Advisory services to support the recovery of school infrastructure in Mexico affected by the September 2017 earthquakes

EXECUTIVE SUMMARY

Global Program for Safer Schools

December 2018

The recovery of school infrastructure in Mexico affected by the September 2017 earthquakes

“The seismic performance of the schools designed and built with modern regulations, as well as with an adequate maintenance, was much higher than the schools with poor design and / or lack of maintenance. A strategy to increase seismic resistance should consider seismic rehabilitation with modern regulatory criteria – for design and construction-, as well as a culture of supervised maintenance and sustainable conservation over time “

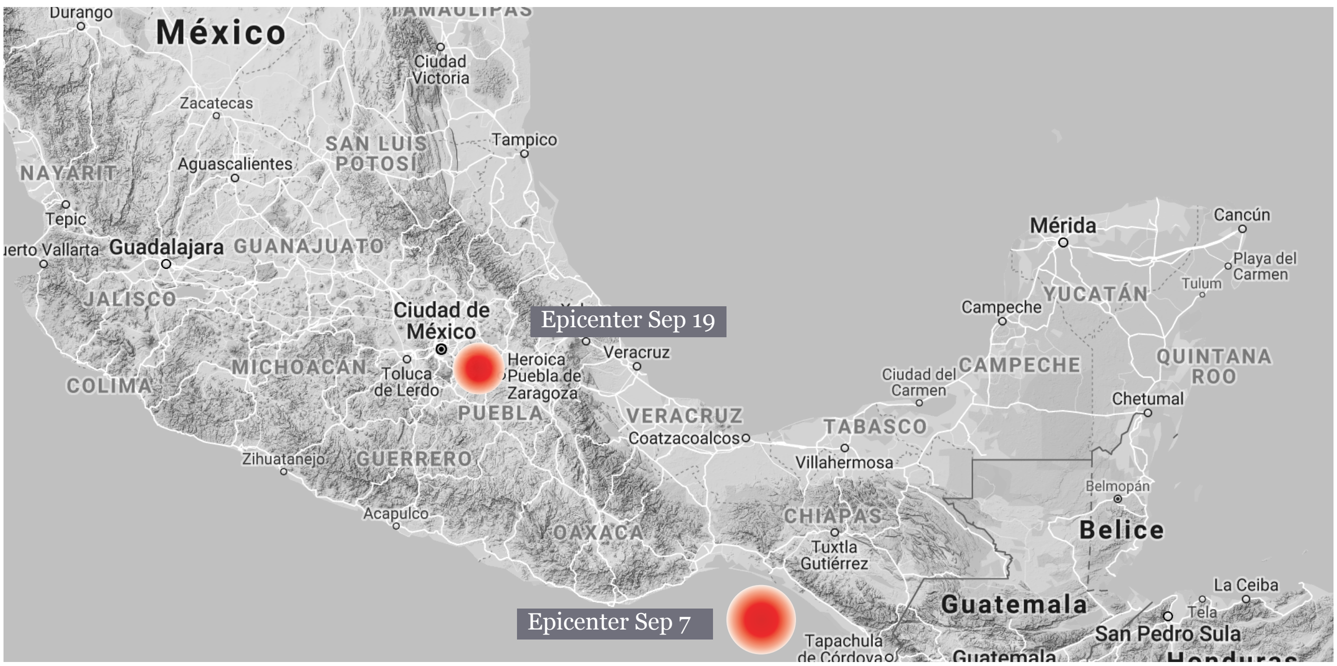

Figure 1. Map of two powerful earthquakes in Mexico on September 7 and 9, 2018.

Background

In September 2017, Mexico was struck by two powerful earthquakes: the Tehuantepec event on September 7, a M8.2 instraslab earthquake approximately 87 km south of Pijiapan, was the strongest in decades affecting the southern states of Chiapas and Oaxaca.

On September 19, the Puebla-Morelos event, a Mw7.1 intraslab earthquake, struck Central Mexico approximately 60 km southwest of Puebla, and 114 km southeast of Mexico City. Damages were concentrated in the states of Puebla, Morelos, Mexico and Mexico City.

