Types and Sizes of Structures in Post Gorkha Earthquake Rural Housing Reconstruction

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Abstract

Gorkha earthquake damaged large proportion of low strength masonry structures which created need of large scale housing reconstruction. The owner driven approach of housing reconstruction adopted by Government of Nepal made home owners responsible for selection of structure type, size and construction of the house with technical and financial support from the government. Documentation of the structure typologies built after an earthquake is one of the important factor to understand the reconstruction process. This paper delineates the types and sizes of structures built after the earthquake with respect to family size and caste/ethnicity through descriptive and comparative analysis of data. Stone Masonry with Mud mortar (SMM) and Brick Masonry with Cement mortar (BMC) share the highest percentage of houses reconstructed, 45.2 % and 34 % respectively. Less than 4% of reconstructed houses were 2 storied or above whereas 78.77% houses are one storied and 17.8% houses are one story and attic high. The mean plinth area of reconstructed houses was found to be 361.1 sq. ft. which was significantly impacted by caste/ethnicity of people and structure type built. It was found that people were interested to use local construction material for reconstruction and built SMM and BMC structures which were modification to existing typologies with introduction of seismic bands and restriction to size and height. New structure type like hybrid, light frame steel and timber were constructed in rural areas.

Key words: Structure type, Plinth area, Housing reconstruction, Minimum requirement

1. Introduction

Mud bonded brick or stone masonry buildings are the common characteristics for housing structure in rural areas with stone masonry preferred in hilly region of Nepal (CBS, 2014b; DUDBC, 2011). The houses in rural hilly areas have a rectangular plan and are situated on sunny slope of hills with longer façade facing towards south (Bodach et al., 2014). The stone masonry structures in rural Nepal are generally 1-3 storied with shallow foundations (Varum et al., 2018). Most of the houses are constructed with weak materials and even when they were constructed using good materials like cement mortar, fired brick, reinforced concrete, their construction quality was poor making these houses perform poorly during the earthquake (Bothara et al., 2016). The 7.6 magnitude earthquake, with the epicenter about 80 km north-west of Kathmandu in Barpak, Gorkha hit Nepal on 25 April 2015 which was later named as Gorkha Earthquake (NPC, 2015; NSC, 2015). Out of the 498,852 fully damaged houses, 474,025 houses were low strength masonry, 18,214 were cement mortared masonry and only 6,613 were reinforced concrete houses (NPC, 2015) which was due to the poor seismic performance causing fatalities (Goda et al., 2015). This created a need for reconstruction of these houses with seismic standards to provide shelter for affected people.

Housing and human settlement sector was the severely affected by the earthquake with highest recovery needs (NPC, 2015; NRA, 2016). Government of Nepal adopted owner driven reconstruction approach for housing reconstruction after the Gorkha Earthquake, 2015 making home owners responsible for selection of and construction of size and type of structure to be built (NPC, 2015). A disaster can be an opportunity to build better than the past condition (Ophiyandri et al., 2010) and housing reconstruction efforts can help to minimize the possible future disaster effects by making the community more sustainable and resilient (Labadie, 2008). Considering this reality, to ensure Build Back Better in housing reconstruction the Government of Nepal supported home owners through multiple tranches of grant assistance receivable only after technical verification (NRA, 2015)

National Reconstruction Authority (NRA) deployed engineers to earthquake affected areas and created technical standards, design catalogues, inspection guidelines and other manuals to guide the housing reconstruction process. NRA deployed over 1,300 engineers and as many sub-engineers and assistant engineers to the eleven worse affected districts to facilitate distribution of housing grant and provide technical assistance to beneficiaries on the first anniversary of the Gorkha Earthquake (Post, 2016). NRA introduced prototype designs through the design catalogue based on the National Building Code (NBC) with the aim to support beneficiaries to start the reconstruction of their homes by providing flexible house designs which can be adopted and adapted in all earthquake affected areas (DUDBC, 2015). The design catalogues displayed seismic resistant design and construction methods by using many images to facilitate easy understanding of house owners. The prototype introduced in volume I of design catalogue were modification to existing typologies with seismic bands and restriction to size and height which were Stone Masonry with Mud Mortar (SMM), Brick Masonry with Mud Mortar (BMM), Stone Masonry with Cement Mortar (SMC), Brick Masonry with Cement Mortar (BMC) (DUDBC, 2015). NRA discouraged prefabricated buildings as one of the policy framework for reconstruction is promotion of use of local material and skills to restore traditional architecture (NRA, 2016). NRA also introduced Minimum Requirements (MR) to check and ensure the standard for seismic resistant building design based on NBC. MR published in booklets could be easily understood by non-technical persons and consisted of ten sections, namely, site selection, shape/size of building, materials, foundation, vertical member, plinth, walls, doors/windows, horizontal band and roof, including planning, preparation and construction (DUDBC, 2015).

