NUMERICAL SIMULATION OF A STEEL – CONCRETE COMPOSITE BOX GIRDER USING FE APPROACH

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Abstract- In this paper, a three dimensional (3D) finite element (FE) model of an opened section steel – concrete composite box (OSSCCB) girder was analyzed to investigate the effect of the intermediate diaphragms on the load carrying capacity of the girder having a span of 30 m by using nonlinear inelastic analysis. The numerical model was verified with experimental results to ensure the accuracy of the FE model.

Keywords- ABAQUS, Composite box girder, FE Analysis, Nonlinear Inelastic Analysis.

I. INTRODUCTION

Recently, OSSCCB girder has become popular in modern highway construction due to its high bending and torsional rigidity and rapid construction. Many studies associated with analyses of composite box girder have been undertaken during the past several decades. However, researches related to the OSSCCB girder considering the effect of intermediate diaphragms have been still limited. In this study, an accurate 3D FE model of OSSCCB girder was proposed and analyzed by using the ABAQUS software [1]. The FE model was verified by comparing its results with the test results obtained from the experiment of Zhang and Fu [2]. The comparisons showed a good agreement. A parametric analysis was carried out to study the effect of the intermediate diaphragms on the capacity of the OSSCCB girder having a span of 30 m.

II. FINITE ELEMENT MODELING

A 3D finite element model of the OSSCCB girder was developed as shown in Fig.1. A solid element was used to model the concrete slab, whereas shell elements were used to model the rebar, steel flanges, webs, diaphragms and stiffeners of the OSSCCB girder. The tie constraints were used between the concrete slab and the top flanges of the steel box girder to generate the composite action between them. The hinged and roller supports were applied at both ends of the girder as the boundary conditions. Hognestad's [3] and Liang et al.'s model [4] were used for concrete model in compression and in tension, respectively. In addition, the concrete damaged plasticity model was used to consider the different progression of strength characteristics under tension and compression.

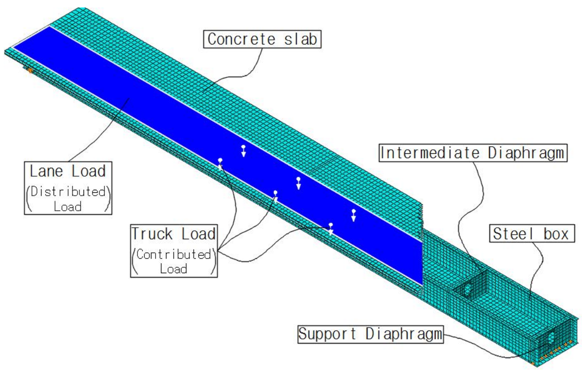

Fig.1 The OSSCCB girder bridge model in ABAQUS

On the other hand, the nonlinear behavior of steel material was described by the tri-linear stress-strain relation, whereas the nonlinear behavior of the rebar was described by the bi-linear stress-strain relationship without strain hardening behavior. Most of material property values used in the model were taken from the test of Zhang and Fu [2].
To conduct the parametric study, the highway bridge loading as specified by AASHTO LRFD 2012 [5] is applied to the models. The Strength Load Combination I including truck load, lane load and self-weight was used in this model. The truck load and lane load were applied according to provision 3.6.1.3 in AASHTO LRFD 2012 [5] in order to cause the critical effects on the OSSCCB girder.

III. VALIDATION OF FE MODEL

The OSSCCB girder tested by Zhang and Fu [2] was used for the purpose of validating the FE model. Material properties used in the test of Zhang and Fu [2] were invoked in this analysis. A comparison of load – deflection relationship of the OSSCCB girder between the FE analysis and test is shown in Fig. 2. This figure shows that the vertically applied mid-span load and the corresponding vertical deflection obtained from the FE analysis result agree well with that of experiment. It can be seen that the ultimate load obtained from this model is 323.1 KN, which is 0.97% higher than the experiment result. On the other hand, the OSSCCB girder was failed by the crushing of the top face of the slab at the mid-span area as shown in Fig.3a.

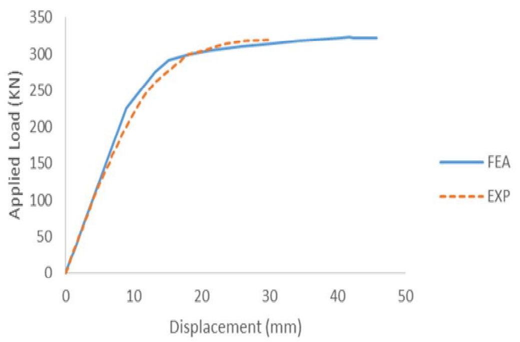

Fig.2 Comparison of load – deflection relationship

This failure mode describes a good agreement with the experimental observation as shown in Fig.3b. It can be concluded that the finite element modeling is reliable and can predict the structural behavior of the OSSCCB girder accurately.

