TEST RESULTS OF CYCLIC TESTING ON DUCTILE PRECAST END-DIAPHRAGMS OF SLAB-ON-GIRDER CONCRETE BRIDGES

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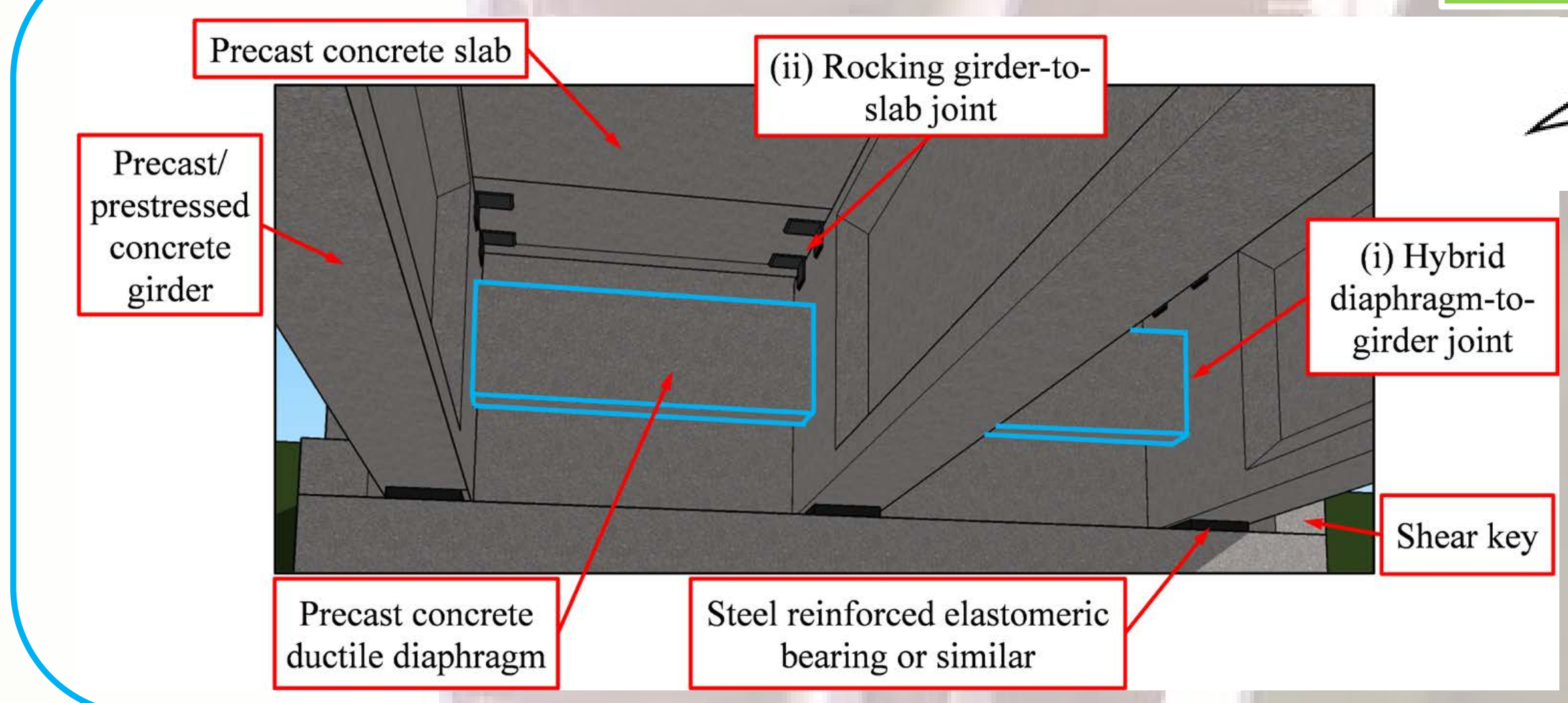
INTRODUCTION

