# A Study on Safety of Reconstructed Regions after 1990 Rudbar-Manjil Earthquake in Iran

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## ABSTRACT

*Recovery and post-recovery stages are crucial parts of a risk management system to achieve several objectives: to return the affected area to pre-disaster stage after the catastrophe, to organize essential elements for the prevention of the next disaster, and to increase the capacity of the society. It is important to evaluate the functionality of this stage in any reconstruction program. This paper makes an effort to study the long-term results of reconstruction and recovery (recovery for short) efforts after 1990 Rudbar-Manjil Earthquake in Iran. It evaluates both the vulnerability of the existing buildings and, based on that, the region's safety. Two separated analyses have been used for the evaluation of buildings' vulnerability: 1) survey of random buildings, and 2) the regional analysis. The results indicate that two decades after the event, more than 80% of the existing buildings are still seismically vulnerable, which shows that recovery efforts has failed to improve the region's safety. In this investigation, to establish a safe development culture in future disasters, it is proposed to have a pre-designed recovery plan with the following strategies: 1) Maximum use of local construction technology and technique in the recovery stage; 2) Designing a comprehensive and steady educational program to teach the safe and new methods of reconstruction to local workers; 3) Creation and promotion of an effective system of supervision.*

**Keywords:**
Collapse Margin Ratio (CMR); Incremental Dynamic Analyses (IDA); RC Frames; Iranian Seismic Standard

## 1. Introduction

Recovery after a disaster is an important issue in seismic risk reduction programs though it had received little attention in the literatures. This stage, as mentioned by Godschalk [1] and MCDEM in Rotimi et al [2], is 'the coordinated efforts and processes to affect the immediate, medium and long-term holistic regeneration of community following a disaster'. Its importance in risk reduction and sustainable development (SD) has been acknowledged in a number of studies and recognized as a "unique time" to reduce and eliminate long-term risk in the region [3-4]. Hence, it is crucial to implement a good reconstruction program to create a safe community in the affected region.

The reconstruction and recovery (henceforth recovery for brevity) period start right after the catastrophe, continuing for several years. This procedure may provide a platform to put a community in the safe developmental path. Nevertheless, as many previous studies and experiences have shown, the communities do not return to the safe developmental path and just create another vulnerable community. Thus, it is crucial to study the previous restorations and identify the main reasons of their failures and successes.

Since the restorations take several years, the previous events should be studied in different periods after the disaster to capture all possible weaknesses. Most of the available studies are conducted right after disasters and during the reconstruction with limited studies being carried out a long time after the disaster itself in development stages. For this reason, it is important to conduct the research long after the disaster.

Iran is located in the very active seismic hazardous region. Several major earthquakes have caused much damage and human loss. It is significant to reconstruct and develop communities in a safe manner so that future losses might be reduced. In the first stage, it is crucial to study the short-and long-term results of previous experiences and modify possible shortages. For doing so it has been attempted in this study to explore the reconstruction and development processes, more than two decades after the 1990 Rudbar-Manjil earthquake in Iran. Since the earthquake has had significant impact on the traditional risk management system, the performance of the recovery in this earthquake is a major indicator of other disaster's restoration performance.

## 2. Review of Literature

Recovery is the major concern of officials and the residents of the affected region after a disaster. A few months after any disaster is the golden time for designing and implementing comprehensive, efficient, and sustainable recovery. Previous experiences have shown that due to absence of predesigned recovery programs and pressure from the public and politicians to start the recovery in a short time after disasters, an ideal plan is usually never devised [4-7]. Therefore, the recovery phase usually starts with inadequate or temporary strategy, leading to unstable situation or complications in the implementation.

Comfort et al [6] reported an unsuccessful recovery of Latin America's communities following hurricanes, where, due to incomprehensible decisions by the authorities and lack of thorough solutions for recovery, 'disasters move the community, a region, and a governmental system from temporary state to temporary state'. Jigyasu [7] reports a non-sustainable development case during the rebuilding of the Latur earthquake in 1993. Lack of proper supervision on strengthening and retrofitting of damaged buildings, it failed to transfer safe construction technology, making mistakes in the method of repairing and retrofitting buildings. The study demonstrated that: 1) a clear and fast method of retrofitting should be available to be implemented after disasters, and 2) the method and technology of safe construction should be transferred to the locales in a steady manner during the recovery stage. Hill and Gaillard [7] reported a successful result of reconstruction after 1931 earthquake in New Zealand. The key decision and strategies in this reconstruction was: 1) immediately started the reconstruction, 2) it was a balance between the continuity and change; and 3) it was based on "decentralized, integrative decision-making process".

