Seismic retrofitting
of
lifeline structures in Uttarakhand

A report

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November, 2012

Preface

Earthquake is a harsh reality in all the tectonically active areas of the world, of which Himalaya is an integral part. The region has been jolted a number of times by earthquakes and has witnessed massive losses in the past. It is however a fact that despite growth in the understanding of the processes responsible for earth's shaking present levels of scientific and technological advancement does not allow precise earthquake forecasting. Nevertheless nature reminds us repeatedly of the approaching threat by the minor tremors that shake us quite often. Magnitude and the likely devastation by the future earthquake as highlighted by the scientific community, specially so for the state of Uttarakhand is a cause of concern for the state government, as also for an organization dedicated to the cause of disaster management in the state.

Our previous encounters with earthquakes convince us of the devastating potential of such events but it is really hard even to visualize the likely damage that can be inflicted by an earthquake that is say 50 or 70 times more powerful than the one that devastated Uttarkashi or Chamoli. Gains of all economic growth and development since the creation of the state can well be eroded in a few seconds of ground shaking.

We all realise the seriousness of the threat. Long periods of quiescence between successive devastating earthquakes however dilute our focus from earthquake safety related issues and it is not easy to sustain the level of enthusiasm on this important issue amongst the masses as also the policy makers. This is reflected in the proliferation of inappropriate construction practices which is responsible for enhanced seismic vulnerability of the built environment.

The nature of losses inflicted by seismic events across the globe clearly show that investments made on seismic safety related features pay rich dividends and magnitude of the loss is clearly relatable to the nature and quality of infrastructure in the area. Assessment of the likely seismic performance of the existing building stock and taking measures for improving seismic performance of the buildings have the potential of minimizing the earthquake induced losses.

This publication focuses on retrofitting of existing structures and is based upon the experiences gathered while undertaking retrofitting of four Government Inter Collages in Dehradun and Tehri Garhwal districts of Uttarakhand. It is hoped that the publication besides providing an overview of the retrofitting technique would also be useful for those interested in carting out retrofitting of their structures.

We, at Disaster Mitigation and Management Centre encourage you to share, discuss and debate over the contents of this publication so as to bring forth awareness amongst the masses on this highly important and pertinent issue. We welcome your comments and quarries on the report and we value both.

Financial support for undertaking retrofitting of the schools by Temasek Foundation through Nanyang Technological University, Singapore is gratefully acknowledged. Cooperation, support and guidance from Mr. Gerald Yeo of Temasek Foundation, Prof. Bing Li and Prof. Huang Yin – Nan of NTU and Prof. D.K. Paul and Prof. Yogendra Singh of IIT, Roorkee is highly appreciated. Cooperation from all involved in facilitating the program at NTU Singapore is acknowledged.

Effort put in by Mr. Manik Jain and Mr. Piyush Bharti of PEC University of Technology, Chandigarh in documenting various retrofitting steps is acknowledged. Mr. S.A. Ansari of UCMCA carried out the retrofitting and this work would not have been completed proficiently without his experience and innovative spirit. Workmanship and dedication of the entire UCMCA team is appreciated.

Hard work and effort put in by Dr. Girish Chandra Joshi from the inception of the concept to the actual execution of the retrofitting work is appreciated. The colleagues at DMMC are thanked. But for their cooperation and encouragement this would not have been possible.

We acknowledge guidance and support from the Chief Secretary, Government of Uttarakhand Shri Alok Kumar Jain, Principal Secretary, Disaster Management, Government of Uttarakhand Shri Om Prakash and Secretary, Disaster Management, Government of Uttarakhand Shri D.S. Garbyal.

6th November, 2012
DMMC, Uttarakhand Secretariat

(Piyoosh Rautela)
Executive Director, DMMC

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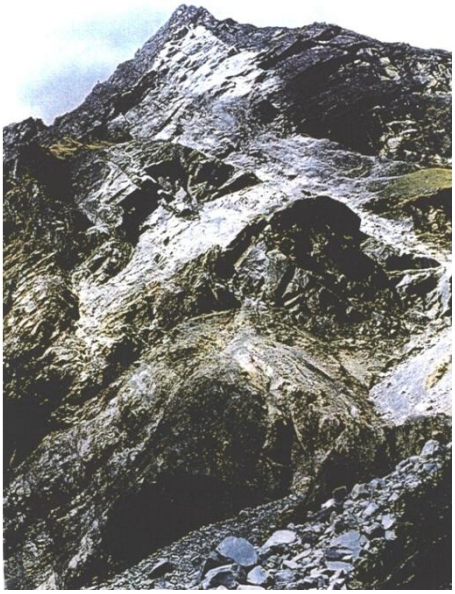
Introduction

The state of Uttarakhand comprises of 13 districts that are grouped into two divisions (Kumaun and Garhwal) and has a total geographical area of 53,484 sq km. The state has a population of 1,01,16,752 (Census of India, 2011) of which rural population constitutes about 69 percent of the total (70,25,583). The child population (0 - 6 years) of the state is 13,28,844. There are 69,97,433 literates in the state and the total agricultural area of the state is about 9, 83,967 hectares.

The state is connected by road, rail and air and there are two civilian airports (Jolly Grant in Dehradun and Pantnagar in Udham Singh Nagar) and three airstrips (Naini Saini in Pithoragarh, Chinyalisaur in Uttarkashi and Gauchar in Chamoli).

The state comprises mostly of the rugged hilly terrain that and is prone to natural disasters by virtue of its evolutionary history. The state has witnessed two major earthquakes in the recent past (Uttarkashi 1991 and Chamoli 1999) besides a number of landslides (Figs. 1 and 2) that are common in the state especially during the monsoon season.



Figs. 1 and 2: View of the Malpa and Varunavrat landslides in the state.

Hailstorms, cloudbursts, flash floods, forest fires, avalanche and drought are other calamities to which the state is vulnerabile. Every year the state faces

massive losses and small and marginal farmers of the hills lose substantial portion of their agricultural lands permanently in these events.

Monsoon season coincides with the pilgrim season and people in large numbers visit the state. Disruption of roads due to disasters (Figs. 3 and 4) causes many hardships to the people visiting the state, as also to local people.

Figs. 3 and 4: View of the disruption of transport network by landslides in the state.

Hill agriculture in the state has some distinctive peculiarities that include; i) small landholdings; almost all farmers being small and marginal farmers, ii) the agriculture is of subsistence type and yields little or no marketable surplus and iii) most agricultural land is rain fed. Fluctuations in meteorological parameters therefore, have severe adverse impact upon the lives of common people. Soil loss, soil degradation, soil erosion and arable land lost to land slide or subsidence adversely affect life support strategy of the masses.

The remote and hilly topography of the region affords limited economic opportunities and the purchasing power of the rural hill folk is generally low. Therefore, disaster affected communities have to be provided assistance over extended periods so as to help them re-establish their livelihoods.

Recurring and ever increasing disaster induced losses hamper the pace of growth and development in the state and warrants efforts from every quarter to reduce human misery as also economic losses due to disasters.

Uttaakhand: Disaster vulnerability

Continued subduction of the Indian Plate beneath the Eurasian Plate consumed the intervening oceanic plate and led to the collision of the alien landmasses. This caused deformation, upliftment, metamorphism and shearing of the sediments deposited in the hitherto intervening ocean basin (Tethys) along with the rock mass of the two Plates involved in orogeny. Since the Plate collision around 55 Ma the Indian Plate is continuously drifting north – northeastward at an average rate of 45 – 50 mm/year (Besse and Courtillot, 1988, Dewey et al., 1989). Global Positioning System (GPS) measurements conclusively indicate that the Indian Plate is moving northeast at a rate of 55 mm/year of which 18 – 22 mm/year is accommodated within the Himalaya (Bilham et al., 1997) and the remaining is taken care of further north in Tibet and Asia (Avouac and Tapponier, 1993, Peltzer and Saucier, 1996). This ongoing convergence is responsible for both neotectonism and seismicity in Himalaya, Tibet and the adjoining areas.