The September 2017 earthquakes caused 477 deaths, 98 and 369 during the September 7 and 19 events, respectively. 228 fatalities occurred in Mexico City alone. Due to the large geographical area affected by the earthquakes, 171,494 housing buildings were damaged; from them, 111,628 exhibited moderate repairable damage, and 59,866 housing buildings were deemed to be reconstructed.

In the health sector, over 170 medical units, of different size and complexity, were damaged. 2,394 historical monuments, including churches, exhibited local collapse and damages of distinctly different intensity.

In the school sector, 19,194 school campuses were damaged: 12,014 were reported with minor damages (broken window glasses, for example), 6,970 with moderate and moderate/severe damage, and 210 with very severe damaged that prompted their reconstruction. No casualties were recorded in school facilities. All prototype school buildings withstood the temblors without collapse. Only four collapses were recorded of buildings that were either built informally (following self-construction procedures) and that were used as accessory buildings, not for classrooms.

Wted total damage is 2.5 US billion; rehabilitation and reconstruction in the education infrastructure alone will cost an estimated 20 billion pesos (US$1 billion). The Secretariat of Public Education (SEP), through the National Institute for School Infrastructure (INIFED) leads the recovery and reconstruction efforts in the education sector. INIFED is the planning and regulatory agency of the Federal Government for school infrastructure; its norms and regulations are compulsory in Mexico.

Each state, except Mexico City where INIFED is still responsible for the local educational infrastructure, has its own agency for school infrastructure construction, operation, maintenance and conservation.

Scope of the WB-INIFED-IIUNAM project

Aimed at supporting the recovery of school infrastructure affected by these earthquakes, the World Bank partnered with INIFED and the Institute of Engineering of the National Autonomous University of Mexico (IIUNAM).

The main objective of the project was to contribute and inform the school reconstruction process through evidence-based knowledge and promote a broader safer school program countrywide. This activity was implemented as part of the cross-collaboration activities between the Disaster Risk Management (DRM) and Education Units from the Latin American and Caribbean Region with support from the Global Program for Safer Schools (GPSS).

As part of this effort, the GPSS is developing the Global Library of School Infrastructure (GLoSI), a live repository of evidence-based knowledge about the structural performance of school building typologies and alternatives to reduce its' seismic vulnerability.

Specific objectives of this advisory services project were to inform and document the recovery process, in particular for the:

1) Design of the recovery strategy for school infrastructure;
2) Seismic vulnerability reduction strategy for new school infrastructure and existing school infrastructure which will be intervened; and
3) Information platform to evaluate the building performance in future earthquakes.

Recovery plan for school buildings

In the aftermath of both events, INIFED implemented a Recovery Plan for School Buildings applicable in the 11 most affected Mexican states (i.e. Chiapas, Mexico City, Hidalgo, State of Mexico, Michoacán, Guerrero, Oaxaca, Puebla, Tlaxcala and Veracruz).

Firstly, structural safety was assessed and a damage intensity level was assigned. Three damage levels were used. Minor damage was assigned when structural capacity was not affected in a significant way. Those damages were subsequently repaired following the INIFED Rehabilitation Catalogue for Buildings with Minor Damages, which was purposely developed for the Plan. Moderate and moderate/severe damage was recorded when repairable damages were observed; this category included buildings that required strengthening (and stiffening) of the existing structure.

In the case of very severe damage, INIFED opted for building demolition and its substitution with a new prototype facility.

According to INIFED, almost 90% of rehabilitated buildings will be ready by end of November 2018; the remainder is scheduled for July 2019. From INIFED records, the total number of school campuses and school buildings in the most affected states was 69,411 and 264,358, respectively. Thus, damaged schools in both events (19,194) corresponded to 27.6% (19,194/69,411) of the total; 10.3% of all school campuses had buildings with moderate to very severe damage.

Approved financial resources for the recovery (rehabilitation and reconstruction) efforts amount to 915 MUSD a per September 2018. Funds have come from four sources:

- Insurance of school infrastructure, SEP – 90 MUSD, 35 MUSD for Mexico City.
- Natural Disasters Fund, FONDEN – 455 MUSD, 64 MUSD for Mexico City.
- Fund for school infrastructure, CIEN – 334 MUSD, 29 MUSD for Mexico City.
- Program for the Education Reform – 35 MUSD, 3 MUSD for Mexico City.

