International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 12, December 2016
www.ijates.com
ijates
ISSN 2348 - 7550

SEISMIC VULNERABILITY ASSESSMENT OF EXISTING HOSPITAL BUILDINGS IN IMPHAL CITY

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ABSTRACT

Modern civilization has faced frequent devastating disaster in the last decade due to major earthquakes. Therefore, it has jeopardised the existing building stock and hence necessitated their vulnerability assessment. Such assessments are helpful for the administrators to adopt appropriate measures that can reduce the loss of human lives and properties. The past history of earthquake particularly the damage associated to the structures is an important unit in seismic vulnerability.

The present study deals with the seismic vulnerability assessment of an important existing Reinforced concrete building of public interest- a hospital- situated in Imphal city, Manipur. Imphal city lies in a longitude of 93°56'E and a latitude of 24°44'N, which is the capital of Manipur state in the North-east part in India. North-east India is one of the seismically active regions out of the most active regions in the world. This region falls under Zone-V of the earthquake Zonation map of India (zone of most severe seismic hazard) according to IS1893:2002. A field survey of some of the existing hospital buildings in Imphal was carried out and a preliminary assessment of seismic vulnerability was made.The Rapid Visual Screening (RVS) was done by using RVS form by Prof.Arya. one of the hospital buildings which were found to be vulnerable from RVS was evaluated using numerical analysis, using SAP2000 in order to assess their vulnerability for Simplified Vulnerability Assessment (SVA). The deficient members observed from the output are suggested for strengthening and retrofitting.

Keywords: Disaster, RVS, Seismic, SVA, Vulnerability Assessment.

1. INTRODUCTION

1.1 General Introduction

India has witnessed devastating disasters to humans and buildings, particularly to the urban areas due to some major earthquakes in the last decade. Though earthquake is a low probable event but it has very high consequences. During the last 15 years, India has experienced 10 major earthquakes that have resulted huge loss of life mostly (over 90%)

due to collapse of manmade structures. The damages and even the collapse of structures are mainly responsible for this huge loss of life, cost for repair and rehabilitation and the loss due to business interruption. The main reasons behind collapse and loss of structures are poor constructions of structures without understanding their seismic performances. Hence preparation's against earthquake is the only option to combat this deadly event. More importantly the performances of existing structures against seismic activity are essential to be studied to quantify its seismic vulnerability.

1.2. Relevance of the study

The M6.7 earthquake of January 4, 2016 struck at 4:35am IST with its epicentre located in the Tamenglong district (24.83°N 93.66°E) of Manipur about 30 km west of the state capital Imphal. The earthquake was strongly felt in all North-eastern states of India, Bangladesh and Myanmar. The worst affected regions are Imphal, Tamenglong, Noney and Thoubal. A few aftershocks of magnitude less than M4.0 were also felt within a day of the main shock. A part of the north-east India, especially Assam, Nagaland and Mizoram also experienced intense shaking during earthquake.

The earthquake occurred as a result of strike-strip faulting in the plate boundary region between the Indian and the Eurasian plate. This boundary region has a history of experiencing large and great earthquakes. The largest event was M8.0 in 1946 on the Sagaing fault about 220 km to the southeast of the 2016 earthquake. Another event of M7.5 in January 1869, (Cachar Earthquake) caused widespread damage in Imphal city. Other nearby damaging events include a M7.3 earthquake 150 km to the east of the 2016 event in the Indo-Burma region in August 1988, and a M6.0 earthquake 90 km to the Southeast in December 1984 causing several fatalities and injuries.

Even though the Indian standard code for seismic design, IS 1893:2002, has identified the North-eastern part of India, including Imphal city, as the zone of most severe seismic hazard (zone V), it was rather perplexing to discover that a great majority of buildings seriously lacked earthquake resistant features, which are so essential for a satisfactory seismic performance in the design level shaking. Several RC buildings in Imphal suffered varying degree of damage, from minor damages to complete collapse, during this earthquake.

