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Restoration Efforts Following the Nepal Earthquake

On April 25, 2015 at 11:56 AM, a violent earthquake with a magnitude of 7.8 shook Nepal's capital city of Kathmandu for approximately 50 seconds. Its epicenter was located in the Ghorka district of Nepal, near the Kathmandu valley, affecting many of its surrounding villages and towns. The earthquake was so strong it even affected nearby countries China and India. (1) Just half an hour after the first large earthquake, a powerful aftershock struck the same district for about 30 seconds, with a still large magnitude of 6.6. (1) Many historic buildings and temples were ruined, including the Dharahara Tower, wherein 50+ people were found, trapped under its collapse. (2) The name Kathmandu actually derives from the original temple Kasthamandap, which is a temple that was said to have been built from a single tree. This was a temple that was not only a tourist attraction, but also a very important structure to the citizens of Nepal. Historically, visitors would gather there for important ceremonies, and the temple's main purpose was to be a community center. Not only was this temple significant many years ago, but also up until its destruction, locals would set up fish, fruit, and other food stands while awaiting their potential customers. (13) The original founder of the city, King Gunakam Dev modified the name Kasthamandap (the Sanskrit translation) to a more modern "Kathmandu." Now all that is left of the temple are splinters and dust. On this day alone, an extraordinary 36 more aftershocks were recorded in Nepal. Currently, the death toll in Nepal is upwards of 8,000 people, with more than 17,800 injured and 366 still missing. (1)

It is clear to say that anyone who has been remotely informed about the devastating events in Nepal would be deeply affected by these facts. As an architecture student, one of my initial thoughts (besides deep sympathy) was: How can I improve the state of Nepal's architecture through my knowledge? I have always been interested in learning about reconstructing buildings after they have been destroyed by natural disasters. Being in architecture however, especially sparked my interest specifically towards building reconstruction, and wanting to learn about how I, as an individual can help to get people back on their feet by utilizing my resources. I always believed that we were put into this world to help others, in any way that we can, and I feel as though I was put here to help others through architecture. This project was a perfect opportunity to put two and two together - being affected sympathetically by the earthquake and having a desire to learn more about building restoration/helping those who are or have been less fortunate.

This paper's purpose is to briefly describe the devastating events from the 2015 Kathmandu earthquakes and aftershocks, focusing mainly on building and architectural failures. The damage that the earthquake caused to the city of Kathmandu will be described through observations of structural damage based on photographs, reports, and other documented information. It will describe how these buildings failed, why they failed, and will propose a possible solution as to how through architecture, one could create a built environment that is less susceptible to devastations such as these. The proposal will include suggestions for more reliable resources and materials that could possibly be used to build in Nepal, basic structural methods of improvement, and overall advancements that could improve the poor state of this developing country. The hope is that this paper will be helpful to the improvements and efforts of restoration to those currently still residing in the city still prone to earthquakes. The goal is to inform myself as well as others on ways to always improving the lives, and sustaining the lives of those who are less fortunate through building methods.

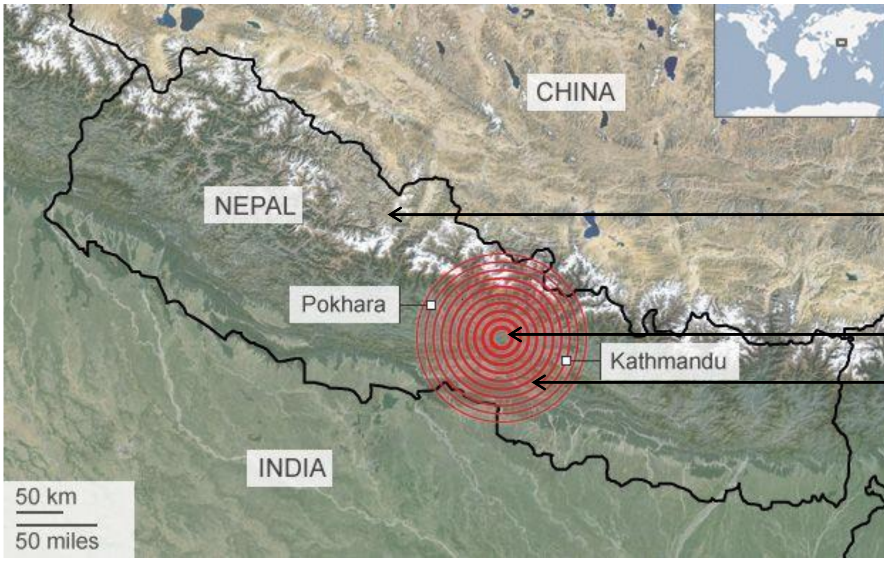

Figure 1.**Map of Nepal with Case Studies Identified & Locations (32)**

1) Kasthamandap Temple
2) Typical brick masonry buildings
3) Hanumandhoka Temple Complex
4) Typical concrete building
5) Rural/Earthen structures
6) Bamboo structures

Wood structures: Wood generally is a durable, easy, quick and cheap structural material, especially when it is locally abundant with a base of skilled carpenters. However in countries where construction is more developed, codified methods are used with structural calculations and construction oversight/enforcement.

#1. Kasthamandap Temple

General Information: Kasthamandap literally translates to "the wooden pavilion". It is a three-story wooden temple located in Kathmandu's Durbar Square, built sometime in the 12th century. The plan of the temple is a simple, square shape, and the roof is a hip-shape, in a pagoda style, made from brick. Four main shrines are located on the first floor of the temple, which you can see in the architectural drawings. (Fig.6). These shrines are all carved from stone, and placed in some sort of heavy stone masonry alcove. The temple was said to have been built with the use of the wood from a single tree, and is constructed as a timber frame. (3) Its distance to the epicenter of the earthquake was approximately 172 km. (106.876 miles.) (4)

Primary Structural Material: Wood, a "Sal" tree, which is a type of hardwood tree found in Nepal. (5) It is reported that the temple was built without the use of nails, or any other metal fasteners, just pure wood joinery. (6) The 4 massive primary center columns are also made from wood. (7)

Failure/Damage Observation: The main structure has completely collapsed. The wooden parts of the structure seemed to have failed where longer, extended wooden posts or beams were, mainly towards their middles. It is apparent also that the wooden structures seemed to have failed at their ground connections as well because as you can see, a lot of the wooden elements are lifted out of their supports. The temple's main connections consisted of wooden joinery, and very few joints/connections are still visibly intact. The shorter wooden compositions seemed to survive (such as the red picket fence in the front.)

