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Reduction of Base Shear: A Review on Different Observations that Reduces Base Shear in Multistoried Buildings

Kamal Muvel[1], Prof. Prachi Chincholikar[2]
[1]M. Tech. Scholar, [2]Assistant Professor, Department of Civil Engineering, Vikrant Institute of Technology and Management, Indore (M. P.), India

Abstract: India, now classified among the world's most densely populated countries, faces a pressing issue of land scarcity in its major urban cities. To address this challenge, constructing taller buildings emerges as a compelling solution, offering enhanced functionality within limited space. This study conducts an extensive review of relevant literature, examining a wealth of previous research conducted that reduced the base shear. The information collected from this survey forms the initial research objectives for our upcoming technical investigation.
Keywords: Base shear reduction, shear wall, column, multistory building

I. INTRODUCTION

The current trend in construction aligns closely with financial norms to ensure cost-effective building projects. However, this focus on economic efficiency sometimes conflicts with the imperative of ensuring structural stability, which remains a formidable challenge. Achieving structural stability often necessitates the use of substantial structural elements, which can run counter to the prevailing economic drive. A critical consideration here is the additional expense required to earthquake-proof structures, including the incorporation of supplementary stiffness-resistant elements. Among these, shear walls emerge as a fundamental requirement for modern tall buildings. Shear walls not only enhance seismic resilience but also contribute to the overall stability of towering structures.

However, the inclusion of heavy reinforced concrete components not only increases the total weight of the structure but also escalates its base shear, presenting a dual challenge in terms of structural integrity and economic feasibility.

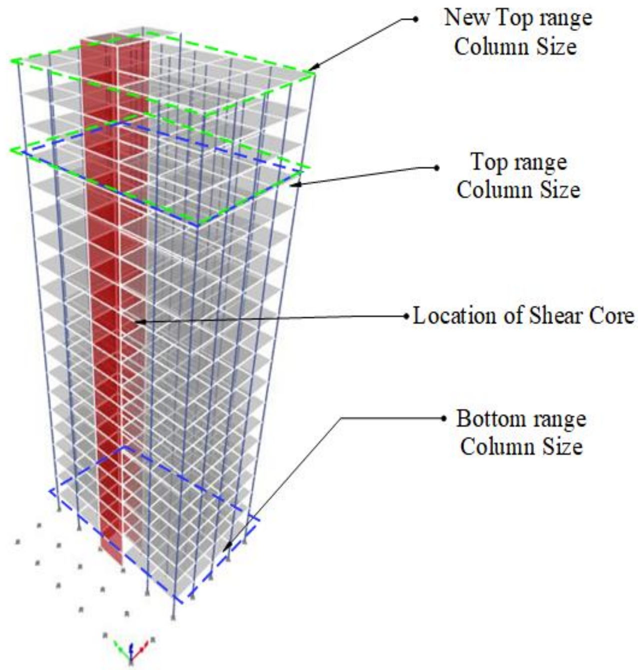

Fig. 1: Structure with Dual Structure Configuration showing different column sizes at different levels

II. CRITERIA OF BASE SHEAR REDUCTION

The theory that supports the reduction of base shear in a complete structure involves the strategy of lessening the size of structural members or trimming them down in the context of multistoried buildings. The reduction of base shear is a critical consideration, particularly when designing multistory buildings to withstand seismic forces. Any approach aimed at reducing this base shear also contributes to the reduction of the structure's self-weight.

III. REVIEW OF LITERATURE

In this research paper, the impact of building height on base shear, lateral forces, and storey drift. To perform the evaluation, the STAAD software has utilized and compare the results with the guidelines outlined in IS1893 (Part1:2002). Specifically, the engagement the seismic coefficient method (SCM) specified in IS1893 (Part1:2002) and obtain results in STAAD using this approach. The study involves modelling two buildings with plan areas of 15m x 9m and 25m x 15m, while varying the building height at 3m, 6m, 9m, and 12m. Although the modification of the geometrical properties of the structures have been done by keeping the seismic properties constant. These buildings are situated in zone II region. The obtained results for base shear and other design parameters from the STAAD software align with IS1893:2002. Additionally, a spring dashpot mass model has plotted to illustrate the lateral forces for the different buildings. Furthermore, the percentage change in storey shear for each building has observed. Notably, observation says that as the height and area of the building increase, the base shear and storey drift also increase. (Mohd Zain Kangda et. al.)

This paper investigates the seismic response of Multi-Degree-of-Freedom (MDOF) systems with combined base shear-limiting and moment-limiting mechanisms in tall buildings. The study includes a parametric analysis of various parameters and examines base displacement, rotation demands, seismic force amplification, peak floor acceleration, peak roof drift, and absorbed energy. The numerical modeling methodology is validated against small-scale shaking table tests. The parametric study uses 20 Ground Motions scaled to different seismic hazard levels in Los Angeles. The results provide insights for designing base shear and moment dual-mechanism systems to mitigate higher-mode effects and enhance seismic resilience in tall buildings. (Chiyun Zhong et. al.)

