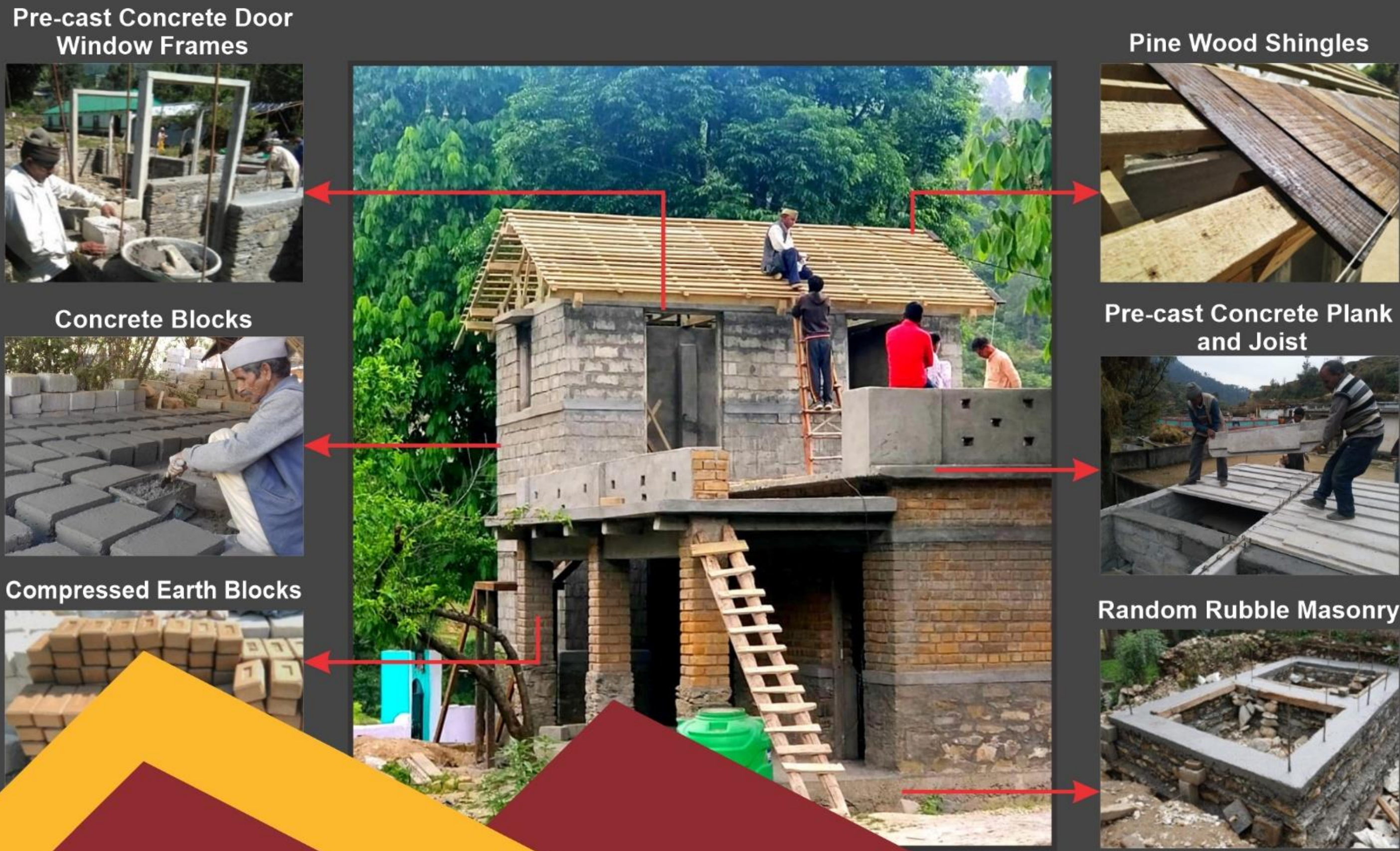

DESIGN AND TECHNOLOGY FOR DISASTER-RESILIENT, ENVIRONMENTALLY RESPONSIBLE BUILDINGS IN MOUNTAIN REGIONS (UTTARAKHAND)

Habitat Package

सत्यमेव जयते
Government of India
Department of Science & Technology
Ministry of Science & Technology

Development Alternatives

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ABOUT DST TIME LEARN PROJECT

The project **Delivery Model for Eco-Friendly Multi Hazard Resistant Construction Technologies and Habitat Solutions in Mountain States** implemented in Uttarkashi by Development Alternatives under the Department of Science and Technology (DST) TIME-LEARN programme focuses on - sustainable construction in mountain regions through an integrated approach which enables resource optimization, livelihood generation and climate change through construction practices.

The project introduced environment friendly building materials and hazard resistant construction systems in the region. It established a local delivery system for these products and services through group and individual enterprises. The solutions offered by the project include Stabilized Compressed Earth Blocks (SCEB) using local soil, Concrete blocks, improved stone masonry with vertical reinforcement for ductility, precast roofing elements for improved and safer RCC-based practice and Timber shingle based roofing.

Delivery systems for these technologies have been created through building capacity of local community – women groups for SCEB, local carpenters for improved timber roofing and individual micro enterprises for the pre-fabricated construction products. The materials were introduced in the project through intensive community and market discussions. These have been assessed by an independent group of professionals. As it incorporates high "localization" component in material production and building construction processes, thus provide evidence of a high local economy development and local resilience potential if disseminated widely and mainstreamed in public and private construction projects.

ACKNOWLEDGEMENT

The preparation of the document 'Design and technology habitat package for disaster resilient, environmentally responsible buildings in mountain regions, focussing on Uttarakhand' has been a rewarding and collaborative journey that has benefited from the participation of diverse spectrum of stakeholders who have contributed immensely to the package. We would like to take this opportunity to thank them all for their generosity in providing their time and effort.

We would extend our heartfelt gratitude to *Dr. Debpriya Dutta,* Head and Advisor, Scienst'G' and *Dr. Sunil Aggarwal*, Scientist 'E' from Science for Equity, Empowerment & Development (SEED) Division, Department of Science and Technology (DST), Govt. of India for approving the project to Development Alternatives for piloting this initiative in Uttarakhand. We would also like to express our gratitude towards *Dr. Ruchi Badola,* Scientist 'G' from Wildlife Institute of India (WII) for being the coordinating organization of the TIME LEARN program and ensuring the quality of the project along with 21 other core projects being implemented under the Program.

We would like to thank our implementation partner, Himalayan Environmental Studies and Conservation Organization (HESCO) for being our partner in mobilizing the communities, conducting trainings and implementation of pilot models. We are grateful to *Dr. Anil Prakash Joshi,* Founder of HESCO for providing his valuable inputs in the project for further scaling up the work in mountain states. Our special thanks goes to *Dr. Rakesh Kumar*, Principal Scientist from HESCO for coordinating and ensuring the timely implementation of the project. We would also like to acknowledge our technology partners, Forest Research Institute (FRI), Dehradun for providing the technology support in training and piloting *Chir* pine timber shingle with timber truss under-structure roofing system along with its appropriate treatment technology in the region. Special thanks goes to *Dr. Rajendra Desai*, Joint Director and Managing Trustee of National Centre for People's Action in Disaster Preparedness (NCPDP) for providing technical assistance to build disaster resilient buildings in the region.

Our sincere thanks to *Mr. Devendra Patwal*, Disaster Management Officer, Uttarkashi for providing his valuable suggestions and feedback from government perspective to take the work further in district and state of UUttarakhand. Our sincere thanks goes to the field team consisting of *Dwarika Semwal, Gajendar Singh Rana and Vinod Chamoli* who worked on ground to mobilize the activities in three villages and coordinated the entire project. We are indebted to the entire community especially to the women group who has come forward and participated in the activities of mud block and other precast concrete material production. Last but not the least, we acknowledge the relentless support of DA team including entire Policy and Planning team, Product Development Team, TARA Machine team whenever required to implement the project in the field. A special mention to *Hriday Ray, Pramod Singh, Shyam Narayan Prasad, K.P Singh, Sureshanand and Ramanand for providing on field training.*

Our sincere thanks to all.

PREFACE

The Habitat Package has been developed as complete Technology Package with Options for Eco-Friendly Disaster Resistant Construction practices for mountain regions. It has been a challenging and rewarding task to introduce and demonstrate a new construction approach in rural areas of Uttarkashi district, Uttarakhand. The system which incorporates and provides answers to some of the key issues of development – resources, livelihood and climate change.

The solutions implemented by the project in three demonstration buildings and the experience of engagement with local community and entrepreneurs bring forth lessons which can inform a larger strategy for mainstreaming sustainable construction in mountain regions. Participatory approach has been followed through the implementation methodology, right from the research and assessment stage to technology demonstration stage. This was a critical aspect for technology integration and technology adaptation among communities.

Our attempt will be rewarding if this habitat package serves the Uttarakhand government in achieving their sustainable development and disaster risk reduction agendas. This package will seek to generate consensus regarding action needed on various fronts such as policy to enable efficient use of mountain resources, decision making in line with green procurement, micro-enterprise based delivery systems and building requisite capacities of mountain communities.

