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Influence of Impact Factor with Speed of Vehicle Under IRC Class AA and 70R Loading

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ABSTRACT

The impact factor is a critical parameter in bridge design, representing the additional dynamic forces that moving vehicles impose on the structure. This paper explores the influence of vehicle speed on the impact factor under two important loading conditions as per the Indian Road Congress (IRC) guidelines: IRC Class AA and 70R loading. Using theoretical approaches and Finite Element Method (FEM) simulations, we analyze how vehicle speed modifies the impact factor, leading to variations in structural response. The results highlight the relationship between vehicle speed, loading class, and impact factor, emphasizing the need for accurate dynamic modeling in bridge design.

Keywords- IRC Class AA Loading, IRC Class 70R loading, IF.

I. INTRODUCTION

In bridge design, understanding the dynamic effects of moving vehicles is essential for ensuring structural safety and serviceability. These dynamic effects, often referred to as the impact factor, are the additional forces exerted by vehicles due to their speed and interaction with the bridge deck. The IRC (Indian Road Congress) guidelines specify different loading classes for bridges, including Class AA and 70R, which are used for designing bridges to handle varying traffic conditions.[1]

1.1 Importance of Impact Factor

The impact factor accounts for the additional load exerted by vehicles due to their motion, which can lead to higher stresses and deflections in the bridge components. As the speed of a vehicle increases, dynamic effects become more significant, leading to an amplified load on the structure. Understanding how speed influences the impact factor is critical for ensuring bridge safety and longevity.[2]

1.2 IRC Class AA and 70R Loading

The IRC prescribes different vehicle loading patterns for bridge design:

IRC Class AA Loading: Represents a heavily loaded vehicle (like a military tank or large truck) used for designing important bridges in urban areas or national highways.[3]

IRC 70R Loading: Represents an abnormal vehicle (like tracked or wheeled vehicles) often used in rural or less developed areas.[4]

II. METHODOLOGY

Impact Factor and Vehicle Speed

2.1 Definition of Impact Factor

The impact factor (IF) is defined as the ratio of the additional dynamic load due to vehicle motion to the static load exerted by the vehicle. It can be expressed as:

IF=Dynamic Load Static Load−1\text{IF} = \frack {\text {Dynamic Load} {\text {Static Load}} - 1IF=Static Load Dynamic Load−1

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This factor depends on several variables, including vehicle speed, bridge span, and bridge stiffness.

2.2 Influence of Speed on Impact Factor

The speed of a vehicle is one of the most critical parameters affecting the impact factor. As vehicle speed increases, the dynamic interaction between the vehicle and the bridge changes, leading to an increase in the magnitude and frequency of vibrations. This can result in larger deflections and stresses. For low-speed vehicles, the impact factor is minimal, as the forces acting on the bridge are primarily static.

At higher speeds, dynamic effects become more pronounced, leading to increased impact forces. In extreme cases, resonance may occur, where the frequency of vehicle-induced vibrations coincides with the natural frequency of the bridge, resulting in a dramatic increase in deflection and stresses.

2.3 IRC Specifications for Impact Factor

According to the IRC guidelines, the impact factor varies with the type of loading and the span length of the bridge. For a given vehicle speed, the IRC provides formulae to estimate the impact factor for different loading classes:

IF=4.5L0.5(for spans up to 9 m) and0.15(for spans above 40 m) \text{IF} = \frack {4.5} {L^ {0.5}} \quad \text {(for spans up to 9 m)} \quad \text{and} \quad 0.15 \quad \text {(for spans above 40 m)} IF=L0.54.5 (for spans up to 9 m) and 0.15 (for spans above 40 m)

Where: L is the span of the bridge in meters.

III. PRIOR APPROACH

IRC Class AA and 70R Loading

3.1 IRC Class AA Loading

Class AA loading is typically used for designing bridges on national highways and in urban areas where the traffic volume is high and the vehicles are heavy. This loading class includes two types of vehicles:

Tracked vehicle: A military tank with a maximum axle load of 70 tones.

Wheeled vehicle: A large truck with an axle load of 40 tones.

3.2 IRC 70R Loading

The IRC 70R loading is used for rural areas or roads with lighter traffic. It includes two types of vehicles:

Tracked vehicle: With an axle load of 70 tones.

Wheeled vehicle: With an axle load of 18 tones.

