Effect of errors on execution and design of key details in the object

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ABSTRACT

Key details must be given major attention in design and execution of a building. Errors which may lead to increase of damage in case of an earthquake and additional loads, can be of different nature, especially those related to beam-column joints. There should be strict attention to details execution by the supervision engineer and contractor. The contractor and the supervisor should correct the design errors, if such exist. The execution in an improper way can have major consequences. The local ductility on the cross-section of vertical elements and their importance is vital for the building. The severity and extent of such damage shall be illustrated with some examples from a recent earthquake in Albania, as the lead author was invited by the state institutions of Albania to assess the degree of damage to school buildings. The paper shall discuss observed damage, possible causes in relation to design errors, as well as some solutions that may be employed for the renovation of damaged buildings.

Keywords: Concrete, earthquake, building, design, errors, responsibility

INTRODUCTION

During the visits in Albania in the assessment of the damage of the objects, we encountered some errors during the execution of the details. Working out the details of the structural elements correctly has a great value for the building. Conform implementation of the project and strict supervision will not only increase the sustainability to seismic impacts but also the age of the building. During the inspection we encountered destruction not only of old buildings but also of new ones. Therefore, the details of the joints between the columns and the beam, reinforced concrete walls and slabs, foundations, placement of seismic walls have a major role in the building and great care must be taken in execution. Care should be added especially for seismic areas starting from the first stages of design, preparation of the main project and execution, in the phase of construction and supervision of works. Errors encountered are of various natures. The damages are also of various kinds. In most cases the damages show the degree of the earthquake. However, the biggest damages are due to age, errors in the realization of details, lack of strict supervision and in certain cases even the design drafted not conform standards for areas with high seismicity. Improper execution of the details of the structural elements has a high cost for the building and the investor. The building will be damaged in duration even if we will not have additional impacts from the earthquake. In this paperwork I have presented some details which were not realized correctly and the alternative way of realization. In seismic areas particular importance has the analysis of local ductility of vertical elements. Checking the local ductility of vertical elements and meeting the condition according to EC8 will provide a security for the building in the resistance to additional seismic impacts. This increases the quality of construction, increases the bearing capacity and duration of the building. In this paperwork are presented the most serious damage that occurred by illustrating them with examples and photos from the field, the quality of damage and the possibility of repairing them or not. The value of the investment and the possibility of the building's duration to such earthquake or even higher. All this in compliance with European technical norms of construction such as Eurocodes (EC0-EC9) and local technical regulation. In this paperwork there are proposed ways of rectification of buildings to be vital and sustainable. Finally, we have the conclusion of this paperwork, which summarizes the opinion and the way of future research and opportunities to address field problems and construction of capital projects.

BUILDING AND DAMAGES DESCRIPTION

During the visit to Albania after the earthquake that occurred in November 2020, we encountered various damages to various objects. The facilities were built from the 1930s until recent years. The damage is mainly cracking of the plaster, which is mainly in accordance with the description in the European norms for this type of earthquake as in photo 1. The damages were also structural, especially in cases when the execution of the basic elements was not done adequately. We encountered non-compliance with the protective layer according to photo 2, failure to realize the detail of the reinforcement according to technical conditions, minimum dimensions of supporting columns photo – 6&8, improper positioning of seismic walls in accordance with the technical conditions in seismic areas or even without seismic walls. In the old buildings there were cracks in the plaster due to thick layers of plastering, displacement of bricks and damage to the bounding between them see photo 3. In the superstructures of the buildings there were cracks in the part which was superstructure or added. Now we will illustrate with pictures these defects according to the description above.


Photo 1 Photo 2


Photo 3 Photo 4

There were also cases of buildings built in 1990-2000 where the beam was supported on the wall and had no connecting strip, which moved it towards the longitudinal axis of the beam as in photo 5.


Photo 5


Photo 6

The damages were evident from the age and the absorption of moisture and as consequence there was the corrosion of the reinforcement as in picture 7. From the corrosion of the reinforcement, we have an increase in diameter which with the action of additional earthquake forces has led to the appearance of damages and cracks.


Photo 7


Photo 8

FAILURE ALONG CONSTRUCTION AND HOW MUST CONSTRUCT RIGHT

During the design, execution, supervision and maintenance of the project, errors are made. Errors are of different natures such as: instant errors, unnoticed errors or during design elaboration, errors from non-compliance with technical norms in the respective areas, errors from investor pressure, errors in execution due to negligence, errors due to ignorance, errors in the supervision phase, and errors also during the maintenance of the building.