The Himalaya has been seismically active and has witnessed four great earthquakes (Mw $\geq$ 8.0) in the previous 113 years; 1897 Western Assam, 1905 Kangara, 1934 Bihar – Nepal and 1950 Eastern Assam (Arunachal) earthquakes. Arya (1990) indicates possibility of around 80,000 persons being killed if the 1905 event repeats during daytime. Validated by the toll of the 2005 Kashmir Earthquake this assertion highlights the issue of rising seismic vulnerability in the region due to rapid growth of population and infrastructure. Entire Indian Himalaya falls in Zone IV and Zone V of Earthquake Zoning Map of India (IS 1893:2002, Part 1) and in the state of Uttarakhand entire area of Pithoragarh, Bageshwar, Chamoli and Rudraprayag districts and some area of the Almora, Champawat, Tehri, Uttarkashi and Pauri Garhwal districts fall in Zone V. In the recent past (1991 and 1999) the state of Uttarakhand has witnessed two moderate magnitude earthquakes with their epicenters at Uttarkashi and Chamoli respectively. The state however falls in the seismic gap of 1935 and 1905 great earthquakes and has not witnessed a major

earthquake for more than previous 200 years. This enhances seismic risk in the region.

Evolutionary history of the terrain, geotectonic setup of the rocks, ongoing tectonic activities, high relative relief and concentrated seasonal precipitation together make the state of Uttarakhand prone to a number of natural hazards. Besides earthquakes the area is frequently devastated by landslides, cloudbursts, flash floods, floods, avalanches, droughts, lightening, cold waves and hailstorms.

Geo-tectonic history of the rocks comprising the terrain makes the state highly prone to mass wastage and enhanced pore water pressure together with increased down-slope ward forces and reduced frictional forces aggravate this problem during the monsoon season. Landslides in the state are particularly common along two zones lying in close proximity of two major tectonic discontinuities i.e. Main Boundary Thrust (MBT) and Main Central Thrust (MCT).

During spells of concentrated and abnormally high rainfall events the hilly areas often face large scale devastation due to cloudburst and flash floods while the downstream plains face the problem of flood and water logging. A number of human lives are lost in these events almost every year (Fig. 5).

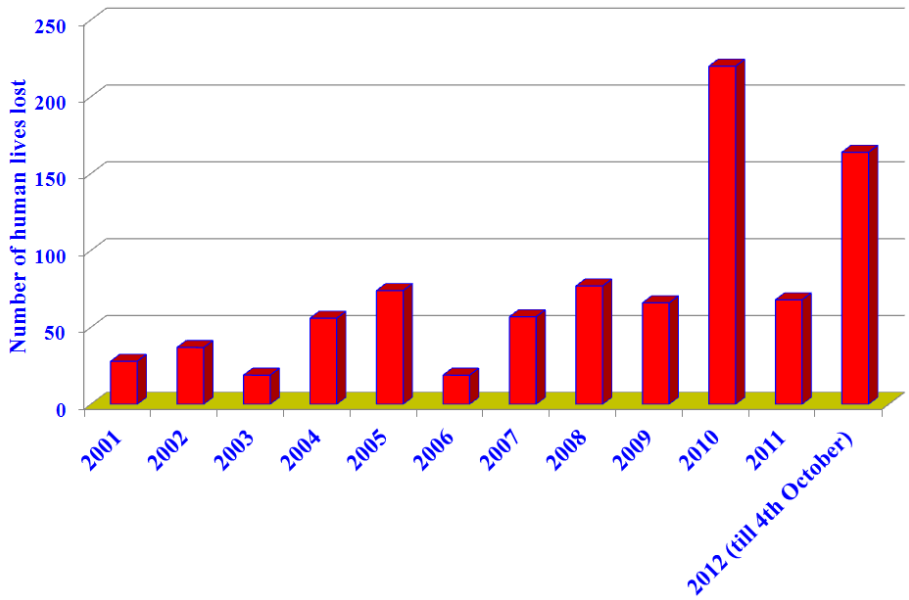


Fig. 5: Year wise loss of human lives due to natural disasters in Uttarakhand.

Every year, the state faces massive losses, particularly during the monsoon season, due to rain, landslide, cloudburst, flood, water logging and flash flood events. These cause disruption of transport infrastructure, water supply, telecommunication and huge quantum of private and public infrastructure is routinely lost.

Besides natural disasters, the state also experiences significant human life loss due to road accidents (Fig. 6), particularly during the monsoon season, which also coincides with the *Yatra* (pilgrimage) season.

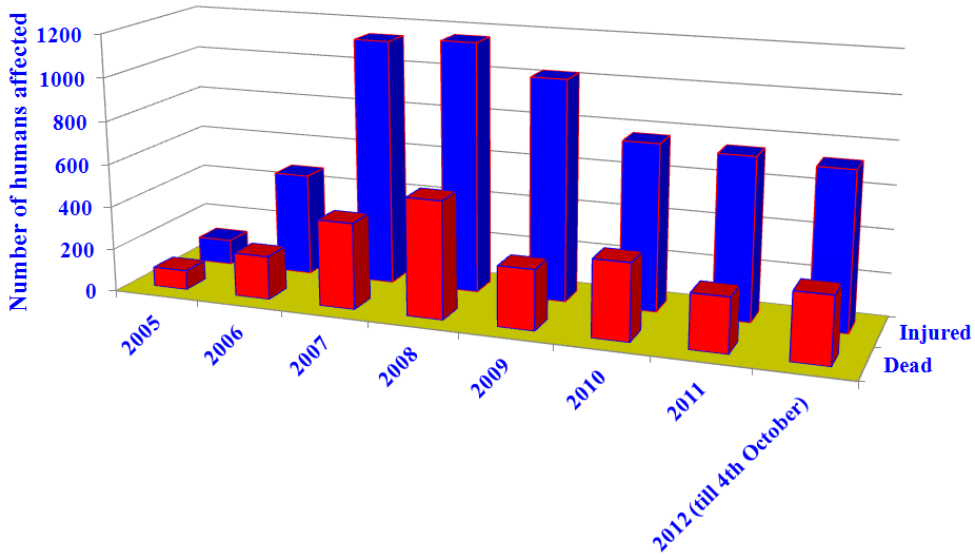


Fig. 6: Year wise loss of human lives due to road accidents in Uttarakhand.

Despite being vulnerable to many disasters earthquake is a major concern for the state of Uttarakhand because of the magnitude of the loss it can inflict. Seismic risk is however a direct function of the state of built environment or vulnerability of the building stock. Improving the seismic performance of the built environment is therefore highly important and this exercise should logically start from lifeline infrastructure.

Uttarakhand: Disaster impact and the way forward

Repeated disaster incidences adversely affect the pace of economic growth and development and these impose recurring and ever increasing pressure upon the public exchequer. This seriously warrants efforts from every quarter to reduce human miseries as also economic losses due to disasters in Uttarakhand.

Despite being prone to multiple disasters and having suffered major losses by landslides and flash floods (Table 1) earthquake remains major concern for Uttarakhand.

Table 1. Losses incurred by landslides in Madhyamaheshwar and Kali Ganga valleys in August 1998.

Sl. No.	Head	Number
1.	Human lives lost	103
2.	Affected villages	34
3.	Affected families	1,767
4.	Affected population	9,792
5.	Cattle loss	423
6.	Houses damaged	1,276
7.	Agriculture land loss (in ha)	411

In the previous 20 years this region has experienced two earthquakes of magnitude more than 6 on Richter Scale (Uttarkashi, 1991 and Chamoli, 1999). These earthquakes, though of moderate magnitude caused immense loss of life and property (Table 2) which highlights the vulnerability of the built environment and warrants action for reducing seismic vulnerability.

Table 2. Summary of losses incurred in 1991 Uttarkashi and 1999 Chamoli earthquakes.

	1991 Uttarkashi Earthquake	1999 Chamoli Earthquake
Human lives	768	106
Injured humans	5,066	395
Cattle lost	3,096	327
Houses damaged (full)	20,242	14,724
Houses damaged (partial)	74,714	72,126

Despite immense scientific progress there still exists high degree of uncertainty in earthquake prediction, in space and time. Thus for reducing earthquake induced losses one is left with the only option of ensuring adequate performance by the built environment during an earthquake event. Changes in

the techno-legal regime and ensuring compliance of the same together with strengthening the existing infrastructure to improve its seismic performance are thus identified as high priority areas warranting prompt action.

In an effort to assess and reduce the vulnerability of the built environment and that of the communities to various disasters, Disaster Mitigation and Management Centre (DMMC) of the Department of Disaster Management, Government of Uttarakhand has undertaken a number of initiatives over the past several years. Significant amongst these include, i) awareness generation to ensure voluntary compliance of disaster safe technologies and development of audio-visual information, education and communication (IEC) material in vernacular, ii) inclusion of disaster management in school curriculum to help raise awareness levels of the masses, iii) training of masons and petty contractors in earthquake safe construction practices to address the basic fact that most constructions in the state are non-engineered, iv) inclusion of earthquake safety measures in building bye laws, v) assessment of seismic vulnerability of the built environment using rapid visual assessment (RVA) technique, vi) seismic retrofitting of the few public buildings in particular the schools, and vii) training of engineers and architects in earthquake safe construction and retrofitting of existing structures.

