

功能性支承系統評估與補強工法案例

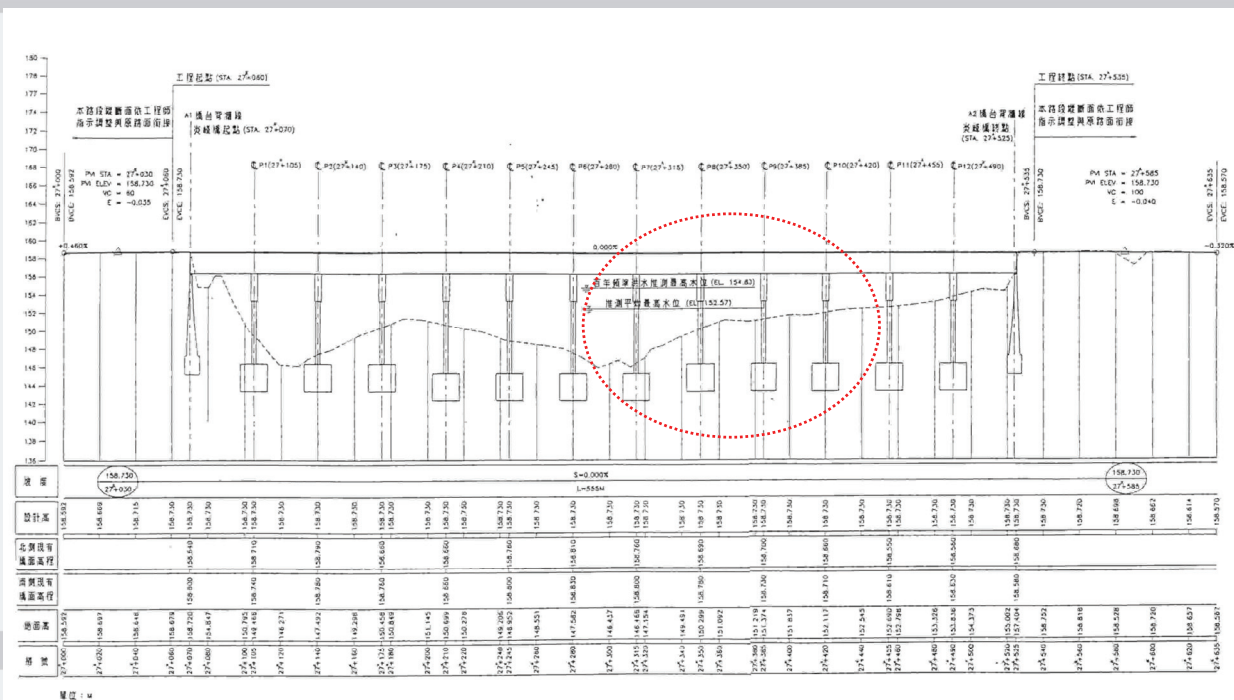
盧智宏

時間：99年5月12日

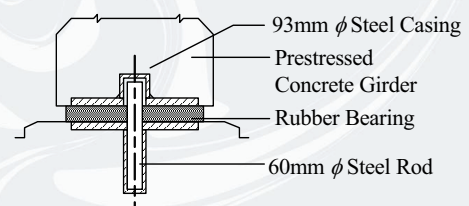
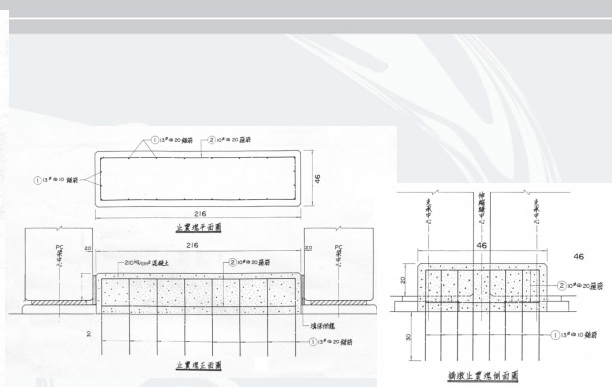
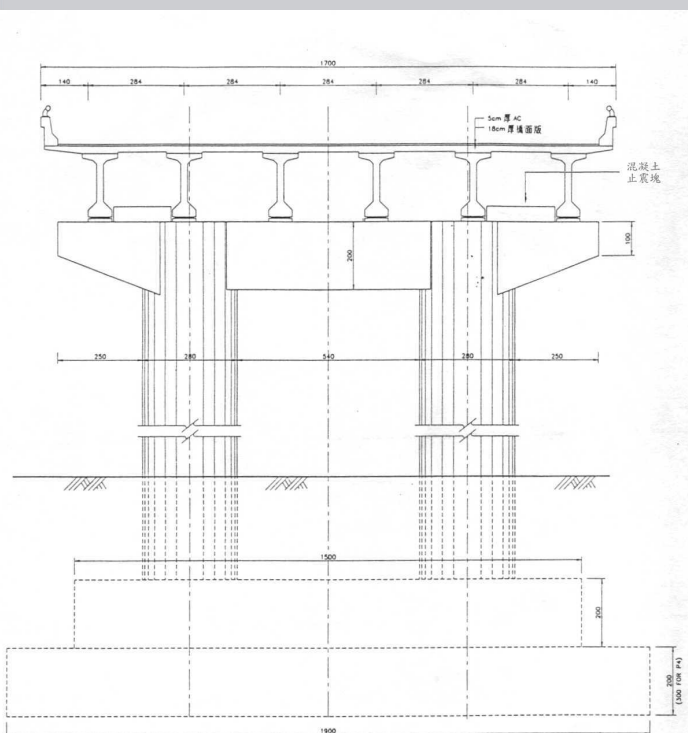
橋梁基本資料

