Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 2 (2024)

Design of Compressed Stabilized Earth Bricks (CSEB) for Earthquake Resisting Building in Nepal

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Abstract**:** This study focussed on determining values for characteristics utilised in current design calculations, such as Young's modulus, density, compressive and tensile strength, and the first natural period of a CSEB building, by in-field testing. Finding a reliable numerical model of a CSEB building was another goal of this work. A CSEB building's dynamic reaction to an impulse was evaluated in the field. This test was accomplished to calibrate the mass and stiffness distribution of the model and validate the numerical model. The results of a review of the literature on the subject of earthquake design for masonry and CSEB structures led to the development of design recommendations for the CSEB buildings constructed by Build over Nepal. Three inquiries vis-à-vis design deviations that arise from observations made during the CSEB building's construction were also addressed. The young's modulus test density analysis and compression strength test and tensile strength test were performed on the CSEB material and found the positive results. It is observed that manufacturing of blocks are reliant on on the manufacturing process and not depends on the curing of the blocks. Compressive and tensile strength would be increased after the curing process it was 11.8 MPa (tensile strength) and 1.81 MPa (compression strength).

Keywords**:** Compressed stabilized Earth bricks, Compressive strength, tensile strength, young's modulus, density.

1 Introduction

Nepal is a country which is situated in south Asia and the bordered of china to the north India to the south, east and west. Nepal is culturally rich with diverse population and a history intertwined with Buddhism and Hinduism. The sudden vibration of earth is commonly known as Earthquakes. To understand the earthquake and handled the effect of earthquakes on structure it is important to understand the theory of earthquake [1].

The Gorkha region of Nepal, Saturday 25th of April the largest earthquakes is strucked, naming the gorkha earthquakes (government of Nepal 2015). The Gorkha earthquakes reached 7.8 M on richered scale and large amount of aftershock. The large number of population is situated in Nepal in rural area and cities are very less. Both were affected, estimated of 8760 casualty, 22330 injuries and 8 million people were affected after the earthquakes. There would me a large number of losses of infrastructure and properties. The estimated about US$8 billion with the need reconstruction [3].

After the Gorkha earthquake Non-Government organization were decided to design the Earthquakes resistance building (EQRB) with the help of materials and different components which is used in the earthquakes resistance building. The technique was totally based on the locally available material and resources available in Nepal. For the rural area people need different types of techniques and urban area people need different technique to the based on there financial aspects. Different types of scheme were run by the government of Nepal with the collaboration of Non-Government organization of Nepal like; rural housing reconstruction program (RHRP). The funding of this program was doing by Nepal rural housing reconstruction program multi donor trust fund 2016. The rural housing reconstruction program rebuilt with the help of Government of Nepal. The main objectives of this program was that houses destroyed by Earthquakes in Nepal is Rebuilt with Earthquakes resistance techniques with safety from the Government of Nepal (GON).

1.1 Material used after Gorkha Earthquake in Nepal

After the Gorkha incident in Nepal, the Government of Nepal taken initiation to design building with the earthquakes resistance material. They start using compressed stabilized earth block (CSEB) and stone blockes. These material are in hollow for the better interlocking. [2] The hollow material were provided the better Earthquake resistance properties as compare the normal material which are used in the building construction. These hollow material were made up of locally available material like soil with cement and water. The material were prepared with the help of machine and cured till 28 days after the moulding and then used in construction. This material is totally depends on the types and quality of material wich is locally available in Nepal. The main disadvantages of these material is that the material they found in different in other part of Nepal so the strength of bricks found different.

1.2 Seismic zones in Nepal

The maximum area about 90% of the world, earthquakes occurs in the area of pacific ocean called the "**Ring of the fire**" it is also called circum pacific belt. Which is stretched through Himalaya and Nepal is about 5%-6% of the earthquakes (U.S geologist survey 2016) figure 1.2 below shows the alpide belt on a map of pacific belt