In order to take this mandate further DMMC joined hands with Temasek Foundation and Nanyang Technological University (NTU), Singapore to implement training and capacity-building programme on seismic strengthening of master and local builders in Uttarakhand. Financial support for this initiative was channelised through NTU by Tamseak Foundation, Singapore. Indian Institute of Technology (IIT), Roorkee provided technical support for ensuring successful implementation of this program.

The objective of this initiative was to undertake demonstration strengthening (retrofitting) of four identified school buildings against earthquake loads and to enhance the capacities of the local masons through their involvement in this exercise. After primary survey of a number of school building to assess their

suitability for being included in this exercise four government schools at Ranipokhri, Dobhalwala (both in district Dehradun), Fakot and Nainbagh (both in district Tehri Garhwal) were selected under this program for being retrofitted. 80 local masons were also trained in earthquake safe construction practices as also in seismic retrofitting techniques during the course of the retrofitting exercise. Given below are the various important steps taken for successful completion of this initiative.

1. Selection of two schools each in Dehardun and Tehri Garhwal districts of Uttarakhand for seismic retrofitting works.
2. Identification of suitably qualified persons for being trained as master trainers. These were intended to help in the execution of the retrofitting works besides training the local masons.
3. Training of master trainers at the Department of Earthquake Engineering, IIT Roorkee.
4. Analysis of the building weaknesses and preparation of detailed retrofitting plan.
5. Identification of the 80 local builders and masons for engaging them in the retrofitting training program to be organised during the execution of the retrofitting works.
6. Actual execution of the retrofitting works in accordance with the plan so prepared for the same.
7. Awareness generation to promote seismic retrofitting methods in the other schools.

Seismic retrofitting

Earthquakes are known to differentially effect the built environment of the affected area. Damage incurred by the structures is a function of the performance of the buildings during an earthquake event and it is universally recongised that the losses can be significantly reduced by conscious efforts to improve the seismic performance of the buildings.

Seismic retrofitting is a technique of improving building performance during an earthquake event by introducing suitable modifications in the existing structures so as to make these more resistant to seismically induced ground motions and / or soil failure events. Better understanding of seismic demand on structures through recent seismic experiences has led to universal acknowledgement of the need of seismic retrofitting. Prior to the introduction of modern seismic codes, in late 1960s in developed countries and in late 1970s in many other parts of the world, most structures were designed without adequate detailing and reinforcement for seismic protection.

Seismic retrofitting is therefore a technique of providing more resistance to seismic activity in the existing structures. In the buildings this process typically includes strengthening of weak connections that are generally found in roof to wall connections, continuity ties, shear walls and the roof diaphragms. Retrofitting is thus a combination of technical interventions in structural system of an existing building that include actions amed at upgrading its seismic resistance so that it becomes safer under the effect of probable future earthquakes. Retrofitting is thus intended to improve the resistance to earthquake activity by optimizing the strength, ductility and earthquake loads.

It is worth noting that the strength of the buildings is generated from their structural dimensions, materials, shape, and number of associated structural elements and retrofitting attempts at improving the building strength through well planned structural interventions in these features of the building.

The required ductility in a building is primarily achieved through good detailing together with quality and type of materials used while the earthquake load is a function of the site response, mass of the structure, and the degree of seismic resistance in the building. In the light of these facts retrofitting involves introduction of appropriate interventions in the building so as to enable it to perform better during earthquakes.

Retrofitting need

Retrofitting is needed where the assessment of structural capacity of the building indicates insufficient capacity to resist the forces of expected earthquake intensity and the ensuing damage is likely to exceed the acceptable limits. It is important to note that poor quality of materials and damage to structural elements are not the sole reasons for retrofitting a building. Changes in the building's function, environmental conditions and building codes could also give rise to retrofitting need.

Execution of retrofitting work

Retrofitting is a technical exercise and has to be undertaken under the supervision of trained and experienced personnel. In most retrofitting works structural engineer has a major role to play. Structural capacity of the building has to be first assessed and analyzed based on which appropriate retrofitting technique has to be designed so as to eliminate the structural deficiencies.

Before taking up any building for retrofitting it is always advisable to assess the appropriateness of this exercise. Some of the factors that are considering are briefly discussed below.

a) ***Technical aspects***: This includes testing of building materials and structural analysis. These help in understanding the condition of the structures in relation to the existing building codes.

b) ***Cost implications***: Cost benefit analysis must be carried out before the decision to retrofit a building is taken. The cost likely

to be incurred on retrofitting has to be compared to the cost of reconstruction of the same.

c) ***Importance of building***: Each building is built for a specific purpose. Moreover some old buildings have additional significance attached to them. The importance of the building has therefore to be considered while deciding to go in for retrofitting of the same.

d) ***Availability of adequate technology***: Some of retrofitting techniques require a high end technology to implement it. Availability or access to the technology has to be therefore considered while deciding to go in for retrofitting.

e) ***Skilled workmanship to implement the proposed measures***: For successful retrofitting availability of skilled workmen is a major constraint and therefore this aspect has to be considered while deciding to go in for retrofitting.

f) ***Duration of works***: Some of retrofitting works might be over in a short duration while the others might take long duration to complete. Hence, it is important to take into the consideration the duration of works.

Advantages of retrofitting

Advantages that retrofitting enjoys over the reconstruction of a building are as enumerated below.

a) ***Operational convenience***: Retrofitting can be carried out while the building is still operational so the functional aspects related to the structure need not be shut down or transferred to an alternative location.

b) ***Economy***: The option of retrofitting is generally recommended where it works out to be a cost effective as compared to

reconstruction. The economic aspects can however be overlooked in case of heritage buildings.

c) ***Resource constraints***: Retrofitting generally requires less of resource mobilisation.

d) ***Time***: Retrofitting generally takes less time as compared to reconstruction.

e) ***Maintenance of original building configuration***: Retrofitting does not significantly change the building configuration and shape. This is particularly important when dealing with buildings with cultural, historical and architectural significance.

f) ***Pollution***: Retrofitting of the building results in less debris as compared to reconstruction. It is therefore a relatively greener option of ensuring building safety.

Retrofitting process

A building has to undergo three steps before it is considered for seismic retrofitting. These are screening, evaluation and retrofit.

a) ***Screening*:** Screening entails assessment of the buildings so as to ascertain the level of seismic risk these are exposed to. A simple and relatively non-technical procedure is adopted for this and the main objective is to determine if the building requires to be investigated in detail. Major factors that are taken note of under this exercise include i) building location, ii) soil condition, iii) type and uses of the structure, iv) obvious building irregularities, v) presence and absence of non-structural hazards, vi) building age, vii) building importance and viii) occupancy characteristics.

b) ***Evaluation*:** In the evaluation process, detailed investigation is performed on buildings that show medium to high priority in the screening exercise. The objective at this stage is to evaluate the performance of the buildings and to identify the vulnerabilities in

structural and non-structural systems together with their components with regard to the seismic load.

c) ***Retrofit (retrofit)*:** Seismic retrofit becomes necessary if seismic performance evaluation shows that the building does not meet the requirements as enumerated in the current building code and is likely to suffer severe damage or even collapse during a seismic event. The retrofitting of a building requires an appreciation for the technical, economic and social aspects of the issue in hand. Change in construction technologies and innovation in retrofit technologies present additional challenge to structural engineers in selecting a technically, economically and socially acceptable solution.

Levels of modification

Level of safety to be introduced in an existing structure through retrofitting would have major implication upon the resources likely to be mobilised for undertaking the same. Decision on the level of retrofitting is generally taken on the basis of the importance and use of the building; public safety however gets the highest priority. Various points to be considered before deciding on the level of retrofitting are as given below.

a) ***Public safety only*:** The goal is to protect human life, ensuring that the structure does not collapse upon its occupants or passerby, and that the occupants get enough time to make a safe exit. Under severe seismic shaking conditions the structure might be rendered useless, requiring demolition and reconstruction.

b) ***Structure survivability*:** The goal is to ensure that the structure remains safe for exit and can be put to use after extensive repair. The option of reconstruction is thus ruled out. This is typically the lowest level of retrofit applied to bridges.

c) ***Structure usability*:** The goal here is to ensure that the functional aspects of the building are not disrupted by seismic event. The structure may however require extensive repair or replacement of components so as to ensure that it performs satisfactorily during the next major seismic event. This is typically the lowest level of retrofit recommended for lifeline structures. It is often the most economical level of retrofit option for transportation infrastructure such as rail and highways, bridges and tunnels. This level of retrofit is also required for the water supply and fire fighting infrastructure that are required to function after an earthquake.

