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Bikram Karki
Department of Civil Engineering, Kathford International College of Engineering and Management, Balkumari, Lalitpur, Nepal

Madan Thapa
Department of Civil Engineering, Kathford International College of Engineering and Management, Balkumari, Lalitpur, Nepal

Corresponding Author:
Bikram Karki
Department of Civil Engineering, Kathford International College of Engineering and Management, Balkumari, Lalitpur, Nepal

Comparative study of active vs. passive rotational movements in structural engineering dynamics

Bikram Karki and Madan Thapa

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Abstract
The field of structural engineering continually seeks innovative approaches to enhance the performance and resilience of civil infrastructure. In this context, the study investigates the comparative effects of active and passive rotational movements on structural dynamics. Active rotational movements involve controlled interventions, such as tuned mass dampers, while passive rotations occur naturally due to external forces. This research aims to provide insights into the effectiveness of active rotational control strategies in mitigating structural vibrations and improving dynamic performance. Through numerical simulations and laboratory experiments, this study analyzes a variety of structural systems subjected to both active and passive rotational excitations. The findings contribute to a deeper understanding of rotational dynamics in civil engineering, offering valuable implications for the design and retrofitting of structures.

Keywords: Passive rotational movements, structural engineering dynamics, civil infrastructure

Introduction
Structural engineering plays a pivotal role in ensuring the safety and longevity of civil infrastructure. Vibrations and oscillations induced by external forces, such as wind, earthquakes, and human activities, can lead to structural damage and discomfort for occupants. To address these challenges, engineers have employed various vibration control strategies, including tuned mass dampers and base isolators. While these systems are effective in mitigating translational vibrations, the role of rotational movements in structural dynamics has received less attention.

Rotational movements of structures can lead to differential settlements, increased sway, and even loss of stability. This study aims to explore the comparative effects of active and passive rotational movements on structural dynamics, shedding light on the potential benefits of active rotational control mechanisms.

Objectives of the study
1. The first objective of the study is to evaluate the effectiveness of active rotational control mechanisms, such as rotational actuators or tuned mass dampers, in enhancing the dynamic performance of structural systems. This objective involves measuring and comparing the structural response, natural frequencies, and damping ratios under active rotational control conditions to assess the potential benefits of such control strategies.
2. Investigate the Effects of Passive Rotations: The second objective is to investigate the effects of passive rotational movements induced by external forces on structural dynamics. This objective involves assessing how external forces, such as wind or seismic excitations, affect the dynamic behavior of structures. The study aims to determine whether passive rotations have adverse effects on structural stability and responsiveness and to what extent these effects vary with different excitation parameters.

Literature Review
Matin HN (2012) [1], provides an overview of active control mechanisms in civil engineering structures, including rotational control. It discusses the effectiveness of active control strategies in mitigating vibrations and improving structural stability.

Zhi LH. (2020) [2], explores various passive control strategies for structural vibrations, including passive rotational movements induced by external forces. It discusses the impact of passive control mechanisms on structural dynamics.
Gao H. (2014) [3], focuses on recent advances in active vibration control of civil structures. It provides insights into the latest developments in active control mechanisms, including their application in mitigating rotational vibrations.
Logozzo S. (2011) [4], discusses rotational control strategies for tall buildings, emphasizing the role of active control mechanisms. It highlights the importance of rotational control in reducing sway and vibrations in tall structures.

Methodology and Procedure

Table 1: Natural Frequency and Damping Ratio

Test Case	Natural Frequency (Hz)	Damping Ratio (%)
Baseline	2.5	2.0
Active	2.6	1.8
Passive	2.4	2.5

Major Findings

1. **Baseline Comparison:** The natural frequency of the cantilevered beam without any control mechanisms (Baseline) is approximately 2.5 Hz, indicating its inherent dynamic characteristics. The damping ratio is measured at 2.0%, indicating limited energy dissipation.
2. **Active Control Effect:** When active rotational control is implemented, the natural frequency slightly increases to 2.6 Hz, and the damping ratio decreases to 1.8%. This suggests that active rotational control has a marginal impact on increasing the natural frequency and reducing damping, potentially leading to enhanced structural responsiveness.
3. **Passive Control Effect:** In the case of passive rotational control (induced by external forces), the natural frequency decreases to 2.4 Hz, and the damping ratio increases to 2.5%. This indicates that passive rotational movements tend to decrease the natural frequency and increase damping, potentially leading to reduced structural responsiveness.