1.3. Objectives

The objective is to assess the seismic vulnerability of a Hospital building of Imphal city. The Hospital Building under study will undergo seismic vulnerability assessment by 3 levels of procedures (developed by Padmshree Prof. S. Arya), namely

I. Rapid Visual Screening (RVS), a procedure requiring only visual evaluation and limited information
II. Simplified Vulnerability Assessment (SVA), procedure requiring limited engineering analysis based on information from observations and structural drawings or on site measurement, and

III. Detailed Vulnerability Assessment (DVA), procedure requiring detailed computer analysis, similar to or more complex than that required for design of a new building. This procedure is recommended for all the important lifeline buildings. The study will finalize the seismic vulnerability of the Hospital building and according to that, a comparative analysis for different methods of repairing and retrofitting will be made.

II SEISMIC VULNERABILITY ASSESSMENT

2.1. RVS Procedure

Rapid Visual Screening has been conducted on one of the hospital buildings i.e. Chamber hospital in Imphal. Here, the RVS procedures of Prof. Arya have been used to evaluate the buildings. During the field survey the infill walls are made of brick masonry. RC Columns are tied together with RC beams at the slab levels. Foundations are usually in the form of isolated footings. According to survey, architectural and structural drawings were not available in Chamber hospital.

From the collected data obtained from the site visit, the vulnerability assessment of the building has been carried out and the details of the assessment of the building are shown in RVS forms.

2.2. Observations of the RVS Procedure

From the vulnerability assessment, Chamber Hospital falls under Grade 4 (G4) in which heavy structural damage and very non-structural damage occurs. G4 damage includes large cracks in structural elements with compression failure of concrete and fracture of rebar's; bond failure of beam reinforcing bars; tilting of columns.

Since, the results of Chamber Hospital falls under G4, it will experience severe structural damage from RVS analysis. Hence, further analysis i.e., SVA is carried out for the said building.

Fig1. Chamber Hospital

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ISSN 2348 - 7550

RVS FORM FOR REINFORCED CONCRETE FRAME (RCF) / STEEL FRAME (SF) BUILDINGS FOR SEISMIC HAZARD (by Padmshree, Prof. Anand S. Arya)

Seismic Zone V, All Buildings (Also for Seismic zone IV Important Buildings)

1.0 General Information

- 1.1 Seismic Zone ✓
- 1.2 Building name CHAMBER HOSPITAL
- 1.3 Use Residential ☐ Office ☐ School ☐ Hospital ✓ Others ☐
- 1.4 Address: THANGAL BAZAR Pin 795001
- 1.5 Other Identifiers
- 1.6 No. of Stories G+4
- 1.7 Year Built 1980
- 1.8 Total Covered Area; all floors (sq.m) 1438.8
- 1.9 Ground Coverage Sq.m) 239.8
- 1.10 Soil Type: SOFT

2.0 RC / Steel Frame Building Typology

2.1 Foundation Type

- 2.1.1 Individual footing Yes ✓ No ☐
- 2.1.2 Individual footing with connecting beam Yes ☐ No ✓
- 2.1.3 Beam Raft foundation Yes ☐ No ✓
- 2.1.4 Full solid raft Yes ☐ No ✓
- 2.1.5 Pile foundation Yes ☐ No ✓
- 2.1.6 Any other (describe)

2.2 Flat Roof or Floor

- 2.2.1 RC slab or T beam Yes ✓ No ☐
- 2.2.2 Steel beam and plate deck Yes ☐ No ✓
- 2.2.3 Flat slab or flat plate Yes ☐ No ✓
- 2.2.4 Overall depth of floor / roof Yes ☐ No ✓
- 2.2.5 Any other (describe)

2.3 Pitched roof Understructure

- 2.3.1 RCC Elements Yes ☐ No ✓
- 2.3.2 Steel Truss / rafter / purlin Yes ☐ No ✓
- 2.3.3 Any other (describe)

2.4 Pitched Roof Covering

- 2.4.1 CGI Sheets Yes ☐ No ✓
- 2.4.2 A.C. Sheets Yes ☐ No ✓
- 2.4.3 Fiber sheets Yes ☐ No ✓
- 2.4.4 Any other (describe)