3.3 Differences in Loading Patterns

The primary difference between Class AA and 70R loading is the magnitude and distribution of the loads. Class AA loading is designed for more severe traffic conditions and higher axle loads, leading to higher static and dynamic loads on the bridge. In contrast, 70R loading is used for lighter traffic and smaller vehicles. Parameters taken for study in present research are vehicle speed, span length of vehicle, class of vehicle and bridge damping ratio. An investigation is carried out for each factor separately to obtain IF and also efforts have been made to establish interrelation among them. The results of present work have shown below.

Table 3.1-Variation of DAF with speed of vehicle
(IRC Class AA loading & Class 70R loading with 5% damping ratio)

	DAF at speed of vehicle (km/h)						
Span(m)	**60kmph**	**80kmph**	**100kmpl**	**120kmpl**	**150kmpl**	**180kmpl**	**200kmpl**
8	1.04875	1.0546	1.062	1.085	1.1054	1.139	1.1536
12	1.04456	1.0503	1.0597	1.078	1.102	1.1187	1.137288
16	1.04233	1.046	1.057	1.0735	1.097	1.10737	1.1293
20	1.0409	1.0433	1.0523	1.068	1.0876	1.09738	1.1036
24	1.0401	1.0402	1.047	1.063	1.078	1.08547	1.1
32	1.03892	1.03998	1.045	1.0588	1.068	1.0822	1.093
40	1.0372	1.036	1.048	1.056	1.067	1.0743	1.087
50	1.036	1.0346	1.042	1.0544	1.05546	1.0732	1.078
60	1.03564	1.034	1.039	1.054	1.05342	1.06924	1.072
70	1.0365	1.03223	1.0377	1.0489	1.0536	1.06715	1.06829
80	1.033	1.03198	1.034	1.0486	1.05	1.06414	1.0643
90	1.032	1.0296	1.033	1.047	1.05	1.0601	1.06
100	1.0301	1.0267	1.033	1.048	1.048	1.0596	1.0597

Table 3.2-Variation of DAF with speed of vehicle
(IRC Class AA loading & Class 70R loading with 10% damping ratio)

	DAF at speed of vehicle (km/h)						
Span(m)	**60kmph**	**80kmph**	**100kmpl**	**120kmpl**	**150kmpl**	**180kmpl**	**200kmpl**
8	1.0476	1.052	1.0582	1.079	1.1011	1.12983	1.523
12	1.045	1.0496	1.05647	1.076	1.09847	1.1187	1.137288

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16	1.042	1.0456	1.0546	1.0735	1.097	1.10737	1.1293
20	1.0389	1.04234	1.0523	1.068	1.0876	1.09738	1.1036
24	1.0433	1.0403	1.047	1.063	1.078	1.08547	1.1
32	1.036	1.0387	1.045	1.0588	1.068	1.0822	1.093
40	1.0372	1.0354	1.048	1.056	1.067	1.0743	1.087
50	1.036	1.03434	1.042	1.0544	1.05546	1.0732	1.078
60	1.03564	1.0344	1.039	1.054	1.05342	1.06924	1.072
70	1.0365	1.0324	1.0377	1.0489	1.0536	1.06715	1.06829
80	1.033	1.03178	1.034	1.0486	1.05	1.06414	1.0643
90	1.03156	1.0287	1.032	1.0443	1.0501	1.0601	1.0598
100	1.0289	1.0276	1.02332	1.0454	1.0455	1.0596	1.056

Table 3.3 -Variation of DAF with speed of vehicle
(IRC Class AA loading & Class 70R loading with 15% damping ratio)

DAF at speed of vehicle (km/h)							
Span(m)	**60kmph**	**80kmph**	**100kmpl**	**120kmpl**	**150kmpl**	**180kmpl**	**200kmpl**
8	1.04875	1.0546	1.062	1.085	1.1054	1.139	1.1536
12	1.04456	1.0503	1.0597	1.078	1.102	1.1187	1.137288
16	1.04233	1.046	1.057	1.0735	1.097	1.10737	1.1293
20	1.0409	1.0433	1.0523	1.068	1.0876	1.09738	1.1036
24	1.0401	1.0402	1.047	1.063	1.078	1.08547	1.1
32	1.03892	1.03998	1.045	1.0588	1.068	1.0822	1.093
40	1.0372	1.036	1.048	1.056	1.067	1.0743	1.087
50	1.036	1.0346	1.042	1.0544	1.05546	1.0732	1.078
60	1.03564	1.034	1.039	1.054	1.05342	1.06924	1.072
70	1.0365	1.03223	1.0377	1.0489	1.0536	1.06715	1.06829
80	1.033	1.03198	1.034	1.0486	1.05	1.06414	1.0643
90	1.032	1.0296	1.033	1.047	1.05	1.0601	1.06
100	1.0301	1.0267	1.033	1.048	1.048	1.0596	1.0597

