A case Study of Seismic Performance of Buildings Located at Waknaghat and Kandhaghat, Solan, H.P

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ABSTRACT

The Himalayan belt of India lies near the fault separating Indo-Australian and Eurasian plate. It is but natural that this area is seismically active and lies in zone V. Despite this fact, most of the buildings in Himachal Pradesh have poor configurations and construction quality. In this paper, an effort is made to study structural irregularities and construction defects of buildings situated in Waknaghat and Kandaghat (district Solan, HP). Some of the factors which were included in the survey were: offsets, hanging columns, setbacks, soft storey, unequal heights of the column, re-entrant corner, cantilevered slabs loaded above, open ground storey etc. Along with abovementioned defects, other irregularities like verticality of columns, poor bricks quality, and poor workmanship were also acknowledged. Although, irregularities in a building should not be accepted and non-engineered buildings if constructed, should not be more than 3-stories. Buildings must be designed according to the codal provisions and should be considered for 3-D dynamic analysis. However, an effort has also been made to suggest some remedies for the above mentioned irregularities and defects.

Keywords: configurations, re-entrant corner, irregularities, offsets, soft storey.

1. INTRODUCTION

A building that lacks *symmetry* and *discontinuity* in geometry, mass, or load resisting elements is called as *irregular building*. IS 1893 (part 1):2002 has categorized irregularities in to two main types: (i) Horizontal Irregularity (ii) Vertical Irregularity. Horizontal irregularities refer to asymmetrical plan shapes like L, T, U or even discontinuities in the horizontal resisting elements such re-entrant corners whereas Vertical irregularities referring to sudden change of strength, stiffness, geometry, and mass. In this paper, an effort is made to study structural irregularities and construction defects of buildings situated in Waknaghat and Kandaghat (district Solan, HP). The objective of the presented study is to know about the current construction practices being used by local masons for non-engineered buildings. It is found that most of the buildings have such defects which lead to discontinuity in seismic load paths. There are chances of failure of such buildings during strong ground shaking. For any building more than three stories, structural engineer must be consulted and for any building with irregularity, a 3-D dynamic analysis must be carried out.

2. SEISMIC HISTORY

The majority of the areas of Himachal Pradesh lie in Zone V and the few lies in zone IV. This state is very close to the fault line separating the Indo-Australian and the Eurasian plate. Record of past 50 years has verified the above statement. Large earthquakes have occurred in all parts of Himachal Pradesh, the biggest was the Kangra Earthquake of 1905. It had a moment magnitude of 7.8 and at least 28, 000 people were killed in the Kangra Dharamsala region of Himachal Pradesh. Another earthquake which took place near Kullu (H.P) on 28 February 1906, with a moment magnitude of 6.4. Damage and casualties were caused in the Bashahr-Shimla hill states. Besides these there are scores of smaller faults, like the Kaurik Fault which triggered the 1975 earthquake with a moment magnitude of 6.8. This earthquake struck in the early afternoon of January 19, 1975. It caused havoc in parts of the Kinnaur, Lahaul and Spiti regions of India. 60 people were killed in this sparsely populated region [1]

2.1 Soil Type

Solan district presents an intricate mosaic of high mountain ranges, hills and valleys with altitude ranging from 300 to 3000 m above MSL. The altitude of the hill ranges is higher in northern parts whereas south-western part of the district is represented by low denuded hill ranges of Siwalik [1] The soils of the State can broadly be divided into nine groups. These are: (i) Alluvial Soils (ii) Brown Hill Soil, (iii) Brown Earth (iv) Brown Forests Soils (v) Grey Wooded Orpodzolic Soils (vi) Grey Brown Podzolic Soils (vii) Planosolic Soils (viii) Humusand Iron Podzols (ix) Alpine Humus Mountain Speletal Soils. The Soil Found In The Districts Of Mandi, Kangra, Bilaspur, Una, Solan, Hamirpur And Sirmaur Is Generally Brown, Alluvial And Grey Brown Podzolic, Kullu And Shimla Have Grey Wooded Podzolic Soils, While Kinnaur, Lahaul And Spiti And Some Parts Of Chamba District Have Humus Mountain Speletal Soils [2]

