CHAPTER 4

ANALYTICAL RESULTS AND EVALUATION ON EXISTING RCC BUILDING

4.1 GENERAL

A three storied existing hostel building was taken up for the investigation. The building was considered as bare frame and Infilled frame subjected to earthquake forces as specified in the IS code for Zone- III along X and Y directions. For the seismic evaluation, a Pushover analysis was performed. The analysis showed that the behavior levels of various components of building for different specified performance objective as per ATC 40. Based on this evaluation it was concluded that the building needs retrofitting to enhance its performance to the required level.

4.1.1 Base Shear

a) Bare frame

The base shear was calculated by using from IS 1893(part- 1)-2002 and SAP2000 software as 580 kN and 650 kN in X and Y directions respectively.

b) Infill frame

The base shear was calculated by using IS 1893 (part- 1)-2002 and SAP2000 software as 580 kN and 680 kN respectively in X and Y directions respectively.
Though Fundamental natural period of vibration ($T_a$), is different for frame with and without infill, since $S_a/g$ is 2.5, there is no difference in base shear ($V_b$) in both cases as per calculation of IS 1893 (part-1)-2002.

4.1.2 Pushover Curve

a) Bare Frame

Pushover curves for the building in X and Y direction are shown in Figure 4.1 and Figure 4.2. These curves depict the global behavior of the frame in terms of its stiffness and ductility. For bare frame base shear from pushover analysis was 1288 kN at a displacement of 0.180 m in the X direction. The base shear from pushover analysis was 2924 kN at a displacement of 0.030 m in the Y direction. In the Y direction the base shear was more compared to the X direction because of configuration of the columns in the frames.

![Figure 4.1 Bare Frame Pushover Curve in X- Direction](image)

Ductility Factor = Ultimate load/Yield load
= $1288.426/987.011$
= 1.305

Stiffness = Linear Load/Corresponding Deflection
= 82,250 kN/m

Figure 4.1 Bare Frame Pushover Curve in X- Direction
Figure 4.2 Bare Frame Pushover Curve in Y -Direction

b) Infill Frame

Pushover curves for the building in X and Y directions are shown in Figure 4.3 and Figure 4.4. For infill frame base shear from pushover analysis was 1381 kN at a displacement of 0.36 m in the X direction and base shear from pushover analysis was 3270 kN at a displacement of 0.023 m in the Y direction. Therefore, infill frame stiffness would result in more resistance to earthquake force when compared to the bare frame resistance. Thus the use of the infill, had increased the base shear capacity of the structure.

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\text{Ductility Factor} = \frac{\text{Ultimate load}}{\text{Yield load}} = \frac{2923.675}{2171.5} = 1.346
\]

\[
\text{Stiffness} = \frac{\text{Linear Load}}{\text{Corresponding Deflection}} = 2,71,437 \text{ kN/m}
\]
Figure 4.3 Infill Frame Pushover Curve in X -Direction

Ductility Factor = Ultimate load/Yield load
= 1381/1028.469
= 1.342

Stiffness = Linear Load/Corresponding Deflection
= 1,02,846 kN/m

Figure 4.4 Infill Frame Pushover Curve in Y –Direction

Ductility Factor = Ultimate load/Yield load
= 3049.009/2349.6
= 1.297

Stiffness = Linear Load/Corresponding Deflection
= 2,61,068 kN/m
4.1.3 Capacity Spectrum and Building Performance Level

Capacity spectrum is the capacity curve transformed from base shear versus roof displacement co-ordinates into spectral acceleration versus spectral displacement (Sa Vs Sd) co-ordinates. The performance point is obtained by superimposing demand spectrum on capacity curve transformed into spectral coordinates. To have desired performance, every structure has to be designed for the spectral acceleration corresponding to the performance point.

a) Bare Frame

The bare frame performance point was obtained at a base shear level of 1016.436 kN and displacement of 0.015 m in the X direction as shown in Figure 4.5. In that performance point, the structure reached immediate occupancy level as shown in Figure 4.6. The performance point was obtained at a base shear level of 1,330.743 kN and displacement of 0.0044 m in the Y- direction as shown in Figure 4.7. In that performance point, the structure reached collapse prevention level as shown in Figure 4.8. Therefore, it is found that the structure is more critical in the Y direction compared to the X direction.
Demand Spectrum  Capacity Spectrum  Domain Curve

Figure 4.5 Capacity Spectrum for Bare Frame in X-Direction

Figure 4.6 Hinges Formation in X- Direction at Performance Level
Figure 4.7 Capacity Spectrum for Bare Frame in Y-direction

Figure 4.8 Hinges Formation in Y direction at Performance Level
b) Infill frame

The infill frame performance point was obtained at a base shear level of 1090.675 kN and displacement of 0.018 m in the X direction as shown in Figure 4.9. The performance point was obtained at a base shear level 1632.520 kN and displacement 0.005 m in the Y-direction as shown in Figure 4.10. The structure’s condition at the performance point is discussed later based on failure mechanisms.

