13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 2971

INDIGENOUS SKILLS AND PRACTICES OF EARTHQUAKE RESISTANT CONSTRUCTION IN NEPAL

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SUMMARY

There is a surprising dearth of historical reference to devastating earthquake in ancient literature on the South Asian subcontinent which is the citadel for one of the most ancient civilizations of the world that produced tall architectural style such as "pagoda". There are enough evidences of seismic –resistant elements in traditional building typologies and construction practices. Some of these practices have been passed on from generation to generations. A survey of vernacular building types in various parts of Nepal revealed several earthquake-resistant features being incorporated in local building constructions. These included symmetric configuration, small length-to-breadth ratio, symmetrically located small openings; a low floor-height, and a limited number of stories. Use of wooden studs that are found to render resistance to lateral loads, and the energy-dissipating property of some of the typical construction details are example of earthquake-resistant elements used in indigenous constructions. Numerous residential private buildings in the historical city of Bhaktapur are more than 400 years old and they have survived at least 3-4 major earthquakes of intensity IX-X. Signatures of two to three earthquakes are seen in the same temple of Chandeshwori at Banepa. Existence of hundreds of such ancient temples and monuments in Kathmandu indicate the use of earthquake-resistant elements in the structures, because there were at least four earthquake episodes that produced intensities IX MMI or greater in parts of Kathmandu Valley in the past three centuries. During the program of mason training conducted by the National Society for Earthquake Technology-Nepal (NSET) under its School Earthquake Safety Program, one of the elderly craftsmen ('Karmi') was surprised to see similarities between NSET engineer's insistence for a 'tie band' around the masonry structure and his grandfather's preaching 'always put a wooden (tie) band around the building at sill level, lintel level and at the floor level. Carve it in 'naga' (snake). It will protect your house'. There were several such surprises! It is conspicuous throughout the Himalayan region that the traditional knowledge of building construction did have the practice and methods of securing the stability of buildings against earthquakes. But many of the "good practices" are being lost in the advent of new construction technologies based on the use of cement concrete.

This paper describes the indigenous knowledge and traditional wisdom on earthquake resistant technology in Nepal, and the importance of systematic exploration in this knowledge field, in order to capture what was already accepted by the society, and the need to incorporate some of those methods and approaches in

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our current efforts towards increased seismic safety, especially in the rural environment where the traditional construction materials such as stone, timber, brick, mud, and bamboo are still used widely.

INTRODUCTION

Nepal is one of the ancient civilizations of the world. The earliest inscription found in Kathmandu Valley within the World Heritage Site of Changunarayan area dates back to 425 AD. The town of Bhaktapur, one of the three main settlements of the valley, is stated to have been established in the 9th century AD. Nepal has a rich tradition of story-telling, and the historical events are described in several family trees, especially of the rulers. Surprisingly, in these writings and inscriptions, references to damage by historical earthquakes are found few and far between.

On the other hand, there are been a tradition of high building structures in Nepal since long. "Pagoda", the multi-tiered roofed temple, is regarded by the locals as an indigenous architectural style, dating back to early ages and influenced the development of similar structures in India and China, Parajuli et al. [1]. Description of tall structures in Kathmandu, "in the middle of the palace there is a tower of seven storeys roofed with copper tiles. Its balustrade, grilles, columns, beams, and everything therein are set about with fine and even precious stones ….", is believed to have been written by the Great traveler Wang Hiuen-tse about 657 AD, London [2]. The narrative also states that "the houses of the Nepalese were made of wood and the walls were carved and painted".

In Bhaktapur, there are several buildings that are believed to have been constructed more than 100-200 years ago. Many of these buildings, made in brick in a "special" mortar, are still used as residential structures. Throughout the Kathmandu Valley, there stand several multi-tiered temples that date back 2-3 centuries.

During the Great Bihar-Nepal Earthquake of 1934, only the topmost tier of the famous five-tiered pagoda of Nyatapola of Bhaktapur was slightly twisted and the main structure remained unharmed while several surrounding buildings, only 2 or 3-story buildings sustained widespread damage including collapse of many structures.

All these facts pertain to Kathmandu Valley, which consists of a 300m thick lake-bed of very weak clayey silt and sand that is susceptible to a very high degree of liquefaction during an earthquake. Obviously, earthquake-resistance is in-built, in a certain level, in the traditional structures of Kathmandu otherwise there would not have been a consistent tradition of a particular architectural style such as "pagoda" in the valley, neither would there be standing temples, such as the Chandeshwory Temple of Banepa, where one could clearly see in the standing structure, the signatures of two devastating great earthquakes of 1833 and 1934.

This conclusion is further supported by several anecdotes that the authors and their co-workers of the National Society for Earthquake Technology-Nepal (NSET) encountered while implementing the Kathmandu Valley Earthquake Risk Management Project (KVERMP) during 1997-2003, and the Kathmandu Valley Earthquake Risk Management Action Plan Implementation Project (APIP) since 2002 Kathmandu Valley.

