



Seismic performance of segmental columns-supported bridges (SCSBs)

Kaiming Bi

The Hong Kong Polytechnic University, Hong Kong, China

The 5th International Bridge Seismic Workshop
6 May 2026 Changsha, China

Contents

1. Background

**2. SCSBs subjected to far field/near fault
ground motions**

**3. SCSBs subjected to across-fault ground
motions**

1. Background



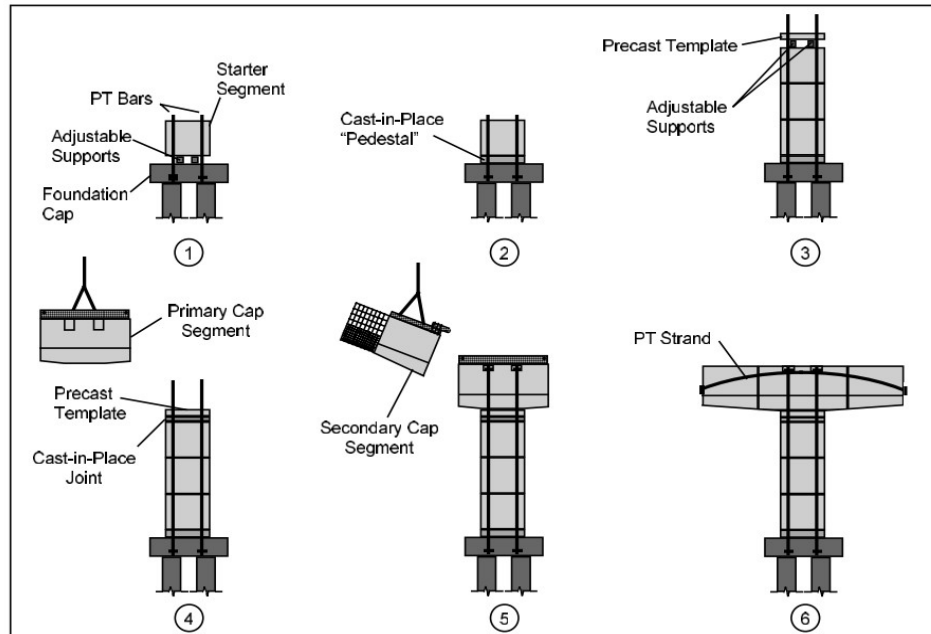
Segmental column-supported bridges



Applications



Parthenon Temple



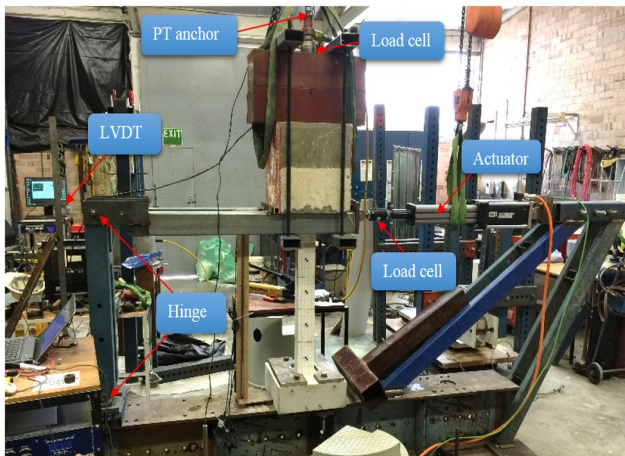
- a. Shorter construction time
- b. Less site disruption
- c. Better quality control
- d. Lower environment impact
- e. Safer working conditions
- f. Smaller residual displacement



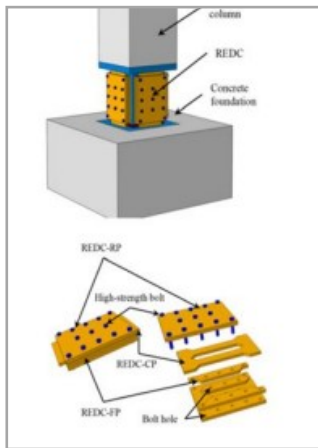
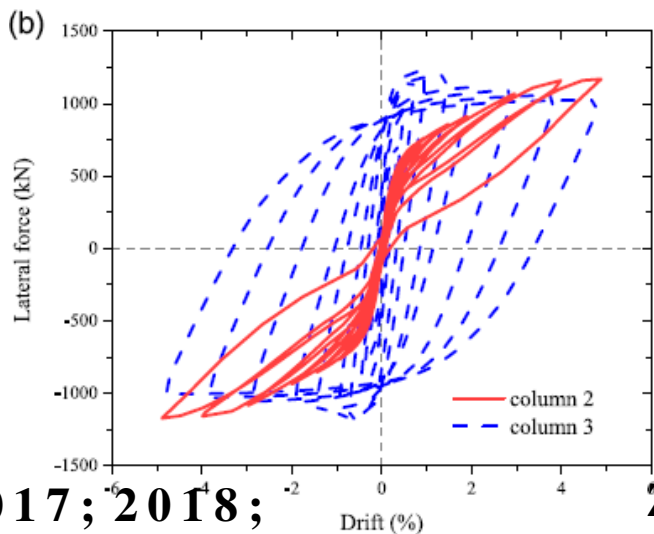
Hong Kong-Zhuhai-Macao Bridge



1. Background



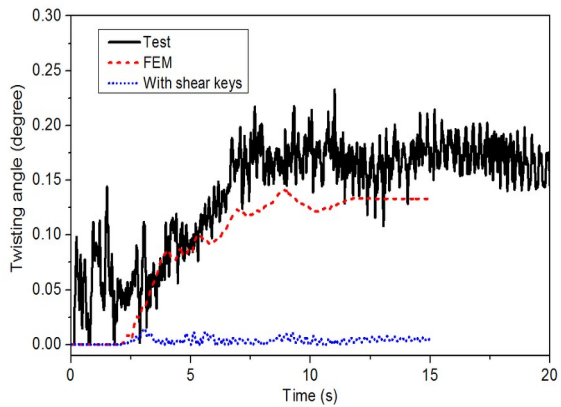
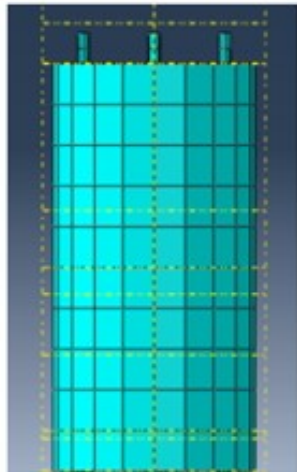
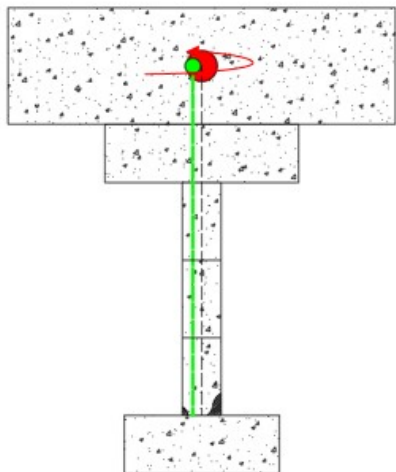
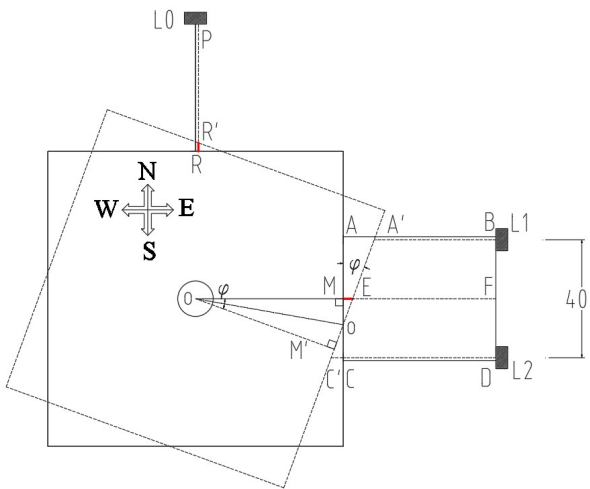
Li et al. (2017; 2018; 2019)



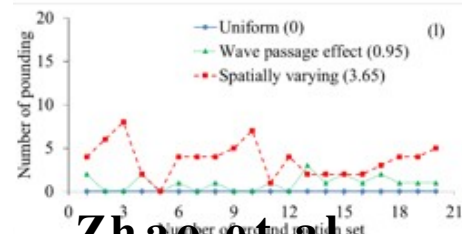
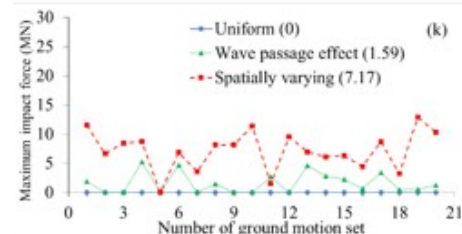
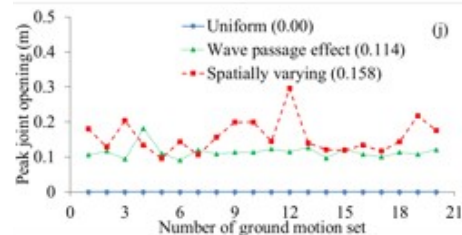
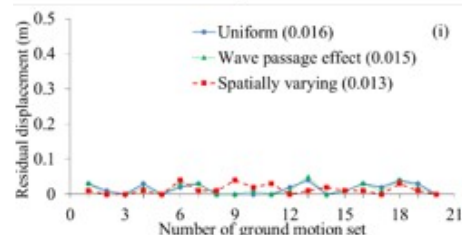
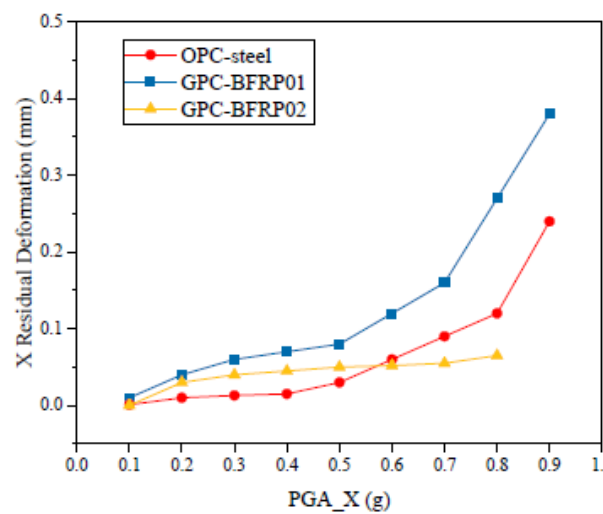
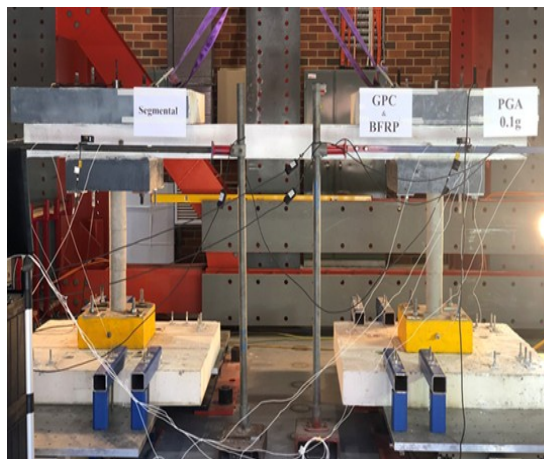
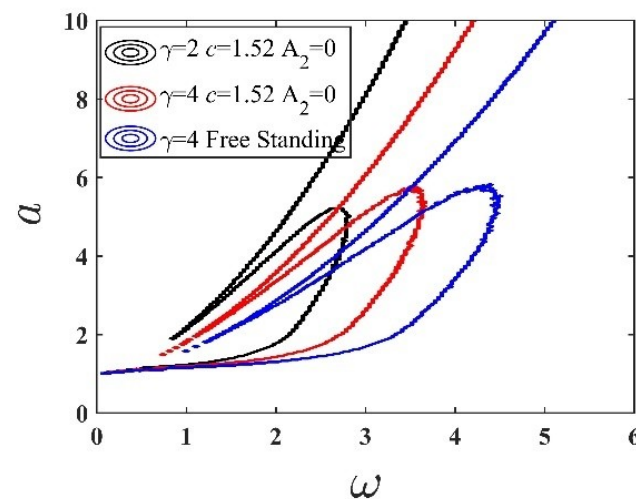
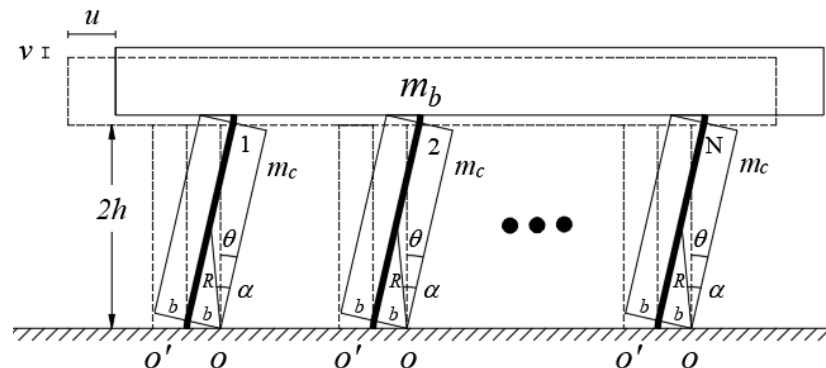
Zhang et al. (2022)



