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A Comparative Analysis of Reconstruction Strategies Employed in Major Earthquakes of Indo-Pak Region

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Abstract

Housing is one of the most important needs of mankind. A secure and properly planned house gives comfort to the people living in it, while keeping them safe from the harsh environment, unwanted people and animals, simultaneously. Apart from human casualties, the other most striking and usually the most visible effect of natural disasters is the destruction of houses. Loss of house has a devastating effect on the privacy, livelihood and dignity of individuals. An effective program for the reconstruction of houses for those affected in a natural disaster is critical to ensure the restoration of the society's economy, cultural identity and dignity. For many humanitarian organizations, employing professional construction companies is the most common and quickest way of rebuilding houses in the aftermath of a disaster. However, every strategy has its own risks and limitations and there is a growing awareness among countries regarding how to mitigate these situations. This study carefully examines the reconstruction strategies employed in earthquake affected buildings of Kashmir, Pakistan and Gujrat, India. The analysis concludes in favor of the proper fulfillment of byelaws for seismic resistant construction and enforcing the law of training for laborers and local people in the redevelopment of the earthquake hit area.

Keywords: disaster, earthquake, mitigation, reconstruction

Introduction

Kashmir earthquake hit on October 8, 2005 and it was one of the most destructive earthquakes in the recent history of the Indo-Pak subcontinent. The magnitude of the earthquake was recorded as M 7.6 at the Richter scale (UN-HABITAT, 2010). The source of the earthquake was located at the Balakot-Bagh reverse fault towards the north of Islamabad, federal capital of Pakistan. The calamity also affected the

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neighboring countries of Afghanistan and India. The shocks of the earthquake were sensed in almost all the countries of South Asia (Kazmi, [2013](#)).

The earthquake caused a death toll of approximately 75,000 people. It also caused injuries to more than 80,000 people and most of them were disabled as a result of amputations. More than 2.8 million people became homeless as a result of 455,000 partial or total collapse of buildings. The overall economic loss was close to 5.2 billion US dollars (Mumtaz, Mughal, Stephenson & Bothara, [2008](#); Javed, Khan, Penna & Guido, [2006](#)).

