Housing Recovery and Reconstruction Platform

Hollow Concrete Blocks: Production and Use in Earthquake Affected Districts

May 2018

About HRRP

The Housing Recovery and Reconstruction Platform (HRRP) was established in December 2015 to take over supporting coordination of the post-earthquake housing reconstruction from the Nepal Shelter Cluster, as it returned to the pre-earthquake format as a standing cluster. The platform provides coordination support services for the National Reconstruction Authority (NRA), Building and Grant Management and Local Infrastructure (GMALI) Central Level Programme Implementation Units (CLPIUs), other relevant government authorities, and Partner Organisations (POs). Phase 3 of the HRRP was approved by the Government of Nepal (GoN) at the beginning of March 2017 and will run until the end of February 2019. HRRP3 is primarily funded by DFID Nepal and CRS Nepal. Other financial contributors and implementing partners include Oxfam, Caritas Nepal, Plan International, National Society for Earthquake Technology-Nepal (NSET), and Habitat for Humanity.

The HRRP has 12 District Coordination Teams (DCTs) primarily focused on the 14 districts most affected by the 2015 Gorkha earthquake (1 team covers the three districts in the Kathmandu Valley) and providing support to the 18 moderately affected districts where feasible. The DCTs are made up of a Coordinator, a Technical Coordinator, and an Information Management Officer. The DCTs are supported by a District Management Team (DMT) made up of a Coordinator, Technical Coordinator, and Information Manager. The DMT provides day to day guidance and support to the DCTs as well as targeted capacity building and has a roving presence across all districts. The national team includes general coordination, technical coordination, and information management expertise and supports the link between national and district level.

Areas of Focus

The HRRP has four main areas of focus:

- Monitoring and documenting the housing reconstruction process
- Improving coverage and quality of socio-technical assistance
- Addressing gaps and duplications
- Advocacy and Communications

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1.0 Executive Summary

This report presents the findings of two rounds of HRRP data collection on the production and use of Hollow Concrete Blocks (HCBs) across the districts affected by the 25 April 2015 Gorkha earthquake. The Nepal Standard: 119/2042 provides the minimum requirements for HCBs in construction in Nepal. HCBs are pre-cast cement concrete blocks with one or more large holes and consist of Portland cement, water, sand and aggregates. HCBs have many properties which make them a popular construction material for housing in earthquake zones, including that they have a high compressive strength if prepared properly, and their light weight, due to the cavity, decreases the dead load. The cavity also enhances the thermal insulation and other advantages are the fast construction, the durability and the low maintenance of HCBs.

Very soon after the earthquake it became clear that HCBs were becoming an increasingly prevalent material for housing construction and that HCB production was scaling up to meet demand. Interestingly, a 2008 study on 'Existing Practice and Improvements in Concrete Block Wall Construction' under the Asian Disaster Preparedness Center (ADPC)[1] found that people already felt that if there was a large earthquake that HCB would be a preferred material during the reconstruction. 48% of respondents felt this was because construction is faster with HCBs than with other materials, 30% felt that it would be because HCBs would be easily available, 14% felt HCBs would be preferred because they can be made 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.

The Department of Urban Development and Building Construction (DUDBC) Design Catalogue for Reconstruction of Earthquake Resistant House Volume 2, published in March 2017, includes approved designs for two-storey HCB confined masonry and masonry building. However, households are generally not following these designs and GoN engineers are unable to provide other alternatives or information. 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[2], prepared by the Earthquake Engineering Research Institute (EERI)[3], 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".

The objective of the two rounds of HRRP data collection was to analyse the production and use of Hollow Concrete Blocks (HCBs) across the earthquake affected districts. 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[4].

The main findings from the data collection and block testing are as follows:

- The daily production capacity varies greatly amongst producers. The overall daily average across all districts is 600 HCBs; an average of 655 HCBs for the first round of data collection and 580 HCBs for the second round of data collection.
- The average across all districts from the first round of data collection was 57 NPRs per block and for the second round of data collection was 58 NPRs per block. It is interesting to note that quality seems to have limited impact on cost. The ten weakest blocks (with compressive strength ranging from 12.74 kg/cm2 to 20.4 kg/cm2) have an average cost of 56 NPRs per block.