3.0 Structural Frame Types *

3.1 RC beam-post buildings without Earthquake Resistant Design, (built in Non-engineered way). Yes ✓ No ☐

3.2 C Steel Frame (RCF/SF) of ordinary design for gravity loads, without Earthquake Resistant Design Yes ☐ No ✓

3.3 Moment Resistant Frame –(RCF/SF) of ordinary design, without Earthquake Resistant Design Yes ☐ No ✓

3.4 Moment Resistant Frame – (RCF/SF) with ordinary Earthquake Resistant Design and with ordinary in-fill walls. Yes ☐ No ✓

3.5 Moment Resistant – (RCF/SF) with high level of Earthquake Resistant Design and special ductile details. Yes ☐ No ✓

3.6 Moment Resistant Frame – (RCF/SF) with high level of Earthquake Resistant Design and special ductile details and with well designed in-fill walls/braces.* Yes ☐ No ✓

3.7 Moment Resistant Frame– (RCF/SF) with high level of Earthquake Resistant Design, special ductile details and with detailed RC shear walls or, detailed steel braces & cladding. Yes ☐ No ✓

** Indian Standards IS:13920-1993, IS:1893-2002, and SP6(6)-1972*

4.0 Special Hazard

4.1 High Water Table (within 3m below ground level) & if sandy soil, then liquefiable site indicated. Yes ☐ No ✓
(If yes, Increase damageability grade by 2 units upto G5)

4.2 Severe Vertical Irregularity in building Yes ✓ No ☐
(If yes, Increase damageability grade by 2 units upto G5)

4.3 Severe Plan Irregularity in the building Yes ☐ No ✓
(If yes, increase damageability grade by 1 unit upto G4)

4.4 Land Slide Prone Site Yes ☐ No ✓
(If yes, it may lead to damageability grade G5)

5.0 Non-structural Building Components

Whether the following non-structural building elements are present and stabilized against the earthquake?

5.1 Divisions/partition (brick wall/wooden partitions)
- Provided Yes ✓ No ☐
- Stabilized against Earthquake Yes ✓ No ☐

5.2 Façade elements (cladding/decorative elements)
- Provided Yes ☐ No ✓
- Stabilized against Earthquake Yes ☐ No ✓

5.3 False Ceilings
- Provided Yes ☐ No ✓
- Stabilized against Earthquake Yes ☐ No ✓

5.4 Brick parapets / pillars / planters etc.
- Provided Yes ✓ No ☐
- Stabilized against Earthquake Yes ✓ No ☐

5.5 Roof Chimneys
- Provided Yes ☐ No ✓
- Stabilized against Earthquake Yes ☐ No ✓

5.6 RC / Masonry Water Tank on Roof
- Provided Yes ☐ No ✓
- Stabilized against Earthquake Yes ☐ No ✓

5.7 Signs/display boards etc.
- Provided Yes ✓ No ☐
- Stabilized against Earthquake Yes ✓ No ☐

Note: Assessment of 5.0 does not modify the damageability grade of the building, but non-structural damage could be harmful to occupants

Abbreviations:

RC: reinforced concrete, RCF: reinforced concrete frame, SF: steel frame, CGI: Corrugated Galvanized Iron Sheets, AC: Asbestos Cement Sheets, URM: unreinforced masonry, R/F reinforcement

International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 12, December 2016
www.ijates.com
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ISSN 2348 - 7550

6.0 Probable Damageability in few / many RCG/SF Buildings

RC or Steel Frame Building type(*See Table-1*)	C / C+	D	E / E+	F	URM Infill
Damageability in Zone V, Very High Intensity MSK IX or more *See Table-2)*	G4 / G3	G3	G2 / G1	G2 / G1	G4

Note: + sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated. Surveyor will identify the building type, encircle it, also the corresponding damage grade.

7.0 Recommended Actions during evaluation

If the **damageability grades** are:

- G1/G2 : building may be considered seismically safe.
- G3 : the building will not be likely to collapse, but subject to moderate to heavy damage. In such case, the building may be recommended for retrofitting.
- G4/G5 : the building is unsafe and will need re-evaluation and retrofitting.

