

Earthbag as Alternative Building Technology for Nepal

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Abstract

Earthbag technology is the sustainable and cost effective method for using ordinary soil to create disaster resistant structures of superior strength and durability. It builds safe, appealing, and cost effective structures out of ordinary soil. As it is stronger, cheaper, and less harmful to the environment compared to conventional buildings constructed by brick and cement, it is generally considered the most promising of sustainable building techniques. Though it has been used for long time of period, constructing permanent structure with this technology is a new concept to the world. In case of Nepal, this technology got famous only after 2015 earthquake. Nepal Government has approved earthbag technology as one of the model house for reconstruction and also included in its DUDBC catalogue volume II in 2017. People are not aware about this technology. Research related to the environmental aspect and durability of earthbag buildings had been done by many. There is also some research done related to cost of earthbag buildings, but there is limited research done regarding the social aspect of these types of buildings. Rural poor of Nepal are not being able to afford proper shelter for themselves. They are either staying in temporary structure or constructing houses without any guidance. Even though earthbag buildings are environmentally friendly and could withstand natural disaster like earthquake and flood, people do not prefer it. Nepalese people get highly influence by society and Nepalese society being conservative and reserved, they find it hard to accept new change, be it new culture or technology. Earthbag technology being new to the society it is important to know about its social aspects and acceptance level, for it to succeeded. This research paper study about the socio economic impacts of earthbag buildings and also identifies the factor affecting its acceptance in society. For this, Bolgaun, Sindupalchowk and Chitre, Kakani have been selected as case area. Earthbag buildings have been studied through different parameters of social and economic dimensions. The study is limited to residential buildings.

Keywords

Earthbag Buildings, Socioeconomic aspects, Social Acceptance, Rural Poor

1. Introduction

Earthbag technology is the sustainable and cost effective method for using ordinary soil to create disaster-resistant structures of superior strength and durability. It builds safe, appealing, and cost-effective structures out of ordinary soil. As it is stronger, cheaper, and less harmful to the environment compared to conventional buildings constructed by brick and cement, it is generally considered the most promising of sustainable building techniques [1]. Earthbag has been in used since centuries ago. Originally earthbags were used for flood control and military bunkers because they are easy to transport to where they need to be used, fast to assemble, inexpensive and effective at their task of warding off both water and bullets. [2] The use of sandbags has

generally been associated with the construction of temporary structures or barriers. Using sandbags to actually construct houses or permanent structures has been a relatively recent invention. During 1976, the German professor Gernot Minke, after many experiment, developed the technique of using bags filled with pumice to erect walls. His first successful experiment was with cor belled dome shapes (an inverted catenary) which was obtained with the aid of a rotating vertical template mounted at the center of the structure. But the technology of constructing permanent structure out of earthbag, was popularized by the Iranian-born American based architect named Nader Khalili. He named his technology super adobe technology where the bags are filled with earth of the site, overlapping one another connecting by barbed wire, to give consistency to the structures.

It was stated that there were 55 earthbag buildings constructed in Nepal before earthquake hit Nepal in April 2015. All 55 buildings, survived the 7.8 magnitude earthquake with no structural damage. iNGOS and NGOs, such as Good Earth Global, Steadfast Nepal and First Steps Himalaya have been implementing the earthbag technique to build homes and schools since the 2015 earthquake. They are working in different parts of Nepal, especially in remote areas. They are helping those people rebuilt their homes who cannot afford to do by themselves. These organizations collect funds and ask for volunteers from all around the world. After almost two-year of struggle, Good Earth recently managed to make Nepal the first country in the world to officially approve of earthbag technology and adopt it as a safe and recommended building technique.

1.1 Problem Statement

On April 25 2015, Nepal was struck by a 7.8-magnitude earthquake, followed by a 7.3-magnitude earthquake on May 12, 2015, killing in total nearly 9000 people and injuring 22,400. About 800,000 houses were damaged or destroyed and brought 8 Million people to the state of being homeless Out of 75 districts, 31 were most affected, and out of that number, 14 districts were severely affected. Among all the buildings that had been damaged, most of building lies in remote areas where the accessibility is difficult. Some of the areas takes days to reach by road and some areas cannot be reached even through vehicles. Reconstructing buildings with modern technology and materials would be expensive in these remote areas as the terrain lands make transporting materials a tough and expensive task. Earthquake has triggered landslide in many affected area resulting accessibility to affect areas more difficult.

These facts are generally affecting the rural poor, who cannot afford proper shelter. They are left with no other choice. Either they live in temporary structures or construct their houses with traditional technology without earthquake resistant techniques, holding back in materials, labors and design, to save money. Due to these kind of negligence in construction, buildings tend to degrades quickly even in best of time and when another disaster strikes they won't stand a chance to survive. It will be endless cycle of constructing and reconstructing the affected buildings if reconstruction is not done in sustainable way.