"Vaastu", the ancient art of architectural planning for the city and individual buildings and also their contents, is also indicative of the traditional wisdom to accommodate to the natural environment. Although the term, and the concept, may seem to have been vulgarized now and hence apparently lost their inherent importance for some, the original stipulations of Vaastu may remain valid in most cases in terms of the drive towards conformity with the physical environment.

The traditional system of "occupational castes" for example, "Sikarmi" (carpenter), "Dakarmi" (mason), "Lohakarmi" (blacksmith) etc was the basis for continuation of the traditional skills and wisdom and their

continued application and integration into the building constriction process by passing the knowledge from generation to generation. Unfortunately, loss of the "caste" system, which otherwise is regarded progressive, has contributed to much misunderstanding of the logic of behind the use of a particular element of construction, and the traditional methods have been turned into rituals. There is adhoc subjectivism in the incorporation or deletion of this or that element. This has led to even misplacement or wrong placement, or partial placement of a certain element without proper integrity. For example, the timber tie (Nash in traditional language), which used to be a regular feature in the buildings of the past has started appearing only on two sides rather than on all the four walls as was the case was earlier. The very concept of "Nash" has been ritualized and misinterpreted, which has led to a significant loss of earthquake-resistance in the buildings of today.

This paper tries to make an initial exploration on the traditional wisdom and skill of earthquake-resistant technologies in the Nepal Himalayas, and examines the need for further researches into the area with the overall aim of improving the earthquake resilience of the 22 million Nepalese by rediscovering what was acceptably practiced by the society in the past.

RECORDED EARTHQUAKE RESISTANT ELEMENTS IN VERNACULAR BUILDINGS IN NEPAL

Following the devastating Udaypur Earthquake of 1988, Thapa [3], Nepal, implemented the Building Code Development Project, which also looked into the prevailing practices of construction in the various geographical areas of Nepal. The following excerpts are drawn for one of the reports of the Project (BDPC [3]).

"The buildings in the Solukhumbu region have vertical and horizontal timber posts embedded in the masonry. The double framed doors and windows act as reinforced openings".

"Buildings in and around Kali Gandaki valley have unique detailing for supporting the floor. Vertical posts are erected at strategic points along the walls to support the flooring system. Each floor is supported by different framing systems independent to each other. Thus the wall is only partially used to support the flooring and used as the curtain wall".

"The Gurungs and Magars of the central part of the hill area used to make oval shaped or circular buildings with a sloping roof in the past. Some of the houses surveyed were more than 150 years old. These buildings are relatively stronger than the conventional rectangular buildings".

These quotations show that incorporation of earthquake-resistant elements in building construction was prevalent in the different parts of Nepal as Solukhumbu is located in the Everest region of Nepal, while the Kali Gandaki Valley lies in central Nepal and the Gurungs and Magars are the local ethnic groups spread over the entire central Nepal from its east to west.

It is axiomatic to conclude that a more systematic study would reveal more details of the seismic resistant techniques adopted and ingrained in the local practice of building construction.

The following section provides a summary of the earthquake-resistant elements found in the traditional building typologies. The authors must caution that that all of the positive elements are found on a single building, but even when employed separately, these elements do seem to provide increased resistance to the individual buildings to withstand the earthquake loading.

OBSERVED EARTHQUAKE RESISTANT ELEMENTS

1. Symmetric Configuration: Most of the traditional buildings are rectangular in shape. These simple configurations in plan make the building more stable.
2. Small length to breadth ratio: In most of the buildings the length to breadth ratio was found 1.5 or less. (BCDP)
3. Symmetrically Located Small Openings: Openings are found relatively small and symmetrically located. The small openings increase the length of the façade and substantially increase the stiffness of the building.
4. A low floor-height and a limited number of stories: In all cases the storey height was found less than 2.5 m and the number of storey limited to 2 story (BCDP).
5. Wooden bands: In temples wooden bands around the building at sill level, lintel level and at the floor level can be found curved as "Naga". These bands protect the walls from out of plane failures as well as provide integrity between different structural elements by connecting orthogonal walls.
6. Vertical Post at corners: These vertical posts at corners act as vertical tensile reinforcement. These protect the building from damage due to tensile cracks in the building. In some cases they provide some redundancy in the system which is very useful to withstand earthquake force.
7. Wooden Corner Stitch: In addition to wooden bands, corner stitch can be found which connects orthogonal walls and protects from separation at corner.
8. Wooden Pegs: Proper connection of all wooden elements by wooden pegs can be seen in traditional buildings, which helps for proper connection of roof and floor with wall as well as the different elements of roof or floor.
9. Boxing of openings by wooden frames, either all around or along both edges of the masonry wall provided strength around the openings.
10. Use of wooden wedges, carpentry joints (dovetailing etc.) provided passage for easier energy dissipation.

