Trial Design Study On Earthquake Resilient Bridge With Tall Piers

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- Tall pier，why?

The map of highway constrcution in China

- Tall pier， why?

  - location
  - expense
  - technique

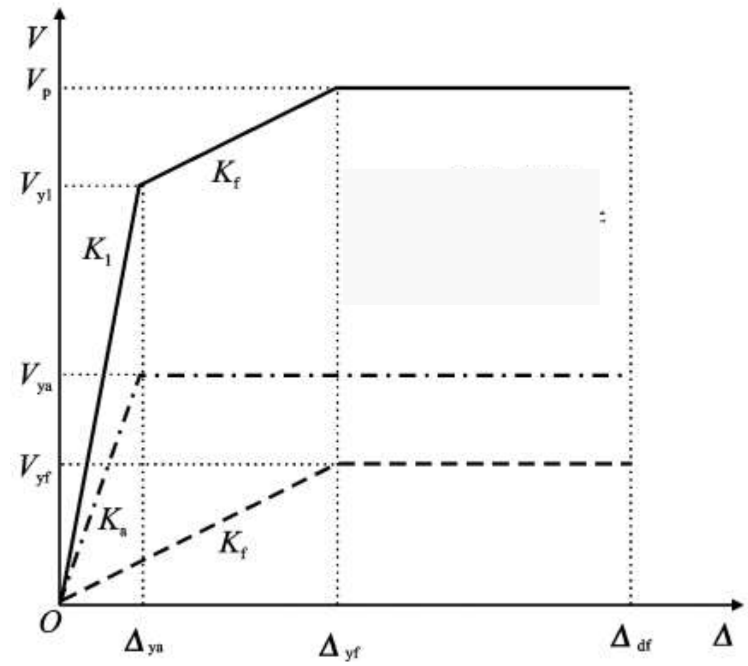
Limitation

- mass distribution
- high-order mode and the P-Δ effect
- construction machines and period

- difficult to repair after earthquake

- The “fuse”, Resilience

The seismic design concept of bridges has been developed from earthquake resistant or mitigation to the post-earthquake resilient. Based on the design concept of the seismic resilience, there are a number of ways to achieve structural resilience after earthquake through adopting **rocking structure, self-centering structure, replaceable component** and so on



The way to realize the resilience

The concept of replaceable component structure originally put forward by Roeder and Popov, who proposed the design concept of "structural fuse" when studying eccentric braced steel frames.

Some typical examples include the bi-steel columns with buckling restrained braces (BRB) and the bi-steel columns with steel energy dissipating coupling beams were proposed by El-Bahey S, Bruneau M.

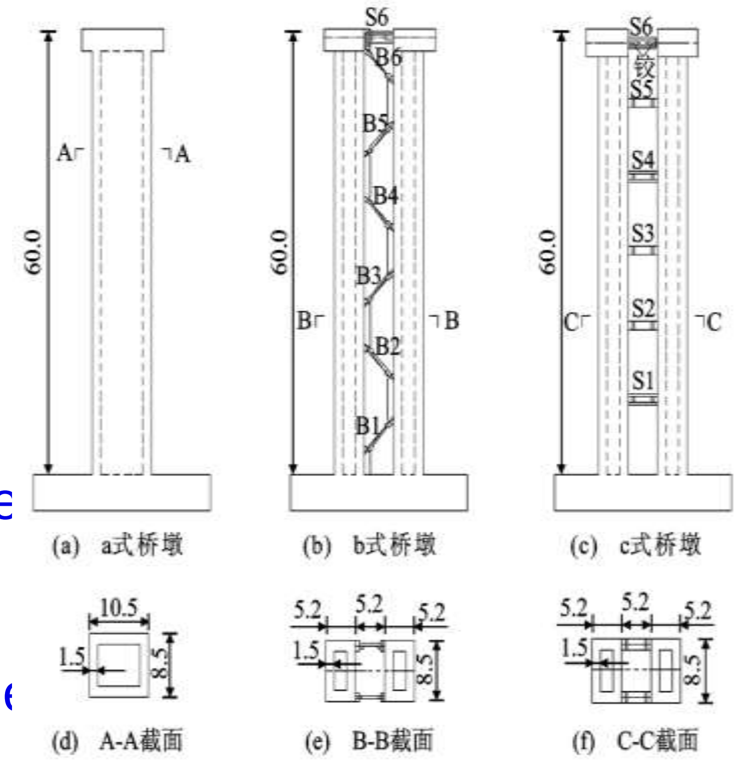
Roeder C, Popov E (1977): Inelastic behavior of eccentric braced steel frames under cyclic loadings. *Report No.77, Berkeley*, Earthquake Engineering Research Center, University of California.

