# Structural Report

Taleju Temple, Patan Durbar Square

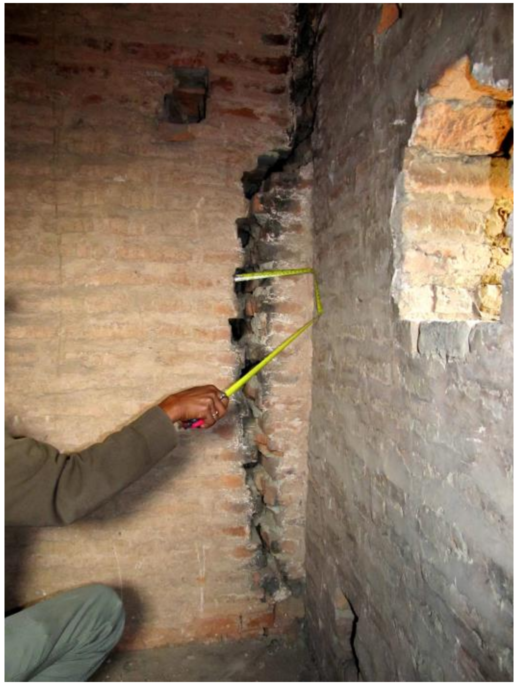
## 1. Scope

In the following, the structural condition and proposed retrofitting measures for Taleju Temple, situated at the north-east corner of Mul Cok on Patan Durbar Square, are addressed. As an integral part of Kathmandu Valley Preservation Trust's (KVPT) effort to restore the Mul Cok compound, it is intended to seismically upgrade the structural fabric of Taleju Temple. The overall concept aims for methods that are unobtrusive, as far as possible reversible, and in line with the traditional construction techniques of the building.

## 2. History

In the great 1934 earthquake, the second and third tier of Taleju temple collapsed completely, as historic evidence confirms. In the aftermath of this catastrophic event, the temple and the lower portions of the north wing of Mul Cok were rebuilt, although a variety of small alterations was introduced. The rebuilt parts of the masonry wall used lime instead of mud mortar.

Damage from the 1934 Earthquake. Upper two levels of roof were completely collapsed in Taleju and adjacent wing on west lost more than half.




During the small September 2011 earthquake, the building performed comparatively well, although many of the already existing cracks widened.

## 3. Brief overview of the existing condition

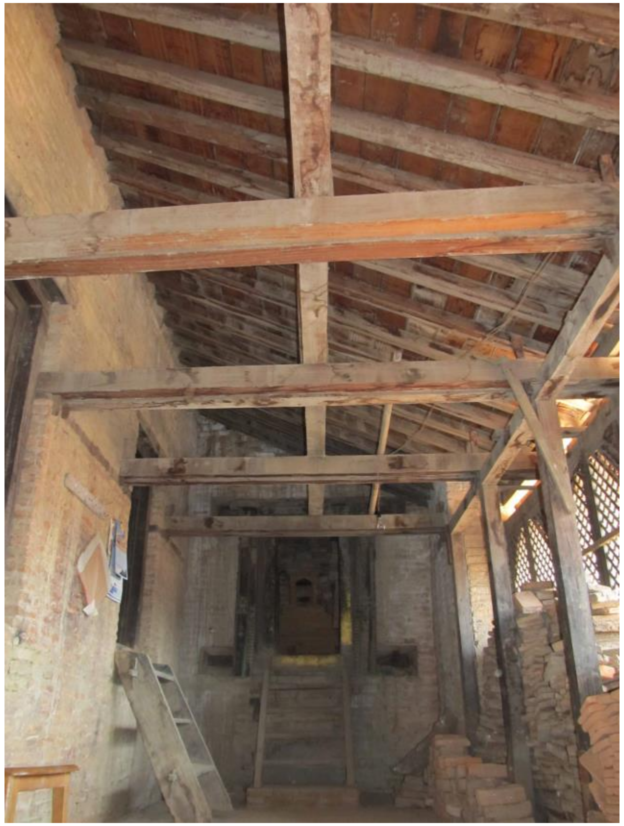
One of the most distinct structural features of Taleju consists certainly in its massive masonry core. This core extends uninterrupted from the ground floor level to the bottom of the third floor level, where it stops just beneath the sanctum. At ground level, the core measures 8.10m x 4.65m. Wooden elements are integrated into the core in a frame-like fashion, supposedly for additional bonding. The outer faces of the core appear to be overall in a good condition. Nothing is known about the internal composition of the core. The infill could consist of brick rubble or even just mud. (The reasons for the introduction of the core are religious, not structural, as the sanctum of the god “Taleju” has to have a connection to the ground.)

