Christian Commission for Development in Bangladesh

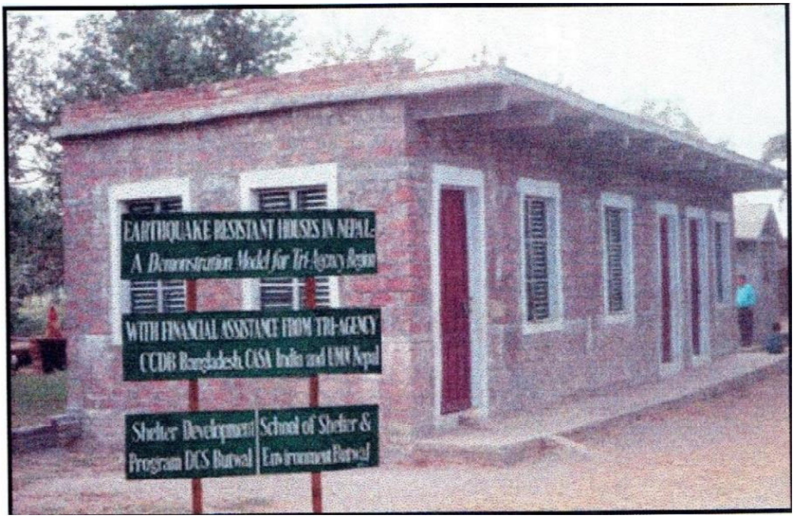
church's auxiliary for social action

United Mission to Nepal

EARTHQUAKE RESISTANT HOUSES IN NEPAL:
A Demonstration Model for Tri-Agency Region

PROJECT COMPLETION REPORT

December 1999



प्रविधि विकास

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ACKNOWLEDGEMENT

Earthquake Resistant Houses in Nepal: A Demonstration Model for Tri-Agency Region (ERH) Project has produced thirty-five skilled workers, nineteen earthquake resistant houses for twenty families, and a community resource center. Shelter Development Program (SDP) of Development and Consulting Services (DCS) Butwal was involved as a leading agency to implement the project initially conceived by Tri Agency Network. The network comprises of Churches Auxiliary for Social Action (CASA) India, Christian Commission for Development in Bangladesh (CCDB) Bangladesh and United Mission to Nepal (UMN) Nepal. Cooperation from all sectors including beneficiary community was one of the basic requirements of the project. Institutions and individuals involved actively participated which resulted in the successful completion of the project and it was possible to achieve all the expected outputs though it took a bit longer time as planned.

Shelter Development Program sincerely acknowledges the Tri-Agency Partnership for the financial support and its constant motivation provided to the project through the mid-term evaluation meeting in Puri India, exposure visits to the project site from its high-level delegates and experts in the related field.

SDP DCS Butwal sincerely thanks Mr. Murari Binod Pokhrel Director, Disaster Response Program (DRP) UMN for providing a leading role to carry out the project activities, his constant support and cooperation extended during the implementation of the project. SDP honors the encouragement and guidance provided to the project team in a timely manner by Mr. Dhananjay Pathak, Tri-Agency coordinator from UMN Headquarters.

SDP express its gratitude to Mr. Noel Vagela from Methodist Eng. Co. Delhi through CASA despite of his busy schedule visited and stayed at the rural site to provide creative comments and valuable suggestions to the project proceedings. His encouraging remarks constantly motivated the project team. He generously contributed seed money to one of the potential beneficiaries. He was not in a position to construct his house, but this donation ultimately made him possible to acquire a disaster resistant house. Similarly, the Tri- Agency Delegates from Bangladesh, India and Nepal who visited the project site and expressed inspiring words to the team, contributed for the progress of the project and is equally acknowledgeable.

The “every day” support and cooperation provided by School of Shelter and Environment (SSE) as an executing partner specially by Mr. Subas Chandra Poudel really helped a lot in making the assignment easier and successful. Therefore, SSE's Subas Chandra Paudel need acknowledged for his contribution.

The Project beneficiaries who were required to provide active participation and full cooperation to the project were involved beyond the expectation of the project team. Obviously, the project would not have been so successful without the support from the local authorities and the beneficiary community. SDP expresses its hearty gratitude to local leaders, influencing personnel, beneficiaries including everyone who directly or indirectly supported the project.

SDP DCS highly acknowledges Mr. Muktar Kurmi and Ram Tilak Kurmi, who, without any hesitation donated 400 square feet of their personal land free of cost to construct a community resource center where villagers gained knowledge and skill of low cost appropriate technology which made the project successful.

The keen interest shown by Dr. Ian Davis, Director Oxford Center for Disaster Studies (OCDS), whose voluntary comments and suggestions were really useful in implementing the project and need hearty acknowledgement.

The comments and suggestions provided by National Society of Earthquake Technology (NSET) Nepal also needs to be acknowledged.

SDP, a program within DCS Butwal expresses its sincere thanks to Mr. Bhawany Shanker Upadhyaya, Director, DCS and Dr. Rameswor Maharjan, Manager, Research and Development Division for their constant motivation and support and guidance extended to carry out the project activities more efficiently and effectively.

As a Project Team leader, I would like to thank my colleagues Mr. Ashok Basnet, Ms. Benu Gurung, Mr. Surya Bahadur Dhakal and Gopal Neupane who really worked hard to accomplish the noble task. At the end, I would like to acknowledge all the DCS staff who directly or indirectly provided necessary support and services to the project. Lastly, but not least, Mr. Bijaya Upadhyaya who contributed with his innovative ideas and who invented construction technology and played key role in making this Tri-Agency model project a success is thankfully acknowledged.

Program Leader
Shelter Development Program.
December, 1999

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1.0 INTRODUCTION

Shelter Development Program (SDP) DCS, Butwal and School of Shelter and Environment (SSE) have jointly completed **"Earthquake Resistant Houses in Nepal: A Demonstration Model for Tri-Agency Region (ERH).** This project facilitated the flood victims of Basantapur, a village in southern Nepal, to construct 20 Earthquake Resistant Houses including one community resource center and one primary school building. This project was financed by Tri-Agency, a network arrangement among Christian Commission for Development in Bangladesh (CCDB) Bangladesh, Church's Auxiliary for Social Action (CASA) India and United Mission to Nepal (UMN) Nepal. ERH was initiated on 1st September 1997 and was completed on 31% June 1999. It was initially planned to end on 31st December 1998 but was extended for three months due to heavy rain during 1998 monsoon and it was further delayed due to local election. This report is a brief of the activities planned and carried out during the project and the achievements made by the project.

2.0 BACKGROUND

Disaster Response Program UMN, SDP in DCS and SSE were looking for an appropriate site for the project. SDP and SSE were insisting the project to be implemented in north-western part of Nepal but this could not be used as an effective demonstration project due to the remoteness of the area. Secondly, it would be difficult to find 12 to 16 individuals willing to build the houses in one year. Access to any location within Kathmandu valley is easy but a community willing to build 12 to 16 simple load bearing earthquake and flood resistant houses within a year could not be identified even with the help of National Society for Earthquake Technology (NSETNepal). At the same time SDP DCS received a request from a community.

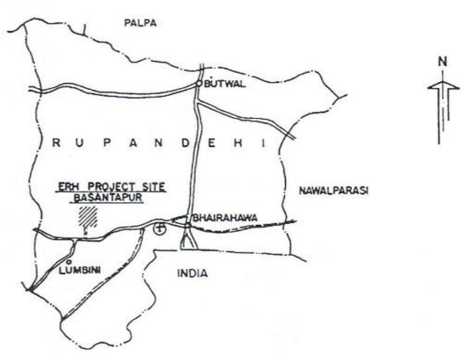


Figure 1 Project Location

Twenty-two houses were destroyed by a flash flood in July 1996 in Basantapur ward number 8 of Dhamauli Village Development Committee in Rupandehi district. Six, out of 22 households rebuilt their houses after the flood using conventional technology, which is vulnerable to flash floods. Rest of the households could not even afford to build in the same manner and requested SDP DCS, Butwal for technical and financial assistance. A team from Disaster Response Program (DRP) UMN Headquarters and DCS visited the site and this location was finalized with the recommendation of DRP.

The criterion set for ERH project almost matched with the request, however the villagers would not accept earthquake a major risk as they had never felt it. But no part of Nepal can be considered safe from earthquake as it is on the high-risk zone. Seismic hazard mapping and risk assessment conducted during the preparation of National Building Code Nepal has assigned this area a factor of 0.9. The similar factors for Kathmandu valley and northern Nepal are 1 and 1.1 respectively.

Basantapur village

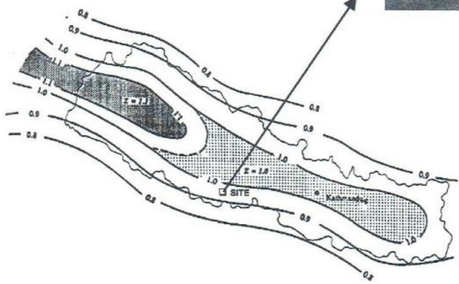


Figure 2 Seismic Zoning Map of Nepal and project site

Zone Factors for Municipalities

Municipality	Factor	Municipality	Factor	Municipality	Factor
Bhadrapur	0.93	Byas	1.00	Ilam	0.97
Bharatpur	0.99	Damak	0.96	Janakpur	0.89
Bidur	1.00	Dhangadi	0.90	Kathmandu Valley	1.00
Birendranagar	1.02	Dhankuta	1.00	Mahendranagar	0.91
Biratnagar	0.93	Dharan	1.00	Nepalgunj	0.91
Birgunj	0.85	Dipayal	1.10	Pokhara	1.00
Butwal	0.9	Gaur	0.82	Tulsipur	1.00

Flash flood and fire were the main concern of the community and they did not consider earthquake as a risk though the research has proved that the area is not safe from earthquake. It was then decided to incorporate disaster resistant components in the buildings to be built so that the buildings will be safe from fire, flood, wind and earthquake.

2.1 **CURRENT SITUATION**

The traditional buildings of Nepal are found to be highly vulnerable to earthquake. Earthen and Low Strength Masonry load bearing walls without any foundation and a heavy roof on top are the main features of these buildings. They collapse during the earthquake, resulting huge loss of life and property. Complete prevention of damage from any intensity of earthquake is not possible. However, such destruction can be considerably reduced by proper techniques using conventional building materials. Buildings built with seismic resistant construction technology may suffer with small damages and cracks but will avoid sudden collapse during a quake. Further such damages can be repaired with a nominal cost and the building will be as strong as earlier.

Owner builders themselves construct private residential buildings in Nepal. It is estimated that 90 % of the existing housing stock in Nepal are owner built. These owner builders do not have access to the technical input from professional technician / engineer. They rely on local "Naike" and or "Mistries" (the local head mason) to look after the construction activities. These "Naikes" and "Mistries" are unknown to basic engineering concepts and completely unaware of seismic resistant technology. Most of them are illiterate and have acquired the skill through trial and error.

2.2 **ERH PROJECT**

Earthquake Resistant Houses (ERH) in Nepal: A Demonstration Model for Tri-Agency Region was formulated to :

- Demonstrate how earthquake resistant houses can be built.
- Provide skills to community members to build earthquake resistant houses by learning by doing approach.
- Train local people in building and maintenance of their own houses.
- Identify earthquake resistant village as a social lab (for effective replication effect)
- Prepare and disseminate information within country and in the region.

3.0 **GOAL**

The goal of this project was to make effective use of the expertise / technology available in the region to reduce the seismic vulnerability of non-engineered owner-built buildings by mobilizing locally available human and physical resources, and demonstrate / disseminate the achievements in the region.

3.1 **OBJECTIVES**

The following five objectives were articulated to achieve the set goal for the project.

- Sensitize the community members in Basantapur of Dhamauli VDC to be aware of natural hazards and their effects on building with special emphasis to earthquake by 30 Sept. 1998 by means of Non-Formal education classes.
- Make the selected beneficiaries in the community aware of the availability of simple economic techniques of better seismic resistant buildings by 31 January 1998.
- Conduct three training programs to train 30 to 45 persons including building technicians, masons, carpenters and those involved in construction sector to construct better seismic resistant buildings by September 1998.
- Support 12 to 16 households within the community to construct better seismic resistant buildings including a community center for the community by 30 September 1998. (This shall be done with full participation of the community so that the skill could be transferred to the community, enhance its sustainability and replication effects).
- Prepare final report and audiovisual materials to disseminate the information within the region by 31 December 1998.