It is also shown that having a pre-impact recovery and reconstruction plan could facilitate the reconstruction phase with more acceptable results [3, 8] and helps to evade temporary decisions, preventing a fragile situation. A well-planned reconstruction and recovery phase should be consisted of several elements outlined in the literature (see [9]). Based on UNOCHA adaptation, the post disaster management involves three phases [10]: emergency relief and interventions, short-term recovery and rehabilitation, and longer-term reconstruction. The main elements of the long-term safe development and risk reduction program can be applied in the last phase; it is composed of three stages [1, 11]: 1) structural engineering, 2) building codes standards, and 3) land use planning and property acquisition (i.e. set of regulation to determine how the construction should be conducted in the hazard prone areas). Wu and Lindell [3] organized the mitigation measures in three categories: 1) community protection works (e.g. dams, levees, and the protection of lands against hazards); 2) land-use practices; and 3) building construction practices (e.g. building design, construction, and building codes). In each of these stages, a well-known and well-defined action has been identified and described (see [12]).

Among these stages, conducting of the land-use and building construction practices deal with many stakeholders in the society. Hence, their implementations encounter difficulties and need a smart sort of planning as well as multi-disciplinary actions such as the selection of design/material/location, and integration of approaches [8]. For designing such plans for future catastrophes, it is needed to study the experience of past events.

Several studies have been conducted in the long-term effect of recovery strategies on communities, except the study by Hill and Gaillard [4], most of other studies focusing on the social and economic aspects of resettlements [11-12] and based on available information, no investigation has been conducted on the long-term housing and the safety of the built environment after the disaster that directly address the sustainability of reconstruction and the redevelopment stage of the risk reduction program.

## 3. Description of the Event and Studied Region

The earthquake is one of the major natural hazards in Iran. On average, one major seismic event will happen in every 10 years, causing a significant amount of damage and loss of life in the country. In recent years, several major earthquakes have hit different parts of Iran, each having an impact on the country's risk reduction system. The most influential one is Rudbar-Manjil. This M7.6 earthquake occurred on June 20, 1990 in the north west of Iran near the cities of Manjil and Rudbar and was sensed in most of northern parts of the country. It claimed more than 37000 lives and left more than 400000 people homeless [13]. More than 100000 buildings were destroyed or severely damaged. The earthquake caused damage in a vast area of three provinces of Iran: Gilan, Qazvin, and Zanjan. The affected zone is located in the Alborz region, north of Iran, between the Caspian Sea in the north and the Iranian plate in the south, which is a seismically active region, being located in the relatively high seismicity zone of Iran.

The quake caused damage to many residential, commercial, industrial structures and lifelines. Many major infrastructures experienced different degrees of damages such as: Sefid-roud dam, Loushan power plants, cement plants, etc. [14]. It is believed that this event was the first incident in the modern history of Iran to affect a major settlement [14]. The cities of Manjil and Rudbar were nearer to the epicenter and, thus, were destroyed completely. In addition, the most important cities in the northern part of Iran including Tehran, Rasht, Zanjan, and Qazvin suffered damages [13]. The isoseismal map of the affected regions is shown in Figure (1).

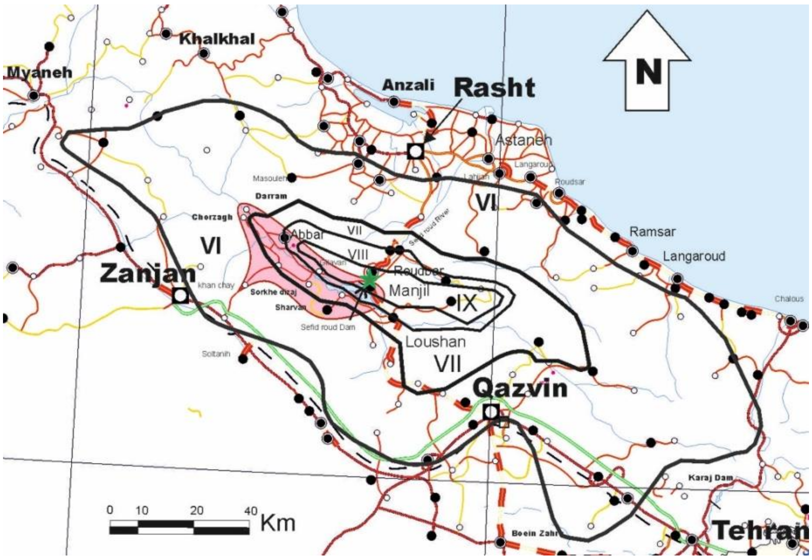



**Figure 1.** The isoseismal map of the 1990 Manjil-Roudbar Earthquake. The quake epicenter is shown in the map by a star mark. The study region which is located in the most affected area is indicated by the shaded area (reproduced based on Tavakoli and Ramzi [14]).

