Life-cycle seismic performance assessment of coastal rectangular bridge piers considering in-plane non-uniform corrosion

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Contents

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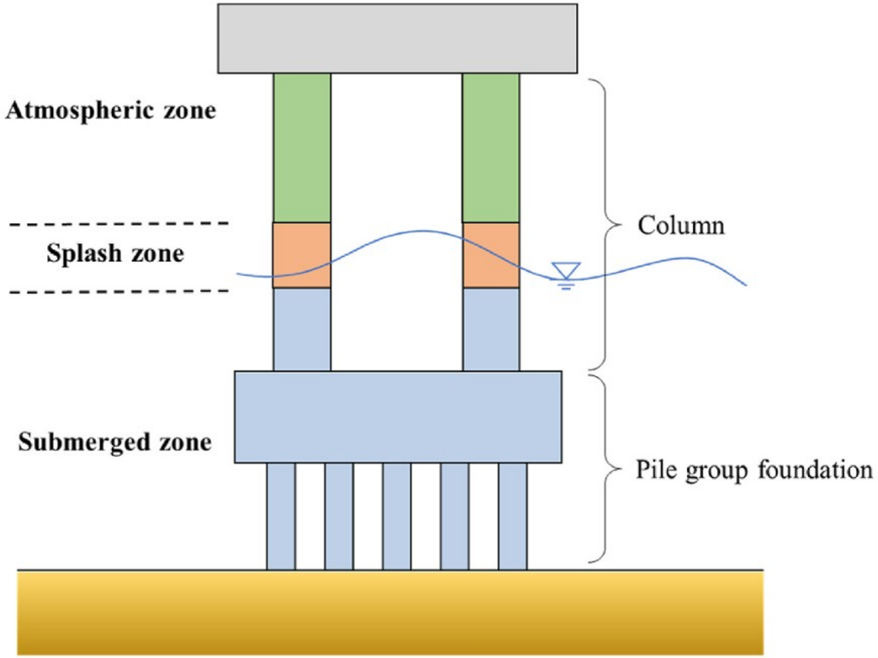
1. Background

Coastal bridge piers are susceptible to non-uniform corrosion

Coastal bridges are exposed to aggressive marine environments throughout their service life



Existing studies have focused on corrosion variation along the pier height (Lu et al.)

In-plane non-uniform corrosion has received limited attention.

1. Background

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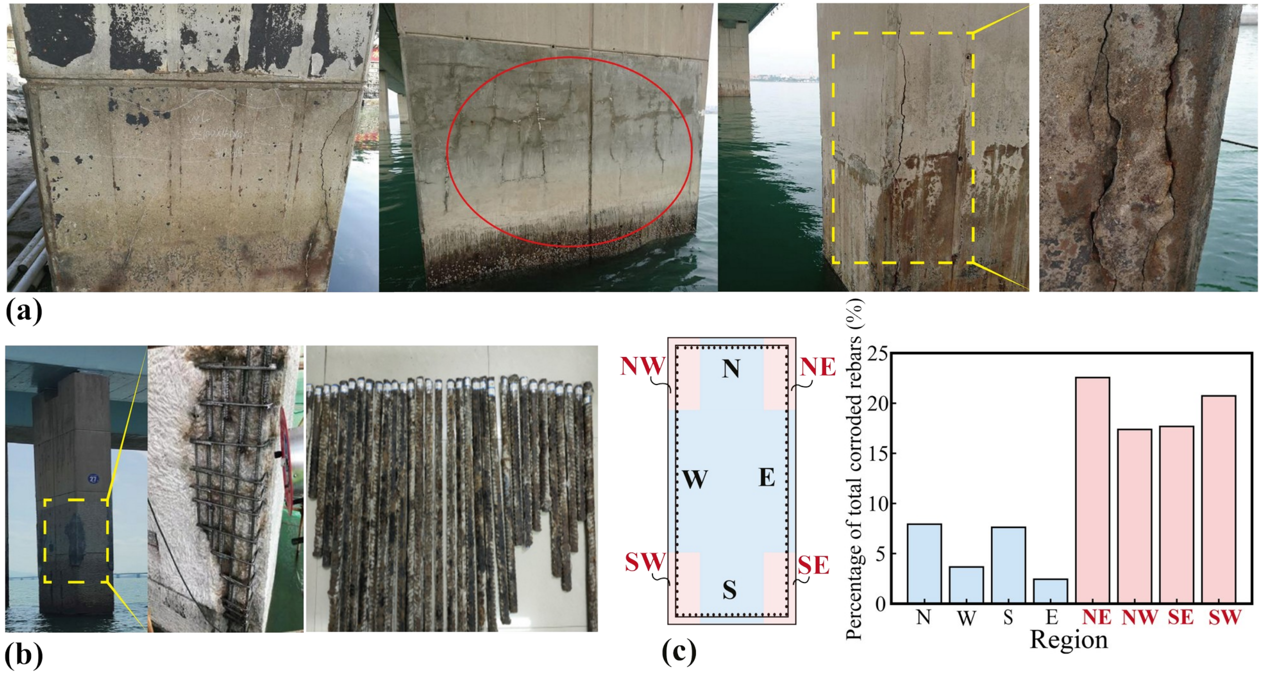
In-plane non uniform corrosion



Investigation results of in-plane non-uniform corrosion of coastal rectangular bridge piers in Xiamen