[1] *'Existing Practice and Improvements in Concrete Block Wall Construction', ADPC*

[2] *Seismic Design Guide for Low-Rise Confined Masonry Buildings, EERI*

[3] *https://www.eeri.org/*

[4] *HCBs are being used for reconstruction in more than 5 districts but HRRP District Coordination Teams were unable to conduct interviews in other districts.*

- The average curing time across all producers is just 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 worrying that there seems to be a trend in curing times reducing from the first round of data collection to the second. This can be seen in Kavre, Makwanpur, Nuwakot, and Sindhupalchok and only Dhading saw a small increase in the average curing time. Most HCB producers cure the HCBs for only seven days, but there are also HCB producers curing blocks for as little as three days.
- The mix ratios used by producers varies greatly, with almost no producers following the requirements of the Indian Standard IS 2182 (Part 1) – 1979. In some cases, it was not possible to collect responses on mix ratio as producers were very unhappy about being asked this information and were unwilling to share.
- Across both rounds of data collection conducted by HRRP 110 hollow concrete blocks have been tested in the Central Material Testing Laboratory, Institute of Engineering, Pulchowk to determine their breaking (or compressive) strength. Of these, 86 (or 78%) failed to meet the compressive strength requirements specified in the Nepal Standards NS 119/2042.
- Households using HCBs have limited access to information on building with HCBs but there was an improvement on this between the first and second rounds of data collection.
- Some of the reasons for choosing to build with HCBs include that it is possible to build quickly, HCBs are easier to store, less water is required to build with HCBs, and that neighbours had built with HCBs and people wanted to build the same style of house.
- Most households reported that the masons that worked on their houses had experience working with HCBs

Based on these findings the report concludes by suggesting a set of next steps which include continuing documentation of production and use of HCBs, developing a manual for HCB construction under the NRA Standardisation Committee for Reconstruction of Earthquake Resistant Houses, and developing and implementing support packages for HCB producers to improve quality of blocks.

2.0 Background

It became clear very early on in the post-earthquake housing recovery that Hollow Concrete Blocks (HCBs) were becoming an increasingly prevalent material for housing construction, and that existing HCB producers were expanding and new HCB producers were being established to meet 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.

HCBs have 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. Additional advantages are the fast construction, the durability and the low maintenance of HCBs. Therefore, HCBs can be a popular construction material for housing in earthquake zones.

A Build Change 'Post-Disaster Reconnaissance Report' presenting survey work conducted from 5-19 May, includes interesting information on concrete blocks from immediately after the 25 April 2015 Gorkha Earthquake. The report indicates that particularly in semi-urban areas a higher use of HCBs was seen, with HCBs used as infill in RC frames, and includes an interesting story from Bahunepti where "a home close to the block maker's facility in Bahunepati was recently built, using the "better" blocks. The house was said to have suffered no damage in either the main April 25th earthquake or the large May 12th aftershock. Although the block walls of the house had been plastered over, no cracking was visible in the exterior walls"[5].

A 2008 study on 'Existing Practice and Improvements in Concrete Block Wall Construction' under the Asian Disaster Preparedness Center (ADPC)[6] found that 27% of respondents were using HCBs for structural walls, 30% for infill walls, 38% for compound walls, and 5% for other uses. The report also shows that people already felt that if there was a large earthquake that HCB would be a preferred material during the reconstruction. 48% of respondents felt this was because construction is faster with HCBs than with other materials, 30% felt that it would be because HCBs would be easily available, 14% felt HCBs would be preferred because they can be made 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. The report suggests that this expected move to HCBs after a large earthquake would be similar to experience on housing reconstruction in Pakistan after the October 2005 earthquake or in Indonesia after the 2004 tsunami. The report also found that 84% of block producers had not received any formal training on block production and the average compressive strength of the block samples tested was 35.82 kg/cm2, well below the limiting value of 51 kg/cm2 as per Nepal Standard: 119/2042.

