



Modal Analysis of Two Adjacent Buildings of Different Heights and Different Material Subjected to Wind Load

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Abstract: This study aims to evaluate the dynamic response of two buildings with different heights and materials—one a taller steel structure and the other a shorter concrete structure—under wind-induced harmonic loading using ANSYS Workbench. Modal analysis is conducted to identify natural frequencies and mode shapes, while harmonic response analysis assesses behavior under a 50 MPa wind load. The objective is to assess how material composition and geometric differences influence structural performance and resilience under dynamic wind loading. The results indicate that the steel building exhibits better dynamic performance and higher safety margins compared to the concrete building under wind-induced excitation.

Keywords: Steel, concrete, wind, mode shapes, dynamic response

1. Introduction

Wind-induced loads often govern the design of high-rise buildings due to their dynamic nature [1]. As a result, detailed structural dynamics analysis is essential for safety and serviceability. Finite-element software such as ANSYS Workbench enables detailed simulations of these effects [2]. In this study, two

idealized building models are developed: a tall steel frame (50 × 25 × 500 mm) and a shorter concrete frame (80 × 30 × 250 mm), separated by about 70 mm. Modal analysis is first conducted on each structure to extract natural frequencies and corresponding mode shapes [3]. The natural frequencies reflect each building's stiffness and mass distribution. Steel (with Young's modulus $\approx$ 200 GPa) is nearly an order of magnitude stiffer than



typical concrete ($\approx 17\text{--}30$ GPa), so the steel tower is expected to exhibit higher-frequency modes [4]. The computed mode shapes reveal how each structure would deform in its fundamental vibrational modes under free vibration. Following modal extraction, harmonic response analysis simulates forced vibration under wind loading of 50 MPa. Pressure load is applied alternately to one building at a time, while the dynamic response of the other is recorded. By comparing these metrics between the steel and concrete models, the study assesses the impact of material properties and aspect ratio on dynamic performance [5].

2. Methodology

This study was conducted using ANSYS Workbench to simulate and analyze the dynamic behavior of two adjacent buildings with differing heights and materials. The taller structure was modeled with structural steel, and the shorter with concrete. Both buildings were assigned fixed supports at the base and meshed using the multizone method to ensure accurate results. The analysis comprised two phases. In the first, modal analysis was used to extract natural frequencies and mode shapes, which reflect the structures' stiffness and dynamic characteristics. In the second phase, harmonic response analysis was

performed by applying a 50 MPa sinusoidal wind load alternately to each building. The dynamic response of the non-loaded structure was measured in both cases. Performance metrics including directional deformation, equivalent stress, fatigue life, and safety factor were computed and compared to assess how material type and geometry influence the structures' behavior under wind-induced loading.

3. Result and Discussion

The results of the simulation are categorized into two parts: modal analysis and harmonic response analysis. Each provides valuable insight into how the two structures—steel and concrete—perform under dynamic loading.

Modal Analysis: The modal analysis revealed that the taller steel structure exhibited lower natural frequencies compared to the shorter concrete building. This is attributed to its higher slenderness ratio and lower stiffness-to-mass ratio. The first three mode shapes for each building demonstrated typical vibrational patterns, including fundamental bending and torsional modes.

Table 1: First three mode shapes of Steel building

Parameter	Mode Shape 1	Mode Shape 2	Mode Shape 3
Frequency	81.749 Hz	162.3 Hz	219.01 Hz

(Hz)			
Max Deformation (mm)	5.0256e-014 mm	1.4006e-014	52.68 Hz

Table 2: First three mode shapes of concrete building

Parameter	Mode Shape 1	Mode Shape 2	Mode Shape 3
Frequency (Hz)	81.749 Hz	162.3 Hz	219.01 Hz
Max Deformation (mm)	28.568mm	28.508mm	2.4836e-013mm

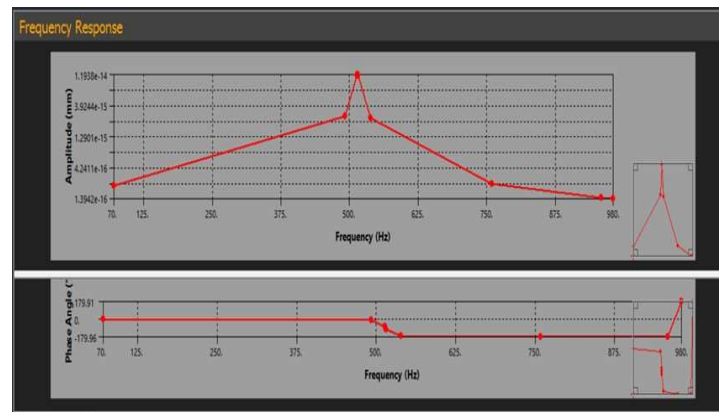
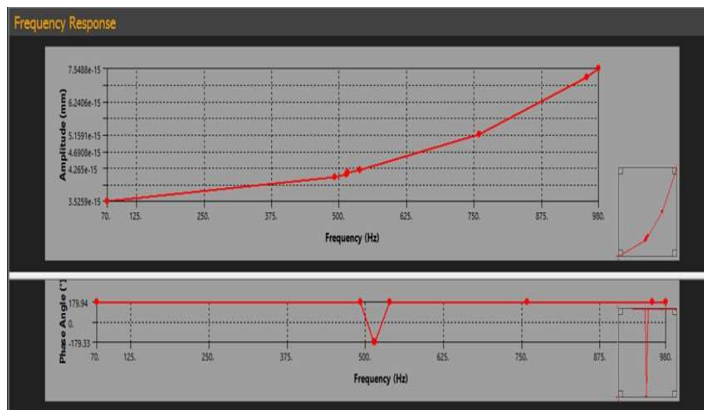