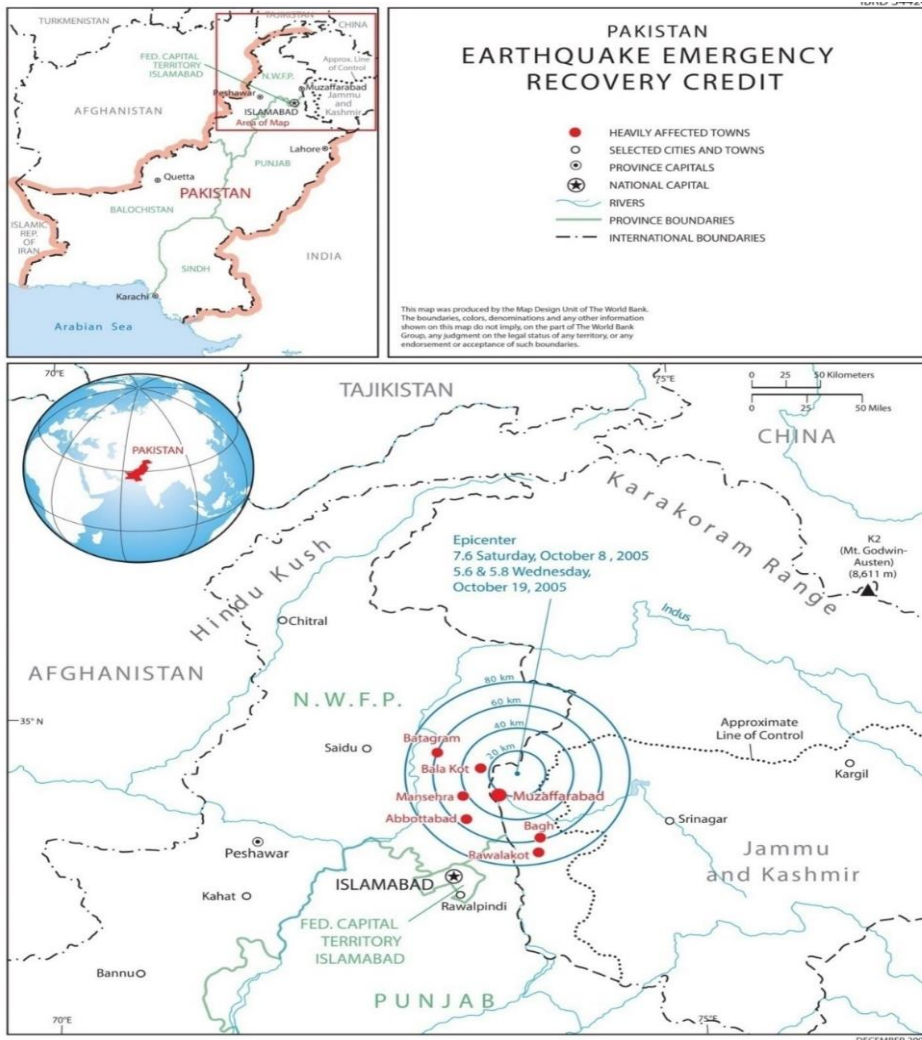


Figure 1. Geological location of 2005 earthquake

Source: www.worldbank.org

Pakistan has a large percentage of population which belongs to the low-income group. The overall conditions of the affected areas were worse than those created by disasters such as Rita and Katrina. The main reason was the hilly terrain and damaged communication networks. Women, children and elderly people were among the worst sufferers ((ERRA, [2009](#)). The most affected buildings were:

1. Residences
2. Schools
3. Healthcare facilities
4. Communication network centers
5. Utilities
6. Public administration and utilities (World Bank, [2010](#))

2. Research Methodology

The purpose of this research is to analyze the reconstruction strategies employed after two major earthquakes of similar magnitudes, that is, Kashmir earthquake in Pakistan (2005) and Gujrat earthquake in India (2001). The objectives of this research are:

- (a) to explore the strategies used to manage resources after an earthquake,
- (b) to study earthquake resistant construction techniques, and
- (c) to formulate a strategic plan for post-disaster cities.

Data was collected through the survey of literature including research articles, government organizations' websites, books and magazines and it was used for the comparative analysis of reconstruction strategies employed in the above mentioned areas.

3. Literature Review

Earthquakes occur all over the globe with a greater possibility of occurrence at the boundaries of tectonic plates. World's most powerful earthquake occurred in Chile in 1960 and it had a magnitude of M 9.5. Earthquakes of magnitude greater than M 7.0 and less than M 8.0 on Richter scale are categorized as 'major' earthquakes, while earthquakes with a magnitude greater than M 8.0 are categorized as 'great' earthquakes. Pakistan has a history of experiencing major earthquakes which usually occurred in the Himalayan region. The earthquakes struck regions of Pakistan and India are listed below in the Table 1.

From the history of earthquakes, it can be inferred without a doubt that these types of earthquakes will reoccur in future. Researchers have developed many formulas to predict future earthquakes. The probability of occurrence of an

earthquake having a magnitude greater than M 6.5 in Kashmir and the Himalayan region of Pakistan is more than 80% with a return period of 20 years (Yadav, Shanker, Chopra & Singh, [2010](#)).

