Action Research

Re-enforcement of Mud Grain Storage and Mud Houses

Mercy Corps Nepal
Kailali Disaster Risk Reduction Initiatives-11
July 2010

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Kailali Disaster Risk Reduction Initiatives - II

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Foreword

Mercy Corps Nepal is pleased to release the enclosed Action Research Report - *Re-enforcement of Mud Grain Storage and Mud Houses*. This report is the result of a pilot study of simple techniques for re-enforcement of walls of mud-clad houses and grain storages units in ten communities in Kailali District in the Far Western Region of Nepal. The study were conducted as part of a wider Disaster Risk Reduction Project – *the Kailali Disaster Risk Reduction Initiative*– supported by the European Commission through its Humanitarian Aid and Civil Protection department (DG ECHO) under the fifth DIPECHO Action Plan for South Asia.

Annual flooding in the region results in great losses of property and livestock, the destruction of irreplaceable assets, the erosion of land, the spoilage of stored foodstuffs and, too often, even the loss of life. The monsoon season 2008 was no different, more than 20,000 households in the district were affected; many of these households suffered severe damage to homes and belongings. One of the main reasons for such loses is the fact that the houses are constructed with mud walls that were swept away by swift water flows, and consequently the items inside the houses were swept away or displaced. Likewise, mud household grain storage units were destroyed or lost in swift waters, resulting in significant loss of food supplies. In order to reduce the risk of future such losses Mercy Corps decided to explore options for introducing simple, low-cost, replicable techniques to reinforce mud walls and mud grain storage units. In doing so, the Mercy Corps Disaster Risk Reduction team identified and reviewed available documentation, but did not find any documentation of the performance and effectiveness of such techniques. Mercy Corps therefore initiated a study of the performance of various mud plasters and introduced the most success techniques to communities.

Mercy Corps would like to thank all those who made this study possible, including: the target communities who tested the techniques; Sabin Joshi who carried out the study; the Mercy Corps and Nepal Red Cross Society team implementing the *Kailali Disaster Risk Reduction Initiative* project; and ECHO and its DIPECHO Fifth Action Plan for South Asia.

Mercy Corps hope this repost offers practical insight into how such techniques can be replicated in and with communities living in mud clad houses.

Ulla Dons
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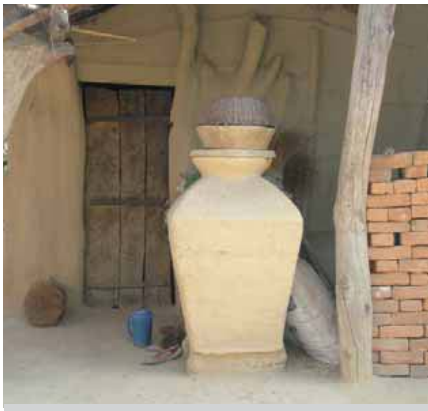
1. Introduction

Mercy Corps (MC) Nepal is currently implementing a Disaster Risk Reduction (DRR) project named Kailali Disaster Risk Reduction Initiatives under the DIPECHO 5th Action Plan jointly with NRCS Kailali District Chapter in flood prone communities in Kailali district. One proposed activity of the project is to pilot techniques for re-enforcement of the traditional mud grain storage urns and houses in flood prone areas. A study was conducted on the performance of various mud plasters applied to model houses when flooded with water. Based on the findings of the research, training was conducted for members from the flood affected communities to enable them to recreate the mud plasters in their respective communities. The project also supported the communities by providing materials and technical support for demonstrations.



Traditional grain storage unit

2. Rationale

The traditional mud houses and mud grain storages in the flood affected communities are at a high risk of damage during flood as mud can easily erode by flowing water and it loses its strength when soaked in water. Although lives can be saved through disaster preparedness and timely response, the communities regularly lose houses and food grains during flooding. Thus it is important to come up with some techniques to re-enforce these houses and grain storage. It is also essential for those techniques to be economical, easily replicable and confirm to local practice and culture.

3. Objectives

- To identify the different possible plaster mixes and their application techniques in mud houses.
- To test the effectiveness of these plasters in protecting the mud houses and mud grain storages from water.
- To compare the performance of the different plasters and recommend the best plaster.
- To demonstrate the mud plasters to the representatives from the communities and to train them for preparation and application in their communities.
- To support the communities in application of the plasters and monitor their work.

4. Materials and Methods

Traditional mud house

Two model huts were constructed for the purpose of studying the behavior of various mud plasters on traditional mud houses during flooding. Local materials and local manpower were employed to make sure that these houses resembled the existing houses in the flood affected communities. Similarly, four mud grain storages (deheri and kotali) were also installed inside these houses to assess the strengthening effect of the plasters on those grain storages.

