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Importance of Plinth Beams on the Seismic Response of Rc Moment Resistant Frames

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Abstract— Base flexibility of structures affects the force and displacement demands on frame elements during earthquakes. Rotational restraint at column bases can be increased by providing plinth beams. This study evaluates the effects of plinth beams at various heights from the base on the seismic response of RC moment resistant frames. Six storey buildings with different column base flexibility conditions such as fixed base, hinged base and hinged base with plinth beams were considered for the analytical study. Plinth beams provided at the base and various heights from the base such as 0.5m, 1m and 1.5m. Pushover analysis and response spectrum analysis were performed on the building models using ETABS 2013 software. Providing a plinth beam between ground storey column helps in controlling the seismic demands in RC frame buildings and plinth beams at 1.5m height from the base shows maximum shear force demand and less bottom storey displacement.

Index Terms— Plinth beams, pushover analysis, response spectrum analysis, shear force, storey displacement

1 INTRODUCTION

In RCC frame structure, plinth beam acts as a tie, as a beam at ground level itself. More recently, RCC plinth beams are being recommended for their earthquake-resistant properties. A plinth beam is constructed depending upon the type of the structure of the building and nature of the soil. It provides additional stability in regard to settlements of the building and earthquake damages. Sunitha et al. (2015) investigates influence of rotational restraint at column bases on seismic behaviour of SMRFs. Non linear static pushover analyses performed using SAP 2000 on buildings with three levels of column base restraints namely, hinged base with taller ground storey, hinged base with plinth beams and equal storey height above plinth and fixed base with taller ground storey. ASCE 7 permits building to be considered fixed at the base for thepurpose of determining seismic loads [ASCE 7, 2005]. But, at least four types of base restraints are recommended for modelling of buildings, namely; (a) hinged, (b) hinged, with grade and/or plinth beams, (c) fixed, and (d) partial restraint, with different degrees of foundation flexibility modelled through soil elements. The change in base restraint alters deforrmability of buildings significantly.

Flexibility of column bases in RC moment resisting frame buildings alters seismic demands imposed in frame members. This paper examines analytically six such column base restraint conditions, and understands the implications of such considerations on imposed seismic demands.

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2 NUMERICAL STUDY

Six storey buildings with different column base flexibility conditions such as (a)fixed base, (b)hinged base and (c)hinged base with plinth beams at base, (d)at 0.5m, (e)1m and (f)1.5m heights from the base were considered for the analytical study. Pushover analysis and response spectrum analysis were performed on the building models using ETABS 2013 software.

All buildings are 6-storey tall with: 24m×20m plan, 4m typical bay length, 3.5m typical storey height and 5m ground storey height. Live load considered is of 4kN/m2 at typical floor and 1.5kN/m2 on terrace. Dead load includes that due to 200 mm thick URM exterior infill walls (with 20% openings) and 100 mm thick interior URM infill walls. Beam dimensions: 0.3m x0.45m. Column dimensions used are 0.45m x 0.45m for all models. Slabs are of 150mm thickness. Fe415 grade steel and M30 grade concrete are considered in design. 0.8% steel was provided for columns in accordance with IS 456:2000.

