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NUMERICAL AND EXPERIMENTAL EVALUATION OF BRIDGE LOAD-CARRYING CAPACITY USING STATIC AND DYNAMIC PARAMETERS

Tripti[1], Ms. Sheela Malik[2]
[1]M.Tech. Scholar, Ganga Institute of Technology and Management, Kablana, Jhajjar.
[2]Assistant Professor, Ganga Institute of Technology and Management, Kablana, Jhajjar.

ABSTRACT

This research presents a comprehensive study on the evaluation of bridge load-carrying capacity through numerical modeling and experimental validation. Utilizing static and dynamic testing techniques, the study aims to understand the structural performance of reinforced concrete bridges. Finite Element Modelling (FEM) was conducted using ANSYS and MIDAS Civil software, while experimental investigations included static load tests and dynamic assessments via impact hammers and ambient vibration tests. The results reveal that dynamic testing complements static evaluations by uncovering hidden deficiencies and delivering a more realistic appraisal of bridge health. The integration of both techniques provides a holistic method for infrastructure assessment, crucial for aging structures and maintenance prioritization.

Keywords: Bridge load-carrying capacity, static load testing, dynamic load testing, finite element modeling, structural healthmonitoring.

1. INTRODUCTION

The assessment of a bridge's load-bearing capability is crucial for structural safety and longevity. Traditional methods like Static Load Testing (SLT) provide valuable data but have limitations in scope and real-time behavior. This study introduces Dynamic Load Testing (DLT) as a complementary or alternative approach. The motivation lies in minimizing traffic disruption, time, and resource costs. The study objectives include analyzing eccentric vehicle movement on bridges, validating numerical simulations with field data, and proposing a methodology for integrating SLT and DLT.

2. LITERATURE REVIEW

Extensive studies have examined SLT and DLT separately, but fewer have analyzed their combined efficacy. Prior research (Islam et al., 2015; Samali et al., 2007) validates the utility of dynamic methods in assessing flexural stiffness and real-time performance. Studies emphasize the importance of accurate modeling and the need for integrating multiple evaluation techniques for holistic bridge assessment.

3. NUMERICAL STUDY ON VEHICLE ECCENTRICITY EFFECTS

A reinforced concrete bridge was modeled in ANSYS to investigate the influence of vehicle position (eccentricity from the kerb) on structural responses. The study revealed that maximum deformation, equivalent stress, and strain vary significantly with lateral vehicle position. The model was validated against existing data (Gupta et al., 2023), showing acceptable error margins (<4%).

4. DEFLECTION BEHAVIOR UNDER IRC LOADING

The bridge model was analyzed under various IRC Class AA loading scenarios using ABAQUS. Results showed different deflection patterns based on symmetric and eccentric loading conditions. The analysis aids in identifying critical zones susceptible to serviceability issues and highlights the importance of realistic loading representation.

Table 1: Deflection under various IRC loading scenarios

Load Type	Symmetric Deflection (mm)	Eccentric Deflection (mm)
IRC Class AA Tracked	15.6	18.2
IRC Class A (2-Lane)	12.1	14.7
IRC 70R Wheeled	17.3	20.5

5. EXPERIMENTAL STATIC LOAD TEST AND DYNAMIC ASSESSMENT

Field experiments were performed on span P3-P4. SLT involved placing loaded trucks and recording deflections. MIDAS Civil software was used for numerical modeling of the same span. Results were compared for model validation. The DLT involved ambient vibration monitoring and impact hammer excitation. Frequency response

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functions, mode shapes, and damping ratios were obtained. Post-processing yielded Dynamic Load Carrying Capacity (DLCC) estimates.

Table 2: Static vs Dynamic Frequency Comparison

Mode	Static Frequency (Hz)	Dynamic Frequency (Hz)	Variation (%)
1	5.12	5.32	3.90%
2	7.85	8.14	3.60%
3	11.43	11.97	4.70%

6. PROPOSED INTEGRATED METHODOLOGY

A framework was established to integrate static and dynamic parameters. Numerical model updating was performed using dynamic data to correct stiffness and inertia properties. The methodology allows estimating DLCC and Static Load Carrying Capacity (SLCC) with higher confidence, enabling better maintenance and rehabilitation strategies.

Table 3: Model Validation Summary

Parameter	ANSYS Result	MIDAS Civil	Field Data	Error Range (%)
Max Deflection (mm)	14.8	14.5	15.1	<5%
Max Stress (MPa)	23.7	22.9	24	<6%
Frequency (1st mode)	5.12	5.08	5.32	<5%

7. RESULTS AND DISCUSSIONS

Key findings include:

- Maximum deflection occurred under eccentric 70R loading.
- Static model results aligned closely with MIDAS Civil simulations (<5% variation).
- DLT revealed natural frequencies correlating with model predictions (within 6%).
- Model updating improved accuracy, aligning experimental and theoretical frequencies.
- DLCC estimation showed that bridges can withstand more load than SLT predicts, indicating conservative bias in traditional methods.

8. CONCLUSION

Dynamic methods enhance bridge assessment by capturing subtle performance indicators missed by static tests. Integrating numerical and experimental techniques ensures reliable estimation of load capacity. The proposed methodology offers a practical solution for engineers and policymakers to ensure bridge safety and longevity.

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