Given the advantages of HCBs, and the fact that they are used widely pre- and post-earthquake in Nepal, they seem an ideal construction material to promote for the housing reconstruction and the Department of Urban Development and Building Construction (DUDBC) Design Catalogue for Reconstruction of Earthquake Resistant House Volume 2 includes approved designs for two-storey HCB confined masonry and masonry building. However, 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)[8], 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

[5] *Build Change Post-Disaster Reconnaissance Report - Gorkha EQ Nepal, May 2015*

[6] *'Existing Practice and Improvements in Concrete Block Wall Construction', ADPC*

[7] *Seismic Design Guide for Low-Rise Confined Masonry Buildings, EERI*

[8] *https://www.eeri.org/*

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 the 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 collection took place in November and December 2016 and data was collected from Dhading, Dolakha, Gorkha, Kavre, Makwanpur, Nuwakot, Rasuwa, and Sindhupalchok[9]. The data collection was not conducted in the three districts in the Kathmandu Valley or any of the 18 moderately affected districts due to HRRP funding gaps at this time meaning those areas were not covered. The second round of data collection was conducted in October and November 2017 and data was collected from Bhaktapur, Dhading, Dolakha, Gorkha, Kaski, Kathmandu, Kavre, Lalitpur, Makwanpur, Nuwakot, Rasuwa, and Sindhupalchok. As there are no HCB producers in Sindhuli, Ramechhap, and Okhaldhunga data 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 (CMTL IOE).

This report presents the findings of the HRRP research and concludes with a set of suggested 'next steps' which may serve to improve the quality of HCBs and construction practices using HCBs both for the housing reconstruction and for longer term resilience in the housing sector.

[9] *HRRP presentation of findings from first round data collection, 14 December 2016*

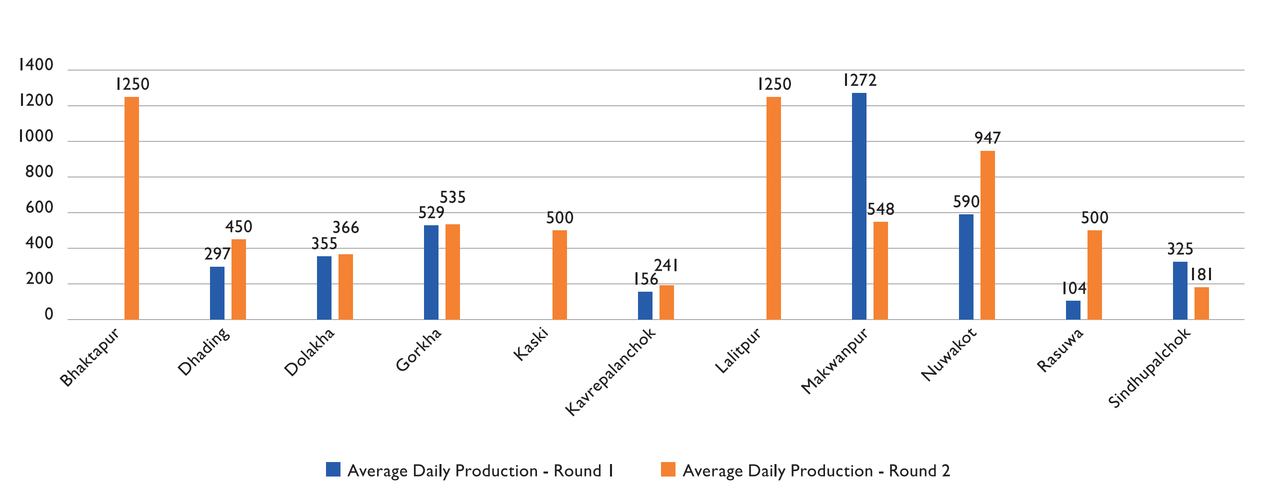
3.0 HCB Production

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 questionnaire used to guide the interviews is provided in Annex 1. The compressive strength testing section presents the results of testing of 110 block samples collected from the block producers.

3.1 Production Capacity

The daily production capacity varies greatly amongst producers. The overall daily average across all districts is 600 HCBs; an average of 655 HCBs for the first round of data collection and 580 HCBs for the second round of data collection. One producer from Dhading, in the second round of data collection, has been excluded as their daily production capacity is significantly higher compared to the other producers at 220,000 pieces per day.

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. A comparison of average daily production rates across districts and the two rounds of data collection can be seen in the graph and table below.



