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REPORT ON RETROFIT PROCEDURE OF SCHOOL BUILDINGS IN IRAN

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ABSTRACT

One of the most important undertakings of Iranian government in reducing the seismic vulnerability of the country against the earthquake is "Study and performing Retrofitting of the Important Buildings and Lifelines" which covers 7 structural groups and was enacted since 2003 in the form of possession of stock finances. The school buildings are one of the major structural groups in the aforementioned plan. In parallel, the preliminary guideline for structural retrofit was prepared in 2003. Besides the aforesaid guideline, 4 billion US dollars was granted by the Iranian Parliament according to 4th Development Plan in order to demolish and reconstruct the seismically dangerous schools and retrofitting the vulnerable ones. "State Organization of School Renovation, Development and Mobilization of Iran" is responsible for execution of seismic risk reduction plan in the educational buildings throughout the country. This report is a brief review of the national project and achievements for retrofitting school buildings in Iran.

ENACT OF THE DEMOLITION, RECONSTRUCTION AND RETROFITTING OF SCHOOLS LAW

Iran is located in one of the most seismically active regions and catastrophic earthquakes of every decade have left a lot of casualties and financial damages. This necessitates undertaking national plan in order to reduce the earthquake prone risk to as minimum as possible. It is obvious that in this plan, the more important buildings should receive more attention and priority. The importance of each building is determined based on some parameters like functionality, serviceability of the building after earthquake, and the possible human and financial losses. School buildings, are one of the most important buildings, because, they contain accumulated population and they have crucial role in post disaster management.

Based on code 2800 (Iranian code for seismic resistant design of buildings), school buildings are assigned to the category of the buildings with high importance which ranks second after the buildings with very high importance like nuclear facilities (BHRC-PN S 253, 2005). Regarding this importance, 4 billion US$ was granted by the Iranian Parliament in 2007 according to 4th

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Development Plan in order to demolish and reconstruct the seismically dangerous schools and retrofit the vulnerable ones. According to this law, 132000 classrooms should have been demolished and reconstructed and 126000 ones should have been retrofitted. It is noteworthy that the quality control of these projects was within International Institute of earthquake Engineering (IIEES) responsibilities. This state organization is responsible for execution of seismic risk reduction plan and the demolition and reconstruction plan (2007) in the educational buildings.

INTRODUCTION TO STATE ORGANIZATION OF SCHOOL RENOVATION, DEVELOPMENT AND MOBILIZATION OF IRAN

The establishment of this state organization which is one of the branches of Ministry of Education dates back to 1975 and this organization formally started its work in 1976. The responsibilities of this organization are construction, development, renovation and reconstruction of the school buildings and also providing them with facilities and equipment throughout the country. Fulfilling these responsibilities leads to similar details throughout the country and also classified architectural and structural plans in school buildings.

TECHNICAL CERTIFICATE OF SCHOOL BUILDINGS

In 2004 and based on a national plan, a comprehensive database about the structural specification of all school buildings was prepared. This database consisting of 74 items includes vast spectra of information e.g. the number of students to the situation of the foundation and the building facade. The most important items in this database are: the number of students and staffs, the geometrical and technical specification of the structure, the possible hazards to the building like earthquake or landslide.

For this project, more than 380000 classrooms in 100000 school buildings were analysed by the staff of the ministry of education. One of the most important outcomes of this database was classification of school buildings in the stability point of view in three categories: 135000 school buildings in demolition and reconstruction category, 126000 school buildings in vulnerable category which needed retrofitting and 139000 school buildings in resistant category. This evaluation provided the primary tools for scheduling the first 5 years of the project from 2006 to 2010. So, the technical certificate of schools buildings had a key role in enacting of the demolish, reconstruction and retrofitting law. Based on the experiences learned during 5 years of execution of this project, the technical certificate of school building has been revised and completed. The new certificate is better than the previous one in different aspects. The extension in the parameters for data gathering, the method for data gathering and data storing are of examples which have been modified in the new certificate.

