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Flexural behavior of Stone Beams Strengthened with Prefabricated Prestressed CFRP-reinforced Plates

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Introduction and Objectives

Introduction

- Due to the inherent defects and brittleness of natural stone, brittle fracture would occur in stone beams without obviously visible signs. To improve the general behaviour and safety of the stone structure, bare stone flexural members need to be strengthened to improve their performance.
- The existing methods for strengthening stone beams have some limitation.

External steel wires	Damage the original appearance of the structure; poor durability.
External prestressing	Large site limitations; difficulties in operation.
NSM CFRP bars	Difficulties in overhead handling and site grooving.

Objectives

- Propose a strengthening technique for stone beams-external prefabricated prestressed CFRP-reinforced stone plates, and present an investigation on the performance of strengthened stone beams.
- Investigate the effects of CFRP reinforcement ratio and prestress level on the strengthening effect.

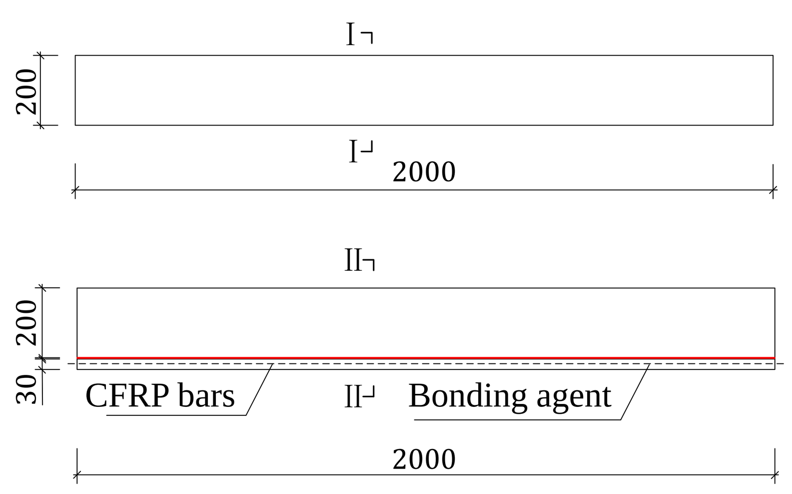
Methodology

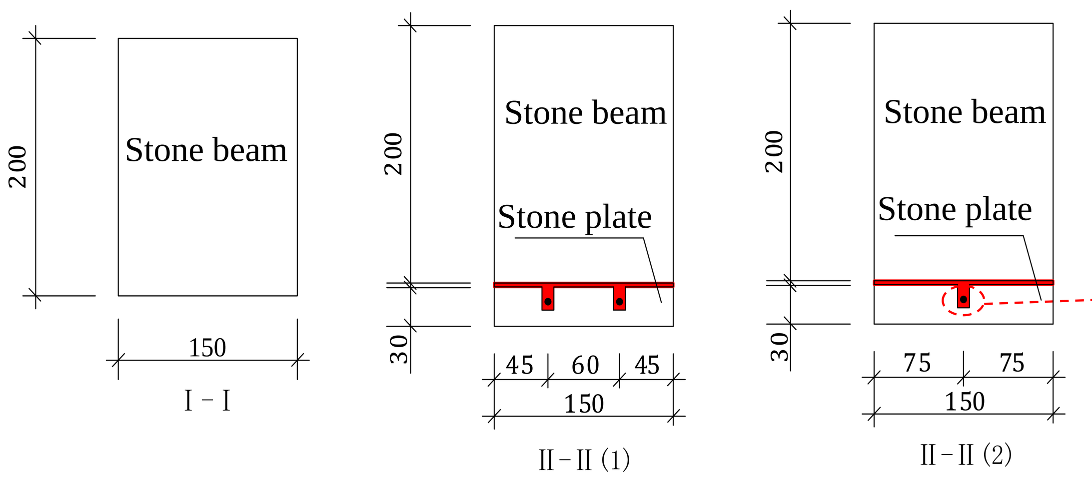
Specimen information

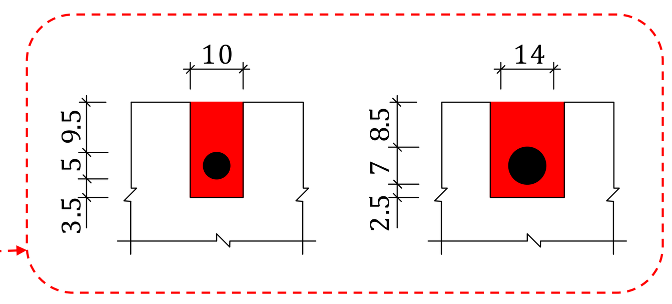
- Stone beam: 150 × 200 × 2000 (width(b) × height(h) × length (l)).
- Prefabricated prestressed CFRP-reinforced stone plate: 2000 × 150 × 30 (length (l) × width(b) × thickness (t)).