After completion of construction of the huts, the following four different varieties of non-erodible mud (NEM) plasters were prepared and applied to the walls of the hut up to three feet height above ground level.

a) Cement based NEM (Cement stabilization)
b) Cement-lime based NEM (Cement-lime stabilization)
c) Bitumen based NEM (with wheat straw)
d) Bitumen based NEM (with paddy straw)

4.1. Details of the Huts

- The huts were constructed in a trench of dimensions 22′ x 6′ x 2′ (L x W x D) so that the trench could be filled with water to replicate the effect of rain water during flooding.
- The size of each hut was 8′ x 3′ x 6′ (L x B x H).
- The structural posts and roof beams were made of bamboo.
- The walls were made of khariyo tied with bamboo sticks and plastered with mud and bhusa (wattle and daub type).
- Roofing was done with khar tied with bamboo sticks.

4.2. Preparation and Application of Non-Erodible Mud (NEM) Plasters

The NEM plasters were prepared as described below and applied into the walls of the huts and the grain storages. The three faces of the outer walls of the huts were plastered whereas one face was not plastered so that we could compare the effectiveness of plaster against the regular mud walls. The inner walls were not plastered except for one wall.

Bitumen based NEM was applied in one hut and cement and lime based NEM was applied in the other. Similarly, one set of deheri and kotali was plastered with bitumen based NEM and another set was plastered with cement and lime based NEM.

4.2.1. Cement based NEM (Cement stabilization)

a) 1 bucket (0.75 cu. ft.) of mud generally used by local communities for plastering mud houses was used. The mud was crushed and sieved through a screen to remove organic matter and debris.
b) As this soil consisted mostly of clay particles, an equal amount of sand (1 bucket) was also sieved and mixed with the mud to raise the sand content to 50%.
c) 3.1 kg (5% by vol.) of cement was added to mud and mixed thoroughly.
d) 1/2 bucket (25% by vol.) of water was added and mixed to make paste-like mortar.
e) Loose particles and irregularities were scraped off from the mud wall with a broom.
f) The wall was moistened by sprinkling water. The water was allowed to be soaked up by the wall and water was sprinkled again.

Mixing mud and cement

g) The plaster was applied over the wall up to 3 ft. height from the ground with hand starting from top and proceeding towards the bottom. The plaster thickness was maintained at about 12mm.
h) The same plaster was also applied over a deheri.
i) Cracks up to 1 mm wide appeared as the plaster started drying up.
j) Curing of the plaster was done by wetting the wall at frequent intervals for 3 days.
k) Th e cracks were filled up with mortar of similar consistency on the next day.
l) The plaster was allowed to set for about 3 days and plastered with slurry of mud and cow dung prepared in 1:1 ratio.

4.2.2. Cement-lime based NEM (Cement-lime stabilization)

a) 1.5 buckets (1.125 cu. ft.) of mud was crushed and sieved through a screen to remove debris and organic matter.
b) The soil contained mostly of clay so 2.5 buckets (1.875 cu. ft.) of sand was added to the mud to obtain the sand content of about 60%. The sand was also sieved before mixing with mud.
c) 2 kg (1.5% by vol.) of cement was added to the mud in dry state and mixed thoroughly.
d) 1 bucket (25% by vol.) water was added to the mixture and mixed to make mortar.
e) 1.2 kg (2.5% by vol.) of hydrated lime was slaked mixed in water for about 30 minutes.
f) The slaked lime putty was added to the mortar and mixed thoroughly.
g) The mud wall was soaked and plastered with the mortar in a similar way as the cement based NEM. The plaster was also applied to a kotali.
h) As the plaster started drying cracks up to 2 mm appeared on the plaster surface.
i) The cracks were filled up with similarly prepared mortar the next day.
j) The plaster was cured by wetting with water at frequent intervals for 3 days.
k) Final coat of mud and cow dung (1:1) was applied over the plaster after 3 days.