For constructing strong, earthquake resistant building, conventional technology is not only the option. This technology is way more harmful for environment. Building materials used in conventional buildings like cement and brick are toxic to the environment. From the phase of raw material extraction to the demolition phase, these materials bring negative effect on environment. Conventional buildings are not constructed with consideration of climate of the area. The materials used in these buildings are not climatic responsive. In summer season, they are hot and in winter they are cold. This cause the extra use of active energy to maintain thermal comfort within the building during whole operational phase. Therefore, it shows that the ongoing reconstruction method is not sustainable. To solve this problem, different construction technologies should be introduced to people which can be afforded by all families, are environment friendly and disaster resistant. Earthbag technology is one of these alternative building technology. It is environment friendly as it usage limited amount of factory made building materials. It is affordable as it uses locally available materials and saves transportation expenses, as it doesn't require machine and equipment to construct and locally available labors can be used.

1.2 Research objective

1. Main objective

The general objective of this research is to study feasibility of earthbag building through socioeconomic aspect.

2. Specific objective

- To know about the present situation of earthbag buildings that have been constructed in Nepal.
- To identify the factors that are affecting social acceptance of earthbag technology in case of Nepal.

1.3 Limitation

- The research is based on Specific case. Case areas for this research is the residential community where Earthbag buildings coexist with other buildings. Schools or any kind of public buildings constructed by Earthbag technology is not included in study.

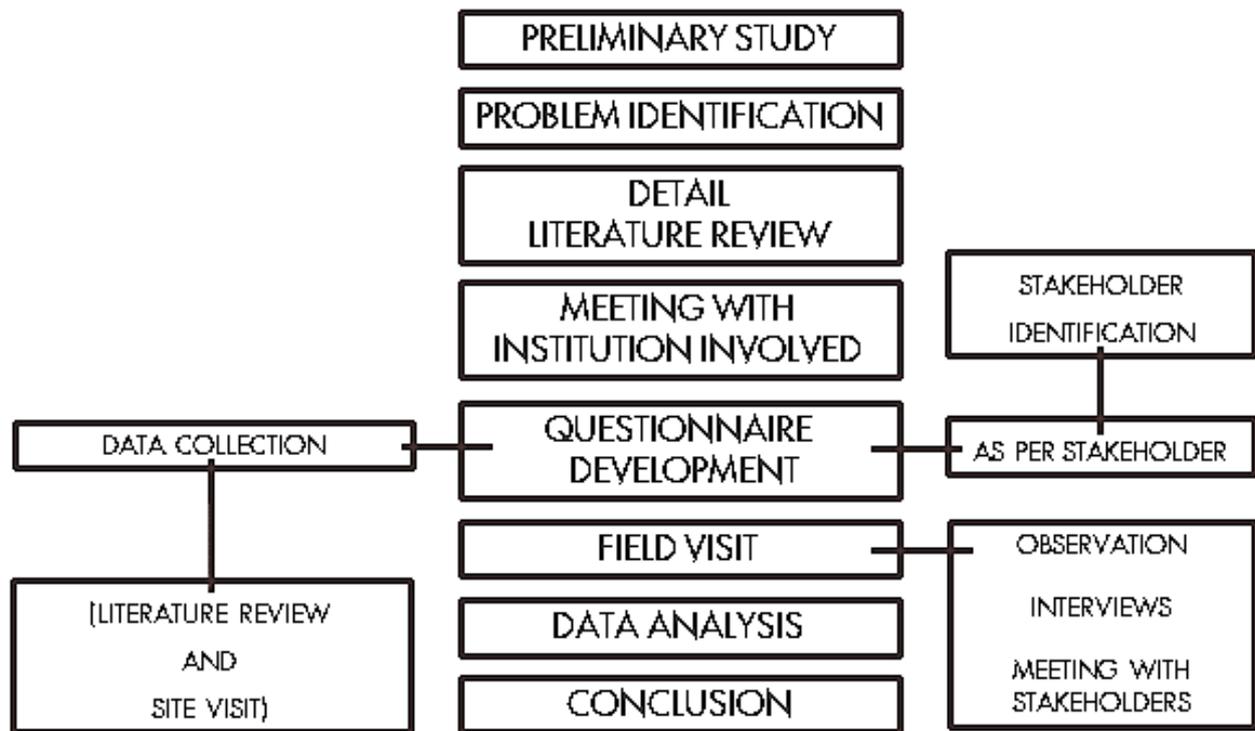


Figure 1: Conceptual Framework

- The study is focused on socioeconomic aspect of the Earthbag buildings, specially focusing on its social acceptance.

2. Methodology

The objective of this research is to do feasibility study of earthbag building through socio-economic aspect. This research is done to check whether the earthbag buildings constructed in Nepal are socially and economically sustainable so that it can be used as one of the alternative technology. For this, the vital source of knowledge accumulation is through the local inhabitants who are actually residing in the case area. The information gained through discussions with focus group participant, observation and unstructured questionnaire survey. The research investigates about the social and economic sustainability of earthbag buildings and local knowledge and understanding of people living in Case area. Thus, the research is qualitative. Qualitative data is gathered through individual interviews, semi-structured and unstructured questions.

