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OPTIMIZING STRUCTURAL DESIGN PARAMETERS FOR TALL BUILDING IN HIGH WIND ZONE : A REVIEW

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Abstract

This study focuses on optimizing structural design parameters for tall buildings located in high wind zones. The research addresses the critical challenges associated with designing structures that can withstand the dynamic forces imposed by strong winds, particularly in urban environments where tall buildings are prevalent. The optimization process involves a comprehensive analysis of various design parameters, including material selection, shape optimization, and damping systems, with the aim of enhancing structural performance while minimizing construction costs. Through advanced computational simulations and sensitivity analyses, the study identifies key factors influencing the structural response to high winds and proposes optimized design solutions. Findings underscore the significance of aerodynamic considerations, as well as the potential benefits of incorporating innovative materials and damping technologies to achieve optimal structural resilience in high wind-prone areas. Moreover, the research highlights the importance of a holistic approach that balances structural efficiency, cost-effectiveness, and safety in the design of tall buildings exposed to challenging wind conditions.

Keywords: Structural design parameters, tall buildings, High wind zones, Dynamic forces, Optimization process, etc.

I. INTRODUCTION

Over the past thirty years, the world has witnessed a remarkable surge in the construction of towering buildings that exceed the staggering height of 150 meters. This upward trajectory has been nothing short of exponential, with each passing year witnessing even more ambitious projects taking shape. Notably, it is the Middle East and Asia that have spearheaded this architectural revolution, with an unyielding appetite for creating these awe-inspiring structures. But these super-tall buildings, soaring beyond the 300-meter mark, present a brand-new set of challenges to engineers, particularly in the realms of structural and geotechnical design.

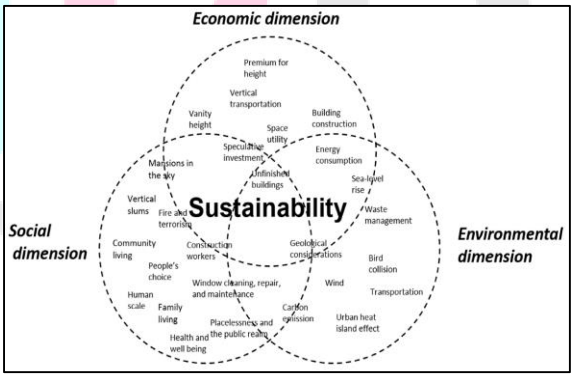

Fig.1 Development of Tall buildings
(Source: Internet)

A. Typical high-rise foundation settlements

An interesting observation arises from the buildings supported by piled rafts in the stiff Frankfurt clay. Despite settling more than 100mm, which may initially appear excessive, these structures demonstrate a satisfactory performance. This raises the intriguing possibility that the tolerance for settlement in tall structures may surpass the conventional design values of 50-65mm.

Table 1 The Settlement of Tall Structure Foundations example

No.	Foundation type	Founding condition	Location	No of cases	Settlement/ pressure mm/MPa
1	Raft	Stiff clay	Houston	2	227-308
		limestone	Amman; Riyadh	2	25-44
2	Piled Raft	Stiff clay	Frankfurt	4	218-258
		Dense sand	Berlin; Niigata	2	83-130
		Weak Rock	Dubai	5	32-66
		Limestone	Frankfurt	1	38

(Source: Internet)

B. FOUNDATION DESIGN ISSUES

The following issues need to be addressed in the design of the Foundations for high-rise buildings:

1. **Ultimate Capacity**: The foundation of a high-rise building must possess the necessary strength to withstand various types of loads, including vertical, lateral, and moment loading combinations.
2. **Effects of Cyclic Nature**: High-rise buildings are susceptible to cyclic forces caused by wind, earthquakes, and even wave loadings in some cases. It's imperative to evaluate how these repetitive and dynamic loadings impact the foundation's capacity and movements.
3. **Overall and Differential Settlements**: Settling is an unavoidable characteristic of any building, and high-rises are no exception. However, it's essential to manage both overall and differential settlements effectively. Overall settlements pertain to the building's vertical movement as a whole, while differential settlements refer to variations in settlement within the high-rise footprint and between high-rise and low-rise areas.
4. **External Ground Movements**: Foundations of high-rise buildings must also consider the potential effects of externally-imposed ground movements.
5. **Earthquake Effects and Liquefaction**: Earthquakes pose a significant threat to high-rise buildings, and their impact on foundation systems must be thoroughly understood.

C. FACTORS AFFECTING FOUNDATION SELECTION

The type of foundation to support a tall building include the following:

- Location and type of structure.
- Magnitude and distribution of loadings.
- The Ground conditions.
- Access for construction equipment.
- Durability requirements.
- Installation effect on adjacent foundations, structures, people.
- The Relative costs.
- Local construction practices.

