SEISMIC SAFETY IN OWNER-BUILT BUILDINGS

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SUMMARY

Nepal has a history of recurring earthquakes which lead to periodic death and damage. The extent of damage is high because the majority of buildings in Nepal are built without considering seismic safety requirements. More than 98 % of the buildings in the country are *owner-built*. Building permit systems do not exist in rural areas. In municipal areas, some rules and building permit systems exist, although these are not effective. Qualified civil engineers and technical support professionals are concentrated in urban centres but the majority of the urban population also perceives their services to be unaffordable. In both urban and rural areas, traditional craftsmen without any training in seismic safety play pivotal roles. Modern materials and skills are unaffordable or inaccessible. These constraints are incompatible with the introduction of stringent standards for seismic safety. Even in accessible areas, where modern materials are used, seismic safety provisions are not incorporated in owner-built buildings.

In response to the 1988 earthquake, a National Building Code Development Project (NBCDP) was formulated which prepared a building code for the country. The code attempts to address the structural safety of all types of buildings. It includes the prevailing construction types and materials, following simple criteria based upon height, number of storeys and configuration. Its formulation was guided by the need to suit low economy; lack of trained manpower, low awareness levels, and limited accessibility. Enforcement of stringent rules, or even a requirement that there be professional advice for the design of small buildings, would be inappropriate. The code prescribes simple practices to be adopted in building construction to meet requirements for seismic safety. These may involve nominal additional cost. To achieve progressive improvement, the code provides for regulating pre-engineered buildings made of modern materials (fired brick in cement mortar, reinforced concrete buildings) and non-engineered buildings made of traditional materials (stone, wood, earth, etc.) within its main body. In addition, associated documents recommend a framework for introducing and implementing codified provisions by focusing on the capacity-building of professionals, enforcing authorities and regulating bodies.

THE NATIONAL SCENE

A majority of Nepal's 21 million population live in rural areas in owner-built buildings, mostly inaccessible by vehicular means. A high illiteracy rate (60 %), coupled with low income levels, has resulted in poor awareness of seismic safety. The average per capita income of about US $ 210 is severely skewed in favour of urban households (NASC, 1997). The low per capita income and low proportion of cash income affect people's access to modern building materials and technical services for building construction. The problem is further aggravated by a lack of transport facilities. In remote parts of the country, the cost of foreign materials is five to six times higher than the cost at their origin due to the high cost of porterage.

According to the Nepal National Housing Survey, 1991, there are three million dwelling units in the country. Of these, 2.7 million (90 %) are in rural areas where there are only domestic buildings. Approximately 94 % of families, irrespective of income status, own their own dwelling. In urban Kathmandu Valley, the owner-occupancy rate is 66 % (HMGN/MHPP, 1991b). While the ownership and distribution of housing presents a fairly satisfactory

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picture, in terms of physical quality (NASC, 1997) these buildings have poor seismic safety aspects (HMGN/ MHPP, 1994d). More than 98 % of these buildings are owner-built (HMGN/ MHPP, 1991b). The artisan plays a pivotal role in construction.

On the other hand, some of the largest known earthquakes: Great Assam (1897), Kangra (1905), Nepal-Bihar (1934) and Assam (1950) (all earthquakes of magnitude greater than M 8) have occurred in the Himalayan region in the last hundred years (Gaur, 1993). In 1993, the Seismic Hazard Mapping and Risk Assessment for Nepal identified some 92 active earthquake sources in Nepal and in the area extending 150 km beyond the territory of Nepal (HMGN/ MHPP, 1994c). The hazard analysis shows that many of them can trigger catastrophic earthquakes of magnitude larger than M 8. The 1934 Nepal-Bihar earthquake, a single event of magnitude M 8.3, caused the loss of 8519 lives, and the destruction or damage of 207 000 buildings (Rana, 1936). Similarly in 1988, in the magnitude M 6.4 Udaypur earthquake, 721 people lost their lives and some 66 000 buildings suffered destruction or damage. These examples clearly call for some sort of basic minimum seismic safety requirements to be incorporated in owner-built buildings through innovative, simple, codified provisions.