4.2.3. Bitumen based NEM (with wheat straw)

a) 2 buckets (1.5 cu. ft.) of mud was mixed with 2 buckets (1.5 cu. ft.) of fine sand to obtain mud with 50% sand and 50% clay.
b) Water was added to the mud and kneaded to obtain a uniform paste.
c) 5.5 kg of wheat straw (bhusa) chopped into 20mm lengths was added to the mud paste and kneaded until the bhusa was distributed uniformly.
d) The mix was kneaded twice daily for 7 days to decompose the straw. Water was added while kneading to prevent the mix from drying.
e) 10 kg of 80/100 grade bitumen was taken in a barrel and heated till it melted.
f) The molten bitumen was poured into another barrel containing 2 litre of kerosene with constant stirring to prepare cut-back bitumen.

g) 5 kg of the cut-back bitumen was mixed with the mud and straw mixture prepared earlier and kneaded to obtain a uniform mix.
h) Mud walls were moistened by sprinkling water. Water was allowed to be soaked by the all and moistened again.
i) The NEM plaster was applied on the mud wall up to 3′ height from the ground. The plaster of about 12 mm thickness was applied with hand by starting from the top and proceeding towards the bottom. This mixture was used to plaster 1 wall of the hut and a deheri.


Mixing mud and bitumiin

j) The plaster was allowed to dry for 3 days. Cracks were not visible in the plaster.
k) Stabilized mud slurry was prepared by mixing ½ bucket mud and ½ bucket cow dung with water to make uniform paste. 1.5 kg of cut-back bitumen was added to the mixture.
l) The slurry was applied over the NEM plaster to give the plaster a smooth finish.

4.2.4. Bitumen based NEM (with paddy straw)

a) Mud and sand were prepared using similar quantity and procedure as that for NEM with wheat straw.
b) 5.5 kg of paddy straw (bhusa) chopped into 50 mm lengths was added to the mud paste and kneaded until the bhusa was uniformly distributed.
c) The mix was kneaded twice daily for 7 days to decompose the straw. Water was added while kneading to prevent the mix from drying.
d) 5kg of cut-back bitumen prepared earlier was added to the mix and kneaded.
e) The NEM thus prepared was applied to 3 walls of the hut and a kotali.
f) The application procedure was same as that for NEM with wheat straw.
g) The plaster was allowed to dry for 3 days.
h) Cracks were not visible in the plaster so stabilized mud slurry prepared earlier was applied over the NEM plaster to give the plaster a smooth finish.

4.3. Tests performed on the plasters

a) After complete drying of the NEM plasters, the trench was gradually filled with water up to one feet height above the ground level. The water was left for 24 hours and allowed to be soaked up by the ground. After the water dried, the damage done by water to the plastered surfaces and the mud walls without plaster was observed.
b) Similarly, the trench was filled again up to about two feet on the next day. The water level was maintained for 48 hours by constantly adding water to the trench. The performance of the plasters was observed after 48 hours of flooding.

c) The plasters and the mud walls were also put to test under a high impact water jet to assess the resistance of the plaster to erosion by water. The damage made to the walls when subjected to a water jet for about five minutes was observed.

5. Observations and Findings

5.1. After flooding for 24 hours

NEM plastered versus traditional mud plaster tested for water resistance. Bitumin NEM to the left.JPG

- There was considerable damage done by water to the walls which were not plastered. The mud plaster was eroded and the bamboo and khariyo in the walls were exposed slightly.
- No damages were visible in the walls plastered with bitumen based NEM.
- The deheri and kotali plastered with bitumen based NEM were intact and the insides were dry.
- There were no visible differences seen between the bitumen based NEM prepared with wheat straw and that prepared with paddy straw.
- Minor cracks, which formed during drying of plaster, were exposed around the corners of wall plastered with cement based NEM. The wall however was intact and the plaster was not eroded by water.
- The walls plastered with cement-lime based NEM were also intact. No cracks were visible in the plaster.
- The cement based plaster applied to the deheri peeled off around the bottom part wetted by water due to lack of binding between the plaster and its surface. The loss of binding could have been due to the smooth surface finish and the circular shape of the deheri. The bottom part inside it was wet due to seepage of water through the base.
- The kotali plastered with cement-lime based NEM collapsed as had been floated by water during flooding and water had flowed inside it.

5.2. After flooding for 48 hours

- The mud in the walls that were not plastered was further eroded. The underlying bamboo and khariyo were exposed.
- The walls plastered with bitumen based NEM did not show any signs of wearing away.
- The deheri with bitumen based NEM was damaged. Water soaked up through the base as the base was not plastered.
- Kotali plastered with bitumen based NEM was also damaged due to ingress of water. It was also floating in the water during flooding.
- Outer layer of cow-dung and mud applied over the cement and cement-lime based NEM peeled off. Some cracks were visible around the corners. The plasters were not damaged by water.
- The deheri plastered with cement based NEM did not collapse even though the plaster had peeled off. However, water had seeped in through the base.