Ontology for this research is earthbag buildings are not accepted by society even though it has many

advantages. It has less negative impacts on environment and is comparatively less expensive than contemporary building, making it affordable to every income group. The buildings are approved by Government of Nepal and proven to be strong enough to withstand earthquake and flood but still the number of people willing to construct their house with this technology is less. The source of information for this research are the people of the case areas and literature studies done in this particular topic. As people of society and their perceptive were included in this research, it goes with constructivist paradigm. Constructivists claim that truth is relative and that it is dependent on one's perspective. One of the advantages of this approach is the close collaboration between the researcher and the participant, while encouraging the participants to tell their stories. The research approach was inductive because the data were collected to make an analysis of case area. The primary data was collected in field through in depth semi structured interviews, direct observation, participant observation, questionnaire and focus group discussions. Photography, audio recording and field notes were used as tools.

2.1 Parameters of study

Figure no. 2 and 3 shows the list of social and economic parameter identified.

Dimension	Indicators Parameters	Performance Parameters
Social	Cultural	- Respects to Cultural Values and the surrounding context - Respect to beauty of the place - Maintenance of heritage value or existing
	Health and comfort	- Thermal quality - Acoustic quality - Indoor air quality - Lighting conditions - Ventilation conditions - Material toxicity - Safety and health for workers - Impact on global community
	Safety and service quality	- Safety and durability (safety in use, feeling of safety, meeting current regulation) - Safety from disaster (fire, earthquake, flood) - Regulated building maintenance - Security of house
	Aesthetics quality of building and functionality	- Usability (access to building, orientation, adjustability, Space requirement) - Adaptability (versatility and protection, technical service life, adaptability to climate change)

Figure 2: Social Parameters [3]

Economic	Affordability	Performance Parameters
Economic	Affordability	- Material <i>(material used, material costing, accessibility of material, availability of material, Protecting materials from destructive elements such as sun, temperature variations, rain or wind or migration of moisture- laden air through defects in the envelope)</i> - Labors <i>(labor costing, availability of labors, Time of completion)</i> - Provision of loan and government supports
	Operational cost	- Active energy required for maintaining comfort inside the building - Maintenance <i>(maintenance cost, frequency of maintenance, part of building to maintain, choose minimum maintenance materials)</i>
	Recovery cost	- Recycling potential and ease of demolition - Reusing building materials or components

Figure 3: Economic Parameters [3]

2.2 Key informant Stakeholder Identification

- Locals living in earthbag building
- Locals not living in earthbag building but around one
- Organizations working in earthbag buildings

- Er. Roshan K. Jha (Managing Director of Good earth Nepal)
- DN Dhital (Project Manager of Good earth Nepal)

- Local Government
- Government of Nepal
- NRA and DUDBC
- Engineers and architects
- Local Labors
- International Volunteers and national volunteers
- International and national Donors

3. Case Area

In order to fulfill the defined objective, the study area has to be chosen in such a place where the community exists which has ample number of earthbag buildings along with other types of buildings. The study of social and economic aspects of earthbag buildings has to be done in a society or community where families who stay in earthbag buildings and families who stay in other types of buildings co-exist. There are few numbers of earthbag buildings constructed in Nepal and among them number of schools (public buildings) are high. Even if residential buildings are constructed, there is one or two earthbag buildings in village. Therefore, Bolgaun Village and Chite Village has been chosen for the case area for this research. There are 11 earthbag buildings in Bolgaun Village and 6 in Chitre Village.

3.1 Bolgaun, Sindupalchowk

Bolgaun is a small village situated in Pachpokhari Thangpal Gaupalika in Sindupalchowk. The gaupalika covers area of 436 km² and has density of 48.08/km² according to 2011 Central Bureau of Statistics Nepal. The village is a Tamang community where Sonar Loshar, Maghe Sankranti, Dashin and Tihar are celebrated as their main festivals. The village is approx. 54 Km. away from Kathmandu and approx. 25 Km. away from Melamchi. It takes 5 to 6 hours in bus to reach Baruwā and from there 2 hours of walking to reach Bolgaun Village. There is no any access through public transportation in the village. It lies in the high level of Sindupalchowk, therefore winter last long in this village and snowfall occurs

during winter season. The people in this village depends upon agriculture and animal husbandry.

Sindhupalchowk is one of the worst-affected districts as a result of the earthquake that took place on the 25th April. While the initial epicenter of the earthquake was in Gorkha district, the highest magnitude (6.7) aftershock took place in Sindhupalchowk district 17km south of Kadari . As for Bolgaun Village, whole village has been destroyed in 2015 Earthquake. Many people lost their lives and many properties were damaged. The village had gone on huge loss. Still after 4 years the disaster struck, families are staying in temporary structure as they cannot afford proper shelter. Nimbin Health and Welfare Association from Australia with the help of Good Earth Nepal constructed 11 residential buildings with earthbag technology. These 11 buildings have been scattered in the village along with other residential buildings.

