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PRODUCTION & USE OF HOLLOW CONCRETE BLOCKS IN RECONSTRUCTION AFTER GORKHA EARTHQUAKE

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Abstract

When Nepal was hit by the devastating earthquake of Magnitude 7.8 on 25th April 2015, 498,852 private houses were destroyed according to the Post Disaster Needs Assessment Report. During the post-earthquake reconstruction there was huge scarcity of bricks for the construction of load bearing structures in the affected districts of Nepal. Thus, the earthquake victims started constructing their houses using the alternative materials such as Hollow Concrete Blocks (HCBs) to construct load bearing masonry buildings in those areas. However, the HCB producers were producing the blocks to meet the reconstruction demand, without considering the quality as per Nepal Standard. HCBs are pre-cast cement concrete blocks with one or more large holes and consist of Portland cement, water, sand and aggregates. HCBs are typically available in the nominal block sizes of 400×200×200 mm, 400×150×200 mm and 400×100×200 mm as per Nepal Standard: 119/042.

After the 2015 Gorkha earthquake, Housing Reconstruction & Recovery Platform (HRRP) collected data to analyse the production and use of HCBs across the earthquake affected districts in November-December 2016 and October-November 2017. The data collection methodology included semi-structured interviews with HCB producers, questionnaire interview with households constructing with HCBs, and collection of block samples for compressive strength laboratory test. Interviews were conducted with 76 block producers across 11 districts, with compressive strength testing carried out on 110 blocks, and interviews with 37 households that have built with HCBs, across 5 districts.

The study found that there is extensive production and use of HCBs for the reconstruction in almost all earthquake affected areas. However, the average compressive strength of the collected block samples was found to be 39.6 kg/cm2, which is very low compared to the limiting value of 51 kg/cm2. This suggested that the use of such weak construction materials is in opposition to the GoN approach of Build Back Better and may add to more human casualties in future disaster. The study further identified the need of technical documentation of such alternative materials along with the quality guidelines for producers as well as users.

Keywords: hollow concrete block; laboratory test; Gorkha earthquake; compressive strength; reconstruction

1. Introduction

On April 25, 2015, a 7.8 magnitude earthquake struck Nepal. Following a strong shake on May 12 (7.3 magnitude), and a sequence of aftershocks, the Government of Nepal (GoN) reported the death toll of 8,700 while those injured reached 25,000. A Post Disaster Needs Assessment (PDNA) [1], completed in June 2015, reported total damages and losses of about US$7 billion, with reconstruction needs of about US$6.7 billion.

As the earthquake sequence destroyed 498,852 houses mostly traditional brick and stone in mud mortar structure occupied by the rural poor and rendered another 265,000 houses at least temporarily uninhabitable.

The Rural Housing Reconstruction Program focused on restoring affected housing in 32 affected districts while providing technical support to enhance the government's ability to improve long-term disaster resilience. To support the reconstruction process in the country, Government of Nepal has decided to provide a cash grant of NPR 300,000.00 for reconstruction and NPR 100,000.00 for retrofitting under the Grant Disbursement Procedures for Private Houses Destroyed by the Earthquakes, 2073 (2016) [2].

It became clear at the early stage of post-earthquake housing recovery that Hollow Concrete Blocks (HCBs) were becoming an increasingly prevalent construction material, and that existing HCB producers were expanding along with new HCB producer being established to meet the demand. HCBs are pre-cast cement concrete blocks with one or more large holes and consist of Portland cement, water, sand and aggregates. HCBs are typically available in the nominal block sizes of 400×200×200 mm, 400×150×200 mm and 400×100×200 mm as per Nepal Standard: 119/042 [3].

It has a high compressive strength if mixed and cured appropriately and the reduced weight, due to the cavity, decreases the dead load. Furthermore, HCBs use less concrete than solid concrete blocks and the cavity enhances the thermal insulation. Its additional advantages include fast construction, high durability and low maintenance. Therefore, HCBs popularity has been increasing in the reconstruction in earthquake zones.

