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Analysis and Design of High-Rise Steel Building With and Without Bracings: A Review

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Abstract : The significance of high-rise steel buildings lies not only in their visual prominence on city skylines but also in the engineering challenges posed by factors such as wind loads, seismic forces, and the need for cost-effective construction. Steel, chosen for its superior strength-to-weight ratio, enables the creation of slender structures with a harmonious blend of functionality and architectural appeal. This paper aims to delve into the role of bracings, which serve as pivotal elements in ensuring lateral stability and mitigating the effects of dynamic forces. Through an extensive literature review, we examine various types of bracing systems, including diagonal, cross, and eccentric configurations, and their impact on the structural integrity of high-rise steel buildings. The investigation involves a comparative analysis between buildings with and without bracings, considering structural stability, cost implications, and resilience to environmental forces. Furthermore, the study explores innovative design approaches and optimization techniques, shedding light on advancements in creating more efficient and sustainable tall steel structures. The findings from this literature review contribute to a deeper understanding of the challenges and opportunities inherent in the analysis and design of high-rise steel buildings. By synthesizing existing knowledge and identifying gaps in current research, this paper sets the stage for future endeavors aimed at refining structural design methodologies, enhancing safety standards, and advancing the sustainable development of high-rise steel buildings.

IndexTerms **- High-rise steel buildings, Structural analysis, Structural design, Bracings, Lateral support systems, Steel structures**

I. INTRODUCTION

The design and analysis of high-rise steel buildings represent a pivotal area in structural engineering, where the interaction of architectural aesthetics, structural integrity, and safety converge. As the demand for tall structures continues to rise in urban landscapes, engineers and researchers grapple with the challenges posed by factors such as wind, seismic forces, and cost efficiency. This literature review provides an introduction to the analysis and design of high-rise steel buildings, with a specific focus on the presence or absence of bracings – a critical component influencing the structural performance and stability of these towering structures.

SIGNIFICANCE OF HIGH-RISE STEEL BUILDINGS:
High-rise steel buildings have become emblematic features of modern city skylines, embodying architectural innovation and urban development. The utilization of steel as a primary construction material for tall structures is driven by its exceptional strength-to-weight ratio, allowing for both structural efficiency and design flexibility. The inherent properties of steel facilitate the creation of slender and aesthetically pleasing buildings that can withstand various external forces.

STRUCTURAL CHALLENGES:
The design of high-rise steel buildings presents unique challenges, primarily due to the dynamic nature of environmental forces such as wind and seismic loads. The height of these structures amplifies the impact of lateral forces, necessitating sophisticated engineering solutions to ensure stability, occupant safety, and structural resilience. The interaction between these external forces and the structural components becomes a critical consideration in the design process.

ROLE OF BRACINGS:
Bracings, or lateral support systems, play a fundamental role in mitigating the effects of lateral loads on high-rise steel buildings. These systems contribute to the overall stiffness and lateral stability of the structure, influencing factors such as drift, sway, and dynamic response. The incorporation of bracings into the design introduces an additional layer of complexity, as engineers must balance structural requirements with architectural and economic considerations.

OBJECTIVES OF THE LITERATURE REVIEW:

This literature review seeks to explore and analyze existing research and studies related to the analysis and design of high-rise steel buildings with and without bracings. The primary objectives include:

Understanding Structural Behavior: Investigating how high-rise steel buildings respond to various loading conditions, including wind, seismic forces, and gravitational loads.

Examining Bracing Systems: Exploring the different types of bracing systems employed in high-rise steel buildings, such as diagonal, cross, and eccentric bracings, and assessing their effectiveness in enhancing structural performance.

Comparative Analysis: Evaluating the comparative performance of high-rise steel buildings with and without bracings, considering factors such as structural stability, cost implications, and resilience.

Identifying Design Innovations: Investigating innovative design approaches and optimization techniques aimed at improving the efficiency and safety of high-rise steel buildings, particularly in the presence of bracings.

STRUCTURE OF THE LITERATURE REVIEW:

The subsequent sections of this literature review will delve into specific studies, methodologies, findings, and challenges related to the analysis and design of high-rise steel buildings. Through a comprehensive examination of existing literature, this review aims to contribute valuable insights to the ongoing discourse on creating structurally sound and economically viable tall steel structures.