3.2 **ACTIVITIES PLANNED**

The following major activities will be carried out to meet the objectives.

- Finalize project plan.
- Pursues participation from the community and local agencies.
- Motivate the community and form user groups.
- Prepare training materials.
- Conduct first training program.
- Construct community resource center.
- Conduct second training program.
- Facilitate the construction of earthquake resistant houses for selected owner builders of the community.
- Conduct third training program.
- Document the activities of project and prepare final report
- Disseminate the project achievements.

4.0 **ACTIVITIES CARRIED OUT**

4.1 **FINALISE PROJECT PLAN**

SDP along with its executing partner SSE prepared a draft outline and submitted to DRP in August 1997. After getting approval of this draft document a memorandum of understanding (MOU) was prepared and signed on 1st September 1997 by DCS Director and Director DRP. A detailed project proposal was prepared and submitted for approval during the last week of September 1997. Project activities were initiated immediately after the proposal was finalized. A project office was established in Basantapur on 17th November 1997.

4.2 **PURSUE PARTICIPATION**

Project staff conducted series of meetings to brief the planned activities and requested for the active participation from the local authorities like VDC, the Ward along with the beneficiaries. Dhamauli

VDC has actively supported the project as per the commitment made earlier. It provided a plot for the community center and helped mobilize human resources when required. The ward committee has been negotiating with the VDC to upgrade the access road to Basantapur and some river training works along the western bank of Koilihawa River.

4.3 **MOTIVATE/MOBILIZE THE COMMUNITY**

A user group comprising of one member from the beneficiary families is formed. A five-member executing committee is formed from among the beneficiaries to coordinate the various activities regarding the project. A literacy class was conducted by the executing agency on the request of the executive committee for two and a half months. This class was conducted in the evening hours and many of the villagers even outside the beneficiary community actively participated in the non-formal sessions and have now become literate. More than 25 illiterate persons can now read and write but need constant practice to speed up the reading and writing capability.

One of the families donated 400 square feet of land for the project as the land provided by the VDC was not sufficient to construct the community center as per the size executive committee decided to build. The committee also relocated site for the community center as per the request from the village dwellers. Initially it was planned to be constructed in between Koilihawa River and the access road. The building is now located on the existing access road. The plot assigned for the community center is converted to the access road to the village. This has provided the community center more open space. Further the distance from the river to the building is increased by about 5 meter, which provides better safety against flash floods. The villagers also actively participated to fill the ditch in between the road and the river, which has now made the access road 4.5-m wide as against the existing width of 3 m.

4.4 **VIDEO TRAINING**

Preparation of audiovisual components for the dissemination of the technology is a necessity. It was decided that one of the project members would be trained to operate a video camera to reduce the filming cost. Accordingly orientation training for operating video camera was organized. The project coordinator who was also enveloped in preparing "Safe Shelter" a 19-minute video film on effects of earthquake on buildings and techniques to minimize them attended the orientation program. He was involved in the filming of the video strip and the strip has been edited and a twenty minuets long video documentation on the project has been prepared.

4.5 **PREPARE TRAINING MATERIALS**

A detailed lesson plan was prepared for the training in simple Nepali language. The syllabus contains two parts viz. Fabrication of Building Components and Construction technology. The first part was planned for three weeks and the second for seven weeks.

4.6 **CONDUCTION OF FIRST TRAINING PROGRAM**

The first training program began on 4th of February as against the planned schedule for 15th January 1998. The rescheduling was done due to two factors. One of them was that the suggestions from the Tri-Agency Review Meeting if any could be incorporated in the project; and the other was the community members were still busy in their farm, and it was better to start a little later than planned.

This on-the-job training was conducted for 52 consecutive days attended by 10 men and 4 women. The trainees learned various fabrication and construction activities starting from batching of materials for mortar and concrete to making of rat-trap bond masonry walls. Four of them can now build masonry wall on cement mortar. Four women also acquired the skill of making masonry walls but still hesitate to work independently. The remaining two have better skill in bar bending and placement of steel reinforcement.

4.7 **CONSTRUCTION OF COMMUNITY RESOURCE CENTER**

Community center was planned to be built as a by-product of the training program. At the end of the first part of the first training program the community center was ready till roof level including the toilet block. The community center comprises of one hall, one office/utility room, a bathroom, a toilet and a hand pump. The hall is 4m wide and 8m long where as the utility room is 3m wide and 4m long

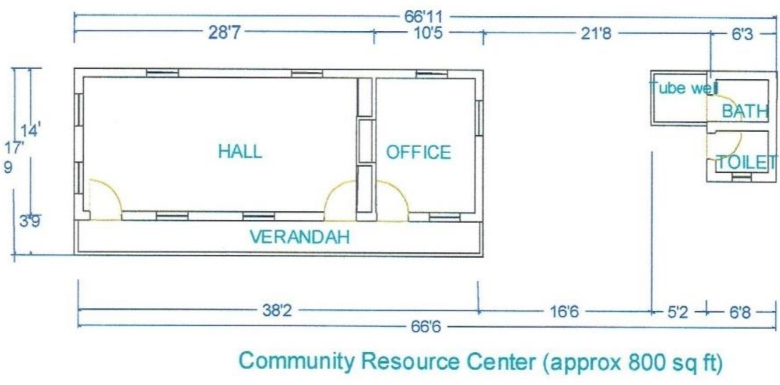


Figure 3 Schematic Plan of CRC

All the fourteen participants from the first training program and new ten members from the village attended the second part of the first training program, which lasted for another 40 days, These trainees learnt to fabricate lean concrete blocks, bamboo-Crete walls and pre-cast RCC components like joist and slabs. After the precast elements were ready to be placed all the villagers joined hand to put these elements on their respective places. The pre-cast joists and slabs were fixed on top of the wall on 28th of May 1998. The community center was used as ERH office after it was completed.

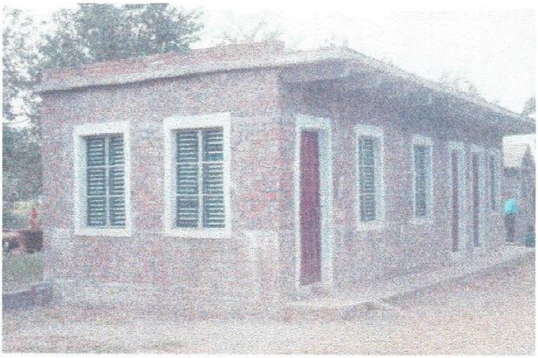


Figure 4 Community Resource Center

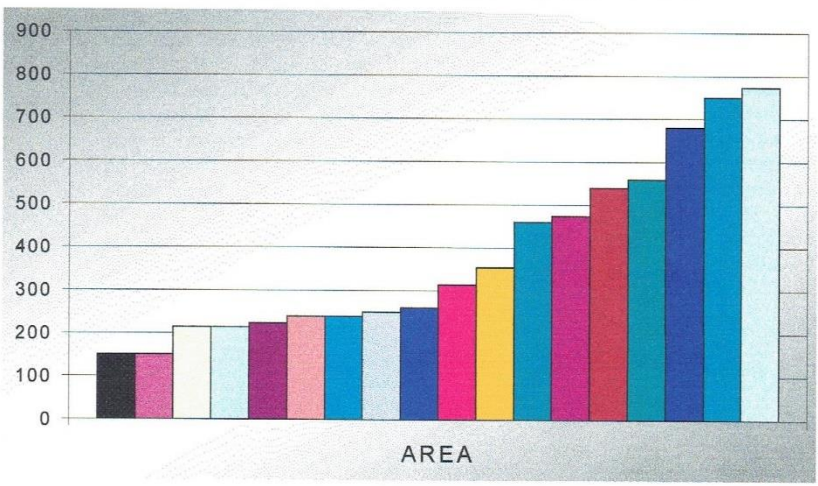
4.8 **CONDUCT SECOND TRAINING PROGRAM**

The second training program and the construction of private buildings were planned to be carried out in parallel. Some of the relatives of the beneficiary families joined them to help the construction activities and acquired the skill in close coordination with the trainers the project has provided. Total of 24 persons acquired the skill required for the technology introduced by the project from the two training programs.

4.9 **FACILITATE THE CONSTRUCTION OF ERH**

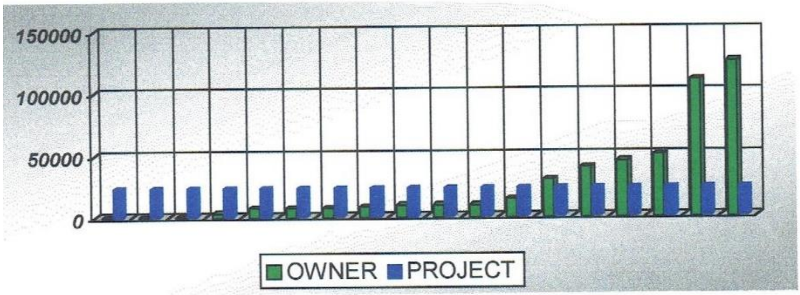
The number of houses has increased from 16 to 18, as it was very difficult for the project to screen among the victims. One of the beneficiaries, living in a joint family got separated after the initiation of the project. The two brothers shared the contribution from the project as well. Thus the number of the houses increased to 19. The project had to accommodate the victims who were affected in an equal intensity. This has reduced the contribution to each household by 6,000 and was revised at 24,000 for each family as against 30,000 planned earlier. The owners' contribution varied as they have different financial status. Some of the beneficiaries were not able to spare any amount for the building and had to construct one room single storied building units with the project contribution alone. This has resulted in buildings with different size and design. The Schematic Plan of each building is annexed to this document. The plinth area of various individual buildings is shown in the following chart.

Plinth Area of Individual Buildings (square feet)



The project contribution in terms of materials required to reduce the vulnerability against natural disaster with special attention to earthquake amounts to NRs. 24,00 and is equal irrespective of the building size. The following chart gives a brief glance about the sharing of cost in between beneficiaries and project.

Sharing of Cost in Individual Buildings (Rs.)



Contribution from the project to the split families is taken as one unit for the computation of this chart.

Eight houses were started on the firs phase. The remaining households started building their houses in the second phase. Seven beneficiaries selected brick masonry in rat trap bond and the remaining built their houses in composite masonry. Over burnt bricks are embedded in 1:5:8 plain cement concrete to build composite walls. This wall came out to be 20 % cheaper as compared to the rat trap bond wall which costs 30 % less as compared to the conventional brick masonry wall. Most of the beneficiaries decided to use the on the site prefabricated RCC roofing system. This system is 30 % economic as compared to conventional cast in situ RCC roof. A few beneficiaries opted for the conventional cast in situ roof because the prefabrication system takes a bit longer time to construct. All the houses have used frame less doors. Some have used frame less windows, others have used timber and or steel windows. All the families have started to live in their new houses they built themselves for their families. They are happy with the houses though some of them have plans to render their dwelling unit for a better look. Building materials used for various components by each household is tabulated bellow.

Building Materials Used in Various Components

SN	Name	Materials Used		
		Walls	Shutters	Roof
1	Rajaram (Rajesh) Murau	Composite Masonry	Frame-less Timber Shutters	Pre-cast RCC
2	Rambriksh Chaudhari Kurmi	Composite Masonry	Frame-less Timber Shutters	Pre-cast RCC
3	Bindaram Yadav	Composite Masonry	Frame-less Timber Shutters	Pre-cast RCC
4	Prahlad Ahir Yadav	Composite Masonry	Frame-less Timber Shutters	Pre-cast RCC
5	Rajendra Yadav	Composite Masonry	Frame-less Timber Shutters	Pre-cast RCC
6	Puranmasi Dhadi	Composite Masonry	Frame-less Timber Shutters	Pre-cast RCC
7	Sadhu Dhadi	Composite Masonry	Frame-less Timber Shutters	Pre-cast RCC
8	Loutu Murau	Composite Masonry	Frame-less Timber Shutters	Pre-cast RCC
9	Ramlot Yadav	Brick in Rat Trap Bond	Steel frame & Timber Shutter	Cast in situ RCC
10	Suryanath Dhadi	Composite Masonry	Frame-less Timber Shutters	Pre-cast RCC
11	Ghanshyam Gupta	Composite Masonry	Frame-less Timber Shutters	Pre-cast RCC
12	Ramlalit Kurmi	Brick in Rat Trap Bond	Frame-less Timber Shutters	Cast in situ RCC
13	Ramsagar Yadav	Brick in Rat Trap Bond	Steel frame & Timber Shutter	Cast in situ RCC
14	Tibbhu Kurmi	Composite Masonry	Frame-less Timber Shutters	Cast in situ RCC
15	Muktar (Jawahir) Kurmi	Brick in Rat Trap Bond	Steel frame & Timber Shutter	Cast in situ RCC
16	Ramesh Yadav	Composite Masonry	Steel frame & Timber Shutter	Cast in situ RCC
17	Ramtilak & Ramsagar Kurmi	Brick in Rat Trap Bond	Steel frame & Timber Shutter	Cast in situ RCC
18	Shanker Yadav	Brick in Rat Trap Bond	Steel frame & Timber Shutter	Cast in situ RCC

Note:

Ramsagar and Harischandra separated after the project initiated so two brothers shared the contribution from the project.