Build Change 'Post-Disaster Reconnaissance Report' [4] indicated that mostly in semi-urban areas affected by the 2015 Earthquake, use of HCBs were found to be higher especially as an infill material in RC frame structures. Similarly, a 2008 study on 'Existing Practice and Improvements in Concrete Block Wall Construction' under the Asian Disaster Preparedness Center (ADPC) [5] found that HCB would be one of the most preferred alternative material for construction in case of any future earthquake. Among the total respondents in the study 48% of respondents felt this was because construction rate is faster with HCBs than with other materials, 30% felt that HCBs would be easily available, 14% felt HCBs would be preferred because they can be prepared on site, and 8% felt that people would move away from traditional construction materials because of fears that they could not be used to build earthquake resilient structures.

With the increasing use of the alternative materials such as HCB, Department of Urban Development and Building Construction (DUDBC) prepared Design Catalogue for Reconstruction of Earthquake Resistant Houses Volume 2 [6] in March 2017 which included approved designs for two-storey HCB confined masonry and masonry building. However, households are generally not following these designs and NRA engineers are unable to provide technical solution regarding this as no proper technical studies on HCB were conducted in Nepal. It is also of concern that the quality of the blocks and the construction can have a huge impact on the performance of a house during a seismic event. The Seismic Design Guide for Low-Rise Confined Masonry Buildings [7], prepared by the Earthquake Engineering Research Institute (EERI), warns that "hollow masonry units should be used with caution in non-engineered buildings". Observations from the 2010 Haiti earthquake and 2010 Maule, Chile earthquake found that poor performance of confined masonry walls built using hollow concrete blocks was "mostly due to poor quality of concrete block units".

In order to analyse the production and use of Hollow Concrete Blocks (HCBs) across the earthquake affected districts, HRRP has conducted two rounds of data collection with HCB producers and households that are building / have built with HCBs. The first round of data and block sample collection took place in November and December 2016 mainly from Dhading, Dolakha, Gorkha, Kavre, Makwanpur, Nuwakot, Rasuwa, and Sindhupalchowk districts. The second round of data and sample collection was conducted in October and November 2017 from Bhaktapur, Dhading, Dolakha, Gorkha, Kaski, Kathmandu, Kavre, Lalitpur, Makwanpur, Nuwakot, Rasuwa, and Sindhupalchowk districts. As there are no HCB producers in Sindhuli, Ramechhap, and Okhaldhunga districts data and sample was not collected in these districts in either round. The data collection included semi-structured interviews with HCB producers and with the households constructing with HCBs as well as the collection of sample HCBs for compressive strength testing. Block samples were collected from all producers interviewed, and these were sent for compressive strength testing at the Central Material Testing Laboratory of the Institute of Engineering, Tribhuvan University.

2. HCB Production after Gorkha earthquake

This section presents findings from interviews with 76 block producers across 11 districts and over two rounds of data collection with the first in December 2016 and the second in November 2017. The compressive strength testing section presents the results of testing of 110 block samples collected from different block producers.

2.1 Production Capacity

The daily production capacity varies greatly amongst producers. The overall daily average across all earthquake affected districts is 600 HCBs; an average of 655 HCBs from the first round of data collection and 580 HCBs from the second round of data collection.

Bhaktapur, Lalitpur, and Nuwakot have the highest HCB production capacity, while Sindhupalchowk, Kavre and Dolakha are well below the daily average production capacity. It is interesting to note that HCB production in Makwanpur appears to have reduced a lot since the first round of data collection, whilst production in Rasuwa and Nuwakot has gone up.

