SEISMIC ANALYSIS OF SOFT STOREYS STRENGTHENED USING EQUIVALENT DIAGONAL STRUTS

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Abstract

Earthquake in different parts of the world demonstrated the hazardous consequences and vulnerability of inadequate structures. Soft storey is a storey in which the stiffness is less than 70% of the storey above or less than 80% of the combined stiffness of the storey's above. In a multi-storied building, soft storey is adopted to accommodate parking which is an unavoidable feature. With the advancement in field of high rise construction, various types of frame arrangements have been emerged. Le Corbuiser popularly known as LC was one of the pioneers of, what is now called five points of modern architecture. Hence, he deviced the concept of soft storey, in which stiffness is altered, along with storey height to achieve an asthetic view. The present study is an attempt to analyse soft storeys strengthened using equivalent diagonal struts. The equivalent diagonal struts method was proposed by Stafford Smith and Hendry, in which the concept of equivalent width was formulated mathematically. The total cases studied are 14 (7 with struts and 7 without struts). Seismic zone II is considered in the analysis. Results are analysed in terms of bending moments, shear forces, nodal displacements and storey displacements. Graphical outputs are also generated.

KEY WORDS: Struts, diagonal, soft, storey, strength, seismic, static.

I. INTRODUCTION

Soft storey is a common building weakness. The term soft storey explains one level of a building that is appreciably more flexible than the stories above it and the floors or the foundation below it.
Buildings are classified as having a soft storey if that level is less than 70% as stiff as the floor instantly above it or less than 80% as stiff as the average stiffness of the three floors above it. Open ground storey buildings are called soft storey building, whereas their ground storey may be soft or weak. The soft or weak storey commonly exists at the ground storey level, but it might be at any other storey level. Soft storey buildings are characterized by having a floor which has a lot of open spaces for example; Parking garages are often soft stories, as are restaurants or floors with lots of windows.
The behaviour of soft storey building in earthquake is very crucial because soft storey building is more flexible in seismic condition, vibration is happen in soft storey building so we provide shear wall in soft storey building (shear wall resist the effect of earthquake)

Reinforced concrete frame structures have become common form of construction with masonry infill in urban and semi urban areas in the world. The infilled frame term denotes a composite structure formed by the combination of a moment resisting plane frame and infill walls. The infill masonry may be of brick, concrete blocks, or stones. Ideally in present time the reinforced concrete frame is filled with bricks as non-structural wall for partition of rooms because of its advantages such as, thermal insulation, durability, cost and simple construction technique.

An Earthquake is a sudden slipping or movement of a portion of the earth's crust or plates, caused by a sudden release of stresses .Earthquake epicenter are usually less than 25 miles below the ear surface and are accompanied

and followed by a series of vibrations. The earth has four major layers: The inner core, outer core, mantle and crust.
The crust and the top of the mantle make up a thin layer on the surface of earth. But this layer is not a single cover, it is made up of many pieces like jigsaw covering the surface of the earth. These keep slowly moving around each other, slide past one another and bump into each other. These puzzle pieces are called tectonic plates, and the edges of the plates are called the plate boundaries. The plate boundaries are made up of many faults, and most of the earthquakes around the world occur on these faults. Since the edges of the plates are rough, they get stuck while the rest of the plate keeps moving. Finally, when the plate has moved far enough, the edges unstick on one of the faults and there is an earthquake

There is major advantage of this type of buildings functionally but from seismic performance point of view such structures are considered to have increased vulnerability. Though multi- storeyed buildings with parking floor (soft storey) are vulnerable to collapse due to seismic forces, their construction is still popular. The open ground storey buildings are usually designed as framed structures without regard to structural action of wall (masonry infill walls). In the present practice of structural design in India infill walls are considered as non- structural components and their strength and stiffness contribution are ignored. The effect of infill panels on the response of RC frames subjected to seismic action is widely accepted and has been subject of numerous experimental and analytical investigations over last 5 decades.