El-Bahey S, Bruneau M (2012): Bridge piers with structural fuses and bi-steel columns. II: Analytical investigation. *Journal of Bridge Engineering*, **17**(1): 36-46.

The way to realize the resilience

McDaniel and Seible found that the steel coupling beam served as a "**structural fuse**" and yielded under moderate and large earthquakes while the **tower column remained elastic**.

Xie and Sun applied the double-column piers with buckling restrained braces (BRB) and ste energy dissipating beams in tall-pier bridges. The effectiveness of these replaceable components in controlling the seismic damag was validated through finite element (FE) analysis.

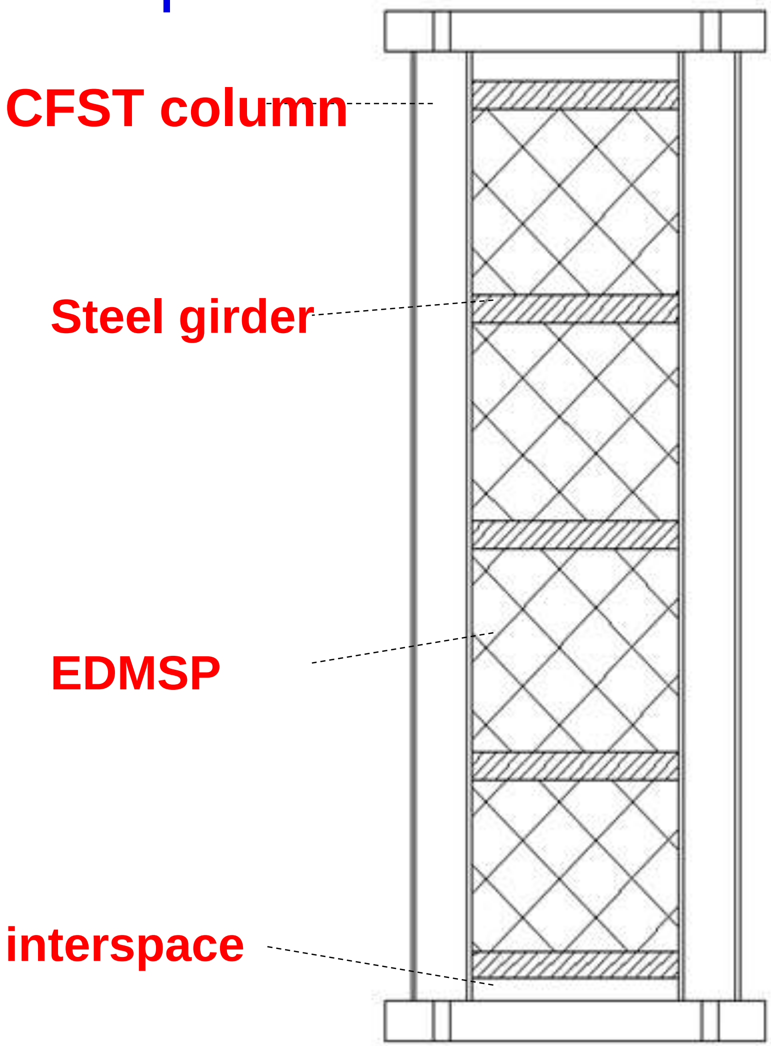


Sun ZG, Hua CJ, Shi Y, et al (2015): Seismic design of bridge bents with BRB as structural fuse. Journal of Vibration and Shock, 34(22): 199-205. (in Chinese)

