THE INFLUENCE OF INITIAL MOMENT ON THE ULTIMATE LOAD-CARRYING CAPACITY OF THE COMPOSITE GIRDER UNDER FLEXURE

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1. INTRODUCTION

In recent years, unshored steel-concrete composite girders have been extensively used in highway bridges with a span length from 30m to 60m. In unshored construction, composite systems eliminate the need for temporary shores. Initially, a steel girder is erected to carry the dead loads but as the poured concrete hardens, the steel girder and concrete slab carries the total loads and forms a composite system. Few studies on predicting the ultimate behavior of unshored composite girders accounting for each construction stage are available. In addition, the effect of initially applied moment on the ultimate behavior of composite girders for unshored construction has not been fully investigated. This paper attempts to investigate the effects of initial loading on the ultimate load-carrying capacity of composite sections with slender I-girders under pure flexure.

2. NUMERICAL MODEL

A 3D finite element model (Fig. 1) is developed using a general-purpose nonlinear finite element program DIANA[1)]. An aspect ratio of 3 for the web plate is adopted for the model girder, which is larger than the allowable maximum aspect ratio of 1.5 specified in JHBS[4)]. Table 1 shows the dimensions b_{uf}, t_{uf}, t_w, t_{lf} referring to width and thicknesses of all steel plate girders with a depth of 3m without any horizontal stiffeners and a lower flange width of 1.2m. Two-slab widths, b_c of 1.5m and 2m were taken, while a constant slab thickness of 300mm was employed. The material nonlinearities were combined with geometric nonlinearities. The structural steel grade is SM490Y, whose yield strength is 355MPa and was modeled using the isotropic hardening with the von Mises yield criterion. Concrete is assumed to be isotropic material prior to cracking with a compressive strength of 40MPa, and Mohr-Coulomb yield criterion along with the associative flow rule and isotropic strain hardening are employed. From symmetry of the structure and loading, it is sufficient to model only the left half of the girder. Four-node shell elements were used to model steel girder plates and eight-noded solid elements for concrete slab. The initial imperfections[3)] were included in the web panels in the form of half-sine waves with a maximum amplitude, of $b_w/250$, where b_w is the web depth.

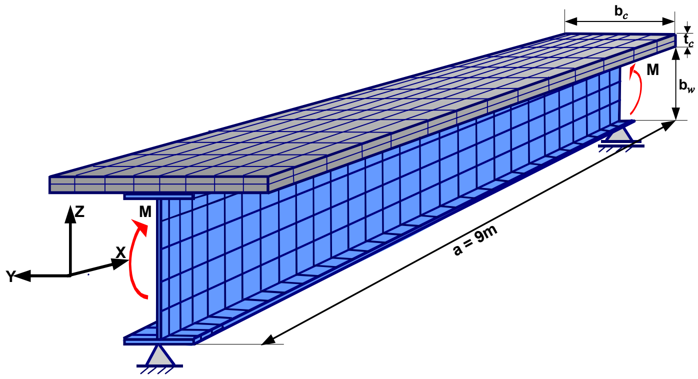

Fig. 1. Finite Element Girder Model

3. NUMERICAL RESULTS AND DISCUSSION

In order to investigate the effects of initial moment, which is not properly covered by current design codes, numerical analyses were conducted on unshored girders with different slenderness ratio, b_w/t_w ranging from 130 to 200 for b_c=1.5m and from 130 to 231 for b_c=2m. A program was developed to perform moment-curvature analysis for sections in Table 1. Fig. 2 shows the bending moment and curvature relationship obtained from the numerical analysis accounting for the initial moment applied to the steel section first. The magnitudes of the initial moment, M_1 were assigned to 30, 40 and 50% of the yield moment of the steel sections, M_{ys}. For practical purposes the maximum value of normalized initial moment is taken as 0.5. As an example, Fig. 3 shows the failure mode for CS1.5a, which demonstrates the buckling of the web plate. Fig. 4 shows the plot between the normalized ultimate moments M_u/M_y and the normalized initial moments M_1/M_{ys}, where M_y stands for the yield moment of a composite section accounting for the initial moment and M_u is the maximum moment obtained from analysis. In the first case corresponding to b_c=1.5m (Fig. 4a) M_u occurs before yielding when $M_1/M_{ys} < 0.4$. For girders with higher normalized initial moment of 0.4 and 0.5, indicating that only a slight increase of normalized initial moment is enough to cause large increase in M_u/M_y ratio. As the initial moment increases, both yield and ultimate moments decrease. M_u/M_y ratio when the curve crosses through a value of 1.0 shows the boundary between Class 3[2)] and Class 4 sections. Girders with higher slenderness ratios (b_w/t_w = 143 ~ 200) at M_1/M_{ys} = 0.3 and M_u/M_y < 1.0 exhibit Class 4 behavior.

