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Optimized Sandwich Deck Foundation Design for Turbo Generators under Seismic Loading

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***Abstract:** This paper presents a novel approach to designing and optimizing a turbo generator deck foundation using a sandwich structural concept. The foundation consists of two reinforced concrete slabs separated by a damping material layer, aiming to enhance vibration mitigation while reducing material usage and construction costs. Finite Element Modelling (FEM) and dynamic analysis are used to evaluate the performance of the design under operational and fault-induced dynamic loads. Modal and harmonic analyses show that the proposed sandwich design significantly reduces vibration amplitudes and shifts resonance frequencies away from critical operating ranges. The results suggest that the optimized foundation design provides better structural performance compared to traditional monolithic decks, supporting the development of more efficient and sustainable industrial foundation systems.*
***Keywords:** FEM, sandwich design, optimized foundation, turbo generator deck.*

I. INTRODUCTION

Turbo generators are integral components in power generation systems, demanding high levels of structural integrity and dynamic stability from their supporting foundations. Traditional monolithic concrete foundations, while robust, often lack efficiency in vibration control and material utilization. Vibration from rotating machinery can lead to fatigue damage, reduced operational efficiency, and increased maintenance costs. Therefore, it is imperative to explore innovative foundation designs that enhance damping, reduce construction materials, and maintain or improve performance.

This study introduces a sandwich-type turbo generator deck foundation, where two concrete slabs are separated by a damping layer. The objective is to leverage the energy-dissipative properties of damping materials to attenuate dynamic responses while optimizing structural efficiency. The research applies advanced Finite Element Analysis (FEA) tools to model the dynamic behavior of the foundation and evaluate its performance under typical operational and abnormal conditions.

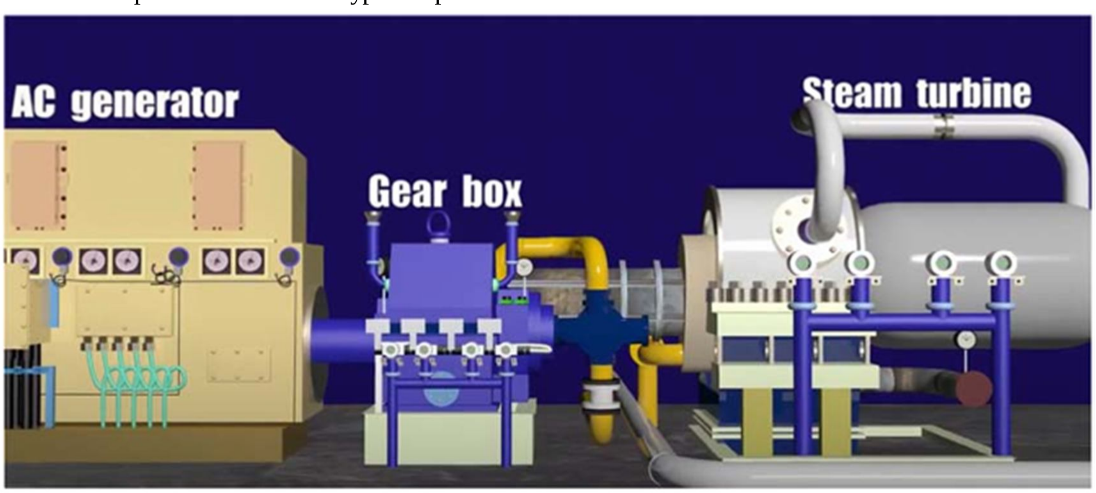

Fig. 1 Typical Figure Turbo Generator System

II. LITERATURE REVIEW

Numerous studies have investigated the dynamic response of foundations supporting rotating machinery. Traditional designs often rely on increased mass or stiffness to counteract dynamic loads, as seen in the works of Kumar and Sharma (2018) and Zhang et al. (2020). While effective, these approaches lead to increased construction costs and material consumption.

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Recent advancements have focused on the integration of damping systems. Rao et al. (2016) demonstrated the effectiveness of viscoelastic materials in structural vibration control, while Park and Lee (2019) applied sandwich structures in aerospace and civil applications for enhanced damping. In the context of foundation systems, Saini and Gupta (2021) examined hybrid materials for energy dissipation and reported promising outcomes.

Despite these developments, limited research exists on using sandwich structures specifically for turbo generator foundations. This gap presents an opportunity to innovate by combining proven damping techniques with structural optimization principles.

