Damage assessment of the longitudinal connection of simple supported-to-continuous girder bridges constructed with hollow slabs

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Abstract Simple supported-to-continuous girder bridges are commonly and widely used in bridge engineering in China. For this type of bridges, normally, the longitude connections are casted in-site by concrete. The quality of the casted concrete is difficult to control. After a large number of field surveys, damages are often found in the transversal and longitudinal connections. These damages may result in unfavorable effects to the bridge system and shorten the durability of the bridges. Therefore it is of great interests to investigate the behavior of the concoctions on this kind of bridges. This paper presents a numerical study of the longitudinal connections of simple supported-to-continuous girder bridges. Then by series parametric study, the effect of the damages on the connections on the mechanical behavior of the bridge is investigated.

Introduction

For the reasons of easily construction and economic, simple supported-to-continuous girder bridges are commonly and widely used in bridge engineering in China. For this type of bridges, normally, the longitude connections are casted in-site by concrete. The quality of the casted concrete is difficult to control [1-4]. After a large number of field surveys, damages are often found in the transversal and longitudinal connections. These damages may result in unfavorable effects to the bridge system and shorten the durability of the bridges [5]. Therefore it is of great interests to investigate the behavior of the concoctions on this kind of bridges. Now, only a few qualitative methods for the assessment of the longitudinal connection are available in JTG/T H21-2011 and JTG/T J21-2011 [6-8]. This study presents a numerical study on the effect of strength reduction of the connections on the performance of the bridges. Based on the results, a damage assessment method is proposed for the longitudinal connection of simple supported-to-continuous girder bridges.

Numerical modeling parameters

In this section, the numerical modeling parameters will be presented first. The numerical calculation model is based on the Chinese standard manual for hollow section slab bridge, in which a prototype of a 16 m with 5 spans is selected as the example, see Fig. 1. M1~M3、d1~d3 are bending moment and deflection in the middle of the spans, respectively.
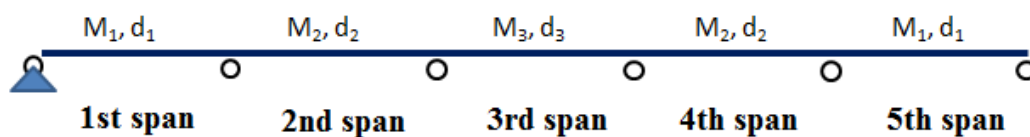

Figure 1, Calculation model of a simple supported-to-continuous girder bridge

The load applied on the calculation model is based on the Chinese standard (JTG D60-2004). The internal forces are calculation as a class structural member. The load applied on slab is re-calculated using a load transfer factor. The connection of the slab and concrete girder is regarded as stiff moment

connection. The numerical calculation is carried out by FEM method using truss or beam element. The damage of the longitude connection is considered by strength reduction of the concrete.

Effect of damage at longitudinal connection on the performance of bridge

Influence on the side span (1st and 5th span)

With different bending stiffness (damages are introduced) of the connection, under only live load, the maximum bending moment is summarized in Table. 1; under live load + dead load, the maximum bending moment is summarized in Table. 2. For the convenience of analysis, the values in Tables 1 and 2 are normalized as of D_{EI} (damage factor) and μ_M. $D_{EI}=1-(EI)/(E_0I_0)$; $\mu_M=M/(M_0)$. (E_0I_0) and M_0 are the inital stiffness and bending moment when there is no damages, see Fig. 2.