The settlements of the Bolgaun village has similar characteristic to other Tamang Village settling in cold areas of Nepal. It is compactly built settlement with stone paved roads. Several houses are typically attached to each other reducing the exterior wall surface exposed to the coldness. Traditional houses have an elongated form, oriented towards the sun to enhance solar gains. The buildings are of two storeys. The upper storey is used for storage of grain and other household possessions, while the elevated ground floor is used as a kitchen, dining place, and bedroom. The traditional buildings in this village have usually a balcony on the first floor and a veranda beneath it in front of the main entrance. In all houses the open hearth, normally located in the center of the kitchen. It plays an important role because it is not only used for cooking. It is also the only comfortably warm place where the family members can sit during colder nights and in the winter season. The porch located at the entry to a Tamang house also serves as a protected semi-open space. These semi-open spaces provide comfortable places. Walls are made of locally available stones; stonework is either dry or bound together with basic mortar made of soft clayed earth. In Tamang houses the outer walls are made of dry stonework while the entry facade of the first floor is made of timber. Inner walls of main living spaces are often planked with timber lathes. No openings are placed in the back side of the houses which are not sun-faced and for effective exposure to the winter sun; openings are placed along the south east face of the

house. The size of openings is generally small for preventing cold wind to enter the house. [4]

Table 1: Demographic data of People living in Earthbag Building in Bolgaun

SN	Duration	Occupation	Members
1	2 years	Labor(Earthbag Building)	3
2	4 months	-	2
3	2 years	Agriculture	2
4	1.5 years	-	2
5	2 years	Remittance	1
6	1.5 years	Labors/Agriculture	3
7	1 year	Agriculture	2
8	1 year	-	1
9	1 year	Remittance/Labors	6
10	Incomplete	Labors	2
11	1 year	Agriculture	3



Figure 4: Earthbag Buildings in Bolgaun

3.2 Chitre,Kakani

Chitre is a small village situated in Kakani Gaupalika (Ward no.4) in Nuwakot District. Kakani Gaupalika covers 88 km² and had density of 301.4/km² according to 2011 Central Bureau of Statistics Nepal. The village is a Tamang community celebrating losar, Dashin and Tihar as their main festivals. It is approx. 30Km. away from Kathmandu. There is no direct access of public vehicles to the village. It takes 2 to 3 hours travel in bus to reach Kaulekhana and 1 hours of walking from Kaulekhana to the village. Chitre village is known for strawberry and poultry farming. Kakani is flourishing in tourism sectors as well. The picnic spots and trout is famous among the tourist. The weather of this village is similar to Kathmandu. It is cold in winter and hot in summer in Kakani.

Nuwakot district is another district that suffered extensive damage in 2015 Earthquake of Nepal.

Initial estimates based on Government data of damaged buildings in the affected districts, suggested that 51% of the population of Nuwakot have been affected by the earthquake. According to Government estimates from 12 May, 30,000 buildings were destroyed in the earthquake and 15,000 are partly damaged. Highly affected were the northeast VDC of the district where reportedly all infrastructure and houses are destroyed. Chitre village has been highly affected by 2015 earthquake resulting many people to stay in temporary structure. Lamas has helped village in reconstruction but Good Earth Nepal has also helped to construct 6 Earthbag Buildings in the village. Settlements in this village have rather of scattered and dispersed character. Houses are placed on the hill terrace along the slope with the rectangular shape whose longer facade faces towards the south, south-east or south-west. The traditional buildings are of two storeys with pitch roof. The ground floor is main living area which is also open space designated for activities like cooking, dinning meeting and worshipping. The first floor is primarily used as granary and storage for family’s valuables and, possibly, as bedroom if the space in ground floor is not sufficient for all family members. The wall is mostly constructed of locally available stone with clay and earth as main mortar. The openings are mainly situated at the long side of house and the back walls often have no openings. [4]



Figure 5: Earthbag Buildings in Chitre

Table 2: Demographic data of People living in Earthbag Building in Chitre

SN	Duration	Occupation
1	1.5 years	Agriculture
2	1.5 years	Agriculture
3	1 years	Agriculture
4	Incomplete	-
5	1 years	Labor(Earthbag Building)
6	Not rebuild	-

4. Findings, Analysis and Discussion

4.1 Bolgaun Village

The village was approached by organization (Good earth Nepal) with propose to construct 22 earthbag buildings in the village as support to earthquake victims. Through many community base meetings and discussion, they selected the families to get support. Their first priority was those families who don’t have government support and single member household. The villagers had no idea about earthbag buildings before good earth Nepal introduced it to them. They were unsure about this construction technology. As buildings were being constructed villagers came to know more about earthbag technology. Out of 22 buildings, only 11 were constructed because few of them refuse to construct their house with earthbag and other lost their land in road expansion

4.1.1 Social Aspects

1. Cultural

Earthbag technology being new approach, it doesn’t continue the legacy of traditional building of Bolgaun Village. As explained above, traditional buildings were of 2 storeys constructed using locally available stone and clay and earth mortar and wood as supporting members. Ground floor was used for cooking, dinning and bedrooms whereas upper floor were used for storage. As the constructed earthbag buildings are single storey with single room, same cultural of space division is not maintained. The shape of building is rectangular and the orientation is same as traditional buildings but the proportion of the building were not proper as compare to traditional building of the village. Pitch roof have been used in earthbag buildings but the slope is not maintained as in traditional buildings. Traditional buildings have open hearth in ground floor. The fire in hearth is not used for cooking but also used to heat up the room during winter. Family members gather around the hearth at evening. They cook and chit chats together as a family; this time act as socializing time for family. Since burning fire inside the earthbag is not allowed, this culture of socializing with own family has been discouraged. This is also one of the reasons why some families are not living in earthbag

building but temporary structure adjoined to it where they can burn fire and socialize with family members.