The package has been divided into six sections – providing the background of the issue, criteria followed for selected sustainable building technologies, technology options developed under the project, case study showing the combination and implementation of technologies and lastly, recommendations for scaling up.

We sincerely thank Department of Science and Technology (DST) SEED Division, for giving us the privilege of being a part of this extremely important initiative. We hope that this will be benefitted by government of Uttarakhand and other mountain state in India, Ministry of rural development and Disaster management and mitigation departments.

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Dr. Debpriya Dutta

Head and Advisor, Scientist 'G'
SEED Division
Department of Science and Technology

FOREWORD

Science for Equity, Empowerment and Development (SEED) Division under the Department of Science and Technology, Government of India developed the concept of *Technology Intervention for Mountain Ecosystem- Livelihood Enhancement through Action Research & Networking* (TIME- LEARN) Program. Under this program, an innovative mechanism has been developed for promoting Science and Technology (S&T) based organizations to develop and implement innovative solutions for mountain specific problems in the Western Himalayan states of Uttarakhand, Himachal Pradesh and Jammu and Kashmir.

This Habitat package documents the eco-friendly, low-cost, disaster resilient building material technologies proposed in Uttarakhand region to address the shift in construction practices from traditional to cement based practices in mountain regions leading to high energy intensive, seismic vulnerable buildings. This Habitat package along with detailed packages of each building technology covers detailed specifications and their localized methods of production and construction processes. This would serve local government, entrepreneurs to adapt such eco-friendly technologies in their practices, schemes and programs.

I take this opportunity to express my utmost gratitude to Development Alternatives Group for piloting these technologies in the region of Uttarkashi and establishing micro-enterprise based delivery systems of these technologies on the ground through trainings and capacity building programs. I would also like to extend my gratitude to various implementation and technology partners involved in the various stages of the project, due to which such initiative became a reality.

I am sure that the package would serve the bigger picture in the framework of disaster risk reduction, in alignment with National Disaster Mitigation Plan (NDMP) 2019 agenda. It would also serve the Sustainable Development Agenda of Uttarkhand state by promoting resource optimization through environment friendly building technologies and add to its employment generation agenda by creating livelihood opportunities specifically in such challenging pandemic scenario.

Dr. Debpriya Dutta

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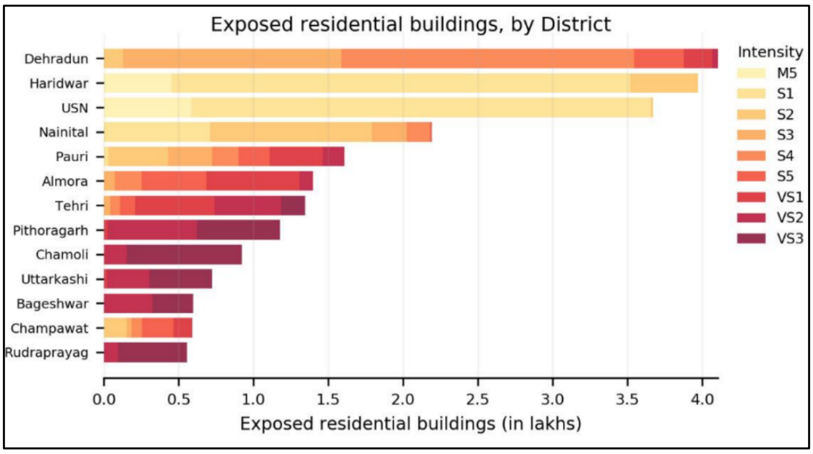
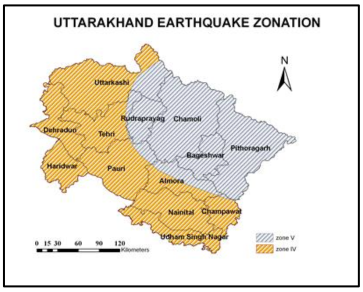
1. Introduction

Mountain regions are major eco-systems representing the inter-related ecology of our planet. They are a key source of water, minerals, forest and agricultural products and their stability is essential for the health of the global ecosystem. Mountain ecosystems are, however, rapidly changing and this change is being accelerated by collective impact of development. Mountain regions in India, as is commonly the case in other parts of the world, lie in disaster prone zones – particularly prone to tectonic shifts. The way the built environment is planned and constructed has a big impact on the degree of damage due to these extreme natural events.

Uttarkashi is situated in the extreme north -west corner of Uttarakhand, bounded with Tibet and Kinnaur district of Himachal Pradesh to its north. The district faces a range of disaster-risks. With majority of the district lying in seismic zone IV, it is highly vulnerable to seismic activity of intensity which can cause heavy damage. According to a study of disaster risk[1] in Uttarakhand, earthquakes and fluvial floods are the two major disaster risks in the region. According to the assessment, "the average annual economic loss, based on the probabilistic assessment of earthquake and fluvial flood risk is about INR 2,545 Crores and that the losses due to earthquake are far more significant, accounting for more than 95% of the total loss. Residential buildings and critical buildings (health centres, schools, government buildings) account for 57.4% and 4.4% of these losses".





Source: Disaster Mitigation and Management Centre, Govt. of Uttarakhand

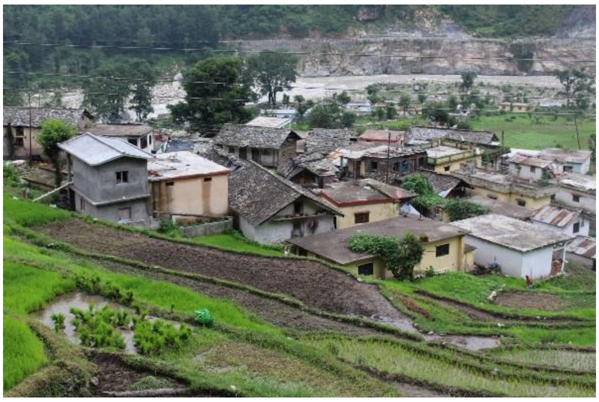
Construction practices in the mountain regions have been changing rapidly, mainly under the influence of cement concrete and red brick-based practices, where the construction materials are coming from plain regions. These are perceived as stronger, particularly to resist earthquakes. The penetration of materials like cement and steel and workforce from plain regions (such as Bihar) have accelerated this change. Burnt clay bricks which are transported from kilns in the plain regions (such as Roorkee) are being used as an alternative to traditional stone masonry. However, looking at the construction challenges from an eco-friendly approach, two challenges were identified – one was the technical incorrectness of Reinforced Cement Concrete (RCC) based construction practices in the region which is counter-productive and results in increased vulnerability of buildings and second is the high dependency on high energy materials like burnt clay bricks, steel and cement which are transported from far-away plain regions.

In addition, most masons in rural areas, as was observed in the project implemented in Uttarkashi, have incomplete and incorrect knowledge of RCC- based construction practices which severely undermines the capacity of contemporary construction to be able to resist damage by earthquakes.

[1] Disaster Risk Assessment of Uttarakhand – State Level Assessment Volume 3A- under Uttarakhand Disaster Recovery project – jointly conducted by DHI Water & Environment (S) Pte Ltd., Asian Institute of Technology, and Evaluacion de Riesgos Naturales, Mexico DF - http://usdma.uk.gov.in/PDFFiles/Atlas_Vol3A_20190131.pdf

The high prevalence of non-local construction materials also undermines local economy and erodes opportunities for skill development among local community. Traditional construction practices using stone masonry and timber floors/roofs have seen a steady decline in skilled masons who are technically proficient.

Current construction trends in rural areas of Uttarkashi



Brick and RCC slab construction in Siror village

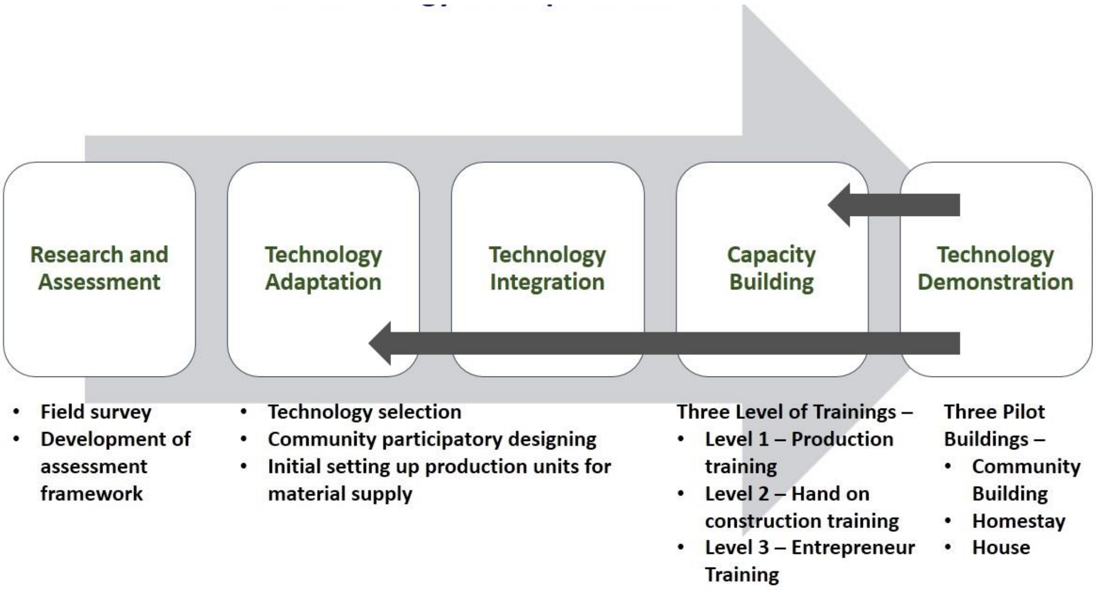
RCC columns and beams combined with traditional stone masonry in Kamad village

