International Journal on Recent and Innovation Trends in Computing and Communication
Volume: 4 Issue: 6
ISSN: 2321-8169
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Performance of Residential Buildings during Nepal Earthquake

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Abstract: Earthquake do not kill people, unsafe the buildings do. Earthquake is a naturally occurring process in which tectonic plates release strain developed in them over years. Earthquake cannot be avoided. Nepal Earthquake of magnitude 7.8 once again reminds us the need of earthquake resistant design and construction. Extensive loss of human life and property occurred due to this earthquake. In this paper, an effort is made to study the probable cause of failure of buildings in Nepal. Different types of buildings and structures are observed with various structural irregularities and defects. Thus, Safety measures to prevent future damage due to earthquake are also suggested.

Keywords: *magnitude, earthquake, structural irregularities, defects, damage.*

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1. INTRODUCTION

Nepal is a landlocked country which lies along the southern slopes of the Himalayan Mountains. It has India on its southern, eastern and western borders, and the Tibetan Autonomous Region of the Peoples' Republic of China to the north [1]. Nepal lies in seismic hazard zone V. The country's high seismicity is related to the movement of tectonic plates along the Himalayas that has caused several active faults. A total of 92 active faults have been mapped throughout the country by the Seismic Hazard Mapping and Risk Assessment. The entire country falls in a high earthquake intensity belt: almost the whole of Nepal falls in high intensity scale of MMI IX and X for the generally accepted recurrence period. The seismic zoning map of Nepal, which depicts the primary (shaking hazard), divides the country into three zones elongated in northwest-southeast direction; the middle part of the country is slightly higher than the northern and the southern parts. The main reason behind Earthquake in Nepal is that 45 million years ago, the Indian continent collided with the Southern Tibet. The Indian continent is driven under Tibet, pushing lightweight sediments upwards and thus giving rise to Himalayas. Nepal sits across the boundary between India and southern Tibet which are still moving towards each other by 2 metres per century. This movement creates pressures within earth, which builds up and can be only released through earthquakes. The soils of Nepal are highly variable and are derived mainly from young parent material (Manandhar 1989). Soils have been classified on the basis of soil texture, mode of transportation, and colour, and are broadly divided into:-

- Alluvial soil
- Sandy and alluvial soil
- Gravelly soil
- Residual
- Glacial soil

2. NEPAL EARTHQUAKE

On Saturday April 25, 2014, at 11:56 AM local time (6:11 AM GMT), at a depth of about 15 km, a major, 20second earthquake struck approximately 80 km northwest of Kathmandu, Nepal (Figure 1) [1]. Conflicting reports of the strength were registered by the US Geological Survey, the China Earthquake Networks Centre, and The India Meteorological Department, ranging from 7.8 to 8.1.35 minutes after the initial shock, a second major quake of magnitude 6.6 struck, causing further damage to already weakened buildings. Avalanches in Himalayan regions have been reported, and climbers on Mt. Everest (the tallest peak in the world) have been hit by such events. On Saturday night, people in Kathmandu spent the night sleeping in the streets and open areas to avoid being trapped inside structurally weakened building in case of collapse or further quakes. At 12:54 PM, Sunday April 26th, shortly after the 24 hour mark from the initial quake, another large 6.7 aftershock hit, spreading panic throughout the nation [2]. This triggered more avalanches on Mt. Everest, causing many to fear that the death toll on the mountain could rise quickly in the next few days. The first earthquake registered at least 7.8 on the Richter Magnitude Scale, the same magnitude as the San Fransisco Earthquake of 1906. At least 43 tremors of magnitude 4.5 or greater have been felt in the 34 hours since the initial event, with a major aftershock of 6.6 felt 35 minutes after the initial major quake. By Tuesday April 28th, at least 4,400 people have been declared dead in Nepal. Casualties have been reported in India, Bangladesh, & Tibetan China where avalanches were triggered by the large quake. Dharahara Tower, a nine story tower built in 1832 and a major landmark in Kathmandu, crumbled, with little of the base remaining [2].

