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# Inelastic Seismic Analysis of Reinforced Concrete Frame Building with Soft Storey

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## Abstract

Most of the multi-storey buildings are constructed with brick masonry infill in India keeping first storey opened. Though infill wall may not resist the gravity load but it contributes significantly on response behavior of buildings during earthquake. In general, buildings are designed as a complete bare frame, stiffness of infill is not considered and so changes in dynamic behavior of buildings are ignored. In seismically active areas, open first storey buildings are not desirable due to stiffness irregularity introduced on that storey. This paper presents the importance of infill wall stiffness in the modeling and of preventing the indiscriminate use of soft first storey in the buildings. Due to computational effort mostly elastic analysis is concerned by building codes. In this study inelastic damage indices of element, storey and overall building subjected to ground motion are analyzed. Dynamic characteristics and damage pattern of soft storey building are evaluated when infill wall stiffness are considered. Modified Park & Ang model is used to calculate damage indices. Modeling and analysis of the building are performed by nonlinear analysis program IDARC 2D. Damaged state of structure whether elements are cracked, yielded or failed are observed during this analysis. Response parameters such as floor displacement, storey drift, and base shear are also obtained.

**Keywords**: RC frame, Infill wall, In-elastic analysis, Soft storey, Ground motion, Storey drift, Park–Ang damage indices.

## 1. Introduction

Construction of masonry infill is a common practice. It dissipates energy when building is subjected to a lateral force due to earthquake. Because of non availability of simple and realistic analytical models, its significance in analysis of buildings is generally neglected. Buildings with soft storey are also a major problem. An open first storey is allocated to accommodate parking or reception lobbies. Larger storey drift occurs on first floor soft storey than the upper storeys which are stiffer[7]. Lateral force developed on building and shear induced on the base of building during earthquake depends on mass and stiffness of structure, irregularity introduced due to soft first storey causes damages on columns when the ground shakes.

## 2. Building Description

Each building has ground floor plus four storeys with a floor height of 3m. Unit weight of concrete and masonry are taken as 25 kN/m$^3$ and 19 kN/m$^3$ respectively. Floor finish load and water proofing load are taken as 0.5 kN/m$^2$ and 1.5 kN/m$^2$ respectively. Earthquake load acts only in the horizontal direction.

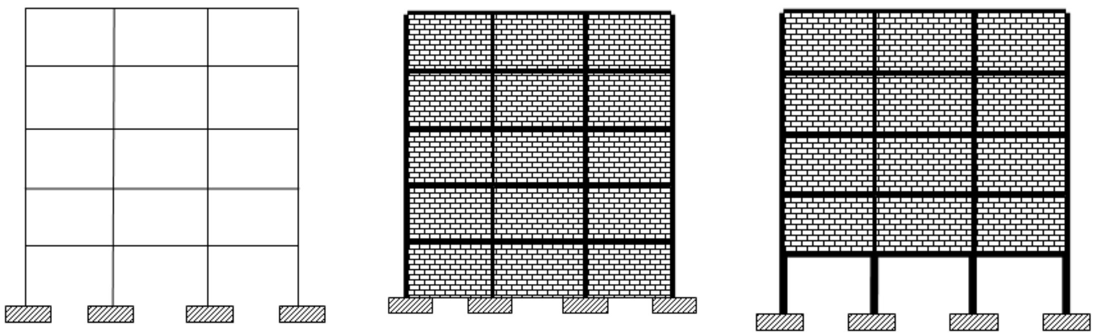

**Fig. 1a**: Type 1 building elevation **Fig. 1b:** Type 2 building elevation **Fig.1c:** Type 3 building elevation

**Fig. 1**: Elevation of all example buildings.

Three types of building are analyzed: a) Type 1 building designates ordinary moment resisting bare frame, b) Type 2 building designates ordinary moment resisting frame with infill, c) Type 3 building designates ordinary moment resisting frame with soft first storey. Plan geometry and height are same for all types of building. Elevation of type 1, type 2 and type 3 buildings are shown in fig. 1a, fig. 1b and fig. 1c respectively.

## 3. Analysis of Building

All buildings are analyzed as Ordinary Moment Resisting frames. Design is carried out in STAAD-Pro[3]. Time-history analysis and inelastic damage analysis of buildings are performed using IDARC 2D[4]. Elcentro ground motion is taken with peak ground acceleration of 0.34g with duration 26.5 sec. Properties of beams and columns are taken as 250mm x 350mm and 350mm x 350mm respectively, for all types of buildings. Walls are 220 mm thick including plaster.

## 4. Results and Discussion

Lateral ground floor displacement for type 1,type 2 and type 3 buildings are shown in fig. 2. Ground floor displacement for type 1, type 2 and type 3 buildings are 20.46mm, 21.43mm and 27.99mm.Due to soft first storey, ground floor displacement for type 3 building is higher by 36.80% and 30.61% in comparison to type 1 and type 2 building respectively.