II. LITERATURE REVIEW

1. **Modelling of Bracing Systems for Seismic Behaviour of High Rise Steel Building, V. Singh, This study mainly emphasised on compare the seismic behaviour of high-rise steel building with different types of bracing systems**. Non-linear static analysis were performed to observe the structural performance on high rise steel building of heights 10,15,20,25,30 and 35 storeys. For this study, four types bracing systems were used: V-Braced frames (VBF), Chevron Braced frames (CBF), X-Braced frames and Self-centring energy dissipating braced frames (SCEDBF). The performance of different types of bracing system has been evaluated by changing the parameters like height of building and different types of lateral load pattern. It has been observed that different braced frames performed well in terms of storey displacement, inter-storey drift ratio, base shear capacity and performance point when compared with moment resisting frame in high-rise steel buildings. It has been observed that VBF and CBF performed similar manner under seismic event and XBF and SCEDBF performed similar manner. It can be concluded that, based on obtained results, that the use of VBF, CBF, XBF and SCEDBF enhances the seismic performance of overall structure.
2. **Steel Braces Optimization Design of Steel Tall Building Based on Stiffness Performance Sensitivity Data, Miftahurrahma Rosyda**, Complex high-rise steel structures have many design variables. Through sensitivity analysis of grouping of different types of components, it can be determined that optimizing the form, quantity and arrangement of steel braces can effectively reduce the maximum inter-story drift, which is the controlling wind response of the structure, so as to save the time cost of optimization. Adjusting the form, quantity and arrangement of steel braces to achieve the ideal steel consumption on the premise of satisfying the limit of maximum inter-story drift is a process of re-analyzing the modified results and guiding the next modification until the results converge. An effective re-analysis method can also reduce the calculation times and save the time cost of optimization. In the optimization process, sensitivity analysis and reanalysis are indispensable. In this paper, high-rise braced steel frame structure is taken as the research object and the steel braces are divided into groups according to different vertical zones and different plane positions, to analyze the sensitivity of maximum inter-story drift under wind load to different groups of steel braces, and to study the reanalysis method of specific steel structure system, specific design constraints, and specific optimization variables, so as to achieve rapid and efficient optimization design. Finally, a 150 m high-rise steel structure residence is taken as an engineering case to verify the correctness of sensitivity analysis results of high-rise steel structure for wind vibration stiffness performance control, and the effectiveness and practicability of re-analysis method in optimization design.
3. **Comparative Analysis of Steel Buildings With and Without Bracings in Nepal, The past few years has seen a remarkable increase in the construction of steel framed buildings in Nepal.** This has provided a much-needed architectural relief to urban centers full of RC buildings. The main reasons for this current proclivity towards steel buildings can be attributed to the faster time of erection of steel buildings, its light weight resulting in easier handling and cheaper transportation, and lower material cost. However, because of its flexible nature, an unbraced steel building will have higher storey displacement when compared to the RC buildings. For mid-rise and high-rise buildings, the steel frames need to be equipped with braces to keep the storey drifts and displacements within acceptable limits. This will result in a stiffer building and hence result in increased base shears and bending moments. This change in base shears and storey drifts along with the building’s fundamental time period may not be similar for different positions of braces despite the use of similar bracing sections. This paper aims to find such differences, if any, to aid designers in selecting optimum position for braces while designing steel framed buildings.
4. **Diagrid and Bracing System Comparative Structural Performance and Sustainability Concept, Mohammad Zunnoorain, Ganesh Jaiswal**, One of the intriguing structural design concepts for robust tall structures is the diagrid (diagonal grid) structural design. Due to its attractiveness and structural efficiency, Diagrid, a new design trend for tall, complicated structures, has arisen. Using a compact grid of diagonal members, Diagrid's façade structural system resists both lateral loads and gravity loads. As opposed to a traditional steel frame, it employs less structural steel, resulting in a more environmentally friendly building. This research uses ETABS to examine the structural performance of tall structures made of Diagrid steel and tall buildings with various bracing systems. Therefore, the purpose of this study is to contrast the lateral displacement brought on by wind and earthquake load between high-rise structures (buildings) using the diagrid system and those using other bracing systems. The use of diagrid and other bracing systems in relation to the natural frequency of high-rise structures (buildings) is also investigated in this study. A 40-story building model has been taken for analysis in E-Tabs 2016, with a plan area of 1296m2 (36-meters x 36-meters) and 144 meters tall.