The structural types of buildings in the region prior to the event can be classified into two major classes: non-engineering and engineering. Those buildings that were not designed in accordance with the available engineering codes are categorized as non-engineering buildings. Wooden, non-reinforced masonry, adobe, and semi-steel (in this system, the gravity load is carried by a combination of simple steel structure in the center of building and non-reinforced masonry bearing walls located in the perimeter of the structure with no proper lateral load system existing) structures are non-engineering buildings. The confined masonry, steel, and concrete buildings, mostly designed based on practical codes, can be classified as engineering structures. Generally, engineering buildings behave far better than non-engineering ones [13], but due to the insufficient design and construction quality, they suffered significant structural and non-structural damages too. Since the first regulation of seismic building design was introduced a year prior to the incident, most of the buildings were not designed for the earthquake and were mostly non-engineering buildings, resulting in the vast devastation of the built environment.

The high vulnerability of buildings reveals a massive need for development in the field of earthquake engineering in Iran. This event marks the initial point of modern seismic risk management program by introducing modern building codes [15]. It led to the training of engineers and students along with the establishment of institutions to supervise the codes implementation in cities. Since then, substantial research, development, and implementation has started and, as a result, many changes in the design and construction of the buildings have been introduced nationwide. After two decades from the start of the program evolution, the time has come to evaluate the achievements and outcome of that development effort as an indication of the whole system's success during this period. Until now, many studies have been conducted in the field of prevention, preparedness, and emergency response stage of the program but little research has been conducted in the recovery and reconstruction ones.

The reconstruction effort in the region, which was the first major earthquake reconstruction project in Iran, started right after the earthquake and became the backbone of the reconstruction efforts since then. This process conducted in a systematic and controllable fashion. The reconstruction loan were given to the owner of the house gradually by improvement in reconstruction. For reconstruction of the houses, owners should hire the qualified workers and construct the building according to approval reconstruction type of houses. This period of development of the region called the "reconstruction period".

After this stage that takes around five years, many reconstruction and development has been conducted in the region. Development in this stage, which is called "development period", follows the general trend of construction and development in the country. In this stage, the seismic code was introduced and many structures are supposed to be designed and constructed based on that code. However, since the code was not fully implement and after the major damages in the 2003 Bam earthquake, another major turning point in Iran's risk management [15] was happened. After the Bam earthquake, a new edition of seismic code was introduced, and its enforcement became more serious.

## 4. Study Methodology of Evaluation of Safety of Region

In order to evaluate the sustainability and effectiveness of the recovery efforts after 1990 Rudbar-Manjil earthquake, it is required to evaluate the safety of a region after reconstruction. Hence, in this study, the safety of existing buildings in the most affected area is evaluated by quick survey of buildings. In which, random buildings of different taxonomies are selected and their vulnerability is examined by a simplified methodology. In addition, possible weaknesses of the buildings in the region in the design and constructions of buildings are identified and used for further conclusions.

The survey has been conducted in one of the reconstructed parts of the 1990 Rudbar-Manjil earthquake. The studied region is mostly located in the Tarom district of Zanjan province along with Manjil city in the Rudbar district of Gilan province. The general location of the area and the intensity of the earthquake are shown in Figure (1). As can be seen, the intensity in the studied region varies from VI to IX, indicating that weak structures were severely damaged in these areas. According to the available information, the region was fully reconstructed after the quake [13].

To select buildings for evaluation in villages and cities, each village was divided into two parts and each city into four. Based on the density of buildings in each region, several buildings have been selected randomly. Their vulnerability is evaluated by a simplified screening methodology of the FEMA-154 [16]. This method is fast and relatively accurate to evaluate numerous structures. In the methodology, the structural type is identified and, based on existing shortages on that the seismic vulnerability, is evaluated. In the methodology with the help of fill-out form, a basic score has been assumed to each type of structure and the score is modified in accordance with other parameters such as irregularity. The final score defines buildings' vulnerability level.

Given the fact that limited structural types have existed in the study area and fall into two main categories of engineering and non-engineering, the FEMA-154 methodology can be followed in a more simplified procedure as shown in Figure (2). The "base score" of non-engineering structures are lower than the acceptable level in the FEMA-154 methodology, which is expressed by "cutoff score" (see Table 1). Therefore, these buildings can be considered as "vulnerable". The engineering structures possess enough "base score" but may have other problems, making them vulnerable. This type of vulnerability cannot be identified in FEMA-154 methodology. Thus, they are considered for other phases of evaluation. In the first phase, the deficiencies in the general configuration of structures are examined (e.g. the integrity of the lateral load carrying system, irregularity, etc.) and those with no deficiencies are classified as safe. In the second phase, the structure with no serious deficiencies is categorized as weak, the rest are considered as vulnerable. Serious deficiency can be described as: 1) missing the element or discontinuity in the lateral load system, 2) obvious mistakes in design and detailing, and 3) missing vertical ties in confined masonry buildings. A weak building in this study is a building, categorized as safe in FEMA-154, but due to some minor errors, incapable of being identified by the methodology, cannot be considered as an absolutely safe building. The results of vulnerability evaluation are shown in the following section.