2. Health and Comfort

The materials used for constructing earthbag buildings are environment friendly and natural. These types of buildings use limited amount of factory made materials like polythene bags, cements and rods, therefore there is less chance of indoor air contamination. The indoor air quality is maintained through natural cross ventilation as shown in figure 6. But as Bolgaun is cold area, the residents rarely open windows. To maintain good indoor air quality, burning firewood inside the building is not allowed. The thermal insulation of earthbag building is good as its thermal mass is high. For single room, 2 nos. of windows and a door allows enough daylight inside the buildings. As mentioned above windows are not opened due to cold climate, daylight through door are only being used. Still they don't have to use artificial lighting in daytime.

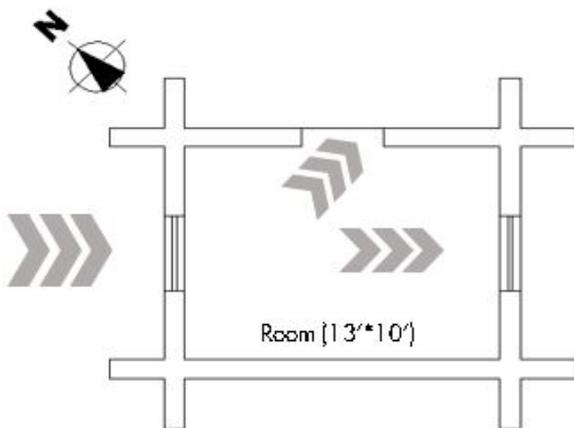


Figure 6: Provision of Cross Ventilation in Building

3. Safety

The strength of earthbag building is increased by using rebar, buttresses and lintel band which helps building to resist the force from earthquake. Residents feel safe to stay in the building. The earthbag building are resistant to earthquake, safe from flood and fire. Maintenance have not been required still the study time. The building does not required maintenance frequently. Earthbag technology is simple to construct. It doesn't require special

machine or equipment. Due to this, safety of workers is maintained. The relationship between owner, contractor and workers were good. As there were international volunteers working in this project, local people got to learn new things from them and volunteers got chance to learn new cultural of Bolgaun Village. The figure 7 represents the opinion of 11 families who are living in earthbag buildings regarding the safety of buildings. It shows that percentage of people believing that earthbag building are safe from earthquake are high where as they were not sure about safety for fire and other hazards. Literature has shown that earthbag building is safe from fire and flood. But the graph shows that people are unaware about it.

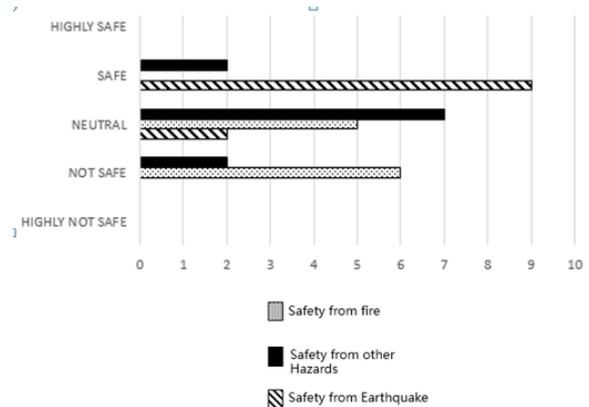


Figure 7: People's opinion on safety of building

4. Aesthetics quality of building and functionality

All 11 houses are of singled room with same size of room (10'*13'). While designing and planning the house local's opinions were not included. Their requirement of spaces is not incorporated in design. They were not even asked for requirement of space they want in their own house. Rebuilding local's houses were their first priority at that time. As they were living in temporary structure, for them to construct a permanent house was huge thing. Therefore, locals had no problem with the space management in earthbag buildings during designing phase. As they are living in the building now, families having more than two family members don't have enough space. Therefore, they have either added the storey or constructed another building. Out of 11

families, 2 families have added storey with lightweight materials, 3 families have constructed permanent structure using different technology rather than earthbag technology and 4 families have constructed temporary structure for kitchen and store. For those families who have not extended living space have either one or two family members. As per their culture, they have high respect towards their guests. Some families are using earthbag building for guests and they themselves are living in temporary structures adjoined to earthbag. As seen in figure, the number of people unsatisfied with the plan of earthbag building is higher than others. This shows that the existing earthbag building does not fulfill the space requirements of residents and culturally not sustainable.