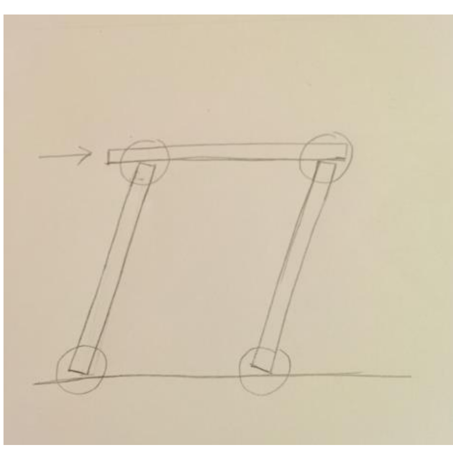

Figure 2 **Structural Diagram of Wood during an earthquake.** When a lateral load (left and right force) strikes a wood structure, the connections (joints) are likely to displace, and the vertical elements may break in their centers

Figure 3 **Kasthamandap as it stood before the earthquake (8)**

Figure 4 **Kasthamandap, in the aftermath of the earthquake (9)**

Figure 5 **Kasthamandap's destruction, from an above view** (10)

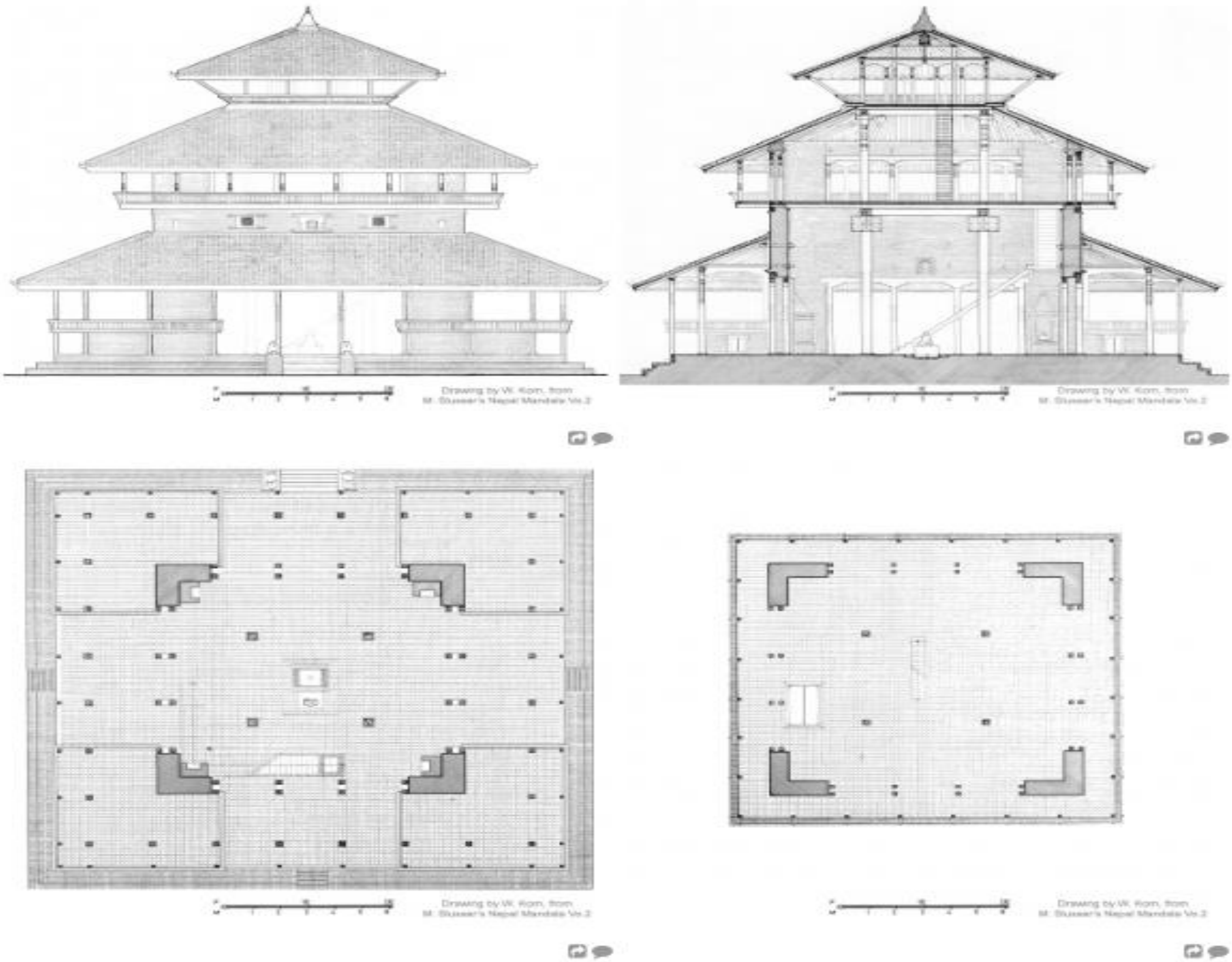

Figure 6 **Architectural drawings** (from top left to bottom right respectively: elevation, section, first floor plan, second floor plan) (11)

