SEISMIC ANALYSIS OF MULTISTOREY BUILDING WITH FLOATING COLUMN

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Abstract—In present scenario buildings with floating column is a typical feature in the modern multistory construction in urban India. Such features are highly undesirable in building built in seismically active areas. This study highlights the importance of explicitly recognizing the presence of the floating column in the analysis of building. Alternate measures, involving stiffness balance of the first storey and the storey above, are proposed to reduce the irregularity introduced by the floating columns. FEM codes are developed for 2D multi storey frames with and without floating column to study the responses of the structure under different earthquake excitation having different frequency content keeping the PGA and time duration factor constant. The time history of floor displacement, inter storey drift, base shear, overturning moment are computed for both the frames with and without floating column.

I. INTRODUCTION

Many urban multistorey buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first storey. Whereas the total seismic base shear as experienced by a building during an earthquake is dependent on its natural period, the seismic force distribution is dependent on the distribution of stiffness and mass along the height.

The behavior of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path; any deviation or discontinuity in this load transfer path results in poor performance of the building. Buildings with vertical setbacks (like the hotel buildings with a few storey wider than the rest) cause a sudden jump in earthquake forces at the level of discontinuity. Buildings that have fewer columns or walls in a particular storey or with unusually tall storey tend to damage or collapse which is initiated in that storey. Many buildings with an open ground storey intended for parking collapsed or were severely damaged in Gujarat during the 2001 Bhuj earthquake. 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.

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The term floating column is also a vertical element which (due to architectural design/site situation) at its lower level (termination Level) rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it.

There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the ground floor. These open spaces may be required for assembly hall or parking purpose. The transfer girders have to be designed and detailed properly, especially in earthquake zones. The column is a concentrated load on the beam which supports it. As far as analysis is concerned, the column is often assumed pinned at the base and is therefore taken as a point load on the transfer beam. STAAD Pro, ETABS and SAP2000 can be used to do the analysis of this type of structure. Floating columns are competent enough to carry gravity loading but transfer girder must be of adequate dimensions (Stiffness) with very minimal deflection.

II. OBJECTIVE OF PRESENT WORK

The objective of the present work is to study the behavior of multistory buildings with floating columns under earthquake excitations. Finite element method is used to solve the dynamic governing
equation. Linear time history analysis is carried out for the multistory buildings under different earthquake loading of varying frequency content. The base of the building frame is assumed to be fixed. Newmark’s direct integration scheme is used to advance the solution in time.

III. REVIEW OF LITERATURE

Maison (1984), Members of ASCE have performed the computer analysis of an existing forty four story steel frame high-rise Building to study the influence of various modeling aspects on the predicted dynamic properties and computed seismic response behaviors. The predicted dynamic properties are compared to the building’s true properties as previously determined from experimental testing. The seismic response behaviors are computed using the response spectrum (Newmark and ATC spectra) and equivalent static load methods.

Also, Maison (1991), Members of ASCE computed dynamic properties and response behaviors OF THIRTEEN-STOREY BUILDING and this result are compared to the true values as determined from the recorded motions in the building during two actual earthquakes and shown that state-of-practice design type analytical models can predict the actual dynamic properties. Arlekar (1997) said that such features were highly undesirable in buildings built in seismically active areas; this has been verified in numerous experiences of strong shaking during the past earthquakes. They highlighted the importance of explicitly recognizing the presence of the open first storey in the analysis of the building, involving stiffness balance of the open first storey and the storey above, were proposed to reduce the irregularity introduced by the open first storey.

Awkar (1997) studied responses of multi-story flexibly connected frames subjected to earthquake excitations using a computer model. The model incorporates connection flexibility as well as geometrical and material nonlinearities in the analyses and concluded that the study indicates that connection flexibility tends to increase upper stories' inter-storey drifts but reduce base shears and base overturning moments for multi-story frames.

Balsamoa, Colombo (2005) performed pseudodynamic tests on a RC structure repaired with CFRP laminates. The opportunities provided by the use of Carbon Fiber Reinforced Polymer (CFRP) composites for the seismic repair of reinforced concrete (RC) structures were assessed on a full-scale dual system subjected to pseudodynamic tests in the ELSA laboratory. The aim of the CFRP repair was to recover the structural properties that the frame had before the seismic actions by providing both columns and joints with more deformation capacity. The repair was characterized by a selection of different fiber textures depending on the main mechanism controlling each component. The driving principles in the design of the CFRP repair and the outcomes of the experimental tests are presented in the paper. Comparisons between original and repaired structures are discussed in terms of global and local performance. In addition to the validation of the proposed technique, the experimental results will represent a reference database for the development of design criteria for the seismic repair of RC frames using composite materials.

