A Review on Stability analysis of Multi-Story Building with Underneath Satellite Bus Stop having Service Soft Story and Floating Columns

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Abstract— The masonry infill walls are considered as non-structural element and their stiffness contribution are ignored in the analysis when building is subjected to seismic loads, but it is considered while we studying stability analysis. 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. One of the problems is affected from wind load. The calculation methods are computer assisted through the use of the software, STAAD Pro and 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 soft storey effects are managed to overcome the future damages of the storied structures.

Key words: Satellite Bus Stop, Service Soft-Storey

I. INTRODUCTION

A. 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 story as used for the moment of Bus terminals (commonly known as Satellite bus stop). These type of building not having masonry infill walls and their stiffness contributions are analysis when building is subjected to seismic loads. RC frame building with open ground story is known as a soft story, similar soft story effect can be observed when soft stories 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 story is by adding shear walls to the tall buildings.[5]

B. Satellite Bus Stop

The Multi-storied buildings with open ground storey as used for the moment of Bus terminals, commonly known as Satellite bus stop. These type of building not having masonry infill walls in the ground floor. The height of the soft storey is double then the normal height of the storey. In India there are so many satellite bus stops are built. Also in our state Bangalore, Mysore having these type of bus stops. Ex: Shivajinagar, ITPL, Vijaynagar, Jayanagar, Yeshwanthpur etc., some of examples are shown in figure 4 below.

Fig. 1: BMTC Satellite Bus Stands, (a)ITPL Bangalore, (b)Jayanagar Bangalore, (c) & (d)Vijaynagar, and (e)& (f)Yeshwanthpur, Bangalore[20]

C. Structural Stability

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.[14]

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[1]. Combined they result in the critical buckling mode displayed in Figure 1.

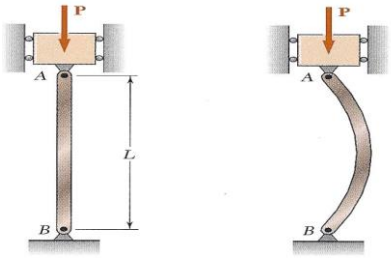

Fig. 2: Buckling of Column

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]

II. LITERATURE REVIEW

A. *Stability of Tall Buildings*

David Gustafsson mentioned about the methods used for stability Analysis of columns, solid shear walls, pierced shear walls, coupled and uncoupled components, cores, single storey structures and multi-storey structures. The examination performed in order to ascertain advantages for different stabilizing components and systems. Analysis were made of 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 importance of pure torsion is somewhat neglected in these methods and therefore a method was devised for including a components torsional resistance in the calculations.[1]

B. *Structural Stability*

Zdeneik P. Baziant's paper attempts an 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]

C. *Stability Analysis of Steel Frame Structures: P-Delta Analysis.*

Mallikarjuna mentions in his paper the stability requirements of tall structures. Tall building structure requires stability because it consists a lot of frame structure with different width and height. 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. Wind creates inward and outward pressures acting on building surfaces, depending on the orientation of the surface such as flat. This pressure increases uplift on parts of the building, forcing the building apart if it is too weak to resist the wind loads. Therefore, the most important thing to overcome this problem is the connection between beam and column in a frame such as rigid or pin ended should be considered for a realistic design it will become instable structure which means loss of some situation and come close to a failure such as buckling and sway if the structure cannot sustain for a certain load whether from dead load, imposed load, wind load and also natural phenomena like earthquake.[3]

Seismic Analysis of Multi-Storied Building with Underneath Satellite Bus Stop and Intermediate Service Soft Storey Having Floating Columns.-

Shrikanth is mentioned, the present problems and use of soft-storey and its effects in structures. As we know that increasing population and the land value in the past few year's bus stands in populated cities is a major problem. So that constructions of multistoried buildings with open first storey is a common practice in metropolitan cities (which commonly known as satellite bus stops). These type of buildings having no infill walls in ground storey, but all upper story's in filled with masonry walls are called soft first storey or open ground storey building. Soft story's at different levels of structure are constructed for other purposes like lobbies conference halls and for the service story's etc. The presence of infill wall can improve the performance of the building in seismic analysis, and the best way to reduce the effect of soft storey is to provide the shear walls at perfect location and of correct shape to the building. And also he mentioned that use of similar soft storey effect can be observed when soft stories 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.[4]

