Damage Assessment of a RC Rigid-Frame Arch Bridge Affected by Wenchuan Earthquake

Graduate School of Kyushu Institute of Technology　Student Member　○Zhongqi SHI
Kyushu Institute of Technology　Member　Kenji KOSA
Jiangsu Transportation Institute　Member　Jiandong ZHANG
Nippon Engineering Consultants Co., Ltd.　Member　Hideki SHIMIZU

1. Introduction

The Wenchuan Earthquake, occurred on May 12th, 2008, had a magnitude of 8.0 by CEA. Xiaoyudong Bridge, which is a 4-span, rigid-frame arch bridge, was damaged extensively in this earthquake. For verifying the dynamic performance of this type of bridge, damage ranks are compared between actual failure and analytical result.

2. Objective Bridge

Totally 4 spans were arranged. Elevation view from upstream for Span 1 & 2, without entire collapse, is shown in Fig. 1 for instance. Arch legs from each side and girder form the arch frame. It composes a single rigid-frame with inclined legs. A span has five rigid-frames connected by crossing beam, arch slab, and extending slab.

To judge the failure, damage ranks are defined in Table. 1, and marked in Fig. 1 (note: “2-1: B/A” stands for damage rank for Point 2-1 is B of actual failure and A of analytical result). We can see that extreme damage occurred to the left side of Span 1 (shadowed part), and damage of Span 1 was slightly more severe than Span 2, possibly caused by the surface fault which acrossed behind A1. Thus, Span 2 is chosen as the representative to be compared with following anlaytical result. For girder, joints with arch leg (Rank B for 2-1 & 2-3) were more greatly damaged than mid-span (Rank C for 2-2); while for legs, bottoms of inclined leg (Rank B for 2-4 & 2-5) were affected more severely than that of arch legs (Rank C for 2-6 & 2-7).

Table. 1 Defination of Damage Rank

Rank	Defination	
	Actual	Analysis
A	Resistance totally lost	Beyond ultimate
B	Through-out crack, or resistance partly lost, or obvious deformation	Yield
C	Cracks	Crack
D	No damage	No damage

3. Dynamic Analysis

Single frame of Span 2 is used to establish the 2-D frame model. Rigid element is set to footings, beam on the top of pier and joints between legs and girder. Horizontal and rotational springs under P1 and P2, supporting and friction spring upon P1 and P2 are assumed based on former studies. Additionally, tri-linear M-Φ relationships are calculated by the axial forces under dead load. Bajiao wave by Wenchuan EQ are used for both E-W and U-D directions (spectra shown in Fig. 2).

Max plastic ratio distributions are calculated according to $\mu_{max}= \Phi_{max}/ \Phi_y$, and shown in Fig. 3. For the girder, 2-1 and 2-3 receive most serious failure beyond ultimate stage (as their μ_{max} reached at 26.8 and 19.5 respectively), thus are defined as Rank