OWNER-BUILT BUILDING CONSTRUCTION PRACTICE

The informal sector of owner-builders produces at least 98 % of the dwellings in Nepal. These efforts are characterised by their individualised decisions. Owner-builders also seek advice from friends and neighbours. Professional advice is rarely sought (even in urban areas) and, if solicited, is limited to the preparation of submission drawings for municipality permits. The owner himself deals with materials, suppliers and issues of labour contracts. The owner-builders tend to do as much themselves as possible to keep costs down. The labour input by owners themselves is high in rural areas. Even quite a “poor” household constructs its own house in rural areas.

The traditional artisans play pivotal roles in construction activities. They provide overall technical and organisational support. In most cases, these craftsmen get on-the-job training from their elders or seniors, and skills are transferred from generation to generation.

BUILDING TYPOLOGY

The building typology is governed by the use of indigenous materials and technology in rural areas of the Terai (plains), hills and mountains. The traditional dwelling is a hut made of bamboo, wood and mud; or a load-bearing masonry structure made of earth, adobe, stone or brick in mud mortar; or a timber-framed structure. Cement and steel were introduced in the 1950s. Their use is increasing, but is limited to accessible urban pockets and to areas where the economy is relatively better. Two distinct building typologies are dominant in owner-built buildings:

Traditional Building: Mountain and hill dwellings are built of stone in mud mortar, and often without mortar. Walls are thick and openings are limited. Fired bricks and adobe are common walling material where stone is not available. Most of the houses have between one and two and a half storeys. Height is low at around 1.8 to 2.1 m. Floors are generally made of a thick layer of soil on a timber structure. Roofs are generally duo-pitched with gable walls at their ends. Roofing material is thatch, tile, corrugated iron sheet (CGI) or slate over mud supported on a timber structure. CGI sheeting is a new proposition and is rapidly replacing other roofing materials. Houses in rain-shadow areas in the mountainous region have flat mud roofs. Traditional houses on the Terai plains are one-storey huts made of bamboo with wattle-and-daub walls which are plastered with a mixture of cow dung and mud. Their roofing is generally made of thatch or tiles, but CGI sheet is rapidly replacing other traditional roofing materials. Other house types include wooden, adobe and brick houses, one to two storeys high, with lime or concrete floors and a roof supported by a timber structure. Dwellings constructed of loose timber frames, with timber floor and cladding and tile or CGI sheet roofs, are also common close to forests.

Buildings built with Modern Materials: There are two different types of owner-built buildings in this category. They are (a) modern load-bearing masonry buildings and (b) reinforced concrete framed buildings. Buildings with 230 to 250 mm thick load-bearing masonry walls are generally constructed of fired brick or stone in cement mortar and these walls are mostly unreinforced. Floors are made of timber, cast-in-situ reinforced concrete (RC), or reinforced brick and concrete (RBC) slabs. Roofs are made of CGI sheeting or tile on a timber structure, cast-in-situ RC, or RBC slabs. Reinforced concrete framed or hybrid types of structures are emerging in recent times in central core urban areas with scarce space. These buildings use RC beam-column frames and RC slabs. Unanchored brick or stone or block walls are placed randomly in two directions. In upper storeys, cladding and partition walls are commonly of half-brick, and ground floor cladding walls are one-brick thick.

Owner-built buildings in Nepal use various types of wall and flooring/roofing materials. Their relative use is given in Tables 1 and 2.

Table 1

Walling material Region	Soil, or Soil + Stone	Soil + Wood, Soil + Bamboo, Soil + Thatch	Wood or Bamboo	Fired Brick	Adobe	Concrete Block	Others
Himal Rural	88.5	6.0	1.7	3.8	0.0	0.0	0.0
Hill Urban	31.9	5.0	1.7	55.5	4.9	1.7	0.3
Hill Rural	88.3	7.8	2.4	1.0	0.3	0.2	0.0
Terai Urban	19.4	61.1	8.5	28.4	3.6	0.7	0.5
Terai Rural	19.2	60.6	7.3	6.9	3.7	0.1	2.2

Source: HMGN/ MHPP, 1991b.