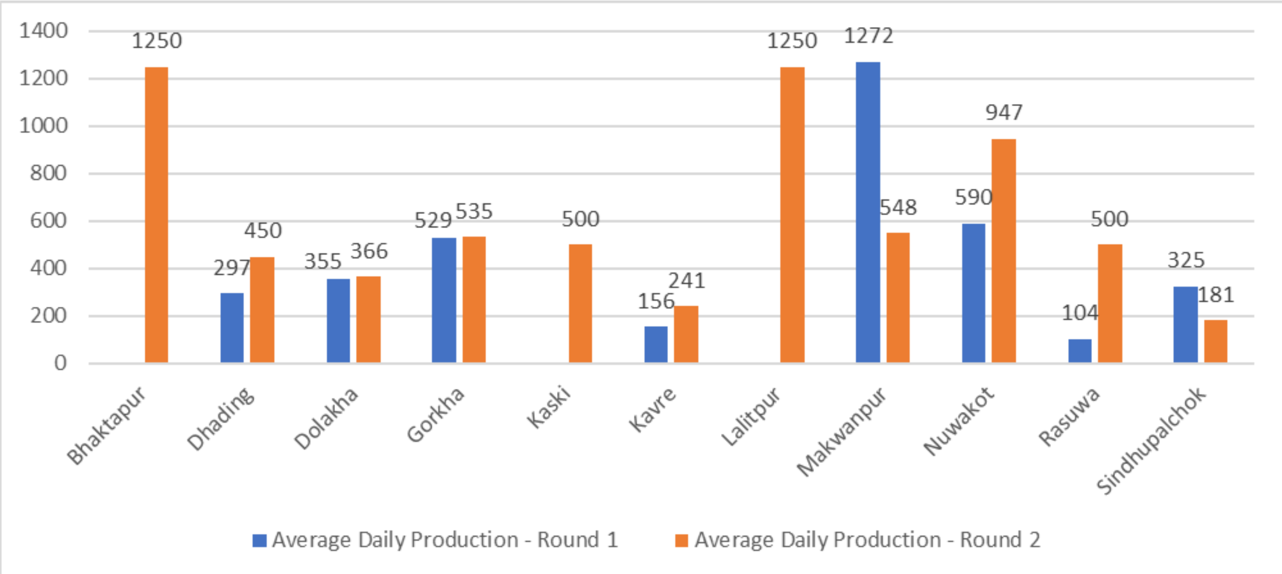

Fig. 1 – Comparison of average daily production rates across earthquake affected districts

2.2 Price per Block

The price per block varies across producers and districts. The average price across all districts from the first and second round of sample collection was NPR 57 and NPR 58 per block respectively. It is interesting to note that quality seems to have limited impact on the cost of the block. The ten weakest blocks (with compressive strength ranging from 12.74 kg/cm^2 to 20.4 kg/cm^2) have an average cost of NPR 56 per block.

The cost of blocks is highest in Dhading and Rasuwa, whereas the cost in Dhading has increased by more than 50% from round 1 data collection and the cost in Rasuwa has decreased by 20% since round 1 data collection. The cheapest blocks are in Makwanpur where the average cost per block is NPR 33 which is below the overall average.