During the inspections of objects damaged by the 6.4 magnitude earthquake in Albania we have encountered all these types of errors. We will now analyze some of the errors and the way they work properly.

Errors in the design phase

If we look carefully at the stagnation of the object in the design, we notice that we have negligence in respecting the regulations for areas with high seismicity repeated in the return period of 465 years. In most cases we have soft catheters which bring problems and errors in the reaction object to additional seismic impacts as in photos 2 & 6 & 8. We do not have a good setting of the object's inclination to its mass. The solutions encountered in fig.1 are unfavorable for seismic areas because they represent the soft floor. While in other floors we have filling the spaces between the columns and beams. Satisfactory solution is the presentation in figure 2, where the response to seismic loads is given by reinforced concrete walls. With this way of placing the walls we will meet an important seismic requirement by eliminating the soft floors that have posed a problem everywhere where we had earthquakes. of larger dimensions.

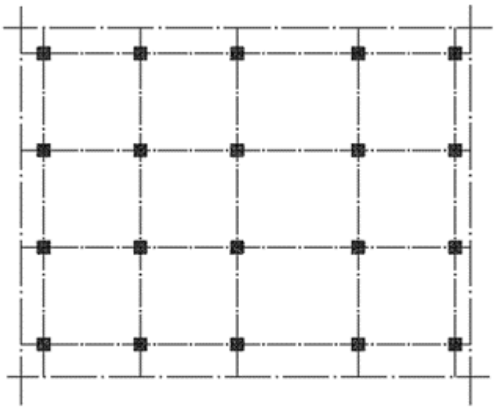
Figure .1 Not good solution, Soft floor

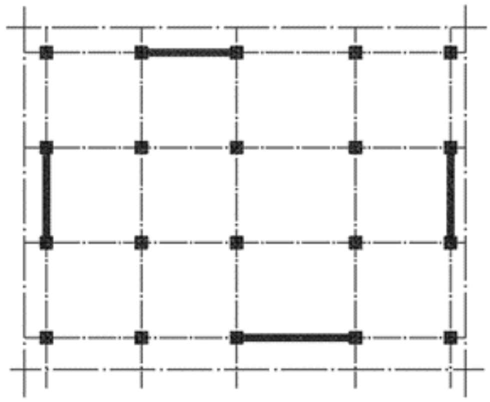
Figure. 2 Solutions that meets seismic requirements

Another error encountered in the design phase is presented in photo 5, where we have the support of the beam in the wall and it is not connected to a beam in the walls of the building. Here is its displacement from the support in the direction of the longitudinal axis of the beam. In seismic areas it is advisable to provide staggering beams to have a better connection of them. In figure 4 we will present one of the appropriate ways of execution, while figure 3 shows the way executed as in photo 5. The object is built in 1995 and it is not of a high floor to present such damages that it has gone into total collapse.

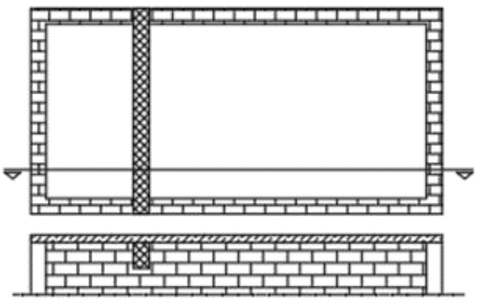
Figure 3. Executed way in photo 5

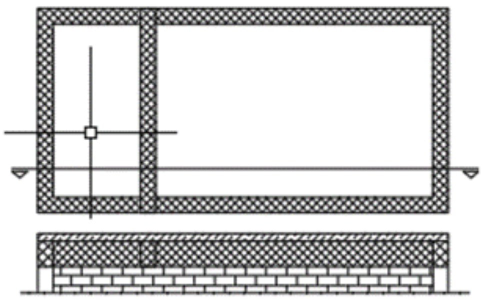
Figure 4. The way it should be executed

Errors in the Construction and Supervision Phase

Execution error not good according to the site view, we now have the connection between the column and the beam. In picture 9 below we present the error in realization, while in figure 5 will present the regular way of execution according to EC8. Resistance for bending forces and cross section forces according to rule 3a of EC8 we have: for primary seismic beams framing into exterior columns, the effective flange width is taken, in the absence of a transverse beam, as being equal to the width bc of the column (fig.5.b) or if, there is a transverse beam of similar depth equal to the width increased by 2hf on each side of the beam (figu.5.a) [1]