Hewes and Priestley (2002)



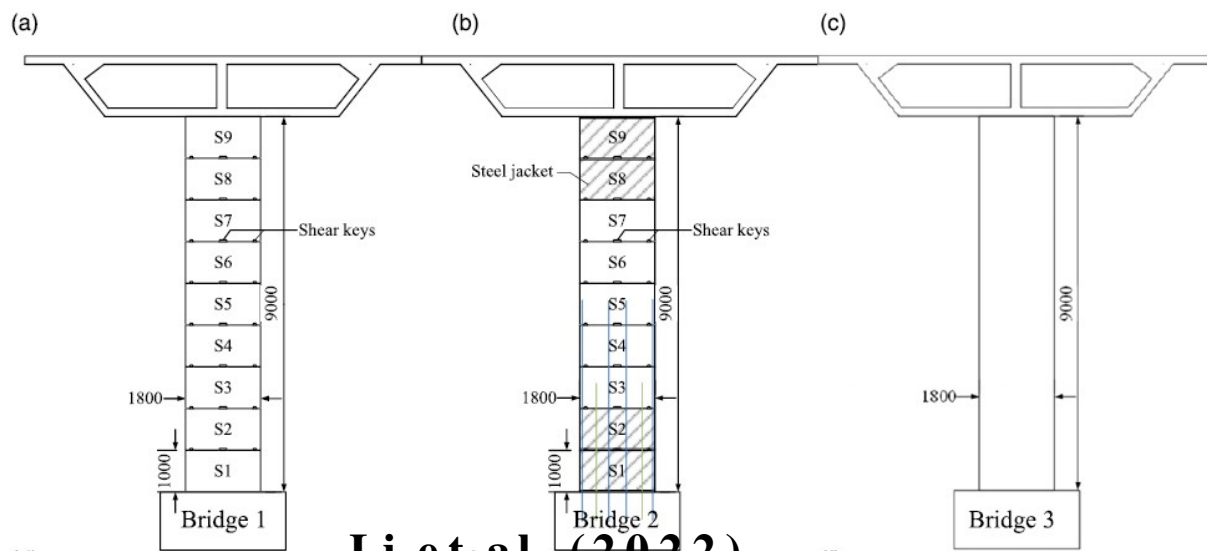
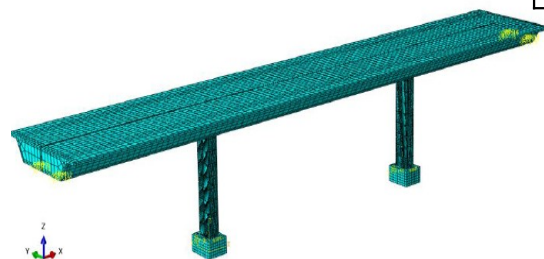
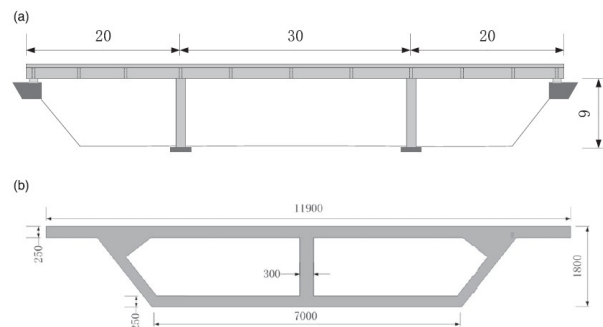
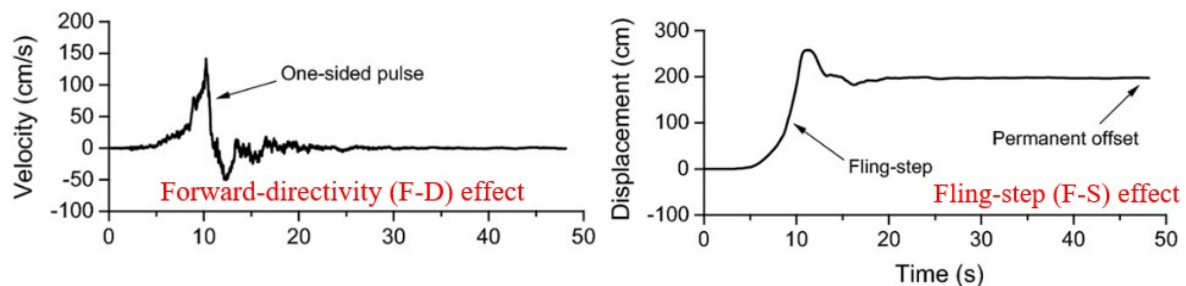
Li et al. (2019; 2020)

Zhao et al.
(2017)

**He et al. (2025;
2026)** ^{ω}

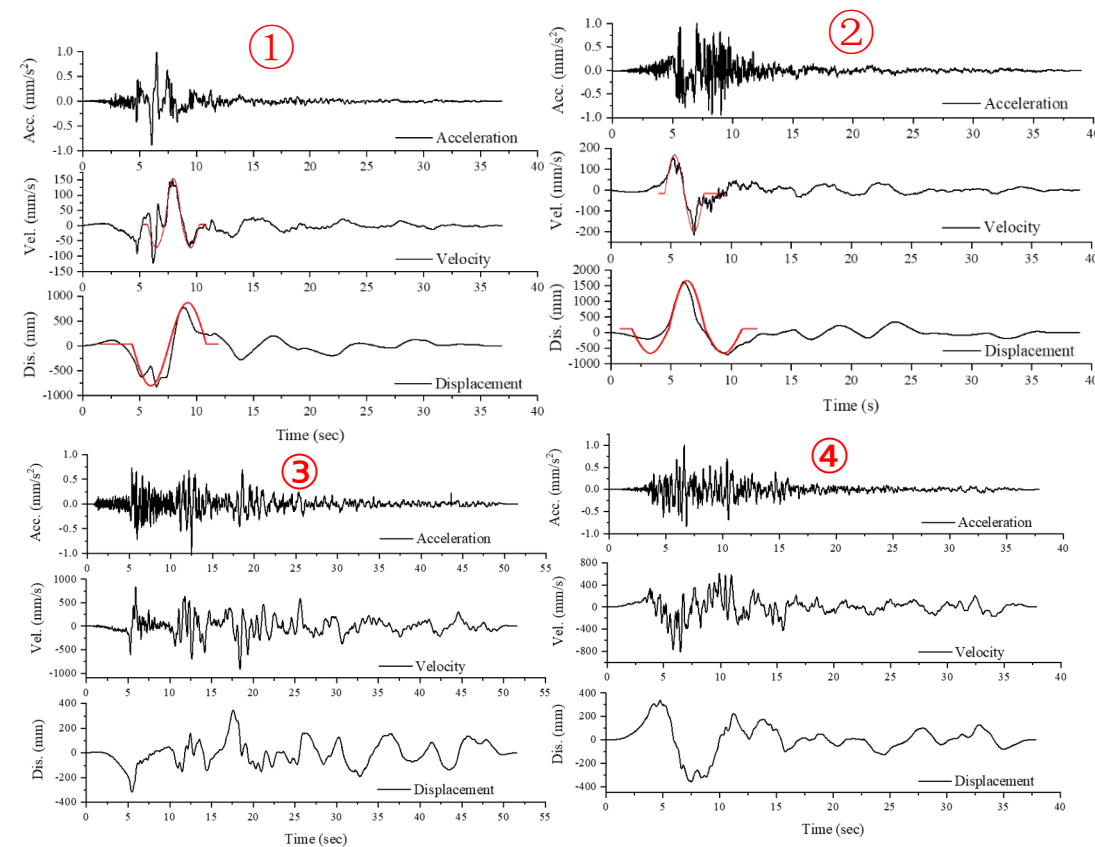
0.30g

2. SCSBs subjected to far field/near fault ground motions



Li et al. (2022)

