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Analysis of RCC Industrial Chimneys: A Review

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Abstract: ***Industrial RCC chimneys are tall and slender structures used for the controlled discharge of gases from industrial facilities. Their considerable height and geometric proportions make them sensitive to environmental actions, particularly wind and earthquake loading. The structural response of such chimneys is influenced by parameters such as height, diameter, geometry, material properties and the nature of applied loading. The present paper reviews research related to the analysis and design of RCC industrial chimneys, with emphasis on wind effects, seismic response, governing loads, geometrical variations, aerodynamic behaviour and numerical modelling. Published studies have employed conventional analytical procedures, STAAD.Pro-based structural analysis and Computational Fluid Dynamics (CFD) to investigate different aspects of chimney performance. Several studies have examined wind and earthquake effects separately or comparatively, while others have investigated the influence of chimney dimensions and edge geometry on structural and aerodynamic response. Research involving STAAD.Pro demonstrates the usefulness of numerical structural modelling for evaluating load effects and response characteristics, whereas CFD-based investigations provide information about airflow and pressure behaviour around chimney surfaces. The reviewed studies collectively demonstrate the importance of considering structural geometry, environmental loading and dynamic behaviour during RCC chimney analysis. The paper also identifies areas where existing analytical approaches can be integrated to obtain a more comprehensive understanding of RCC industrial chimney behaviour.***
Keywords: RCC chimney, Industrial chimney, Wind load, Seismic load, Structural analysis, STAAD.Pro, CFD.

I. INTRODUCTION

Industrial chimneys are important structural components of thermal power plants and other industrial facilities, where gases generated during industrial processes are discharged at a suitable elevation. Reinforced cement concrete (RCC) is commonly adopted for tall chimney structures because of its structural strength, stiffness and suitability for large-scale construction. Due to their considerable height and slender configuration, RCC chimneys behave differently from conventional building structures and are particularly sensitive to lateral environmental actions. Therefore, proper structural analysis is essential for assessing their behaviour under different loading conditions.

The structural response of an RCC industrial chimney is influenced by several factors, including its height, diameter, geometric configuration, material properties and applied loads. Wind acting over the exposed height produces lateral forces and bending effects, while earthquake excitation generates inertia forces associated with the mass of the structure. Previous studies have investigated wind and seismic effects on RCC chimneys and have also examined the identification of governing loading conditions for design [1], [6], [7], [9], [10]. Studies considering different wind speeds further indicate that changes in environmental loading can significantly affect the structural response of a chimney [2].

Geometry is another important factor in chimney analysis. Variations in height and diameter can modify the structural properties and response of the chimney [8], [9], [11]. In particular, tapered configurations result in changes in section dimensions along the height, which can influence stiffness and mass distribution. Apart from structural geometry, the external shape of a chimney can also affect its interaction with wind. CFD-based studies have therefore examined different edge configurations and wind effects to understand the aerodynamic behaviour around industrial RCC chimneys [3], [5].

Different analytical technologies have been applied in existing research. Conventional analytical procedures are useful for determining loads and understanding the basic structural behaviour of chimney systems. Numerical structural analysis using software such as STAAD.Pro provides an efficient approach for modelling chimney structures and evaluating their response under different loading and geometric conditions [1], [2], [11]. Advanced numerical simulation using ABAQUS has also been explored for studying RC chimney behaviour under multiple loading parameters and investigating optimization possibilities [12]. CFD, in comparison, focuses mainly on airflow, pressure distribution and aerodynamic characteristics around the chimney [3], [5].

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The existing studies demonstrate that no single parameter is sufficient to describe the behaviour of a tall RCC industrial chimney. Wind, seismic effects, structural geometry and aerodynamic characteristics can influence the response in different ways. Therefore, the present review focuses on research related to the analysis of RCC industrial chimneys, with particular emphasis on wind and seismic loading, governing design actions, geometric effects, STAAD.Pro-based structural analysis and CFD-based aerodynamic investigations. The review further compares the approaches reported in the selected studies and identifies areas where these analytical perspectives can be brought together for a more comprehensive understanding of RCC chimney behaviour.