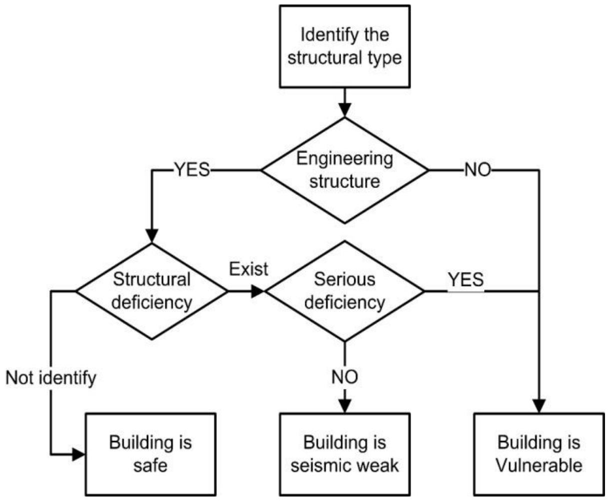


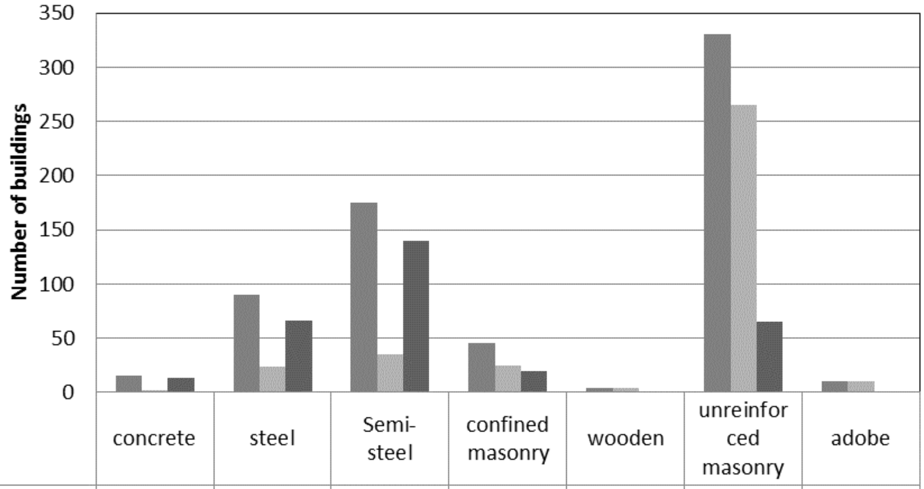

**Figure 2.** The flowchart of simplified seismic evaluation methodology, modified according to FEMA-154 [16].

**Table 1.** The "base score" of non-engineering buildings in FEMA-154 methodology (2003). The "cutoff score" that is an acceptable score for safe buildings is 2 for these structures.

| Building Type | Base Score | Vulnerability Level in This Study |
|---|---|---|
| URM | 1.8 | Vulnerable |
| C3 (URM Infill) | 1.6 | Vulnerable |
| S5 (URM Infill) | 2 | Weak-vulnerable. |

## 5. Results

A total number of 669 houses (304 in cities and 365 in villages) were surveyed in the region, comprising several structural types shown in Figure (3). The most observed forms of structures were:




| | concrete | steel | Semi-steel | confined masonry | wooden | unreinforced masonry | adobe |
|---|---|---|---|---|---|---|---|
| city | 13 | 66 | 140 | 20 | 0 | 65 | 0 |
| villages | 2 | 24 | 35 | 25 | 4 | 265 | 10 |
| sum | 15 | 90 | 175 | 45 | 4 | 330 | 10 |

**Figure 3.** Number of observed buildings in the survey and their classifications based on their locations and structural taxonomies.

unreinforced masonry, semi-steel, and steel. This figure varies between the villages and cities. Dominating types were unreinforced masonry and semi-steel in the villages and cities respectively, whereas the least structural types were adobe and wooden, abandoned after the earthquake. Generally, more than 84% of houses can be considered as non-engineering structures.