Ramtilak and his son Ramsagar combined the two contributions from the project to make a duplex unit for their residence.

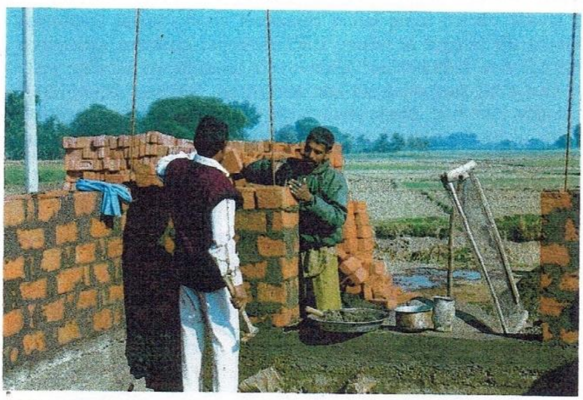


Figure 5 Earthquake Resistant Houses Being Constructed

4.10 **CONDUCT THIRD TRAINING PROGRAM**

It was felt necessary to involve people form outside the community with special preference to those working in construction sector in the final training program. This would considerably increase the chance of replication effect in other areas. Further the community in and around the project area were found to work more like receivers of the technology rather than transmitters. The other fact is that those working in the construction sector do not afford a training program like this without any training allowances to compensate their daily wages. The project initially had plans to train people without any training allowances. The community members accepted this on the ground that they will be supported with materials and also using the community building they build. The beneficiaries are not in a position to pay for any labor. It was necessary to look for an alternative way to make some fund available for the training allowance. This issue was discussed with the Tri-agency Coordinator and DRP Director in UMN and the portion of unspent budget under "Tri-Agency Input" in the project document was transferred to "Training Program". An amount of 65,000 added to the training program. Thus the project was successful in producing fourteen skilled masons from outside the beneficiary community. The project has altogether produced 38 skilled persons who can independently work in the field of disaster resistant houses. The list of trainees is annexed to this report.

4.11 **SUPPORT SCHOOL CONSTRUCTION**

The beneficiaries including all the community members were impressed by the technology and process incorporated in ERH project. The community initiated a project to construct a building for Shree Janahit Prathamik Vidhyalaya at Dubihawa ward number 9 of Dhamauli VDC. The community secured commitment from the VDC authority to support their program. The VDC committed Rupees thirty thousand initial grant for the school building. The community members requested ERH project to support the school construction along with the commitment to providing free unskilled labor for the construction. ERH project accepted the request and the supported the school with materials required for the seismic resistant components and the technical input. The building is now ready and being used by the primary school.

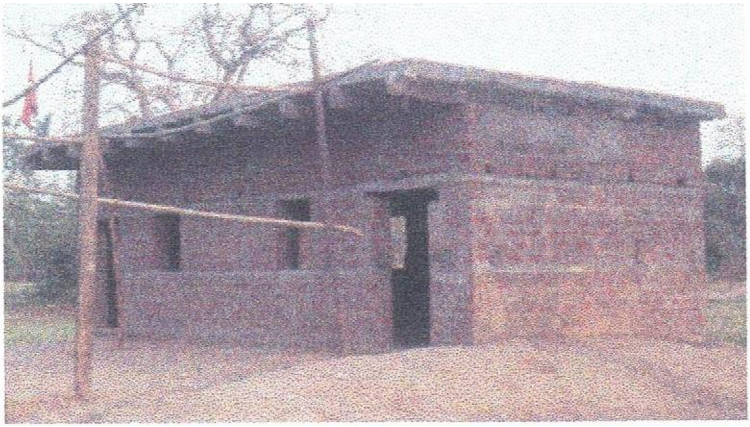


Figure 6 Shri Janahit Prathamik Vidhyalay

4.12 **DOCUMENT THE ACTIVITIES AND PREPARE FINAL REPORT**

All of the major events are documented in various mediums like Brochure, Slide, Photograph including one 17-minuet long video documentary film in English. A Nepali version of the video documentary is being prepared. Introductory brochures of the cost-effective building components used in the project are prepared and annexed to this report.

4.13 **DISSEMINATE THE PROJECT AND ITS ACHIEVEMENTS**

People from different works of life were invited to visit the site and the project organized observation tours for various communities and institutions that accepted the invitation. The following list presents the major visitors to the project at different stages of the project.

- A high level team from the local authority including Chief District Officer HMG/Nepal and Chairman of Rupandehi District Development Committee.

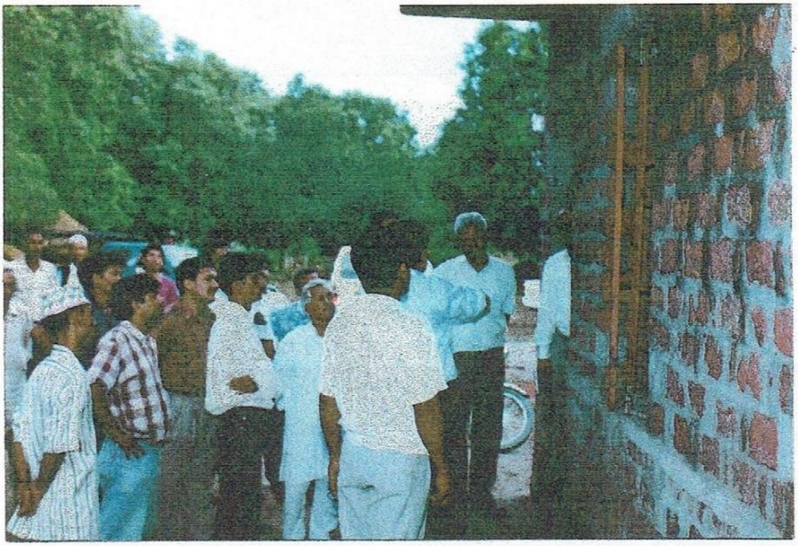


Figure 7 District Officers at ERH Site

- Mahilwar Housing Cooperative, an initiative taken to improve themselves by a squatter community in Mahilwar.
- Community forestry user group members from Butwal.
- Community Members of Nirdhan Project a micro financing NGO. Nirdhan Project has plans to provide long term loans amounting up to NRs. 60,00 for building a house to its community members.
- Delegates form Tri-Agency Partnership Organizations from India, Bangladesh and UMN, Nepal have visited the site at various stages of the project and provided feedback to the project which was found to be very useful.

Figure 8 Tri Agency Team at ERH Project Site

- The project proceedings and the achievements were also presented during the "Earthquake Safety Day" Celebrations 16 to 18 January 1999 at Bhrikuti Mandap in Kathmandu. The three-day event was jointly organized by Ministry of Science and Technology and National Society for Earthquake Technology Nepal. Prime Minister Girija Prashad Koirala inaugurated the program. The general people were impressed by the achievements of the project and were asking for institutions who provide technical support to the public.

Wider application through replication of the technology is the goal of dissemination. The result of the dissemination strategy adopted by the project has started to come out. Some of the components introduced by the project is being incorporated in three of the four houses under construction in the village. This is a positive indication towards replication of the technology and processes in a wider range with appropriate changes to suit the site of the community that decides to adopt the method.

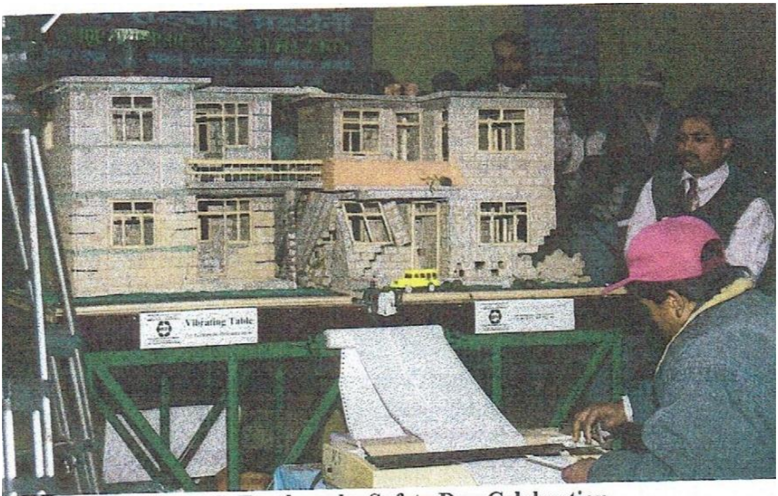


Figure 9 Earthquake Safety Day Celebration

5.0 **FINANCIAL STATEMENT**

The total budget of the project which is one million five hundred ten thousands Nepali Rupees which was divided into various headings for accounting purpose as per the existing system of DCS, Butwal. The budget allocated for each heading and the respective final expenses are presented in the following table.

Planned and Actual Expenses of the Project

Planned and Actual Expenses of the Project

SN.	AC Code	Description	Expenses	
			Planned	Actual
1	1036-SDP A	Salaries and Benefits	175,000.00	175,000.00
2	1036-SDP B	Office Supplies	20,000.00	8,859.92
3	1036-SDP C	Travel and Daily Allowances	170,000.00	213,757.95
4	1036-SDP D	Training Program	145,000.00	173,291.60
5	1036-SDP E	Minor Capital	20,000.00	9,926.85
6	1036-SDP F	Construction Materials	710,000.00	669,308.81
7	1036-SDP G	Documentation	40,000.00	55,868.00
8	1036-SDP H	Miscellaneous	20,000.00	14,889.00
9	1036-SDP I	Consultancy	210,000.00	189,097.87
			1,510,000.00	1,510,000.00

6.0 **CONCLUSION**

ERH Project is an innovative community owned and managed disaster resistant housing project designed to transfer the simple techniques to minimize the effect of disasters, with special emphasis to earthquake in residential buildings; and provide disaster resistant building construction skills as a tool to enhance their income level. It is probably the first rehabilitation project in Nepal, initiated and completed successfully in full and active participation of the affected families.

Eighteen families rendered homeless by the flash floods have constructed eighteen disaster resistant houses themselves for their families. They have also constructed a primary school and a community resource center. These buildings cost about 20% less as compared to the prevailing construction technology.

The project has also produced 38 skilled building workers who can produce cost effective building components from the locally available building materials and construct, disaster resistant buildings. These buildings cost less than the houses constructed using the prevailing construction technology.

All the concerned key actors participated actively in the project. Active and wholehearted participation of the beneficiary community has certainly boosted the ownership feeling among the community members. The technology introduced by the project is being appreciated and accepted by those outside the beneficiary community. Participation of their relatives in the construction activities has enhanced the possibility of its replication and continuation of the technology after the project ends.

The beneficiaries have well understood the strength of community participation in enhancing their living condition. They are now convinced that no one can help them better than themselves. This is reflected in their action as they have positively influenced the VDC authorities to support them in their endeavors. The VDC have provided an amount of Rs. 30,000 for the primary school construction with additional technical assistance from ERH project. The VDC authorities have also committed to support them in river training works at the bank of Koilihawa River. This has clearly shown the increased bargaining capacity of the community with the political leaders and self-confidence within themselves.

It can be concluded that the demonstration model project has successfully completed. All the expected outputs have been achieved as planned, though, it had to be delayed by about three months from the planned schedule due to some unavoidable circumstances.

