POST-TENSIONED HIGHWAY BRIDGE'S SUPERSTRUCTURE INRELATION TO THE SPAN TO DEPTH RATIO

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Abstract

The slenderness ratio, or span-to-depth ratio, is a crucial design parameter for bridges that has an impact on structural behavior, construction costs, and aesthetics. According to a study of 86 constant-depth girders, conventional ratios have not changed much since 1958. Because recently developed high-strength concrete has improved mechanical properties that permit for thinnersections, these conventional ratios are now in question.[6,7] The paper finds the best ratios for a high-strength concrete 7-span highway viaduct by comparing material consumption, cost, and aesthetics. Two kinds of bridges are looked into: cast-in-situ solid slabs are cast on a false work box-girder. The results show that the span-to-depth ratio has little effect on total construction costs in the following ratio ranges:10-35 and 30-45, respectively, for thetwo types of bridges. As a result of this finding, higher ranges of ratios can now be selected without significant cost premiums, compared to conventional values (i.e., 18-23 and 22-39). This gives aesthetic expressions more freedom.[8,9]

Introduction

The bridge design is very complicated design and in the designing of bridge deck the most important parameter is span to depth ratio which is also called as slenderness ratio. This ratio is generally used to fix the superstructure depth and it is chosen during the conceptual designing before any detailed calculation performed[10]. The selection of the ratio at an early stage of the process of design gives the approximate dimension which is necessary for the analysis of bridge girders and cost efficiency and aesthetic merits of the design in comparison with alternative design concept. Span to the depth ratio is generally selected based on the field experience and some values used in previously constructed bridges with satisfactory performance[11,12]. The ratio can also be determined by optimizing the combinations of ratios and superstructure depth to create cost efficient and aesthetic structure but this requires an iterative process therefore the optimization of the span to depth ratio in every design concept, it is common to select ratios from the given ranges of conventional values. The selection of span to depth ratio is generally critical in the design of bridge with girders because the cost of materials and construction of the superstructure is directly affected by span to the depth ratio. For example, using high span to depth ratio reduces the volume of concrete and increases the requirement of prestressing force and simplifies the construction, because in a lighter structure the cost of the bridge is highly dependent on the proportion of the superstructure[13,14]. So the selection of span to depth ratio is very important for economy. Some proven ranges of span to depth ratios over the past decades given by different organization and Authors for different types of bridges, like; cast in situ box girder, cast in situ slab, and precast segmental box girder[15].

Problem Identification

The study of 86 used bridges has been done to presents the variations of span-to-depthratios. Specifically, the study determines the range of ratios typically used for construction and examines its variations over the past 49 years. Two types of bridge decks are analyzed[16,17].

(i) box-girder bridge deck (ii) solid slab bridge deck

Table no. 1 Summary of Cast in Situ Box Girder

Bridge. No.	Bridge Name	Location	Year	Span	Span to depthratio
1	Grenz Bridge at Basel	Switzerland	2000	35.4	17.7
2	Sart Canal-Bridge	Belgium	2002	36	12
3	WeyermannshausBridge	Switzerland	1987	35.75	18.9
4	Eastbound Walnut Viaduct	U.S.A.	1986	38.6	23
5 & 6	Taiwan High Speed Rail (1) & (2)	Taiwan	2000	40	11.4
7	Pregorda Bridge	Switzerland	1974	40	22.2
8 & 9	Almese Viaduct & Condove Viaduct	Italy	1990	40	18.2
10	Gravio Viaduct	Italy	1992	40	18.2
11	Borgone Viaduct	Italy	1992	40	18.2

As stated before, the typical slenderness ratios for solid slab bridges vary considerably with time and bridge function[18,19]. The effect of slab type (i.e. solid or voided), on the other hand, is not as significant. According to the literature discussed in Chapter 1, the recommended span-to-depth ratios for solid slab are likely to be higher than the ones for voided slab, because voided slabs are commonly used to reduce own weight for longer span lengths that have need of slabs thicker than 800mm (Menn 1990). In fact, the study by Cohn and Lounis (1994) recommended that the optimum depth for voided slab is 13% to 21% thicker than the depth for solid slab, resulting in most favorable ratios of approximately 30.45 for solid slab and 25.1 for voided slab[20]. The sample in this study indicates a little difference in slenderness ratios between the two slab types. Voided slabs have span to depth ratios that range from 19 to 35 and for solid slabs (excluding the pedestrian bridges) the range is from 22 to 39. These results are reasonable, because a voided slab is theoretically an intermediate cross-section between a solid slab and a box-girder and its range of span to depth ratios is expected to be in between the ratios solid slab and box-girder.