A construction is divided into two parts from the point where there is a soft storey of the constructions with equal rigidity between the storeys; the displacement of the peak points at the moment of a earthquake causes the other building with a soft storey to get damaged because the construction with a soft storey cannot show the same rigidity. For example the top point of a ten-storey building with no soft storey performs 10 cm displacement, another building with the same specification but having a soft storey at the entry floor and with no necessary precaution can show the same displacement 10 cm at this floor level. According to this outcome, a soft storey in upper storeys of the building is not so effective

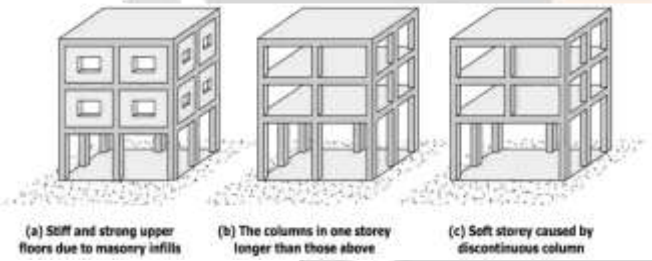

Fig. 1: Example of soft storey

II. OVERVIEW OF WORK

Present research work deals with comparative study of behaviour of soft storey building frames considering geometrical configurations under earthquake loading. The framed buildings are subjected to lateral load and vibrations because of earthquake and therefore lateral load analysis is necessary for these frame structures. The fixed base system are analyzed by employing different equivalent diagonal struts frame structures in seismic loading by means of STAAD.Pro software. The responses of the same building frames are studied and evaluate the best geometry which satisfy lateral loading.

III. LITERATURE REVIEW

Literature review allied to the seismic analysis of multi-storey building was carried out. The objective was to discern the strength of different multi-storey buildings for different seismic zones. It was observed that many researchers, scholars and consultants have worked extensively on seismic zones, seismic design, importance of seismic analysis, modern design methods, design formulae etc.

Fig. 2: A multi-story at site with floating column

Dhiraj D Ahiwale , Rushikesh R Khartod (2020) Open ground construction is quite prevalent from last 25 years in metropolitan India. Buildings with open ground stories are to be particularly exposed to collapse, and severe damage under earthquake excitation. Although, many buildings constructed in recent times have been observed adverse effect during Bhuj earthquake. In present work, twelve storied building are taken into account and the performance of structure evaluated by using pushover analysis in SAP 2000 software. The analytical results discussed in the nature of capacity curve, structure performance point and plastic hinge development pattern. Result indicated that, there are formations of plastic hinges at ground storey column level. To counteract the total collapse of soft storey structures, there is need to retrofit the open storey. Therefore, the alternative measures are recommended to get better the reaction of soft storey like RC shear wall, steel bracing, and infill wall.

Mr. Raghavendra S. Deshpande (2018) Open first storey is now a days unavoidable feature for most of the multistory buildings in urban areas for vehicle parking, shops etc. Many earthquakes in the past, have demonstrated the potential hazard associated with soft first storey buildings. The first storey become soft and weak relative to the upper stories, since the first storey is composed of only columns while the upper stories are divided by unreinforced masonry infills. Structurally those unbalances are unhealthy and the soft first storey buildings are well known for being susceptible to collapse through past big earthquakes. In the present paper, an investigation has been performed to examine the behavior of various alternative models of same reinforced concrete moment resisting frame building with an open first storey & unreinforced masonry infills in the upper stories. The structural action of masonry infill panels of upper stories has been taken into account by modeling them as equivalent diagonal struts. The parameters discussed include fundamental natural periods, stiffness of open first storey in relation to the upper storey, lateral displacements, inter-storey drift by linear elastic analysis using ETABS analysis package. It is noticed that significant change in stiffness between the soft storey and upper storey is responsible for increasing the strength demand on first storey columns. The objective of this paper is to promote safety without too much changing the constructional practice of reinforced concrete structures

Mohammed Irfan Hussain (2017) In this study, an industrial building is selected for the study, to study the seismic performance of soft storey buildings, there are six 3D mathematical models have been developed using ETABS. The various parameters have been studied, storey drift, storey displacement, forces and time period, storey shear, modes shapes. Subsequently adopting the control measures to reduce the effect of soft storey in terms.