Table 1
List of Major Earthquakes in India and Pakistan

Location (Latitude/Longitude)	Date and Time (UTC)	Magnitude
Awaran, Pakistan (26.951°N 65.501°E)	2013-09-24 11:29:47	M 7.7
Southwestern Pakistan (28.777°N 63.951°E)	2011-01-18 20:23:23	M 7.2
Kashmir, Pakistan (34.539°N 73.588°E)	2005-10-08 03:50:40	M 7.6
Gujrat, India (23.419°N 70.232°E)	2001-01-26 03:16:40	M 7.7
Pakistan (29.976°N 68.208°E)	1997-02-27 21:08:02	M 7.1
Iran-Pakistan border region (27.793°N 62.054°E)	1983-04-18 10:58:51	M 7.0
Off the coast of Pakistan (24.927°N 63.601°E)	1945-11-27 21:56:54	M 8.1
Assam, India (26.637°N 93.852°E)	1943-10-23 17:23:21	M 7.2
Pakistan (28.941°N 66.477°E)	1935-05-30 21:32:57	M 7.5
Quetta, Pakistan (29.784°N 67.365°E)	1931-08-27 15:27:21	M 7.2
Ghotki, Pakistan (28.074°N 69.333°E)	1909-10-20 23:41:22	M 7.0
Himachel Pradesh, India (32.636°N 76.788°E)	1905-04-04 00:49:59	M 7.9

(Source: <https://earthquake.usgs.gov>)

3.1. Earthquake Mitigation Organizations

The 2005 Kashmir earthquake caused massive damage including damage to infrastructure, residential houses and structural damage. Its strong impact left 2.8 million people without shelter and approximately 400,000 houses were fully destroyed and damaged. The government of Pakistan allocated US\$1.2 billion for

the reconstruction of houses. Major reasons for extensive damage included the negligence of seismic considerations in building design, untested construction materials, and inappropriate site selection.

Table 2

Summary of 2005 Earthquake Damage (ERRA, n.d.)

SUMMARY TOTAL DESTROYED AND DAMAGED HOUSING UNITS.						
Districts	%Urban	Total Units	Destroyed	Damaged	Total Damaged	Total Damaged %
AJK AFFECTED DISTRICTS						
Mhgzaffarabad	12	123,679	69,943	28,273	98,221	79
Bagh	5	59,623	33,806	21,208	55,014	92
Poonch	11	61,678	12,823	38,882	51,705	84
AJK Total	10	244,980	116,572	88,368	204,940	84
KPK AFFECTED DISTRICTS						
Shangla	0	67,003	15,661	10,821	26,482	40
Mansehra	14	203,09	31,323	43,282	74,605	37
Kohistan	0	74,087	4,350	18,395	22,745	31
Abbotabad	19	153,819	6,961	27,051	34,012	22
Battagram	0	44,585	28,712	8,657	37,369	84
KPK Total	11	542,603	87,007	108,206	195,213	16
TOTAL (KPK+AJK)	10	787,583	203,579	196,574	400,153	51

Various disaster mitigation authorities were established by the Government of Pakistan in association with the World Bank, United Nations and Asian Development Bank to cope with the tragic devastation. Earthquake Reconstruction and Rehabilitation Authority (ERRA) was established in 2005 and later on National Disaster Mitigation Authority (NDMA) also came into existence. These organizations played a significant strategic role in establishing new methods of rehabilitation and reconstruction. They developed safer construction techniques by revising seismic zoning of the country, setting seismic provisions in building codes, training the labor and generating public awareness for seismically safe construction. ERRA developed a strategy that home owners will reconstruct their own houses while adopting the following points:

1. Controlled inspection of construction process at different levels of house construction.
2. Construction of houses with easily acquired material to maintain sustainability and to retain cultural norms.
3. Preparation of a damage assessment program team to inspect the building damage precisely.
4. Distribution of funds through local bank branches upon significant completion of the prescribed stage of a housing unit.
5. Recycling the debris and using it in the reconstruction of houses.

6. To ensure that the houses will be safe from any other earthquake in future, building components should be lightweight and easy to install. Thinner walls and lighter roofs which remain firmly connected with each other will be installed.