Methodology & Analysis

The study have been done for prestressed concrete road bridge for ,Cat in situ Box Girder Bridge and Cast in situ Solid Slab Bridge deck to optimize their slenderness ratio. The purpose of this analysis is to compute the amount of prestressing force and the concrete strength needed to satisfy design requirements for bridges with varying span lengths and slenderness ratios. These material consumption results are then used to compute the costof construction as a function of span-to-depth ratio. By analyzing the variations in construction cost and aesthetic impacts, the study determines the most economical span to depth ratios for different bridge types like box girder bridge, solid slab bridge etc . The two types of post-tensioned bridge are considered ie cast-in-situ box-girder, cast-in-situ solid slab [21,22].

This chapter describes the analysis of two types of bridges, material properties,applied loads, ultimate and serviceability limit states design requirements, as well as some preliminary analysis assumptions [23].

Plan and Elevation of Bridge Considered for Analysis

For the analysis 7 span highway bridge viaduct has been considered for analysis. In the analysis, the span length and span-to-depth ratio are varied in the bridge deck to generate the analysis cases illustrated. It should be noted that for cast-in-situ box-girders, cases with spans of 100 m are included in the study mainly for comparison purposes. In the industry, however, such long spans are generally constructed with cantilever method in regions where high labour costs needed for the extensive use of false work [24].

High Strength Concrete

Prestressed concrete requires concrete which has a compressive strength at a reasonably early age, with comparatively higher tensile strength than ordinary concrete. Low Shrinkage, minimum creep characteristic and high value of Young's modulus is age generally deemed necessary for concrete used for prestressed members. Many desirable properties such as durability impermeability and abrasion resistance age highly influenced by the strength of concrete with the development of vibration technique in 1930 it became possible to produce without much difficulty high strength concrete having 28 days cube compressive strength in the range of 30 to 70 Newton‘s per square millimeter the minimum 28 days cube compressive strength prescribed in the Indian Standard code IS:1343-1980 is 40 Newton‘s per square millimeter for pre tension members and 30 Newton‘s per square millimeter for post tension members the ratio of standard cylinder 2 cube strength may be assumed to be pointed in the absence of any elegant test data minimum cement content of 300 to hundred 60 kg per meter cube is prescribed mainly to Cater to the durability equipments in high strength concrete mixes the water content should be as low as possible with due date to adequate workability in the concrete should be suitable for common compaction by the means available at the site it is general practice to adopt vibration to achieve through compaction of concrete used for prestressed members.

Load Combinations

Stresses for design should be calculated for the most sever combinations of loads and forces. Four load combinations are generally considered important for checking for adequacy of the bridge. These are given in Table 7.2 and are also specified in IS 1915 - 1961.

Table 2 Load combinations

Sl.No.	Load combination	Loads
1.	Stresses due to normal loads	Dead load, live load, impact load and centrifugal force
2.	Stresses due to normal loads +occasional loads	Normal load as in (1) + wind load, other lateral loads, longitudinal forces and temperature stresses
3.	Stresses due to loads during erection	•
4.	Stresses due to normal loads + Occasional loads + Extra-ordinaryloads like seismic excluding wind load	Loads as in (2) + with seismic load insteadof wind

Design Specification

The adequacy of the prestressed Concrete box girder and solid slab section should be checked for the following considerations –

Stress at transfer and at service

Stress at top fiber and stress at bottom fiber causing due to dead load, live load and due to prestressing force should not be more than the permissible limits recommended by IS code

Result Analysis & Discussion

Analysis Results of Cast in Situ Box Girder

This section summarizes the analysis results which include the structural response under ULS and SLS, the material consumptions, and the factors that limit further increase of slenderness ratios.

Structural Behavior and Dimensioning

Table 3 describes the ultimate strength at the most critical location, for all 21 cases.

