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EVALUATION AND RETROFITTING OF STRUCTURES DAMAGED DUE TO JAN 26, 2001, GUJARAT (INDIA) EARTHQUAKE

P. S. PAJGADE[1] **S.S. KULKARNI[2]**

SUMMARY

Colossal loss of life and property was observed due to Jan 26, 2001 earthquake. Seismic evaluation of structures is the most important feature, which must be undertaken and as per requirements of the structures suitable retrofitting measures must be adopted so that loss of life and property can be prevented during future probable earthquake. In this paper evaluation of various buildings is explained. This include following types of buildings

Load bearing buildings
Various load bearing buildings are considered and their evaluation and retrofitting methods are explained in detail.

Framed structures
Framed structures located at different distances from epicenter are considered. Evaluation of these buildings and required retrofitting measures are explained.

INTRODUCTION

In the Gujarat earthquake, it was once again proved that in majority of the buildings there was violation of codal provisions. Repair and Retrofitting is most important for saving the loss of lives and property due to probable earthquakes.

LOAD BEARING BUILDINGS

Bhachau was the town nearest from epicenter (10 to 15km away). MSK intensity at Bhachau was X. Almost all framed structures collapsed. Interestingly response of few load bearing buildings was better. Only four to five load bearing buildings were in good condition. This proves that if proper precautions are taken then load bearing buildings can survive intensity X. Photo No 1 shows partially damaged load bearing building.

1 Professor,
College of Engineering Badnera
34, Laxminarayan Nagar, Amravati - 444606(M.S.)
Phone (0721) 2671070, Cell no. (091) 9422855343
E-mail: ati_ppajgade@sancharnet.in

2 Ret. Professor,
Applied Mechanics Deptt. V.R.C.E. Nagpur 12, Buty Plot,
Laxminagar,) Nagpur – 440022 (India) Ph (091)(712) (2225485)
E-mail: sureshskulkarni@rediffmail.com
Cell no. (091) 9422108330

Photo No 1 Partially Damaged Load Bearing Building

Photo No 2 Partially Damaged Load Bearing Building Another View

In this building continuous lintel band was provided. Due to provision of lintel band this building survived. Band at sill level was not provided. The effect of this can be seen prominently, that is cracking and bulging of wall at sill level (Photo No. 2). Due to provision of continuous lintel band there was no appreciable damage to the structures above lintel level.

Retrofitting Measures

Provide temporary support to the slab and lintel. Remove bulge portion of brick wall between sill and lintel level. Provide band at sill level in new brick work, anchor bars for sill band in existing wall. Fix welded wire mesh to the cracked portion of wall where severe cracks are developed. Also fix chicken wire mesh to the wall, plaster this wall by rich cement mortar.

Photo No 3 Severely Damaged Load Bearing Building

Photo No 3 shows severely damaged building at Bhachau. This building was damaged due to very large opening provided in the front wall. Sill band was also not provided. Looking at condition of the building it is better to reconstruct this instead of repair.

Buildings At Railway Station Aundh

This is located about 20 km away from epicenter. The building of Railway Station was constructed in load bearing stone wall. For front verandah, dummy R.C.C. Columns starting from plinth level were provided. Verandah slab was provided at lower level.

Response of Buildings

Railway Station Building was badly damaged. (Photo No 4 and 5)

Damage to staff quarters was minimum. Continuous lintel band was provided to the staff quarter and other earthquake resistant features were observed.

Reasons For Failure Of Railway Station Building

1. As slabs were provided at different level proper diaphragm action was not developed. Continuous R.C.C. lintel was provided but precautions regarding continuity of bars and development length were not taken. (Photo No 4 and 5) Due to these reasons there was opening of joints and

anchoring of ends of stirrups of beams and lateral ties for columns (Photo No 6) were not done which resulted in opening of these ties leading to failure of structural element.

Photo No 4 Damaged Railway Station Building Rear View

Photo No 5 Damaged Railway Station Building Side View, In The Background Staff Quarters Can Be Seen Which Are In Intact Condition.

