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STANDARD DESIGN FOR EARTHQUAKE RESISTANT BUILDINGS AND AID TO BUILDING CODE IMPLEMENTATION IN NEPAL

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ABSTRACT :

Main source of earthquake risk in the developing countries are absence of earthquake resistance elements in buildings and low level of awareness despite the fact that the knowledge required for improving seismic performance of building is available since long. A majority of buildings are still being constructed without any consideration of earthquake forces, making them highly vulnerable to earthquakes. Buildings are usually constructed by informal processes led primarily by local masons, petty contractors and house-owners, who are not formally trained in academic environment. For earthquake safer communities, all individual buildings need to be designed for earthquake resistance. However, it is not feasible to design structurally all buildings because of cost involved, lack of trained manpower for earthquake resistant design, and construction. Likewise, growing urban population and unplanned development of new urban centers are the cause of increasing risks.

For making communities safer, all new constructions need to be earthquake resistant and should follow the provisions of building codes. However, it is not affordable to the common people to have there buildings designed as per requirements by professional engineers. On the other hand, common residential homes have many similarities, common features like small plan area, average 2-3 stories, and construction materials. Such buildings can have similar designs that can be presented as standard design templates so that common people simply use such designs for making their houses. This study was carried out for developing a standard design set of buildings under the ProVention Consortium Applied Research Grants for Disaster Risk Reduction.

This paper presents the approaches and methodology used for arriving at the ten most prevalent building plans development, dissemination strategies and recommendations to all stakeholders. The distribution of standard design sets of documents to the communities, the social workers and disaster related organizations as an awareness tool will create the demand for earthquake-resistant construction and beneficial to all who are directly involved in construction industry, house owners and even policy level personnel. A survey for the use of this templates and contribution towards improving seismic performance of new buildings will be under taken in near future.

KEYWORDS: Earthquake-resistant, Non-engineered, Disaster Risk, Standard Design

1. INTRODUCTION

Experiences in recent earthquakes, particularly in developing countries, conclusively demonstrate that we are far from reaching this goal. The gap between developed and developing countries is widening: four of every five deaths caused by earthquakes in the twentieth century occurred in developing countries. In the task of Earthquake-disaster mitigation, acquiring the state-of-the-knowledge is only the first step; the most important and perhaps the more difficult step is to translate that knowledge into state-of-the-practice. Unfortunately, developing countries have not been very successful in translating the knowledge into better earthquake-resistant construction practices. To ensure aseismic construction, Earthquake Engineering knowledge needs to spread to a broad spectrum of professional engineers within the country, rather than confining it to a few organisations or individuals as if it were a super-speciality. While we do require "specialists" to tackle many aspects of

Earthquake Engineering, it is also essential to popularize basic Earthquake Engineering practices widely enough so that the professional engineers themselves can carry out good aseismic construction, without having to seek the advice of "specialists". Earthquake-resistant construction requires seismic considerations at all stages: from architectural planning to structural design to actual construction and quality control. Such an overall approach to aseismic construction will not develop until Earthquake Engineering is integrated with the mainstream Civil Engineering and the professional engineers (and architects) are drawn into the process. In fact, too often we tend to equate aseismic design and construction with simply a dynamic analysis of structure.