L m	L/d	Flexural strength			Shear strength		
		MULS	Mr.	MULS/ Mr.	V	Vr	Vb
		(kNm)	(kNm)	%	kN	k N	kN

35	10	17685	18200	97	2661.66	2069	592.66
	15	16589	17985	92	2388.24	2200	188.24
	20	16041	17310	93	2251.53	2150	101.53
	25	15385	16300	94	2169.504	2012	157.504
50	10	22557	24250	93	3906	3710	196
	15	22194	23300	95	3348	3280	68
	20	21887	22800	96	3069	2850	219
	25	21623	22430	96	2901.6	2712	189.6
	30	20200	21530	94	2790	2609	181
60	10	38043	39110	97	4902.96	4712	190.96
	15	32522	33700	97	4099.44	3801	298.44
	20	29762	32510	92	3697.68	3593	104.68

First, under ULS, the table5.1 describes the relationship between the flexural strength demand (MULS) and moment of resistance (Mr).

Table 5.1 also shows the shear strength comparison where V=ultimate shear force Vr=shear strength, Vb=balance shear. For balance shear force 12mm dia @ 200mmc/c bar is provided

Table 5.2 also compares stresses with the factored crushing stress. Stresses (Finf) cannot exceed the concrete compressive stress (fck = 20 MPa) to avoid crushing during service. And no tension is permitted in this analysis to avoid the cracking.

Concluding Remarks

The results of this cost study are summarized in Table 5.19 which shows the percentage changes in cost when optimal ratios instead of the conventional ones are used. Cost variations over the analysis range of ratios are also included within the parentheses. For all three bridge types, the cost-effective ratios are higher than the conventional ratios, but the actual cost saving associated with using optimal ratios is less than 5.8%.

Table 4 Summary of cost study

	Cat in situ box-girder	Cast in situ solid slab
Analysis range of ratios	10 - 35	30 – 50
Typical range of ratios	17.7 - 22.6	22 – 39
Conventional ratio	20.1	30.2

Cost-optimal ratio	25	40
Cost component		
Concrete	-5.1% (41.55%)	-19% (22%)
Prestressing tendon	+28% (285%)	+53% (61%)
Reinforcement steel	-1.3 %(17%)	-5.3 % (5.7%)
Total superstructure	-0.6 %(19%)	-11% (11%)
Total construction cost	-0.4 %(11%)	-5.8 %(6.2%)

The results in found to be insensitive to changes in material unit price and construction cost breakdown. The optimal ratios, however, are determined based on parameters defined specifically for this study such as cross-section dimensions and span arrangements. If these parameters are altered, the optimums would likely be different. For example, the optimal ratios might increase if thicker webs are used for box-girders, because the prestressing requirement is reduced for slender cases due to the more efficient tendon layout as discussed earlier. Therefore, the actual values of optimal ratios determined in this study are expected to change in a real situation.

Conclusion & Future scope

Girder-type bridges have commonly been designed using conventional slenderness ratios which have not changed significantly despite recent development in material strengths and construction technologies. This study determines the optimum slenderness ratios for two types of girder bridges constructed with high-strength concrete: cast-in-situ box-girder and solid slab, the ratios are optimized based on material consumption and total construction cost. The results of this thesis are summarized as follows.

Conventional Span-to-Depth Ratios

A study of 86 constant-depth girder bridges reveals that the typical ranges of slenderness ratios are 17.7 to 22.6 for cast-in-place box-girder, 22 to 39 for cast-in-situ solid slab, and 15.7 to 18.8 for precast segmental box-girder. The study demonstrates that theratios for cast-in-situ box-girders have not varied significantly from 1958 to 2007. The study also indicates that cast-in-situ solid slabs constructed after 1975 are mostly voided slabs with slenderness ratios below 25 due to the more stringent code requirements in recent years.

Maximum Span-to-Depth Ratios

The maximum span-to-depth ratio, which satisfies safety, serviceability, and constructability requirements, varies with bridge type and span length. For cast-in-situ box- girder with spans of 35m, 50m, and 60m, the maximum ratios are 25, 30, and 35 respectively. These values are restricted by the interior box cavity height requirement whichis necessary to provide sufficient space for workers. The maximum ratio is also 35 for the span of 75m; it is limited by the number of tendons that can fit inside the webs of the box girder section.

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