Promotion of multiple technologies was found to be successful compared single one as one of the technology was continued even after the post disaster construction helping livelihood of trained masons and minimizing possibility of home owners using other unsafe technologies (Vahanvati & Mulligan, 2017). The volume II of design catalogue recognized twelve other technologies which were developed to pave way for use of alternate materials and technologies in the housing reconstruction process (DUDBC, 2017). The technical inspection guidelines consisting of check-sheets were developed as a practical tool for engineers to check whether each section meets the MR or not (NRA, 2017c). Although MR restricted the SMM and BMM houses to one story and attic, people added a floor using light materials to fulfill their functional requirements. This triggered NRA to develop Hybrid Structure Manual to provide construction guideline to emerging new construction typologies (NRA, 2017b). NRA also developed manuals and catalogue displaying measures to correct the houses which were noncompliant with respect to MR (NRA, 2017a, 2019).

Documentation of the structure typologies built after an earthquake is one of the important factor to understand the reconstruction process. This paper aims to delineate the types and sizes of structures built after the earthquake under the government's housing reconstruction program with respect to family size and caste/ethnicity.

2. Methodology:

The study has been conducted in two of the most earthquake affected districts, Gorkha and Sindhupalchok of Nepal (NPC, 2015). Both Gorkha and Sindhupalchok districts fall in same physiographic regions- Hill, Middle Mountain and High Mountain (LRMP Nepal, 1986; Mainali & Pricope, 2017) with all beneficiaries studied for this research located in Hill and Middle Mountain region. Due to similarity in physiographic locations, similar traditional building material like stones, soil and timber are available in the study areas (Bodach et al., 2014) which should be reflected in structure type. Data from Emergency Housing Reconstruction Project (EHRP) database is used for this research. This data is collected through interview of household heads and maintained in database through efforts of its staffs. As of March 2020, this database covers 95,117 beneficiaries in a total of 109 wards (91 in Sindhupalchok and 18 in Gorkha). The information of structure type, no of story and plinth area of houses in respect to aspects like caste/ethnicity and family size has been studied for this research. However, the information of all these variables are not complete for the whole 95,117 beneficiaries so the analysis was conducted using the available information only.

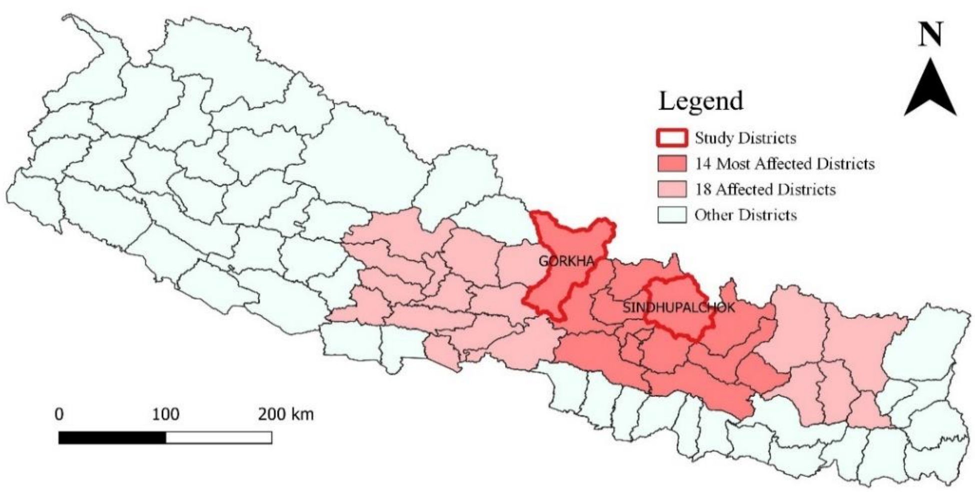

Figure1 Study area and other affected districts in Map of Nepal (NPC, 2015; Survey Department, 2020.)

Analysis of categorical variables with categorical variables was conducted using Pearson's Chi-square test of independence (McHugh, 2013) which was followed by a post hoc analysis using an adjusted α value as described by Bonferroni (Beasley & Schumacker, 1995) for significant results. In the same way a Games Howell post hoc analysis has been used to compare the multiple levels of categorical variables and numeric variables like areas for ANOVA tests which revealed significant results.

This study includes nine categorizes of structure types which consists of eight commonly built types namely SMM, BMM, SMC, BMC, Reinforced Cement Concrete (RCC), Hybrid, Light frame steel structure and Light frame timber structure out of the types recognized by NRA. All other structures except the above eight types were categorized as "Others" which included structures like hollow block, compressed stabilized earth block, confined masonry, etc. (DUDBC, 2015, 2017; NRA, 2017c, 2017b, 2018).

The categorization of caste/ethnicity was done in five groups (CBS, 2014a) namely Brahmin-Chhetri, Dalit, Janajati, Newar-Thakali and Others. Brahmin-Chhetri and Newar-Thakali are included as facilitated groups. The caste/ethnic groups which doesn't belong to above mentioned categories or who did not want to mention their caste/ethnicity were kept in Others category. The family size has been classified into five categories namely, nuclear family with up to two members, small family with 3-4 members, extended small family with 5-6 members, large family with 7-8 members and extended large family having more than 8 members for the study (CBS & UNDP, 2016). The family size doesn't include family members who are living outside the house.

