Micro-tremor Response of Buildings in high Seismic Areas: A Case Study on RC Framed Building in Chandigarh, India Part II: Response of building

by

Narender Bodige, Hima Chandan, Pradeep Kumar Ramancharla, Ito T, Takano K

in

3rd International Engineering Symposium - IES 2013
(IES 2013)

Report No: IIIT/TR/2013/-1

Centre for Earthquake Engineering
International Institute of Information Technology
Hyderabad - 500 032, INDIA
March 2013
Micro-tremor Response of Buildings in high Seismic Areas: A Case Study on RC Framed Building in Chandigarh, India Part II: Response of building

B Narender¹, D Hima Chandan¹, R Pradeep Kumar², T Ito³ and K Takano⁴

¹Ph.D scholar, Earthquake Engineering Research Centre, International Institute of Information Technology, Hyderabad, India. narender.bpg@research.iiit.ac.in and hima@research.iiit.ac.in
²R. Pradeep Kumar, Associate Professor, Earthquake Engineering Research Centre, International Institute of Information Technology, Hyderabad, India. ramancharla@iiit.ac.in
³T. Ito, Interfaculty Initiative in Information Studies/Earthquake Research Institute, The University of Tokyo, t-ito@eri.u-tokyo.ac.jp
⁴K. Takano, Professor, Earthquake Research Institute, The University of Tokyo, takano@eri.u-tokyo.ac.jp

Abstract: The Indian Seismic Code IS: 1893-2007 indicates that about 60% of India’s land area is under threat of moderate to severe earthquake shaking. Also according to census 2011, number of houses exposed such high hazard is almost 80%. This is due to uneven population distribution. In order to find out the potential risk to housing for a city, it is necessary to evaluate Hazard (H), Exposure (E) and Vulnerability (V). Since, vulnerability of a building is combination of many factors like, planning, design, execution and maintenance; it is very difficult to assess the same for entire city. As a case study, a 3-storey RC framed building has been selected in the Union Territory of Chandigarh, which lies in high seismic area; and vulnerability of the same to nearby earthquakes is studied. Building vibration sensors (accelerometers) have been installed at appropriate locations on the building and data acquisition is done. In companion paper, data is acquired first by using micro-tremor observation system and later by using permanent sensors. In this paper, event accelerations recorded at the ground were normalized to earthquakes in zone IV and zone-V areas and response of the building is studied. Fragility curve has been developed for the building area.

Keywords: Micro-tremors, RC framed building, Vulnerability, Fragility

Introduction

Most of the existing buildings are in seismically active zones and are designed for gravity loads only. A large number of them need seismic evaluation due to various reasons such as, noncompliance with the codal requirements, updating of codes, design practice and change the use of the building. However, the existing structure in the earthquake region like Chandigarh has to be provided by some rehabilitation to sustain the expected performance level. Chosen as study, The Union Territory of Chandigarh, located just south of the Himalayan Frontal Belt, has been included in Seismic Zone IV of the Seismic Zonation Map (BIS, 2002. Increasing urban population city like Chandigarh is grown; buildings are constructed horizontal and vertical direction in nearby area. These buildings more severely damage for future earthquake. To decreasing deterioration of structure and increasing PGA at site, these buildings reduce its capacity and, it leads to collapse of structure. It is known that the building degradation will progress during long years after it was built. The
 Twist deformation or the localization of the deformation caused by the shape imbalance or the strength imbalance of the building may be generated. These may cause the unexpected damage when strong ground motion of large earthquake was received. Therefore, it is desired that the effective earthquake proof countermeasure has been done beforehand by investigating peculiar weak point of buildings. To understand seismic response of existing building using vibration sensors. As a case study, a 3-storey RC framed building has been selected in the Union Territory of Chandigarh, which is located Panjab University. Building vibration sensors (accelerometers) have been installed at appropriate locations on the building and data acquisition is done. The main objective of this study is (1) Evaluation of dynamic parameter of building by using permanent sensors data, (2) Evaluation of dynamic parameter of building for normalized event data with zone-IV and Zone-V and (3) Generate the fragility curves.