Figure 2. Construction techniques used by ERA (ERA, [2014](#))

3.2. Reconstruction Strategies

Reconstruction of a house after damage or total destruction can be done in different ways. The various contexts and aspects of rebuilding a house once damaged are analyzed to make the most appropriate decision in selecting one or multiple approaches of reconstruction. The various aspects of reconstruction are as follows:

1. Costs of reconstruction
2. Social safety and improvements in housing
3. Renewal of livelihoods
4. Political environment and cultural perspective
5. Individual's personal priorities for comfort, capacity and empowerment

It is imperative to take the community on board for consultation, while analyzing and scrutinizing all dynamics before choosing any or combined approaches for the reconstruction of houses. This researcher differentiates between five approaches for the reconstruction of damaged houses on analytical grounds. These rebuilding approaches are applicable to permanent housing as well as transitional ones (World Bank, [2010](#)). These five approaches are as follows:

1. Cash Approach

In the cash approach to rebuild damaged houses financial aid is provided but no technical assistance is provided (UN Refugee Agency, [2011](#)).

2. Owner Driven Reconstruction

This approach comprises both regulations and technical assistance alongside unconditional financial help. This approach aims to ensure that homeowners reconstruct their own houses (Global Shelter Cluster, [2015](#)).

3. Community Driven Reconstruction

Financial support and material assistance is provided through communities which actively participate in post-damage reconstruction (Cliffe, Guggenheim, & Kostner, [2003](#); Sharmaa, [2018](#)).

4. Agency Driven Reconstruction *In Situ*

In this approach, damaged houses on pre-catastrophe locations are reconstructed by governmental or non-governmental organizations (NGOs) by employing a construction company as a third party (Charlesworth & Ahmad, [2005](#)).

5. Agency Driven Reconstruction at Relocated Site

Governmental or non-governmental organizations (NGOs) build houses at a new geographic location through a construction firm (World Bank, [2010](#)).

According to the World Bank’s data for disaster management, following are the thresholds, constraints and situations described in the reconstruction process. Both case studies had the room for the application of most of the strategies.

Table 3

World Bank’s data for disaster management (World Bank, [2010](#))

Reconstruction approach	Degree of household control	Form of assistance		Role of actors			Location	
		Financial	Technical	Community	Agency	Contractor	<i>In-situ</i>	New site
Cash Approach	Very high	Cash only	None	None	None	Household may hire	Yes	No
Owner-Driven Reconstruction	High	Conditional cash transfer to household	TA/Training of household	None	Project oversight and training	Household may hire	Yes	No
Community-Driven Reconstruction	Medium to high	Transfer to household or community	TA/Training of community and household	Project organization and oversight	Project oversight and training	Community may hire	Yes	No
Agency-Driven Reconstruction <i>in-Situ</i>	Low to medium	Funds handled by agency	Limited or none	Limited	Management of project	Agency hires	Yes	No
Agency-Driven Reconstruction in Relocated Site	Low	Funds handled by agency	Limited or none	Limited	Management of project	Agency hires	No	Yes

3.3. ERRA, House Reconstruction Model

Following are some points based on ERRA's model of house reconstruction to facilitate the speedy recovery of housing damage:

- All construction documents, shop drawings, bill of quantities, and material schedules and criteria for walls and roof installation should be clearly defined.
- The regional government shall set up sites to facilitate the affected people with an uninterrupted supply of construction material. The local government shall work with the private sector at all levels to facilitate the purchase of material.
- Disasters of this magnitude give birth to incidents like property and land disputes between owners and tenants, frequently. Policies should be in written form to curb these issues in a timely and effective manner.
- The reconstruction of houses was estimated to be completed in three years with a combination of skilled and unskilled labor in the work force. Skilled labor included masons, site engineers, supervisors, surveyors, steel fabricators, plumbers and electricians. The semi-skilled and unskilled labor were assigned to work directly under the supervision of these people. A total of 54,000 skilled and 80,000 unskilled labor was proposed to complete the job in the right time (ERRA, [2006](#)).
- Moreover, ERRA established housing reconstruction units in the affected areas. These units distributed the building material and served as technical training institutes for homeowners, so that they can build their own houses (ERRA, [2007](#)).

