Mechanical Characterization of Traditional Brick Masonry in Kathmandu, Nepal

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Executive Summary of Project Report

The Gorkha Earthquake struck the Kathmandu Valley in Nepal on the 25th of April 2015, causing the destruction of about half a million buildings and severely damaging the surviving structures. The reconstruction has fuelled a renewed demand for construction materials, and in particular bricks, which continue to be a favourite choice due to the abundance of clay in the valley, accessible cost, and the widespread bricklaying skills.

As the reconstruction began, both local and foreign experts have been trying to implement improved methods of construction and also support production and use of improved construction materials, to reduce the vulnerability of buildings against seismic action.

This project aimed at carrying out a systematic and rigorous mechanical testing campaign to brick and mortar samples in current use.

Traditional masonry buildings in Nepal are built with slightly wedge-shaped bricks called *Daci Apa* used as facing brickwork, with thin joints of mortar. Internally, the core masonry is built with standard rectangular *Ma Apa* bricks, which are set in coarse jointed mortar.

New bricks were sourced from two manufacturers within the Kathmandu Valley, *Dakshin Barai* (DB) and *Mahakali* (MK).

DB provided 12no daci apa bricks and 12no ma apa bricks, MK provided 12no daci apa bricks. For each group of 12 bricks, 6 were tested in uniaxial compression, and 6 were tested in 3-points bending. The daci apa bricks have the large opposite faces which are not parallel, and were made such by applying a layer of cement mortar.

Historic bricks salvaged from current or recent reconstruction projects of *Char Narayan* and *Harishankara* Temples, dating from the 16th and 17th Century, respectively, were also tested in the same conditions to provide a strength comparison.

The bricks were measured and weighed, and dry and wet weights were also recorded, and density calculated.

The results of the mechanical compressive tests are summarised in the following graphs:

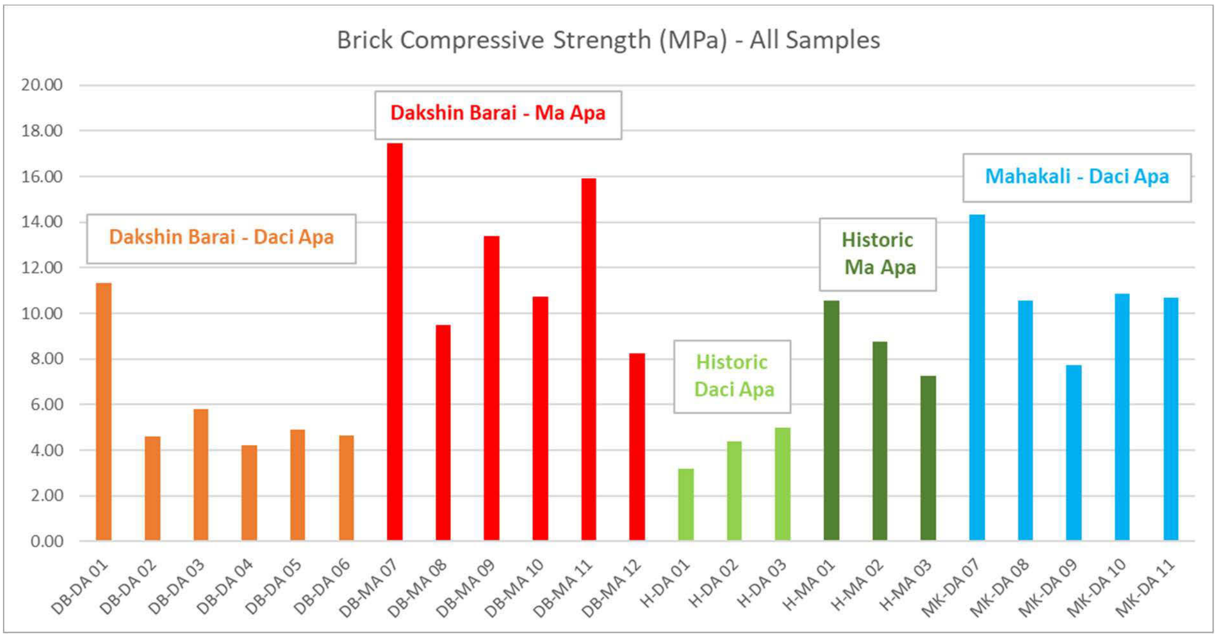


Figure 1: Brick Compressive Strength – All Samples

Looking at the DB Daci Apa bricks, the DB new bricks have an average compressive strength of 5.92MPa, 41% higher than the historic bricks, which have an average of 4.20MPa. However, excluding one isolated and very high new brick result (DB-DA01), the others have an average of 4.84MPa, i.e. only 15% higher than the historic bricks. The MK new bricks have an average compressive strength of 10.83MPa, i.e. 158% higher than the historic bricks.