An experimental study on the retrofitting effects of reinforced concrete columns damaged by rebar corrosion strengthened with carbon fiber sheets

Han-Seung Lee[a,*], Tadatsugu Kage[b], Takafumi Noguchi[c], Fuminori Tomosawa[d]

Experimental investigation on the cyclic performance of reinforced concrete piers with chloride-induced corrosion in marine environment

Anxin Guo *, Haitao Li, Xi Ba, Xinchun Guan, Hui Li

Ministry-of-Education Key Laboratory of Structural Dynamic Behavior and Control, School of Civil Engineering, Harbin Institute of Technology, Harbin 150090, China

updates

Nonlinear dynamic behaviour of severely corroded reinforced concrete columns: shaking table study

Xiao Ge[1] · Matthew S. Dietz[1] · Nicholas A. Alexander[1] · Mohammad M. Kashani[2]

This phenomenon has been reported and summarized by other researchers

Seismic impact of non-uniform corrosion remains unclear

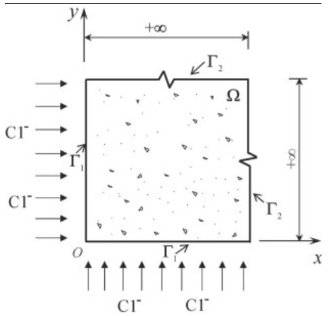
2.Corrosion initiation and propagation

Corner bars are more severely corroded due to the two-dimensional diffusion of chloride ions, while the mid-face bars are exposed to unidirectional chloride diffusion.

the chloride concentration of the cross-sectional concrete remains constant

the chloride concentration in the corner zones is 2.01 times that in the mid-face zones.

$$T_{cor} = X_1 \left[\frac{d_c^2}{4 k_e k_t k_c D_0 \left(t_0^n \right)} \left(\mathrm{erf}^{-1}\left(1 - \frac{C_{cr}}{C_s} \right) \right)^{-2} \right]^{\frac{1}{1-n}}$$

