Review on Collapse Behaviour and Strengthening Techniques of Soft Storey Buildings

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Abstract

Now a day’s in reinforced-concrete framed structure walls are not continued in the ground storey for the requirement of parking or for commercial space and also the height of the ground storey is increased for the head room requirement. Such buildings are called soft storey buildings. Due to lack of spaces, increasing parking demands and functional requirement, construction of soft storey building is increasing day by day. Such arrangement of parking and shopping space without infill walls and increased height causes stiffness irregularities in the building. The sudden reduction in lateral stiffness and mass in the ground storey results in higher stresses in the ground storey columns under seismic loading. Hence the building is totally collapsed due to soft storey effect during earthquake. Seismic performance of these buildings can be increased by strengthening techniques. A review regarding its collapse behaviour and strengthening techniques is summarized in this paper.

Keywords: Soft Storey, Earthquake, Lateral stiffness, Collapse Behaviour, Strengthening Techniques

I. INTRODUCTION

Earthquakes are the most disastrous and unexpected natural calamities in the world. Technically, earthquake may be defined as “vibrations induced in the earth’s crust due to internal or external causes that virtually shake up a part of the crust and all the structures and living and non-living things existing on it”. Earthquakes in India, China, Nepal, Japan, Indonesia and many other parts of the world killed hundreds of thousands of people. Earthquakes do not kill the people but unsafe buildings do. The various factors which contribute to the unsafe buildings are vertical and plan irregularities, strength and stiffness irregularity, mass irregularity, torsion irregularity etc. Due to urbanization and increase in population most of the reinforced building has a special feature i.e. ground storey is left open for the purpose of social and functional needs like vehicle parking, shops, reception lobbies, a large space for meeting room or a banking hall etc. Such buildings are often called open ground story buildings or soft story buildings. These buildings have no infill walls in ground storey, but upper storeys are with infill walls. In these arrangements, the upper floors are more rigid than their base. In such buildings the dynamic ductility demand during probable earthquake gets concentrated in the soft storey and the upper storey tends to remain elastic. Hence many building structures having soft stories suffered major structural damage and collapsed in the recent earthquakes. According to IS 1893 (Part 1): 2002 clause 4.20, soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.[9]. There are many factors which contribute towards soft storey formation, which occur during the design and construction process of the building. They are stiff and strong upper floors due to masonry infill, a floor structure significantly higher than upper floors, discontinued columns etc. Strengthening of soft storey building is needed to improve its seismic performance. This can achieved either by local strengthening method or by global strengthening techniques.

A. Soft Storey Collapse Behavior

The essential characteristic of a soft first storey consist of a discontinuity of strength and stiffness. Strength is defined as the ability of the material to support a load without breaking (physical failure) and Stiffness is defined as the ability of the material to distribute a load and resist deformation or deflection (functional failure). If all storeys are approximately equal in strength and stiffness, the entire building deflection under earthquake load is distributed approximately equal at each floor. If any floor is significantly less strong or more flexible, a large portion of the total building deflection tend to concentrate in that floor, with consequent concentration of stresses at the upper floor connection accompanied by large plastic deformations. In addition most of the energy developed during the earthquake is dissipated by the columns of the soft stories. In this process the plastic hinges are formed at the ends of columns which transform the soft storey into a mechanism. Such building act as an inverted pendulum which swing back and forth producing high stresses in columns and if columns are incapable of taking these stresses or do not posses enough ductility, they could get severely damaged and which can also lead to collapse of the building.
II. STRENGTHENING TECHNIQUES OF EXISTING SOFT STOREY BUILDINGS

The seismic performance of the structures with soft storey can be improved either by strengthening the ground storey columns (i.e., local modification) or by reducing the seismic demand through the supplemental energy dissipation mechanisms (i.e., global modification). Several local modification techniques (e.g., steel jacketing, concrete jacketing, steel caging, FRP jacketing, etc.) are used to enhance the lateral strength, stiffness and inelastic deformation capacity of the deficient RC columns.

A. Addition of infill wall

Addition of RC structural wall into existing frame is one of the common approaches which effectively can control global lateral drift. Application of this technique into soft storey of a structure helps to stiffen the frame in that level and reduces the soft storey effect accordingly. In this method consequent foundation strengthening is also necessary since overturning moment and base shear concentrates at the stiffer infill location. Lateral load resistance capacity of a soft storey frame can be improved with the addition of masonry infill as well. This approach will increase the stiffness of the frame and reduce the demand on the existing frame. However this option may not contribute to the improvement of ductility.

B. Addition of Braces

Incorporation of bracing is another common effective approach which can be designed to provide stiffness, strength, ductility and energy dissipation. In this approach connection between bracing and frame is very important to act integrally with the structure without any failure at connection during earthquake. In the past years number of researches has been performed on structures associated with steel bracing showing the improved performance of the RC structure (Badoux and Jirsa 1990, Bush et al. 1991). This technique can effectively reduce the risk of soft storey frame by providing adequate stiffness to the frame. Different types of bracing which have been proposed and applied include concentric bracing, eccentric bracing, and post tensioned steel bracing and buckling restrained bracing.

C. Using steel jackets (steel cages)

Steel cages are externally attached to the existing RC columns in order to increase their shear and axial strengths through the passive confinement of the column concrete. The objective of this strengthening technique, henceforth referred as ‘column retrofit (CR)’, is to investigate the seismic performance of the deficient RC frame due to increase in the lateral strength and the plastic rotational capacity of the ground storey columns. The RC frame with strengthened ground-storey columns (termed as CR frame) exhibited the higher the lateral strength (3.6 times that of the RC frame) and the energy dissipation potential. However, such strengthened frames may not withstand all strong ground motions.

D. Energy Dissipation Device

The vibration of the structure and hence lateral displacement and drift can be effectively reduced by dissipating energy with the implantation of frictional, hysteretic and viscoelastic damper within the building. Installation of energy dissipating devices provides damping to the primary structure along with increasing stiffness of the structure. In a study fluid viscous damper was used for the rehabilitation of a historical non ductile soft storey concrete structure and the strategy was found as cost effective method and helpful in the preservation of historical appearances (Miyamotto and Scholl 1996)

E. Base isolation

Base isolation of the structure is one of the novel approaches of structural retrofit. In this approach the response of the building is reduced through decoupling from the ground motion. Installation of bearings between superstructure and substructure allows the energy to dissipate in significant manner.

III. CONCLUSIONS

Soft storey is an undesirable characteristic but from functional point of view it is necessary. Soft storey building shows poor performance during the earthquake. Several retrofitting techniques are there to improve the performance of soft storey building. An optimum strengthening technique needs to be adopted as solution which will ensure desirable performance of structure. Appropriate knowledge, expertise, guidelines and research on retrofit methods, in understanding design concept and construction procedures are required for the successful applications of these retrofitting methods. Accumulation of all these phenomena accompanied by well planned government policy and support can offer a safer structural system with improved earthquake resistance.
AKNOWLEDGEMENT

It is my privilege to express sincere thanks to my project guide, Dr. C Prabha, Associate Professor, Civil Department, MACE for her advice and assistance throughout the project. I would also like to express my sincere gratitude to all my friends and classmates for their help and support.

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