- 地理位置：南投縣草屯鎮省道，屬重要橋梁。
- 橋梁型式：PCI預力梁、混凝土構架式橋墩、橡膠支承墊。
- 設計年代：民國73年竣工，屬民國49年版橋梁設計規範。
- 補強後耐震性能目標：
 - 設計地震等級：PL1 – 0.36G
 - 中度地震等級：PL3 – 0.11G

案例分析橋梁簡介(一)



案例分析橋梁簡介(二)



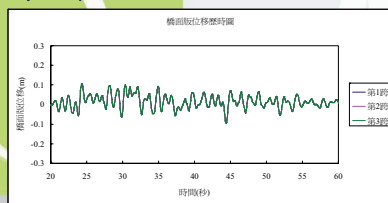
Bearing Detail (Hinge End)

耐震能力詳細評估方法

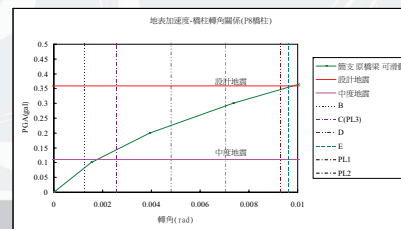
- 非線性動力歷時分析 (NTHA) - 設定非線性元素模擬各結構構材之非線性特性，選用能與工址設計反應譜相符之三個地震歷時資料做為輸入地震力。

- 增量動力分析 (Incremental dynamic analysis, IDA) 方法 - 以最大地表加速度指標，由地震歷時之PGA為0.1g起逐步放大至0.5g，分別紀錄分析模型中的各桿件結構或橋梁系統之最大反應，即可建立地表加速度與結構性能之曲線圖。

輸入地震歷時首筆



擷取最大反應



放大地震歷時再分析

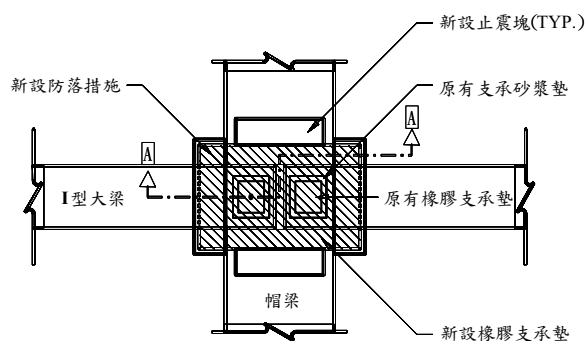
支承摩擦滑動現象



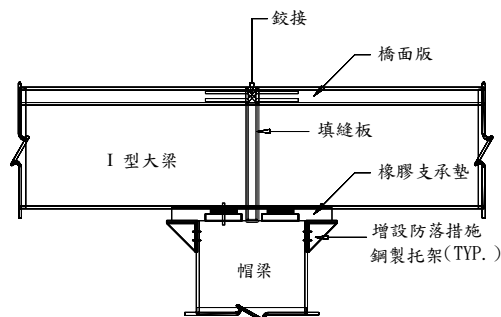
- 盧智宏，「橋梁防落裝置耐震行為之研究」，國立台灣大學土木工程學研究所碩士論文，民國九十一年六月，2002。
- 張國鎮、郭拱源、劉光晏、盧智宏，2004，支承系統對橋梁耐震行為之影響－921集集地震橋梁震害之探討與醒思，結構工程，第十九卷第二期，pp.55-73，2004年6月。

結構系統補強與功能性支承補強工法介紹

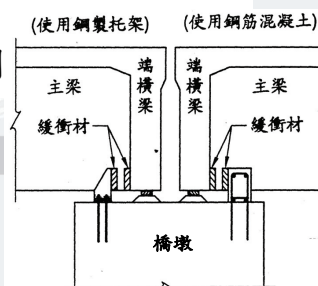
- 功能性支承系統補強工法：使支承有適當摩擦力，強震下可產生摩擦滑動機制，並使用位移限制裝置限制滑動位移，允許其損壞避免傳遞過大地震力，且須提供足夠防落長度確保不落橋。