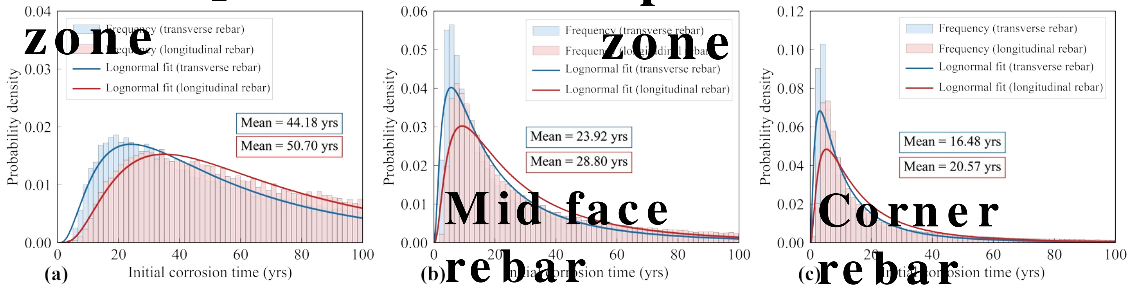


Atmosphere zone

Splash-tidal zone

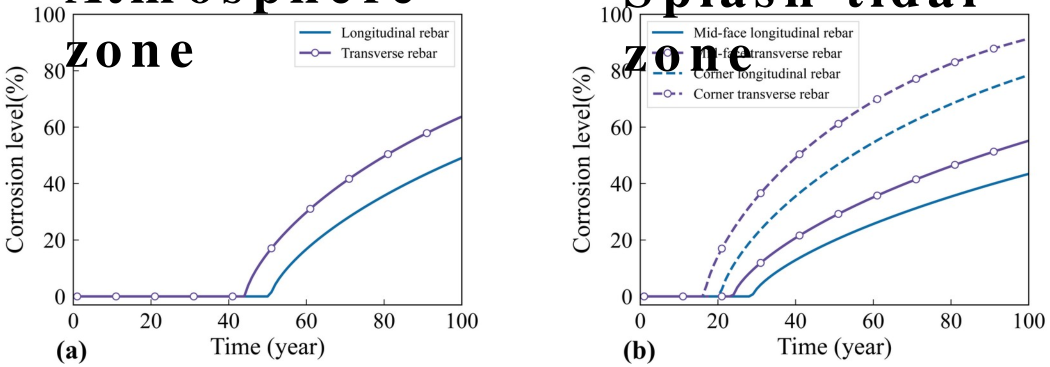
Mid face rebar

Corner rebar



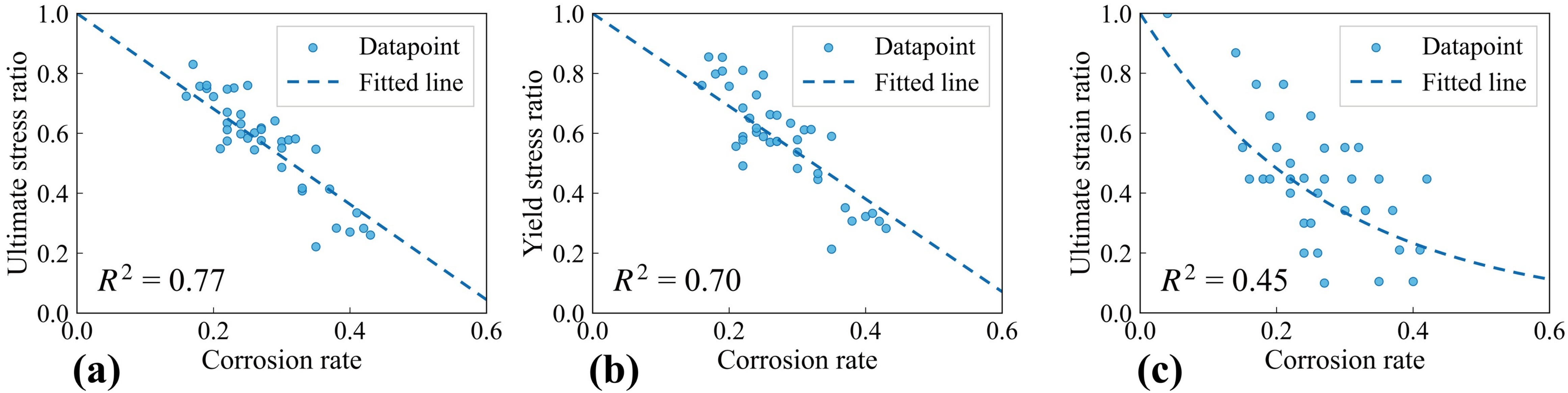
Atmosphere zone

Splash-tidal zone



2.Corrosion initiation and propagation

The time-dependent properties of rebar were established based on the tensile tests of in-situ corroded rebar extracted from actual coastal piers.



3.Finite element model

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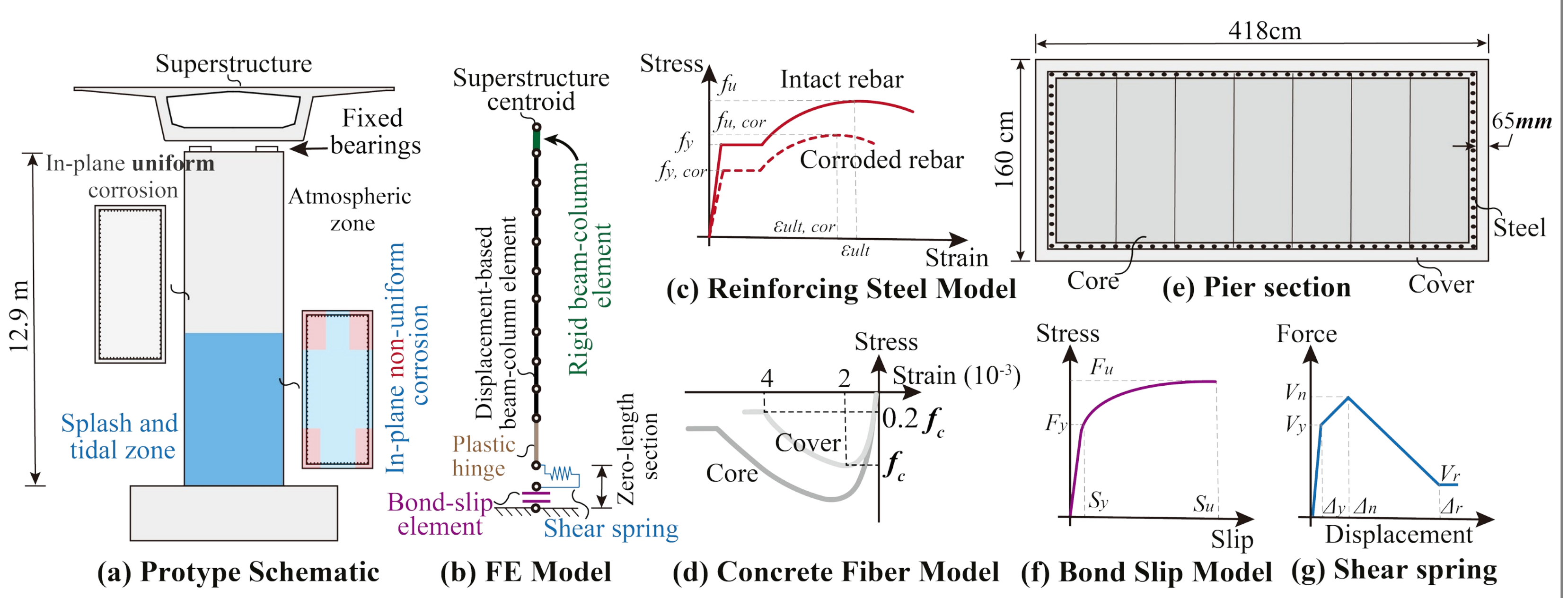
- Establish the finite element model on the OpenSees platform

(1) A FE model was developed to capture failure modes and flexure–shear coupling in corroded piers.