SELECTION OF PROJECT AND COMPATIBLE STRATEGY FOR RETROFITTING

As previously stated, this organization deals with the problematic school buildings in two ways: demolition-reconstructing and retrofitting. Considering the differences between these two ways adds to the importance of proper selection and classification of the projects. Classification and prioritizing school buildings is the first stage in projects. This classification is divided into two phases: the first phase has something to do with the general policies related to all school buildings throughout the country. The second phase concerns with the decision making processes for each school buildings.

The main aim is to reach highest safety level with specific fund. The main question in this part is that "which school building should be demolished and reconstructed and which one should be retrofitted?" For answering this question, one should answer the questions below (Mahdizadeh, 2010):

1- How much is the price of the school building? (Combination of the structure's price, architecture preponderance and the facilities)

2- How much is the cost of retrofitting? (All the structural, architectural and facilities' implementations)

3- How much would be the expected life of the building after retrofit? (Architectural preponderance after retrofit)

Answering all these questions requires in-depth studies for 100000 school buildings. So at the beginning in 2004, studies were confined to rapid screening of school building. It classified all the school buildings in three structural types: satisfying, retrofit needed and demolition-reconstruction needed for general planning and budget estimation processes. In the next stage and during the retrofitting studies processes, each of the abovementioned questions was answered with an acceptable accuracy. Finally, it was decided whether a typical school building should be demolished-reconstructed or retrofitted. In 2010 and based on the experiences gained from previous projects, the technical certificate of school buildings was revised.

This time, besides the structural specifications of each building, a proper estimation about the architectural condition and the facilities of the school buildings were made in order to better answer the aforementioned questions. Accordingly, the classification of the school buildings has been modified. In the new classification, rapid screening forms have been used, and the school buildings were fallen into one of the seven types below:

- Satisfying schools: The schools which were designed based on the final version of seismic design code of Iran, and all of necessary specifications were considered. These schools were constructed after 2006.
- Buildings with low retrofitting preference: The buildings which were constructed based on previous versions of seismic design code of Iran from 2001 to 2006. Moreover, other buildings which were constructed out of this period, and were assigned to satisfying schools based on rapid screening forms were considered to this category.
- Partial rehabilitation schools: These school buildings have sufficient resistance against earthquake but have problems in slab integrity. A large number of school buildings with jack arch slab with low integrity are the main reason for considering this type of school buildings.
- Typical Retrofitting Pattern (TRP): Most Iranian single-story masonry buildings are assigned to this type. These buildings have similar deficiencies, so typical details and methods of retrofitting could increase their performance level to life safety.
- Demolition-reconstruction needed schools: The schools which retrofitting cost is more than 50% of demolition and reconstruction cost , buildings with low quality of architectural aspect, or located on developing areas that will need larger educational area in the future are considered in this category.
- Schools without sufficient price for spending money: Most Iranian schools in rural areas and population of these areas decreases over time.
- Complete retrofitting: Frame structural buildings without any lateral load-bearing system of or serious deficiency in this mechanism are considered in this category. These school buildings should be studied in details (screening evaluation, analysis report, retrofitting preliminary plan and final retrofitting plan). As it is obvious, this process takes a long time for finalization.

In the next step, preference of retrofitting among school buildings is determined based on seismic hazard, population of schools and development program of region.

QUALITATIVE EVALUATION OF THE SCHOOL BUILDINGS TO BE RETROFITTED

The number of classrooms which should be retrofitted is more than 126000. Most of these classrooms were constructed by a unique organization, and some similarities could be observed in these school buildings. An overview to the qualitative evaluation of these buildings could conduct the general strategy of retrofitting method or research funds.