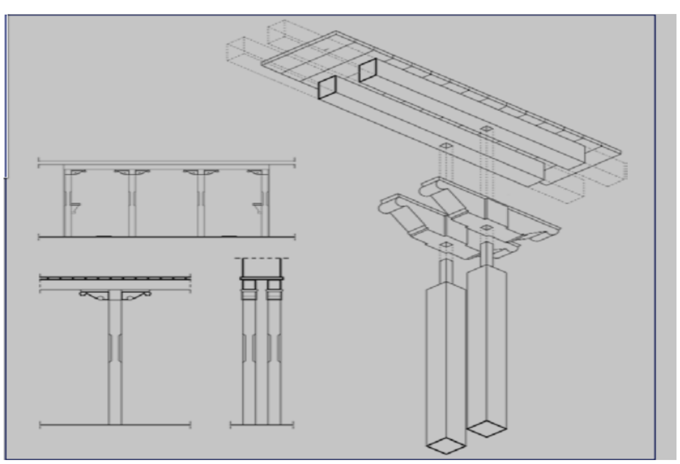

Figure 7 **Elegant wooden joinery detail (11)**

Brick-framed or total masonry: Many structures in Nepal are built with brick masonry. They are sometimes part of a composite system with structural wood frames. Although stone or brick masonry can at times be a very strong material, buildings in Nepal were unable to withstand earthquakes as strong as the one that hit Kathmandu.

#2 Typical Brick Masonry Building

General Information: As with most other buildings in Kathmandu, the plan of typical brick buildings is simple, and follows a rectangular/square geometry, without the use of curvature. Roofs are also flat.

Primary Structure Material: Fired Brick

Failure/Damage: Brick, stone masonry and concrete material tend to fail easily under earthquake forces due to weakness when subjected to tensile stress. The reason is because masonry as a construction method is a brittle system. Materials used in brittle construction systems usually do not deform when they break, nor does the system allow for much deformation among its components. When subjected to lateral forces (such as an earthquake), it will usually crack and /or break in a diagonal direction. In the picture of the brick building after the earthquake, you can see that a lot of the brick units are still in their whole form, however have been detached from the wall with cracks in a diagonal direction. In this situation, the mortar bond that held the bricks together was the weak link. As one may already notice in the before picture of this brick building, the construction quality is already poor. Some bricks in the pattern seem to be missing, and some are even extruding more than others. Proper, quality construction techniques contribute greatly to how it will perform during an earthquake. (31)

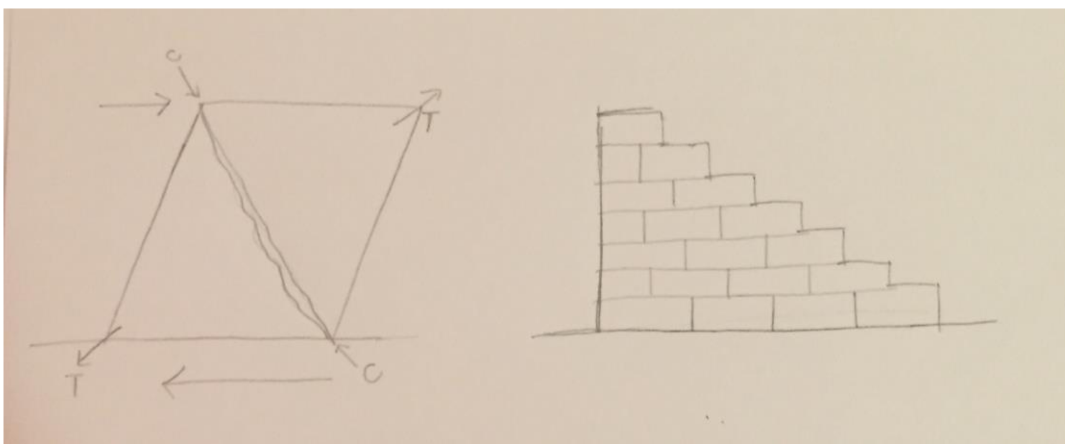

Figure 8 **Structural diagram of how brick will perform during an earthquake.**
The arrow pointing left at the bottom of the diagram shows the ground acceleration, the way that the Earth will shift during the earthquake. The arrow pointing right at the upper left shows the force of the earthquake, the way that the earthquake will tend to push the brick. Arrows labeled “T” show the directions where tension is present, and the arrows labeled “C” show the directions in which compression is present.

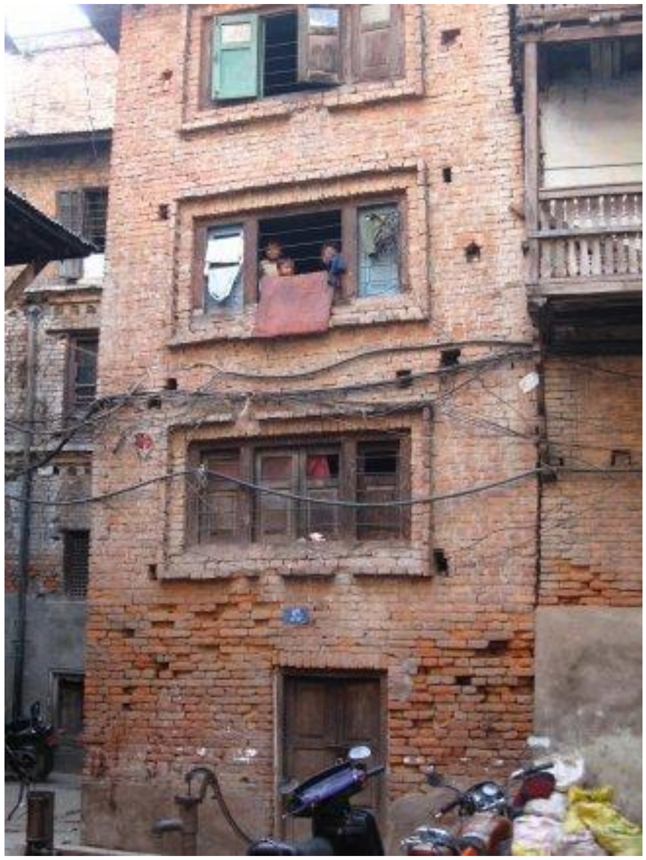

Figure 8 **Typical brick masonry building, before the earthquake**

Figure 9 **Brick building, after the earthquake (12)**

#3 Hanumandhoka

General Information: The Hanumandhoka temple complex was built in 1672. (13) The plan of each temple is a simple square. The site plan below shows the layout of where each temple is located in this main square. The roof of the temple is in the pagoda-style.