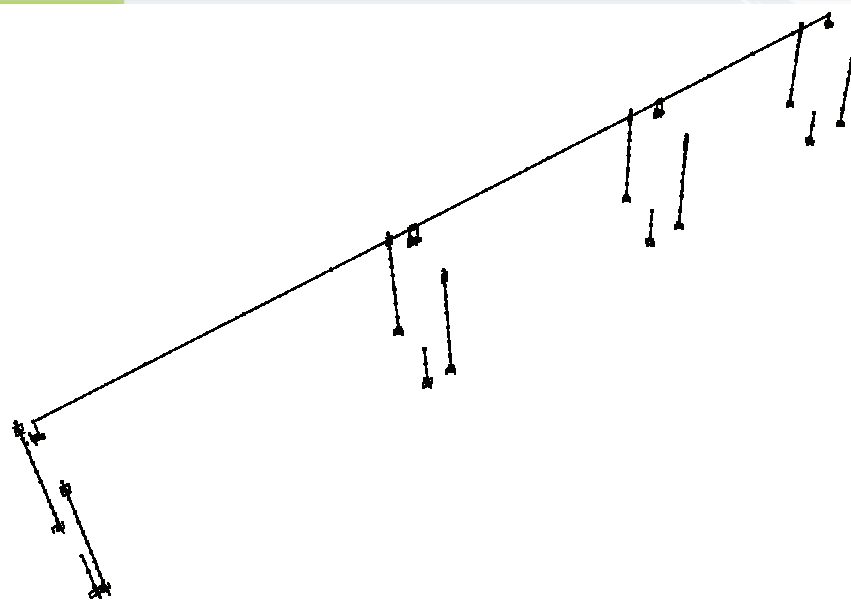
橋墩增設橡膠支承墊



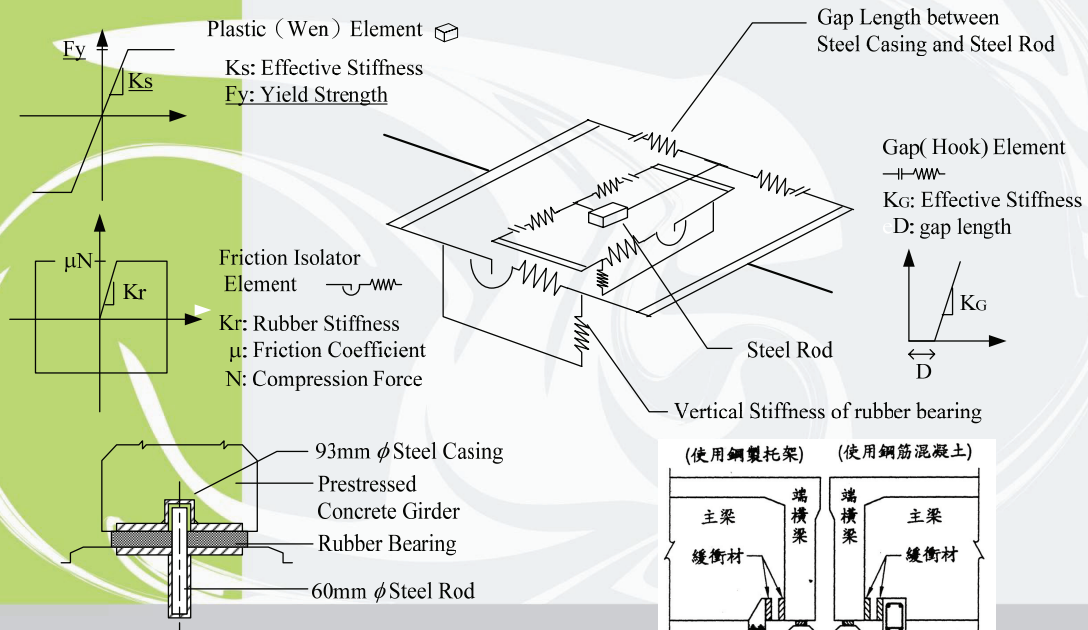
A-A剖面圖



分析模型說明



功能性支承模擬



Bearing Detail (Hinge End)

Friction isolator元素 – 支承摩擦滑動

Link/Support Property Data

Link/Support Type:

Property Name: Set Default Name

Property Notes: Modify/Show...

Total Mass and Weight:

Mass: Rotational Inertia 1:

Weight: Rotational Inertia 2:

Rotational Inertia 3:

Factors For Line, Area and Solid Springs:

Property is Defined for This Length In a Line Spring:

Property is Defined for This Area In Area and Solid Springs:

Directional Properties:

Direction	Fixed	NonLinear	Properties
☒ U1	☐	☒	Modify/Show for U1...
☒ U2	☐	☒	Modify/Show for U2...
☒ U3	☐	☒	Modify/Show for U3...
☐ R1	☐	☐	Modify/Show for R1...
☒ R2	☒	☐	Modify/Show for R2...
☐ R3	☐	☐	Modify/Show for R3...

Fix All Clear All

P-Delta Parameters:

OK Cancel

Link/Support Directional Properties

Identification:

Property Name:

Direction:

Type:

NonLinear: ☒

Properties Used For Linear Analysis Cases:

Effective Stiffness:

Effective Damping:

Shear Deformation Location:

Distance from End-J:

Properties Used For Nonlinear Analysis Cases:

Stiffness:

Friction Coefficient, Slow:

Friction Coefficient, Fast:

Rate Parameter:

Radius of Sliding Surface:

OK Cancel

Plastic (Wen) 元素 – 位移限制裝置

Link/Support Property Data

Link/Support Type: Plastic (Wen)

Property Name: KEY

Property Notes:

Total Mass and Weight:

Mass: 0.0

Weight: 0.0

Rotational Inertia 1: 0.0

Rotational Inertia 2: 0.0

Rotational Inertia 3: 0.0

Factors For Line, Area and Solid Springs:

Property is Defined for This Length In a Line Spring: 1

Property is Defined for This Area In Area and Solid Springs: 1

Directional Properties:

Direction	Fixed	NonLinear	Properties
☒ U1	☒	☐	Modify/Show for U1
☒ U2	☐	☒	Modify/Show for U2
☒ U3	☐	☒	Modify/Show for U3
☒ R1	☒	☐	Modify/Show for R1
☒ R2	☒	☐	Modify/Show for R2
☒ R3	☒	☐	Modify/Show for R3

Fix All

Clear All

P-Delta Parameters:

Advanced...