Table 1. Qualitative evaluation of school buildings(Mahdizadeh, 2010)

Type of Structure	%	Type of Roof	%	Number of	%
Masonry	88.53	Jack arch	79.96	1 story	86.09
Steel	7.98	Wood	9.70	2 story	12.40
Concrete	2.00	Concrete	4.99	3&More	1.51
Other	1.49	Other	5.35		

ACTIONS CYCLING IN RETROFITTING PROJECTS

Procedure of complete retrofitting is a comprehensive method of evaluation that starts from project selection and covers all steps of study and finally enters to part of construction. Project management a large amount of these projects adds to the importance of accurate control. In this circulation, selection of retrofitting and geotechnical and material consultants is the next step after the project selection stage. Totally, qualitative report, geotechnical and materials testing, analysis report, preliminary retrofitting plan, final retrofitting plan are presented. All of this process is controlled by peer reviewer.

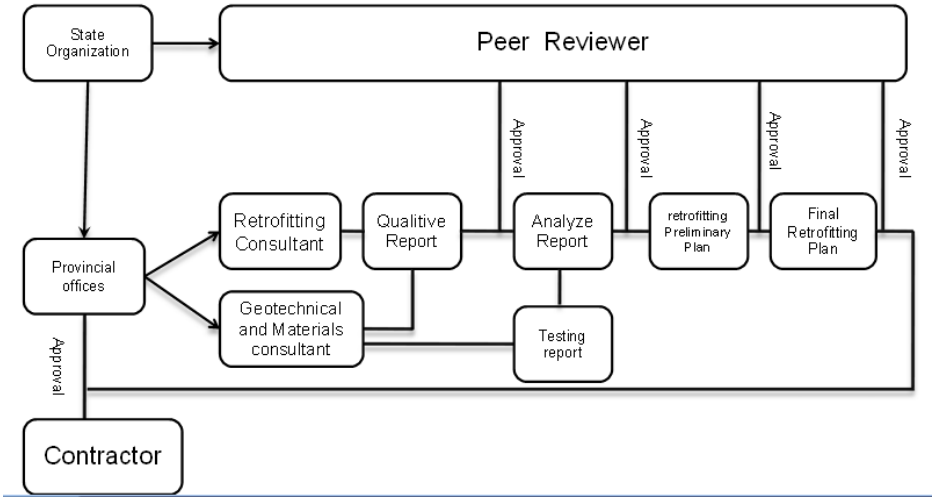


Figure 1. Schematic Representation of the Study Process of Retrofitting Projects

DEVELOPMENT OF NEW METHODS FOR RETROFITTING OF SCHOOL BUILDINGS IN IRAN; TYPICAL RETROFITTING PATTERN

The results of studies reveal that the retrofitting process in Iran is a very time-consuming and costly one. Covering all the stages in this process for structures with close details and specifications has been rarely experienced before in any countries. It was because this organization has been considered new methods and criteria for its retrofitting projects. In more than two years the different methods were studied and discussed. Various reports in this realm have been published and the results finally came in the form of new instructions about the new method for retrofitting of school buildings – Typical Retrofitting Pattern (TRP). The utilization of these new instructions was started in 2009 on limited number of school buildings and led to satisfactory results.

Typical retrofitting patterns increase performance level of buildings to assumed target level with specific methods; however, minor deficiencies exist after retrofitting by this strategy. Required time for seismic evaluation based on this strategy considerably decreases because the long-time preparing and verification are eliminated. This organization follows three following goals in development of these methods:

1-Reducing the studying time of retrofitting projects: since a lot of school buildings should have been retrofitted according to unique methods and because of the close structural details, passing all the steps in retrofitting procedure for each of them is not logical. Moreover, this will require much longer period of time to achieve our goals in retrofitting of all school buildings in 5 years.

2- Increasing the speed and quality of execution of projects: since implementation of these instructions leads to a unique retrofitting specifications and details, this will result in fast adaptation of the contractors with the executive methods and providing them with the equipment for a repetitive process.