Studies have shown that Nepal lies in eleventh high earthquake risk zone of in the world. Geography plays key role on Building construction practices in Nepal. The high Himalayas, the middle Hills and the Tarai are the three physiographical regions possess different construction practices mainly due to physical and meteorological properties governed by geography. The practice also depends on the socio-economical and political conditions: urban and rural areas of human settlement differ much in building preferences and practices. In addition, availability of the construction materials influences the construction culture.
New buildings in Nepal are built by convention, rather than being specifically designed. The overall process is very informal to the extent that technically ignorant owners and craftsman often make decisions on structural elements. Even in urban areas where building permit process is mandatory, actual incorporation of seismic safety into the coordination is not uniform. This has resulted in highly vulnerable buildings in Nepal even when these are constructed of modern materials and technology. These buildings in the environment of high seismic hazard and low seismic awareness/ preparedness have created very high level of risk to human life and their property.
Understanding the cultural and socio-economic aspects of Nepal, non-engineered and informality in building construction, the Nepal National Building Code Development Process in 1992-1994 took a very pragmatic policy decision. In contrast to conventional approach of Building Codes, it classified the buildings in four groups: a) State-of-the-art, b) professional engineered, c) pre-engineered and d) non-engineered with the aim to facilitate the incorporation of seismic safety in all classes of buildings. Further, the approach adapted was to move gradually from non-engineered to pre-engineered and to engineered. Accordingly, it developed a few guidelines on pre-engineered construction as well.

2. RATIONALE OF THE WORK

For making communities safer against earthquakes, all buildings should be made earthquake resistant. To achieve this goal, all buildings need to de designed for earthquake resistance. However, it is not feasible to design structurally all building because of cost involved in design, lack of trained manpower for earthquake-resistant design and construction. It is a dilemma in itself. However, Considering the similarity in residential buildings, solutions can be developed by creating a set of standard design, of buildings which would encompass typical architectural drawings, their structural designs, bill of quantities, specifications etc. It will assist the potential house-owner to choose a standard design that meets his requirements from the set of designs. This work will help to move from the practice of creating non-engineered buildings to pre-engineered practice.

3. OBJECTIVES

The research has two principal objectives:

i) Develop standard architectural design/ drawings of a set of typical residential buildings with different configuration and size, to cater to the housing needs of people belonging to different economic strata (low to medium).

ii) Develop structural design/ drawings of these building with different structural system complying with the requirements of the National Building Code; prepare appropriate bill of quantities and specifications.

The current research under the Provention grant focuses on residential buildings. Although residential apartments type building has being constructed in Nepal, but the process still lies at embryonic stage. Generally such buildings are designed and supervised by technicians, and hence expected to be engineered.

4. METHODOLOGY

A review of previous reports and articles helped to visualize the building construction scenario. The current trend of building construction was also discussed with the other stakeholders in the building construction sector. The overall methodology of the research is as followings:

5.1 *Reconnaissance survey*

Before developing the final survey formats the grantee had visited the Kathmandu valley and few fringe areas. Based on the available information collection and idea gain by the field reconnaissance, the final survey format was prepared. The sites are Kathmandu, Lalitpur, Bhaktapur and other outside valley.

5.2 *Survey format development*

Household survey is the key activity to collect the required field data in the research. Therefore, a survey form (See Annex) was developed incorporating all essential questionnaires to collect information for proceeding and analysis. The survey form consists of building typology, number of storey, building dimension, size of column, maximum length of beam etc which are the major parts for the structural details. The plans of the existing buildings were the requirements of this survey.

5.3 Survey team

The survey team which consists of three person of the civil engineering background was formed. All the member of the team was described about the need of the data, requirement of research and clear description of their duties. Brief orientation about the earthquake risk, the current construction practice in the field and the key points to be considered for the earthquake resistant construction was conducted by the grantee.

5.4 Detail survey and data collection

The survey was carried out at different areas of Kathmandu valley and outside in order to collect structural engineering information and consideration of earthquake resistance features of existing buildings. The survey of about 135 reinforced concrete non-engineered buildings was done.

5.5 Data entry and Analysis:

The information, data collected in building survey was entered in Excel sheet. The data was analyzed through the geometrical dimensions of building structural elements and consideration of earthquake resistance elements during design and construction etc. All this available information was thoroughly studied based on which the researcher drafted a survey format, which was recorded a) building typology, b) number of storey, c) plinth area, d) building design process, e) size of column, f) maximum length of beam, g) overall building dimensions and h) plan of building. Analysis of the survey data considered also an identification of deficiencies and positive practices in the buildings.