If any **Special hazard** -

- Special hazard (4.0) is found, hazard should be removed or prevented.
- Special hazard (5.0) is present, either remove it, or stabilize against earthquake.

8.0 Attach Sketch Plan with section

9.0 Attach Photographs of the building

Surveyor's sign: Sandhya Date: 5-4-16

Name: SOIBAM SANDYARANI DEVI

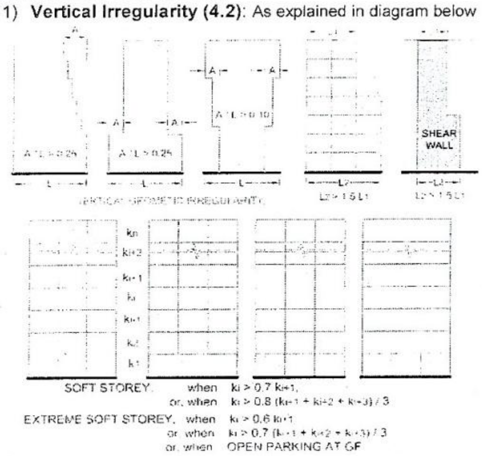
QUICK GUIDE FOR READY REFERENCE

Equipments to be carried by the Surveyor:-

1) Digital Camera, Measuring tape
2) Hard board with clip, Pen (black), pencil, eraser
3) Adequate no. of survey sheets, RVS guidelines.

EXPALANTORY NOTE:-

1) **Vertical Irregularity (4.2)**: As explained in diagram below



2) **Plan Irregularity (4.3): As explained in diagram below**

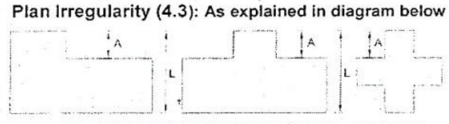


Table 1: Reinforced Concrete Frame Buildings (RCF) and Steel Frames (SF)

Type	Description
C	a) RC Beam Post buildings without ERD or WRD, built in non-engineered way. b) SF without bracings having hinge joints. c) RCF of ordinary design for gravity loads without ERD or WRD. d) SF of ordinary design without ERD or WRD
C+	a) MR-RCF/MR-SF of ordinary design without ERD or WRD. b) Do, with unreinforced masonry infill. c) Flat slab framed structure. d) Prefabricated framed structure.
D	a) MR-RCF with ordinary ERD without special details as per IS: 13920*, with ordinary infill walls (such walls may fail earlier similar to C in masonry buildings.) b) MR-SF with ordinary ERD without special details as per Plastic Design Hand Book SP:6(6)-1972*.
E	a) MR-RCF with high level of ERD as per IS: 1893-2002* & special details as per IS: 13920*. b) MR-SF with high level of ERD as per IS: 1893-2002* & special details as per Plastic Design Hand Book, SP:6(6)-1972*
E+	a) MR-RCF as at E with well designed infills walls. b) MR-SF as at E with well designed braces.
F	a) MR-RCF as at E with well designed & detailed RC shear walls. b) MR-SF as at E with well designed & detailed steel braces & cladding. c) MR-RCF/MR-SF with well designed base isolation.

IS:13920-1993, "Ductile Detailing of Reinforced concrete structures subjected to seismic forces-Code of Practice" IS:1893(Part-I) 2002, "Criteria for Earthquake Resistant Design of Structures". SP:6(6)-1972, "Plastic Design of Steel Structures—Handbook"

Abbreviations: *ERD : Earthquake Resistant Design, WRD: Wind Resistant Design, MR : Moment Resistant jointed frame*