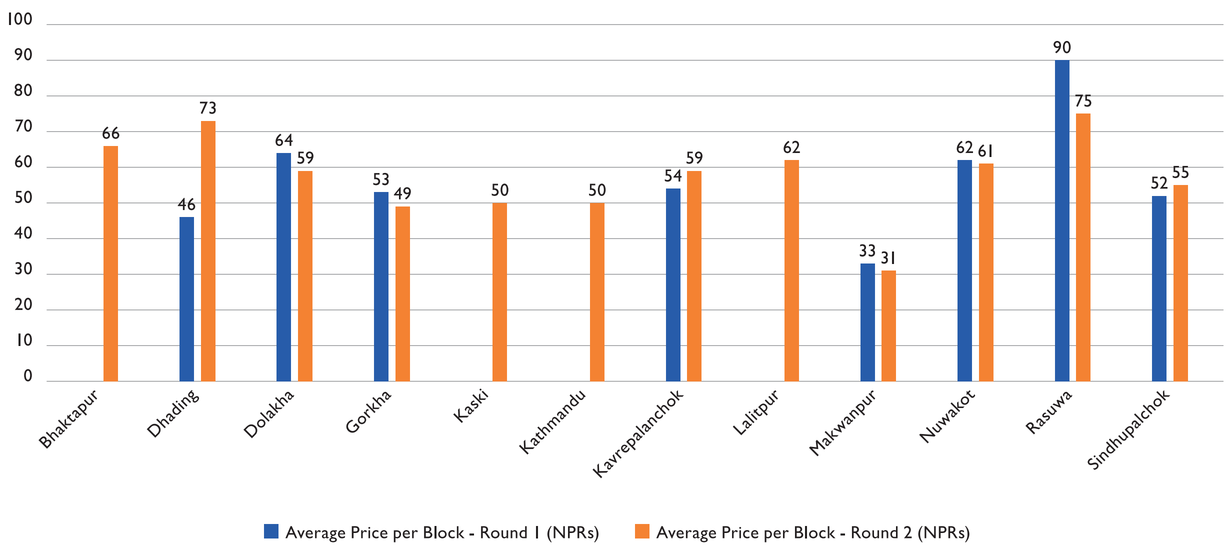
It is important to note that the information on producers in Kaski does not cover the full extent of HCB production in the district and is from just 2 producers. There are more than 25 producers in the district, including many of the biggest and oldest producers in that region. Blocks from Kaski are sent to Tanahun, Lamjung, Gorkha, and Parbat. Construction with HCBs has been seen to very prevalent in many of the 18 moderately affected districts. For example, in Lekhnath Municipality, Pokhara, Kaski more than 600 houses have been constructed using hollow concrete blocks. More information on this can be found in Section 4.0 'HCB Use' below.

Lekhnath Municipality, Pokhara, Kaski: hollow concrete block production at 'Pokhara Block Udhog'. They produce 30 blocks from one bag of cement, and blocks cost between 40 and 60 NPRs per piece depending on the quality. They produce a maximum of 400 blocks per day.

3.2 Price per Block

The price per block varies across producers and districts.

The graph below presents the average price per block by district and round of data collection:



The average across all districts from the first round of data collection was 57 NPRs per block and for the second round of data collection was 58 NPRs per block. It is interesting to note that quality seems to have limited impact on cost. The ten weakest blocks (with compressive strength ranging from 12.74 kg/cm2 to 20.4 kg/cm2) have an average cost of 56 NPRs per block.

The cost of blocks is highest in Dhading and Rasuwa, where 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 well below the overall average.