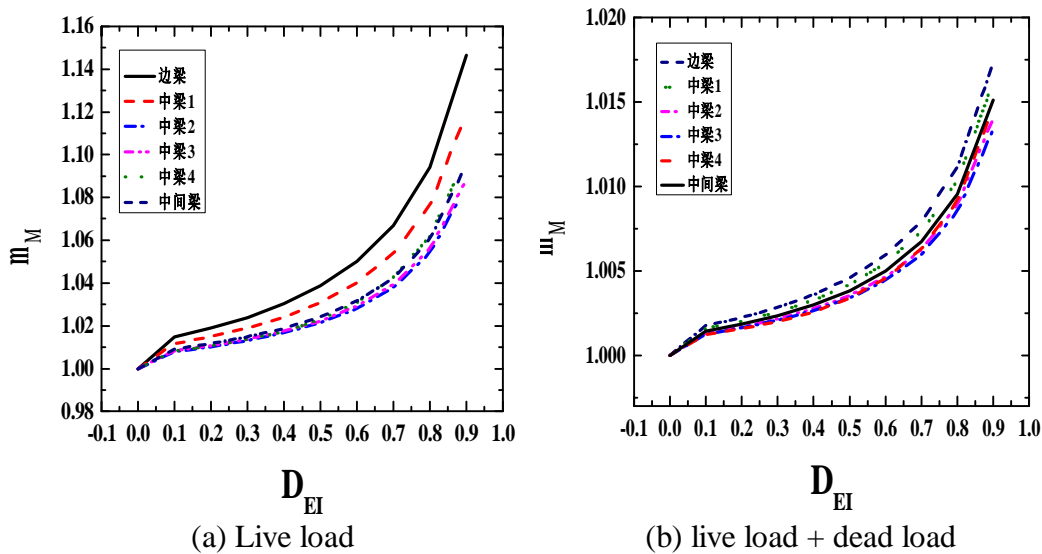(a) Live load   (b) live load + dead load

Figure 2. The trend of damage of 1st and 5th span

From Tables 1 and 2 and Fig. 2, it can be seen that (1) for case a and b, the maximum bending moment increases with the increase of damage factor. This indicates that for a bridge system, the bending stiffness of on span will influence the bending moment of all spans. (2) When only the live load is considered, the influence of damage on the bending moments of each span is different, the side span 1 and 5 are more influenced. When $D_{EI}<0.4$, the increase of bending moment are not important, less than 3%; when $D_{EI}>0.6$, the influence is important, more than 5%. When $D_{EI}=0.9$, the increase of the bending moment reaches the maximum 14.6%. For the other spans, when $D_{EI}<0.5$, increasing of bending moment is less than 5%. When $D_{EI}=0.9$, the maximum increment is 9.9%. (3) When the live load and dead load are considered together, the influence could be ignored, less than 1.6%.

No	DEI=1-(EI)/(E₀I₀)									
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
side span	391.31	397.14	398.72	400.68	403.17	406.43	410.93	417.52	428.16	448.63
span 1	342.83	346.85	347.96	349.33	351.09	353.40	356.59	361.31	368.94	383.75
span 2	438.61	442.09	443.10	444.35	445.94	448.03	450.94	455.24	462.27	476.04
span 3	402.88	406.25	407.22	408.39	409.91	411.89	414.65	418.73	425.40	438.49
span 4	393.96	397.25	398.17	399.31	400.75	403.00	406.14	410.76	418.32	433.15
Middel span	428.97	432.89	434.00	435.34	437.08	439.35	442.51	447.19	454.85	469.90

Table 1 Beindg moment with live load (KN*m)

No	DEI=1-(EI)/(E₀I₀)									
	0.0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
side span	3305.66	3311.49	3313.07	3315.03	3317.52	3320.78	3325.28	3331.87	3342.51	3362.98
span 1	2524.94	2528.96	2530.07	2531.44	2533.2	2535.51	2538.7	2543.42	2551.05	2565.86
span 2	2660.81	2664.29	2665.3	2666.55	2668.14	2670.23	2673.14	2677.44	2684.47	2698.24
span 3	2655.48	2658.85	2659.82	2660.99	2662.51	2664.49	2667.25	2671.33	2678	2691.09
span 4	2666.79	2670.08	2671	2672.14	2673.58	2675.83	2678.97	2683.59	2691.15	2705.98
Middel span	2711.38	2715.3	2716.41	2717.75	2719.49	2721.76	2724.92	2729.6	2737.26	2752.31

Table 2 Beindg moment with live load + dead load (KN*m)

Influence on the middle-side span (2nd and 4th span)