Primary Structure Material: The primary structural material of the temple is wood, (timber frame). Brick however is an infill material for this temple. The brick used in the construction of the temple was called “Telia” which means “covered in oil.” This type of brick was popular during the 1600s. (14) Structural safety was probably not considered when it was built, since Telia brick has a shiny coat it was used for design purposes and facades. (30)

Failure/damage: As mentioned before, brick tends to fail easily in earthquake situations. However, looking at the Hanumandhoka Temple, failures were both in the brick and the timber framing. As you can see, wooden posts and beams have been broken at the joints and most of the individual bricks are still intact. This implies that the mortar or the bond between the bricks was the weak part of the structure. There are some bricks that seem to have cracked a bit and not in its full shape.

Figure 10 **Hanumandhoka as it stood before the earthquake (15)**

Figure 11 **Hanumandhoka destruction from earthquake (16)**

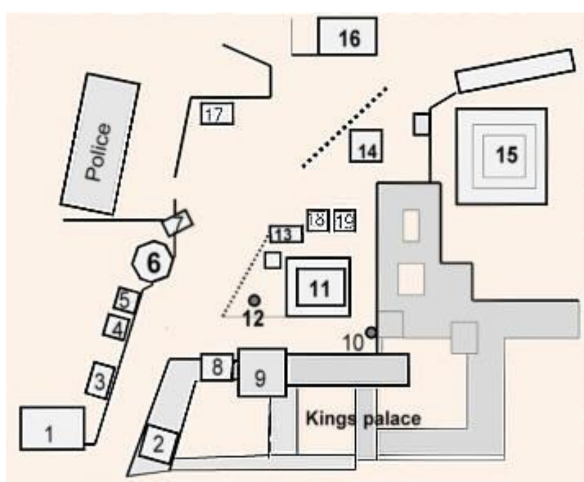

Figure 12 **A site map of the Hanumandhoka Complex (17)**

Concrete Buildings: A decent amount of buildings in Nepal are built with the use of concrete. Many of them however, are not "properly" built because they lack critical structural components.

#4 Typical Concrete Buildings

General Description: Concrete buildings in Nepal are typically rectangular shaped in plan. (About 6 meters in width and 3-10 meters in length.) The roof shapes of concrete buildings vary. When finished, roofs are typically flat. Unfinished buildings are common since in Nepal they are constantly building upwards. In these buildings you can see metal stays or rebar protruding from the top of the unfinished structure. Reinforced concrete was introduced in the late 1970s. (18)

Primary Structural Material: Concrete, sometimes rebar, and sometimes brick infill in a concrete frame.

Failure/damage observation: In Nepal, construction does not seem to incorporate techniques for strong and well reinforced concrete. (19) As a result, when they build with concrete, they do not properly prepare the molds, and do not leave space for any other crucial structural materials such as steel reinforcing bars. However, in the "newer" (built in late 1970s) concrete buildings of Kathmandu, rebar has been used quite frequently in construction, but it is not clear how much oversight or code enforcement exists to make sure the rebar is placed properly. Today, about only 40% of Kahthmandu is constructed with the use of reinforced concrete. Unfortunately, many of the older (built before the 1970s) concrete buildings are built with the absence of rebar, causing those buildings to fail much more readily than others. (18) Concrete is a brittle material, so as you can see in figures 14,15 and 16, when exposed to high-stress situations, concrete will crack where most of the pressure is and crumble into tiny pieces, without deformation. An earthquake as a lateral load shifts the ground in a certain direction. For example if the earthquake moved the ground to the left, due to inertia, a structure tends to stay to the right, causing its bottom left and top right corners to move into tension, and the opposite corners fall into compression. (See brick diagram, figure 8) In figure 15, you can really see the direction in which the earthquake shifted these buildings.

Figure 13: **Typical concrete community in Nepal, before the earthquake (12)**

Figure 14 **Interior of a damaged concrete building.** Here, you can see clearly the direction in which the earthquake caused the crack to travel. (12)


Figure 15 **Damage to concrete buildings after earthquake** (20)


Figure 16 **Screenshot from footage of a concrete building collapse during earthquake** (21)

#5 Rural earthen/Adobe: Adobe is a heavy material not well-documented but existing in some areas of Nepal. Its non-structural purposes include mortar in brick walls and as a mud plaster paving for laying tile on roofs. A large amount of Nepal's population lives in the hills. (about 53%) Those who reside here deal with great climactic changes, where it can be incredibly hot in the summer, and below freezing in the winter. (19) Figure 19 shows a traditional Newari house in the hills. Earthen structures have high thermal mass and are more comfortable in extreme temperatures. (24)

General Information: Adobe houses, as with most other houses in Nepal have simple, rectangular plans. They usually have a gable shaped roof, built with other materials such as wooden lumber. Most adobe houses are only 1-2 stories high, this may help their structural performance in an earthquake.
Primary Structural Materials: Adobe (mud brick) consisting of local soil, possible addition of straw and clay, and water.
Failure/damage observation: Adobe when constructed to resist earthquake forces will have some reinforcement within the walls. It is apparent that in Nepal, there is no structural reinforcement since the walls seemed to have crumbled to the ground, as it is another brittle material. The before (fig 17) and after (fig 18) pictures of the adobe house are not the same house. It is crucial to note the difference between the materials of the two roofs depicted. In the first, a much heavier roof seems to be made of brick and in the second, a lighter, metal corrugated roof, with damage to the house that was not as bad as it could have been with a heavier roof.