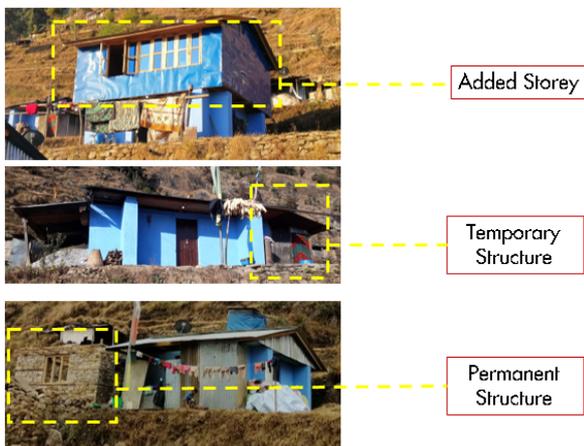


Figure 8: Addition of space

4.1.2 Economic Aspects

1. Affordability

For constructing earthbag buildings in Bolgaun, almost all materials had been provided by Good Earth Nepal. The expenses people had to bear were for wood for openings and roofs. These expenses range from Rs. 60,000 to Rs.1,00,000. The expenses vary according to the use of wood for openings and roof. Locally available materials were used like stone, earth and wood and materials from previous house were also used which decreased price of building materials. The nearest market for building materials is Melamchi which is approx. 30 km away from village. Transportation cost is comparatively high because of distance. There is still continuation of perma and volunteers

were available through good earth Nepal. So, Labor charges were comparatively lesser. Labor cost at the time of construction were Rs. 350-400 per person per day but now it has been increased to Rs. 600 to Rs. 800. Labours were readily available at the time of construction but now labours are not easily available. There are no any consult or contractor that have technical knowledge about construction method of earthbag building. Therefore, if people have to construct earthbag building at present time, it seems difficult. Time of construction vary according to the availability of labors since this technology is labor driven. Usually it took 5 to 6 weeks to complete standard size earthbag buildings with 4 to 5 labors. When earthbag buildings were constructed in this village, it was not included in DUDBC Catalogue, so people didn't get governmental support. Since 2017 the governmental supports (Rs. 3,00,000) is provided to earthquake victim if earthbag building is constructed as per the guidelines provided. But people in this village are still unaware of it.

2. Operational Cost

Earthbag walls exhibit high levels of thermal mass, which is the measure of a material's ability to absorb, store and transfer heat. The room temperature of earthbag building in Bolgaun village tends to increase during summer season because CGI sheet is used as roof. Thin layer of CGI sheet won't be able to stop heat to transfer into the building for long period of time. All 11 buildings have CGI sheet roof but some families have used wood as false ceiling which protect from heat in summer and cold during winter season. They have not used active energy to maintain cool environment inside the room during summer. As the village get cold in winter, extra energy in form of firewood is used to maintain thermal comfort inside the building. The firewood is collected from community forest. Earthbag buildings are to be plastered as soon as wall is constructed because when polypropylene bags are exposed sun and rain frequently, it gets damaged and the strength of building is decreased. All 11 buildings are cement plastered for protection. Maintenance has not been required till date. So, no any cost is spent in maintenance.

3. Recovery Cost

The most material used like earth, stone and wood are recyclable. Even if the building is demolished these materials can be used for constructing another building. As the binding material is barbed wire, it is easy to demolish the building. No any equipment or dynamite will be required.

4.2 Chitre Village

Chitre Village was not severely damaged by Bolgaun village. Good earth Nepal helped one family to construct the earthbag building as a model house. Then interested families contacted Good earth Nepal. Like in Bolgaun, for selecting the families they didn't go through community base meetings and discussion. The villagers had no idea about earthbag buildings before good earth Nepal introduced it to them. They were unsure about this construction technology. As buildings were being constructed villagers came to know more about earthbag technology. 6 earthbag buildings were constructed almost 3 years back but because they did not plaster as soon as the wall was constructed 4 buildings were damaged. After that only 3 houses were reconstructed.

4.2.1 Social Aspects

1. Cultural

The earthbag building constructed in Chitre doesn't address the culture value of the place. The size and shape of the building is same to earthbag building constructed in Chitre whereas traditional buildings in Chitre are totally different. Traditional buildings as seen in figure, were of 2 storeys constructed using locally available stone and mud with wood as supporting members, with balcony in first floor and projected pidi in ground floor. As the constructed earthbag buildings are single storey with single room, appearance of earthbag building is totally different from traditional building. The shape of building is rectangular and has pitch roof as in traditional building but the proportion of the building were not proper as compare to traditional building of the village. There are buildings where storey is added with lightweight material and tried to bring back the essence of traditional building but they could

not maintain the proportion of building.

2. Health and Comfort

As natural building materials where used like earth, it is environmental friend and doesn't affect the health of people living in the building. Factory made material as polythene bags, cements and rods, are less comparison to conventional building. The dominant building material is earth which is good for health of people. The indoor air quality is maintained through natural cross ventilation as in earthbag building of Bolagaun. The thermal insulation of earthbag building is good as thermal mass of earth is high. But since CGI sheets have been used for roof, heat transfer rate is increased. Therefore, they feel hot in summer season and cold in winter. The gap between roof and wall is not closed properly. During winter season cold air enters the building through these gap and during windy season all dirt are carried inside the building through the gap. The daylight is sufficient through 2 nos. of windows and door. Roof are projected which act as shading device.