6.1 **Impact**

Even the poorest of the poor in Basantapur have now learned to mobilize their resources in a better way. This was possible because they never thought it would be possible for them to construct a disaster resistant houses, though a small single room dwelling unit. The eighteen families who were living in temporary huts were surprised to know that they had mobilized a total of about one million rupees within about twelve months. This was beyond their imagination and they would have never accepted the project if they knew that they were required to mobilize a million rupees for the rehabilitation.

The technology introduced by the project is being transferred in the vicinity of Basantapur. Four houses being constructed around Basantapur (after the project completed) have used the construction technology introduced by the project.

National Society of Earthquake Technology (NSET)-Nepal has taken special interest on the successful model. The Chairman along with the General Secretary has visited the project site and complemented on the successful achievement of the project.

6.2 **Lessons Learnt**

Institutions striving to enhance the living condition of the marginalised and the poor get concentrated on the "backward" or the "less privileged ones" as they are the potential beneficiaries. This some how ignores the relation in between the rich ones or the influential persons with their beneficiaries. Coming to technology transfer the influential mass or the "rich ones" should be used as a vehicle medium of technology transfer. If such an innovative technology would have been used in one of the influential persons in the community it would have been more easily and widely transferred. As all the poor ones would be normally trying to achieve the position that this influential person is enjoying. The marginalized group cannot afford to do this as their economic condition does not allow them. When such technology is provided to the poor ones the rich ones not only tend to ignore it but also take negatively because they are not benefited (status - quo).

Periodic but timely motivation is essential to boost the technology transfer. This is clearly observed by the two houses being built in conventional method in the project area. The owner was involved as an active partner in the construction of the primary school and the contractor was trained in the school for the improved technology. This contractor when asked about the reason of diverting to the prevailing construction practice told that he is used to work as his employer says. Both the employer and the contractor know the benefits about the technology, have confidence in it but not using it. The owner of house said that there was no one to advise about the new technology and he was surprised to our question. The builder when persistently asked about it hesitantly disclosed that the new technology would decrease his working days and eventually earn less from the same building.

7.0 **RECOMMENDATION**

- More exposure visits have to be organized for wider dissemination of the project.
- The project needs to be very well documented for further dissemination. The achievements of the project have to be shared to maximum possible audience through workshops, seminars, exchange visits etc.
- The activities should not end up as a project but initiate a continuous process by following up of the trainees and provide technical support to the trainees by arranging refresher training of short duration.
- Networks and institutions like TRI-AGENCY, UMN should facilitate the key actors (like DCS, SSE, NSET-Nepal and the beneficiary community) to replicate the achievement and learning of this project with the required alterations and improvements in at least two hilly areas of Nepal (prone to earthquake).

Appendix 1

Technologies Used

1. Lean Concrete Bricks
2. Stonecrete Blocks
3. Stonecrete Wall
4. Brick Masonry in Rat-trap Bond
5. Cast-in-situ Slab over Pre-cast RCC Joists

LEAN CONCRETE BRICKS

1.0 **INTRODUCTION**

Lean Concrete Bricks (LCB) are one of the alternatives to conventional fired clay bricks. These walling units are manufactured locally. Cement sand and aggregates are mixed with water in a certain proportion to make these bricks. LCB do not need to burn and the energy required to produce is considerably reduced as compared to conventional bricks. The owner builder can easily make LCB on their free time and construct houses for themselves. This will make these bricks affordable to the owner reducing the cash out-flow.

2.0 **BACKGROUND**

Bricks are widely used to construct buildings since the pre-historic times and will be continued. Easy manufacturing process and availability of raw materials in abundance are the major factors that have made bricks a popular walling unit. The reason for its wider use is also because it is handy and easy to build. Many institutions and individuals are engaged in research and development of affordable alternatives to conventional bricks. They are spending their time and effort to reduce the consumption of fertile clay and level of environmental pollution.

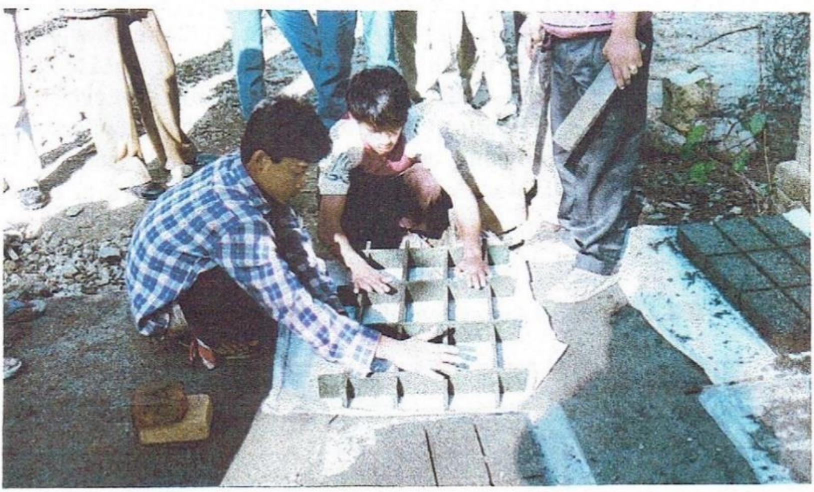
2.1 **Rational**

Cost of construction materials is increasing rapidly and the purchasing capacity of the general public, specially the economically weaker population is declining. The demand of adequate permanent shelter is much more than what is being achieved. There is an absence of the institution or organization that provides permanent adequate shelters to the poor. Individual owner builders are some how filling this gap. Labor based technology for he production of building materials/components and methods of construction is a primary need.

2.2 **Basic Requirement**

Cost effectiveness of any building component is governed by the availability of local materials in the particular site. LCB will be most cost effective for people living in areas where bricks are not produced and or cost high and at the same time sand and aggregates are easily available and affordable. Cement should also be available in a reasonable price. Further if the owner builders family have plenty of free time they can also make use of this technology to cash the free time by making these walling units.

The production of these units will require a plain and leveled casting yard. A casting yard of about 100 square meter is required for a plant to produce 1000 bricks per day. An additional space to store materials, stack final product and water storage for mixing and curing is required.



A gang mold that can produce 9 bricks in one batch.

3.0 **PRODUCTION PROCESS**

Lean Concrete Bricks can be produced manually with simple molds and tools. The owner builder can produce it on her/his construction site by him/herself. The size of LCB is made similar to burnt clay bricks (23cm long 11cm wide and 6.5 cm thick) to make it compatible. One part of cement five parts of sand and eight parts of aggregates is thoroughly mixed at the dry stage. It is then turned into a homogeneous mixture after adding water. This mixture is poured into the molds and compacted to cast LCB.

De-molding is done after about ten to fifteen minuets. It is air dried for six to twenty four hours depending on the quality of cement used and the climatic condition. Curing is done after this for three weeks before they are used in a wall. Materials required for LCB and the production cost is presented in the following table.

Production cost for 1000 LCB

Description	Quantity	Unit	Rate	Amount (Rs.)	Remarks
Cement	4.00	BAG	270.00	1,080.00	*The price of bricks will be less if the owner builders make it using their free time. The materials alone will cost Rs. 1.75 only per brick.*
Sand	0.75	CUM	175.00	131.25	
Aggregate	1.15	CUM	450.00	517.50	
Labor	7.00	MD	80.00	560.00	
Sub-total				2,288.75	
Add 3 % for tools and plants				68.66	
Total cost of production for 1000 bricks				2,357.41	
Total cost per brick				**2.35**	

Rate obtained from practical experience in TBT and ERH projects.

4.0 **ECONOMY**

The unit price of the bricks shown in the table is achieved in Basantapur during the execution of Earthquake Resistant Houses in

Nepal: A Demonstration Model for TriAgency Region (ERH) Project. Unit price of the block alone will not provide the full information about its cost effectiveness. The cost effectiveness of these units are even higher after the wall is built and rendered with plaster. It is because these LCB will have minimum variations in size and does not have recessed "frog" as in the case of local bricks. This results in reduced consumption of mortar for masonry. At the same time the wall surface is also smoother as compared to local bricks. This will facilitate to render the wall with a thin layer of plaster and save cement. The following table compares the cost of a 23cm thick and 6m long. The height of the wall is assumed to be 3.5m. The cost of this wall after plaster will be Rs 12033.83 if the local kiln bricks are used. The same wall will cost Rs. 10076.30. Thus the use of LCB can save about 16 % if one opts to hire labors to make LCB. If the owners family opts to make use of their free time the savings in terms of cash-flow will increase up to 30 % as compared to the same wall built with local kiln bricks.

Comparison of walls made with LCB and LKB

Description	Lean Concrete Brick Wall				Local Kiln Brick Wall			
	Qtty.	Unit	Rate	Amount	Qtty.	Unit	Rate	Amount
Bricks for masonry	2400	NUM	2.35	5,640.00	2400	NUM	2.65	6360.00
1:6 mortar for masonry	0.91	CUM	1765.00	1,606.15	1.18	CUM	1765.00	2,082.70
Mason for masonry	8.0	MD	125.00	1,000.00	8.0	MD	125.00	1,000.00
Labor for masonry	10.0	MD	80.00	800.00	10.0	MD	80.00	800.00
1:6 mortar for plaster	0	CUM	1765.00	0.00	0.315	CUM	1765.00	555.98
1:4 mortar for plaster	0.263	CUM	2358.00	620.15	0.263	CUM	2358.00	620.15
Mason for plaster	2	MD	125.00	250.00	3	MD	125.00	375.00
Labor for plaster	2	MD	80.00	160.00	3	MD	80.00	240.00
Total Cost for Wall				**10,076.30**				**12,033.83**

STONECRETE BLOCKS

1.0 **INTRODUCTION**

Stonecrete Block is an affordable alternate walling unit. This can be made in various sizes to achieve desired wall thickness 10, 15, 20, cm of wall. The height and breadth of these blocks are respectively 15 and 30 cm. The tools and plants including technology of production is so simple that any one can make it if interested. These masonry units can be used to construct load bearing masonry buildings as well as curtain walls in framed structured ones.

2.0 **BACKGROUND**

Construction of random rubble stone masonry is common in almost all parts of Nepal. The people in the Terai (southern plains) mostly use river boulders and those in the hilly areas use quarry stone. Due to uneven sizes of stone the wall thickness varies from 40 to 60 cm. This results in high consumption of manpower and materials that makes the wall unnecessarily heavy and expensive. These walls could be made thinner by using dressed stones. Dressing of stones is again another costly affair. Stonecrete Blocks provide a better solution to this problem by making use of these irregular stones to make uniform and regular sized masonry blocks of varying thickness.

2.1 **Rational**

Stone is available in the natural form, which has high compressive strength. Stone is used in all kinds of construction from roads and bridges to dams and buildings. Such a versatile and cheap material is being expensive as the construction activity is increasing. We need to find a way out to minimize the use of these materials in an effective manner. Reducing the normal wall thickness from 40–60 cm to 20–25cm can save more than 50 % of stone consumption including the manpower to construct these walls. Further it is difficult to achieve desired bonding with the irregular sized stones that makes the wall vulnerable. Stonecrete Blocks are designed to take care of these problems. Stonecrete block wall is much cheaper than the normal stone masonry and is strong enough to make load-bearing buildings up to two stories. These units can also be used as curtain walls in framed structures.

2.2 **Basic Requirement**

Cost effectiveness of any building component is governed by the availability of local materials in the particular site. Stonecrete Blocks will be most cost effective for people living in areas where bricks are not produced and or cost is high and at the same time stone and sand is easily available at an affordable price. Cement should also be available in a reasonable price. Further if the owner builder’s family have plenty of free time they can also make use of this technology to cash the free time by making these walling units and selling to potential builders within the communities nearby.

The production of these units will require a plain and leveled casting yard. A casting yard of about 150 square meter is required for a plant to produce 1000 blocks per day. An additional space to store materials, stack final product and water storage for mixing and curing is required.

3.0 **PRODUCTION PROCESS**

Stonecrete Blocks can be produced manually with simple molds and tools. The owner builder can produce it on her/his construction site him/herself. The length and height of blocks are 30 and 15 cm respectively. The thickness of the block can have three options 10, 15, and 20 cm so that wall of desired thickness can be made. Battery mold can be used to produce more number of blocks at the same time or a single mold may be used in a small-scale production unit.