4. Case Analysis of Gujrat Earthquake

The purpose of undertaking this case study is to contribute to the current discussion by elucidating local views about house rebuilding in the wake of the catastrophic earthquake which hit Indian state of Gujarat on January 26, 2001 (UNDP, [2009](#)).. It killed over twenty thousand people, while approximately a hundred and sixty seven thousand were fatally injured. According to the estimates, the number of houses completely demolished in the quake was nearly 0.34 million across the state, with an overall damage to more than one million houses. Over seven thousand and six hundred villages and settlements were hit, with more than three hundred villages slated down to earth. Educational and healthcare facilities, irrigation systems and water facilities were rendered dysfunctional as well. It was fortunate that twenty one out of a total of twenty five districts of the state of Gujarat survived the disaster. However, the largest and the poorest district of the state suffered the most. It was

estimated that ninety percent of casualties and about eighty five percent loss of assets were recorded in Kutch. This study is based on the Gujarat disaster because of three major reasons (Encyclopedia of Britannica, [n.d.](#)). Firstly, the recorded figure of houses damaged in the affected area was quite big.

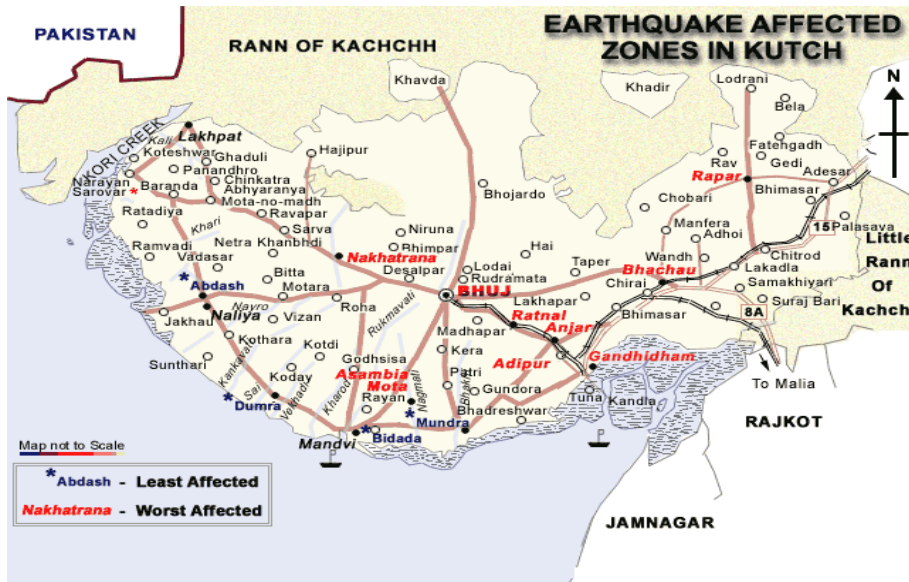


Figure 3. Earthquake Affected Zones in Kutch

Secondly, owner driven approaches to the reconstruction of houses was implemented on such a large extent for the first time ever. Gujarat government supported own-build reconstruction for more than a million houses. Thirdly, the existence of countless non-legislative offices and private enterprises worldwide, as well as the use of combined approaches ranging from contractual worker-driven recreation of whole towns helped particular groups and provided a chance of relative examination of the benefits and disadvantages of various procedures and systems.

The main part of reconstruction work after the seismic tremor was carried out by the Gujarat government under the Gujarat Emergency Earthquake Reconstruction Project (GEERP). The administration additionally welcomed national and global legislative, non-administrative and private associations to participate in the reconstruction exertion by “embracing” influenced towns under a joint public-private course of action. To summarize the estimates, 75 offices assumed control over the full recreation of 272 villages, most of them in Kutch. Different NGOs offered reconstruction help without formally receiving a full town or gave full lodging to particular target bunches (Barenstein, [2006](#)).