3-Reducing the cost of retrofitting process: the total cost of the project greatly depends on the required time of the project, the speed of execution and the amount of necessary equipment of the contractors. So repetition of the projects details and equipment will result in considerable cost saving in the retrofitting projects.

There are four retrofitting methods developed by the organization: two of them were completed and utilized in 2010. From the two remaining, one of them is in the studying and research phase and the other which was not technically and economically justified was abandoned. The methods of this organization are as follows.

I. TYPICAL RETROFITTING BY SHEAR WALL PATTERN

In this method there are some design tables containing the capacity of the shear walls and the piles with known details of the reinforcements, concrete and soil. A typical engineer can simply calculate the base shear of the building and in doing so, can evaluate the required number and length of shear wall(s) for reaching the calculated base shear capacity. In the calculation of the number and length of shear wall(s), the load-bearing capacity of the masonry walls is neglected.

The roof of buildings which should be retrofitted is usually jack-arch which should be converted to composite concrete. Also specifications have been proposed for the connection of roof and walls which leads to improvement of the in-plane and out-of-plane wall performance. In this method, one meter of the upper height of walls is reinforced. This method was successfully implemented in some of school buildings in summer 2010.

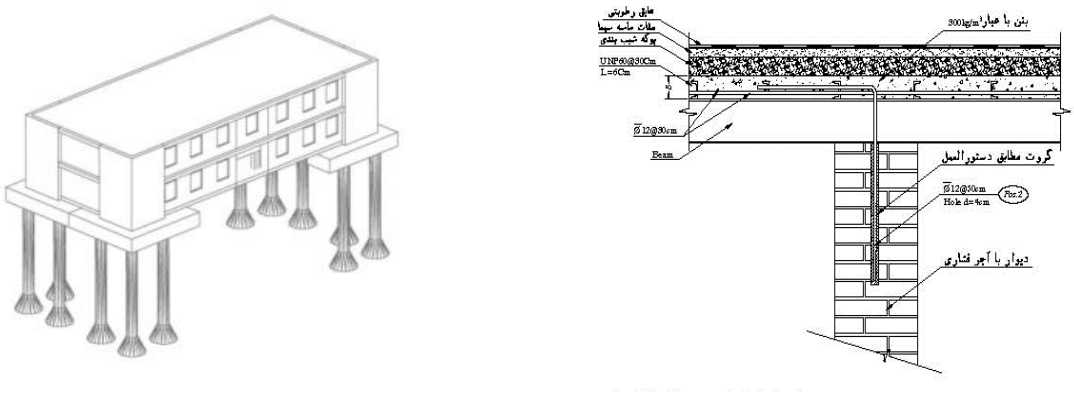


Figure 2. Schematic overview and detail of retrofitting by shear wall pattern

Figure 3. Samples of retrofitted school buildings with shear walls

II. TYPICAL RETROFITTING BY PERIPHERAL SHOTCRETE PATTERN

This method has been chosen based on the successful experiences from other countries and numerous experiments on masonry walls. In this method, the surrounding area of the single-story URM building is shotcreted. The size of rebar and the thickness of concrete are chosen in such a way that can fulfil the seismic demand of each building. In calculation of the base shear of buildings, the total weight of the structure plus the brick walls are considered and load-bearing capacity of the walls is neglected. The roof of the buildings in this class is usually jack-arch which should be converted to composite concrete. This method was also successfully implemented in some of school buildings in 2010. Figure 5 shows some samples of this project which have been executed in summer 2010(Borzouie & Mahdizadeh, 2012).