Figure 17 **Adobe house before earthquake (22)**

Figure 18 **Adobe house after earthquake (23)**

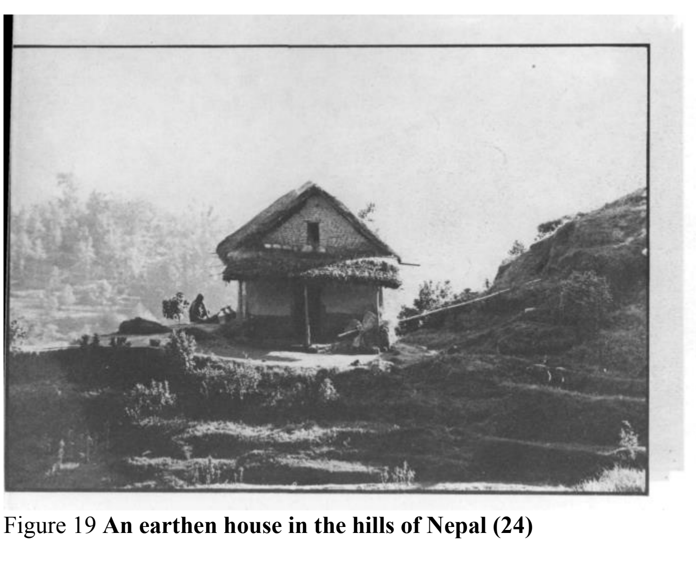

Figure 19 **An earthen house in the hills of Nepal (24)**

#6 Bamboo: Bamboo grows abundantly in eastern, central and western Nepal and is a very strong, resilient (able to return to its natural state even after being bent) material. (27) It generally grows in altitudes of 1000m-2900m in the forests and mountains of Nepal. (25) Additionally, it is a popular material because it can also be used to create better air circulation.

General Information: Bamboo structures typically have rectangular shaped plan, usually with a gable-shaped, hut-style roof. Bamboo seems to be a material that has been more recently used since its discovery of its strength and sustainability. (27)
Primary Structural Material: Bamboo. When using bamboo as a building material it is common to cut through the bamboo's hollow core and to insert metal reinforcement such as nuts, bolts, anchor bolts, etc. (26) See figure 22. However, in Nepal, it is hard to tell exactly how they were able to build with bamboo, but it is likely that with their experience with wood joinery, that they made some sort of bamboo joinery system.
Failure/Damage Observation: Bamboo as a material can be very strong. Its hollow center is helpful to its structural ability. I was unable to find pictures of bamboo structures that were affected by the earthquake; this could mean that bamboo structures were possibly not affected by the earthquake because of its strength and flexibility. With bamboo structures, builders receive clear feedback toward obtaining a stable structure by incorporating diagonal members. Diagonal members/cross bracing strongly support a structures stability and load path. The bamboo structure depicted uses diagonal members in both directions so that when the lateral load comes from one direction, one cross-piece will be in tension and the other compression, and vice versa when the load direction is reversed. See figure 25.

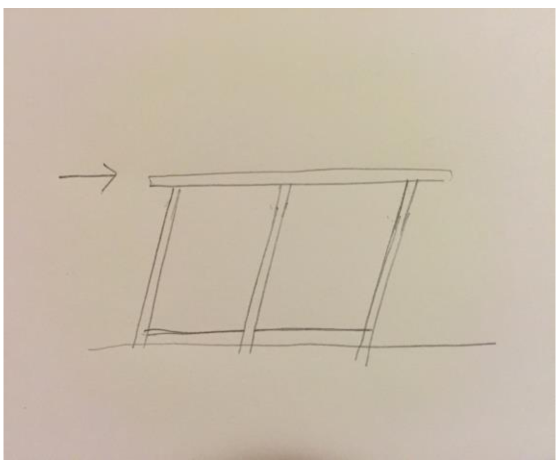

Figure 24 **Structural diagram.** Arrows pointing right show motion of the earthquake, and how it will push the bamboo structure.

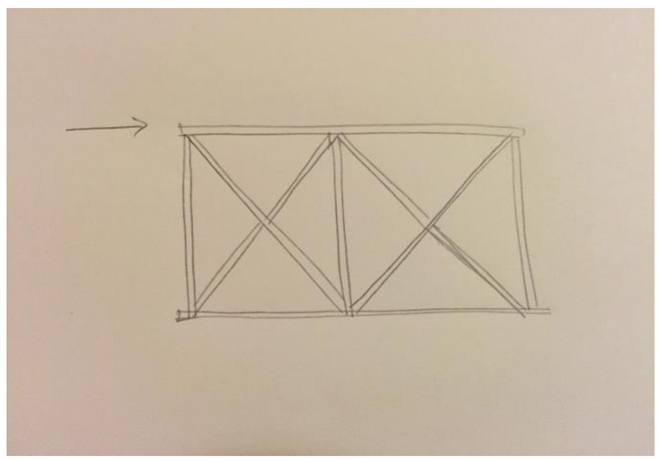

Figure 25 **Structural diagram with diagonal bracing** where lateral forces will not be able to bend the bamboo structure.

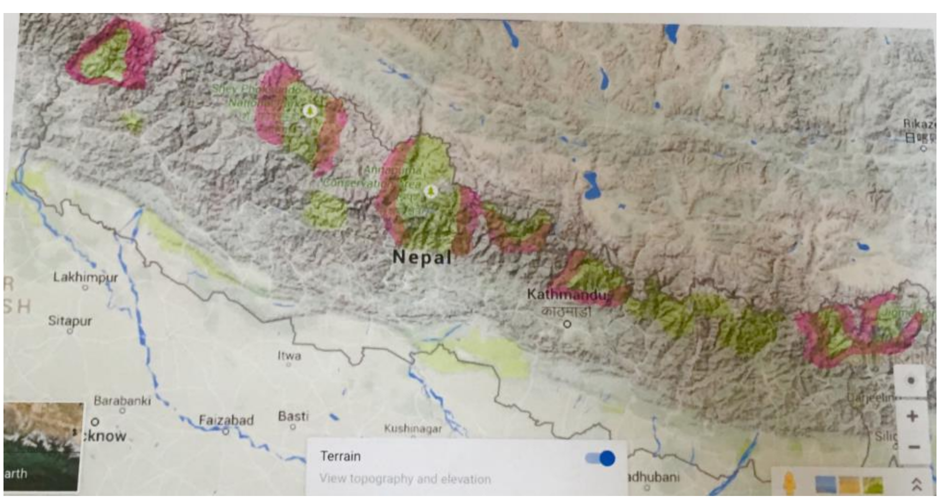

Figure 21 **Rough map of bamboo growth in Nepal** Areas highlighted indicate the general bamboo growth (4)