5. Data Analysis and Findings

On the basis of literature review, it was observed that the movement of the outermost fragmented layer of earth causes earthquakes and the reason behind it is the internal complex mechanism happening within the earth. This mechanism provides the required energy to the outermost layer to float, move and eventually cause an earthquake. The theory of tectonic plates provides sufficient explanation about this phenomenon. According to this theory, earth's crust is made up of different pieces of broken plates which may collide (converge), move apart (diverge) or slide over each other at their boundaries. This convergence, divergence and sliding of the so-called plates causes earthquakes and gives rise to the concept of continental drift.

Energy dissipated from the source of an earthquake travels in the form of waves. These waves cause the shaking of the ground above. As a result, vibrations are transferred to the structures and buildings constructed on the ground. Shaking of the structures excites a dynamic response which is quite different from a static response and it may cause damage to the structure.

5.1. General Guideline for House Reconstruction

5.1.1. Site selection criteria. In order to use the donated funds to reconstruct houses, proper site selection criteria should be defined. The following points shall explain the criteria in detail:

- The selected site should be on a leveled surface with appropriate reinforcements at both vertical and horizontal axis. Use of wood, burned bricks, regional stone, mortar and concrete masonry units for new construction and retrofitting is highly recommended.
- The selected site should be away from the risk of landslides, with appropriate plantation on inclined areas as protection from landslides. Moreover, it should be away from river banks to avoid the risk of flooding.
- The building should be designed with proper retaining walls and barriers. Moreover, the site selected should have the capacity to hold its foundations firmly.
- The selected site should be away from areas ruptured and torn by the earthquake. The building should be at a minimal distance of 250 m from these lines and tall trees.

5.1.2. Planning criteria. The layout of the houses should be carefully designed in symmetrical proportions to avoid future calamities.

- Buildings planned in a proportionate shape such as a square, circle or rectangle have the ability to resist the vibrations caused by an earthquake as compared to the buildings designed in an irregular shape, as shown in Figure 4.
- The walls should be appropriate in height and length and well connected with interior walls.

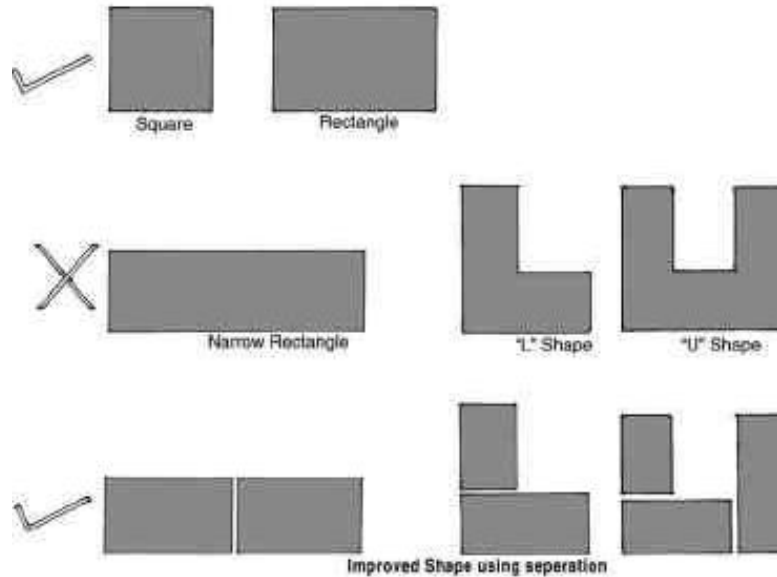


Figure 4. Building shape for earthquake resistance

5.1.3. Construction details with earthquake resistance criteria. The construction of all structural and architectural members such as foundations, drainage and walls should essentially comply with seismic considerations which are stated as follows:

- Building structure should suit soil conditions and bearing capacity and must be well connected with the foundation. The depth of the foundation should be less in rocky areas and should be increased by one foot in case of a double story structure.
- The building should be protected from water at all levels, especially its foundations. It is highly recommended that a damp proof course layer of mortar is applied at the plinth level before the walls are erected. The runoff water should be directed to a drain properly, so that it does not affect the walls and the foundations.

