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COMPARATIVE ANALYSIS ON SIMPLY SUPPORTED PRE-STRESSED BOX BEAMS IN SRI LANKAN HIGHWAY BRIDGES

A thesis submitted to University of Moratuwa in partial fulfillment of the requirement
for the Degree of Master of Engineering in Structural Engineering Design

Submitted by



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ABSTRACT

The National Road network of Sri Lanka consists of 4326 bridges. There are 365 bridges which have the length more than 30m .Only 800 bridges are made of prestressed concrete superstructures and all others are with reinforced concrete, steel and arches.

The most popular types of prestressed beams used in Sri Lanka are inverted T, M, I, and the box beams. The inverted T and M beams are widely used. Further, for 30m span simply supported bridges, space rectangular box beams and spaced trapezoidal box beams were used. For the continuous bridges big spine beams also have been used with post tension pre-stressing system in recent bridge constructions.

For longer span bridges, box beams are highly suitable. Generally box beam has higher torsional capacity because of its closed geometry. The enhanced torsional stiffness of the box beam sections improves the load distribution properties for the superstructure. It has higher bending carrying capacity and requires reduced beam height compared to other beam section for a particular span. Hollow spaces in box beams can be used for services and it is also aesthetic.

In Sri Lanka 19% of the existing bridges are with prestressed concrete and presently many highway projects are under construction. Therefore, the usage of box beams will improve the effect on the time of construction, cost, construction easiness, aesthetic considerations and utility services. There are different types of box beams available that can be used for this simply supported span range. They are standard box beam, standard U beam and spaced box beams. The rectangular spaced box beam has been used for a two lane bridge in a 30m simply supported span and the trapezoidal spaced box beam has been used for a four lane elevated flyover in Sri Lanka. Comparative analysis and design on all these box beams are useful for future bridge constructions.

This research is concentrated on the design of 30m simply supported four lane bridge super structures using the above different types of prestressed box beams separately. The results of analysis and design and the properties of the beams are compared.

The total width of the designed bridges is 17.4m. It has a central reserve of 1.2m. There are four lanes, each lane is 3.5m width. There are two pedestrian walk ways of 1.1m width.

All the bridge decks were modeled in SAP 2000 for the grillage analysis. Loading was done according to BS 5400: Part 2, 1978, and bending moments, shear forces and torsional moments were found for critical load combination. Prestressing designs were carried out for all beams and the final results are compared. Cost for each deck also compared. The different launching methods adapted for these Bridges are also compared. Conclusions and recommendations are laid down based on these compared results.

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NOTATIONS

f_{cu}	-	characteristic compressive strength of concrete
f_y	-	characteristic tensile strength steel
f_{ci}	-	compressive strength of concrete at transfer
V_{co}	-	shear capacity of section uncracked in flexure
V_{cr}	-	shear capacity of section cracked in flexure
f_{cp}	-	compressive stress of the centroidal axis due to prestress
b	-	breadth of the section
d	-	effective depth
h	-	height of the section
I	-	second moment of area of the section
I'	-	second moment area of the transformed section
x	-	neutral axis depth
f_{pb}	-	tensile strength in tendon at failure
Γ_3	-	product of γ_{f1} and γ_{f2}
	-	partial safety factor for strength
Z_t	-	sectional modulus of the beam with respect to top fiber
Z_b	-	sectional modulus of the beam with respect to bottom fiber
M_i	-	bending moment due to imposed load
M_{insitu}	-	bending moment due to insitu concrete
e	-	eccentricity of the tendon
r	-	radius of gyration
y	-	distance measured from the centroidal axis $x - x$
M_d	-	bending moment due to dead load
f_t	-	allowable concrete tensile stress at transfer
f_c	-	allowable concrete compressive stress at transfer
f_t'	-	allowable tensile stress in concrete under service condition
f_c'	-	allowable compressive stress in concrete under service condition
A	-	cross sectional area
α	-	short term prestress loss factor
β	-	long term prestress loss factor
P_i	-	initial prestressing force
P_e	-	effective prestressing force
E_c	-	Young's modulus of concrete
E_s	-	Young's modulus of steel
n, α_e	-	modular ratio
b_{max}	-	maximum dimension of the section
c	-	torsional constant of the section
y_t	-	distance from the centroidal axis to top extreme fiber
y_b	-	distance from the centroidal axis to bottom extreme fiber
σ_t	-	stress at top extreme fiber
σ_c	-	stress at bottom extreme fiber

f_{pu}	-	characteristic tensile strength of tendon
L_e	-	effective span of the beam
L	-	distance measures from the end of the beam
K	-	coefficient of unintentional effect
Γ_{PS}	-	internal curvature of the tendon
σ_{cen}	-	concrete stress at the point of centroid of the cable
P_{loss}	-	lost prestress force
ϵ_{cu}	-	ultimate compressive strain in concrete
ϵ_{ps}	-	strain in tendon steel prestressive force
ϵ_u	-	tensile strain in concrete at the failure of the section
Z	-	lever arm
f_{pb}	-	tensile stress in the tendon at failure
S_v	-	link spacing
A_s	-	area of tension reinforcement
A_{sv}	-	area of two legs of link
M_c	-	moment capacity of the section
M_u	-	ultimate moment applied
f_s	-	shear stress in concrete
f_{cp}	-	compressive stress in concrete at centric
V	-	shear force
M	-	bending moment
R	-	value of $\frac{h_{max} h_{min}^3}{h_{max}^3 + h_{min}^3}$
v_t	-	torsional stress
a	-	deflection of the beam
k_1	-	constant depending on the concrete bond across shear plane under consideration
K_1	-	constant depending on shape of the bending moment diagram
y_{p0}	-	half side length of the end block
y_0	-	half side length of the loaded area
F_{bst}	-	bursting tensile force in concrete
a_{cr}	-	distance to the point crack considered to the surface of the nearest bar
c_{nom}	-	nominal cover to the outermost reinforcement
d_c	-	depth of the concrete in compression
a'	-	distance from the compression face to the point at which the crack width is being calculated
M_g	-	SLS moment due to permanent load
M_q	-	SLS moment due to live load
ϵ_s	-	strain in the tension reinforcement, ignoring the stiffening effect
ϵ_1	-	strain in concert at the level where cracking is being considered, ignoring the stiffening effect

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