Figure 26 **Older bamboo school being built** (24)

Figure 27 **Bamboo house being built,** showing cross bracing. (28)

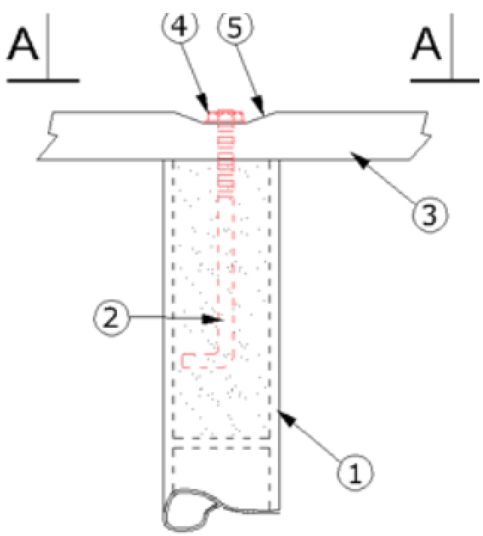

Figure 22 **Section cut through bamboo column showing connection detail. (26)**

1) Shows the bamboo pole's diametrical cut.
2) Anchor bolt
3) Top ring beam
4) Washer + nut
5) Space created by ring beam

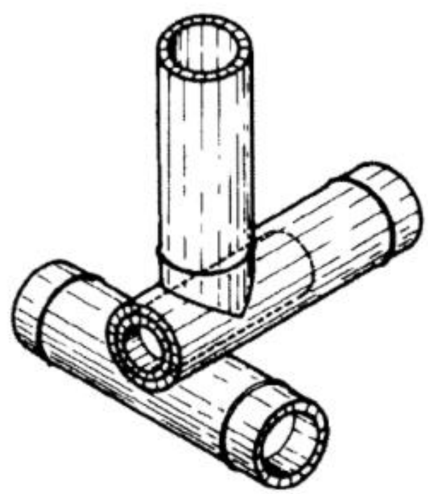

Figure 23 **Bamboo joint (26)** without metal hardware present. This picture shows a bamboo joint where another tiny member has been placed into the middle piece for more support. Lashing (cord or rope) is present at the ends of each member.

Species (Local name)	Eastern	Central	Western	Midwestern Nepal	Status
Ampelocalamus patellaris (Nibba, Ghopi bans, Lyas bans) Syn. *Sinurindinaria jainiana*	•		•		Not so common, between 1200-1800 m, used for weaving, construction and flutes
Arundinaria bamboos	•				Rare, above 2900 m, browsed by yak and wild animals, make arrows, brushes and straws.
Bambusa arundinacea	+			#	Not so common, upto 1000 m, used for construction purpose.
B. balcooa (Dhanubans, Ban bans)		•		#	Common, upto 1600 m, used for poles, scaffolding, weaving, house wall, beams, erosion control.
B. glaucescens var. solida (Syn. *B. multiplex*)		#			Recently introduced in garden.
B. multiplex (Chinese hedge bamboo)		•			Introduced from China, commonly planted in Kathmandu used for weaving and hedges.
B. nepalensis (Tamabans, Phusure bans)	•	•	•		Common, upto 1500 m, used for construction, weaving, shoot edible, a multi purpose species.
B. nutans subsp. *Nutans* (Tharubans, Sate bans)		•	•	#	Common in the hills from 1000-1500 m, not found in terai, used for construction, weaving, poles.
B. nutans subsp. *cupulata* (Malbans)	•	•		#	Common upto 1500 m for weaving, poles, fodder.
B. tulda (Kada bans, Karaicho bans, Chab bans)		•		#	A rare bamboo in Nepal, upto 1000 m for construction, fodder.
B. vulgaris	+	+			Rare upto 1200 m, used for house construction, ornamental, introduced in garden.
B. vulgaris form *Kimmei*		#			Ornamental, recently introduced.
B. almaii (Mugibans)	•	#			Cultivated, in eastern Nepal for weaving, upto 1000 m, popular in Terai.
Borinda chigar (Chigar)					Not so common, found between 2600-3100 m, used for weaving and shelter for wild animals, rodents, birds.
B. emeryi (Kalo nigalo)	•				A rare species, used for weaving, from 2600-3200m.
Cephalostachyum latifolium (Syn. *Schizostachyum latifolium*) (Ghopi) bans, Murali bans)					A rare species, used for weaving and to make flutes, fodder, between 1500-2000m.
Dendrocalamus hamiltonii (Choya bans, Ban bans)	•	•	•	#	Common, semi-cultivated upto 1500 m, used for weaving, shoot rarely eaten, fodder.
D. hookeri (Kalo, Bhalu bans)	•				Common, cultivated species 1200-2000 m, shoot edible, fodder, culm for roofing, construction.
D. giganteus (Dhungre bans, Rachhasi bans)	•				Few and mostly in eastern Nepal upto 1000 m, used for support and container.
D. strictus (Latthi bans)				#	Below 1000 m, becoming rare, used for paper pulp, construction.
Drepanostachyum falcatum (Tite nigalo, diu nigalo) (Syn. *Sinarundinaria falcata*)			•	#	Common, between 1000-2000 m, used for weaving and fodder.
D. intermedium (Tite nigalo) (Syn. S. *intermedia*)	•				Common between 1000-2000 m, used for weaving and fodder.
D. khasianum (Ban nigalo) (Syn. S. *Jainiana*)		'		#	Common, between 1000-2000 m, used as fodder.
Himalayacalamus brevinodus (Malinge nigalo)	•				Common between 1800-2200 m, used for weaving, shoot edible and fodder.
H. cupreus			•		Common, between 2300-2800 m, used for weaving.
H. fimbriatus (Tite nigalo)		•	•		Common, between 1000-1800 m, used for weaving and fodder.
H. porcatus (Seto nigalo)		•			Rare, between 2000-2300m.
H. hookerianus (Padang)	•				Common between, 2000-2500 m, used for weaving and fodder.
H. falconeri (Thudi nigalo, Singhane)	•	•			Common, between 2000-2500 m, used for weaving, shoot edible.
H. asper (Ghumre nigalo, Malinge nigalo)		•	•	#	Rare, between 1800-2300 m used for weaving.
Melocanna baccifera (Lahure bans)	•		•		Common upto 1400 m, used for construction and weaving.
Phyllostachys nigra (Nigalo, Kalo nigalo)		#			Common, garden species in Kathmandu, young shoot edible.
Pleioblastus sp.		#			Introduced in Kathmandu potted plant.
Sasa megalophylla		#			Recently introduced in garden in Kathmandu.
Thamnocalamus spathiflorus (Rato nigalo)		•			Common, from 2800-3500 m, not commonly used but eaten by wild animals like red panda, bears, birds, shelter, for domestic animals.
T. spathiflorus subsp. *Nepalensis* (Jarbuto)		•	•		Common, from 2800-3500 m, used as fodder by wild and domestic animals, shelter for birds, monkeys and rodents.
Yushania maling (Malingo, Khosre malingo)	•				Common, between 1600-3000 m, used for fencing, brushes.
Y. microphylla (Mailing, malingo)	•	•			Rare, between 2300-3500 m, browsed by yak and wild animals.