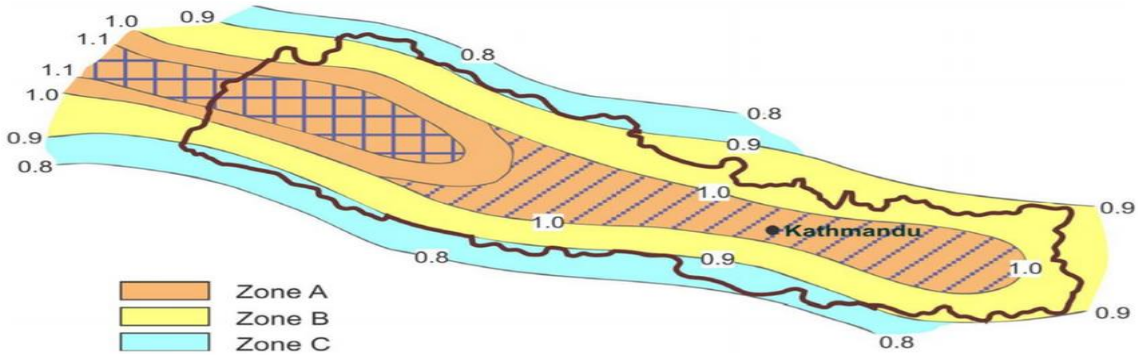

Figure 1: Seismic zones in Nepal

1.3 Measurement of earthquake

There are mainly two method for the measuring the earthquake in major scale and the system: the Rechter scale and mercalli sacle

2 literature review

In 2019, [1] Anaya Kumar Mishra, Ramesh Thing; they studied that examine the seismic characteristics of the 17 models that NRA has provided by conducting desk research, field trips, focus groups, and interviews with key informants.

The National Building Code (NBC) is the basis for 17 models of NRA-provided designs that include characteristics such as plinth band, sill band, lintel band, vertical core, stitch and gable band that are earthquake-resistant. It is advised to raise awareness among home owners, neighbourhood contractors, and other relevant stakeholders about earthquakes and their potential consequences on building structures. In a similar vein, government agencies in the communities should provide soil tests in order to facilitate efficient home building. **In 2004, Amod Mani DIXIT et.al** they described the Native knowledge and conventional wisdom about earthquake-resistant technology in Nepal; the significance of methodical research in this field to identify what society has already accepted; and the necessity of incorporating some of those techniques and strategies into our current efforts to increase seismic safety, particularly in rural areas where traditional building materials like stone, timber, brick, mud, and bamboo are still widely used In order to improve the earthquake resilience of the 22 million people who live in Nepal, their paper attempts to conduct a preliminary investigation into the traditional knowledge and expertise of earthquake-resistant technologies in the Nepal Himalayas. It also looks at the need for additional research in this area. **In 2015, T. Pokharel and H.M. Goldsworthy,** their document summarises the reconnaissance survey of a significant 7.8-magnitude earthquake that struck Nepal's Gorkha District on April 25, 2015. A series of aftershocks, including a 7.3-magnitude earthquake on May 12, 2015, followed. To date, there have been 8969 casualties as a result of this, and thousands of people have been left homeless as 900,000 dwellings and temples have suffered partial or total damage. A thorough discussion of issues related to Nepal's current methods is held, and some recommendations for better design and construction are put out. The article highlights several significant issues, including as code compliance, construction quality control, and inadequate readiness. They made a review research on April 25, 2015, at noon, a public holiday in Nepal, a magnitude 7.8 earthquake struck, severely damaging the surrounding area. The death toll would have been significantly greater if the earthquake had happened at night or during a working day. There were no injuries despite the damage to numerous government buildings and educational institutions. For farming or other reasons, a large number of people were outside their homes, which also helped to lower the death toll. **In 2020, J. Bothara , R. Desai et.al[5]** done experiment based earthquake resistant prototype design of residential buildings in Nepal, For relatively little extra money, the suggested designs offer economically disadvantaged populations earthquake resilience alternatives. The suggested technique might be implemented in other seismically active regions of the world, especially in developing nations that experience socioeconomic problems and accessibility challenges such to those faced by Nepal. This would enable the general public to have affordable access to seismic safety. Their article presents designs for residential buildings that blend the widely accessible local stone and mud for construction with foreign elements like steel wires and welded wire mesh (WWM) to increase the buildings' seismic resilience. A shock tables test was used to experimentally test a ½ scale constructed model building in order to verify the earthquake resistance of these proposed designs. The fact that all of the building models withstood the applied shocks without experiencing any unstable modes of failures is sufficient proof that well-designed stone masonry structures made with a combination of carefully placed materials inside stone in mud mortar can be made earthquake-resistant enough. **In 2018, J. K. Bothara1 , D. Dizhur2 and J. Ingham [6],** they made a research on the most impacted areas covered an area of about 30,000 square kilometres and featured rough terrain consisting of hills, mountains, and dispersed towns that were not accessible by land vehicles. The Build Back Better (BBB) reconstruction strategy, which the Nepali government has embraced, mandates that any new construction be earthquake-resistant. In order to comply with this requirement, contemporary materials like steel and cement, expert construction methods, and quality control are typically needed. Usually, the only abundant reconstruction materials found locally are stone and mud. In earthquake-prone places, especially higher up, hardwood is hard to come by, and treating local softwood or importing hardwood are usually out of the question. The minimal amount of funding available exacerbates the situation further. These elements present financial, logistical, and technical difficulties for reconstruction that is earthquake-resistant. As a result, for the best use of local personnel and resources with little to no expertise with imported materials, novel construction systems and procedures are needed. First-hand experience with the creation of such building approaches is presented here. **In 2013, Nooreddin Azimia and Ali Asgaryb,[8]**, in their research, they investigated rural residents' preferences for earthquake resilience in house construction through the use of a choice experiment (CE). For a CE study, a total of 300 households were recruited from randomly selected villages in the central districts of Guilan Province, Iran. The households were required to make a choice between several houses that varied in terms of size, exterior and interior designs, earthquake resistance, and the required construction loan. According to our findings, the typical inhabitant would rather spend more money on larger, better-designed homes with superior external and interior architecture than on more earthquake-resistant homes. These findings suggest that rural residents are open to taking out loans to make improvements to their homes. The findings support the finding that many newly constructed homes in the past are not resistant to hazards. Better materials are used in the construction of the majority of new homes, but this does not always translate into homes that are more resistant to hazards. To determine whether any control measures are in place and how resistant to hazards the new homes are, more follow-up research must be carried out. Furthermore, we only included a small number of home features in our analysis. Future studies could examine the relative significance of social and consumption issues at the same time.