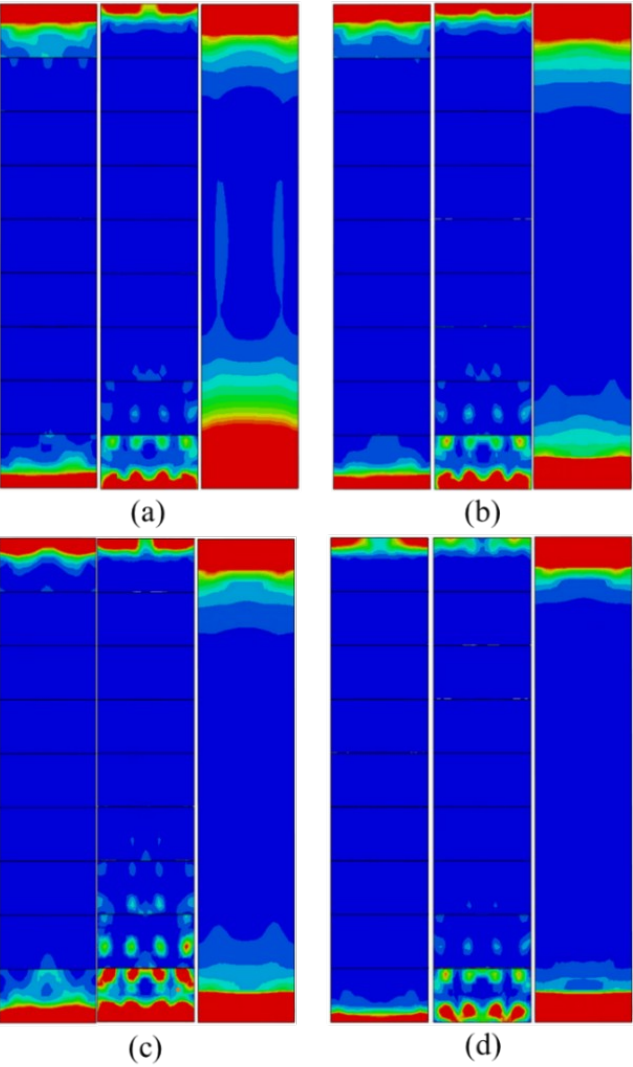
Earthquake event: 1979 Imperial Valley			Station	Original PGA	Input duration
Near-fault ground motion	Pulse record	Fling-Step	① El Centro # 7	0.34g	45s
		Forward-directivity	② El Centro # 5	0.35g	50s
	No pulse record		③ Chihuahua	0.27g	60s
Far-field ground motion			④ Calxico-E	0.28g	45s



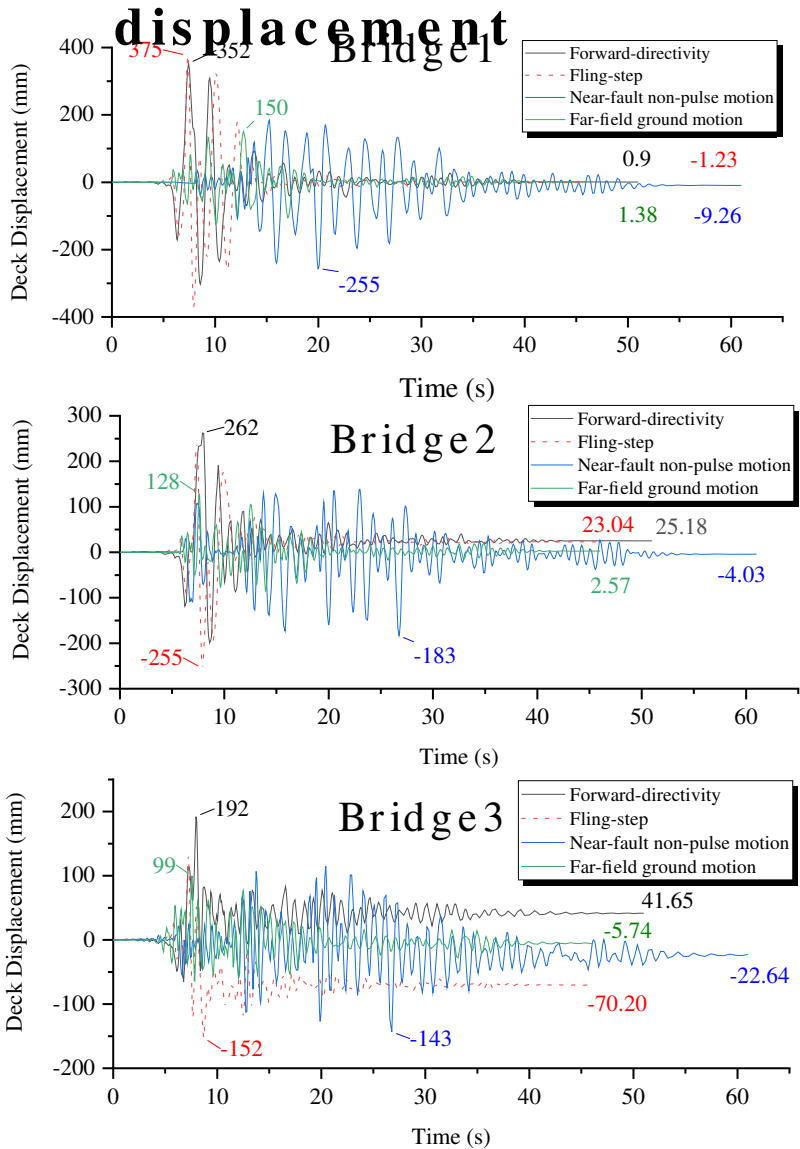
2. SCSBs subjected to far field/near fault ground motions



• Damage modes



• Deck displacement

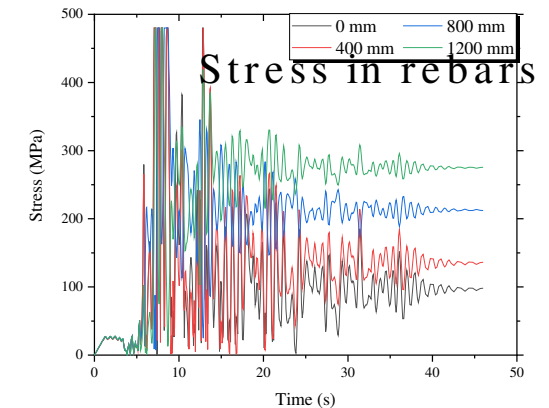
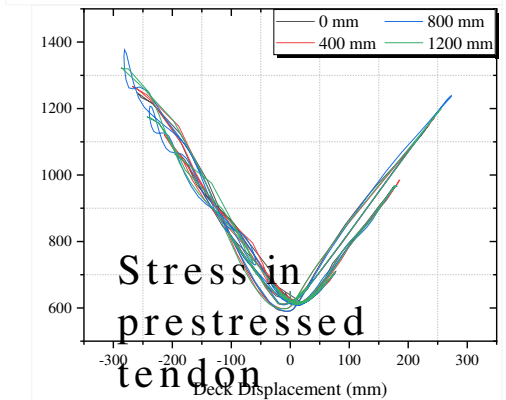
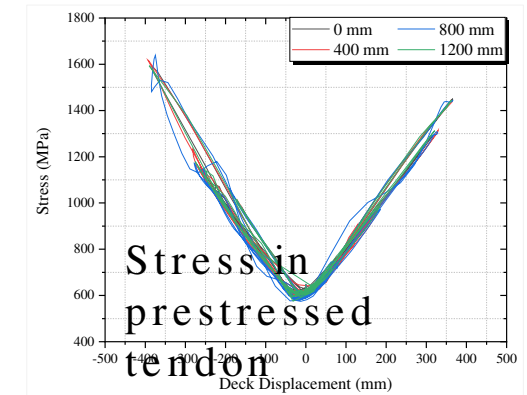
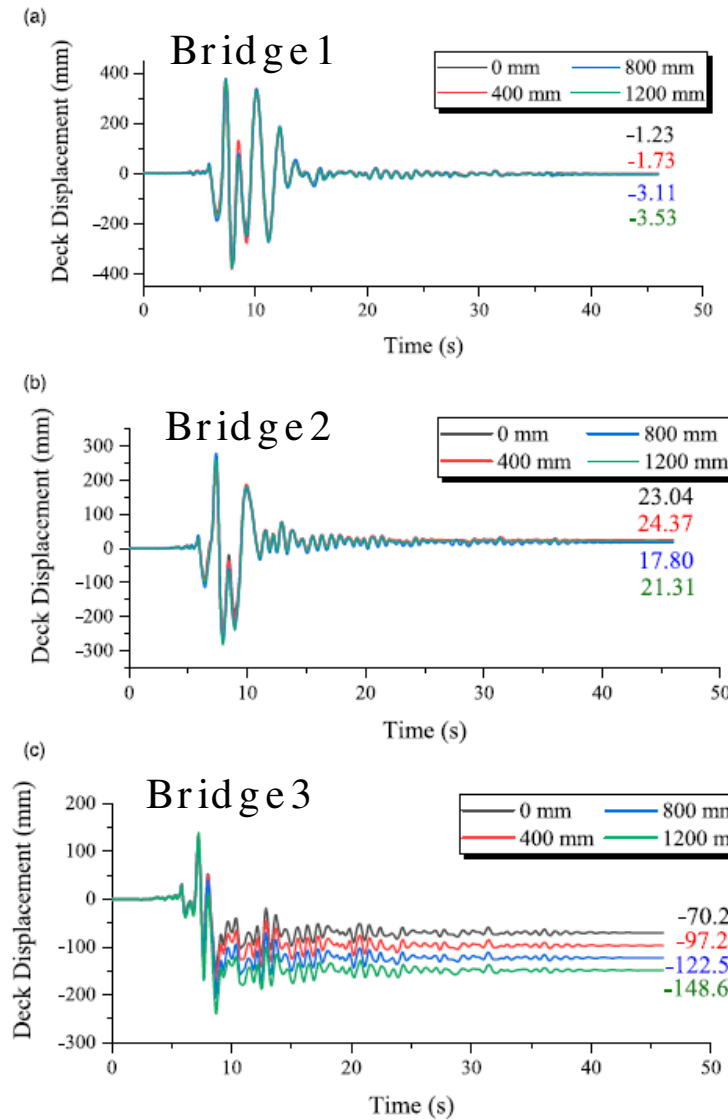
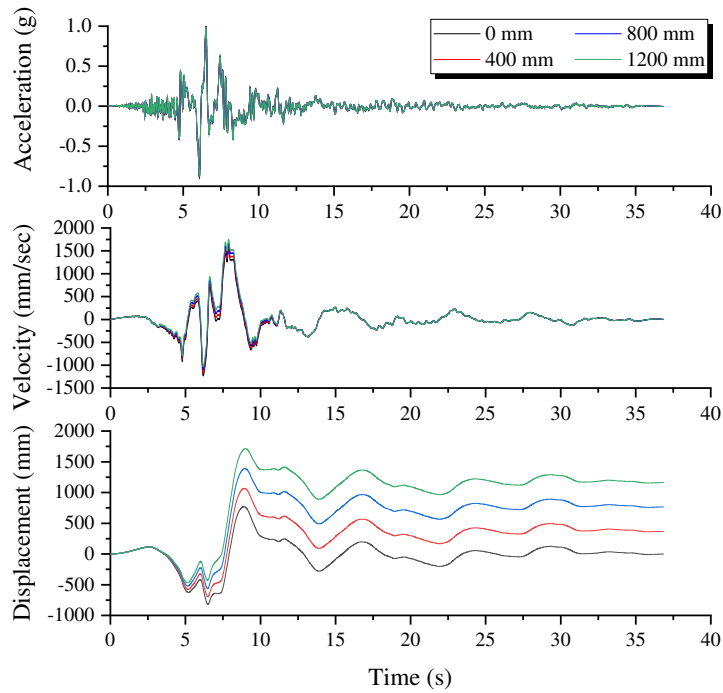