Shear walls play a crucial role in providing structural stability against lateral loads such as wind and seismic forces. These systems can be constructed using reinforced concrete, plywood/timber, unreinforced masonry, or reinforced masonry. Different types of shear walls include coupled shear walls, shear wall frames, shear panels, and staggered walls. This research aims to study and analyze various approaches to enhance shear walls and their behavior under lateral loads. In buildings with soft storeys, shear walls bear the majority of the lateral loads in the lower portions, while the frame supports the loads in the upper portions. This configuration is commonly seen in high-rise buildings in India, where the lower floors are used for parking or commercial purposes, while the upper floors are designated for residential use. (Ms. Priyanka Soni et. al.)

Tall towers and multi-storey buildings face lateral forces from wind or earthquakes, requiring rigidity and stability. Shear walls provide stiffness, strength, ductility, and energy dissipation. Openings in shear walls for functional purposes reduce stiffness. This study examines the effects of different opening sizes in shear walls on multi-storey buildings. 30-storey prototype buildings with various shear wall openings are analyzed using E-TABS software and Response Spectrum Method. (Ms. Ruchi Sharma et. al.)

This paper presents a static loading test conducted on RC shear walls with openings to examine the impact of different numbers and layouts of openings. All specimens had the same equivalent perimeter ratio of openings (0.4). The results revealed that the shear strength, failure mode, and deformability of RC shear walls were significantly influenced by the variations in the number and layout of openings. Moreover, the overturning moment at the bottom of shear walls with openings was smaller compared to those without openings, as the rotation at the bottom reduced due to the presence of openings. FEM analysis successfully simulated the hysteresis loops and failure progression of shear walls with openings, demonstrating good agreement with the experimental findings. (Masato Sakurai et. al.)

The ACI 318-02 building code highlights the potential benefits of using high strength steel as confining reinforcement in reducing congestion caused by high concrete strengths. As per CAN3-A23.3-M94 and NZS 3101:1995 standards, an increased volumetric ratio of confining reinforcement is required with higher concrete strengths. However, in some cases, achieving a high volumetric ratio of confining reinforcement may lead to impractical tie spacings. To address this, NZS 3101:1995 standards permit the use of high strength steel (up to 800 MPa) as tie reinforcement. The focus of this research is to determine the practical limit at which rectilinear ties can be strained under moderate to high axial load levels and reversed cyclic lateral displacement excursions when using high strength steel as confining reinforcement. (Oguzhan Bayrak et. al.)

This paper presents an analytical study conducted on High Strength Concrete (HSC) building frames using a nonlinear dynamic analysis program called IDARC-M.

The program, initially designed for analyzing normal reinforced concrete frames, was modified to predict the response of HSC frame structures. Unlike conventional investigations focusing solely on HSC beam-column connections, this study considers these connections as an integral part of the ten-story HSC frame under examination. The inelastic behavior of an interior beam-column connection on the first floor was analyzed. The findings indicate that the use of HSC enhances column capacity, increases the rigidity of beam-column joints, reduces the influence of lateral reinforcement distribution in beams and columns, and decreases the fundamental natural period of the frame. Moreover, the type of column support at the foundation level significantly impacts the drift of the studied building frame. (Ibrahim G. Shaaban et. al.)

This paper discusses the use of self-consolidating concrete (SCC) with Alccofine -1203, superplasticizer, viscosity modification agent, and crimped steel fiber in RC beam-column joints. Eight RC column joints with M25 grade concrete were tested, varying the Alccofine percentage. Results showed that Alccofine -10% had higher loading capacity than Alccofine -5% and Alccofine -15% in SCC RC beam-column joints. Nonlinear finite element analysis (FEA) using ANSYS software was conducted, showing good agreement with experimental results. The experimental deflection ductility was 1.57, while the predicted ductility was 1.59 for Alccofine -10%. ANSYS software proved suitable for predicting self-consolidating concrete behavior in beam-column joints. (G. Vimal Arokiaraj al.)

The research investigates the behavior of concrete columns reinforced with new high-strength steel under eccentric loading. Ten columns were tested, varying the transverse reinforcement amount and yield strength, eccentricity, and longitudinal reinforcement yield strength. Compression and tensile failure patterns were observed for columns with small and large eccentricity, respectively. Using high-strength transverse reinforcements allowed for achieving the same level of post-peak deformability and ductility with a lower amount of reinforcement in columns with small eccentricity. High-strength longitudinal reinforcement enhanced the bearing capacity and post-peak deformability of the columns. The study discusses three different equivalent rectangular stress block parameters for predicting the bearing capacity of columns with high-strength steel, concluding that the China Code GB 50010-2010 overestimates the bearing capacity while the American Code ACI 318-14 and Canada Code CSA A23.3-04 align well with test results. (Yonghui Hou et. al.)