Specimen	d_f	n	ρ_f(%)	δ_f
P1	—	—	—	—
P-1d5-0.2	5	1	0.45	0.20
P-2d5-0.2	5	2	0.95	0.20
P-1d7-0.2	7	1	0.91	0.20
P-2d7-0.1	7	2	1.93	0.10
P-2d7-0.2	7	2	1.93	0.20
P-2d7-0.3	7	2	1.93	0.30

d_f: diameter of CFRP bar; n: number of CFRP bars; ρ_f: reinforcement ratio; δ_f: prestress level

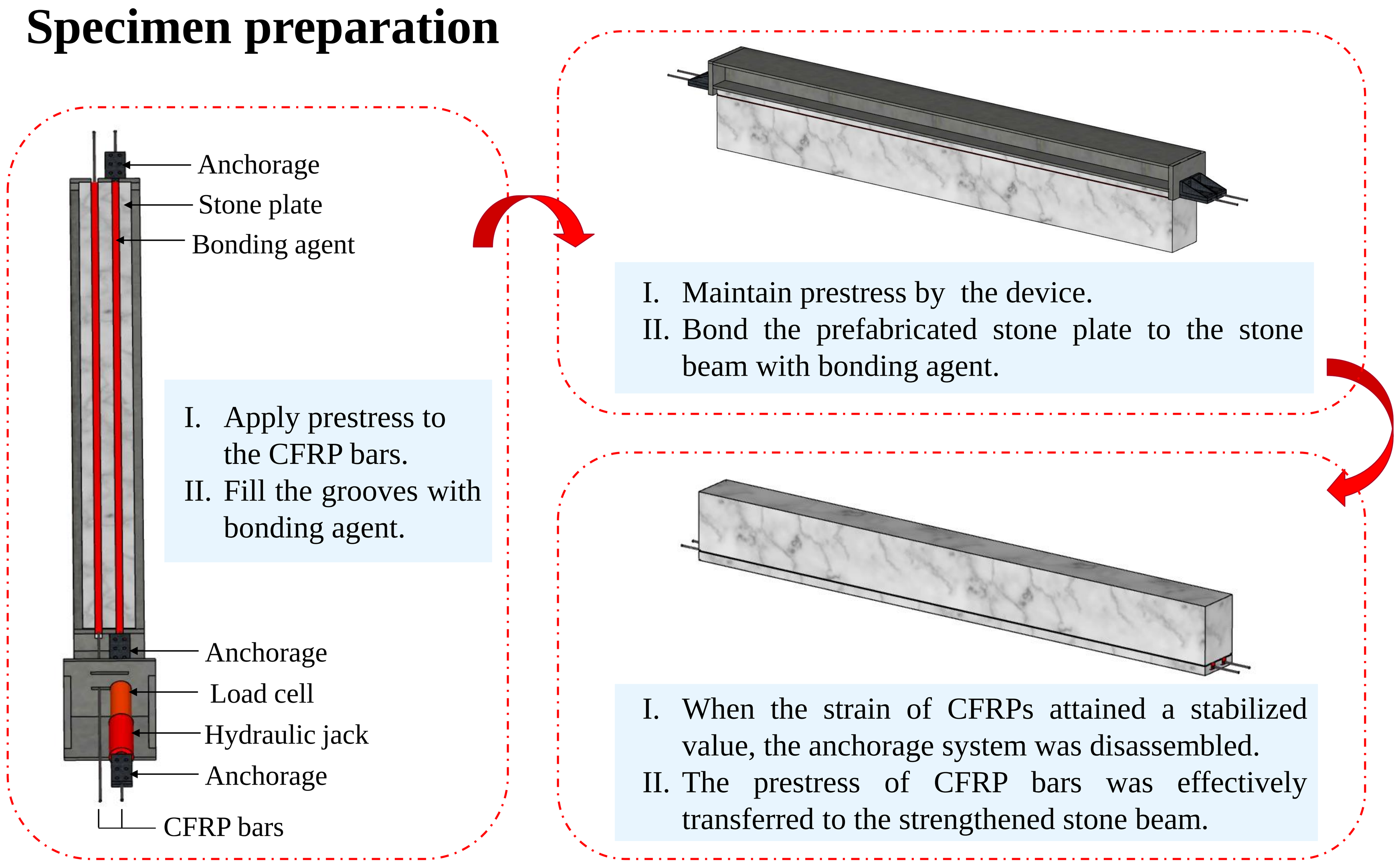






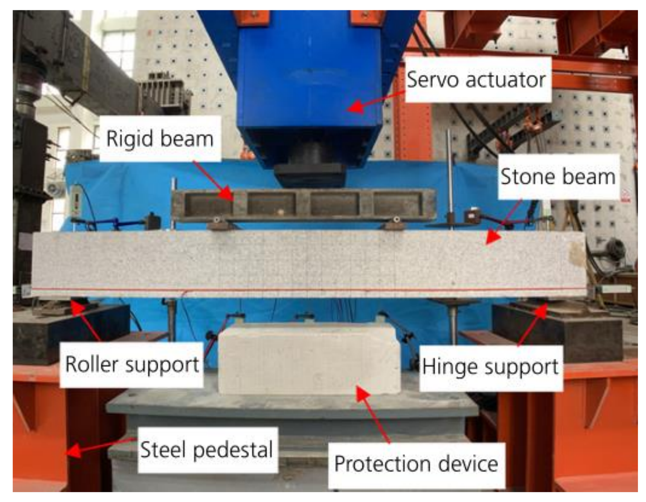
