Transfer of Earthquake Resistant Building Technologies At Grassroots in Kashmir

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1. Brief description of Kashmir earthquake

The Kashmir Earthquake of October 8, 2005 with magnitude measuring at 7.5 on Richter Scale brought damage, death and destruction to parts of Kashmir. The primary cause of the damage and destruction is the **total ignorance about the earthquake resistant construction in the society at large including the building artisans**. It is, hence, important that in order to ensure long-term safety of the most number of people in the region, the people including building artisans are educated in the earthquake resistant building technologies through their **demonstration accompanied by hands-on training**. It is well recognized that majority of structures in the quake affected area, as in all rural and semi-rural areas of the country including houses and infrastructure buildings, are built using the Vernacular or Traditional Building systems by local masons who play an additional role of engineers.

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Abstract:

The Kashmir earthquake witnessed much damage and destruction of masonry structures since these structures lacked earthquake resisting features on account of the ignorance among the people and building artisans. These structures along with infrastructure buildings were built with vernacular building technologies of the area that utilize mainly the local materials. Since earthquakes could recur in Kashmir it is imperative that the people are aware of such features and building artisans are knowledgeable in them. After the earthquake on account of myths and absence of scientific outlook people have begun to go for technical options that are not viable.

A program of technology transfer was taken up to promote the technologies that are viable in the region based on demonstration and training with an objective of creating awareness in the communities and training masons in how to construct earthquake resistant vernacular buildings. Subsequent to identifying the causes of various types of damage suffered by the buildings remedial measures were evolved based on the relevant IS Codes and demonstration construction was taken up.

Training was focused on hands-on approach while efforts were put in to impart the understanding about why the masonry structures performed poorly, the ways to ensure ductile behavior of masonry structure and how various earthquake resisting features behave. Two way interaction was adopted with the masons to evolve the structural details that were viable in the distant villages in this hilly region. Efforts were put in to build confidence of the masons to build their capacity to convince the house owners to adopt the viable technologies for their long term safety.

Key words:

Vernacular, Local, Viable, Mason, Training

2. Common Building Types

➢ Traditional Building Technologies, economics, weaknesses

In Kashmir the most popular building technologies depend primarily upon the locally available materials as well as the locally available skills. Barring some exceptions, the structures have masonry load bearing walls. Only in recent times people have started building RC frame structures for homes and small infrastructure buildings. The most common building materials are bricks, stone (rubble), mud, timber of different types, Galvanized Iron sheets, etc. In recent years RCC has also become popular with some. Lime once used for masonry is rarely used now on account of limited availability.

Table 1: Commonly Used Building Systems

Component	Options - Description	Popularity	Status
A. Roof	Timber planks and Shingles on timber understructure – two sided pitched	Poor	Extinct
	Mud on timber understructure - flat	Poor	Extinct
	Corrugated Galvanized Iron (CGI) Sheeting on timber - pitched	High	Current
	RCC Slab	Moderate	New
B. Wall	Un-Coursed Rubble (stone) Walls	High	Current
	Un-burnt Bricks	Poor	Limited
	Brick	Moderate	Current
	Timber in with Stone or Brick infill	High	Current
	Mud as a mortar	Moderate	Current
	Cement as a mortar constituent	Limited	Current
Floor	Timber	High	Current
	RCC	Little	Current

Preference is greatly dictated by what is available locally which varies from place to place, since this has a great bearing on the cost. Stones are used in the hilly areas since there they are most easily available. Wood is often used as posts, horizontal struts and diagonal bracings, with infill of stone to construct ***Dhajji*** type walls that are very thin and light.

3. Types of Damage & Reasons

Delamination of UCR wall

Collapse of UCR wall

Damage to *Dhajji* wall infill

Roof box lying on ground

It has been observed that the damaged buildings include those having stone masonry as well as brick masonry. The area of Kashmir that has been most severely affected is hilly, where stone is the predominant material of walling.