3. Safety

Likewise in case of Bolgaun, for strengthening the building rebar, buttresses and lintel band are used. The earthbag building is resistant to earthquake, safe from flood and fire. They are facing problem from rats. As the building is made of earth, it is easier for rats to make hole through the wall and enter the building. rats also enter through the gap between wall and roof. As the earthbag buildings are easy to construct and doesn't require heavy equipment and special machines, safety of workers is maintained during construction period.

4. Aesthetics quality of building and functionality

The earthbag buildings constructed in this village are of same size (10'*13'). People's opinion and requirement were not considered while designing the building. Alteration in design of building was not allowed. The families living in earthbag building have another house for their other family members. A husband and wife is only using earthbag building as their bedroom whereas their

parent's bedroom and kitchen and other functional spaces are in another building. All building owner having joint family have another house. This shows that the single room earthbag building doesn't fulfill the space requirement of the joint family

4.2.2 Economic Aspects

1. Affordability

Earthbag buildings were constructed in supervision of Good earth Nepal. The support they provided were in material was polythene bags and barber wire. They helped to erect the wall. Other materials for openings, roof and finishing were to be bear by owner themselves. As finishing were left up to owner, they didn't plaster the wall in time as they cannot afford. Because of this, wall was damaged and out of 6 buildings, 4 had demolition and rebuild. This caused their expenses to increase. These expenses range from Rs. 80,000 to Rs.1,50,000. The expenses vary according to the use of wood for openings and roof and according to addition of storey. Locally available materials were used like stone, earth and wood and materials from previous house were also used which decreased price of building materials. The nearest market for building materials is Kathmandu which is approx. 30 km away from village. Transportation cost is comparatively high because of distance. There is still continuation of perma tradition in the village. Some volunteers were available through Good earth Nepal. Due to this Labor charges were comparatively lesser. Labor cost from perma is Rs.1000 per day per person whereas if labors from outside the village is used the charge is Rs. 1500 per day per person. Labors were readily available at the time of construction. But the skilled labors are gradually decreasing. As can be seen in buildings, the finishing works are not good. There are no any consult or contractor that have technical knowledge about construction method of earthbag building within the village. But Kathmandu is not far from Chitre. If they want to construct earthbag building in present time they can contact the supervisor easily. Time of construction vary according to the availability of labors since this technology is labor driven. Usually it took 5 to

6 weeks to complete standard size earthbag buildings with 4 to 5 labors. When earthbag buildings were constructed in this village, it was not included in DUDBC Catalogue, so people didn't get governmental support. Since 2017 the governmental supports (Rs. 3,00,000) is provided to earthquake victim if earthbag building is constructed as per the guidelines provided. But people in this village are still unaware of it.

2. Operational Cost

Even though it gets hot in summer and cold in winter, they have not used extra energy to maintain comfort level. During winter season, they do burn firewood for heat but as they are not allowed to burn it inside the building, people didn't had knowledge that earthbag should be plaster as soon as the erection of wall is finished for it to be not affected by weather. they didn't plaster on time and 4 earthbag building had to rebuild again. Other than that, maintenance is not required.

3. Recovery Cost

The most material used like earth, stone and wood are recyclable. Even if the building is demolished these materials can be used for constructing another building. As the binding material is barbed wire, it is easy to demolish the building. No any equipment or dynamite will be required.

4.3 Social Acceptance

1. New technology

Any new technology or innovation or any new thing in the market will not be accepted by people over the night. People believe what they see. In case of Bolgaun village, during earthquake, almost all buildings were either totally demolished or damaged. Only one building seen in figure 9 which was construction in frame structure was standing still. That gave an impression to the people that frame structure can withstand earthquake. Therefore, post-earthquake scenario is drastically changed from that of pre earthquake seen in figure 10. People started to construct building with concert pillars and brick or stone



Figure 9: R.C.C. building not damage in Earthquake



Figure 10: Post earthquake scenario of Village

infill. Even though they have to pay double the price for building material as transportation charge is high, they preferred to construct their building in same technology. The case is similar to Chitre village too. They have seen old traditional building being demolished in front of their eyes during earthquake whereas R.C.C. frame structure building surviving the earthquake. But they could not understand the factor that traditional buildings have been surviving since 100 of years but R.C.C. buildings are around few years. Earthbag being new to people, they hesitate to accept it. They are unsure about the technology even though earthbag is proved to be one of the promising sustainable building.

2. Awareness

Earthbag technology may have international recognition but rural area of Nepal is still unaware about the earthbag building. In case of

both the village, people were not aware of earthbag building. They came to know about earthbag buildings only after the organization team had introduced them. They had small workshop about how the buildings would be constructed from earth. Even when explained, people didn't understand the mechanism of technology. Their first question would always be the related to possibility of erecting building simply with earth and bag. Therefore, first house act as model house for the village. In this first project, people get to know about the process of constructing earthbag building step by step. It is important for any new technology to be known by people.