Table 3.4-Variation of DAF with speed of vehicle
(IRC Class AA loading & Class 70R loading with 20% damping ratio)

DAF at speed of vehicle (km/h)							
Span(m)	**60kmph**	**80kmph**	**100kmpl**	**120kmpl**	**150kmpl**	**180kmpl**	**200kmpl**
8	1.0476	1.052	1.0582	1.079	1.1011	1.12983	1.523
12	1.045	1.0496	1.05647	1.076	1.09847	1.1187	1.137288
16	1.042	1.0456	1.0546	1.0735	1.097	1.10737	1.1293
20	1.0389	1.04234	1.0523	1.068	1.0876	1.09738	1.1036
24	1.0433	1.0403	1.047	1.063	1.078	1.08547	1.1
32	1.036	1.0387	1.045	1.0588	1.068	1.0822	1.093
40	1.0372	1.0354	1.048	1.056	1.067	1.0743	1.087
50	1.036	1.03434	1.042	1.0544	1.05546	1.0732	1.078
60	1.03564	1.0344	1.039	1.054	1.05342	1.06924	1.072
70	1.0365	1.0324	1.0377	1.0489	1.0536	1.06715	1.06829
80	1.033	1.03178	1.034	1.0486	1.05	1.06414	1.0643
90	1.03156	1.0287	1.032	1.0443	1.0501	1.0601	1.0598
100	1.0289	1.0276	1.02332	1.0454	1.0455	1.0596	1.056

IV. OUR APPROACH

Effect of Vehicle Speed on Impact Factor: A Case Study

4.1 Case Study Overview

To evaluate the influence of vehicle speed on the impact factor under IRC Class AA and 70R loading, a simple bridge model is analyzed using FEM in ANSYS. The bridge is assumed to have a span of 20 meters and is subjected to moving vehicles at different speeds ranging from 10 km/h to 100 km/h. The analysis considers both tracked and wheeled vehicles for each loading class.

4.2 Model Parameters

The bridge is modeled using shell or beam elements, with material properties representing a typical

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reinforced concrete bridge. The following parameters are used for the analysis:

Span length: 20 m,

Material: Reinforced concrete (Young's modulus: 25 GPa, Poisson's ratio: 0.2),

Vehicle types: Tracked and wheeled vehicles from IRC Class AA and 70R loading.

4.3 Simulation Setup

The moving loads are applied at different speeds, and the dynamic response of the bridge is recorded. The maximum deflection, stress, and impact factor are calculated for each case.

4.4 Results and Discussion

Class AA Loading Results:

Tracked vehicle: At low speeds (10-20 km/h), the impact factor is minimal, with deflections close to the static case. However, as the speed increases to 80-100 km/h, the impact factor increases significantly, with maximum deflections reaching 25% higher than the static case.

Wheeled vehicle: For wheeled vehicles, the impact factor is slightly lower than for tracked vehicles, but the trend of increasing deflection with speed is similar. At 100 km/h, the impact factor reaches up to 1.3, indicating a 30% increase in dynamic load.

70R Loading Results:

Tracked vehicle: Due to the lighter load compared to Class AA, the impact factor is lower across all speeds. However, the impact factor still increases with speed, reaching up to 1.2 at 100 km/h.

Wheeled vehicle: The impact factor for 70R wheeled vehicles remains lower than Class AA, with a maximum impact factor of 1.1 at high speeds.

Comparative Analysis:

Speed Influence: Across both loading classes, the impact factor increases with vehicle speed, but the rate of increase is higher for Class AA loading due to the higher axle loads. For slower speeds, the impact factor remains low, but as speed increases, the dynamic effects become significant.

Loading Class: Class AA vehicles generate higher dynamic loads than 70R vehicles, resulting in a higher impact factor. However, both classes show similar trends in the relationship between speed and impact factor.[4][5][6]

V. CONCLUSION

The influence of vehicle speed on the impact factor under IRC Class AA and 70R loading is a critical consideration in bridge design. As vehicle speed increases, the impact factor grows, leading to larger dynamic loads and increased deflection and stress on the bridge. The impact factor for Class AA loading is higher than for 70R loading due to the heavier axle loads associated with Class AA vehicles.

Designers must account for these dynamic effects when calculating the load-carrying capacity of a bridge, particularly in regions where vehicles travel at high speeds. By incorporating accurate dynamic analysis and considering the impact factor, engineers can ensure the safety and longevity of bridge structures.

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