		Bridge 1	Bridge 2	Bridge 3
Near-fault fling-step motion	Peak displacement (drift)	375 (4.17%)	255 (2.83%)	152 (1.69%)
	Residual displacement (drift)	1.23 (0.01%)	23.04 (0.26%)	70.20 (0.78%)
Near-fault forward-directivity motion	Peak displacement (drift)	352 (3.91%)	262 (2.91%)	192 (2.13%)
	Residual displacement (drift)	0.90 (0.01%)	25.18 (0.28%)	41.56 (0.46%)
Near-fault non-pulse motion	Peak displacement (drift)	255 (2.83%)	183 (2.03%)	143 (1.59%)
	Residual displacement (drift)	9.26 (0.1%)	4.03 (0.04%)	22.64 (0.25%)
Far-field ground motion	Peak displacement (drift)	150 (1.67%)	128 (1.42%)	99 (1.1%)
	Residual displacement (drift)	1.38 (0.02%)	2.57 (0.03%)	5.74 (0.06%)



2. SCSBs subjected to far field/near fault ground motions

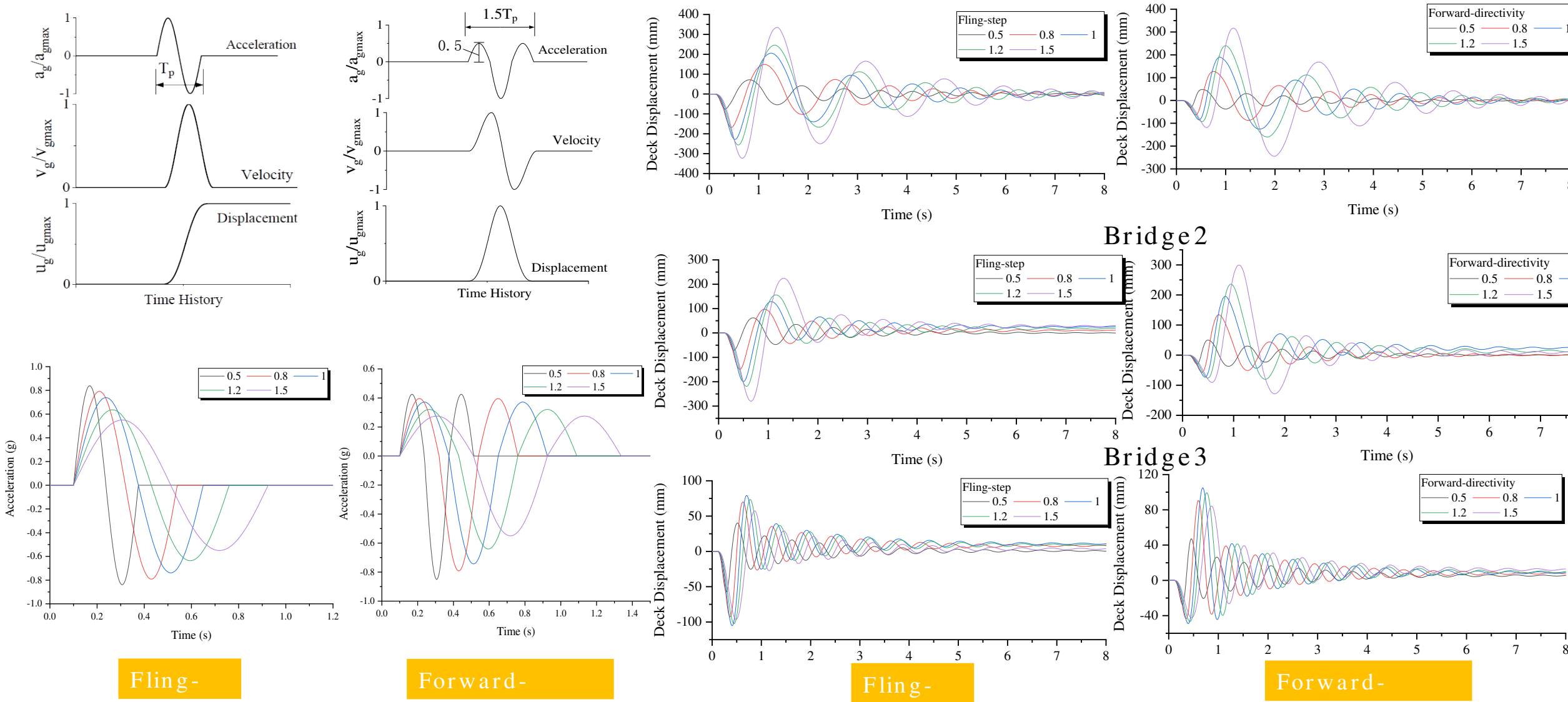
Influence of permanent ground displacement





2. SCSBs subjected to far field/near fault ground motions

Influence of pulse period

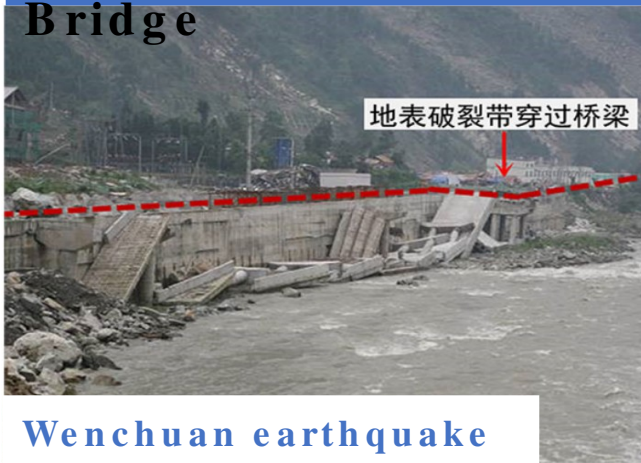


3. SCSBs subjected to across-fault ground motions



Bridges crossing fault-rupture zones

Yingxiu Shunhe Bridge



Wenchuan earthquake

Xiaoyudong Bridge



Wenchuan earthquake

Wuxi Bridge



Chi-chi earthquake

Mingzhu Bridge



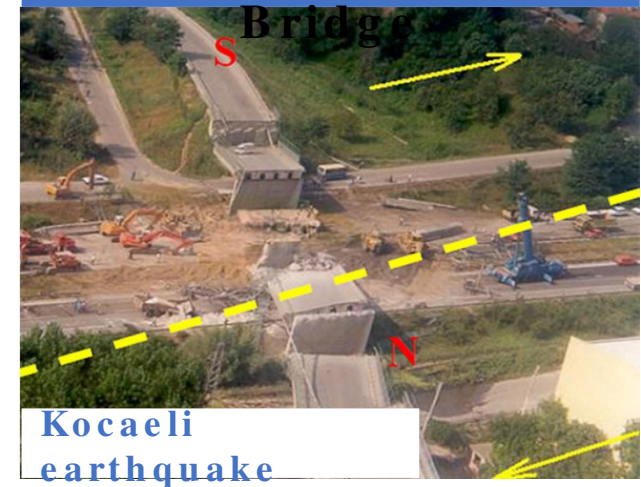
Chi-chi earthquake

Bolu Viaduct No.1



Duzce earthquake

Arifiye Overpass Bridge



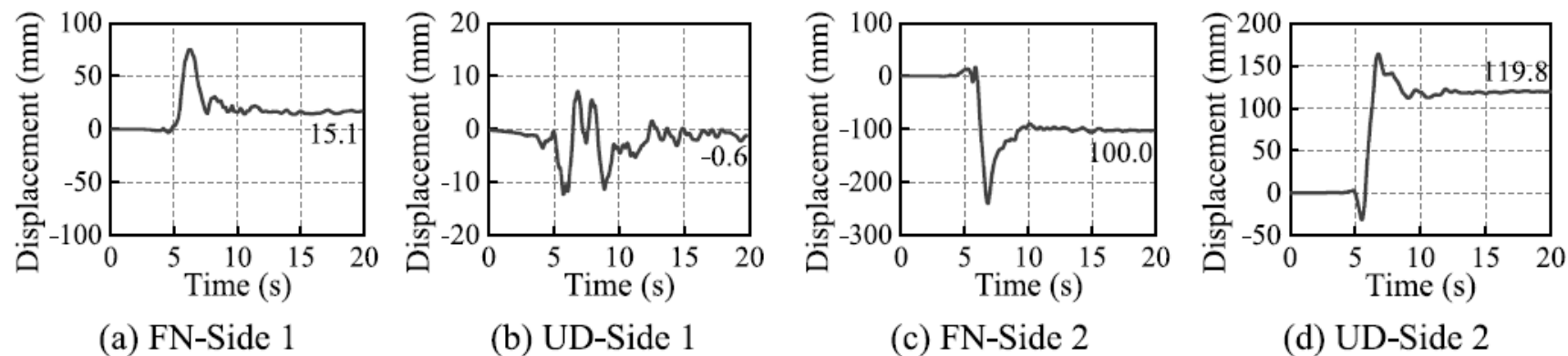
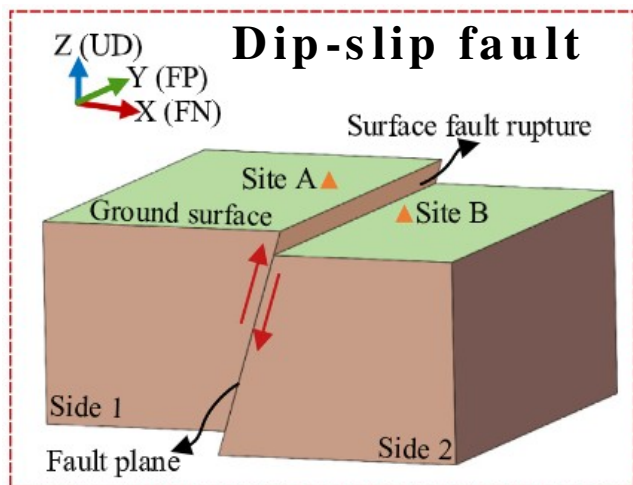
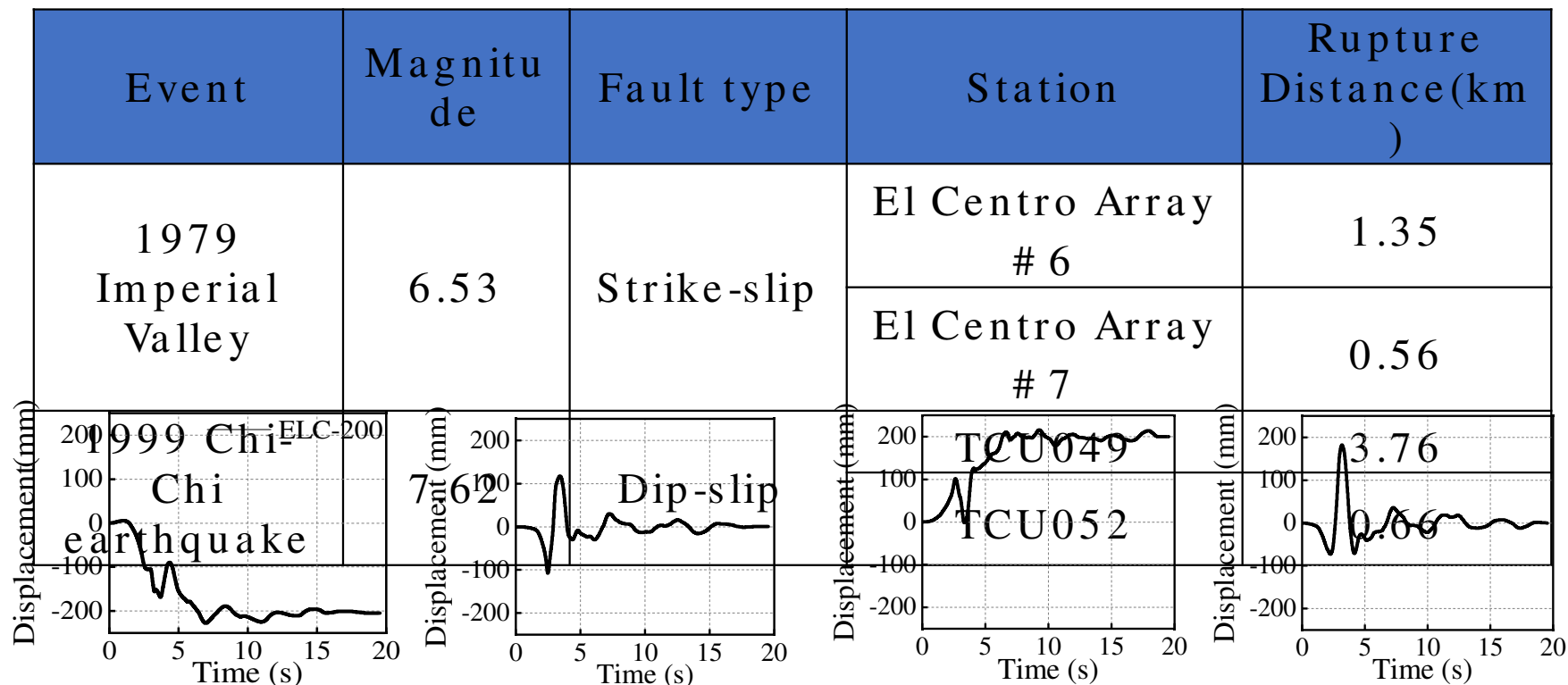
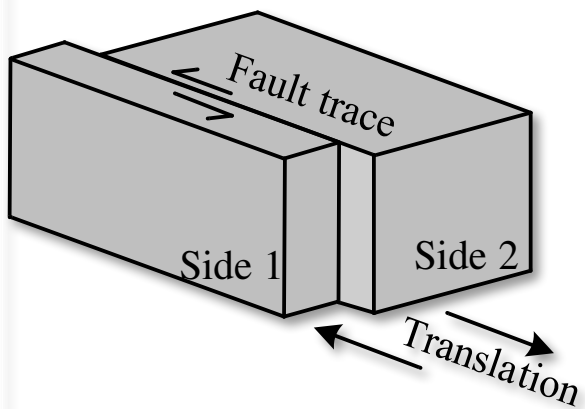
Kocaeli earthquake