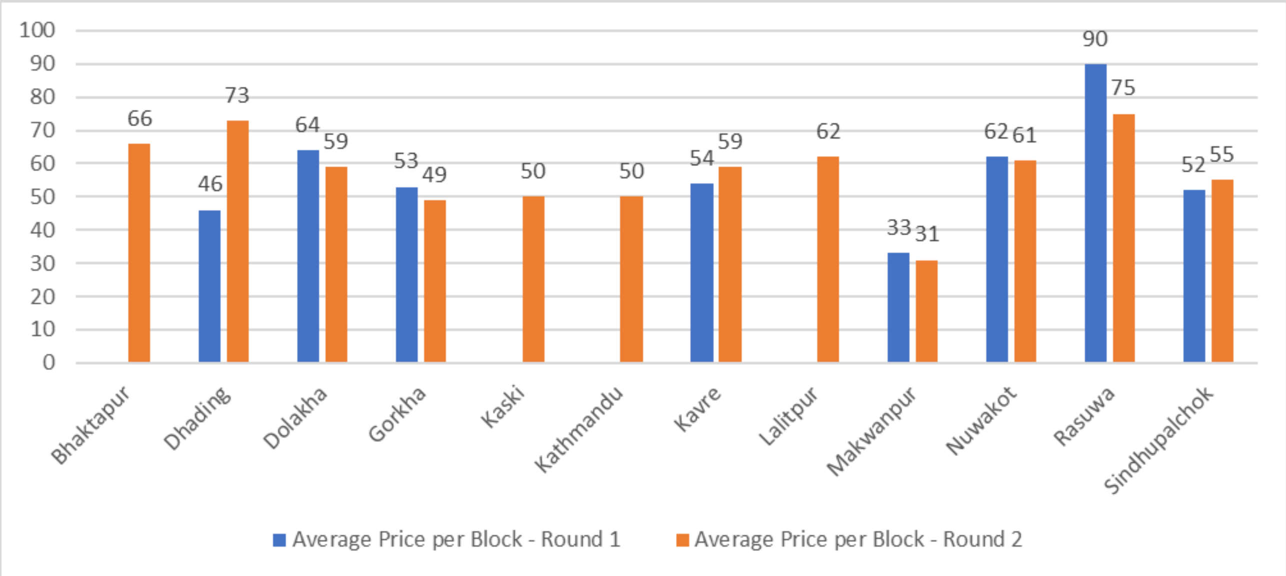

Fig. 2 – District wise average price per block

2.3 Curing

The Nepal Standard NS: 119/2042 does not specify required curing times but refers to the Indian Standard Specification for Concrete Masonry Units Part 1 Hollow and Solid Concrete Blocks IS 2185 (Part 1): 2005 [8]. As per the Indian Standard IS 2185 (Part 1): 2005 and IS 456: 2000 [9] HCBs should be cured for at least 14 days to permit a complete moisturization.

The average curing time across all producers is found to be 11 days and in the most recent set of data collected, Gorkha is the only district with an average curing time of greater than 14 days (16 days). It is perturbing that there seems to be a trend of reduction in curing times from the first round of data collection to the second. This trend was observed in Kavre, Makwanpur, Nuwakot, and Sindhupalchowk districts whereas only in Dhading district small increase in the average curing time was found. Most HCB producers cure the blocks for only seven days, but there are also producers curing blocks for as little as three days.

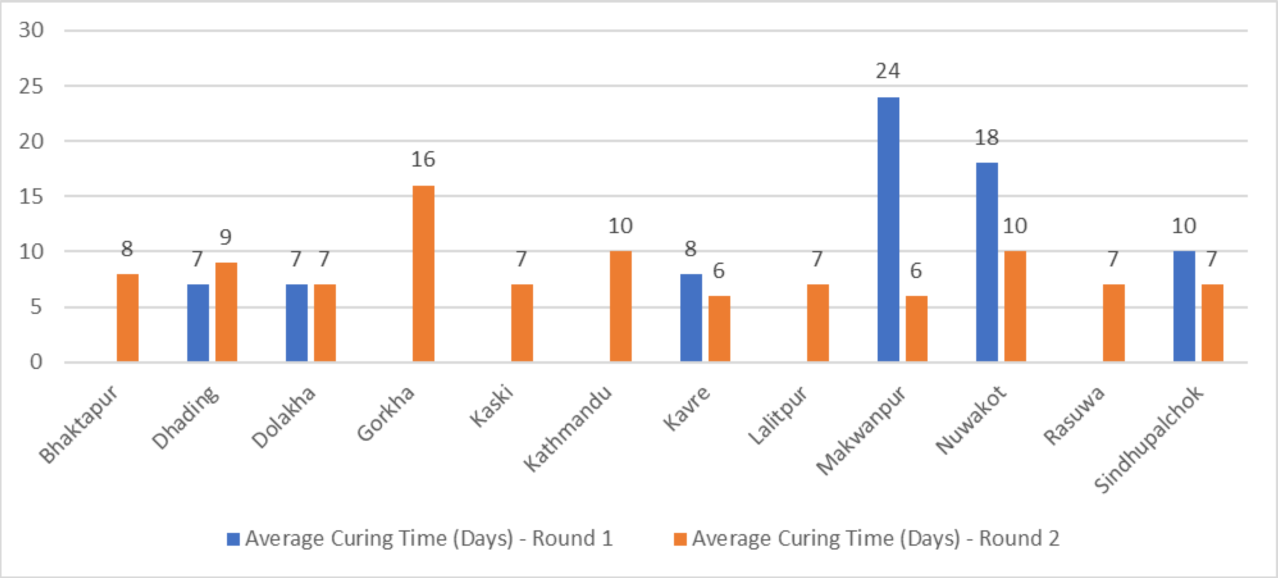

Fig. 3 – District wise average curing time in days

The majority of producers use 'sprinkle' method for curing which involves either pouring or hosing water over the HCBs between two to four times per day, with other producers using a 'ponding' method where the blocks are submerged in water.

Fig. 4 – HCB laid in the sun after production in Dolakha (L) and blocks submerged in a pond in Dolakha (R).