Plinth area and number of story data were taken to study size of the house. Total carpet area wasn't studied as most of the houses (over 96%) were less than two story. There were different technical standards to build one story house compared to one story with attic (DUDBC, 2015). Attic is counted as separate story while studying the number of story for better results.

3. Results:

3.1. Types of Structure

Most of the household constructed SMM structure followed by BMC with 45.2% and 34% household adopting these structures respectively (Figure 2). RCC structure was constructed by 13.9% households. BMM structures was the least preferred type.

a. Structure type and caste/ethnicity

A Pearson's chi-square test of independence was conducted showing that the independent variable Caste/Ethnicity caused a significant change, $\chi 2$ (32, n = 89784) = 2329.75, $p < .001$, on the dependent variable Structural Typology with a small (Cramer's $V = .08$) effect size. The condition for expected count less than 5 was violated for only 4 cells (8.9%), hence the results of Pearson's chi-square test were referred. A Post Hoc analysis using a Bonferroni adjusted alpha level of .0011 (.05/45) revealed that Others (44.8%) group built significantly higher number of BMC structures than Brahmin-Chhetri (38.0%), Dalit (36.7%) and Janajati (29.6%) groups (Table 1). However, the group Newar-Thakali (34.2%) was found to be independent from choice of BMC structures. In case of RCC structures, Newar-Thakali (23.6%) had significantly highest number and Dalit (7.5%) had significantly lowest number than all other Caste/Ethnicity. However, in case of SMM structures, Janajati (49.7%) and Dalit (47.8%) had the two highest proportions while Newar-Thakali (34.6%) and Others (33.4%) group had the lowest proportions.

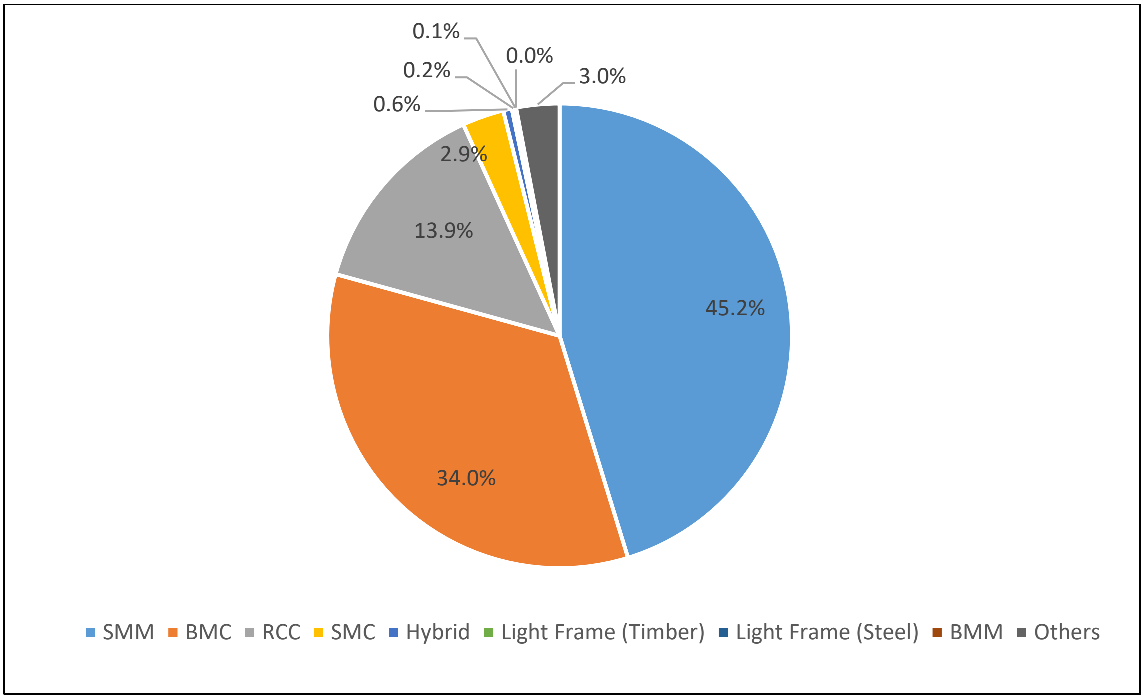

Figure 2 Type of Structure

Table 1 Structure type and caste/ethnicity

Structure*Caste/Ethnicity	Brahmin-Chhetri	Dalit	Janajati	Newar-Thakali	Others	Total
	N, R%	N, R%	N, R%	N, R%	N, R%	N, R%
BMC	10448, 37.95%*	2842, 36.67%*	12287, 29.56%*	3268, 34.23%	1525, 44.82%*	30370, 33.82%
BMM	1, 0.00%	3, 0.03%	13,0.03%	2, 0.02%	1, 0.02%	20, 0.02%
Hybrid	280, 1.01%*	24, 0.31%	157, 0.37%*	42, 0.44%	5, 0.14%*	508, 0.56%
Light Frame (Steel)	29, 0.1%	6, 0.07%	40, 0.09%	19, 0.2%	4, 0.11%	98, 0.1%
Light Frame (Timber)	48, 0.17%	27, 0.35%	115, 0.27%*	6, 0.06%*	1, 0.02%	197, 0.22%
Others	642, 2.33%*	314, 4.05%*	1354, 3.25%*	304, 3.18%	115, 3.38%	2729, 3.04%
RCC	3639, 13.22%*	582, 7.51%*	5645, 13.58%*	2253, 23.60%*	583, 17.13%*	12702, 14.14%
SMC	714, 2.59%*	247, 3.18%	1277, 3.07%	346, 3.62%*	32, 0.94%*	2616, 2.91%
SMM	11726, 42.59%*	3704, 47.8%*	20673, 49.74%*	3305, 34.62%*	1136, 33.39%*	40544, 45.15%
Total	27527, 100%	7749, 100%	41561, 100%	9545, 100%	3402, 100%	89784, 100%