Table 2

Roofing material Region	Thatch or Straw	Mangalore or Concrete Tile	Traditional Tiles	Soil + Stone, Soil + Wood	RCC or RBC	CGI Sheet	Asbestos or Tin Sheet	Others
Himal Rural	26.2	0.0	0.0	50.4	4.1	11.5	4.5	3.3
Hill Urban	3.1	12.0	1.4	1.4	34.3	41.6	5.4	0.8
Hill Rural	38.6	1.2	0.2	6.9	1.2	36.3	4.4	11.2
Terai Urban	27.4	1.7	10.8	1.0	20.8	15.9	5.4	21.0
Terai Rural	71.9	1.8	22.7	0.4	1.1	0.6	1.0	0.5

Source: HMGN/ MHPP, 1991b.

VULNERABILITY ANALYSIS

The existing owner-built building stock suffers from many weaknesses due to poor technology and improper use of construction materials. The traditional buildings have, to some extent, configuration problems, but mainly lack structural integrity in their components. These buildings inherently use weak construction materials. Even buildings with modern construction materials which have received architectural design input, suffer from serious configuration problems. A lack of integrity in structural components, under-sized structural sections and anchorage problems are also common in these buildings. Good construction processes are often disregarded. All these factors have made a majority of the building stock vulnerable – to a degree that even a small seismic event can cause severe damage. The recent Ms 6.5 magnitude Chamoli earthquake that hit the Garwal region in India led to severe localised damage in traditionally-built village buildings within Nepal as far as 140 km from the epicentre.

The National Building Code Development Project (NBCDP) developed vulnerability functions for different groups of buildings in Nepal for carrying out quantitative vulnerability assessments. The development of these functions was based on building damage data from the Manjil (Iran) earthquake (HMGN/ MHPP, 1994d). A nation-wide detailed survey of 54 representative buildings in Nepal was carried out for this purpose. The buildings were grouped and their relative strengths and weaknesses were analysed. The findings were compared with the data from the Manjil earthquake and the functions were adjusted for building stock in Nepal. These functions are shown in Figure 1.

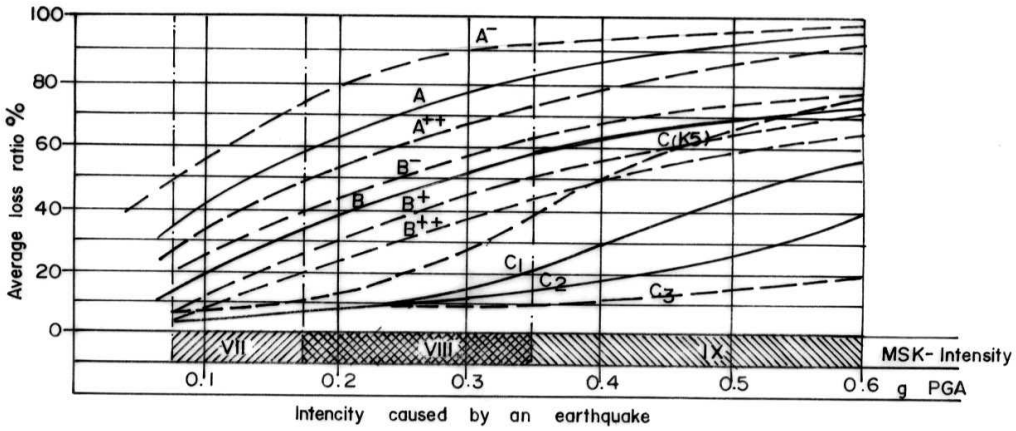

Figure 1

(Note: Damage ratio is expressed in terms of economic loss to a single building unit with respect to its reconstruction cost).

A = Buildings in field stone, rural buildings, adobe house, mud house (1 to 1.5 storeys).

