spilling of concrete cover, buckling of reinforced rods • Large cracks in partition and infill walls, failure of individual infill panels
Grade 4 (G-4)	• Very heavy damage (heavy structural damage, very heavy non-structural damage)  • Serious failure of walls; partial structural failure of roofs and floors	• Very heavy damage (heavy structural damage, very heavy non-structural damage)  • Large cracks in structural elements with compression failure of concrete and fracture of rears; tilting of columns. Collapse of a few columns or of a single upper floor
Grade 5 (G-5)	• Destruction (very heavy structural damage) • Total or near total collapse 	• Destruction (very heavy structural damage) • Collapse of ground floor or parts (e. g. wings) of buildings 

2.2 Reconstruction strategy

The overall earthquake reconstruction plan was prepared and implemented by a newly constituted government agency, National Reconstruction Authority (NRA), starting from 25 December 2015. To implement school reconstruction strategy, however, a different government agency, Central Level Project Implementation Unit (CLPIU), under the Ministry of Education was setup, which is basically engaged in recovery and reconstruction of damaged schools through necessary coordination, communication, and collaboration with all relevant government agencies, international and national non-government organizations (INGOs and NGOs), and development partners. In the local levels, District Level Project Implementation Units (DLPIU) were setup under CLPIU to focus at implementing and monitoring the recovery and reconstruction work within their territories.

The 14 most-affected districts (i.e., Gorkha, Dhading, Nuwakot, Rasuwa, Sindupalchok, Dolakha, Ramechhap, Kathmandu, Makwanpur, Bhaktapur, Lalitpur, Kavre, Sindhuli, and Okhaldhunga as indicated in Figure 1) were prioritized for emergency response through implementation of recovery and reconstruction program. Towards building the school reconstruction strategy in the most-affected districts, the Department of Education constituted a committee for overall damage data management and reconstruction strategy including collection, compilation, and dissemination of the data to the concerned agencies. A total of 14 Under Secretaries of the Department of Education were deputed as the focal persons for collecting the damage data from the 14 districts and for supporting the committee in the data compilation as well as to implement the reconstruction program.

3 Results, Discussion, And Implication

3.1 Nation-wide school building damage scenario

According to the data collected and availed by the Department of Education, the 2015 Nepal Earthquake affected the school facilities of 53 out of the 75 administrative districts in Nepal. The status of loss and damage in the 53 districts is graphically presented in Figure 5, Figure 6, and Figure 7. As indicated in Figure 5, about 44% of 21,117 schools were directly or indirectly affected by the earthquake. Likewise, as in Figure 6, of about 231,000 total number of classrooms in the 53 districts, nearly 10% (i.e., 22,371) classrooms completely collapsed, a little more than 6% (i.e., 13,818) classrooms sustained major damage (i.e. cracks on walls, significant cracks on doors and window corners, out of plum or tilting of building structure, cracks on pillars and beams, significant cracks on infill walls), and about 8% (i.e., 18,436) classrooms sustained minor damage (i.e., minor/hair cracks on building corners and door and windows, minor cracks on infill wall, and no damage on beams and pillars in case of framed structure building.

In general, earthquake shaking or the intensity is inversely proportionate to the distance from the epicenter, and we could expect that the damage ratio would have been greater in areas close to the epicenter than those farther from the epicenter. Figure 7 is more or less evident that this holds true except for a few cases of heavy damage in farther districts and less damage in closer districts. Figure 1 also indicates that the effect of the 2015 Nepal Earthquake is more prominent in eastward districts than the westside districts irrespective of the epicentral distance. This more pronounced damage (or shaking) in the eastern parts than the western has been attributed to the directivity effect of the 2015 Nepal Earthquake (Koketsu et al. 2016).

3.2 Rapid damage assessment in the 14 most-affected districts

According to the annual Flash Report 2015 published by the Department of Education (DOE 2015), in the 14 most-affected districts, there are 5,799 schools, 924,929 students, 15,353 school buildings, and 60,798 classrooms. The post-earthquake survey data indicate that more than 5,000 (i.e., 86%) of these schools were affected by the earthquake, as shown in Figure 8. Figure 9 shows the district-wise distribution of the schools affected by the earthquake, and Figure 10 and Figure 11 show the status of classroom damage of the affected schools in the 14 districts consisting of more than 18,000 (i.e., 30%) collapses (or fully damaged), more than 8,000 (i.e., 13%) major damages, and more than 10,000 (i.e., 17%) minor damages. The level of damage to the school buildings in terms of affected classrooms in some of the severely hit districts, such as Gorkha, Sindhupalchowk, and Nuwakot (Figure 11) is comparatively prominent in terms of ratio of completely damaged classrooms. The damage data indicate that about a total of 1,411 (about 97%) out of 1,448 schools were affected by the earthquake in these three districts. It was also found that a total of 7,838 (about 54%) classrooms were completely damaged, 2,463 (about 17%) classrooms sustained major damage, and 1,887 (about 13%) classrooms sustained minor damage in the same three districts (refer to Figure 10). These figures indicate the high vulnerability of school buildings in those localities.