Xie W, Sun LM (2015): Investigation on seismic damage control for twin-column tall piers by supplemental energy dissipation elements. Journal of Vibration and Shock, 34(20): 98-103. (in Chinese)

- Design of new composite tall pier

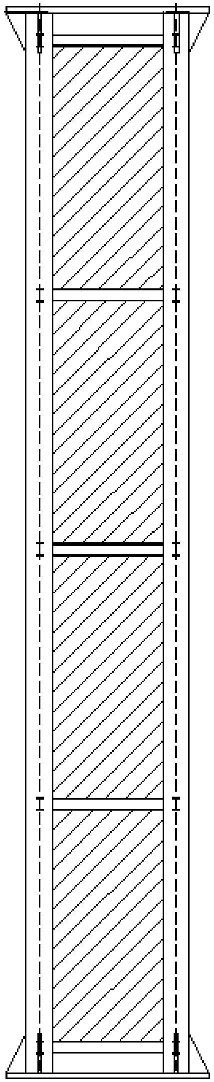
The newly proposed composite tall pier consists of a four-limb CFST column and EDMSPs. The EDMSPs serve as both energy dissipating components and sacrificial components. Meanwhile, the I-shape steel beams are installed every 10~15 m to connect the four limbs of the CFST column.



Redesign principle

1. The axial load bearing capacity of the new composite tall pier is equivalent to the prototype pier;

2. The height and flexural stiffness in the longitudinal direction of the new composite tall pier are equivalent to those of the original one.



Design concept of new composite tall-pier

The structural design concepts of the new composite tall-pier bridge are as follows:

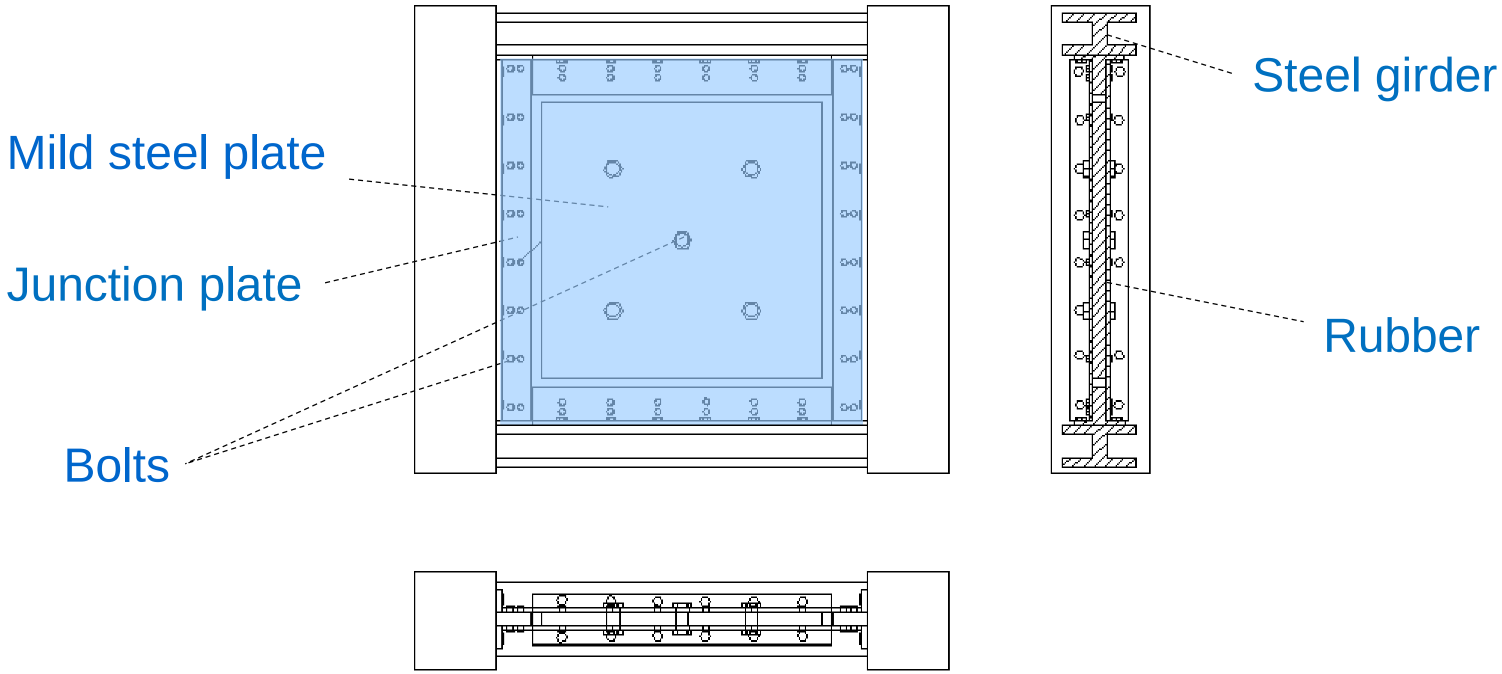
(1)Under serviceability limit states: the four-limb CFST column and the EDMSPs **form a box section to provide sufficient flexural and torsional stiffness**.