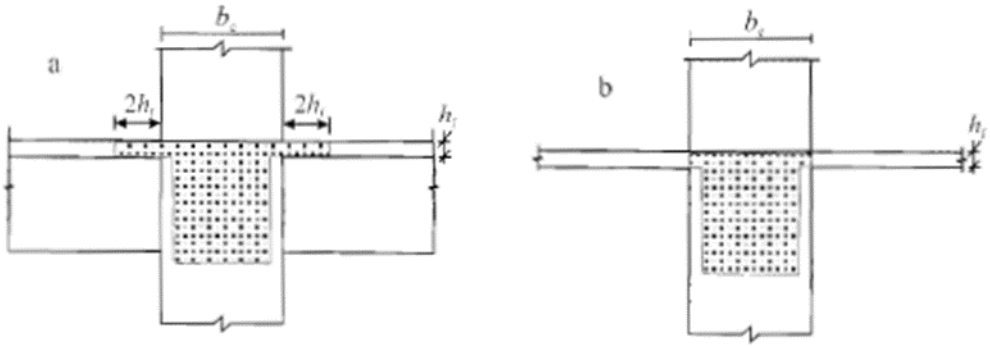

Figure.5 Effective flange width b_{eff} for beams framing into columns [1]

In figure 7 we present figuratively how the regular way of reinforcement for objects in seismic areas is. This detail satisfies the seismic requirements of reinforcement. In detail (fig.7.b) it is presented how reinforcement should be placed in the beam junction to meet the seismic requirements for buildings in areas with seismicity that should not be neglected by the designer and the contractor. In our inspections it was noticed the omission in reinforcement of beams and columns near the joint has not been respected the recommendation of EC8 that near the node to have a density of staff as in fig.7a. Therefore, designers must always take into account that in their deign must respect the technical conditions and norms for areas seismic and have a more rigorous supervision of the implementation of works on site.

The control of local ductility also plays an important role in the pillars, always taking into account the observance of the normalization coefficient of the axial force νd. The main condition is not to exceed the value of 0.65 by EC8 [1] which is expressed by the formula: ($\nu_d = N_{Ed} / A_c f_{cd}$).

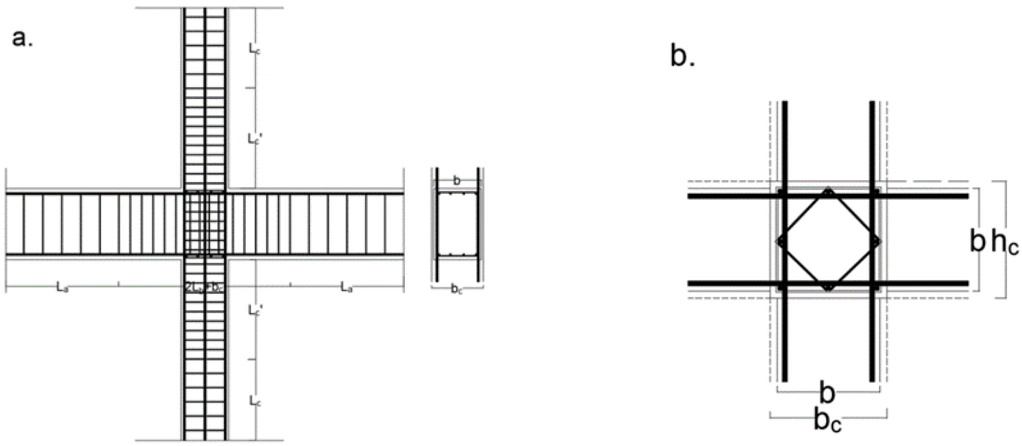

Figure 6 a. Outline of beam column connection armature, b. the detail of the connection of the column beam joint

Another error during the design, supervision or execution that we have encountered will be presented in photo 9. In this photo we have the error of connecting the stairs with the floor slab or beam. Such an error is often encountered in our projects but also in execution not according to the detail design which is a serious omission of the supervisor of works.

Photo 7. Wrong ladder support

Photo 8. Short element ladder support

In picture 10 we have the creation of the short element in the column which is a mistake when designing the stair support. Always in seismic areas we must eliminate such elements by creating stairwells for and walls to support the stairs in the area between floors.