D. *A Review on Study on Strengthening of Soft Storey Building for Seismic Resistance.*

Arunkumar studies on the effect of first soft-storey in the RC frames buildings. And they perform poorly when an earthquake happens. The soft story with infill wall influence the behavior of structure when subjected to lateral forces. He concluded that use of infill walls will increases the lateral load carrying capacity of structure. When masonry infill are considered to interact with their surrounding frames the lateral load carrying capacity of structure largely increase. Earthquakes that occurred recently have shown that a large number of existing reinforced concrete buildings especially soft storey building are vulnerable to damage or even collapse during a strong earthquake. The first storey of the building behaved as a soft storey in which the columns were unable to provide adequate shear resistance during the earthquake.[5]

E. Structural Stability

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.[6]

F. Structural Response of High Rise Buildings For Different Soft Storey Heights and Approaching Methodology

Prakash Sangave explain the reason of soft storey in his paper, it is due to accommodation of vehicles and their movements at ground levels infill walls are generally avoided, which creates soft storey effect. It should be noted that 70 to 80 % of buildings of urban areas in India fall under the classification of soft storey. It is a typical feature in the modern multi-storey constructions. The majority of buildings that failed during the Bhuj earthquake (2001) and Gujarat earthquake were of the open ground storey type. The collapse mechanism of such type of building is predominantly due to the formation of soft-storey. As per Indian Standard IS 1893: 2002, the Columns and Beams of the open ground storey are to be designed for 2.5 times the storey shears and moments calculated under seismic loads of bare frames. This Multiplication Factor value however does not account for number of story's, number of bays, type and number of infill walls present, etc., and hence it is independent of all of the above factors. In his study includes analysis of (G+7) RCC Framed building analyzed using Seismic Coefficient Method (SCM) as per IS 1893: 2002. In modelling the masonry infill panels, Equivalent diagonal Strut method is used.

G. A Seismic Analysis of RC High Rise Structural Building with Multiple Soft Storey at Various Level using Etab

Md. Zakir Ali's paper 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.[8]

H. P-Delta Effects on Tall RC Frame-Wall Buildings

Sullivan, Pham and G.M. Calvi's paper explained about the P-delta ratio, that is appear to have been set to ensure a minimum reloading stiffness during cyclic response and with due consideration for the likely ductility demands imposed on structures. In this paper, the design of a 45-storey reinforced concrete frame-wall case structure is used to highlight the significance of the p-delta limit within the modal response spectrum analysis procedure of the Euro code 8. It is found that the strength of the structure is dictated by the P-delta limit for seismic actions, despite anticipated storey drifts and ductility demands being relatively low. A series of non-linear time-history analyses using a suite of spectrum-compatible real and artificial accelerograms, indicate that P-delta effects do not have a significant influence on displacements or storey drifts of the tall building. The likely causes of this behavior are identified, making reference to earlier investigations into P-delta behavior and with consideration of substitute structure concepts. To investigate the significance of the P-delta ratio further, a series of SDOF studies are undertaken for systems designed with P-delta ratios of up to 0.85. The results demonstrate that the p-delta ratio has little influence on the behavior of long-period systems subject to real earthquake records and therefore it does not appear appropriate to impose strict limits on the P-delta ratio. Instead, it is recommended that the P-delta effects be evaluated for tall-building systems as part of an overall assessment of their response, using advanced non-linear time-history analyses with real records and within a large-displacement analysis regime.[9]

I. Study of P-Delta Effect on Tall Steel Structure

Neeraj, Maheswerappa and Dattatraya studied about the high rise buildings require high frame structure stability for safety and design purposes. This research focused on P-Delta effect on the Tall Steel Structures and compared with linear static analysis. In this study, a 40 storey steel frame structure is modelled by using SAP2000 structural analysis software with the consideration of P-delta effect. At the same time the Influence of different bracing patterns have been investigated. For this reason five types of bracing systems including X, V, Single Diagonal, Inverted V, with unbraced model of same configuration are modelled and analyzed. The framed structure is analyzed for Earthquake load. After analysis, results showed that displacement due to P-Delta effect is 40% more compared to linear analysis and increase in the axial force is about 8% for bare frame. The X bracing proved to be more stiff and effective with respect to linear analysis and P-Delta analysis. The decrease in the displacement is about 47.5% and 47.9% for linear and second order analysis.[10]