(2) Under E1 level earthquake: **The structure remains elastic**.

(3) Under E2 level earthquake: **only the EDMSPs yield**.

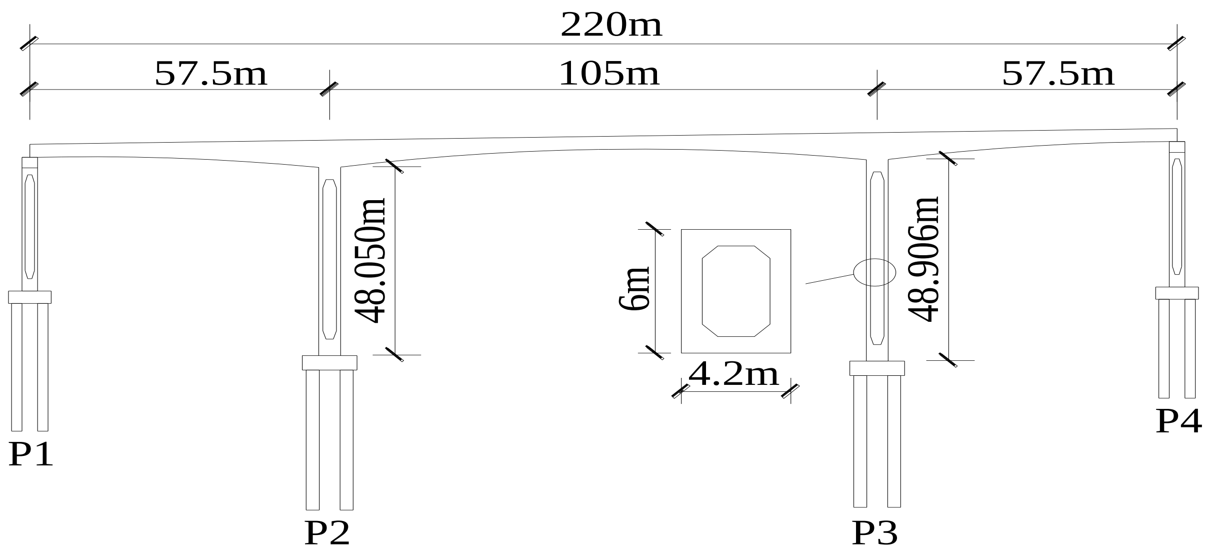
EDMSP in research and development

The EDMSPs :energy dissipating mild steel plate



Photos of the EMDPS

The prototype bridge



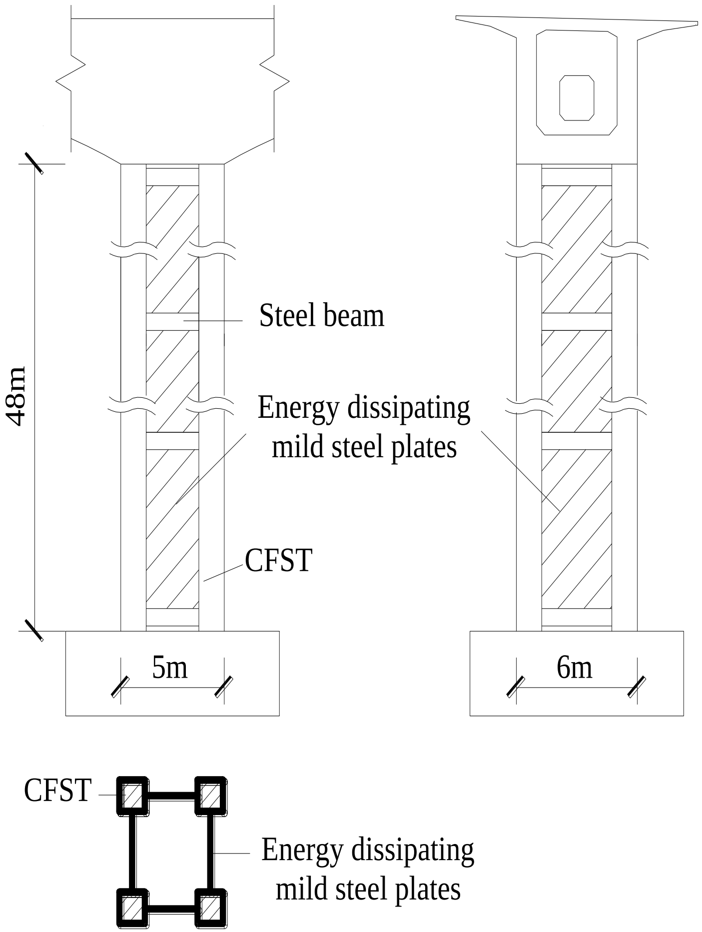
Main parameters:
The height of the main pier (i.e., *H*) is 48m. The width of the pier in the in transverse direction (i.e., *a*) is 6m and the longitudinal width (i.e., b) is 5m. The thickness of the box-section (i.e., *t*) is 0.8m.

Redesign of the prototype bridge

(1) Q345 steel and C50 concrete are used in the four-limb CFST column. The sectional dimension is 1.2m×1.2m with a thickness of 25mm. The sectional steel ratio is 8.16%.

(2) The EDMSP between the concrete-filled steel tubular columns is made of LYP100 low-yield point steel plate with a thickness of is 25mm

(3) In addition, the Q345 I-shaped steel beams with a sectional dimension of 400×146×16.5mm are installed every 12m along the height of the pier.