**Seismicity of Chandigarh**

The Union Territory of Chandigarh is located on the Indo-Gangetic Alluvium, very near to the active tectonic zone. The seismicity in this region is due to movements along several faults, thrusts as well as lineaments. The Himalayan Frontal Thrust, the Main boundary Thrust, the Krol, the Giri, Jutogh and Nahan thrusts lie in this region. Besides that there are scores of smaller faults, like the Kaurik Fault which triggered the 1975 earthquake. The Himalayan earthquakes have their epicenters very close to any of the terrain bounding thrusts i.e. Main Central Thrust (MCT), Main Boundary Thrust (MBT) or Himalayan Frontal Thrust (HFT). Due to its location it weathers dozens of mild earthquakes every year. Large earthquakes have occurred in all parts of Himachal Pradesh, the biggest being the Kangra Earthquake of 1905. There were two more big quakes, but they were not nearly as powerful as the 1905 jolt. The first was in 1906, a 6.4 near Kullu and the second was a 6.8 in Lahual-Kinnaur Spiti in 1975 along the Indo-China Border. The area is also vulnerable to possible future large earthquakes in the Central Himalayas. According to GSHAP (Global Seismic Hazard Assessment Program) also, these areas would expect to have a maximum PGA of 0.08g to 0.32g. The seismic effects in this zone vary from site to site depending on the geological, geomorphological and geotechnical conditions (Bhatia et.al. 1999)

**Description and details of Existing Building**

The three storeys RC infilled framed building is oriented in exact N-S and E-W directions respectively as shown in fig.1. It is located 30° 45’ 39” N, 76° 46’ 2” E. The building has 3 floors with 3m wide corridor on each floor in the center along longer lateral dimension and rooms on each side of the corridor. There are four rows of columns along EW direction of the building and 32 rows of columns along NS direction. The outer columns on front and rear side or elevation of the building are totally exposed. The columns at the outer corners of the building are rectangular of size 0.7 x 0.35 m and the columns in the inner rows of the building are rectangular of the size 0.65 x 0.4m. Beam dimensions are in EW and NS direction are 0.65 x 0.53m and 1.0 x 0.4 m. Between 15th and 16th columns of last two rows from entrance semi spiral staircase is provided from one floor to the next. Between 31st and 32nd column of first two rows of columns dog legged staircase is provided from one floor to the next floor. The height of each floor is 3.94m. Thickness of the slab is 0.2m. Sunshades of 0.2m depth and 1.1m width are provided at a distance of 1.77m below the slab which is attached with columns and resting on walls. The thickness of inner walls along EW direction is 0.8m and thickness of rest of the walls is 0.4m. In this building there is an expansion joint at provided at distance of 23.6m from right side of the building which is after 25th column. Here we dividing whole building into two blocks, one is left side of expansion joint which is block-1 and another one is right side of expansion joint treat as block-2. This building is existed in zone-IV.
conditions are clayey silt soils and the entire building is supported on an isolated footing. As integrity, beams and columns are connected but except in EW direction and along this, lintels are connected. Brick walls are resting on the slabs and beams along EW and only beams in NS direction.

Material properties

The material properties was measured using Rebound hammer test for this buildings. Structural this building had expansion joint, for this study we divied existing building as two blocks i.e block-1(Before expansion joint which is represents column1 to column 25 and Block-2 column 26 to column 32. In both blocks Rebound test was done ground floor to second floor. All exterior column elements at ground floor and few members in interior column and beam elements on each floor level was taken. From rebound hammer, firstly we get the rebound number and then from chart determine the compressive strength of members. Based on obeservation data, assumed each floor average values, which are presented in Table.1. It shows that all exterior column elements are given good concrete quality and all interior column and beam elements are given that fair concrete quality compared to table.1(IS 13311 Part-2-1992). Block-2 element have less strength as compared to Block-1 and in floor wise also strength is decending oder.