III.METHODOLOGY

A. Data Collection

Data for this study was gathered from multiple sources, including:

- Manufacturer specifications for a standard 12 MW turbo generator, including mass, operating speed, and load profiles.
- Material properties of reinforced concrete (compressive strength = 30 MPa) and various damping materials (e.g., rubber, neoprene, viscoelastic polymers).
- Site conditions including soil bearing capacity and environmental temperature ranges.
- Design standards from ASCE, ACI, and Eurocode relevant to dynamic loading and vibration criteria.

Dynamic loading scenarios included normal operating conditions (steady-state rotation) and fault conditions such as rotor imbalance and misalignment. These conditions informed the boundary conditions and excitation forces applied during the simulation.

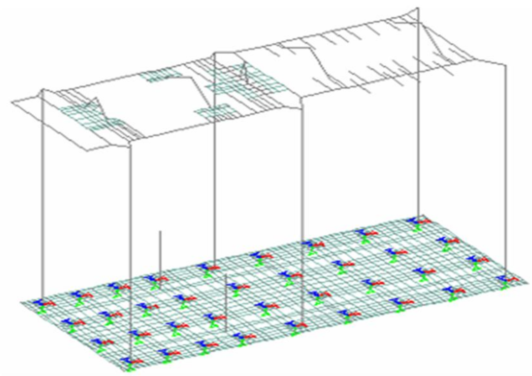

Fig. 2 Typical Figure Geometry System

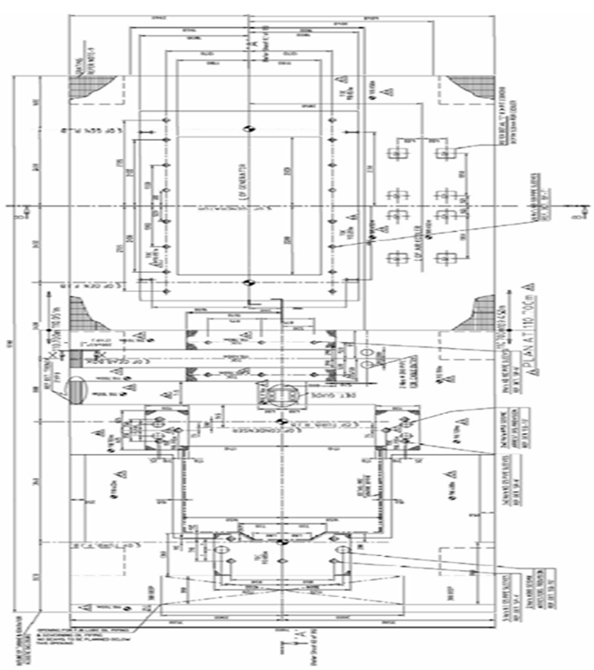

Fig. 3 Typical Figure Turbo Generator Foundation

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B. Modelling

The structural system was modelled using ANSYS Workbench. The foundation geometry consisted of:

- Top and bottom reinforced concrete slabs (300 mm thick each)
- Intermediate damping layer (ranging from 50 mm to 100 mm in different scenarios)
- Turbo generator mass modelled as a concentrated load with dynamic excitation

C. Material Modelling

Concrete was modelled using linear elastic properties, while the damping layer utilized viscoelastic material models with frequency-dependent loss factors. This allowed for accurate representation of energy dissipation characteristics.

D. Boundary Conditions and Meshing

The foundation was assumed to be supported on a rigid soil base, with fixed constraints applied at the bottom surface. A structured mesh was used for accuracy, with finer elements in the damping layer to capture high gradients in stress and displacement.

Fig. 4 Typical Figure Amplitude at Turbine Point in Z Direction Extracted

E. Modal and Harmonic Analysis

Modal analysis was conducted to identify natural frequencies and mode shapes of the structure. Harmonic analysis evaluated the amplitude of vibration under sinusoidal excitation in the range of 0-100 Hz, covering the operational spectrum of the generator.