Buildings' vulnerability was assessed by the simplified screening method (see Figure 2). The results from this inspection are presented in Figure (4). Results show that in total, more than 80% of observed buildings are vulnerable to an earthquake similar to 1990 Rudbar-Manjil, which is almost comparable to 84% percentage of non-engineering buildings in the region shown in Figure (3). The figure is higher in villages, about 83%, and about 75% in cities. This level of vulnerability suggests that the recovery after the event do not provide an acceptable safety level for the region and the development is not sustainable. It means that, again, significant losses are expected in any future earthquake.

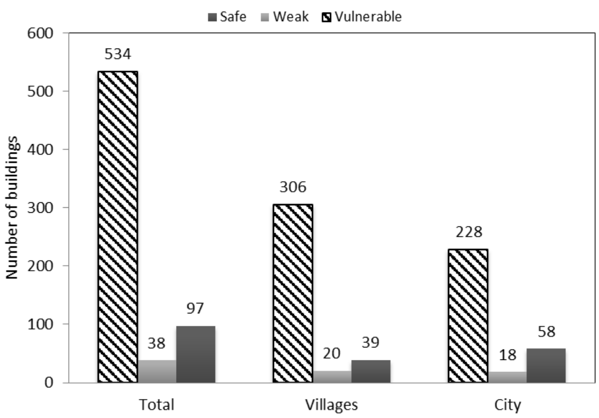



**Figure 4.** Number of safe, weak and vulnerable buildings, observed in survey method in cities and villages.

It seems a systematic failure in the recovery has occurred and several parameters may have contributed to the situation, needing to be identified. The existing structures in the study region are built during two decades of development through evolution of the risk management system in Iran. During this progress, several changes have been introduced in the design and construction, directly affecting the buildings' vulnerability. The main changes can be classified by the time of construction and divided into three periods: 1) before the earthquake, 2) reconstruction period, and 3) development period. The "before the earthquake" period related to those buildings survived after the quake and may not be rebuilt. The ratio of buildings in this period is very low. The "reconstruction period" and "development period" are defined previously.

The ratio of buildings in each time zone is shown in Figure (5). According to the figure, it can

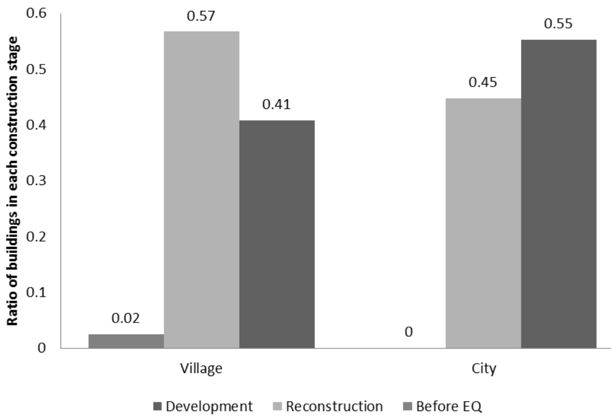
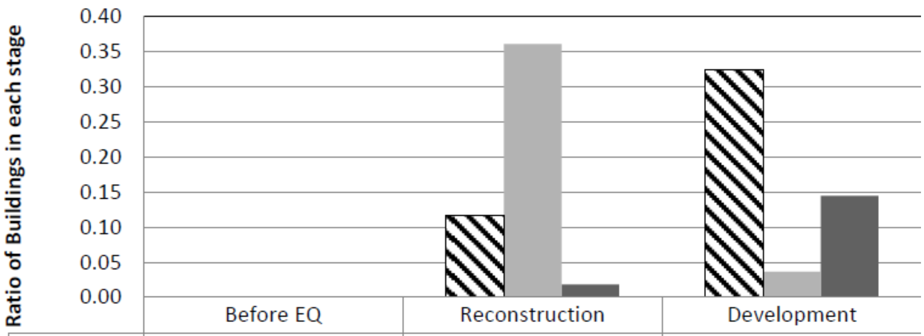



