DETERMINATION OF CRITICAL LOADING ON A SLAB CULVERT BY COMPARING INDIAN CODE (IRC) AND BRITISH CODE (BS)

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ABSTRACT

Mumbai is a densely populated city in India with the problem due to traffic congestions is rapidly increasing. The development of infrastructure would diminish these congestion problems. In this research paper, culvert slab design has been carried out, pertaining to critical load. This article details the comparative analysis of live load on the deck of a slab culvert by Indian Roads Congress (IRC) and British Standard (BS) code of practice. The loads causing the adverse effects in each code are identified to be Class AA tracked (IRC) for Indian code and HB loading (BS) for British code. On comparative analysis between the two codes the critical loading was found to be for BS- HB loading.

Further this extreme condition can be made as the design criteria for bridges, to cope up with the adverse conditions created by any vehicular class pertaining to IRC and BS.

KEYWORDS: Critical Loading, Slab Culvert, Indian Code (IRC), British Code (BS).

INTRODUCTION

India is one of the largely populated countries in the world, where the population in 2001 had increased 4 fold as compared to 1901 [8, p4 Table 1]. Therefore in such places the need for infrastructure is of prime importance. Mumbai being its financial capital, a seamless transportation network would substantially boost its operational efficiency. Thus structures such as bridge gain dominance over conventional roadways. A culvert is small bridge which spans up to 6m. It may be subjected to the heaviest of loadings as per the location and the diversity in traffic. In this paper, the Indian and British codes have been compared for various loads to find the critical loadings. This study of relative comparison between the codes is adopted by detailed manual calculations [9].

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The main aim of this research paper is to enhance the knowledge of slab culvert design criteria with simpler understanding.

**METHODOLOGY**

For the analysis of critical loading, a slab culvert of 6m span and 7.5m width has been chosen. Preliminary dimensions based on the design parameters are computed and the loading standards as per respective codes are analysed [Flowchart: 1]. Initially loads causing the adverse effects are identified for each code. Finally the critical loading is determined by comparative analysis of live load bending moments and shear force.

![Flowchart](image)

**DESIGN PARAMETERS**

The design criterion for any bridge depends upon its span and width of carriageway [5]. With this data, a structural designer can propose the most efficient and economical bridge. The selected data for the relative comparison between the codes is as follows.

- Clear Span: 6m
- Carriageway width: 7.5m
- Sidewalk: 1m (both sides)
- Bearings: 400mm [7, p119]
- Wearing Coat: 80mm

**PRE-LIMINARY DIMENSIONS**

On the basis of the design parameters these basic dimensions of the slab are taken.

**DEPTH (D)**

The thickness of the slab is taken in the range of 80-90mm per m span of slab. The larger depth is needed for small spans to satisfy the shear criteria [7, p118].

\[
D = \frac{80 \text{mm}}{\text{m length of span}} \\
= 80 \times 6 \\
= 480\text{mm}
\]
Provide $D = 550\text{mm}$

Taking effective cover = $50\text{mm}$

Effective depth ($d$) = $500\text{mm}$

**EFFECTIVE LENGTH OF SPAN ($L_{\text{eff}}$)**

As per IS: 456, Clause 22.2 p34,

For a simply supported span, its effective length ($L_{\text{eff}}$) is lesser of

(i)[$\text{Clear span} + \text{effective depth (lc+d)}]=6.55\text{m}$

(ii)[$\text{Clear span} + \text{width of supports (lcc)}]=6.4\text{m}$

$L_{\text{eff}}=6.4\text{m}$

**LOADING STANDARDS**

The design of superstructure depends up on various loading conditions, which the component must withstand conforming to the serviceability criteria. In order to form a consistent basis for the design of bridges, the various loadings classified by the Indian Roads Congress (IRC) and the British Standard (BS) are explained in detailed.

**THE INDIAN ROADS CONGRESS (IRC): STANDARDS**

Prescribed in IRC: 6-2000 are four categories of loadings as follows:

**IRC CLASS AA LOADING: [2, CLAUSE 207.1, PP. 10-11]**

It consists of a tracked type of vehicle simulating an army tank of 700kN and a wheeled type representing a heavy duty vehicle of 400kN.

