

MANUAL ON
“RETROFITTING OF EXISTING VULNERABLE
SCHOOL BUILDINGS – ASSESSMENT TO RETROFITTING”
PART I

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Mission of Save the Children

To create lasting, positive change in the lives of children in need

Vision of Save the Children

A world in which every child is ensured the right to survival, protection, development and participation as set forth in the United Nations Convention on the Right of Children

This book is developed by Save the Children, Construction Quality & Technical Assistance (CQTA)

in collaboration with

Center for Disaster Mitigation - Institute of Technology Bandung (CDM -ITB)

PREFACE

Schools are institutions providing an education as well as a common place for community gatherings and meetings. They should be models in providing examples of quality education and the enhancement of the environment & physical facilities. Schools not only provide opportunities for formal education, but also for social development and personal growth.

Despite this, there are millions of schools around the world that are unsafe. There is an urgent need to create greater awareness of safer school construction in new schools, while at the same time making sure that the existing school buildings are safe. This can be done through the implementation of general practices of safe school construction and the retrofitting of existing school buildings.

Creating a culture of safe school construction is possible and need not be as complicated as some may seem. It can be implemented simply by establishing standards of design and construction of school buildings, developing a local building code and ensuring that the code and standards are met. The challenge is the thousands of unsafe existing school buildings around the globe where millions of children are at risk. Recent disasters such as the earthquake in Pakistan and China, the cyclone in Bangladesh and the infamous hurricane Katrina in the USA have caused the destruction of thousands of schools and with them the lives of many students and teachers. This shows the urgent need to make schools safer for everyone.

Save the Children initiated the creation of safe and child friendly school construction. Save the Children is conducting workshops and trainings as well as developing guidelines and manuals to support this initiative.

These documents are based on best practices in Indonesia, the most seismic prone country in the world. We believe these resources could be useful for other countries facing similar challenges as well as other organizations working on building the capacities of local authorities to effectively implement safe and child friendly school buildings.

We would like to thank Dr. Krishna Pribadi, Dr. Dyah Kusumastuti and Mr. Edwin Lim from the Center for Disaster Mitigation - Institute of Technology Bandung, and Mr. Hari Darshan Shrestha for their contributions on the development of this document.

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Save the Children

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The solutions for mitigating earthquake hazard for school buildings are different for new buildings and existing buildings, with respect to the challenges faced by each category. The common procedure for earthquake mitigation of buildings is as follows:

- a. For new buildings, the mitigation measures include the design and construction process. The design of the buildings must comply with the current building code, and the construction must be appropriate following design specifications and drawings.
- b. For existing buildings, the mitigation measures consist of assessing the structural performance to resist design earthquake forces based on current building codes. If the assessment found that structures are not adequate, retrofitting strategies should be designed to improve the building's performance.

2. Principle of Retrofitting

a. Concept of Retrofitting

Retrofitting is technical interventions in structural system of a building that improve the resistance to earthquake by optimizing the strength, ductility and earthquake loads. Strength of the building is generated from the structural dimensions, materials, shape, and number of structural elements, etc. Ductility of the building is generated from good detailing, materials used, degree of seismic resistant, etc. Earthquake load is generated from the site seismicity, mass of the structures, important of buildings, degree of seismic resistant, etc.

Due to the variety of structural condition of building, it is hard to develop typical rules for retrofitting. Each building has different approaches depending on the structural deficiencies. Hence, engineers are needed to prepare and design the retrofitting approaches.

In the design of retrofitting approach, the engineer must comply with the building codes. The results generated by the adopted retrofitting techniques must fulfill the minimum requirements on the buildings codes, such as deformation, detailing, strength, etc.

b. Decision for Retrofitting

Retrofitting is needed when the assessment of structural capacity results in insufficient capacity to resist the forces of expected intensity and acceptable limit of damages.

It is not merely poor quality of materials and damage of structural elements serves as the reasons to retrofit a building. Change of the building's function, change of environmental conditions, and change of valid building codes could also be the reasons for retrofitting.

Retrofitting must be conducted by experts from each field. In most retrofitting process, an engineer plays the main role. An engineer must assess and analyze the structural capacity. An engineer must also design the best retrofitting techniques to strengthen the structural deficiencies. The role of the novice is restricted to identify the possibility of insufficiency of building capacity.

Some factors that should be considered in order to decide whether to retrofit or not are:

a) Technical aspect

The technical aspects include the testing of materials and structural analysis. These measures are important to understand the condition of the structures related to the recent building codes.

b) Cost intervention

Cost and benefit analysis must be conducted before the decision is made. The next sub-chapter will explain this issue further

c) Importance of building

Each building is built for its own purpose. Some old buildings have extra values, such as historical values, that will strongly affect the final decision.

d) Availability of adequate technology

Some of retrofitting techniques need a "modern" technology to implement it. A decision of retrofitting must consider whether the region provides such technology.

e) Skilled workmanship to implement the proposed measures

Some of retrofitting techniques need unusual construction method to implement it. A skilled workmanship must be provided to implement the proposed measures.

f) Duration of works.

Some of retrofitting works will consume less time to finish it, but others take more time to complete. Hence, it is important to take into the consideration the duration of works.

c. Cost-Benefit of Retrofitting

Cost-Benefit analysis is sometimes conducted to determine whether retrofit or rebuild the building is more feasible. Most studies imply that retrofitting of an existing structure is more feasible than to build a new building. Retrofitting is also a favorable approach to strengthen the building capacity to the external loads, e.g. earthquake. The advantages of adopting retrofitting approach, despite of reconstructing the building, can be listed as follows:

- a. When retrofitting approach is adopted, retrofitted building can still be operated.
- b. Retrofitting will take relatively less construction cost with the same structural performance achievement.
- c. Retrofitting will involve relatively less resources, either human resources or natural resources.
- d. Retrofitting will not significantly change the building configuration and shape. It is preferable when the retrofitted building has historical values.
- e. Retrofitting the building will produce less debris than reconstructing the building.

Besides the advantages, retrofitting also has several disadvantages as follows:

- a. The skill of the worker must comply with the adopted retrofitting approaches.
- b. Limited access of the construction site since the building could be still in function.

It is important to note that the analysis must consider all parameters that can affect the decision. All costs and savings (including casualties and serviceability period) over a long period of time should also be taken into account.

d. Retrofitting Process

The retrofitting of a structure involves improving its performance under earthquake loadings through one or more of these following measures:

- 1) Increasing its strength and/or stiffness
- 2) Increasing its ductility
- 3) Reducing the seismic forces.

The measures can be done through modification to one or more of the following parameters:

- 1) Columns
- 2) Beams
- 3) Bracings
- 4) Walls
- 5) Foundation
- 6) Horizontal diaphragms
- 7) Joints between structural elements
- 8) Masses
- 9) Period of vibrations

When implementing these measures to buildings, it is importance that:

- 1) The buildings provide the required degree of seismic resistance
- 2) The chosen approaches are simple and economical to implement

It is important to note that the retrofitting of structural elements should not be conducted for only an individual element or groups of elements. The good performance of the whole structural system must be ensured. For example, when retrofitting is only conducted for some columns, attention should be placed to prevent worsening distribution of earthquake forces in the structural elements.

In general, the retrofitting process can be categorized into 3 categories as follows:

1. Assessment and Analysis
2. Design of Retrofitting Techniques/Approach
3. Construction/Implementation of Retrofitting

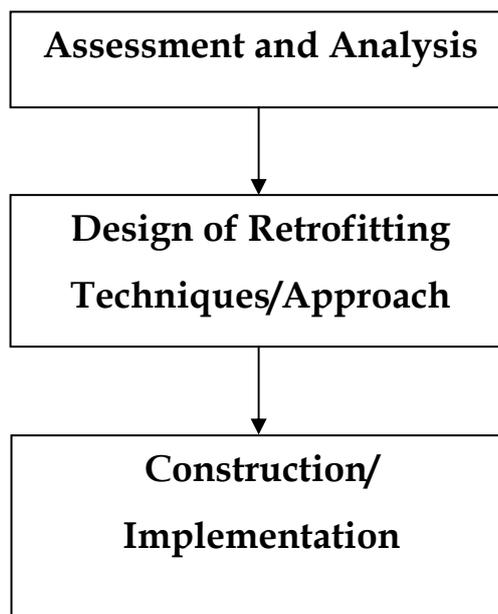


Figure 3 General Process of Retrofitting

3. Vulnerability Assessment

Seismic retrofitting becomes an important issue because it includes protecting life and property in future earthquake as well as protecting investments, lengthening building's usable life, reducing demands on post earthquake rescue resources, protecting historic structures, shortening business interruption, and reducing relocation needs/demands. Based on the large scope of the impacts of seismic retrofitting, all parameters regarding the impacts should be considered in the decision-making.

Vulnerability assessment plays an important role in decision-making measures. The purpose of carrying out a vulnerability assessment analysis of an existing building is to determine the level of risk associated with loss of serviceability and severe damage or collapse. With the risk quantified, rational decisions can be made as to whether the buildings should be retrofitted or replaced.

a. Vulnerability Assessment for Novice (Teacher and Community)

Before conducting the assessment, basic knowledge on the types of structural elements is a compulsory. Following is an illustration to describe the structural elements of building.

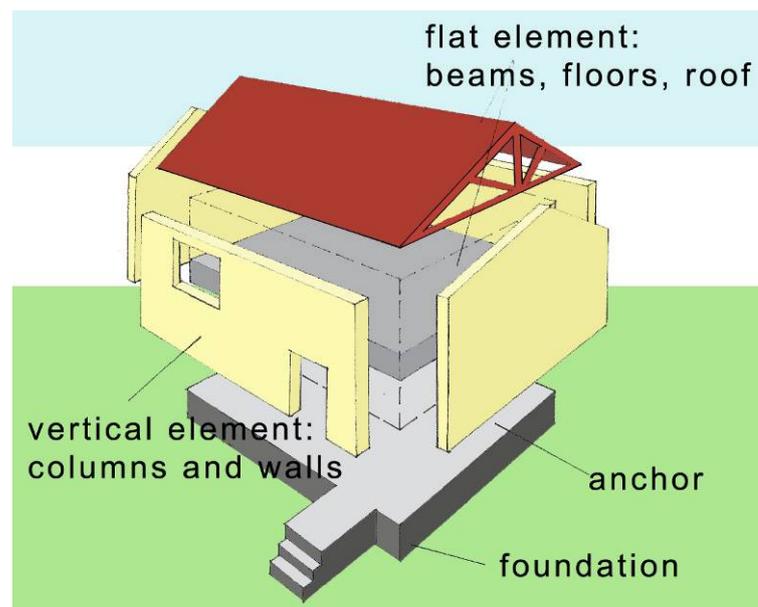


Figure 4 Structural Elements (Courtesy of *Panduan Konstruksi dan Perkuatan Bangunan Sekolah Tahan Gempa*, CDM-ITB 2008)

It should be noted that the vulnerability assessment for novice is restricted in identifying the possibility hazard of the buildings. Indeed, a consultation to the structural engineer is needed for designing the further vulnerability assessment and retrofitting approach.

In general, the criteria of an earthquake resistant building are described as follows:

1) Simple and symmetrical building layout

Simple and symmetrical layout will give a good performance of the building when subjected to earthquake loads. Rectangular or square building layout is categorized as a simple and

symmetrical building layout. When the layout is not symmetric, dilatation should be provided to separate the building. The following illustration describes typical building layout and their performance to earthquake forces.

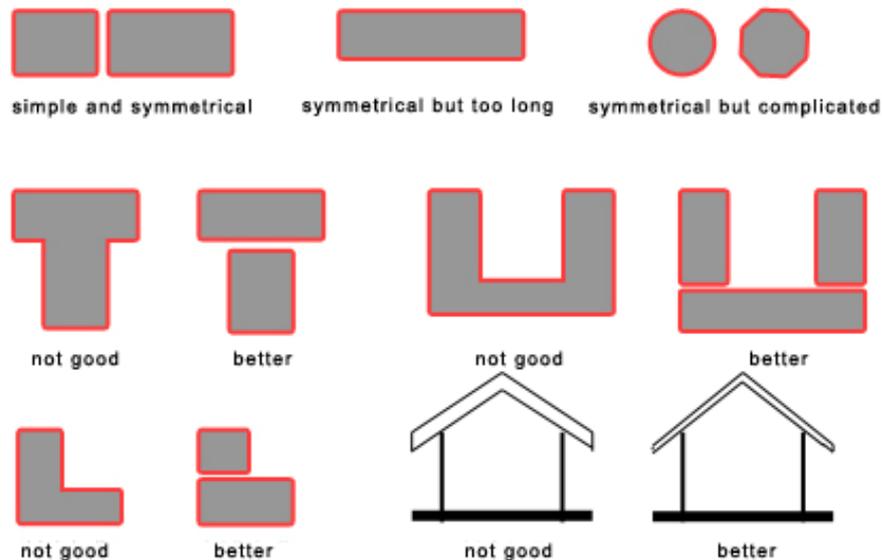


Figure 5 Plan Configuration (Courtesy of *Panduan Konstruksi dan Perkuatan Bangunan Sekolah Tahan Gempa*, CDM-ITB 2008)

2) Proper site area

Some of the areas are prohibited for construction of building. Areas located on a slope and coastal areas are very vulnerable to natural disasters. It is also suggested not to construct a building on the sandy soil with thickness of more than 1 m, to prevent upraisal of building.



Figure 6 Site Condition (Courtesy of *Panduan Konstruksi dan Perkuatan Bangunan Sekolah Tahan Gempa*, CDM-ITB 2008)

3) Proper connection of structural elements

Experience shows that most of the damages due to earthquakes occurred in the connection area, such as beam column connection, roof trusses-beam connection, column-foundation connection. It should be noted that all of the elements must be properly tied up together to provide the structural integrity when earthquake occurs.

Common weaknesses found in masonry buildings are as follows:

- Inadequate structural layout (unsymmetrical)
- Insufficient load-bearing capacity of the walls
- Inadequate connection between the walls.
- Poor quality materials or work methods in the construction.

The vulnerability assessment is usually conducted in 3 stages:

1) Visual investigation.

This assessment is to determine the existing structural condition, based on the age of the buildings, environment condition, structural type, site of seismicity, etc. The visual assessment is usually conducted together with structural investigation. The results of the investigation will assist in conducting detailed structural analysis.