A high level of retrofit is required for ensuring that the primary structure is undamaged and its functionality is maintained after an earthquake. This level of retrofit ensures that the repair related requirements after an earthquake are of cosmetic nature; for example minor cracks in the walls. This is the minimum acceptable level of retrofit for hospitals.

d) **Structure unaffected:** This level of retrofit is preferred for historic structures of high cultural significance.

Retrofitting methods for URM buildings

There exist a number of methods for undertaking seismic retrofitting of structures. Depending of the retrofitting objectives that include increase in the load, deformation, and / or energy dissipation capacity of the structure (FEMA, 2000) together with availability of resources and technical expertise a suitable retrofitting methodology can be chosen. Various common methods of retrofitting of unreinforced masonry (URM) buildings are described in the sections below.

Surface treatment

Surface treatment is a common method that has largely been developed through experience. It incorporates different techniques that include i) ferrocement, ii) reinforced plaster, and iii) shotcrete. This treatment is intended to cover the masonry exterior and affects the architectural or historical appearance of the structure.

Ferrocement

Closely spaced multiple layers of hardware mesh of fine rods with reinforcement ratio of 5 - 8 percent that are completely embedded in a high strength (15 - 30 MPa) cement mortar layer of 15 - 60 mm in thickness makes the ferrocement reinforcement. The mortar is trowelled on through the mesh with covering thickness of 1 - 5 mm. The mechanical properties of the ferrocement depend on the mesh properties. However, typical mortar mix consists of 1 part cement and 1.5 - 3 parts sand with water - cement ratio of 0.4. The behaviour of the mortar can be improved by adding of a low - cost fibre, such as polypropylene. Ferrocement is ideal for low cost projects as it is cost effective and can be carried out by not so skilled workers. It improves both, in - plane and out – of - plane behaviour. The mesh helps in confining the

masonry units after cracking and thus improves the in -plane inelastic deformation capacity.

Reinforced plaster

This method consists of application of a thin layer of cement plaster over high strength steel reinforcement. The steel can be arranged in diagonal or vertical and horizontal mesh configuration. The strength improvement through this method depends on, i) thickness of strengthening layer, ii) cement mortar strength, iii) reinforcement quantity, iv) means of reinforcement bonding with the retrofitted wall, and v) degree of masonry damage.

Shotcrete

This method involves spraying of **s**hotcrete overlays over the surface of a masonry wall across a mesh of reinforcing bars. The shotcrete overlay is typically reinforced with a welded wire fabric at about minimum steel ratio for crack control. The thickness of the shotcrete can be adapted to the seismic demand. In order to transfer the shear stress across shotcrete - masonry interface, shear dowels are fixed using epoxy or cement grout into the holes drilled into the masonry wall. Shotcrete significantly increases the ultimate load of the retrofitted walls. This technique dissipates high - energy due to successive elongation and yield of reinforcement in tension. Shotcrete is relatively convenient and cost effective as compared to in - situ cast jackets.

Grout and epoxy injection

Grout injection is a popular strengthening technique as it does not alter the aesthetic and architectural features of the existing building. The main purpose is to restore the original integrity of the retrofitted wall and to fill the voids and cracks that have developed in the masonry due to physical and chemical deterioration and / or mechanical action. In multi - wythe masonry walls grout injection into the empty collar joint enhances composite action between

adjacent wythes. The success of a retrofit by injection depends on the injectability of the mix used and the injection technique adopted. The injectability of the mix is influenced by its mechanical properties as also physical and chemical compatibility with the masonry to be retrofitted. For injection, epoxy resin is generally used for relatively small cracks (less than 2 mm wide) while cement based grout is considered to be more appropriate in case of larger cracks, voids, and empty collar joints in multi-wythe masonry walls. This retrofitting technique improves the overall behaviour of the retrofitted URM.

External reinforcement

Steel plates or tubes are used as external reinforcement in the existing URM buildings. Steel system can also be attached directly to the existing diaphragm and wall. In one of the methods horizontal elements are connected to two vertical members (via pin connections) that are placed next to the existing wall thereby creating an in - fill panel.

Relative rigidity of the original structure and the steel bracings being used as a retrofitting measure is an important factor to be taken into consideration as in an earthquake, cracking in the original masonry structure is expected and after sufficient cracking has occurred, the new steel system would have comparable stiffness and would be effective (Hamid *et al*. 1996, Rai and Goel 1996).

Confining URM using RC tie columns

Confined masonry with RC frame system represents one of the most widely used masonry construction systems in Asia and Latin America. The basic feature of confined masonry structures is vertical RC or reinforced masonry tie columns that confine the walls at all the corners and wall intersections as well as at the vertical borders of door and window openings. In order to be effective, tie columns have to connect with tie beams along the walls at floors level. The confinement prevents disintegration and improves ductility and

energy dissipation in URM buildings, but has limited effect on the ultimate load resistance. The amount of reinforcement and concrete dimensions for this system is determined on the basis of experience, and depends on the height and size of the building. Generally used in new structures, such confinement is hard to be achieved in existing masonry buildings.

Post – tensioning

Post - tensioning involves application of compressive force to masonry wall. This force counteracts the tensile stresses resulting from lateral loads. This technique is mainly used for retrofitting of structures characterized as monuments. This is partly due to the lack of knowledge about the behaviour of post - tensioning masonry. Alloy steel thread bars are used as post – tensioning tendons, although mono - strand tendons are not very uncommon. Major drawback of using steel bars lies in their corrosion. Fiber reinforced plastics however present a promising solution to this problem. Tendons are placed inside steel tube (duct) either within holes drilled along the mid plane of the wall or along groves symmetrically cut on both the surfaces of the wall. Holes are then cement grouted and external grooves are filled with shotcrete. It is worth noting that the tendons are fully restrained and not free to move in the holes. This holds good even if the tendon is unbounded i.e. no grout is injected between the duct and the tendons. Moreover leaving the holes un - grouted simplifies the strengthening procedure and allows future surveillance, re - tensioning, or even removal of the post - tensioning bars. Anchorage of post - tensioning in masonry is however more complicated than in RC as masonry has a relatively low compressive strength.

Centre core technique

The centre core system consists of a reinforced, grouted core placed in the centre of an existing URM wall. A continuous vertical hole is first drilled from the top of the wall to its base. Depending on the thickness of the URM wall

and the retrofitting requirement the diameter of the same may vary between 50 and 125 mm. With existing technology, this core can be drilled precisely through the entire height of two or three storey masonry wall. The drilling is a dry process with the debris removal being handled by a vacuum and filter system that keeps the dust to a minimum. After placing the reinforcement in the centre of the hole filler material is pumped from the top of the wall to the bottom so that the core is filled from the bottom under pressure that is controlled by the height of the grout. The vertical structural member provides strength to the wall and enhances its capacity to resist both in - plane and out – of - plane loading.

State of the schools before retrofitting

Preliminary survey of a number of schools in Dehradun and Tehri Garhwal districts was first undertaken (Fig. 7). The selection of schools for retrofitting was done on the basis of, i) logistics, that included proximity to the road, ease of approach, availability of local builders and masons and construction material, ii) impact, that included proximity to the habitations, prominence or visibility, and iii) condition of the building and retrofitting requirement.

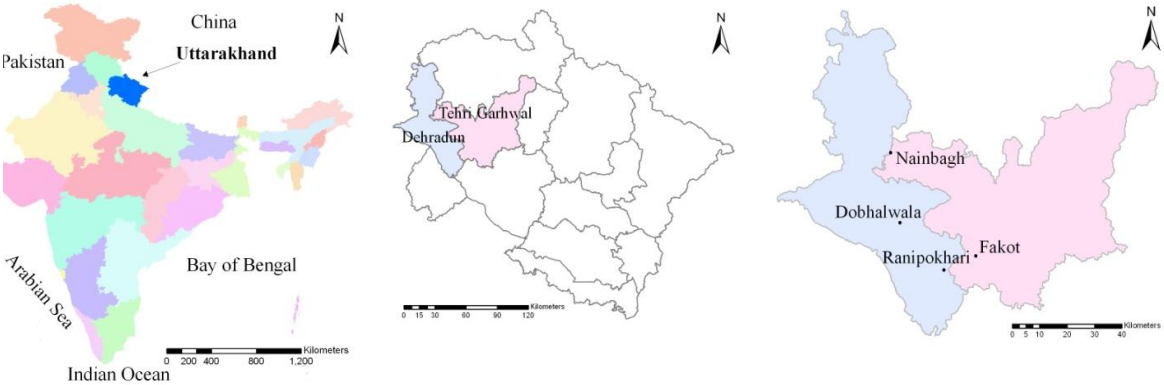


Fig. 7: Location of the schools selected for retrofitting.