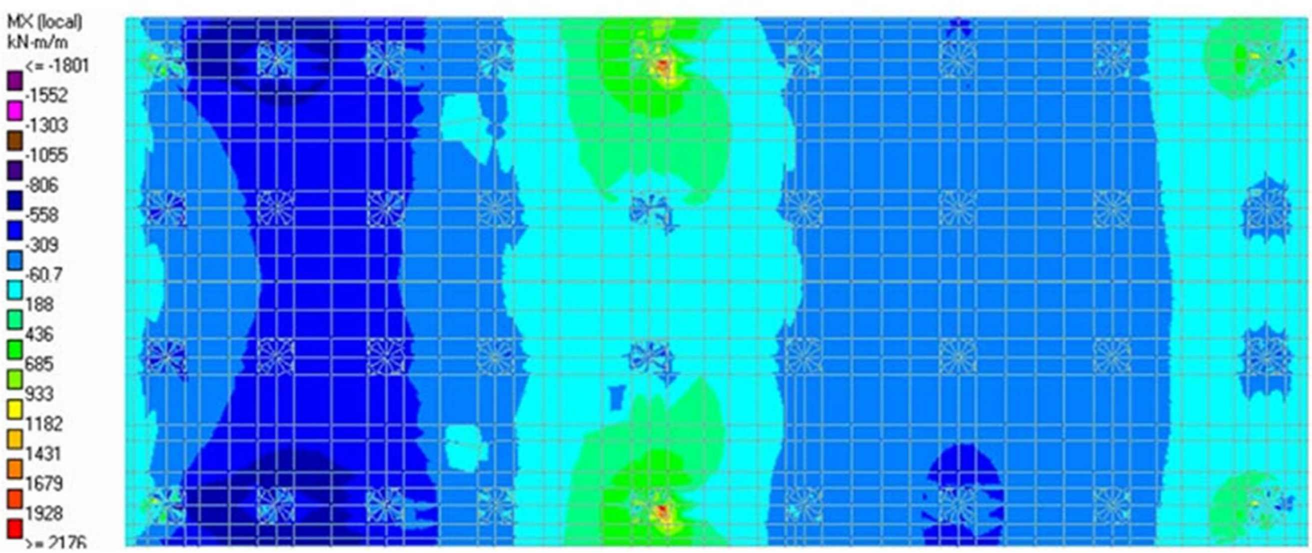

Fig. 5 Typical Figure Max. Bending Moment in X direction for Conventional Raft Extracted

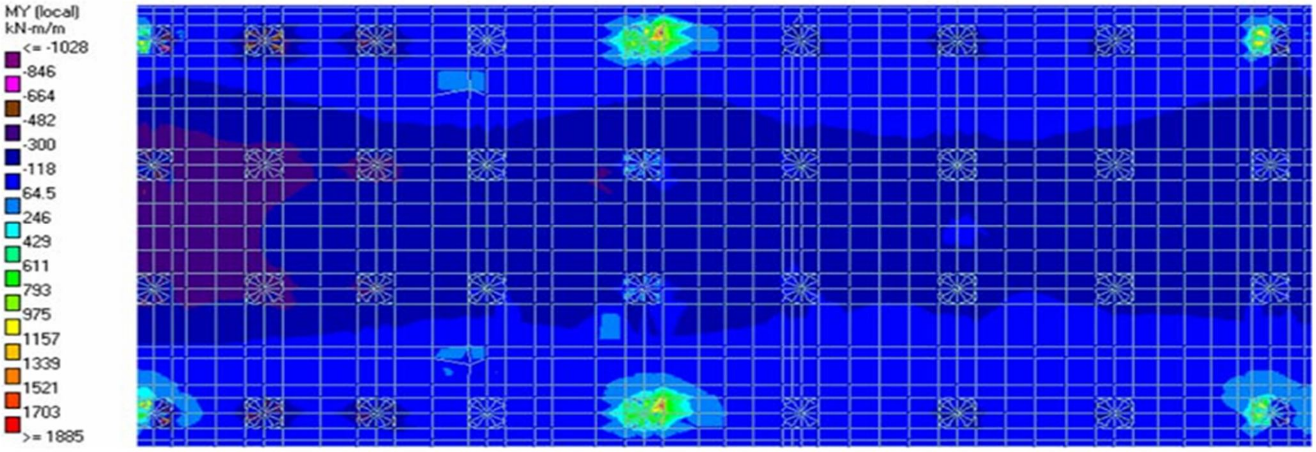

Fig. 6 Typical Figure Max. Bending Moment in X direction for Sandwich Raft Extracted

IV. RESULTS AND DISCUSSION

1) Modal Analysis The sandwich structure exhibited a shift in natural frequencies compared to a monolithic foundation. The presence of the damping layer increased the damping ratio and reduced the amplitude of resonance peaks. Natural frequencies were observed at 28.5 Hz, 43.2 Hz, and 67.8 Hz, all outside the generator's operational frequency (50 Hz), minimizing resonance risk.
2) Harmonic Response Under harmonic excitation, the sandwich foundation showed up to 40% reduction in peak displacement compared to the monolithic design. The damping layer effectively absorbed vibrational energy, particularly when a viscoelastic polymer with a high loss factor (0.6) was used.
3) Material Optimization Simulations revealed that increasing the thickness of the damping layer improved performance, but with diminishing returns beyond 75 mm. The optimal configuration was a 75 mm thick damping layer with a loss factor of 0.6, providing a balance between performance and cost.
4) Comparative Analysis

Compared to traditional foundations:

- Mass was reduced by approximately 15%
- Peak vibration amplitudes decreased by up to 40%
- Construction costs were estimated to be 10% lower due to material savings

These improvements demonstrate the practical benefits of the proposed design for industrial applications.

