從花蓮地震談及橋梁跨越斷層對耐震性能的影響

Hung Hsiao Hui (洪曉慧)
國家地震工程研究中心 橋梁組
2018/05/29

簡報大綱

- 花蓮地震橋梁震損調查
- 過去地震經驗
- 跨越斷層橋梁受震行為分析
- 比較與討論
0206 花蓮地震

中央氣象局地震報告

表：1000221號
日期：100年2月6日
時刻：20時50分41.2秒
位置：北緯25.124度，東經121.912度
震源：花蓮縣政府北偏東方，183公里
地震深度：10.9公尺
再震規模：6.0

圖片：中央氣象局

from Central Weather Bureau

備註：本次使用中央氣象局提供的地震深度資料

105

勘災團隊 國震橋梁組

Chin-Kuo Su (蘇進國)
Chi-Lon Jang (江奇融)
Bo-Han Lee (李柏翰)
Chun-Chung Chen (陳俊仲)
Hung Ihsiao Hui (洪曉慧)
Investigation route - Day I (Feb 8)

Destination 1: Qixingtan Bridge

Destination 2: Hualien Bridge

Investigation route - Day II along Meilun Creek

Fault location is from CENTRAL GEOLOGICAL SURVEY
Nearby Strong-Motion Stations

<table>
<thead>
<tr>
<th>PGA (gal)</th>
<th>Z</th>
<th>NS</th>
<th>EW</th>
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<tr>
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<td>397.08</td>
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<td>338.37</td>
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<td>HWA060</td>
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<table>
<thead>
<tr>
<th>PGV (cm/s)</th>
<th>Z</th>
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<th>EW</th>
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<td>HWA060</td>
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Jiali Elementary School (嘉里國小)-HWA028
Qixingtan Bridge

Completed in 2013

Configuration of Qixingtan Bridge

Specially designed support

Horizontal: Movable
Vertical: adjustable

Will not be affected by the differential displacements between substructure
Major damage of Qixingtan Bridge

Qixingtan Bridge
Qixingtan Bridge

Expansion joint
Surface rupture
A2 abutment

Stop point 2
2018/02/08 11:30

Qixingtan Bridge

Land slide
P2 pier
P1 Pier

Stop point 3
2018/02/08
Qixingtan Bridge

The subsidence of the approach embankment
Qixingtan Bridge

subsidence of A2 abutment backfill
**Qixingtan Bridge (P2)**

P2 rigid connection
No damage at all

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**Hualien Bridge**

Upstream side
1st generation bridge (southbound)

Downstream side
2nd generation bridge (northbound)
Hualien Bridge

1st generation
Year 1968, width 8.1–11.45 m

2nd generation
Year 2002, width 10.7–20.06 m

Northbound route (2nd generation bridge)
Southbound route (1st generation bridge)

Seismic retrofitted by steel plate jacketing and extension of foundation
Seismic retrofitted by steel plate jacketing and retrofit of caisson foundation (P5–P12)
Hualien Bridge (P10)

Damage on the hinge connection of deck
Hualien Bridge (P11)

Crack on the cap beam

1st generation

Hualien Bridge (P12)

1st generation

2nd generation
Hualien City NO.3 Bridge

Hualien City NO.3 Bridge
Hualien City NO.3 Bridge
Shangzhi Bridge

PCI bridge
Completed in 2001
Simply supported bridges

Crush in the expansion joint
Sidewalk star damage
Crack in the RC stopper

Shangzhi Bridge
Shangzhi Bridge
921 地震經驗

1999年土耳其地震經驗

8月17日 Kocaeli 地震 / 規模 M=7.4

Arifiye高架橋

- 四跨預製簡支梁
- 60度斜橋
- 支承為橡膠支承墊
1999年土耳其地震經驗

8月17日 Kocaeli 地震 /規模M=7.4


1999年土耳其地震經驗

11月12日 Duzce 地震 /規模M=7.2

土耳其博盧高架橋 (Bolu Viaduct)

- 59跨之連續簡支梁橋
- 跨徑約40 m
- 盤式支承，搭配能量消散裝置（Energy Dissipation Unit，EDU）

Bridges crossing active faults may be subjected to large differential displacements between adjacent piers and/or abutments due to surface faulting. Therefore, it is important to provide the sufficient displacement capacity.