**p<.001, At Bonferroni adjusted α=.0011*

b. Structure type and family size

A Likelihood Ratio chi-square test for independence was conducted showing that the independent variable family size did not cause a significant change, $\chi 2$ (32, n = 7419) = 20.26, p = .95, on the dependent variable structural typology. The Likelihood Ratio was adopted instead of Pearson's Chi-Square because 17 cells (37.8%) had expected count less than 5.

3.2.Number of Story

One story and one story with attic houses were constructed by over 96% beneficiaries with 78.77% one story houses and 17.80% one story with attic houses (Figure 3). Houses over two story high were built by less than 1% beneficiaries.

a. Number of story and structure

A Likelihood Ratio chi-square test for independence was conducted showing that the variable Structural Typology did not cause a significant change, $\chi 2$ (56, n = 80352) = 50.64, p = .68, on the variable Number of Story. The Likelihood Ratio was adopted instead of Pearson's Chi-Square because 38 cells (52.8%) had expected count less than 5.

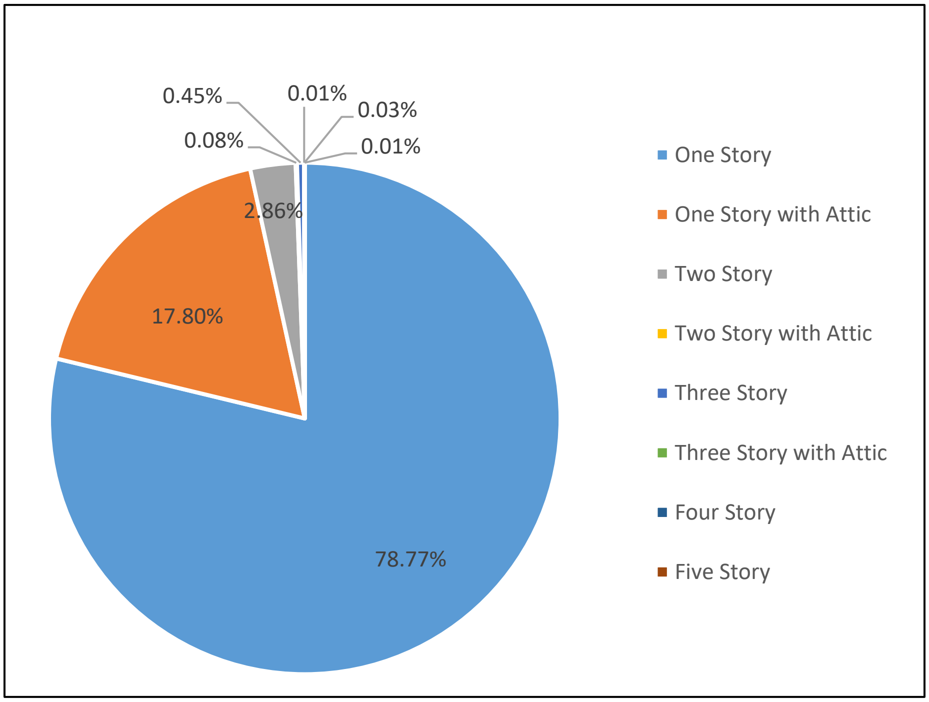

Figure 3 Number of story

b. Number of story and caste/ethnicity

A Likelihood Ratio chi-square test for independence was conducted showing that the independent variable Caste/Ethnicity did not cause a significant change, $\chi 2$ (28, n = 85114) = 27.16, p = .51, on the dependent variable Number of Story. The Likelihood Ratio was adopted instead of Pearson's Chi-Square because 14 cells (35.0%) had expected count less than 5.

c. Number of story and family size

The Likelihood Ratio chi-square test for independence was conducted showing that the independent variable family size caused a significant change, $\chi 2$ (16, n = 7634) = 168.35, *p*< .001, on the dependent variable Number of Story with a small (Cramer's *V*= .07) effect size. A Post Hoc analysis using a Bonferroni adjusted alpha level of .002 (.05/25) revealed that there was a significant association for family size Nuclear, Small and Extended Small with Story/Height of One Story and One Story with Attic. The analysis revealed that a significantly higher (*p*<.001) percentage (87.3%) of Nuclear families built only One Story in comparison to Small (80.0%) and Extended Small (73.8%) while a significantly higher (*p*<.05) percentage (22.7%) of Extended Small built One story with Attic in comparison to Small (16.4%) and Nuclear (9.1%) families. We found that the percent of Small and Extended Small families building Two Story structures was also higher (3.3%) in comparison to Nuclear family (3.2%) but the association was not significant (*p*>0.05) in all cases.