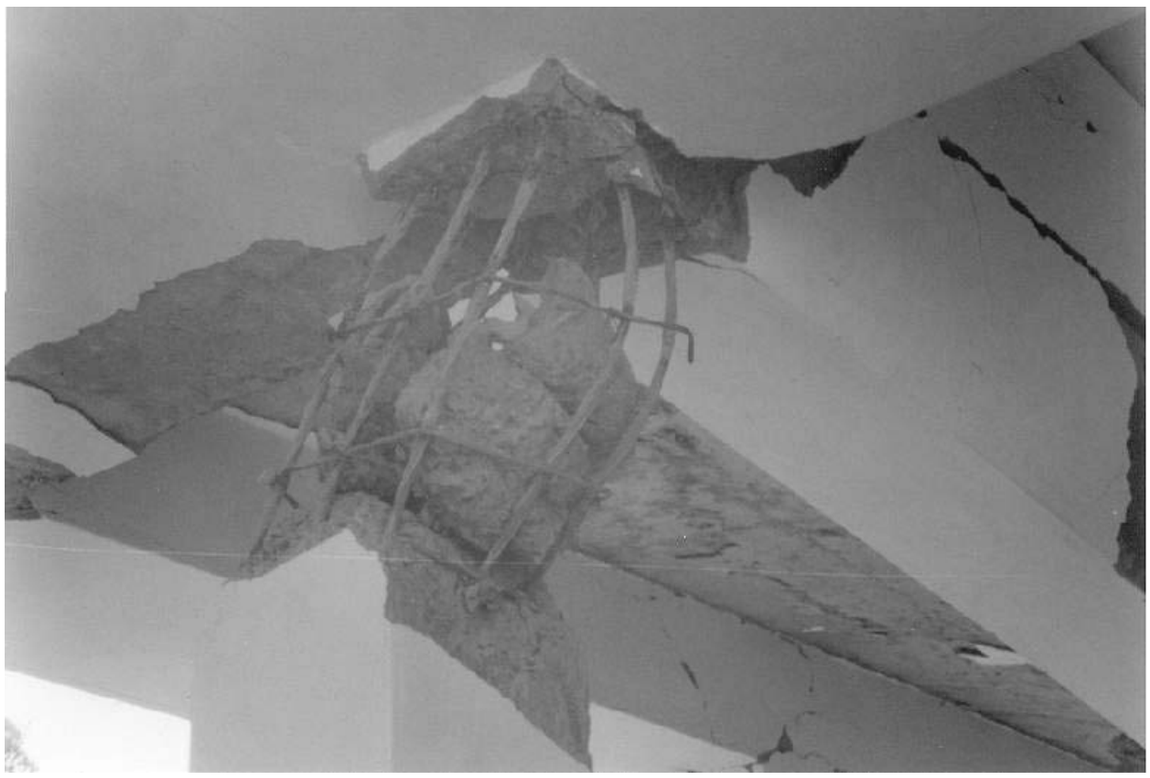


Photo No 6 Crushing Of Column Due To Improper Detailing

FRAMED STRUCTURES

Following are the main reasons for failure of framed structures

1) Short column effect 2) Flexible ground floor (Soft storey) 3) Pounding effect 4) Appendage effect 5) Lack of proper detailing 6) Poor workmanship etc.

Short Column Effect

It was observed in the past several earthquakes that, since slab is very strong in its own plane it acts as rigid diaphragm. Due to this action displacement of all columns at floor level will be same. Fig 2 shows the plan for a building. Column no 8 is supporting midlanding beam and slab at 1.6m level. Same column is also supporting floor slab at 3.60 m level. Fig 2(B) gives stiffness of column if its supported length (height) is 3.6m. Fig 2(C) gives stiffness of column for supported length (height) of 1.6m. If all columns are having same dimensions then stiffness of column no 8 will be eight (8) times more compared to stiffness of all other columns. This is due to its supported length fifty percent compared to all other columns. Column, which is short, will become stiff and will carry very large bending moments and shear forces compared to other columns. If this bending moment and shear force is more than the capacity of column then its failure is possible. Columns, which support midlanding, invariably become short columns. Some times main beam is provided at lintel level. Due to this, columns connected by lintel beams become short columns. Loft slab provided on toilet portion also changes the behavior of columns on which loft slab is supported.