In general, the visual investigation measures can be listed as follows:

- Mapping the site condition
- Sketching of the overall layout, include the structural system, dimension and geometry of elements, spacing, loading system, etc.
- Mapping of the detail structural damage, e.g. spalling, pops-out, cracking and its pattern, corrosion, discoloration, etc.
- Observation of deflection and displacement on the structural elements
- Observation of the deterioration of materials.

It is suggested that the investigation is documented by either camera or video camera for further evaluation and analysis.

2) Structural investigation.

The structural investigation can be divided into structural investigation for upper structure and structural investigation for sub-structure.

a) Structural investigation for upper structure

There are many methods/techniques available for upper structure structural investigation. In general, the methods are divided into 2 categories, non-destructive test (NDT) and semi-destructive/destructive test (DT).

Non Destructive Test is conducted to assess the upper structure condition, and suggested to be conducted as much as possible to give proper description and evaluation on material properties. Some of the commonly used NDT are Schmidt Hammer Test and Ultrasonic Pulse Velocity Test (UPV). Schmidt Hammer Test is not intended to get the concrete strength directly, and a correlation formula should be used to obtain the

compressive strength. The procedure of Schmidt hammer test refers to ASTM C 805. Ultrasonic Pulse Velocity Test (UPV) is intended to check crack depths by measuring the concrete density. The procedure of UPV test refers to ASTM C 597.

On many occasions, semi-destructive/destructive test ((S)-DT) is also conducted. The most common (S)-DT is Core Drill Test. The purpose of this test is to get the concrete's strength by drilling the existing concrete on site and testing it at the laboratory. Semi-destructive/destructive test should be conducted carefully to prevent the excessive deterioration of structural elements. To get a good result of structural testing, it is suggested to combine both non-destructive test and destructive test.



Figure 9 Non-destructive Testing Tools

b) Structural investigation for sub-structure

Structural investigation for sub-structure includes the investigation for soil properties and foundation. There are many techniques for investigating soil properties. The most common used techniques for single story structure are hand boring and soil penetration test.

Investigation of the foundation can be carried out by digging the soil to check the existence of the foundation, including the dimensions and the bearing area.



Figure 10 Soil Penetration Test

3) Detailed structural analysis.

Detailed structural analysis is conducted to estimate the structural behavior when subjected to applicable loads. Results from structural investigations should be used for the detailed structural analysis. The results of structural analysis will be used for designing of retrofitting approaches/strategy.

c. Vulnerability Assessment for People in Charge.

Seismic Retrofitting decision-making may become a complex problem since many aspects (management, societal, environment, technical, etc) should be considered prior to retrofit. Some of the aspects that should be considered by the people in charge in deciding to retrofit or not are:

- Number of affected buildings
The number of affected buildings will give the description of the scope of retrofitting works.
- Acceptable level of risk defined by the selected rehabilitation performance objectives
- Duration of the program
The duration of retrofitting process and the possibility of the building to operate while retrofitting must be considered in decision-making.
- Number of residents in the buildings
The number of residents will determine the decision of retrofitting. The larger number of residents in the buildings, the greater possibilities of the building to be retrofitted.
- Cost and Benefits of retrofitting or other alternatives
All cost and benefit of all possible alternatives should be known for conducting the cost-benefit analyses
- Societal impacts
Society awareness, protection on the historic buildings, structures or areas that represent unique community, loss of employment, priority of building to be retrofitted are some of societal issues that should be considered
- Politics
In some cases, political intervention could strongly affect the decision of retrofitting.
- Economic impacts
Loss of revenue, loss of trading place, and loss of investment are some of economical issues that should be considered.
- Environmental impacts
Amount of debris generated and environmental impact from Non-strengthened should be considered when assessing the environmental impacts.

4. Retrofitting of School Building.

a. Introduction

As explained in the previous chapter, retrofitting can be a favorable approach because of its advantages compared to reconstructing of buildings. There are several stages in the retrofitting process. The following chart describes the stages of retrofitting.

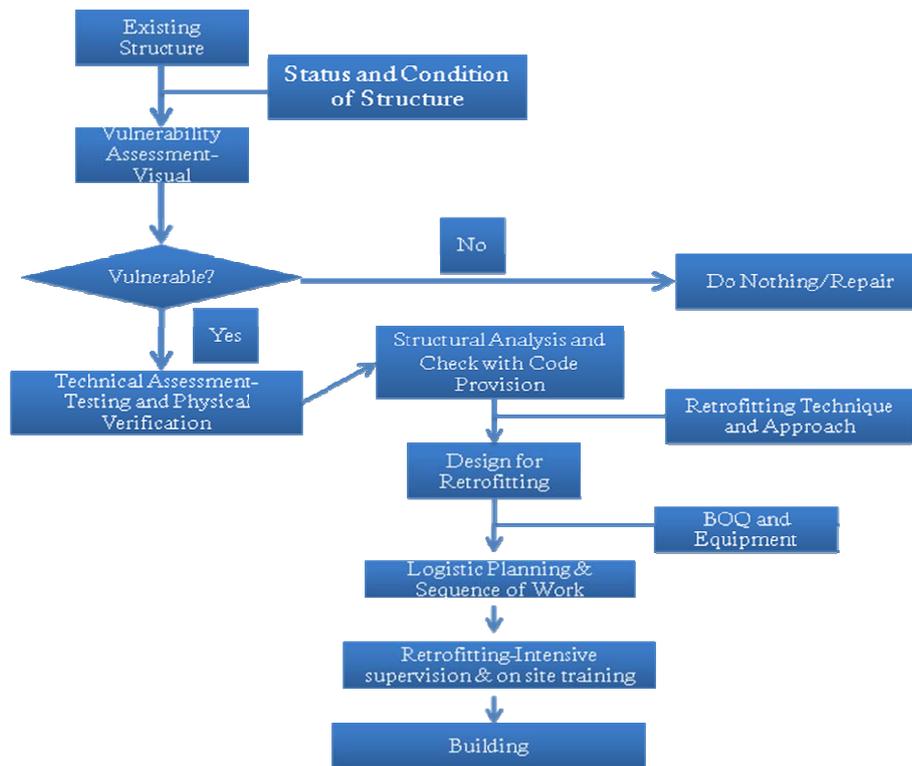


Figure 12 Retrofitting Stages

1. Visual Observation

Visual observation is the first stage of vulnerability assessment. In this stage the building is investigated visually to get the *rough* information of the structural condition. In conducting the visual observation, it is suggested to take documentations of the building's condition and write down the structural deficiencies observed for further investigation. From the results of visual observation, structural investigation is then conducted.

2. Structural investigation

Structural investigation is part of vulnerability assessment on buildings. In structural investigation, the investigator will collect some data related to existing structural condition for further analysis. It is suggested that the investigator prepare the equipments for the investigation. Some of equipments, e.g. writing tools, documentation tools, technical drawing, should be prepared. The others equipments are related with the structural test to be conducted, based on the needs of investigation.

3. Structural analysis

Structural analysis is carried out after completing the investigation. In structural analysis, the existing building is analyzed and subjected to earthquake forces based on current building codes. The results of the structural investigation should be used for determining the existing buildings' properties. The structural condition is evaluated whether it is vulnerable or not. If the building is vulnerable, then design of the retrofitting approach should be conducted.

4. Design of retrofitting approach

The retrofitting approach adopted should consider the followings criteria:

a) The degree of seismic resistance required for the buildings.

The buildings must be designed to provide enough strength and ductility when subjected to earthquake forces. It should also be noted that the buildings must be designed for a certain acceptable damage level. For school buildings, the buildings must not have structural damage due to earthquake.

b) The chosen approach is simple and economical to implement

In designing the retrofitting approach, the techniques should be compatible to the skill of the workers. The techniques should be simple and economical to implement.

5. Construction/ implementation

The construction of the buildings should consider duration of construction. The construction process must be supervised intensively to ensure the quality of works.

b. Various Techniques on Retrofitting

There are various techniques on retrofitting. The retrofitting strategy can be conducted by strengthening the overstressed members, reducing the force distribution, reducing the seismic demands, etc.

In implementing the retrofitting approach, the techniques adopted must be appropriate with the structural deficiencies. For example, if the structural assessment shows lack of stiffness of the structure, the possible retrofitting techniques could be to increase the structural elements dimensions or to insert more structural elements, etc.

In this chapter, some common retrofitting techniques will be presented. However, it should be noted that the decision of which techniques to be implemented must be decided by an engineer.

1) Inserting structural elements

A need of inserting of structural elements is due to intentions of reducing force distributed in each element (by reducing the span of structural elements). Moreover, inserting new structural elements will increase the structural stiffness of overall structure. In inserting the new structural elements, the following criteria should be taken into consideration:

- A good detailing must be provided in the connection areas, e.g. in beam-column joint, beam-foundation connection, column-foundation connection.

- The structural dimensions and materials properties should be equal (not a compulsory) to the old structural elements to provide good forces distribution, e.g. the dimension of the new column should be the same with the old one.
- In the construction process, temporary support may be needed in inserting the new structural elements.

Additional structural element is needed when:

1. Force distribution is needed to reduce
2. Structural stiffness is needed to increase
3. Total area of wall without vertical structural element > 9 m²

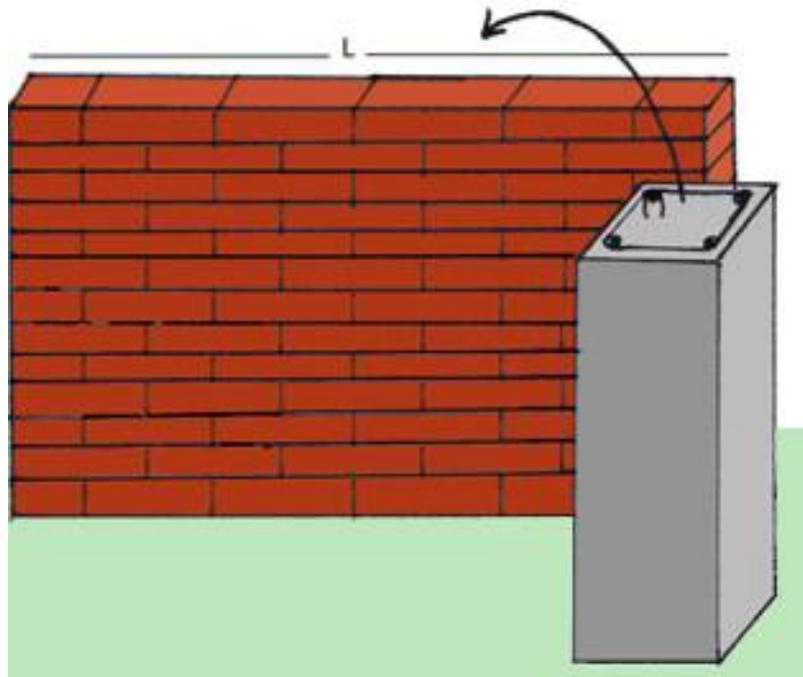


Figure 13 Addition of Reinforced Concrete Column (Courtesy of *Panduan Konstruksi dan Perkuatan Bangunan Sekolah Tahan Gempa, CDM-ITB 2008*)

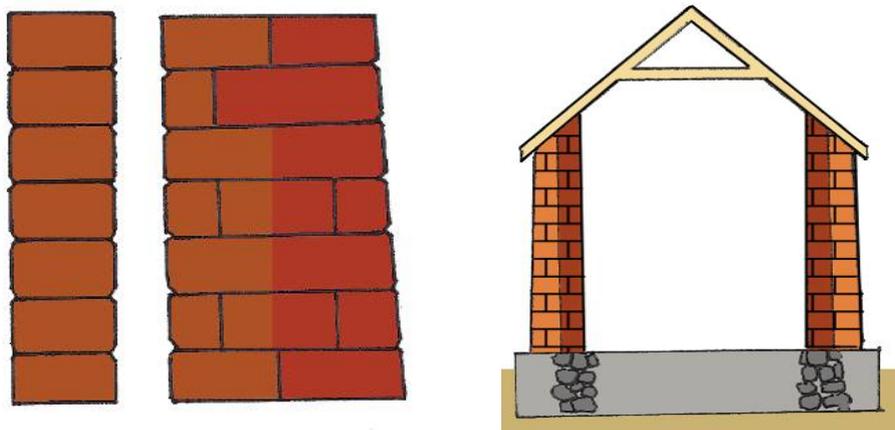


Figure 14 Addition of Buttress in Masonry Structure

- 2) Implementing horizontal and vertical seismic belts (iron wire mesh) in masonry building
The iron wire mesh is usually implemented to strengthen the masonry walls. It is typically applied on the location of beam and column, and crossly applied at the edge portal of buildings. The wire mesh is applied at the both surface of masonry and the wire mesh is also anchored to maintain the position and integration

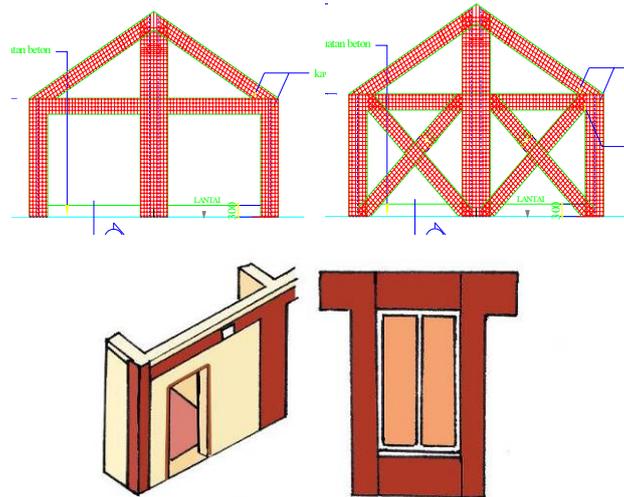


Figure 15 Strengthening with Seismic Belts

3) Jacketing of structural elements for RC elements (Beam and Column)

The concept of concrete jacketing is an addition of a relatively thick layer of reinforced concrete in the form of a jacket around the existing structural elements (usually columns). Jacketing will enhance the flexural strength, ductility and shear strength of the structural elements.