As it mentioned in the previous section, the same analysis method is adopted in this section. The results for live load and live load + dead load are summarized in Tables 3 and 4. The normalized curves are shown in Fig. 3.
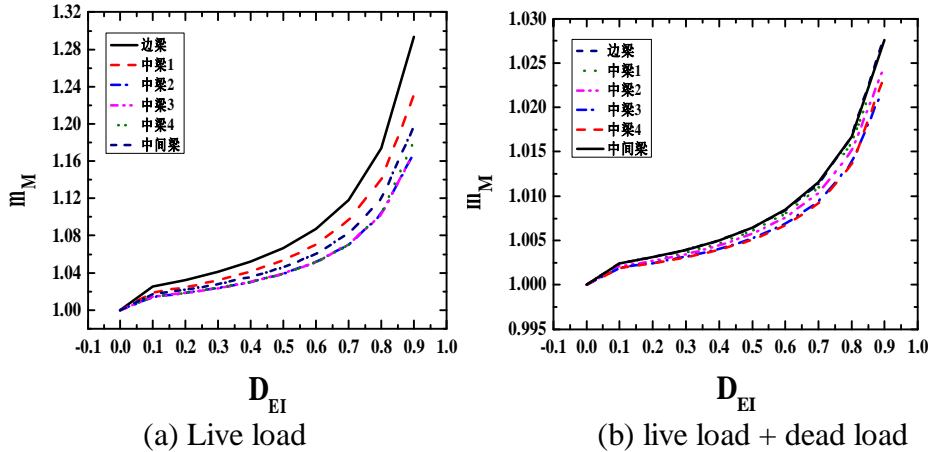

(a) Live load (b) live load + dead load

Figure 3. The trend of damage of 2nd and 4th span

From Tables 3 and 4 and Fig. 3, it can be seen that (1) for case a and b, the maximum bending moment increases with the increase of damage factor. This indicates that for a bridge system, the bending stiffness of on span will influence the bending moment of all spans. (2) When only the live load is considered, the influence of damage on the bending moments of each span is different, the side span 2 and 4 are more influenced. When $D_{EI}<0.2$, the increase of bending moment are not important, less than 3%; when $D_{EI}>0.4$, the influence is important, more than 5%. When $D_{EI}=0.9$, the increase of the bending moment reaches the maximum 29.4%. For the other spans, when $D_{EI}<0.5$, increasing of bending moment is less than 5%. When $D_{EI}=0.9$, the maximum increments are 23.1%、16.95%、16.96%、18.2% and 19.7%; (3) When the live load and dead load are considered together, the influence could be ignored, less than 2.8%.

No	$D_{EI}=1-(EI)/(E_0I_0)$									
	0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
side span	309.41	317.23	319.38	322.06	325.50	330.06	336.45	346.02	363.26	400.25
span 1	279.33	284.68	286.24	288.26	290.84	294.28	299.10	306.36	318.57	343.78
span 2	381.63	387.04	388.63	390.60	393.15	396.55	401.34	408.58	420.80	446.29
span 3	346.16	351.13	352.56	354.35	356.66	359.73	364.06	370.62	381.71	404.88
span 4	340.03	344.96	346.35	348.08	350.32	353.30	357.50	363.87	375.35	401.90
Middle span	371.28	377.66	379.46	381.68	384.55	388.37	393.75	401.90	415.67	444.53

Table 3 Beindg moment with live load (KN*m)

No	$D_{EI}=1-(EI)/(E_0 I_0)$									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Side span	3223.76	3231.58	3233.73	3236.41	3239.85	3244.41	3250.8	3260.37	3277.61	3314.6
span 1	2461.44	2466.79	2468.35	2470.37	2472.95	2476.39	2481.21	2488.47	2500.68	2525.89
span 2	2603.83	2609.24	2610.83	2612.8	2615.35	2618.75	2623.54	2630.78	2643	2668.49
span 3	2598.76	2603.73	2605.16	2606.95	2609.26	2612.33	2616.66	2623.22	2634.31	2657.48
span 4	2612.86	2617.79	2619.18	2620.91	2623.15	2626.13	2630.33	2636.7	2648.18	2674.73
Middle span	2653.69	2660.07	2661.87	2664.09	2666.96	2670.78	2676.16	2684.31	2698.08	2726.94

Table 4 Beindg moment with live load + dead load (KN*m)

Conclusions

This paper presents a numerical parametric study on the effect of damages on the longitudinal connection of simple supported-to-continuous girder bridges constructed with hollow slabs. From the results it can be seen that, the longitudinal connection plays very important role in the mechanical behavior of the whole system of the bridge. The maximum bending moment increases with the increase of damage factor. This indicates that for a bridge system, the bending stiffness of on span will influence the bending moment of all spans. In the Engineering practice, this effect should be paid with more attention during construction and bridge management and routine maintenance .

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