5.3. After subjecting to water jet

- The un-plastered mud walls were easily eroded in about 3-4 minutes of impact from the water jet. The mud and bhusa were washed away and the khariyo were exposed.
- The plastered walls showed greater resistance to the water jet.
- Only a small patch was observed in the wall plastered with bitumen based NEM after being subjected to water jet for about five minutes.
- The lower portion of the same wall, which was soaked in water during two days of flooding, showed lower resistance. A patch could be made with less difficulty indicating that the wall would easily get damaged.
- The wall plastered with cement stabilized mud also showed similar resistance to the water jet. The cracks formed during plastering were exposed but no damage appeared within five minutes.
- The wall plastered with cement-lime stabilized mud was also resistant to erosion when exposed to the pressure of a water jet. A piece of plaster peeled off between the cracks. Water had seeped through the cracks during flooding for two days making the bond between the plaster and wall surfaces weak.
- The water jet could only make a small patch in the upper portion of the wall which was dry and strong.

6. Recommendations from the research

- All the four different plasters mixes tested in the mud houses were effective in preventing the damage caused by the inundation of water.
- Both the bitumen based NEM plasters prepared with wheat straw and paddy straw were equally resistant to damage by water. Thus, either wheat or paddy straw can be used for preparing NEM depending on the availability.
- The inner faces of the mud walls that were not plastered were damaged easily, so it is recommended that the NEM plaster should be applied to both the inner and outer faces. The recommended plaster height should correspond to at least the height of previous inundation. As the inner faces are not usually damaged from rain these may be plastered up to a lower height only. The minimum height of the plasters for inner and outer faces of the walls shall not be less than 1 feet and 3 feet above the ground level respectively.
- Although the NEM plasters are non-erodible, it is not completely impermeable to water. It can only offer higher resistance to seepage of water. As soil loses its strength when it is soaked in water, the deheris are very much susceptible to damage during flooding. The application of NEM plaster to the deheris can impart a greater strength to it as compared to those which are not plastered.
- Water was found to soak up inside the deheri through its base, so the base should also be plastered with NEM. It is also recommended that the deheri be placed in a firm and elevated base.
- It is also important to note that a hole should be created in the lower portion of the deheri in frequent intervals to take out food grains from it. The hole should then be sealed with mortar prepared with mud and bhusa. It should be noted that this area cannot be effectively sealed

with non-erodible mud plaster, so it is a weak point which can permit the ingress of water into the deheri during a flood.

- The cement and cement-lime based plasters were also effective in resisting erosion by water, but the formation of minor cracks in the plaster allowed water to pass through it. The cracks developed due to higher clay content in the mixture. Higher clay content makes the wall dry and shrink faster, which again causes cracks. The development of cracks on these plasters could be minimized by increasing the fraction of sand up to 75%.
- The bitumen based plasters were found to provide better resistance to erosion, better bonding with wall, they were less permeable to water and exhibited better strength than the cement and lime based plasters. However, the cost of materials, time and the skill required for the application of bitumen based plasters are comparatively higher than those for the latter ones. The cost of bitumen and kerosene required for 1 sq. ft. of bitumen based NEM summed up to approximately Rs. 10 whereas that for cement and lime was about Rs. 1.5 only. Thus, it is recommended to explain the costs involved as different plasters are demonstration so that households can choose one according to their requirement and availability of funds.

7. Implementation and Monitoring

7.1. Training

An on-site training was conducted for 26 participants from the different communities (2 each from the ten KDRRI-II communities and 1 each from the six KDRRI-I communities) at Thengarpur in Bhajani, Kailali. The purpose of the training was to introduce the non-erodible mud plasters to the representatives from the flood affected communities, who in-turn shall introduce it in their respective communities.

The training was more oriented towards disseminating the skills in a practical way than providing the theoretical concept. The training started with a brief introduction about the concept of using non-erodible mud plasters for re-enforcement of mud houses and grain storages. The major portion of the training was concentrated on the preparation and application of the plasters.

A model hut similar to the one built for the research work had been constructed in a trench to demonstrate the performance of the plasters after flooding for 24 hours. The training was conducted for all of the three different types of the plasters (viz. bitumen based, cement based and cement-lime based plasters). The participants were actively engaged in the preparation of the plaster mixtures and its application in the model hut and the two deheris. The three different plasters were applied to the three faces of the hut, whereas one face was left without the NEM plaster. Similarly two deheris were also plastered with bitumen and cement-lime based plasters.

Plastering of Model Hut

The plasters were left to dry and set for two days before flooding the trench. Unfortunately the monsoon rains started from the same day the training started. The bitumen based plaster could not gain adequate strength as it was still wet due to the frequent rainfall. The deheris were also damaged while in the trench as they were soaked from the rain. Nevertheless the demonstrations were still successful as found in the following comments.