A- = A-type building but with 3 storey height (2 storied in between A and A-).

A+ = A-type clay buildings but with horizontal and vertical timbers incorporated.

B = Buildings with mud mortar, ordinary brick, large blocks, natural dressed stone or half-timbered buildings with height up to 1 to 1.5 storeys, or with cement mortar in brick masonry and height up to 3 storeys.

B- = B-type rural buildings with traditional materials and height up to three storeys, or brick masonry buildings in cement mortar with large openings with irregular plans and height up to five storeys.

B+ = B-type rural buildings with improved configurations in case of rural buildings, or brick masonry buildings in cement mortar with compact plans, permissible openings and height up to three storeys.

B++ = Strengthened initially, or retrofitted as for earthquake-resistant brick buildings of B, B-, B+

C1 = Strengthened good quality brick buildings in cement mortar (with seismic reinforcement, up to 3 storeys)

C2 = Normally designed Reinforced Concrete (RC) buildings (designed for normal load only) or mason-designed 3 storey RC buildings (Kathmandu Valley)

C3 = Specially designed RC buildings.

C(k5) = Mason-designed 5 storey RC buildings (Kathmandu Valley).

Figure 1 : Vulnerability Functions

(Source: HMGN/ MHPP, 1994d.)

THE NEPAL NATIONAL BUILDING CODE

The NBCD Project worked under the general philosophy that, in the prevalent socio-economic condition in Nepal, it would be impractical to enforce any standard that required 100 % engineered buildings. Even soliciting the advice of engineers is difficult. The need is to move from non-engineered to pre-engineered and then to 100 % engineered buildings in the long run. Subsequently, different sets of standards were prepared to cater specific needs of different

building types. The application of these standards is divided into four levels depending on importance and location of the buildings, and level of capability required for design and construction. These are:

i. International state-of-the-art

ii. Professionally engineered structures

iii. Rule of thumb

iv. Guidelines for rural construction

The National Building Code (NBC) emphasises pre-engineered as well as non-engineered owner-built buildings for the safety of the majority of the people. It has therefore included several innovative documents on the seismic safety of such buildings in its main body (HMGN/ MHPP, 1994a).

IMPLEMENTATION PLAN FOR REACHING THE OWNER-BUILDERS

The NBC has placed a focus on owner-built buildings. Almost 100 % of owner-built buildings are constructed without considering seismic safety. The technology for improvement is available, the need is felt by the concerned authorities is felt, but there is an unbridged gap between the technical know-how and owner-builders. It is not an easy task to bridge the gap and convey solutions to owner-builders. Scattered settlements, inaccessibility, non-affordability and obscurantism are barriers for change. In order to bring about changes in traditional construction practices, it is necessary to change the mindset of traditional/ local masons and craftsmen who historically have been the trusted partner and construction advisor to the owner-builders. They are the vehicles for change. For reaching the owner-builder, the NBC implementation plan, which outlines the requirement for institutional, legal, and training and awareness-raising frameworks, divides buildings into two groups: urban (accessible) and rural (inaccessible).

RURAL CONSTRUCTION GUIDELINES

The NBC has Rural Construction Guidelines in order to address the requirement of non-engineered buildings built with traditional materials for rural as well as urban areas. These guidelines encompass buildings with traditional/indigenous materials, which are not subjected to modern quantitative analysis and design. The guidelines are based on the analysis of some 50 typical, prevailing, traditional building types. The guidelines include low-strength masonry and earthen buildings and are aimed at advising the local masons, craftsmen and owner-builders. The stress is on simple improvements that should be made to current practice to improve the seismic resistance of buildings. These improvements can be incorporated without making significant changes in building practices, and at nominal cost.

These guidelines have been conceived to be advisory for rural areas where the building permit system is not in place. Where such a system is in place, such as in municipal areas, these guidelines become mandatory. The emphasis, therefore, is to get these guidelines implemented by both formal and informal processes.

