WEB SLENDERNESS RATIO CONSIDERING INITIAL BENDING MOMENT EFFECT ON COMPOSITE GIRDERS DURING CONSTRUCTION PHASE

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1. INTRODUCTION

For economical design, an unshored steel-concrete composite girder is the demand of the modern highway bridges. In unshored construction, two phases are considered i.e., construction phase and composite phase. During the construction phase only the steel girder is subjected to the initial bending moment resulting from dead loads. Composite action takes place when the poured concrete hardens, and both steel girder and concrete slab carry the total loads. No existing codes deals with the effect of the initial bending moment on web slenderness limits of unshored composite girders accounting for construction phase. In this paper, the effects of initial bending moment on the web slenderness ratio of composite girders for unshored construction have been investigated. This investigation is done through parametric study using the finite element method. Finally, web slenderness limits for compact and noncompact composite sections are proposed and compared with the existing AASHTO and Eurocode web slenderness limits.

2. FINITE ELEMENT MODEL

A 3D finite element model (Fig. 1) is developed using a nonlinear finite element program DIANA. An aspect ratio of 3 for the web plate is adopted for the model girder. Both material and geometrical nonlinearities were considered. The structural steel grade SM490Y, whose yield strength is 355MPa was used whereas concrete was assumed to be isotropic material prior to cracking with a compressive strength of 40MPa. The symmetry condition was exploited to model only the left half of the composite girder. Four-node shell elements were used to model steel girder plates and eight-noded solid elements for concrete slab. The initial imperfections were included in the web panels in the form of half-sine waves. In order to investigate the effects of initial bending moment, phased numerical analyses were conducted on unshored girders with width-thickness ratios, b_w/t_w between 120 and 231 and different concrete slab widths. Initially, only steel girders were subject to four different magnitudes of the initial bending moments i.e, M_1 =0, 30, 40 and 50% of the yield moment of the steel sections, M_{ys}. The ultimate load-carrying capacity was obtained and the sections were classified in three categories as compact, noncompact and slender depending on the load producing failure.

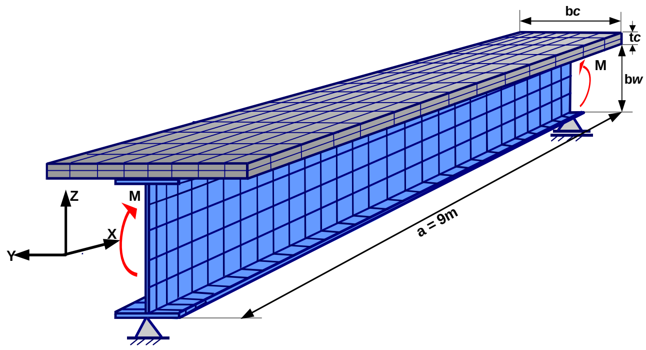

Fig. 1 Finite Element Girder Model

3. PROPOSED WEB SLENDERNESS LIMITS

From the numerical results, it was found that the compact sections are not influenced by the initial bending moment and the results support AASHTO's compact limit. Hence, the compact web width-thickness limit, which represents the boundary between the compact and noncompact sections as shown by dotted lines in Fig. 2 becomes independent of M_1 and is given as

$$\frac{b_w}{t_w} \le \frac{59\varepsilon}{\alpha} \quad (1)$$

where $\varepsilon = \sqrt{235/f_y}$ where f_y is the yield strength of steel in MPa and α is the proportion of web depth in compression obtained from the ultimate strain distribution. Furthermore, for noncompact sections our numerical results indicate that the boundary between the noncompact and slender sections for M_1=0 [Fig. 3(a)] follows Eurocode class 3 limits and hence the Eurocode's class 3 limits will be used as the basis for the proposed noncompact limit. The effect of the magnitudes of M_1 on b_w/t_w is shown in Fig. 3. Finally, the width-thickness ratio limits for noncompact sections are proposed as

For $\psi > -1.0$
$$\frac{b_w}{t_w} \le \frac{52\varepsilon\Lambda}{(0.67+0.33\psi)} \quad (2)$$

