Case Studies of Seismic Retrofitting – Latur to Kashmir & Lessons Learnt

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Seismic Retrofitting for reduction of vulnerability of a structure is a relatively new concept in India. It was only after Latur Earthquake of 1993 that retrofitting was taken up on a substantial scale as a part of the earthquake rehabilitation program under which many public buildings were retrofitted. The quantum got substantially increased in the aftermath of 2001 Kutchch Earthquake.

In spite of all that got done retrofitting as an option, a technique, a profession or a business is still in its infancy. This is manifested by five indicators – (a) A delivery system for retrofitting does not exist; (b) Official Schedule of Rates (SOR) of any government agency does not include seismic retrofitting; (c) Contractors and skilled artisans knowledgeable in this are scarce; (d) People at large have no knowledge of the option of retrofitting; and (e) Information on retrofitting is hard to find. As a result the use of **retrofitting as a tool for managing the earthquake risk is fraught with too many obstacles**, putting it beyond the reach of an ordinary person.

In India, it would not be an exaggeration to say that over **80%** buildings that consist of **non-engineered masonry** are vulnerable against the hazard of future earthquake. These cover a broad range of buildings starting from small mud houses in remote villages all the way to the moderately large infrastructure buildings in cities. With the country witnessing a large number of deaths and incurring huge losses every year resulting from disasters it is important that the vulnerability of these non-engineered masonry structures is reduced through retrofitting.

Fortunately, a substantial amount of pioneering work has been done in different parts of the country on seismic retrofitting of "non-engineered masonry" buildings, although by a few individuals. This includes the (a) development of regional technical guidelines in a number of regions, (b) making of public awareness materials in the regional languages, and (c) most importantly, the actual execution of retrofitting of local variants of masonry structures coupled with some artesian training on retrofitting. Since each region poses significantly different context, such an effort required fresh approach to evolve the solutions to tackle the problems on hand peculiar to the area. This involved different building technologies, different materials, difficulties of access, unreliability of electric power, unavailability of basic as well as special materials needed for retrofitting etc. The retrofitting work carried out in various regions, although on a small scale, offers a number of lessons that could be valuable for the further development of retrofitting as well as for its promotion as the most attractive option for reducing vulnerability.

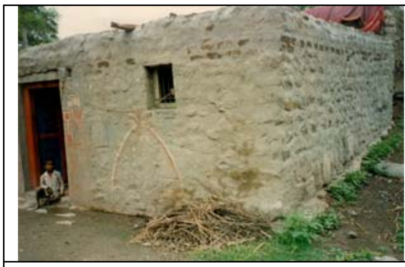
Four case studies are taken in this paper. This includes (a) a house in a village in Latur region, (b) a Road & Building Department Office cum Storage building in a small Gujarat town, (c) a small school in mountainous border region of Kashmir, (d) a large 3 storey school of Delhi Municipal Corporation. **The author was involved in the conceptualization as well as the execution of each one of these projects.**

(1) Latur, Maharashtra: -
Context: Post earthquake rehabilitation with the government financial assistance for quake affected people, and retrofitting guidelines prepared by Prof. A.S. Arya
Financial assistance: Material by ASAG, labour by owner.
Predominant building system: Mud roofing on timber deck supported on timber columns- Maalwad style - and walls of random rubble in mud mortar.
<u>Case Study: House of Haribhau in Nagarsoga village, Year 1994</u>:
Primary objective: To get first hand understanding of retrofitting – "Learning while Doing".
Building System: Heavy Mud roofing on self supported timber deck and Random Rubble Masonry walls in mud mortar
Building Area: 2 large rooms – 40 sq.m.
Damage Category: G 2
Retrofitting Measures: Restoration of damages followed by (a) Stitching of stone wythes with Cast in-situ RC Stitching Elements, (b) Installation of roof level RC Band after removal of the upper part of the walls including the projection above the roof, (c) Installation of Knee Braces at the junction of timber columns and beams.
Executing Agency: ASAG with the help of local masons and the house owner.
Special Features Used First Time By Author:

