4th JCI & ACI Joint Seminar
Sustainable and Resilient Concrete Structures
-Codes and Practices-

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Small Hall,
Sapporo, Japan
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Toward a Development of Resilient Structures using Precast and Prestressed Concrete Structural Components

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Background

Needs to accelerated on-site bride construction
Accelerated Bridge Construction (ABC)

- New bridges
- Replacement due to deterioration
- Replacement due to seismic damage

Use a precast concrete components
Details of connections between

- precast concrete member and cast-in-place concrete member
- precast and precast concrete members

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Background (cont.)

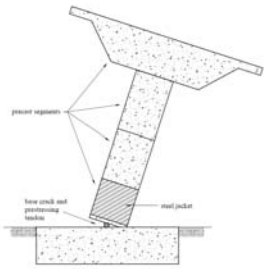
Precast Concrete Bridge Columns

Seismic issues

- Seismic resistance
- Energy dissipation capacity

Detail in the practical design

- PC tendons (sometimes unbonded) are used to control an energy dissipation capacity of the PC column.
- Simple connection may be realized by reducing the number of reinforcing bars at the connection portion.



Hewes, J.T. and Priestley, J. N. (2001)
Seismic Design and Performance of Precast Concrete Segmental Bridge Columns, Caltrans, UCSD / SSRP-2001/25

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Background (cont.)

◎new build and rebuild for damaged or aging structures

⇒quick construction

➡ Prefabricated components

◎restoring just after the earthquake disaster

⇒ self-centering and small residual displacement

➡ Prestressed concrete

Precast Prestressed Concrete (PCaPC) bridge piers

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Objectives

Comparison

- Monolithic PC column v.s. Precast PC column

Energy dissipation capacity

- To confirm **the energy dissipation** of the PCa-PC columns during reversed cyclic loading

Residual displacement

- To confirm **the re-centering performance** the PCa-PC columns during reversed cyclic loading

Damage evaluation based on visualization

- In order to evaluate the damage in the PCa-PC columns during earthquake, **image analysis** was conducted in the loading tests.

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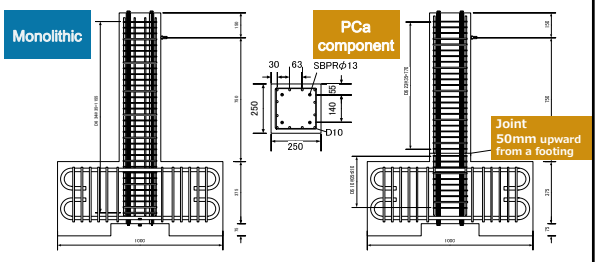
Experimental Parameters

Parameter

- **PC monolithic specimen (Monolithic)**
- **PC specimen with a joint (PCa)**



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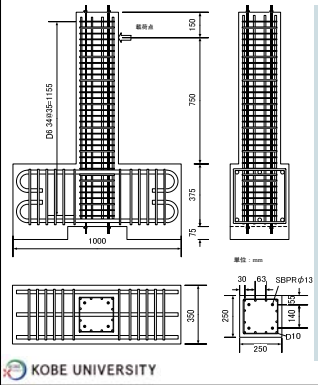
Specimens 7



- PC bars
  SBPR(930/1180) 4×Φ13mm
- Long. rebars
  SD345 12(or 4)×D10
- Hoop
  SD295 D6@35
- Prestressing
  4MPa
- Concrete Strength
  35N/mm²

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Specimen preparations 8

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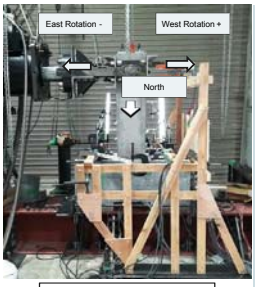
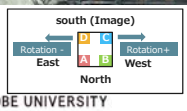
Loading setup and measurements 9





- 300 kN Capacity Actuators
- Set member angles for loading sequence

$$\text{Member angles} = \frac{\text{lateral displacement}}{\text{height of the column}}$$

2 cycles for each displacement
0.25, 0.50 , 0.75, 1.0, 1.5, 2.0, 2.5, and 3.0%rad
1 cycle for each displacement
3.5, 4.0, 5.0, 6.0, 7.0, 8.0%rad, (9.0, 10.0%rad)

- Strain measurements for PC bars and reinforcing bars

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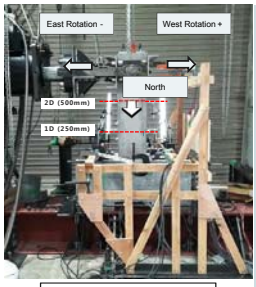
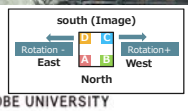
During loading test 10