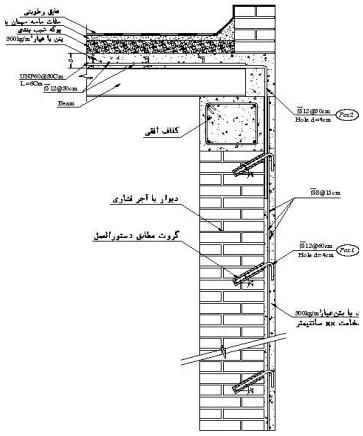


Figure 4. Samples of retrofitted school buildings with shear walls

Figure 5.Samples of retrofitted school buildings with peripheral shotcrete

III. TYPICAL RETROFITTING BY SAFE ROOM PATTERN

In this method, a steel frame is constructed for each classroom regardless of the capacity of the building, the variety of construction, structural and non-structural specifications. The aim of this method is to prevent falling of the debris on the students in the classrooms. The different parts of the steel frame is designed and manufactured in order to be assembled easily and fast (in the telescoping manner). In this way it can be guaranteed that the steel frame is tight inside the classroom. Of the advantages of this method is fast recycling of the retrofitting material in the case of demolish-reconstruction plan. However this method does not have enough chances to compete with other methods technically and economically and was not implemented vastly.

Figure 6. Schematic overview on retrofitting by safe room pattern

IV. Typical retrofitting by center core method

State Organization of School Renovation, Development and Mobilization of Iran has developed retrofitting techniques in the scope of increasing the accuracy and speed of study and execution of the projects. Also it has worked on the modern methods especially for the brick buildings with historical background. This issue seems important considering that ministry of education of Iran possesses a lot of school buildings with more than 70 years of age. Moreover, there are numerous historic brick buildings in Iran and retrofitting them by the conventional retrofitting techniques can endanger and intrude their historical value.

The center core method is one of the specialized retrofitting techniques for masonry buildings against earthquakes and was first implemented in U.S. in 1987 for retrofitting of some masonry buildings. The first step of this method is excavating vertical holes with specific diameter in the whole height of the wall and in determined distances. In the next step, the holes are filled with rebar and grout and this will result in improvement in seismic performance of masonry walls. Since in this method no apparent damage is posed to the architecture of the building and all the rehabilitation actions are outside the building, this method can be the best and the only solution for the buildings with historical importance and the buildings for which it is desired to maintain their service and functionality. In Iran, numerous historic masonry buildings which require stabilization against earthquake can provide good opportunities for this method to be vastly implemented (Mahdizadeh & Borzouie, 2012).

Figure 7. Alborz high school in Tehran with more than 120 years of age

General strategy for retrofitting

General performance of masonry buildings in previous earthquakes shows that although strength of walls was much higher than earthquake force, several cracks appeared on them. These cracks divide the masonry walls to major parts that oscillate independent from the masonry building. Most of damages in masonry buildings are rooted in lack of stability of these elements in masonry buildings. So, retrofitting process of masonry building can be divided into two main categories: The first step is to provide sufficient total strength of masonry building against earthquake shaking, and in the next step, stability of each element should be provided. The general methods for retrofitting of masonry buildings are combination of these two methods which has been implemented by this organization in recent years. The goals in the first step can be achieved by one of the aforementioned methods. Also the second step i.e. providing stability of structural elements is based on two concepts: First, providing general integrity of the building and second, predicting damage location, and providing the stability of the cracked walls. Consideration of these two concepts is important to propose retrofitting patterns. In some cases providing of sufficient strength of elements leads to meeting with these two concepts' requirements. In contrast, in other cases it may not happen. As a result, besides operations to provide strength in building, additional operations should be done to provide stability of elements. Figures 8 to 10 depict some examples of the implemented methods.