An analysis of the available data in the 14 most-affected districts (refer to Figure 1) reveals that there are 63% classrooms built of load bearing masonry walls, about 21% classrooms built of reinforced cement concrete (RCC) framed structure, about 13% classrooms built of steel framed structure, and about 4% classrooms built of other materials such as timber, thatch, etc., as indicated in Figure 12 and Figure 13. Moreover, an analysis of the material type used in the classroom wall construction reveals that about 49% are built of stone in mud, about 31% are built of brick in cement, about 8% are built of stone in cement, about 4% are built of brick in mud, about 1% are built of bamboo, and only 0.2% are adobe, as presented in Figure 14. These figures are evident that majority of the school buildings in the most-affected districts are constructed of load bearing masonry walls (refer to Figure 12 and Figure 13) and majority of the walls are built of stone with mud mortar (refer to Figure 14), which are both highly vulnerable to earthquake shaking. Moreover, school buildings built of stone and brick masonry walls in mud mortar were damaged very heavily, whereas those built of brick masonry in cement-sand mortar, reinforced cement concrete (RCC) frame, and steel frame were only partially damaged. From the building damage pattern in the earthquake-affected areas, it can be well interpreted that the main issues associated with the building collapse are poor quality construction materials, delamination of the walls, lack of diaphragm, re-entrant corner, wall junction failures, lack of seismic bands, mixed construction method (i.e., ground floor stone masonry and upper floor brick masonry), lack of integrity between different structural members/elements, failure in beam column joint, and so on.

3.3 Reconstruction experience

Nepal still lacks a compressive policy to guide planning, design, and construction of the school buildings. Many school buildings, even today, are constructed by the communities without following any design standards, construction guidelines, and technical supervision. The management of public schools is largely a responsibility of the local communities. The government provides minimum financial support to run the schools while the rest must be managed by the communities. As the school management committees always have a tendency to run the schools with inadequate annual budget it increases the likelihood that poor construction materials and poor workmanship are used in constructing the school buildings, which makes them quite vulnerable to earthquake shaking.

In addition, most rural school buildings are constructed of locally available materials, such as adobe, stone rubble in mud mortar or brick in mud mortar. Maintenance and repair work are also not common. Site specific hazard and risk analyses (Bhandary et al. 2021; Takai et al. 2016) are also not considered during design and construction. Although some model building designs are available, they are not entirely suitable for all locations. Therefore, formulation and implementation of an appropriate policy as well as a strategic plan is necessary for an improved seismic safety of school buildings, especially after the 2015 Nepal Earthquake. So, while planning rebuilding of the school, new construction and retrofitting or maintenance of hundreds of thousands affected school buildings, such as by adopting the Build Back Better (UNISDR 2015) approach within a limited period of 3 to 5 years was almost impossible from the existing government resources. Nevertheless, there was an urgent need of reconstruction and retrofit of existing earthquake-damaged or vulnerable school buildings to ensure the safety of a huge number of school-going children and protect the properties from expected future earthquakes.

Two options for improving the seismic safety of school buildings might have been: 1) demolishing the existing vulnerable buildings and replacing them by new buildings and 2) retrofitting or seismic strengthening of the partially damaged or vulnerable buildings. The first one is obviously easy and attractive from technical point of view, but it may be uneconomical (Dixit et al. 2014; Paudyal and Vishokarma 2013) and less feasible not only because of the cost involved but also the magnitude and duration of the disturbance to functioning of the schools. The duration of construction-related disturbance is normally estimated to be 4 to 5 times longer in the first option (i.e., about one year) than in the second one (i.e., 2 to 3 months) (Dixit et al. 2014; Paudyal and Vishokarma 2013). The second option is economical, attractive, and new. It also provides a good opportunity of learning more to the community, school management committee, teachers, and students (Cardona 2007; Paudyal and Vishokarma 2013; Shaw et al. 2004). Moreover, implementation of school reconstruction/retrofitting program through the second option would also provide an opportunity of social dialogue, increased awareness, preparedness planning, and mason training thereby creating an opportunity of replication and hence inculcating a culture of safety in the community as well (Sharma and Gupta 2007; UNISDR 2005).

So, the reconstruction of hundreds of thousands damaged school buildings at once was very challenging for the government mainly because it required tremendous financial resources, a large number of construction companies, adequate technical manpower to supervise the construction activities, adequate quality control mechanism, such as material testing laboratory, and enough construction materials which are almost impossible in a developing country like Nepal. It was hardly possible for the Government of Nepal to allocate immense financial resources only for the purpose of new construction and retrofitting of the school buildings. However, the reconstruction of school buildings and retrofitting the existing vulnerable buildings (i.e., damaged, partially damaged) after the 2015 Nepal Earthquake were an urgent need for ensuring an appropriate teaching and learning environment in the schools as soon as possible.

After the 2015 Nepal Earthquake, it was necessary for the government to implement school reconstruction program with minimum cost without compromising the structural safety of the schools. For this, timely formulation of an appropriate reconstruction strategy and its implementation was an important step. So, based on the status and extent of damage to the school buildings in the 14 most-affected districts, a reconstruction strategy was formulated and implemented through the government's reconstruction authority. The school reconstruction strategy is presented in a process-flow format in Figure 15, and the details of the main steps and actions in the adopted reconstruction plan are described in the following sub-sections.

3.3.1 Rapid visual vulnerability assessment

As a quick method of easily identifying the damaged buildings that might pose risk of life or injury, the rapid visual vulnerability assessment is a reliable method for seismic vulnerability assessment of buildings. This method mainly helps determine the need of more sophisticated and detailed seismic vulnerability assessment (Paudyal et al. 2009), and is also useful in shortlisting the buildings to which simplified vulnerability assessment procedure should be applied. The rapid visual screening method is designed to be implemented in ranking the school seismic strengthening needs without performing any structural calculations. In this step, as also mentioned elsewhere in the methodology section, the damage grades mentioned in the European Macroseismic Scale 1998, Vol. 15 (Table 1; EMS 1998) were adopted in categorizing the school buildings in the affected districts into following three types.