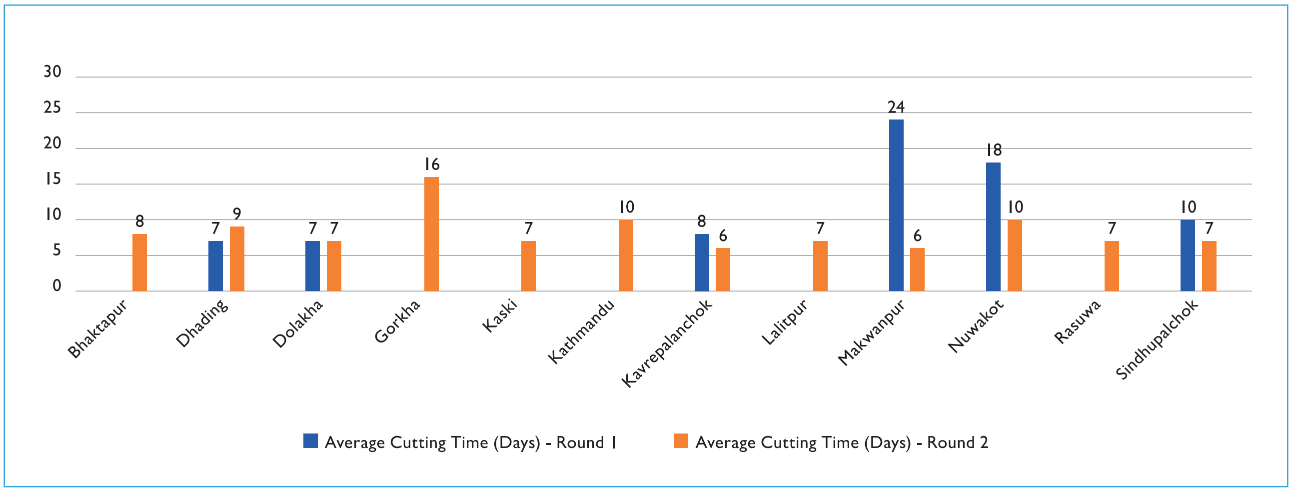
The full dataset, available here, provides a breakdown of price per block by size but not all producers reported the prices by size so this has not been considered in the analysis provided above.

Variety of quality and shape of blocks available.

3.3 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 2182 (Part 1) – 1979 (Reaffirmed 2003). As per the Indian Standard IS 2182 (Part 1) – 1979 HCBs should be cured for at least 14 days to permit a complete moisturisation.

The average curing time across all producers is just 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 worrying that there seems to be a trend in curing times reducing from the first round of data collection to the second. This can be seen in Kavre, Makwanpur, Nuwakot, and Sindhupalchok and only Dhading saw a small increase in the average curing time. Most HCB producers cure the HCBs for only seven days, but there are also HCB producers curing blocks for as little as three days. A small percentage of HCB producers cure the blocks for between 20 and 30 days. Several HCB producers indicated that they are aware that seven days is not sufficient curing time but they sell at this point due to high demand. It is possible that the reduction in curing times between round 1 and round 2 data collection could be linked to ever increasing demand. This is a worrying trend as it may indicate that the quality of HCBs is decreasing further due to demand.



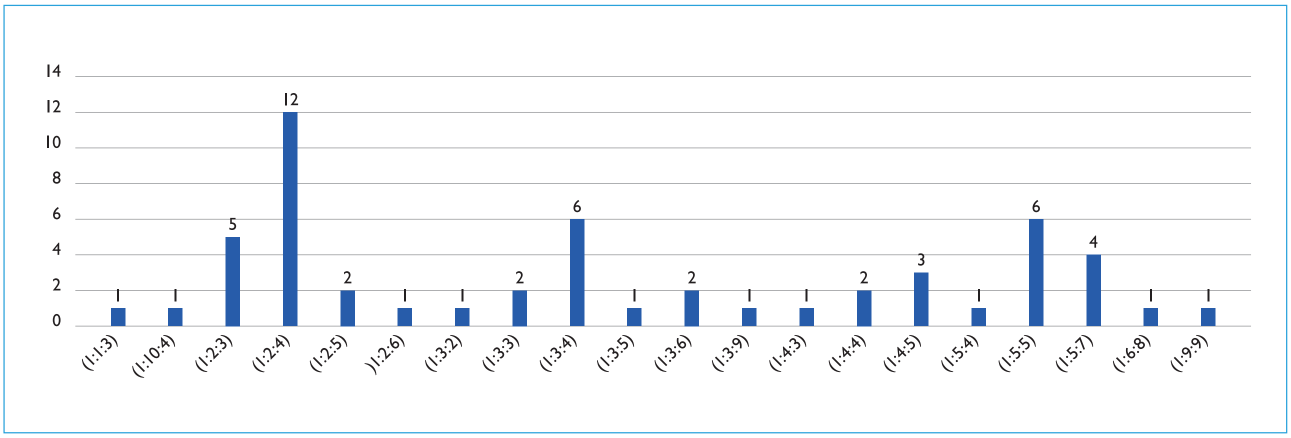
The majority of producers use a 'sprinkle' method for curing which involves either pouring or hosing water over the HCBs between two to four times per day, with other producers using a 'ponding' method where HCBs are submerged in water.