- Seismic strips should be provided at different levels of a wall. A seismic strip constitutes a beam that connects all parts of the wall and binds them together. Seismic strips should be applied at three levels, while closely bonded together at all sides of the building.
- The load bearing area of the lintels should be sufficient to transfer the load onto the wall without putting a lot of stress on the wall.
- The roof of the building should be lighter in seismic prone areas, so that it may easily transfer load onto the walls. Wooden truss can also be used as part of the structure to bear the load of the roof, as shown in Figure 5. Heavier roofs, inappropriate foundations, abrupt openings in the walls, poor connection of structure and site conditions are the main causes of damage and these should be avoided, as shown in Figure 6.

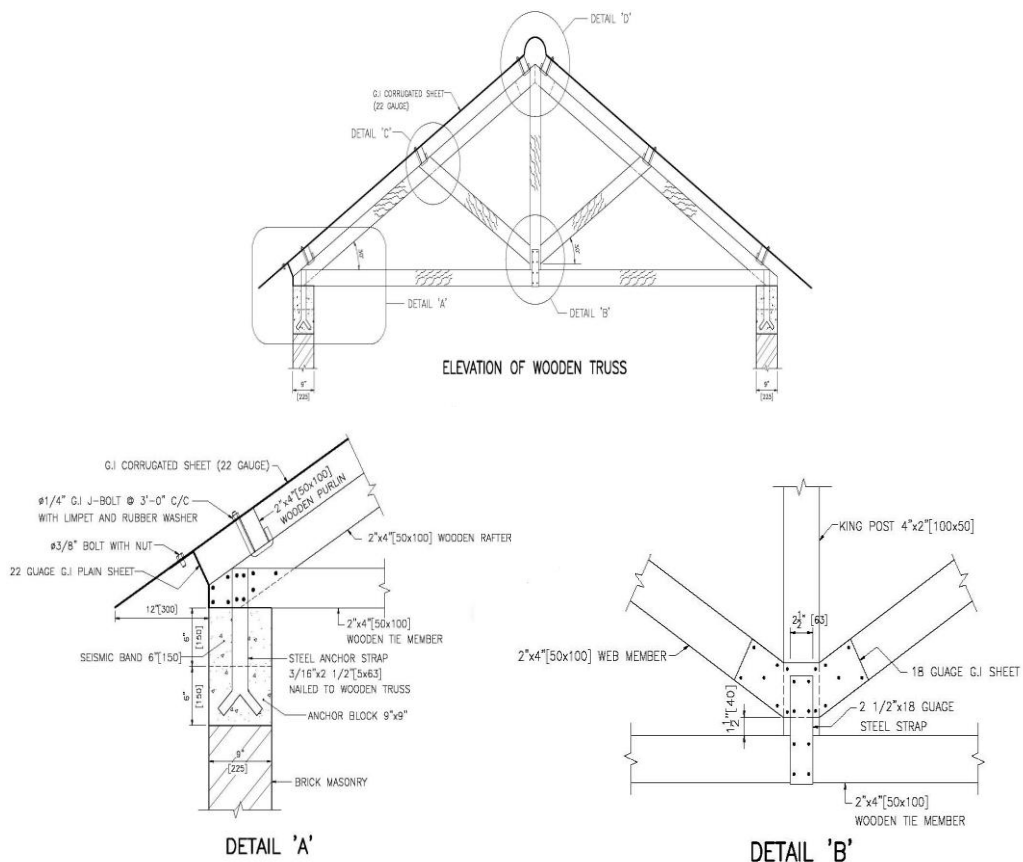


Figure 5. Detail of wooden truss for earthquake resistant house

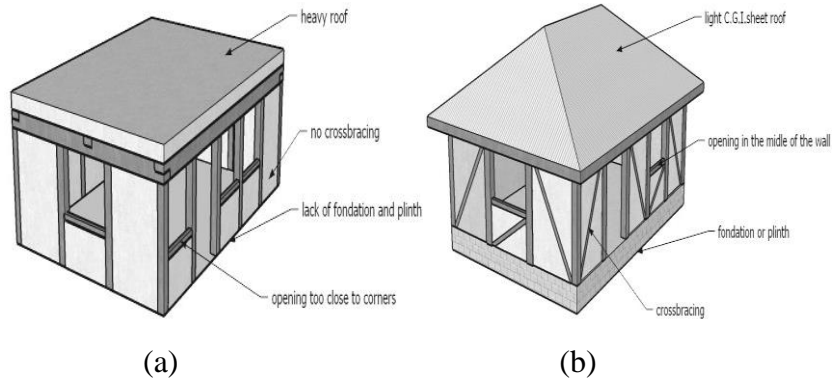


Figure 6. (a) Inappropriate house reconstruction model (b) Appropriate house reconstruction model

5.1.4. Rehabilitation and renovation criteria for existing buildings.

Renovation is a process intended to improve the existing condition of a building. To make building safe from earthquakes, following points should be considered in this regard:

- The affected building should be evaluated before any type of retrofitting work can commence. The building should be carefully examined to determine the amount of damage done and materials to be employed, such as checking the foundations and examining different aspects of structure. The structure should be carefully examined by a licensed structure engineer. Repair work can be divided into two categories, that is, structural and non-structural.
- If during the inspection, it is determined that there are cracks in the roof, then it should be immediately fixed with a key bolted at a right angle position.
- If the evaluation of a building determines that its roof has been seriously damaged, then it is recommended that the roof is surgically removed, leaving behind only the trusses as framework for the new roof. The new roof ought to be lighter than the previous one and it should be installed according to earthquake resistant specifications.