Table 2: Grades of Damageability of RCF/SF Buildings

Grade	Description
G1	*Negligible to slight damage (no structural damage, slight non-structural damage)* Fine cracks in plaster over frame members or in walls at the base. And Fine cracks in partitions & infills.
G2	*Moderate damage (Slight structural damage, moderate non-structural damage)* Cracks in columns & beams of frames & in structural walls. Cracks in partition & infill walls; fall of brittle cladding & plaster. Falling mortar from the joints of wall panels.
G3	*Substantial to heavy damage (moderate structural damage, heavy non-structural damage)* Cracks in columns & beam column joints of frames at the base & at joints of coupled walls. Spalling of concrete cover, buckling of reinforced rods. Large cracks in partition & infill walls, failure of individual infill panels.
G4	*Very heavy damage (heavy structural damage, very heavy non-structural damage)* Large cracks in structural elements with compression failure of concrete & fracture of rebar's; bond failure of beam reinforcing bars; tilting of columns. Collapse of a few columns or of a single upper floor.
G5	*Destruction (very heavy structural damage)* Collapse of ground floor parts (e.g. Wings) of the building.

*NOTES: The grades of damage in steel and wood buildings will also be based on non-structural and structural damage classification (shown in **bold** print in above Table2. Non-structural damage to infills would be the same as masonry building.*

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ISSN 2348 - 7550

2.2. SVA Using Numerical Analysis

The Simplified Vulnerability Assessment is carried out on Chamber Hospital which was found to be vulnerable in RVS procedure. Here, the re-evaluation of the building is done by numerical analysis using SAP2000. The building is evaluated by linear analysis considering the thirteen load combinations for RCC as per IS 1893:2002. If the building members are found to be deficient, member sizes are increased and analysis will be done again.

The base of the Chamber Hospital building has horizontal dimension of 11.0 m x 21.8 m. It has two bays along X-axis and seven bays along Y-axis in the ground floor. In the remaining four floors, it has three bays along X-axis and seven bays along Y-axis. The height of each room is 3.2 m. Height of the building is 16.0 m. The Material properties are assumed to be M20 Grade concrete and Fe 415 steel for the yield strength of the longitudinal and shear reinforcement. The details of the plan and elevation of the building are shown in fig.2 and fig.3respectively. The sectional properties of various elements obtained are based on gravity analysis and use as initial sizes for further analysis, presented in Table 1.