Specimen dimensions and strengthening details (dimensions in mm)

Specimen preparation



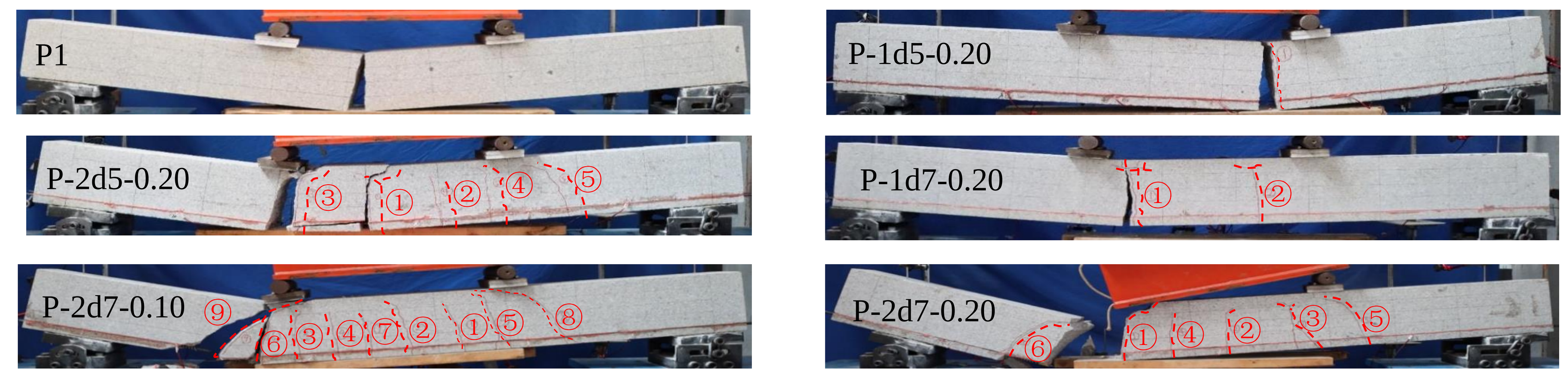
Testing Method

- **Four-point bending** tests were conducted under **displacement control**.
- The loading rate was set as **0.2 mm/min** prior to cracking followed by a rate of **0.4 mm/min** until the end of testing.