- Installation of Cast in-situ RC Stitching Elements involving making of dumbbell shaped holes through the stone wall
- Installation of RC Band in the "*Maalwad*" style existing house involving the partial dismantling of masonry wall
- Knee Braces for different configurations of timber columns and beams – fabrication by local metal work shops

Problems Encountered:

- No awareness of retrofitting option among people. As a result not many people were interested in this option. Lack of confidence among engineers did not help this process.
- Complicated selection process of a house (simple with no major damage) to work upon because of lack of experience of restoration, retrofitting and random rubble masonry.
- The risk and the skills involved in the installation of Cast in-situ RC Stitching Elements

	
Retrofitting & Restoration completed	Knee braces at beam-column joint
	
Upper Wall removed for band installation & Roof deck opened for repairs	Cast in-situ RC Stitching Element being plaster

- Thick stone walls precluded use of electric drill for making holes
- Improvisation of tools for making holes in random rubble wall
- Lack of necessary skill with masons required intensive hands-on training of masons

"Learn while you work" approach coupled with the understanding of vernacular masonry system and application of engineering common sense helped tackle the problems on hand.

Two more houses were retrofitted subsequent to which a large area level retrofitting program was taken up. A complete delivery system was evolved for effective and efficient execution of the program. In all 900 masons were trained and 150 houses retrofitted.

2. Gujarat:

Context: Post earthquake rehabilitation with financial assistance for quake affected people from Government of Gujarat and retrofitting guidelines prepared for GSDMA by Prof. A.S. Arya

Objective: Demonstration and training of Government engineers.

Financial assistance: BMTPC, Government of India, New Delhi.

Predominant building system: Tiled roof or RC slab over stone, brick or concrete block masonry walls.

Case Study: R & B Office cum Storage at Patadi town, Year 2002:

Primary objective: To demonstrate the technology and to train government engineers.

Building System: AC Sheeting over wooden understructure supported on Random Rubble Masonry in cement mortar

Building Area: 4 rooms and a passage – 80sq.m. covered area

Damage Category: G 2

Retrofitting Measures: (a) Stitching of stone wythes with Cast in-situ RC Stitching Elements, (b) WWM Seismic Belt at eave level, (c)

Vertical Reinforcing Bars in corners anchored to walls and encased in micro concrete, (d) Encasing of wall openings with WWM Seismic Straps, (e) Roof diaphragm improvement with the help of Diagonal Ties made of 13 gauge pre-tensioned multiple strand GI wires and timber struts, (f) Strengthening of connections between roofing elements, (g) Anchoring of elements of roof understructure to walls, (h) closing off of a window opening and, (i) Restoration of earthquake damage

Executing Agency: NCPDP with the help of local masons.

	
Gable & Lintle Seismic Belt, Stitching element, window blocking	Lintle & Ridge Seismic Belt, Roof Bracing, Stitching Elements

Special Features Used First Time By Author:

- Additional Seismic Belt with WWM for extra high walls. Extensive use of Seismic Belt with WWM for encasement of openings.
- Anchoring of roofing elements to support walls
- Blocking off of a window opening

Problems:

- Absence of awareness about the significance of retrofitting in public as well as R & B engineers resulted in to little learning by them for future use.
- Absence of necessary skills with masons required their training and more supervision.

With wide firsthand experience of retrofitting in Latur region from technical angle it wasn't difficult to take up retrofitting activities. A major program was taken up for the government for awareness building in 480 villages and training of 6000 masons.

3. Kashmir:

Context: Post earthquake rehabilitation with financial assistance for quake affected people from Government of Gujarat and retrofitting guidelines prepared by Prof. A.S. Arya.

Objective: Training of masons and peoples' awareness & confidence building in retrofitting..

Financial assistance: Aghakhan Foundation.

