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REVIEW PAPER ON ECONOMICAL DESIGN OF EXTRA DOSED BRIDGE ON A HIGHWAY

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Abstract: Extra Dosed bridge, which is generally considered as the intermediate design solutions between the cable stay bridges and cantilever constructed box girder bridge, have become an attractive structural solution for the past 10 years. The main purpose of this paper is to provide an overview on different parameters such as tower height, girder depth, load distribution between cable and girder, and how these parameters influence the design criteria, cost and feasibility of the structure. This paper also provides a relative comparison, between the design theory proposed by Jacques Mathivat and the existing bridges that were built during those days.

Index Term: Extra Dosed Bridge, tower height, girder depth, load distribution between cable and bridges.

1. INTRODUCTION

The concept of Extra Dosed Bridge was first introduced by Jacques Mathivat in 1988 describing an innovative cabling concept. In case of Extra dosed bridge, the cables were placed above the deck, rather than within the cross section of the deck as in case of Girder bridges.
However, extra dosed Bridge should be differentiated with Cable Stayed Bridge. These bridges can be differentiated visually based on tower height in proportion to main span. Extra Dosed Bridge has shorter tower height as compared to cable stayed bridge and the cable inclination ranges between 15-17 degree in case of extra dosed Bridge.
This reduced cable inclination in Extra dosed bridge leads to increase in axial force in the deck and decrease in vertical forces at the anchorages. Thus, the function of extra dosed cable is not only to provide the vertical support, but also to prestress the deck. Extra dosed bridge is characterised by low live load stress.

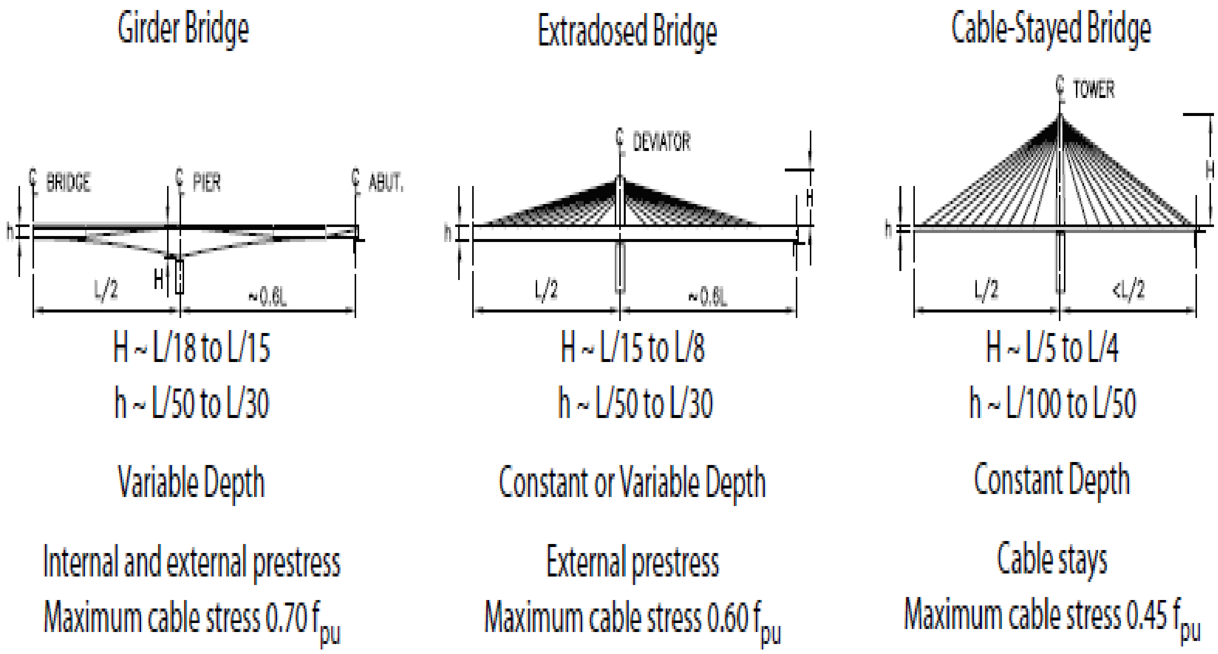


Figure. 1 [1]