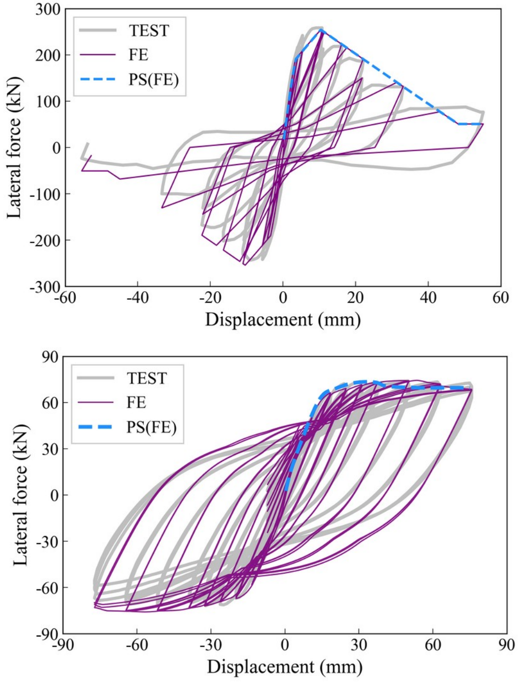
(2) incorporating the effects of **corrosion** on: ✓ Strength ✓ Buckling ✓ Bond-slip behavior ✓ Failure models

Finite element model



(a) Protype Schematic (b) FE Model (c) Reinforcing Steel Model (d) Concrete Fiber Model (e) Pier section (f) Bond Slip Model (g) Shear spring

Model validation



4. Life-cycle seismic fragility analysis

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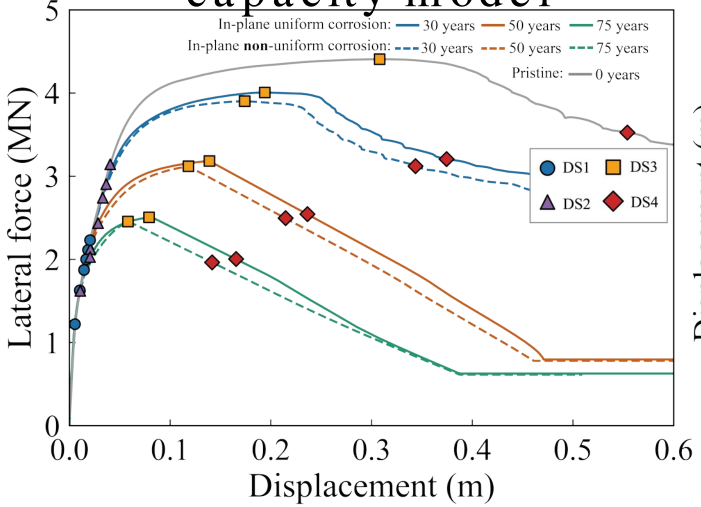
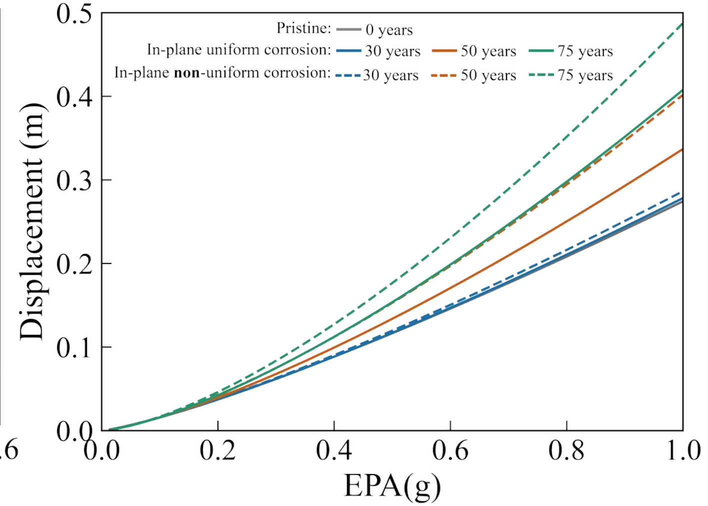
For coastal piers exhibiting different failure modes, multi-level seismic capacity thresholds were determined based on pushover analyses. Subsequently, probabilistic seismic demand models were developed using the cloud approach.

seismic capacity and demand

Seismic failure mode, damage state, and capacity model



Probabilistic seismic demand model



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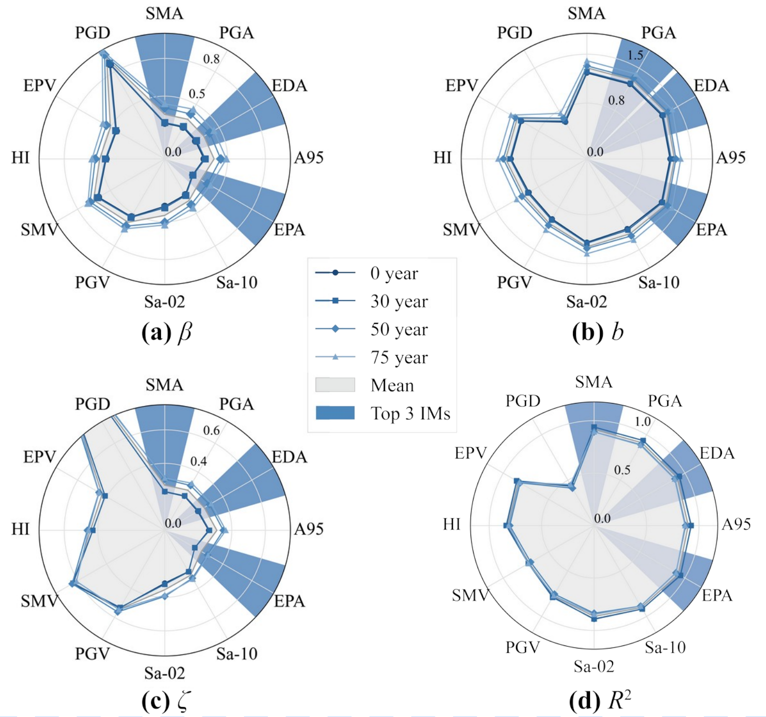