OK

Cancel

Link/Support Directional Properties

Identification:

Property Name: KEY

Direction: U2

Type: Plastic (Wen)

NonLinear: Yes

Properties Used For Linear Analysis Cases:

Effective Stiffness: 57700000

Effective Damping: 0

Shear Deformation Location:

Distance from End-J: 0

Properties Used For Nonlinear Analysis Cases:

Stiffness: 57700000

Yield Strength: 257620

Post Yield Stiffness Ratio: 0

Yielding Exponent: 20

OK

Cancel

Gap元素 – 大梁與位移限制裝置間隙

Link/Support Property Data

Link/Support Type: Gap

Property Name: GK

Property Notes:

Total Mass and Weight:

Mass: 0.0

Weight: 0.0

Rotational Inertia 1: 0.0

Rotational Inertia 2: 0.0

Rotational Inertia 3: 0.0

Factors For Line, Area and Solid Springs:

Property is Defined for This Length In a Line Spring: 1

Property is Defined for This Area In Area and Solid Springs: 1

Directional Properties:

Direction	Fixed	NonLinear	Properties
☐ U1	☐	☐	Modify/Show for U1
☒ U2	☐	☒	Modify/Show for U2
☒ U3	☐	☒	Modify/Show for U3
☐ R1	☐	☐	Modify/Show for R1
☐ R2	☐	☐	Modify/Show for R2
☐ R3	☐	☐	Modify/Show for R3

Fix All

Clear All

P-Delta Parameters:

Advanced...

OK

Cancel

Link/Support Directional Properties

Identification:

Property Name: GK

Direction: U2

Type: Gap

NonLinear: Yes

Properties Used For Linear Analysis Cases:

Effective Stiffness: 0

Effective Damping: 0

Shear Deformation Location:

Distance from End-J: 0

Properties Used For Nonlinear Analysis Cases:

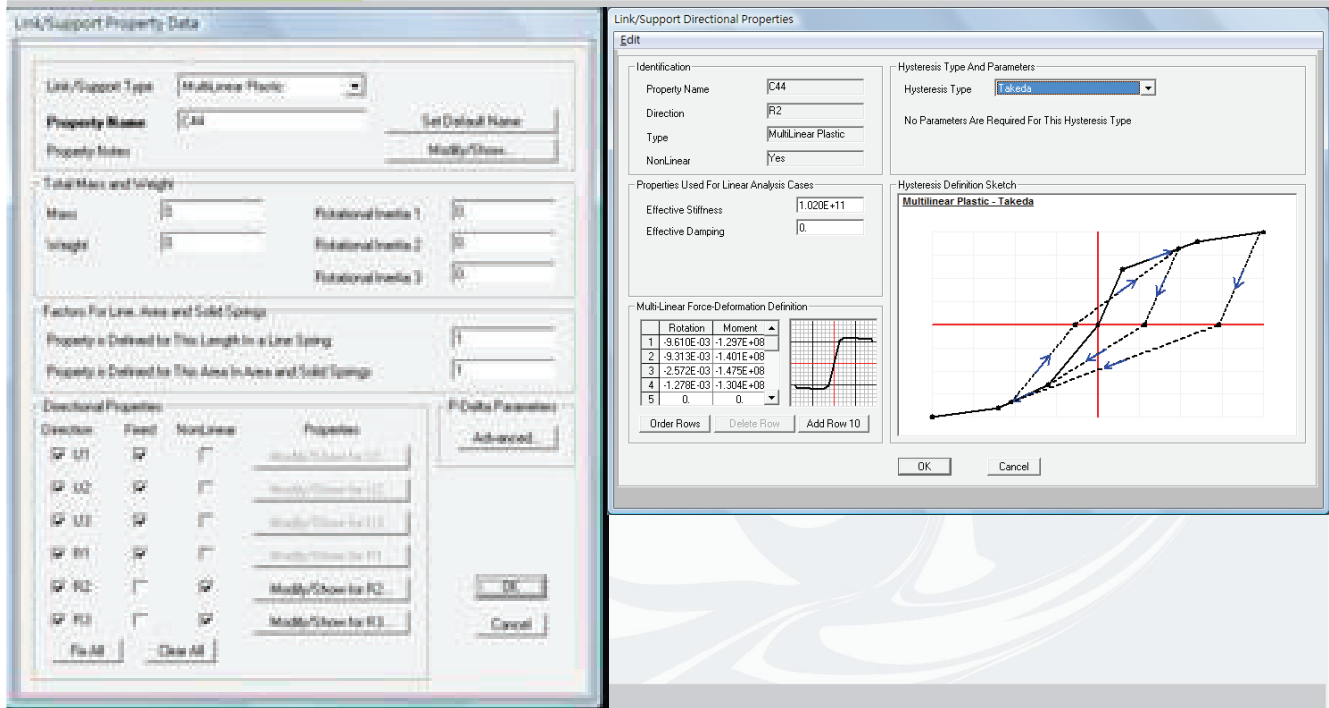
Stiffness: 5.770E+10

Open: 3.3

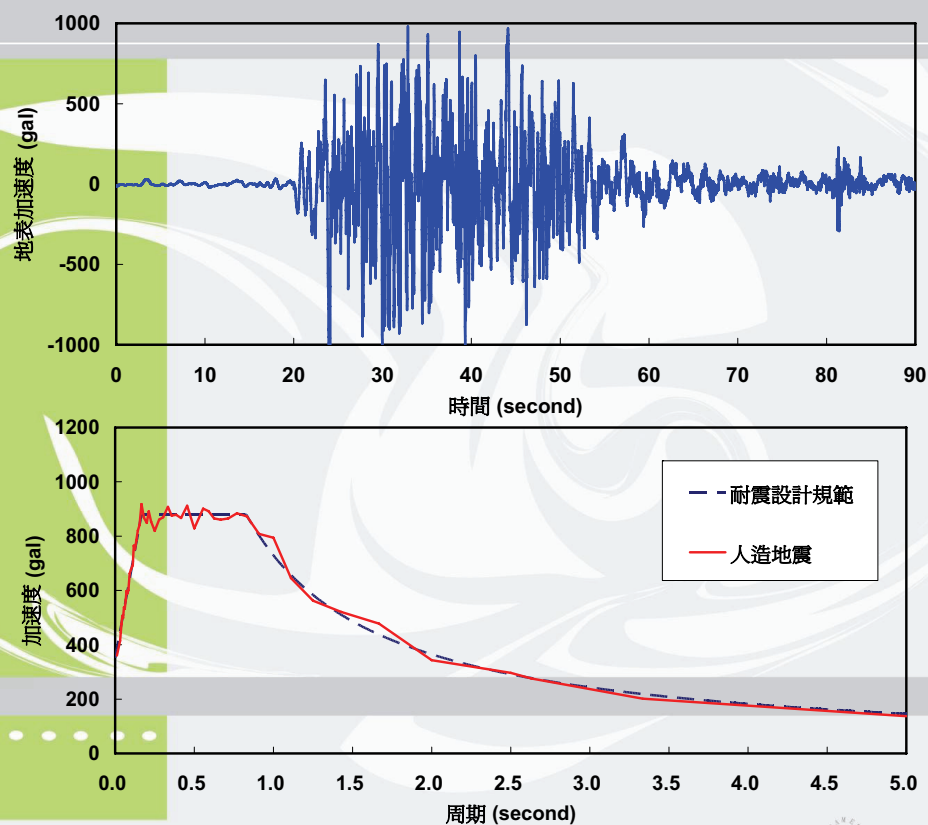
OK

Cancel

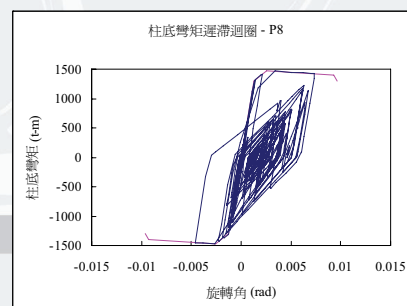
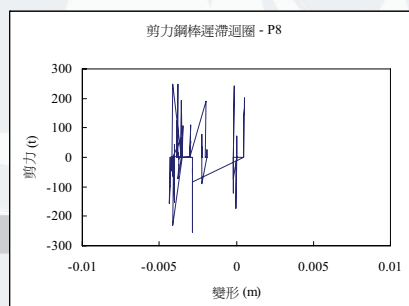
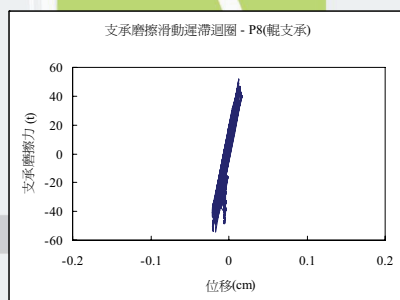
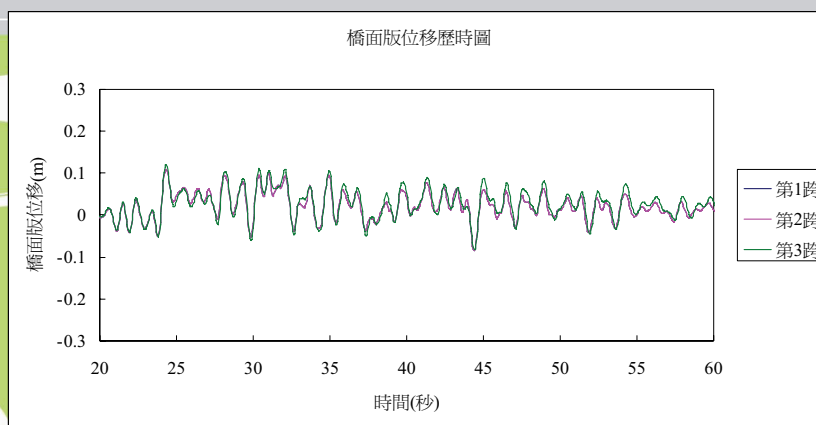
橋柱模擬與塑性鉸設定