Information platform of school buildings damaged by the 2017 September earthquakes

An electronic information platform for data analysis and school building assessment was developed for the project. Data from INIFED´s earthquake reconnaissance formats was manually input into the platform. Data from Chiapas, Mexico City, Guerrero, State of Mexico, Morelos, Puebla, Tlaxcala and Veracruz are included. Database comprised:

- General information of school campuses (address, geographical coordinates, school level, and number of students, faculty and administrative staff, etc.);
- Specific information of school buildings (such as prototype, construction materials, availability and type of power, water, drainage and special installations; structural system, type of roof system, foundation system, type and intensity of structural and non-structural damage);
- Information about external facilities (such as sport facilities, flagpole, civic plaza, etc.); and
- When available, photographs and sketches.

The information platform includes 12,444 building records. A school campus with no reconnaissance format was deemed to be undamaged. Thus, the database developed included 13.2% of all school campuses damaged and 35.3% of school campuses with moderate to very severe damage, according to INIFED´s damage tagging.

Information quality in INIFED´s formats was classified based on the consistency and completeness of data. A green grade was assigned to school buildings when its data was consistent and sufficient for data analysis; 2,617 building records were found in this category. A yellow grade was given to those records when all other information was complete but photographs and sketches were missing or were unclear; 2,590 buildings were assigned in this category. A red grade was given to 7,237 buildings either because earthquake reconnaissance formats lacked of relevant or because information for data analysis and building assessment (such as the type of construction material, type and intensity of damage, for example) is inconsistent.

Information from INIFED's format was complemented with information from the National System of School Information managed by INIFED. Age of construction and type of school service (general, rural, etc.) were added to the platform.

School buildings were classified according to the construction material (masonry, concrete, steel) and prototype. Prototypes were those that INIFED and its predecessor, CAPFCE, have designed, constructed and regulated over the past 74 years. When a building did not follow a prototype (either because materials or dimensions were distinctly different) or when different materials were used (like adobe or prefabricated walls), school buildings were classified as “atypical” (46% of all buildings were deemed to be “atypical”).

Structural and non-structural damage characteristics were included in the platform. Structural damage included wall, column, beam, slab, joint and foundation element distress. When available, type and intensity of damage was input. Non-structural damage comprised damage in façade elements, infill walls, finishes, windows, lighting fixtures, water tanks, parapets, fallen objects and fences. When available, distress due to lack of or improper maintenance, such as efflorescence and corrosion, was also registered.

To support INIFED’s efforts in data collection and to minimize data heterogeneity and/or lack of data in critical fields, an electronic system was developed. This system is based on IIUNAM’s temblor reconnaissance formats. The system runs as an application in smart electronic devices. The system is designed to work either online or offline. When connected to internet services, data is automatically transferred to the information platform.

In the development of the information platform, the need for a post-earthquake reconnaissance protocol and structural safety evaluation method became apparent (see Recommendations). Training and certification of damage evaluators and building inspectors is also indispensable.

Damage assessment through the information platform

Using the information platform developed, damage assessment according to the type of material and structural system, age of construction, damage intensity and location with respect to earthquakes’ epicenters was carried out. Masonry structures were found to prevail in Chiapas and Oaxaca, where dispersion of population among small communities is typical. More steel-moment frame structures in Oaxaca than in Chiapas were identified. Concrete- and steel-moment frame structures were more frequent in the State of Mexico and Mexico City, as they correspond to urban areas.

Age of construction is a key parameter for assessing a structure´s vulnerability. In the case of Mexico, the 1985 Mexico City earthquake represents a point of inflection in earthquake-resistant design of structures. In the aftermath of this killer event, the capital city´s design codes and standards were revised and enhanced.

These improvements led to stronger and stiffer structures, built with better materials and stricter inspection rules. Still with shortcomings and areas or opportunity, stricter design and construction rules and enforcement paid off during the September 2017 events; 38 buildings suffered total collapse, out of which only one had been built after 1985.