In the figures below we will present a solution that satisfies the technical construction and seismic requirements. Figure 8 a schematically shows how the connection of the stairs to the area between floors is executed, which is totally wrong.

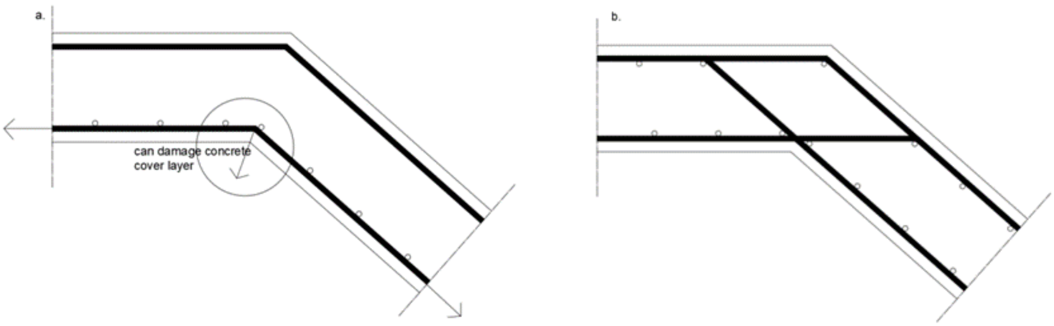

Figure 9. a. Wrong reinforced support, b. Right reinforcement support.

Figure 9 shows the possibilities of eliminating the short column element. The possibility to meet the best seismic requirements is the construction of the stair cage, which eliminates the possibility of collapse of the support. We have now presented the support of the stairs in the wall cage with reinforced concrete fig.9a, then we have, the support on the side walls again in reinforced concrete or retaining wall fig. 9b, which represents a satisfactory solution. Whereas in fig.9c is shown the support only in the front wall which is a better solution than the support in the columns that creates the short element.

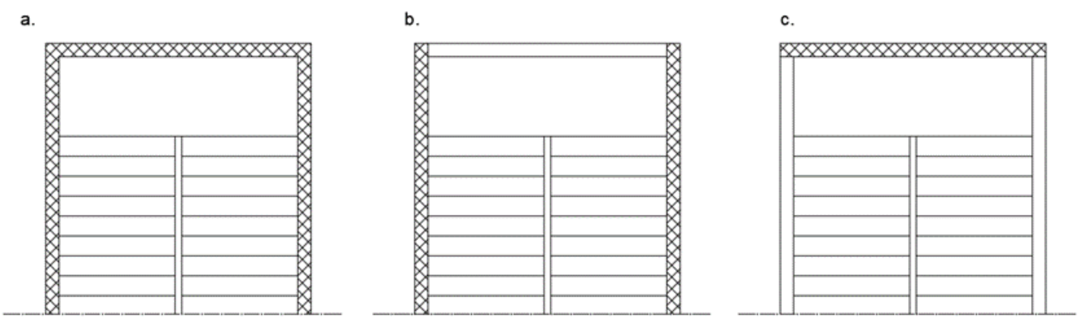

Figure 10. Ways of supporting the stairs by eliminating the support on the column

Following we will present the defects presented by the thick layer of plaster which is a problem in itself during the action of dynamic seismic impact. In photos 1 & 3 we have cracks which are due to adequate sampling of the plastering layer, exceeding the optimal layers without the use of reinforcement additives, such as reinforcement meshes, FRP or other connecting additives. Whereas in photo 4 we have cracks instead of continuing the superstructure. In this sequence the connection is not treated properly using materials which accept the eventual stretching forces from dynamic impacts.

REHABILITATION OF BUILDINGS

Before deciding on rehabilitation or renovation of damaged elements a commitment is first required to identify the damage and address the reasonableness of the rehabilitation or renovation. In every phase of the rehabilitation process acceptability criteria plays the decisional role, from the initial evaluation, to design process and quality assurance of the erection process. [2]. It follows that we have several stages of evaluation to come to the decision for rehabilitation of objects damaged by seismic or earthquake actions. The stages that must be followed in this process are: Strategy document, concept document and detail document. Each stage contains the activities that must be followed. Very important is the purpose of the performance of facilities in rehabilitation. A rehabilitation Objective consists of one or more rehabilitation goals, each goal consisting of the selection of a target Building Performance Level and Earthquake Hazard Level [3], see fig10.