Looking at the Ma Apa bricks, the historic set has an average compressive strength of 5.59MPa, i.e. 33% higher than the historic Daci Apa. Looking at the new bricks, DB has an average compressive strength of 12.54Mpa, i.e. 124% higher than the historic bricks.

Overall the new bricks are considerably stronger in compression compared to the historic bricks, and this is a positive improvement in the brick industry. Variability appears quite high, but the limited number of samples does not allow a full assessment of this parameter.

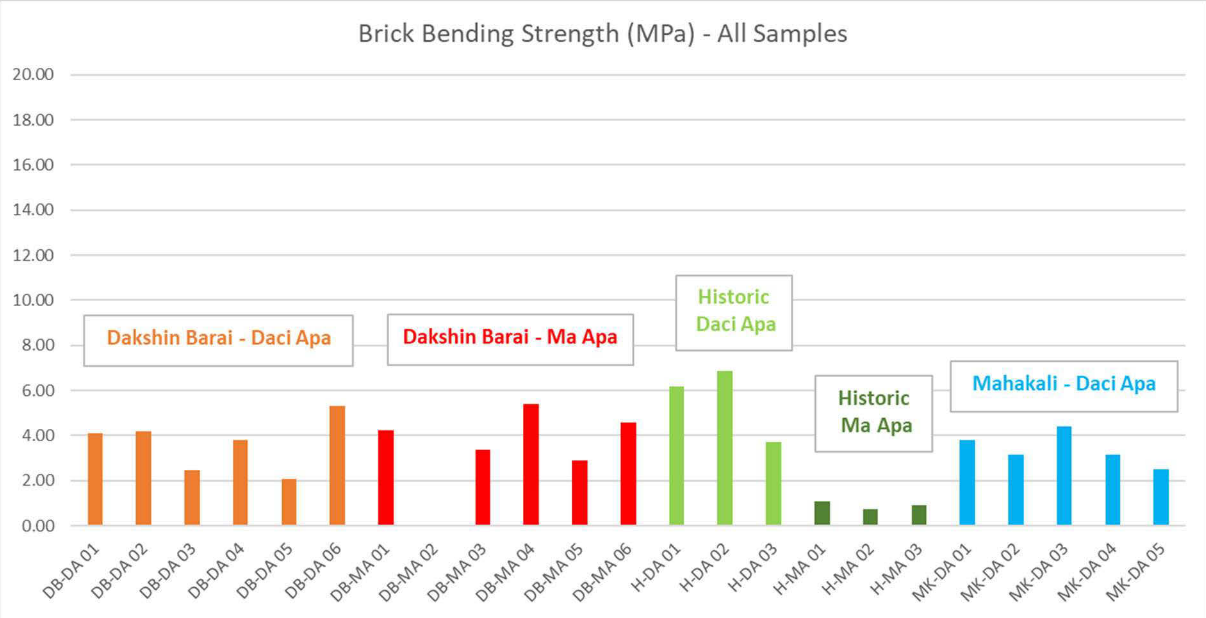


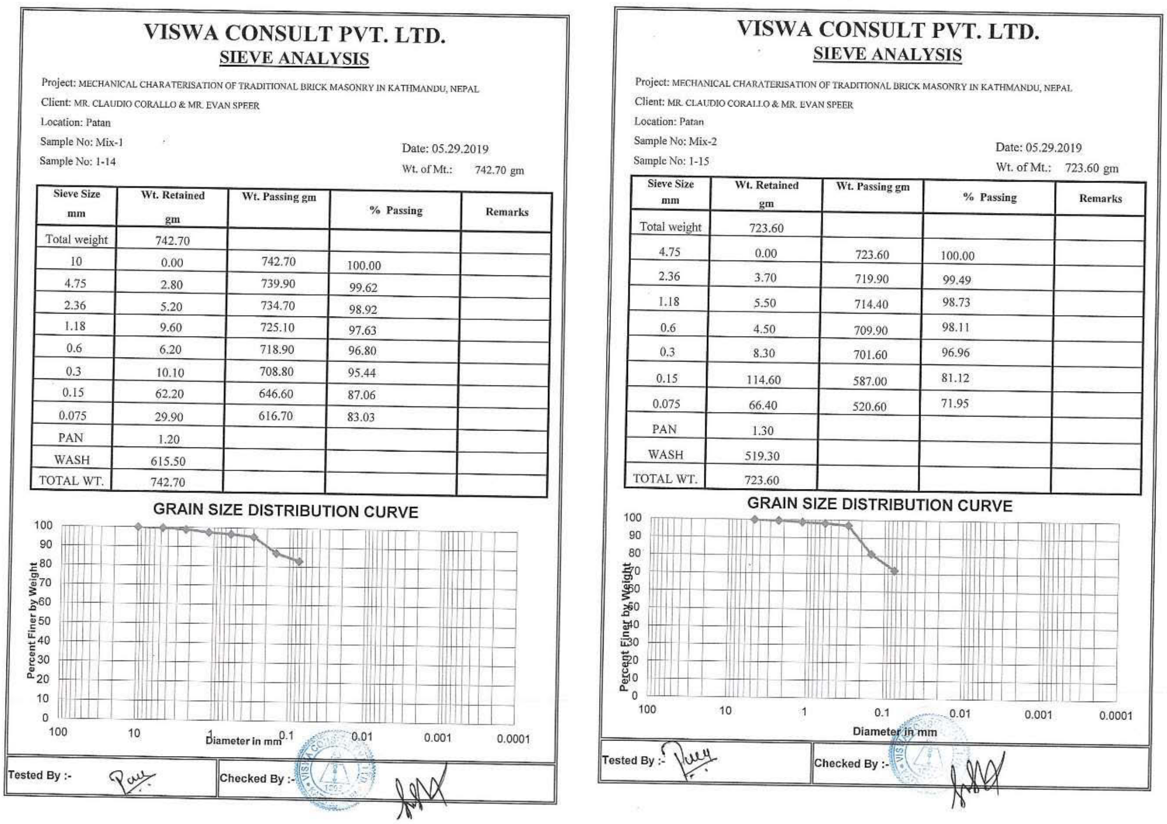
Figure 2: Brick Bending Strength – All Samples

The above figure shows that the historic bricks have a bending strength of 5.59MPa (daci apa) and 0.91Mpa (ma apa). This shows a very sharp difference between the two groups, with the ma apa performing considerably less than the daci apa. The opposite was true for the compressive strength, although the difference was not this evident. Regarding the new bricks, the DB daci apa (average bending strength 3.65MPa) and MK daci apa (average bending strength 3.41MPa) have a very similar performance, while the DB ma apa (average bending strength 4.09MPa) has a slightly higher performance. The pronounced variation observed in the historic set in bending in not evident in the new bricks, which appear to be of higher strength, and more uniformly performing across the range.