- South (CD plane)
  Digital image captures to use image analysis
- North (AB plane)
  Crack width measurement by using crack scaling
- East (AD plane) for jointed specimen
  Crack opening displacement
- Others
  Deformation measurement using displacement transducers

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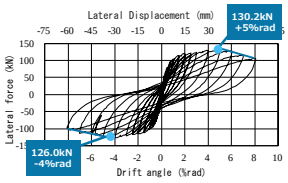
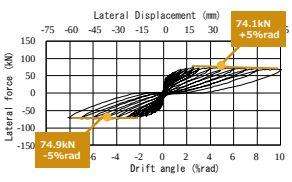
Lateral force – Drift angle relations 11

Monolithic



PCa component



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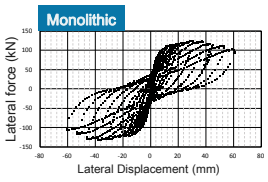
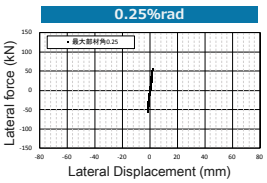
Energy absorption caluculation 12

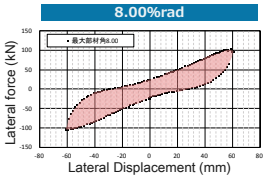
Monolithic



0.25%rad



8.00%rad



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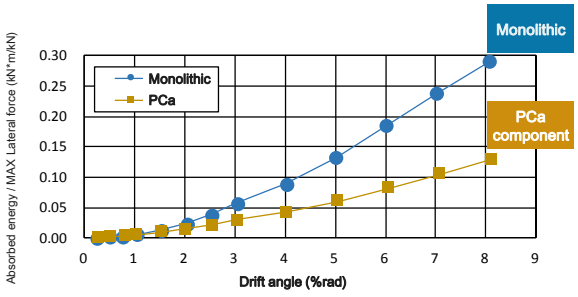
Accumulated energy absorption 13



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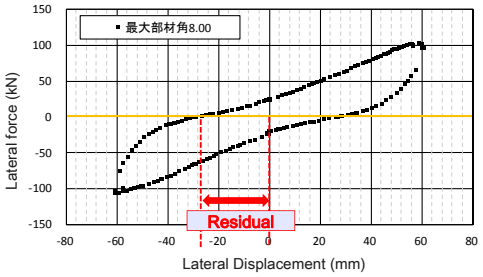
Residual displacement calculation 14



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Residual lateral displacement at LP 15

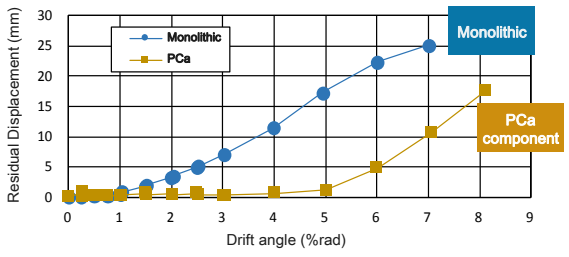

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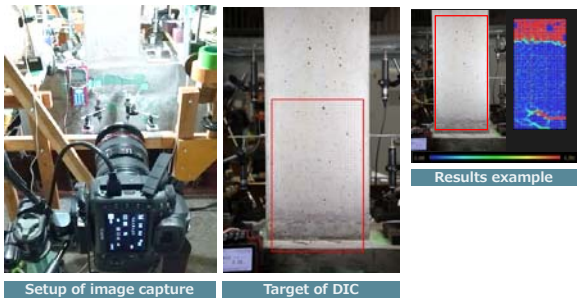
Image analysis by DIC 16



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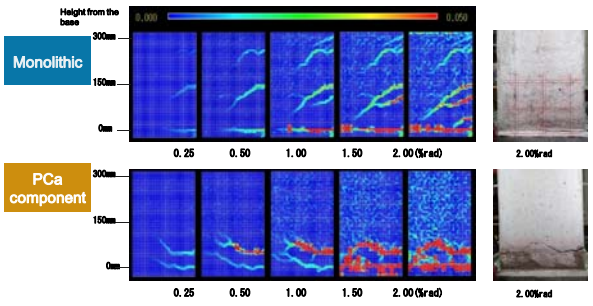
Tensile strain distribution 17



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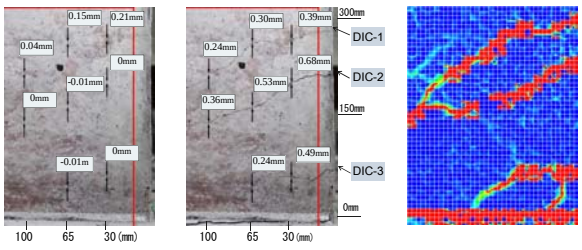
Crack widths (monolithic) 18