Advantages of the new composite tall pier

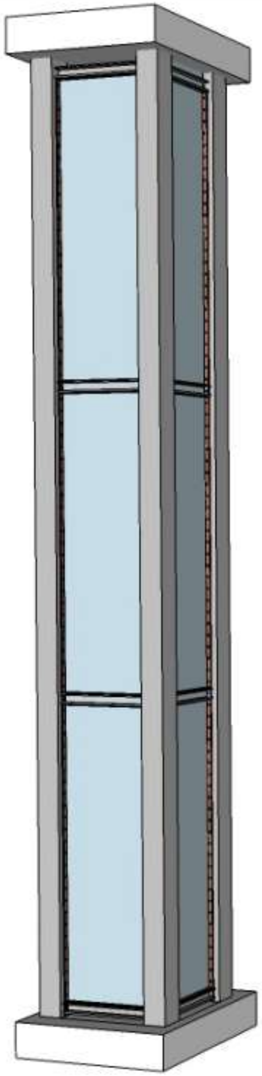
(1) **Static performance**: the new composite tall pier has the same advantages as the conventional RC/steel box-section tall pier.

(2) **Seismic performance**: the new composite tall pier has the same advantages as the structure equipped with energy dissipating devices.

(3) Construction: the new composite tall pier has the same characteristic of rapid construction as the steel structure.

FE models of the new composite tall pier

For the new composite tall-pier bridge, the superstructure and the basin type support adopt the same modeling strategy as the prototype bridge. The four limbs of the CFST column and the I-shape steel beams are also modeled by the B31 element. The steel tube is defined by the *rebar keyword. The USteel01 material in the PQ-Fiber subroutine is adopted for the steel tube. Meanwhile, the confinement effect of the concrete is considered by the constitutive model proposed by Han. The EDMSPs are modeled by the S4R shell elements.



