論文の内容の要旨

ABSTRACT OF DISSERTATION

Introduction of New Housing Method in Nepal Following the Vernacular Method Hybrid with 2×4 Technology Transfer from Japan

在来工法と日本型 2x4 技術の融合に

よるネパールにおける新たな住宅工法の導入可能性

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Nepal, the Federal Democratic Republic country, is a small, landlocked country, isolated in the Himalayas, with its two dominant neighbors China and India in the north and south. Nepal lies in between latitudes of 26 and 30 degrees north and longitudes between 80 and 88 degrees east, with the area of 147200 square kilometers and extends approximately 145-241 km. north to south and 850. Km west to east. Although Nepal is very small in area just 0.1 % of the earth's surface, it is richest countries in the world in the terms of bio-diversities due to its unique geographical position and altitudinal variations. The altitude of the country ranges from less than 100 meters above sea level in the Terai, to the highest point of the earth, the summit of Mount Everest as 8,848 meters above the sea-level.

Nepal occupying the central most part of the Himalayan region that lies on the northern part of Indian tectonic plate is seismically very active. Annually thousands of tremors of various intensities occur in this region. History shows that Nepal has hosted several large earthquakes in the cycle of hundreds years or less, and it is pity to say that the settlements in Nepal are still non-engineered and hardly few percentage of houses are earthquake resilient buildings. Recently in 2015 Gorkha earthquake of magnitude 7.8 has hit in the eastern part of Nepal. The severe impact of 2015 Gorkha earthquake is reflected in terms of 8790 causalities, 22300 injuries and 498852 houses completely or partially collapsed and other 256697 houses partly damaged *((NPC) National Planning Commission, Government of NEPAL, Vol B: Sector Reports, Nepal Earthquake 2015)*. On the other hand, Nepal consists of 83% rural population and about 90% of total houses in Nepal are non-engineered constructions which prove the huge existence of Vernacular non-engineered residents (*Central Bureau of Statistics (CBS); 2012*).

Thus the contemporary architecture and building technology of modern reinforced concrete houses as well as unreinforced masonry and adobe houses in Nepal are being criticized after the failure in each earthquake in the past and huge losses was noticed during natural calamities. On the other hand, unreliable and inefficient settlement of haphazard residential buildings need to be revised in the organized way for the development of society with comfortable and safe dwellings for the future generation.

In a contrary, most of the Vernacular architecture which still stands after several earthquakes in the past has proven its resistance against the earthquake. Vernacular architecture is the result of hundreds of years of experiences and optimization to provide a comfortable shelter in their respective environment. The Vernacular houses are built with locally available building materials, with known construction technologies utilized by local craftsmen based on their building experiences and skills. While looking back to the history contemporary architecture of Nepal mainly centralized in the capital has been highly influenced by foreign architecture. In around 1876 while Rana rulers traveled to Europe they brought home the classical and French renaissance architecture to capital. These imported architectures slowly were spread to other parts of Nepal hence standing as an identity for status and modernity. After many decades the introduction of reinforced concrete in 1950s from India, was a symbol for transition from traditional to modern society replacing the brick walled, stoned, wooden and thatched houses made of local materials into block and RC structures. This marked the transition period for residential housing from traditional to so call modern in the society of Nepalese people. Throughout the world, Vernacular housing constructions are significantly occurring and their rational and resilient features are nowadays more recognized in terms of sustainability (*Oktay, D., and Pontikis K, 2008; Jordan, P., and O'Neill, S 2010*). Non-engineered Vernacular dwellings exist in most part of the worlds and thus there have been many study going on and been done in finding out the structural and architectural properties of indigenously constructed Vernacular buildings like in Nepal old monuments, temples and even the Newari houses are being studied.

However, in this study, the Vernacular architecture of Nepal in three different geographical regions the High-hill, Mid-hill and the Terai (plain) region have been surveyed, studying their structures, building materials and the technology. Its geographical diversities that has resulted in large climatic variations from hot sub-tropical climate to extremely cold climate has been a cause for variety of unique architectural buildings with unique cultural expressions in different ethnic groups. The first and foremost factor influencing the Vernacular construction practices is related to the availability of local building materials. As Nepal is geographically diverse, local building materials also differ accordingly though wood has been and is still the most frequently used materials. For example, Adobe (mud blocks

or whole walls), Masonry (stone, clay, or concrete blocks) and timber, frequently, a combination of materials has been used in the construction. The another determining factor is the building layout, that is, the typical shape of a building plan, usually related to many cultural, historical, geographical and urban planning traditions. The building layout also varies according to the altitudinal variations, which proves the experiences of the locals, regarding their comfort and suitable dwellings on the basis of their climatic variations.