5. **Seismic Comparison of Diagrid and X-Bracing System in Highrise Building, Vishal Desai, V.M Bogar, Mohammad Zunnoorain,** The diagrid (diagonal grid) structural design is one of the fascinating structural design ideas for sturdy tall constructions. Diagrid, a new design style for tall, intricate structures, has emerged due to its aesthetic appeal and structural effectiveness. Diagrid's façade structural system resists both lateral loads and gravity loads by utilizing a small grid of diagonal components. As it uses less structural steel than a conventional steel frame, making the structure more environmentally friendly. This study makes use of ETABS to assess tall structures built of Diagrid steel and tall structures using different bracing techniques. Being thin makes high-rise structures extremely vulnerable to lateral forces, thus they must be constructed to provide safety and comfort in accordance with user needs. In order to combat the lateral stresses that are most common in high-rise structures, diagrid and X-bracing systems have been created. In this study, the seismic behaviors of diagrid and X-braced systems are compared.

6. **To Study and Analyze Effects of Bracing in Design of Building, High rise structure thanks to its exposure to varied gravity loads, lateral loads and therefore the exponential height of structure has become a costlier solution.** The increasing cost of concrete structure and therefore the time interval of construction in concrete high rise structure has given chance to explore and research new technologies and new materials to form the structure more stable and economical. One among the solutions is to supply bracings to the member. There are many conveniences of the bracing systems in order that they're widely used. These are: Braced frames are accessible to all or any sorts of structures like bridges, aircrafts, and cranes. There's no need of highly skilled laborers if the bolted connections are utilized and plus there's no deformation problem at the connection. The paper also includes the various sorts of braces which may be used appropriately and therefore the comparison between buildings with members without braces and buildings with braces.

7. **Research and analysis on super high-rise building structure design, Mariagiada Maiorana**, For the safety design of super high-rise building, to improve the structure performance and fuel economy of the most effective structure of the two methods is to reduce the level of load. The efficiency of the structure of the lateral can be realized by reducing weight of the former, the latter can be done by improving the material properties and structure of component to resist lateral force around, supporting measures such as to implement. This paper studies and analyzes the structural design methods of super high-rise building, and summarizes its structural system and basic selection in detail, and finally expounds the structural design concept of green concept in super high-rise building. Based on the height of super tall building, the foundation type, fixed end type, and wall type should be paid attention to in the structural design. Safety design should focus on how to solve the reverse problem of high-rise buildings and wind design. For the earthquake area, due to the excitation effect of earthquake, the structural design of super high-rise buildings also needs to be designed with anti-seismic scheme. In the design of super high-rise buildings, the design concept of green building can be adopted simultaneously, which is environmentally friendly and saves energy, thus reducing the construction cost.

8. **A Review on the Analysis of Building with Different Types of Bracings, Nandona Goswami**, Bracing is one of the most extensively used lateral load resisting systems in multi-storied frame structure. It helps in reducing structure damage or collapse during an earthquake. To know the responses of providing bracings in high rise buildings is the aim of this study. Hence, it is necessary to demonstrate work on the analysis, design and post effects of bracings when seismic forces act in a building. In this paper, a review is taken out over the analysis and design of buildings with and without bracings to study more detail analytical results and conclusions to find its effectiveness in reducing the impact of lateral loads on high rise buildings in case of an earthquake. Keywords: earthquake, bracings, ETABS, SAP2000, StaadPro

9. **Seismic Analysis of Steel Building with Bracing, Ms. Aradhya Anna Alex, M. S.,** As we know that construction of steel buildings is popular nowadays. To protect buildings from earthquake by providing bracings are very common. Bracing help to resist the lateral load during earthquake. Bracings are providing in structure at various configuration. This paper illustrates the effect of new bracing configuration with existing x bracing configuration. The seismic analysis of the structure has been carried out using ETABS Software.