Approach

An integrated sustainable approach was adopted where sustainable building construction practices can add to the ***local economy generation, create disaster resilient infrastructure, enhance natural resource optimization and encourage social inclusion*** in the state. It has been envision that such an approach would lead to increase livelihood opportunities, improved environment, construction of disaster safe buildings and community participation in building processes. Such approach was achieved through four work areas on the ground - **Technical** in which masons and carpenters were trained in disaster resilient construction techniques, **Environmental** in which building technologies which low carbon, resource efficient and add value to local resources were introduced, **Economical** in which local building material enterprise were setup to produce and supply green building materials and construction services, **Social** in which women and youth were involved through skill development and local skill base up-gradation.

In total six new building technologies (walling and roofing) were introduced and demonstrated– Reinforced Random Rubble masonry, Stabilized Compressed Earth Blocks, Concrete Blocks, Chir pine timber shingle roofing with timber truss understructure, Precast reinforced concrete door window frames and Plank & Joist for roofing – which can be locally produced, maximizes the use of local materials, optimises the use of cement and steel and which can be standardized for structural integrity.

Methodology



Research and assessment –At the outset, a baseline assessment was conducted in four villages of the Uttarkashi district to understand the local habitat design, current trends of construction and gaps/ shortcomings which make buildings vulnerable in the region. This helped in identifying the key criteria for appropriate technology selection and, subsequently, for evaluation of sustainability of the **implemented** technologies in the given regional context.

Technology adaptation & Technology integration –The following critertia/ indictors were used for technology selection – ***Hazard resistance*** – *Earthquakes and high velocity winds* - Structural integrity of building –proxy attribute of technical correctness of prevailing construction, ***Environmental impact -*** This is a hybrid attribute combining criticality of resource use and Embodied energy***, Local Economy Component -***% contribution to village economy***, Affordability -*** Cost of construction of wall/roof and maintenance***, Climate responsiveness-*** Resistance to transfer of heat and cold***, Cultural integration-*** Link with traditional construction practice***.***

Capacity building – Three level of trainings were conducted for the capacity building of local masons, artisans, carpenters and women's groups.

Level 1: Community based production and supply - This training has been divided in two parts – one is *Production training* of new building materials and second is *Mason training* in disaster safe construction practices. The production training was conducted with local artisans, masons and carpenters from four to five different villages in the region. The artisans were trained in the production of Stabilized Compressed Earth Blocks (SCEB), Concrete Blocks and Timber under structure and shingle roof, Precast RCC Plank, Joist and Door window frames. The mason training was conducted with local masons in which disaster safe construction techniques were theorized and demonstrated in the pilot building.

Level 2: Construction training and technical support – This training was majorly conducted during the construction of demonstration building through site supervisor and technical experts at different stages of construction.

Level 3: Micro-Enterprise training and market support – the project team has worked with the entrepreneur to develop a business plan, a strategy for product pricing and communication information for product marketing. This training was conducted for hands on support for enterprises by actual production orders to women's groups, enterprises and construction service orders to masons and carpenters.

Technology demonstration – The technologies has been demonstrated in three building typologies at three different villages of Uttarkashi region – Community building at Kamad village, Homestay at Bagi village and House at Siror village. Technology demonstration has also been an essential part of capacity building of local masons and technology adaptation among communities.

This was further strengthened by setting up delivery systems of the technologies in these villages. A system for localized delivery and availability of the building material and the access to the requisite skilled masons to implement the technology. The core of this delivery model is about anchoring the production and delivery services in the local region.

2. Criteria for Sustainable Construction in Mountain Regions

Sustainability is understood in terms of its three components – **environmental, social and economic**. What is equally important is to define and assess sustainability in response to a given regional context for a practical interpretation of sustainability based on regional realities. For instance, resistance to natural hazards is a non-negotiable pre-requisite for any construction technology in mountain regions of India and therefore, integral to sustainability. Uttarkashi is is largely representative of mountain regions of Uttarakhand. Certain performance criteria or attributes have been identified to prioritize technology options which are sustainable for the region. In response to the major challenges faced in mountain regions of India and the emerging construction scenario in those regions, the following attributes were considered for technology selection.

Attributes	Measurement/ assessment metric
Hazard resistance – *earthquakes and high velocity winds*	Structural integrity of building –proxy attribute of technical correctness of prevailing construction practices- *qualitative*
Environmental impact	This is a hybrid attribute combining criticality of resource use and Embodied energy – Megaloule - *quantitative*
Local Economy Component	% contribution to village economy – quantitative
Affordability	Cost of construction – INR/m^2 of wall/roof and maintenance- *quantitative*
Climate responsiveness	Resistance to transfer of heat and cold – U-value in W/m^2 K, *quantitative*
Cultural integration	Link with traditional good practice – *qualitative*

1. Resistance to Natural Hazards

The response to natural disasters is a function of construction quality and structural details with respect to particular building materials/ techniques which are used. Technically speaking, earthquake resistance can be built into the structure using any material – whether natural materials like stone and timber or processed material like cement and burnt brick. It can be ensured with good quality construction and correct structural detailing There are IS Code specifications for resistance to earthquakes, floods and high velocity winds and guidelines framed by leading technical institutions such as NICEE (National Information Centre of Earthquake Engineering)-IIT Kanpur for enhancing disaster resistance of construction.

While documenting prevailing building practices in the region, it was common to see incorrect practices in cement and RCC based construction. For instance, absence of roof level beams in attempted RCC frames, very low awareness of good quality concrete for in-situ application, incorrect reinforcement detailing are some of the widely observed problems. This widespread lack of basic technical skills is, in fact detrimental to hazard-resistance. Therefore, it becomes critical to enhance technical correctness of practice through introducing basic-essential tools, standardization and quality control mechanism.

2. Environmental Impact

This attribute is concerned with environmental implications of materials and construction technology. This can be assessed on the basis of two factors – Embodied energy and Critical Resource use. **Embodied energy**, a universally recognized attribute for environmental impact, is the cumulative energy consumed in constructing a wall or roof component of a building- including energy use in production of raw materials, transportation of raw materials to site and construction. Transportation is a major concern in mountainous regions, given the fact that cement, steel and bricks are all sourced from faraway plain regions. **Critical resource use** - is understood from the point of view of minimizing the negative impact of natural resource exploitation which is inevitable in the case of primary materials like cement, steel, sand and stone. Based on the criteria of Scarcity and Environmental Degradation, **Resource Criticality Index** for primary construction materials can be derived specifically for mountain regions.

3. Local Economy Component

This attribute is concerned with augmentation of the local economy through components of construction activity. Depending on the distance between construction site and nearest supply point of ready-to-use materials, 'local' can be interpreted for mountain regions with respect to the nearest small market for materials and also the radius which contains all essential service providers needed for construction in the region. There are two sub-attributes of Local Economy Component. **Percentage Cash Flow in the local economy** signifies % of money spent on a particular construction technology which stays in the local system. **Job creation** signifies number of man-days of local employment generated by various stages of implementing a construction technology.

4. Affordability

Affordability is an important concern, especially in the hilly districts which make up the bulk of the nearly 3/4th rural population. The current convention with regards to cost of a 'pucca' house is burnt brick masonry and RCC construction. The cost of burnt brick masonry and RCC slab construction is in the range of INR 10-12000 per m^3 and INR 4000-5000 per m^2. The traditional (random rubble) stone masonry walls cost in the range of INR 2500-3500 per m^3. The practice of slate stone for sloping roofs has taken a backseat due to environmental regulations- a piece of slate costs around INR 40 today. Transportation expense of reaching materials to often remote sites, accounts for 15-20% of the overall cost of building. The potential for cost-efficiency largely lies in **utilizing local materials more efficiently** and **reducing transportation** through localized material production units.

5. Climate Responsiveness

The loss of indoor thermal comfort efficiency has been a major outcome of brick and cement based practices in mountain regions. The feeling of discomfort indoors due to cement plastered brick walls and cement-concrete floors is a common experience of the rural community, often manifest in the form of joint-pains especially among the aged. The replacement of min 18" thick stone masonry walls with thinner 9" brick walls has a direct impact on thermal comfort through both reduction in thermal transmittance (U-value, W/m^2K – *the lower the better*) and in thermal mass (capacity to absorb heat energy). The U-value of burnt brick masonry is about 2.2 W/m^2K- about 30% more than traditional stone masonry walls. The RCC roof slabs of typically 100mm thickness, also have a high U-value of 4.2 W/m^2K. However in some cases, RCC slabs are used as intermediate slabs in double storey buildings, with a sloping roof in the upper storey – this is able to minimize exposure of RCC slabs.