D. SOIL CONDITION

The soil condition is an essential fled of analysis in earthquake engineering; this soil condition is defined as “The physical condition of the soil and its dynamic properties, which have divided according to standard Indian code into hard soil (Rocky), medium soil, soft soil. In view of structural engineering, the engineering community discussed SSI only when the basement motion by interaction forces as compared to the ground motion of free Feld.

E. SCOPE OF THE STUDY

The present project work is targeted to Interpretation of consequences of wind loadings on design of foundations of tall structure having different soil conditions such as Rock or Hard soils(I), Medium or stiff soils (II), Soft soils (III) under wind loads. In this research attempt is made to interpret the consequences of wind action on tall structures as per revised IS 875 part III. It involves the preparation of models of Tall RCC building by using FEM based software. Then Wind analysis of the Tall RCC building as per Indian codes. After that comparison of effect on foundation design results due to wind effect will be done and conclusion will be drawn based on the result of analysis.

II. LITERATURE REVIEW:

Z. bayati, (2020) In conclusion, their investigation demonstrated the effectiveness of utilizing optimized multi-outrigger systems in reducing seismic response and improving the overall stability of tall buildings. By implementing the appropriate number of outriggers, we can enhance structural performance, decrease element and foundation dimensions, and ultimately achieve greater safety and cost efficiency.

S. Pourzeynali, (2008) In summary, the suppression of dynamic response in tall buildings supported by elastomeric bearings is a complex challenge, but one that can be overcome through the power of genetic algorithms. By carefully optimizing the parameters of the base isolation system and accounting for nonlinearity, we can craft buildings that are not only structurally robust but also resistant to dynamic forces. This research opens new doors for the field of architecture and engineering, paving the way for safer, more resilient structures in the future.

Dimitris Mavrokapnidis (2019) In conclusion, it's evident that tall buildings have a profound effect on the environment. Through our exploration of structural systems, we've unveiled the substantial embodied energy and CO2 emissions associated with these architectural wonders. As we move forward, it's crucial to consider the environmental implications of our ambitious architectural aspirations. By adopting sustainable practices and incorporating eco-friendly structural designs, we can mitigate the environmental impact of tall buildings. The future lies in our hands, and it's up to us to ensure that our architectural feats don't come at the expense of our planet.

M.F. Huang (2015) In conclusion, our integrated computational design optimization method offers a comprehensive approach to the performance-based design of tall buildings subjected to wind excitation. By considering multiple performance objectives, accurately predicting inelastic drift performance, and implementing optimal design strategies, we can ensure the safety and resilience of these structures. Through practical application, we have demonstrated the efficacy of our framework, paving the way for the creation of wind-resistant buildings that can withstand extreme wind events with confidence.

M. Gu, (2004) In this paper, 15 tall building models have been tested with high-freq. force balance tech. in a wind tunnel to obtain the first-mode generalized across-wind dynamic forces. The development of these new formulas is a remarkable achievement in the field of structural engineering. By providing comprehensive insights into across-wind loads, these formulas guide us towards constructing safer and more resilient buildings. This newfound transparency empowers architects, engineers, and designers to make informed decisions and create structures that withstand the forces of nature.

Yi Li (2020) In conclusion, this pioneering approach to wind-resistant design for modern tall buildings holds incredible promise. By combining a genetic algorithm, an improved penalty function, and a dynamic calculation method for ESWLs, the team has unlocked a powerful tool for the efficient and effective design of resilient structures. With the possibility of minimizing weight while meeting safety and serviceability requirements, the potential impact of this approach is immense. The future of wind-resistant design is undoubtedly set to reach new heights. To substantiate the effectiveness of their approach, the team decided to put it to the test in a real-world scenario. They adopted a 60-story rectangular reinforced concrete frame structure, modeled after the CAARC standard tall building. The results were nothing short of impressive. The example clearly showcased the prowess of the proposed optimal design procedure in wind-resistant design.

H.P. Lou (2021) Through their analysis, they aimed to identify the most economical structural system for a specific earthquake zone and plan. By evaluating factors such as base shear, time period, top story displacement, story drift, and seismic weight of the structure, we can make informed decisions regarding the choice of structural system. These insights contribute to the ongoing advancements in the construction industry, ensuring the safe and efficient construction of tall buildings. To gain a better understanding of the performance of different structural systems, they explore the analysis of a G+53 story concrete structure. This structure was analyzed using the ETABS V16.0.0 software package, considering different earthquake zones.

Aydin Shishegaran (2022) In order to obtain accurate and reliable results, they adopted both indirect and direct calculation methods based on SAP2000. This comprehensive approach guarantees a robust evaluation of the selected indicators. By employing such diverse calculation methods, we aim to eliminate biases and provide a thorough analysis of each structural design. study serves as a valuable asset for those involved in the field of structural engineering, particularly in the context of designing tall buildings. By assessing and comparing the sustainability of different lateral force-resisting systems, we aim to equip professionals with the knowledge and insights necessary to make informed decisions. As the construction industry continues to evolve, it is crucial to prioritize sustainability in order to create buildings that are not only awe-inspiring in their architectural grandeur but also environmentally conscious and resilient.