3. STRUCTURAL IRREGULARITIES AS OBSERVED IN BUILDINGS

3.1 Column Offsets

The building shown in Fig. 1 is a hotel under construction located in Waknaghat. Column of upper storey has a horizontal offset with the lower column. It may be due to the poor workmanship. Due to the misalignment of the reinforcing bars and improper or no bonding of two columns, there is a possibility of sudden failure of this joint during an earthquake. At the construction stage, care must be taken to avoid this irregularity correct alignment in the columns of the building and by employing good workmanship.

Fig. 1: Column Offset

Fig. 2: Soft Storey

3.2 Soft Storey

A soft storey is one in which the lateral stiffness is less than 70% of that in the storey immediately above, or less than 80% of the combined stiffness of the three stories above. The essential characteristic of a weak storey consists of a discontinuity of stiffness, which occurs at the second storey connections. This is caused by lesser strength or increased flexibility and also the structure results in excessive deformations in the first storey of the structure, which in turn results in concentration of forces at the second storey level.

Fig. 3: Soft Storey

Fig. 4: Soft Storey

These stories are more likely to get collapsed or were severely damaged during earthquake. Many buildings with an open ground storey (soft storey) were observed (shown in Fig. 2, 3 and 4) in Kandaghat. Fig. 2 shows a residential house being constructed and the ground and first floor are left empty whereas a house is dwelled in second storey. Fig. 3 and Fig. 4 are also good examples of soft storey. This defect can be minimized by constructing shear walls at the ground level so as to eliminate the discontinuity in the lateral load resistance path and to increase stiffness of soft storey (making it comparable with other stories).

3.3 Hanging Columns and short columns

Fig. 5: Hanging columns or Floating columns

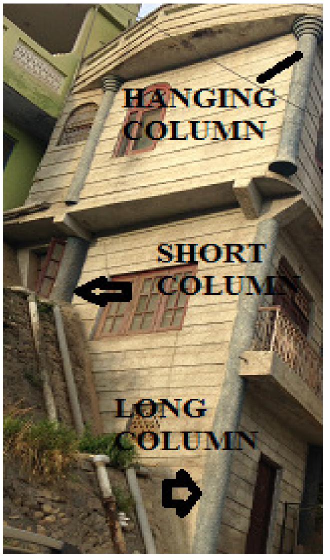

Fig. 6: Floating and short columns

Buildings with columns that hang or float on beams at an intermediate storey and do not go all the way to the foundation, have discontinuities in the load transfer Path. It may lead to catastrophic failure of buildings. The buildings shown in Fig. 5 and Fig. 6 are located in the main market of Kandaghat. Fig. 5 is a residential building where people dwell in first and second storey and ground storey is used as shopping area. This building has hanging column whose load is going nowhere but borne by beams only. Fig. 5 clearly show that the column do not continue up to the foundation but rather end at an upper level. Due to this, Shear is induced to overturning forces to another resisting element of a lower level [3] Thus, site Engineer must be aware of the fact that load transfer path should be continuous. All the columns and walls must extend to the foundation in order to mitigate horizontal ground motions. Fig. 6 also shows a residential building with a numbers of hanging, long and short columns (discussed in coming text). There must not be any floating columns in buildings.

3.4 Set Backs

According to IS 1893 (part 1): 2002, plan configurations of a structure and its lateral force resisting system contain re-entrant corners, where both projections of the structure beyond the re-entrant corner are greater than 15% of its plan dimension in the given direction [4] Buildings with vertical Setbacks cause two types of problems: (i) Sudden jump in earthquake forces at the level of discontinuity: The area in the building suddenly increases and the stress decreases. This creates a jump in the stress at the level of discontinuity (ii) Torsion. This defect can be eliminated by constructing the walls around the two free sides as shown by black line so as to produce a uniform regular plan building. Fig. 7 is a residential building located in Kandaghat which contains a re-entrant corner.