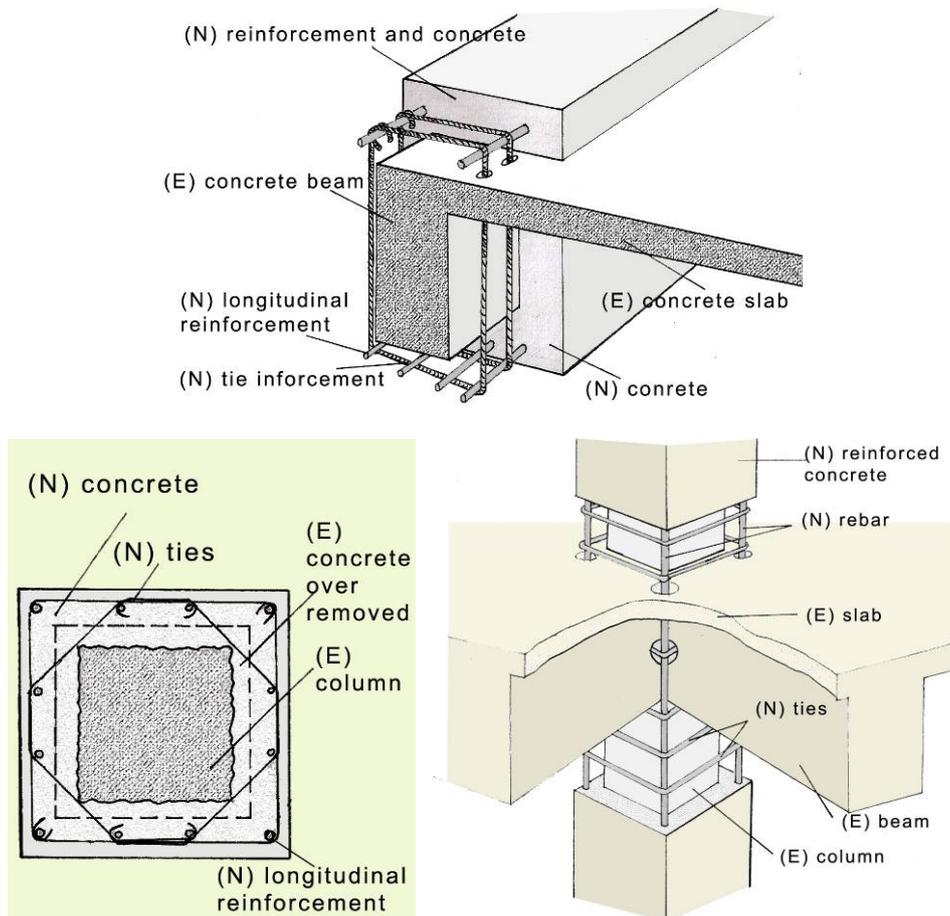


Figure 16 Concrete Jacketing

4) Strengthening roof trusses and roof diaphragms

In strengthening the roof trusses, an addition of diagonal truss connecting two adjacent roof trusses will increase the stiffness of the roof diaphragm system. Moreover, adding the diagonal bracing in the same level of beam will also increase the stiffness of the roof diaphragms.

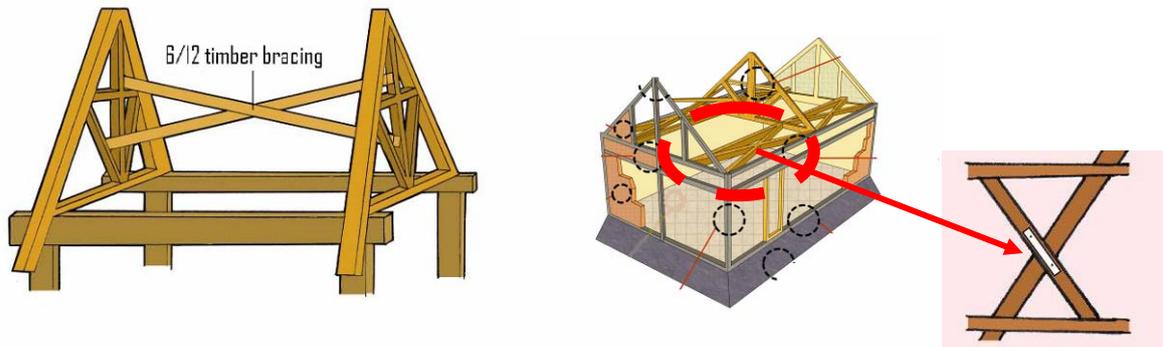


Figure 17 Strengthening Roof Trusses (left) and Roof Diaphragms (right) (Courtesy of *Panduan Konstruksi dan Perkuatan Bangunan Sekolah Tahan Gempa, CDM-ITB 2008*)

5) Strengthening Concrete Diaphragm.

The major deficiencies found in the concrete diaphragm are inadequate in-plane shear capacity of the concrete diaphragm and inadequate flexural capacity. In strengthening shear capacity, overlaying the existing concrete diaphragm with new reinforced concrete topping slab and reducing the shear by providing supplemental vertical-resisting elements will improve the capacity. In strengthening the flexural capacity, casting a new chord member integral with the slab after removing the edge of diaphragm slab and reducing the flexural stress by providing additional vertical-resisting elements will improve the flexural capacity.

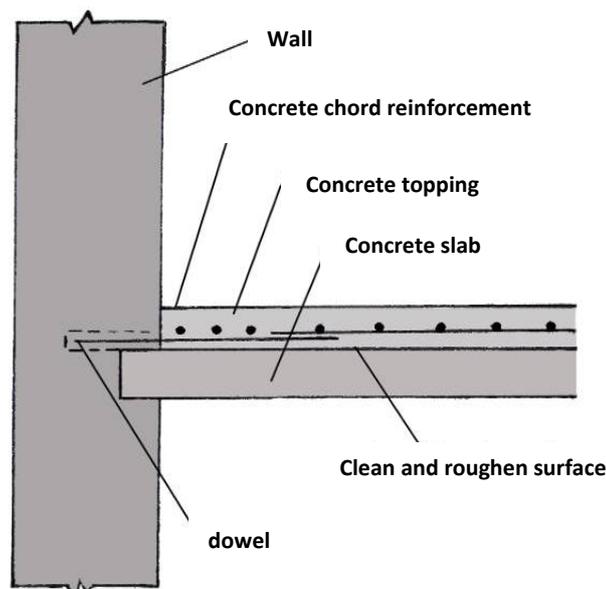


Figure 18 Strengthening Concrete Diaphragm with a New Topping Slab and Chord

6) Strengthening techniques for continuous or strip wall footings

The principal deficiencies usually occurred in the footings are the excessive soil bearing pressure due to overturning forces and excessive uplift conditions due to overturning forces. There are many techniques available for strengthening both deficiencies. Each technique has both advantages and disadvantages. A judgment should be made to choose the best techniques based on the existing conditions.

a) Strengthening techniques for excessive soil bearing pressure

The problem of excessive soil bearing pressure caused by seismic overturning forces can be mitigated by:

- Increasing the bearing capacity of the footing by underpinning the footing ends and providing additional footing area
- Increasing the vertical capacity of footing by adding new drilled piers adjacent and connected to the existing footing
- Increasing the soil bearing capacity by modifying the existing soil properties

To provide additional footing area (technique 1) or add new drilled piers (technique 2) could be costly and disruptive alternatives. An alternative of modifying the existing soil properties by injecting chemical grouts could be a better cost-effective technique.

b) Strengthening techniques for excessive uplift conditions

The excessive of uplift forces caused by seismic overturning moments can be improved by:

- Increasing the uplift capacity of the existing footing by adding drilled piers or soil anchors
- Increasing the size of the existing footing by underpinning to mobilize additional foundation and soil weight
- Reducing the uplift forces by providing supplemental vertical-resisting elements

Providing significant increase of uplift capacity is most effective by adding drilled piers or soil anchors. However, it should be noted that all interior foundation works will be costly and disruptive than exterior foundation works.

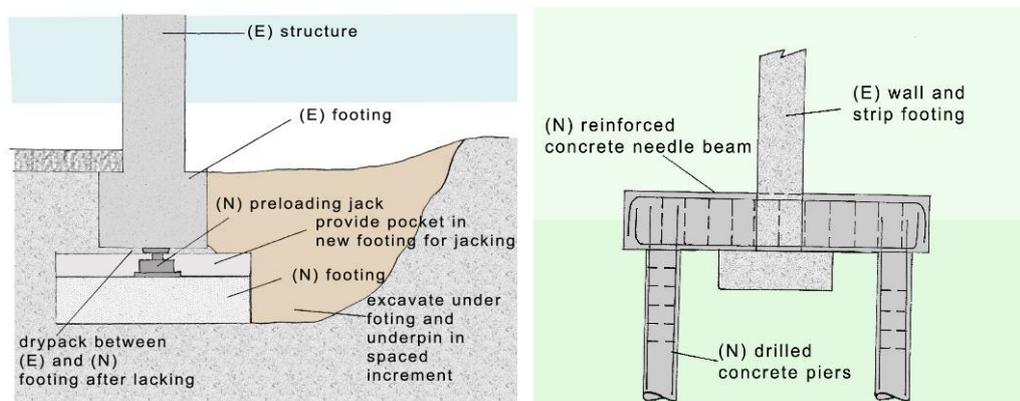


Figure 19 Underpinning of the Existing Foundation and Addition of Drilled Piers

7) Decreasing Demand on Existing Building.

Many choices are available to decrease the demand on existing building. One of the simplest methods is reducing the weight of the building, hence it will decrease the earthquake load subjected to the building. Techniques that have been utilized to reduce weight include removing the upper stories of a building, changing the use of the buildings, replacing heavy roof system with light assembly roof system, and removing heavy appurtenance (such as parapets, balconies, water towers, or equipments).

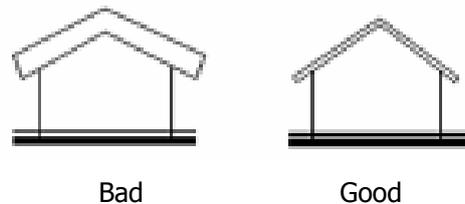


Figure 20 Reducing the Weight of the Building by Using Light Weight Roof System

The other methods, more technical and relatively more expensive, also can be adopted by providing seismic isolator and supplemental damping to decrease the demand on the building.

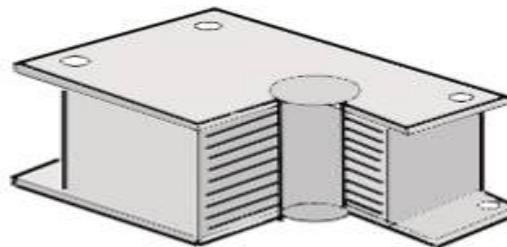


Figure 21 Lead Rubber Bearing

c, Retrofitting of Non-Structural Components

Non-structural components can be damaged when earthquake earthquakes occurred. Some of the damaged components may fall down and cause injuries or fatalities. Three principal causes of nonstructural damage are differential motion or deflection of the structures, insufficient capacity, and building separation. For example, different story displacement and deflection of structural elements may cause damage on windows, insufficient anchorage capacity of non structural elements together with shaking due to earthquake may cause falling down and damage of components, and connecting elements of two separated building including the non-structural components will suffer serious damages due to pounding on the structures.

In general, non-structural components can be categorized to architectural components, utilities components, and furniture and contents. The principal idea of strengthening those non-structural elements is to provide adequate restraint to the elements. Before retrofitting the non-structural elements, assessment is needed to determine the deficiencies occurred.

1) Architectural Components

Most of the buildings have the architectural components. There are many purposes of architectural components, such as for aesthetic, spacing-flow, etc. Examples of the architectural components include partitions and ceilings, windows, doors, lighting, interior or exterior ornamentation, exterior panels, and parapets. Following figures show the technique for strengthening some architectural components.