Ahmed Elshaer (2017) They concluded an innovative approach known as the Building Corner Aerodynamic Optimization Procedure (AOP). By combining optimization algorithms, large eddy simulation (LES), and an artificial neural network (ANN) based surrogate model, we aim to effectively reduce wind load.Through the Building Corner Aerodynamic Optimization Procedure, we have demonstrated how a holistic approach combined with optimization algorithms, large eddy simulation, and artificial neural networks can effectively reduce wind load. By addressing corner mitigation in particular, we emphasize that even minor adjustments can have a significant impact on overall structural integrity and architectural design. The presented examples highlight the potential for substantial reductions in wind-induced responses, paving the way for more sustainable and resilient tall building designs

Maryam Asghari Mooneghi (2016) This paper serves as a comprehensive resource for various techniques that can be employed to reduce wind loads on buildings. Whether you are an engineer, architect, or simply interested in understanding the intricacies of wind mitigation strategies, this article provides valuable insights that can prove beneficial in various fields.With this comprehensive review, we aim to shed light on the critical aspects of aerodynamic mitigation techniques, empowering engineers and designers to create sustainable, wind-resistant structures. By harnessing the power of computational tools and optimizing designs, we can usher in a new era of architectural excellence that takes into account the challenges posed by wind loads.

Matin Alaghmandan (2014) Designing tall buildings is a multidimensional challenge that demands the utmost creativity, expertise, and attention to detail. By prioritizing the reduction of the along wind effect through an integrated approach, architects and structural engineers can achieve a balance between functionality, aesthetics, and sustainability. Let us embark on this architectural journey together, creating tall buildings that not only stand tall and proud but also embody the very best of human ingenuity and creativity. This method creates an innovative computational workbench to design efficient tall buildings regarding the along wind effect by connecting an architectural parametric design procedure by Auto Lisp (AutoCAD), a Computational Fluid Dynamics program (ANSYS), a structural analysis program (ETABS) and a genetic algorithm-based optimization procedure of Par Ge.

Fei Ding (2020) This paper shows as the wind continues to challenge the boundaries of our built environment, it is imperative that we embrace new approaches to design and engineering. The concept of autonomous dynamic morphing opens up a world of possibilities, showcasing the potential to create buildings that not only withstand the forces of the wind but also embrace them as a source of inspiration and innovation. The journey towards dynamic facades has just begun, and it is an exciting time for those involved in shaping the future of our cities.

P. Mendis (2007) Designing tall buildings requires a comprehensive understanding of wind behavior and its impact on structural integrity. While simple quasi-static treatment may suffice for shorter structures, advanced wind design approaches are necessary when it comes to skyscrapers. By considering dynamic response, interference from other structures, wind directionality, and cross wind response, engineers can develop more precise and reliable designs. Additionally, wind tunnel testing serves as a valuable tool to refine design assumptions and ensure the safety and stability of tall buildings in the face of wind forces. By embracing these advanced approaches, we can continue to push the boundaries of architecture and create awe-inspiring structures that stand tall against nature's forces.

Peter Irwin, (2008) In conclusion, wind and tall buildings share a delicate balance. While wind presents challenges in the form of lateral loads, careful design and utilization of innovative techniques can effectively mitigate these effects. Moreover, wind offers a myriad of benefits, including the generation of clean energy and improved comfort through natural ventilation. By embracing wind-driven solutions, we enhance not only the structural resilience of tall buildings but also their contribution to a sustainable future.

Vinay Chandwani, (2014) the design of high-rise buildings is influenced by various factors such as urban, climatic, geological, architectural, and constructive considerations. These factors contribute to the complex nature of conceptual design in high-rise building projects. In order to minimize risks and maximize the investment attractiveness of high-rise building projects, it is essential to dedicate sufficient effort to the conceptual design phase. The success of the final design heavily relies on a well-executed conceptual design, which takes into account all the technical features and aims to provide everything necessary for a large number of people to live and work in a vertical habitat.

III. CONCLUSION

The study on optimizing structural design parameters for tall buildings in high wind zones underscores the critical importance of addressing the unique challenges posed by environmental forces. Through a comprehensive analysis of structural design variables, such as material selection, cross-sectional geometry, and damping systems, the research has illuminated key considerations for enhancing the resilience and performance of tall structures in the face of elevated wind loads. By optimizing these parameters, engineers can significantly contribute to the development of safer and more efficient tall buildings, ensuring their structural integrity and safeguarding the well-being of occupants. The findings of this study not only advance our understanding of structural engineering principles in high wind zones but also provide valuable insights for practitioners and researchers working towards sustainable and robust urban development in regions prone to adverse weather conditions.

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