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A Review on Stability Analysis of Multi-storey Building with Underneath Satellite Bus Stop having top soft storey and Moment transfer beams

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Abstract - RC frame building with open ground storey, and similar soft storey effect can be observed when soft storey at different levels of structure are constructed. The building with discontinuity in the stiffness and mass subjected to concentration of forces and deformations at the point of discontinuity which may leads to failures of members at the junction and collapse of building. The method used for stability analysis of columns, shear walls, coupled and coupled components, cores, single storey and multi storey structures are studying. Buildings and structures are consider stable with lateral supports by using either bracing systems or shear system or both such as wall to ensure the stability of the building. There have been so many cases in which the structures failed due to instability which require P-Delta analysis. One of the problems is affected from wind load. The calculation methods are computer assisted through the use of the software, ETAB/SAP2000. Comparisons of results are made between the methodologies, software and different models with different parameters. The P-Delta Analysis of the walled framed structure is done by use of the software. This is how the top soft storey effects are managed to overcome the future damages of the storied structures using moment transfer beams.

Key words: Satellite Bus Stop, stability of building, Soft-Storey, moment transfer beams.

1. INTRODUCTION

1.1 General

The increase in demand for tall structures requires that a structural engineer is familiar with the buckling phenomena that can occur in a building. The engineer must have an understanding of working calculation methods for designing this type of structure and must having confident in using them. Due to increasing population and land value since from the past few years that bus stands are major problem in populated cities. So construction of Multi Storied buildings with open ground softstorey as used for the movement of Buses (commonly known as Satellite bus stop). These type of building not having masonry infill walls. RC frame building with open ground storey is known as a soft storey, similar soft storey effect can be observed when soft storeys at different levels of structure are constructed. From the past earthquake it has been observed that a building with discontinuity in the stiffness and mass subjected to concentration of forces and deformations at the point of discontinuity which may leads to the failure of members at the junction and collapse of building. Most economical way to eliminate the failure of soft storey is by adding shear walls to the tall buildings.

1.2 Satellite Bus Stop

Nowadays due to increasing population and the land value since the past few years bus stands in populated cities is a matter of major problem. So that constructions of multi storied buildings with open first storey is a common practice in metropolitan cities (which commonly known as satellite bus stops). Hence the trend has been to utilize the ground storey of the building for the movement of the busses and people can use this as bus terminals. These type of buildings having no infill walls in ground storey, but all upper storeys infilled with masonry walls. Soft storeys at different levels of structure are constructed for other purposes like lobbies conference halls and for the service story's etc. we are considering ground soft storey for movement of busses and top soft storey.Eample of satellite bus stop as shown in fig 1 it is in England in Preston Lancashire.

Fig 1. Satellite Bus stops

1.3 STABILITY

Stability means:

The resistance offered by a structure to undesirable movement like sliding, collapsing and over turning etc. is called stability.

- ✓ Stability depends upon the support conditions and arrangements of members.
- ✓ Stability does not depend upon loading

Structural stability can also be defined as **"The power to recover equilibrium".** It is an essential requirement for all structures.

Stable structure

A structure is said to be stable if it can resists the applied load without moving or a structure is said to be stable if it has sufficient number of reactions to resists the load without moving.

Unstable structure A structure which has not sufficient number of reactions to resists the load without moving is called unstable structure.

Stability of frames

A frame is said to be stable if it satisfy the following condition.

- ❖ The number of unknown reactions must be greater than or equal to available equations of equilibrium.

Stability is a field of mechanics that studies the behavior of structures under compression. When a structure is subjected to a sufficiently high compressive force or stress, it will have a tendency to lose its stiffness, a noticeably change in geometry, and becomes unstable. When instability occurs, the structure loses its capacity to carry the applied loads and is incapable of maintaining a stable equilibrium configuration.

Buckling is a phenomenon which occurs when a structure is subjected to axial load suffers uncontrolled large displacement, transverse to the load. Transversal buckling, i.e. in plane, has two contributions, bending and shear. The bending deformation causes a curved shape. The shear deformation results in straight inclined shape. Combined they result in the critical buckling mode displayed in Figure 02.

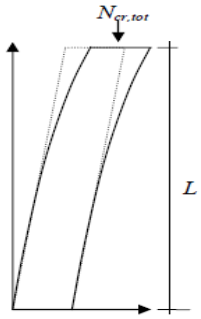

Fig 02. Combined bending and shear

Examples of structural instability include: buckling of a column under a compressive axial force, lateral torsional buckling (LTB) of a beam under a transverse load, sideways buckling of an unbraced frame under a set of concentric column forces, buckling of a plate under a set of in-plane forces, and buckling of a shell under longitudinal or axial stress, etc.