- Minor damage buildings (less vulnerable) – Grade 1 (G1) type
- Damaged buildings (vulnerable) – Grade 2 (G2), Grade 3 (G3) and Grade 4 (G4) type
- Collapsed buildings – Grade 5 (G5) type

Using the rapid visual vulnerability assessment data, the "Collapsed buildings" were shortlisted and at the same time, the debris management plan was made. Then, the reconstruction plan for the new buildings was made. As a transitional arrangement for running the classes in the collapsed school locations, temporary or semi-permanent classrooms were built as per requirements. Likewise, a list of "Minor damage buildings" (i.e., G1 type based on the EMS-98) requiring only minor repair work was prepared, which was done by simply following the maintenance guidelines with minimum financial support from the government and community. However, the “Damaged buildings” (i.e., G2, G4 and G5 type as per the EMS-98) needed further investigation because they were highly vulnerable to collapse and it was not easy to ascertain the exact state of damage level by only going through the rapid visual vulnerability assessment. Those school buildings that sustained partial damage (i.e., vulnerable buildings) were supported by temporary or semi-permanent classrooms as a transitional arrangement to run the classes until the damaged buildings would be retrofitted. This way, the rapid visual vulnerability assessment was an important activity for the first screening of the building damage.

3.3.2 Detailed vulnerability assessment

The detailed vulnerability assessment was aimed for “Damaged buildings” (i.e., vulnerable buildings; G2, G3 and G4 type as per EMS-98), as identified in the rapid visual vulnerability assessment. This method utilizes engineering information such as size and strength of lateral load resisting members and more explicit information on the design ground motion. These data are used for carrying out a highly simplified analysis of building structures in order to estimate the building drift. Since a good correlation exists between building drift and damage, the analysis results can be used to estimate the potential seismic risk of the buildings. From this analysis method, we can make an appropriate decision on retrofitting methods to be used in strengthening the structural members. So, using the detailed vulnerability assessment method, we developed a detailed program and implementation modality for retrofitting the school buildings. This also helped to reduce the cost of preventative measures used without compromising the structural safety of the buildings.

The detailed vulnerability assessment helped to identify the most critical buildings that needed retrofitting/strengthening program, which were categorized in the following three ways based on the urgency of retrofitting program.

- Buildings requiring minor retrofitting or retro-maintenance program
- Buildings requiring retrofitting program
- Buildings requiring demolition, debris management, and reconstruction program

Based on the availability of budget and manpower, a phase-wise implementation plan was also prepared. Priority went to the school buildings that required immediate retrofitting.

3.3.3 Reconstruction and retrofitting stage

For the maintenance or retro-maintenance of the damaged school buildings, a short-term plan was made by the communities even with a little support from the government using retro-maintenance or maintenance guidelines. Retrofitting and reconstruction of the damaged school buildings, however, may need longer time and may require immense financial resources. So, for retrofitting and reconstruction, medium- to long-term programs (refer to Figure 15) were made.

Reconstruction and retrofitting of the school buildings were mainly done in two ways: 1) construction through a contractor (i.e., construction firm) and 2) construction through communities (i.e., implemented by the school management committee, SMC). From the technical point of view, the construction using a registered contractor was preferred over the construction through communities. As schools are not only for basic education but may also be used as emergency shelters during and after disasters, the school buildings must be disaster resilient. Moreover, retrofitting or reconstruction of complex or big buildings necessitates adequate technical knowledge, which cannot be overlooked. Only qualified and registered construction contractors can do these works. These works also need intensive construction supervision by well-trained technicians. Nevertheless, for the construction and retrofitting of small sized and structurally simple school buildings (e.g., one to two story), the communities can be asked to do the job using the prototype design. In this case, construction supervision must be done by trained technicians, which will help to make the constructed facilities disaster resilient. Separate provisions for material quality testing and construction quality control mechanism are prerequisite to maintain and assure the specifications of the constructed facilities. Moreover, a strong school construction management mechanism is also necessary to run the construction project without any delays.

For small-sized school (i.e., number of students $\leq$ 200), SMC and INGOs/NGOs modality of reconstruction (in which the communities were directly involved) was adopted and the reconstruction was done in incremental basis while the bigger schools (i.e., number of students > 200) were reconstructed by hiring the contractors. In the smaller schools, the priority was given to rebuilding the classrooms while in the bigger schools, apart from rebuilding the damaged classrooms, facilities like laboratory, library, computer lab, music room, teachers' rooms, separate toilets for boys and girls, toilets for physically-disabled students, water tap, furniture, solar backup, fencing, footpath and gates, etc., as per specific needs identified in the project design, were also built.

One of the advantages of community involvement in school building reconstruction and retrofitting programs is potential reduction in the project cost. Local community people can contribute to the programs by providing donations or self-labor. In a developing country like Nepal, the community participation in these programs largely helps to reduce the project cost. It also helps to make the project sustainable. By involving the community, the financial transparency of the programs is also ensured since the involved community people are regularly informed of the financial issues such as the amounts received from different sources and spent in different construction activities. This way, they feel the projects to be their own and involve themselves in maintenance of the constructed facilities in the long run efforts.

3.3.4 Awareness building program for community participation in maintenance

As also highlighted by Sharma and Gupta (2007) and Shaw et al. (2004), disaster prevention is a cultural issue. To build a culture of disaster prevention, various programs and international campaigns have been lunched in different parts of the world, but in some of the most vulnerable and disaster-prone areas, there are still a large set of things that must be addressed for this purpose. Besides making various efforts to reduce loss of life, destruction of property and disruption of society and economy, the objectives of disaster prevention programs also include building safer communities, particularly focusing on community participation in disaster prevention efforts, training programs for local masons and technicians, and disaster prevention-related training programs to students, teachers, and communities (e.g., Ando et al. 2007; Paci-Green et al. 2015; Parajuli 2020; Ronan et al. 2010; Tuladhar et al. 2014; Tuladhar et al. 2015).