2.4 Mix Ratio

There are no recommended or required mixing ratios mentioned in the Nepal Standard NS: 119/2042. However, the Nepal Standard NS:119/2042 references the Indian Standard Specification for Concrete Masonry Units Part 1 Hollow and Solid Concrete Blocks IS 2185 (Part 1): 2005. As per the Indian Standard IS 2185 (Part 1): 2005 the concrete mix shall not be richer than one part of volume of cement to six parts of volume of combined aggregates before mixing.

The mix ratios used by producers varies greatly, with almost no producers following the requirements of the Indian Standard IS 2185 (Part 1): 2005. In some cases, it was not possible to collect responses on mix ratio as producers were offended being asked about it and were unwilling to share any such information.

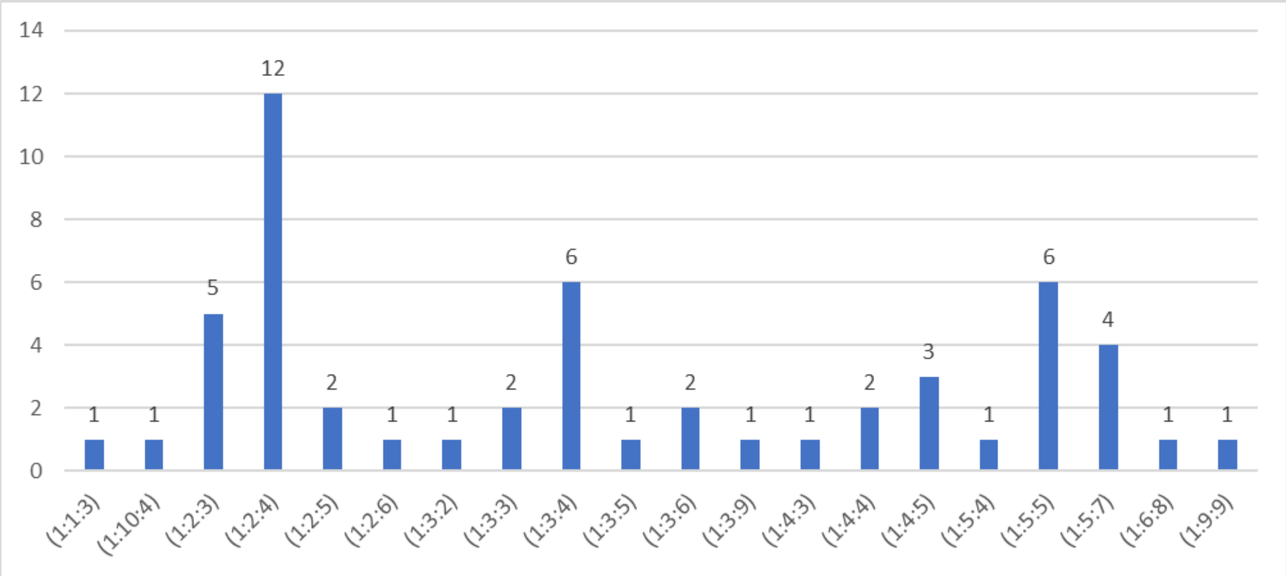

Fig. 5 – Mix ratios distribution as per the HCB producers

2.4 Compressive Strength Testing

As per the Nepal National Standards (NS 119:2042), HCBs are required to meet the following mechanical properties as shown in Table 1.

Table 1 – HCB mechanical properties requirement as per Nepal Standards NS 119:2042

Test	Min. No. Block Samples	Limiting Value	Units
Compressive Strength	8	51	kg/cm^2
Block Density	3	1600	kg/m^3
Drying Shrinkage & Moisture Movement	3	0.04 & 0.03	%
Water Absorption	3	240	kg/m^3

Across both rounds of data and sample collection conducted by HRRP, 110 hollow concrete blocks have been tested at the Central Material Testing Laboratory, Institute of Engineering (IOE), Tribhuvan Unversity to determine their compressive strength. Among the total sample 86 (or 78%) failed to meet the compressive strength requirements specified in the Nepal Standards NS 119:2042. Figure 6 illustrates the range of the compressive strength of the tested blocks.