Fig 1: Frequency response graphs for both cases

Harmonic Response Analysis:

The harmonic response analysis involved the application of a 50 MPa sinusoidal wind pressure alternately on each structure, while measuring the response of the adjacent building.

Case 1: Load applied to the steel building

The concrete structure exhibited limited deformation, with maximum response occurring near its resonant frequency (~980

Hz). The stress levels remained low, and no structural failure was observed.

Case 2: Load applied to the concrete building

The steel structure responded with higher deformation and stress amplitudes, particularly near 514 Hz. However, the structure maintained a high safety factor and excellent fatigue resistance, reflecting the favorable performance characteristics of structural steel under cyclic loading.

Table 3 Frequency Response of Concrete Building Frequency Response of Concrete Building

Frequency (Hz)	Amplitude (mm) Steel Building	Amplitude (mm) – Concrete Building
70	2.21e-16 mm	3.53e-15 mm
491.56	2.66e-15 mm	4.04e-15 mm
513.27	1.17e-14 mm	4.10e-15 mm
514.33	1.1938e-014mm (Peak)	4.12e-15 mm
514.38	1.19e-14 mm	4.13e-15 mm
514.43	1.19e-14 mm	4.13e-15 mm
515.49	1.17e-14 mm	4.15e-15 mm
538.26	2.48e-15 mm	4.23e-15 mm
758.59	2.36e-16 mm	5.41e-15 mm
958.32	1.43e-16 mm	6.73e-15 mm
980	1.39e-16 mm	7.5488e-015 mm(Peak)

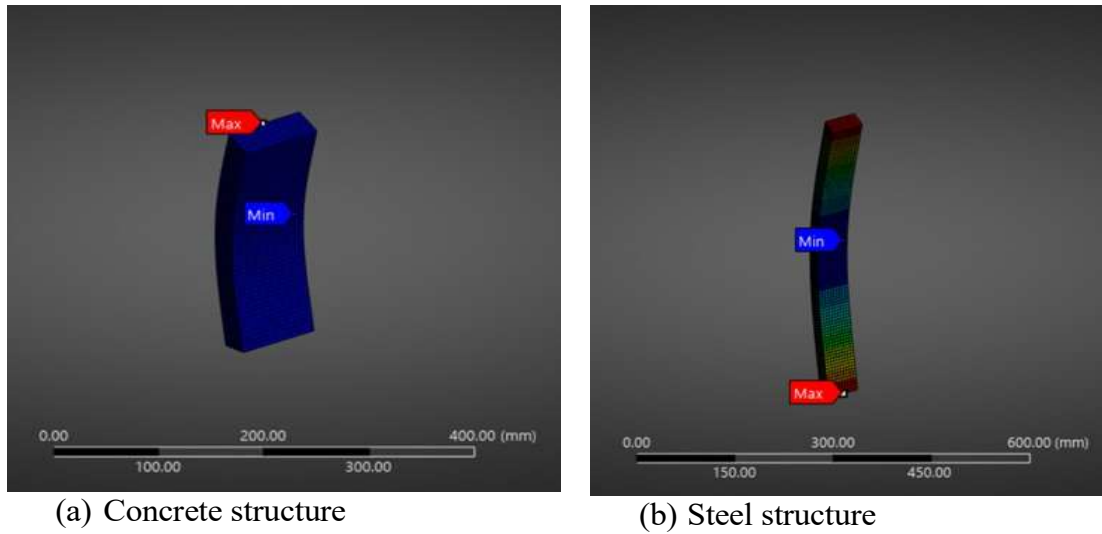


Fig 2: Directional Deformation for both cases

The concrete building exhibited higher stiffness and natural frequencies but failed under cyclic loading, reflecting poor fatigue resistance. The steel structure, though more flexible, maintained low stress levels and demonstrated strong fatigue life and safety margin. These results highlight the superior dynamic resilience of steel and the importance of material ductility in wind-resistant design.

4. Conclusion

This study evaluated the dynamic performance of steel

and concrete buildings under wind-induced loading using ANSYS. While the concrete structure exhibited higher natural frequencies, it failed under cyclic loading. In contrast, the steel building showed better fatigue life, safety, and overall resilience. These results emphasize the importance of material selection and geometry in wind-resistant structural design.

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