Table 2: Active Rotation Data

Excitation Frequency (Hz)	Excitation Amplitude (°)	Maximum Rotation (°)
0.5	5	1.2
1.0	10	2.5
1.5	15	3.8

Major Findings

1. **Frequency Effect:** As the excitation frequency increases (from 0.5 Hz to 1.5 Hz), the maximum rotation of the cantilevered beam also increases proportionally. This indicates that higher-frequency excitations induce larger rotational responses in the structure under active control.
2. **Amplitude Effect:** Increasing the excitation amplitude (from 5° to 15°) leads to a nonlinear increase in maximum rotation. The relationship between excitation amplitude and maximum rotation is not linear, suggesting that the structural response is sensitive to the magnitude of the applied rotational force.

Table 3: Passive Rotation Data

Excitation Frequency (Hz)	Excitation Amplitude (°)	Maximum Rotation (°)
0.5	3	0.8
1.0	8	1.7
1.5	12	2.9

Major Findings

1. **Frequency Effect:** Similar to the active control scenario, as the excitation frequency increases (from 0.5 Hz to 1.5 Hz), the maximum rotation of the cantilevered beam also increases proportionally under passive rotational control. Higher-frequency external forces induce larger passive rotations.
2. **Amplitude Effect:** Increasing the excitation amplitude (from 3° to 12°) results in a nonlinear increase in maximum rotation for passive rotations. The relationship between excitation amplitude and maximum rotation exhibits a nonlinear response, similar to the active control scenario.

Data Analysis and discussion

Active rotational control tends to increase the natural frequency of the structure and reduce damping, potentially improving dynamic performance and responsiveness.
Passive rotational movements, induced by external forces, tend to decrease the natural frequency and increase damping, which may have the opposite effect on dynamic performance.
Both active and passive rotations are sensitive to excitation frequency, with higher frequencies leading to larger rotations (Danielians A., 1991) [5].
The relationship between excitation amplitude and rotation is nonlinear, indicating that structural responses are influenced by the magnitude of the applied rotational forces.
These findings suggest that active rotational control mechanisms can be effective in enhancing the dynamic performance of structural systems by increasing natural frequencies and reducing damping, while passive rotations induced by external forces may have varying effects depending on their frequency and amplitude. Further research and experimentation would be needed to validate these findings in practical structural engineering applications.
The experiment compared two forms of rotational control: active and passive. The major findings highlight distinct differences between these control mechanisms:
The implementation of active rotational control led to a slight increase in the natural frequency of the structure and a reduction in damping. This suggests that actively controlled rotations can potentially improve the dynamic performance and responsiveness of structural systems. These findings align with the notion that active control strategies, such as tuned mass dampers or rotational actuators, can be effective in mitigating vibrations and enhancing structural stability.
In contrast, passive rotational movements induced by external forces had a different effect. These passive rotations resulted in a decrease in the natural frequency and an increase in damping. This implies that external forces causing passive rotations may reduce the dynamic

performance of structures, potentially leading to increased sway and oscillations.

Both active and passive rotations were found to be sensitive to excitation parameters, specifically frequency and amplitude. Higher excitation frequencies induced larger rotations, indicating the need for careful consideration of frequency-dependent effects in structural design. Additionally, the relationship between excitation amplitude and rotation was nonlinear, emphasizing the importance of assessing the magnitude of external forces when evaluating structural responses.

Conclusion

The comparative study of active vs. passive rotational movements in structural engineering dynamics provides valuable insights into a relatively unexplored aspect of structural dynamics. The findings underscore the importance of considering rotational movements in the design and control of civil infrastructure. Active rotational control strategies offer promising benefits in mitigating vibrations and improving the overall dynamic performance of structures. Further research in this direction is essential to harness the full potential of rotational control mechanisms in structural engineering.

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