- The joints at the corner of the earthquake affected buildings tend to get weaker and cracks begin to appear in them after a certain period of time. It is recommended that such a building is repaired by bolting keys after applying mortar at the joints. Those can also be fixed by putting a wire mesh on the affected wall and applying mortar afterwards to cover it.
- In case of roof, the ring beam is affected the most when an earthquake hits. In such a case, the damaged or missing ring beam should be replaced by a new ring beam or a concrete wall plate to make the building functional again.

6. Conclusion

The common factor among both case studies were the reconstruction processes in which financial grants were paid in stages on subsidized rates to the affected home owners based on the damage inspection methodology. The cash approach can be very transparent and effective in owner driven reconstruction process, if granted through controlled inspection via appropriate administrative framework. The Gujarat state formed their own Gujarat State Disaster Management Authority (GSDMA), with all their procedures and research outcomes posted on their website. Pakistan had the disadvantage of having the earthquake affected terrain in the vicinity of disputed areas, which further slowed down the process of reconstruction. Important infrastructure such as roads and road networks were immediately destroyed and because of the hilly terrain of the region, the affected areas were not easily accessible to all international and local NGOs. It took a while for the infrastructure to be restored and to get the reconstruction work started. GSDMA won several awards from international agencies including UN for successful reconstruction of houses. Moreover, all the reconstruction strategies were successfully applied with maximum satisfaction percentages listed in the public questionnaires and surveys. In case of Pakistan, the building code was revised with updated seismic provisions. Later on, after the eighteenth amendment, energy guidelines were also incorporated to overcome the energy crisis in the country. Until now, building code has not been enforced which requires the involvement of code enforcement agents for periodic inspections and testing. It has been observed in many case studies that reconstruction strategies give the best results when the government has a successful administrative framework, both at urban and rural levels.

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