0.50%rad 2.00%rad 2.00%rad

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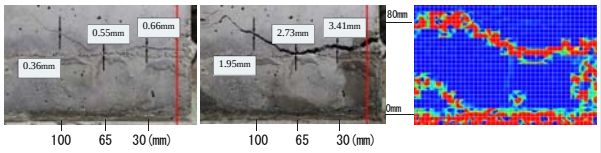
Crack widths (with joint) 19

Close up view at bottom the column



0.50%rad 2.00%rad 2.00%rad

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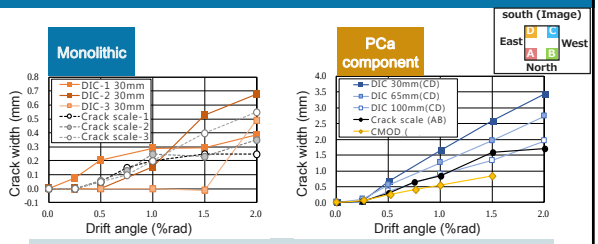
Crack width measured at each drift 20



- Crack width increases as increasing an angle of the member (increase in the lateral displacement).
- Crack width at same displacement
  Monolithic < PCa
  → Damage was concentrated at the joint portion.

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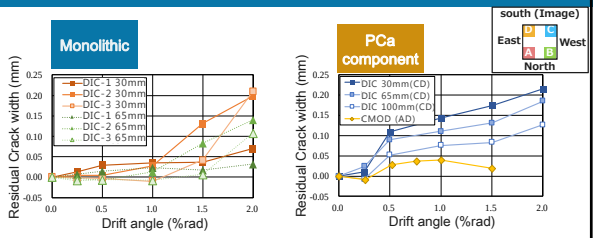
Residual "Crack width" at 0 kN loads 21



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Concluding remarks 22

- **The cumulative energy absorption** of the PC specimen with a joint was **half** of that of the PC monolithic specimen at the member angle of 8% rad.
- **The residual lateral displacement** of the PC specimen with a joint was **smaller** than that of the PC monolithic specimen through the loading.
- **Image analysis** using a digital image correlation method can capture the strain distribution during the loading test. The results clearly show that the damage was **localized at the joint portion** of the bottom of the column.
- The Image analysis can also measure **the crack width at the focused location** through the loading test.

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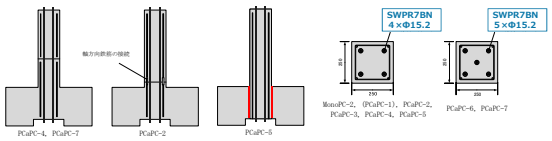
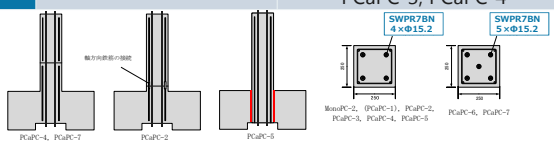
Future research plan 23

Specimen ID	Constructio n	# of PC strands ※4MPa	Location of joint	Joint of rebars
MonoPC-2	Monolithic	4	----	----
PCaPC-2	PCa	4	0 D	Yes
PCaPC-3	PCa	4	1.5D	Yes
PCaPC-4	PCa	4	1.5D	No
PCaPC-5	Pca	4	In the footing	----
PCaPC-6	Pca	5	0 D	No
PCaPC-7	PCa	5	1.5D	No



Future research plan (Comparisons) 24

No.	Parameters	Speciments
①	Mono vs PCa	MonoPC-2, PCaPC-2
②	PC strands, Cross sectional area and layout	PCaPC-2, PCaPC-6
		PCaPC-3, PCaPC-7
③	Location of joint(s)	PCaPC-2, PCaPC-3, PCaPC-5
		PCaPC-6, PCaPC-7
④	Joint in the footing	MonoPC-2, PCaPC-5
⑤	Longitudinal rebar, Cross sectional area and layout	MonoPC-1, MonoPC-2
		PCaPC-1, PCaPC-2
		PCaPC-3, PCaPC-4



Acknowledgements

- JSPS (Japan Society for the Promotion of Science)
  R2904
  Globalization of Research on Urban Resilience against Multiple Natural Hazards(巨大地震に対する創生型居住環境のレジリエンスに関する研究のグローバル化)
- JSPS (Japan Society for the Promotion of Science)
  JP15KK0208, 25709040
  Sensitivity of Volumatic Heterogeneity in Concrete Materia on Shear Resisting Mechanism of Reinforced Concrete Beams(体積変化に起因したコンクリート中不均一損傷がRCはりのせん断特性に与える影響評価)
- Hanshin Expressway Foundation
  Study on Resilient Concrete Structures in terms of Precast and Prestressed Concrete Bridge Columns

Thank you for your attention.