TABLE1.Initial member sizes considered for analysis

Members	Size in mm
Column at all floor	450 x 450
Beam at all floor	350 x 350

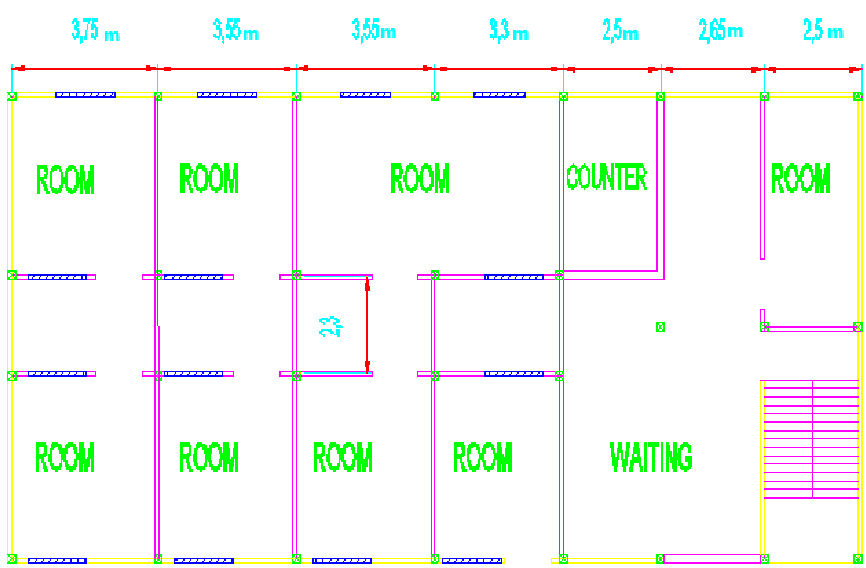

Fig.2. Plan of the Building

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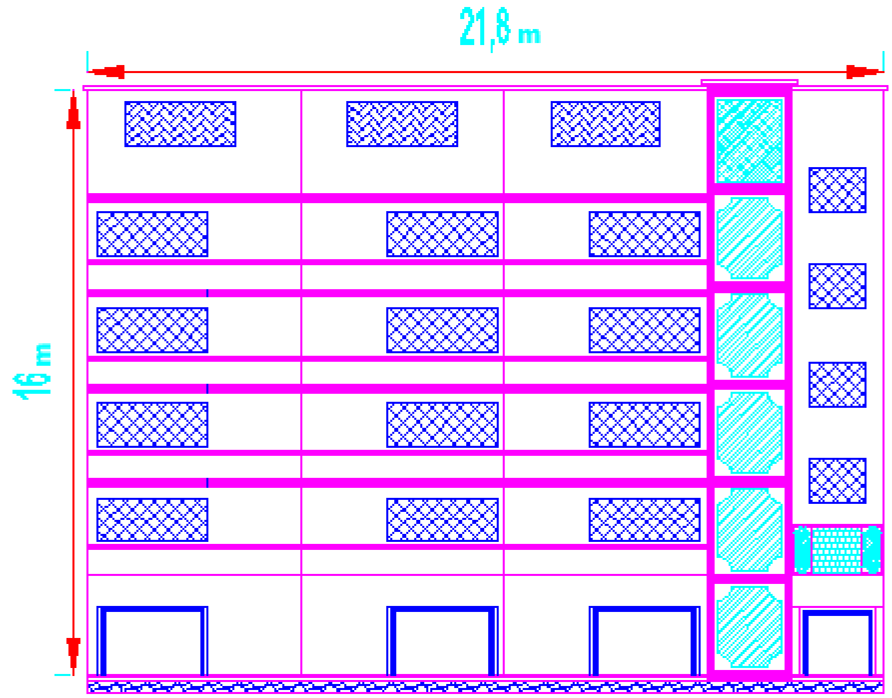

Fig.3. Elevation of the building

2.3. Analysis considering the thirteen load combination

The thirteen load combination as per IS 1893:2002 is considered in the analysis of the existing sizes of the members and the results are given in the form of a 3D Model as an output of analysis by finite element package SAP2000.The loads on the structure are as per IS 875 Part 2 1987. Live load for the roof is taken as 1.5 KN/m^2 and for the floor 3kN/m^2. The thickness of the floor is assumed as 150 mm. The walls are half brick. Dead load is the self-weight of the structures in which the self-weight of the member is automatically involved by SAP 2000 on the calculation. The weight of the slab was distributed to the surrounding beam. The foundation system for building is an isolated foundation.

Analysis exposes some weakness in the building. The dotted line in the output of analysis shows structural failures of beams and columns. Some columns are built as floating columns. It shows that the columns and beams at the ground floor and the first floor fails; indicating excessive ductility demand in the ground and the first storey column, which may lead to collapse indicating unacceptable performance and need to be retrofitted. The output of the analysis in 3-D model is shown in fig. 4, fig.5 and fig.6 respectively.

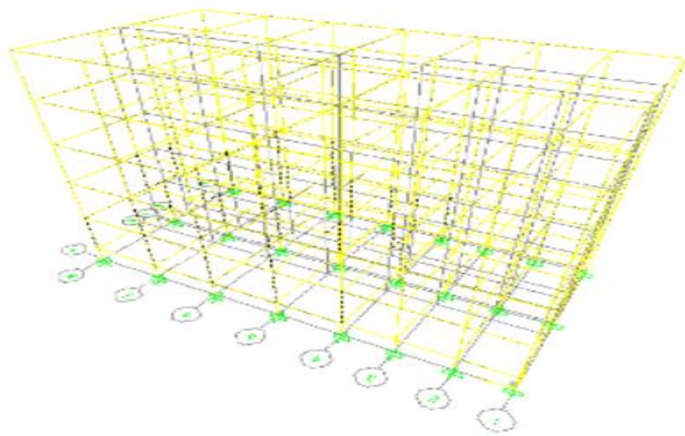

Fig.4. 3-D model showing failed columns and beam of the structure.