Experimental results and discussion

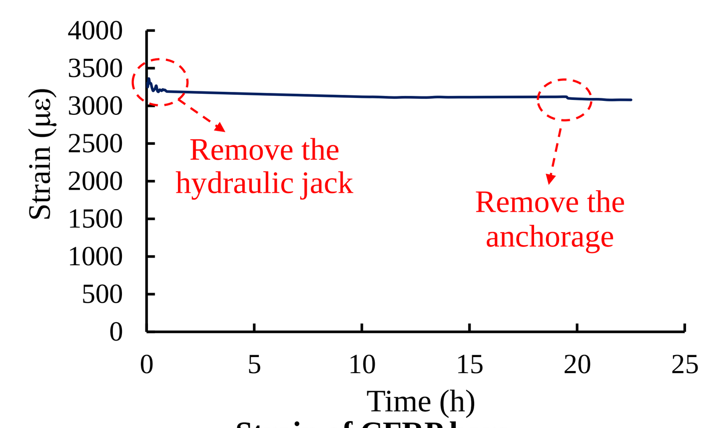
Failure mode



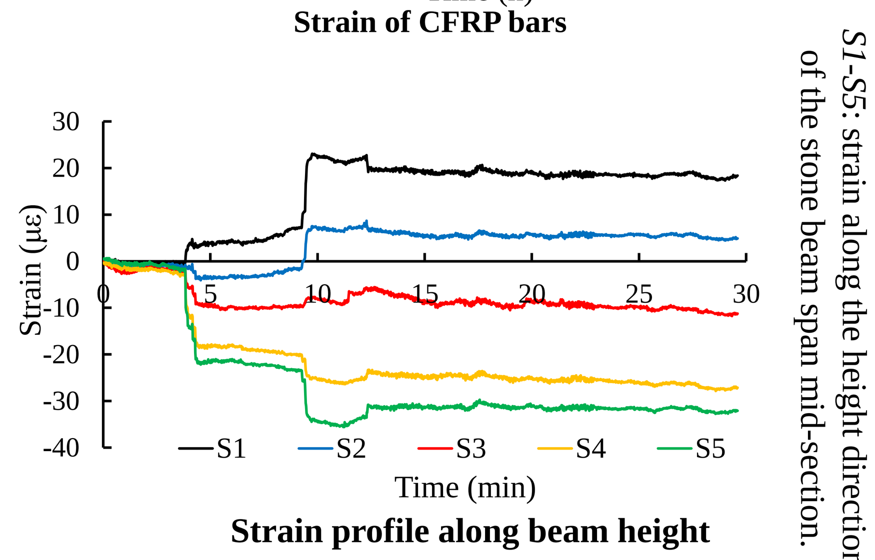
Note: The numbers on the specimens indicate the order of crack formation.

Strain variation in prestress release process

- The stone strain distribution at midspan was in line with the linear law, and the neutral axis was roughly half the height of the strengthened stone beams .