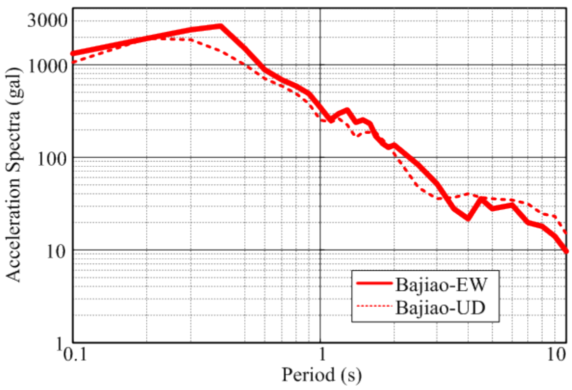

Fig. 2 Response Acceleration Spectra

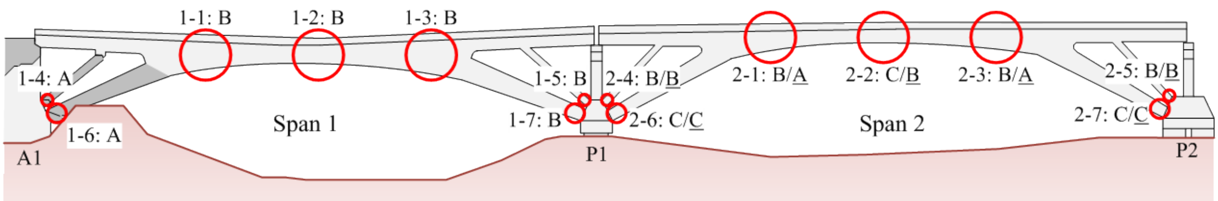

Fig.1 Elevation View (upstream) of Span 1 & 2 and Comparison of Damage Ranks (point No.: rank of actual/analysis)

Keywords: rigid-frame arch bridge, Wenchuan Earthquake, damage rank, dynamic analysis
Address: 〒804-8550 Kyushu Institute of Technology, 1-1, Sensui, Tobata, Kitakyushu, TEL: 093-884-3123

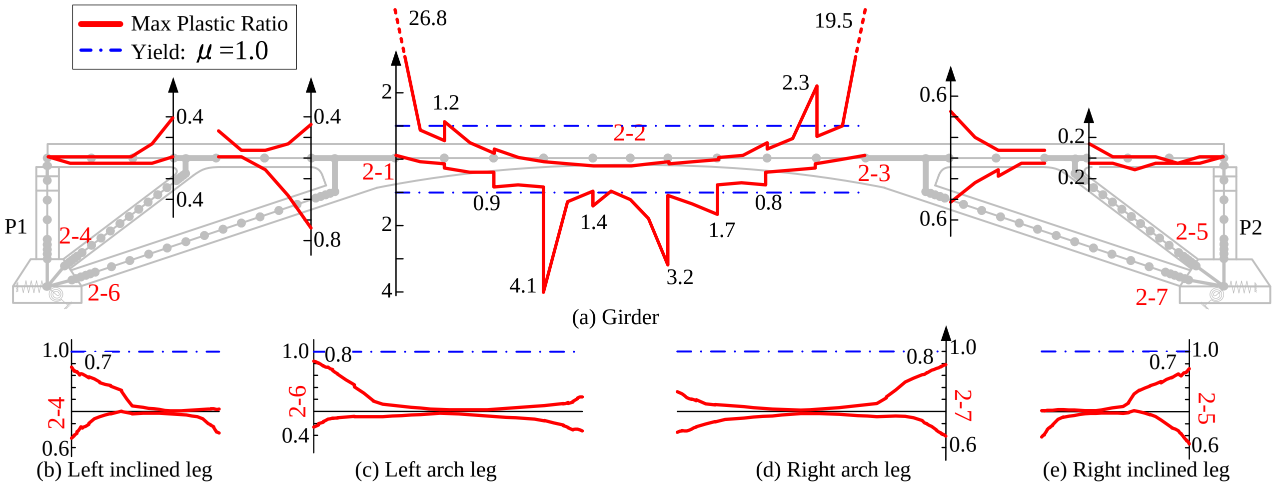

Fig. 3 Max Plastic Ratio Distribution

A. This can be also confirmed in M-Φ history in Fig. 4. The points around 2-2 in mid-span also damage notably, with μ_{max} ranges from 1.4 to 4.1 (Rank B). Besides, the bottoms of leg (2-4 and 2-5 for inclined legs, 2-6 and 2-7 for arch legs, from (b) to (e) in Fig. 3) are found have severe response as well (μ_{max} from 0.7 to 0.8). 2-5, right bottom of inclined leg, yields due to extensive decrease of axial force at 37.42s, as shown in Fig. 5. Then 2-4 yields due to M-N effect as well. Thus they are defined as Rank B. The actual axial force for 2-4 and 2-5 varies notably from -140% to +149%, compared with that under only dead load. This is the most important phenomenon that affects failure of inclined legs. However, only crack occurs to 2-6 and 2-7 (Rank C), even by axial force variation. Besides, development of deformation is shown in Fig. 6, with first 3 yields being the representatives. Thus, joints of girder with arch legs and bottoms of both inclined legs are considered as the crucial points for this bridge.