In the case of schools, after 1985, a large rehabilitation program was developed by CAPFCE (INIFED’s predecessor). Different rehabilitation schemes (see below) were also implemented. Wall jacketing, new concrete walls and frame bracing with steel elements (hot rolled sections or posttensioned cables) were mostly used. Also, prototype designs, structural drawings and construction specifications for new construction were modified accordingly.

Two-thirds of structures in the database were built before 1985. For masonry structures (all with a single story), little difference was found in damaged schools built before or after 1985. Conversely, damage frequency and intensity in reinforced concrete (RC) and steel structures was consistently less in buildings built after 1985.

Regarding damage intensity, 75% of buildings in the database exhibited minor damage. Damage was concentrated in walls (load-bearing walls in masonry structures, and infill walls in RC and steel frame structures). Only 13% and 4% of damaged masonry structures experienced light and severe distress in walls, respectively. Typical damage in masonry walls were inclined cracking and, in few cases, flexural cracking in buttress walls.

For concrete structures, most damage was concentrated in columns, especially due to the "short column" effect. Although CAPFCE's and INIFED's drawings clearly specified a typical 20-to-25-mm separation between columns and sill walls, existing walls were directly constructed against columns. Under earthquake-induced lateral displacements, stiffer columns had to resist larger shear forces for which they were under designed and not detailed for.

Moreover, column transverse reinforcement was widely spaced (at 300 mm typically) and was made of stirrups with 90-deg bends at the ends. The need for improved construction inspection is evident. Beam shear cracking and concrete spalling were seldom observed. In few cases, beam-column joint cracking and spalling were recorded.

Severe damage in steel structures was local buckling of columns steel plates in buildings built in the 1960's and 1970's. Columns were made of cold-formed light-gauge members welded to achieve a complex box-type cross section. Local buckling caused segmental welds to fracture, thus leading to column shortening.

Due to the large variability in the "atypical" category, it was difficult to systematically assess building performance. Structures with non-ductile detailing and lack of seismic design were apparent.
As indicated above, four buildings collapsed. Two were "atypical" masonry structures; one was a steel structure and the fourth was similar to a prototype masonry structure. Collapses seem to be associated to low quality construction and lack of seismic design.

The GLoSI methodology was applied to masonry, concrete and steel school buildings. For masonry, 11 building types were identified and their taxonomy, based on GLoSI attributes, was developed. Age of construction (before and after 1985) and span lengths (size of classrooms) were key parameters for the classification. Typical classroom dimensions were 6 by 8 m. Masonry buildings have one to four classrooms.

Similarly, for concrete buildings, 13 types were identified. Differences were the age of construction, number of stories (one, two and three) and seismic zoning for which they were designed. Three building types were structures that were rehabilitated by adding new concrete walls in the long direction (parallel to corridors) and using infill walls in the short direction as seismic-resisting elements.

For steel structures, five types were identified, corresponding to moment frames designed in 1966, 1970, and 1984, with light or concrete floor systems, that represented 14%, 69% and 6% of the total number of steel structures (11% was "atypical").

Figure 2. Partial collapse of the school building.

Figure 3. Short column type of damage in school building.

Buildings inspected and dynamically measured

To complement building performance assessment, school buildings were inspected in Morelos, Oaxaca and Mexico City. Buildings were selected to be representative of construction materials, prototypes, and years of design and construction.

A total of 124 school buildings in 32 school campuses were field inspected. The dynamic characteristics of 14 structures were measured using ambient vibration testing. Measured buildings included five tested by the Mexican National Institute for Electricity and Clean Energies and two by a group of American researchers who visited Mexico sponsored by the U.S. National Science Foundation.

During the visits, the lack of knowledge of the year of construction of buildings and of the existence of a maintenance record by school authorities was recurrent.

In some cases, when comparing data recorded in INIFED's reconnaissance formats with the existing structure and damage features, differences and inconsistencies were identified. Such finding supports again the recommendation (see below) to implement a post-earthquake assessment methodology, including a strategy for its sustainability over time.

In some cases, low-quality or inadequate construction materials were observed. This is the case of river gravel and pebbles used for on-site concrete fabrication.