Table 1: Composite girder dimensions (mm)

Girder	t_w	b_{uf}	t_{uf}	t_{lf}	b_c	b_w/t_w
CS1.5a	23	570	26	59	1500	130
CS1.5b	21	550	25	59	1500	143
CS1.5c	19	520	24	62	1500	158
CS1.5d	17	485	23	63	1500	176
CS1.5e	15	460	21	64	1500	200
CS2.0a	23	570	26	59	2000	130
CS2.0b	21	550	25	59	2000	143
CS2.0c	19	520	24	62	2000	158
CS2.0d	17	485	23	63	2000	176
CS2.0e	15	460	21	64	2000	200
CS2.0f	13	425	20	65	2000	231

Keywords: initially applied moment, unshored construction, phased analysis
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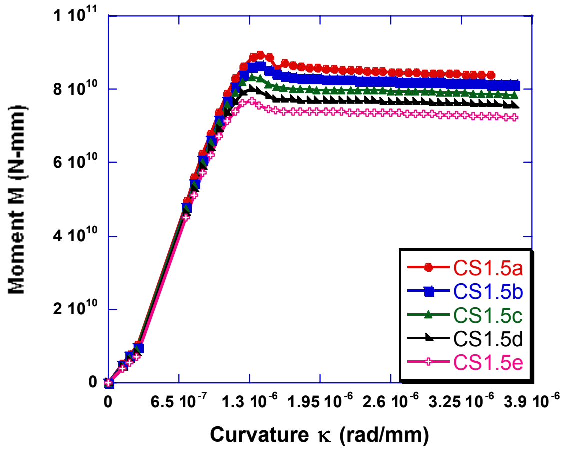


Fig. 2. Moment - Curvature Relationship (M1=0.3Mys) for bc=1.5m

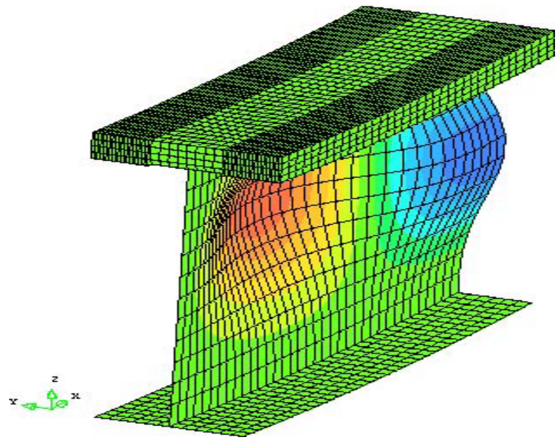
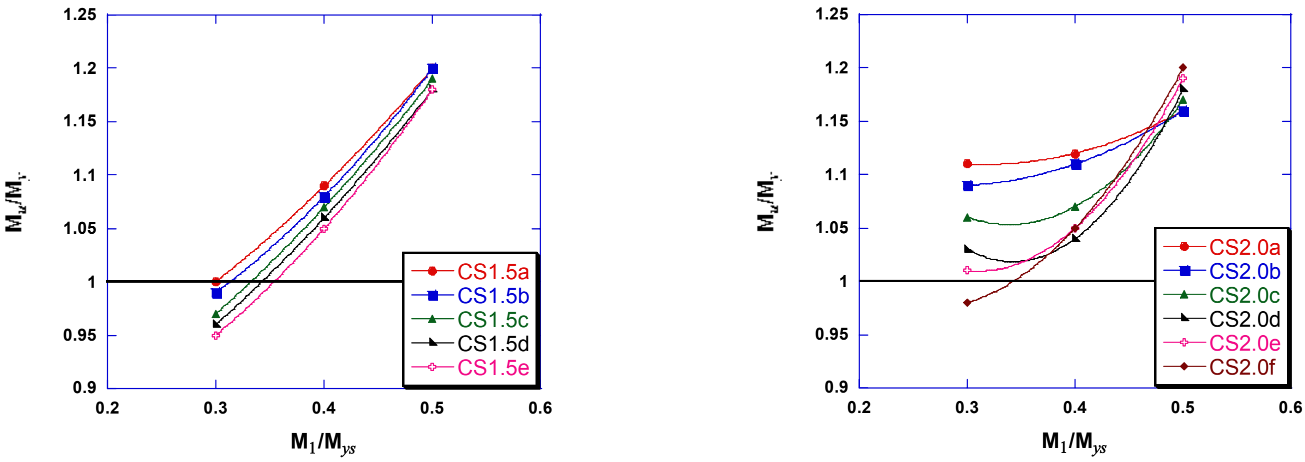


Fig. 3. Failure mode for CS1.5a

For b_c=2m (Fig. 4b), the normalized moments plot shows a comparable trend as the first case. However, for stockier sections the increase in M_u/M_y ratio is large while for slender sections the increase is less. All the sections except CS2.0f show Class 3 behavior. It can be observed from Fig. 4 that as M_1/M_{ys} increases, the girder behavior tends to shift from elastic towards plastic. The difference between the results of the two cases is due to the position of the neutral axis.



(a) b_c=1.5m (b) b_c=2m

Fig. 4. Effect of initial moment on ultimate moment

It is worth specifying that the ultimate strength of each girder section under various initial moments were found to be only around 0.10% different. For any girder, the full plastic moment resistance cannot be sustained as the rotation develops due to local buckling of the slender I-girders. On contrary, the girders reaches a maximum moment M_u, which is less than the full plastic moment, followed by the decline in resistance as the curvature increases.

4. CONCLUSIONS

Based on numerical analysis the following conclusions are made:

1. The M_u/M_y ratio used to judge the section class increases with increasing initial moment M_1.
2. Girders with slender sections at M_1=0.3 M_{ys} exhibit Class 4 behavior. However, with increasing M_1/M_{ys} the section class changes from Class 4 to Class 3.
3. Even though M_u/M_y increases with increasing M_1, the yield moment, M_y decreases and M_u itself does not change much.

5. REFERENCES

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