3 Material and Methodology

In any research work the main think is the identification of the problems occurs. In Nepal the material which are using the manufacturing of houses are not earthquakes resistance. Therefore we design the material for building which can be used in building, these material have many property like earthquake resistive, durability, strength etc.

In this project the main steps are involve are:

- Preparation of the field study of Nepal (mostly affected for earthquakes)
- Gathering the data from government of Nepal and sites.
- Analysis of data collected
- Design of CSEB (compressed stabilized earthen bricks).
- Test on materials
- Application of material for earthquake resistance.

The flow chart is shown for the steps involve in the designing the material for earthquake resistance material. Firstly we study about the field regarding the earthquake region in Nepal, which area is more affected from Earthquake (EQ) and what is the impact of that desteroysion. Then we will collect the data from site and office of government of Nepal which is near by these affected area. After the collecting we will analyse the data for finding a conclusion regarding data. And then we design the material which will used in the earthquake resisting building. And doing test on that material and application will start on site.

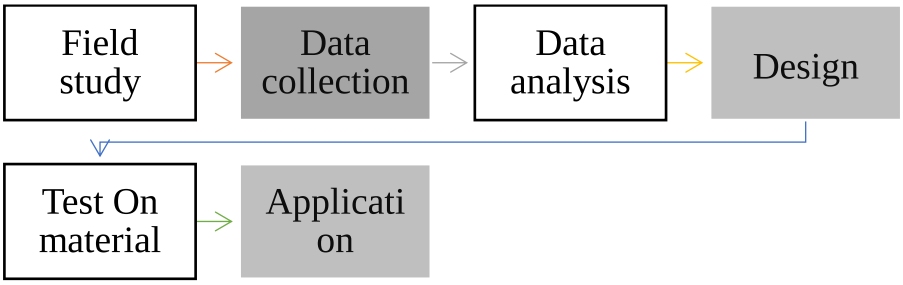

Figure 2: Steps involve in investigation and designing of earthquake resistance material

This is the field observation in Nepal regarding the Earthquakes of many area of Nepal. It also includes the functional background of material used in the construction to resist the Earthquakes in Nepal. It is better understanding of Compressed stabilized earthen bricks in Nepal that they are suitable for country environment or not and what are the effect of environment of that type of material on nature [6].

During the construction of that type of building many problems are arises and resolved by the experienced engineers and killed labour. Manjhigaon village is rural area of Nepal. The following observation and analysis are done in this village of Nepal. The soil were taken from this village for manufacturing of hollow bricks and analysis were done by engineers in Nepal. Manjhigaon in Village of central Nepal the population of that village is approximate 3000. The area of Manjhigaon is 45550 km2 (according to national population and housing census 2011, Government of Nepal). Location of Nepal village is 27.67 N 86.15 E Coordinate. The all data for seismic and earthquake are arrange for the analysing. The data of earthquake are really very drastic painful because continuously we are doing better approach for earthquake resistance for future betterment and improvement. [10] The silt particles and clay are used in the bricks for the making bricks. But after the came with contact with water it will becomes damp so why we are not using the cement for the binding purpose. We can used cement in sand and silt to bind the soil, the percentage of cement is 5% is nominal but the upper limit of cement is 9%-10% for the earthquake resistance building. (With hollow interlocking block 2005) for the reach strength maximum it is required to curing the material once in a day for proper strengthening. It will continuously for the four weeks. It will be dependent on the atmospheric condition.