Through ambient vibration testing, most significant vibration frequencies were identified. Relations between fundamental period vs. number of stories were developed for sites with soft soils (soils type III) and firm soils (soils type II). Such relations were found to be consistent with those obtained in earlier testing programs.

Numerical modeling of school buildings

From the 29 building types identified, index buildings were selected for further study via mathematical modeling. Selected buildings were those that were more frequently affected and that showed distinctly different damage types and intensity. Four masonry index buildings were chosen. These structures had one to four classrooms; all had been designed for Zones C and D with external buttresses. Zones C and D are those with highest seismic hazard according to the Design Manual of Civil Works of the Federal Commission of Electricity (CFE).

CFE is Mexico´s public utility, whose manuals are used as reference in regions where building codes are not available. It is important to note that Mexico is a federate republic so that 2,446 municipalities are entitled, by the Mexican Constitution, to develop and enforce their building code. In most cases, municipalities (of different size and complexity) use the Mexico City Building Code (MCBC) and its technical standards for design and construction as model code. This is typically complemented with CFE´s seismic and wind design requirements.

Five concrete index buildings were selected for numerical modeling and performance assessment. Three corresponded to structures designed in 1970 with one, two and three stories (moment resisting frame structures); two were designed in 2011 with one and two stories (moment frames with concrete shear walls). No steel structures were selected to be further analyzed as their frequency was much smaller than for masonry and RC buildings.

Linear elastic and nonlinear static (so-called pushover) analyses were carried out. Material properties (strengths and modulus of elasticity), geometry and structural systems were taken from INIFED´s structural drawings. Analysis were made with the help of a commercially available software. Columns and beams were modeled as bar elements; walls and staircase ramps as shell elements and slabs as in-plane rigid membranes. Models were fixed at the base. For the RC two-story index building, a soil-structure interaction analysis was performed to validate structural periods measured during the ambient vibration testing. Loads (dead, live and reduced live for seismic events) and load combinations were taken from the MCBC. Cracked section properties for concrete and masonry elements were assumed.

Design spectra were those obtained from CFE´s and from INIFED's regulation for design of schools. The latter is based on the former, with some simplifications that typically lead to slightly larger demands. CFE design spectra are regional uniform hazard spectra. Design spectra for Zones C and D, and soil types I, II and III (rock, firm and soft soil, respectively) were calculated at specific locations. Factors were applied to increase seismic demands (importance factor of 1.5) and to reduce demands (seismic behavior factor of 2 and an overstrength factor of 2). Redundancy and irregularities factors were also included; redundancy factor depended on the number of bays in the direction of analysis. In the case of INIFED's regulation, similar modification factors to those in CFE were used, except for the redundancy factor that is constant for all cases. Elastic spectra calculated from recorded ground motions during the September 2017 earthquakes in Chiapas, Oaxaca and Veracruz were also used to compare against calculated response.

For the nonlinear static analysis, concentrated plasticity models were assumed for beams, columns and walls under flexure, and for wall under shear, following ASCE-41 requirement. For masonry walls, a performance-based model developed by Riahi, Elwood and Alcocer was used. This model includes three limit states corresponding to first wall inclined cracking, lateral strength and ultimate; ultimate is defined as the load to 80 percent of lateral strength. Typically, lateral strength is about 1.3 times the cracking load.

Building performance was assessed through the N2 method developed by Fajfar. Building performance acceptance criteria were consistent with ASCE-41. In the case of school buildings, Mexican regulations implicitly expect an Immediate Occupancy (IO) performance level. Story shear – roof displacement capacity curves were calculated using a commercially available software. Calculated capacity curve was then simplified to an elastoplastic curve, by following ASCE-41 requirements. Calculated and simplified capacity curves were then compared to design spectra in the form of capacity design spectra. To define the IO range, SEAOC's recommendation was followed; IO range was bounded by the yield displacement and 30% of inelastic displacement capacity. For masonry structures, nonlinear static analyses were performed for masonry compression strengths of 3 and 4 MPa.