10. **Comparative Analysis between Various Types of Bracings for Steel Building in Seismic Zones, Mr. Prafull J Barge, D. N. Shelke**, In this research paper we are preparing a relative report on a G+13 tall structure. In this structure we will contrast exposed casing and edges having various types of bracings at the corners. A three dimensional structure is taken, 13 stories is taken with story tallness of 3m. The bars and segments are intended to withstand dead and live load only. Seismic tremor loads are taken by bracings. The bracings are given just on the fringe sections. Here auxiliary displaying and examination is finished utilizing investigation programming Etabs which is a limited component based programming apparatus. A tall structure will be analyzed for seismic loading corresponding to various seismic zones. Effectiveness of bracings in reducing lateral displacements and their efficiencies during the earthquake is to be investigated. So the objective is to do comparative analysis between symmetrical G+13 storey RCC building with bracings and similar building without the bracings using commercially available software. Bracing play important role in keeping structure stable. Earthquake produces inertial forces in structure. X-bracing system has shown good results when it comes to reducing lateral displacements. As much as 26% decrease in lateral displacements in Z-Direction and up to 53% reduction in lateral displacements along X-direction is observed. But X-bracing arrangement shows most increase in value of Maximum bending moment (24.86%) and support reactions (30%).Base shear values are same in both directions. Since number of bracings along X-directions were more, bracings shown good performance in lateral displacements along X-axes. Diagonal bracing shows overall good performance considering Lateral displacements (45.58%), Support reactions (26.77%), and maximum bending moment (14.16%).Weight of the structure remains almost same. Not more than 2 percent change in weights of structure. Since base shear is dependent on weight, base shear also remain similar. Keywords: Comparative Analysis, Bracings, RC Building, Seismic Zones

11. **Analysis of the Feasibility of a Diagrid Bracing System in Tall Buildings**, The primary goal of this study is to provide a superior lateral load-resisting system. In this study, the diagrid structural system is considered, with the shear wall core present at the center part of the building and the diagrid bracings provided at the outer periphery of the structure, which is formed of steel material. The diagrid, which is made up of inclined diagonal steel sections, allows the diagonal member to function axially to resist lateral loads. Due to its structural effectiveness and versatility in architectural planning, the diagrid structural system has recently been used in tall buildings. A 14-story Diagrid composite building is selected, and its analysis and design results are presented. The Diagrid bracing system is connected to the end bays, the diagrid bracing system is connected to the mid-end bays,

and the diagrid bracing system is connected to the end bays these are the three different types of models that have been studied. The diagrid bracing system has been modeled by using structural steel material, and the remaining structure has been modeled by using concrete material. A standard 60 m x 60 m floor plan has been considered. FEM-based software called ETABS has been used to model and analyze structures. A PT slab and a PT band beam have been used in the model frame for the span of 10 m. By considering all possible load combinations, all structural members made of steel and concrete are analyzed by IS: 800:2007 and IS: 456:2000, respectively.

12. **Study and Comparison of the Performance of Steel Frames with BRB and SMA Bracing, Mohsen Jalalvandi, Ahmad Soraghi, S. M. Farooghi-Mehr, Abbas Haghollahi, Designing steel structures with Concentric Braced Frame (CBF) lateral systems has been common in recent decades.** This type of bracing has a quite unstable and complicated behavior in relatively intense earthquakes. This study tries to improve the seismic behavior of steel frames with CBF braces equipped with Shape Memory Alloy (SMA) and Buckling Restrained Braces (BRBs). In this manner, a multi-story building with inverted V chevron bracing was considered. Nonlinear time-history analyses have been performed using OpenSEES software. The dynamic responses of frames with SMA and BRB braces were compared. The results showed that the SMA and BRB braces provide energy dissipation in the nonlinear zone and can reduce maximum interstory drift. The comparison of those bracing systems revealed that implementing SMA in braces also led to a reduction in permanent displacement of the structures due to the elasticity property of the SMA bracing system. The energy dissipation of structures with the BRB system was higher than that of structures with the SMA bracing system.

13. **Comparative Study of Diagrid Steel Building with Conventional Steel Braced Building, Matthias Baumgart**l, Diagrid structural system is widely used for tall steel buildings due to its structural efficiency, architectural design, interior design point of view due to column free area and aesthetic potential provided by the unique geometric configuration of the system. This paper provides comparative study of diagrid steel building of different five inclinations with horizontal and conventional steel building with inverted V-bracing. Also comparison made of varying inclination throughout the height for G + 36 storey steel structure considering earthquake forces and wind load, having plan dimensions of 40 m × 40 m and keeping storey height 3.6 m. The models are exported to structural engineering software such as ETABS for design and analysis. Results comparison made for storey displacement, storey drift, storey shear, steel quantity consumed.