Table 2 Number of Story and Family size

Family size	Story					
	One	One with Attic	Two	Two with Attic	Three	Total
	N, R%	N, R%	N, R%	N, R%	N, R%	N, R%
Nuclear	2812, 87.30%*	294, 9.13%*	104, 3.23%	1, 0.03%	10, 0.31%	3221, 100%
Small	2071, 80.0%**	424, 16.37%**	86, 3.32%	1, 0.04%	8, 0.30%	2590, 100%
Extended Small	1107, 73.85%*	341, 22.75%*	49, 3.26%	0, 0.00%	2, 0.13%	1499, 100%
Large	222, 82.52%	37, 13.75%	9, 3.34%	0, 0.00%	1, 0.37%	269, 100%
Extended Large	47, 85.45%	7, 12.72%	1, 1.81%	0, 0.00%	0, 0.00%	55, 100%
Total	6259, 81.98%	1103, 14.44%	249, 3.26%	2, 0.02%	21, 0.27%	7634, 100%

**p*<.001, ***p*<.002, *At Bonferroni adjusted* α=0.002

3.3.Plinth Area

The mean plinth area of house among 88,366 households was 361.1 sq. ft.

a. Plinth area and structure type

RCC houses had the highest mean plinth area of 569.4 sq. ft. followed by Light Frame (Steel) structure with 428.5 sq. ft. Mean plinth area of BMM houses was the lowest with 289 sq. ft. BMM, SMM and Others structures had lower mean plinth area than total mean plinth area.

A one-way between subjects' ANOVA was conducted to compare the structural typology of the house on mean plinth area to determine if the choice of structure played any role in the square footage area of house. The database used is considered to be normally distributed due to central limit theorem for very large database (N=95711) (Ghasemi & Zahediasl, 2012). The *Levene's* F test revealed that the homogeneity of variance assumption was met (*p*=-.594). The comparison of mean plinth area to structural typology failed to satisfy the homogeneity of variance assumption (*p*<0.001). As such, the *Welch's* F test was used. The ANOVA test revealed a statistically significant effect of structural typology on mean plinth area, at p<.05, [*Welch's* F(8,361.85)=2137.25, *p*<0.001]. The estimated omega squared (w^2 =.27) indicated that approximately 27% of the total variation in mean plinth area is attributable to differences of structural typologies.