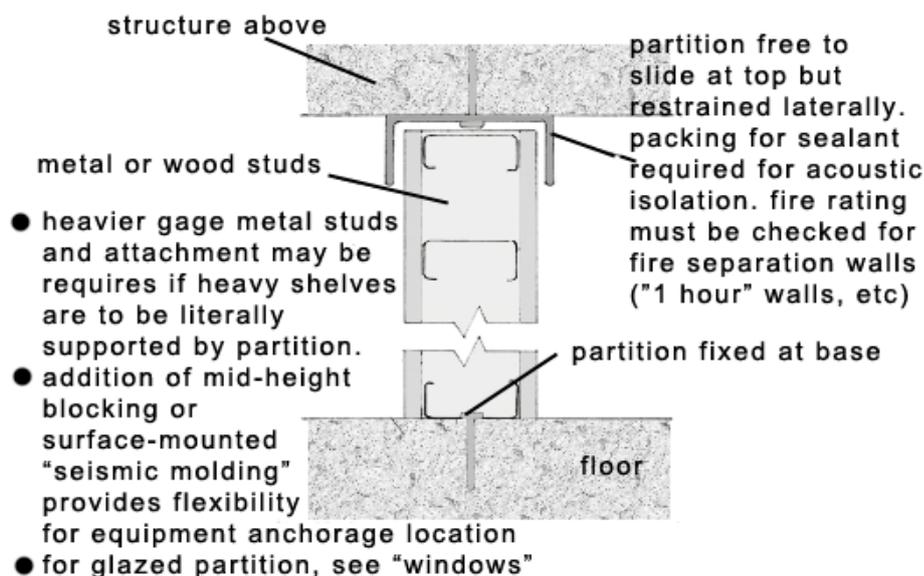


Figure 22 Built-in Full-Height Partition

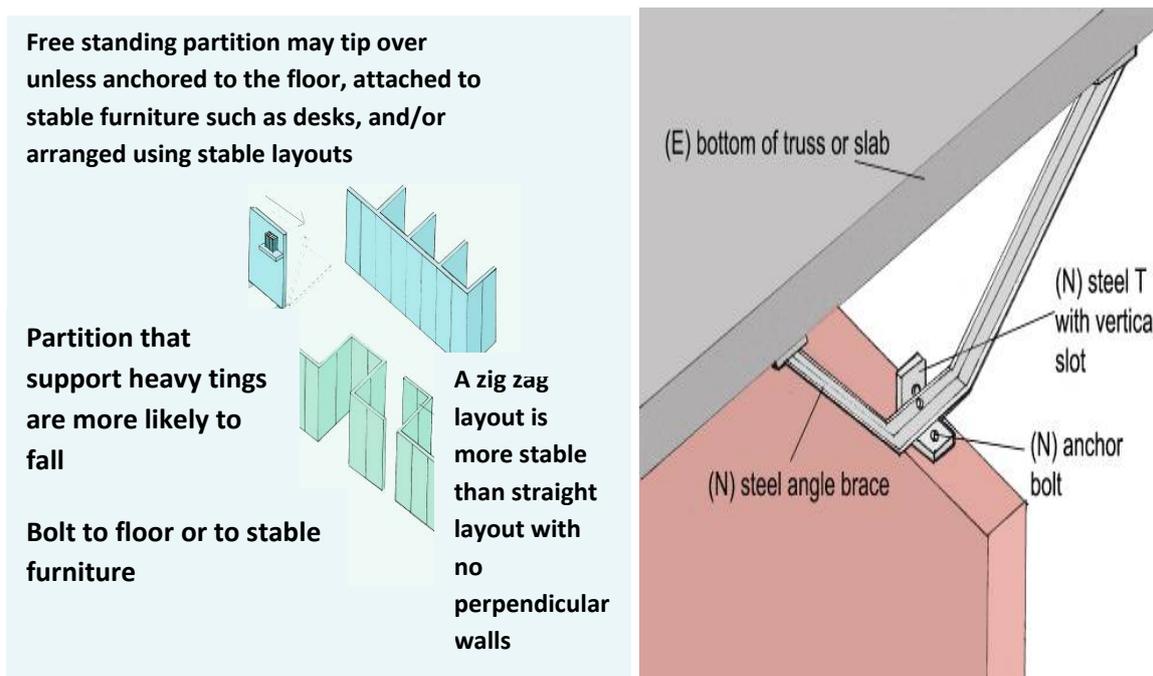


Figure 23 Built-in Partial-Height Partition

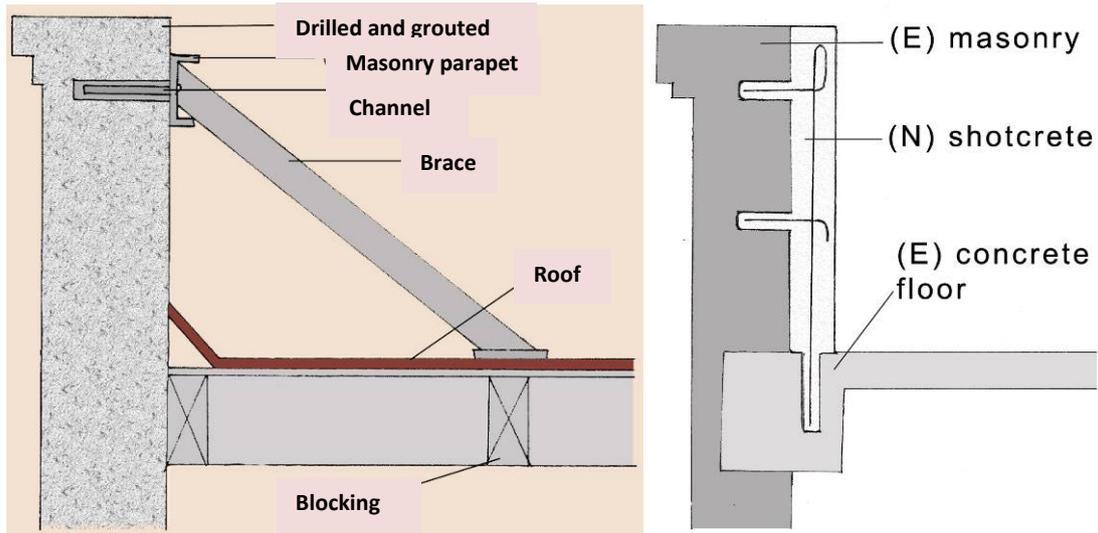


Figure 24 Parapets

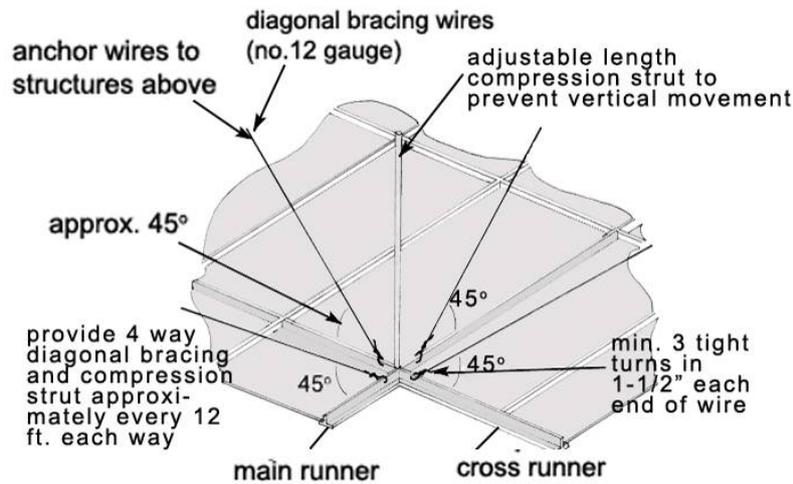


Figure 25 Ceilings

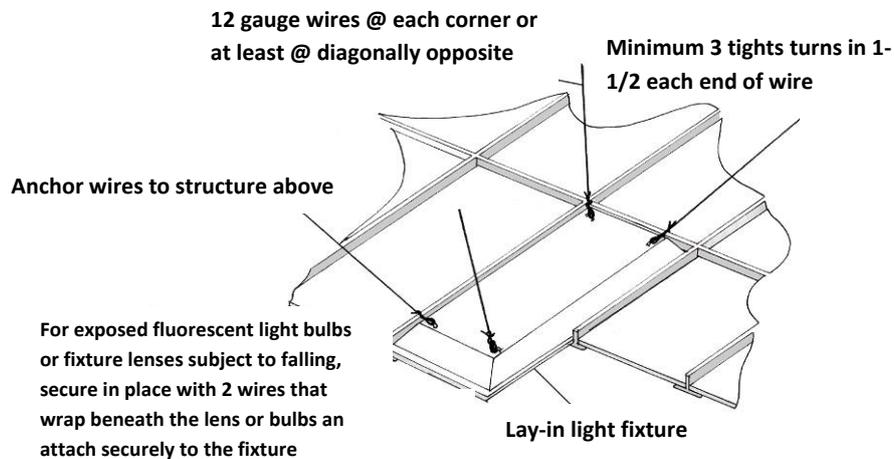


Figure 26 Lighting Fixtures

To prevent damage to stairs, they should be modified to allow them to slide at landings with proper details. This is desirable for flexible frame buildings. Next, to prevent damage to windows, it is suggested to use tempered glass. Tempered glass will reduce the seismic hazard. It may still break, but in a small dull fragments. Polyester shatter resistant films will help holding together fragments of any panels that crack in earthquake.

2) Utilities Components

Examples of the utilities components include mechanical and electrical equipments and distribution systems, piping and conduit, tank, fire extinguisher, etc. Following figures show some techniques of strengthening utilities components

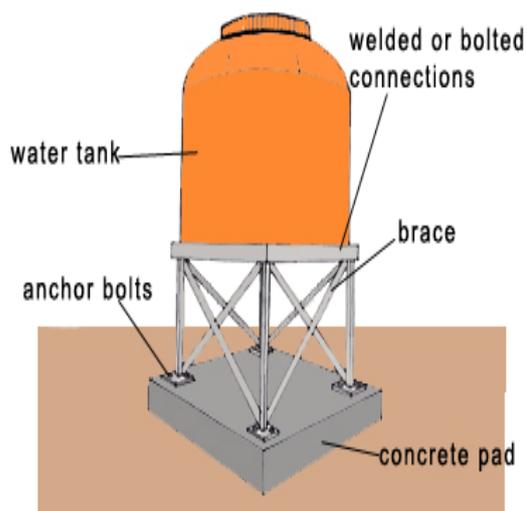


Figure 27 Tank

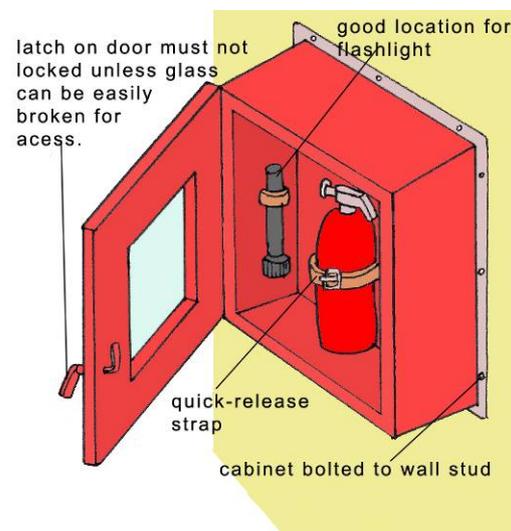


Figure 28 Fire Extinguisher and Cabinets

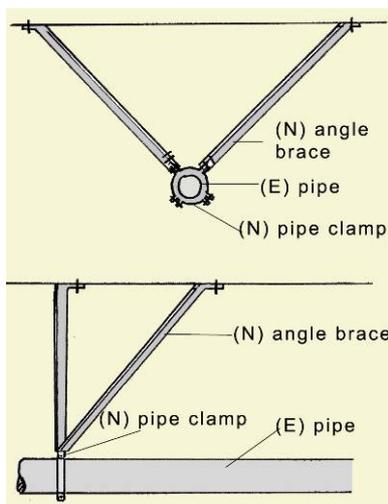


Figure 29 Piping System

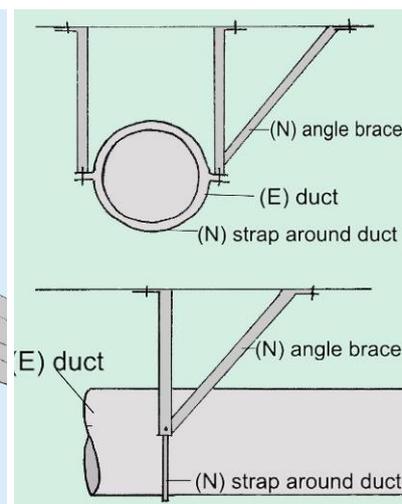
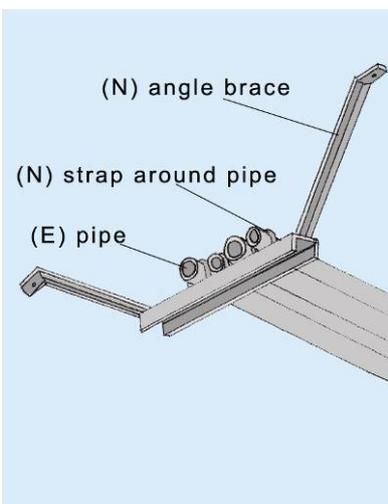


Figure 30 Ducting System

3) Furniture and Contents

These are non-structural components that belong to occupants of the building. Examples include office, computer, and communication equipment, cabinets and shelving for record and supply storage, library stacks, kitchen, furniture, movable partitions, lockers and vending machine.