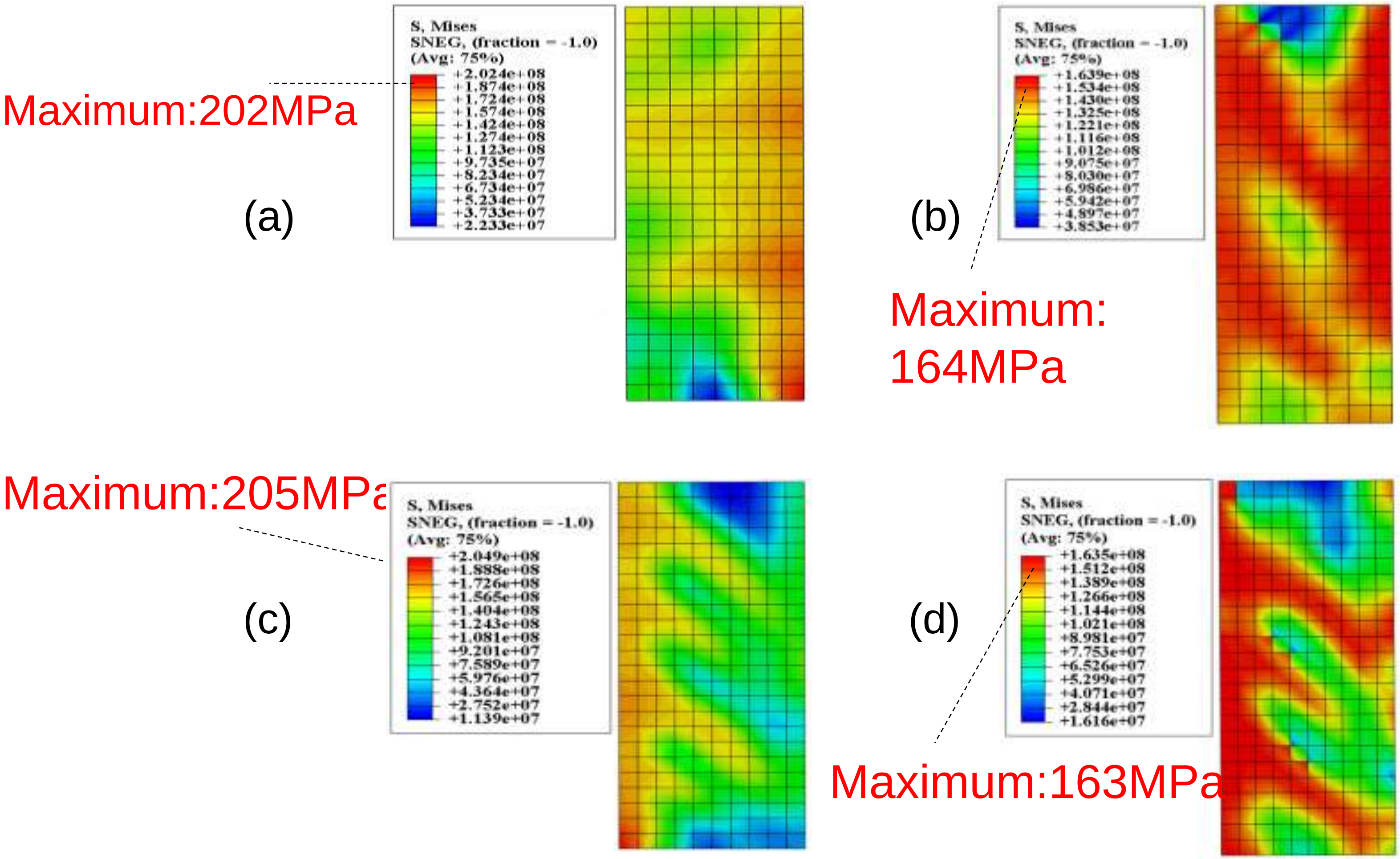
Ground motion input

According to the site condition of the prototype bridge, three sets of ground motion are selected based on the **I-class site**, of which 2 sets are natural ground motion records and the other one is an artificial for ground motion sets. The magnitudes of the selected ground motions are adjusted according to the **seismic design intensity of the bridge (i.e., VIII degree).** Each ground motion set contains three components and all three components are input simultaneously. The bridges are analyzed under both **E1 and E2 level** earthquake. The maximum seismic responses under 3 sets of ground motions are recorded.

- Damage indices and corresponding damage states of RC main piers

Main pier	Control section	Longitudinal		Transverse	
		Damage index	Damage level	Damage index	Damage level
2#	Bottom	0.28	Moderate	0.36	Moderate
	Top	0.13	Slight	0.00	No
3#	Bottom	0.29	Moderate	0.39	Moderate
	Top	0.14	Slight	0.00	No

Mises stress distribution of the EDMSPs



Stress distribution of the EDMSPs: (a) bottom plate (longitudinal); (b) top plate (longitudinal); (c) bottom plate (transverse); (d) top plate (transverse)

- Comparison of maximum lateral displacements under E2 level earthquake

Position	Direction	Maximum displacement/cm		Ration