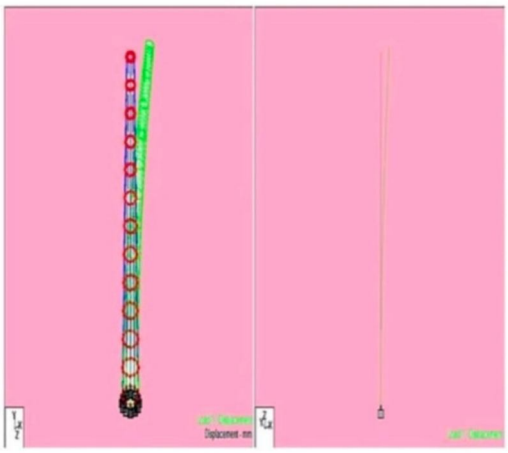


Fig. 1: Industrial RCC Chimney Shaft Model. Source: Adapted from [1]

II. LITERATURE REVIEW

A. Wind and Seismic Load Analysis

Wind and earthquake actions are among the principal environmental loads considered in the analysis of tall RCC industrial chimneys. Because chimneys are slender structures with a large exposed height, lateral loading can produce significant shear forces, bending moments and displacement. Yadav et al. investigated a 100 m self-supported RCC chimney using STAAD.Pro V8i SS6 and considered both seismic and wind analyses. The study used a lumped-mass modelling approach and evaluated the resulting design actions before carrying out the chimney design. The authors reported that wind effects were more significant than earthquake effects for the chimney considered in their study [1].

Bombile and Shaikh examined the behaviour of an RCC chimney under different wind-speed conditions using STAAD.Pro. Their work focused on understanding how changes in wind speed affect the structural response of the chimney. The study demonstrates the importance of considering the environmental wind condition when assessing a tall

RCC chimney because variation in wind speed changes the magnitude of the lateral action applied to the structure [2].

Praseep and Prasad investigated the governing loads for the design of a 60 m industrial RCC chimney. Their study considered the principal loads acting on the chimney and examined their relative influence in identifying the condition controlling the structural design [6]. The identification of a governing load is important because the critical load combination determines the structural demand used in subsequent design calculations.

The comparative study titled Comparison of Wind Load and Earthquake Load on Chimney examined the effects produced by the two major environmental actions [7]. Such comparison is useful for understanding whether wind or seismic action produces the more critical structural response for a particular chimney configuration.

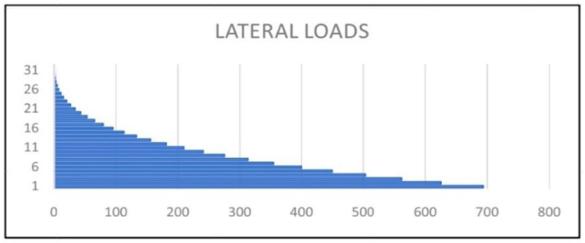


Fig. 2: Lateral loads acting on an RCC chimney. Source: Adapted from [8].

Ramteke et al. investigated the design and analysis of an RCC chimney subjected to wind loading and earthquake forces [10]. The study considered environmental loading conditions and evaluated their effects on the structural system. Together with the other studies, this work demonstrates that both wind and seismic actions need to be examined before establishing the critical design condition.

The 2026 study by Raghupathi et al. also considers wind, seismic and geometrical effects in the analysis of a self-supporting RCC chimney. Its scope includes height-to-diameter and top-to-base diameter relationships along with structural response parameters such as stress, bending moment and lateral displacement [9].

Overall, the reviewed studies establish that environmental loading is a fundamental component of RCC chimney analysis. However, the relative contribution of wind and seismic action depends on the chimney geometry and the environmental conditions adopted in the analysis. Therefore, evaluating both loading conditions provides a basis for identifying the governing structural demand [1,2,6,7,9,10].

B. Geometrical and Structural Parameters

The geometry of an RCC chimney directly influences its structural characteristics because changes in height and diameter affect stiffness, mass distribution and slenderness. Consequently, geometric parameters have been investigated in several of the selected studies.

Tulasi Sai Krishna and Mallika Chowdary investigated an RCC chimney associated with an 800 MW thermal power plant at Vijayawada [8]. Their work included preliminary and analytical calculations and considered dead load, wind load, earthquake load and temperature effects. The study also incorporated software-based analysis, providing an example of how conventional calculations and numerical modelling can be combined for an industrial RCC chimney.