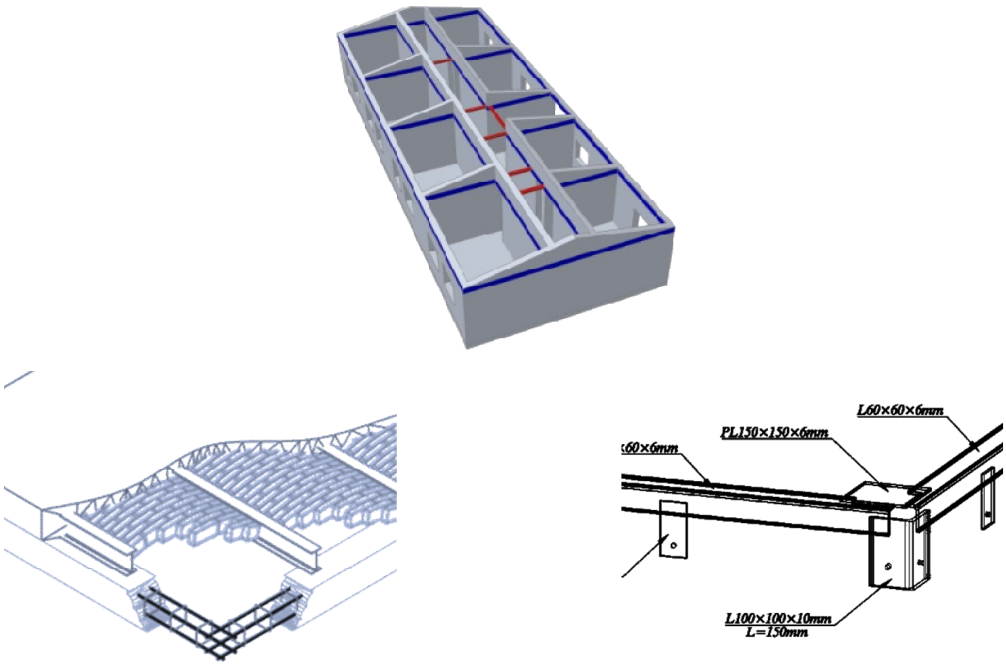
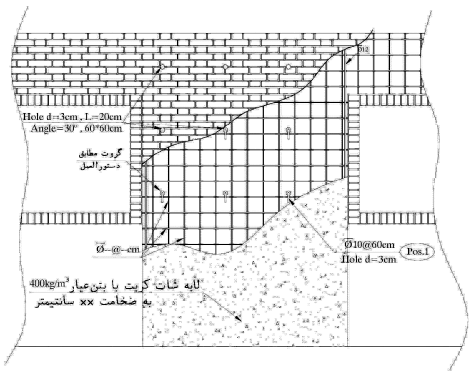