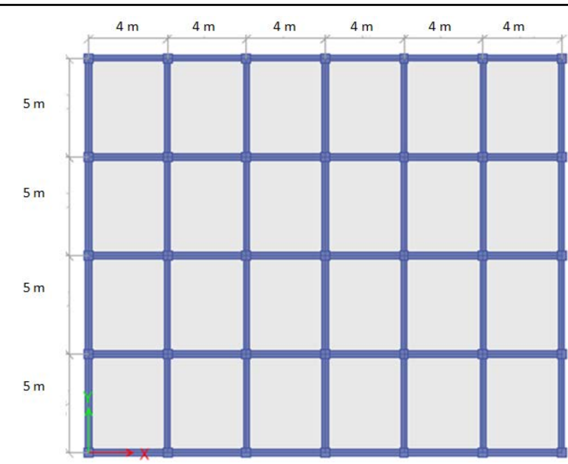

Fig. 1. Plan of the building

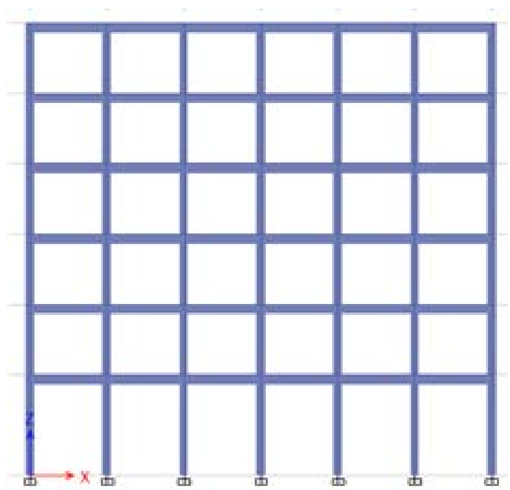

Fig. 2 Building with fixed base

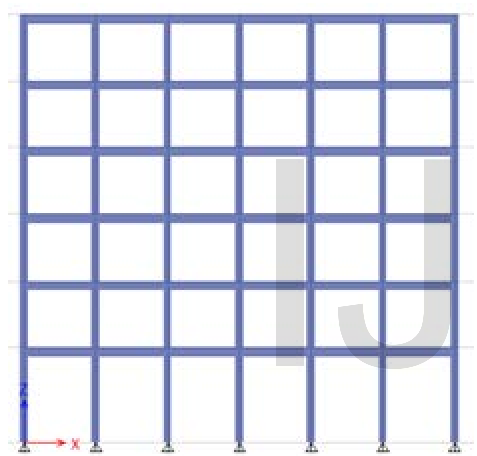

Fig. 3 Building with hinged base

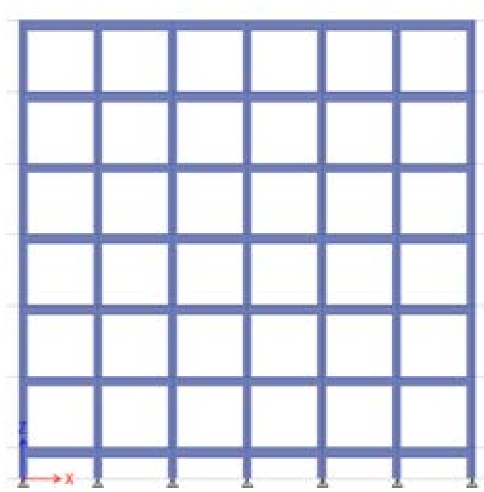

Fig. 4 Building with hinged base and plinthbeam located at 1.5m height from base

3NON-LINEAR STATIC PUSH-OVER ANALYSIS

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The equivalent static lateral loads approximately represent earthquake induced forces. A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out upto failure, thus it enables determination of collapse load and ductility capacity. On a building frame, and plastic rotation is monitored, and lateral inelastic forces versus displacement response for the complete structure is analytically computed. This type of analysis enables weakness in the structure to be identified. Static pushover analysis is an attempt by the structural engineering profession to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design.

The ATC-40 and FEMA-356 documents have developed modeling procedures, acceptance criteria and analysis procedures for pushover analysis. These documents define force deformation criteria for hinges used in pushover analysis. As shown in Figure 1, five points labeled A, B, C, D, and E are used to define the force deflection behavior of the hinge and three points labeled IO, LS and CP are used to define the acceptance criteria for the hinge. (IO, LS and CP stand for Immediate Occupancy, Life Safety and Collapse Prevention respectively.) The values assigned to each of these points vary depending on the type of member as well as many other parameters defined in the ATC-40 and FEMA-356 documents.