Table 2: Types of Damage and causes

No.	**Descriptions**	**Cause**
A	**Walling**	
1	Corner vertical crack	Poor wall to wall connection, opening too close to corner
2	Diagonal crack	Too many wall openings including doors, windows, inbuilt cup-boards, spacing between openings too little
3	Horizontal crack	Excessive bending stresses caused by vertical bending resulting from inadequate lateral support to wall, extra high wall, pitched roof imparting lateral thrust on wall due to absence of truss action etc.
4	Vertical crack	Excessive bending stresses caused by horizontal bending resulting from excessive wall length, absence of strong connection between the exterior wall and the cross walls (including *Dhajji Diwar*, absence of diaphragm action due

No.	Descriptions	Cause
		to low rigidity in attic timber floor, absence of anchoring of attic floor to wall etc.
5	Bulging in UCR wall	Poor interlocking between outer and inner wythes of wall and absence of through stones
6	Delamination in UCR wall	Poor interlocking between outer and inner wythes of wall and absence of through stones
7	Collapse of a portion of wall	Excessive local damage resulting in to instability of a portion of wall
8	Cracking at lintel bearing	Inadequate bearing length and absence connection between the lintel and the band
9	Falling off of stone infill in Dhajji Diwar	Absence of containment of infill material
10	Collapse of *Dhajji Diwar*	Poor connection between *Dhajji Diwar* and base as well as ceiling
B	**Roof & Floor**	
1	Breaking of individual element	Rotten material
2	Collapse, partial or full	Lack of anchoring of roof to wall and collapse of support wall

As in the earlier earthquakes in the subcontinent, the poor construction quality and absence of earthquake resisting features are the prime reasons for the damage. The basic laws of masonry construction including the rigor required by modern materials like cement and steel are routinely violated. This has contributed greatly to the vulnerability of structures. One observation that is peculiar to Kashmir earthquake is that the roofs have suffered little or no damage in many houses. The walls collapsed bringing the roofs down, often, in intact condition.

4. Remedial Measures For New Buildings

Besides improving the construction quality by adhering to the basic rules of good construction practice this involves introduction of earthquake resisting features

Table 3: Measures for Preventing Earthquake Damage in New Construction

No.	Damage	Remedial Action

No.	Damage	Remedial Action
A	**Walling**	
1	Corner vertical crack	Build all walls at same time ensuring proper wall to wall connection, install seismic bands at lintel and/or eave levels, keep openings away from corners
2	Diagonal crack	Reduce number of openings and their sizes, install lintel level band or connect lintels to eave level band, increase gap between openings
3	Horizontal crack	Install vertical reinforcing bars at each wall to wall junction, anchor attic floor and intermediate floor to walls
4	Bulging/Delamination in UCR wall	Ensuring proper interlocking between outer and inner wythes by proper placement of stone and using adequate through stones
5	Collapse of a portion of wall	Overall improvement in the structure as mentioned above
6	Vertical crack	Ensure proper connection between walls including *Dhajji Diwar*, install eave and/or lintel level continuous bands in all walls, improve diaphragm actions of attic floor and intermediate floor by proper nailing of floor planks, installing floor planks in different diagonal directions in different parts of floor, anchoring floors to walls, improving the in-plane shear strength of *Dhajji Diwar* by installing proper bracing & strut system.
7	Cracking at lintel bearing	Adequate bearing length and connecting lintel and the band
8	Falling off of stone infill in Dhajji Diwar	Providing containment of infill material with chicken wire mesh nailed to wall faces
9	Collapse of *Dhajji Diwar*	Ensuring proper connection between *Dhajji Diwar* and bands
B	**Roof & Floor**	
1	Breaking of individual element	Better maintenance, anchoring of elements to wall bands

No.	Damage	Remedial Action
2	Collapse, partial or full	Better maintenance, anchoring of elements to wall bands , Installing minimum two nails at each joint between floor plank and floor joist.

(**1**. Government of India, October 2005, **2**. IS:4326 – 1993, **3**. IS: 13828 – 1993)

5. Post Earthquake Construction Scenario

The past experiences of NCPDP have shown that after a destructive earthquake much fear prevails about reconstruction of houses using the same materials as before the quake. Due to lack of scientific outlook in our societies myths too quickly take roots. All this brings the traditional housing process to standstill, and new trends come up and soon gain momentum. Kashmir was no exception. (a) People have **lost confidence in their stone construction** and they want to use bricks instead since the engineers have been recommending this. Interestingly they do not have any objection to mud mortar since they saw construction in cement mortar also collapse. But bricks do not provide a viable alternative in the hills. (b) In place of load bearing masonry, a rather **unviable option of RC frame construction** is also making inroads. Very high transportation cost for non-local materials like cement, steel, aggregates, sand etc. and low level of local skills make it non-viable. But people perceive their safety in RC construction rather than in masonry. But NCPDP experience indicates that upgrading of local stone masonry with features shown in Table 4.1 is most viable and most easy to transfer, and hence, replicable.