6. Cultural Integration

The issue of cultural discontinuity as a result of new brick-and-RCC practices is also important- more so because it is relatively intangible and becomes evident over a number of years. The prevalence of brick and RCC is already visible as the biggest change in the built environment. It is related to the issue of climate responsiveness which is an intrinsic feature of traditional construction.

3. Design Approach – Structural Concerns

Disaster resistance is the primary requirement of any building constructed specially in mountain regions. Structural safety of the given building technologies was essential pre-requisite for architectural design. Technically speaking, earthquake resistance can be built into the structure using any material – whether natural materials like stone and timber or processed material like cement and brick- with good quality construction and correct structural detailing.

Over the last decade, technical documents, aimed at construction personnel – both engineers and artisans- have been developed by leading institutions with focus on non-engineered construction in rural areas. Some key reference documents in this regard are –

- IS 4326 : Design and construction of earthquake resistant buildings and IS 13828 : Improving Earthquake resistance of low strength masonry buildings-Guidelines
- Guidelines for Earthquake resistant non-engineered construction – IAEE and NICEE (National Information Centre of Earthquake Engineering)
- Manual on Hazard Resistant Construction in India – developed under GOI-UNDP-DRM Programme
- Guidelines for earthquake resistant construction in the National Building Code of India.

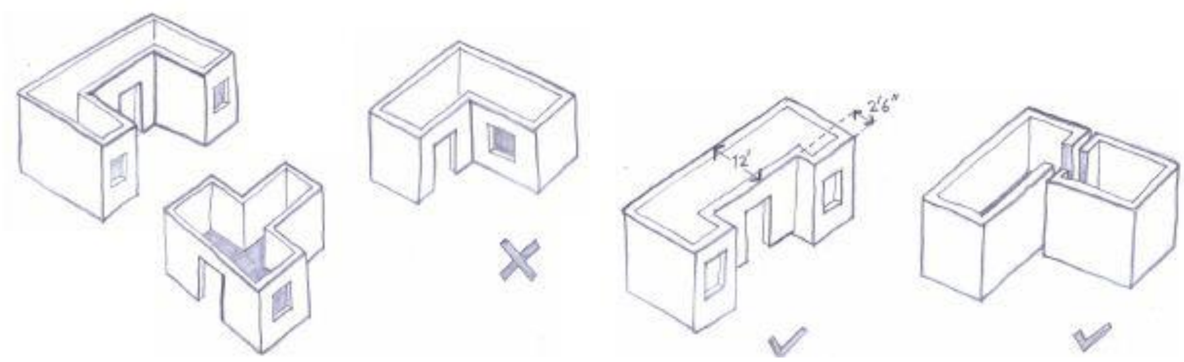
Three demonstration buildings have been constructed as part of the project – a community building in Kamad village, an Eco-tourism home stay in Bagi village and a residential building in Siror village. The design and structural details of these buildings have been developed in accordance with the above documents. ***Kindly refer the Design Compendium for specific details of these buildings.***

Below is a summary of the main design and structural concerns, **especially for load bearing construction,** which are reflected in the demonstration buildings.

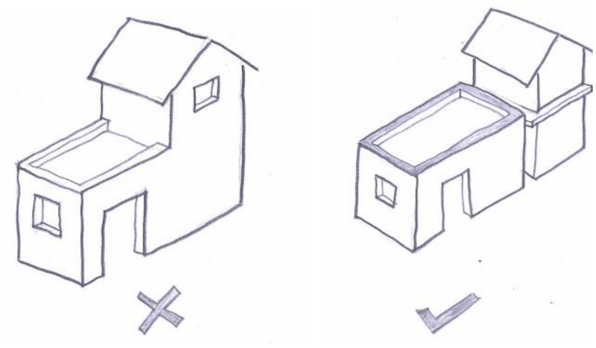
1. Building Shape and Size

The main concerns in this regard are Plan Regularity and Vertical Regularity. While the former applies to architectural plan of any given building, the latter mainly applies to double storeyed (or higher) construction which is becoming increasingly prevalent in residential construction in mountain regions.

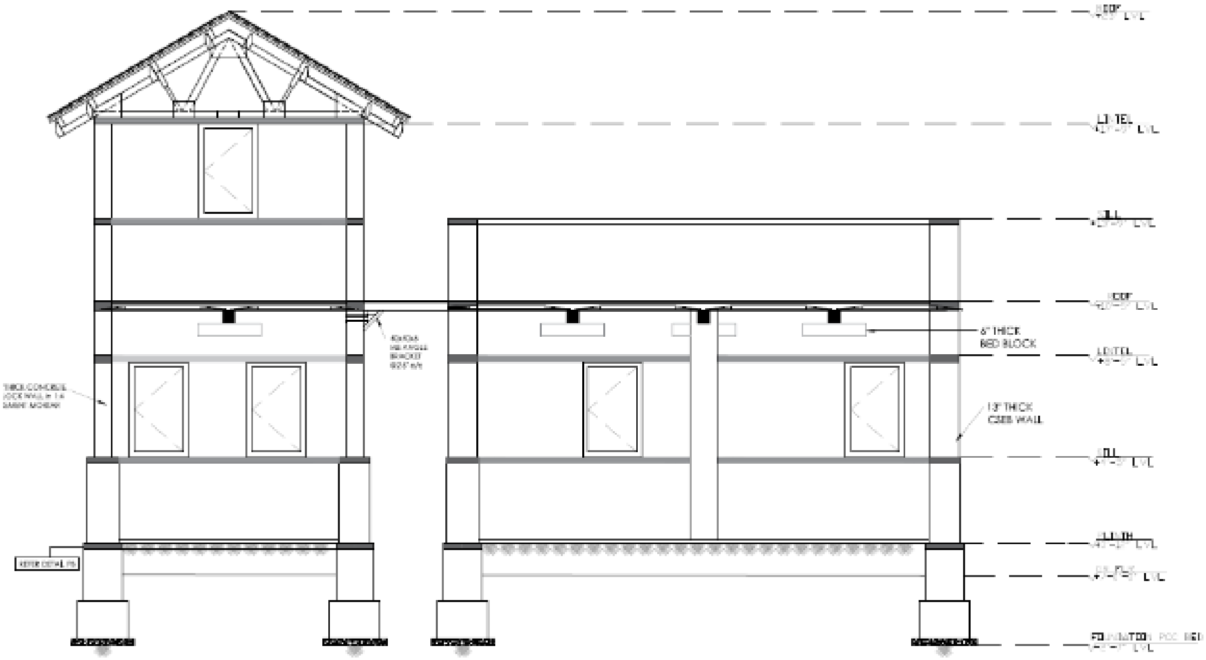
Plan Regularity - In case of irregular plans, such as in the case of L-shape plan, the projecting section should not be more than 15% of the dimension of the structure. If this is not possible, then there should be a separation between the two parts of the building



Vertical regularity - In case of buildings with a floor above, there must be no vertical irregularity due to the respective designs of both floors. This could be a small room on the upper floor which causes asymmetry in the structure. This will result in torsion under seismic conditions, which is not permitted in Category E buildings, unless a static analysis for seismic forces is carried out. Vertical symmetry must be maintained across the length of the structure. If vertical symmetry cannot be maintained, then there must be a structural separation between the single story and the double storied part of the building.

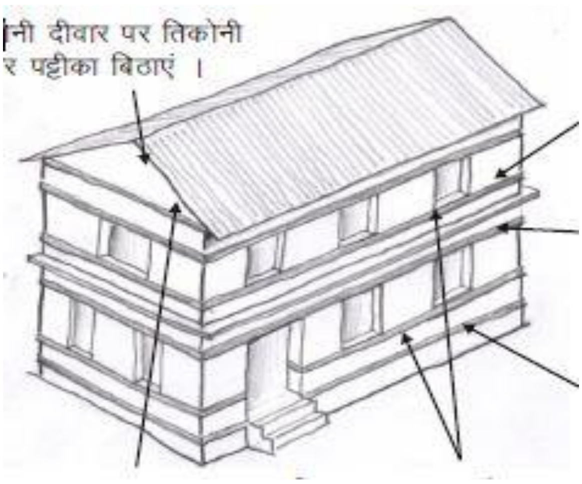


This has been demonstrated in the community building in Kamad village. A connecting corridor was provided between the single storied and double storied parts of the building. The corridor is connected with the ground floor section of the building and is simply supported on brackets provided in the double-storied section. This will ensure that torsion caused by asymmetric constraint to lateral forces will not arise in case of earthquake.