(a) β (b) b (c) ζ (d) R^2

4. Life-cycle seismic fragility analysis

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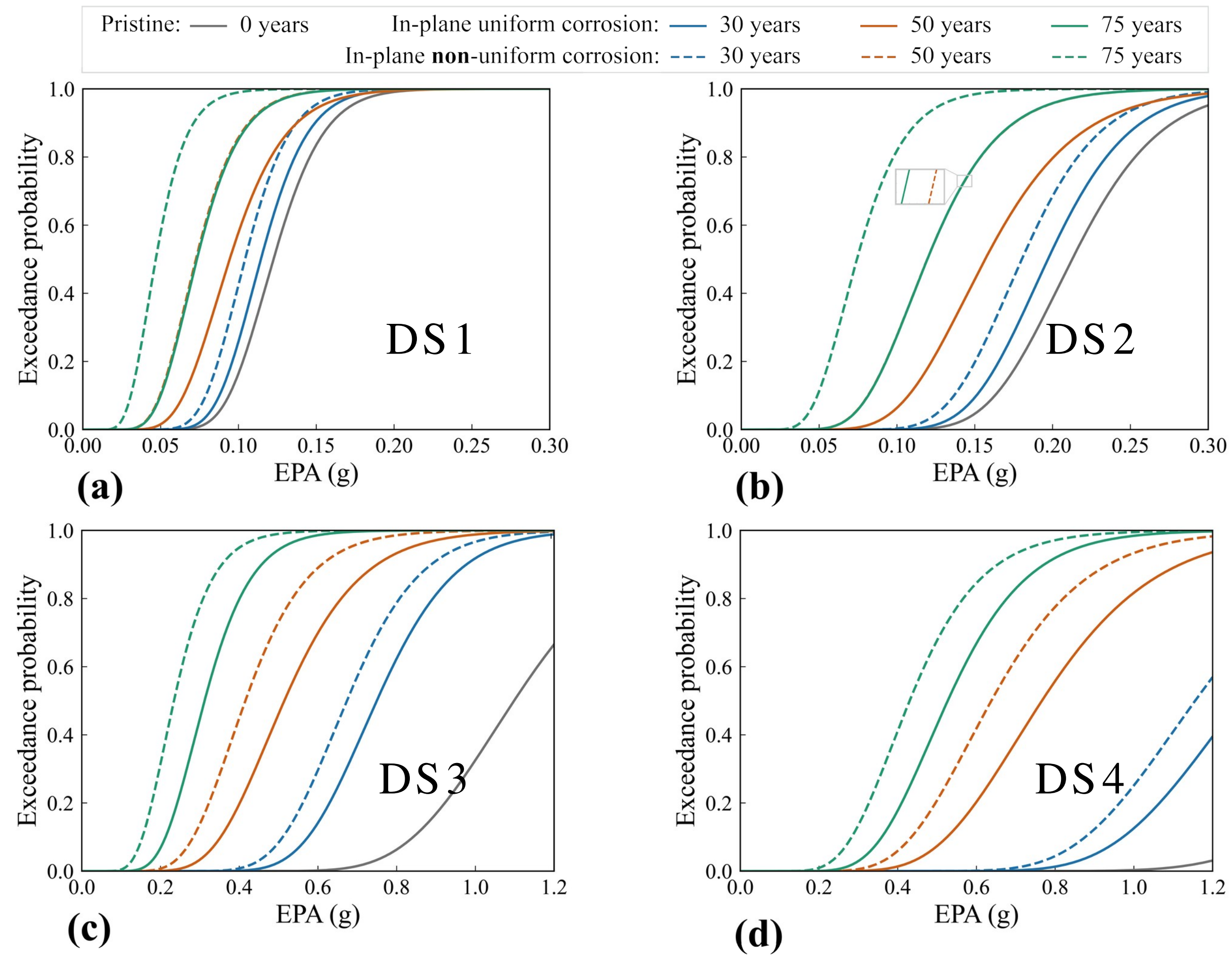
Figure depicts the lifetime seismic fragility of the pier at four different damage states under corrosion.

- Over the service life, the seismic fragility of bridge piers increases significantly with increasing corrosion mass loss ratios.
- In-plane non-uniform corrosion further increases the seismic damage risk of bridge piers.