![Demand Spectrum](image)

**Figure 4.9 Capacity Spectrum for Infill Frame in X-Direction**
4.1.4 Plastic Hinge formation

a) Bare frame

In the X direction plastic hinge formation of the building was observed at different displacements levels. Plastic hinge formation starts with beam ends and later on proceeds to base of columns of lower stories and then propagates to upper stories and continues with the yielding of interior intermediate beams. However, yielding occurs at designated events such as B (yielding), IO (Immediate occupancy), LS (Life safety) and last hinge CP (collapse prevention) respectively, the amount of damage in this direction was expected to be limited based on the predicted displacements as below.
The first hinge formation occurs at a load of 664.45 kN and at a displacement of 0.007 m as shown Figure 4.1. The typical moment versus rotation curve for first hinge formation of beam element is shown in Figure 4.11. Figure 4.12 shows the idealized moment rotation curve for first hinge formation of beam element of initial yielding, immediate occupancy and collapse prevention. The moment and rotation value for point B (Yielding) were 1.576 kNm and 0.0017 radians respectively. The moment and rotation value for point IO (Immediate occupancy) were 1.785 kNm and 0.0254 radians respectively. The moment and rotation value for point CP (Collapse Prevention) were 1.934 kNm and 0.0356 radians respectively.

Figure 4.11 Typical Moment versus Rotation Curve for First Hinge Formation of Beam Element in X-Direction
Figure 4.12  Idealized Moment versus Rotation Curve for First Hinge Formation of Beam Element in X-Direction

In the Y direction Plastic hinge formation starts with beam ends and base columns of lower stories, then propagates to upper stories and continues with yielding of interior intermediate beams. It has found that the CP (Collapse Prevention) has reached earlier as compared to X direction. In addition, three hinges of beams has reached C (Ultimate moment). The amount of damage is more in the Y direction as compared to the X direction.

The first hinge formation occurs at a base shear and displacements of 596.41 kN and 0.002 m as shown in Figure 4.2. The typical moment versus rotation curve for first hinge formation of beam element is shown in Figure 4.13. Figure 4.14 shows the idealized moment rotation curve for first hinge formation of beam element of initial yielding, collapse prevention and
ultimate moment of resistance. The moment and rotation value for point B (Yielding) were 7.347 kNm and 0.00146 radians respectively. The moment and rotation value for point CP (collapse prevention) were 7.408 kNm and 0.00156 radians respectively. The moment and rotation value for point C (Ultimate moment of resistance) were 8.008 kNm and 0.00251 radians respectively.

Based on the analysis, the beam first reached its capacity and it took a rotation of 0.00156 radians at performance point level.

![Figure 4.13 Typical First Hinge Formation of Moment versus Rotation Curve for a Beam Element in Y-Direction](image-url)
In the case of Infill frame, for the X direction the plastic hinge formation starts with infills, columns and beams as shown in Figure 4.15. This is not acceptable for design consideration as the column failed before beams. The base shear and displacement values were 691.272 kN and 0.001 m in the X direction when the first hinge formed in the infill as shown in Figure 4.3. The typical first hinge formation of moment versus rotation curve for a critical column element is shown in Figure 4.16. Figure 4.17 shows the idealized moment rotation curve for a critical column element of initial yielding. The moment and rotation value for point B (Yielding) were 52.785 kNm and 0.0528 radians respectively.
Figure 4.15 Sequence of Hinges Formation in X-Direction

Figure 4.16 Typical First Hinge Formation of Moment versus Rotation Curve for a Column Element in X-direction
For Y direction, the plastic hinge formation starts with infills followed by columns and beams as shown in Figure 4.18. This is also not acceptable for design consideration as the column fails before the beams. The base shear and displacement values were 263.756 kN and 0.001 m in the X direction when the first hinge formed in the infill as shown in Figure 4.4. The typical first hinge formation of moment versus rotation curve for a critical column element is shown in Figure 4.19. Figure 4.20 shows the idealized moment rotation curve for a critical column element of initial yielding. The moment and rotation value for point B (Yielding) were 106.434 kNm and 0.0328 radians respectively.

The sequence of hinge formation indicates that the column hinge forms before the formation of beam hinges. This gives rise to strong beam-weak column and not advisable for earthquake design concept. Hence, the
columns in the building have to be retrofitted so that they do not reach their capacity before beams.

Figure 4.18 Sequence of Hinges Formation in Y- Direction

Figure 4.19 Typical First Hinge Formation of Moment versus Rotation Curve for a Column Element in Y-direction
4.2 CONCLUSIONS

In this chapter, analysis results and evaluation of existing hostel building are presented. The bare frame and infill frame building were evaluated by the pushover curve, capacity spectrum, building performance level and plastic hinge formation level using software SAP 2000 version 11. In fact, this building is acting as bare frame because of analyses as well as design of the frames which were carried out by considering the mass but neglecting the strength and stiffness of the contribution of infill. Therefore, the entire lateral load is assumed to be resisted by the frame only.

Based on the bare frame analysis result, it is concluded that, in event of earthquake occurs in Coimbatore region which is located in Zone-III, this existing hostel building will first yield in the Y direction because of weak beams. The base shear capacity was low in the Y direction as compared to the
X direction for first hinge formation levels and also at the performance point level, this building reached immediate occupancy level in the X direction and collapse prevention level in the Y direction. It is found that this building is more critical in the Y direction when compared to the X direction.

From the above discussion it is clear that the building is more vulnerable in the Y direction and therefore weak beams in the Y-direction must be strengthened by locally available strengthening techniques, before an occurrence of earthquake.