In low plain regions of the sub-tropical region the single row of houses along the road with wide-open yard in the front and undivided spatial form, the high ceilings facilitate the easy penetration of air throughout the house. Likewise, the Vernacular buildings in Mid-hill regions are aligned linearly in east-west direction along the contour lines so as to protect from cold wind from the northern Himalayas. Houses in Dhampus, one of the villages in Mid-hill regions are compact, rectangular and oval shapes. Though the houses made of stone masonry incorporated with timber frames have revealed several earthquake-resistant features in its traditional flavor, they are still unsafe for living due to non-engineered constructions and their heavy weighted roof structure. In the region of High-hill areas just below the mountains, where the temperature is very low throughout the year, the buildings are closed round shape with few windows and wood as the main building materials so as to keep the temperature inside of the house suitable for comfort living. In the district called Rasuwa in High-hill region, most of the dwellings are of wooden structures with stone foundations beautifully decorated with colors and paintings of traditional values. The structures are built by post-beam elements whereas the walls are built in mixed varieties, some are stone walls while most of them are local wooden cladding. During past earthquakes these buildings have shown less damages suggesting high resistance against the seismic forces. However, lack of insulation, gaps/openings on the walls, inefficient doors and windows, the indoor environment is not preferable for severe cold during the winter season in such mountainous areas.

In most of the Vernacular structures, traditional timber frame buildings are built where structural and finish elements fit together using complex wooden joinery. On site, these components are tightly fit together using traditional equipment like hammer, saw and wood peg that last for centuries. In Vernacular housing, post-beam method used frequently in Nepal. Post and beam used as the only structural system connected by wood pegs that put onto the holes in mating frame elements has stiff connection.

After surveying and studying in detail of the Vernacular structures, I found that the technology has been inherited from the past with the experiences from the resistibility during the past earthquakes for timber framed structures while the vulnerability of adobe and masonry structures to earthquake still

exist. However, these vernacular buildings have not been revised to upgrade and withstand the more powerful seismic forces, meet the modern living style and fulfilling the criteria for comfort dwellings.

Here in this study proposed and introduced HYBRID house is a "A residential structure that developed a theory of hybrid construction method of Nepalese Vernacular technique of post and beam with 2×4 wooden frame structure transferred from Japan. This was executed solely to preserve the traditional technique of building, which has been proven to have earthquake resilient features in the history of Nepal."

Hybrid house was found to be defined by several authors, builders, researchers etc. in their different concept. Among them some are as follows: "A residential structure which contains both residential and business spaces for different activities; residents of that structure occupies and manages both spaces; and such housing is intentionally designed to incorporate both spaces" (*Ahrentzen, S; 1991*).

In Japanese Building Code the term Hybrid has been addressed which indicates the various forms of construction techniques adapted in Japan. First is hybrid of construction technique, blending post & beam with plate form-frame. The second is for mixing materials, such as concrete ground floor and wood-frame upper floors, *(Christopher Gaston; 2004).*

Thus to carry out the concept of the hybrid house in this project, Nepalese Vernacular technique of Post and Beam wooden house integrated with Japanese 2 by 4 shear wall panel method is introduced in order to build structurally workable and viable house in Nepal. The traditional prefabrication of the timber frame, essentially precuts, was being replaced by site assemblage of factory-produced studs. The light-frame wooden-panel of height 2,440mm was made of studs of 38×89mm with spacing at 455mm distance, with structural sheathing in the inner side of the panel with Gypsum board (12×910×1810mm) with help of screw. Glass wool (t=60), as insulator is sand-witched in between inner and outer panels. The full width (=910mm) of Gypsum board panel was placed along the wall volume and then nailed to the beam and post. In this wooden panel of light-frame with structural sheathing used, post-beam frame structure acts as vertical load; whereas, shear wall components such as 2 by 4 lumbers act as horizontal shear forces. These structural members were joined and connected by precut locking system and steel connector (t=6mm). For the roof, locally available stone slate and aluminum sheet is used and between the slates there is sheet used to waterproof gap. This dual structural system: Post and Beam structure and shear wall paneling is considered to be feasible hybrid timber structures incorporated to build earthquake resilient Hybrid model house for the first time in Nepal incorporating the modern facilities to provide the minimum standard of living as defined by the UN habitat which are lacking in most of the present dwellings of Nepal.

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