**Figure 5.** Ratio of observed buildings in different construction periods in cities and villages.

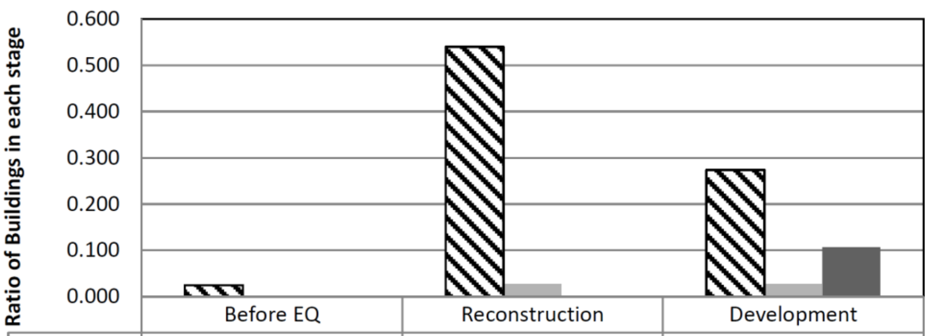
be concluded that half of the observed buildings are constructed during the recent years and most of the new buildings are located in the cities. Figure (6) shows the ratio of vulnerable buildings in different construction periods. It is shown that almost all of the buildings were built during "reconstruction period" and most of them, which are built in the "development period", are vulnerable. In addition, it can be observed that safety of recent houses has been increased, but still the ratio of vulnerability is quite high. This indicates that the culture of safe construction has not been implemented in the region.

The buildings' classification is presented in Figure (7), which considers steel and concrete buildings as engineering buildings and all the rest (shown in Figure 7) as non-engineering. It can be noted that almost all of the buildings constructed during the reconstruction period and more than half of them, built during "development period", in cities and villages were non-engineering. Since all of the non-engineering buildings are vulnerable, building them in seismic regions is not acceptable in the code. This demonstrates none or poor code enforcement.




| | Before EQ | Reconstruction | Development |
|---|---|---|---|
| safe | 0.00 | 0.02 | 0.14 |
| weak | 0.00 | 0.36 | 0.04 |
| vulnerable | 0.00 | 0.12 | 0.32 |

(a) In Cities



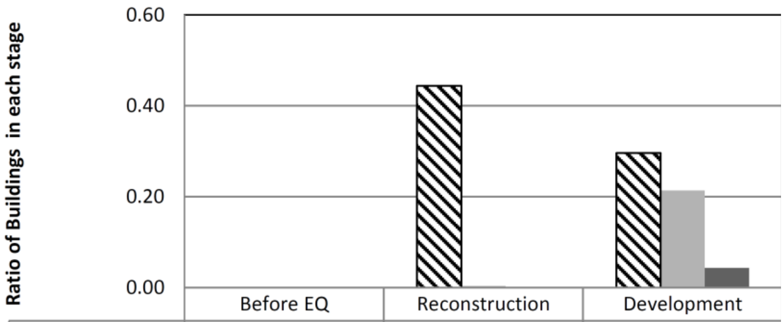

| | Before EQ | Reconstruction | Development |
|---|---|---|---|
| safe | 0.000 | 0.000 | 0.107 |
| weak | 0.000 | 0.027 | 0.027 |
| vulnerable | 0.025 | 0.540 | 0.274 |

(b) In Villages

**Figure 6.** Ratio of observed buildings' vulnerability in different construction periods.

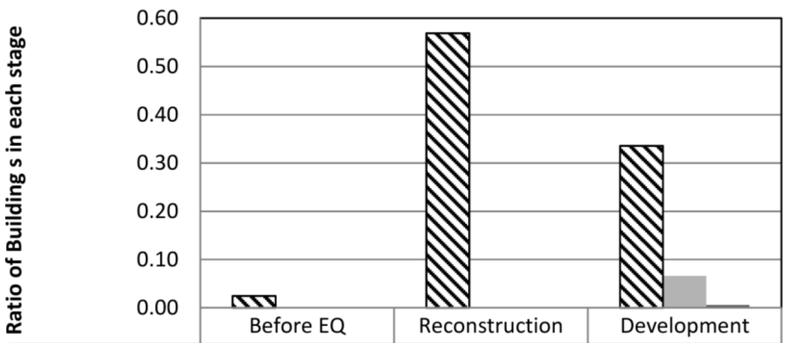
Some of sample observed structures are studied in detail to demonstrate main problems. In Figure (8), four samples in the rural areas have been shown. Samples "a" and "b" are typical structures in the "reconstruction period", and samples "c" and "d" are typical structures in the "development period". "a" is a vulnerable unreinforced masonry house with wooden roof without any proper lateral resistant system and a vulnerable adobe annex (such annexes are common in the region) which constructed without any permission and/or supervision in the "reconstruction period". "b" shows a school with structural system of unreinforced masonry with horizontal tie in the roof level. The structural system was acceptable in the time of construction, but according to the current code of practice, it is classified as weak because of the lack of vertical ties. "c" demonstrate a vulnerable unreinforced masonry brick structure without any appropriate lateral load resistant system. While it is constructed in recent years, it did not receive acceptable engineering supervision. "d" is a new building categorized as safe because it is built according to the latest code.