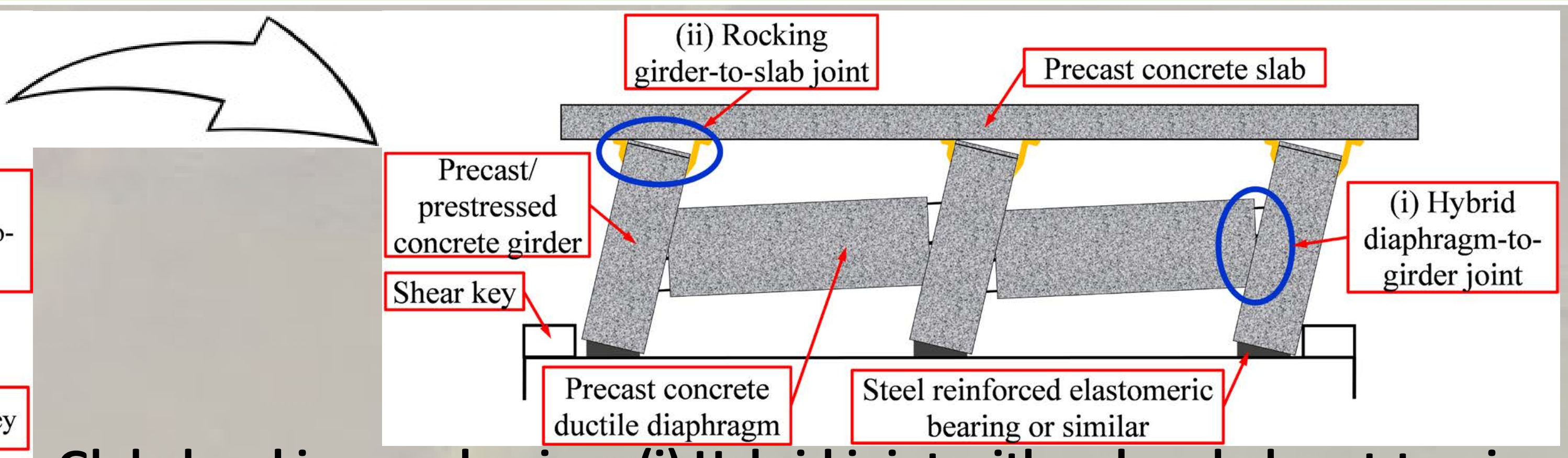
The 2010 Chile earthquake evidenced the importance of the seismic structural function of end-diaphragm beams on concrete bridges[1]. Nevertheless, according to the author knowledge and research, both experimental work and seismic design provisions for diaphragms on concrete bridges are very limited. By contrary, in the case of steel bridges, Zahrai and Bruneau[2] developed a system of ductile end-diaphragms for slab-on-girders steel bridges[3] in order to solve distresses suffered by the superstructure and mainly by the substructure during the most important earthquakes during the past three decades. The initial proposal of these authors has evolved until it became the Type 2 Global Seismic Design Strategy (GSDS) of the AASHTO Guide Specifications for LRFD Seismic Bridge Design[4] that applies only to steel superstructures, and likewise it forms part of other important seismic design and retrofit codes in USA.

AIM

Following the concept proposed by Zahrai and Bruneau[2,3], and Weldon[5] in the case of the structural solution, the aim is explore the use of concrete ductile end-diaphragms that act as fuses during extreme events, like the Type 2 GSDS of the AASHTO Guide[4], for the transverse seismic resistance of simple supported reinforced or prestressed concrete bridges, including its use as part of ABC solutions, in the case of the design of new structures, or in the performing of the rehabilitation of in-service infrastructure.