2. LITERATURE REVIEW

Mermigas in his report [1] discusses the evolution of extra dosed bridges over the years, and compares them with the design theory that was originally developed by Mathivat in 1988. The Odawara Port bridge in Japan (1994), was the first extra dosed bridge to be built. The Bridge has two cell box girder, and was supported on three spans by Extra Dosed cables in a semi fan arrangement. The Bridge has two plane cable with 8 strands of Extra Dosed cable per half span. The stress range due to live load in the cables was limited to 15-38 Mpa [1].

The Sunniberg Bridge, Switzerland (1998), is a 5 span bridge with maximum span of 140m. The bridge was designed for two plane cable, with 8-10 cables per half span and each cable consist of 125-160 numbers of 7mm diameter wires having an ultimate tensile strength of 1600Mpa and was designed for a maximum allowable stress of 0.5 f_{pu} [1]. The Ibi and Kiso river bridge Japan (1999), are two other bridges having a total length of 1379m and 1145m respectively with maximum span of 271.5m and 275m. The precast deck segment used M60 grade concrete with dimension of 5m in length, 33m in width, and 7m in depth [1].

The Extra Dosed Bridge built over the kelani river Colombo, is 3 span bridge with maximum main span of 140m and end span of 100m each [2]. The bridge has 2 plane cable consisting of 12 number of cable per half span each and each cable having 27-37 number of tendons having an ultimate tensile strength of 1850 Mpa with maximum allowable stress of 0.6 f_{pu}.

According to Kasuga [3], due to similar structural behaviour of Extra Dosed bridge and Cantilever constructed segmental bridge, the ratio of side span length to main span length should be in range 0.6-0.8. The Extra Dosed cable that are anchored near the pylon can almost be considered as powerless therefore Chio in 2000 recommends that the first cable should be anchored at a distance 0.18 to 0.25 from the mid span, however this value differs from Mathivat proposed theory which suggests that the first cable should be anchored at a distance of 0.1 from the mid span. But the bridge that was constructed over the Kelani river its first extra dosed cable was anchored at a distance of 0.2 from the mid span and 0.13 from the start of the pylon.

3. DESIGN CONCEPT OF EXTRA DOSED BRIDGE

- The extra dosed bridge allows the designer to distribute the live load between the cables and girder, by changing the stiffness ratio of these two elements. Ogawa and Kasuga (1998) define an index **β** as the distribution of the live load to the stay cables and claims that this index also represents the stiffness ratio between stay cables and girders.

$$\beta = \frac{\text{Load carried by stay cables}}{\text{Total vertical load}}$$

The boundary between extra dosed bridges and cable-stayed bridges is suggested to occur at **β = 0.30**,
corresponding to a live load stress range in the cables of around 50 MPa. The distribution index is higher for point loads than for uniform loads, because the girder locally distributes the point load to cables surrounding the point of loading, not to all cables in the span. The vertical stiffness of a cable anchored at the deck is related to the inverse of its length and decreases as the length increases (i.e. as we move away from the pier towards the midspan). Therefore, a point load applied at midspan will distribute more evenly to adjacent cables than a point load applied closer to the pier.

- When the superstructure rest on pier as simply support, the live load on one span causes bending in girder which results in downward displacement of loaded girder and upward displacement of adjacent span.
  In case of bridges whose piers are embedded with superstructure, any rotation of the superstructure will be partially restrained by the substructure. This will reduce the bending moment in the girder, since some moment is resisted by piers.