2. Foundation

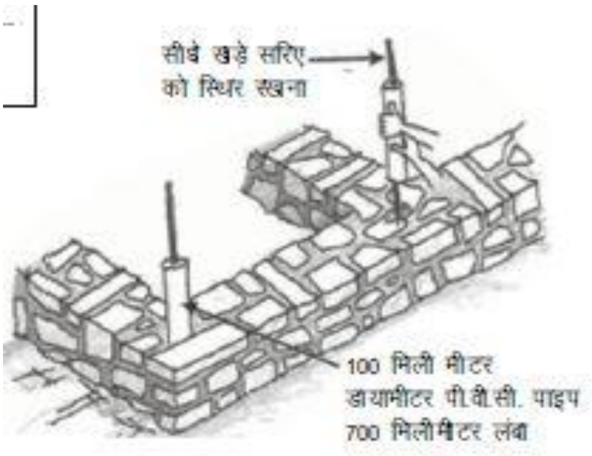
Strip footing in mortar ratio not leaner than, 1:6 is to be provided under all load bearing walls of the structure and all eccentric foundations are to be avoided. The depth of the footing is still a strata with sufficient bearing capacity. It is observed that rocky strata is found at shallow depths of 2-3 feet in most parts of Uttarkashi. A 150mm deep RCC plinth beam is to be provided across the thickness of the walls, for all load bearing walls.



All vertical reinforcement for wall corners and T-junctions will commence at the base concrete of the strip footing and will end at the roof level beam of the building, with correct reinforcement anchorage details at both ends.

Verandah using RCC slab – This is a very important design concern in buildings in mountain regions. It is observed that many residential buildings provide a verandah at the front of the house across the entire length of the building. In many cases, this involves a combination of two different structural systems – a masonry structure for the main building and an RCC-based extension for the verandah.

The RCC slab of the verandah must be structurally integrated with the main building. The supporting beams of the verandah slab must bear fully on the load bearing walls of the main structure at one end and on another RCC beam at the other end which connects all the vertical supports at the top. The vertical supports can be reinforced masonry columns in which the reinforcement at the core is anchored into the RCC beam running at the top of columns. The bottom of columns must also be tied with a 150mm deep RCC beam supported on a masonry footing underneath.



3. Seismic bands

Continuous RCC bands must be provided on all walls of building – both external as well as internal walls - at plinth, sill, lintel and roof level. The bands must be must be the same thickness of the walls and 75mm thick thick to provide adequate cover to the single layer of reinforcement.

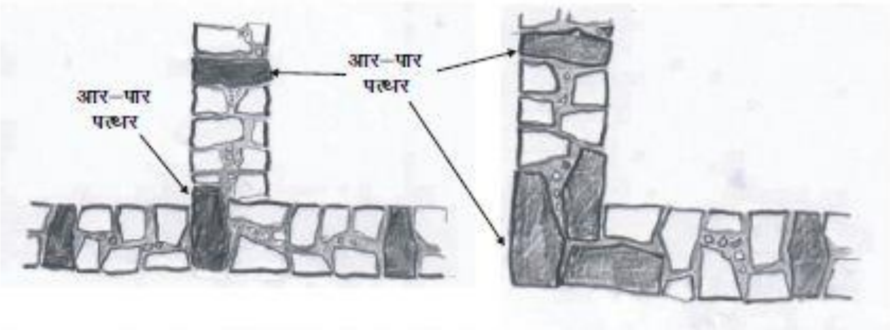
4. Vertical reinforcement

Single rod vertical reinforcement should be provided at all corner, T-junctions and on both sides of all openings to impart ductility to the masonry walls. Laps in reinforcement bars will be minimum 50 times the diameter of the bar. Corner and T-junction reinforcement will run from foundation concrete to roof band, door reinforcement from plinth till roof band and window reinforcement from sill level to lintel level.

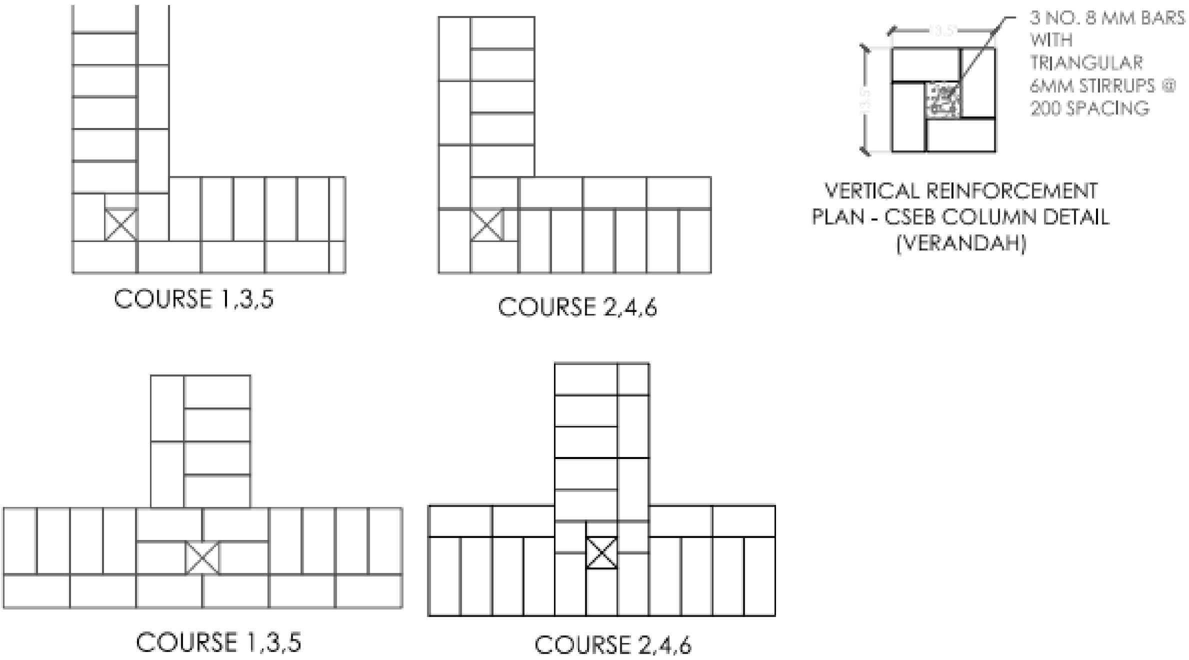
For single storey building – 12mm bar
For double storied building - 6mm in ground floor and 12mm in upper floor

5. Masonry

In case of stone masonry, the inherent strength achieved through proper placement of stones is very important. In particular, the use of header stones (which run for at least 75% of the wall thickness) is critical. Adequate through stones should be identified from the stone pieces before starting the masonry. All masonry should be constructed in 1:4 cement:sand mortar.



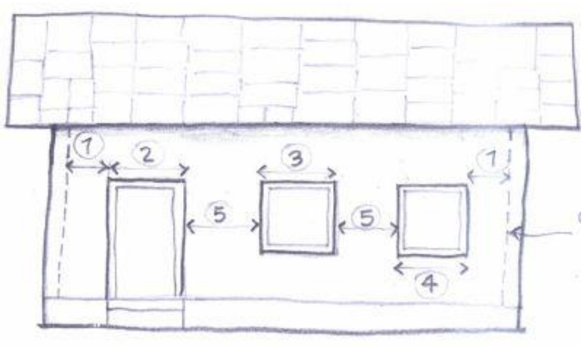
The layout of brick/ concrete block/ SCEB in each course of masonry should allow for continuous vertical cavity of minimum 60mm for the bar and grouted with concrete made with not more than 10mm size aggregates. Length of a 9" thick masonry wall should not exceed 12' given a height of not more than 10'. If longer walls are needed, then pilasters should be provided to strengthen the masonry – thickness of pilasters should not be less than thickness of wall in which they are provided. In case of veranda, reinforced masonry column can be provided instead of RCC columns.



6. Roof

The slab should be designed to behave as Rigid diaphragm, which is necessary for transferring shear forces to the shear walls. Bearing for RCC joists should extend to the full thickness of walls. The joist for the verandah will have a minimum bearing of 4” on masonry.

7. Door and window openings



All openings should be at a distance of at least 450mm from the inside corner of rooms and must be at least 600mm apart. The cumulative width of openings should not be more than 50% of the total length of the unsupported wall.

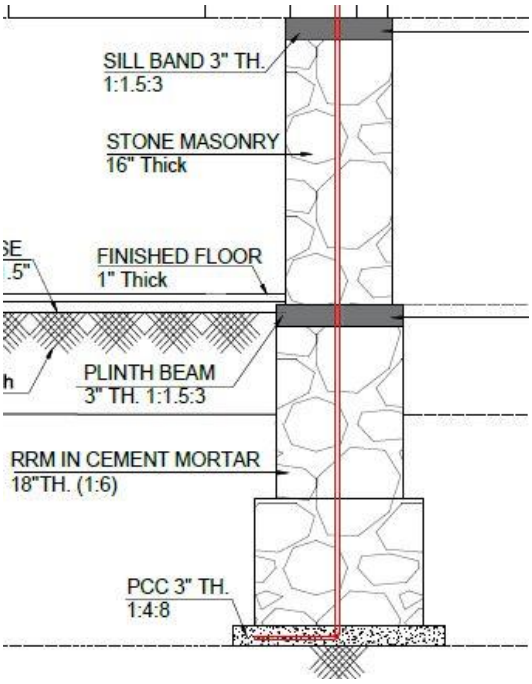
4. Technology Options

Provided that the basic structural design of the building satisfies the requirements as listed in the previous section, the technology options listed in this section can be integrated into the building as per their specific details. Given below are brief profiles of the technologies introduced in the project in Uttarkashi. Kindly refer the Technology Packages for more details.