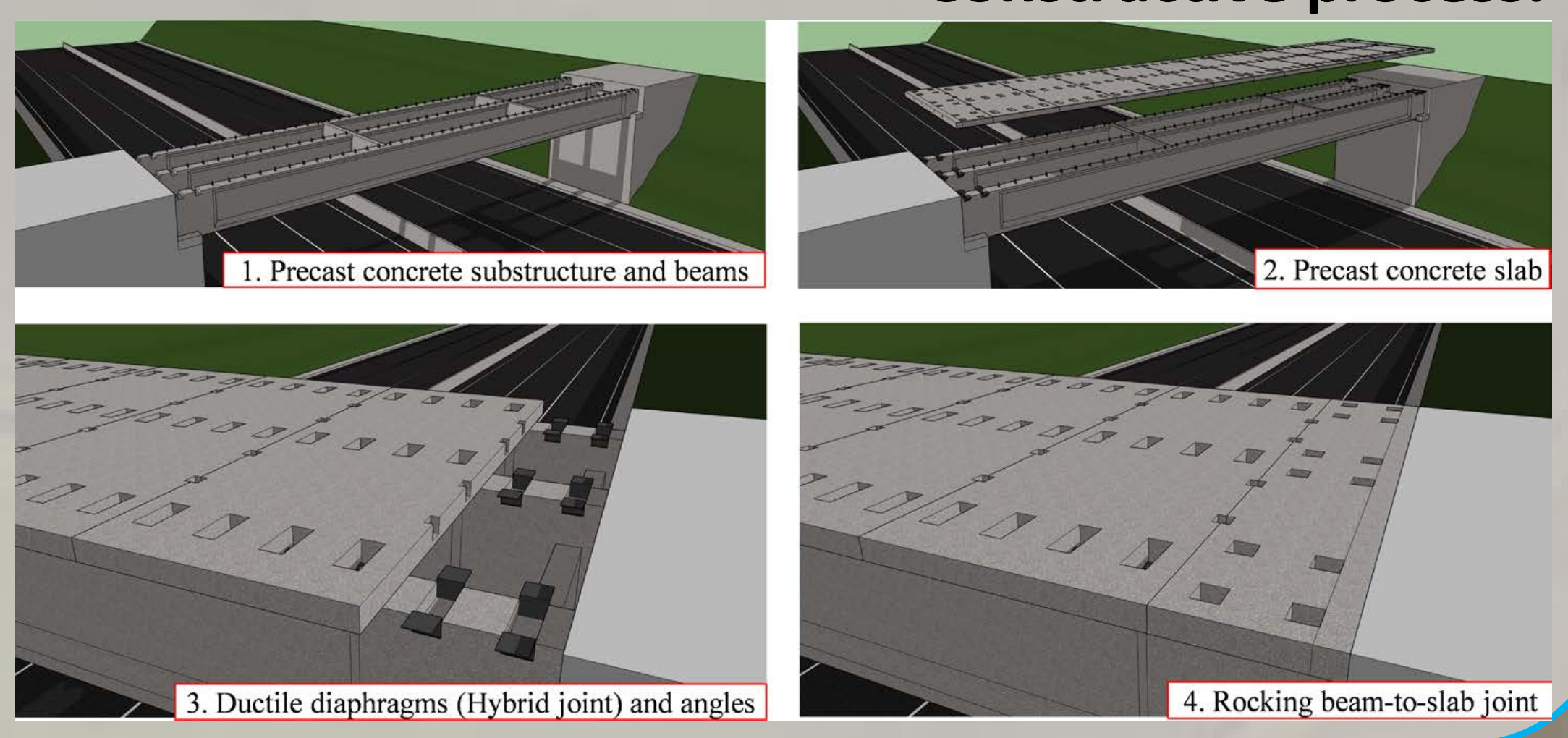
PROPOSED SOLUTION



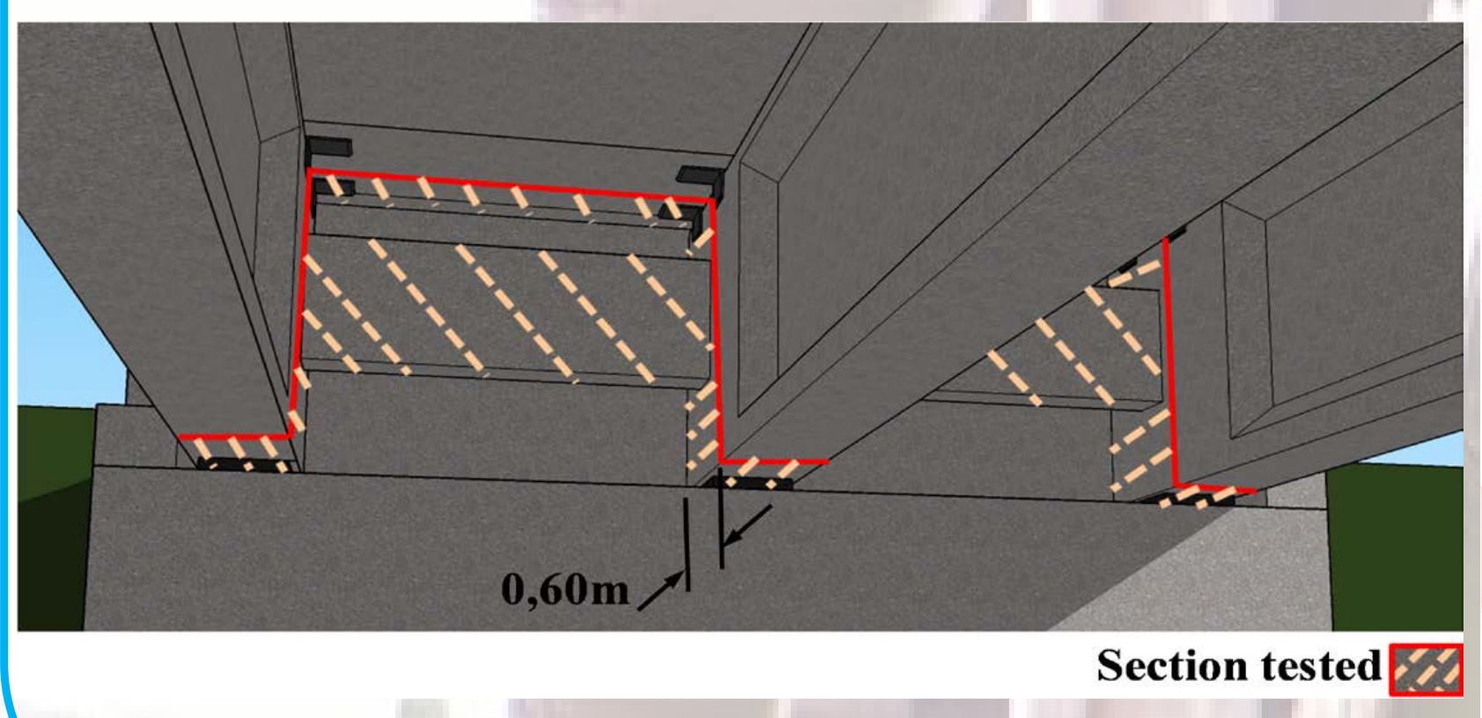


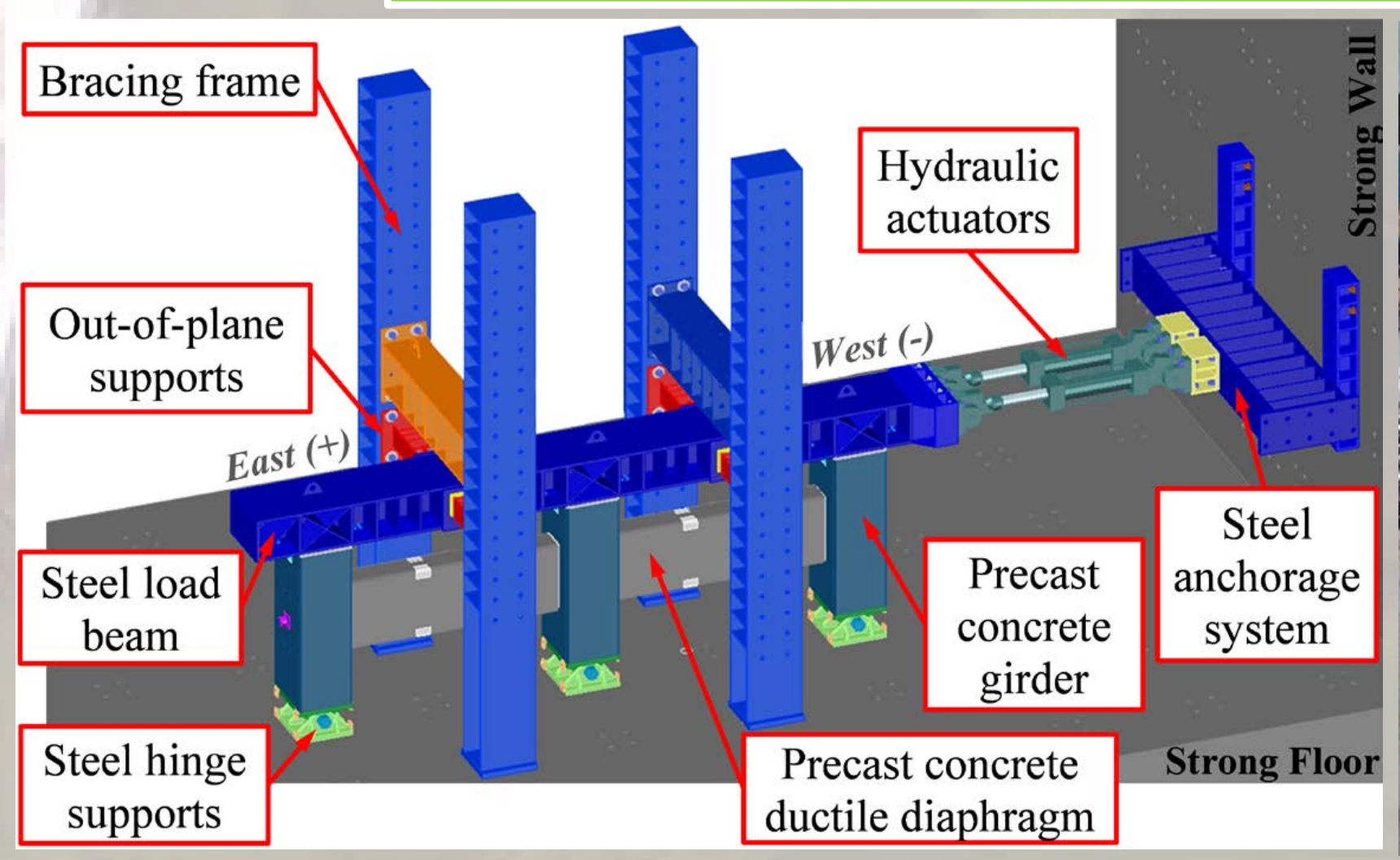
Global rocking mechanism: (i) Hybrid joint with unbonded post-tension and mild-steel reinforcement / (ii) Partially restrained (PR) connection

Constructive process:


1. Precast concrete substructure and beams
2. Precast concrete slab
3. Ductile diaphragms (Hybrid joint) and angles
4. Rocking beam-to-slab joint