Following four schools were thus selected (Fig. 7). The details of individual schools are provided in the subsequent sections.

Sl. No.	**District**	**School**
1.	Dehradun	Government Girls Inter College, Ranipokhri
2.	Dehradun	Government Inter College, Dhobhalwala
3.	Tehri Garhwal	Government Inter College, Nainbaag
4.	Tehri Garhwal	Government Inter College, Fakot

Government Girls Inter College, Ranipokhari, Dehradun

Building Details: The school is situated at Ranipokhri that is situated at a distance of 25 km from Dehradun on Dehradun – Rishikesh highway. The school was observed to have been constructed in many stages with the oldest part being constructed around 55 years ago. There are five blocks in the school designated A, B, C, D and E respectively. The school has 20 rooms including the kitchen, computer room and office. All the blocks are single storeyed and Figure 8 shows the layout of the school building.

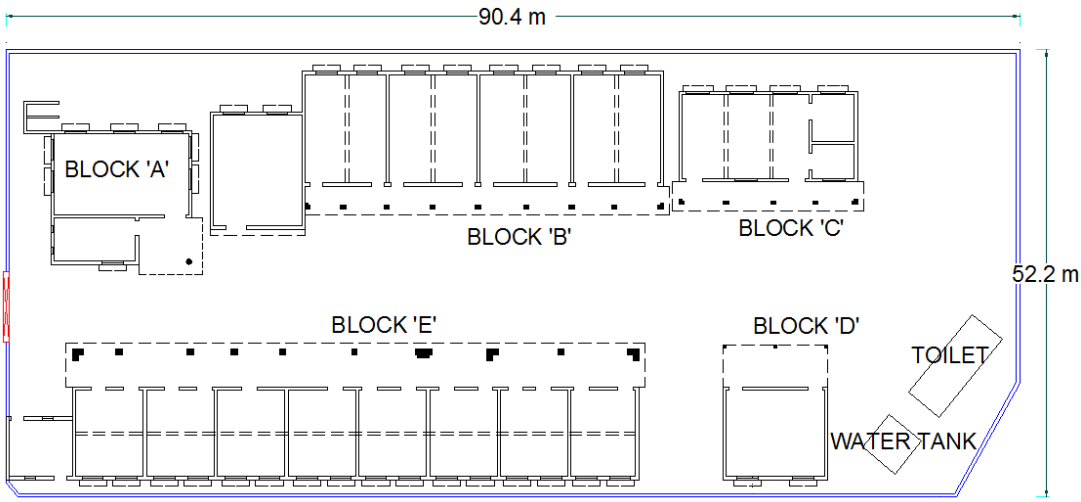


Fig. 8: Layout of the school building at Ranipokhri, Uttarakhand.

The school is constructed on a uniform plane with all the blocks being situated at the same elevation. Being a single storey structure it has a unique centre of mass and centre of stiffness through which the design eccentricity is calculated.

Except for C and D blocks that have a height of 3.7 meters all other blocks have a height of 3.0 meters. With increase in the height of the structure its seismic vulnerability is generally enhanced as the building height is proportional to the amount of forces it has to resist during an earthquake. Figures 9 and 10 depict the state of the school building before retrofitting.

Fig. 9: Photograph of the school building block 'B' at Ranipokhri, Uttarakhand

Fig. 10: Photograph of the school building Block 'A' at Ranipokhri, Uttarakhand.

Government Inter College, Dhobhalwala, Dehradun

Building Details: The school is situated in Dehradun city at a place called Dobhalwala. The school was observed to have been constructed in many stages and its oldest portion was constructed about 45 years ago. There are six blocks in the school designated A, B, C, D, E and F. All the blocks are single storeyed. Figure 11 shows the layout of school building.

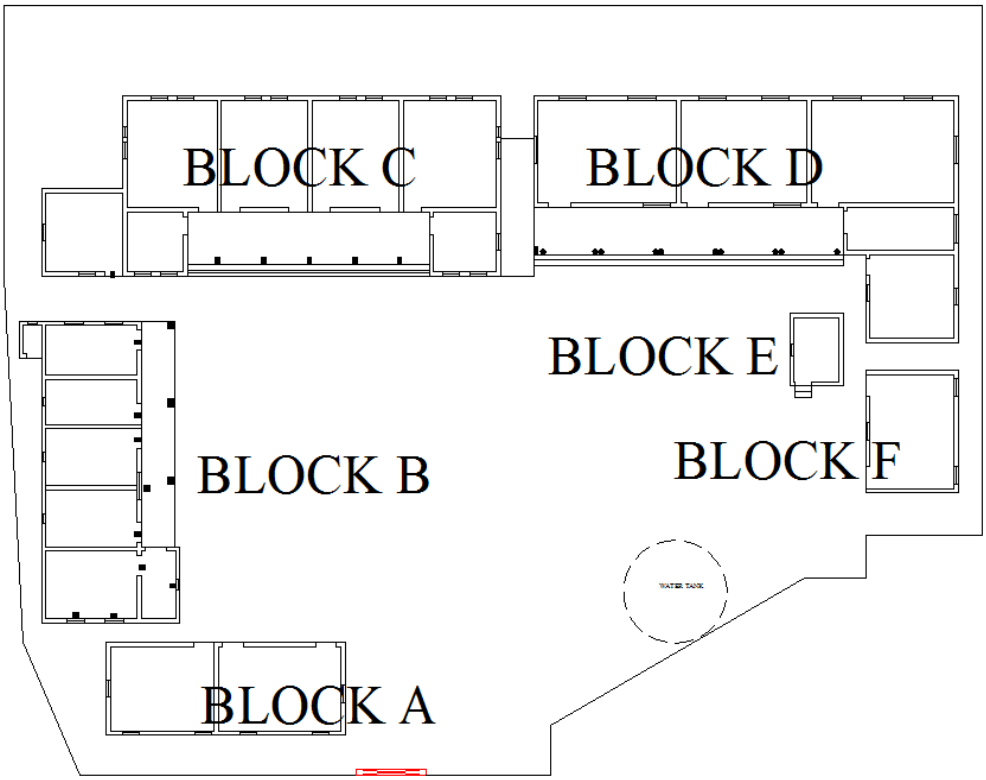


Fig. 11: Layout of the school building at Dobhalwala in Dehradun city.

The school is constructed on a uniform ground with all the blocks being located at the same elevation. Being a single storey structure the building has a unique centre of mass and centre of stiffness through which the design eccentricity is calculated. Except for C and D blocks that have height of 3.7 and 4.2 meters respectively all other blocks have a constant height of 3.0 meters.

Some parts of B and C blocks were observed to be wrecked. Honeycombing was clearly visible in the roof in some parts (Fig. 12). Honeycombing refers to voids in concrete that are caused by the mortar not filling the spaces between the coarse aggregate particles. It is an aesthetic problem but depending on the depth and extent it may reduce durability, performance and structural strength of concrete.

Fig. 12: View of oneycombing in the roof of the structure.

Fig. 13: Exposed steel reinforcement of the roof.

A part of the A block was observed to have been constructed using random rubble (RR) masonry of 230 mm thickness while the rest was constructed using brick masonry. The roofs of most of the blocks were not in good condition. This is owed to i) honeycombing of concrete, and ii) exposure of steel reinforcement (Fig. 13). The exposed reinforcement is prone to corrosion and the corroded steel reinforcement is often not able to bear the imposed loads properly.

In addition, bleeding of concrete was visible in few portions of the roof. Bleeding is a particular form of segregation in which some of water from the concrete comes out to the surface of the concrete, as water has the lowest

specific gravity amongst all the ingredients of concrete.

Cracks of several kinds were clearly visible in the building (Figs. 14 and 15). These include structural cracks, shear and diagonal cracks, lack of regular maintenance and construction cracks due to joining of two different structures.

Fig. 14: Joint crack observed in the school building at Dobhalwala.

Fig. 15: Shear / diagonal crack observed in the school building at Dobhalwala.

Government Inter College, Nainbagh, Tehri Garhwal

Building Details: The school is situated at Nainbagh on Yamunotri National Highway. Nainbagh is located at a distance of 40 and 50 kilometers respectively from Mussoorie and Vikasnagar. The school was observed to have been constructed in stages with its oldest portions being constructed about 35 years ago. The school has 18 rooms including kitchen, computer room and office. All the blocks are single storeyed constructions. The school is constructed on a uniform ground. The school is a double storey structure with no irregularities (Figs. 16 and 17). It therefore has a unique centre of mass and centre of stiffness through which the design eccentricity is calculated.