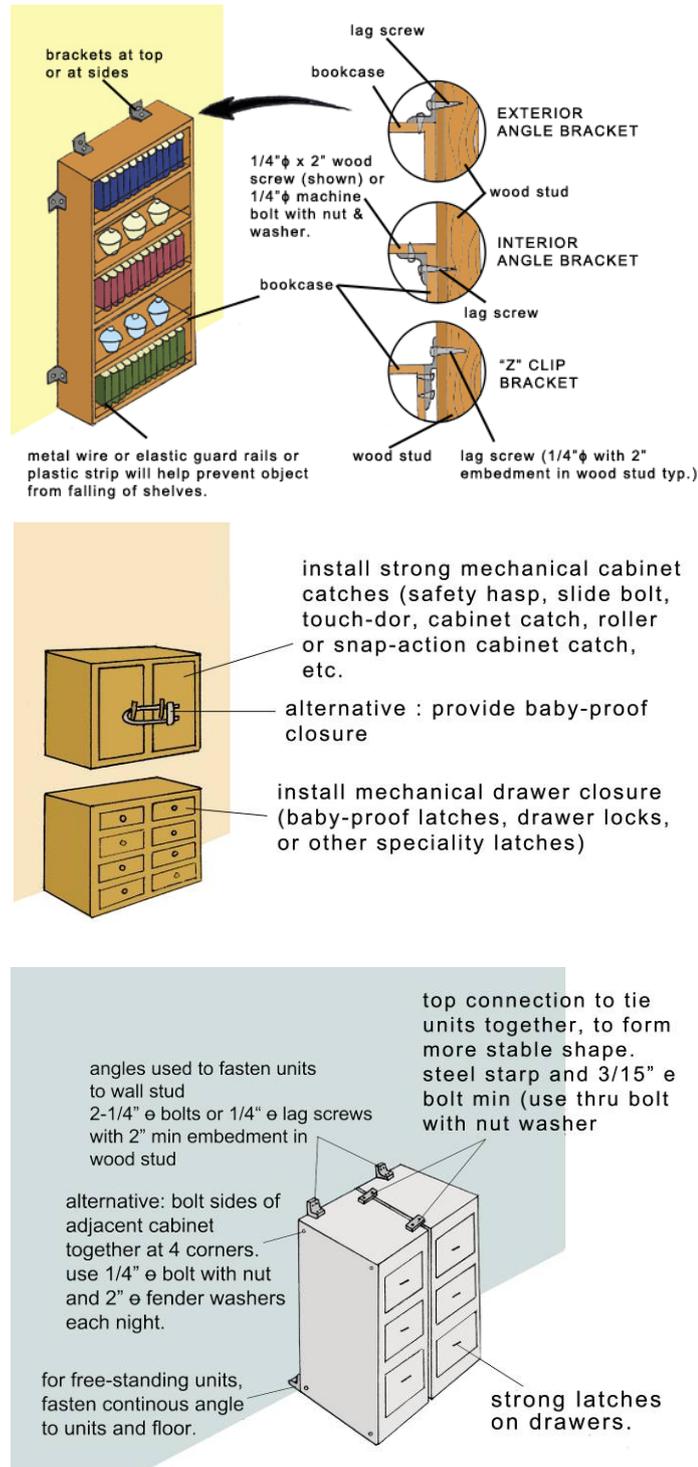


Figure 31 Tall Shelving, Filing Cabinet, Drawer and Cabinet Latches

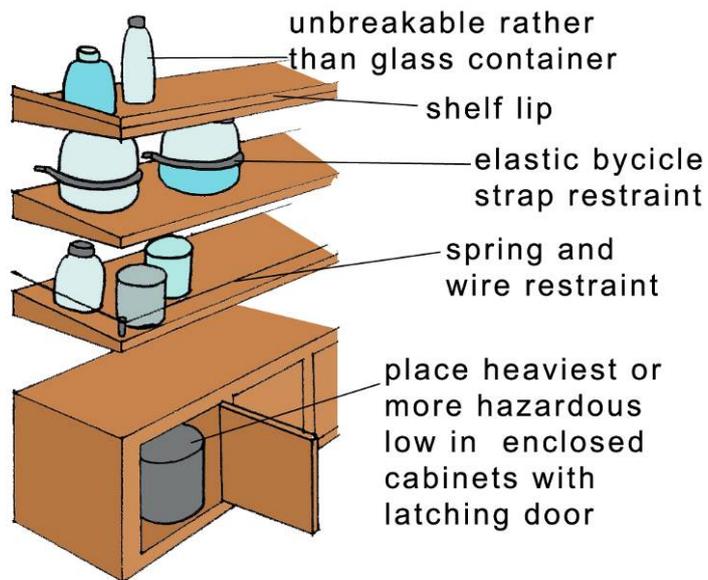


Figure 32 Containers of Hazardous Materials

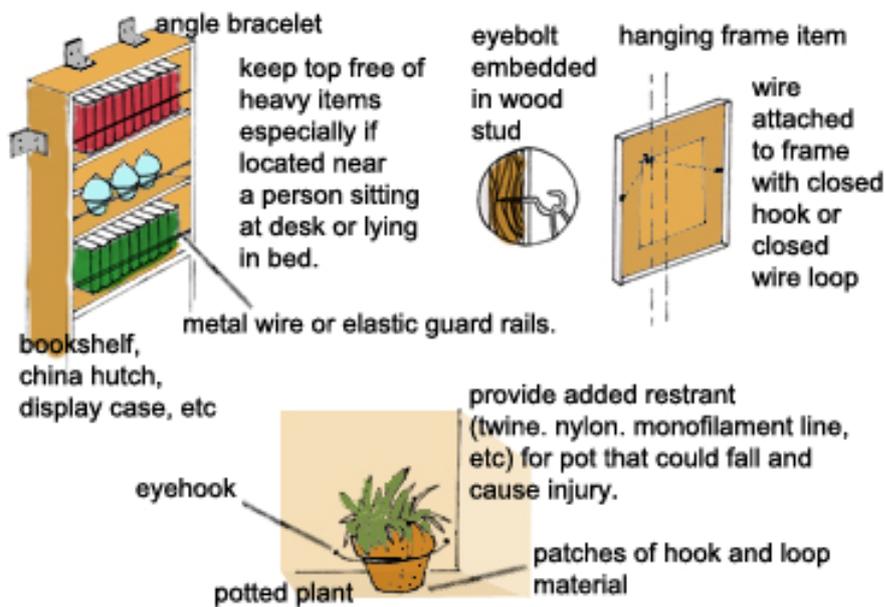


Figure 33 Miscellaneous Furniture

b. Condition of Existing Structure

Many problems were found when the visual survey and structural investigation were conducted. The problems found could be listed as follows:

1. Inadequate foundation system (shallow foundation, no tie beam). The foundation system was exposed on some places and no support was provided on areas with eroded soil surface.
2. Inadequate roof framing system, poor wall-roof connection, and poor roof truss element and connection. The roof was in dire need of repair as the construction shown excessive deformation on the top of the building.
3. Damages found on walls, with cracks and gaps found on some places, due to lack of structural elements (beams and columns).
4. Poor materials and detailing on the structures.
5. Poor sanitation facilities.



Figure 35 Existing Condition of SDN Padasuka II

c. Structural Analysis

Using the results from structural investigation, the buildings were analyzed to evaluate the structural performance under all applicable loads, including earthquakes. The structure was modeled as such that the structural elements (beams and columns) formed the structural frame, while masonry walls were modeled as plate elements. Both structural frame and plate elements provided lateral resisting system for the structure. The foundation provided support for the structural frames. The roof trusses were also modeled using truss elements. Material properties used for the analysis were based on results of structural investigation. The structural deficiencies/weaknesses were also included in developing the structural model.

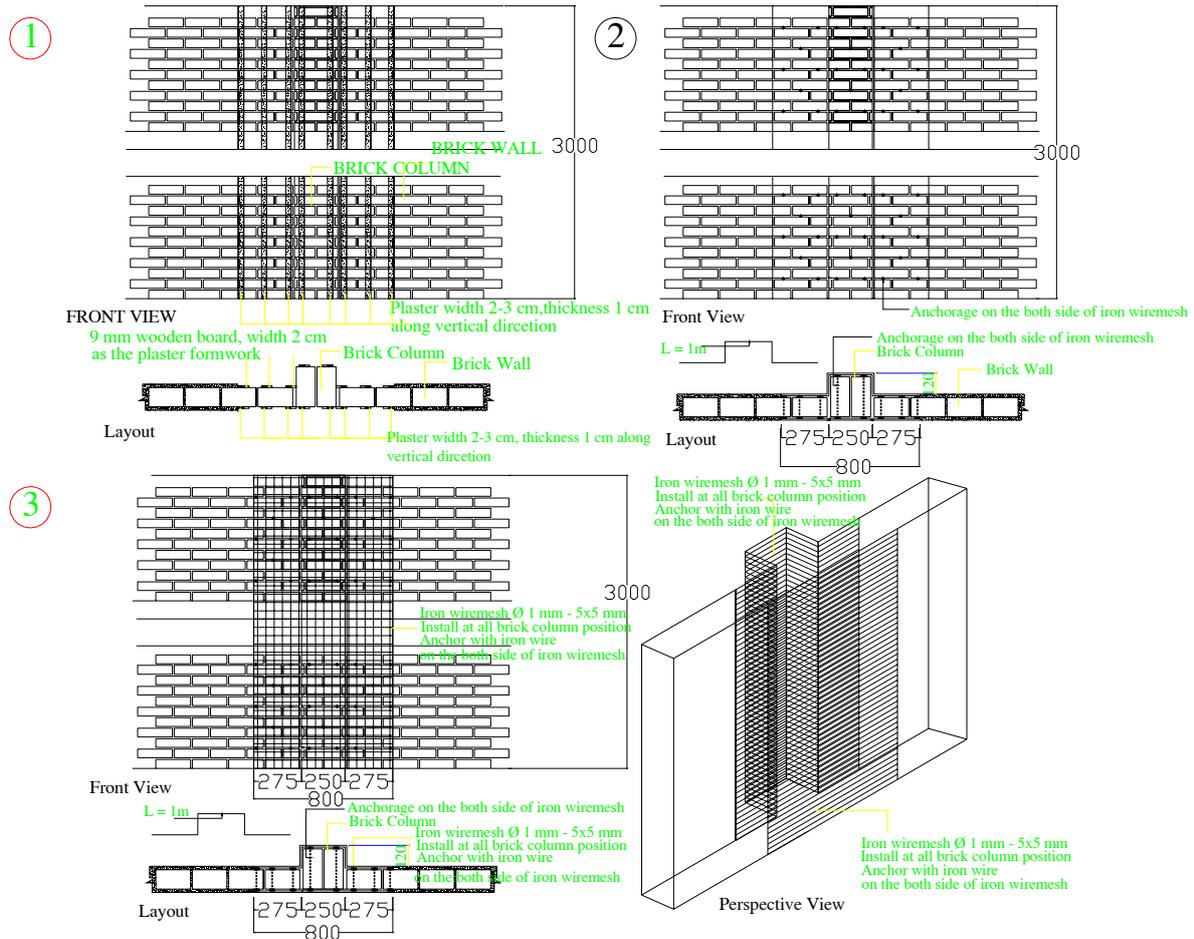
The design criteria followed the Performance Based Design, where the structure was expected to have minor/limited damage under design earthquake (elastic behavior). The seismic design level was obtained from the current building codes, with a PGA of 0.24g. The structural analysis was conducted using response spectra approach.

Results from structural analysis show that the structure did not have adequate capacity in resisting lateral loads. Checking of connection capacity also revealed unsatisfactory results. Moreover, the trusses required improvement to be able to support all applicable loads. Combined with data obtained from visual and structural investigations, results from structural analysis were then used to design appropriate retrofitting approach.

d. Retrofitting Approach

The buildings were retrofitted using iron wire mesh for strengthening wall elements, inserting columns on building corners. The wire mesh was installed in the locations of ordinary beams and columns, as well as diagonally on the perimeter walls. The wire mesh was installed on the both side of the wall and anchored using iron wire. Tie beams were added underneath the walls for strengthening the foundation system. The roof system was retrofitted using proper material and detailing. Repair was conducted for nonstructural elements such as doors/windows and ceilings. Finishing/cosmetic repair and improvement of sanitary facilities were also conducted for the schools buildings

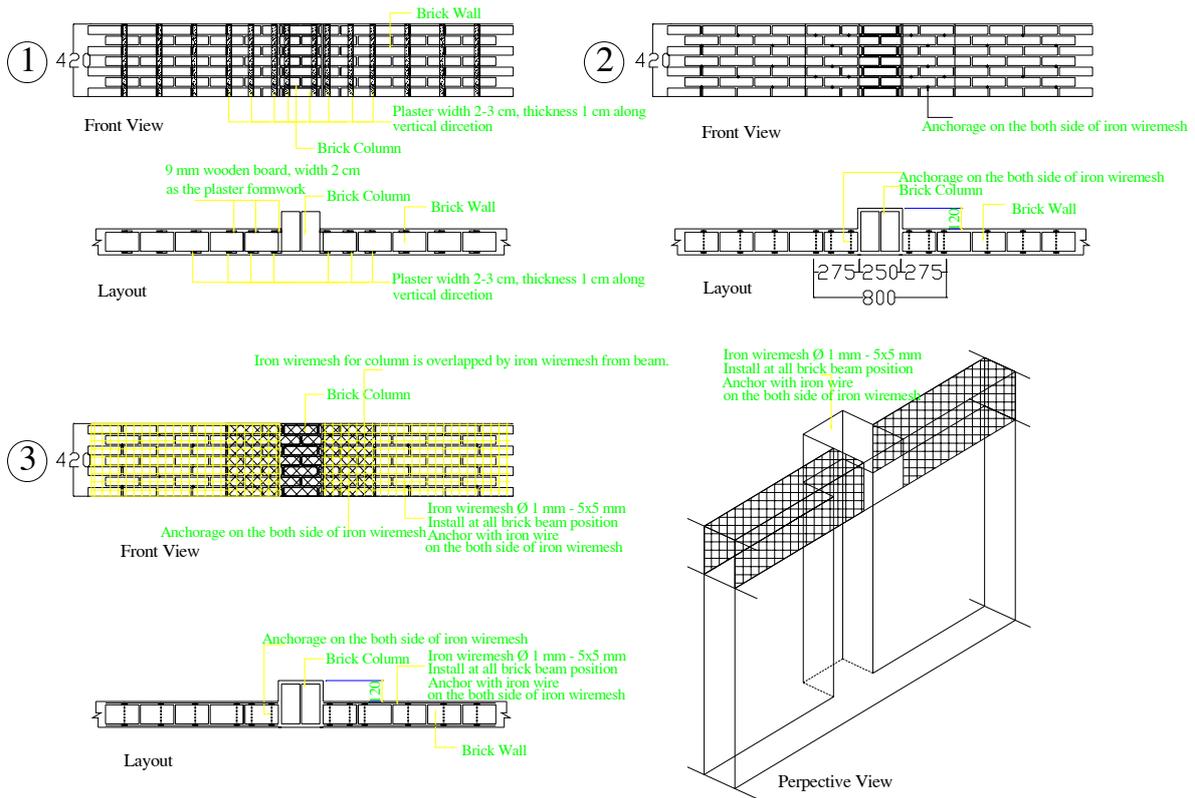
DETAIL OF COLUMN WITH IRON WIREMESH REINFORCEMENT



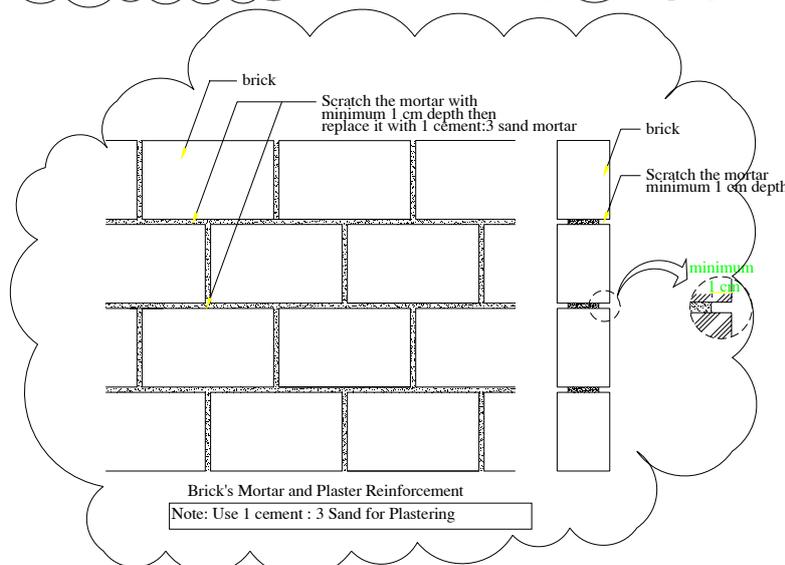
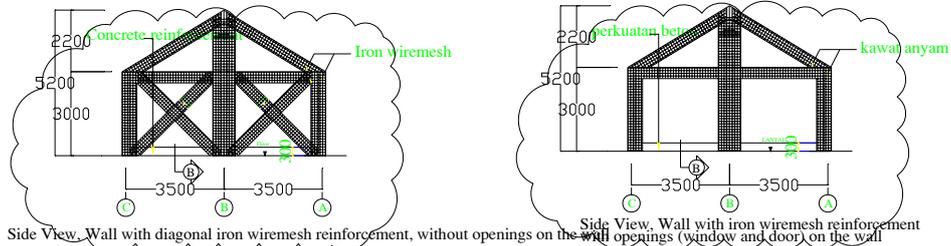
(a) Retrofitting strategy for columns of SDN Padasuka II

Figure 36 Retrofitting of SDN Padasuka II (Courtesy of PT Teddy Boen Konsultan)

Detail of Beam with Iron Wiremesh Reinforcement

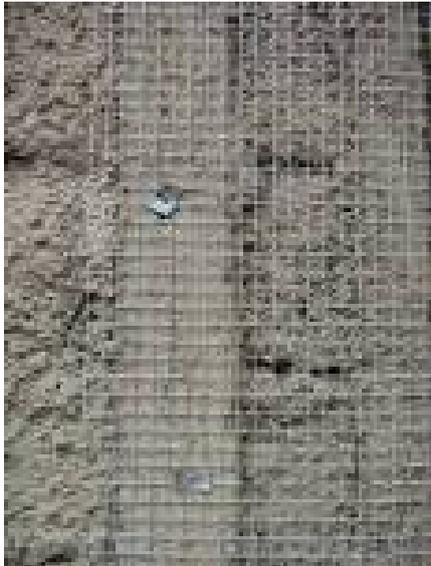


(b) Retrofitting strategy for beams at SDN Padasuka II



(c) Retrofitting strategy for walls of SDN Padasuka II

Figure 36 Retrofitting of SDN Padasuka II (Courtesy of PT Teddy Boen Konsultan) (cont'd)



(a) Application of Iron Wire-mesh in Column Position

Figure 38 Retrofitting Works for the Wall

f. Post-earthquake Condition

On September 2nd 2009, approximately 7 months after the retrofitting works completed, a 7.3 Richter scale earthquake occurred with the epicenter located south of Tasikmalaya. The earthquake caused damages on many buildings, including the buildings at Bandung County. Survey was then conducted to evaluate the post-earthquake condition of SDN Padasuka II.