Raghupathi et al. specifically examined the influence of geometrical parameters along with wind and seismic loading [9]. The study considered parameters such as the height-to-diameter ratio and the top-to-base diameter ratio. The structural response was evaluated using parameters including stresses, bending moments and lateral displacement. This indicates that the proportions of the chimney are not merely geometric characteristics but are directly associated with its structural behaviour.

Devraj, Modi and Jaldhari investigated the effect of height-to-diameter ratios on chimney structural properties using STAAD.Pro [11]. Four different chimney models were considered, and the analysis focused on quantities such as shear stress, bending moment, membrane forces, displacement and absolute pressure. The study therefore provides a direct numerical examination of how changes in chimney proportions influence structural response.

The importance of geometric properties is also reflected in the 100 m chimney investigation by Yadav et al., where the authors note that the dimensions of an RCC chimney influence its structural behaviour under dynamic loading [1].

The studies under this theme indicate that height, diameter and their ratios are important variables in chimney analysis. For tapered configurations, the influence of geometry becomes particularly relevant because the cross-sectional dimensions change along the height rather than remaining constant. Hence, structural analysis of such chimneys should account for their actual geometric configuration rather than treating the structure as a uniform cylindrical system.



Fig. 3: Geometrical representation of an RCC chimney. Source: Adapted from [11].

C. CFD and Aerodynamic Behaviour

Conventional structural analysis generally evaluates the response of the chimney after wind forces have been established, whereas Computational Fluid Dynamics (CFD) can be used to investigate the interaction between airflow and the external chimney surface. The selected literature therefore provides an additional aerodynamic perspective on RCC chimney behaviour.

Pandey, Verma and Agrawal investigated different edge configurations of an RCC chimney using CFD and Fluid Structure Interaction (FSI) analysis in ANSYS [3]. The study considered sharp-edged, chamfered and filleted chimney configurations and examined parameters including pressure, drag force and velocity. The investigation showed that changing the edge configuration alters the aerodynamic characteristics of the chimney. Among the configurations studied, the filleted edge produced the lowest drag force according to the reported results [3].

Khan and Roy investigated wind effects on an industrial RCC chimney using CFD and FLUENT-14 [5]. Their analysis considered atmospheric boundary-layer characteristics, mean velocity variation, turbulence intensity, pressure distribution, pressure coefficient and velocity vectors. The study demonstrates how CFD can be used to investigate the flow field around an industrial chimney rather than considering wind only as an externally applied structural load.

The two studies address different but complementary aspects of wind behaviour. The investigation by Pandey et al. focuses on the influence of external edge geometry on aerodynamic response, whereas Khan and Roy examine the characteristics of the surrounding atmospheric flow and pressure field [3,5].

These findings indicate that chimney shape can influence the interaction between wind and the structure. Therefore, aerodynamic characteristics provide useful supplementary information when studying the wind response of RCC chimneys. However, CFD-based aerodynamic analysis and structural analysis serve different purposes: CFD primarily describes flow and pressure behaviour, while structural analysis determines the resulting structural response.

D. Numerical Modelling and Advanced Analysis

Numerical modelling has become an important method for investigating RCC industrial chimney behaviour because it allows structural response to be evaluated for different loading and geometric conditions. Among the selected studies, STAAD.Pro is repeatedly used for structural analysis.

Yadav et al. modelled a 100 m RCC chimney using STAAD.Pro V8i SS6 with a lumped-mass approach and performed separate wind and seismic analyses [1]. The numerical model was subsequently used to determine the design values associated with the investigated loading conditions.

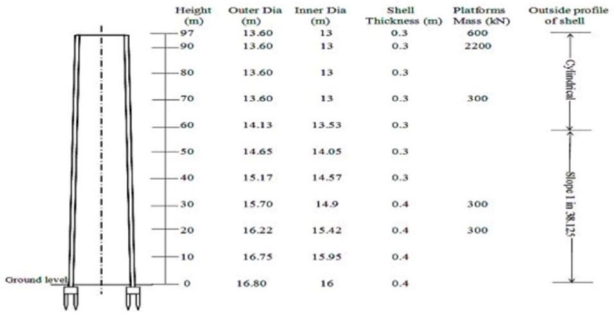


Fig. 4: Shell and concentrated load profile of a 97 m tall power station chimney. Source: Adapted from [5].