Shobha. L et. al. (2016) Since long Masonry Infills (MI) are being used to fill the voids between the horizontal and the vertical structural elements such as beams and columns. But, when Laterally loaded, the masonry infill tends to interact with the RC frame, changing the structural behavior. In this work masonry infill is replace by Equivalent Diagonal Strut (EDS), whose width is calculated using the various relations proposed by the researchers. Variation in the Deflection and the Stiffness in the frame by modeling the masonry infill as equivalent diagonal struts and performing the linear analysis. The software technique is being used for the analysis.

Vikunj K. Tilva at. al. (2016) In the present era we are spotting that the load bearing structures are substituted by the RC frame structures because of its sustainability against the earthquake, durability, long life span and also high strength. Structural fall down implies that the structural system is unable to withstand its own gravity loads. In this paper, symmetrical frame of commercial building (G+5) located in different seismic zones and different soil condition is considered by modeling of initial frame. Which contain the requirements of computation of stiffness of infill masonry wall frames by modeling infill as a “Equivalent diagonal strut method” and IS 1893-2002. In which it shows that infill panels increase the stiffness of the structure. Different parameters like displacement, storey drift, and base shear are calculated for the different storey height.

N. Sivakumar , D. Saranyadevi , K. Sathish (2015) Though multistoried buildings with open (soft) ground floor are inherently vulnerable to collapse due to earthquake load, their construction is still widespread in the developing nations. Social and functional need to provide car parking space at ground level far out-weighs the warning against such buildings from engineering community. An investigation has been performed to study the behavior of the columns at ground level of multistoried buildings with soft ground floor subjected to dynamic earthquake loading. The structural action of masonry infill panels of upper floors has been taken into account by modeling them as diagonal struts. Finite element models of six, nine and storied buildings are subjected to earthquake load in accordance with equivalent static force method as well as response spectrum method. It has been found that when infill is incorporated in the model, modal analysis shows different mode shapes indicating that dynamic behavior of buildings changes when infill is incorporated in the model. Natural period of the buildings obtained from modal analysis are close to values obtained from code equations when infill is present in the model. This indicates that for better dynamic analysis of RC frame buildings with masonry walls, infill should be present in the model as well. Equivalent static force method produces same magnitude of earthquake force regardless of the infill present in the model.

IV. OBJECTIVE OF RESEARCH

In this work G+5 storey (six storey) building is taken in which floor wise (changing soft storey position form first to six storey) soft storey is analysed and its contribution in the behaviour of the structure is examined. Soft storey is very flexible so our purpose is to strengthen it by proving equivalent diagonal struts at centre and corner and find out the effective equivalent diagonal struts pattern which stands against wind and earthquake loading. The investigation is to be carried out by conducting-

(a) Modelling of building frames with different patterns of equivalent diagonal struts
(b) Analysis of frames considering wind and earthquake parameters
(c) Critical study of results in term of moments, forces and displacement.