Predominant building system: Corrugated Galvanize Iron (CGI) sheet roofing on Timber Principal Rafters that are securely connected to the timber attic floor joists to form a triangular box. The roof-attic floor assembly resting on random rubble masonry in mud or cement mortar. Intermediate floor consisting of timber joists and timber plank flooring.

Case Study: Primary School in Sultan Daki village, Year 2006:

Primary objective: To demonstrate technology in Kashmir context and train the local masons and create awareness.

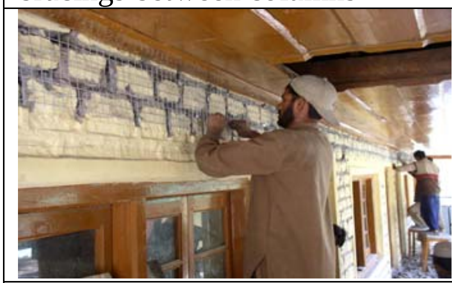
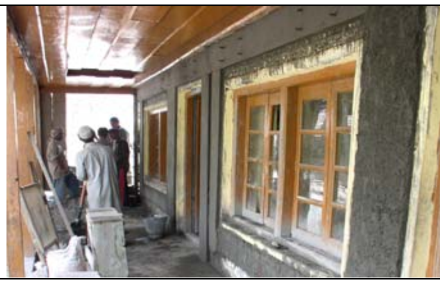
Building System: CGI Sheeting over wooden understructure anchored to wooden attic floor deck which in turn supported on Random Rubble Masonry in cement mortar

Building Area: 3 rooms and a verandah – 150sq.m.

Damage Category: G 3

Retrofitting Measures: (a) Stitching of stone wythes with Cast in-situ RC Stitching Elements, (b) WWM Seismic Belt at eave level, (c) Vertical Reinforcing Bars in corners anchored to walls and encased in micro concrete, (d) Encasing of wall openings with WWM Seismic Straps, (e) Roof diaphragm improvement with the installation of timber bracings and struts, (f) Strengthening of connections between roofing elements, (g) Anchoring of attic floor to walls with the help of vertical rebars and special MS brackets, (h) Diagonal timber bracings between timber columns in verandah. And (I) Restoration of earthquake damage

Executing Agency: NCPDP with the help of local masons who were all getting trained while working on this building.

	
Retrofitting completed with bracings between columns	Roof to Wall Anchoring
	
Installation of WWM for Lintle level Seismic Belt	Seismic Belt & Opening Encasement

Problems Encountered:

- Absence of awareness about retrofitting in public as well as local masons resulted in to some skepticism about retrofitting the school in the beginning
- Local village level politics and lack of awareness for retrofitting called for meetings and lobbying

- Retrofitting was not a part of government program. This meant that no help would come from government engineers and in turn they did not learn anything from this
- Lack of necessary skill with masons required intensive hands-on training of masons
- Reaching the remote site with limited transportation and security checks made it more difficult.
- Procurement of galvanized WWM of the desired specifications demanded a lot of extra efforts and resulted in to a delay of one month.
- Thick stone walls and unreliable electric power supply precluded the use of electric drill

With wide firsthand experience of retrofitting in Latur, mountainous Uttarakhand, and Gujarat from technical angle it wasn't difficult to take up retrofitting activities. Based on the experience of this school and Kupwada District Hospital a detailed manual on Retrofitting and Restoration was prepared for UNESCO.

Special Features Used First Time By Author:

- Anchoring of the triangular roof/attic box to stone walls using special brackets
- Diagonal timber bracings between timber columns,

4. Delhi:

Context: Pre-earthquake risk mitigation effort with financial assistance from BMTPC, and with technical guidance from Prof. A.S. Arya.

Predominant building system: Two to three storey high load bearing brick masonry walls supporting RC slab roof and intermediate floor

With wide firsthand experience of retrofitting in different regions of the country including urban areas from technical angle it wasn't difficult to take up retrofitting activities.

Case Study: Ramnagar Primary School of Delhi Municipal Corporation, Year 2007:

Primary objective: To demonstrate technology, train Municipal engineers, and raise awareness.