Fig. 1: Nepal map showing Epicentre [1]

3. EXAMPLES OF BUILDING FAILURES

3.1 Masonry Failure

Masonry binding a very wide range of material, such as brick, block, stone etc., joined with different type of mortar, etc., that shows different mechanical properties. Masonry may be used with or without reinforcement. Properly detailed reinforced masonry may be designed to resist earthquake forces. The inadequate performance of masonry building in earthquake is because of the following reasons [3].

i. The material is brittle and its strength degradation due to load repetition is severe.
ii. Masonry contains large weight because of thick walls. So the inertia forces are larger.
iii. Large stiffness of the material, which leads to large response to earthquake waves of short natural period.
iv. Quality of construction is not adequate because of quality of the locally manufactured masonry units, unskilled labour, etc., that leads to large variability in strength.

The Following building failed in Nepal earthquake due to poor construction practices like lack of brick bonds, higher thickness of mortar joints and perpends in two consecutive courses matching.

Fig. 2 Kathmandu's historic Basantapur Durbar Square, before and after the 7.8-magnitude earthquake which reduced it to rubble [1]

Fig. 3 People gather in Durbar Square for security reasons. Complete masonry failure [1]

Fig. 4 The Iconic Bhimsen Tower before and after the earthquake [1]

To improve the seismic behaviour of a masonry building, the building should achieve the following objectives [4].

i. The building should neither be slender in plan nor have re-entrant corners. Such buildings should be divided into simple rectangular blocks with adequate gaps minimum 15 mm for box-type construction.
ii. The earthquake response of a masonry wall depends on the relative strengths of the brick and mortar. The bricks must be stronger than the mortar and should have a compressive strength not less than 35 N/mm^2.
iii. The interlocking of masonry courses at the junctions should be checked as the walls transfer loads to each other at their junctions. To obtained full bond between perpendicular walls, it is necessary to make a stepped joint by making the corner first to a height of 600 mm and then build the wall in between them. Otherwise, a toothed joint can be made in both the walls, in lifts of about 450 mm.
iv. For single storey construction the wall thickness should not be less than one brick. For the buildings of up to three storeys, the thickness should not be less than one and half bricks for the bottom storeys and one brick in the top storey. It should also not be less than one sixteenth of the length of wall between two consecutive perpendicular walls.
v. Horizontal reinforcement should be provided in wall to strengthen them against horizontal in-plane bending. Provision of horizontal bends should be made at various levels, in particular at the lintel level. The lintel bend ties the walls together and creates a support to the walls loaded in the weak direction.
vi. The opening should not be eccentrically located on the structural plan, since eccentricity of the central of the stiffness relative to the centre of gravity causes torsional moment.
vii. The shear reinforcement should be provided in the walls to ensure that their ductility behaviour is adequate.

3.2 Shear Failure

In masonry walls without openings, shear failure often takes place in wall piers and spandrels. Shear failure is likely to occur in wall elements with small height-to-length ratio. Shear failure tends to be brittle, with low energy dissipation capacity and severe strength degradation due to load repetition [5].

The building failed in Nepal earthquake due to poor construction practices diagonal shear failure is occurred in the masonry walls.

Fig. 5 Shear failure in masonry wall after earthquake in Nepal [11]

3.3 Inverted Pendulum Effect

This failure is occurred due to heavy mass placed on the top of minaret cause the excessive deflection and acceleration during earthquake in Nepal.

Fig. 6 Failure of minaret due to poor construction [11]

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3.4 Crack on the Road

Fig. 7 A huge cracks have opened up in this road after the Nepalese capital was rocked by a 7.8-magnitude tremor [11]

4. STRUCTURAL FAILURES

4.1 Stiffness Irregularity

The stiffness irregularity arises when there is a substantial reduction in lateral stiffness in any storey with respect to that in upper storey. The storey with reduced stiffness is called soft storey. According to IS 1893:2002, A soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above. Figure 9 shows the failure of soft storey [6].