3. SCSBs subjected to across-fault ground motions

Typical fault ruptures

Strike-slip Fault



3. SCSBs subjected to across-fault ground motions



Strike-

Dip-

Segment

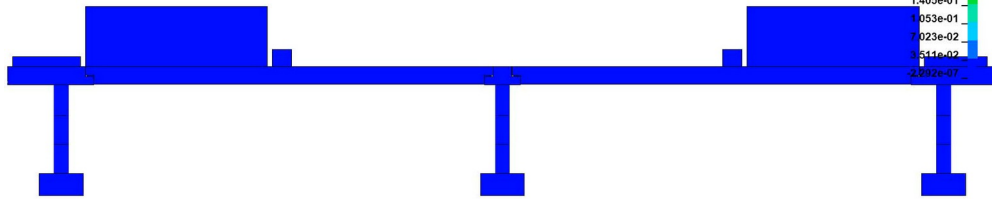
Song et al.
(2026)

Monolithic

Song et al.
(2026)

LS-DYNA keyword deck by LS-PrePost
Time = 0
Contours of Effective Plastic Strain
min=-2.29187e-07, at elem# 191559
max=0.35115, at elem# 253731

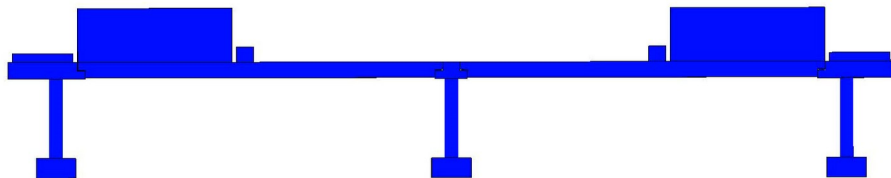
Effective Plastic Strain
3.512e-01
3.160e-01
2.809e-01
2.458e-01
2.107e-01
1.756e-01
1.405e-01
1.053e-01
7.023e-02
3.511e-02
-2.29187e-07



89.77 frame/sec

LS-DYNA keyword deck by LS-PrePost
Time = 0
Contours of Effective Plastic Strain
min=-6.37508e-07, at elem# 184124
max=0.384024, at elem# 233909

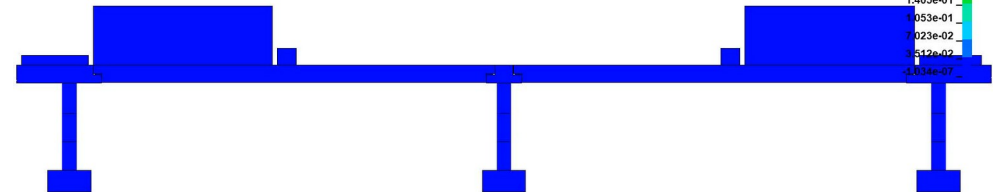
Effective Plastic Strain
3.840e-01
3.456e-01
3.072e-01
2.688e-01
2.304e-01
1.920e-01
1.536e-01
1.152e-01
7.680e-02
3.840e-02
-6.375e-07



145.16 frame/sec

LS-DYNA keyword deck by LS-PrePost
Time = 0
Contours of Effective Plastic Strain
min=-1.03404e-07, at elem# 191544
max=0.35115, at elem# 253731

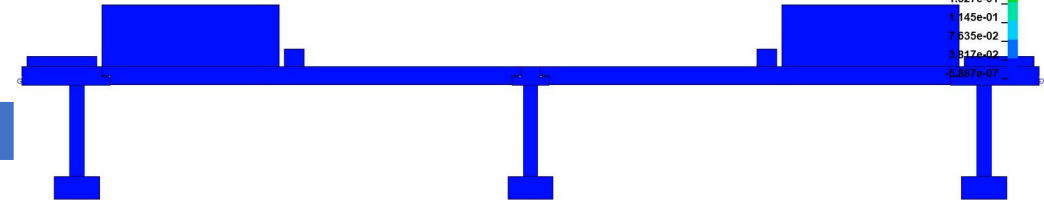
Effective Plastic Strain
3.512e-01
3.160e-01
2.809e-01
2.458e-01
2.107e-01
1.756e-01
1.405e-01
1.053e-01
7.023e-02
3.511e-02
-2.29187e-07



86.07 frame/sec

Time = 0
Contours of Effective Plastic Strain
min=-5.88695e-07, at elem# 184081
max=0.381735, at elem# 233909

Effective Plastic Strain
3.817e-01
3.436e-01
3.054e-01
2.672e-01
2.290e-01
1.909e-01
1.527e-01
1.145e-01
7.635e-02
3.817e-02
-5.88695e-07

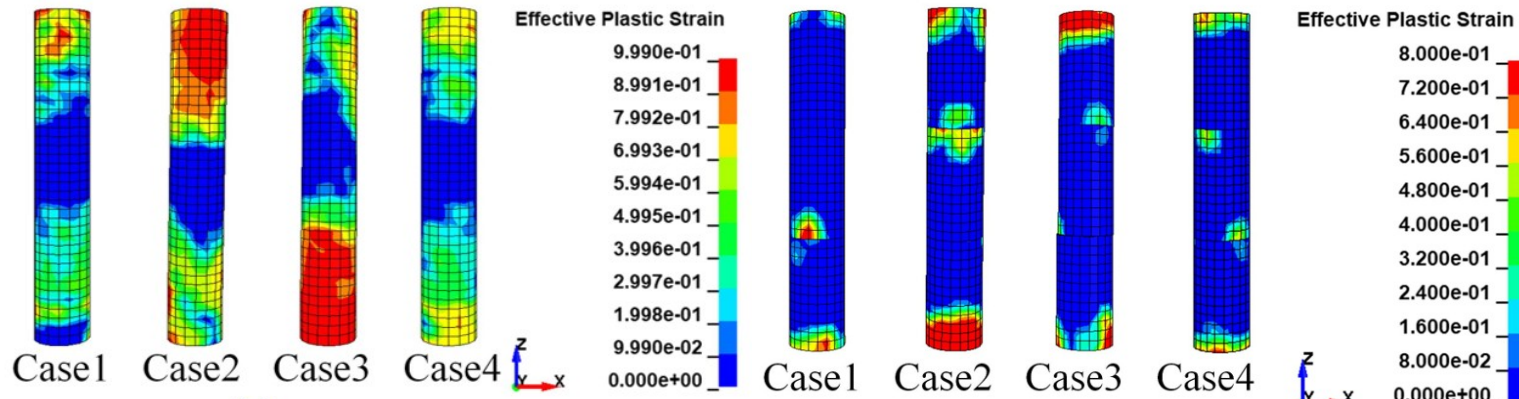
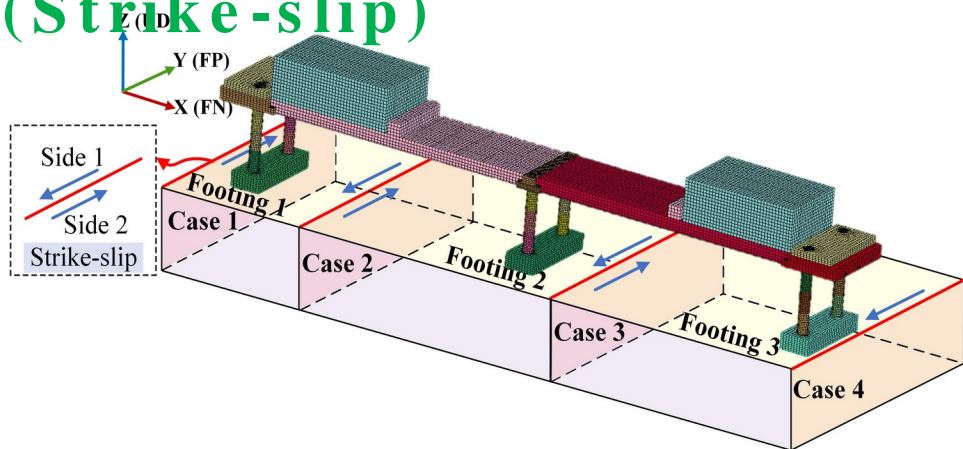