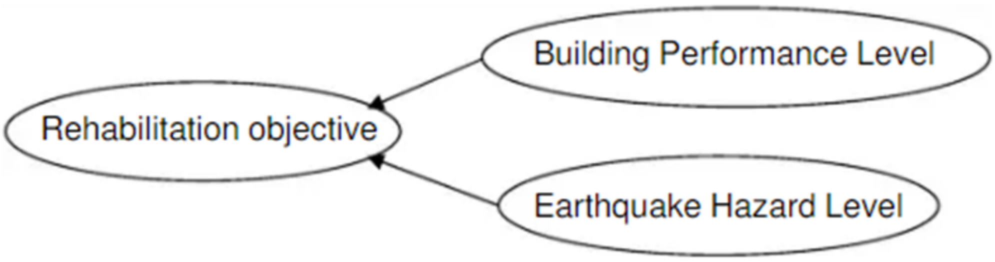

Figure 11. Establish Rehabilitation Objective Principles [3]

Ones that the performance level for structural and non-structural elements have been establish the designer could decide the target building performance level [2]. So, we must first determine the goals of the action and the level of rehabilitation and earthquake risk. Ones that the performance level for structural and non-structural elements have been establish the designer could decide the target building performance level [2].

Throughout our facility evaluation engagement, we need to have general analysis and facility modeling requirements. Due to the dynamic nature of seismic action, the structural model should adequately represent not only the distribution of stiffness, but also the distribution of mass with the structure [2]. During the course of evaluation, we need to take into account the stiffness, deformations and the level of current inelasticity, where their stiffness is based on the elastic module to the real values of force. Special attention should be addressed to joints between structural elements, which do not explicitly model when their stiffness differs significantly from the fully rigid or pinned assumptions, or when their strength is lower than one of the connected elements [4]. Therefore, during the evaluation phase impact of secondary effects has high impact and their stability after the action of the earthquake. When a structure is very flexible under lateral loads, a first-order analysis may underestimate substantially forces and deformation. [2] The stability check will be done using the formula for the stability coefficient θ_i.

If it passes the necessary verifications of the evaluation, then it goes to designing in stages to complete the detailed design, for the realization of rehabilitation.

Some of the ways of rehabilitation is using concrete, injection of cracks, use of rabic metal meshes, use of different polymers for wall reinforcement. In the case of the most severe damage to the columns, different hydraulics should be used to raise the facility to the previous level before deformation and start with repairs, always if it passes the evaluation test by the relevant engineer.

We will now give some examples of rectifications in following figures.

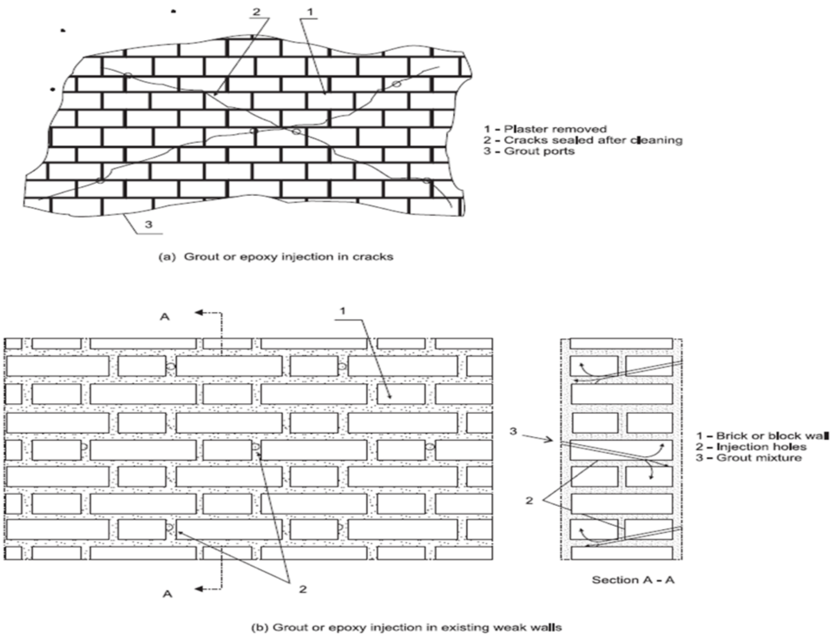

Figure 12. strengthening of existing masonry [5]