For $\psi \le -1.0$
$$\frac{b_w}{t_w} \le 77\varepsilon\Lambda(1-\psi)\sqrt{-\psi} \quad (3)$$

where $\psi = (\alpha'-1)/\alpha'$ in which α' is the proportion of depth of web in compression and Λ is the coefficient used to account for initial bending moment effects. Now, in order to include the effect of coefficient Λ, the effect of stress gradient, ψ is extracted. This is shown in Fig. 4 and the lower bound limits of slender sections shows the effect of initial bending moment and Λ is given below as a quadratic function of M_1/M_{ys}

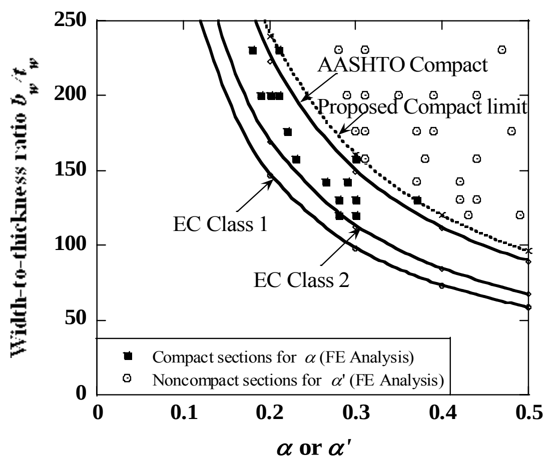

Fig. 2 Proposed Web slenderness limit–Compact sections

$$\Lambda = 1 - 0.1\frac{M_1}{M_{ys}} + 2.31\left(\frac{M_1}{M_{ys}}\right)^2 \quad (4)$$

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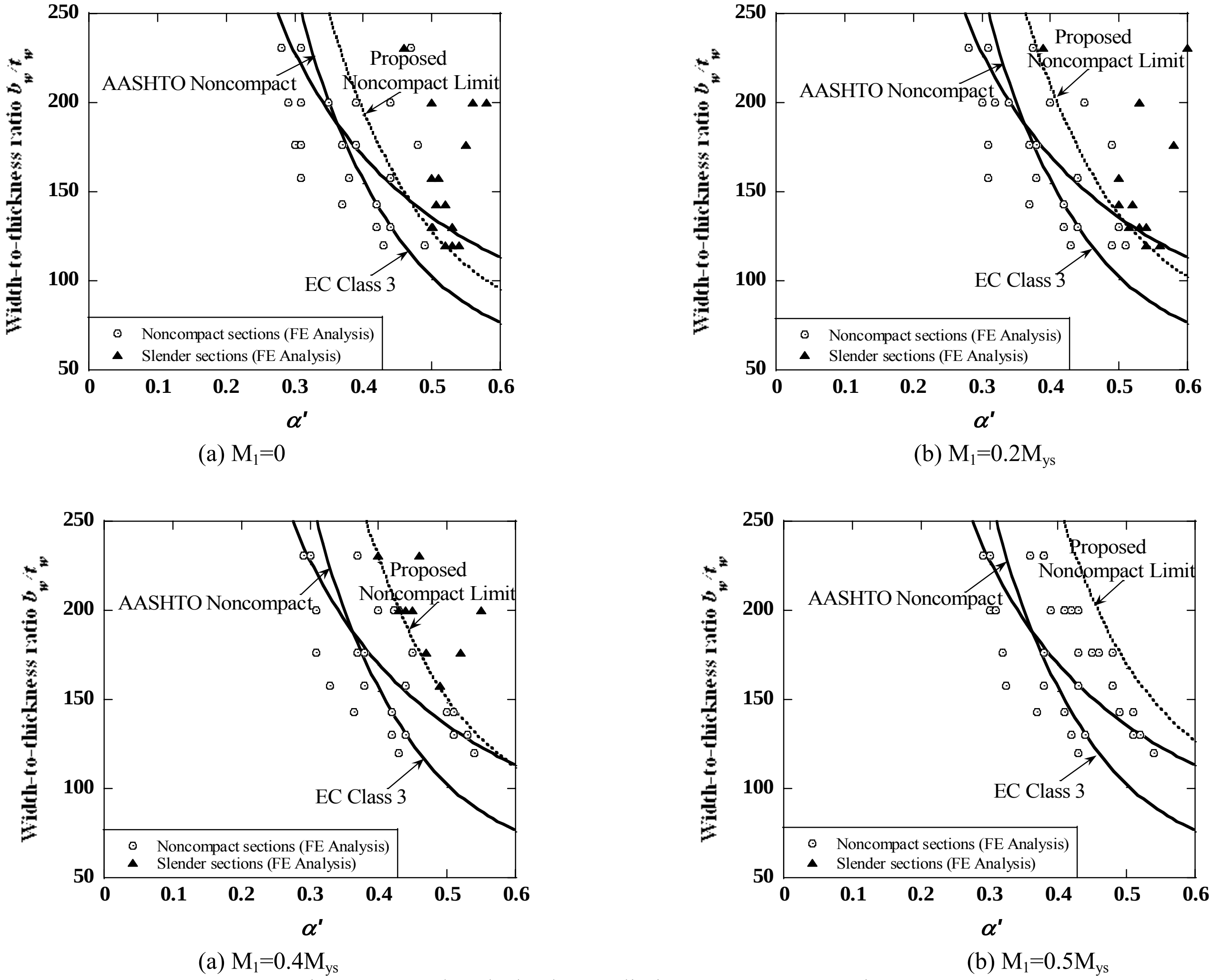