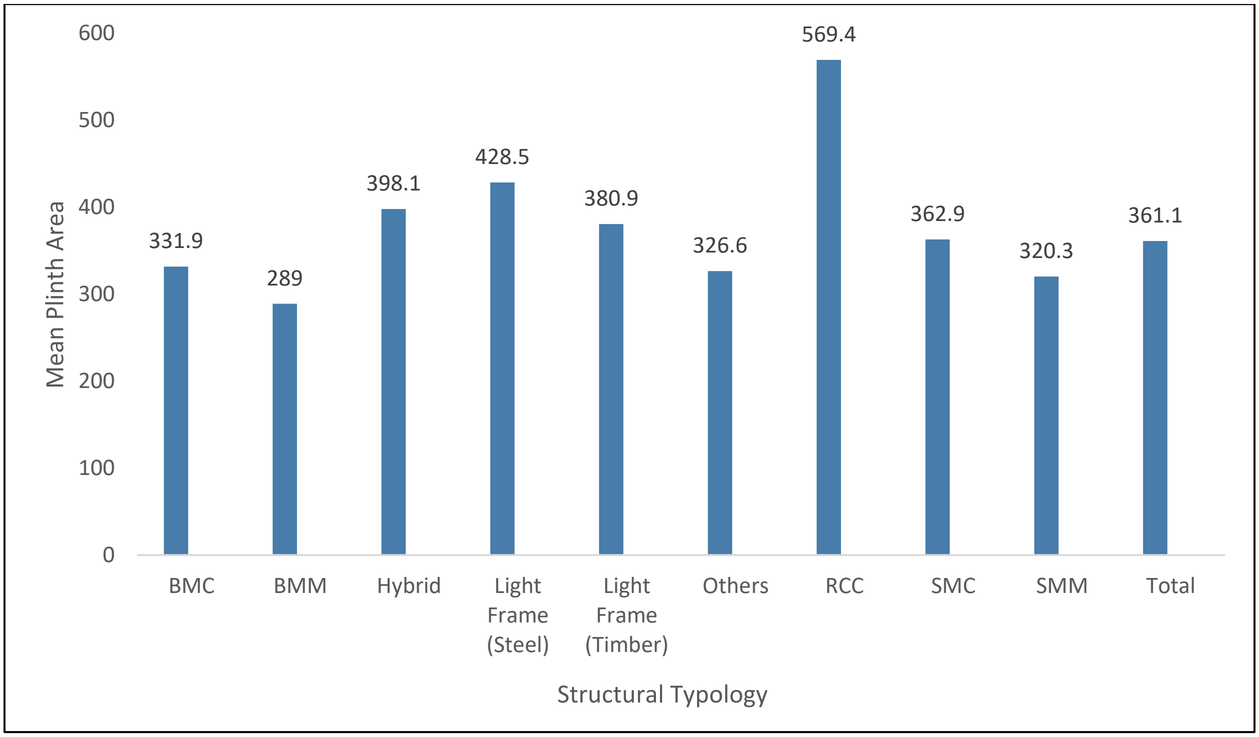

Figure 4 Mean Plinth area w.r.t. structure type

Post hoc comparisons, using the Games-Howell post hoc procedure, were done to determine which pairs of the structural typologies differed significantly. These results are given in Table 4 and indicate that BMC (M=331.89, SD=130.03) structure had significantly higher plinth area than SMM (M=320.26, SD=115.50) with an effect size 0.12 and significantly lower plinth area than Hybrid (M=398.11, SD=132.39), Light Frame Steel (M=428.48, SD=179.02), Light Frame Timber (M=380.92, SD=146.48), RCC (M=569.43, SD=202.51) and SMC (M=362.88, SD=144.50) with effect size 0.71, 1.04, 0.53, 2.56 and 0.33 respectively. Similarly, BMM (M=288.97, SD=131.21), structure had significantly lower plinth area than Hybrid, Light Frame Steel and RCC structures with effect size 1.17, 1.49 and 3 respectively. Again, Light Frame Steel had significantly higher plinth area than Others (M=326.63, SD=120.37), SMC and SMM structures with effect size 0.8, 0.51 and 0.85 respectively but significantly lower mean plinth area than RCC structures with effect size 1.11. Light Frame Timber structures also reported significantly higher mean plinth area than Others and SMM with effect size 0.52 and 0.58 respectively but significantly lower than RCC with effect size 1.81. Others category structures reported significantly lower mean plinth areas than RCC and SMC with effect size 2.83 and 0.42 respectively. While RCC reported significantly higher mean plinth area than SMC and SMM with effect size 1.44 and 1.73 respectively. In fact, RCC had higher mean than all the structural typology and SMM reported significantly lower mean plinth scores than SMC with effect size 0.41.

Table 3 Post hoc scores of plinth area by structural typology

Structure	Mean	Mean Differences (Effect Sizes are indicated in parentheses)								
		1	2	3	4	5	6	7	8	9
1. BMC	331.89									
2. BMM	288.97	42.91								
3. Hybrid	398.11	-66.23* (0.71)	-109.14** (1.17)							
4. Light Frame (Steel)	428.48	-96.59* (1.04)	-139.51** (1.49)	-30.37						
5. Light Frame (Timber)	380.92	-49.03* (0.53)	-91.95	17.19	47.56					
6. Others	326.63	5.26	-37.66	71.48* (0.76)	101.85* (0.80)	54.29* (0.52)				
7. RCC	569.43	-237.54* (2.56)	-280.46* (3.00)	-171.32* (1.81)	-140.95* (1.11)	-188.51* (1.81)	-242.8* (2.83)			
8. SMC	362.88	-31.00* (0.33)	-73.91	35.23* (0.37)	65.6** (0.51)	18.04	-36.25* (0.42)	206.55* (1.44)		
9. SMM	320.27	11.62* (0.12)	-31.29	77.85* (0.82)	108.21* (0.85)	60.66* (0.58)	6.36	249.17* (1.73)	42.62* (0.41)	

**p<.001, **p<.05*

Table 4 Descriptive statistics of structural typology

Structural Typology	N	Mean	Std. Deviation
BMC	30054	331.888	130.0315
BMM	19	288.974	131.2112
Hybrid	505	398.114	132.3972
Light Frame (Steel)	98	428.48	179.0265
Light Frame (Timber)	197	380.921	146.4896
Others	2648	326.63	120.3743
RCC	12309	569.433	202.5127
SMC	2583	362.884	144.5081
SMM	39953	320.265	115.5034
Total	88366	361.056	160.8282

b. Plinth area and caste/ethnicity

The mean plinth area of houses of Newar-Thakali group was the highest at 384.4 sq. ft. while it was lowest for Dalit group at 323.5 sq. ft. Mean plinth area of all caste/ethnic groups except Dalit was higher than overall mean plinth area.