5.Parametric study

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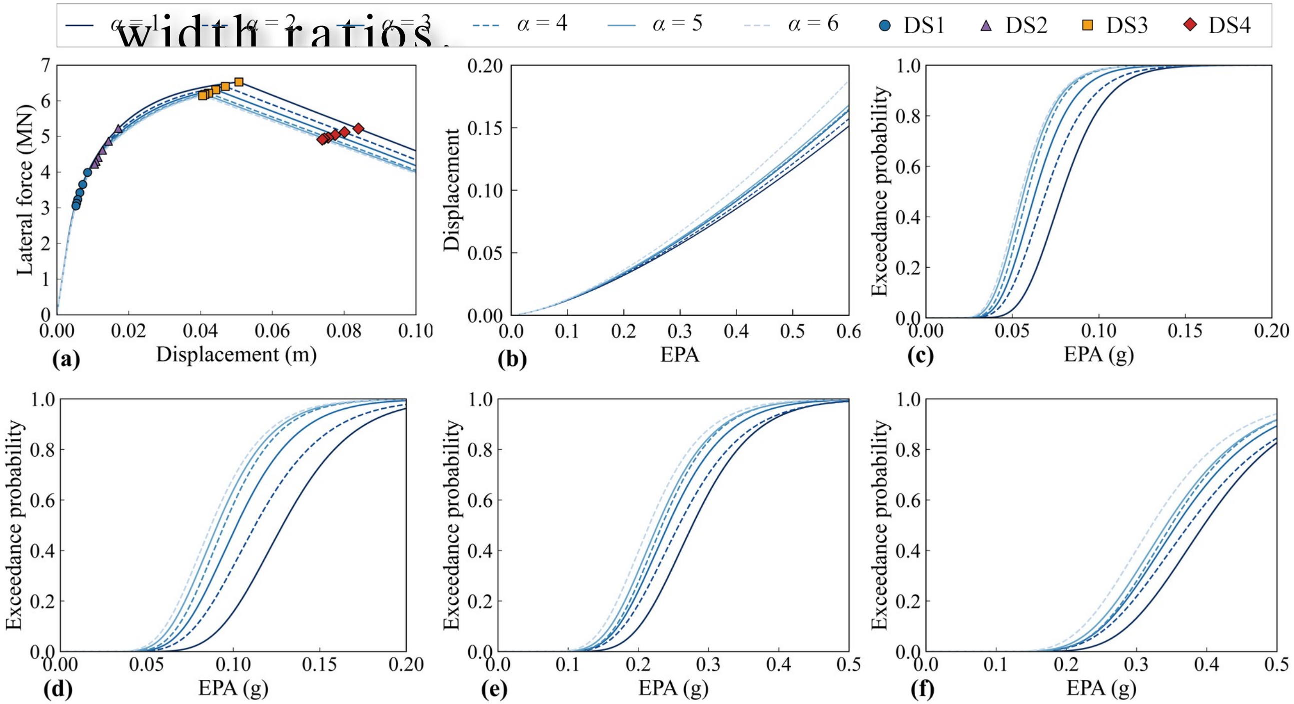
The influence of the non-uniform corrosion on the seismic fragility was quantified for piers with various corrosion mass loss rate, axial load ratios, heights, and length-to-width ratios.



Case	$l_{cor, ave}$	α (%)	L / D	H (m)
C00 (reference)	30%	10	3	9
C01	25%	10	3	9
C02	35%	10	3	9
C03	30%	5	3	9
C04	30%	15	3	9
C05	30%	10	2	9
C06	30%	10	4	9
C07	30%	10	3	12
C08	30%	10	3	6

