Calculation of Bridge Safety Factor in India

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Abstract— The manufacturing of constructions in development area is past the different industrial efficiency. This looks to be trouble in development subject to solve. The introduction of PLM (Project Lifecycle Management) to development enterprise can be the answer for the problem. There are a number duties and steps in the building industry, and PLM is a gadget that can unify and manage them. Under PLM system, evaluation and diagram is the most vital issue, and these days BIM (Building Information Modeling) is clue to clear up for the issue. BIM is a 3D based totally modeling technique that consists of facts on consecutive work processes; planning, design, construction, and maintenance. In this study, the gadget of evaluation and graph applicable to PLM and BIM was once proposed and this device was once utilized to a standard civil structure, RC bridge column.

Keywords: Bridge Safety, PLM (Project Lifecycle Management), BIM (Building Information Modeling)

I. Introduction

Bridges are the constructions that spans are horizontally between the support, and the characteristic of the bridge is to lift vertical loads, so the vertical hundreds can be pointed or disbursed load. The prototypical bridge is pretty easy for two helps preserving up the beams. The assist should be robust ample to lift the structural loads. Spans constantly designed as quick as possible; also, lengthy spans are justified a top foundation. Bridges are vital to each and every modern-day highway. But they are no longer viewed or understood in the equal way thru everyone. There are kinds of bridges with exclusive materials. Most of the people, when they are going to the job or different places, tour over the bridge every day, so they don't recognize the bridge, however they simply appear the roadway railing on the different side. The earliest bridge used to be stepping stones, and it was once the easiest one bridge ever.

A. Types of Bridges

- There are seven kinds of bridge designs that have been tailored and improved over the years.
- Although the truss bridges layout is considered as the strongest suspension bridge graph is the one which can supply stretch utmost.
- The most luxurious bridge is the suspension bridge with these days. There are special kinds of bridges, whilst typically, their constructions can be to one of the seven major types.

1) BEAM BRIDGES

Fig. 1: Beam bridges

2) TRUSS BRIDGES

Fig. 2: Truss bridges

3) CANTILIVER BRIDGES

Fig. 3: Cantiliver bridges

4) ARCH BRIDGES

Fig. 4: Arch Bridges

5) TIED ARCH BRIDGES

Fig. 5: Tied Arched bridges

6) SUSPENSION BRIDGES

Fig. 6: Suspension bridges

7) CABLE STAND BRIDGES

Fig. 7: Cable stand bridge

II. BRIDGE SAFETY FACTOR CALCULATION METHODOLOGY:

For the assessment of protection of bridges used in Europe and the United States ("ultimate restrict state"), a bridge safety factor is calculated thinking about the elements stated above. The bridge protection issue shows whether or not the bridge is safe to function below sure damages, defects, and visitors flows, or whether or not it is unsafe, and it is quintessential to restriction the total weight of heavy vehicles. Process to compose assumptions for calculating the protection thing of bridges have been started seeing that 1970. American (Nowak, A. S. and Gruni, H. N., 1994; Frangopol, D. E. and Estes, A. C., 1997) and Canadian (Allen, D. E., 1992; Bartlett, F. M., Buckland, P. G., Kennedy, D. J., 1992) scientists have paid much attention to the coaching of assumptions in their lookup works. The American Bridge Design Standard (AASHTO, 2010) offers the following system for calculating the bridge safety factor:

$$RF = \frac{\phi_c \phi_s \phi R_n - (\gamma_{DC} DC + \gamma_{DW} DW)}{\gamma_{LL}(LL + IM)}$$

where: ϕc – situation aspect (usually is assumed as 1.0); ϕs – gadget issue (usually is assumed from 0.85 until 1.0); ϕ –resistance aspect (if no evaluation carried out, assumed as 1.0); Rn – nominal resistance of bridge deck; γDC – load element for structural factors and attachments (usually is assumed as 1.25); DC – lifeless load of structural aspects and nonstructural attachments; γDW – load thing for carrying surfaces and utilities (usually is assumed as 1.50); DW – lifeless load of sporting surfaces and utilities; γLL – load aspect for stay masses (1 table); LL – vehicular stay load; IM – vehicular dynamic load allowance (2 table).

Table 1. Load factors for live loads (γ_{LL})

Heavy duty vehicles	Load factor for live loads	Number of heavy vehicles per day ≤1000	Number of heavy vehicles per day ≥1000	Unknown number of heavy vehicles
Routine vehicles	γ_{LL}	1.65	1.80	1.80
Special permits vehicles	γ_{LL}	1.40	1.50	1.50

Table 2. Dynamic load allowance (IM)

Bridge span	IM
Bridge span 40 m or less	33%
Bridge span more than 40 m – smooth carriageway wearing surface without defects in deck joints	10%
– small irregularities in carriageway wearing surface	20%
– rough carriageway wearing surface, high impulses when moving heavy vehicles	30%

Scientists at the National Building and Civil Engineering Institute have developed a methodology for calculating the safety factor of bridges. For bridges built in this country, their safety factor is calculated using the following expression:

$$RF = \frac{\Phi \cdot R_d - \gamma_G \cdot G_n}{\gamma_Q \cdot G_Q \cdot DAF}$$

where: Φ – bridge deck potential discount factor; Rd – diagram resistance of bridge deck; Gn – attribute fee of permanent action; GQ – attribute fee of variable action; γQ – load thing for variable masses (assumed according to the go with the flow of heavy cars over the bridge beneath investigation, however now not much less than 1.40); γG – load element for permanent) loads (assumed equal to 1.20); DAF – dynamic amplification factor.