Blocks are laid in the sun after production in Dolakha (L) and blocks submerged in a pond in Dolakha (R).

3.4 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 2182 (Part 1) – 1979 (Reaffirmed 2003). As per the Indian Standard IS 2182 (Part 1) – 1979 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 2182 (Part 1) – 1979. In some cases it was not possible to collect responses on mix ratio as producers were very unhappy about being asked this information and were unwilling to share. The graph below shows the mix ratios that have been used by producers, it is noteworthy to mention that the mix ratios are as reported by producers and HRRP did not verify whether the reported ratios are accurate.



The grading of the aggregates, and the water to concrete ratio has not been assessed as part of this report. It is recommended to analyse this in a separate study. It would be particularly interesting for HCBs that failed the compressive strength testing to further understand the underlying issues in the production of HCBs. The required aggregate grading ratio as per the Nepal Standard NS: 119/042 are as follows:

Sieve Size	Recommended Range
12.5 - 10mm	10 - 15%
10 - 4.75mm	20 – 25%
4.75 – 0.3mm	50 – 55%
0.3 – 0.075mm	5 – 10%

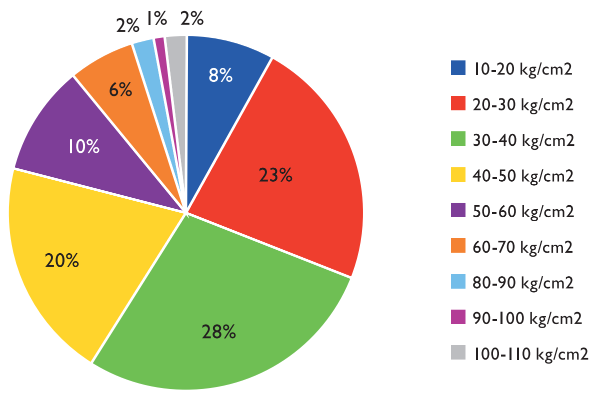
Aggregate mixing, Makwanpur

3.5 Compressive Strength Testing

As per the Nepal National Standards for HCBs (NS 119:2042), HCBs are required to meet the following mechanical properties:

Test	Min. No. Block Samples	Limiting Value	Units
Compressive Strength	8	51	kg/cm2
Block Density	3	1600	kg/m3
Drying Shrinkage & Moisture Movement	3	0.04 & 0.03	%
Water Absorption	3	240	kg/m3

Across both rounds of data collection conducted by HRRP 110 hollow concrete blocks have been tested in the Central Material Testing Laboratory, Institute of Engineering, Pulchowk to determine their breaking (or compressive) strength. Of these, 86 (or 78%) failed to meet the compressive strength requirements specified in the Nepal Standards NS 119:2042. The pie chart below illustrates the range in 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)[10] found that the average compressive strength of the block samples tested was 35.82 kg/cm2. The average compressive strength of the block samples tested under the HRRP research was 39.6 kg/cm2. Both are well below the limiting value of 51 kg/cm2.

The full set of test results can be accessed on the HRRP Google Drive. This public dataset has been anonymised, but each of the producers involved in the research has received their test results individually.

Block testing in the central material testing laboratory, IoE.

[10] *'Existing Practice and Improvements in Concrete Block Wall Construction', ADPC*

4.0 HCB Use

This section presents findings from interviews with 37 households that have built with HCBs, across 5 districts[11] and over two rounds of data collection with the first in December 2016 and the second in November 2017. The questionnaire used to guide the interviews is available in Annex 2.

4.1 Choosing HCBs

The most common reasons reported for choosing to construct with HCBs were as follows:

- There is a scarcity of water for construction so HCBs chosen because they require less water to build with
- HCBs are cheaper than other materials
- HCBs are quicker to build with than other materials
- Households had seen neighbours building with HCBs and wanted to construct their house in the same manner
- Good stone is not available
- Stone is hard to store
- Bricks are expensive to transport to the area
- HCBs protect well from cold weather, e.g. HCB have a good thermal performance

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)[12] which found that people already felt that if there was a large earthquake that HCB would be a preferred material during the reconstruction. 48% of respondents felt this was because construction is faster with HCBs than with other materials, 30% felt that it would be because HCBs would be easily available, 14% felt HCBs would be preferred because they can be made 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.