(a) M_1=0 (b) M_1=0.2M_{ys}

(a) M_1=0.4M_{ys} (b) M_1=0.5M_{ys}

Fig. 3 Proposed Web slenderness limits –Noncompact sections

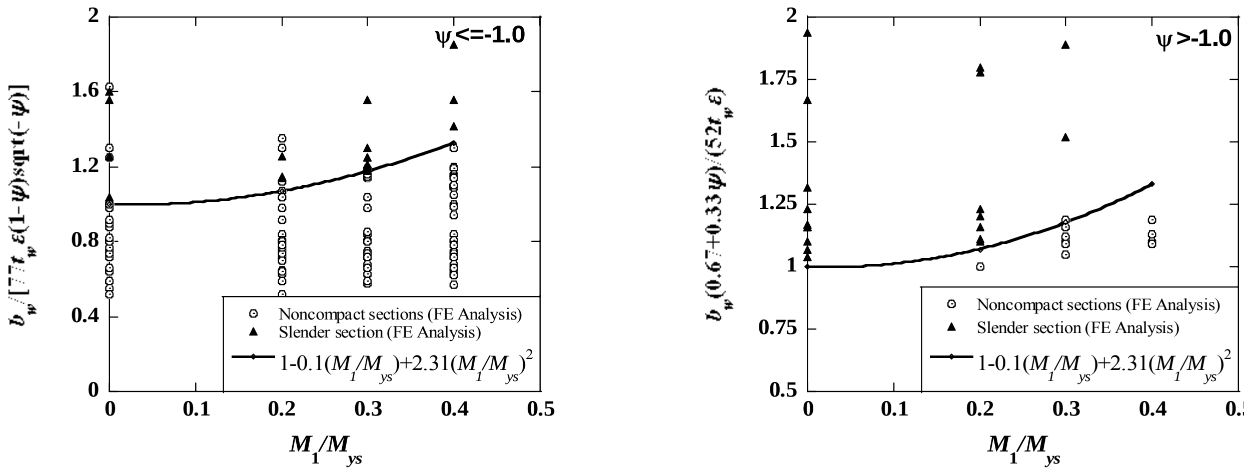

Fig. 4 Determination of Λ

4. CONCLUSIONS

The proposed web width-thickness ratio point to following conclusions:

1. Thinner web plates than that stipulated in AASHTO and Eurocode can be employed.
2. The compact limit is independent of initial bending moment effects.
3. The noncompact web slenderness limits are dependent on the initial bending moment and the existing limits are found to be conservative.