3. 'Pakki Ghar'

Pakki ghar means frame structure building of concrete pillars with brick or stone infill. Everyone dream of having pakki ghar. If you have a pakki ghar, your standard in society

automatically get high. This is how society has been working in Nepal. If to be quoted one of the local of Bolgaun words, “Everyone wants pakki ghar. They construct them even if they have to take loans and be in debt for lifetime. “ In Bolgaun village, people who have earthbag building have also constructed another building which is not of earthbag (Figure 11). It would have been easier for them to construct earthbag building adjoining the existing one. But as they said, they have one mato ghar and now they want one pakki ghar.

4. Flexibility in design

All the earthbag buildings that have been constructed for residential purpose are of similar size and shape. The buildings are single roomed and are of size 10’*13’. Even people wants to change the plan of building they were not allowed. As earthbag buildings depends upon buttress, even to add a room buttress has to be added. For adding additional opening too, buttress has to be added. Additional floors cannot be added without proper structural study of buildings. People who have not chosen earthbag technology for reconstruction have main problem with the flexibility in design. As they have seen, the earthbag buildings constructed in their village are single roomed where floor cannot be added. They found earthbag buildings less spacious and for family having many family members single roomed building is not enough.

5. Conclusion and Recommendation

5.1 Conclusion

The objective of the research is to know about the social and economic aspect of the earthbag buildings. As explained above, social sustainability of earthbag building in term of culture and aesthetics quality of building and functionality is not maintained. The cultural value of traditional building and surrounding context is not addressed. The main problem seen is in functionality of the buildings. The earthbag building were of single room and with same size in both the village. But as residential buildings required many functional spaces like for cooking, dinning or bedrooms, single room is not being able to fulfil these

functions. The social sustainability through health and comfort and safety and service quality of earthbag building is maintained somehow. The earthbag buildings are made of natural material so the health of occupants is not harmed. It is dominant building materials of earthbag building is earth which is good thermal mass itself. Therefore, indoor temperature is maintained and occupant’s comfort is not disturbed. Earthbag buildings are good resistant of earthquake and flood. It is safe from fire too. So, the occupants living in earthbag buildings feel safe and secure. The earthbag building seems to be somehow economically sustainable as it uses locally available materials and local labours. The construction technology is simple and doesn’t required special equipment and tools. The maintenance is not required frequently and due to climatic responsive building materials use of active energy are also not so high. But as the labours cost are increasing rapidly and people having proper technical knowledge about earthbag technology is not available within the village, in near future the cost of constructing earthbag building will be increased. As earthbag technology is labour driven technology, availability of labours and the wages of labours plays important role in economic sustainability of earthbag buildings. Another objective of this research is to know about the current situation of earthbag constructed in Nepal. The earthbag building that have been constructed in Bolgaun village are in good condition in comparison to that of Chitre Village. As all phase of construction of earthbag buildings are taken care by Good earth Nepal, the finishing is good. But in case of Chitre village, organization supported them only to erect the wall. Villagers got choice to choose labours for finishing, therefore the quality is not maintained as they go for cheaper workers. Last objective of this research is to know about the factor affecting social acceptance of the earthbag buildings. Only one reason cannot cause the social accepting factor. There may be many reasons behind it but four common issues were found in both the site. The issues were:

- Earthbag technology is new to people and anything new takes time to get accepted.
- People were not aware of earthbag buildings. Even though government have approved the technology, people have no idea about earthbag buildings before organization introduced them.
- Pakki Ghar is every man’s dream. They want



Figure 11: Earthbag building and pakki ghar of same owner

a house which is constructed of concrete pillar and brick walls, not the one which is constructed with earthbag. People are not aware about the advantages of earthbag buildings.

- Earthbag buildings are not flexible in design or at least the model earthbag buildings that have been constructed in village are not. So when the space requirement of villagers is not fulfilled, they choose those technologies which fulfilled their requirements

5.2 Recommendation

- As the earthbag technology is new concept, people should be awarded about it. The engineers and technical people working in rural area of the country in reconstruction projects should informed people about the option 'earthbag building'. Earthbag building is one of the suitable alternative building technology for rural Nepal. People should know about it. If for residential buildings, earthbag technology is not used then it can be used for public buildings like schools and health post where local people can be involved in construction process. Workshops can be held where people are trained about the technology.
- Almost all the residential earthbag buildings that have been constructed in Nepal are of similar shape and size. People have conceived the idea that earthbag building can be of that form. They don't have idea about other option of earthbag buildings. The experiments in design and plan of earthbag buildings should be done. Earthbag buildings are not a rectangular room with two windows at two sides of



Figure 12: Other option of Earthbag building

building and a door at the front façade. Proportion of earthbag building should also be maintained with the traditional building so that the visual effect is not deteriorated, especially the roof of the building.

References

- [1] Kateryna Zemskova Nathan Belofsky. Bringing earthbags to the people-a new, democratic approach to sustainable building. 2018.
- [2] Kelly Hart. *Earthbag Architecture: Building Your Dream with Bags*. Hartworks, 1st edition, April 27, 2015.
- [3] Luís Bragança Joana B. Andrade. Analysis of the impacts of economic and social indicators to sustainability assessment. 2011.
- [4] Hamhaber Johannes Bodach Susanne, Lang Ing. Werner. Climate responsive building design of vernacular architecture in nepal. 2014.