A gang mold that can produce 16 bricks in one batch.

One part of cement five parts of sand and eight parts of aggregates is thoroughly mixed at the dry stage. It is then turned into a homogeneous mixture after adding water. This mixture is poured into the molds to cast blocks. The first layer is two centimeters thick. After this, broken pieces of stones are kept on top of this first layer. These stone pieces can either be quarry stone or river boulders. These pieces should have the size to be accommodated in the mold with a minimum of two centimeters gap in between the two stone pieces or wall of the mould. The concrete mix is poured to fill the gap in between and compacted manually. De-molding is done after about ten to fifteen minutes. It is air dried for six to twenty four hours depending on the quality of cement used and the climatic condition. Curing is done after this for three weeks before they are used in a wall. Materials required for Stonecrete Blocks and the production cost is presented in the following table

Production cost for 100 Blocks of various sizes.

ITEM	UNIT	RATE	30 X15 X 20		30 X 15 X 15		30 X 15 X 10	
			QTTY	COST	QTTY	COST	QTTY	COST
Materials								
Cement	BAG	270	1.4	378	1.05	283.5	0.6	162
Sand	CUM	175	0.25	43.75	0.18	31.5	0.12	21
Aggregate	CUM	250	0.4	100	0.3	75	0.2	50
Stone	CUM	300	0.55	165	0.5	150	0.25	75
Material cost				686.8		540		308
Mason	MD	125	0.5	62.5	0.4	50	0.3	37.5
Labor	MD	80	2	160	1.75	140	1.5	120
Labor Cost				222.5		190		157.5
Tools/plant	L/S			175		150		125
Total				1084		880		590.5
Cost / Block				**10.84**		**8.8**		**5.905**
				= 11.00		**= 9.00**		**= 6.00**

Rate obtained from practical experience in TBT and ERH projects.

4.0 **ECONOMY**

The unit price of the blocks presented in the table is based on the "Earthquake Resistant Houses in Nepal: A Demonstration Model for Tri-Agency Region" (ERH) Project. A 20cm thick block is about 5.5 times larger than the local brick. 5.5 bricks cost rupees 14.5, where as a block cost only 11 rupees. Its cost effectiveness further increases while building wall as it consumes very little mortar and manpower. The only draw back of this block is that it is heavier than bricks. A 20 cm block weighs about 18 Kg. But this is very much justified by the cost saved and also considering a hollow concrete block that weighs as much as 21 KG. The following table compares the cost of 6m long and 3.5 m high wall.

Comparison of walls made with LCB and LKB
(6 m long and 3.5 m high wall)

Description	Stonecrete Block wall (20 cm)				Local Kiln Brick Wall (23 cm)			
	Qtty.	Unit	Rate	Amount	Qtty.	Unit	Rate	Amount
Masonry units	455	NUM	11.0	5,005.00	2400	NUM	2.65	6360.00
1:6 mortar for masonry	0.55	CUM	1765.00	970.75	1.18	CUM	1765.00	2,082.70
Mason for masonry	4.0	MD	125.00	500.00	8.0	MD	125.00	1,000.00
Labor for masonry	7.0	MD	80.00	560.00	10.0	MD	80.00	800.00
1:6 mortar for plaster	0	CUM	1765.00	0.00	0.315	CUM	1765.00	555.98
1:4 mortar for plaster	0.263	CUM	2358.00	620.15	0.263	CUM	2358.00	620.15
Mason for plaster	3	MD	125.00	175.00	3	MD	125.00	375.00
Labor for plaster	3	MD	80.00	240.00	3	MD	80.00	240.00
Total Cost for Wall				**8,070.9**				**12,033.83**

Cost of wall after plaster will be Rs 12034 if the local kiln bricks are used. The same wall will cost Rs. 8071 if built in Stonecrete Blocks. Thus, the use of Stonecrete Block can save more than 32 % if one opts to hire labors to make Local Kiln Bricks. If the owner’s family affords to make use of their free time the savings in terms of cash-flow will increase up to 50 % as compared to the same wall built with Local Kiln Bricks.

STONECRETE WALL

1.0 INTRODUCTION

Raw materials are processed to make walling units like bricks, blocks etc. and used to make walls. Stonecrete wall uses the basic materials to make a wall avoiding the process of changing these basic materials into masonry units. This saves time and resources spent in fabrication of walling units. Concrete mix and the filler material is put into a simple mould and compacted to make stonecrete wall. This is similar to construction of Rammed Earth Wall.

2.0 RATIONAL

Stone is available in the natural form, which has high compressive strength. Stone is used in all kinds of construction from roads and bridges to dams and buildings. Such a versatile and cheap material is being expensive as the construction activity is increasing. We need to find a way out to minimize the use of these materials in an effective manner. Reducing the normal wall thickness from 40–60 cm to 20–30cm can save more than 50 % of stone consumption including the manpower to construct these walls.

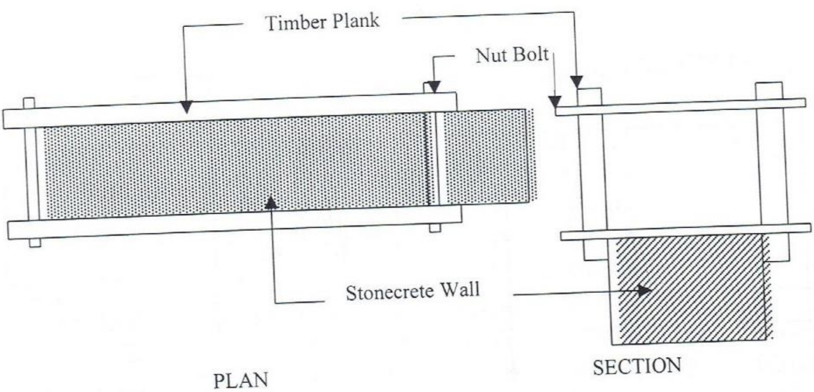
Brick factories produce large amount of over burnt bricks. These bricks are smaller and irregular in size and shape. It is much stronger than the regular bricks but cannot be used in a wall. It can be used to replace stones in stonecrete wall.

3.0 BASIC REQUIREMENT

Cost effectiveness of any building component is governed by the availability of local materials in the particular site. Stonecrete Walls will be most cost effective in the locations where stone and or over burnt bricks are available in plenty and do not cost much. Cement, Sand and aggregate should also be easily available at an affordable price.

4.0 **CONSTRUCTION PROCESS**

Stonecrete wall can be constructed manually with simple molds and tools. The owner builder themselves can construct the walls for their buildings. A simple form made up of two timber planks and a few pairs of nut bolt as shown in the following figure is required. Local carpenters can easily make these units.



A Simple form to construct stonecrete wall.

One part of cement five parts of sand and eight parts of aggregates is thoroughly mixed at the dry stage. It is then turned into a homogeneous mixture after adding water. This mixture is poured into the forms to make two- and half-centimeter-thick compacted layer in line and level to construct wall. Filler materials are placed on top of this layer. Broken pieces of stone or over burnt bricks can be used as filler material. These filler materials should have the size to be accommodated in the form with a minimum of two and half centimeter gap in between the two pieces or wall of the form-work. The concrete mix is poured to fill the gap in between and compacted manually. De-molding is done immediately after the form is filled and compacted uniformly. The form is cleaned and placed in position to continue construction of wall. The construction process is a bit slower as compared to the construction of wall with bricks or blocks, but saves a lot. The succeeding layers can be built after 24 hours. The wall should be cured with clean water for three weeks.

5.0 **ECONOMY**

The following table compares the cost of 6m long and 3.5 m high wall. The cost of this wall after plaster will be Rs 12034 if the local kiln bricks are used. Stonecrete wall of the same size will cost only Rs. 6550.00. Thus, the use of Stonecrete wall can save more than 45 % if one opts to hire labors to construct Stonecrete wall. If the owner's family affords to make use of their free time the savings in terms of cash-flow will increase up to 60 % as compared to the same wall built with local kiln bricks without decreasing the durability and strength of the wall.

Comparison of Stonecrete wall and LKB wall
(6 m long and 3.5 m high wall)

Description	Stonecrete Wall (23 cm)				Local Kiln Brick Wall (23 cm)			
	Qtty.	**Unit**	**Rate**	**Amount**	**Qtty.**	**Unit**	**Rate**	**Amount**
Bricks		NUM		-	2400	NUM	2.65	6,360.00
1:6 mortar for masonry		CUM		-	1.18	CUM	1765	2,082.70
Cement	7.245	BAG	270	1,956.15	0	BAG		-
Sand	1.328	CUM	200	265.65	0	CUM		-
Aggregate	2.125	CUM	225	478.17	0	CUM		-
Filler Material	2.657	CUM	230	611.00	0	CUM		-
Mason for masonry	10	MD	125	1,250.00	8	MD	125	1,000.00
Labor for masonry	12	MD	80	960.00	10	MD	80	800.00
1:6 mortar for plaster	0	CUM	1765	-	0.315	CUM	1765	555.98
1:4 mortar for plaster	0.263	CUM	2358	618.98	0.263	CUM	2358	620.15
Mason for plaster	2	MD	125	250.00	3	MD	125	375.00
Labor for Plaster	2	MD	80	160.00	3	MD	80	240.00
Total Cost for Wall				**6,549.94**				**12,033.83**
				= 6,550.00				**=12,084.00**

BRICK MASONRY IN RAT-TRAP BOND

1.0 **INTRODUCTION**

Laying out bricks in atypical method while constructing a wall makes rat-trap bond. Bricks are laid on edge so that one brick thick cavity wall is formed. In other words Rattrap bond is used to create hollow block wall out of burnt clay bricks. This will save 25 to 30 % of the materials and manpower required as compared to the conventional solid brick wall. Further the smooth finish on both the internal and external surface will be economic to render the wall with cement sand plaster.

2.0 **BACKGROUND**

Bricks are widely used to construct buildings since the pre-historic times and will be continued. Easy manufacturing process and availability of raw materials in abundance are the major factors that have made bricks a popular walling unit. The reason for its wider use is also because it is handy and easy to build. Many institutions and individuals are engaged in research and development of affordable alternatives to conventional bricks. Wider use of the recently developed alternatives to the bricks will certainly take more time and bricks will be continued to be used in wall even ion the days to come. Optimum, effective and efficient use of bricks is also an important issue to be dealt with. Rat-trap bond wall will reduce the consumption of bricks and cement. These walls can be load bearing for a normal residential building up to two-story height and can be very well used in any story in as curtain and or partition wall of a frame structured building.

2.1 **Rational**

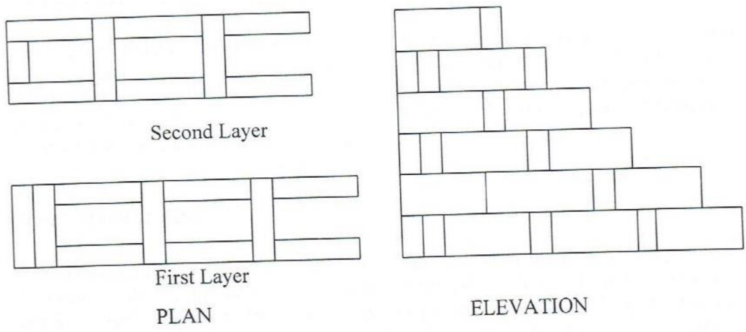
Cost of construction materials is increasing rapidly and the purchasing capacity of the general public; especially the economically weaker population is declining. The demand of adequate permanent shelter is much more than what is being achieved. There is an absence of the institution or organization that provides permanent adequate shelters to the poor. Individual owner builders are some how filling this gap. Labor based technology that minimizes the use of conventional materials without decreasing the strength and durability of building materials/ components is a primary need.

2.2 **Basic Requirement**

The conventional masons need to be trained to build rat-trap bond in a masonry wall. This can be done by organizing an on-the-job orientation / training program of one to two week duration for the masons. At the initial stages for a few weeks the speed of construction will be a bit delayed. The masons will build rat-trap bond wall faster than the conventional solid walls after they are used to with the new technique.