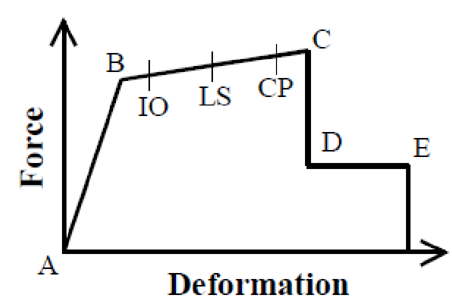

Fig. 5 Force-deformation for pushover hinge

Pre-defined non-linear hinge properties corresponding to FEMA 356 hinge model were assigned to columns and beams of the building models and pushover analyses were performed. Nonlinear hinges assigned to beams and columns at relative distances 0.1 and 0.9 from the ends. Load Application is displacement control.

4 RESPONSE SPECTRUM ANALYSIS

A response spectrum is simply a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency, that are forced into motion by the same base vibration or shock. Response spectra are very useful tools of earthquake engineering for analyzing the performance of structures and equipment in earthquakes, since many behave principally as simple oscillators. Ground motion records of the earthquakes Northridge and Kocaeli are shown in the figure 6. From the strong motion data, response spectra of these earthquakes for 5% damping are generated using the software PRISM which is a program for seismic response analysis of structures idealized as single-degree-of-freedom systems. The corresponding acceleration response spectra is shown in figure 7. The generated response spectra are used for response spectrum analysis in ETABS.

5 RESULTS AND DISCUSSION

Figure 8 shows the pushover response curve of buildings with different column base restraints. Plinth beams increases the shear force demand in ground storey columns. Building with plinth beams provided at 1.5m from the base shows higher shear force demand. Base shear decreases with decrease in the distance between base and plinth beam