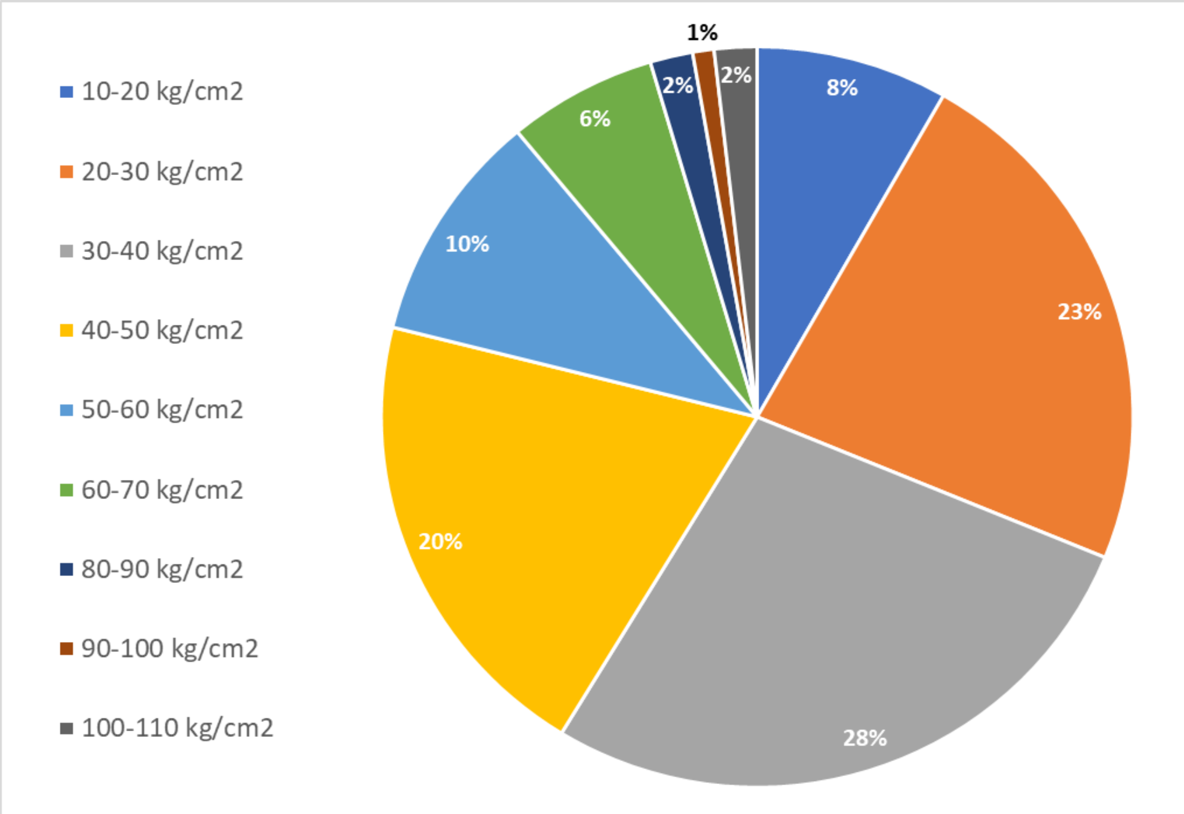

Fig. 6 – Variation of compressive strength of the tested blocks

The 2008 study on ‘Existing Practice and Improvements in Concrete Block Wall Construction’ under the Asian Disaster Preparedness Center (ADPC) [5] found that the average compressive strength of the block samples tested was 35.82 kg/cm^2. The average compressive strength of the block samples tested under the HRRP research was 39.6 kg/cm^2. Both are well below the limiting value of 51 kg/cm^2.

Fig. 7 – Block testing at central material testing laboratory, IoE, Tribhuvan University

3. Use of HCB in reconstruction after Gorkha earthquake

This section presents findings from interviews with 37 households that have built houses using HCBs, across 5 districts based on the data collection in December 2016 and November 2017.

3.1 Choosing HCBs

The most common reasons reported for choosing to construct with HCBs were scarcity of water for construction, cheaper than other materials, quicker to build, good thermal performance, lack of availability of other construction materials such as good stone and bricks, and high transportation cost of bricks to the earthquake affected areas. Also, the households had seen neighbors building with HCBs and wanted to construct their house in the same manner.