Based on the survey conducted, there was no significant damage on SDN Padasuka II, with only a few non-structural cracks occurred. From the post-earthquake condition, it can be concluded that the retrofitting approaches adopted on SDN Padasuka II has successfully prevented the buildings from major damage. As a comparison, there were some schools and houses located near SDN Padasuka II that were strongly affected by the earthquake shaking. Following figures show the post-earthquake condition of SDN Padasuka II.



Figure 43 Post-earthquake Condition

6. Case Studies: Retrofitting of School Building: SDN 13 Syamtalira Arun (Save the Children project, with design and technical assistance from Syiah Kuala University)

a. Introduction

SDN 13 Syamtalira Arun is located at North Aceh. The school building consists of 2 rooms. The school has approximately 400 students. In general, the structural system before retrofitted was reinforced concrete frames with infill masonry walls.

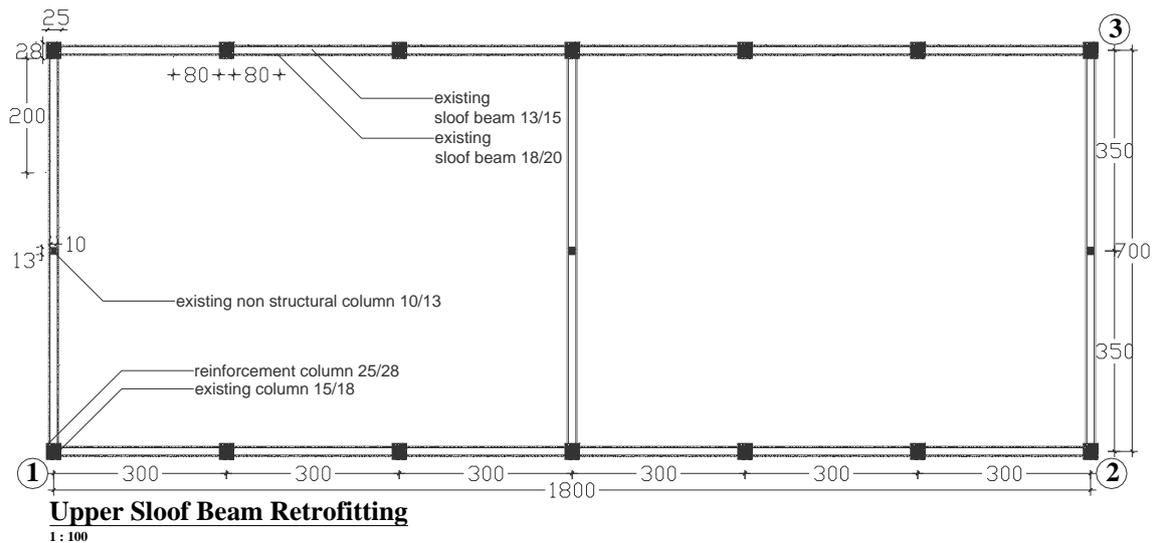


Figure 44 SDN 13 Syamtalira Arun Layout

b. Status and Condition of Structure

From the initial survey, there were some major problems found in SDN 13 Syamtalira Arun, i.e:

1. Cracks on walls
2. Cracks on structural member
3. Poor workmanship
4. Poor quality construction



Figure 45 Existing Condition of SDN 13 Syamtalira Arun

c. Assessment

1) Visual Assessment

In the visual assessment, the following measures were conducted:

- Rapid visual inspection and assessment
- Collection of design and drawing
- Topographical information of site
- Site measurement of main structural member
- Inspection of cracks and location
- Judgment of the construction quality
- Evaluation of workmanship
- Inspection of material used and its quality



Figure 46 Visual Assessment

2) Technical Assessment

Based on the results from the visual assessment, the technical assessment was conducted. In the technical assessment, some of the physical verification and partial/non-destructive tests were carried out, and the technical assessment measures included:

- Review and evaluation of design, specification & drawing
- Comparison of size and quality between design drawing and state of the structure in site
- Check with code provision, mainly size of main structural member and reinforcement bar

based on results of structural investigation. The structural analysis was conducted based on the following codes:

- PPI 1983 – Loading standard
- SNI -03-2847-2002 – Standard for design of concrete structures
- SNI 03 – 1726 – 2003 – Standard for earthquake resistant building

The structural analysis revealed that the open frame structure did not have adequate capacity in resisting lateral loads. Combined with data obtained from visual and structural investigations, results from structural analysis were then used to design appropriate retrofitting approach.

e. Design Recommendation

Retrofitting strategy was decided based on the results of technical assessment. Due to the approach of open frame system (walls were not considered as lateral resisting elements), the retrofitting design required that structural element sizes (beams and columns) to be increased to provide larger load resistance capacity. Hence, the following design approaches were proposed:

1) Retrofitting on structural member

– Foundation

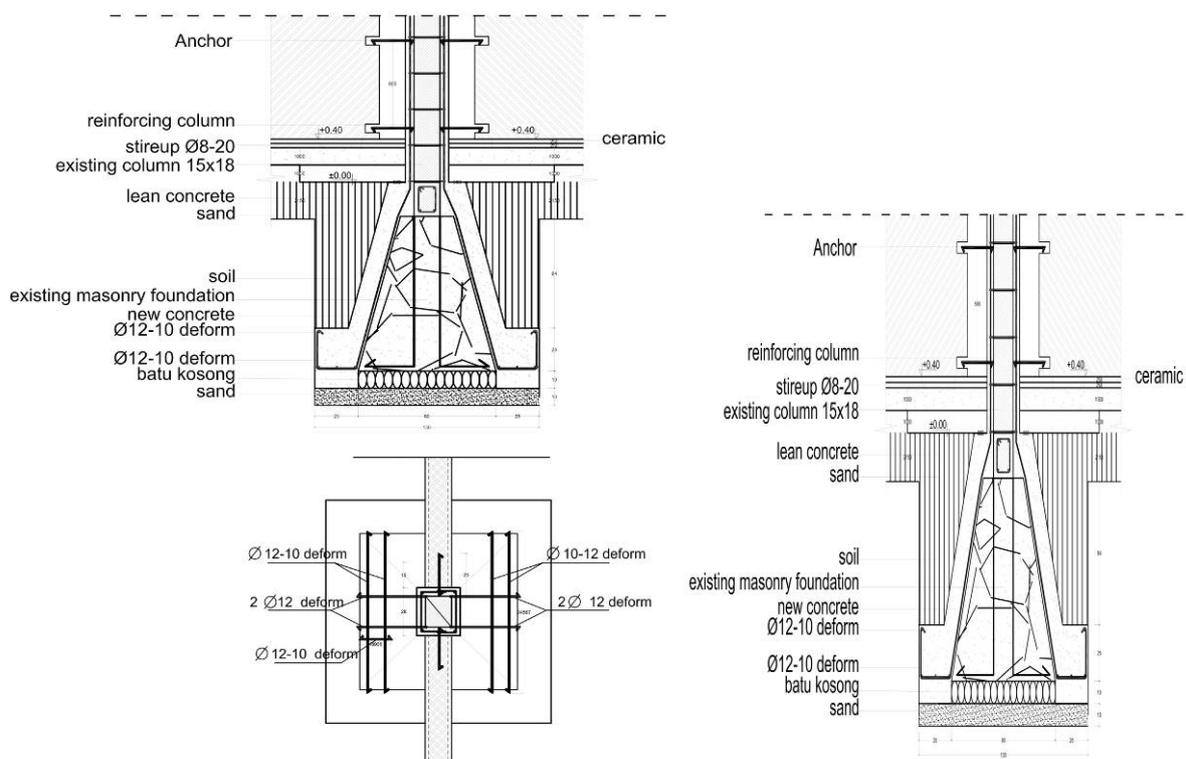


Figure 48 Retrofitting of Foundation

– Beams

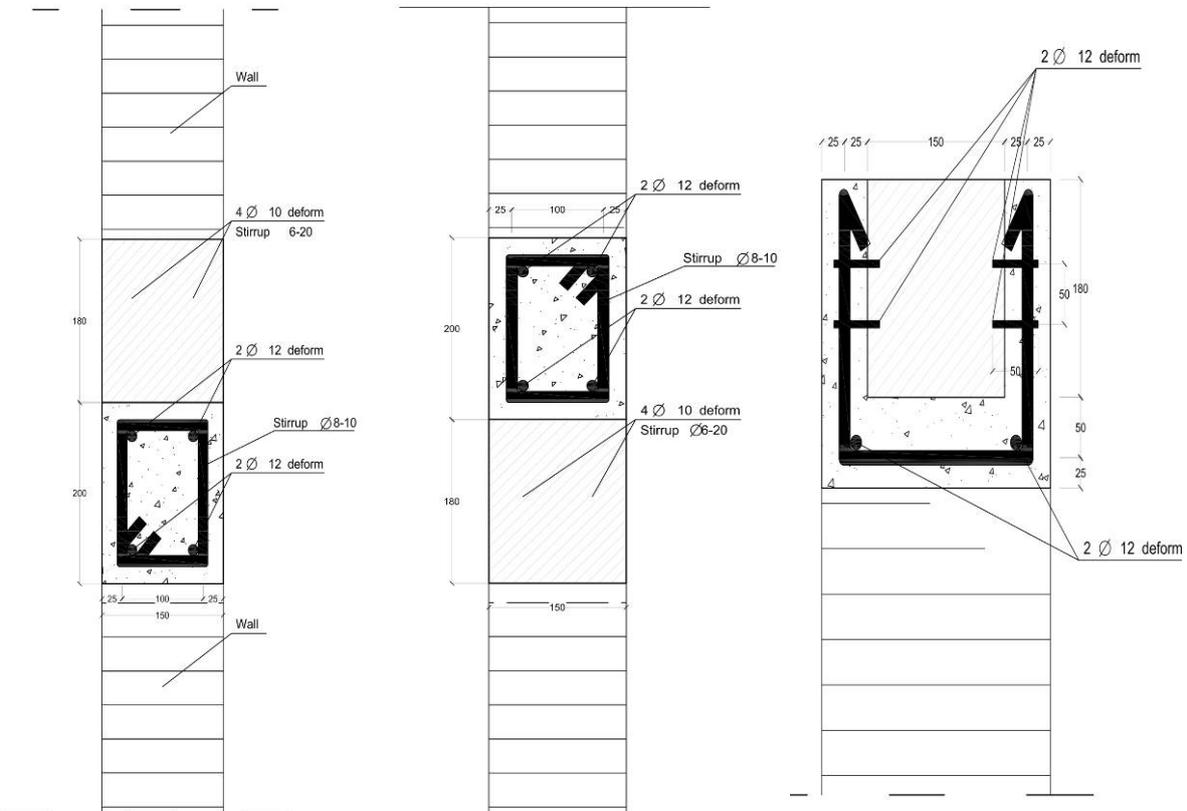
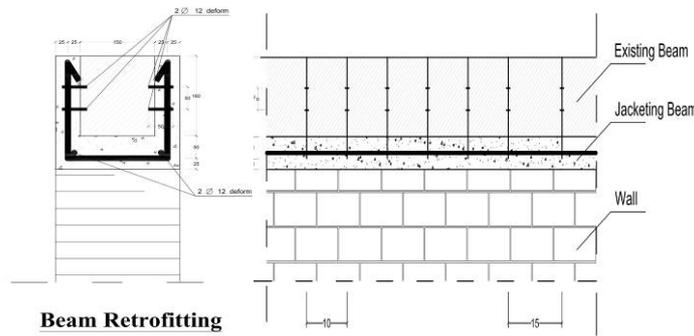
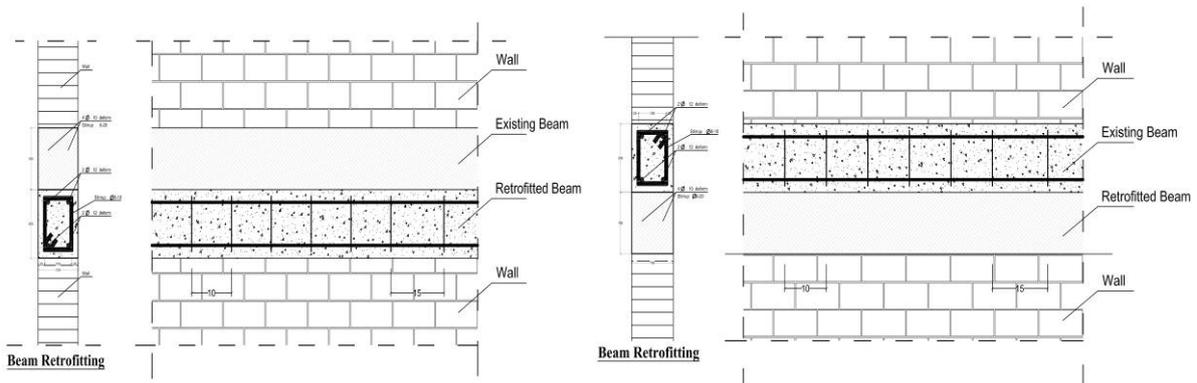