Technology	Advantages
Reinforced stone masonry	The technology increases the ductility of traditional Random Rubble type stone masonry, adds to local economy.
Stabilized Compressed Earth Blocks	An alternative to red burnt clay bricks, can be locally produced using locally available raw material like soil. The technology can be produced on simple manually operated machines, adds to local economy and provides better thermal comfort as compared to burnt bricks in cold weather conditions of the region.
Concrete Blocks	It is an alternative to red burnt clay bricks. The material can be locally produced with mechanical compaction which improves its quality significantly.
Chir Pine shingle roofing on timber under structure	*Chir* pine timber is abundantly available in the region, the technology can be locally produced and treated, hence it adds to the local economy generation. The structure is light in weight, it is an alternative to heavy slate roof.
Precast RCC Plank and Joist Roof slab	The technology enables faster construction of roof slabs, eliminates the need for scaffolding support and also reduces steel consumption in RCC slab construction by 20%, can be locally produced, production can be operated in a local enterprise mode.
Precast RCC Door Window Frames	RCC door window frames were introduced as a durable alternative, which is highly amenable to small scale localized production.

Reinforced stone masonry

Stone masonry continues to be practiced in the region, despite increased difficulty in accessing stone for construction. Although the senior masons are aware of the importance of correct placement of stone for more strength of masonry, there is negligible awareness of ways to increase the earthquake resistance of stone masonry through embedded reinforcement. The purpose of introducing reinforcement is to increase ductility of traditional Random Rubble type stone masonry in lean cement mortar. Two types of reinforcement are incorporated – (a) Single bar vertical steel in critical locations - corners, wall junctions and sides of door-window openings, and (b) Horizontal seismic bands with 2 steel bars at the plinth, sill, lintel and roof level. These measures have been proposed by the NICEE (National Information Centre for Earthquake Engineering – IIT Kanpur) over last several years as part of guidelines for earthquake resistant non-engineered construction, particularly in rural areas. In addition, the practice of providing through stones to increase the inherent strength of stone masonry against de-lamination was strictly implemented.



Technical specifications

Reinforced stone masonry	Stone masonry	Thickness of stone masonry has to be minimum 15 inches. It can vary from 15 inches to 18 inches depending on the availability of space and stone.
	Reinforcement	Single reinforcement bars – 12 mm for single storey and in double storey - 16 mm at ground level and 12mm at first floor level. Reinforcement has to be embedded from the foundation level with an L bend of 15 inches in PCC.

Stabilized Compressed Earth Blocks

SCEB is a replacement for burnt clay bricks which are transported from more than 200 km away to rural areas. The main raw materials for SCEB – soil and coarse sand are locally available – hence SCEB are a good option for local production of masonry material. SCEB are made by compressing earth/ soil mix by simple mechanical means. The basic concept underlying compressed earth blocks is densification of the soil mix using external energy- this imparts them sufficient strength, eliminating the need to fire them in as kiln, like in the case of burnt clay bricks. Coarse sand is usually added to the soil mix which results in better densification of the soil mix leading to better strength. A small percentage of stabilizer – most commonly 5-10% cement is added to the soil mix to increase strength of blocks and their resistance to water. Since the blocks produced are uniform and well-finished in appearance, cement plaster on the walls can be avoided. One of the biggest benefits of using SCEB in the project was the involvement and leadership of women from the community in producing SCEB. ***Kindly refer the SCEB Technology Package for specific details of production and construction of this technology.***

Technical specifications

Stabilized Compressed Earth Block	Size	Depends on the block press used to produce the blocks. Some common sizes possible with different presses are- 230 x 115 x 75mm 230 x 190 x 100mm, 305 x 143 x 100mm 290 x 290 x 100mm
	Soil characteristics	Recommended particle size composition- Organic matter less than 1% Clay content 5-15%, strength reduces beyond 15% clay content Sand content – 60-70% Silt content 15-35%, combined silt+clay 30-40% **Non-expansive soil**- the clay in the soil should not expand in wet conditions.
	Design Mix	The objective of design mix is to arrive at a composition indicated above. For a given soil, generally sand and stabilizer quantities are to be determined for a good mix. Stabilizer : 7-8% Ordinary Portland Cement by weight of block Lime stabilization may also be done, but it is generally appropriate for very clayey soils.
	Density	The fresh block must have a density of at least 2.05 g/cc or 2050 kg/cm3
	Compressive Strength	Given the right design mix, as indicated above, indicative wet compressive strength at 28 days 4% cement stabilization – 35-45 kg/cm2 8% cement stabilization – 60-70 kg/cm2
	Water absorption	Not more than 15% by weight of block after 24 hours
Mortar	Design Mix	Composite mortars like cement-lime mortar or cement-soil mortar are better suited for use in SCEB masonry. When soil is used in the mortar, it should have a clay content of about 20%. Generally, cement mortar will have a good strength but poor plasticity and flow characteristics and is therefore not ideal for SCEB masonry. Recommended mix- Cement-lime-mortar 1:1:6, cement-soil mortar 1:2:6 or 1:2:7 or mud mortar. Cement-sand mortar 1:6

Applicability

The technology is particularly well suited where blocks can be produced for a cluster of houses – for instance, 20 houses in a village, since SCEB is suited for mass production by group of local people. The major criteria for cost-effectiveness is availability of appropriate soil *(generally falling in the range specified in specifications above)* in sufficient quantity and possibility to produce blocks closer to the construction site to avoid transport costs. It is also important that the block production is backed by a good understanding of quality parameters for producing SCEB. Therefore, training of construction personnel is necessary in SCEB construction.

Concrete Blocks

Concrete blocks are large sized masonry units made by compacting a well graded concrete mix. Since they can be produced easily using simple moulds, they are already being produced by house-builders in the mountain region. Although it is an appropriate material for localized production, there is no awareness of its basic requirements for quality- namely the correct mix and adequate compaction. This has resulted in very poor quality blocks being made and used in construction. The project introduced a small vibrating table and basic tools and accessories for a uniform mix quality. In addition to regular blocks, special blocks with a single cavity were produced for incorporating single bar vertical reinforcement wall using a well graded cement concrete mix. ***Kindly refer the Concrete Block Technology Package for specific details of production and construction of this technology.***

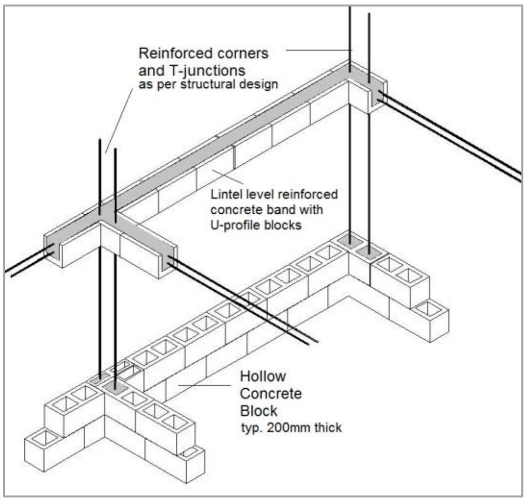
Technical specifications

Raw materials	Cement	Ordinary Portland Cement Grade 33(IS 269) or 43(IS 8112), or Portland Pozzalana cement grade confirming to IS 1489 Part I
	Coarse aggregate	Different sizes for a well-graded mix. This can include sizes from 6mm, 10mm, 20mm and even 40mm depending on availability of raw material and the performance requirements of block.
	Fine Sand	Sand should be washed and should not contain dirt Stone dust may also be used confirming to Grading Zone II as per IS 383:1970
	Fly Ash	Fly ash confirming to IS 3812 may be used for part replacement of fine aggregate upto a limit of 20%
	Design mix	Lean concrete mix of 1:3:8 or 1:5:8
Cement concrete block Open and closed cavity Hollow Blocks(Load Bearing), and Solid Blocks(Load bearing)	Size	Sizes can be customized as per mould, some common sizes are – Length – 16 inch, 12 inch, 8 inch Width – 3 inch, 4 inch, 6 inch, 8 inch Height – 5 inch, 6 inch, 8 inch
	Compressive strength(hollow-open and closed cavity)	Broadly classified into Class 5.5, 7, 8.5, 10, 12.5, 15 – corresponding to Average Compressive Strength not less than 55, 70, 85, 100, 125,150 kg/cm^2
	Compressive strength(solid load bearing)	Broadly classified into Class 4 and 5 corresponding to Average Compressive Strength not less than 40 and 50 kg/cm^2
	Water absorption	Not more than 6% of the mass after immersion in cold water for 24 hours
Mortar for masonry	Design Mix	Cement Sand mortar 1:6

Applicability

Concrete has a wide application in construction across various parts of a building – from foundation to columns to roof, because it can be formed into various shapes. One of such use is Concrete blocks which have been in use in India for nearly four decades and are commonly found in all parts of the country- both rural and urban. They also owe their popularity to the fact that speed of construction is enhanced since the blocks bigger than burnt bricks.