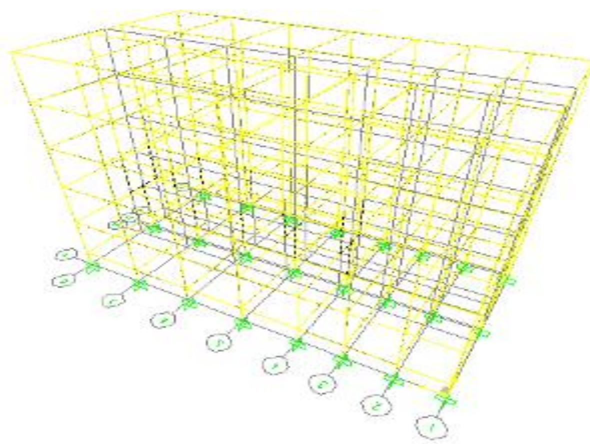

Fig. 5.3-D model of the structure after retrofitting

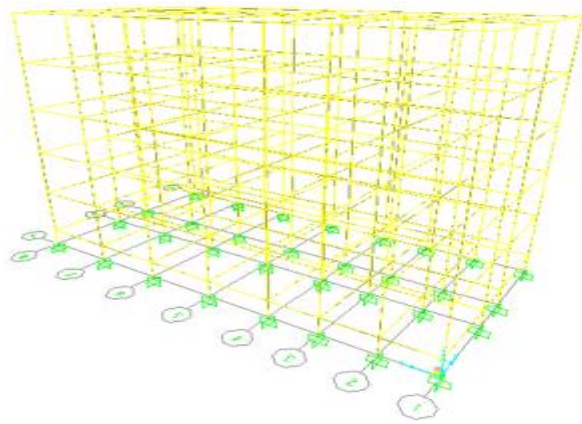

Fig.6. 3-D model after redesigning of the structure

2.4. Result of SVA

The level-2 procedure (SVA) has been completed on the Chamber hospital building and the performance objectives have been imposed to satisfy the code compliance and to insist favourable failure pattern. Columns and beams in the ground floor and the first floor were found deficient. 30 numbers of column members and 5 numbers of beams were found deficient (overstressed). The cross-sectional area has been increased and reanalysed and some column members were found safe and few column and beams remain failed. Thus, the cross-sectional area has been increased and redesigned and found safe. The structures were redesigned, correcting the vertical irregularities by removing the floating columns and then the structure was found to be safe without any deficient in column and beam. Thus, retrofitting is not the best or suitable choice for this condition.

III CONCLUSION

Problem of assessment of safety of existing structures against various loads, including earthquake load, has been recognized world over. In developing countries, about 50% of the construction industries resources are being utilized for the problems associated with existing structures. Many countries have developed standards for assessment of existing structures. In India, the problem is slowly showing it's extend.

In the Imphal city, the need of assessing building as an earthquake safety measure is a must. Some of the hospital buildings were found to be non-engineered structures, thus making the structure vulnerable to earthquake. This is mainly due to lack of awareness on the concept of seismic design code and ignorance of the people.

In our present study, Chamber hospital has been surveyed in the Level-1 procedure (i.e. RVS procedure). The building was found to be vulnerable and hence require level-2 procedure. In the Level-2 procedure, the chamber building was evaluated by Numerical Analysis using SAP 2000. Considering the thirteen-load combinations as per IS 1893:2002, the hospital building was found to be deficient in 30 columns and 5 beams out of the total members. In older RC hospital building, column failures were more frequent since the strength of beams in such construction was kept higher than that of the column. Thus, increasing the cross-sectional area and enlarging the member sizes with the concept of strong column-weak beam, the building was not found to be safe. The building was recommended for retrofitting through column jacketing and beam jacketing. However, after redesigning by removing the floating column of the structure, the building was analysed further and was found to be safe. The retrofitting was not needed after this later analysis. Hence, from the view of the analysis, redesigning the hospital building is the most suitable recommendation to prevent from seismic hazard.

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