1.4 Soft Storey

The ground storey of a building which consists of open space for parking is known as soft storey. When a sudden change of stiffness takes place along the building height. When the drastic reduction of stiffness is observed is known as soft storey.

A soft story known as weak story is defined as a story in a building that has substantially less resistance or stiffness or inadequate ductility (energy absorption capacity) to resist the earthquake-induced building stresses. Soft story buildings are characterized by having a story which has a lot of open space. Parking garages, for example, are often soft stories, as are large retail spaces or floors with lots of windows. If a building has a floor which is 70% less stiff than the floor above it, it is considered a soft story building (UBC-1997, IBC-2003 and ASCE-2002). Failures of soft storeys can be seen in fig 3(a,b,c,d)

Fig 3(a) Ground soft storey failure, Fig 3(b) Intermediate soft storey failure

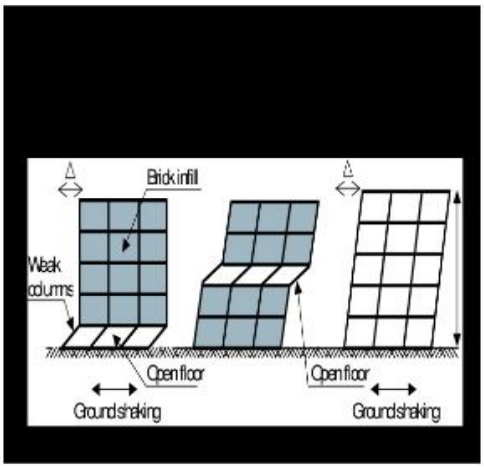

fig 3(c)Ground soft storeyfailure fig 3(d) soft storey failure pattern

1.5 Moment Transfer Beams

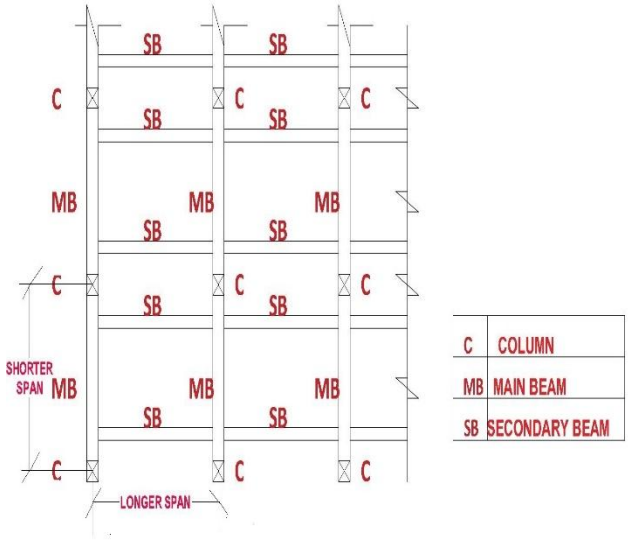

fig 04 NormalPlan of beams and columns

It is well-understood concept and an inevitable law of statics that loads must be transferred between beams and columns. Main beams are the beams connecting to the columns and secondary beams are the beams supported on the main beams. In the fig Secondary beams are nothing but Moment transfer beams.

Main beams can be of two types:-

1) **Simply supported or shear connected:** The beam-column junction is designed in such a way that no moment is transferred to the columns only the shear force is transferred from the beams to the columns, the moment is carried by beam itself.
2) **Fixed or moment connection type**: The beam-column junction is designed in such a way that moment as well as shear is transferred to the columns from the beam. All the six degree of freedom of the body is restrained.

In this study we are considering main beams are along shorter span and secondary beams (moment transfer beams) are along longer span. so, this is a satellite bus stop the depth of the beam is very high (due to heavy loads) along both sides, it is not comfortable for double decker buses therefore we are selecting main beams are along shorter span and secondary beams (moment transfer beams) are along longer span for easy movement of busses, Effect of moment transfer beams we are studying and how much floors we can go. Moment transfer beams are considering to transfer bending moments and shear forces.

2. LITERATURE REVIEW

2.1 General

Various research works and experiments have been carried out since a long time all over the world to understand or to ascertain the stability of the RC building in various zones. The concept of modelling and analysis technique used for this purpose has also been getting improved with advancement of engineering and technology as well as with past experience.