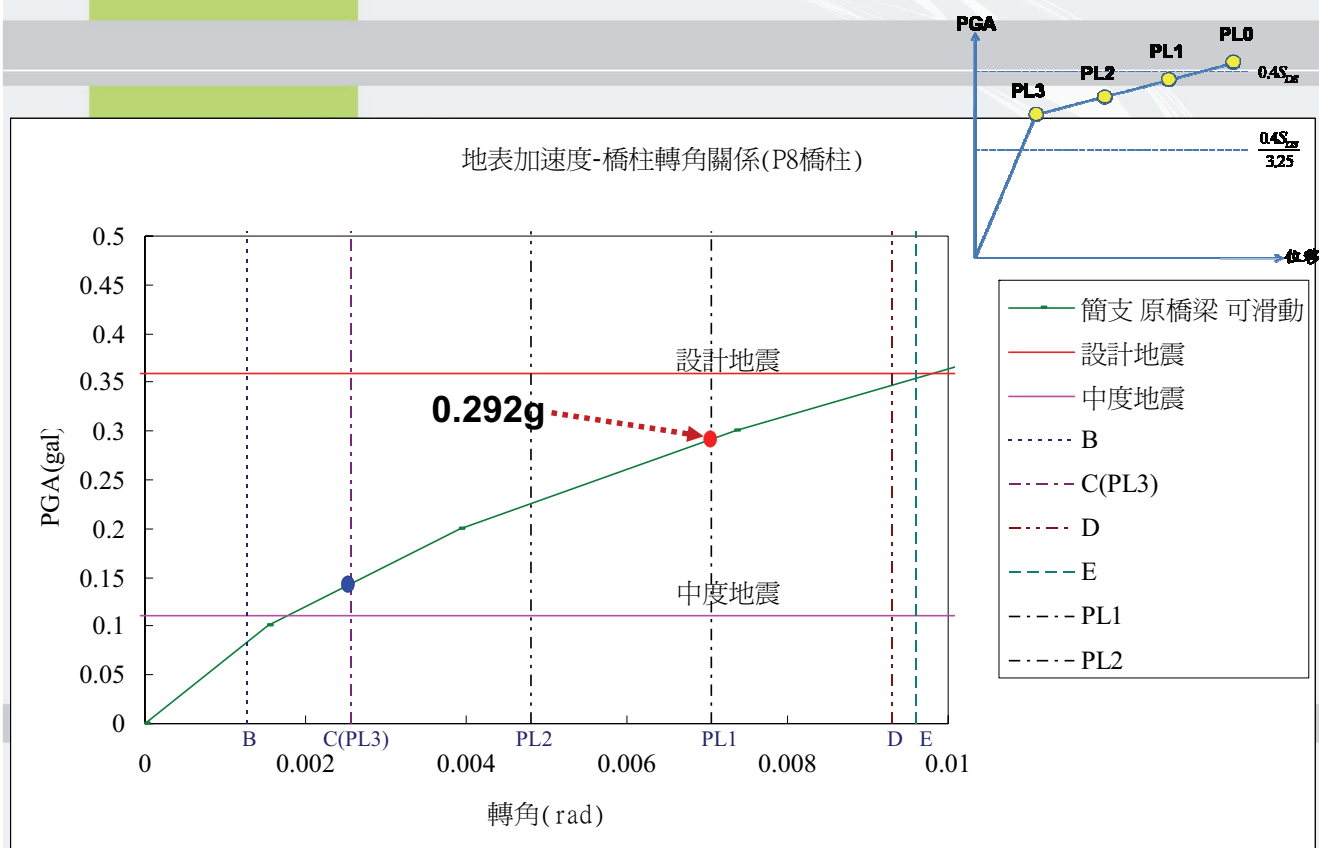
人造地震加速度歷時



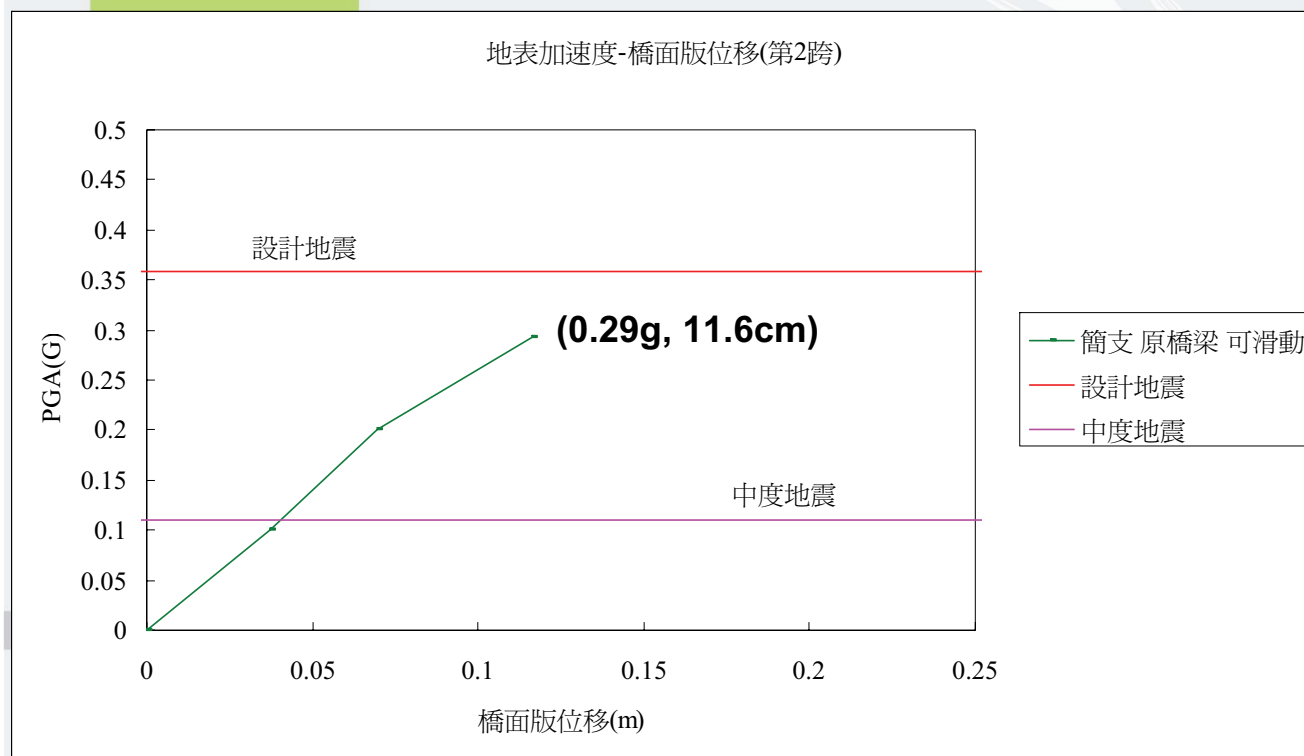
分析補強前系統反應 - 0.3g



補強前地表加速度與橋柱轉角關係



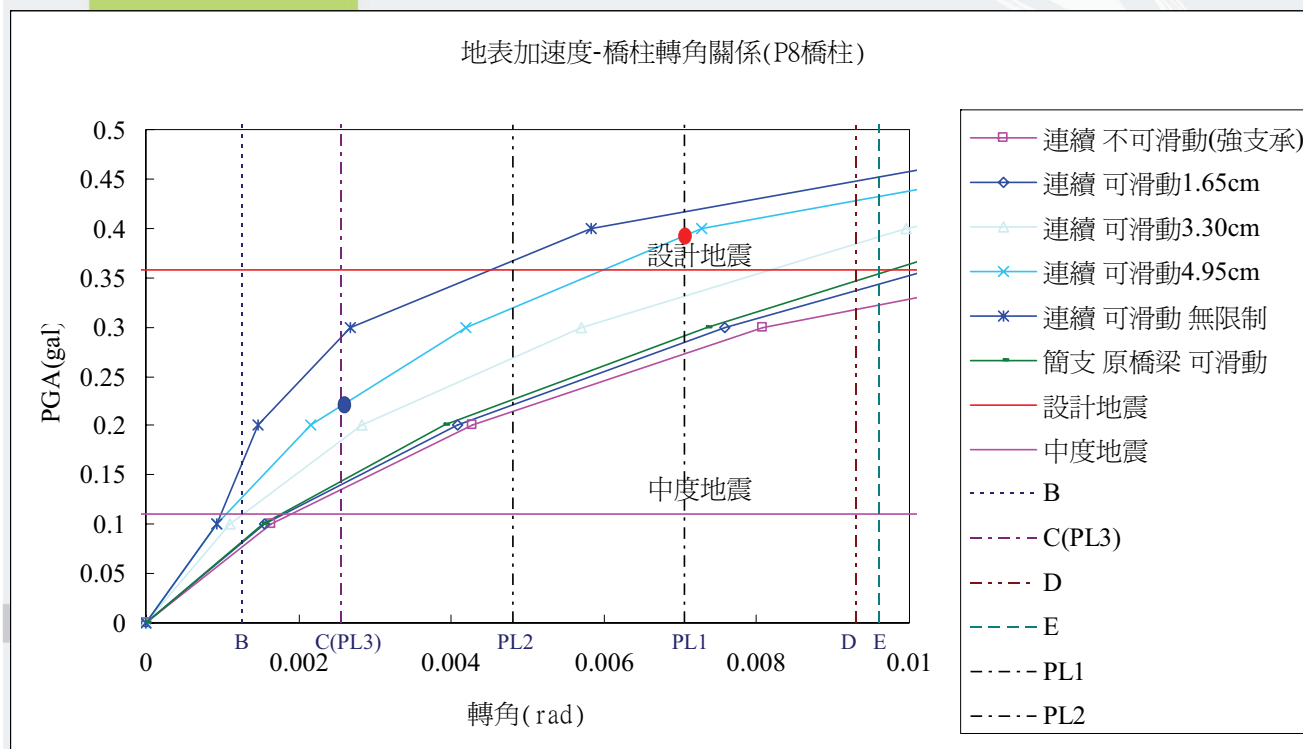
補強前地表加速度與橋面版關係圖



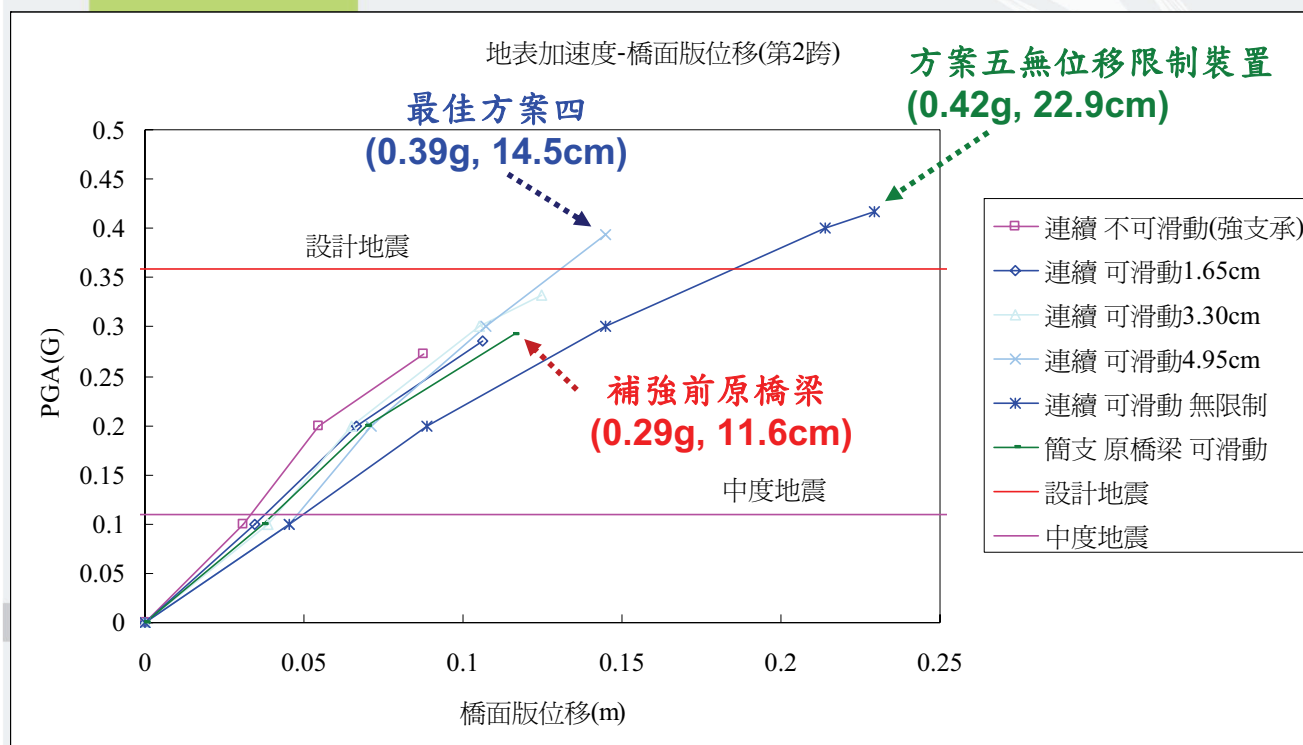
擬定案例橋梁結構系統補強方案

	上部結構連續化	可否摩擦滑動	位移限制裝置與大梁間距
方案一	連續	不可滑動(強支承)	無