- **Preparation of Compressed stabilized earthen bricks (CSEB):** Compressed Stabilized Earth Bricks (CSEB), also known as compressed earth blocks (CEB), are construction materials made primarily from soil mixed with a stabilizing agent such as cement or lime and compressed using a hydraulic press or manual compression. It will be helps the resistance the seismic waves. These bricks offer an eco-friendly and sustainable alternative to traditional fired clay bricks. Here are some key points about CSEBs.

- **Manufacturing Process:** The manufacturing process involves mixing the soil with the stabilizing agent and water to create a homogenous mixture. This mixture is then compacted into a brick mold using a hydraulic press or manual compression. After compression, the bricks are left to cure and dry naturally. The below flow chart is the gives a idea of manufacturing process of compressed stabilized earthen blocks. The preparation process for compressed stabilized earth bricks (CSEBs) involves several steps to ensure the quality and strength of the final bricks. Here's a general outline of the preparation process.
- **Mix Design:** Determine the mix proportions of soil, stabilizer, and water based on the soil test results and desired brick properties. Generally, a small percentage of stabilizer (typically 5-10% by weight of soil) is added to the soil mixture. The water content should be carefully controlled to achieve proper compaction and curing.

Figure 3: CSEB manufacturing machine

- **Compressive strength testing:** A destructive strength test was performed on both the hollow interlocking blocks used in MajhiGaun and on the blocks with the dimensions 240x240x90 $mm^{3.}$. A field block tester from *Auroville Earth Institute* was used, a drawing of the block tester is shown in Figure 26. As canbe seen in Figure 26 a lever arm is used to decrease the required load to break the block. It is also important that the field tester has a proper counter-weight. From the results of a three pointbending test the compressive and tensile strength were calculated by formulas derived by *Auroville Earth Institute* (Maïni, Production and Use of Compressed Stabalised Earth Blocks, 2010). The force applied on the block is given by:

$$F = (\text{load on plate} + \text{load of plate}) * L_e \qquad [\text{kg}]$$

- **Tensile strength testing:** In tensile test there are two test sample are taken for the testing. The test experiment was under the two different load condition is performed. One is the 250 kg and other is 260 kg.

4 Result and discussion

In this chapter the result were discussed which is performed the previous chapter. All the test were experimentally performed in chapter number 3. The experiment was performed for the young's modulus and density of compressed stabilised earth bricks and also compressive strength test of bricks and tensile strength of bricks were performed. After the experiment result are analysed in the chapter 4.

- **Result Analysis of Young's modulus and Density of** Materials **(CSEB):** Table 4.1 shows the calculated values of Young's-modulus for the 20 blocks. The table shows that Young's-modulus of the CSEB in Majhi Gaun ranged from 1.63-4.91 GPa, with an average value of 2.74 GPa. The density ranged from 1470.6-1719.5 kg/m3 with an average of 1548 kg/m3.

Block	Density	P-Velocity	Poisson's ratio	Young's Modulus
	[kg/m³]	**[m/s]**	**-**	**G Pa**

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1	1583.7	1654.7	0.25	3.61
2	1538.5	1419.8	0.25	2.58
3	1470.6	1228.7	0.25	1.85
4	1583.7	1597.2	0.25	3.37
5	1538.5	1432.1	0.25	2.63
6	1470.6	1273.6	0.25	1.99
7	1470.6	1466.8	0.25	2.64
8	1583.7	1666.7	0.25	3.67
9	1629.0	1608.4	0.25	3.51
10	1696.8	1782.9	0.25	4.50
11	1719.5	1851.9	0.25	4.91
12	1538.5	1312.8	0.25	2.21
13	1583.7	1315.8	0.25	2.28
14	1538.5	1127.5	0.25	1.63
15	1515.8	1321.8	0.25	2.21
16	1493.2	1382.2	0.25	2.38
17	1493.2	1357.7	0.25	2.29
18	1538.5	1280.6	0.25	2.10
19	1493.2	1360.9	0.25	2.30
20	1493.2	1283.5	0.25	2.05

Table 1: Result data for Young's modulus and density of CSEB materials

- **Result analysis of Tensile strength of interlocking Blocks:** The lack of some various reason only two test were performed on the blocks. These gives the various information regarding earthquake stability. After the analysing the block results it is observed that the mean value of tensile strength was recorded 1.78 MPa. It is good for strength point of view for the seismic waves. They will resist the earthquake occurring on the structures. The graphical representation are shown below.