So, during the reconstruction phase and after handing the reconstructed schools over to the communities, awareness building programs were frequently held, which mainly include direct involvement of communities in reconstruction activities, seminars to make the local stakeholders understand the disaster risk and school disaster safety, regular maintenance and repair trainings, and so on.

Community participation in disaster prevention programs also has various challenges, such as how to improve the communities' understanding of the risk they face, how to empower them with abilities to act towards reducing the risk, how to manage the consequences of a disaster, and so on. Yet, community engagement in school reconstruction programs builds a trust of the locals in the ongoing reconstruction activities. Without their involvement, the reconstruction program implementation may be sometimes misunderstood. Paci-Green et al. (2015) conducted a survey in this relation after the 2015 Nepal Earthquake. They report that the community-engaged projects showed better knowledge of disaster risk and earthquake-resistant construction technology in people. Moreover, they have developed a tendency to advocate safer construction practice after the 2015 Nepal Earthquake. This is also evident that community engagement and awareness building during the school building reconstruction programs are very important. So, community engagement in reconstruction program not only helps to reduce the project cost but also helps to make it sustainable and raises peoples' awareness level on disasters, their impact, and their preventative measures.

4 Concluding Remarks

About 9,000 schools were affected by the 2015 Nepal Earthquake. Preliminary damage assessment shows that in the 14 most-affected administrative districts, about 86% of the total number of schools were affected and about one million students were out of the schools for a long time. Of the 86% affected schools and their total 60,798 classrooms, about 30% classrooms were completely damaged, about 13% sustained major damage, and about 17% sustained minor damage. All this led to a serious challenge to planning reconstruction program for a large number of school building at a time. Need of immense financial resources, a large number of construction contractors and trained technical manpower to supervise the construction activities, efficient quality control mechanism, and availability of enough construction material were the major issues confronted during the reconstruction panning. In this paper, based on the damage data and the steps of experience in rebuilding the schools after the 2015 Nepal Earthquake, three main steps in school reconstruction strategy are highlighted as follows.

First, a rapid visual seismic vulnerability assessment of the affected school buildings was done to quickly identify the buildings that might pose a risk of life and injury, and to categorize the buildings in different groups, such as collapse/fully-damaged buildings, partial-damage/vulnerable buildings requiring seismic strengthening, and less-vulnerable buildings requiring minor repair and maintenance programs only. Second, a detailed vulnerability assessment was done for the partial-damage/vulnerable buildings so that they could be categorized as per the type of retrofitting techniques necessary and financial resources required for implementing the retrofitting program. This helped in launching the program in priority order as per the urgency of retrofitting works in schools. Third, the reconstruction and retrofitting program was designed in such a way that it would enhance community participation in all the stages of program implementation, i.e., from the planning stage to reconstruction and maintenance stages of the school buildings. It is emphasized that community engagement in a construction program improves the local people's knowledge of risk of disasters and earthquake-resistant construction technology, and they develop a tendency to advocate for safer construction practice targeting any expected future earthquake disasters in Nepal. Community participation not only helps to reduce the cost of the project but also helps to make it sustainable and raises people's awareness on disasters, their impact, and preventative measures.

The whole Himalaya Region as well as the Nepal Himalaya expect frequent earthquakes. So, to prepare for any future earthquakes, sharing of experiences of pre- and post-disaster activities including the reconstruction and rebuilding plan is always important in creating disaster-safe and disaster-resilient communities. The recent past earthquake disasters in the region as well as in other parts of the world are evident that economically weak nations are hit the hardest and lose the most because they are less prepared and less resilient to the natural disasters. So, this experience of rebuilding and reconstructing the school buildings after the 2015 Nepal Earthquake is also supposed to work as a reference to other parts of the world.

Declarations

Availability of data and material

All the data and materials used are mentioned in the manuscript.

Competing interests

The authors declare that they have no competing interest.

Authors' contributions

YRP compile data and performed the analysis. He also drafted the manuscript. NPB gave suggestions on methodology and conclusions. NPB also revised the manuscript and reorganized the overall structure. Both authors read and approved the final manuscript.

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Figures

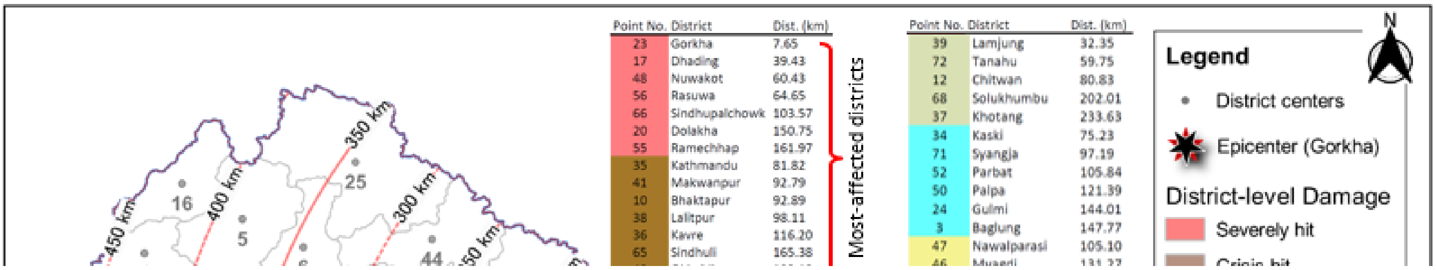

Figure 1

Administrative districts affected by the 2015 Nepal Earthquake including the most affected 14 districts (PDNA 2015)