<table>
<thead>
<tr>
<th>Members</th>
<th>Floors</th>
<th>Average strength (f_{ck} N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block-1</td>
<td>Ground floor</td>
<td>37.53</td>
</tr>
<tr>
<td></td>
<td>First floor</td>
<td>37.53</td>
</tr>
<tr>
<td></td>
<td>Second floor</td>
<td>37.53</td>
</tr>
<tr>
<td>Interior column</td>
<td>Ground floor</td>
<td>16.50</td>
</tr>
<tr>
<td></td>
<td>First floor</td>
<td>16.00</td>
</tr>
<tr>
<td></td>
<td>Second floor</td>
<td>13.75</td>
</tr>
<tr>
<td>Beams</td>
<td>All floors</td>
<td>16.25</td>
</tr>
<tr>
<td>Block-2</td>
<td>Ground floor</td>
<td>27.60</td>
</tr>
<tr>
<td></td>
<td>First floor</td>
<td>27.60</td>
</tr>
<tr>
<td></td>
<td>Second floor</td>
<td>27.60</td>
</tr>
<tr>
<td>Interior column</td>
<td>Ground floor</td>
<td>16.50</td>
</tr>
<tr>
<td></td>
<td>First floor</td>
<td>16.00</td>
</tr>
<tr>
<td></td>
<td>Second floor</td>
<td>13.75</td>
</tr>
<tr>
<td>Beams</td>
<td>All floors</td>
<td>16.25</td>
</tr>
</tbody>
</table>

Sensors location and Data acquisition

Nine sensors are installed; in each floor three sensor are presents and which are kept alignment of parallel to building as shown in fig.2. These sensors placed left, middle and right of building and also placing in floor wise from ground to second floor. These sensors aligned parallel to building which exact NS and EW direction. These IT kyoshine sensors are connected through network cable and connected with mac-mini. From mac-mini, collect the data do the analysis and also send thee data to server where data monitoring is taken. Once obtained the data from mac-mini, using seismo single software, done the base line correction and filter data corresponding band pass filter and range of frequency of interest.

Description of structural model
The dead and live loads are taken IS: 875 Part-1 and II based on its functional utility of building. It is the Educational institution in the first and second floor and third is 1.5 kN/m². Unit weight of brick has taken as 20 kN/m³. The material Properties of beam and columns elements are used as 20 kN/m².

mention above table.1 and Fe 415 steel. The analysis and designed is carried out according to Indian Code IS456:2000 only gravity loads case and 2D frame analysis is performed using SAP2000 Nonlinear Version.11. A description of the modeling details is provided in above discussion. Beam and column elements are modeled as nonlinear frame elements with lumped plasticity by defining plastic hinges at both ends of the beams and columns. SAP2000 implements the plastic hinge properties described in FEMA-356 (or ATC-40). SAP2000 provides auto-hinge properties and recommends PMM hinges for columns and M3 hinges for beams. Once the structure is modeled with section properties, steel content and the loads on it, auto hinges are assigned to the elements (PMM for columns and M3 for beams). After assigning all properties of the models, the displacement-controlled pushover analyses of the models are carried out. In this study, target displacement is taken 4% of building height.

Event of Earthquake

In this study we have chosen an event which was occurred in J&K and Himachal Pradesh region, on 26 July 2012 at GMT 05:31 AM Local time and lat long of 33.20N and 76.3E and intensity was Mw 3.8. Event is recorded in nine sensors location of the Existing building. Data is extracted two mints in both NS and EW direction of Block-1 and Block-2. These data is done base line correction and Butterworth-band pass filter range of 2.0 Hz to 50 Hz used for this study. Using seism signal software, generate the Fourier spectrum and from this calculate the transfer function of building and its results are shown in fig.3 (a) and 3(c) respectively. In Block-1, fig.3 (a) and fig.3 (b) are represents that in NS and EW direction and fig.3(c) is represents that in NS and EW direction of transfer function. From transfer function results, it was observed that natural frequency of structure during event of earthquake in N-S direction in Block-1 is 4.13 Hz and 4.26Hz and Block-2 is 5.02 Hz. Similarly E-W direction natural frequency of Block-1 is 3.34 Hz and 3.4 Hz and Block-2 is 3.14Hz respectively. Block-2 has high natural frequency as compared to Block-1 along N-S direction. In Block-1 has high natural frequency as compared to Block-2 along EW direction. From observation, in block-2 infill walls are presented all direction as compared to block-1. This infill effects which is increasing stiffness along NS direction. Block-2, along EW direction natural frequency is less because, at expansion joint beam elements are just resting on wall not connection with column due to this block-2 natural frequency values along EW direction less compared to block-1.