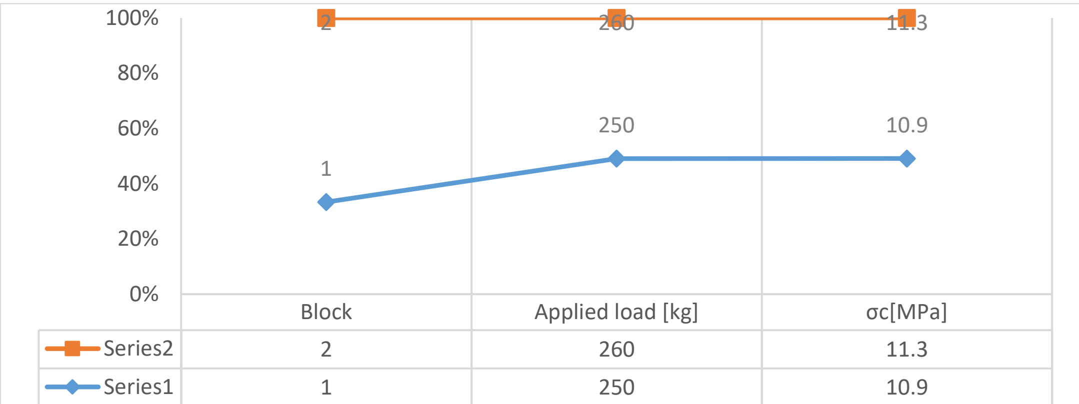

Figure 4 : Result analysis of Tensile strength for Blocks

- **Result Analysis of compressive strength of interlocking Blocks:** The result were analysis for the compressive strength of CSEB to resist the earthquake. It is main factor which influence the seismic waves for construction of building. The data will shown in below table 4.3. block 1 which have applied load is 250 kg and it is gives the compressive strength of 10.9 MPa. And other block 2 which have 260 kg load which is increased and that gives the value of compressive strength of 11.3 MPa.

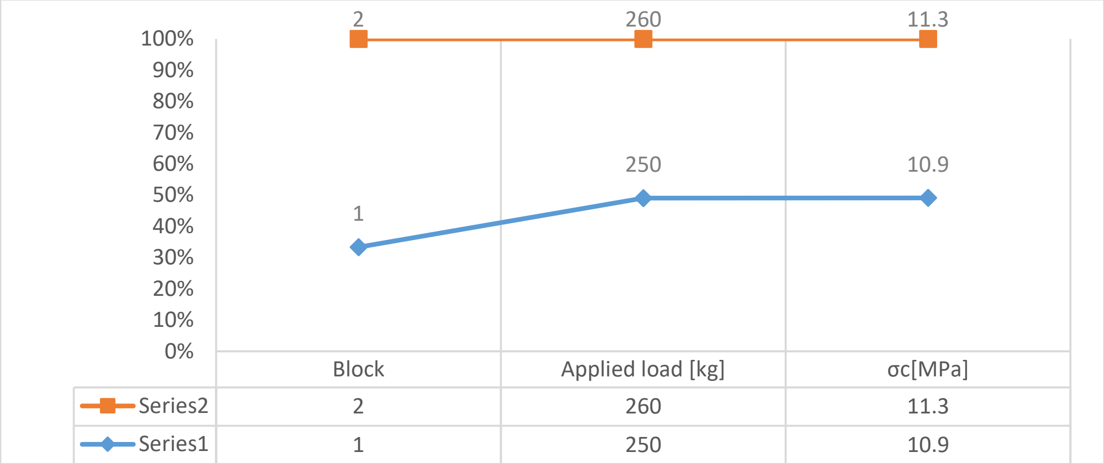

Figure 5: Result analysis of compressive strength of blocks.

5 Conclusion

Centered on the investigation of training or experiment it can be determined that the young's modulus is dependent on the machine or equipment being used for the production of the blocks (that is for degree of compaction of the mixed material). It is also observed that the percentage of cement used in the mature have to be considerable influenced. If we were increased the coarser particles in the mixture the young's modulus will increased gradually. And the curing does not influence the young's modulus of the material (Blocks). After the young's modulus the tensile test and compressive test were conducted and it was found that the property of compressed stabilized earth bricks are also depends on the machine of types of machine or it will be manufacturing of bricks process. The following points has to be observed during the experiment and Result analysis-

- The young's modulus of the materials are depends on the type of machine used for the manufacturing.
- The machine has to be good compression impact for better density impact.
- If the density of material of blocks will more than the bricks will be more compressive strength and the tensile strength value.

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