**IRC CLASS 70R LOADING: [6, PP. 20-21]**

In addition to the above two types, it also includes a train of vehicles on seven axles with a total load of 1000kN.

**IRC CLASS A LOADING: [2, CLAUSE 207.1, P12]**

Class A consists of a heavy duty truck with two trailers having axle loads ranging from 114kN to 27kN.

**IRC CLASS B LOADING: [2, CLAUSE 207.1, P13]**

Similar to Class A, Class B has the same axle configuration but of lower specifications of loads ranging from 68kN to 16kN.

**THE BRITISH STANDARD (BS): STANDARDS**

Prescribes two main loadings in BS 5400: Part2: 1978 as follows:

**HA LOADING: [1, CLAUSE 6.2, P32]**

It represents normal traffic in Britain consisting of a uniformly distributed load of 30kN (for loaded lengths up to 30m) and a knife edge load of 120kN.

**HB LOADING: [1, CLAUSE 6.3, P33]**

It represents very heavy abnormal loadings for various axle configurations. The number of units of HB loading ranges from 25-45, with each unit equal to 10 kN per axle.

**LOAD ANALYSIS**

For the given width of carriageway of 7.5m, two notional lanes of BS (BS 5400-2 1987 Clause 3.2.9.3.1, p2) and two lanes pertaining to IRC (IRC 6-2000, Table 2, p14) can be accommodated. Taking into account the no of lanes and the respective loading for each code, the critical loading is determined.

**INDIAN ROADS CONGRESS (IRC): LOAD ANALYSIS**

Between Class A and B of IRC, Class A would produce the worst effects for a bridge as it has the higher loadings for the same axle configuration [2, Clause 207.1, pp. 12-13]. In Class AA, the tracked type produces the adverse effects [2, Clause 207.1, pp. 10-11]. Similarly in Class 70R, the tracked type exhibits the limiting case for design considerations [6, pp. 20-21]. And among the above four classes,
the critical case becomes of Class AA tracked for the given span and width.

**BRITISH STANDARD (BS): LOAD ANALYSIS**

For standard road conditions, the HA loading is adopted for design. However for abnormal or exceptional loading conditions, the HB loading becomes the governing criteria. Hence in order to include the worst combination of loads for the design, the HB loading is adopted for a minimum inner axle spacing of 6m to produce the adverse effects [1, 6.3.1, p. 33].

**LIVE LOAD BENDING MOMENT AND SHEAR FORCE**

For the design of any structural element, shear force and bending moment are the two most important parameters. To obtain maximum bending moment, the loads are placed in the central zone of the span.

The maximum shear force for a simply supported span occurs at the supports. Hence the vehicle is such place that the load dispersion just touches the support, forming the critical case. Ultimate limit state considers the strength of the structure up to failure. Whereas the serviceability limit state considers the functional characteristics of a structure rendering it unfit for use. Hence we adopt the serviceability criteria to find the design bending moment and shear force, to ensure that the design is within the permissible limits of cracking and deflection. Free Body Diagrams (FBD’s) have been used to manually calculate the bending moment and shear force for the respective cases.

**IRC (CLASS AA TRACKED)**

(a) Load=700kN [2, Clause 207.1, p10]

(b) Impact allowance=19.75% [2, Clause 211.3, p22]

Impact Factor (I.F) =1.198

Impact force = I.F *Load

=838.25kN

(c) Dispersion effect [3, B3. P.278]

i) Effective length of slab on which Load acts ($l_{ef}$)

$$l_{ef} = \frac{\text{Contact Area} + 2(D_{slab} + d_{count})}{u}$$

=4.86m

ii) Effective width of slab on which load act ($b_e$)

$$b_e = a.a.\left(1 - \frac{a}{l_e}\right) + b$$

where,

$$\alpha = \text{constant, depends upon ratio}\ \frac{b}{l_e}$$

b = width of the slab

a = distance of c. g. of concentrated load from the nearer support

a= 3.20m (from fig 7.1.1 - for BM)

a= 2.43m (from fig 7.1.2- for SF)

$L_e$ = effective span i. e. $L_{ef}$

$$b_1 = \frac{\text{Contact Area} + 2(d_{count})}{u}$$

$b_2$ = 5.554m (for Bending moment calculation)