Figure 8. Providing integrity by using of steel members



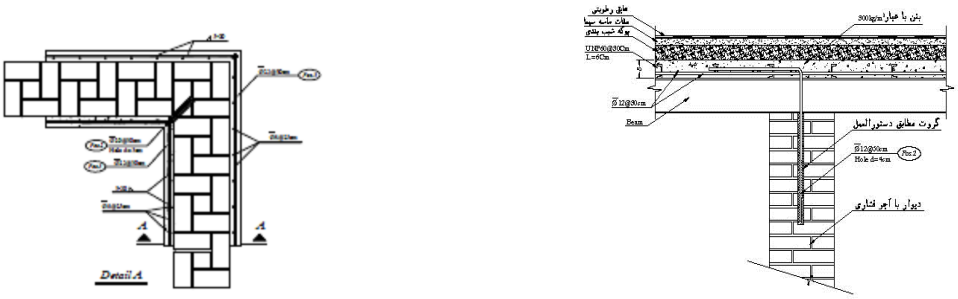


Figure 9. Current details for providing stability in masonry building

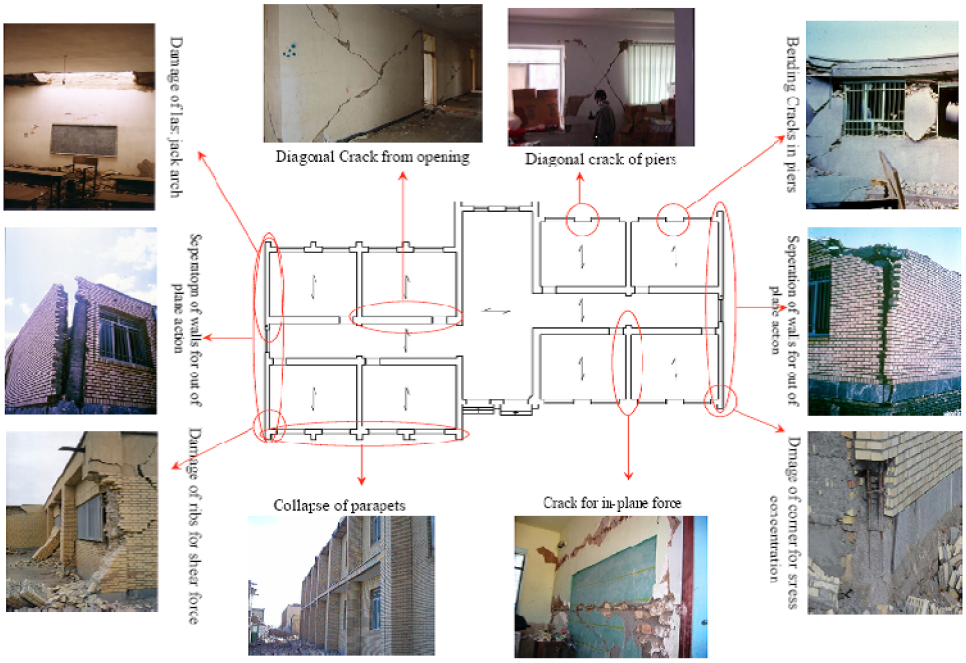


Figure10. Damages and cracks in masonry buildings (Yekrangnia & Mahdizadeh, 2009)

EFFECT OF RECENT STRATEGIES ON COST OF RETROFITTING PROJECTS

There are three approaches have been implemented in school retrofitting projects: Typical Retrofitting patterns (2010 up to now), modifying retrofitting patterns based on cost distribution and performance level of structural elements, correction of details. Fig.11 shows the variation of school retrofitting cost according to time in recent years. These data is presented based on analyses of 90 schools in different provinces of Iran. As can be seen, the average retrofitting cost was about 175US$ (per m^2) in 2008 and following from the new strategies resulted in reduction of 100US$ (per m^2). Furthermore, the variation of total costs in different projects has decreased by pursuing of these strategies. Accurate estimation of time and cost is the direct result of this reduction. Also the cost of each major part of retrofit and renovation projects in complete retrofitting-renovation projects and TRP's are compared in Fig.12 which shows considerable reduction in each part and also more allocation to structural part.