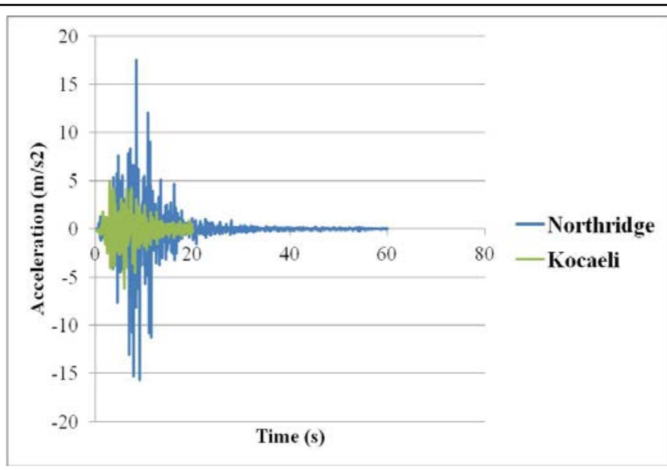

Fig. 6 Ground motion of the earthquakes Northridge and Kocaeli

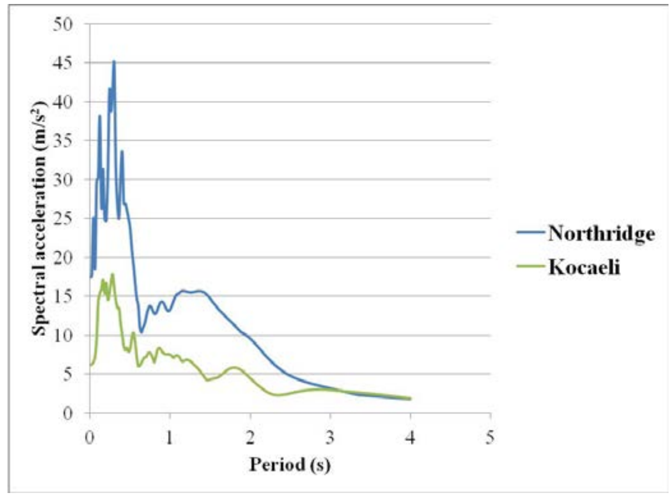

Fig. 7 Spectral acceleration: Northridge and Kocaeli

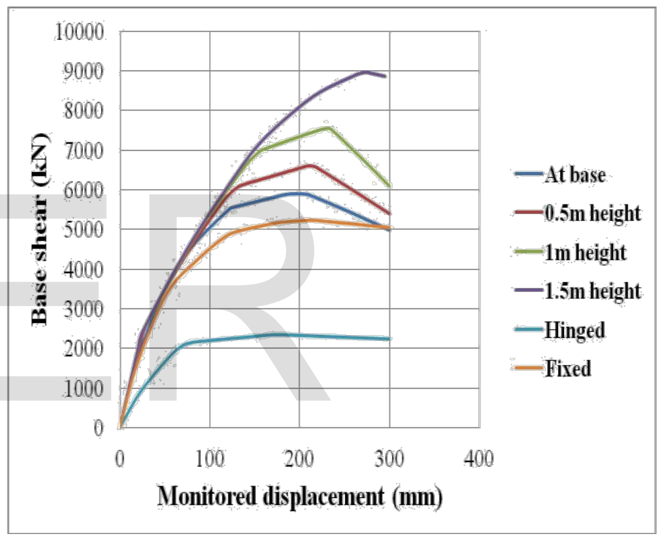

Fig. 8 Pushover response curve

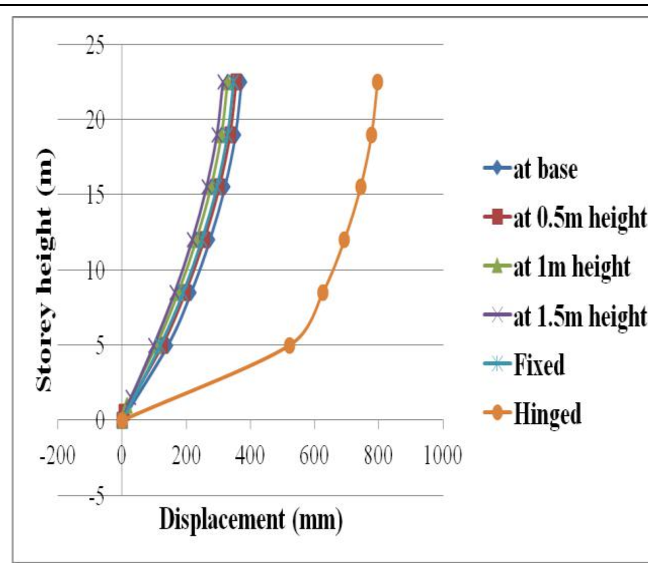

Fig. 9 Storey response plot of Northridge earthquake

Figure 9 and 10 shows storey response plots of buildings from response spectrum analysis using Northridge and Kocaeli earthquake data. Building with plinth beam at 1.5m from base shows less displacement compared to others. Building with hinged base shows large displacement.

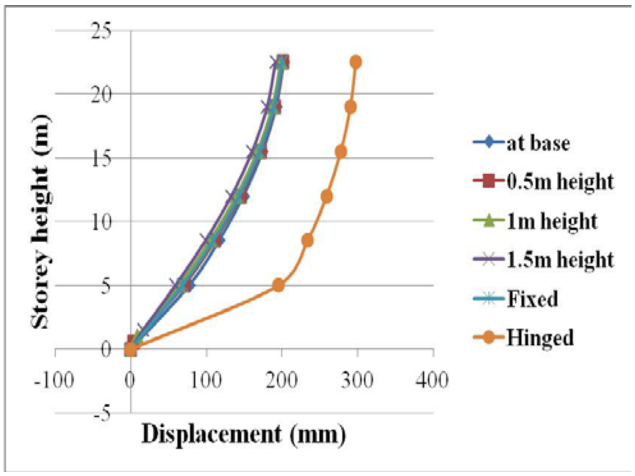

Fig. 10 Storey response plot of Kocaeli earthquake

6 CONCLUSIONS

According to the results of the analytical study on buildings with different column base restraint conditions such as fixed base, hinged base and hinged base with plinth beams at base, at 0.5m, 1m and 1.5m heights from the base it is observed that considering plinth beams in the analytical model of the building improves the shear force demand and reduces the bottom storey displacement. Building with plinth beam at 1.5m height shows better results than other buildings. As the distance between the column base and the plinth beam decreases storey displacements increases.

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