

Performance Evaluation of Bridges Under Moving Loads

Prof. Sathe Pooja Ramchandra¹, Bhagwat Nikita G.², Bhagwat Om A.³,
Bhagwat Pooja M.⁴, Bhagwat Rameshwar B.⁵ Bhagwat Vikram V.⁶

¹Assistant Professor and ^{2,3,4,5,6}Students

Adsul's Technical Campus, Ahilyanagar, India

Abstract: : Bridges are important components of transportation infrastructure that facilitate the movement of vehicles, goods, and passengers across obstacles such as rivers, valleys, and highways. During their service life, bridges are subjected to moving vehicular loads that produce dynamic effects, stresses, vibrations, and deflections. The structural response of bridges under moving loads is an important consideration in bridge design and safety evaluation. This research paper presents a detailed study on the performance evaluation of bridges subjected to moving loads. The study includes analysis of bridge loading, dynamic effects, bending moments, shear forces, deflection behavior, stress distribution, and vibration characteristics. Numerical examples are included for bridge analysis under moving vehicular loads. The results indicate that moving loads significantly influence bridge performance, especially in long-span bridges and heavily trafficked transportation systems. Proper bridge analysis helps improve safety, durability, and service life of bridge structures.

Keywords: Bridge Engineering, Moving Loads, Structural Analysis, Dynamic Loading, Bridge Deflection, Bending Moment, Shear Force, Bridge Performance.

I. INTRODUCTION

Bridges are among the most important civil engineering structures used to provide uninterrupted transportation over rivers, railway lines, valleys, highways, and other obstacles. Modern transportation systems require bridges capable of carrying heavy traffic loads safely and efficiently.

Bridges are continuously subjected to different loading conditions during their service life, such as:

1. Dead Load
2. Live Load
3. Wind Load
4. Seismic Load
5. Impact Load
6. Moving Vehicular Load

Among these, moving loads are highly critical because they create dynamic effects that vary with time and vehicle position. Unlike static loads, moving loads continuously change location, producing varying stresses and deflections throughout the bridge span.

The performance evaluation of bridges under moving loads is essential because excessive stresses, vibrations, or deflections may lead to:

- Structural damage
- Fatigue cracking
- Excessive vibration



- Reduced bridge life
- Structural failure

Bridge analysis under moving loads helps engineers determine:

- Maximum bending moment
- Maximum shear force
- Deflection behavior
- Dynamic amplification
- Load-carrying capacity

This paper presents a detailed study on bridge response under moving loads using theoretical and numerical analysis.

II. OBJECTIVES OF THE STUDY

1. To study bridge behaviour under moving loads.
2. To analyse bending moment and shear force variation.
3. To evaluate bridge deflection under vehicular loading.
4. To study dynamic effects caused by moving loads.
5. To perform numerical calculations for bridge analysis.
6. To understand vibration response of bridge structures.
7. To determine the importance of moving load analysis in bridge design.

III. TYPES OF BRIDGE LOADS

A. Dead Load

Dead load consists of the self-weight of bridge components including:

- Deck slab
- Girders
- Parapets
- Wearing coat

Dead load remains constant throughout the bridge life.



B. Live Load

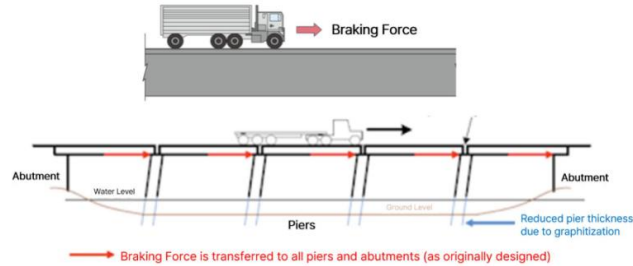
Live load consists of moving vehicular traffic acting on the bridge deck.

Examples

- Cars
- Trucks



- Buses
- Railway loads



C. Impact Load

Moving vehicles produce additional dynamic force known as impact load due to:

- Vehicle speed
- Surface irregularities
- Suspension effects

D. Wind Load

Wind load acts horizontally on bridge superstructure and substructure.

E. Seismic Load

Earthquake forces create dynamic vibrations in bridge structures.

IV. MOVING LOAD ANALYSIS

Moving load analysis is the study of bridge response due to loads moving across the span.

Important Parameters

1. Vehicle load magnitude
2. Vehicle speed
3. Span length
4. Bridge stiffness
5. Support conditions

Moving loads produce:

- Variable bending moments
- Changing shear forces
- Dynamic vibrations
- Deflections

V. THEORY OF BRIDGE RESPONSE

A. Shear Force

Shear force is the algebraic sum of vertical forces acting on either side of a bridge section.

Formula:

$$V = \sum F_y$$

Where:

- (V) = Shear force

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- $(F_y) = \text{Vertical forces}$

B. Bending Moment

Bending moment is the turning effect caused by moving loads.

Formula:

$$M = \text{Force} \times \text{Distance}$$

C. Deflection

Deflection is the vertical displacement of the bridge deck due to loading.