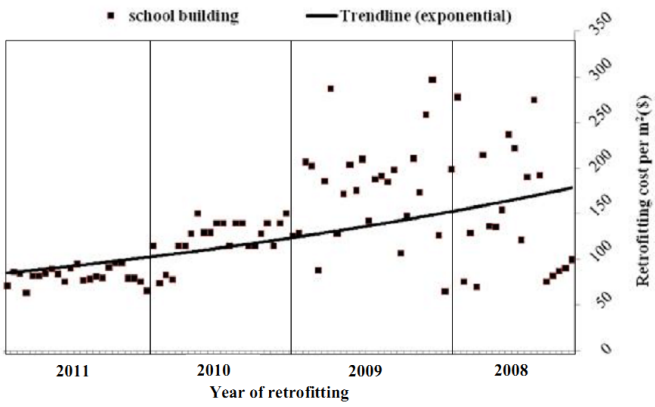


Figure 11. Variation of retrofitting cost of schools in recent years

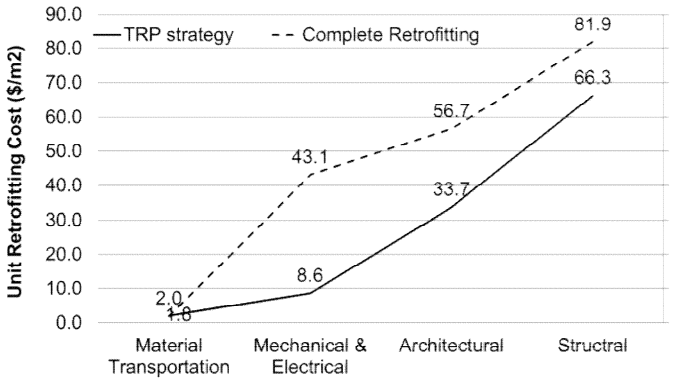


Figure 12. cost of each major part of retrofit and renovation projects

ACHIEVEMENTS OF THE DEMOLITION, RECONSTRUCTION AND RETROFITTING SCHOOLS LAW

An overview on achievement of last eight years is presented in this section. In figures 13 and 14, numbers of retrofitted and reconstructed classrooms and fund distribution from 2006 to 2010 are shown.

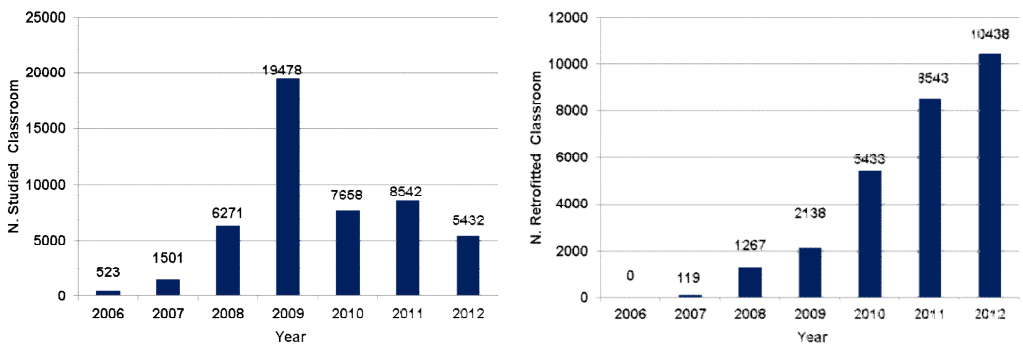


Figure 13. Number of studied and retrofitted classrooms from 2006 to 2012

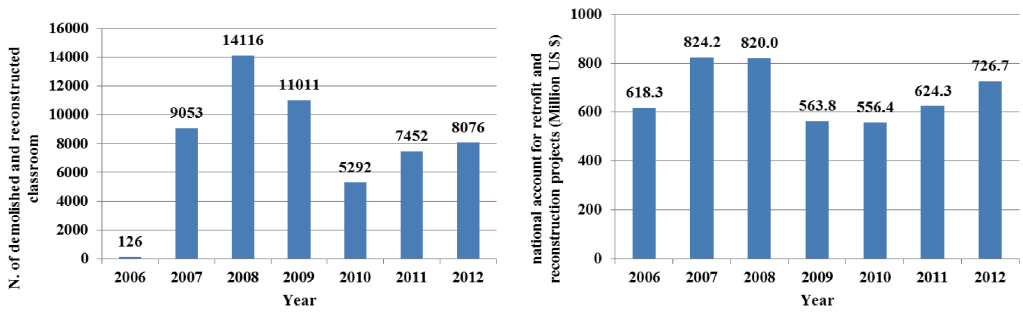


Figure 14. Number of demolished and reconstructed classrooms, the distribution of expenses from national accounts for demolition, reconstruction and retrofitting of school buildings from 2006 to 2012

According to the statistics, Iran has upgraded seismic safety of more than 28000 classrooms (equal to 1 million m^2) in the form of retrofitting and more than 55000 classrooms (equal to 6.5 million m^2) in the form demolition and reconstructing from 2005 to 2012. It is noteworthy than although the number of reconstructed classrooms is considerably higher than the retrofitted ones, the rate of retrofitting projects is increasing compared to the decreasing rate of the reconstruction projects.

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