14. **Optimal Mixed Placement and Capacity Distribution of Buckling-Restrained Braces and Conventional Braces on a Large Metal Spatial Structure Without Rigid Diaphragm Assumption, Yuki Terazawa, Miho Fujishima, Toru Takeuchi**, This paper presents a design application of the proposed generalized response spectrum analysis (GRSA)-based seismic optimization method to a large metal spatial structure (constructed in Japan) where a rigid diaphragm assumption is not available and displacement responses are disproportionally distributed in a story. It also discusses the optimal mixed placement and capacity distribution of buckling-restrained braces (BRBs) and conventional braces (CBs) to minimize both the story drift response and the number of BRBs (i.e., the introduction cost of expensive energy-dissipation devices used as dampers). GRSA is a quick and efficient analysis method for estimating the reduced seismic responses of structural models with a large degree of freedom, and GRSA-based computational optimization enables a more efficient seismic design process than trial-and-error approaches with time-consuming nonlinear response history analysis. In this study, the efficiency is verified through a comparison with the Japanese standard BRB design method. According to the results, the optimal design solution by the proposed method has approximately 20% less steel tonnage of BRBs than that obtained from the standard method, whereas the seismic performance is equal to or better than the others. Moreover, although engineers should still consider the possibility of damage concentration, the brace configuration of the substructure where BRBs and CBs are arranged in adjacent stories is the most effective for reducing both the number of BRBs and the story drift response.

15. **Comparative Analysis of Multistorey RCC and Semi-Rigid Steel Frame with Cross Bracings Subjected to Mainshock and Aftershock Earthquake Sequence, Sharad C. Srivastava, Dinesh Narain Srivastava**, Strong Ground Motions have a significant impact on structural analysis and design. Seismic evaluation is deemed necessary for the quality, reliability, and feasibility of existing and developing structures. Earthquakes are even more disastrous when a mainshock is succeeded and preceded by aftershocks of higher magnitude. Most of the time, these aftershocks are ignored during analysis. In the last few decades, steel buildings have been crucial to the construction sector. On the other hand, RCC frames are commonly designed structures for commercial purposes and cost-effectiveness. IS 1893 (Part:1)-2002 Criteria for Earthquake Resistant Design of Structures and IS 13920-2016 Ductile Detailing of RC Structures Subjected to Seismic Reactions are majorly used for Seismic Analysis. Steel bracings in the structural system increase the ductility and stiffness of the frame structure. That can be arranged in a variety of ways, such as X, diagonally, alternatively, V, inverted V, K, etc. Cross bracings are used in this paper for the design of a typical multi-story (G+9) semi-rigid steel frame and a typical RCC frame is designed of the same dimensions. Both the frames are modelled and compared using ETABS software and a static nonlinear Time History analysis is executed to examine the performance of both the frames under the Mainshock and Aftershock of Chamoli earthquake. The Mainshock and Aftershock results of the Chamoli earthquake are extracted from the Centre for Engineering Strong Motion Research Ground Motion Database. Base shear, joint displacement, kinetic energy, and story displacement are a few of the variables of Time History Analysis that affect how well a building performs during mainshock and aftershock earthquakes. When analysing the outcomes, it is important to take into account that each of these factors significantly affects how a building responds to seismic loads.

CONCLUSION

The analysis and design of high-rise steel buildings with and without bracings constitute a complex and dynamic field at the intersection of architecture and structural engineering. Through an extensive literature review, we have gained valuable insights into the multifaceted considerations involved in creating structurally sound and aesthetically pleasing tall steel structures. The role of bracings as lateral support systems has been a focal point in our exploration, revealing their significant impact on structural stability and response to environmental forces. The comparative analysis between buildings with and without bracings has underscored the importance of these lateral support elements in enhancing resilience, reducing sway, and mitigating the effects of dynamic loads, such as wind and seismic forces.

The studies reviewed have demonstrated the diverse array of bracing configurations, including diagonal, cross, and eccentric bracings, each influencing the structural behavior in unique ways. This diversity allows for tailored solutions based on the specific requirements of a given project, considering factors such as architectural constraints, cost implications, and environmental considerations. The literature also highlights ongoing efforts in the field to optimize the design of high-rise steel buildings. Innovations in design approaches, the application of advanced technologies such as Finite Element Analysis (FEA), and the exploration of sustainable practices underscore the commitment of researchers and practitioners to continually refine and advance the state-of-the-art in tall building engineering. Challenges remain, particularly in addressing the economic viability of high-rise steel structures and ensuring their long-term sustainability. The cost-effectiveness of different bracing systems, as well as their environmental impact, needs to be carefully considered in the design process. Additionally, the integration of optimization techniques and advancements in materials technology presents avenues for further research to enhance the efficiency and performance of these structures.

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