Photo No 12 shows failure of column due to short column effect. Due to provision of beam at lintel level, column became short column attracting large amount of forces. This caused shear failure of columns.

Flexible Ground Floor (soft storey)

In actual analysis of framed structures, generally contribution of infilled wall is not considered, but infilled walls act as diagonal struts. Infilled walls increase the strength and stiffness of framed structure. Due to plastic deformation infilled walls help a lot in energy dissipation during earthquakes. Due to requirement of parking space, generally ground floor is kept open as shown in Photo No 7. Due to this stiffness of ground floor will be less compare to other floors. Special precaution must be taken while

designing these columns otherwise failure is possible. Photo No 7 is from Ahmedabad, 250 km away from the epicenter. MSK intensity at Ahmedabad during this earthquake was V. As per seismic zoning map of India Ahmedabad is located in zone III where the probable intensity as per Comprehensive Intensity Scale (MSK) is VII. In Photo No.7 building on left hand side collapsed due to flexible ground floor. Building on right hand side is in intact condition, still seismic evaluation of this

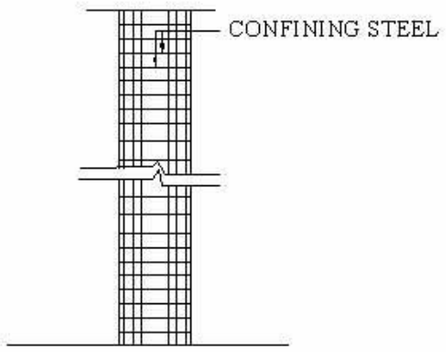


Fig 1 Jacketing of Column.

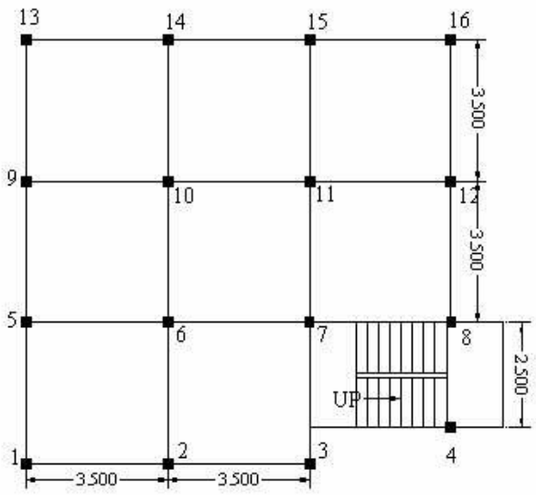
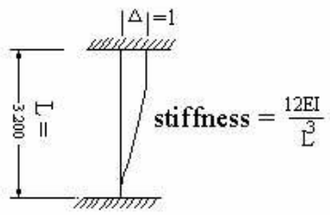
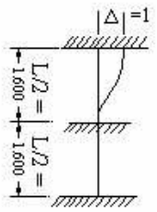


Fig 2 (A) Arrangement of Columns.



(B) Length L



(C) Length L/2

stiffness = $8\left[\frac{12EI}{L^3}\right]$

building is essential because the building must be capable of resisting the MSK intensity VII. There are number of such buildings where seismic evaluation is essential. After seismic evaluation suitable retrofitting measures must be adopted to prevent failure of such buildings during probable earthquakes. Photo No. 8 shows building where infilled walls are provided in some portion of the building. In the critical portion of columns and beams special confining steel is essential. Anchorage of lateral ties is most important. Due to absence of these features the failure of column is visible.

Photo No 10 Shows the crushing of column due to large spacing of lateral ties. Due to provision of beams at lintel level short column effect is also predominant in this columns.

Photo No 7 Frame Structure With Flexible Ground Floor.

Photo No 8 Failure Of Ground Floor Column

Pounding Effect

Two adjacent buildings must be separated by sufficient gap otherwise due to pounding damages to the adjacent buildings are possible Photo No 9 shows the Inspection tower building at Kandala port which was damage due to pounding effect.