5.6 Selection of building data for development of building design sets

There is a wide variety of building typologies in Nepal. The majority of buildings in the urban area are reinforced concrete construction. Other typologies are brick in cement, brick in mud, stone in cement, stone in mud, adobe etc. The reinforced concrete, brick in cement and stone in cement cover more than 80 percentage of the non-engineered building construction in the periphery of the cities and market centers and there is a growing trend to construct as compared to the load bearing structures. Load bearing structures are also built significantly in urbanizing areas and low strength masonry are built massively in rural areas. The detail work like architecture drawings, structural design and drawings, bill of quantity, specifications etc for single building itself is a voluminous work. Considering the time and budget available for the research work, the total number of buildings for detail work was decided ten. Based on these facts, the number of standard design was fixed for each category; reinforced cement concrete (5), brick in cement (2), stone in cement (2) and stone in mud (1).

5.7 Engineering design of selected building

The architecture drawings of the selected buildings were prepared in AutoCAD. And the structural design of the reinforced cement concrete building was done using structural analysis tools: SAP2000 and ETABS. Where as the structural design of load bearing wall system building was done based on the International Association of Earthquake Engineering (IAEE) and Nepal National Building Code (NBC). The Bill of quantities estimation was carried out in Excel sheet.

5. SURVEY DATA ANALYSIS AND FINDINGS

Data collected from survey was entered in Excel sheet and analysis was done there. The survey has revealed the buildings construction trend of Kathmandu valley. Almost all buildings haven't considered earthquake resistance elements during design and construction period although most of buildings (68%) are designed by technician. High involvement of owner is observed on construction process as 67% and 84% of building owner supervised their building themselves during construction. The survey within urban area also showed 92% of buildings are of pillar system i.e. of reinforced cement concrete with pillar size 9" * 9" used by 89% and exceeding use of beam length less than 15' by 73%. The detail of finding is shown in table below:

Buildings Survey Results

Total No of House Survey 135

S.N.	Descriptions								
1	Sampling area	Core	68	Fringe	62	Outside Valley	5		
2	Building Typology	RCC	120	Load Bearing	10	Mud Mortar	5		
3	No of Storey	Max	5	Min	1				
4	Plinth Area(Sq. Ft.)	Max	1633	Min	227				
5	Age of Buld(Year)	Max	16	Min	0				
6	Extention Plan	Yes	41	No	94				
7	Const Process	Owner Built	90	Purchased	12	Contractor	33		
8	Designer	Self	31	Technical	92	Contractor	12		
9	Supervisor	Self	113	Technical	7	Contractor	15		
10	Building Position	Free Standing	75	Confined One Side	45	Two adj side	10	Two opp side	5
11	Size of Pillar	9"x9"	116	9"x12"	12	12"x12"	2		
12	Beam Leangth	More than 15'	35	Less or equal to 15'	95				
13	Cantilever with wall	None	84	One side	31	Two adj side	6	Two opp side	9
13	Length of Cantilever	Max	5' 10"	Min	1' 6"				
14	EQ consideration	Design:				Construction:			
		Yes	5	No	130	Yes	3	No	132

6. DEVELOPMENT OF STANDARD DESIGN SETS OF BUILDINGS

Based on the survey findings and discussion with the focus persons, sample buildings system were selected as Reinforced Cement Concrete (RCC) Frame and load bearing system. The latter was categorized in brick in cement, stone in cement and mud-mortar. The selection of sample buildings for producing their architecture drawings was made by observing the building pattern in survey, the most frequently used building patterns were selected to represent prevailed building pattern of urban area. And three storey buildings with maximum plinth area less than 1000 Square feet were preferred from structural view of residential buildings. The architecture drawings of all sample buildings are prepared before conducting intensive structural design work. The details of structural analysis and design of building of each system is given below:

a) RCC Frame system: The structural analysis and design has been based on the prevailing codes that are in practice in Nepal, the Nepal National Building Code and the IS codes at places. Considering Architectural, Economic and strength demands reinforced cement concrete (RCC) is used as the major structural material. The selected material also confirms the availability and ease in construction. The concrete grade used is M20 as per Indian Standard Specification. This material provides minimum grade of structural concrete and favourable for easy production and quality control as well. Fe415 is provided as longitudinal and shear reinforcing in Beams, Columns, foundations, and slabs wherever RCC is used.
The loads distributed over the area are imposed on area element and that distributed over length are imposed on line element whenever possible. Where such facility is not feasible, equivalent conversion to different loading distribution is carried to load the Model near the real case as far as possible. For lateral load, necessary calculations were performed using NBC 105: 1994 for seismic coefficient method. Different load combinations based on Nepal National Codes are developed and used for design purposes. The load combinations are based on NBC 105: 1994. For seismic loading, mass equivalent to the load that composed of 100% of Dead load and 25% of Live load is taken into consideration. The Earthquake lateral loads were used in the combination from the spectral load cases based on NBC 105:1994: Spectrum for Soil Type III. Spectral load thus developed is the product of structural seismic mass, modal response and respective spectral ordinate. Modal analysis is carried out using FEM Based three dimensional analyses.
b) Load Bearing System: The designs of load bearing structures were done using Nepal National Building code and International Association for Earthquake Engineering guidelines. Nepal National building code addresses the practical issue that it is not practical in Nepal to insist that all small buildings be designed for strength by a professional adviser. Therefore, for classes of buildings not exceeding certain simple criteria as to height, number of storeys and floor area, mandatory rule of thumb (MRT) is provided. Likewise, NBC provides Guidelines for Remote Rural Buildings. The key structural decision was carried out based on IAEE guidelines.

After the completion of structural design, quantity estimation and specification preparation were carried which completely developed the standard design sets of buildings.

7. DISSEMINATION STRATEGY

The outcomes and lesson learned of this research was discussed, as we progressed, among the structural engineers, construction engineers and engineers of local and central government, and within NSET. This study and its results will be discussed also among the practicing engineers and architects attending regular training program of NSET and its partner organizations as a case studies. So far, the discussions and interactions have come to the conclusion that the study as well as the set of designs will be beneficial to all who are directly involved in construction industry, house owners and even policy level personnel. Publication of such document is essential but obviously requires funds.

8. LIMITATION AND CONSTRAINTS

During the survey work, some house owners did not want to cooperate either because they misidentified the survey as a check by the municipality of the house against the plan in the building permit, or the check being that for earthquake-resistance. N the later case, the house-owner’s fear was that the tenants would desert it once they know that the building would not withstand the earthquake security concern was another reason for non-cooperation. The data collection from the outside of the valley is not so easy like in valley due to the travel difficulties, technical difficulties like photocopy and time consuming.
The survey and analysis revealed a very wide diversity in the buildings on structural and other non-structural

components such as sanitary accessories, flooring etc. This required greater extent of idealization of the 'typical' houses than what was considered in the survey design. So, the preparation of bill of quantities and specifications is another difficult issue.
The major problems again will encounter relates to the buy-in of the initiative particularly from the private owners who do not want to bear with additional costs and don't see the immediate benefits of such an initiative.

9. CONCLUSION

The survey has revealed almost buildings were designed by technician and constructed by owner themselves without earthquake resistant consideration. This shows ignorance and lack of knowledge regarding earthquake risk. Therefore, awareness campaigns and training activities for sensitization are immediate need. Moreover, the survey result strongly recommends to improve the existing building practice which may require the reinforcement by respective authority. The research has developed the standard design sets of building for RCC Framed and Load Bearing system both in cement and mortar. The developed design set is fully engineering with consideration of earthquake resistance element. Hence, application of the standard design set will build earthquake resistance building which highly reduces earthquake risk of community.

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