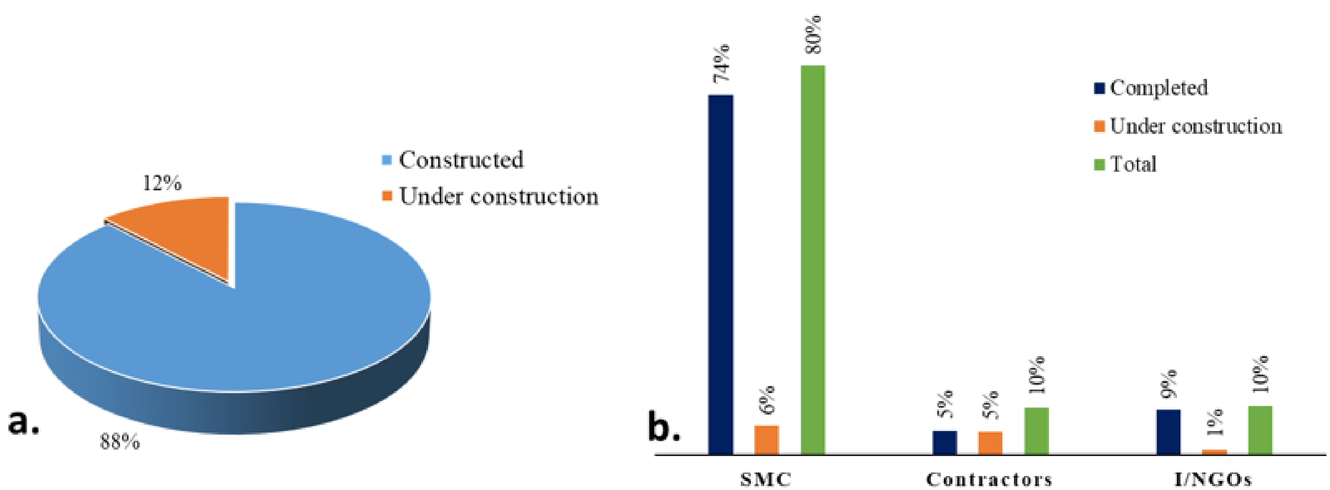

Figure 2

Status of school earthquake reconstruction in the 14 most-affected districts (as of August 2021)

Figure 3

Rapid damage assessment form developed after the 2015 Nepal Earthquake

Figure 4

Typical examples of damage of school buildings during the 2015 Nepal Earthquake: a) reinforced cement concrete, b) steel frame with masonry walls, and c) stone masonry with mud mortar

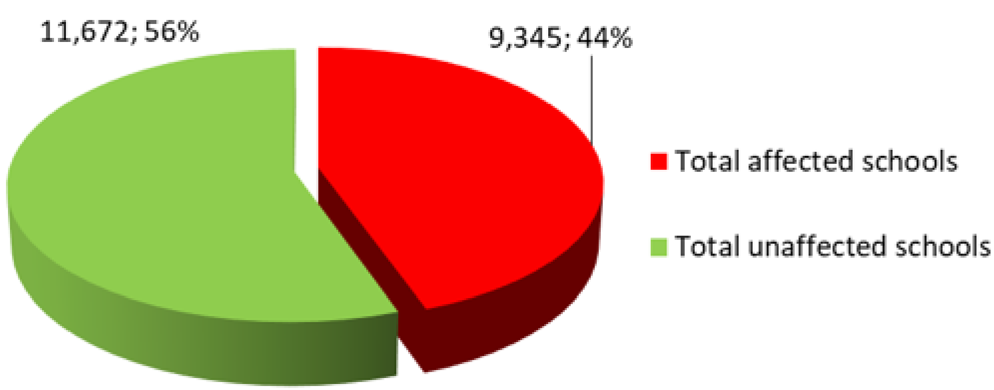

Figure 5

Percentage of affected and unaffected schools in the 53 districts surveyed in this study