3.0 **WALLING METHOD**

Two bricks are laid on edge so that they are adjacent and parallel to begin a wall. These two bricks should be laid in the direction normal to the length of the wall. Another two bricks are then laid on the edge parallel to the length of the wall and flushed to each edge of the bricks laid earlier as shown in the drawing. Next brick is laid on the edge so the “U” shape formed earlier is closed and a cavity is formed. This is continued throughout the length of the wall. The detail of the bond is presented in the figure bellow.



Rat trap bond wall

4.0 **ECONOMY**

The following table compares rat-trap bond wall with the conventional solid wall.

Comparison of walls made in Rat-trap Bond and Normal Bond (10 Sqm)

Description	Brick Wall in Rat trap Bond				Ordinary Brick Wall			
	Qtty.	Unit	Rate	Amount	Qtty.	Unit	Rate	Amount
Bricks for masonry	850	NUM	2.65	2252.50	1150	NUM	2.65	3047.50
1:6 mortar for masonry	0.45	CUM	1765.00	794.25	0.60	CUM	1765.00	1059.00
Mason for masonry	3.00	MD	125.00	375.00	3.75	MD	125.00	468.75
Labor for masonry	4.00	MD	80.00	320.00	5.50	MD	80.00	440.00
1:6 mortar for plaster	0.00	CUM	1765.00	0.00	0.20	CUM	1765.00	353.00
1:4 mortar for plaster	0.20	CUM	2358.00	471.60	0.20	CUM	2358.00	471.60
Mason for plaster	2.00	MD	125.00	250.00	3.00	MD	125.00	375.00
Labor for plaster	3.00	MD	80.00	240.00	4.00	MD	80.00	320.00
Total Cost for Wall				**4703.35**				**6534.85**

Construction cost for a wall is reduced by about 30 % as compared to conventional walling system by adopting rat-trap bond wall. This is a good example of optimum effective and efficient use of the materials currently being used.

CAST-IN-SITU SLAB OVER PRE-CAST RCC JOISTS

1.0 **INTRODUCTION**

Reinforced Cement Concrete (RCC) is one of the most widely used flooring and roofing structural element used for various constructions. The rocketing price of timber has also contributed a lot for its popularity within owner builders. Cast-in-situ Slab over Pre-cast Joists is introduced to optimize the consumption of materials and minimize the shuttering works required for a RCC slab.

2.0 **BACKGROUND**

RCC though a newer building material is now being widely used to construct buildings. Reasons for its popular acceptability is its strength, durability, not eaten by insects and moths. Further RCC can be made at any shape and size. The only drawback is the requirement of heavy and robust form-work is required for RCC. Centralized prefabrication unit for various modular RCC Building components is one of the options to minimize the wastage of raw materials and eliminate the heavy form-works required in each building site. Such a plant may be feasible in those urban areas where transportation facility is available and there is ample space in the building site where lifting cranes can be operated. In other areas on the site pre-fabrication can solve the problems.

2.1 **Rational**

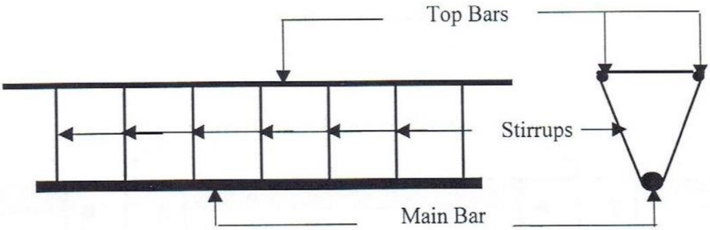
Pre-cast RCC flooring panels and RCC joists can be used to eliminate the form works and optimize the construction materials. The precast elements have to be fixed in such a manner that it will act as a homogenous mass. A diaphragm is also desirable for seismic safety. Further the joints of the flooring panels may develop cracks and leak if used in the roof. Monolithic cast-in-situ Slab over Pre-cast RCC Joist fulfils all these requirements.

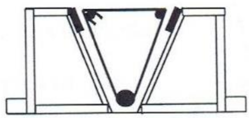
2.2 **Basic Requirement**

It is slightly different to the conventional RCC slab used for floor and roof. Practicing masons can fabricate the joists and place it properly with ample anchorage in the horizontal roof band that runs throughout the wall length. An orientation / training should be organized to fabricate the joists and use typical type of shuttering required for using this techniques. Special form-work is required to produce the joists. A good construction planing is necessary for effective use of this technology to save over all construction time. Further maintaining a grid design in the building will provide better simplicity and reduce the construction cost.

3.0 **PRODUCTION PROCESS**

The joists have trapezoidal section. The bottom width is 7 centimeters and the top is 15 centimeters in cross section. The cress sectional height is 20 centimeters. These joists can be used to floor or roof a room of up to 4 m clear span. The form is made up of timber or metal or even in combination of these two. The form is placed on a leveled ground in perfect line and level. Cover blocks or stone aggregates to raise the reinforcement by one and a half centimeters are placed on the bottom of the mould at thirty-centimeter interval. The steel reinforcement is placed on top of the cover pegs so that the any part of the steel bars is at a distance of minimum one and half centimeter away from the wall of the mould. The following figure illustrates the arrangements before casting.

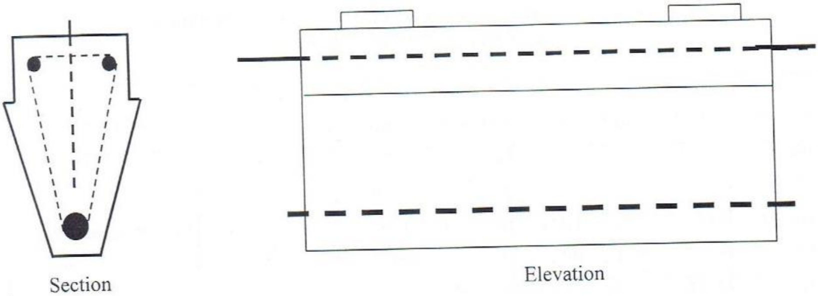




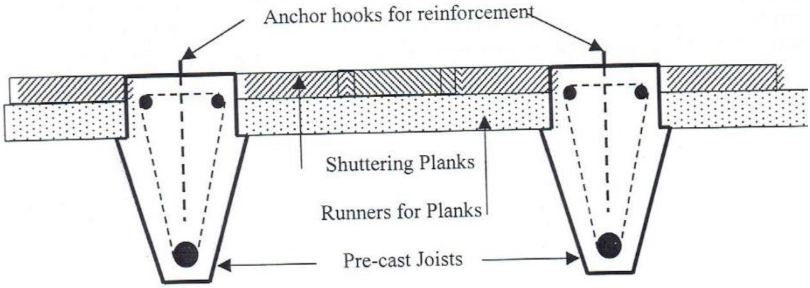
Placing of Reinforcement in Forms before Casting

Cement sand and aggregate is mixed in the ratio of 1:2:4 and mixed thoroughly at the dry stage. It is then turned into a homogeneous mixture after adding water and mixing. This mix is poured and compacted in the mold to cast the joists. The recessed strips at both the sides along the length of the joists are used to anchor the runners for the shuttering for the slabs without using timber props and beams.

De-molding can be done immediately if the moulds are de-mountable. If the mould is not a de-mountable one then the joists need to be kept inside the mold for a minimum of one seek and then lifted lightly. In any case curing should start six to twenty four hours depending on the weather and should be continued for at least three weeks. Only the completely cured joists have to be placed in the required position. The following figure shows a pre-cast joist ready to be fixed in position and the connecting details.



Pre-cast Joist



Placing of Form work for casting slabs over the pre-cast joists

The cast in situ slab over precast joists is only five centimeter thick so the aggregates passing through a 15 mm mesh is required to be used for these slabs. Normal 1:2:4 or M150 grade of Plain cement concrete is used. Six millimeter diameter steel bars are used for the reinforcement. These bars run at an interval of 15 centimeters at the direction normal to the joists and 20 cm at the transverse directions.

4.0 **ECONOMY**

The following table compares conventional cast-in situ RCC slab with Cast-in-situ RCC slab over Pre-cast Joists. A room with an internal dimension of 3.65m by 5.5m (12'-0". X 18-0") is taken as a sample for the comparison.

Comparison of Conventional and Semi Pre-cast Flooring.
Slab area 24.9 SQM (268 SFT)

Description	Conventional Floor Slab				Semi Pre-cast Floor Slab			
	Qtty.	Unit	Rate	Amount	Qtty.	Unit	Rate	Amount
Form works	21.00	SQM	100.00	2,100.00	19.00	SQM	50.00	950.00
PCC 1:2:4	2.49	CUM	2,200.00	5,478.00	1.61	CUM	2,200.00	3,542.00
Steel Reinforcement	150.00	KG	30.00	4,500.00	150.00	KG	30.00	4,500.00
Mason	5.00	MD	125.00	625.00	4.00	MD	125.00	500.00
Labor	12.00	MD	80.00	960.00	12.00	MD	80.00	960.00
Total Cost for Wall				**13,663.0**				**10,452.0**

Construction cost for the slab is reduced by about 23.50 % as compared to conventional slab. This system will decrease the cost by a bit more than 30 % if the slabs are also precast. Pre-cast flooring panels over prefabricated joists is most suitable for intermediate floors.

Appendix 2

Syllabus of ERH Training

1. GENERAL APPROACH

The Training conducted in two consecutive phases in Basantapur ERH site. The first phase covered production technology of cost effective building components and the second phase covered application technology of pre-fabricated components and materials in the building construction.

Phase I : Training on production of cost effective materials and components.
Phase II: Training on application of the cost effective materials and components in building construction.

2. CONSTRUCTION TECHNOLOGIES

The training covered two major topies of building construction technology, firstly, the cost effective technology and secondly the seismic resistant.

i) Producation of cost effective building materials/components and their application technology:
- Lean concrete Bricks
- Stone-Crete Blocks
- Composite Masonry
- Masonry wall in Rat-Trap Bond
- Pre-fabricated RCC Joist, Rafters and Flooring Panels
- Cast in Situ Slab over Pre-fabricated RCC Rafter/Joist
- Frameless Openings

ii) Application of seismic resistant technology:
- Planning configuration of a shelter
- Size, shape and location of openings in a building
- Horizontal Bands
- Vertical Reinforcements
- Corner reinforcements

3. DURATION

The training duration was 60 days @ 8 hours per day with one-hour lunch break.

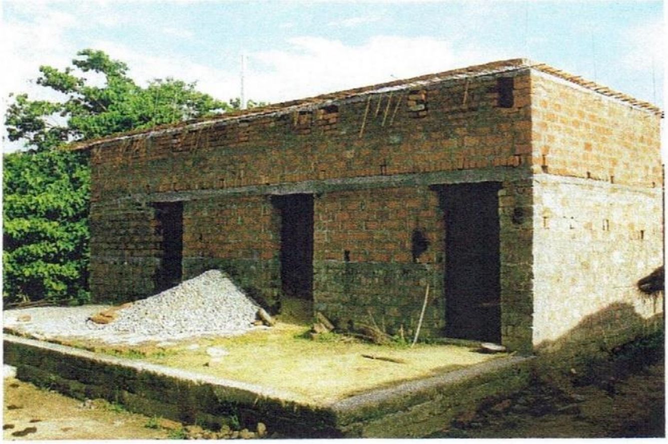
Appendix 3

List of Trainees

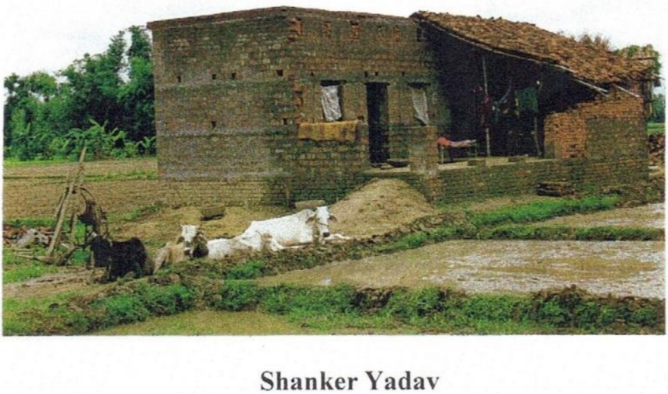
1. Akul Dhadi
2. Amar Kurmi
3. Bimal Pun
4. Binda Ram Yadav
5. Birendra Yadav
6. Budhai Harijan
7. Dhruva Raj Ghimire
8. Ghanshyam Gupta
9. Harishchandra Yadav
10. Jahawir Kurmi
11. Jhinak Kurmi
12. Kumar Kewat
13. Lotu Murau
14. Meghe Kurmi
15. Mrs. Bhandari
16. Mrs. Mewavati Kurmi
17. Mrs. Puranmasi Dhadi
18. Mrs. Ramtilak Kurmi
19. Narayan Prasad Ghimire
20. Phulchand Yadav
21. Prahlad Ahir Yadav
22. Puranmasi Dhadi
23. Rajendra Koire
24. Rajendra Yadav
25. Rajesh Murau
26. Ram Briksh Kurmi
27. Rambriksh Harijan
28. Ramesh Dhadi
29. Ramesh Yadav
30. Ramlalit Kurmi
31. Ramsagar Kurmi
32. Ramsagar Yadav
33. Ramtilak Kurmi
34. Sadhu Dhadi
35. Shanker Yadav
36. Suryanath Dhadi
37. Tibhu Kurmi
38. Toynath Aryal