For buildings built with modern materials (e.g., cement, reinforcing steel), whose permit drawings are mostly prepared by sub-professionals, architects and general civil engineers, a set of "rules of thumb" have been developed. Owners not wishing to employ professional structural designers can benefit from these "pre-engineered rules". These rules contain requisite structural data, dimensions and detailing of structural members satisfying basic seismic safety needs, which could be easily adopted at site.

The thumb-rules are applicable to buildings not exceeding certain simple criteria such as height, configuration, number of storeys, floor area and occupancy. Further limitations are in terms of span, sizes of members and positioning of earthquake-resistant elements.

PRIORITIES IN THE RURAL SECTOR

In the rural sector, the plan recommends giving top priority to schools and health posts when introducing seismic risk measures in inaccessible areas. It further advocates that the measures be achieved, not by using imported materials (cement, reinforcing bars) and related skills, but rather by improving the quality of construction through adopting seismic resistance construction techniques using local traditional materials and skills. This is the basic concept behind the recommended rural construction guidelines. This will set in chain demonstrations for local craftsmen, owners and builders, instil confidence in the adopted technology and generate wider acceptance at the community level.

ROLE OF GOVERNMENT DISTRICT OFFICES IN RURAL SECTOR

The plan identifies the district level office of the "Department of Housing and Urban Development" as the focal point for promoting the concept of safer construction practices at a rural scale. This department has historically been entrusted to act as the designer and the supervisor for construction, rehabilitation, repair and maintenance of district-level public buildings. In addition to this traditional responsibility, the district office is expected to play a more pro-active role in the research and development of seismic-resistant construction technology, including survey, documentation and analysis of positive aspects of traditional construction techniques prevailing in the area of its jurisdiction. This information is to be shared, with other focal points, at various district and central levels in order to assimilate it for the production of do-it-yourself manuals, guidelines, posters, etc. for promoting their application. The district office is also expected to organise awareness and training programmes at various levels and to mobilise the support of NGOs and INGOs working in the district for this purpose.

The co-ordination of district-level line agencies, local administration and district and village-level authorities is yet another task envisaged within the implementation of seismic safety plan. This will ensure that seismic resistance construction techniques are incorporated in all their development endeavours, and that local craftsmen get an opportunity for on-the-job training to enhance their skills. It will also establish networking with other international sister bodies who have similar responsibilities, commitments and vision. International and national networking is expected to provide recognition for the works, exposure and opportunities for participation in appropriate national and international forums. From this will come a continuing education programme, training and higher education in the field, as well as short-term work opportunities abroad which are an indirect motivation package for the focal point staff.

REACHING OWNER-BUILDERS IN URBAN AREAS

Efforts to reach owner-builders in remote and rural areas are basically aimed through a bottom-up approach. The process and approach for the urban areas are basically the same, except that the target group is more accessible. Because a building permit system will exist in some form or level, introducing seismic safety considerations may at first glance appear to be simpler. Also, it is understandable that an outsider might assume that the building construction process in an urban area is more formal and organised, and that the industry is stronger. However, in reality, except for a few larger private buildings, the construction process for owner-built residential buildings in urban areas in Nepal is still informal - with the builders themselves taking the lead in construction organisation and management. The recommended plan therefore takes into account these realities.

It has been proposed that owner-builders in urban areas be reached by multiple means of formal and informal processes. The formal process includes enhancements/ improvements to incorporate strength aspects into the building permit system. It also includes a provision for the regulation of the design professions by means of an Engineering Council Act. Other features are a peer review system, listing and licensing by municipal authorities of all designers responsible for the preparation of the design of such buildings, and the training of the listed designers in design and construction for seismic resistance.

Those professional societies who participated in the revision of the municipal by-laws played key roles in introducing strength aspects to the overall building permit process. The new provision now requires the designer to submit structural design drawings for all buildings whose plinth areas are more than 1 000 sq.ft. Provision for compulsory inspections at pre-defined stages of construction to ensure that construction is carried out in accordance with the approved design drawings is an additional milestone.