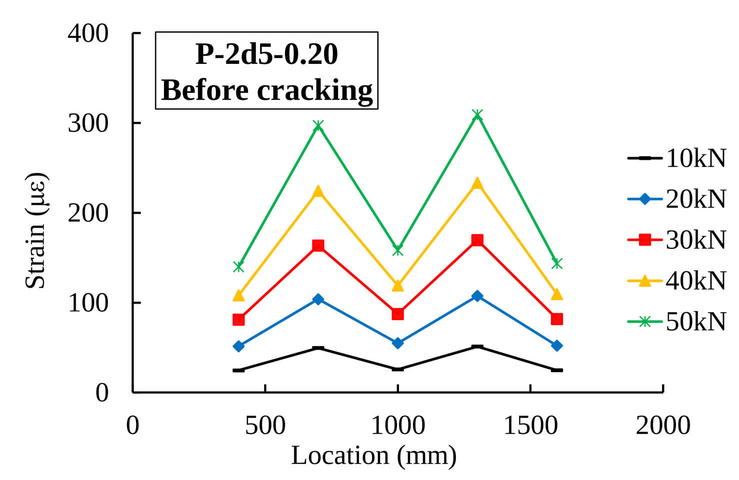
Strain of CFRP bars



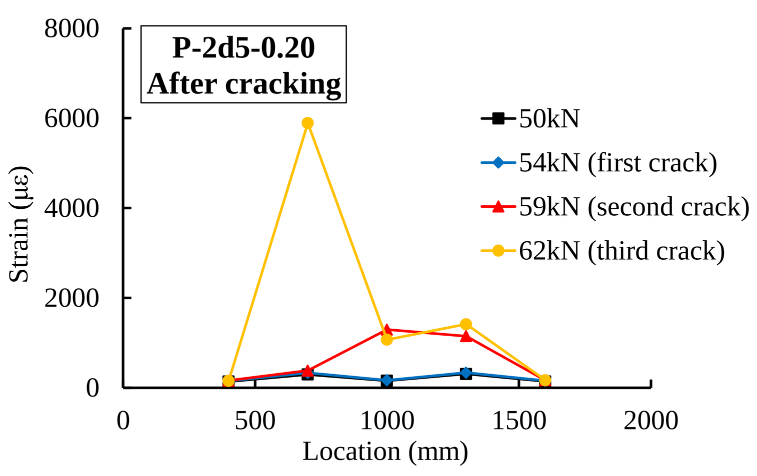
Strain profile along beam height

Strain in CFRP bars

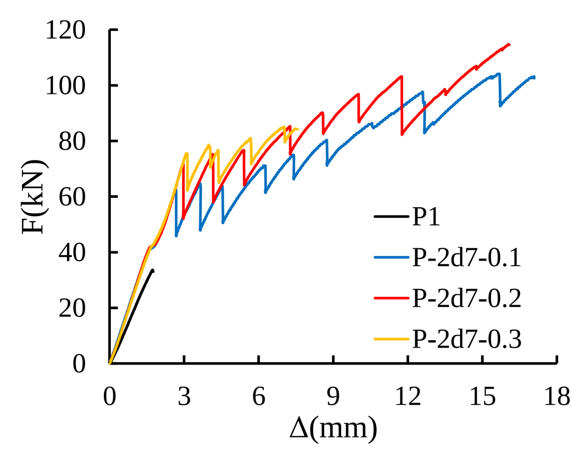
The deformation of CFRP bars and stone beam were coordinated.

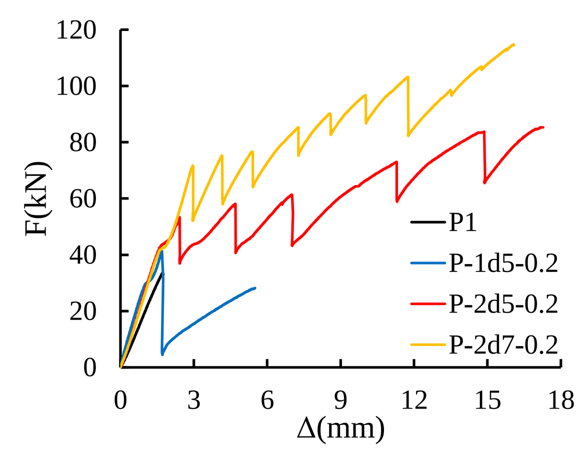


The CFRP bars took the strain instead of the stone beam.

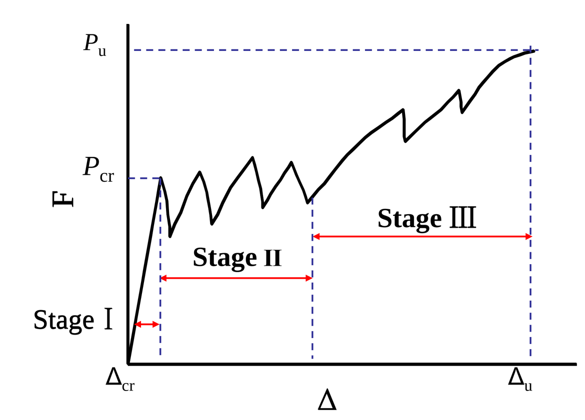


Load–deflection response





Typical load–deflection responses of the strengthened stone beam



Conclusions

- The strengthening technique could effectively change the failure mode of bare stone beams from brittle fracture to a more ductile behavior.
- The strengthened stone beams showed significantly improved flexural strengths and deformation capacities. The maximum increase in the moment capacity was about 113.6% compared with that of the bare stone beam.
- An increase in the CFRP reinforcement ratio and prestress level significantly increased the moment capacity of the strengthened stone beams.