The technology can be widely adopted in place of burnt clay bricks for both load bearing and non-load bearing construction. The production of blocks is economically feasible wherever cement and aggregates are easily available. It is also a viable option for micro-enterprise based local availability of masonry materials in a housing project.



Pine shingle roofing on timber under structure

Chir Pine is one of the most abundant timber resource of many parts of Uttarakhand, including Uttarkashi. There has been a tradition of timber based construction for heavy stone slate roofs in the region, but it is becoming increasingly rare due to stringent control on both timber and stone slates which have proven to cause damage in earthquakes as well. The project aims to re-define this inherently disaster resistant construction practice. With technical support from Forest Research Institute (FRI) Dehradun, *chir* pine timber truss for gable roofs and *chir* pine roofing shingles were introduced in the project. Treatment of timber through dipping wood in a chemical solution is an important part of this technology, which significantly enhances the durability of timber. ***Kindly refer the Timber Truss Technology Package for specific details of production and construction of this technology.***

Technical specifications

Pine shingle roofing on timber under structure	General brief	Roof Types Overview- All joints and parts IS: 2700 – 1987, Code of Practice for Roofing with Wooden Shingles Typical designs of roof trusses from 3m to 6m Nail Jointed Timber Truss For Four meters Span Properties of *Chir* Timber
	Roofing componenets	Truss – common truss types such as King Post, Queen Post, Fink truss
	Timber shingles	400mm x 150mm x 12mm

Applicability

Roof trusses have the benefit of economic use of material (timber/ steel/ bamboo). Composed of individual lightweight pieces, a truss also has advantage in transport and assembly as compared to conventionbal roof structures. But trusses are more labour intensive and also often require connection devices to join members of a truss or to anchor the truss securely to wall masonry. However, if a number of identical trusses are to be manufactured, then there can be significant cost advantage.

Precast RCC Plank and Joist Roof slab

Plank and Joist roof is a system which uses precast RCC elements to construct a flat slab which can also be used as an intermediate floor. It consists of two types of precast structural elements- **Plank** of size 1'x5' functions as a small component of the slab and **Joist** which is a beam (typical section 6"x6" till a span of 13') to divide the roof area and to support the planks. After placing the planks and joists in position, the roof is completed with a layer of nominally reinforced in-situ concrete which ensures monolithic behaviour of all precast elements and also provides a uniformly flat finish. The technology is developed and validated by the Central Building Research Institute (CBRI) Roorkee. It has also been validated after testing by Building Materials and Technology Promotion Council (BMTPC) for construction of intermediate roof slabs. ***Kindly refer the Plank and Joist Technology Package for specific details of production and construction of this technology.***

The technology has been introduced as an alternative to cast-in-situ RCC slab construction which is usually constructed with little attention to technical quality aspects and therefore have proven to be vulnerable to defects and damage during earthquakes. The technology enables faster construction of roof slabs, eliminates the need for scaffolding support and also reduces steel consumption in RCC slab construction by 20%. Converting the RCC slab into smaller components which can be produced in a local micro-enteprise under better quality control.

Technical specifications

Precast RCC Plank	Size	Width 1 feet to 1.6 feet Length 5 feet, ideally, smaller lengths possible, preferably in multiples of 1 feet. Thickness 2 inches, reducing to 1 inch at the two ends.
	Reinforcement	Nominal MS reinforcement Main reinforcement 4 No. 6mm dia Transverse 6mm dia. @ 200mm spacing
	Concrete Mix	M20 grade 1 part cement : 1.5 parts sand : 3 parts coarse aggregate
Precast RCC Joist	Size	6 inch x 6 inch upto a span of 13 feet For larger spans, either depth can be increased or the joist to be designed as a doubly reinforced beam
	Reinforcement	MS, as per design requirements of span, in accordance with IS 456:1978 For upto 13 feet span – 5 No.8mm dia, 6mm dia. Triangular stirrups @150mm spacing
	Concrete Mix	M20 grade 1 part cement : 1.5 parts sand : 3 parts coarse aggregate
In-situ concrete	Reinforcement	6 mm dia bars – 2 each per plank in the haunch portion of the plank 8mm dia bars in both directions @ 200mm spacing in the in-situ concrete above top of planks.
	Concrete Mix	M20 grade 1 part cement : 1.5 parts sand : 3 parts coarse aggregate

Design Principle for a Plank and Joist Roof slab

Plank and Joist technology is a modular construction system based on standardized dimensions of planks and joists. The planks are made to standard dimensions and must have at least 50mm bearing on the joists and walls.

The section of plank and joist roof slab must be considered at the design stage to ensure that the planks and joists fit adequately within the dimensions of the roof slab. The length of the room is therefore fixed in multiples of plank lengths. The width of the room depends on the cross section of the joist. A standard joist of 150mm x 150mm size can span upto 4 metres including the bearing of joists on at least half the wall thickness. The dimensions of the room must be in accordance with the sizes of the planks and their specified bearing on beams. However, the bearing of plank on masonry wall can extend till the entire thickness of the wall. This provides flexibility in the size of the roof slab at its two ends where planks bear on the walls.

Applicability

The technology is best suited for wherever RCC slab is used for a flat slab construction. In mountain areas, verandahs are commonly constructed with flat RCC extensions from existing walls. The plank and joist system is also well suited for these verandahs. The technology can prove economical if the number of planks and joists are more- such as in the case of a 2 or 3 storied buildings. The planks and joists can be produced by a small enterprise where the infrastructure for casting, curing and storage of these elements can be installed at a low investment. Masons can be trained easily in using planks and joists to construct an RCC slab.

Precast RCC Door Window Frames

The traditional use of timber door window frames is today more difficult due to limited access to good quality timber. Steel door window frames have emerged as an affordable option. Hence a local material has been replaced by an industrial material produced far away in an industrial unit. RCC is an excellent material for casting in the profile of door-window frames. It is also more durable than both secondary timber and steel frames. RCC door window frames were introduced as a durable alternative which is highly amenable to small scale localized production.

Technical specifications

Size	10x6.5cm of length 1.6-2.4m
Raw Materials	OPC 43 grade cement, sand of fineness modulus
Concrete Mix	M15; the ratio of cement, sand & aggregates 1:2:4
Reinforcement	Nominal MS reinforcement 4 mm dia - 3 Nos. for main reinforcement

Applicability

The technology is best suited to attain for longevity and high durability of door window frames. RCC frames are best suited in regions with high rainfall – they doesn't require anti termite treatment as required in wood or corrode as in case of metal frames. Since frames are made of RCC, they also provide structural support to the building.

5. Case study – Community Building, Kamad (Uttarkashi)

Community Building, Village Kamad, District Uttarkashi

The proposed technologies were demonstrated in the community building located at one of the assessed villages - Kamad village, Uttarkashi. The design consists of earthquake resistant construction techniques followed by the use of all proposed walling and roofing technologies in the building. The structural safety of the given building technologies was essential for architectural design, hence the building has been designed as two independent structures – one single storey and other is a 2-storey structure, keeping the shape and size of the structures and openings into consideration for seismic resistance. Both the structure are combined with a covered corridor and verandah at the ground floor along with Mild Steel (MS) staircase to access the first floor of the building.

The entire design of the building was based on structural guidelines which have been developed for earthquake resistant construction in the country, with focus on non-engineered construction in rural areas. Following documents were consulted at the design stage for structural integrity of building –

- Guidelines for Earthquake resistant non-engineered construction – IAEE and NICEE (National Information Centre of Earthquake Engineering)

- Manual on Hazard Resistant Construction in India – developed under Government of India-UNDP-Disaster Risk Management Programme.