Appendix 4

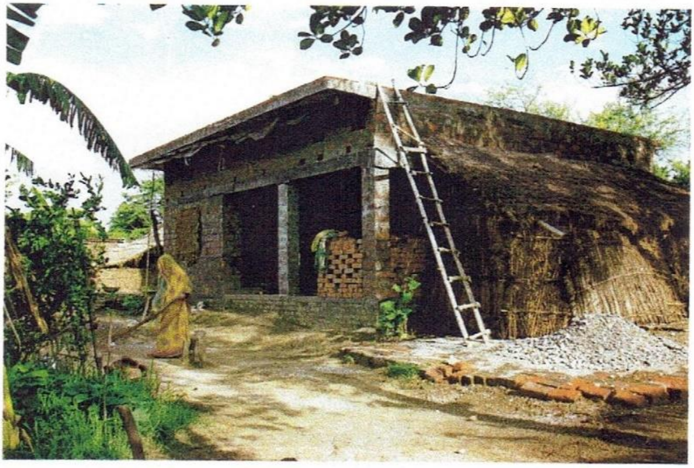
Earthquake Resistant Houses Built by Owners



Ramtilak & Ramsagar Kurmi

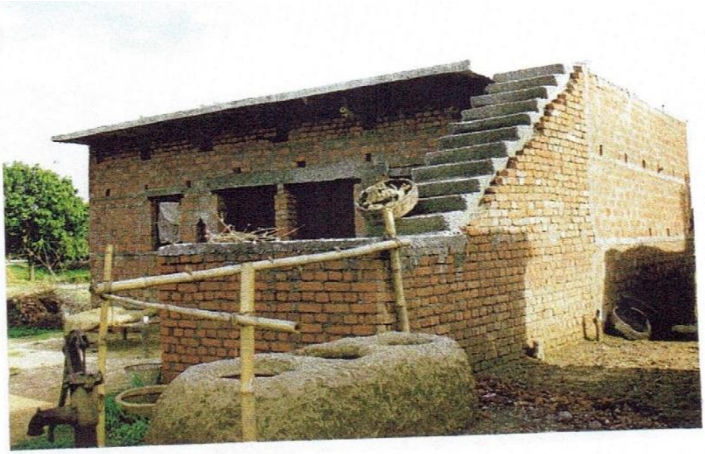


Shanker Yadav



Muktar (Jawahir) Kurmi

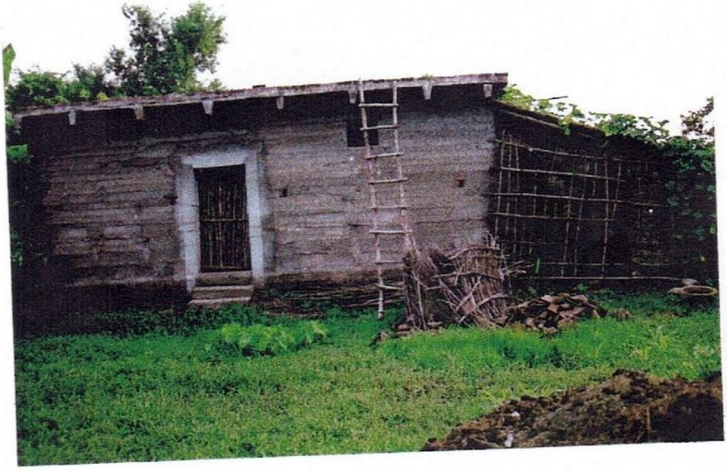
Ramesh Yadav



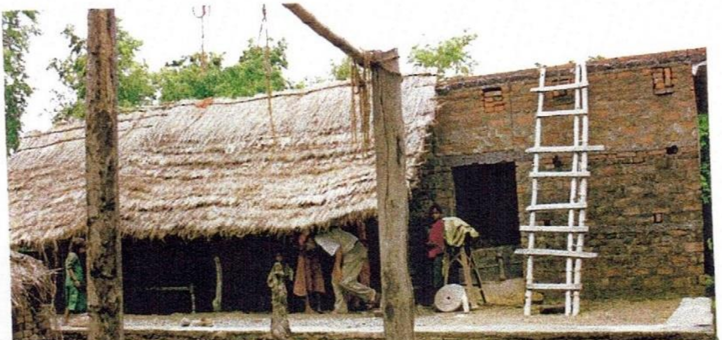
Ramsagar Yadav

Tibbhu Kurmi

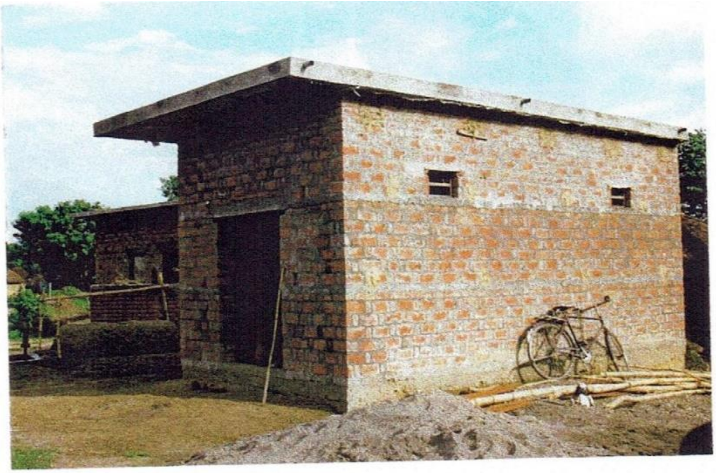
(The house initiated with the seed money provided by Mr. Novel Veghela)