		Conventional RC tall-pier bridge	New composite tall-pier bridge	
Top of piers	Longitudinal	33.96	22.06	35%
Top of piers	Transverse	45.21	18.98	58%
Relative displacement between superstructure and piers		39.20	29.58	25%

Conclusions

(1)Under basic load combination, the new composite tall-pier bridge can provide a **satisfying load bearing capacity and stability**.

(2)Under E1 level earthquake, the new composite tall-pier bridge **remains elastic and has smaller lateral displacement response** than the conventional RC box-section tall-pier bridge.

(3)Under E2 level earthquake, the main pier of the conventional RC box-section tall-pier bridge experiences **moderate damage**. While in the new composite tall-pier bridge, **only the replaceable EDMSPs experience a large extent of plastic deformations**, indicating the characteristic of seismic resilient.

(4)Under E2 level earthquake, the new composite tall-pier bridge has a **small displacement response** than the conventional RC box-section tall-pier bridge due to the **additional damping provided by the EDMSPs.**

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Спасибо

RUSSIAN

Gracias

SPANISH

ありがとうございました。

JAPANESE

CÁM ƠN

VIETNAMESE

Thank You!

ENGLISH

Merci

FRENCH

Ευχαριστώ

GREEK

شكراً

ARABIC

고맙습니다

KOREAN

谢谢

CHINESE