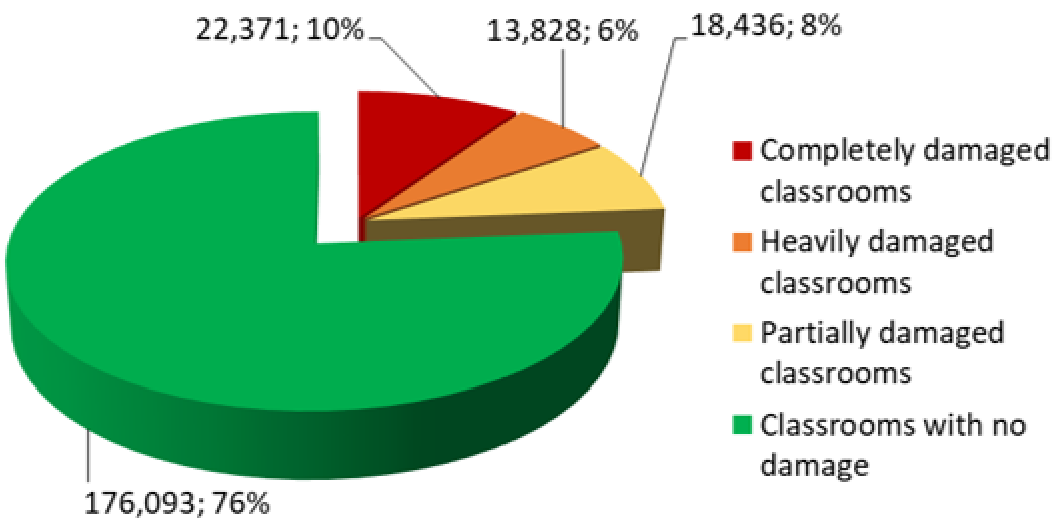

Figure 6

Damage level scenario of the school buildings in the 53 surveyed districts

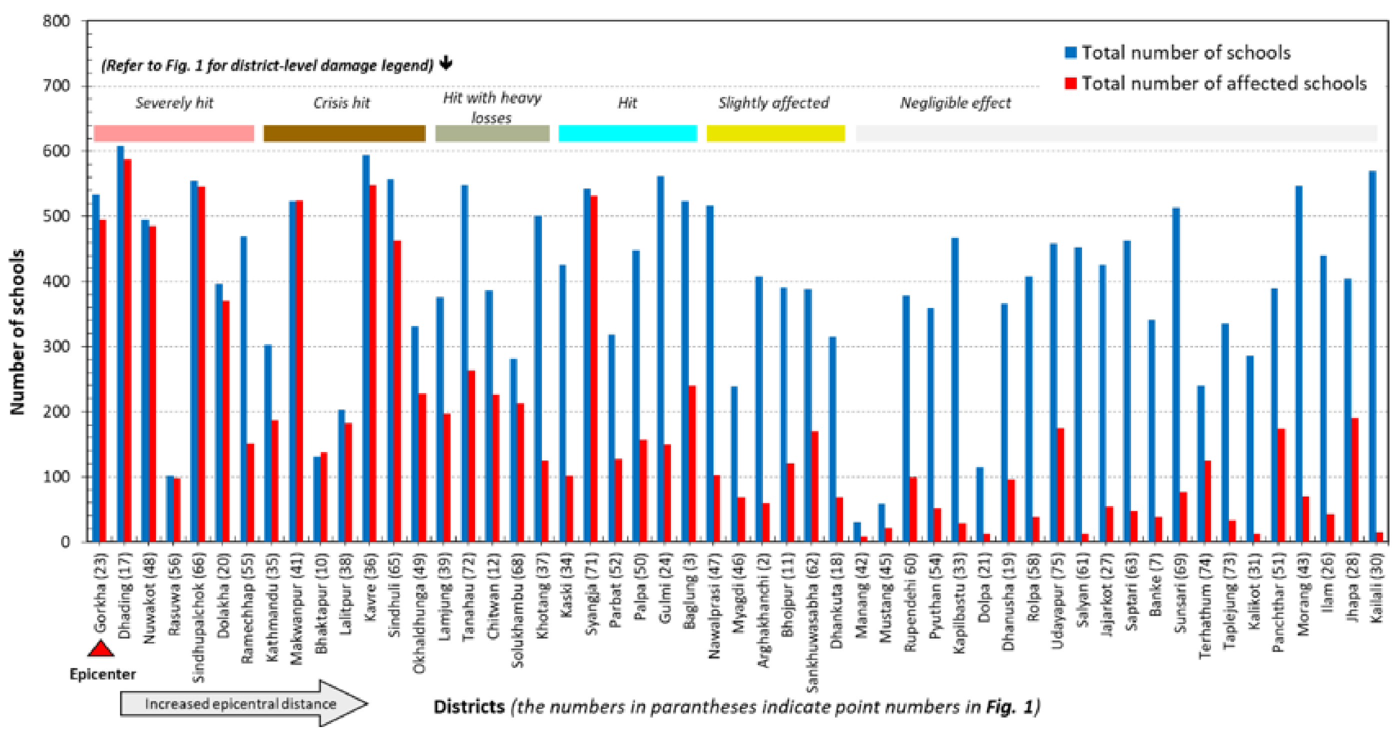

Figure 7

Total number of schools and the number affected by the earthquake in the 53 districts

