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

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for the Degree of Master of Engineering in Structural Engineering Design

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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
$\Gamma_3$ - product of $\gamma_{f1}$ and $\gamma_{f2}$
- 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
$\alpha$ - short term prestress loss factor
$\beta$ - 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 , $\alpha_e$ - 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
$\sigma_t$ - stress at top extreme fiber
$\sigma_c$ - stress at bottom extreme fiber

fpu - 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
$\Gamma_{PS}$ - internal curvature of the tendon
$\sigma_{cen}$ - concrete stress at the point of centroid of the cable
$P_{loss}$ - lossed prestress force
$\varepsilon_{cu}$ - ultimate compressive strain in concrete
$\varepsilon_{ps}$ - strain in tendon steel prestressive force
$\varepsilon_u$ - 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
As - area of tension reinforcement
Asv - area of two legs of link
Mc - moment capacity of the section
Mu - 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 $h_{max} h_{min}^3$
$v_t$ - 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
$\varepsilon s$ - strain in the tension reinforcement, ignoring the stiffening effect
$\varepsilon 1$ - strain in concert at the level where cracking is being considered, ignoring the stiffening effect

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