This study presents experimental data from six concrete specimens subjected to displacement reversals. The specimens were reinforced with different grades of steel bars (Grade 410, Grade 670, and Grade 830) longitudinally. The variables also included axial load and the volume fraction of hooked steel fibers. The transverse reinforcement was Grade 410, and the concrete compressive strength was 41MPa. The test results indicate that replacing Grade-410 reinforcement with reduced amounts of higher-grade steel bars did not reduce the deformation capacity or flexural strength. The findings suggest that using advanced high-strength steel as longitudinal reinforcement in frame members is a viable option for earthquake-resistant construction. (Andres Lepage et. al.)

Recent earthquakes worldwide have emphasized the poor performance of beam-column joints in reinforced concrete moment resisting frame structures. Extensive research has been conducted to understand the complex behavior and ensure the safe performance of these joints, leading to the development of code recommendations. This paper critically reviews the design and detailing aspects of beam-column joints as recommended by well-established codes, namely ACI 318M-02, NZS 3101: Part 1:1995, and Eurocode 8 of EN 1998-1:2003. The codes aim to satisfy bond and shear requirements within the joint. Key observations include ACI 318M-02's requirement of smaller column depth based on anchorage conditions, while NZS 3101:1995 and EN 1998-1:2003 consider shear stress levels for stirrup reinforcement. ACI 318M-02 focuses on providing stirrup reinforcement to maintain the axial load capacity of the column through confinement. The paper identifies significant factors influencing joint design and compares the effect of their variations on design parameters, highlighting substantial differences in shear reinforcement requirements among the three codes. (S R Uma et. al.)

The utilization of reinforced concrete shear walls is widespread in high-rise buildings as an effective means of resisting lateral loads. These structures exhibit high in-plane stiffness and strength, enabling them to withstand significant horizontal forces while supporting the building's vertical load. This study aims to investigate the seismic response of a ten-story reinforced concrete shear wall building, both with and without openings. To achieve this, mathematical modeling was developed and the structure was analyzed using various nonlinear methods, including time history and pushover analysis. Each method offers distinct advantages in terms of accuracy, simplicity, transparency, and theoretical background. Nonlinear static procedures were specifically designed to overcome the limitations of linear methods while maintaining practical applicability. These procedures incorporate performance-based concepts, emphasizing damage control. The analysis was conducted using the SAP2000 software package. A comparative analysis of different parameters such as displacement, storey drift, and base shear was performed for the reinforced concrete shear wall building with and without openings. (Satpute S G et. al.)

The aim of this study was to examine the seismic behavior of columns in Ordinary Moment Resisting Concrete Frames (OMRCF) and Intermediate Moment Resisting Concrete Frames (IMRCF). Two three-story OMRCF and IMRCF structures were designed according to the minimum requirements outlined in ACI 318-02 for design and reinforcement detailing. The study assumed that the building was situated in seismic zone 1, as per the UBC classification. ACI 318-02 specifies less rigorous reinforcement detailing requirements for OMRCF compared to IMRCF or SMRCF (Special Moment Resisting Concrete Frames). Experimental tests were conducted using 2/3 scale model columns to evaluate the seismic behavior of OMRCF and IMRCF columns. Each column was divided into upper and lower parts at the point of inflection. Quasi-static reversed cyclic loading was applied to the specimens with constant or varying axial forces. The variables in this experimental study included the type of axial force (constant or varying, and low or high), the presence of lap splices (with or without lap splice), and the type of moment resisting concrete frame (OMRCF or IMRCF). The results showed that all OMRCF and IMRCF column specimens exceeded the strength requirements specified by ACI 318. Moreover, they demonstrated drift capacities greater than 3.0% and 4.5% for OMRCF and IMRCF, respectively. However, the drift capacity varied depending on the presence of lap splices and the spacing of lateral reinforcement at the ends of the columns. (Sang Whan Han et. al.)

IV. CONCLUSIONS AND OUTLINE OF PROPOSED WORK

Upon a comprehensive analysis of the existing literature and a thorough examination of the overarching theme, it becomes evident that this innovative approach to reducing structural weight has not been previously explored or discussed. The significance of base shear reduction in the context of earthquake resilience has been largely overlooked. Specifically, the reduction in beam sizes at upper floors, as discussed in various multistorey building scenarios, emerges as a viable strategy for mitigating base shear during seismic events.