2.2 Reviews

2.2.1 Stability of Tall Buildings.

David Gustafsson& Joseph Hehir Department of Civil and Environmental Engineering Master's Thesis 2005:12Division of Structural Engineering Concrete Structures Chalmers University of Technology Goteborg, Sweden 2005

David Gustafsson mentioned about the methods used for stability calculations of columns, solid shear walls, pierced shear walls, coupled and uncoupled components, cores, single storey structures and multi-storey structures and examined. The examination performed in order to ascertain advantages for different stabilizing components and systems.

Analyses are made for deflection and buckling combining bending and shear for columns, solid shear walls and pierced shear walls. Calculation methods for single and multi storey structures concerning deflection and buckling due to translation, rotation or a combination of the two are analyzed and the results are compared with finite element analyses results.

The calculation methods are computer assisted through the use of MATHLAB, MATHCAD and EXCEL. Comparisons of results are made between the calculation methods and Finite Element Analysis performed with a programm called SOLVIA.

2.2.2 Structural Stability.

Eric M. Lui Department of Civil & Environmental Engineering, Syracuse University, Syracuse, NY 13244-1240 USA

Eric Lui defines stability is a field of mechanics that studies the behavior of structures under compression. When a structure is subjected to a sufficiently high compressive force or stress, it will have a tendency to lose its stiffness, experience a noticeably change in geometry, and becomes unstable. When instability occurs, the structure loses its capacity to carry the applied loads and is incapable of maintaining a stable equilibrium configuration. Examples of structural instability include: buckling of a column under a compressive axial force, lateral torsional buckling (LTB) of a beam under a transverse load, sideways buckling of an unbraced frame under a set of concentric column forces, buckling of a plate under a set of in- plane forces, and buckling of a shell under longitudinal or axial stress, etc.

2.2.3 Stability Analysis of Steel Frame Structures: P-Delta Analysis.

Mallikarjuna B.N,P.G. Student, and **Prof. Ranjith A** is an Assistant Professor, Department of Civil Engineering, AIT, Chikmagalur, Karnataka, India

MallikarjunaB.N and Prof .Ranjith A. focused on P-delta analysis to be compared with linear static analysis. An 18 storey steel frame structure with 68.9m has selected to be idealized as multi storey steel building model is to taken for their research.

The model is analyzed by using STAAD.Pro 2007 structural analysis software with consideration of P-delta effect. At the same time the influence of different bracing patterns has been investigated. The steel brace are usually placed in vertically aligned spans. This system allows obtaining a great increase of stiffness with a minimal added weight, so it is very effective for existing structure for which the poor lateral stiffness.

The loads considered for the analysis are Gravity load, Live load and Wind load. The frame structure is analyzed for Wind load as per IS875 (part 3)-1987. After analysis, the comparative study is presented with respective to maximum storey displacement and axial force.

2.2.4 An approximate method for lateral stability analysis of Wall-frame buildings including shear deformations of walls.

KanatBurakBozdogan and DuyguOzturk.
Department of Civil Engineering, Ege University, ˙Izmir, 35040 Turkey.

Kanat and Duygu presents an approximate method based on the continuum approach and transfer matrix method for lateral stability analysis of buildings. In this method, the whole structure is idealized as an equivalent sandwich beam which includes all deformations. The effect of shear deformations of walls has been taken into consideration and incorporated in the formulation of the governing equations. Initially the stability differential equation of this equivalent sandwich beam is presented, and then shape functions for each storey is obtained by the solution of the differential equations. By using boundary conditions and stability storey transfer matrices obtained by shape functions, system buckling load can be calculated. Examples are shown that the results obtained from the proposed method are in good agreement with Finite Element Method and the analytical solution which has been developed by Rosman. The proposed method is not only simple and
accurate enough to be used both at the concept design stage and for final analyses, but at the same time takesless computational time than the Finite Element Method.

2.2.5 Stability design of structure with semi-rigid connections.
TomislavIgić, SlavkoZdravković, Dragan Zlatkov, SrđanŽivković, Nikola Stojić.

The paper presents theoretical foundations and expressions of calculations of impacts on the stability of structure, that is, review of the Second order theory in a bridge with members semi-rigid connections in joints. In the real structures in general and the especially in the prefabricated structures the connection of members in the nodes can be partially rigid which can be very significant for the changes in tension and deformation. If the influence of the normal forces is significant and the structure is slender then it is necessary to carry out a calculation according to the second order theory because the balance between internal and external forces really established on the deformed configuration and displacements in strict formation are also unreal. The importance and significance of the calculations and distribution of impact according to the Second order theory were presented in numerical examples as well as the calculation of critical load as well as the buckling length of members with semi-rigid connections in joint.
. In this paper, a calculation according to the Second order theory will be briefly presented, which is particularly important when it is necessary to solve the stability issues of the structures with semi-rigid connections of members in nods, whose application in theory and practice is very difficult, and thus represents a valuable contribution to contemporary structural analysis.