In the developed methodology, the bridge deck dynamic aspect is calculated in accordance to the formulation given in German bridge plan well known (DIN 1072):

DAF = − · 1.4 0.008 L

where: L – bridge span length. The capacity reduction factor of the bridge deck is calculated using the following expression:

$$\Phi = B_R \cdot e^{-\alpha_R \cdot \beta_C \cdot V}$$

where: B_R – the bias of carrying capacity, i.e., the ratio between the true and the design mean resistances of the critical section. In most cases assumed as 1.0, if no more detailed material analysis has been performed; αR – the deterioration factor, accounting for the condition of the bridge (see Table 3); V – the coefficient of variation of the member resistance and is taken 10% when calculated from experiments, 15% when based on design information and 20% if less reliable information is used; βC – the target value of the safety index, taken 3.5 for the normal service life (up to 20 years) and 2.5 for limited service life (up to 6 years or until the next main inspection).

Table 3. Values of deterioration factor (α_R)

Class	Inspected condition	Necessary intervention	Condition rating R_c	Deterioration factor, α_R
1	Very good	No maintenance/repair work required	<5	0.3
2	Good	Regular maintenance work needed	3 – 10	0.4
3	Satisfactory	Intensified maintenance/repair work within 6 years	7 – 15	0.5
4	Tolerable	Substantial repair work needed within 3 years	12 – 25	0.6
5	Inadequate	Immediate posting and repair required	22 – 35	0.7
6	Critical	Immediate closing and repair/strengthening required	>30	0.8

An overview of the methodologies used to calculate the security thing for bridges in unique international locations of the world has shown that they have the equal fundamental parameters, however in another way measured. Each of the methodologies describes four main components: the bearing ability of bridge deck thinking about a range of factors, the results of everlasting and variable loads, and the dynamic hundreds induced by using heavy vehicles. Although these elements are similar, in America and Slovenia one of a kind partial elements are used for everlasting and variable loads, the effect of dynamic masses on the bridge is assessed differently, one-of-a-kind gadget of evaluation of the situation of the bridges, exceptional operating conditions of the bridges. As the elements stated in India are additionally different, this paper gives a methodology for calculating the security component of bridges running in India.

III. CONDITION OF BRIDGES ASSESSMENT IN INDIA

In India, the condition of bridges administered by the Indian Road Administration under the Ministry of Transport and Communications is assessed through the annual and substantive inspections, static and dynamic tests. During the annual inspection, bridges are evaluated using a five-point grading system. Each bridge element is visually inspected, and its condition assessed. The most important factor in the overall estimate of the bridge is the condition of the bearing structures. Because the static and the dynamic tests of the bridges are expensive, therefore they are carried out only for the problematic ones, and for the most of them only one or another type of inspection is carried out. Visual assessment of the condition of the bridge is not objective and sufficient to comprehensively evaluate the condition of the bridges and to plan investments for their repair, because: visual evaluation of the bridge does not always allow to avoid "human factor" errors and it is not clear what impact the defect has on the bearing capacity of the bridge, and how safe it is to operate such a structure in the future. Therefore, from 2015 to 2016, specialists from the Bridge Research Department of the Public Road and Transport Research Institute have developed a new bridge management system, in which appeared the parameter characterizing the bridge safety - the bridge safety factor.

A. Calculation of bridge safety factor in India

In the new bridge administration machine developed in India, it is proposed to calculate the bridge protection issue taking into account the security thing expressions proposed via American and Slovenian scientists, however, by using introducing the notations of everlasting and variable loads, partial thing and dynamic issue used in India. It is proposed to calculate the protection aspect of Indian bridges by way of the following expression:

$$RF = \frac{\varphi \cdot R_d - (\gamma_{G1} \cdot G_{k1} + \gamma_{G2} \cdot G_{k2} + \gamma_{G3} \cdot G_{k3})}{\gamma_Q \cdot Q_k \cdot \mu_{din.}}$$

where: φ – bridge deck potential discount factor; Rd – sketch resistance of bridge deck; Gk – attribute fee of permanent action; Qk – attribute fee of variable action; γQ – load aspect for variable loads; γG – load component for permanent loads; μdin – bridge deck dynamic factor.