Figure 49 Retrofitting of Beam

- Column

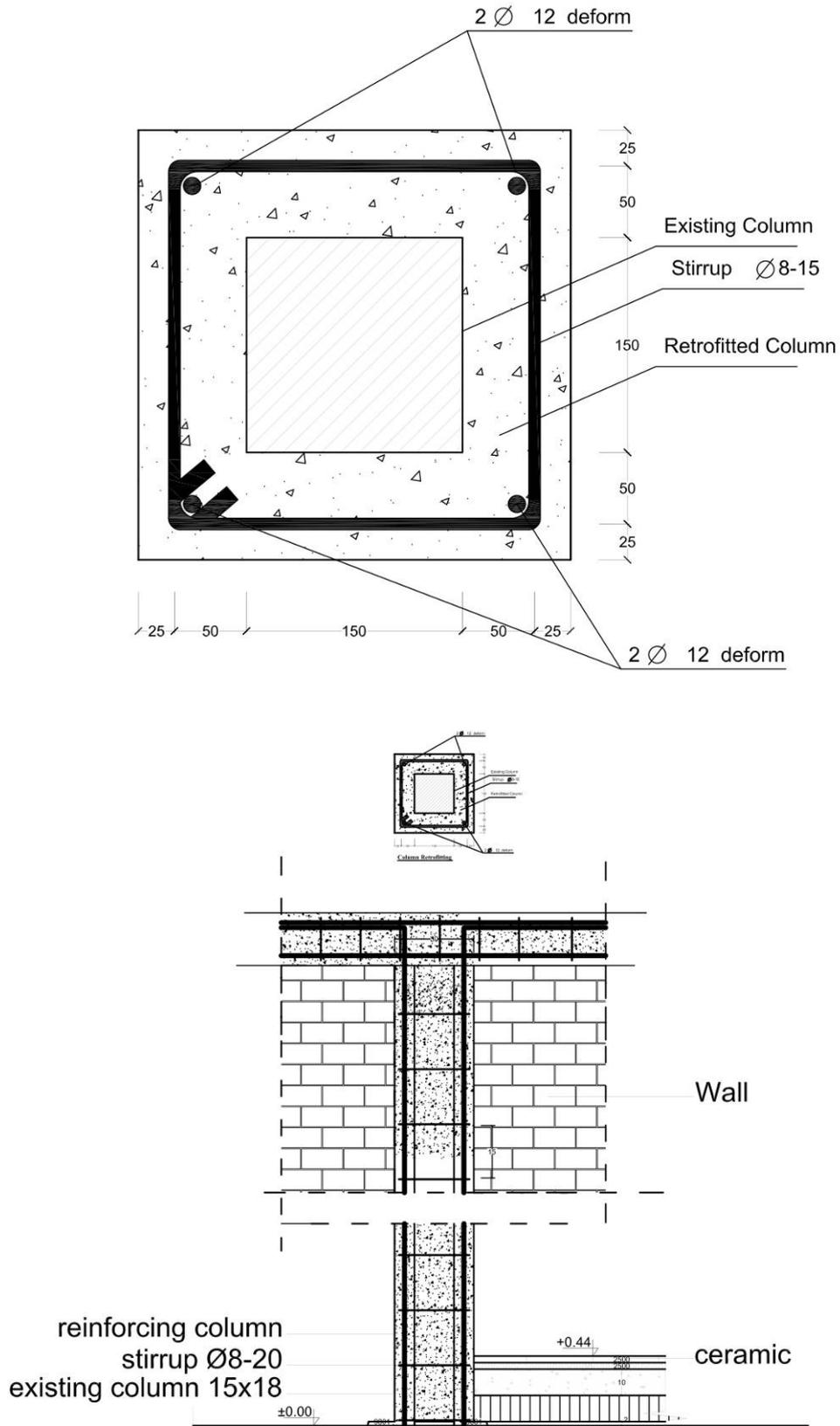


Figure 50 Retrofitting of Column

2) Connection between Wall & Column

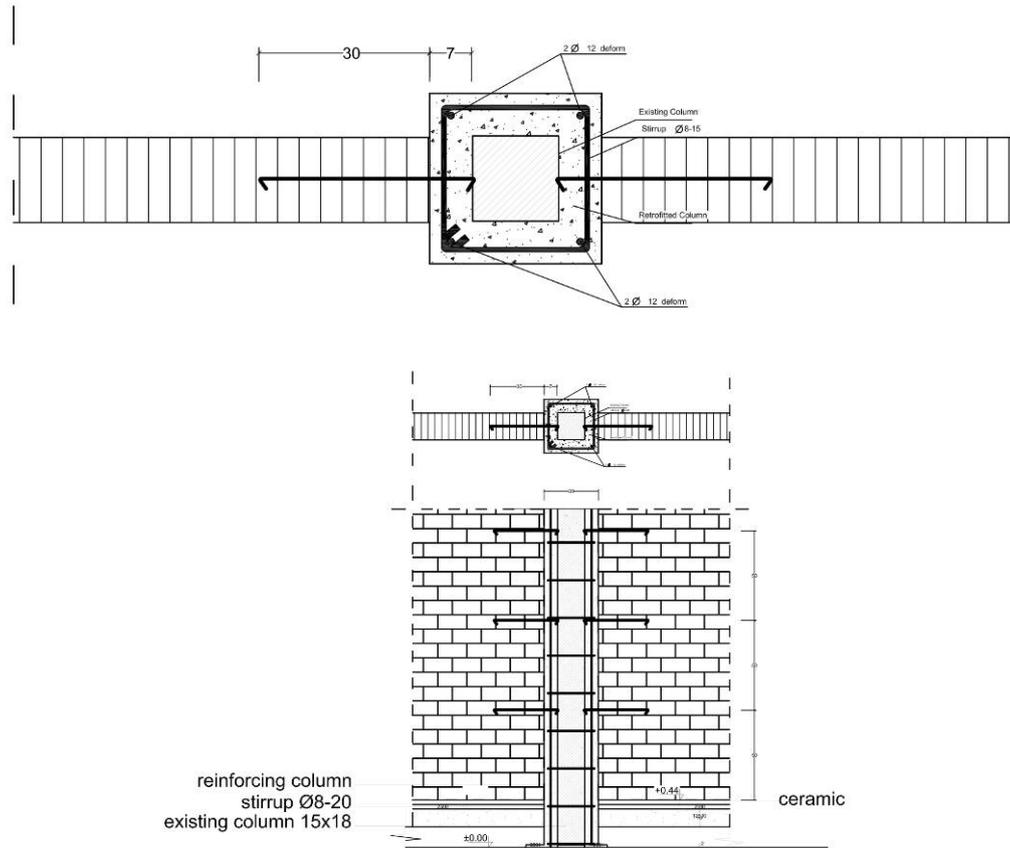


Figure 51 Retrofitting between Wall and Column

3) Retaining structures to protect Foundation

4) Corrective measure on cracks

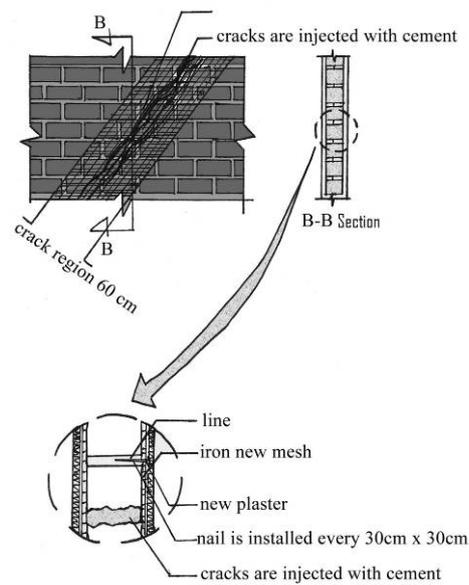


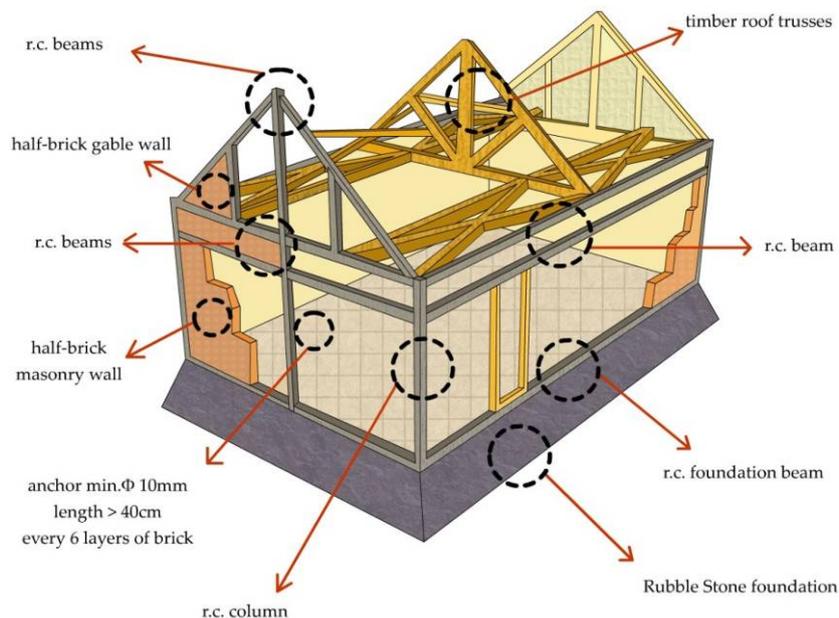
Figure 52 Cracks Injection

APPENDIX

Assessment Tools for Teacher and Community

100 General Information

| | | | | |
|------------|---|--|--------------------------------------|----------------------------------|
| 101 | Name of Building | | | |
| 110 | Geographical Information | | | |
| 111 | Address (street, city, district, province/state) | | | |
| 112 | Locality | <input type="checkbox"/> Urban | <input type="checkbox"/> Sub- Urban | <input type="checkbox"/> Rural |
| 113 | Accessibility | | | |
| 120 | Building Information | | | |
| 121 | Building function | | | |
| 122 | Building ownership | <input type="checkbox"/> Private | <input type="checkbox"/> Public | |
| 123 | Name of owner | | | |
| 124 | Number of residents | Male : | Female : | Children : |
| 125 | Year of Construction | | | |
| 130 | Community Information | | | |
| 131 | Size of district | | | |
| 132 | Majority profession of local/ majority industries | | | |
| 133 | Economic status of majority community member | | | |
| 134 | Society awareness on natural disaster | <input type="checkbox"/> Low | <input type="checkbox"/> Moderate | <input type="checkbox"/> High |
| 140 | Disaster History | | | |
| 141 | What are the major natural disasters in this area? | | | |
| 142 | What are the recent disasters in this area? (fill out the year, type and damages occurred) | | | |
| 143 | Has this building damaged by the natural disaster? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | |
| | if yes, | | | |
| 144 | When and what type of disasters? | | | |
| 145 | Was the building ever been reconstructed/ retrofitted after damaged? | <input type="checkbox"/> Reconstructed | <input type="checkbox"/> Retrofitted | <input type="checkbox"/> Nothing |



300 Structural Components

| 310 | Foundation | | | | Comments |
|--------------|--|------------------------------|-----------------------------|----------------------------------|----------|
| 311 | Is there any foundation system beneath the building? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 312 | Does the foundation free from cracks? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 313 | Is the foundation fully covered with soil and fully supported by the soil? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 320 | Beams | | | | |
| 321 | Does the building have tie beams? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 322 | Does the building have ring beams? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 323 | Are all beams free from damage (cracking, splitting or spalling)? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 330 | Columns | | | | |
| 331 | Does the building have column in every 3 x 3 meter wall area? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 332 | Are all columns free from cracking, splitting or spalling? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 340 | Wall | | | | |
| 341 | Are the walls made from strong materials? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 342 | Are the walls made from light materials? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 343 | Are the walls free from cracks? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 344 | Have the block wall partitions been reinforced by any kind of techniques? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 345 | Do the parapets or cornices have adequate reinforcement? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 346 | Does the unreinforced masonry partition in stairwell have reinforcement? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 350 | Roof | | | | |
| 351 | Are the roof cover made from lightweight materials? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 352 | Is the roof cover properly connected/tied to the roof trusses? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| Total | | | | | |

400 Architectural Components

| 410 | Built-in Partitions | | | | Comments |
|-----|--|------------------------------|-----------------------------|----------------------------------|----------|
| 411 | Are partial-height partitions braced to the structure above the ceiling line? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 412 | If partitions function as lateral support for tall shelving or cabinets, are these partitions rigidly attached or braced to the structure above the ceiling line? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 420 | Ceilings | | | | |
| 421 | Are decorative ceiling panels and/or lattice work securely attached? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 430 | Doors and Windows Egress Routes | | | | |
| 431 | If exit doors are heavy metal fire doors that might stuck during an earthquake, is there a crowbar or sledgehammer located near the exit door to facilitate emergency exiting? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 432 | Are the doors opened outward? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 433 | Are all building utilities, furniture and architectural fixtures securely braced or installed to prevent falling along the egress route? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 434 | Are the windows and doors frames anchored to the column or wall? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 435 | Are the glazed partitions laterally braced to the structure? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 440 | Permanent Ornament | | | | |
| 441 | Are hanging appendages braced or secured with safety cables? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 442 | Are exterior light fixtures properly supported or securely attached to the structure? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |

| | | | | | |
|--------------|---|------------------------------|-----------------------------|----------------------------------|--|
| 443 | Are the flagpoles securely attached to the structure? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 444 | Are exterior billboards or signs adequately anchored? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 445 | Are interior signs securely attached? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 446 | Are the fences securely attached to the ground? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 447 | Are clay roof tiles properly secured to the roof? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 450 | Stairways | | | | |
| 451 | Does the handrail on the stairways adequately anchored/connected? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 460 | Floor and Floor Tiles | | | | |
| 461 | Does the floor have no crack? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 462 | Is the floor tiles intact (detached tile do not exist)? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| Total | | | | | |