IV. FINITE ELEMENT FORMULATION

The finite element method (FEM), which is sometimes also referred as finite element analysis (FEA), is a computational technique which is used to obtain the solutions of various boundary value problems in engineering, approximately. Boundary value problems are sometimes also referred to as field value problems. It can be said to be a mathematical problem wherein one or more dependent variables must satisfy a differential equation everywhere within the domain of independent variables and also satisfy certain specific conditions at the boundary of those domains. The field value problems in FEM generally has field as a domain of interest which often represent a physical structure. The field variables are thus governed by differential equations and the boundary values refer to the specified value of the field variables on the boundaries of the field. The field variables might include heat flux, temperature, physical displacement, and fluid velocity depending upon the type of physical problem which is being analyzed.

V. RESULTS AND DISCUSSIONS:

The frame is taken only by changing the material property and size of structural members. Size and material property of the structural members are as follows:

Size of beam = (0.25 x 0.3) m
Size of column = (0.25 x 0.25) m
Young’s modulus, E= 22.36 x 10^9 N/m^2
Density, ρ = 2500 Kg/m^3

Fig.1 and 2 show the maximum top floor displacement of the 2D frame obtained in STAAD Pro and present FEM and respectively. Free vibration frequencies of the 2D concrete frame with floating column are presented in Table 1. In this table the values obtained in present FEM and STAAD Pro are compared. Table 2 shows the comparison of maximum top floor displacement of the frame obtained in present FEM and STAAD Pro which are in very close agreement.

Table 1 Comparison of predicted frequency(Hz) of the 2D concrete frame with floating column obtained in present FEM and STAAD Pro

<table>
<thead>
<tr>
<th>Mode</th>
<th>STAAD Pro</th>
<th>Present FEM</th>
<th>% Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.486</td>
<td>2.52</td>
<td>1.37</td>
</tr>
<tr>
<td>2</td>
<td>7.78</td>
<td>8.09</td>
<td>3.98</td>
</tr>
<tr>
<td>3</td>
<td>13.349</td>
<td>14.67</td>
<td>9.89</td>
</tr>
<tr>
<td>4</td>
<td>13.938</td>
<td>14.67</td>
<td>5.25</td>
</tr>
</tbody>
</table>

Table 2 Comparison of predicted maximum top floor displacement (mm) of the 2D concrete frame with floating column obtained in present FEM and STAAD Pro.

<table>
<thead>
<tr>
<th>Maximum top floor displacement</th>
<th>STAAD Pro</th>
<th>Present FEM</th>
<th>% Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>118</td>
<td>121.2</td>
<td>2.71</td>
<td></td>
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</table>

In this concrete frames with and without floating column having same material property and dimension are analyzed under same loading condition. Here “Compatible time history as per spectra of IS 1893 (part 1): 2002” is applied on the structures. IS code data is an intermediate frequency content data. IS code data has PGA value as 1.0g This frame is also analyzed under other earthquake data having different PGA value in further examples, hence it has scaled down to 0.2g. The section and material property for present study are as follows:
Young modulus, E= 22.36 x 10^6 kN/m^2, Density, ρ = 2500 Kg/m^3
Size of beam = (0.25 x 0.4) m, Size of column = (0.25 x 0.3) m
Storey height, h = 3.0m, Span = 3.0m

VI. CONCLUSION

The behavior of multistory building with and without floating column is studied under different earthquake excitation. The compatible time history and Elcentro earthquake data has been considered. The PGA of both the earthquake has been scaled to 0.2g and duration of excitation are kept same. A finite element model has been developed to study the dynamic behavior of multi story frame. The static and free vibration results obtained using present finite element code are validated. The dynamic analysis of frame is studied by varying the column dimension. It is concluded that with increase in ground floor column the maximum displacement, inter storey drift values are reducing. The base shear and overturning moment vary with the change in column dimension.

REFERENCES