Regarding the mortar mixes, we made the decision of concentrating on 2no mixes, obtained from the traditional bricklaying Nepali culture, and still in use today in heritage projects.

Mix 1 is a mix of yellow clay from the Kathmandu Valley and water, with no other additions. The clay is obtained from 2-3m below the surface, and traditionally with experienced bricklayers checking the source in person.

Mix 2 is obtained from Mix 1 with the addition of Panga Silt to reduce early cracking due to shrinkage, and it is generally used for the outer skin of masonry and where architecturally exposed. 1 sample per each mix was sieved with the following results:



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SIEVE ANALYSIS

Project: MECHANICAL CHARATERISATION OF TRADITIONAL BRICK MASONRY IN KATHMANDU, NEPAL
Client: MR. CLAUDIO CORALLO & MR. EVAN SPEER
Location: Patan
Sample No: Mix-1
Sample No: 1-14
Date: 05.29.2019
Wt. of Mt.: 742.70 gm

Sieve Size mm	Wt. Retained gm	Wt. Passing gm	% Passing	Remarks
Total weight	742.70			
10	0.00	742.70	100.00	
4.75	2.80	739.90	99.62	
2.36	5.20	734.70	98.92	
1.18	9.60	725.10	97.63	
0.6	6.20	718.90	96.80	
0.3	10.10	708.80	95.44	
0.15	62.20	646.60	87.06	
0.075	29.90	616.70	83.03	
PAN	1.20			
WASH	615.50			
TOTAL WT.	742.70			

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SIEVE ANALYSIS

Project: MECHANICAL CHARATERISATION OF TRADITIONAL BRICK MASONRY IN KATHMANDU, NEPAL
Client: MR. CLAUDIO CORALLO & MR. EVAN SPEER
Location: Patan
Sample No: Mix-2
Sample No: 1-15
Date: 05.29.2019
Wt. of Mt.: 723.60 gm