As per IS 1893:2002, special arrangement needs to be made to increase the lateral strength and stiffness of the soft/open storey. Dynamic analysis of building should be carried out including the strength and stiffness effects of infill walls and inelastic deformations in the members, particularly, those in the soft storey, and the members designed accordingly. Alternatively, the following design criteria are to be adopted after carrying out the earthquake analysis, neglecting the effect of infill walls in other storeys [6]:

i. The columns and beams of the soft storey are to be designed for 2.5 times the storey shears and moments calculated under seismic loads.
ii. Besides the columns designed and detailed for the calculated storey shears and moments, shear walls should be placed symmetrically in both directions of the building as far away from the centre of the building as feasible; to be designed exclusively for 1.5 times the lateral storey shear force calculated as before.

Fig. 8 Collapse of soft storey [11]

4.2 Pounding Effect

When two buildings are located very close to each other or when seismic expansion joints exist, pounding is occurred. So, it is necessary to provide enough space between neighbouring structures so that they do not pound each other. Extra distance is provided between two adjacent buildings in addition to the sway of the buildings in computing lateral displacement, it is necessary to consider plastic deflection, soil-structure interaction and other factors besides elastic deflection [8]. The pounding effect can be easily seen in highly populated cities. This effect can be controlled by placing elastic materials between adjacent buildings or by reinforcing structural systems with cast-in-place reinforced concrete (RC) walls. As per IS 1893:2002, two adjacent buildings. or two adjacent units of the same building with separation joint in between shall be separated by a distance equal to the amount R times the sum of the calculated storey displacements, to avoid damaging contacts when the two units deflect towards each other.

The Following buildings are pound to each other during Nepal earthquake due to closed construction of two buildings.

Fig. 9 Building deflects due to pounding effect during earthquake vibrations [11]

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4.3 Mass Irregularity

Fig. 10 Balcony of the building toppled [11]

When there is substantial difference in mass between two storeys, it is called as mass irregularities. Although mass irregularities are not commonly observed, it may exist in a particular floor due to heavy equipment placed there. This can be seen in Figure 10 where the balcony contains some heavy mass n due to which it got detached and toppled. According to IS 1893-2002, mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storey. The irregularity need not be considered in case of roofs.

Cantilever Projections

i. Vertical projections

Tower, tanks, parapets, smoke stacks (chimneys) and other vertical cantilever projections attached to buildings and projecting above the roof, shall be designed and checked for stability for five times the design horizontal seismic coefficient. In the analysis of the building, the weight of these projecting elements will be lumped with the roof weight.

ii. Horizontal projections

All horizontal projections like cornices and balconies shall be designed and checked for stability for five times the design vertical coefficient.

4.4 Column Failure

Buildings should be designed like a ductile chain. For example, consider the common urban residential apartment construction, the multi-storey Building is made of reinforced concrete. It consists of horizontal and vertical members, namely beams and columns [8].

Fig. 11 Column failure during Nepal Earthquake [11]

The seismic inertia forces generated at the floor levels are transferred through the beams and columns to the ground in the RC frame. The correct building components need to be made ductile. The failure of a column can affect the stability of the whole building, but the failure of a beam causes localized effect. Therefore, it is better to make weak beams and strong columns. This method of designing RC buildings is called strong-column weak-beam design (Fig.12).

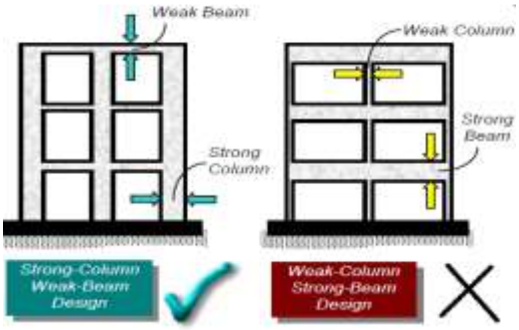

Fig. 12 Strong column-weak beam Design [3]

4.5 Twisting of Building

The twisting of buildings causes different portions at the same floor level to move horizontally by different amounts. Generally it occurs due to Irregularities of mass, stiffness, and strength in a building can result in significant torsional response. Torsion arises from eccentricity in the building layout when the centre mass of the building does not coincide with its centre of rigidity. If there is torsion the building will rotate about its centre of rigidity due to the torsional moment about the centre of structural resistance.

