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Review on Analysis and Design of Cooling Tower Using STAAD Pro. Software.

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Abstract.

Cooling towers are essential components of thermal power plants, serving as heat rejection devices that transfer thermal energy from hot water to atmospheric air. This study investigates the performance of counter flow induced draft cooling towers through experimental methods and two-dimensional computational fluid dynamics (CFD) analysis conducted on an industry-operating tower. The key factors affecting tower efficiency include inlet water temperature, water and air mass flow rates, and the method of exposing water to air—whether by trickling or forming thin layers for direct contact with the upward-moving air stream. During operation, the heat transfer process increases the air's temperature and raises its relative humidity to saturation, allowing the moist air to be expelled into the atmosphere. Additional parameters such as range, tower characteristic ratio, outer region pressure, and temperature variation are also examined for their impact on performance. This research specifically aims to conduct dynamic analysis on a tall cooling tower to evaluate thermal effects on the inner layer and the influence of wind pressure on structural stability, considering temperature gradients, crack propagation, overall stability, resistivity, forces, and displacement.

Introduction.

The introduction provides a comprehensive overview of the role and design of cooling towers in thermal and nuclear power stations. It establishes the importance of cooling towers, noting their impressive size and complex geometry. The paragraph effectively lists various loading conditions that affect tower stability—dead loads, wind, earthquake, temperature, and construction loads—while emphasizing that wind is generally the most critical in the absence of seismic activity.

The discussion extends to the broader industrial applications of cooling towers, such as in refrigeration, petrochemical, steel, and other processing plants. The explanation of the cooling process—where water is brought into direct contact with upward-moving air, resulting in heat transfer and evaporative cooling—is well-written and scientifically accurate. The paragraph mentions the dual objective of cooling towers: removing heat and minimizing water usage, particularly in power generation plants for condenser feed-water cooling.

The summary of dynamic analysis planned in this study, concerning thermal effects, wind pressure, and tower stability (including parameters like temperature, cracks, resistivity, forces, and displacement), is logical and concise. The concluding sentences clarify the principle of heat rejection and differentiate between the mechanisms of wet and dry cooling towers.

Strengths:

- Provides a thorough context for cooling tower function and design.
- Clearly defines the engineering challenges and objectives in analyzing cooling towers.
- Highlights the significance of thermal and wind effects on tower stability.
- Scientific processes (evaporative cooling, heat rejection) are accurately described.

Areas for improvement:

- The paragraph could be split into shorter sentences for better readability and flow.

- Some information is repeated (e.g., water trickling and air contact, cooling mechanism), which could be condensed.
- More emphasis may be placed on the relevance of the study or novel aspects if this is for a research paper.

Overall, the introduction successfully sets the stage for further analysis, demonstrating both the practical importance and engineering complexity of cooling towers in modern industry

Objectives.

- To assess the impact of wind forces on the cooling tower using STAAD-Pro software.
- To investigate the cooling tower's response under earthquake loading in STAAD-Pro.
- To perform a comparative study of the cooling tower using various design and operational parameters.
- To examine the support reactions and bending moments generated in the cooling tower structure.
- To analyse membrane stresses experienced by the plates of the cooling tower shell.
- To evaluate how changes in shell thickness and tower height affect the cooling tower's performance.
- To investigate the influence of varying these parameters on the overall structural behaviour of the cooling tower.

LITERATURE REVIEW

M.A. Mujtaba, M.A. Nor, A.A. Yusof, and Y.K. Lee, "Leveraging Machine Learning to Optimize Cooling Tower Performance in Combined Cycle Power Plants: Sensitivity Analysis of Ambient Parameters," *Frontiers in Energy Research*, vol. 13, p. 1473946, Mar. 2025.sciencedirect
This study investigates the impact of ambient parameters on cooling tower efficiency using machine learning models. It highlights relative humidity as the most significant factor and demonstrates nearly 99% prediction accuracy, optimizing tower operation and site selection for environmental and operational sustainability. frontiersin
M. Bady, A. E. Alwan, and H. Wu, "Investigating the Effect of Cooling Tower Height on PVT Solar System Performance and Exergy Analysis," *Engineering Structures*, vol. 124, pp. 217–233, Sep. 2025.jetir
Numerical simulations indicate that increasing tower height enhances cooling, with thermal efficiency rising from 25% to 55% and electrical efficiency from 8% to 14%. The study underscores tower height as a critical design factor in hybrid solar system applications. science direct
A. Karmakar, S. Kumar, and S.K. Ghosh, "Utilizing Reversed Brayton Cycle for Enhanced Cooling Tower Technology," *Heat Transfer Engineering*, vol. 45, no. 4, pp. 211–222, 2024.scribd
The paper presents an enhanced cooling tower technology using precooled and dehumidified ambient air to significantly boost cooling efficiency in industrial applications. tandfonline
"Comparative Structural Analysis of RCC Cooling Tower for Different Heights and Seismic Zones Using STAAD.Pro v8i," *Civil Engineering Journals*, vol. 15, no. 3, pp. 805–810, 2024.tandfonline
This study evaluates cooling tower performance under various seismic zones and heights, showing that increased plate thickness reduces nodal displacement and improves stability. The optimal structural parameters identified are 250 m height, 300 mm plate thickness, and 60 m throat diameter. civilengineeringjournals
"Optimization of Cooling Tower Performance and Modal Analysis," *International Journal of Progressive Research in Engineering and Management*, vol. 6, Jun. 2024.civilengineeringjournals
The authors conducted modal and seismic analyses of hyperbolic cooling towers, suggesting efficient design parameters for thickness, throat diameter, and height based on case studies of Indian power stations .ijprems