RECENT STUDIES VERIFIED THE EFFECTIVENESS TRADITIONAL CONSTRUCTIONS

An assessment of different typology of buildings using micro-tremor measurements was conducted as a part of the Study on Earthquake Disaster Mitigation in the Kathmandu Valley, the Kingdom of Nepal, by team led by Japanese specialists, JICA [4]. The survey results conclude, - "Traditionally-made Brick-in-Mud structures are stronger than expected and (they) will not … generate pancake destruction like (reinforced concrete) RC frame structure (would). These results lead us to conclude that over 40% (of the) traditional masonry remained (unaffected seriously) in (the) 1934 earthquake, even in the strongly shaken area. Furthermore, the court-yard building with symmetrical shape is considered strong."

The result was accepted by the elder generation of people in Kathmandu as natural.

IMPORTANCE OF SYSTEMATIC STUDY OF TRADITIONAL BUILDINGS

Many good, spontaneously-developed, technological features have been observed in the indigenous communities. But they lack comprehensiveness and widespread coverage. Measures against earthquake hazards have been observed in some cases. However, the reasons behind these measures are largely unknown to the builders. Such developments are extremely difficult for individual and collective comprehension and subsequent application.

REMEMBERING WHAT THE GRANDFATHER SAID

Everybody was happy at the smooth pace of construction works at Bhuwaneshwory Lower Secondary school. NSET was assisting the local community to retrofit the existing brick masonry building that was about 15 years old. NSET engineers were happy that the masons were bending the bars and laying the bricks exactly as they instructed. But they were glad also because the mason earlier asked, "O. K. Sir, we do as you instruct. But could you please explain why you want things this way and not the other way. Please explain the difference." That was the demand for training, the NSET engineers understood, and started the mason-training program.

Classroom lectures for the masons started being held in the evening, in one of the classrooms of the school. The classes were visited not only by the masons, but also by parents and elderly people.

One evening, an elderly person attended the lecture. He was given special seat at the front as everybody respected him. He was the oldest mason, already in his eighties.

At the end of the lecture, he told the NSET engineer how his grandfather taught him the skills of building construction. He summarized:

- Always put a wooden (tie) band around the building at sill level, lintel level and at the floor level. Carve it in "naga" (snake). It will protect your house.
- Secure every third or fifth or seventh joist to the wall plate by driving a lock wedge driven through the joist.
- Multistory high buildings, Arches, existence of numerous windows, brick wall without good "teeth joints", use of brick pieces in the middle of wall width, masonry wall without bands, buildings with heavy upper stories, building in mud mortar are relatively weak.
- For larger buildings, the quality of materials is as important as the quality of construction. Better to consider both.
- For smaller, low-cost dwellings, 1) do not make more than 1 story if constructed with a combination of burnt and un-burnt bricks, 2) dress the stones for construction of stone-masonry buildings in the hills, 3) make the roof as light as possible, 4) use lime mortar for bricks, 5) limit height of brick masonry buildings to 34 hat (50 ft), 6) assure good connection between walls at joints, the whole house should behalf like one structure during an earthquake, 7) construct in one wyeth rather than using pieces to increase the wall section in masonry construction, , 8) avoid columns in brick masonry; better use a timber column
- Build at those places where the past earthquake did not have much affect
- Dig the foundation right up to the rock

The young NSET engineer asked himself a question – who is teaching whom?

The good experiences can only be built up by a systematic summing up of the experiences of generations. This requires a systematic study.

Such study, exploration and analysis are necessary not only because people continue living in such traditional constructions and therefore continue building such construction in the foreseeable future, but also because several of the building typologies are not fully understood and described, and that it is necessary to make statement on seismic stability of such buildings. It is a paradox that the 3-4 storied buildings in bricks and mud mortar, which are standing in the developing world for centuries; do not have adequate methodologies for appropriate design and analysis while such methods are available for 30-storey high buildings!

Additionally, it has been found that improving seismic resistance of buildings is much easier if the interventions are acceptable to the society. Acceptability of safer building construction can not be

achieved unless one has developed a sound scientific basis by studying the vernacular building practices in details. Such study is necessary also to preserve the cultural heritage of a society: historical monuments of seismic countries should be given special attention for safeguarding them against earthquakes. Scientific authentication of seismic behavior is needed before propagating or revitalizing the traditional concepts – it should not be a blind copying process. Affordability, acceptability, and the ease in implementation as well as in communicating the knowledge should perhaps be some of the criteria for selecting the concepts for scientific researches.

To assess strength and stability and likely response to a future earthquake, much information is required about the properties of materials and structural elements, and suitable methods of analysis must be available. Some of the fundamental studies desirable in the short term are:

- Development of more realistic methods of analysis of traditional indigenous buildings.
- Measurements of dynamic responses to assist in estimating periods of vibration and damping characteristics.
- Strengths test on materials and structural elements.
- Chemical and other necessary tests to assess the characteristics of the materials used in the past and the long-term compatibility of the materials.

Such studies for specific societies and communities with typical building typologies and traditional construction practices are necessary also to avoid confusion in decision-making process in the reconstruction phases after an earthquake.

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