2 **2.2.6 Structural Stability.**
Zdeneik P. Baziant Walter P. Murphy Professor of Civil Engineering and Materials Science, Northwestern University, 2145 Sheridan Road, Evanston, IL 60208-3109, USA
Walter's paper attempts a broad overview of the vast field of stability of structures, including elastic and inelastic structures, static and dynamic response, linear and non-linear behavior, energy approach, thermodynamic aspects, creep stability and fracture or damage-induced instability. The importance of stability theory to various fields of engineering and applied science is pointed out and the history of the discipline is briefly sketched. The principal accomplishments are succinctly reviewed, and fruitful recent trends, particularly the stability analysis of damage localization and fracture, are emphasized.

2.2.7 A Seismic Analysis of RC High Rise Structural Building with Multiple Soft Storey at Various Level using ETabs

Syed Mohammad Zakir Ali M.Tech Student (Structural Engineering) **&Amaresha**Assistant Professor Department of Civil Engineering VeerappaNisty Engineering College, SHORAPUR 585224, Dist. YADGIR

Md. Zakir Ali describes that increasing worldwide Development of metro cities in India there is increasing demand in High Rise Building and the effect of masonry infill panel on the response of RC frame subjected to seismic action is widely used. In his study the effect of masonry wall on high rise building is studied, as it is essential to consider the effect of masonry infill for the seismic evaluation of moment resistant reinforced concrete frame. Linear analysis on high rise structure with different arrangement is carried out and for analysis G+9 framed building is modelled. Soft stories are subjected to larger lateral loads during earthquakes and under lateral loading. This lateral force cannot be well distributed along the height of the structure. This situation causes the lateral forces to concentrate on the storey having larger displacement. The lateral force distribution along the height of a building is directly related to mass and stiffness of each storey.

2.2.8 Seismic Performance Evaluation of Multi-Storeyed R C Framed Structural System with the Influence of Ground & Top Soft Storey (Mohammed Tosif Ahmed , Prof. Vishwanath .B. Patil]**.**

Masonry infills are normally considered as non-structural elements and their stiffness contributions are generally ignored in practice. But they affect both the structural and non-structural performance of the RC buildings during earthquakes. RC frame building with open first storey is known as soft storey, which performs poorly during strong earthquake shaking. A similar soft storey effect can also appear at top storey level if a storey used as a service storey. Hence a combination of two structural system components i.e. Rigid frames and RC shear walls leads to a highly efficient system in which shear wall resist the majority of the lateral loads and the frame supports majority of the gravity loads. To study the effect of masonry infill and different soft storey level, 11 models of R C framed building were analyzed with two types of shear wall when subjected to earthquake loading. The results of bare frame and other building models have been compared, it is observed that model with swastika and L shape shear wall with core wall are showing efficient performance and hence reducing the effect of soft storey and also reducing the effect of water pressure in the top soft storey.

2.2.9 Seismic Analysis of Multi-Storeyed Building with Underneath Satellite Bus Stop and Top Soft Storey with Different Types of Shear Wall(Galanna. S. Karningol, Vishwanath. B. Patil].

Normally masonry infills are considered as nonstructural elements and also their stiffness contributions are generally ignored in practice. And also they affect both the structural and non-structural performance of the RC buildings during earthquake. RC frame building with open first storey is known as soft storey, which performs poorly during strong earthquake shaking. A similar soft storey effect can occur if first and top story used as service story. So that a combination of two structural system components i.e. The Rigid frames and RC shear walls leads to a highly efficient system in which shear wall resist the majority of the lateral loads and the frame supports majority of the gravity loads. To study the effect of masonry infill with different soft storey level, and also we were studying 10models of Reinforced Concrete framed building were analyzed with 7 types of shear wall when subjected to earthquake loading. The results of bare frame ,strut frame and other building models have been compared, it is observed that all models with L –type, swastika –type, plus(+)-type, I-type, C-type, U-type ,T-type shear wall with showing efficient performance and hence reducing the effect of soft storey in model 4, model 5 ,model 6,model 7,model 8,model 9 model 10.