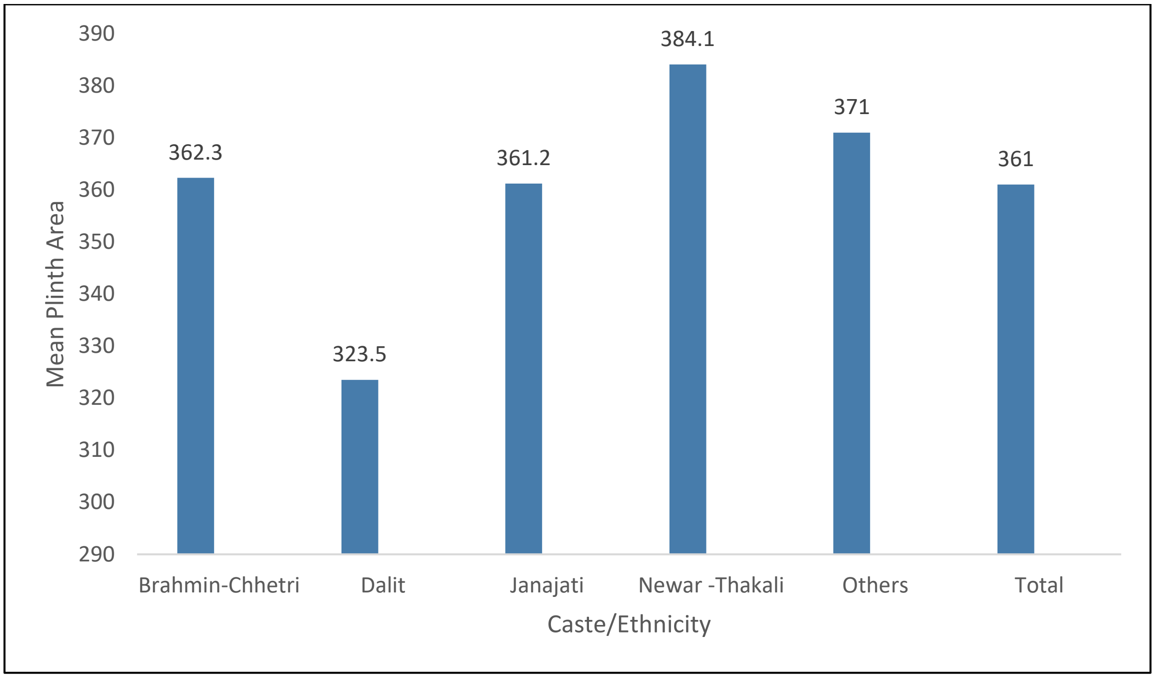

Figure 5 Mean plinth area w.r.t caste/ethnic groups

A one-way between subjects' ANOVA was conducted to compare the differences in mean plinth area based on caste/ethnicity, to determine if it played any major role in the square footage area of house. The database used is considered to be normally distributed due to central limit theorem for very large database (N=88414) (Ghasemi & Zahediasl, 2012). A Games Howell's Post Hoc test was performed between the variables as both, Welch's F test [$F(4, 16332.43) = 222.58$, $p<0.001$] and *Levene's* F test of homogeneity of variance ($p<0.001$) produced significant results. The *Welch's* F test revealed a statistically significant effect of caste/ethnicity on plinth area, at $p<.05$. The estimated omega squared ($w^2 = .01$) indicated that approximately 1% of the total variation in mean plinth area is attributable to differences of structural typologies.

Post hoc comparisons, using the Games-Howell post hoc procedure, were done to determine which pairs of the Caste/Ethnicity differed significantly. These results are given in Table 6 and indicate that Newar-Thakali (M=384.14, SD=167.36) built significantly bigger plinth area than Brahmin-Chhetri (M=362.27, SD=160.22), Dalit (M=323.51, SD=121.41), Janajati (M=361.24, SD=164.90) and Others (M=371.03, SD=160.38) with an effect size of 0.13, 0.41, 0.13 and 0.08 respectively. On the other hand, Dalit built significantly smaller plinth area than Brahmin-Chhetri, Janajati, Newar-Thakali and Others group with effect size of 0.27, 0.26, 0.41 and 0.33 respectively. Brahmin-Chhetri built bigger plinth than Janajati but the results were not significant while the Others group built significantly bigger plinth area than Brahmin-Chhetri, Dalit and Janajati with effect size of 0.05, 0.33, 0.06 respectively.

Table 5 Post hoc scores of plinth area by caste/ethnicity

	Caste/Ethnicity	Mean	Mean Differences (Effect Sizes are indicated in parentheses)				
			1	2	3	4	5
1.	Brahmin-Chhetri	362.271					
2.	Dalit	323.517	38.75* (0.27)				
3.	Janajati	361.241	1.03	-37.72* (0.26)			
4.	Newar-Thakali	384.146	-21.87* (0.13)	-60.62* (0.41)	22.90* (0.13)		
5.	Others	371.036	-8.76** (0.05)	-47.51* (0.33)	13.11* (0.06)	-13.11* (0.08)	

**p<.001, **p<.05*

Table 6 Descriptive statistics of caste/ethnicity

Caste/Ethnicity	N	Mean	Std. Deviation
Brahmin-Chhetri	27326	362.271	160.2206
Dalit	7593	323.517	121.4105
Janajati	41066	361.241	164.9058
Newar-Thakali	9075	384.146	167.3608
Others	3354	371.036	160.3871
Total	88414	361.042	160.812

c. Plinth area and family size

A one-way between subjects' ANOVA was conducted to compare Family Size and mean plinth area to determine if the choice of plinth area depended on the number of people living in the house. The database used is considered to be normally distributed due to central limit theorem for very large database (N=7303) (Ghasemi & Zahediasl, 2012). The *Levene's* F test revealed that the homogeneity of variance assumption was met (p=.45). The one-way ANOVA test reveals that there was no significant difference in plinth area built at the p<.05 level for any Family Size [F(4,88894.41)=0.882, p=0.474]