EXPERIMENTAL PROCEDURE





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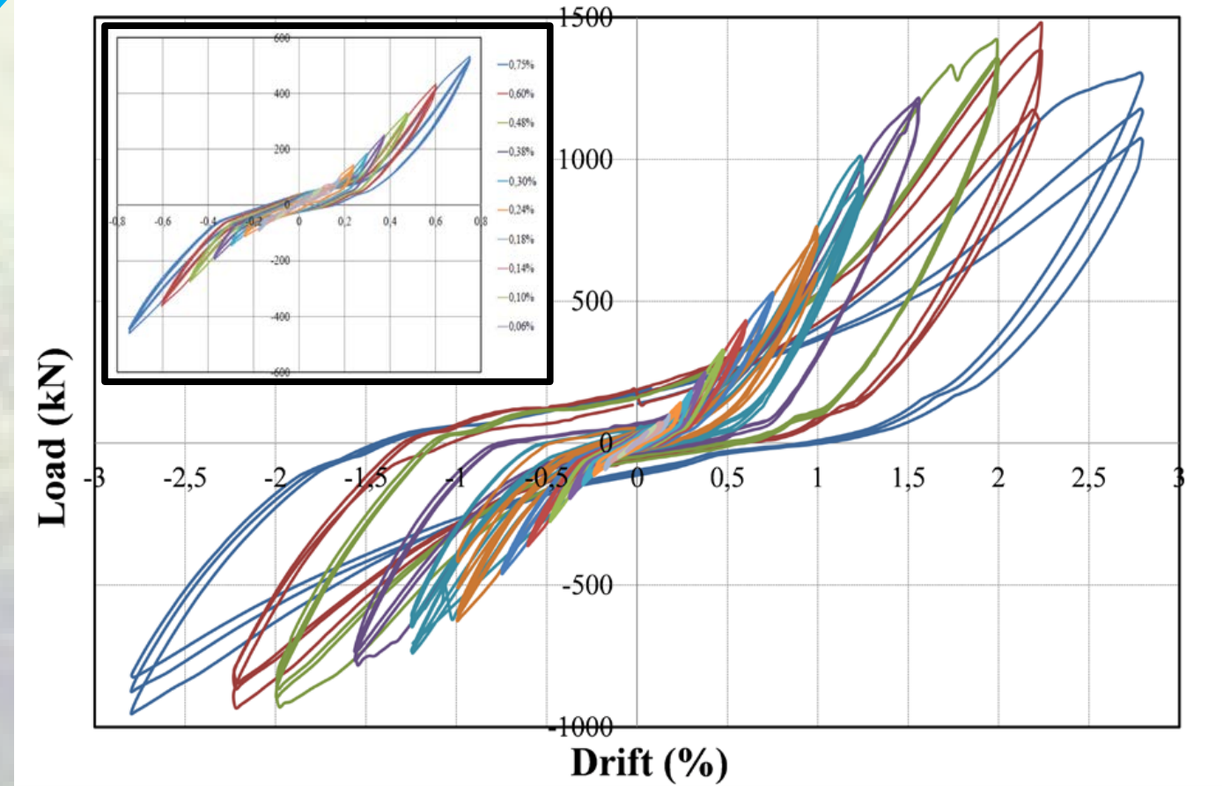
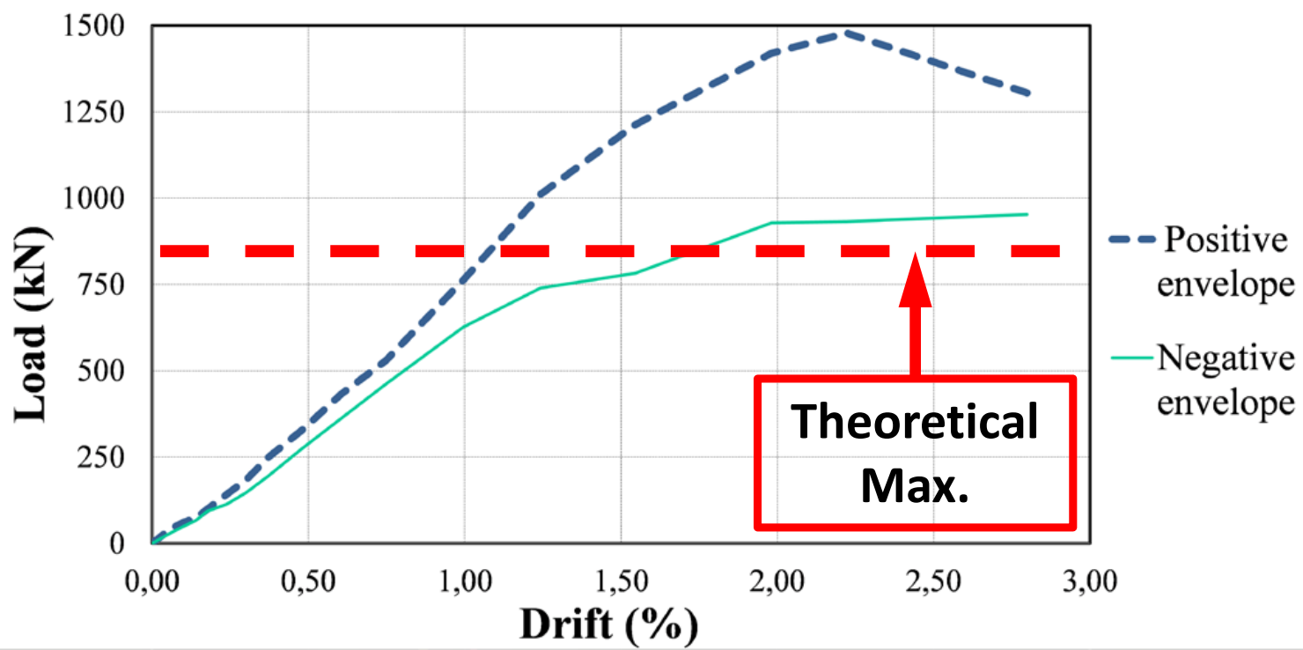
- **The specimen subjected to progressively increasing cyclic lateral displacement.**
- **No dead load applied except for the self-weight of elements.**
- **Three MTS actuators to apply the lateral force simultaneously.**
- **Instrumented for displacement and strain measurements at the points of interest: 33 electrical resistance strain gauges and 20 linear displacement transducers.**
- **A load cell in the post-tensioning steel anchor to measure the actual anchor set loss at prestress transfer and to verify that strands will not yield during the test.**