Figs. 50 and 51: View of Government Inter College Nainbagh, Tehri Garhwal.

Only one block was considered for retrofitting (Fig. 18). This block had a constant height of 3.8 meters for ground floor and 3.2 meters for the first floor.

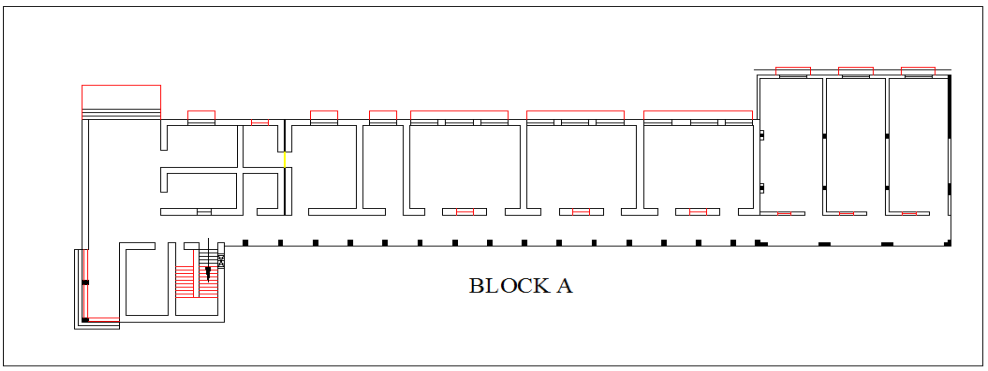


Fig. 18: Layout of the school building at Nainbagh in Tehri Garhwal district.

Government Inter College, Fakot, Tehri Garhwal

Building details: The school is situated at Fakot (near Agrakhal) on Rishikesh – Gangotri National Highway. The construction of the school was observed to have been done in many stages (Figs. 19 and 20).

Figs. 19 and 20: Government Inter college Fakot, Tehri Garhwal.

The oldest part of the school was constructed about 25 years ago. There are five blocks in the school designated A, B, C, D and E (Fig. 21). Of these A block is double storeyed while the rest are single storeyed. The school has 21 rooms including the kitchen, computer room and school office. The school is constructed on an uneven plane with A block being located at the highest elevation. Ground floor of this block had a height of 3.08 meters while the first floor had a height of 2.5 meters.

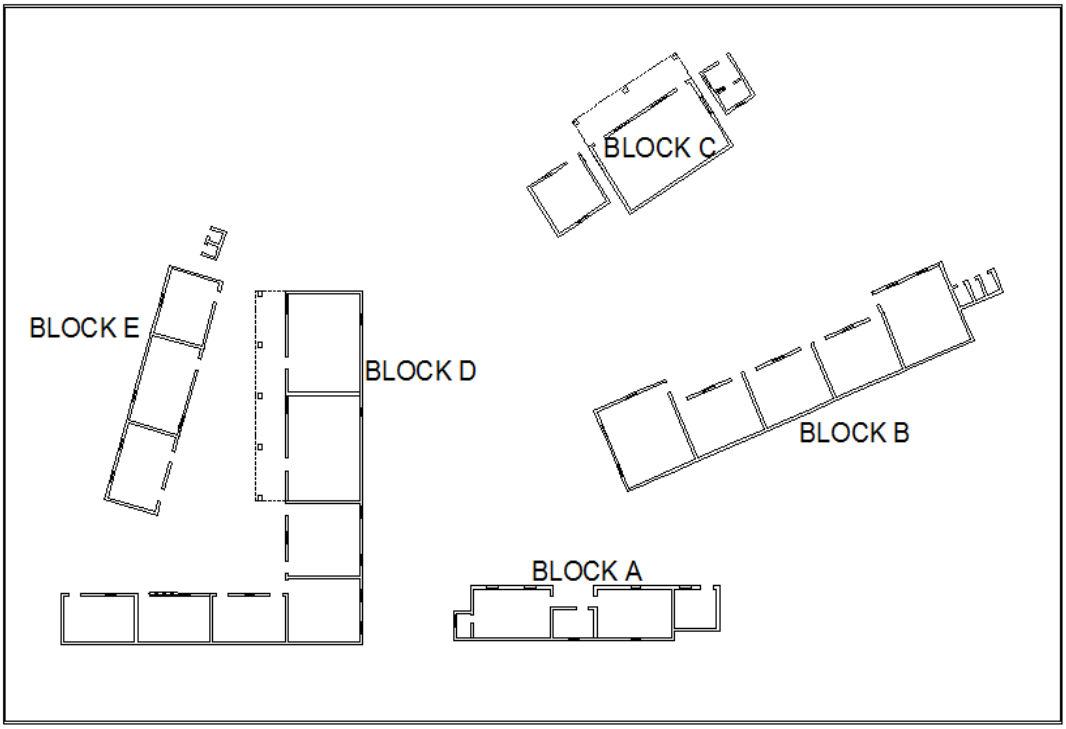


Fig. 21: Layout of the school building at Fakot in Tehri Garhwal district.

Retrofitting procedure

The details of the schools shortlisted for retrofitting were forwarded to IIT, Roorkee that was entrusted with the responsibility of preparing the detailed retrofitting plan. Execution of this plan was done by Disaster Mitigation and Management Centre (DMMC). Step wise details of the retrofitting procedure as per the plan are described in the following sections.

Marking of the seismic bands to be provided

The marking for the seismic bands proposed to be provided at various levels of the structure is the first step of the retrofitting exercise. Markings are done on the surface of the wall using colour and thread (Fig. 22). These markings are intended to guide the stone cutting machine operators in chipping the plaster.

Fig. 22: Markings being done using blue colour and thread.

Fig. 23: Mason using stone cutting machine to chip off at markings.

For making the marks first dip the thread in the coloured dye. Hold both ends of the thread at places across which marking is to be made. Stretch the thread and finally leave it. A straight line would thus inscribed across the surface of the wall at the desired location.

Fig. 24: Mason using chisel and hammer to chip off the plaster.

Fig. 25: Figure showing complete chipping according to the drawing.

Chipping the plaster

Rotary stone cutter is used to cut through the layer of the wall plaster along the markings done previously (Fig. 23). This facilitates removal of the wall plaster from the desired location, i.e. the surface of the wall between the markings. The wall plaster from the desired area is subsequently removed using chisel and hammer (Figs. 24, 25 and 26).

Fig. 26: Figure showing complete chipping of plaster inside the room.

Fig. 27: Mason using rotating cutter to cut wire mesh.

Cutting the wire mesh

In accordance with the specifications given in the retrofitting design the wire mesh (1’’ x 6’’) is cut to the desired dimension using a cutter (Fig. 27). In case cutter is not available at the site the mesh is cut using hammer and chisel (Fig. 28).

Fig. 28: Masons using chisel and hammer to cut wire mesh.

Fig. 29: Figure 4(a): Mason applying epoxy primer using spray.

Treatment of the wire mesh

Epoxy zinc primer is then applied to the wire mesh (Fig. 29). It works as an anti corrosion coating on the steel reinforcement or steel surface. This resists corrosion within the confines of the repair location and avoids the generation of incipient anodes in immediately adjacent locations.

If spray is not available epoxy zinc primer can be applied using a brush (Fig. 30). Use of spray however saves time and labour.

Fig. 30: Mason applying epoxy primer using paint brush.

Fig. 31: Mason applying cement slurry on wall.

Application of cement slurry on the wall

Cement Slurry is then applied on the wall after washing it thoroughly with water (Fig. 31). This ensures that the new cement mortar binds properly with the existing brick masonry.

Application of micro – concrete

1 portion of cement is then mixed with 3 portions of aggregare (of < 6 mm) and appropriate amount of water to prepare the micro - concrete. Acrylic bonding agent and liquid integral waterproofing compound are also added in this.

Acrylic bonding agent is used as i) a bonding agent for both new and old substrates and ii) cement mortar modifier as it provides strong bonds between old and new concrete and improves tensile and flexural strength of concrete and increases the durability of the structure.

Fig. 32: Mason applying first layer of cement mortar.

Fig. 33: Mason drilling holes into the wall.

Liquid integral waterproofing compound is used as an additive for cement concrete / mortar / plaster as its plasticizing properties make concrete cohesive and prevent segregation. It improves the waterproofing properties of cement concrete and plaster after curing.

Fig. 34: Wire mesh being held in position using 6 mm steel bars.