Figure 20 **Chart of bamboo distribution and locations** (25)

Nepal's construction methods are poor. Construction of the Kasthamandap Temple consisted of mostly wood, without the use of nails or any other metal fasteners but rather its structure relied on elegant wooden joinery. It is possible that for centuries, this structure has stood due to these techniques. Wood is a strong structural material as it has the capacity to bend and withstand heavy forces, and it is not brittle. However, a clear suggestion that I have if the temple is rebuilt would be that they use nails, rivets, and other "ductility fuses". To retain the temple's historical value, I would suggest that the elegant joinery remain.

To improve brick as a means for construction, I would suggest that more thorough care be taken when building. For example, brick did not seem to be laid out very carefully in construction, and almost looked like each piece was carelessly thrown into place. The techniques of carefully laying brick with thin mortar joints and carefully "pointing" can lead to a much stronger bond and overall wall system. When rebuilding, brick can be reinforced by incorporating "joint reinforcement." Joint reinforcement consists of thin steel bars that run horizontally between courses of bricks and are shaped like long, flat "H's." If a structure is already built with brick, exterior mesh can be added. During restoration in Indonesia, also a relatively poor country, houses were built to be earthquake-resistant with the use of steel reinforcement between brick, and maybe Nepal construction restoration can follow this technique. (31)

An obvious way that concrete as a structural system can be improved is through greater and well-placed reinforcement, because with a strong enough earthquake, even reinforced concrete buildings may fail. Crucial structural concrete elements such as columns SHOULD contain plenty of rebar. Rebar being within a column can be much, much stronger and safer than a column that is purely made of concrete. It would be similar to a leaf with no veins, the shape would still be there, but when subjected to force, it could crumble easily. As mentioned earlier, some of the newer concrete buildings in Nepal already contain reinforcement, and now is a chance to rebuild all with reinforcement. Another suggestion for concrete buildings would be to not build so high up. Since they tend to build upwards in Nepal, it is easier for buildings to topple over during an earthquake. If buildings were lower to the ground, there would be more stability, causing fewer buildings to fall over.

Bamboo seems to be an effective structural system, as surmised by the conspicuous lack of information about their failures. I encourage the use of bamboo in areas of Nepal where it is accessible, and for those building in Nepal to always look for ways that they can improve bamboo's structural performance.

If citizens must build with adobe, I would recommend that they keep those houses short, and down to 2 stories max. This is because adobe is very heavy, and if even a single chunk of adobe were to fall on someone, it could very easily injure or even kill him or her. When building, I would keep in mind the amount of weight that will be put on the upper parts of the house. For example, I would keep the roofs light. Building roofs with lighter materials such as corrugated metal or aluminum may keep the damage lower than what potential damage capacity could be.

One thing that struck me in the course of my research is the lack of awareness that the citizens of Nepal seem to have. Many of them don't know what is really safe for them, and in turn are forced to believe what they hear by word on the street. While this fact holds true also in non-third world countries even like America, it is crucial especially to Nepal citizens that they are shown some form of construction knowledge since they are not as fortunate as us in terms of buildings being built more properly here. Many citizens believe that concrete buildings are safe to be in should another earthquake strike Nepal. This may be true, to an extent, but not if you are in a concrete building without any form of reinforcement. After the earthquake, citizens had made false assumptions that concrete structures were safer, since they observed that many of those had remained. United Nations Human Settlement (HABITAT) representative, Padma Sundar Joshi stated: "The only reason reinforced concrete structures survived this time was that the intensity and duration of the earthquake was not as big as predicted." (29) What if these citizens believed that <u>all</u> concrete buildings were safe to be in, reinforced or not? Awareness is key to residents of Nepal. Even small tips and facts about construction could save a life, like knowing what kind of building they are in the moment an earthquake strikes, and how they can be aware of the possible dangers that could arise in that specific one. Short classes could be taught by volunteers, giving citizens legitimate information by experienced and knowledgeable workers. Short public service announcements of awareness may go a long way while the country is in the process of getting back on their feet. One little message may be heard by all, and could make the biggest difference. Posters with diagrams or pictures and facts go a long way and pamphlets with such helpful knowledge could be passed out.