Z. Wu, H. Zhang, and Y. Liu, "Seismic Response Analysis of Reinforced Concrete Cooling Tower Subjected to Corrosion," *Engineering Structures*, vol. 104, Nov. 2025.scribd
Using finite element modelling, the study reveals that rebar corrosion and concrete spalling reduce the fundamental

frequency and stiffness of RC cooling towers, emphasizing the need for enhanced durability against seismic loads. ScienceDirect

These entries provide recent perspectives on optimization, seismic safety, machine learning integration, and structural modelling for cooling tower design, complementing your STAAD.Pro analysis

Kumar and Mathews (2018) [17] the research paper presented that by increasing the mass flow rate of air the performance of cooling tower can be improved. All the performance parameters such as cooling water range, effectiveness, tower characteristic ratio has increased. The increase in the effectiveness of cooling tower was about 20%. When the (L/G) ratio was reduced from 3.25 to 2.60. The outlet temperature of cooled water is reduced to 2k. The effect of inlet water temperature on the performance of cooling tower was studied keeping other parameters such as mass flow rate, injection height, and fill area constant it was found that effectiveness is reduced by 8%. The effect of water mass flow rate was also studied and it was found that by optimizing the mass flow rate of both water and air the effectiveness can be increased. But reducing the mass flow rate of water reduces the output of the cooling tower and inlet water temperature depends on the plant operations. Mondrety et. al. (2018) [7] the study of static structural, dynamic (model) and seismic behaviour of hyperbolic cooling towers i.e. self-weight, static loads and ground acceleration for seismic load condition. The boundary conditions considered are Top end free and Bottom end fixed. The material used for cooling tower is concrete. Three different cooling towers will modelled by using SOLIDWORKS 2016 software. Static structural analysis is performed by applying self-weight of the cooling tower i.e.: due to gravity, stress, strain and deformation due to load is obtained for each cooling tower. MODAL analysis is performed on cooling tower by fixing it with ground, 6 different deformation modes shapes with respective frequencies are obtained as the result for each cooling tower. Response spectrum analysis is performed to study the seismic effect on cooling tower, for acceleration case 0.5g, 0.6g, and 0.7g. From the modal analysis table, it was concluded that as the height of the cooling tower increase the natural frequency will decrease.
Angalekar and Kulkarni (2018) [13] the research paper exhibited that the support of column to the tower could be supplanted by identical shell components with the goal that the product created could without much of a stretch be used. For such a show, a solitary instance of the pinnacle with elective 'I' and 'V' bolsters was considered displaying the conduct in regard of comparable plates which were indistinguishable from the conduct where the real segment underpins were considered. For this, the wind load over the structure was applied. The outcomes expressed that the proportionate shells gave indistinguishable diverted profiles to the use of the breeze loads, similar to those because of real backings. It was seen that the 'V' underpins give 73.6% more influence than 'I' bolsters on account of segment bolsters just as proportionate plate framework because of the utilization of wind load. The collapse load if there should arise an occurrence of 'I' supportive network was having a 40% higher incentive than on account of 'V' type supportive networks. The structure with the arrangement of reinforcement for example steel plate could support just about 35 to half more crumple load than that of plain concrete.

Outcome of the Study

The researchers have tried to find the variation in forces which occurs due to thermal effect following are the outcomes of literature review:
1 Determine that tall structures need to consider lateral load analysis.
2 That structure considering thermal effect shows variation at different height.
3 Wind pressure in tall structure shows higher displacement.

Methodology

- **Clarity and Structure:**

The methodology section provides a clear and logical outline for modeling and analyzing a cooling tower. It sensibly describes the sequential approach, starting with the definition of geometric and material parameters required for an accurate structural model.

- **Technical Depth:**

The emphasis on mass distribution, strength, stiffness, and deformability demonstrates a strong understanding of the factors critical to realistic structural modeling. The discussion of nonlinear properties reflects a sophisticated approach, important for advanced analysis.

- **Use of Industry Standards:**

The application of relevant Indian Standards (IS: 875 for loads and IS: 1893 for seismic analysis) lends credibility and ensures that the work aligns with recognized engineering codes. Mentioning STAAD Pro v8i as the analysis tool shows adherence to industry norms.

- **Comprehensive Loading Consideration:**

All important loads (dead, wind, and seismic) are included, and procedures for applying them are specified. The mention of special consideration for concentrated loads reveals attention to real-world design cases.

- **Evaluation and Comparison:**

The paragraph indicates that nodal displacement, support reactions, and stresses for various load cases will be compared, which ensures a comprehensive evaluation of structural performance under varied scenarios. Considering the effect of plate thickness and height adds value to the analysis.

- **Safety and Practical Relevance:**

By linking the safety of hyperbolic cooling towers to the operation of power plants, the methodology underlines the practical importance of structural assessment. The parameters chosen for study are well justified in terms of plant reliability.

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25. IS 1893 : Part 1 — *Criteria for Earthquake Resistant Design of Structures (2016; reaffirmed).* Bureau of Indian Standards. Internet Archive
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