the in-plane non-uniform corrosion level

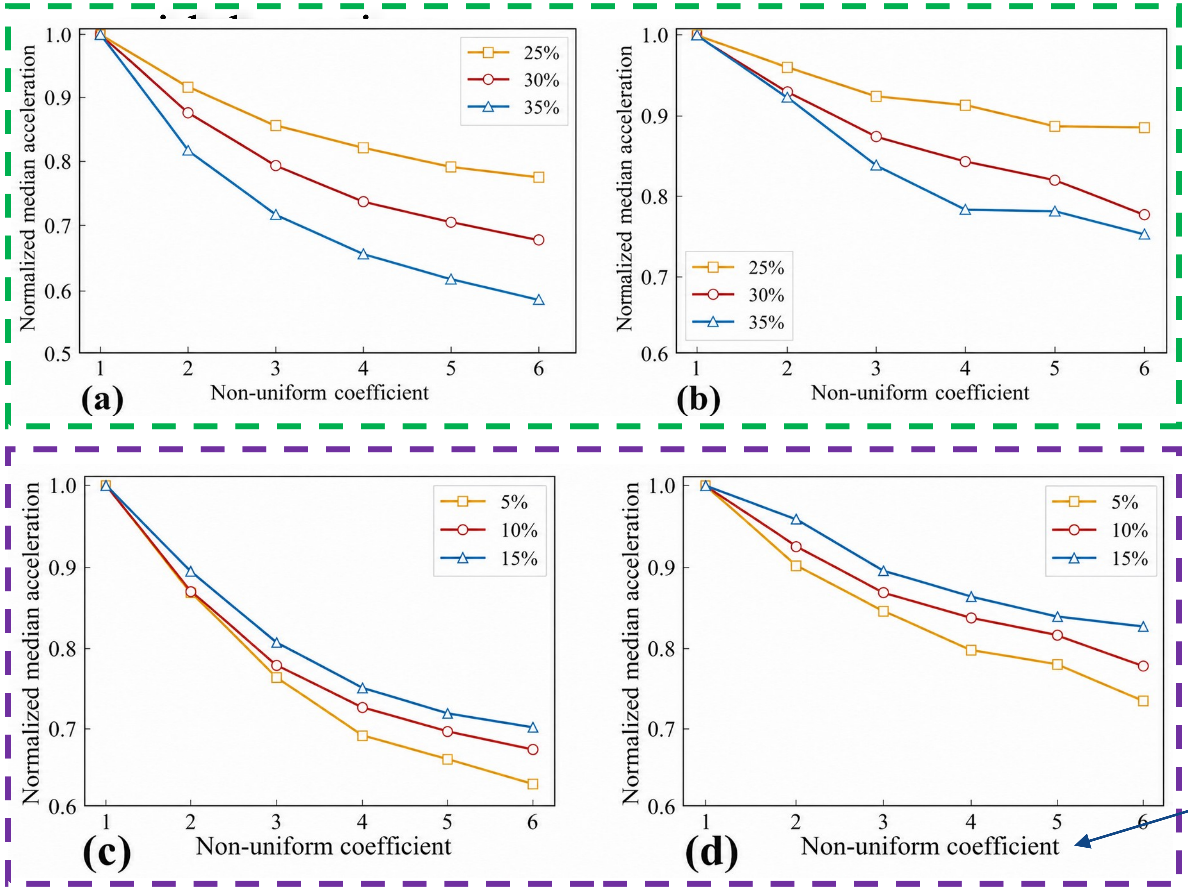
$$\varphi = \frac{Q_c}{Q_m}$$

corrosion rate in the **corner zone**

corrosion rate in the **mid-face zone**

5.Parametric study

The influence of the non-uniform corrosion on the seismic fragility was quantified for piers with various corrosion mass loss rate, axial load ratios, heights, and length-to-



Case	$l_{cor,\,ave}$	α (%)	L/D	H (m)
C00 (reference)	30%	10	3	9
C01	25%	10	3	9
C02	35%	10	3	9
C03	30%	5	3	9
C04	30%	15	3	9
C05	30%	10	2	9
C06	30%	10	4	9
C07	30%	10	3	12
C08	30%	10	3	6

$$\varphi = \frac{Q_c}{Q_m}$$

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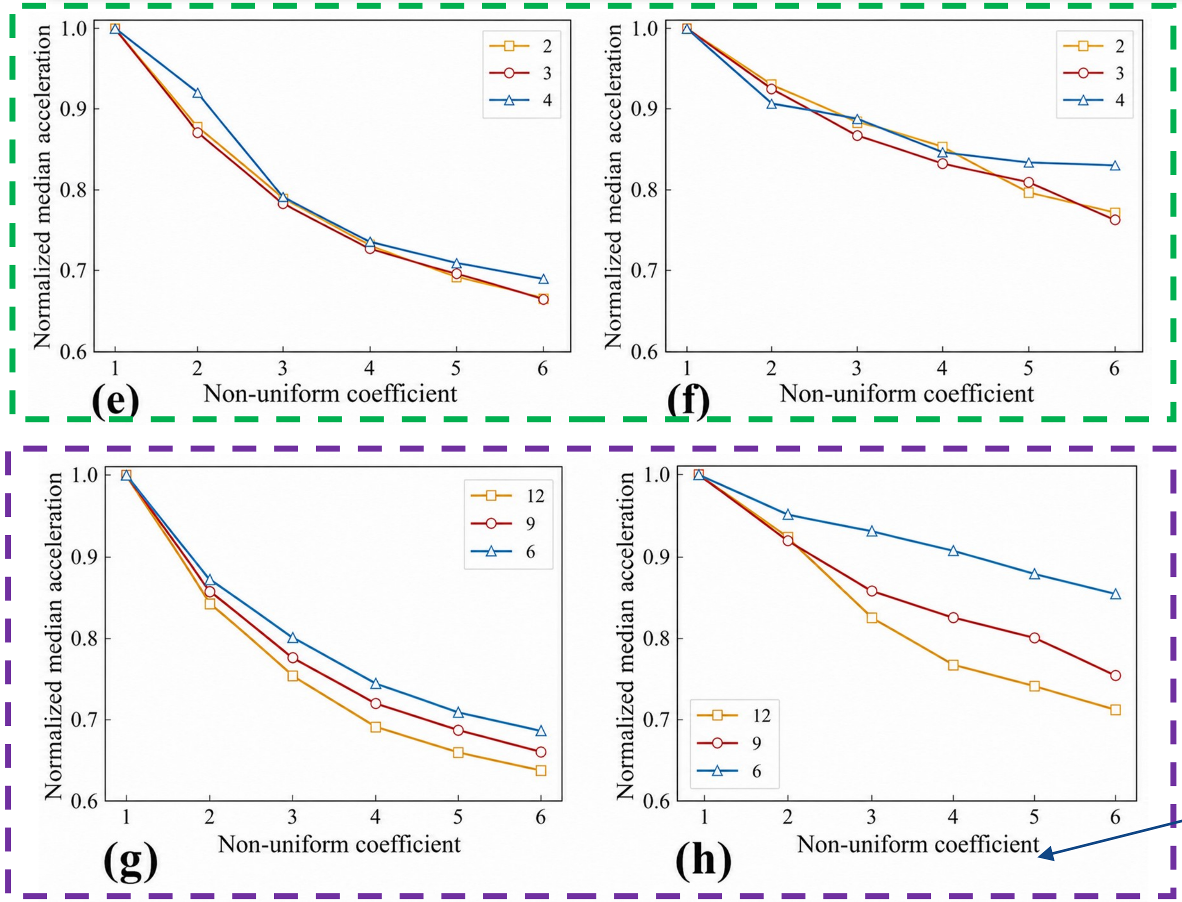