75.55 frame/sec



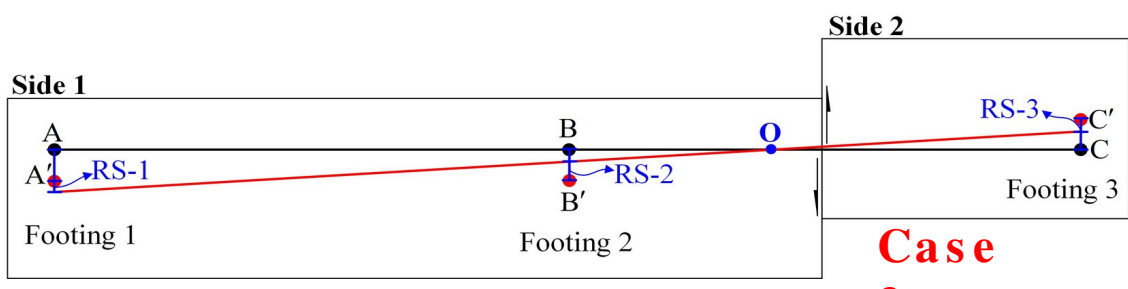
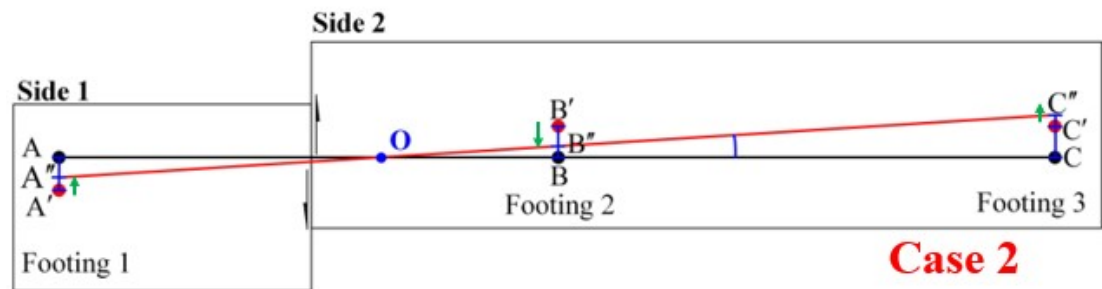
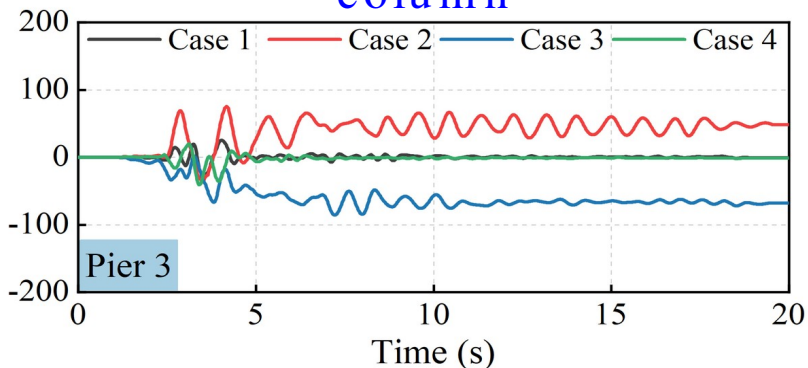
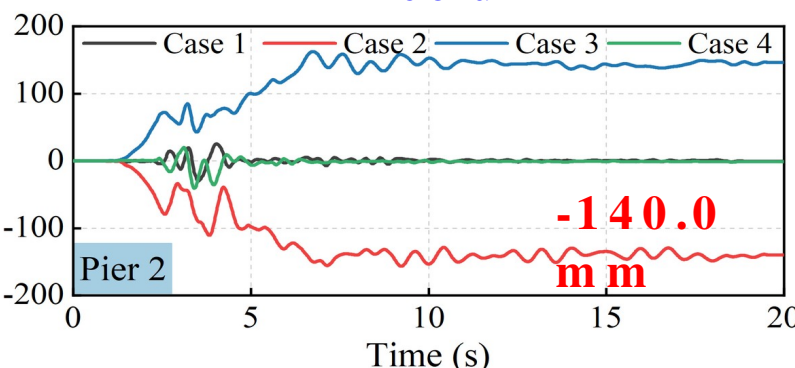
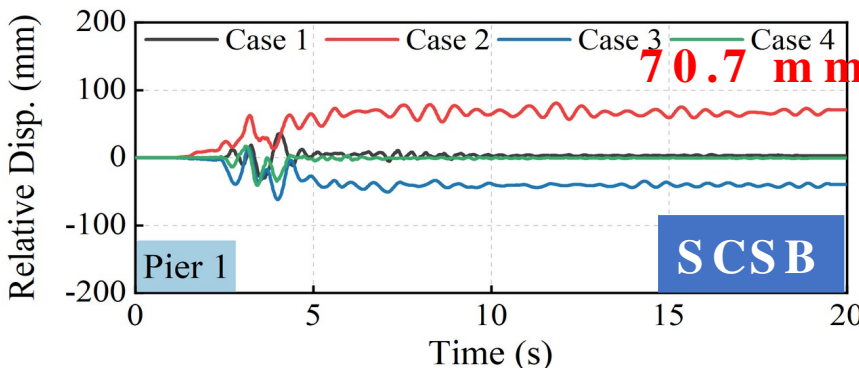
3. SCSBs subjected to across-fault ground motions

Effect of fault crossing locations (Strike-slip)



(a) Monolithic column

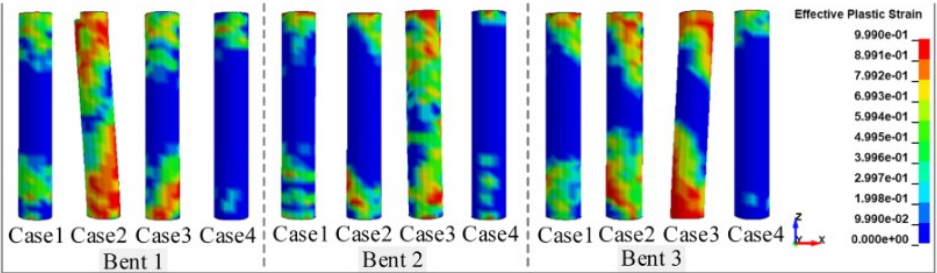
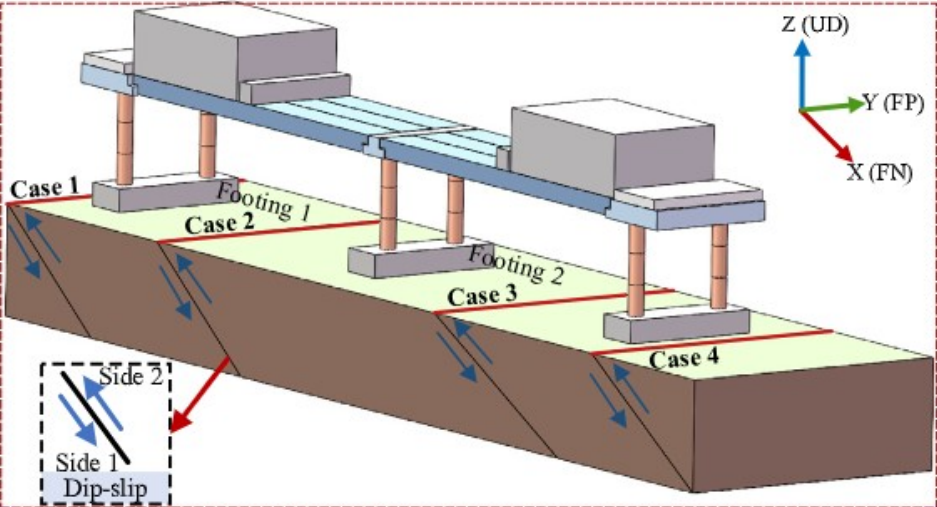
(b) Segmental column



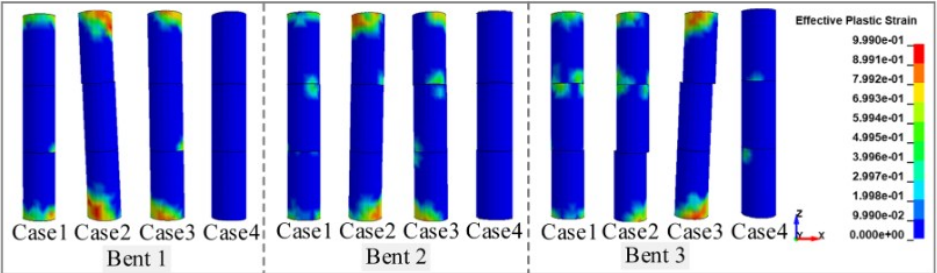


3. SCSBs subjected to across-fault ground motions

Effect of fault crossing locations



(a) MCSB



(b) SCSB

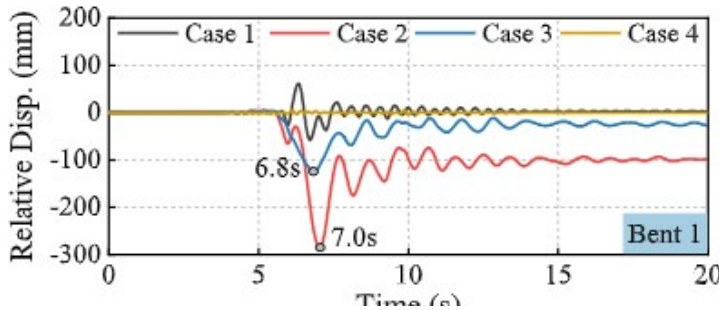
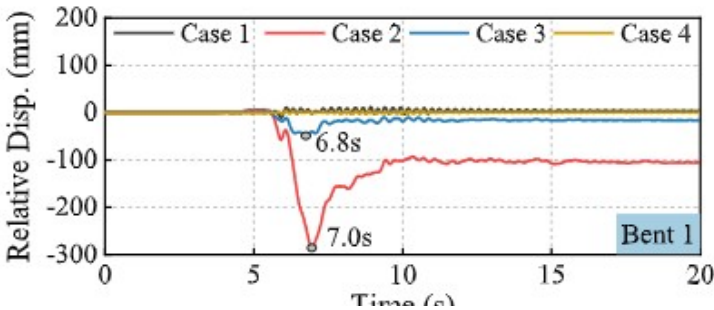
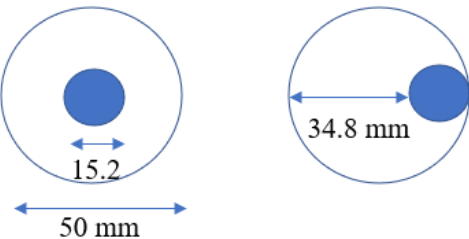


Table 3

Longitudinal residual displacements for different bridges with varied FCLs.