1) The conclusive findings derived from this study can be summarized as follows:
2) It is imperative to conduct lateral effect calculations for both horizontal directions to accurately assess structural stability.
3) Various analytical parameters must be scrutinized and validated in accordance with Indian Standards, ensuring compliance within acceptable limits.
4) Soil composition should be evaluated in alignment with Indian Standardization IS 1893-2016.
5) Seismic zonal analysis should be carried out to analyse data across different seismic zones within the context of dual structural configurations and continuous monitoring of lateral effects, especially in terms of displacements, is essential.

The final work in this field after the conduction of literature review is that there should be an approach to reduce the base shear that increase the stability by using different sizes of column member at different floor levels under actual soil condition that has going to be a major study for upcoming proposed work.

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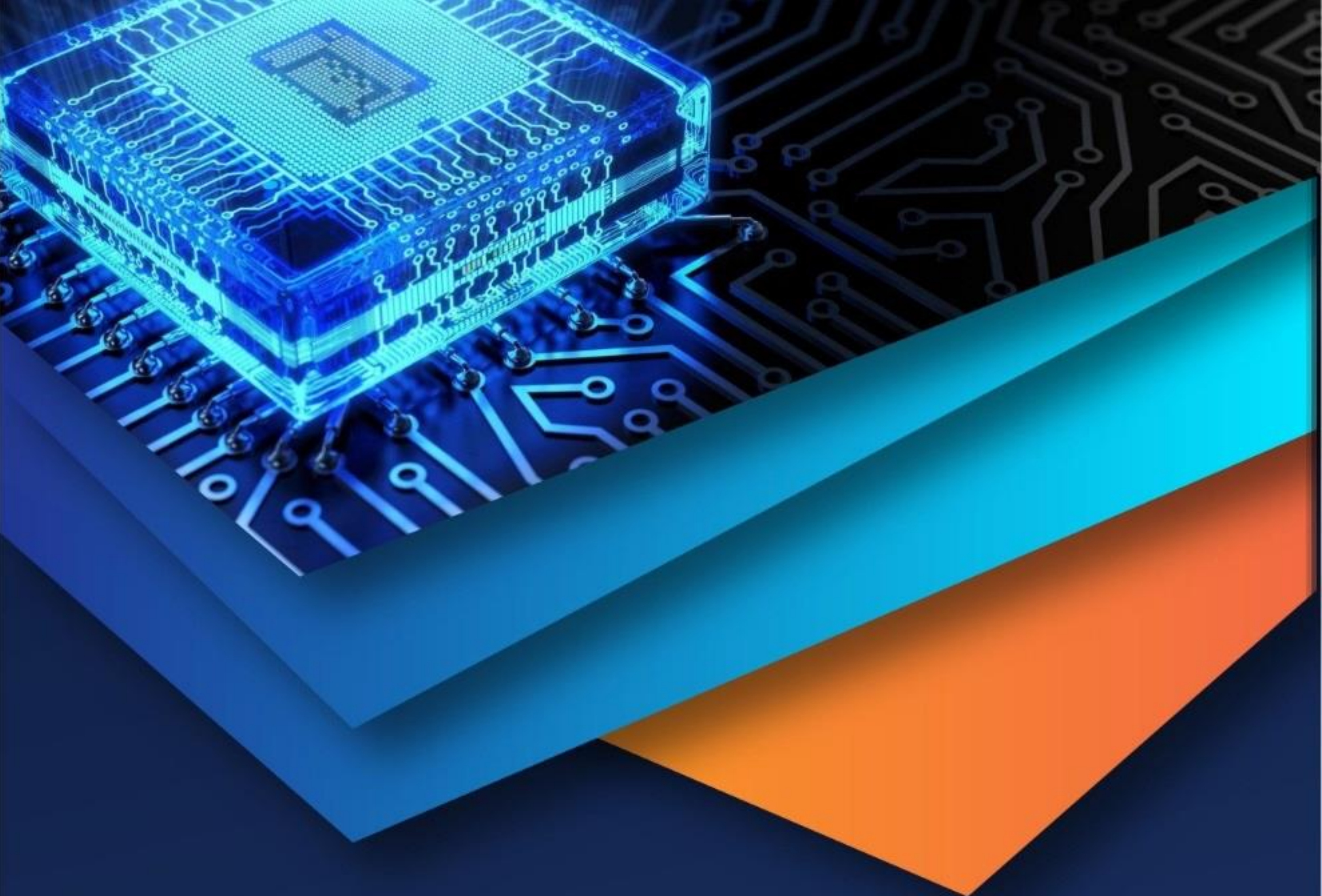

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ISRA JIF IMPACT FACTOR: 7.129

SJIFactor TOGETHER WE REACH THE GOAL IMPACT FACTOR: 7.429

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