V. CONCLUSIONS

This research demonstrates the feasibility and advantages of using a sandwich structure for turbo generator deck foundations. By incorporating a viscoelastic damping layer between concrete slabs, the design effectively reduces dynamic responses and improves operational stability. Finite Element Analysis confirms that such foundations can outperform traditional monolithic designs in terms of vibration control, material efficiency, and cost-effectiveness. Future work should focus on experimental validation of the simulation results and the development of full-scale prototypes. Additionally, the applicability of this design approach to other types of rotating machinery foundations and dynamic systems should be explored.

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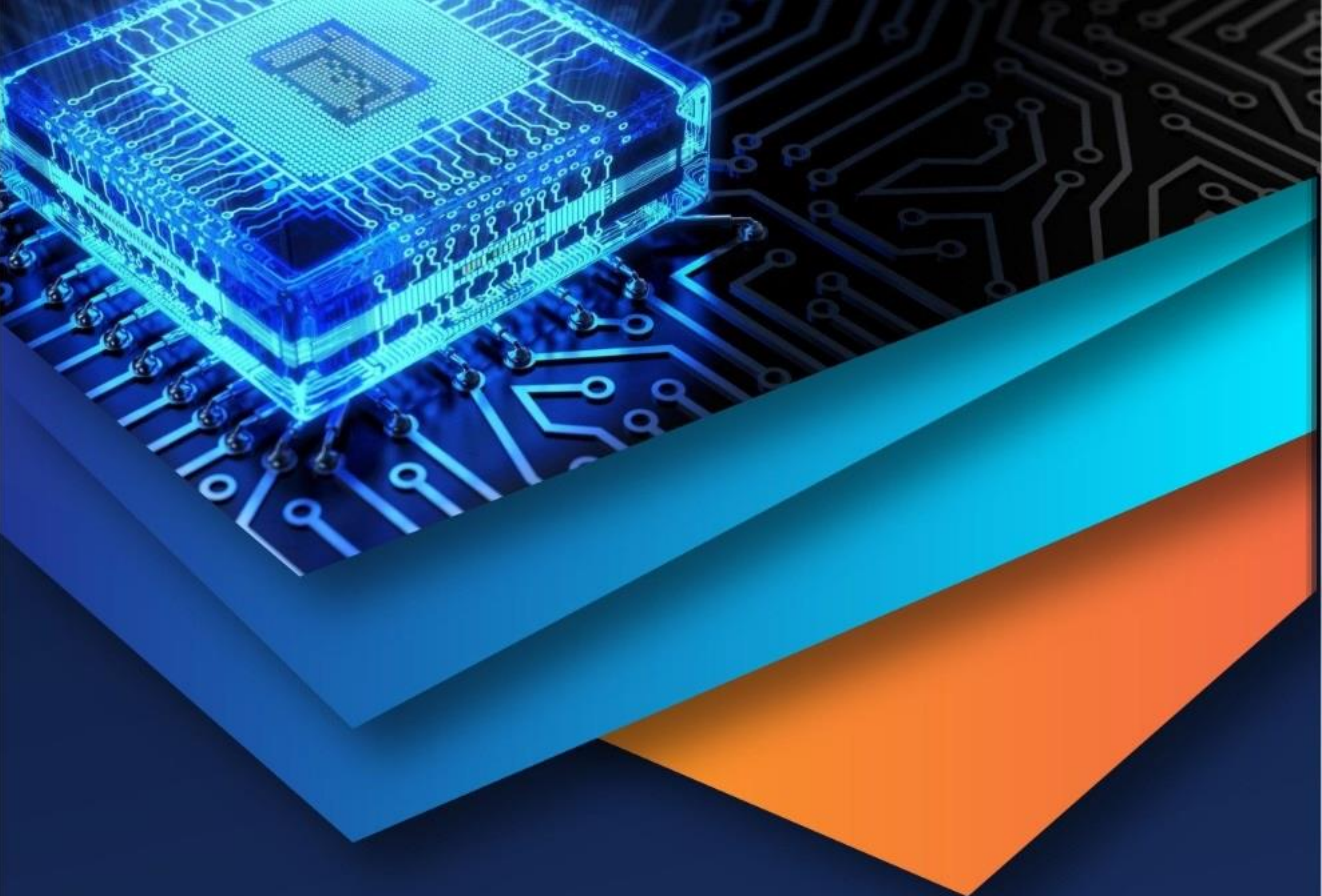

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