Normalization of event data with zonation factor

For continuation of further study, Event as a ground motion has taken at ground floor level i.e. itk00 and itk06 both along N-S and E-W direction. This event was done normalization and multiple with zone factor 0.24g and 0.36g respective direction of motion. 3D modeling was done in SAP2000, Brick Infill’s are not including this modeling part, considering bare frame effect of building with slab treat as shell element and dynamic linear analysis was carried out for both zone-IV and zone-V factor of ground motion and each floor response building i.e. block-1 and block-2 has taken. The results are presented as transfers function shown in fig.4 (a) to
fig.4 (d). Fig.4 (a) and fig.4 (b) are transverse function of zone-IV and fig.4(c) and fig.4 (d) are transverse function of zone-V. In Zone-IV, natural frequency values in N-S direction are 1.79 Hz and 1.73 Hz and E-W direction are 1.78 Hz and 1.76Hz in both block-1 and block-2 respectively. In Zone-V, natural frequency values in N-S direction are 1.76 Hz and 1.72 Hz and E-W direction are 1.70 Hz and 1.75Hz in both block-1 and block-2 respectively. From observation it is conclude that, Zone-IV frequencies are higher values as compare to zone-V frequency values. This building more vulnerable for zone-V as compared to zone-IV. As comparing this values with event data natural frequency are decreases. From observation, it concludes that existing structure will loss stiffness.

Fig.3. (a) Transfer function of building along N-S directions (a) Left side of building block-1(b) Middle of building block-1.

Fig.3. (b) Transfer function of building along E-W directions (a) Left side of building block-1(b) Middle of building block-1.

Fig.3. (c) Transfer functions of building block-2 along (a) N-S (b) E-W.

Fig.3. (d) Transfer function of building along E-W directions (a) Block-1 (b) Block-2.

Fig.4. (a) Transfer function of building along N-S directions (a) Block-1 (b) Block-2.

Fig.4. (b) Transfer function of building along E-W directions (a) Block-1 (b) Block-2.

Fig.4. (c) Transfer function of building along N-S directions (a) Block-1 (b) Block-2.

Fig.4. (d) Transfer function of building along E-W directions (a) Block-1 (b) Block-2.

**Fragility Curve**

The fragility curves are generating from pushover analyses. Pushover results are shown in fig.5 (a) to fig.5 (b) and block-1 maximum load carrying capacity reached up to 2393 kN corresponding roof displacement of 0.07 m and in block-2, load carrying capacity is 601 kN and corresponding roof displacement is 0.38m along EW direction and NS direction in block-1 and block-2 are 142 kN and 2100 kN corresponding displacement are 0.28m and 0.17m respectively. Fragility curve have been developed based on energy principle approach. For Block-1 and Block-2 fragility curves are shown in fig.5(c). From fragility curve, it conclude that the Block-1 in NS and EW direction the displacements are reaches the 0.29m and 0.08m at collapse state and similarly, Block-2 in both NS and EW direction, it reaching displacement at 0.177m and 0.38m respectively. From results it shows that firstly, block-1 collapse along EW direction and in case of block-2 collapse, along NS direction. Because in block-2 structural not integrated at expansion joint.
Conclusion

As a case study, a 3-storey RC framed building has been selected in the Union Territory of Chandigarh, which lies in high seismic area; and Vulnerability of the same to nearby earthquakes is studied. Building vibration sensors (accelerometers) have been installed at appropriate locations on the building and data acquisition is done. Data is acquired first by using permanent sensors. An event occurred July 26, 2012, magnitude of 3.8. Transfer function was done for event data and compared to block-1 and block-2 in both directions. And also done the accelerations recorded at the ground were normalized to earthquakes in zone IV and zone-V areas and response of the building is studied. Zone-V values has high natural period present compared to zone-IV. These values compared to event data, Zone-IV frequencies are higher values ascompare to zone-V frequency values. As comparing this values with event data natural frequency are decreases. From observation, it concludes that existing structure will lose its stiffness from zone factor values compared with event values. Fragility curve has been developed for the building. From fragility curve, it concludes that firstly block-1 collapse along EW direction and block-2 collapse along NS direction.

References