Compared with actual failure explained in Chapter 2, the damaged positions almost coincide well. For girder, joints had Rank B of actual and A of anlaysis, while mid-span had weaker damage than the joints, of Rank C of actual and B of anlaysis. Analysis showed more severe damage, probably due to the safer model established based on design specifications. For legs, Rank B for bottoms of inclined legs and Rank C for arch legs were got for both actual and analysis. Consequently, good coincidance was got for the damaged positions and failure trend in general.

4. Conclusions

(1) Based on the field survey, only Span 2 entirely suvived with limited damage. For girder, joints with arch leg (Rank B for 2-1 & 2-3) were damaged more greatly than the mid-span (Rank C for 2-2); while for legs, bottoms of inclined leg (Rank B for 2-4 & 2-5) were affected more than that of arch legs (Rank C for 2-6 & 2-7).

(2) By analysis, damage would probably occurr to the joints of girder with arch legs and the bottoms of both inclined legs. Compared with actual failure condition, generally good coincidance was got for the damaged positions and failure trend.

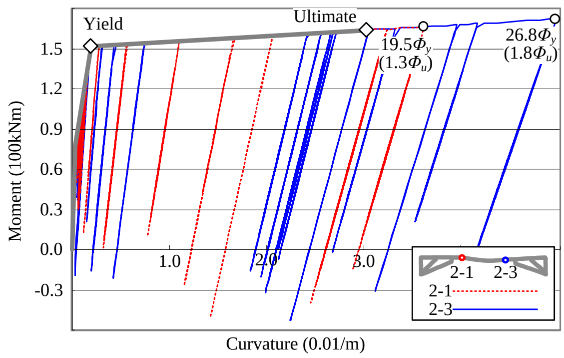

Fig. 4 M-Φ History of Point 2-1 & 2-3

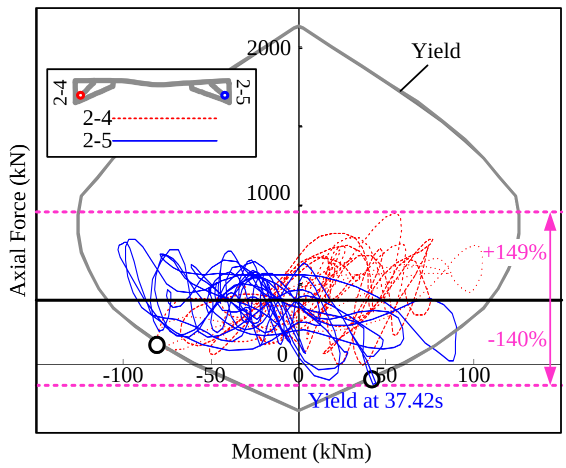

Fig. 5 M-N History of Point 2-4 & 2-5

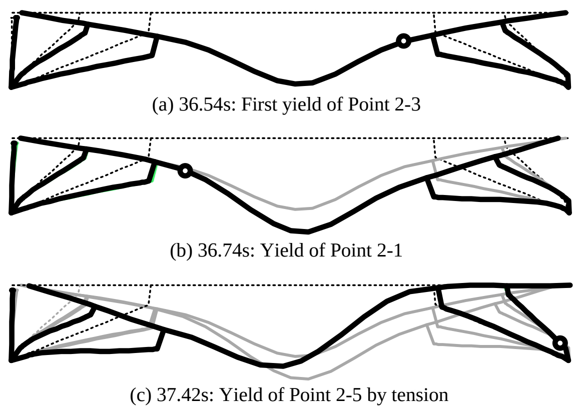

Fig. 6 Development of Deformation