The draft designs prepared on the basis of above guidelines were submitted to an organization National Centre for People's Action in Disaster Preparedness (NCPDP) for The draft designs prepared on the basis of above guidelines were subjected to structural validations by the National Centre for People's Action in Disaster Preparedness (NCPDP). The basis for validating the drawings are provisions of IS 4326: Design and construction of earthquake resistant buildings and IS 13828: Improving Earthquake resistance of low strength masonry buildings-Guidelines. As per IS 4326 this building being a community centre is considered as Category E building, hence design aspects were identified based on the prescriptive recommendations. The design and construction details went through two stages of check and modifications to satisfy requirements for structural safety as specified by NDPDP. **The earthquake resilient components incorporated in the building are as follows –**

Building Shape and Size	• Single storey and double storey parts of the building connected with a corridor simply supported on brackets to ensure that torsion caused by asymmetric constraint to lateral forces will not arise in case of earthquake.
Foundation	• Strip footing has been provided under all load bearing walls.
Seismic Bands	• RCC bands provided at plinth, sill, lintel and roof level.
Masonry (super-structure)	• All corners, T-junctions and sides of door-window openings are re-inforced for ductility with single tor-steel bar
Gable Roof	• Heavy masonry in the gable part of the wall has been replaced with truss and timber plank infill • The gable roof has been constructed with truss using gusset plate joinery and adequate anchorage with wall masonry
Intermediate Slab	• A screed concrete 40mm thick is provided over the planks with 6mm bars @ 6" spacing both ways to ensure diaphragm action of the precast roofing elements • Triangular rings project out of joist for shear connection with the screed concrete.
Door and window opening	• All openings are at least 450mm from inside corner of rooms. • Cumulative width of all openings is Not more than 40% of the total wall length

The architectural design of the community building is comprised of a ground floor of total area 482 sqft with – Community hall, kitchen, store and verandah and first floor of total area 389 sqft with – Guest room and terrace. The proposed technologies were used in the following building elements -

- **Random Rubble Masonry with reinforcement:** For Foundation and masonry till sill level
- **Stabilized Compressed Earth Blocks**: For construction of walls
- **Concrete Block**: For construction of walls (2-storey building)
- **Timber understructure and shingle roof**: For construction of the roof (2-storey building)
- **Plank and Joist roof slab:** For construction of the roof (1-storey building)
- **RCC door-window frames :** For all doors and windows

Specifications of the building -

	Specifications	Quantities
Location	Kamad village, Uttarkashi, Uttarakhand	
Area	Ground floor	482 sqft
	First floor	389 sqft
Architectural design	Ground floor of with – Community hall, kitchen, store and verandah and first floor with – Guest room and terrace. Designed as two independent structures combined with a covered corridor with Mild Steel (MS) staircase to access the first floor of the building.	
Earthquake resilient components	Building shape and size - Structural separation of the ground floor and the double storeyed section connected with a corridor.	
	Foundation- Strip footing has been provided under all load bearing walls.	
	Seismic bands- Continuous RCC bands of 75mm thickness were provided at plinth, sill, lintel and roof level.	
	Vertical reinforcement- All corners, T-junctions and sides of door-window openings are re-inforced with single bar, as specified.	
	Masonry – Wall thickness and material regularity has been maintained.	
	Roof – Concrete screeding with appropriate reinforcement has been maintained.	
	Door and window opening – Opening sizes and appropriate side reinforcements have been maintained.	
Technologies	Reinforced stone masonry - In foundation till sill level masonry.	1473.73 cuft
	Stabilized Compressed Earth Blocks – From sill level to roof level in single storey block.	5250 Nos.
	Concrete Block – From sill level to roof level in double storey block.	1467 Nos.
	Timber understructure and shingle roof- Roofing of double storey block.	99 cuft (Truss)
		2600 Nos. (Shingle)
	Plank and joist roof – Roof of single storey block and intermediate slab of double storey block.	131 Nos. (Planks)
		90 Running ft (Joist)
	RCC door window frames – All doors and windows.	304 Running ft
Cost (Year 2018)		INR 14 Lakhs

6. Way Forward

Learning

The experience of introducing the alternative building technologies in Kamad village illustrates some important points about promoting these technologies at scale. Firstly, there is appreciation of technologies which can be produced at the local level by the community itself, as shown in the case of concrete blocks and SCEB which was a completely new material for the community. The team of women who produced the SCEB value the work as it generates an avenue for income for them. The current generation of masons, many of whom have migrated from plains region is mostly trained in brick and RCC construction and negligible understanding of construction principles for earthquake resistant construction. Training of local manpower will continue to be a critical component of not just using new technologies but also to building safe with conventional technologies.

There is also good potential for small scale precast concrete building elements such as plank and joist roofing elements and door-window frames. The village community felt it is an advantage to be able to build a small roof slab (for instance 12’x12’) in 1 or 2 days with precast elements. The precast elements micro-enterprise established in Matli, Uttarkashi has good potential for its products, which have attracted the interest of a home builders and also the PWD in Uttarkashi. There needs to be a government push for these micro-enterprises by facilitating finance for their improved infrastructure.

Timber such as *Chir* Pine is an abundant resource in the region. Even though it is second grade timber, it has great potential for uses in construction with the help of chemical treatment. Leading institutions like FRI, Dehradun have a rich knowledge base of timber based construction but it has been stagnating for many years with no transfer to real projects on land. The local carpenters trained in the project feel that *Chir* Pine shingles are an excellent alternative to Corrugated Galvanized Iron (CGI) sheets, provided there is an extension of their treatment and production to the villages. There is an urgent need to strengthen the area of timber-based products for construction in conjunction with the sustainable forest management practices which can ensure long-term supply of timber without negative environmental impact. With the right policy support, supplemented with technical support, the resurgence of timber-based practices can be a strong step in the direction of eco-friendly construction in mountainous regions.

Uttarakhand state has envisioned the future of sustainable development and it is critical to create a pathway of such environment friendly and green habitat solutions to achieve that state vision. Looking at the rapidly increasing state infrastructural demand, orientation of state action plan towards green sustainable building techniques and technologies in can go a long way achieving sustainable future of the state. It can be impacted by a collection action from four sides – demand side, supply side, capacity building and knowledge dissemination. At both ground level action and policy formulations like green procurement policy.

Recommendations for state level action

- **Continued emphasis on training of construction manpower in earth-quake resistant construction**

Mountain regions are characterized by diffused volume of construction, influence of dominant construction practices and manpower from plains regions and a strong tradition of non-engineered building. In such a scenario, the role of masons and carpenters assumes greater significance of both design/technical advice and construction services. One of the most critical things is the poor awareness of masons in following the correct RCC and masonry practice for earth-quake resistance. The continuity of traditional knowledge base, largely confined to only a handful of senior masons in each block, is also under question. Correct application of

RCC based practice and strengthening of traditional practices like stone masonry for earthquake resistance are both important aspects to receive continued attention from training initiatives. There are standardized protocols for these, developed both by leading institutions such as IIT-Roorkee and NICEE and civil society organizations. This capacity building should be taken up in a dedicated manner at the district level administration through a mix of longer practice based training programmes and shorter refresher courses.

- **Strengthening the traditional base of timber construction with improved timber-based material and construction system for roof**

Timber is one of the most abundant and valuable resource of mountain regions. It has been part of traditional practice and used in one of the most earthquake-resilient forms of construction in the kath-kuni system. This knowledge base has been declining over the years. However, timber continues to be used structurally as beams for intermediate floor, for door-windows and furniture. Led by environmental concerns, its usage is strictly regulated, though it is challenging to impose regulations across the mountain geography. Sustainable management of forests with involvement of mountain communities is a globally recognized approach to underpin the utilization of timber for its principal applications including buildings and construction. Policy- enabled transformation towards sustainable utilization of timber plays a key role in this. Through the initiative of district administrations and respective Forest departments, it is possible to realize benefits of timber based construction applications without environmental degradation. Equally important is to transfer to the ground, scientific upgrades of timber-based practices. A collaboration between leading scientific institution such as Forest Research Institute and Civil Society organizations can be instrumental in bringing about this transformation. Treatment of secondary grade timber for increased durability and introduction can be achieved with simple, non-electrical means and promoted in mountain regions through local carpentry enterprises

- **Promoting the use of environment-friendly technologies in public buildings and community infrastructure**

Given the emerging prominence of cement-steel and brick based construction practice in mountain regions, it is imperative to promote environment friendly and resource efficient building technologies which can be adapted easily by the local community. The DST TIME LEARN project in Uttarkashi has introduced a range of such technologies in Uttarkashi and demonstrated their use in a variety of buildings. The demand for these technologies can be effectively strengthened with evidence of their adoption in public buildings and community infrastructure. This will also facilitate their green public procurement through inclusion in regional Schedule of Rates and Subsequently in tender documents.

- **Techno-financial support to Micro-enterprises to produce precast RCC-based building products.**

Supply of building products in response to the potential demand in mountain regions is extremely amenable to micro-entrepreneurship. Pre-casting of concrete elements is a scientifically proven way of increasing the resource efficiency of high cement and steel. This is also a way to improve the prevailing low quality of RCC based construction in the region. Enterprises offering products such as precast roofing elements, beams and door-window frames can be located in the urban centres in proximity to the mountain settlements with road access. Financial support to such enterprises and young entrepreneurs in the state is a key requirement to put in place basic and low-cost production infrastructure such as moulds, vibrating tables and electricity back-up. Provisions through state level employment generation programmes such as the PMEGP can be tapped for this purpose.

About Development Alternatives Group

Development Alternatives (DA) is a premier social enterprise with a global presence in the fields of green economic development, social equity and environmental management. It is credited with numerous technology and delivery system innovations that help create sustainable livelihoods in the developing world. DA focuses on empowering communities through strengthening people's institutions and facilitating their access to basic needs; enabling economic opportunities through skill development for green jobs and enterprise creation; and promoting low carbon pathways for development through natural resource management models and clean technology solutions.

Development Alternatives
B-32, Tara Crescent, Qutub Institutional Area
New Delhi 110016, India
Tel: +91-11-2654-4100, 2654-4200, Fax: +91-11-2685-1158
Email: mail@devalt.org, Website: www.devalt.org