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A Review On Stability Analysis Of A Multi-Storey Building With Underneath Satellite Bus Stop Having Top Soft Storey And Floating Columns

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Abstract— The masonry infill walls are considered as nonstructural 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, Soft-Storey, Floating column,

1. INTRODUCTION

1.1 General

As there is rapid progress in the in the development of tall structures in the globe as the result for the increase in the land values and population. Due to increasing population and the land value since the past few years parking of major and heavy vehicles in populated cities is a matter of major problem. So that constructions of multi storeyed buildings with open first storey is a common practice in metropolitan cities (which commonly known as satellite bus stops for bus station parking). Hence the trend has been to utilize the ground storey of the building for the moment 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 are called soft first storey or open ground storey building. Soft storeys at different levels of structure are constructed for other purposes like lobbies conference halls and for the service storeys etc. Generally failures of many engineering structures fall into one of two simple categories: Material failure and Structural instability. The first type of failure, treated in introductory courses on the strength of materials and structural mechanics, can usually be adequately predicted by analyzing the structure on the basis of equilibrium conditions or equations of motion. Structural failures caused by failure of the material are governed, in the simplest approach, by the value of the material strength or yield limit, which is independent of structural geometry and size. By contrast, the load at which a structure becomes unstable can be, in the simplest approach, regarded as independent of the material strength or yield limit; it depends on structural geometry and size, especially slenderness, and is governed primarily by the stiffness of the material, characterized. These structures are to be safe against all the types of failures and behaves safe to serve throughout their life span.

1.2 Structural Stability

The term stability has both informal and formal meanings. As regards the former, the American Heritage Dictionary lists the following three.

1. Resistance to sudden change, dislodgment, or overthrow.
2. **a.** Constancy of character or purpose: tenacity; steadfastness.

b. Reliability; dependability. Related verb: to stabilize. Related adjective: stable. Antonyms: stability loss, instability, to destabilize, unstable.

The formal meaning is found in engineering and sciences, concerning stability of systems. Broadly speaking, structural stability can be defined as **the power to recover equilibrium.** It is an essential requirement for all structures. Stability represents a fundamental problem in solid mechanics, which must be mastered to ensure the safety of structures against collapse. The theory of stability is of crucial importance for structural engineering, aerospace engineering, nuclear engineering, onshore, ocean and arctic engineering.

1.3 Soft storey

The ground storey of a building which consists of open space for parking is known as stilt building and this storey with open space is known as stilt Floor or Soft-Storey. When a sudden change of stiffness takes place along the building height, the storey of which the drastic reduction of stiffness is observed is known as soft storey.. As per IS-1893:2002 (part I). An Soft Storey is the 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.

- ✓ **Extreme Soft Storey :** An extreme soft storey is the one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above.
- ✓ **Soft storey failure:** The shortage of land in the urbanized area has made the engineers to build the first storey of the building with open space for parking, etc. The strength demand on the column in the first storey for these building is also large, but however in the upper stories the forces in the columns are effectively reduced due to presence of brick infill walls which share the forces. If the stiffness of the first floor is significantly less strong or more flexible, a large portion of the total building deflections tends to concentrate in that floor. The presence of walls in upper stories makes them much stiffer than the open ground storey of the building.

Figure: 1 Soft story buildings

Figure: 2 Failure of soft storey

1.4 Shear walls

Reinforced concrete (RC) buildings often have vertical plate-like RC walls called Shear Walls in addition to slabs, beams and columns. These walls generally start at foundation level and are continuous throughout the building height. Their thickness can be as low as 150mm, or as high as 400mm in high rise buildings. Shear walls are usually provided along both length and width of buildings. Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation.

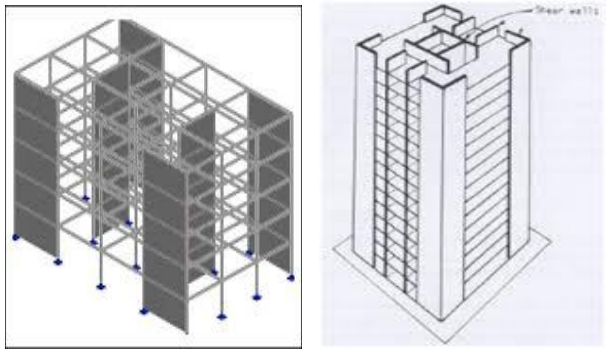

Figure: 3 shear walls.

Reinforced concrete shear-walls are mostly used in buildings due to better observed performance in recent past. In areas of high seismic risk, RC shear walls have

been widely used as main lateral load resisting system in medium & high rise buildings because of their high lateral stiffness. Recent earthquake have shown that only properly designed shear walls can withstand strong earthquake forces with minor damage. The function of shear wall is to resist the effect of lateral and gravity forces and to provide lateral stability to a tall building.

1.5 Floating column

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The term floating column is also a vertical element which ends (due to architectural design/ site situation) at its lower level (termination Level) rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it. Such columns where the load was considered as a point load. Theoretically such structures can be analyzed and designed. In practice, the true columns below the termination level [usually the stilt level] are not constructed with care and more liable to failure.