Examples of buildings in urban areas are shown in Figure (9). "a" and "b" are built during the "reconstruction period", and "c" and "d" are built in the "development period". "a" presents a vulnerable steel structure without any proper lateral resistant system. "b" shows a confined masonry structure constructed according to the code of practice for seismic design of its time. Since most of the regulations for this type of the construction still exist in the code, this building can be considered as safe. "c" is a vulnerable steel structure with significant mistakes: 1) missing bracing in the second floor and 2) significant irregularity in brace location in the first floor. "d" illustrates a typical steel structure with bracing with minimum seismic resistant requirement. It is classified as safe.




| | Before EQ | Reconstruction | Development |
|---|---|---|---|
| Concrete | 0.00 | 0.00 | 0.04 |
| Steel | 0.00 | 0.00 | 0.21 |
| non-engineering | 0.00 | 0.44 | 0.30 |

(a)




| | Before EQ | Reconstruction | Development |
|---|---|---|---|
| Concrete | 0.00 | 0.00 | 0.01 |
| Steel | 0.00 | 0.00 | 0.07 |
| non-engineering | 0.02 | 0.57 | 0.34 |

(b)

**Figure 7**. Ratio of observed building taxonomies in different construction period: a) in cities, b) in villages. Steel and concrete buildings are considered engineering buildings and all other building materials are considered as non-engineering and vulnerable.

(a)

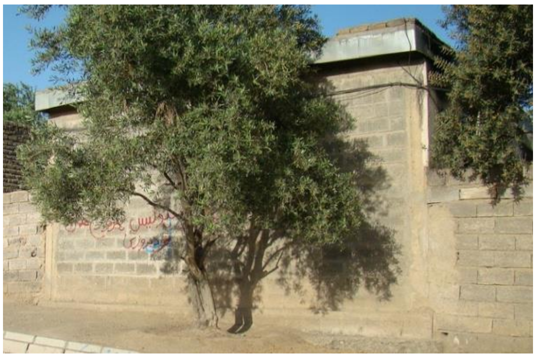
(b)

(c)

(d)

**Figure 8.** Sample of observed buildings in villages in different construction period. a) Unreinforced masonry building with wooden roof without proper lateral resistant system and an adobe annex; considered as vulnerable and constructed in reconstruction period. b) An unreinforced masonry school with horizontal ties in the roof level and missing vertical ties; constructed in reconstruction period and considered as weak, c) An unreinforced masonry brick structure without any appropriate lateral load resistant system; constructed in development period and considered as vulnerable. d) An engineering structure with proper design and construction. Considered as safe building and constructed in development period.

(a)



(b)

(c)

(d)

**Figure 9.** Sample of observed buildings in cities in different construction period. a) A vulnerable steel structure without any proper lateral resistant system; Constructed in reconstruction period, considered as vulnerable structure. b) Confined masonry structure with proper vertical and horizontal ties; Constructed in reconstruction period, considered as a safe structure. c) A steel structure with lack of bracing in second floor and vertical irregularity; constructed in developing period and considered as vulnerable. d) A well-constructed steel structure built in developing stage, considered as safe.

(a) (b) (c) (d)

**Figure 10.** Samples of mistakes in the new and vulnerable constructions: a) An under-construction four-story steel braced structure is shown. The braces did not connect to the first floor so the first floor does not have the lateral load system (shown by arrow in the figure). b) A two-story confined masonry under-construction structure is shown. Inadequate anchorage length of reinforcement in vertical ties has been observed. This create weak joint in ties and cause damages in an earthquake. c) A two-story steel structure has shown. The gusset plate for braces installed in the columns (shown by circle), but no brace was installed for this building. d) A two-story braced steel structure has shown. The missing braces in the first floor is observed.

As it is shown in Figure (7), the majority of new buildings are vulnerable because serious errors in the design and/or construction exist. Four samples of such structures have been shown in Figure (10). These mistakes are just taken from some of the most obvious cases and many more detailed shortcomings has been observed that cannot be covered here.

## 6. Discussion

In this study, the safety of recovery after 1990 Rudbar-Manjil earthquake has been studied through evaluation of vulnerability of the affected region by conducting surveys and analyses of overall structures in the area. Results show that the region is not safe for future moderate to high intensity earthquakes. More than 80 percent of existing buildings in the region, built in the recovery period, are seismically vulnerable. This vulnerability ratio in the villages is still higher. As a result, although the region affected by an earthquake more than two decades ago, is fully reconstructed afterwards in the modern, it is not safe and still vulnerable to an earthquake with same intensity, showing a poor performance of risk management system. An investigation has been conducted to identify the main cause behind this situation.