Fig. 7: Setbacks (Re-entrant corner)

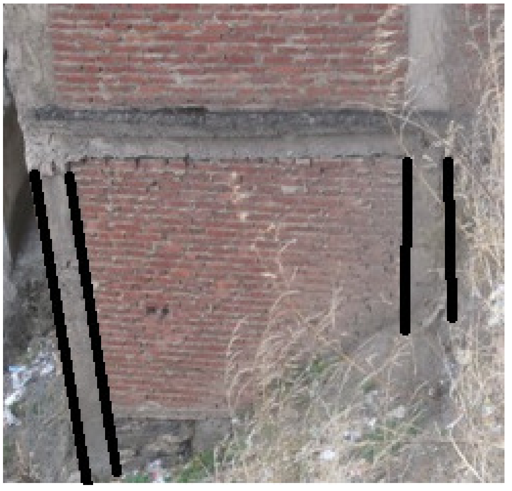

Fig. 8: Long and Short column

3.5 Long and Short Column

Fig. 8 shows a building that is being constructed on a slopy land near Waknaghat. It shows a long and a short column that is highlighted with double black lines. Fig. 6 also contains the same irregularity. Buildings on slopy ground have unequal height of the columns along the slope, which causes ill effects like twisting and damage in shorter columns [5]. Both the lengths of the column must be equal. This can be achieved by constructing masonary wall between the columns to eliminate the height difference between them.

3.6 Cantilever Slab loaded above

The cantilever portion of the building must be used as free spaces like balconies with less loads. If used for regular heavy loads, it may lead to failure during lateral forces generated due to

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earthquake. Fig. 9 shows a commercial building located in the market of Kandaghat. This long building has a cantilever slab that is loaded with heavy machinery. Fig. 10 shows a residential house situated in Kandaghat, in which the cantilever portion has been used as the living room. The extra weight loaded above proves to be detrimental during an earthquake. In order to correct this defect, in Fig. 9, columns must be provided at the cantilever ends as shown by black circles so that load is distributed uniformly. Whereas, in Fig. 10 the bottom portion of the cantilever must be either provided with one more column or must be covered with walls on the two sides.

Fig. 9: Cantilever slab loaded heavily

Fig. 10: Cantilever being used as living room

4. CONCLUSION

There are numerous buildings that are constructed in these locations with a number of structural irregularities in them. Since H.P lies in zone IV and zone V, these areas are more prone to earthquake damage. Thus, various remedies are suggested to come up with these defects.

1. For RCC framed buildings more than three stories, IS 1893 and IS 13920 must be used.
2. Good workmanship is very important to inculcate all design aspects suggested by design engineer.
3. For the masonary buildings, Use of lintel band, as suggested by the Bureau of Indian Standards (IS 13828:1993) proves to be a good option [6]. This seems to suggest that additional horizontal bands, possibly at the sill level and at plinth level, are needed [7] This can be explained more clearly with Fig. 11.

4. Shear wall can be properly employed for increasing the stiffness where ever necessary and must be uniformly distributed. Fig. 12 shows a remedy for a soft storey. The ground storey which was earlier a soft storey is now being provided with shear walls.

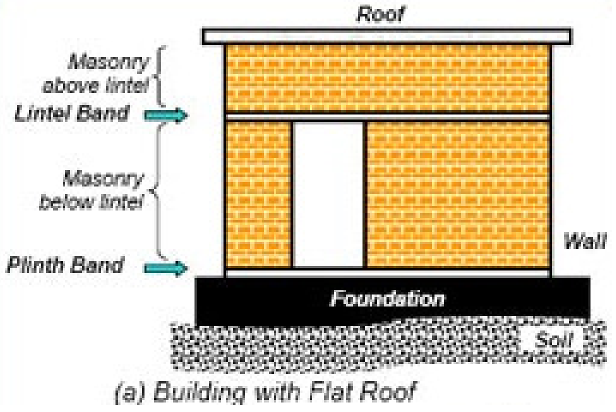

Fig. 11: Lintel bands in masonry houses [5]

Fig. 12: Construction of Shear wall

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