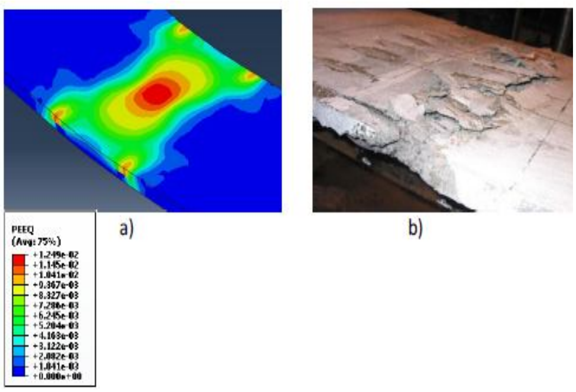

Fig.3 Concrete crushing on the top of slab at mid-span: (a) ABAQUS modelling represented by maximum plastic strain; and (b) experimental observation [2].

IV. PARAMETRIC STUDY

A. Geometries of different models

In this study, 6 different case studies of simple span bridges shown in Table 1 were analyzed. All the dimensions in this table are the minimum values which were selected to satisfy the provision 6.11.2 of AASHTO LRFD standard [5]. The cross – section of the OSSCCB girder without longitudinal stiffeners (WoLS) and with longitudinal stiffeners (WLS) on webs are illustrated in Fig.4.

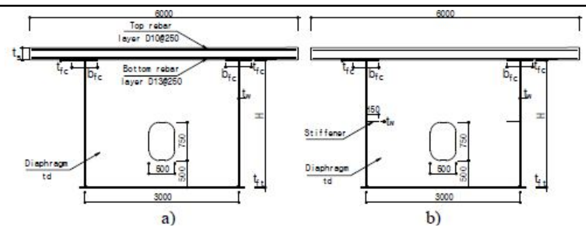

Fig.4 The cross – section of the OSSCCB girder: (a) WoLS; and (b) WLS

Table 1: Geometries of case studies (in mm)

Case	L/H Ratios	H	t_w	b_{fc}	t_{fc}	t_{ft}	t_s	t_d
1	18	1600	12	270	14	14	240	12
2	22	1300	10	220	12	12	240	10
3	25	1200	8	200	10	10	240	8
4	18	1600	8	270	14	14	240	8
5	22	1300	8	220	12	12	240	8
6	25	1200	8	200	10	10	240	8

Note: Cases 1, 2, 3 and Cases 4, 5, 6 corresponding to WoLS and WLS

B. Effect of the number of intermediate diaphragms (N)

In order to investigate the effect of intermediate diaphragms on load – carrying capacity of OSSCCB girder, various number of intermediate diaphragms (*N* = 0, 1, 3, 5, and 7 corresponding to intermediate diaphragms spacing of L, L/2, L/4, L/6, and L/8, respectively) were considered. The relationship between the load factor (*LF*) and *N* obtained from the analysis results are shown in Fig.5. It can be seen that *LF* increases considerably when *N* increases from 0 to 1. However, there are no further significant changes in *LF* when *N* increases from 1 to 7 for all case studies.

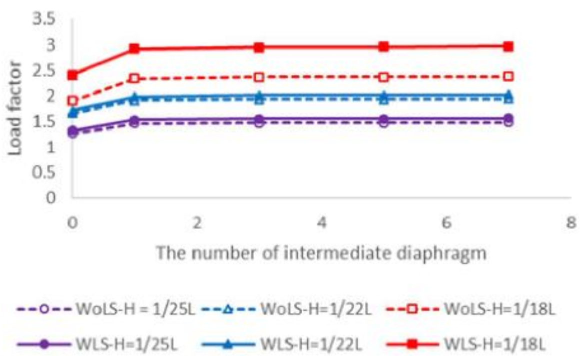

Fig.5 Relationship between *LF* and *N*

Therefore, it can be concluded that one intermediate diaphragm placed at the mid - span is recommended for the girder in this study.

CONCLUSIONS

In this study, effect of intermediate diaphragms on load – carrying capacity of the OSSCCB girder was investigated by using FE analysis. Based on this study, the main conclusions are obtained as follows:

1) An accurate and reliable 3D FE model was represented and the results obtained from the numerical simulation were compared with the experimental data with good agreement.

2) For the OSSCCB girder with 30 m long span and all its dimensions were selected to satisfy the minimum values according to AASHTO LRFD standard [5], one intermediate diaphragm is recommended to install at the mid – span of the girder.

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