The vulnerability of the buildings, built in all periods since the earthquake including the reconstruction stage and the development stage following it, has been observed. Several reasons have been identified for each stage. The main sources of vulnerability of buildings in "reconstruction period" are lack of proper design and constructing buildings due to the insufficient knowledge of safe resistant construction. Since the seismic code just enforced a year before the quake, engineers and technicians did not have enough time to be trained and practice according to the code. In addition, due to the large dimension of devastation and high demand for reconstruction, there was not enough time to train sufficient numbers of engineers and technicians for this purpose. This was intensified by the method that the recovery effort was organized, wherein the government paid the loan and financial aids directly to the building owners to rebuild their own buildings mostly without proper technical supervision. They usually preferred to follow their traditional construction type (the unreinforced masonry), more familiar to them. In addition, the reconstructed buildings did not provide enough space to satisfy the locals' need, hence they often added more rooms to the existing buildings, which were built in such a vulnerable method as mentioned above (see annex in Figure (2a)).

The main explanation for the vulnerability of buildings built in the "development period" is basic mistakes in the design and buildings' construction. This is directly related to a lack of well-trained local engineers as well as limited number of qualified workers to apply the new construction technology. In other words, two decades after the introduction of design code, training of engineers, and different code enforcement organizations, a good construction practice does not exist in the region. This is a proof for poor organized system in the region.

In general, the recreation of vulnerable region stems from two major reasons: First, the recommended method of safe rebuilding (modern steel and concrete structure) was far from traditional techniques of construction, leading into a deep technological gap that needs significant time and energy to be filled. In the traditional practice, people tend to build their houses in a very simple and affordable manner by using local materials such as wood, stone or adobe. In contrast, the new constructions need new materials and modern techniques that in turn require different skill, not existing in the region prior to recovery. On the other hand, from the financial point of view, the recommended method was more expensive and people normally could not afford it. This led to a situation where people preferred to go back to their old habit of constructing buildings (see a high percentage of new non-engineering buildings in Figure 10) or use the new methods with considerable errors. The main reason behind these errors is either the lack of knowledge for correct implementation or needs to reduce the cost. To overcome the problem in the future, it is required to either design a safe building by minimum change in the contemporary methods of construction or develop a steady program to teach the new method of construction to the local engineers and workers, which calls for massive research and development in this field.

The second reason, intensifying the first one, is lack of proper code enforcement in the region. The code enforcement in the cities is conducted by municipalities. In villages, no defined institution exists for doing so. Some few houses in villages that use governmental loans are forced to be built under supervision. Yet, from the present mistakes in the construction of new buildings, it can be concluded that these supervisions have not been effective. The same trend can also be observed in different regions of the country, indicating that a good system of supervision does not receive enough attention nationwide. More study and works should be conducted in this field to improve the code enforcement.

The presented case is an unsafe development after disasters, which demonstrates an ineffective reconstruction practice, adding new findings to the existing literature. Although similar cases have been reported previously for short time development by Alexander [5], Comfort et al [6], and Rotimi [2], the results of this study demonstrate the long-term effect of miss-managed recovery plan has not been reported in the literature. It is shown that the lack of proper planning for future developments after the disaster, push the region to a vulnerable state that can exist as far as 20 years after the implementations. This highlights the significance of having a well-defined recovery and reconstruction plan prior to the event. The study also pointed out that people's awareness of the disaster and structures' vulnerability is not solely enough to move the community to a safer situation. They should be empowered by technical information to construct their houses. If this technical information is compatible with their traditional method of construction, it could be easier in their education and faster for implementation.

## 7. Conclusions

This study examined the safety of reconstructed region after 1990 Rudbar-Manjil earthquake, with its results revealing that most of the existing buildings in the region are vulnerable right now. This shows that the reconstruction and recovery after the quake has not been conducted in a suitable manner. The main reasons behind this phenomenon can be classified as follows: 1) ignorance of local culture and construction practice to design safe buildings, 2) lack of proper and efficient education of local workers to conduct the new methods of reconstruction, and 3) ineffective code enforcement.

To reduce this effect in the future of reconstruction and recovery stages, several measures are suggested to be taken:

- ❖ Use the local capacity in the establishment of reconstruction and recovery strategy.
- ❖ Conduct researches to understand the culture of each district and provide ready-to-use techniques for its reconstruction in the framework of "community base risk management".
- ❖ Try to modify the contemporary methods of construction instead of introducing a new system.
- ❖ Increase the knowledge of local engineers and construction workers in a constant base before and after the disasters.
- ❖ Overhaul the code enforcement system in order to reach a universal and effective supervisory system.

For further study, it is recommended to perform the similar study in different regions and time frame in order to identify other possible shortages in construction process and correct possible problems in future reconstructions. Furthermore, the detail analysis of the buildings and their shortcomings in construction can be carried out and the level of vulnerability and risk in the study region or similar locations can be evaluated.

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