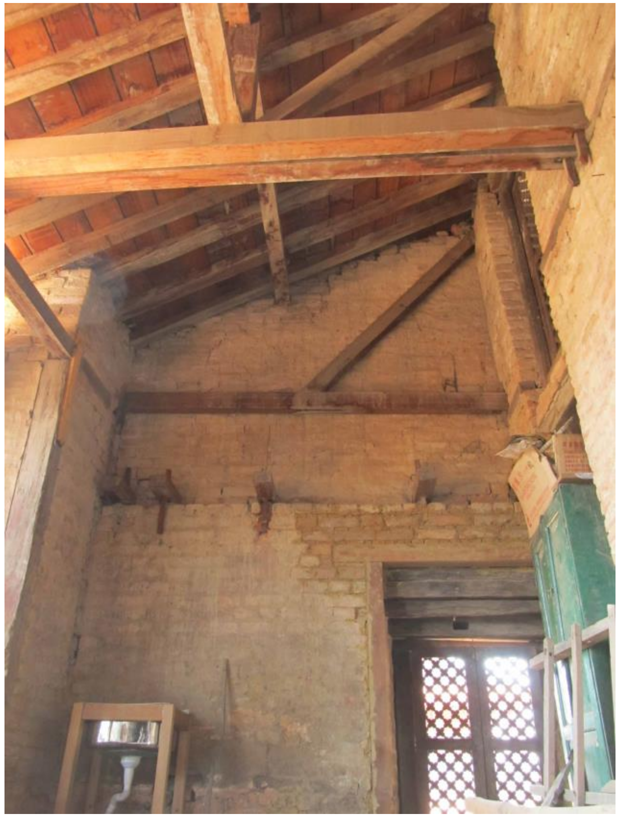
### *Ground Floor / 1st Floor level:*

Masonry walls in both ground and 1st floor level appear to be in a decent condition. Only marginal fissures can be detected. Much of the structural fabric was severely affected by the 1934 earthquake. Some of the walls were completely rebuilt after the earthquake. In other cases, where cracks had appeared, the walls were most likely just repaired with new outer layers of face brick. The rebuilt and repaired walls used lime mortar instead of the hitherto used mud mortar.

***2nd floor level:***

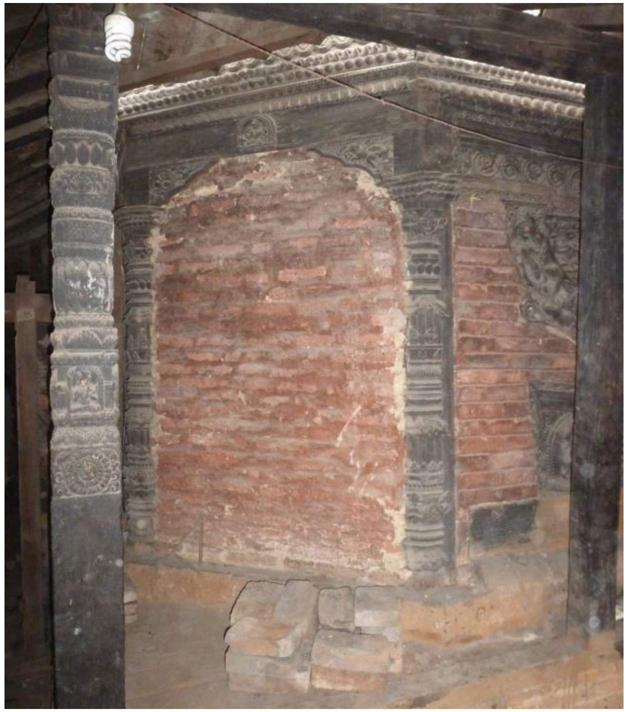
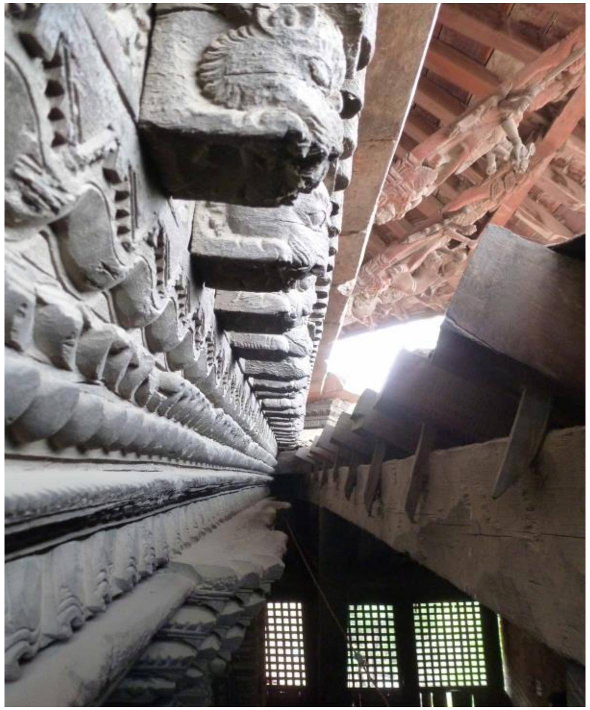
The gallery level, more appropriately the 2.5th floor due to its location as a split level between the 2nd and 3rd floor level. The shear walls facing the courtyard appear to be in a bad condition; there is also no interlocking to the outer 3rd floor sanctum walls. Furthermore, this gallery space is insufficiently braced, with an open roof system covering it and no load distributing elements between the shear walls.