The trench was inundated with water up to about 2 feet. The water was left for 24 hours and allowed to be soaked up by the ground. The plasters in the walls of the hut were found to be intact except for the peeling-off of a portion of the bitumen based plaster which could not set because of the rain. The participants of the training were convinced about the effectiveness of the plasters in protecting the walls of the mud houses during flooding. The deheris were damaged from cracking that developed while handling and placing them in the trench during the rain. As the deheris are large and fragile it is difficult to relocate those to plaster the base. Thus, it was suggested by the participants that it would be most effective to plaster the deheris with NEM at the time of their construction.

The participants also prepared and submitted the action plan for the application of the non-erodible mud plasters on one house and deheri in their respective communities.

7.2. Monitoring

Based on the action plan, the communities were supported through the provision of materials that were not available in the communities (such as the bitumen, kerosene, cement, lime and tin barrels).

Completed Model Hut

However, there were some challenges with the applications

Firstly, most of the communities could not complete the works on time because all the members of the communities were busy in the fields due to the onset of the paddy plantation season.

Secondly, while the works was completed in some of the communities, many needed improvements. As observed in Pachhalapuruwa, Khailad, the thickness of the plaster was less than the required thickness of 12 mm. Likewise the bitumen based plaster was applied without mixing sand in the mud, resulting in development of cracks and soft finish of the plaster.

Similarly, in Thengarpur, Bhajani, the mud walls of the house plastered were cracked and had started to disintegrate. The walls needed to be repaired before applying the NEM plaster. Cracks were visible in the bitumen based plaster due to inadequate amount of straw (bhusa) in the mixture. The cement and cement-lime based plasters had also developed some cracks.

As this was the first application of the NEM plasters, there were some shortcomings in the plaster mixes and its application. The members of the communities can improve their skills with practice and experimentatin. The works for the design of a pictorial brochure on the preparation and application of NEM plasters has been started, which will be a handy reference for the communities.

The most important outcome of the training and application is that the community was able to witness the behavior of the walls of the model huts. The results were observed over three months (monsoon season) and communities were able to see the results themselves. As the huts were constructed in trenches they were regularly "flooded" during these months. The bitumen and the cement-lime based plasters remained totally intact and no damage were observed.

8. Cost

Cost of the bitumen based respectively cement-lime based mud plasters is calculated for the materials required for an area of 20 square feet wall. One cubic feet mud will be sufficient for 20 square feet plaster.

Bitumen based plaster:

S.No	Item	Quantity	Unit	Rate (NPR)	Cost (NPR)	Cost (EURO)
1	Bitumen	1.5	kg	80.00	120.00	1.26
2	Kerosene	0.3	Liter	65.00	19.50	0.21
Total					139.50	1.47

Cost per sq. ft.: NPR 7 (EUR 0.07)

Cement-lime based plaster:

S.No	Item	Quantity	Unit	Rate (NPR)	Cost (NPR)	Cost (EURO)
1	Cement	1.00	kg	20.00	20.00	0.21
2	Lime	0.85	kg	15.00	12.75	0.13
Total					32.75	0.34

Cost per sq. ft.: NPR 1.64 (EUR 0.017)

9. Conclusion

The non-erodible mud plasters, as tested on the model houses, have been effective in reducing the risk of damage to the traditional mud houses due to floods. These NEM plasters have also been well accepted by the communities as they are cost effective and easily applicable.

The implementation of the plasters techniquess in the communities was affected by the start of monsoon and start of paddy plantation season. Most community members were therefore busy in in the fields and were not available for the application of the plasters. The rain also affected the effectiveness of the plasters as they could not set properly. The implementation works could have been improved if all the work had started about a month earlier.

The effectiveness of these plasters in protecting the deheris is yet to be proved. As suggested by the community members, it has been recommended to empty the deheris before the onset of the rainy season and to seal the hole for taking out grains with NEM.

The on site training has been successful in enabling the representatives from the communities to apply the NEM plasters in their communities. The brochure that will be provided to the communities will be helpful in further disseminating the effectiveness of the plasters.

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Glossary

- Bhusa: Local term for chopped wheat or paddy straw
- Deheri: Local grain storage unit made of mud generally used by Tharu communities
- DRR: Disaster Risk Reduction
- DIPECHO: Disaster Preparedness ECHO
- ECHO: European Commission Humanitarian Aid Department
- KDRRI: Kailali Disaster Risk Reduction Initiatives
- Khar: Straw used for roofing in mud houses
- Khariyo: Local grass stem used for constructing walls in mud houses
- Kutali: Local term for smaller grain storage unit made of mud
- NEM: Non-erodible mud

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