For the simply supported bridge with support of neoprene pad, simple spans can tolerate large relative movements, so most of the damage occurs at the expansion joint or hinge connection at the deck, dislocation of the neoprene pad, and the crack of the seismic stopper. However, it is difficult to ensure that the spans do not become unseated, especially for the longitudinal direction.

For a continuous bridge with superstructures integrated with substructures will reduce the probability of total collapse. However, the substructure has to accommodate the amount of relative displacement across a fault.

Simply supported bridges
- can tolerate large relative movements, easy for retrofit and replacement
- difficult to ensure that the spans do not become unseated

Continuous superstructures
- can reduce the risk of collapse
- Superstructure may have a large displacement demand

Continuous superstructures that are integral with their substructures
- can reduce the probability of total collapse
- the substructure has to suffer large displacement demand due relative displacement across a fault.
Observations and Discussions

- Key points: **sufficient displacement capacity**
- Which component to accommodate the displacement demand?

Continuous bridge with bearings that can accommodate relatively large displacements

- (FPS, elastomeric bearings, equipped with **energy dissipation devices**...)
- sufficient support length
- Unseating Prevention Devices
- adding extra confinement in the plastic hinge zones of the substructure to provide the maximum displacement capacity.
橋梁模型

- 四跨連續橋：4@40m =160m
- 橋柱：10m之單柱式圓形RC橋柱
- 位置：南投草屯(近車籠埔斷層)第一類地盤

非線性分析模型

(图示内容涉及桥梁结构和非线性分析的图表和数据)
設計地震

近斷層地震 (Chi Chi earthquake)
反應譜

Acceleration response spectrum

Displacement response spectrum

Design earthquake

非線性動力歷時分析

Input displacement time history records

非跨斷層：同時輸入位移歷時於Zone 1 & zone 2

7組地震力

Fiber element

Zone 1

Zone 2

跨斷層：輸入位移歷時於Zone 1

7組地震力

Fiber element

Zone 1

Fault line

Zone 2
跨/非跨斷層反應比較(設計地震)

支承剪力

柱底扭矩

柱底彎矩-轉角關係曲線

橋梁最大歷時反應之比較(設計地震)

<table>
<thead>
<tr>
<th>地震歷時</th>
<th>設計地震1</th>
<th>設計地震2</th>
<th>設計地震3</th>
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<tr>
<td>歷時最大反應</td>
<td>跨斷層</td>
<td>非跨斷層</td>
<td>跨斷層</td>
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<td>P3柱頂位移 (cm)</td>
<td>34.63</td>
<td>6.75</td>
<td>21.34</td>
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<tr>
<td>P4柱頂位移 (cm)</td>
<td>36.19</td>
<td>6.71</td>
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<td>P3柱頂加速度 (g)</td>
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<td>P4柱頂加速度 (g)</td>
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<td>P3柱頂 ~ M (MN)</td>
<td>4.11</td>
<td>3.06</td>
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<td>P4柱頂 ~ M (MN)</td>
<td>4.20</td>
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<tr>
<td>P3柱頂扭轉 (MN.m)</td>
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<td>P4柱頂扭轉 (MN.m)</td>
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<td>P4柱頂塑性變形比</td>
<td>16.68</td>
<td>2.93</td>
<td>12.22</td>
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θ/θy
結論與討論

- 對於跨越斷層橋梁，分析若未考慮同一座橋相鄰橋柱間之斷層錯動，將低估支承剪力，柱底變形和柱底所受扭矩，但高估柱頂加速度反應。
- 尚須更多橋型比較、支承非線性模擬…不同斷層錯動方向…等等之分析比照，以作為未來擬定跨越斷層橋梁相關設計或減災方案之參考