Sieve Size mm	Wt. Retained gm	Wt. Passing gm	% Passing	Remarks
Total weight	723.60			
4.75	0.00	723.60	100.00	
2.36	3.70	719.90	99.49	
1.18	5.50	714.40	98.73	
0.6	4.50	709.90	98.11	
0.3	8.30	701.60	96.96	
0.15	114.60	587.00	81.12	
0.075	66.40	520.60	71.95	
PAN	1.30			
WASH	519.30			
TOTAL WT.	723.60			

Figure 3: Sieve Analysis of Mortar Mix 1 and 2

30 cube samples were prepared for each mix, samples sleeves were placed flat on raised plyboard under a covered area away from drafts, and covered with a moist jute bag. After 1 week, the samples were very carefully removed from the sleeves and placed in labelled plastic bags until testing. Testing was carried out at 50-56 days curing, with the following results:

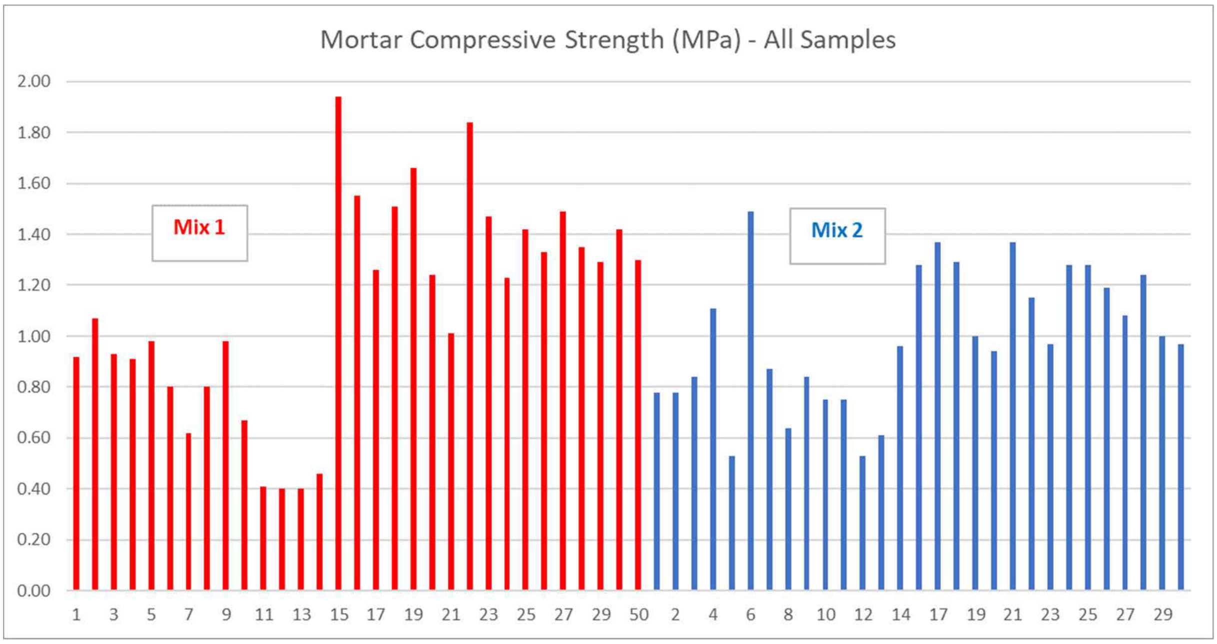

Figure 4: Mortar Compressive Strength – All Samples

The results above show that Mix 1 has a very high variability (Standard Deviation of 0.42MPa) and average compressive strength of 1.12MPa. Mix 2, with the addition of silt, has a much lower variability (Standard Deviation of 0.27 MPa), although the compressive strength if reduced to 1.00Mpa.

Overall the strength of the mortar is very low, at about 1Mpa. From and engineering point of view, this can severely limit the overall strength of the masonry, as failure will occur within the mortar joints creating slip or shear planes.

The testing campaign included also sclerometer tests. Two sclerometers were used for the mortar samples, but with very poor results in terms of consistency, damage to the samples etc. The test overall was not successful and it was not possible to obtain a meaningful and repeatable set of data to correlate with the mechanical tests results, and it was therefore abandoned.

The project has demonstrated with numerical values that the brick industry in Nepal is now capable of producing good quality bricks, with reasonable compressive strength of over 10MPa for some specific types, and also reasonable consistency, a noticeable improvement from historic bricks.

The bedding mortar, still obtained from natural clay and with no additives or with the addition of silt, provides a very weak mix which is the weak link in the masonry assembly. Future studies should concentrate on possible additives which are economic and widely available, and capable of increasing the mortar strength, which will make the loadbearing brick structures considerably stronger overall.