Storey-Based Stability Analysis for Multi-Storey Unbraced Frames Subjected to Variable Loading

For decades, structural engineers have been using various conventional design approaches for assessing the strength and stability of framed structures for various loads. Today, engineers are still designing without some critical information to insure that their stability assessment yields a safe design for the life of the structure with consideration for extreme loads. Presented in this thesis is new critical information provided from the study of stability analysis and design of steel framed structures accounting for extreme loads associated to load patterns that may be experienced during their lifetime. It is conducted in five main parts. A literature survey is first carried out reviewing the previous research of analyzing frame stability including the

consideration of initial geometric imperfections, and also evaluating research of the analysis and design of the increased usage of cold formed Steel (CFS) storage racks. Secondly, the elastic buckling loads for single-storey unbraced steel frames subjected to variable loading is extended to multi-storey unbraced steel frames. The formulations and procedures are developed for the multi-storey unbraced steel frames subjected to variable loading using the storey-based buckling method.[11]

J. Stability Analysis of Frame Tube Tall Buildings

In this thesis a Non-linear analysis and stability check of frame-tube building is done. Nonlinear analysis offers several options for addressing problems of nonlinearity and in this work focus is on Geometric Non-linearity. The main sources can be identified as P-D effect of gravity loading acting on a transversely displaced structure due to lateral loading and can also be due to member imperfections, such as member camber and out of plumb erection of the frame. During analysis the element response keep continuously changing as a function of the applied load so simple step computing methods have been employed instead of direct analytical methods. The problem here is dealt in a piece wise linear way and solved. In this thesis a program using the matrix approach has been developed. The program developed can calculate the buckling load and can do Linear and Non-linear analysis using the Mat-lab as the computing platform.[12]

Nonlinear Stability Analysis of Frame-Type Structures with Random Geometric Imperfections Using a Total-Lagragian Finite Element Formulation.

With the increasing use of lightweight frame-type structures that span long distances, there is a need for a method to determine the probability that a structure having random initial geometric imperfections will become unstable at a load less than a specified fraction of the perfect critical load. The overall objective of this dissertation is to present such a method for frame-type structures that become unstable at limit points. The overall objective may be broken into three parts. The first part concerns the development of a three-dimensional total Lagragian beam finite element that is used to determine the critical load for the structure. The second part deals with a least squares method for modeling the random initial imperfections using the mode shapes from a linear buckling analysis, and a specified maximum allowable magnitude for the imperfection at any imperfect node in the structure. The third part deals with the calculation of the probability of failure using a combined response surface/first-order second-moment method. Numerical results are presented for two example problems, and indicate that the proposed method is reasonably accurate. Several problems with the proposed method were noted during the course of this work and are discussed in the final chapter.[13]

III. Objectives of the Study

The present project work is aimed to study of stability of tall structures with following objectives.

- To study the effect of soft-story in multistory buildings.
- To know the behavior of the building with ground and intermediate soft-storey.
- To study the influence of floating column on structural behavior of multistory building.
- To study the effect of drift, acceleration, displacement, story shear, and infill in multi-story building.
- To study the influence of stability analysis of RC frames.
- To study the influence of stability analysis of Soft-Story's.
- To study the influence of stability analysis of Multi-story building using Software.
- To check the results with both the software i.e., STAAD Pro and ETAB/SAP2000 with different models, parameters, and methodology.

IV. Methodology and Analysis Method

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

A. Overall Buckling Analysis of Frames:

1) 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]

- Shear Mode
- Flexural mode

B. 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, [16]

1) Analytical Method

a) Second-Order Effects of Gravity Loading:

- The P-Delta Effect
- Amplification Factor P-Delta Analysis
- Iterative P-Delta Analysis
- Iterative Gravity Load P-Delta Analysis
- Direct P-Delta Analysis

V. Conclusions

From this literature Review we got some conclusions they are as follows

- 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.
- The shear force and bending moments are higher for ground storey columns with respect to first storey column.
- The shear walls are used to eliminate the lateral load and soft storey effects, when the shear walls are kept

centrally it has not affected much on the behavior of the structure.

- 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.
- Behavior of square column is better than rectangular column, in terms of storey drift, base shear & roof displacement.
- 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.
- The second order effects found to increase the storey displacements at all level of the structure.
- The Axial Force for Continuous type in P-delta analysis is increase 22% has compared to static analysis. Etc.,

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