方案二	連續	可滑動	1.65cm
方案三	連續	可滑動	3.30cm
方案四	連續	可滑動	4.95cm
方案五	連續	可滑動	無限制
補強前原橋梁	簡支	可滑動	1.65cm

補強後各方案地表加速度與橋柱轉角關係



補強後各方案地表加速度與橋面版位移關係



補強方案	橋柱性能水準	對應之橋面版位移
方案一，連續不可滑動(強支承)	0.273g	8.77cm
方案二，連續可滑動1.65cm	0.285g	10.61cm
方案三，連續可滑動3.30cm	0.332g	12.45cm
方案四，連續可滑動4.95cm	0.393g	14.46cm
方案五，連續可滑動無限制	0.417g	22.93cm
補強前原橋梁，簡支可滑動 1.65cm	0.292g	11.61cm

結論

- 增量動力分析方法可求得橋梁構件及整體系統之性能曲線，亦可做為橋梁耐震能力評估使用。
- 功能性支承補強工法使支承有適當之摩擦力，在強震作用下產生摩擦滑動機制，並藉由適當之位移限制裝置限制滑動位移，允許其損壞避免傳遞過大地震力，減少下部結構補強需求，為十分經濟且有效之結構系統補強方式。
- 本補強工法在大地震時上部結構將有較大的殘餘變位與附屬設施損壞現象，較適合用於交通量不大之路段，補強設計時應確實檢核是否有足夠之防落長度，並應搭配適當之防止落橋裝置避免落橋。



報告完畢

恭請指導