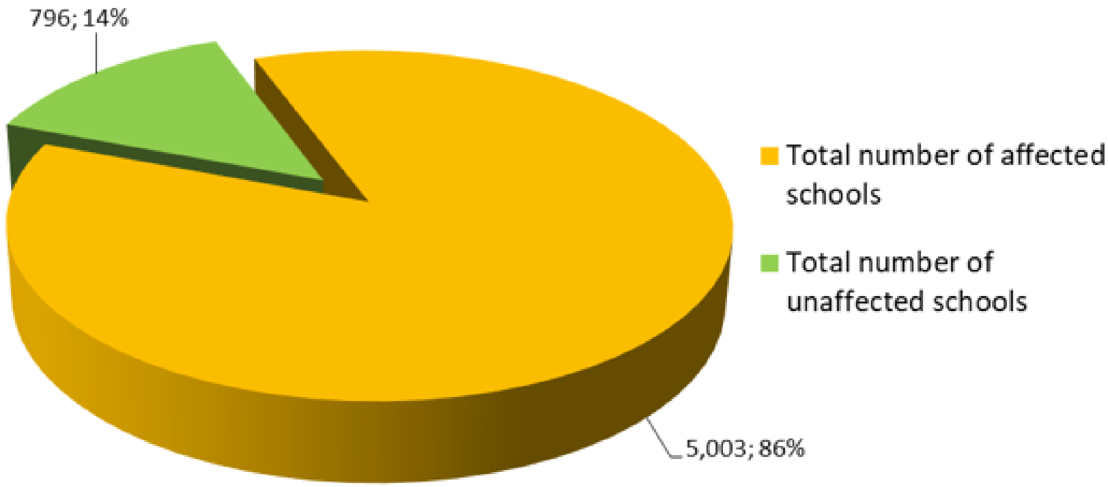

Figure 8

Percentage of the affected schools in the 14 most-affected districts

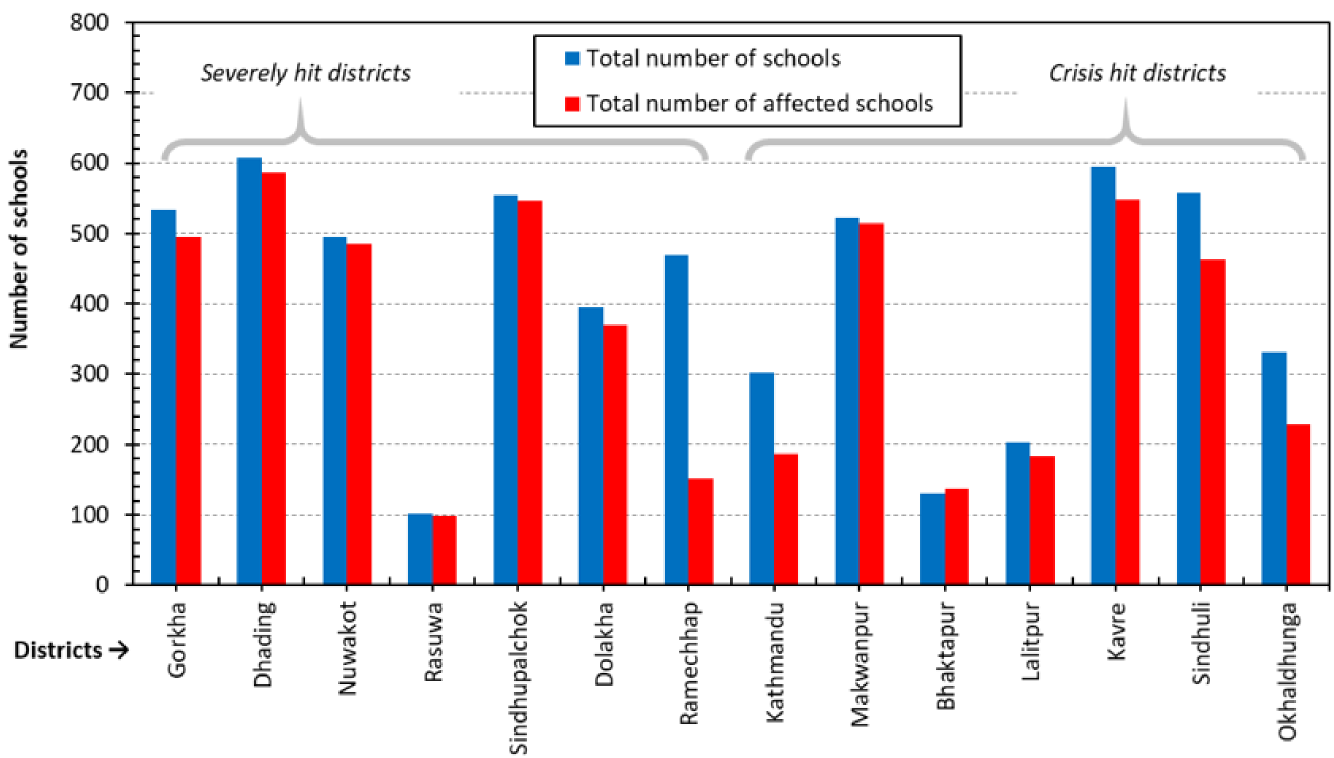

Figure 9

Distribution of the total number and the affected number of schools in the 14 most-affected districts

Figure 10

Distribution of damage level of the classrooms in the 14 most-affected districts

Figure 11

District-wise distribution of the classroom damage levels in the 14 most-affected districts