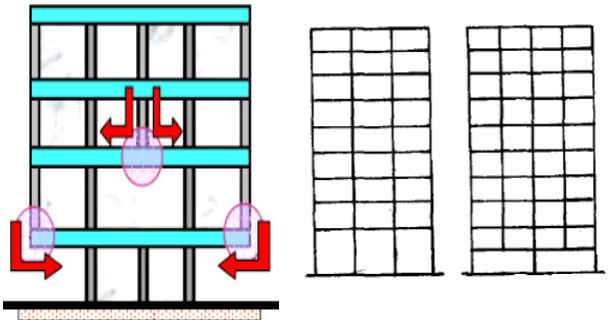

Figure: 4 Floating columns

There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the ground floor.

1.6 Masonry infills

Masonry infill typically consists of brick or precast blocks, constructed between columns and beams of a RC frame. These panels are generally not considered in the design process and treated as non-structural components. The presence of masonry walls have significant impact on the seismic response of an RC frame building, increasing structural strength and stiffness. If in fills are properly considered in the design, then they usually have a beneficial effect on the seismic response of the structure.

1.7 Satellite bus stops

The Multi-storeyed 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.

Figure: 5 Satellite bus stops

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

Mallikarjuna B.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.

Kanat Burak Bozdogan and Duygu Ozturk.

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 takes less computational time than the Finite Element Method.

2.2.5 Stability design of structure with semi-rigid connections.

Tomislav Igić, Slavko Zdravković, Dragan Zlatkov, Srđan Živković, 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.

2.2.6 Seismic Analysis of Multi-Storeyed Building with Underneath Satellite Bus Stop and Intermediate Service Soft Storey Having Floating Columns.
Shrikanth Bhairagond M.Tech Student (Structural Engineering) and **Prof. Vishwanath. B. Patil,** Professor in Department of Civil Engineering Poojya Doddappa Appa College of Engineering Kalaburagi India.

Shrikanth is mentioned, the present problems and use of soft-storey and its effects in structures.. Soft storeys at different levels of structure are constructed for other purposes like lobbies conference halls and for the service storeys etc. This storey is known as weak storey because storey stiffness is lower compare to above storeys. Experience in the past earthquake has shown 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 member's at the junction and collapse of building. 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 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.

2.2.7 Seismic Analysis of Multi-Storeyed Building with Underneath Satellite Bus Stop and Intermediate Service Soft Storey Having Floating Columns by Time History Analysis.

Shrikanth Bhairagond M.Tech Student (Structural Engineering) and **Prof. Vishwanath. B. Patil,** Professor in Department of Civil Engineering Poojya Doddappa Appa College of Engineering Kalaburagi India.

Shrikanth is used time history analysis with the effect of drift, acceleration, displacement, story shear and infill. Masonry infilled RC frames are the most common type of structures used for multi-storeyed building. Stiffness contribution of these masonry infill walls are ignored in the lateral loads analysis. The RC frame building without infill walls are called as soft-storey. These soft-storeys can be of any height of the building. From the past earthquakes it has been observed that a building with discontinuity in the stiffness and mass subjected to lateral loads may leads to the failure of members collapse of structures. And this effect of soft-storey can be reduced by using shear walls in the building. He studied the use of soft-storey in two different locations of the building with floating columns, different types of shear walls and curtailment of shear wall in seismic prone areas are studied. The Model has analysis by using ETABS software. The results shows the infill wall and shear walls gives more strength in seismic analysis of the building and curtailment of the shear wall can be done up to the top of intermediate soft-storey.

2.2.8 A Review on Study on Strengthening of Soft Storey Building for Seismic Resistance.
S Arunkumar, M.Tech Student (Structural Engineering) and **Dr. G. Nandini Devi** Professor in Department of Civil Engineering, Adhiyamaan College of Engineering Hosur, Tamilnadu, India

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.

2 **2.2.9 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.

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

Prof. Prakarsh Sangave, Miss. Jahagirdar Sayyeda Zara S, Mr. Jamdar Ameer Hussain Suhel Ahmed, Mr. Bagalkote Tarique Aziz A, Mr. Doka Md. Rizwan I, Mr. Mashalkar Imran M, Mr. Kudkyal Pramod A

The effort of the experts is explain the reason of soft storey is due to accommodation of vehicles and their movements at ground levels infill walls are generally avoided, which creates soft storey effect. 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 storeys, number of bays, type and number of infill walls present, etc., and hence it is independent of all of the above factors. 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. This study basically includes Four models namely, Frame without masonry infill effect (Bare frame), Masonry Infill frame, Frame with Tie-beam (Tie-beamed frame) and Frame with Bracings (Braced frame) which are analyzed for Soil type I (Hard) considering time period for seismic analysis as per Program calculated and as per Codal provision. The response of columns in Open ground storey are discussed and conclusions are made in this study analyzed on ETABS software.

2.2.11 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 Veerappa Nisty 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.

3. OBJECTIVES

The objectives of present study work is aimed to understand or evaluation of stability of structures with following objectives.

- To study the effect of soft-story in multistory buildings.
- To know the behavior of the building with ground and top 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 of multi-story building using soft storeys.
- 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.

4. MODELING AND ANALYSIS METHODS.

Modeling and Analysis are done by using different computer software for accuracy and time savings. 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

- 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

5. CONCLUSIONS

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

1. 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.
2. The Axial Force for Continuous type in P-delta analysis is increase 22% has compared to static analysis. Etc.
3. The second order effects found to increase the storey displacements at all level of the structure.
4. 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.
5. The shear force and bending moments are higher for ground storey columns with respect to first storey column.
6. Behavior of square column is better than rectangular column, in terms of storey drift, base shear & roof displacement.
7. 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.
8. The effect of masonry infills in the structures increases the stiffness of the structural element.

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