Case	$l_{cor,\,ave}$	α (%)	L/D	H (m)
C00 (reference)	**30%**	**10**	**3**	9
C01	**25%**	10	3	9
C02	**35%**	10	3	9
C03	30%	**5**	3	9
C04	30%	**15**	3	9
C05	30%	10	**2**	9
C06	30%	10	**4**	9
C07	30%	10	3	**12**
C08	30%	10	3	**6**

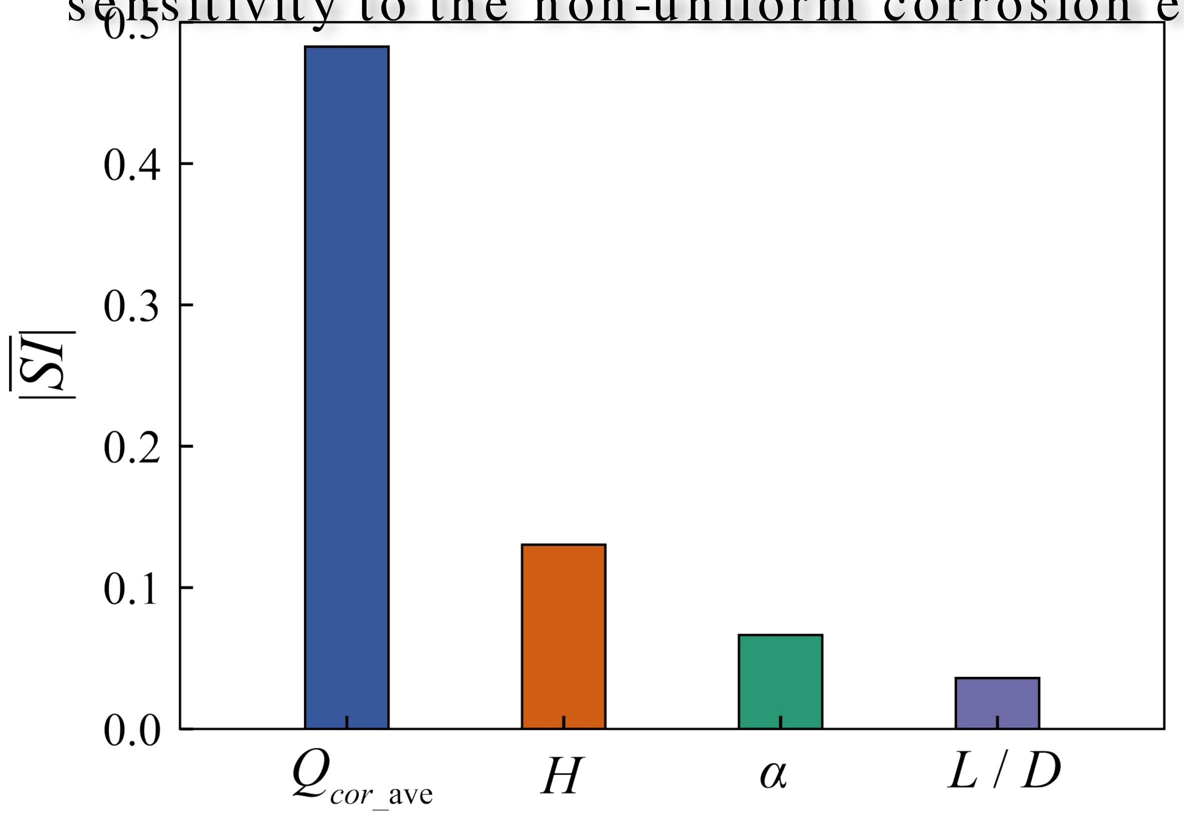
$$\varphi = \frac{Q_c}{Q_m}$$

corrosion rate in the **corner zone**

corrosion rate in the **mid-face zone**

5.Parametric study

Furthermore, the seismic performance of piers with higher mean corrosion level of the cross-section, larger heights and smaller axial load ratios exhibits a higher sensitivity to the non-uniform corrosion effects.



O_1 and O_2 are the corresponding output values;

$$S = \frac{\boxed{(O_1 - O_2)} / \mathrm{Avg}(O_1, O_2)}{\boxed{(I_1 - I_2)} / \mathrm{Avg}(I_1, I_2)}$$

I_1 and I_2 are the input parameter values of the reference case and the comparison case

$$|\overline{S}| = \left| \frac{1}{N} \sum_{k=1}^{N} S_k \right|$$

6.Conclusion

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This paper develops a time-dependent FEM model for bridge piers that accounts for the effects of in-plane non-uniform corrosion. The key conclusions are summarized as follows.

1. Marine chloride-induced corrosion in coastal rectangular RC bridge piers exhibits evident spatial non-uniformity. Corner rebars suffer more severe corrosion than mid-face rebars, while rebars in the splash–tidal zone corrode more severely than those in the atmospheric zone.

2. Over the service life, the degree of sectional non-uniform corrosion first increases and then decreases. Compared with the assumption of in-plane uniform corrosion, in-plane non-uniform corrosion significantly increases the seismic fragility and seismic risk of bridge piers.

3. The effect of in-plane non-uniform corrosion depends on structural and corrosion parameters. Its influence becomes more pronounced with increasing average corrosion ratio of rectangular cross section. Piers with lower axial load ratios and higher shear-span ratios are more sensitive to in-plane non-uniform corrosion, whereas the cross-sectional aspect ratio shows no obvious influence.

Thank You Very Much