6. New Construction – Transfer Process

The task on hand required (a) Demonstration of technology that **is viable**, (b) Evolving the details that are **replicable**, (c) Training local masons to inspire **adequate confidence level** so that they can convince their clients to adopt viable alternative that works. All these three requirements could be handled at a hands-on training site where a demonstration construction is taken up. The process was as follows.

(a) **Evolving demonstration structure design**: This was done jointly with the local masons so that an acceptable structure gets built, with no unrealistic features.

(b) **Highlighting weaknesses in vernacular system**: Using working models the masons were made to understand how a structure behaves in an earthquake, where and why failures commonly occur, and how they can be prevented.

(c) **Adherence to basic construction rules**: With the understanding of inherent weaknesses the hands-on training at a real site was initiated right from foundation construction. These weaknesses were prevented through regimentation, if required. Proper UCR masonry construction with proper interlocking, installation of adequate "through stones", breaking of joints, avoiding cavities, proper wall to wall joints through simultaneous construction of all walls or stepped joints etc. formed the core of this part of the training.

(d) **Introduction of earthquake resisting features**: Some of these features required sustained two-way interaction between the trainer and the trainees.

- **Vertical Reinforcement**: It was a great challenge to convince the trainees to a level that they are able to counter the demand for pseudo RC columns made by the house-owner. The resemblance between the behavior of a tree that generally withstands ground shaking and a house that has ductility induced by such reinforcement was used to convince them in favor of the vertical reinforcement against pseudo RC columns.
- **Effective Binding between various Elements**: High emphasis was placed on the need to bind everything together for better performance. Simple example of a canister, or a bus with all components securely inter-connected was used to convince the trainees of the need for such binding. Elements under consideration were…
    - Plinth RC Band with Vertical Reinforcement & with UCR wall above
    - *Dhajji Wall* with UCR walls & with Plinth and Eave level Bands
    - Between various timber elements of *Dhajji Wall*
    - Between timber elements and masonry infill of *Dhajji Wall*
    - Eave Band with Attic Floor Timber
- **Focusing on Economic viability & Replicability**: During the construction of three successive models the following issues were focused on to bring about improvement in a successive manner.
    - Reduction in cement mortar used in finishing of UCR walls – filling of joints against pointing
    - Reduction in timber used in *Dhajji walls,* attic floor, etc.
    - Simple anchoring of *Dhajji wall* to plinth band
    - Simple connection between *Dhajji wall* to eave band
    - Simple connection between eave band and attic floor deck

- **Focusing on Mason's Communication Skills & Building His Confidence**: Systematic input was made to enable the masons to speak the language of their trainer in order to improve the effectiveness in convincing the house-owner. Special videos made of Shock Table Test Programs were effectively used to demonstrate the effectiveness of the technology in the event of an earthquake.

7. Conclusion

The masons trained through a well conceived and intense hands-on training program could be very effective in promoting and implementing the earthquake resisting building technologies at the grassroots in the earthquake prone areas. Short duration training programs consisting of a few training sessions have limited effectiveness in ensuring the long-term safety against the future earthquake disasters.

References:

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2. IS:4326 – 1993 "Earthquake Resistant Design and Construction of Buildings – Code of Practice (Second Revision)
3. IS: 13828 – 1993 "Improving Earthquake Resistance of Low Strength Masonry Buildings – Guidelines")

Shear keys on top of RC Band

Connecting vertical reinforcement to RC Band


Dhajji wall anchor to UCR wall


Dhajji wall anchored to Band & UCR Wall


Dhajji wall with continuous bracings and improved connections


Chicken Wire Mesh confinement on *Dhajji* wall


Shear connector between *Dhajji* wall and Eave Band


Installing MS angle and single rod connectors for roof structure anchoring in eave band


Installation of attic floor framing


Anchoring roof deck to Eave Band


Shahadra mason trainees


Sultan Daki mason trainees