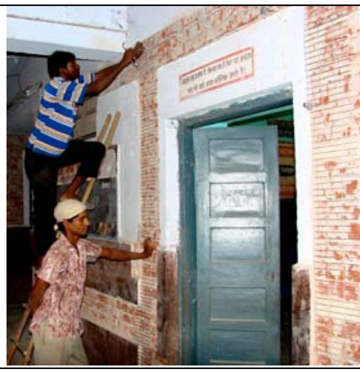
Building System: Three storey building with load bearing brick masonry walls supporting RC slab roof and intermediate floors.

Building Area: G=2 storeys, 24 rooms and lobby – 1816 sq. mt.

Damage Category: N.A.

Retrofitting Measures: (a) WWM Seismic Belt at lintel and sill levels, (b) Vertical Reinforcing Bars in corners anchored to walls and encased in micro concrete, (c) Encasing of wall openings with WWM Seismic Straps, (d) Anchoring of slabs to walls, and (e) Jacketing of masonry columns

Executing Agency: NCPDP with the help of a team of experienced masons and laborers brought from Gujarat.

	
Jacketed Masonry Columns & Seismic Belts	Jacketing reinforcement
	
Lintle & Sill Belts & Window Encasement	Encasement of door way

Problems Encountered, their impact & solution:

- Lack of awareness on the significance of retrofitting meant limited cooperation and support from all different quarters, making the execution task more difficult and more time consuming
- Working in the functioning school building resulted in to unplanned delays and called for regular coordination with school authorities
- No noisy activity such as plaster breaking or drilling work could be done during school hours
- School children played with construction materials resulting in to waste and also disturbed the incomplete work
- Extreme caution had to be exercised for the safety of children
- Procurement of galvanized WWM of the desired specifications and the galvanized 6mm MS bars resulted in to frequent and long delays. Significant variations observed in the quality of galvanizing in the absence of standardization. 6mm galvanized MS bars were delivered in smaller lengths and in tangled conditions.
- Extensive removal of plaster for seismic belts and vertical reinforcement tackled with electric rotary grinder.
- Extensive drilling in to RC slabs for the vertical reinforcement and in masonry columns for installing shear connectors was tackled with good quality heavy duty electric drill

- In the documentation of large buildings some details are always missed, many times due to closed access or obscurity due to plaster. At the time of execution of retrofitting this missing information results in to changes in work plan affecting the budget. And time table
- In large buildings extra items crop up easily. To make sure contractor gets paid for these the MOU would have to be suitably prepared.
- A large team of suitably skilled artisans and laborers had to be taken from Ahmedabad to Delhi since locally they were not available. This increased the labor cost.
- No technology transfer could take place. Thus the unavailability of skilled masons and laborers did not change.

Special Features Used First Time By Author:

- Three storey structure required scaffolding and safety equipment for the workers who were not used to such heights.

Conclusion:

From the experience of the retrofitting projects undertaken at these and other sites the following major lessons in regards to the promotion of retrofitting as the principal option for vulnerability reduction emerge.

- Government policy for "Managing Disaster Risk" must place top priority on vulnerability reduction of existing non-engineered buildings.
- Awareness creation in the community at large about the possible dangers of a future disaster and the significance of retrofitting is a prerequisite for the promotion of retrofitting
- Simple booklets and brochures on the subject must be made easily available in local language
- Government engineers must receive rigorous onsite training in the retrofitting of non-engineered buildings to enable the respective agency to take up retrofitting projects.
- Retrofitting skills must become easily available in the market through the Hands-on training programs for masons
- Public agencies owning buildings must be made aware of the need for retrofitting these buildings to help them assign right priority to retrofitting.
- Special materials required for retrofitting must be available easily.
- For the most common building systems the retrofitting items must be standardized with their specifications, and SOR must be developed and recognized.
- Documentation system also needs to be standardized so that all engineers use the same language of communication.
- Engineering community needs to become proactive in this direction just like in many of the Western countries.