Bombile and Shaikh also employed STAAD.Pro to examine an RCC chimney under different wind speeds [2].

Their approach provides a numerical basis for examining how variation in wind conditions affects the structural behaviour of the chimney.

The work of Devraj et al. extends the use of STAAD.Pro to the investigation of different height-to-diameter configurations [11]. The study analyzed four chimney models and evaluated structural quantities including shear stress, bending moment, membrane forces and displacement. This makes the work particularly relevant to studies in which chimney geometry is treated as a variable rather than as a fixed parameter.

Tulasi Sai Krishna and Mallika Chowdary combined analytical calculations with software-based analysis for an RCC chimney associated with an 800 MW thermal power plant [8]. This approach illustrates the use of numerical analysis as a complement to conventional structural calculations rather than as an independent replacement for them.

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More advanced numerical analysis is represented by Gupta, Choudhary and Sharma, who investigated RC chimney design under multivariate loading using ABAQUS simulations [12]. The use of finite-element modelling provides a more detailed computational framework for investigating structural behaviour when multiple parameters are considered simultaneously.

The selected literature therefore demonstrates several levels of numerical analysis. STAAD.Pro is primarily used for structural modelling and evaluation of forces, stresses and displacement; CFD/FSI and ANSYS are used to investigate aerodynamic and fluid–structure interaction effects; and ABAQUS provides a finite-element framework for more detailed structural simulations [1,2,3,5,11,12].

The numerical studies also demonstrate that the reliability of computational results depends on the assumptions adopted for geometry, material properties, loading, modelling approach and boundary conditions. Consequently, numerical analysis is most useful when the model is supported by appropriate analytical calculations and clearly defined structural parameters.

III. CASE STUDIES

A. Self-Supported RCC Chimney under Wind and Seismic Loading

Yadav et al. [1] investigated a 100 m self-supported industrial RCC chimney subjected to wind and seismic actions. The study used structural analysis to examine the response of the chimney under the two major environmental loads. The results highlight the importance of evaluating both lateral load effects when designing tall RCC chimneys.

B. RCC Chimney for a Thermal Power Plant

Tulasi Sai Krishna and Mallika Chowdary [8] studied the analysis and design of an RCC chimney for an 800 MW thermal power plant. The investigation considered major structural and environmental actions, including dead load, wind load, earthquake effects, and temperature effects. The study demonstrates the need to consider both structural and operational loading conditions in thermal power plant chimney design.

C. Influence of Chimney Geometry on Structural Behaviour

Modi and Jaldhari [11] examined the effect of variations in chimney height and diameter using STAAD.Pro. Different geometric configurations were analysed to study changes in structural response parameters such as shear stress, bending moment, membrane forces, displacement, and pressure. The study indicates that chimney geometry has a direct influence on its structural response and should therefore be considered during preliminary design and structural analysis.

IV. RESEARCH OBJECTIVES

1) To study different types of industrial chimneys and their structural behaviour.
2) To analyse the structural behaviour of RCC industrial chimneys under relevant loading conditions.
3) To validate the conventional RCC chimney analysis using STAAD.Pro software.

V. CONCLUSION

The reviewed studies show that RCC industrial chimneys are slender structures whose structural behaviour is significantly influenced by environmental loading and geometric characteristics. Wind and earthquake effects are important considerations in the analysis and design of tall RCC chimneys.

The literature also indicates that parameters such as chimney height, diameter, and geometric configuration influence structural response. Conventional structural analysis tools such as STAAD.Pro are widely used for evaluating parameters including bending moment, stresses, displacement, and other structural responses.

CFD and advanced numerical techniques provide additional information regarding wind flow, pressure distribution, and aerodynamic behaviour. These approaches complement conventional structural analysis and help in understanding the interaction between chimney geometry and environmental loading.

Based on the reviewed studies, the present work focuses on understanding different types of industrial chimneys and their structural behaviour, analysing RCC industrial chimneys under relevant loading conditions, and validating the conventional RCC chimney analysis using STAAD.Pro software.