The deterioration of the bridge situation is evaluated through calculating the cross section power discount index of the bridge load-bearing constructions in accordance to the following expression:

$$\varphi = \frac{1}{e^{\alpha_R}}$$

The deterioration factor of the bridge elements (αR) directly depends on the condition rating of the bridge load-bearing structures. Since this parameter cannot be expressed in points, Table 4 presents the values of the deterioration factor of the bridge load-bearing structures as a percentage of their condition rating.

Table 4. The deterioration factor values of the bridge load-bearing structures

Bridge rating, in points	Deterioration factor of bridge load-bearing structures, α_R
5	0.05
4	0.10
3	0.20
2	0.25
1	0.35

In India, the Public Road and Transport Research Institute has carried out greater than a hundred and fifty dynamic checks of various types and stipulations bridges, which precisely measured the static and dynamic deflections of the bridges decks and calculated the dynamic elements of the decks from the transferring hundreds of heavy vehicles. According to the effects of performed research, it is proposed to relate the dynamic thing of bridge decks to the ranking of the situation of the bridge deck carrying surface. The approximate equal of the bridge deck dynamic element is given in Table 5

Table 5. Approximate evaluation of bridge deck dynamic factor based on carriageway wearing surface rating in points

Rating of bridge carriageway wearing surface	Bridge deck dynamic factor, μ_{din}
5	1.02
4	1.10
3	1.15
2	1.20
1	1.30

The rating of the bridge carriageway carrying floor is described in points:

- 5 factors – clean carriageway sporting surface, no defects;
- four factors – easy carriageway sporting surface, solely with localised defects; no defects in deck joints;
- three factors – difficult carriageway carrying surface, ruts formed; small depressions fashioned in deck joints;
- two factors – hard carriageway carrying surface, localised defects at the ends of the bridge or along the sidewalk, damaged deck joints;
- 1 factor – very tough carriageway sporting surface, deep ruts formed; deep depressions shaped in the wearing surface at the midspan of bridge deck; very broken deck joints.

B. Evaluation of partial factor of permanent loads acting on the bridge

Bridges in India are designed in accordance to a range of bridge plan standards. Bridges designed in India can be divided into 5 distinctive bridge graph periods. Period I – bridges designed from 1945 to 1948. During this period, permanent masses of designed bridges had been calculated besides partial factors. Period II – from 1953 to 1962. The permanent loads of the bridges designed for the duration of this duration had been additionally calculated besides partial factors. Period III – bridges designed from 1962 to 1984. During this period, the partial aspect of designed bridge deck bearing structures, sidewalks, barriers, and handrails of the bridge was once 1.10. The partial element of bridge deck waterproofing, levelling layer, sidewalk protective coating and asphalt pavement was once 1.50. Period IV – bridges designed from 1984 to 1997. During this period, the partial factor of designed bridge deck bearing structures, sidewalks, barriers, and handrails of the bridge used to be 1.10. The partial factor of bridge deck waterproofing and levelling layer was once 1.30, and for sidewalk shielding coating and asphalt pavement it used to be 1.50. Period V – bridges designed for the reason that 1997 till these days. The partial element of bridge deck bearing structures and overlays designed all through this length and presently being designed in India is assumed to be 1.35. Because of the specific bridge graph periods, the methodology proposes to crew the bridge deck everlasting hundreds into three agencies for every bridge sketch year, and follow extraordinary partial factors:

- partial thing of bridge deck bearing structures, sidewalks, boundaries and handrails of the bridge (γG1);
- partial thing of bridge deck waterproofing and levelling layer (γG2);
- partial issue of bridge asphalt pavement and sidewalk defensive coating (γG3).

C. Evaluation of partial factor of variable loads acting on the bridge

Table 6. Calculation of partial factor for variable loads

Total daily flow of heavy vehicles	Partial factor of variable load
<250	1.40
>250<1000	1.45
>1000<5000	1.55
>5000	1.60

The evaluation of site visitors float depth in India is carried out with the aid of experts of the Road Research Department of the Institute of Road and Transport Research and is a yearly up to date database of the quantity of heavy cars passing thru one or every other monitored bridge per day.

IV. CONCLUSION:

After evaluating three vary methodology for bridge protection issue calculations it used to be located that the main differences are with nodal hundreds coefficients, bridge potential coefficients and dynamic coefficient.

The essential variations evaluating proposed methodology with Slovenian and AASHTO methodology's is that if there are troubles with bridge deck ability we do bridge dynamic trying out and for protection issue coefficient calculation we use actual bridge deck dynamic aspect however now not calculated with the aid of empirical formulas. Bridge dynamic coefficient calculated via empirical formulation relies upon by means of the size of the bridge, however in fact it relies upon via the asphalt floor and roughness.

After evaluating bridge protection elements calculated in desk 7, desk eight and desk 9 it was once discovered that the highest one is with the aid of AASHTO 2010 methodology and the lowest one is by means of methodology proposed in India.

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