***3rd floor level:***

The sanctum of Taleju is situated just above the massive masonry core on the third floor level. The rectangular space is framed by masonry wall, whereas on the eastern and western side an open timber arcade takes up the octagonal shape of the tower. (The western side of the open arcade has been sealed with a masonry wall, supposedly post 1934).

The outer walls that surround the inner sanctum are a later addition. Already in place in 1934, they were also destroyed in the earthquake and rebuilt shortly after. The masonry of these walls is in general in an unsatisfactory condition, partially sloping outwards and apparently built in haste as the substandard execution suggests. An additional roof system was also added, covering the space between sanctum and outer walls. On the inside, this roof is separated from the core by an app. 25cm wide gap (of varying width on different sides). The inner support is provided by wooden beams at each face, which are propped in the corners, and additionally at each third of its length. Thus, no connection is provided between the roof and the inner walls.

***4th floor level:***

The walls step back at mid-height of the fourth floor level. This shift is provided by small wooden beams that are both decayed and undersized, resulting in huge deflections. Above the beams, the masonry is cracked severely due to inadequate support conditions.

***5th floor level:***

This level could at this point only be examined from the fourth floor level. The walls step back again at this level. Unlike below, the beams appear to be in a much better condition at this location.

***6th floor level:***
This level could at this point only be examined from the fourth floor level. No apparent damage/failure could be observed from here.

## 4. Seismic retrofitting concept

An integral element of the ongoing restoration of Mul Cok is the improvement of the seismic behaviour and resistance of Taleju temple. In this manner, the extent of damage and failure during the next grave earthquake is to be substantially minimized. However, it is not the intention of the seismic retrofitting concept to reach a code-compliant level of safety. This would involve interventions so extensive, as to compromise both historic fabric and authentic value of the building. The objective is, in contrast, to introduce a variety of small-scale solutions that are as far as possible in line with the traditional construction techniques of the structure. Following the maxim “minimum intervention – maximum protection”, the sum of installed measures will help to substantially improve the seismic performance of the structure.

The applied retrofitting strategy focuses on means that are in general low-tech, easy to install, and economical. Furthermore, the suggested measures will not alter the existing load path of the structure to avoid a redistribution of stresses. Reversibility of newly installed measures is another priority of the overall concept.

The aim is to increase the overall cohesiveness of the structure. By increasing the shear stiffness of floor plates and roof planes, the building will be more able to act as one single unit in the event of an earthquake. The tying of individual members like wall plates or wooden struts will prevent dislodgement and thus progressive collapse under seismic motion.

At large, the suggested measures will significantly increase the seismic resistance of the building.

## 5. Suggested upgrading measures:

The following described strengthening measures will address and upgrade the most vulnerable parts of Taleju Temple.

### General measures to be taken:

- Patch open cracks with lime mortar. Properties of mortar shall match the original one.
- Stiffen the floor planes with two layers of plywood board in a staggered arrangement to create rigid diaphragms. Provide sufficient ss nails between boards and joists.

### At 2.5th floor level (Gallery space):

- Remove and rebuild all masonry walls surrounding the gallery space, thereby providing sufficient interlocking with the adjacent cross walls and at the transition of the 3rd floor outer walls (at sanctum space).
- Install a horizontal timber truss to stiffen the roof level of the gallery space. Timber diagonals (14cmx14cm) shall be installed between the existing horizontal beams. Blocking shall be provided between the 12mm gap between the pairs of horizontally running beams. Further blocking shall be provided between the ends of the existing beams to provide force-fit connections. Connections to be carried out with 12mm stainless steel bolts and steel plates on bottom and top side of the joints. The thereby achieved warren truss will help to stabilize the upper part of the gallery space.

### At 3rd floor level:

- Rebuild the outer walls of the space surrounding the sanctum.
- Provide continuity between the octagonal sanctum core and the outer wall by introducing a force-fit transition at the roof level. New inner roof beams shall be installed adjoining to the wooden cornice of the sanctum. The beam depth shall make use of the height of the cornice (app. 24cm) below the cornice made of protruding lion-heads. Two columns (instead of the four existing) shall support each of the four beams, situated just before the wooden columns at the corners of the octagonal sanctum. Beams shall be installed along each of the eight faces of the cornice. Connections at the joints shall be executed with steel plates at the top and bottom, plus lap-joints at the four corners of the outer square. The thereby achieved arrangement will tie the inner core to the outer walls of the third floor level.

**At 4th floor level:**

- Provide K – frames made of steel with a horizontal tie below the sagging undersized beams where the walls step back. Install top part of K-frame tightly beneath the transfer beams to relieve them and prevent further deflection. Provide sufficient support at each end and embed the ends in the masonry walls.

**All roof levels:**

- Stiffen the roof levels with two layers of plywood board in a staggered arrangement to create rigid diaphragms. Provide sufficient stainless steel nails between boards and rafters.

- Roof levels: minimize the thickness of the traditional clay bed for the tiles to the absolute necessary to reduce the dead load.

- Wooden struts: Strengthen the connections between the roof structure and the wooden struts by stainless steel straps on the rear.

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