4. Discussion

SMM structure which was common at community before the earthquake was the most preferred structure during reconstruction which can be related to availability of construction materials locally (DUDBC, 2011). BMC structure was also preferred by large number of beneficiaries as the construction from brick is quicker (Humanitarian, 2018). As horizontal and vertical seismic bands were one of the requirement for getting the construction approved for tranche (NRA, 2017c), SMM and BMC structure had these bands which can be seen as a transformation in the construction methods, making the construction more resilient. The number of story and the size of the room was also limited, which has started a new trend of the construction of SMM structure in the rural areas. The load bearing brick masonry less preferred than stone masonry in the rural hilly areas before the earthquake (DUDBC, 2011). Brick is commonly used as an infill wall in the RCC structures throughout Nepal. After the commencement of housing reconstruction program, BMC with seismic band has become one of the popular construction method in the rural hilly areas. It is expected that the introduction of the horizontal and vertical bands has resulted in the significant improvement of the seismic performance of the building as the construction is technically assisted and supervised by trained masons and engineers. Besides SMM and BMC, there has been a construction of new type of structures like hybrid , light frame steel and timber, hollow blocks, CSEB blocks, confined masonry structures after they were introduced by NRA (DUDBC, 2015, 2017; NRA, 2017b). RCC structures was third most preferred structure despite the increased cost, need to transport construction materials and being relatively new technology in rural areas. This might be due to the perception of people about safety of RCC structures as only few of RCC structures were damaged compared to other structure (NPC, 2015).

SMM structures was the most preferred for all caste/ethnic groups except for Others group. Higher preference of SMM was found in Janajati and Dalit compared to Brahmin-Chhetri and Newar-Thakali. RCC structures were significantly constructed at highest number by Newar-Thakali and lowest number by Dalit. The social stratification displays the financial capacity, literacy and exposure to mass media of Brahmins-Chhetri and Newar-Thakali is more than the Dalit and Janajati (Bennett et al., 2008). It was found that family size didn't cause significant change in preference of structure type.

The number of people constructing houses two storied or above was very less compared to pre earthquake times. Technical standards restricted SMM houses to maximum of one story and attic high. Although BMC and SMC houses could be constructed up to two story and attic the requirements for double story was higher compared to single story (DUDBC, 2015; NRA, 2017c). Many people later built upper story with light weight material as single story structure couldn't meet their living functional requirements (NRA, 2017b). It was found that structure type didn't cause significant change determining number of story built. Most of the beneficiaries had built one storied houses even if they had built RCC structure where they could have built multiple floors. Some beneficiaries built smaller houses to receive grant as clear information related to MR wasn't provided to beneficiaries (CFP, 2018). Caste/Ethnicity didn't cause significant change in determining the number of story built. The proportion of one story house was highest for nuclear family and lowest for extended large family.

There is significant difference between mean plinth area of different structure type. RCC structure had the highest plinth area. Field experiences say, the general layout of RCC structure consist four rooms while that of SMM and BMC consists two rooms. Similarly, caste/ethnicity caused significant effect on mean plinth area of the structure build. The mean plinth area of Newar-Thakali was the highest and that of Dalit was lowest. Newar-Thakali constructed highest proportion of RCC houses which had highest plinth area while Dalit constructed lowest proportion of it. It was found that there is no significant difference between plinth area of houses for any family size. The size of the houses is defined according to structure type by the MR and there is a general trend of constructing similar type of the houses in the rural areas. But we can see the increase in number of story for larger family size.

5. Conclusions and Recommendations

This paper presents the types and sizes of structures built after the earthquake in rural hilly areas of Nepal under the government's housing reconstruction program with respect to family size and caste/ethnicity. It was found that people were interested to use local construction material for reconstruction with SMM structure constructed by highest number of beneficiaries. In addition, BMC structure, whose construction is quicker compared to other structures is preferred by large number of people. The socially and economically privileged caste/ethnic groups like Brahmin-Chhetri and Newar-Thakali were found to have constructed higher proportion of new and expensive structures like RCC with higher plinth areas in comparison to other castes.

It was also seen that certain new typologies have emerged during the housing reconstruction process. The houses reconstructed were smaller in terms of plinth area and number of story than the houses which were constructed before earthquake. The people have become more aware about the consequences of the earthquake and limited the size of the houses based on the technical standards. The preference of the number of story of the houses was found to be depended on the family size, which reflects that the people have constructed their houses based on their requirements. The houses with seismic band is a concept in the building code that needed an implementation mechanism. The reconstruction process has become the opportunity to introduce these standards, which will be the basis to make the communities more resilient.

It is recommended to put improvement of local construction techniques and quality of local construction materials at priority during the technical assistance. Government should maintain the technical standards for future construction in these areas and provide technical assistance when necessary. It is needed to study whether the constructed house would be sufficient for people to continue their normal lifestyle. If the reconstructed house is not sufficient, it would be necessary to study about the horizontally or vertically expansion of the house or construction of new structures in addition to it. The type of construction technologies and technical standards that will be used for these expansion will also determine the resilience of community.

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