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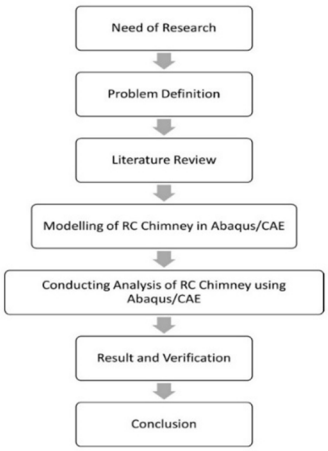
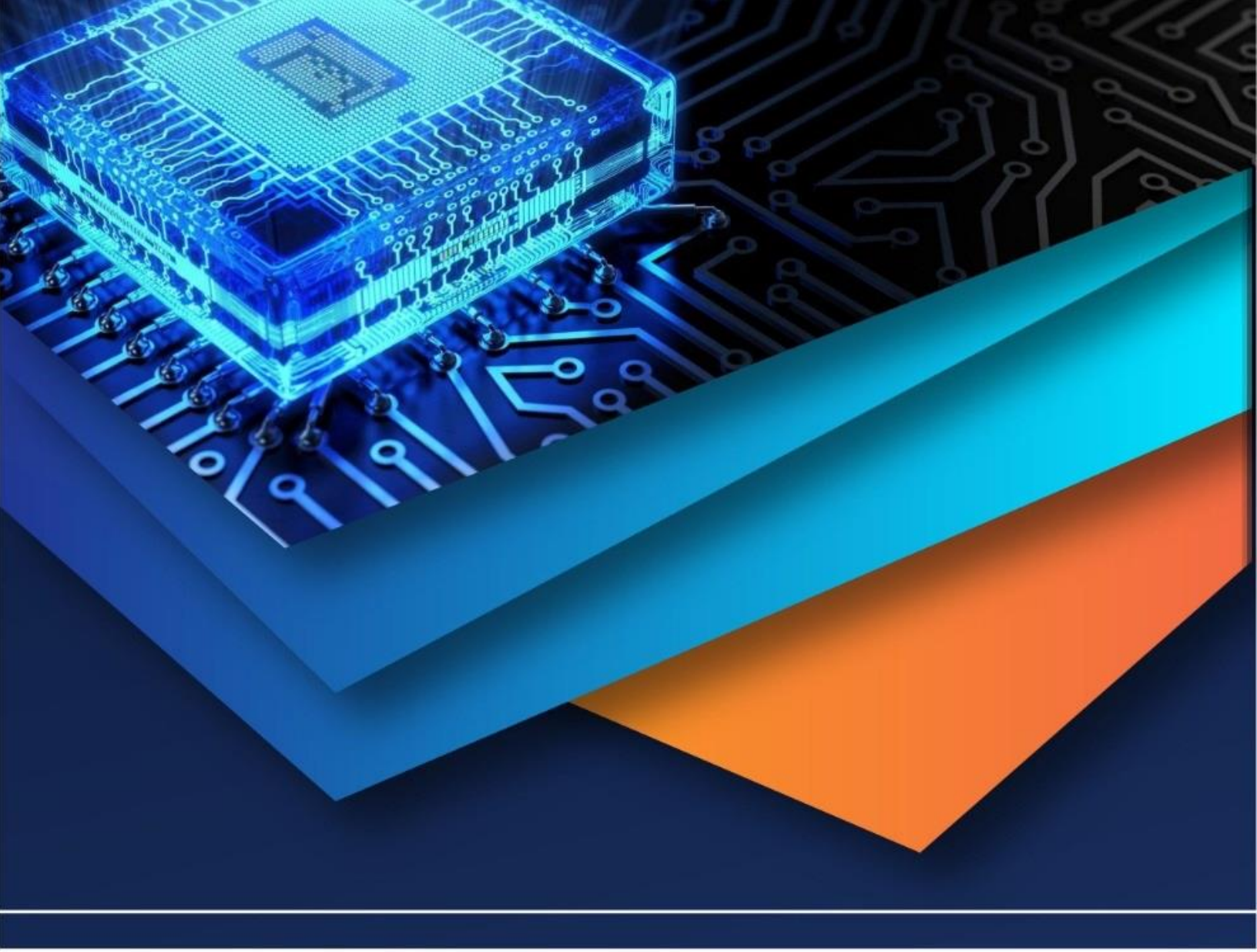


Fig. 5: Methodology of RC chimney analysis using ABAQUS/CAE. Source: Adapted from [12].

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