- The height and configuration of piers also influences the bending moment at the foundation level. Piers that are fixed at the base deform in double bending, thus the moment at base will be like that of girder, unless there is variation in pier configuration. If footing is constrained, a simply supported will be preferred to eliminate the bending moment at the base due to live load.
- The stress range in the cables due to live load is an important consideration for the design of cables against due to fatigue. The SETRA Recommends limiting the allowable stress of a stay cable ***fa*** to between 0.46 and 0.60 of the ultimate tensile strength ***fpu***, for a maximum axial stress range due to live load at SLS $\Delta\sigma L$ between 140 MPa and 50 MPa:

$$f_a \leq 0.46\left(\frac{\Delta\sigma_L}{140}\right)^{-0.25} \times f_{pu} \leq 0.6 f_{pu}$$

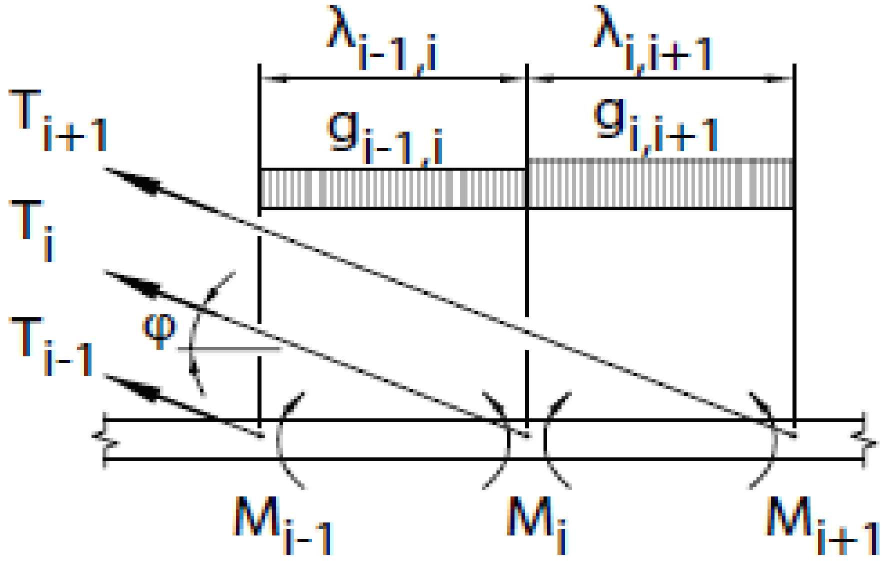
- The Japan Prestressed Concrete Engineering Association's specifies the allowable stress from 0.40 to 0.60 ***fpu*** for a stress range due to live load at SLS ***ΔσL*** between 100 MPa and 70 MPa for a strand system:

$$f_a = \begin{cases} 0.6 f_{pu} & \Delta\sigma_L \leq 70MPa \\ (1.067 - 0.00667\Delta\sigma_L) f_{pu} & 70MPa \leq \Delta\sigma_L \leq 100MPa \\ 0.4 f_{pu} & \Delta\sigma_L \geq 100MPa \end{cases}$$

And between 130 Mpa to 100 Mpa for prefabricated wire system

$$f_a = \begin{cases} 0.6 f_{pu} & \Delta\sigma_L \leq 100MPa \\ (1.267 - 0.00667\Delta\sigma_L) f_{pu} & 100MPa \leq \Delta\sigma_L \leq 130MPa \\ 0.4 f_{pu} & \Delta\sigma_L \geq 130MPa \end{cases}$$

- The cable forces, Ti, can be found from the dead load moments and conversely the dead load moment distribution can be found from cable forces through the following equation.



4. CONCLUSION

From the above studies it can be concluded that that Extra dosed bridge not only helps in saving the material when compared to segmental bridge but also increases the aesthetics of the structure as Menn Stated in 1991 **"the general public was never captivated by modern bridge construction. Beam bridges were largely perceived as boring"** [1]. Moreover, these bridges also come handy when the height of the tower is to be restricted, due to the surrounding conditions. Last but not the least, since the cable are embedded outside the box girder, the replacement of damaged or worn out cable can be easily carried out.
Load distribution factor **β**, that was defined by Ogawa and Kasuga in 1998 [1], plays an important role in reducing the overall cost of the bridge. The term **β**, can also be defined as the stiffness ratio between the cables and the girder. By varying the term **β,** one can calculate the deflection, moments, and shear force for different point. The one with minimum moments and shear force, and deflection in permissible range, can be considered as the most economical value of **β**, the bridge can be designed accordingly.

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