Fig. 35: Figure showing fitting of wire mesh and reinforcement bars.

Drilling of holes

Holes of 8 mm diameter are subsequently drilled through the wall (Fig. 33). The centre to centre distance of 45 cm is maintained between two consecutive holes. 6 mm steel bars are then passed across the wall through these holes.

Fig. 36: Masons fitting the wire mesh and reinforcement bars.

Fig. 37: View of the second layer of micro-concreting.

Application of wire mesh

Wire mesh is then applied to the wall in accordance with the drawings and tied with the wall with 6 mm steel bars that were previously fitted in the wall (Figs. 34, 35 and 36).

Covering the wire mesh with micro-concrete

After fitting the wire mesh on the wall second layer of micro - concrete is applied (Figs. 37 and 38).

Fig. 28: Mason applying second layer of micro-concrete.

Fig. 29: Mason applying third and the final layer of plaster.

Final finish

After applying second layer of micro-concrete third layer of cement mortar is applied so as to give final finish to the wall. The concrete layer after the previous step is rough and slightly uneven. Henceforth to make the surface smooth proper finishing is done by the masons by plastering with cement mortar (Figs. 39, 40 and 41).

Fig. 40: The final finished look of the wall after plastering.

Fig. 41: The final finished look of the wall after plastering.

Alternate ways of work execution

There are several alternatives available for executing the retrofitting works and the methodology described in the previous section is not unique. It is therefore necessary to be conversant with some other methods because due to a number of factors it might sometimes not be feasible to use a particular method. This contingency might arise due to unavailability of machine, manpower or material. Knowledge of alternate methods is therefore necessary for completing the assignment as per the schedule.

In the previous methodology plastering was done in three steps; i) it was first plastered with 1:3 cement mortar or micro-concrete and then the wire mesh was fixed, ii) secondly micro-concreting was resorted to for covering the wire mesh, and iii) third layer of plaster with cement mortar was then applied to give final finishing to the wall.

Using a guniting machine two layers of plastering can however be applied in one go. The steps to be followed till covering of wire mesh with epoxy zinc primer are however common. The steps that follow this are described in the sections below.

Fig. 42: Figure showing the base from which spacer is made; the base is 15 mm thick.

Fig. 43: Figure showing cutting of spacers (2” x 2”).

Fixing the wire mesh

After chipping the plaster holes of 8 mm diameter are drilled through the wall. The centre to centre spacing of 45 cm is maintained between two consecutive holes. The wire mesh is then fixed directly using spacers that are made using

cement mortar and binding wire (Figs. 42 – 46). These are used to maintain certain gap between the wall and the wire mesh. Spacers of 15 mm thickness are used in the present case.

Fig. 44: Binding wire being inserted into the spacers.

Fig. 45: Spacers prepared.

Fig. 46: An individual spacer.

Fixing the spacers

The spacers are fixed between the wire mesh and the wall and tied with the binding wire so that their position remains intact and these do not get displaced while guniting (Figs. 47 and 48).

Fig. 47: A spacer tied between the wall and the mesh.

Fig. 48: A spacer tied between the wall and the mesh.

Concreting

The wire mesh is subsequently covered with micro-concrete. Micro concrete guinting has been used for this purpose. Guniting is the process of conveying desired mixture of dry cement, sand and aggregate under air pressure at high velocity with just sufficient quantity of water for hydration. Guniting machine consists of a twin chamber gun and twin water tanks and is powered by compressor (Fig. 49).

Fig. 49: Dry mix holder (left) and compression chamber (right).

The material is carried under pressure through a pipe and deposited on the desired surface through the nozzle (Figs. 50 and 51). Besides saving time and labour use of gunting machine for concerting ensures proper compaction.

Fig. 50: Nozzle of machine in hand of the mason.

Fig. 51: Micro-concrete coming out at high velocity from the nozzle.

In case guniting machine is not available then compaction of micro-concrete can be done with the help of hand held vibrator as well (Fig. 52). View of the finished school building is given in Figure 53.

Fig. 52: Compaction using hand vibrator.

Fig. 53: The final finished look of School building block.

Training of local builders

Design of tools for developing skilled human resources in earthquake resistant construction and earthquake retrofitting at the local level was an integral component of this project. Besides exposing the neighbouring community to retrofitting technique the program was aimed at encouraging the community to employ local masons for retrofitting and reconstruction.

Training of master trainers was organised at IIT Roorkee and these trained personnel subsequently worked with the local masons during the retrofitting of the schools to demonstrate various retrofitting techniques and in the process passed on the required skills. During the retrofitting the master trainers explained the technical details and the process of carrying out various retrofitting steps to the trainee masons and local builders in vernacular.

The training started with making the participants aware of the earthquake threat that looms large over Uttarakhand and the kind of devastation it is capable of causing. The trainees were communicated the affects that the earthquakes have on built environment together with the causes thereof. They were at the same time made aware of the various common mistakes made during construction works together with weaknesses in prevailing construction practices and were explained implications of the same during an earthquake. They were also appraised of minimum requirements for seismic resistance in different types of buildings. The participants were also communicated the importance of quality building material and workmanship for ensuring the required strength in the structures.

After communicating various techniques of ensuring earthquake safety in new structures the trainees were told ways of making the old houses earthquake safe. They were first told ways of identifying weaknesses in the common masonary house and also techniques of overcoming these through retrofitting. They were then told about various retrofitting elements, such as splints, bands, corner pins and others together with their functions in withstanding earthquake forces.

After each class room session the masons were provided hands on training at the retrofitting site so as to ensure that the training does not remain confined to theory and the masons are in a position to actually practice what they have learnt.

The trained masons are expected to practice earthquake resistant construction and also undertake retrofitting works in their community. With enhanced awareness of the community the trained masons are also expected to command premium wages.

During the course of the retrofitting program 80 masons underwent a rigorous ten-day training course. Additionally all the 80 masons got on – the - job training while retrofitting the school buildings.

Expectations are that all these masons would adopt proper construction and retrofitting techniques when constructing or retrofitting residential buildings in the community. The details of all the trained masons and master trainers are given in Annexure – I.

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Annexure – I

List of masons trained during the retrofitting program

1. Government Girls Inter College Ranipokhari, Dehradun

Sl. No.	Name	Residential address	Province	City / District	Mobile number	Training period
1.	Ajit Singh Pundir	Village Dhammuwala	Uttarakhand	Dehradun	9759450030	02nd – 11th February, 2011
2.	Inder Singh	Village Barkot	Uttarakhand	Dehradun		02nd – 11th February, 2011
3.	Surender Singh Pundir	Village Barkot	Uttarakhand	Dehradun		02nd – 11th February, 2011
4.	Anupam Chauhan	Village Ranipokhari	Uttarakhand	Dehradun	9528240636	02nd – 11th February, 2011
5.	Nausad Ali	Village Lisduabad	Uttarakhand	Dehradun		02nd – 11th February, 2011
6.	Ashok Kumar	Village Fatehpur Tanda	Uttarakhand	Dehradun	8995849593	02nd – 11th February, 2011
7.	Chintamanri Joshi	Village Fatehpur Tanda	Uttarakhand	Dehradun	8410113243	02nd – 11th February, 2011
8.	Mohamad Taseen	Mohalla Muslim Colony	Uttarakhand	Dehradun	9568017142	02nd – 11th February, 2011
9.	Sajjan Lal	Village Tunalka	Uttarakhand	Uttarkashi		02nd – 11th February, 2011
10.	Laxman	Village Tunalka	Uttarakhand	Uttarkashi	9458309474	02nd – 11th February, 2011
11.	Sarjeet Singh	Village Dugiwada	Uttarakhand	Dehradun		12th – 21st February, 2011
12.	Ved Kishore	Village Ghamuu wala	Uttarakhand	Dehradun		12th – 21st February, 2011
13.	Yasheen Ali	Village Listrabad	Uttarakhand	Dehradun		12th – 21st February, 2011
14.	Prem Singh	Viilage Dandi	Uttarakhand	Dehradun		12th – 21st February, 2011
15.	Prem Kishore	Village Listrabad	Uttarakhand	Dehradun		12th – 21st February, 2011

16.	Babu Lal	Village Nagagher	Uttarakhand	Dehradun		12th – 21st February, 2011
17.	Sajjeed Ali	28 GMS Road, Dehradun	Uttarakhand	Dehradun	9758823081	12th – 21st February, 2011
18.	Bhagwan Singh	Village Veshan Garh	Uttarakhand	Dehradun	8979013012	12th – 21st February, 2011
19.	Surveer Singh Sejwan	Village Dandi	Uttarakhand	Dehradun	8954701418	12th – 21st February, 2011
20.	Anil Bisht	Village Ghamu wala	Uttarakhand	Dehradun	9634420487	12th – 21st February, 2011