4.2 Access to Information

None of the households interviewed in December 2016 had received information regarding construction with HCBs but some of the households interviewed during the data collection in October/November 2017 had received information on HCB construction. 15 households in Nuwakot, representing 75% of the interviewed households in Nuwakot, received a HCB training from World Renew and/or were involved in the construction of the demonstration HCB house. In Kavre, all of the households interviewed (3) 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[13] conducted during the first quarter of 2018 found that households in areas where construction with HCBs is prevalent were regularly asking the GoN engineers for designs for HCB houses. The engineers have been providing the designs from the DUDBC Design Catalogue Volume 2 but households are not building according to these designs.

4.3 Construction Process

The majority of households reported that the masons that worked on constructing their home had previous experience working with HCBs. However, this is not necessarily a positive as it may represent replication of bad practices rather than good, and many of the masons that had experience working with HCBs had not completed any training on earthquake resilient construction or construction with HCBs.

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[11] HCBs are being used for reconstruction in more than 5 districts but HRRP District Coordination Teams were unable to conduct interviews in other districts.

[12] 'Existing Practice and Improvements in Concrete Block Wall Construction', ADPC

[13] Documentation from HRRP field visits to 18 moderately affected districts

Most households reported that they have not been able to proceed through the inspection process associated with the disbursement of the Government of Nepal (GoN) housing reconstruction grant. This is mainly to do with confusion about compliance requirements for HCB houses amongst the inspection engineers as the inspection checklist for HCB houses has yet to be finalised. Also, most HCB construction has technical issues that require some form of correction but some work is required to adapt options for corrections from the GoN Corrections and Exceptions Manual so that they are appropriate for HCB structures.

Photos of some examples of the types of houses built with HCBs across the districts are provided below.

Lekhnath Municipality, Pokhara, Kaski: one of more than 600 houses that have been constructed using hollow concrete blocks in this area. Households in the area regularly ask the GoN engineers for designs for HCB houses. The engineers have been providing the designs from the DUDBC Design Catalogue Volume 2, but households are not building according to these designs.

Modi Rural Municipality, Ward No. 6, Parbat (one of the 18 moderately affected districts): Purna Bahadur BK started construction of his 5 room house, with steel frame structure and hollow concrete blocks for the infill walls, just 1 month after the 2015 earthquake. He is still going through the grievance mechanism and he didn't know that this house would not be in line with government standards as there no guidance available previously and the inspection engineers have just been deployed.

Hybrid construction in Dolakha with HCB construction on ground floor and timber and CGI first floor.

RC frame building with HCB infill in Dolakha.

HCB house with steel truss for roof in Nuwakot.

HCB extension to a stone masonry house in Dhading.

HCB Construction Rasuwa.

5.0 Next Steps

Based on the findings of the two rounds of research on Hollow Concrete Blocks conducted by HRRP, as well as the wider reconstruction context, the next steps are proposed as follows:

- Continue documentation and testing of block production in districts
- Develop and implement packages of support for block producers to improve HCB quality
- Continue to document use of blocks, identifying common issues / non-compliances
- Development of manual on HCB construction under NRA technical committee
- Adapt / add options for corrections to the GoN Corrections and Exceptions Manual so that HCB structures are incorporated
- Include information / support on construction with HCBs in TA packages
- Support to GoN engineers, TA field staff, and local officials on HCBs
- Engage HCB producers and vendors as agents of TA
- Development of formal licensing system for HCB producers
- Endorse inspection checklist and develop minimum requirements for HCB construction
- Identify and/or establish testing centres in Rural and Urban Municipalities (Practical Action, with DFID support, have supporting DUDBC in Nuwakot to establish a material testing centre in Nuwakot which just opened and could provide useful lessons in how to approach this)

6.0 Annexes

Annex 1: Producers Questionnaire

Where there are six or less HCB producers in a district, then blocks need to be collected from all HCB producers. If there are more than six HCB producers in a district then blocks should be collected from the six biggest HCB producers. A minimum of two HCBs should be collected from each producer and the following details should be collected:

- How many block producers are there in your district?
- Date of casting – blocks collected should be between 21 and 28 days old
- Proportion of mix
- Curing time and method
- Brand of cement used
- Cost per block
- What is their production capacity? (per day or week or month)
- Type of mold used
- Contact details for producer

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