$b_3$ = 5.291m (for shear force calculation)

iii) Net effective width of slab on which load Acts ($b_{ef}$)

$b_{ef}$ = 7.452m (for BM calculation)

$b_{ef}$ = 7.321m (for SF calculation)

(d) Uniformly distributed load per m width

$$Udl = \frac{\text{Impact Force}}{L_{ef}}$$

Udl= 23.145kN/m (for BM calculation)

Udl= 23.560kN/m (for SF calculation)

(e) Bending Moment (BM): IRC
For maximum bending moment, the uniformly distributed load is centrally applied over the effective length of slab per m width as shown in fig 1.

Form the above figure, the computed BM is,

\[ BM = 111.644 \text{kN-m} \]

(f) Shear Force (SF): IRC

Similarly for maximum shear force, the uniformly distributed load is applied near the support. From the above figure the maximum shear force is developed at reaction RL.

\[ SF = 71.027 \text{kN (RL)} \]

BS (HB LOADING)

(a) No. of units = 30 [1, Clause 6.3, p. 33]

(b) Load per unit = 10kN/axle [1, Clause 6.3.1, p.33]

(c) Total load per axle = 300kN

(d) Axle Consideration

The fore axle for the shortest vehicle will produce the adverse effects for the given span [1, p. 34].

Bending Moment (BM): BS

For max bending, the load is placed such that the distance between the c. g. of loads and the nearest axle is bisected by the mid span as shown in fig 3.

Hence the moment at mid span is,

\[ BM = 690.002 \text{kN-m} \]
(f) Shear Force (SF): BS

For maximum shear force the load is placed at a distance ‘$D_{slab} + d_{coat}$’ (0.63m) from support as shown in fig 4.

The maximum shear is obtained at reaction RL,

$SF = 456.563$ kN

(g) Considering Serviceability Criteria,

$Y_s = 1.1$ [1, Clause 6.3.4, p33]

Design BM = 759.002 kN-m

Design SF = 502.219 kN

RESULT AND DISCUSSION

As per IRC: 6-2000 Live load Combination, Table 2, p14, for carriageway of 7.5m, two lanes can be considered for the design purpose. This criterion also conforms to BS: 5400 Part 2: Specification for Loads 1987 Clause 3.2.9.3.1, p2. With the same preliminary dimensions, various loadings for each code were analysed.

And for Indian Road Congress (IRC), the adverse load was found to be Class AA tracked. While that for British Standard (BS) was HB loading. As per the BS loading, over 4 fold factored live load bending moment was incurred as compared to the IRC loading. And the factored shear force obtained by the IRC (Class AA tracked) is only 21.214% of the shear obtained by the BS (HB) loading. This indicates that the design by the BS code of practice would require very high design specification as compared to that by the IRC code (Table: 1). By considering the serviceability criteria, the factor of safety taken by the BS code of practice for HB loading (Combination 1) is 1.1. Similarly, by the IRC code of practice, factor of safety is 1.5 (in reference to IS 456). This suggests that the design by the IRC code would be safer and that by the BS code would be more economical, for the respective loadings. Overall as the load specification by the BS-HB loading dictates over the IRC- Class AA tracked, the design of bridges by the British code is favoured.

<table>
<thead>
<tr>
<th>Code</th>
<th>Governing Class</th>
<th>Factored live Load Bending Moment (Kn-M)</th>
<th>Factored live Load Shear Force (Kn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRC</td>
<td>AA TRACKED</td>
<td>167.466</td>
<td>106.54</td>
</tr>
<tr>
<td>BS</td>
<td>HB</td>
<td>759.002</td>
<td>502.219</td>
</tr>
</tbody>
</table>

CONCLUSION

The governing load for the IRC code of practice was found to be Class AA tracked and that for the BS code of practice was HB loading. From the comparative analysis of live load bending moment and shear force, we find that the BS-HB loading becomes the critical loading criteria for design of a slab culvert. Also for the respective loadings, the IRC code of practice considers more safety and the BS code of practice favours economy. Overall to cope up with the adverse conditions created by any
vehicular class pertaining to IRC and BS, the design by BS-HB loading can be taken.

REFERENCES