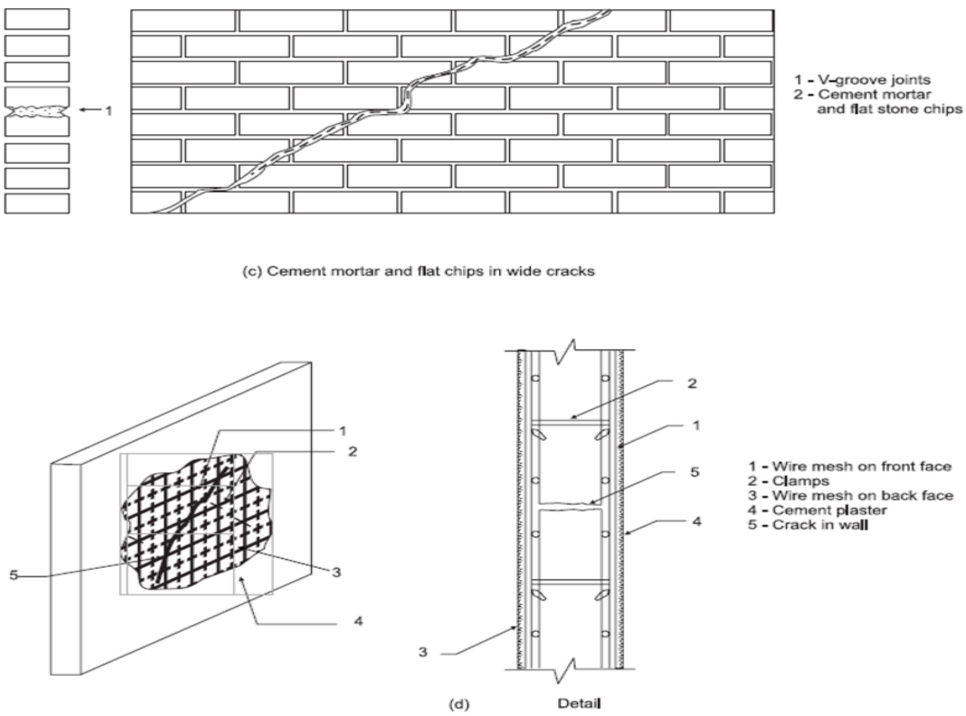

Figure 13. Strengthening of existing width crack masonry [5]

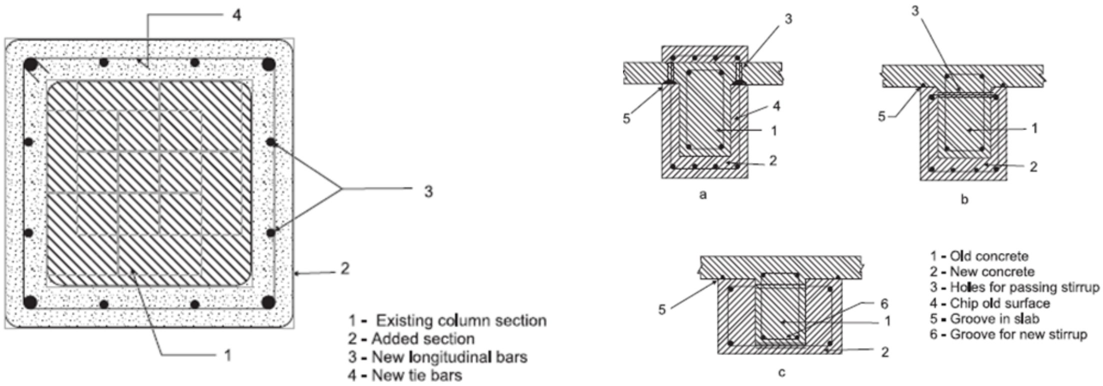

Figure 14. a) Jacketing a concrete column, b) Increasing the section and reinforcement of existing beams

CONCLUSION

Based on the findings from the field and the analysis of defects encountered in the field and the documentation presented, we conclude that the implementation and complying with technical norms for seismic areas would reduce the damage. Before starting renovations or demolition a proper analysis to determine a realistic assessment of the condition of buildings is needed. Damages caused are due to poor maintenance of concrete, inadequate realization of details of structural and non-structural elements. The use of seismic walls will reduce the risk of destruction in mass and the causes of the victims. A more rigorous control of the state institutions is required in the issuance of permits and on-site control for the realization of the objects.

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