Bent	Case	Residual displacement (mm)		Residual drift ratio (%)	
		MCSB	SCSB	MCSB	SCSB
Bent 1	Case 1	4.5	2.5	0.25	0.14
	Case 2	-105.2	-98.3	-5.75	-5.37
	Case 3	-15.6	-27.1	-0.85	-1.48
	Case 4	1.27	0.02	0.07	0.00
Bent 2	Case 1	4.5	2.5		
	Case 2	16.0	24.9		
	Case 3	-17.8	-30.2		
	Case 4	1.27	0.02		
Bent 3	Case 1	4.5	2.5		
	Case 2	13.9	20.8		
	Case 3	102.5	88.9		
	Case 4	1.27	0.02		



3. SCSBs subjected to across-fault ground motions

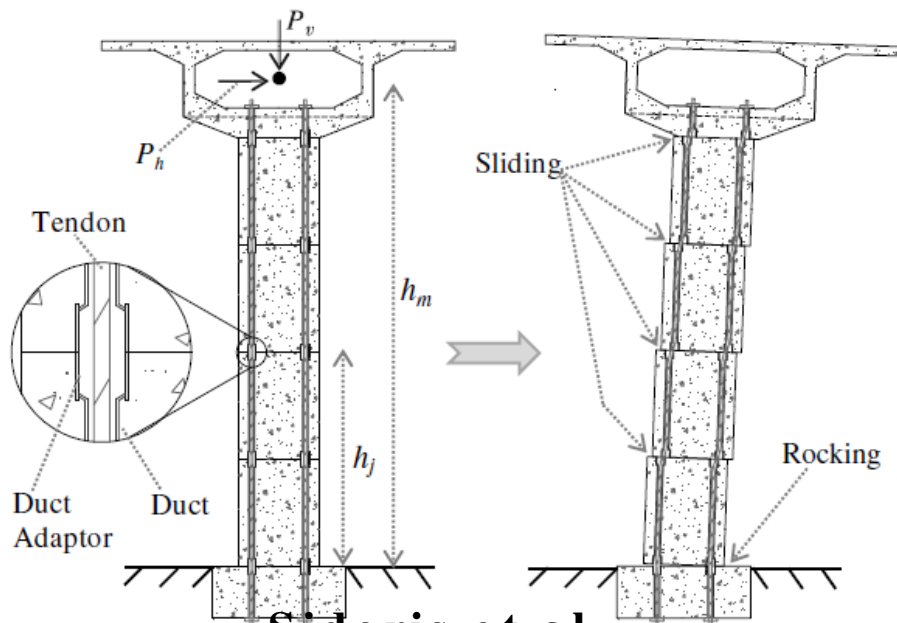
Limitation

- Conventional segmental piers still suffer from local damage.

Strategy

- Use duct adaptors to increase controllable sliding capacity.
- Introduce a curved interface to provide

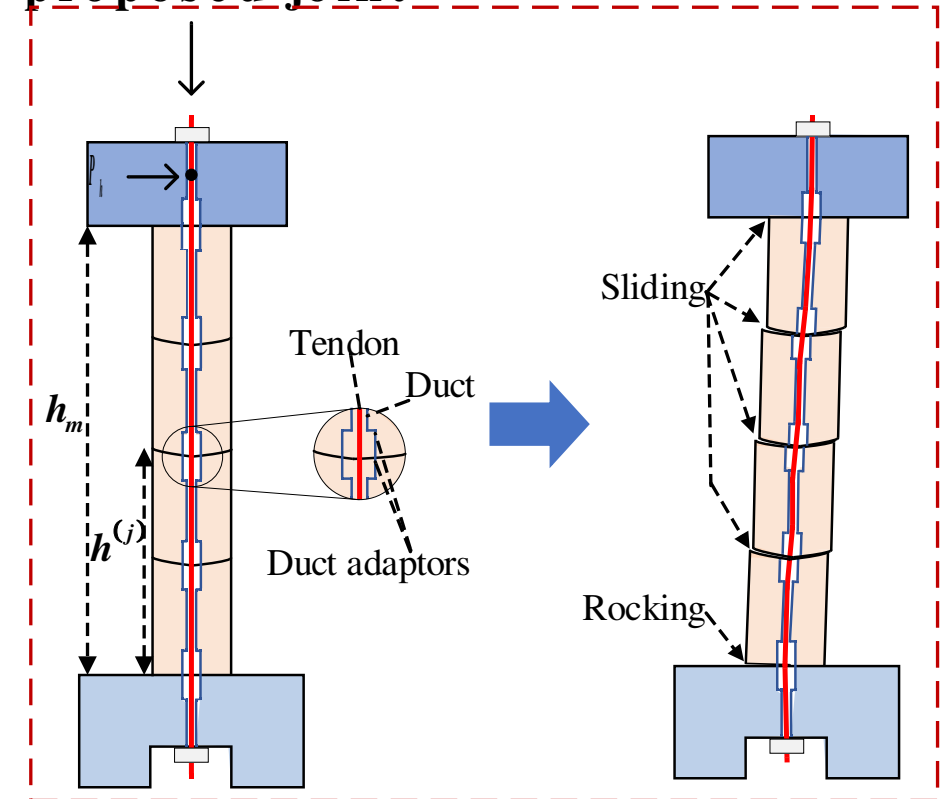
ge



Sideris et al.

(2014)

Conceptual mechanism of the proposed joint



3. SCSBs subjected to across-fault ground motions



Design Objectives

- **Design objective 1: Sliding initiation**

All sliding-dominant joints should initiate sliding before the column reaches its lateral capacity.

$$\mu < \varphi_\mu \mu_0, \quad \mu_0 = \frac{M_0}{h_m N_{c,0}}$$

- **Design objective 2: Stable sliding development**

All sliding-dominant joints should develop stable sliding responses before the ultimate state.

$$\tan \varphi_j = \frac{\langle |u_{sl,j}| - u_{sl,b} \rangle}{2h_{da}} \operatorname{sgn}(u_{sl,j})$$

- **Design objective 3: Tendon safety**

The post-tensioning tendons should remain elastic at the ultimate state.

$$h_{da,max} = \frac{h_m N_{PT} (D_{da} - D_d)}{2M_{ult}}$$

- **Design objective 4: Self-centering capacity**

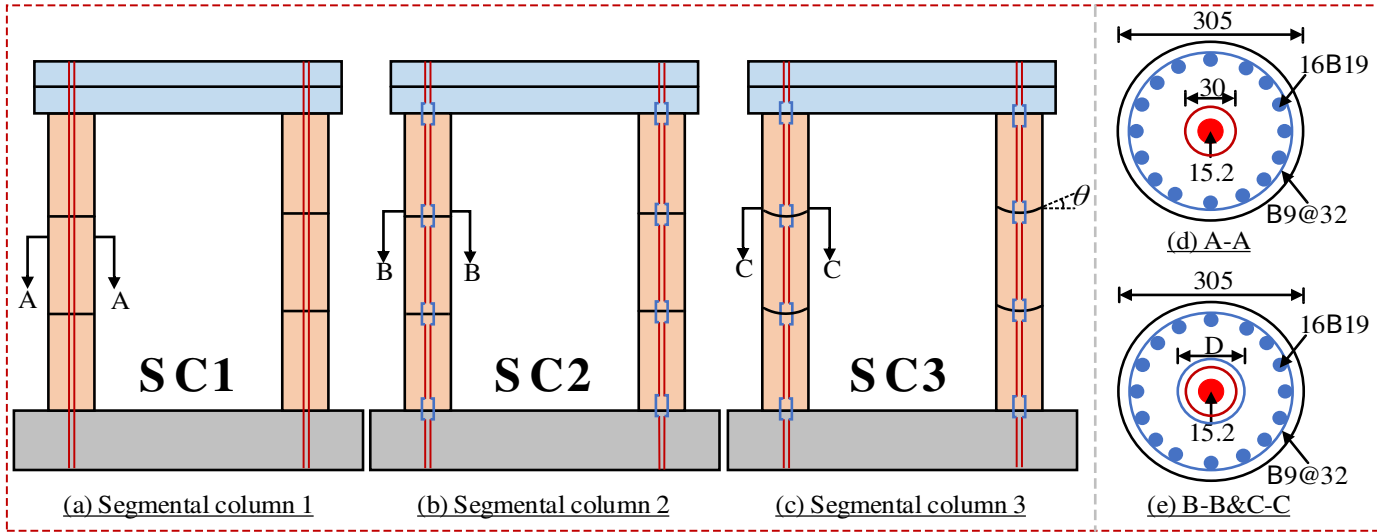
The geometry-induced restoring force should overcome the residual friction during unloading.

$$F_f < F_{recall} \quad \mu N_{c,ult} \cos \theta < N_{c,ult} \sin \theta$$
$$\mu < \tan \theta$$



3. SCSBs subjected to across-fault ground motions

Bridge information



Comparison basis

Same in all models:

- Superstructure and bridge layout
- Boundary conditions
- Material properties

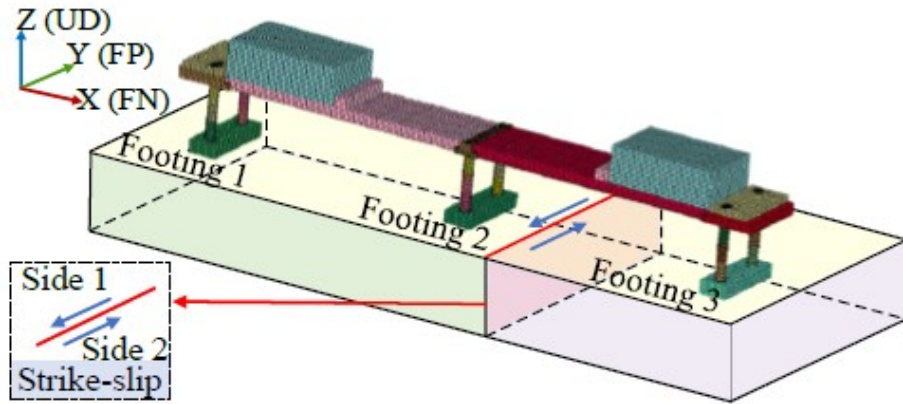
Only the segmental joint configurations are different

Bridge model	Joint configuration	Friction coefficient	Duct adaptor	Curved interface
Segmental column 1	Conventional segmental column	Bridge model	No	No
Segmental column 2	With duct adaptors	Bridge model	Bridge model	No
Segmental column 3	With the proposed joints	Bridge model	Bridge model	Bridge model