The Figure shows the effect of twisting of stair in a building due to the excessive load causes change in eccentricity of building during Nepal earthquake.

Fig. 13 Twisting of building during Nepal Earthquake [11]

5. SAFETY MEASURES TO PREVENT FUTURE DESTRUCTION DUE TO EARTHQUAKE

Following are the safety measures to prevent future destruction due to earthquake:

i. All the reinforced concrete framed structures must be designed as per IS 456, IS 1893:2002 and IS 13920.
ii. Brick masonry buildings should be designed according to IS 13828:1993.

iii. Structure engineer should be consulted for all constructions; let it be a single storey house or a multi storey building.
iv. Dynamic analysis for any building more than three storeys is must.
v. Buildings having simple regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation, suffer much less damage than
vi. The buildings with irregular configurations. Irregularities like mass Irregularities, stiffness Irregularities, torsion Irregularities, re-entrant corners etc must be avoided in all constructions.
vii. Good workmanship is very important to inculcate all design aspects suggested by design engineer. Proper execution of earthquake resistant design at the site is equally important.
viii. The structure should have a direct and continuous load path.
ix. It should be simple and symmetrical.
x. It should not be too elongated in plan or elevation.
xi. The structure should have uniform and continuous distribution of strength, mass, and stiffness.
xii. The structure should have sufficient ductility.
xiii. The structure should have stiffness related to the sub-soil properties.

6. CONCLUSIONS

The Nepal earthquake of 25 April 2015 reflected the performance of various types of buildings. After field reconnaissance in around 3500 buildings of various types, many types of construction as well as structural deficiencies were identified. The common types of failures in RC construction were identified as the soft storey, pounding, shear failure, and other failures associated with construction as well as structural deficiencies like building symmetry, detailing and others. Earthquake is an inevitable phenomenon. But we can go for earthquake resistant design and construction. Government must create a policy to make earthquake resistant design and construction mandatory for all areas lying in severe seismic zones e.g. Nepal, Jammu & Kashmir, Himachal Pradesh, Delhi etc. 60 % of India lies in land which is susceptible to damage due to earthquake. Hence, in every state there should be an earthquake mitigation department.

RFEERNCES

[1]. http://www.worldatlas.com/articles/100023-major-7-8-earthquake-rocks-nepal-kathmandu-scene-of-destruction.
[2]. http://nset.org.np/nset2012/index.php/menus/menuid-58/submenuid-137.
[3]. Murty C.V.R, IIT Kanpur, Learning Earthquake Design and Construction "Earthquake Tip 20".September, 2005.
[4]. Handbook on Seismic Retrofit of Buildings, Central Power Works Department And Indian Building Congress in association with IIT Madras (April 2007).
[5]. Pankaj Agarwal, Manish Shrikhande, Earthquake resistant design of structures, book, Prentice-Hall, (Prentice – Hall of India 2006)
[6]. IS 1893(Part 1): 2002 Indian Standard Criteria for Earthquake Resistant Design Of Structures.
[7]. IS 13920:1993 Indian Standards Ductile Detailing Of Reinforced Concrete Structures Subjected To Seismic Force.
[8]. M. Asharaf, Z. A. Siddiqi, M. A. Javed, "Configuration of Multi-storey building subjected to lateral forces". Asian Journal of Civil Engineering (Building & Housing), Vol. 9, No. 5 Pages 525-537.
[9]. H.-S. Kim, D.-G. Lee "Analysis of shear wall with openings using super elements" Engineering Structures 25 (2003) 981–991
[10]. M. Shariq, H. Abbas, H. Irtaza, M. Qamaruddin "Influence of openings on seismic performance of masonry building walls" Building and Environment 43 (2008) 1232–1240.
[11]. http://www.dailymail.co.uk/news/article-3057610/Incredible-drone-footage-shows-shocking-extent-destruction-Kathmandu-city-rocked-huge-earthquake.html.