Nonlinear static analyses indicate that, for masonry index structures, buildings located in type I soils (rock) are likely to attain IO. In all other cases, more damage is to be expected. Schools in Zone C in soft soil (type III) and in Zone D, in firm and soft soils (types II and III) are likely to exhibit quite severe damage that would compromise the structure stability. Such cases should be revised using more refined models. The prototype could be required to be modified accordingly.

For the case of concrete index buildings, pre-1985 structures could very likely exhibit very severe damage that would compromise its stability under vertical loads. This is consistent with the level of damage recorded after September 2017 events. Therefore, it is recommended (see below) that a continuous seismic risk reduction program for school buildings in Zone C (soils types II and III) and in Zone D (all soil types) is implemented. In contrast, most index buildings designed in 2011 exhibited a very favorable performance, achieving IO under design spectra demands. School buildings in Zone D, soil III, are recommended to be studied under advanced models to verify their performance.

Vulnerability and fragility functions

Isoseismal curves for the September 7 and 19 temblors were calculated. Correlation between seismic intensities and damage level of registered school buildings was investigated. Masonry buildings, with one to four classrooms, and RC frame structures, of one and two stories were studied.

For masonry structures, as expected, the number of structures damaged and damage intensity diminished as epicentral distance augmented. Based on this correlation, empirical fragility functions were developed. Four discrete damage levels (i.e. light, moderate, severe and failure) were used. Functions were calculated for peak ground acceleration (PGA) and wall shear stress. Trends were consistent with expected behavior: the larger the intensity, the higher the probability of more severe damage. From the empirical fragility function, an empirical vulnerability function, in terms of PGA, was calculated.

A similar set of analyses was performed for RC buildings. No correlation between damage frequency and damage intensity with epicentral distance was found. The deficient quality and limited quantity of information are considered as the causes for this lack of correlation. It is recommended that, as a next task after this project is concluded, building information with green grading be revised, and that more detailed cost information on repair and reconstruction be gathered.

Numerical assessment of rehabilitated school buildings

INIFED has gained considerable experience in school building rehabilitation in past earthquakes. Typical rehabilitation schemes used over the years are:

- Jacketing of masonry walls with welded wire meshes (WWM) covered with cement mortar. This technique has been used in load bearing walls in rural schools, as well as in infill walls of concrete and steel moment frames. Typically, meshes with 10- and 6-gauge wires, spaced at 150 mm, are used;
- Addition of new concrete walls to resist earthquake-induced lateral forces; this technique includes construction of flange walls attached to concrete columns. New concrete walls have been added to concrete and steel moment frames with one to four stories high. Typical wall thicknesses are 150 mm for buildings with one and two stories, and between 200 and 250 for taller structures;
- Addition of steel braces made of hot rolled sections. This scheme has been mostly used for steel structures. Typically, 3 in. square tube sections have been used;
- Addition of posttensioned cable bracing. After the 1985 earthquake, 102 RC frame buildings were rehabilitated with cables. Cables were typically posttensioned to 100 MPa;
- Addition of infill walls to increase lateral stiffness and strength of concrete and steel frame buildings. New infills are built against the existing frame elements to enhance monolithic behavior.

Most building prototypes rehabilitated due to the September 2017 events corresponded to masonry structures. The rehabilitation scheme used has been wall jacketing. In the case of RC frame buildings, infill wall jacketing and addition of concrete walls are the dominant rehabilitation techniques. Steel bracing was only added to one four-story concrete building in Mexico City.

Four index buildings were studied numerically. Two corresponded to one-story masonry buildings, with one and four classrooms, that were rehabilitated with wall jacketing. The other two were one- and two-story RC frame buildings rehabilitated with new concrete walls in the long direction and addition of masonry infills in the short direction. Building performance was assessed through nonlinear static analyses. For the case of wall jacketing, the jacket contribution to strength was calculated following MCBC requirements and was added to the masonry contribution obtained from the Riahi et al. model.

Nonlinear static analyses indicated that, for both masonry and concrete index structures, and under design induced forces, buildings are likely to exhibit larger damage than anticipated for IO. Although calculated response does not suggest a significant probability of collapse or severe damage, it is therefore recommended that such cases be revised using more refined models and that, if necessary, structural drawings be modified accordingly.