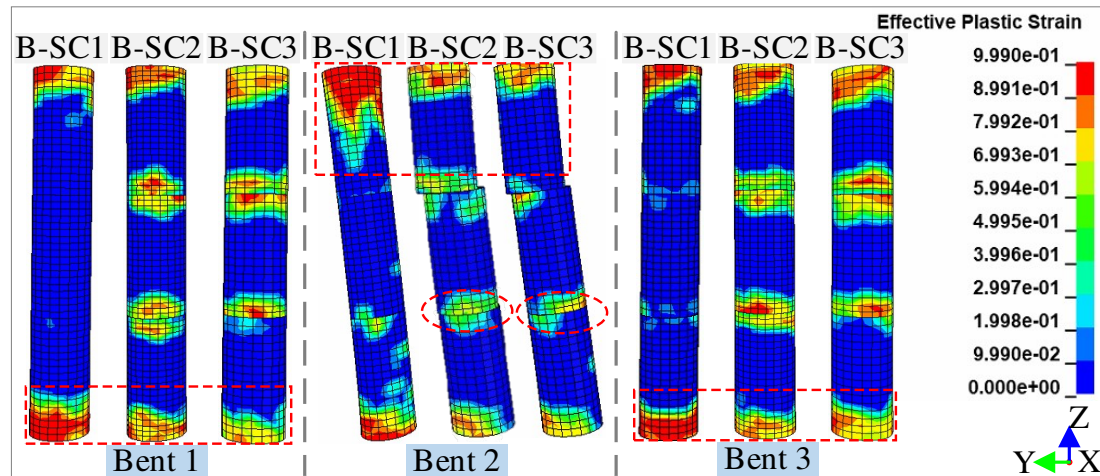
3. SCSBs subjected to across-fault ground motions (Strike-slip)



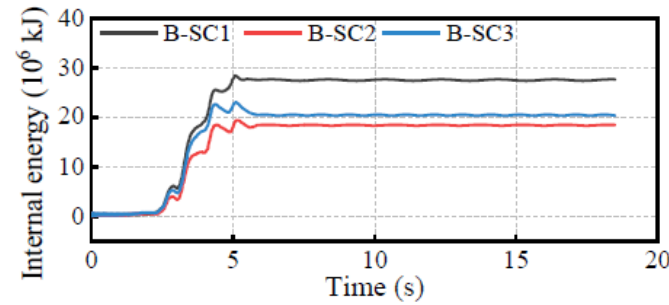
● Fault location



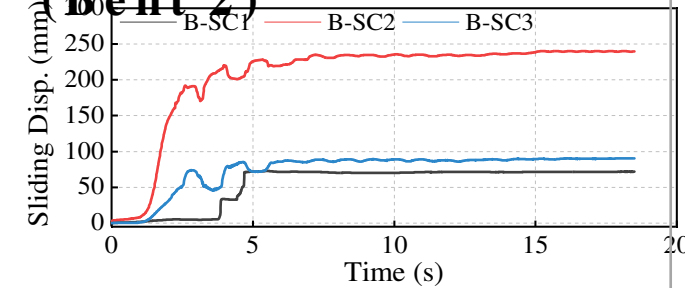
● Damage modes



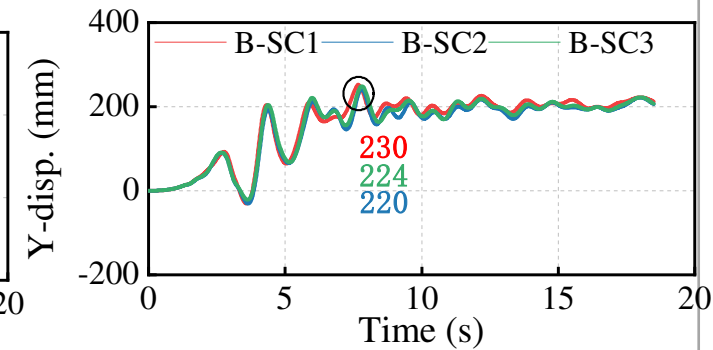
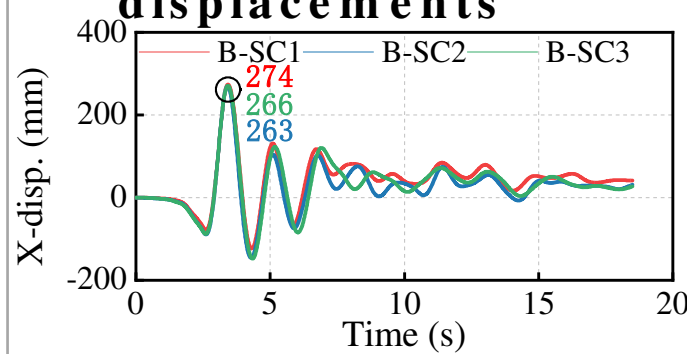
● Internal energy (whole bridge)



● Sliding displacement (Bent 2)



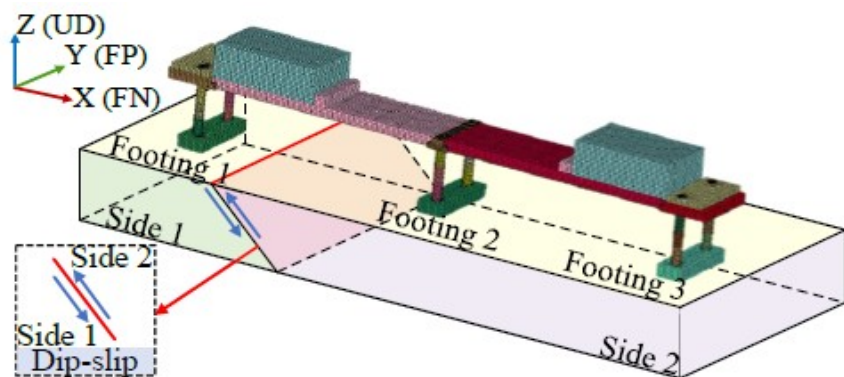
● Bridge girder displacements



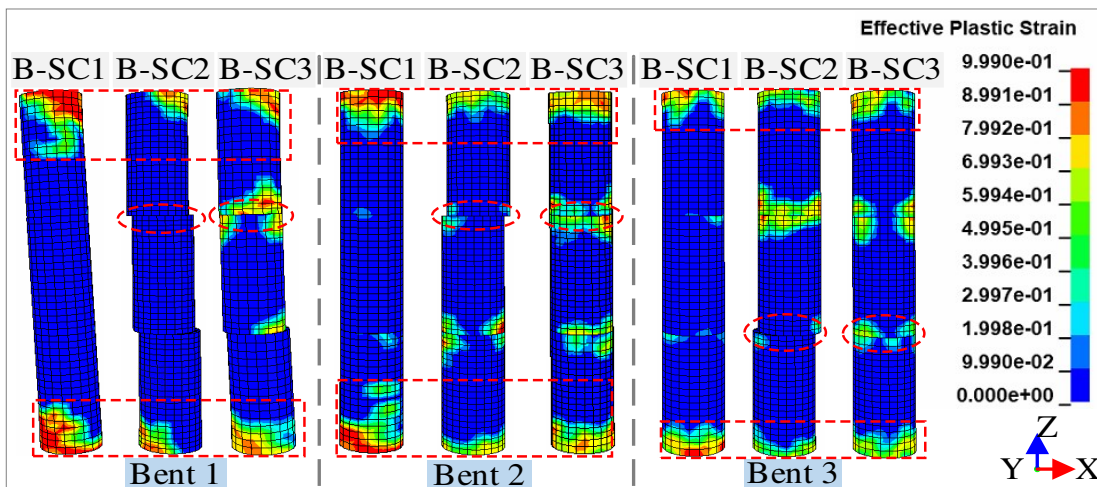
3. SCSBs subjected to across-fault ground motions (Dip-slip)



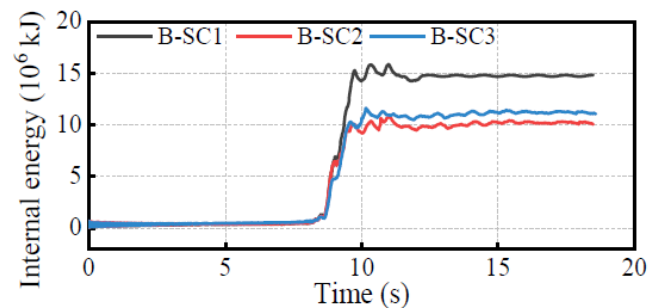
Fault location



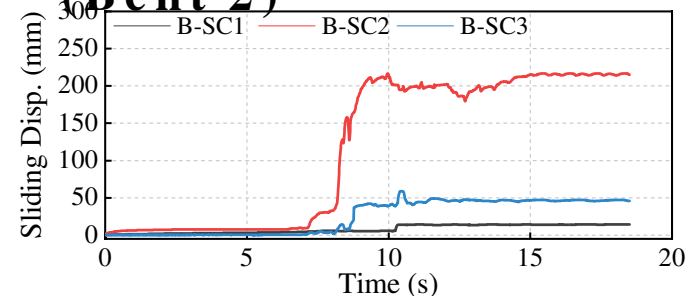
Damage modes



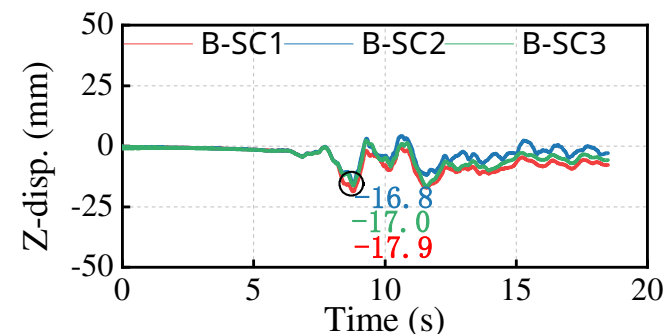
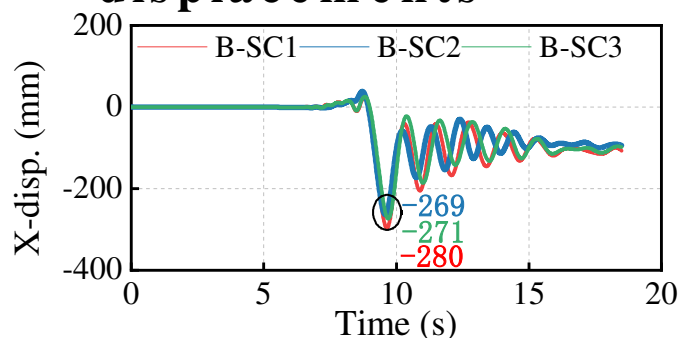
Internal energy (whole bridge)



Sliding displacement (Bent 2)



Bridge girder displacements





1. Systematical studies have been carried out in this area, previous studies mainly focused on the cyclic performance of a single column, relative less studies were carried out on the seismic performance of SCSBs;
2. Compared to MCSBs, SCSBs generally show better performance, irrespective of different ground motion types;
3. Innovative joints can further improve the seismic performance of SCSBs.

Thanks for your attention !

Kaiming.bi@polyu.edu.hk

<https://www.polyu.edu.hk/cee/~kaimbi/>