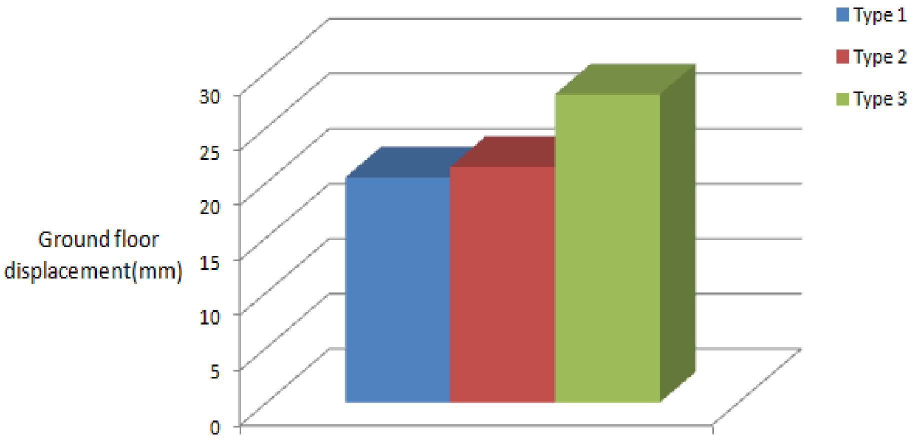


**Fig. 2**: Ground floor displacement for all example buildings.

Base shear for type 1, type 2 and type 3 buildings are shown in fig. 3.Base shear is found to be the maximum for type 2 building and it is higher by 19.72% and 13.92% in comparison to type 1 and type 3 building respectively.

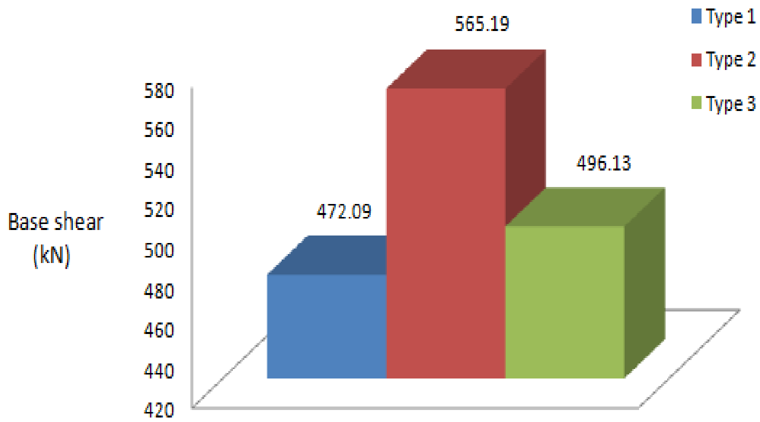


**Fig. 3**: Base shear for all example buildings.

Damage analysis for a structural element is carried out by Park & Ang model, i.e.

$DI_{P\,\&\,A} = \left(\frac{\delta m}{\delta u}\right) + \left(\frac{\beta}{\delta u * P}\right) \int dE$; where $\delta m$ and $\delta u$ represents maximum and ultimate deformations respectively, P is the yield strength of element and $\int dE$ is the absorbed hysteretic energy by element during response history.

At ground floor column, damage index for three types of building are shown in fig. 4.

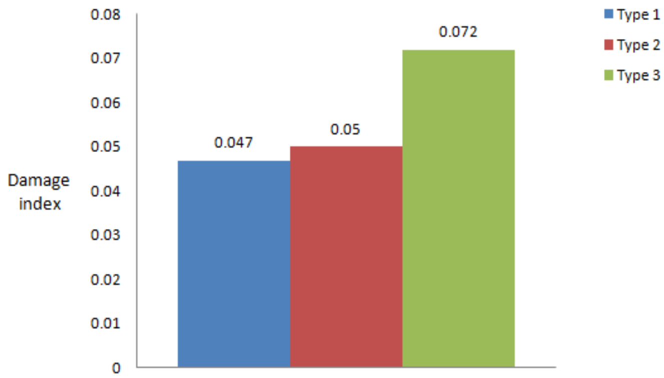


**Fig. 4**: Damage index at ground floor column for all example buildings.

Due to open storey introduced at ground floor, maximum damage occurs at ground floor column for type 3 building and it is higher by 53.19% and 44% in comparison to type 1 and type 2 building respectively.

Storey damage indices are calculated using weighting factors based on dissipated hysteretic energy at component. For type 1, type 2 and type 3 buildings, column-wall damage at ground floor are 0.011, 0.013 and 0.021 respectively. For type 3 building it is higher by 90.91% and 61.54% in comparison to type 1 and type 2 building respectively.

## 5. Conclusions

a) Lateral roof displacement and maximum storey drift is reduced by considering infill wall effect than a bare frame.
b) The drift demands for ground storey column are large for soft storey buildings.
c) Soft storey building shows poor performance during earthquake.
d) Damage indices for ground floor columns and ground storey are very large for soft storey building because it demands larger strength due to introducing mass and stiffness irregularity which influence the lateral force distribution of the building during an earthquake.

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