These responses are quite similar to the findings from a 2008 study on 'Existing Practice and Improvements in Concrete Block Wall Construction' under the Asian Disaster Preparedness Centre (ADPC) [5] which found that people already felt that if there was a large earthquake that HCB would be a preferred material during the reconstruction.

3.2 Access to information

None of the households interviewed in December 2016 had received information regarding construction with HCBs whereas some of the households interviewed during the data collection in October / November 2017 had received information on HCB construction. 75% (15 HHs) of the interviewed households in Nuwakot, received a HCB training from World Renew and were involved in the construction of the HCB demonstration house. In Kavre, all of the households interviewed had received information on constructing with HCB. However, in Makwanpur, Dolakha, and Dhading none of the surveyed households received any information on HCB but several households obtained HCB information from the community. HRRP field visits in the 18 moderately affected districts conducted during the first quarter of 2018 found that households in areas where construction with HCBs is prevalent were regularly asking the NRA engineers for designs of HCB structures. The engineers have been providing the designs from the DUDBC Design Catalogue Volume 2 [5] but households are not building as per the design.

3.3 Construction Process

The majority of households reported that the masons involved in constructing their houses had previous experience using HCBs. However, this is not necessarily positive as it may represent replication of bad practices rather than good, and most of those masons had not received any training on earthquake resilient construction or construction with HCBs.

Most households reported that they have not been able to proceed through the inspection process associated with the disbursement of the GoN housing reconstruction grant. This is mainly associated with confusion regarding the compliance requirements for HCB houses amongst the NRA engineers as the inspection checklist for HCB houses are not published. Also, most HCB construction has technical issues that requires some technical correction which are provided in the Correction / Exception Manual for Masonry Structure [10] published by NRA to address the non-compliance structures.

HCB house construction in Pokhara

RC frame building with HCB infill in Dolakha

HCB house with steel truss for roof in Nuwakot

HCB construction in Rasuwa

HCB extension to a stone masonry house in Dhading

Steel frame structure with hollow concrete blocks infill walls in Parbat

Fig. 8 – Different types of houses built using HCBs across the earthquake affected districts

4. Conclusions and Recommendations

The use of HCBs has been found to be extensive for the recovery and reconstruction in almost all the 2015 Gorkha Earthquake affected areas. Without the proper production guideline and quality testing, the haphazard production of such blocks is adding risk of unsafe construction practices. Through the study, the average compressive strength of the block samples was found to be 39.6 kg/cm^2, which is very low compared to the limiting value of 51 kg/cm^2. This suggested that the use of such weak construction materials is in opposition to the GoN approach of Build Back Better and may add to more human casualties in future disaster. Thus, the production of such weak HCBs must be monitored and technical documents for such practices must be prepared. Based on these findings, we further recommend regular documentation of production and use of HCBs, development of a manual for HCB construction under the NRA Standardization Committee for Reconstruction of Earthquake Resistant Houses and developing and implementing support packages for HCB producers to improve the production quality.

5. Acknowledgements

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6. Copyrights

7. References

[1] Post Disaster Needs Assessment, National Planning Commission, Government of Nepal, 2015

[2] Grant Disbursement Procedures for Private Houses Destroyed by the Earthquakes 2073, National Reconstruction Authority, Government of Nepal, 2016

[3] Nepal Standard: 119/042, Nepal Bureau of Standards and Metrology, 1985

[4] Post-Disaster Reconnaissance Report - Gorkha EQ Nepal, Build Change, 2015

[5] 'Existing Practice and Improvements in Concrete Block Wall Construction', Asian Disaster Preparedness Center (ADPC), 2008

[6] Design Catalogue for Reconstruction of Earthquake Resistant Houses, Volume 2, Department of Urban Development and Building Construction (DUDBC), Government of Nepal, 2017

[7] Seismic Design Guide for Low-Rise Confined Masonry Buildings, Earthquake Engineering Research Institute (EERI), 2011

[8] Indian Standard IS 2185 (Part 1), Bureau of Indian Standards, 2005

[9] IS 456: 2000, Bureau of Indian Standards, 2005

[10] Correction / Exception Manual for Masonry Structure, National Reconstruction Authority, Government of Nepal, 2017