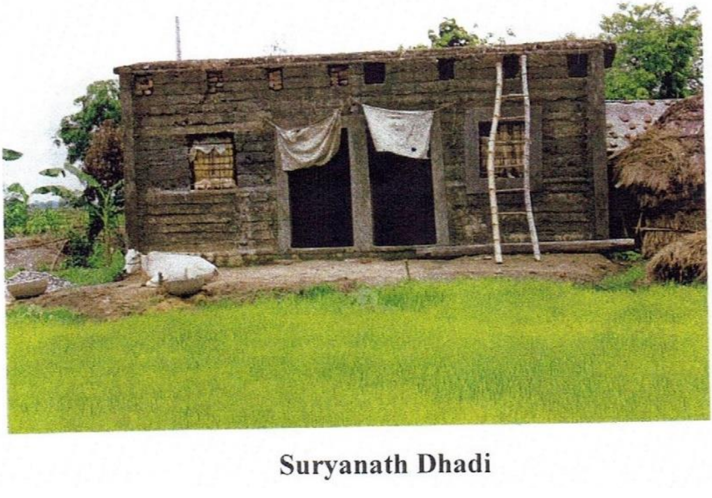
Ghanshyam Gupta



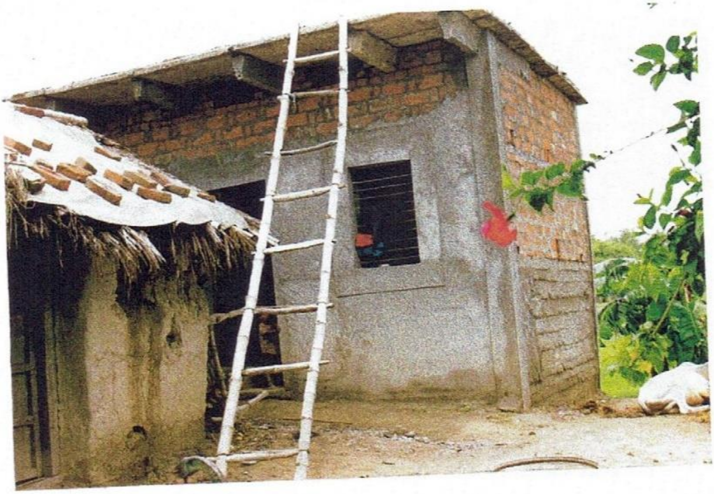
Ramlalit Kurmi



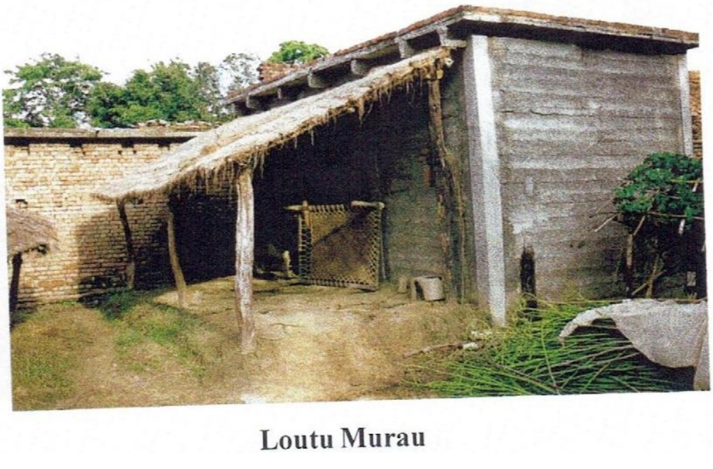
Ramlot (Harishchandra) Yadav



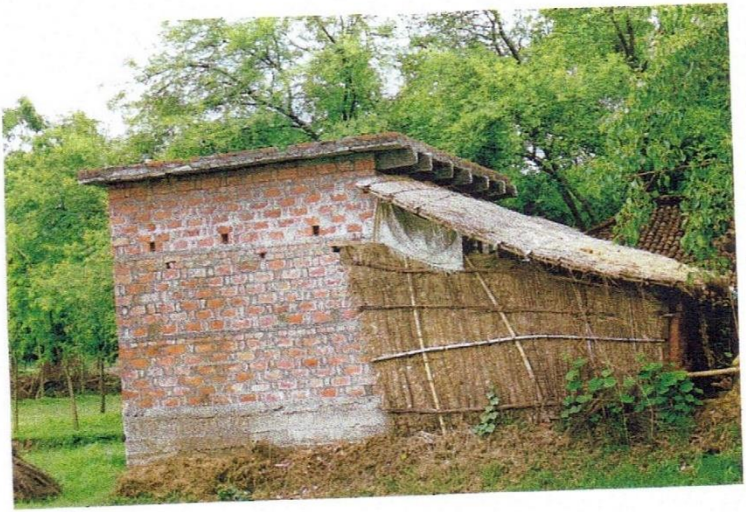
Suryanath Dhadi



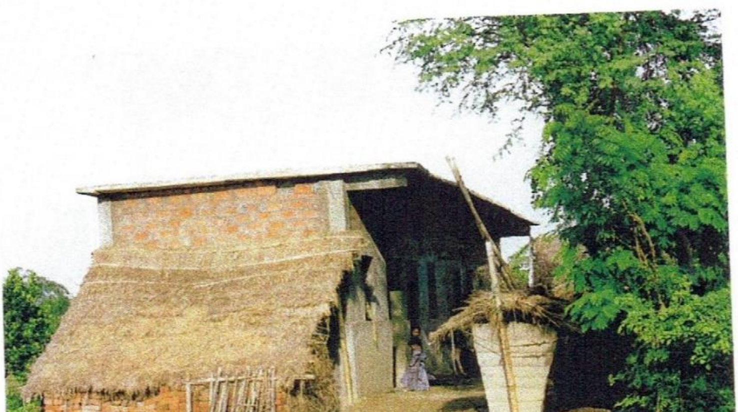
Sadhu Dhadi



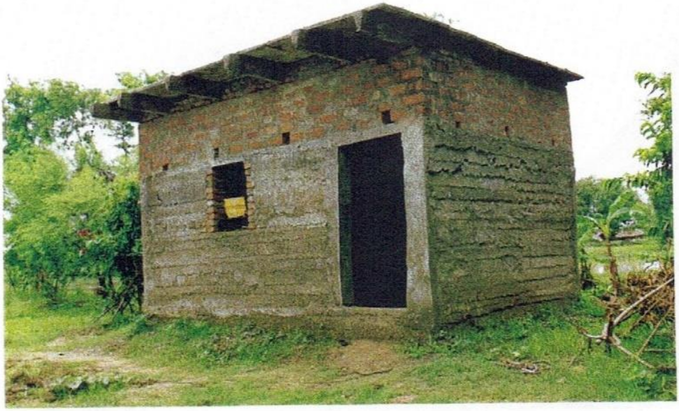
Loutu Murau



Rajendra Yadav

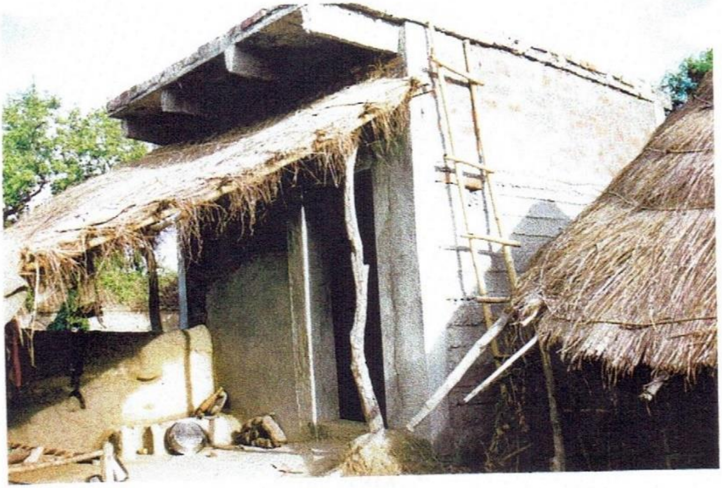


Puranmasi Dhadi

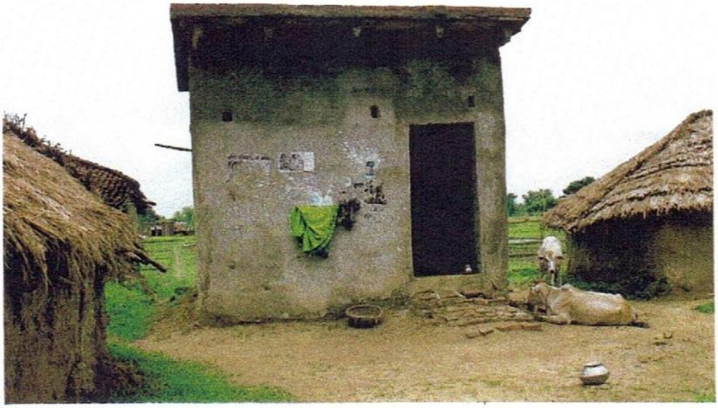


Bindaram Yadav

Prahlad Ahir Yadav



Rajaram (Rajesh) Murau



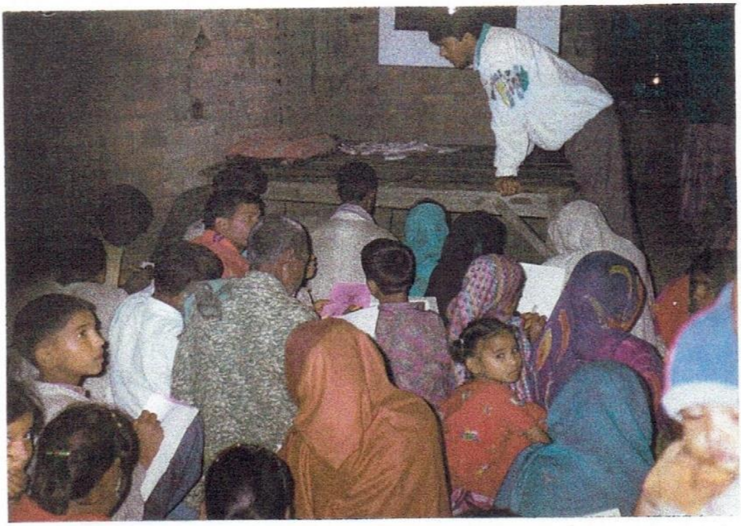
Rambriksh Chaudhari Kurmi

Appendix 5

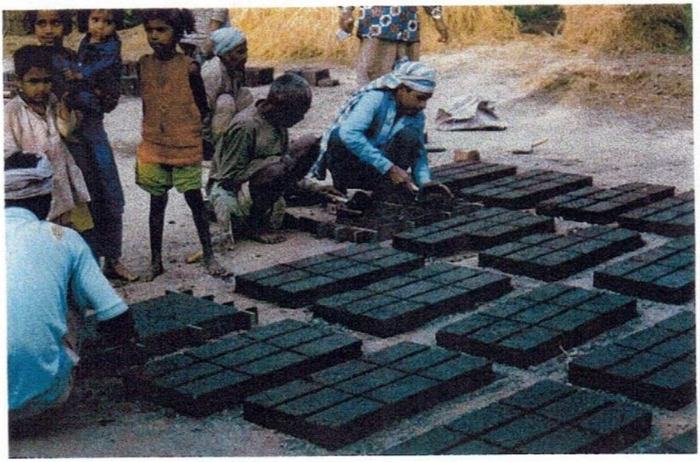
Photographs of ERH Activities

Women also can acquired buidling skill

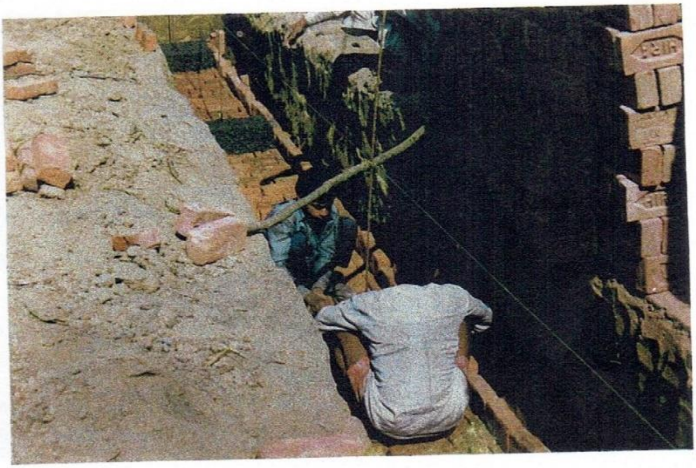
Short break for a snack



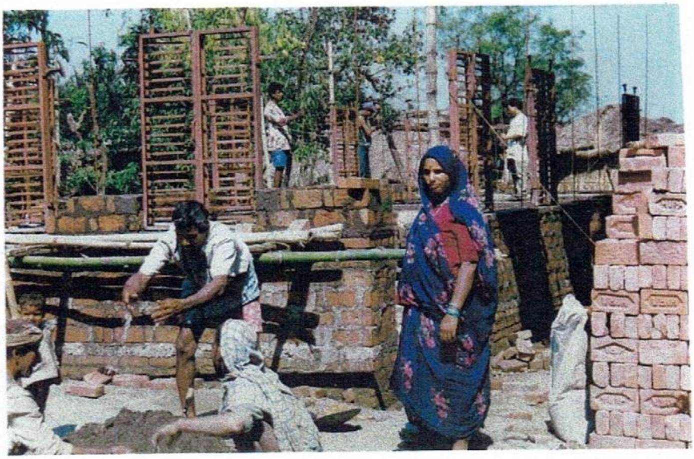
Learning to read and write



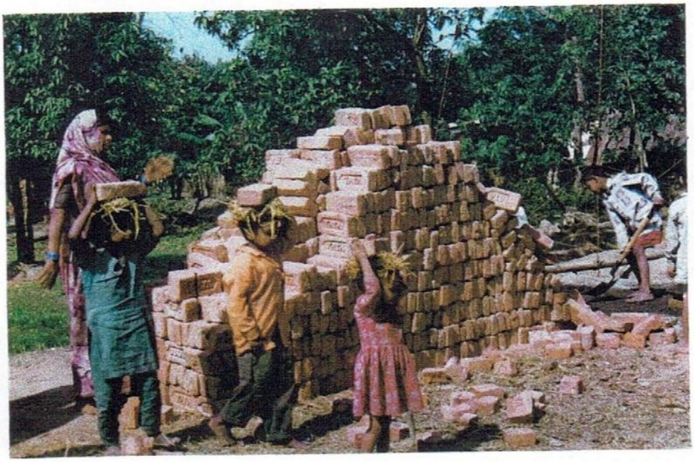
Making of lean concrete bricks



Laying the foundation



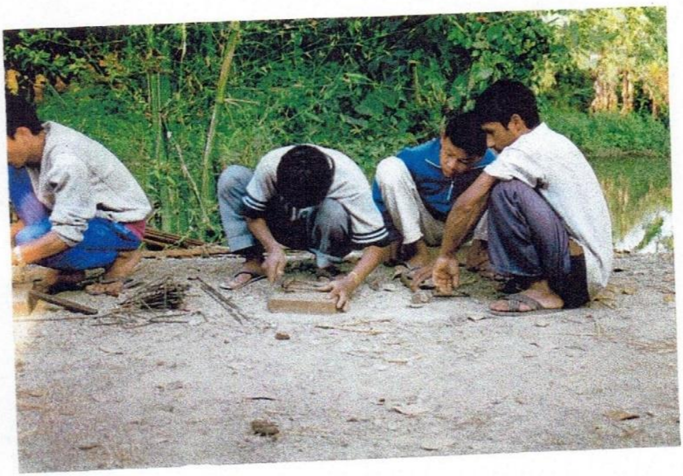
Work in progress, Community Resource Centre



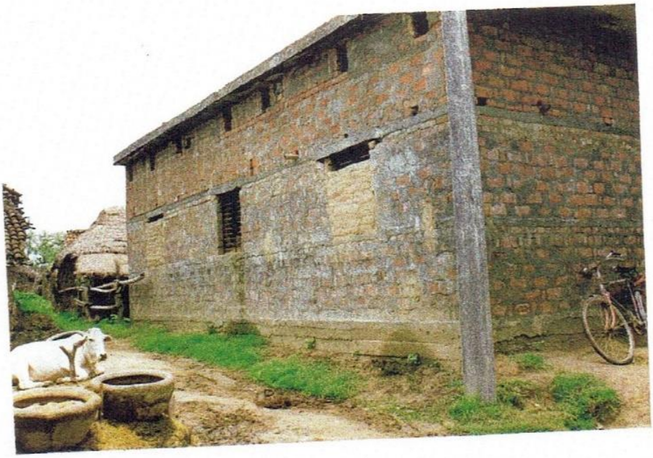
Children volunteer contribution and enjoy joining their parents

Community resource center, bath and toilet unit at far left

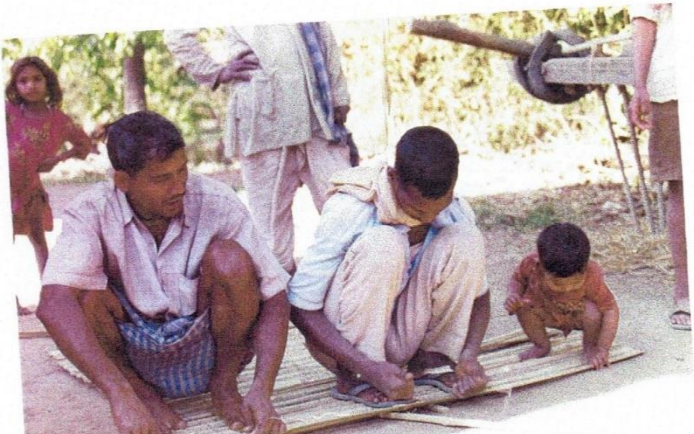
Interaction of the community with the experts



Trainees learn to bend reinforcement steel



Windows! They are needed but we can not afford the shutters!



Bamboo mats for bambocree wall and roof