2. Government Inter College, Dhobhalwala, Dehradun

Sl. No.	Name	Residential address	Province	City/ District	Mobile number	Training period
1.	Sher Singh	Village Shyamliwala	Uttarakhand	Dehradun	9839085447	22nd – 31st March, 2011
2.	Imran	Village Shardahedi	Uttarakhand	Dehradun	9012351382	22nd – 31st March, 2011
3.	Yogendar Kumar	Village Shyamliwala	Uttarakhand	Dehradun	9760704339	22nd – 31st March, 2011
4.	Deepak Kumar	Village Shyamliwala	Uttarakhand	Dehradun	9639490180	22nd – 31st March, 2011
5.	Nwab Malik	Village Shyamliwala	Uttarakhand	Dehradun	8057975086	22nd – 31st March, 2011
6.	Sonu	Village Shyamliwala	Uttarakhand	Dehradun		22nd – 31st March, 2011
7.	Salman	Village Shardahedi	Uttarakhand	Dehradun	9917457827	22nd – 31st March, 2011
8.	Naushad	Village Shardahedi	Uttarakhand	Dehradun	9837509498	22nd – 31st March, 2011
9.	Harun	Village Shardahedi	Uttarakhand	Uttarkashi	9759363544	22nd – 31st March, 2011
10.	kalyan Singh	Village Sherki	Uttarakhand	Uttarkashi		22nd – 31st March, 2011

11.	Tashleem	Village Shardahedi	Uttarakhand	Dehradun	9760438371	1st – 10th April, 2011
12.	Mustfa	Village Sultanpur	Uttarakhand	Dehradun		1st – 10th April, 2011
13.	Shabdhar	Village Shivpur Mandi	Uttarakhand	Dehradun	9897196461	1st – 10th April, 2011
14.	Naushad	Viilage Baeyth	Uttarakhand	Dehradun		1st – 10th April, 2011
15.	Shamshaad	Village Maghawpur	Uttarakhand	Dehradun		1st – 10th April, 2011
16.	Mujaheer	Village Maghawpur	Uttarakhand	Dehradun	8439708524	1st – 10th April, 2011
17.	Taheer	Village Maghawpur	Uttarakhand	Dehradun	9045611843	1st – 10th April, 2011
18.	Irfan	Village Maghawpur	Uttarakhand	Dehradun		1st – 10th April, 2011
19.	Sakeer	Village Maghawpur	Uttarakhand	Dehradun		1st – 10th April, 2011
20.	Muntjeer	Village Maghawpur	Uttarakhand	Dehradun		1st – 10th April, 2011

3. Government Inter College, Nainbag, Tehri Garhwal

Sl. No.	Name of mason	Residential address	Province	City/ District	Mobile number	Training period
1.	Dev	Village Kairad	Uttarakhand	Tehri Garhwal	7579014282	20th - 29th April, 2011
2.	Jaypal	Village Khunaa	Uttarakhand	Tehri Garhwal	9927159611	20th - 29th April, 2011
3.	Bal Bhadur	Village Chilamu	Uttarakhand	Tehri Garhwal		20th - 29th April, 2011
4.	Kamal Singh	Village Gashki	Uttarakhand	Tehri Garhwal	8449982601	20th - 29th April, 2011
5.	Mahendra Lal	Village Khunaa	Uttarakhand	Tehri Garhwal		20th - 29th April, 2011

6.	Narayan Singh	Village Naingaon	Uttarakhand	Tehri Garhwal	9411382482	20th - 29th April, 2011
7.	Dhoom Singh Verma	Village Ubaun	Uttarakhand	Tehri Garhwal	9456301394	20th - 29th April, 2011
8.	Dhoomidas	Village Ubaun	Uttarakhand	Tehri Garhwal	8449685113	20th - 29th April, 2011
9.	Umedh Singh	Village Bandasari	Uttarakhand	Tehri Garhwal	9411383385	20th - 29th April, 2011
10.	Trepan Singh	Village Bandasari	Uttarakhand	Tehri Garhwal	9760116689	20th - 29th April, 2011
11.	Supa	Village Khairad	Uttarakhand	Tehri Garhwal	9456736561	30th April -9th May, 2011
12.	Kirpal Singh	Village Badgaon	Uttarakhand	Tehri Garhwal	9897985154	30th April -9th May, 2011
13.	Dil Bahadur Singh Thapa	Village Nainbag	Uttarakhand	Tehri Garhwal	8755356608	30th April -9th May, 2011
14.	Mahendra Singh Pawar	Village Koti Patti	Uttarakhand	Tehri Garhwal	9411771975	30th April -9th May, 2011
15.	Soban Sing	Village Kairad	Uttarakhand	Tehri Garhwal		30th April -9th May, 2011
16.	Darshan Lal	Village Kharson	Uttarakhand	Tehri Garhwal		30th April -9th May, 2011
17.	Guru Parsad	Village Masras	Uttarakhand	Tehri Garhwal	9410531026	30th April -9th May, 2011
18.	Hardev Singh	Village Koti	Uttarakhand	Tehri Garhwal	9411752916	30th April -9th May, 2011
19.	Suresh	Village Badgaon	Uttarakhand	Tehri Garhwal		30th April -9th May, 2011
20.	Anil Vishwakrama	Village Sandlu	Uttarakhand	Tehri Garhwal	8057089353	30th April -9th May, 2011

4. Government Inter College Fakot,Tehri Garhwal

Sl. No.	Name	Residential address	Province	City/ District	Mobile number	Training period
1.	Ramchandra Nath	Village Khairadhar	Uttarakhand	Tehri Garhwal	9410752344	11th - 20th May, 2011
2.	Abawal Chand Ramola	Village Kashmoli	Uttarakhand	Tehri Garhwal	9997085316	11th - 20th May, 2011
3.	Raghuveer Nath	Village Vtoli (Khanali)	Uttarakhand	Tehri Garhwal		11th - 20th May, 2011
4.	Soban Singh	Village Vdeda (Talla)	Uttarakhand	Tehri Garhwal	8017120478	11th - 20th May, 2011
5.	Mangal Singh	Village Bhigar Kimali	Uttarakhand	Tehri Garhwal	9456789276	11th - 20th May, 2011
6.	Prem Singh	Village Chald Gaon	Uttarakhand	Tehri Garhwal	7830253828	11th - 20th May, 2011
7.	Kamal Singh	Village Bhigar Kimali	Uttarakhand	Tehri Garhwal		11th - 20th May, 2011
8.	Madan Singh	Village Shayud	Uttarakhand	Tehri Garhwal		11th - 20th May, 2011
9.	Govind Singh	Village Pipleth	Uttarakhand	Tehri Garhwal	7500378350	11th - 20th May, 2011
10.	Virendra Kumar	Village Bhinu	Uttarakhand	Tehri Garhwal	9997508197	21st - 30th May, 2011
11.	Madan Lal	Village Bhinu	Uttarakhand	Tehri Garhwal		21st - 30th May, 2011
12.	Rajesh Kumar	Village – Bhinu	Uttarakhand	Tehri Garhwal	9410358375	21st - 30th May, 2011
13.	Rajpal Nath	Village – Khaidadhar	Uttarakhand	Tehri Garhwal	9760655308	21st - 30th May, 2011
14.	Balbeer Singh	Village – Bhinu	Uttarakhand	Tehri Garhwal		21st - 30th May, 2011
15.	Virendra Kumar	Village Bhinu	Uttarakhand	Tehri Garhwal		21st - 30th May, 2011
16.	Vijendra Singh	Village Bhaitan	Uttarakhand	Tehri Garhwal	9456386469	21st - 30th May, 2011
17.	Rajendra Singh	Village Vedada	Uttarakhand	Tehri Garhwal	9410198194	21st - 30th May, 2011
18.	Shrichand Nath	Village Arsh	Uttarakhand	Tehri Garhwal	9410752352	21st - 30th May, 2011
19.	Satya pal	Village Bhinu	Uttarakhand	Tehri Garhwal		21st - 30th May, 2011
20.	Pappu Koli	Village Kashmoli	Uttarakhand	Tehri Garhwal		21st - 30th May, 2011

The detail of master trainer used in these programs

Sl. No.	Name	Residential address	Province	City/ District	Mobile number
1.	Tejpal Singh Chaudhari	Village Naugaon	Uttarakhand	Uttarkashi	8979021004
2.	Brijesh Kumar	Village Mori	Uttarakhand	Dehardun	7579001191