There are many ways that the state of Nepal's current conditions can be improved, and things need to happen one step at a time. I am excited and looking forward to seeing how these positive changes happen throughout the course of the next few years, and maybe in a few months. Through knowledge and awareness, the citizens of Nepal may be able to defy the next potential earthquake.

Works Cited

1. N/A. (2015) “Earthquake Nepal”. *Earthquake Nepal.* Web. <earthquake-nepal.com> June 13, 2015

2. Gardner, David. (2015) “Kathmandu, Nepal, Earthquake. 5 Fast Facts You Need to Know”. *Heavy.* Web. <heavy.com> June 16, 2015

3. N/A. “Kasthamandap”. *Lonely Planet.* Web. <lonelyplanet.com> 4 August 2015.

4. “Kasthamandap Temple, Nepal.” Map. *Google Maps.* 23 July 2009. Web. 1 August 2015.

5. N/A. “Teak Wood vs. Sal Wood vs Mindi (Marindi) Wood”. *Ghar Expert.* Web. <gharexpert.com> 4 August 2015.

6. Ways, David. “Guide to Kasthamandap”. *The Longest Way Home.* 22 May 2015. Web. <thelongestwayhome.com> 2 August 2015.

7. Thapa, Ramesh Jung. “Kasthamandapa.” No Date. Web. <himalaya.socanth.cam.ac.uk> 4 August 2015.

8. N/A. “Freak Street, Kathmandu”. *Virtual Tourist.* No date. Web. <virtualtourist.com> 30 July 2015.

9. N/A. “Scenes From The Aftermath Of Kathmandu Earthquake”. *News Ghana.* 25 April 2015. Web. <newsghana.com.gh> 30 July 2015.

10. “The Superman”. “2015 Nepal Earthquake: Four heritage sites which we will never see again”. *Soul Steer.* 26 April 2015. Web. <soulsteer.com> 3 August 2015.

11. Risal, Dipesh. “Rebuild Kasthamandap”. *Rebuild Kasthamandap.* 7 June 2015. Web. <rebuildkasthamandap.com> 29 July 2015.

12. Ekin, Annette. “Digging to save Nepal’s cultural heritage after quake”. *Aljazeera.* 01 May 2015. Web. <aljazeera.com>

13. N/A. “Hanuman Dhoka”. *Lonely Planet.* Web. <lonelyplanet.com> 4 August 2015.

14. Bonapace, Caterina and Sestini, Valerio. “Traditional Materials and Construction Technologies used in the Kathmandu Valley”. United Nations Educational, Scientific and Cultural Organization. November 2003. Web. <barbara-brink.com>

15. N/A. “Hanuman Dhoka Square Photo”. *Trip Advisor.* 28 July 2015. Web. <tripadvisor.com> 7 August 2015.

16. Sharma, Gopal and Adkin, Ross. “Nepal earthquake: rescue efforts stepped up as quake toll rises”. *The Sydney Morning Herald.* 26 April 2015. Web. <smh.com.au>

17. N/A. “Kathmandu”. *CN Travel.* No date. Web. <cntravelre.com> 28 July 2015.

18. Mallapaty, Smriti. “Reinforced concrete buildings survived Nepal quake” Copyright: Vlad Sohin. *SciDevNet.* 24 July 2015. Web. <scidev.net> 28 July 2015.

19. Traer, Miles. “Stanford earthquake hazards researcher at center of Nepal quake”. *Stanford News.* 22 May 2015. Web. <news.stanford.edu> 20 July 2015.

20. Havan, Omar; Nybo, Thomas; Shrestha, Narenda. “Devastation as earthquake rips Nepal apart: PICTURE STORY”. *Climate Reporters.* 26 April 2015. Web. <climatereporters.com> 28 July 2015.

21. Velecitas, Veledor. “building collapse in aftershock of earthquake in Kathmandu, Nepal live on camera”. *YouTube.* May 2015. Web. <youtube.com> 29 July 2015.

22. N/A. “Nepal, June 2008”. *Auroville Earth Institute UNESCO Chair Earthen Architecture.* June 2008. Web. <earth-auroville.com> 24 July 2015.

23. N/A. “2015 Earthquake in Kathmandu, Nepal”. *Exponent Engineering and Scientific Consulting.* No date. Web. <exponent.com> 25 July 2015.

24. Boch-Isaacson, Joel M. (1987). *Architecture & Construction Management in the Highland and Remote Areas of NEPAL, Kathmandu.* Nepal.

25. Shrestha, Keshab. “Distribution and status of bamboos in Nepal”. *Biodiversity Internation.* No date. Web. <biodiversityinternational.org> 7 August 2015.

26. Village Volunteers. “Manual on Building Bamboo Houses”. No date. Web. <villagevoluneteers.org> 6 August 2015.

27. Ferguson, David, Dr. 2015. “Low-Impact Solutions Providing Human Resource Development”. *Green Growth.* 20 June 2015.

28. Adhikary, Nripal. “Experiment with Locally Constructed Boucherie Treatment Plant in Nepal”. No date. Web. <abari.org> 6 August 2015.

29. Awale, Sonia. "A Concrete Future | Nation | Nepali Times." 21 May 2015. *A Concrete Future | Nation | Nepali Times*. Web. 6 August 2015. <nepalitimes.com>

30. Shakya, Abhijit; Shrestha, Asheshwor Man; Shrestha, Binay Rajan; Joshi, Prabesh; Vaidya, Ujwal Nanda. “A Report on Nyatapola-a marvel of Nepalese Architecture”. No date. Web. 13 August 2015. <oocities.org>

31. Hausler, Elizabeth. “Rebuilding After Disaster”. 10 November 2010. *Slideshare.* Web. 13 August 2015. <slideshare.net>

32. N/A. “Nepal Earthquake Map 2015”. No date. *Awesome Stories.* Web. 14 August 2014. <awesomestories.com>