ROLE OF DESIGN PROFESSIONALS IN URBAN AREAS

Since overall capacity-building at the professional level will have a positive bearing on the quality of design and construction (including on the owner-built buildings), self-regulation of the professions is important. The government has recently enacted the "Engineering Council Act".

The recent enactment of the "Building Act" by the government (following the recommendation of the plan) is yet another positive aspect. Even though acts and regulations alone can not bring about changes in the traditional mindsets of the owner-builders, this enactment could, nonetheless, prove to be a powerful tool in regulating design and construction to the requirements of the building code.

Graduates of academic institutions, vocational training centres, trade schools, etc., are the ones who will be shouldering future responsibilities at different levels in the profession and industry. The plan strongly recommends the incorporation of seismic-resistant design and detailing, as well as guidelines/manuals, in their regular curricula.

The informal processes encompass a host of measures promoted/propagated indirectly though various players in the field. They may not appear to have a direct say in the overall enhancement of quality for safety, but they are influencing the processes to a great extent.

ROLE OF PROFESSIONAL SOCIETIES

Many professional societies in Nepal including NSET - Nepal (Nepal Society of Earthquake Technology) are playing a positive and lead role in propagating the concept of seismic-resistant design and construction – to grass-root communities and to policy levels. The celebration of the first "Earthquake Day" in 1999 and participation in it by high-level government officials (including the Prime Minister, members of a wide range of organisations, school children, national and international non-government organisations, etc.) is an example of how professional societies can be instrumental in bringing about the required changes. The message propagated on Earthquake Day was loud and clear – "Safety from Earthquake Disaster".

NSET, in particular, has been instrumental in advocating the issues related to general and specific seismic safety requirements, including owner-built buildings. Through a partnering approach with various organisations and stakeholders, it is supporting the launching of public awareness programmes. These include : conducting training programs at community levels; integrating seismic resistance into the process of new construction; increasing the safety of school children and school buildings; improving the seismic performance of existing buildings; and increasing the experts' knowledge of the earthquake phenomenon, vulnerability, consequences and mitigation techniques. It is worthwhile noting that NSET was conceived and launched during the course of formulating the NBC and developing the management plan for its introduction.

The NBCDP implementation plan also suggested that the municipal authorities should start a process of listing chief masons, bar-benders and labour contractors in order to reach them – firstly, for providing training in seismic safety construction techniques and, secondly, for issuing license to operate in the urban areas. Since labour contractors, chief masons and bar-benders are the ones who mostly undertake the construction of owner-built buildings and under whose advice owner-builders mostly operate, the training and licensing system once introduced could prove to be a good beginning in this direction.

ROLE OF FINANCIAL INSTITUTIONS

Commercial banks and insurance companies are to be encouraged to recognise the enhanced security of building assets constructed or retrofitted with satisfactorily seismic resistance. Similarly, insurance companies are being urged to differentiate between buildings constructed with and without adequate seismic safety for determining the premiums.

CONCLUSION

Earthquakes in Nepal are recurrent. High casualties and destruction and economic loss result from unsafe buildings. Inherently weak materials, their improper use and poor technology/skills make owner-built buildings unsafe.

Locally available materials will continue to be basic building materials for the majority of buildings in Nepal. The seismic safety of buildings has to be improved by better use of materials, improved technology and skills on one front, and by legal enforcement and awareness raising on the other. In technological aspects, the local craftsmen play pivotal roles. Technicians and engineers have little control over the construction of owner-built buildings. Proper training of a craftsman can built his confidence in using the technology and skills necessary to construct safer buildings.

A National Building Code has been developed which specifically addresses the needs of the owner-builder in both the rural and urban environments. The implementation plan developed at the same time proposes both top-down (legal and regulatory frameworks) and bottom-up (indirect influence) approaches and processes to cover both these environments. These acknowledge the realities of the difficulties in bringing about a quick change to traditional practices, particularly in rural areas. However, they are sufficiently pragmatic to ensure existing structures and resources can be used to effect immediately.

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