Figure 4. Retrofitting of the structure with a reinforced concrete layer.

Figure 5. Retrofitted school.

Recommendations

Based on data gathered and information analyzed, policy, technical, implementation, and sustainability and outreach recommendations are proposed. Such recommendations are considered as areas of opportunity to harness and strengthen INIFED's and state's school infrastructure agencies experience and expertise.

Policy recommendations

a. Incremental seismic risk reduction strategy. A multiannual, systematic and integral strategy for reducing earthquake risk of school buildings is recommended. Strategy must recognize that risk reduction ought to be incremental. Aspects related to budget and financing, risk transfer options, project management, enforcement of codes and norms, sustainability over time, INIFED strengthening as a planning and regulating agency, future developments of school infrastructure should to be included. A loss estimation tool, vulnerability/fragility functions and recovery/rehabilitation costs would serve as support. The strategy should focus in pre-1985 masonry and RC school buildings. The strategy should include annual targets, results and efficiency indicators, and monitoring mechanisms. The strategy will be also supported on the information system, methodologies, guides and manuals proposed below.

b. Document the recovery and reconstruction processes for the September 2017 events. AS indicated above, revise using more refined models, the expected performance of new designs and rehabilitation schemes used.

c. "Atypical" school buildings: problem identification and risk reduction. The size, causes and situation of this phenomenon needs to be better understood. A representative group of structures could be used as a proxy to develop an intervention strategy, supported on investment estimates and communication tools.

Technical recommendations

a. Information system for school buildings with emphasis in seismic risk reduction. Detailed information for each school building should be included and should be available online.

b. Methodology, guide and manual for post-earthquake seismic safety evaluation. A standard methodology for building safety assessment after earthquakes is needed in Mexico. This should include, among others, the number and scope of evaluation levels, damage intensity classification, training and certification of evaluators, on-line damage collection system, and communication and outreach tools.

c. Methodology, guide and manual for seismic rehabilitation of school buildings. Detailed considerations and requirements for the analysis (linear and nonlinear), design, detailing, construction and inspection of rehabilitation techniques should be included. Traditional and innovative schemes should be incorporated. Criteria for determining building demolition is needed.

d. Updated INIFED´s technical norms. Based on lessons learned from the September 2017 events and the 2017 version of the technical norms of the MCBC, INIFED´s technical norms should be revised and updated. Structural drawings for new construction should be revised and modified accordingly. Advanced numerical modeling could be used to support these modifications. The impact of the needs of innovative educational environments and methods (new teaching techniques and models) on school infrastructure should be assessed and included in the design and construction requirements.

e. Guide for construction and construction inspection of school campuses. Best practices from INIFED, state's school infrastructure agencies and construction and inspection companies should serve as the basis for the guide. Requirements and specifications for most common construction materials, systems, methods and procedures should be included.

f. Guide for maintenance and conservation of school buildings. Best practices from INIFED, state's school infrastructure agencies and construction, maintenance and inspection companies should be assessed.

g. Guide for the design, construction, inspection and maintenance of school fences. Best practices from INIFED, state's school infrastructure agencies and construction, maintenance and inspection companies should be assessed. An effort for documenting the benefits of good maintenance through avoided costs (money, downturn, casualties) is suggested.

Implementation recommendation

a. Optimization of seismic risk reduction investments through advanced modeling and refined building assessment. Advanced modeling, coupled with lessons learned, are relevant tools for developing robust financial analyses at the federal and state levels.

Sustainability and outreach recommendations

a. Communication strategy. Strategies, investments, methodologies, etc. should be disseminated among education stakeholders: parents, students, school authorities; construction, inspection and maintenance companies; state's school infrastructure agencies, among others.

b. Outreach strategy. Higher education institutions, research centers, authorities, civil society organizations at the local and federal level, should be engaged and encouraged to participate through policy and technical recommendations and implementation.

c. Training and certification strategy. New norms, methodologies, guides and manuals need to be disseminated and transferred. Certification of specialists, inspectors, technicians, etc. involved in a risk reduction strategy is recommended.

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