V. DESCRIPTION OF STRUCTURAL MODEL

Equivalent Static method of analysis is a linear static procedure, in which the response of building is assumed as linear static manner. The analysis is carried out as per IS: 1893-2002 (Part 1).
A comparison analysis of results by moments, displacements, shear force, storey displacement and axial force has been done. Following steps are considered
Step-1 Selection of building geometry and Seismic zone: The behaviour of all the models is studied for Zone III of Seismic zones of India
Step-2 Selecting a geometry of 6 storey (G+5) of plan area 15m x 15m
Step-3 Modelling of soft storey floor wise and each soft storey floor is strengthen by providing equivalent diagonal struts
Step-4 Selection of Equivalent diagonal struts (200 mm x 200 mm)
Step-5 Formation of load combination
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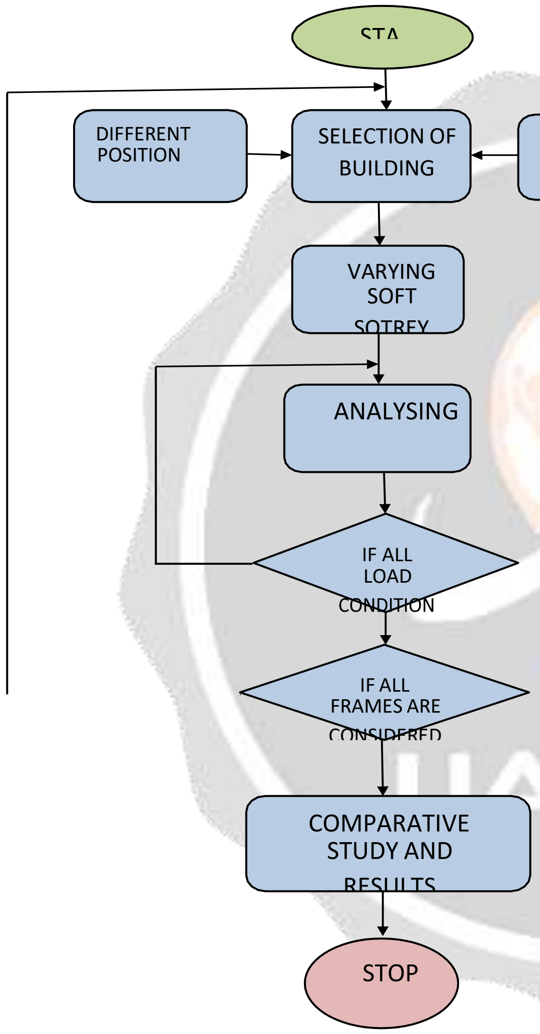
Details of Structure

Following properties of material have been considered in the modeling - Density of RCC: 25 KN/m3
Density of Masonry: 20 KN/m3 (Assumed) Poisson's ratio: 0.17
Young's modulus of concrete: $5000\sqrt{fck}$
The foundation depth is considered at 1.5 m below ground level and the floor height is 1.5 m. Consider beam size 250mm x 450 mm and column size 450 mm x 450 mm.

VI. WORKING FLOW CHART



VII. RESULT

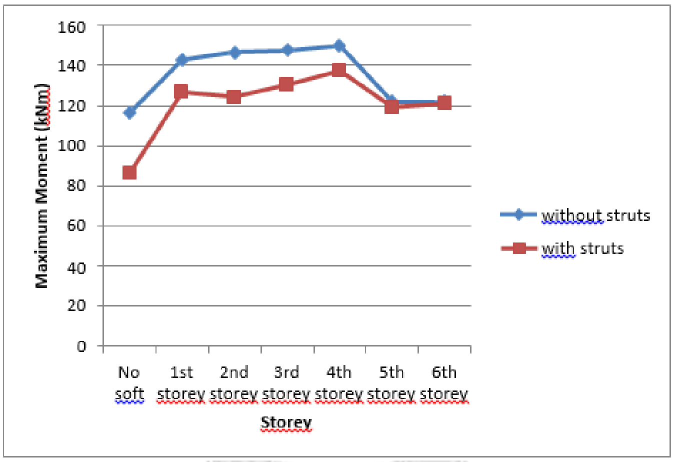


Fig. 7.1: Bending Moment (KN-m)

From above table and graph, it was observed that maximum bending moment is in 4th floor without struts and minimum in without soft storey structure with struts, hence comparing to maximum bending moment and adjacent of same, it was found that struts are approximately 0.79% efficient.