500 Furniture and Contents

| 510 | Electrical Equipment (telephone, television, computer, lights, fan, etc) | | | | Comments |
|--------------|--|------------------------------|-----------------------------|----------------------------------|-----------------|
| 511 | Is important equipment restrained to keep it from sliding off shelving or tabletop? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 512 | Is telephone placed on desktops or counters far enough from the edge that it will not slide and fall down? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 513 | Are the sound system speakers in elevated locations anchored to the structure or hung with safety cables? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 514 | Are the computers and their equipments securely supported, anchored, tethered and/or braced? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 515 | Is computer information vital to office's operation periodically backed up? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 516 | Do hanging fixtures have safety cables to prevent them from impacting each other or window? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 517 | Are the hanging lights or objects securely installed? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 520 | Furniture | | | | |
| 521 | Are bookshelves, racks, and filing cabinets properly anchored to a solid wall or stud, or anchored to the floors? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 522 | Are the bookshelves, racks, and filing cabinets made from proper materials (do not deteriorate)? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 523 | Are bookshelves fitted with edge restraints or elastic cords to keep books from falling? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 524 | Are unanchored cabinets located properly so that they will not fall or slide and block an exit route? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 525 | Are breakable items secured to the shelves or racks, or are they stored in stable units? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 526 | Is the emergency supply cabinet placed in an accessible location that is not likely to be heavily damaged? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 527 | Are wheeled racks/objects blocked to prevent their rolling? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 528 | Are tables made of proper material, strong enough to resist the falling debris? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 529 | Do tables have rounded-shape at the edge to prevent from injury? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 530 | Pictures and Boards | | | | |
| 531 | Are the pictures or boards properly attached to the wall? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 532 | Are the pictures located in proper location that is less vulnerable? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 540 | Hazardous Materials | | | | |
| 541 | Are chemicals stored in accordance with manufacturers' recommendation? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 542 | Are chemical supplies secured with shelf lips of 8- 15 cm high, or are they stored in "egg crate" containers in drawers, so that the containers will not overturn or fall and spill? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 543 | Are the gas cylinders tightly secured? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| Total | | | | | |

600 Utilities and Surroundings

| 610 | Plumbing | | | | Comments |
|--------------|---|------------------------------|-----------------------------|----------------------------------|-----------------|
| 611 | Is the connection of the pumps strong enough to prevent damage when earthquake happening? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 612 | Is the pipeline located not on the evacuation route? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 613 | Are the distribution pumps anchored, or are they mounted on vibration isolation springs with additional seismic lateral restraints? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 614 | Are the pipes free of asbestos insulation, corrosion that could be damaged by movement in an earthquake? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 620 | Other Utilities | | | | |
| 621 | Is the fire extinguisher cabinet or hose cabinet securely mounted? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 622 | Is the fire extinguisher secured with quick-release straps? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 630 | Electrical Equipments | | | | |
| 631 | Are the cable conduits laterally braced? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 640 | Gas or Fuel Supply Pipe | | | | |
| 641 | Is the supply pipe laterally braced? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 642 | Do the pipes have flexible connections at the tank that can accommodate relative movements? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 650 | Surroundings | | | | |
| 651 | Is there any open field for evacuation place? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 652 | Is the evacuation route safe from falling objects? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| 653 | Have any dead/deceased tree limbs that could fall on the buildings been removed? | <input type="checkbox"/> Yes | <input type="checkbox"/> No | <input type="checkbox"/> Unknown | |
| Total | | | | | |

Conclusions:

1. Score for condition and planning assessment :
2. Number of "no" answer for architectural components assessment :
3. Number of "no" answer for utilities and surrounding assessment :
4. Number of "no" answer for furniture and contents assessment :
5. Number of "no" answer for structural components assessment :

Recommendation:

Comments:

Description of the Used of the Assessment Tools for Teacher and Community

In the assessment tools for teacher and community, there are 6 forms that should be filled by teacher or community. First form is general information of the school, second is condition and planning, third is structural components, fourth is architectural components, fifth is furniture and content and sixth is utilities and surroundings. In order to help the assessor relating structural elements assessment, a figure describing structural elements on general building is presented after the first form.

All of the forms, except the first (general information), have assessment score. Second form (condition and planning) uses a numerical number in scoring system and from the third until the sixth form, "yes" "no" checklist is used as the scoring system. Each score can independently affect the final recommendation. Following threshold criterion would assist the assessor or program person in concluding the recommendation.

- If the score for second form (condition and planning) exceeds 4, it is suggested that the building is need of further assessment.
- If the number of "no" answers in third form (structural components) exceeds 1, it is suggested that the building need further assessment.
- If the number of "no" answers in fourth form (architectural components) exceeds 7 (40% of 18 items), it is suggested that the building needs architectural repair.
- If the number of "no" answers in fifth form (furniture and content) exceeds 14 (70% of 21 items), it is suggested that the building needs furniture and content strengthening. Below the value of 15, the community or teacher can strengthen the furniture and content by themselves.
- If the number of "no" answers in sixth form (Utilities and surroundings) exceeds 4 (33.3% of 12 items), it is suggested that the building needs technical assistance in strengthening the utilities components.

All of the threshold presented at the previous paragraph could be abandoned, if, with the knowledge of the assessor, there are some critical items that must be repair/strengthening directly, even though the threshold has not been reached. In this case, please give detail comments including the attachment of the damage photograph (if available).

NB: in the assessment form, an "unknown" option is presented. It is suggested that when the "unknown" option is chosen, the assessor could give comment beside the choice.

Assessment Tool for Engineers

Inspection Information

Inspector :

Organization :

Inspection date :

Time :

Building Description

Name :

Address :

No. of Stories : above ground: below ground:

Approximate Age :

Approximate Area :

Structural System :

Building's Function :

Year of Construction :

Building Materials

Foundation : Concrete/ Stone/ Others ...

Tie beam : Concrete/ Steel/ Wood/ Others ...

Column : Concrete/ Steel/ Wood/ Bricks/ Others ...

Ring Beam : Concrete/ Steel/ Wood/ Others ...

Roof Trusses : Wood/ Light-Weight Steel/ Others

Roof Cover : Zinalume/ Roof Tile/ Others ...

Wall : Bricks/ Conblock/ Bamboo/ Others ...

Detailing/Connection : Reinforcement Bar/ Bolt/ Wire mesh/ others ...

Building Evaluation and Checklist

| Condition | | Hazardous Condition Description | | | Effect on Structural Performance | |
|-----------|---|---------------------------------|----|---|----------------------------------|----------|
| | | L | SS | S | Point | Comments |
| 1 | Overall Structure | | | | (a) | |
| 1.1 | Site Stability | | | | | |
| 1.2 | Gas/Fuel line threat | | | | | |
| 1.3 | Landslide threat | | | | | |
| 1.4 | Liquefactions | | | | | |
| 1.5 | Flood threat | | | | | |
| 1.6 | Plan Irregularity | | | | | |
| 1.7 | Vertical Irregularity | | | | | |
| 1.8 | Stiffness Irregularity | | | | | |
| 1.9 | Pounding Potential | | | | | |
| 1.10 | Other ... | | | | | |
| 2 | Existing of Structural Elements (including the sufficient amount of structural elements) | | | | (b) | |
| 2.1 | Foundation | | | | | |
| 2.2 | Tie beam | | | | | |
| 2.3 | Column | | | | | |
| 2.4 | Ring beam | | | | | |
| 2.5 | Roof trusses | | | | | |
| 2.6 | Bearing wall | | | | | |
| 2.7 | Bracing | | | | | |
| 2.8 | Other ... | | | | | |
| 3 | Dimensioning | | | | (c) | |
| 3.1 | Foundation | | | | | |
| 3.2 | Column | | | | | |
| 3.3 | Tie beam | | | | | |
| 3.4 | Ring beam | | | | | |
| 3.5 | Roof trusses | | | | | |
| 3.6 | Other ... | | | | | |
| 4 | Deflection | | | | (d) | |
| 4.1 | Column | | | | | |
| 4.2 | Beam | | | | | |
| 4.3 | Wall | | | | | |
| 4.4 | Roof system | | | | | |
| 4.5 | Other ... | | | | | |
| 5 | Quality of Materials | | | | (e) | |
| 5.1 | Concrete | | | | | |
| 5.2 | Steel Profile | | | | | |
| 5.3 | Reinforcement bars | | | | | |
| 5.4 | Wood | | | | | |
| 5.5 | Light trusses | | | | | |
| 5.6 | Bricks | | | | | |
| 5.7 | Roof cover | | | | | |
| 5.8 | Conblock | | | | | |
| 5.9 | Wiremesh | | | | | |
| 5.10 | Other ... | | | | | |
| 6 | Deterioration of Materials | | | | (f) | |
| 6.1 | Crack/Spall on Column | | | | | |
| 6.2 | Crack/Spall on Beam | | | | | |
| 6.3 | Crack/Spall on Wall | | | | | |
| 6.4 | Corrosion on reinforcement bars | | | | | |
| 6.5 | Corrosion on Steel Profile | | | | | |
| 6.6 | Wood | | | | | |
| 6.7 | Other ... | | | | | |

| | | | | | | |
|---|--|--|--|--|-----|--|
| 7 | Detailing | | | | (g) | |
| 7.1 | Tie beam- foundation anchorage | | | | | |
| 7.2 | Beam-column connection | | | | | |
| 7.3 | Roof trusses- beam connection | | | | | |
| 7.4 | Wall- column connection | | | | | |
| 7.5 | Roof trusses member connection | | | | | |
| 7.6 | Column-foundation connection | | | | | |
| 7.7 | Spacing of shear reinforcement | | | | | |
| 7.8 | Dimensions of longitudinal bars | | | | | |
| 7.9 | Dimensions of shear reinforcement | | | | | |
| 7.10 | Hook anchorages | | | | | |
| 7.11 | Development length | | | | | |
| 7.12 | Anchorage on both side of element covered with wire mesh | | | | | |
| 7.13 | Other ... | | | | | |
| 8 | Non- Structural Elements | | | | (h) | |
| 8.1 | Ornamentation | | | | | |
| 8.2 | Ceiling/light fixtures | | | | | |
| 8.3 | Partitions | | | | | |
| 8.4 | Stairs | | | | | |
| 8.5 | Pipe line | | | | | |
| 8.6 | Mechanical equipments | | | | | |
| 8.7 | Electrical equipments | | | | | |
| 8.8 | Other ... | | | | | |
| Total Point (a x b x c x d x e x f x g x h) x 100 = | | | | | | |

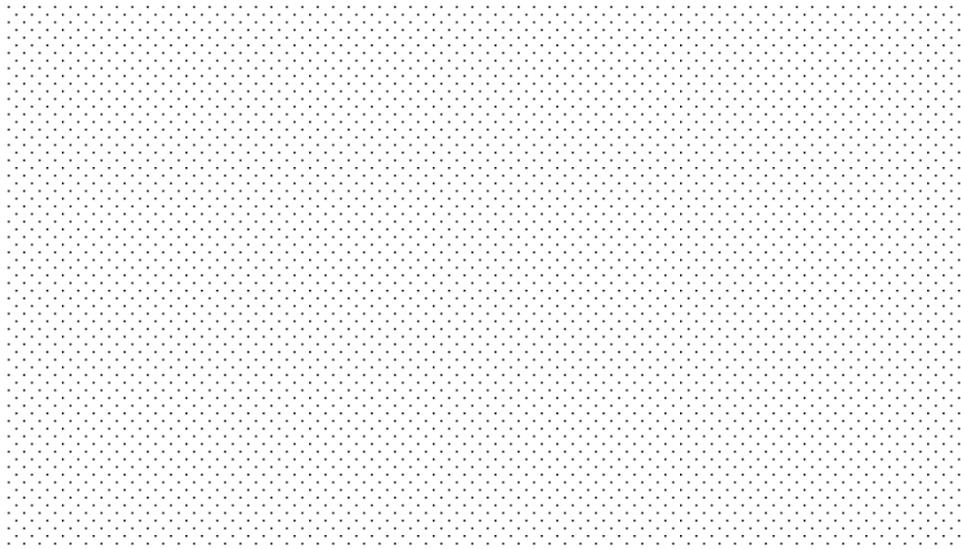
L = Light

SS = Slightly Severe

S = Severe

Point: ≤ 0.4 = Strongly Effected, 0.7 = significant, 1 = insignificant

Sketch:



Summary

Recommendations:

Comments:

Description of the Use of Assessment Tool for Engineers

The first page of the assessment tool contains the general information of the building. The general information considered consists of the information of the structural system, building's material, building's function, building's age, building's area, and number of story.

1. Structural system and building's material will give general description of the building load resisting element, either vertical or horizontal resisting elements.
2. Building's function, number of story and building's area will give general description of the approximate load apply to the building and the complexity.
3. Building's age will give general description on the building codes used on the design and possibilities of material deterioration.

In the second and third page of the assessment tool, there are eight (8) general criteria that will help the engineer to assess the vulnerability of the building. The eight general criteria is overall structural condition, existing of structural elements, dimensioning, deflection, quality of materials, deterioration of materials, detailing, and non-structural elements hazard.

Each criterion consists of some parameters that will help the engineer to assign the point for each criterion. Engineer should assess the condition of each parameters based on the existing condition of the structure. From the condition of each parameter, the engineer should able to judge the point assigned to the each criteria.

It should be noticed that when the engineers decide to assign the point equal to zero (0). It means that retrofit/ rebuild the building is technically strongly recommended, even in other criteria the engineer assign 1 for it. When the point is 1, it means that the building will fine.

After each criterion has the point, the engineer should multiply all the point from the criteria as total point and multiply it by 100. If the total point is 100, it means that the building is totally safe. If the total point is between 2.56– 100, it means that retrofitting is suggested. If the total point is between 0- 2.56, it means that rebuild/ retrofit is highly recommended.

100 = Safe

2.56-100 = retrofit the building

0 – 2.56 = rebuild/ retrofit the building (more than 50% of the building is strongly damaged).

After reviewing the total point, the engineer concludes the assessment in a recommendation whether to retrofit the building, rebuild the building, or do nothing. A sketch of the condition of important features found in the assessment could be drawn on the place available.

Assessment Tools for Program Person

Inspection Information

Name :

Date :

Building Information

Location :

Function :

Number of occupant/user :

Number of building :

Age of the building :

Latest repair/retrofit (year) :

| Impacts on Other Fields | | Yes | No | Comments |
|--|---|-----|----|----------|
| 1 | Does the building have historical values? | | | |
| 2 | Does the retrofitting entail social disruption? | | | |
| 3 | Does the damage on the building harm the surrounding community? | | | |
| Pre-Disaster and Post Disaster Function | | | | |
| 4 | Does the building contribute to community well-being/ public interest? | | | |
| 5 | Does the building act as temporary emergency shelter in post-disaster measures? | | | |
| Budgeting and Benefit | | | | |
| 6 | Does the budget available enough to carry out retrofitting techniques proposed? | | | |
| 7 | Does the budget available enough for regular maintenance? | | | |
| 8 | Does the retrofitting approach give more benefit compare to rebuild the building? | | | |

| Technical Consideration | | | | |
|--------------------------------|--|--|--|--|
| 9 | If the building has damaged, do the investigation and analysis result on acceptable level of risk? | | | |
| 10 | Does the retrofitting technique proposed applicable with the workmanship and resources available around the construction area? | | | |
| 11 | Is the building built based on recent building codes? | | | |

Comments:

Recommendation:

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