Analysis of Bracing Type and Full Web Type of Cross Frame at Girder End

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Summary

Cross frame or cross beam as girder end structure plays an important role during earthquake and is to be designed not to damage for damage prevention of the girder bridge. However, some cross frames with diagonal bracings in inverted V-shape had buckling damage of the bracing due to the lateral seismic force. The cross beam with stiffened full web is recommended now in the latest version of the Specifications for Highway Bridges in Japan. In this paper, load carrying capacity of the cross frame and the cross beam is clarified through pushover analysis and seismic response analysis in the direction perpendicular to the bridge axis.

Keywords: Cross frame; Cross beam; girder end structure; load carrying capacity; pushover analysis; seismic response analysis

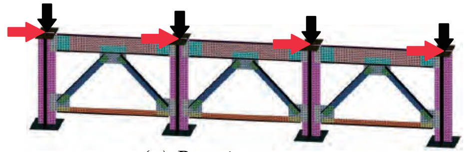
1. Introduction

Cross frame or cross beam as girder end structure is key member to prevent out-of plane deformation of main girders against seismic force. However some cross frames with diagonal bracings in inverted V-shape, here after called as bracing type, had buckling damage of the bracings due to the lateral seismic force. Hence, cross beam with stiffened web plate, here after called as full web type, is recommended in the latest version of the Specifications for Highway Bridges ,SHB, in Japan. On the other hand, some fundamental studies on load carrying capacity of girder end structures are conducted, but their seismic safety against the L2 Earthquake is unclear. Then in this study, load carrying capacity of the bracing type and the full web type of girder end structures is clarified through pushover analysis and seismic response analysis in the direction perpendicular to the bridge axis by using their partial analytical model.

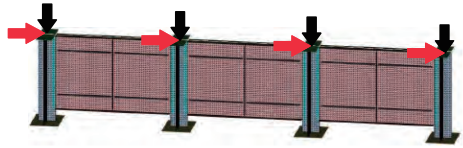
2. Analytical model and analytical conditions

A simple supported and composite girder bridge with four main girders was selected as objective bridge. Fig. 1 shows the analytical model. In pushover analysis, lateral displacement is subjected to the upper chord member after the dead load of the superstructure is equally distributed to each girder end. In seismic response analysis, the L2 Earthquake ground motions, II-I-1 to II-I-3, which are defined in SHB are input.

Two of supporting conditions at the bearings were considered; "Fix" and "Rotation". In the case "Fix", horizontal displacement and rotation are fixed and in the case "Rotation", horizontal displacement is fixed and that rotation is free.



(a) Bracing type



(b) Full web type

Fig.1: Analytical model

3. Analytical result of bracing type

Figure 2 shows the relationship between horizontal load and displacement. Yield loads of the cases Fix and Rotation are about 3.5 and 2.7 times the design seismic load of 418kN.

Table 1 summarizes maximum responses of the displacement and acceleration. Fig. 2 shows time history of displacement response. In the case of Fix, inertia force is 3.9-4.1 times the design seismic load. Almost all the displacement responses are less than the yield displacement of 2.5mm. In the case of Rotation, inertia force is 4.0-4.1 times the design seismic load and maximum displacement increases largely and nonlinear responses can be observed.

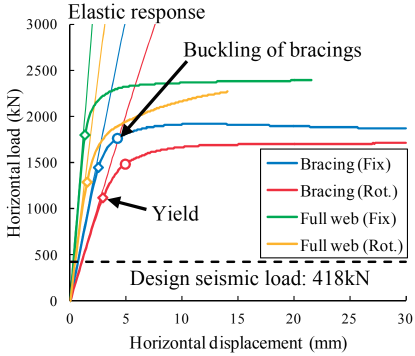


Fig.2: Relationship between horizontal load and horizontal displacement

4. Analytical result of full web type

As shown in Fig. 2, in both the bearing conditions, stiffness changes due to yield of the stiffened column parts at about 1.3mm and predominant shear deformations of the parts are observed. Yield loads in the cases of Fix and Rotation are about 4.3 and 2.9 times the design seismic load.

As shown in Table 1 and Fig. 3, since the full web type has larger shear rigidity compared with the bracing type, smaller displacement responses can be observed. Inertia force is 3.3-3.7 times the design seismic load, but maximum displacement is less than the yield displacement of 1.4mm with a few exceptions, and mostly elastic responses can be observed in both the bearing condition.

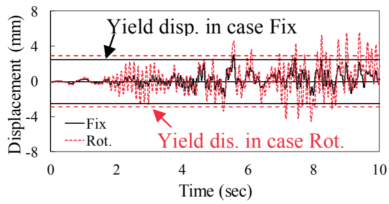
Table 1: Results of seismic response analysis

(a) Bracing type

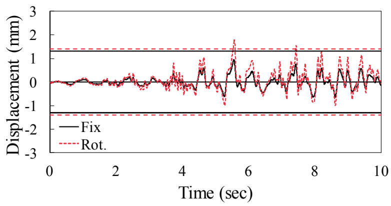
		Natural period (sec)	Max. Disp. (mm)	Max. Acc. (gal)	Max. Inatia force (kN)
Fix	II-I-1	0.10	3.0	995	1,698
	II-I-2		2.7	951	1,624
	II-I-3		2.8	955	1,630
Rotation	II-I-1	0.13	5.6	982	1,677
	II-I-2		5.9	993	1,696
	II-I-3		6.0	1,009	1,722

(b) Full web type

		Natural period (sec)	Max. Disp. (mm)	Max. Acc. (gal)	Max. Inatia force (kN)
Fix	II-I-1	0.06	1.0	857	1,463
	II-I-2		0.9	806	1,375
	II-I-3		0.9	848	1,447
Rotation	II-I-1	0.08	1.8	871	1,487
	II-I-2		1.7	849	1,450
	II-I-3		1.9	904	1,544



(a) Bracing type



(b) Full web type

Fig. 3: Displacement response, II-I-1

5. Conclusions

In this paper, load carrying capacity of a girder end is examined through push over analysis and seismic response analysis. The main conclusions obtained are as follows:

1) Yield load of the bracing type and the full web type are about 2.7-3.5 and 2.9-4.3 times design seismic load, respectively, and seismic response analysis results indicate that the girder end structure, designed according to the Specifications for Highway Bridges in Japan, shows mostly elastic response against the L2 Earthquake except for the bracing type when rotation of the bearing is considered.

2) In this study, seismic safety of girder end structures is examined by only partial analytical model. So it is necessary to examine their seismic safety by full span model as future issue.