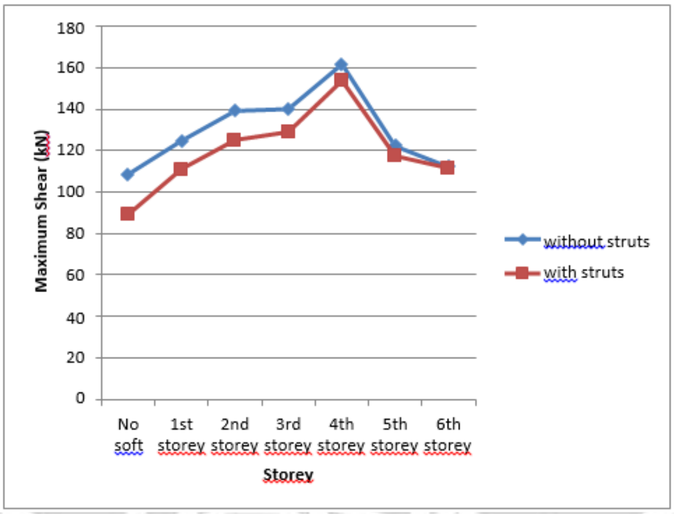


Fig. 7.2: Shear Force (kN)

From above table and graph, it was observed that maximum bending moment is in 4th floor without struts and minimum in without soft storey structure with struts, hence comparing to maximum shear force and adjacent of same, it was found that struts are approximately 0.48% efficient.

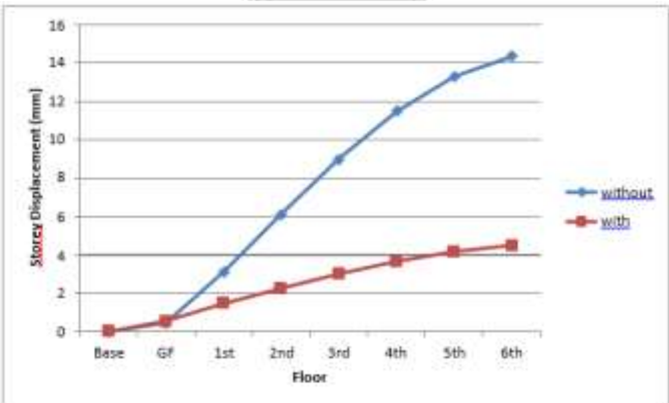


Fig. 7.3: Storey Displacement in no soft storey at X direction

VIII. CONCLUSION

Bending Moments

- It was observed that maximum bending moment is in without struts (equivalent diagonal struts) 4th storey soft building and minimum is in with struts no soft storey building.
- Maximum bending moment was observed in 4th storey soft building and after providing struts (equivalent diagonal struts) in same it reduces, hence struts reduces bending moment.
- While observing nature of graph in both struts and without struts building, bending moment in soft storey at 6th floor is same, hence at top floor there is no need to provide struts.
- With struts provided at floors, it reduces bending moment hence bending moment is directly proportional to area of steel.

Shear Forces

- It was observed that maximum shear force is in without struts (equivalent diagonal struts) 4th storey soft building and minimum is in with struts no soft storey building.
- Maximum shear force was observed in 4th storey soft building and after providing struts in same it reduces, hence struts reduces shear force.
- While observing nature of graph in both struts and without struts building, shear force in soft storey at 6th floor is same, hence at top floor there is no need to provide struts.

Maximum Nodal Displacements

- Maximum nodal displacement in X & Z direction is same, because of symmetrical section.
- It was observed that maximum displacement is in without struts 2nd storey soft building and minimum is in with struts no soft storey building.
- Maximum displacement was observed in 2nd storey soft building and after providing struts in same it reduces, hence struts reduces displacements.
- While observing nature of graph in both struts and without struts building, nodal displacement in soft storey at 6th floor is same, hence at top floor there is no need to provide struts.
- With struts provided at floors, it reduces displacement hence displacement is directly proportional to size of section.

Storey Displacements

- Maximum storey displacement in X & Z direction is same, because of symmetrical section.
- With struts provided at floors, it reduces displacement hence displacement is directly proportional to size of section.
- Storey displacement is increasing as increasing with height.

IX. SCOPE FOR FUTURE WORK

In this study, RCC framed structures have been considered. The study can be extended to built-up frame structures.

This study considered only one seismic zone-II. In further study more seismic zones can be included.

This study deals with plane terrain condition and in further studies sloping ground can be considered.

In this study, thermal effects have not been considered. In further studies the same can be considered.

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