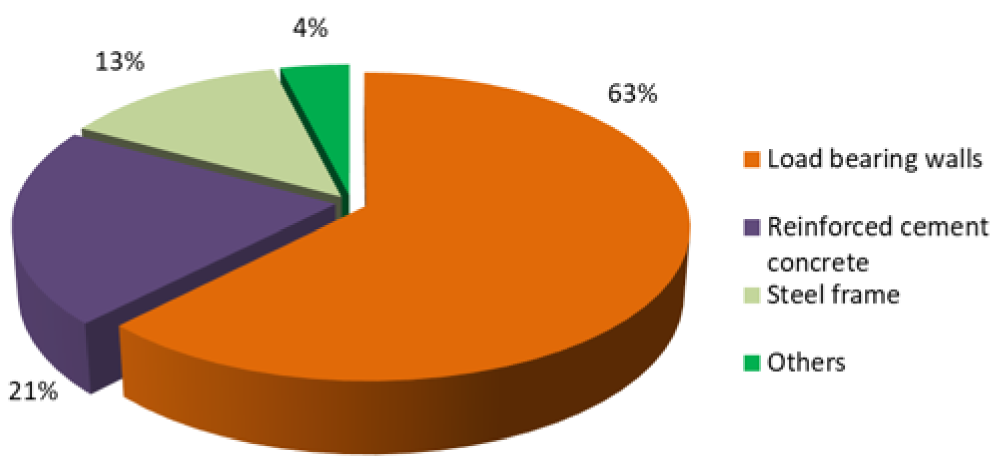

Figure 12

School building construction types in the 14 most-affected districts

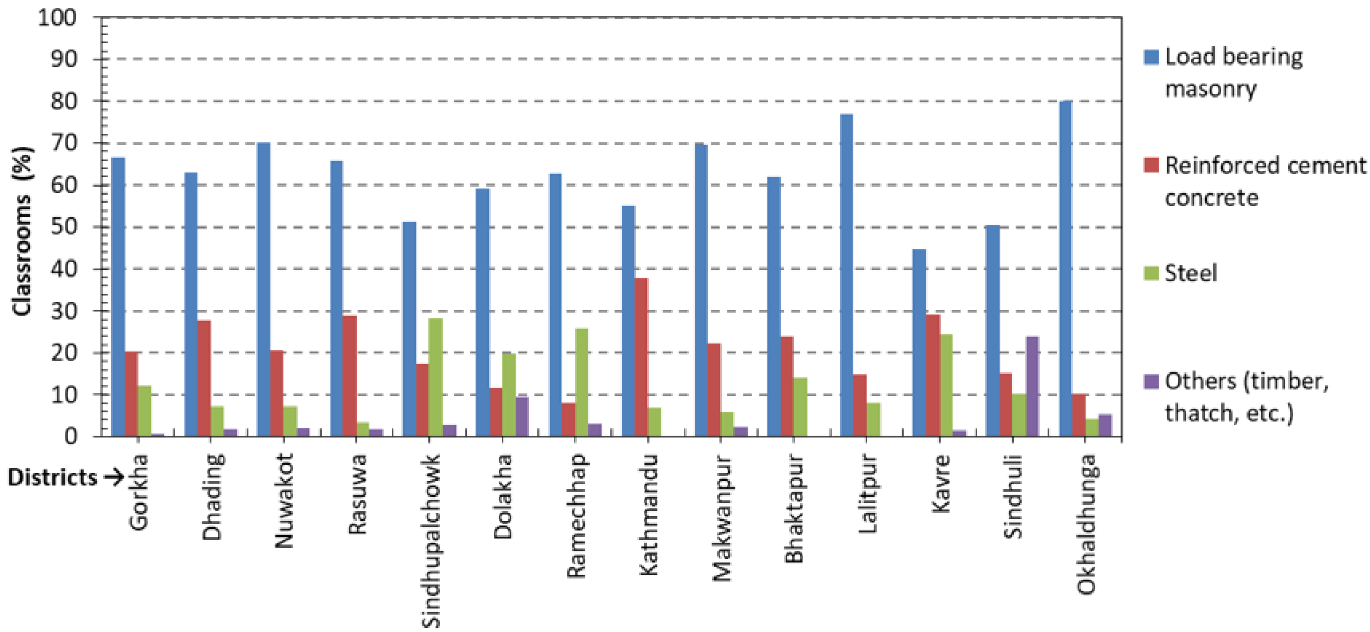

Figure 13

District-wise scenario of classroom types in terms of the material used in construction in the 14 most-affected districts

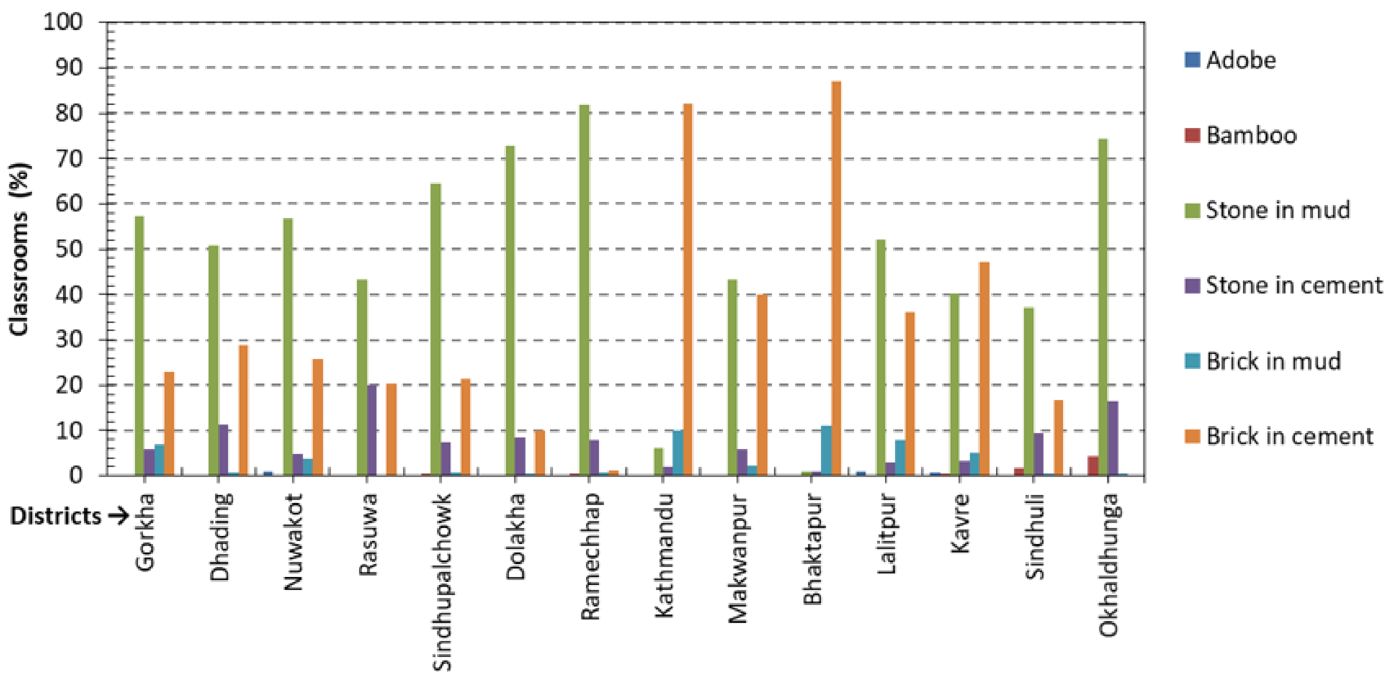

Figure 14

District-wise scenario of classroom wall types in the 14 most-affected districts

Figure 15

Reconstruction strategy for the school buildings after the 2015 Nepal Earthquake