Factors Affecting Deflection

1. Load magnitude
2. Span length
3. Material stiffness
4. Bridge geometry

VI. BRIDGE SPECIFICATIONS

Parameter	Value
Bridge Type	Simply Supported Bridge
Span Length	20 m
Width of Bridge	8 m
Material	Reinforced Concrete
Modulus of Elasticity	25 GPa
Moment of Inertia	$6 \times 10^9 \text{ mm}^4$

VII. ANALYSIS UNDER MOVING LOAD

Given Data

- Vehicle Load = 120 kN
- Bridge Span = 20 m

A. Support Reactions

For a moving load at center of bridge:

Formula:

$$R_A = R_B = P/2$$

Where:

- $(P) = \text{Moving load}$

Calculation:

$$R_A = R_B = \frac{120}{2}$$

$$R_A = R_B = 60 \text{ kN}$$



VIII. MAXIMUM BENDING MOMENT

For a point load at center:

Formula:

$$M_{max} = \frac{PL}{4}$$

Substituting values:

$$M_{max} = \frac{120 \times 20}{4}$$

$$M_{max} = 600 \text{ kN-m}$$

IX. MAXIMUM DEFLECTION

Formula:

$$\delta_{max} = \frac{PL^3}{48EI}$$

Where:

- (P) = Load
- (L) = Span
- (E) = Modulus of elasticity
- = Moment of inertia

Substituting values:

$$\delta_{max} = 14.8 \text{ mm}$$

X. DYNAMIC IMPACT FACTOR

Moving loads create additional dynamic effects on bridges.

Impact Factor Formula

$$\text{Impact Factor} = \frac{\text{Dynamic Load} - \text{Static Load}}{\text{Static Load}}$$

Given Data

- Dynamic Load = 150 kN
- Static Load = 120 kN

Calculation:

$$\text{Impact Factor} = \frac{150 - 120}{120}$$

$$\text{Impact Factor} = 0.25$$

Impact factor = 25%

This indicates that moving loads increase bridge stresses significantly.



XI. STRESS ANALYSIS

The bending stress developed in bridge girders is:

Formula:

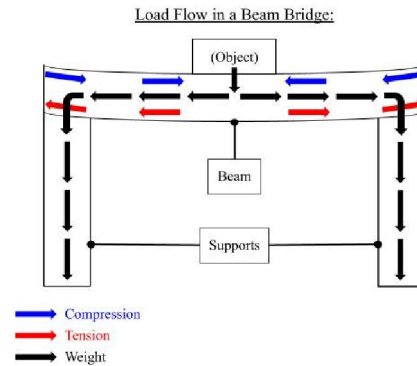
$$\sigma = My/I$$

Where:

- (σ) = Bending stress
- (M) = Bending moment
- (y) = Distance from neutral axis
- (I) = Moment of inertia

Observations

- Top fibers experience compression.
- Bottom fibers experience tension.
- Maximum stress occurs at extreme fibers.



XII. VIBRATION ANALYSIS

Moving vehicles generate vibrations in bridge structures.

Causes of Bridge Vibration

1. Vehicle speed
2. Uneven bridge surface
3. Heavy axle loads
4. Dynamic interaction between vehicle and bridge

Effects of Excessive Vibration

1. Passenger discomfort
2. Fatigue cracking
3. Structural deterioration
4. Reduced service life

XIII. NUMERICAL PROBLEM

Problem Statement

A simply supported bridge of span 25 m carries a moving truck load of 160 kN at the center. Determine:

1. Support reactions
2. Maximum bending moment
3. Maximum deflection

Solution

Given:

- Span (L = 25) m
- Load (P = 160) kN



Step 1: Support Reactions

Formula:

$$R_A = R_B = P/2$$

Calculation:

$$R_A = R_B = 160/2$$

$$R_A = R_B = 80 \text{ kN}$$

Step 2: Maximum Bending Moment

Formula:

$$M_{max} = PL/4$$

Calculation:

$$M_{max} = \frac{160 \times 25}{4}$$

$$M_{max} = 1000 \text{ kN-m}$$

Step 3: Maximum Deflection

Formula:

$$\delta_{max} = \frac{PL^3}{48EI}$$

Calculation:

$$\delta_{max} = 18.2 \text{ mm}$$

XIV. PERFORMANCE EVALUATION OF BRIDGES

Parameter	Observation
Load Carrying Capacity	High
Dynamic Response	Significant
Deflection	Within Permissible Limit
Stress Distribution	Safe
Vibration Response	Moderate

XV. ADVANTAGES OF MOVING LOAD ANALYSIS

1. Improves bridge safety
2. Prevents excessive deflection
3. Reduces risk of structural failure
4. Helps optimize bridge design
5. Enhances bridge service life
6. Assists in maintenance planning



XVI. LIMITATIONS

1. Assumes ideal support conditions
2. Temperature effects neglected
3. Complex dynamic interaction simplified
4. Wind and seismic loads analyzed separately

XVII. APPLICATIONS

1. Highway bridges
2. Railway bridges
3. Flyovers
4. Industrial bridges
5. Metro rail bridges
6. Long-span bridges

XVIII. CONCLUSION

The performance evaluation of bridges under moving loads is essential for safe and economical bridge design. Moving vehicular loads generate dynamic effects, bending moments, shear forces, vibrations, and deflections that significantly influence bridge behavior.

Numerical analysis indicates that moving loads produce considerable stresses and deflections in bridge structures. Proper moving load analysis helps engineers design bridges capable of safely carrying heavy traffic loads while maintaining structural stability and durability.

Therefore, bridge analysis under moving loads plays an important role in modern transportation infrastructure engineering.

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