3. OBJECTIVES OF THE STUDY

3.1 Objectives

- ✓ Creation of 3D building model stability analyses.
- ✓ To perform lateral load analysis for different building models as per the code.
- ✓ To study the behavior of ground and top soft storey of R C high rise buildings.
- ✓ To study the influence of core wall and corner shear walls on the overall behavior of building.

- ✓ To study the effect of stiffness of infill walls on the overall behavior of structure when subjected to lateral seismic loading.
- ✓ To find out the deflections and storey drifts at each storey level using Response Spectrum method, pushover and time history analysis.
- ✓ To observe the level of change of internal forces and storey drift computed with bare frame model and the different models.
- ✓ To know the performance of building with ground and top soft storey, compare with bare frame model.
- ✓ To know the performance of moment transfer beams.

3.2 Scope of the study

The present study is an attempt in the state of art of stability analysis of multistoried reinforced concrete buildings over a satellite bus stop. The focus of attention is to find the performance level of the building over a satellite bus stop with the help of capacity and demand of the building for stability using dynamic analysis.

3.3 Building and Loading

- ❖ The study is carried out by considering a RC frame multi- storey structure with ground, top soft storey and moment transfer beams.

3.4 Modeling and Analysis Method

- 3D modeling for analyses using ETAB/SAP2000
- The building is to be analyses by using Response Spectrum as well as Time History Analysis.

3.5 Parametric Studies

- ✓ The overall behavior of RCC framed building by masonry infill on the overall behavior of the structure under stability analysis.
- ✓ The effects of concrete core wall and Shear walls on the overall behavior of the structure when subjected stability.
- ✓ The effect of ground and top soft storey on the overall behavior of the building when subjected to stability.
- ✓ Effect of moment transfer beams.
- ✓ The effect of drift, acceleration, displacement, story shear, and infill in multi-story building and bare frame.

4. METHODOLOGY AND ANALYSIS METHOD

Modeling and Analysis are done by using Etab/Sap2000 software. The stability analysis of structures are done by following methods.

1. **Overall Buckling Analysis of Frames:**

a) Approximate Methods:
Methods for the determination of the overall buckling load included because first, it indicates an upper bound for the critical gravity load. Second, it allows an assessment of the relative vulnerability of the building to transverse buckling or torsional buckling. And third, it may be used, in a structure for which an approximate P-Delta analysis is approximate to evaluate an amplification factor for the displacements and moments. Using[16]

i) Shear Mode
ii) Flexural mode

2. **Overall Buckling Analysis of Wall Frames:**
Equations of Shear and Flexural Modes provides very approximate estimates of the overall buckling load of a structure in the shear, flexure, and combined shear-flexure modes. A more rigorous analysis for plan-symmetric, uniform wall-frame structures provides solutions for the buckling loads of frame structures at one extreme shear wall structures at the other, and any combination of shear walls and frames by,

Analytical Method

- ✓ Second-Order Effects of Gravity Loading:

- ✓ Second order P-Delta Effect
- ✓ Amplification Factor P-Delta Analysis
- ✓ Iterative P-Delta Analysis
- ✓ Iterative Gravity Load P-Delta Analysis
- ✓ Direct P-Delta Analysis

4.CONCLUSIONS

The following conclusions are made from the whole studies of the reviews of all are as follows

I. The soft story effect is less at intermediate location of the building. A service storey of lesser height can be safer for building at higher level.

II. The second order effects found to increase the storey displacements at all level of the structure.

III. The multi-storey unbraced frames, the column lateral stiffness decreased when increasing the value of the initial geometric imperfections. As a result of the decreasing lateral stiffness, the extreme frame-buckling loads were reduced.

IV. The shear force and bending moments are higher for ground storey columns with respect to first storey column.

V. Behavior of square column is better than rectangular column, in terms of storey drift, base shear & roof displacement.

VI. The shear walls are used to eliminate the lateral load and soft storey effects, when the shear walls are kept centrally it is not affected much on the behavior of structures.

VII. The effect of masonry infills in the structures increases the stiffness of the structural element

VIII. The soft story effect is less at intermediate location of the building. A service storey of lesser height can be safer for building at higher level.

IX. In case of an open first storey frame structure, the storey drift is very large than the upper story's, which may cause the collapse of structure during strong earthquake shaking.

X. The shear force and bending moments are less for moment transfer beams.

XI. By using moment transfer beams we can decrease the depth of beam. It is helpful for heavy loads.

XII. Effect of stability on a building

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