EXPERIMENTAL RESULTS

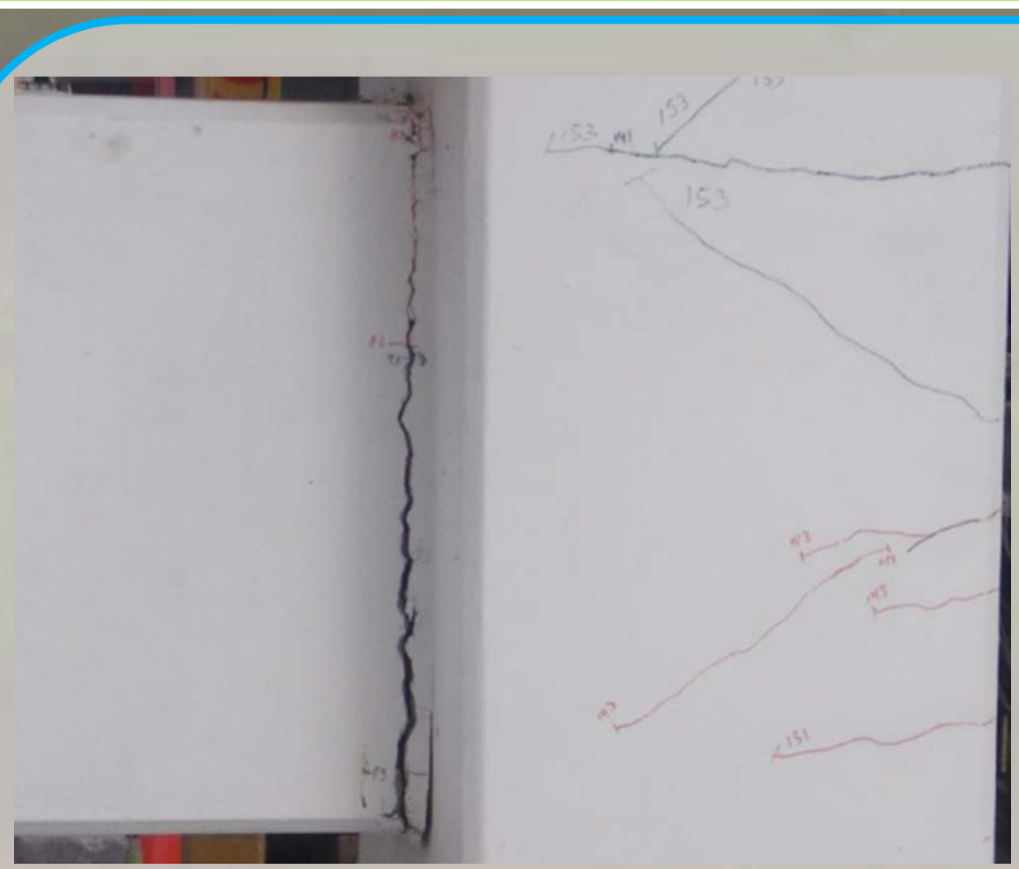


Hysteresis curve



Positive and negative envelopes

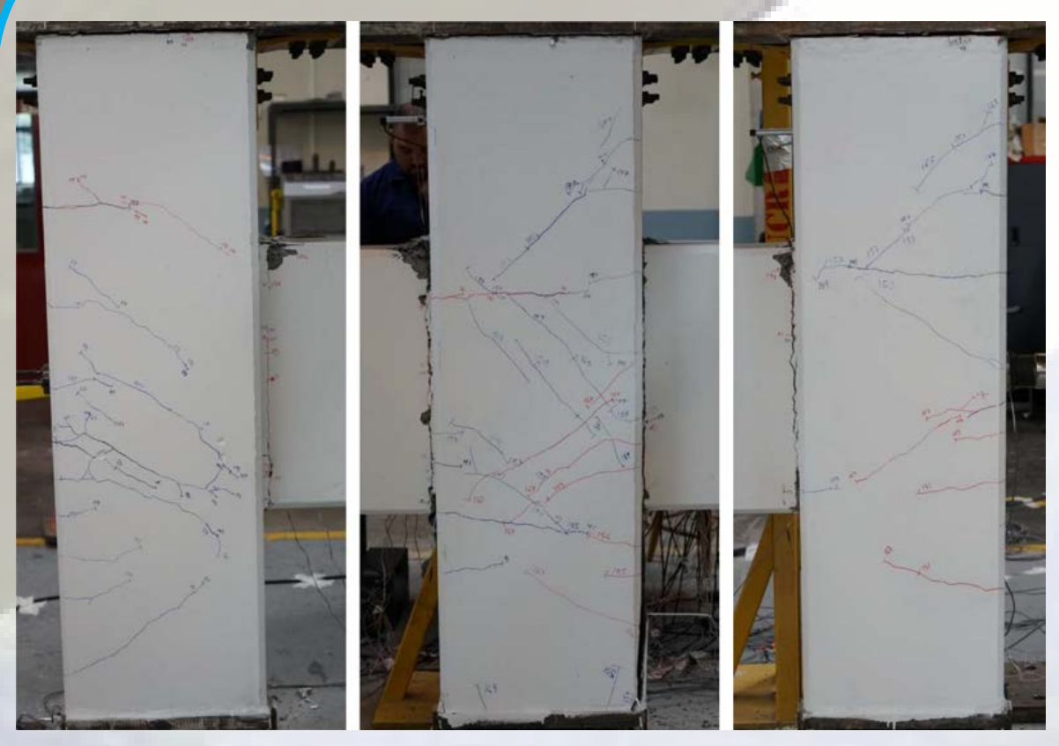
Hysteretic Behavior

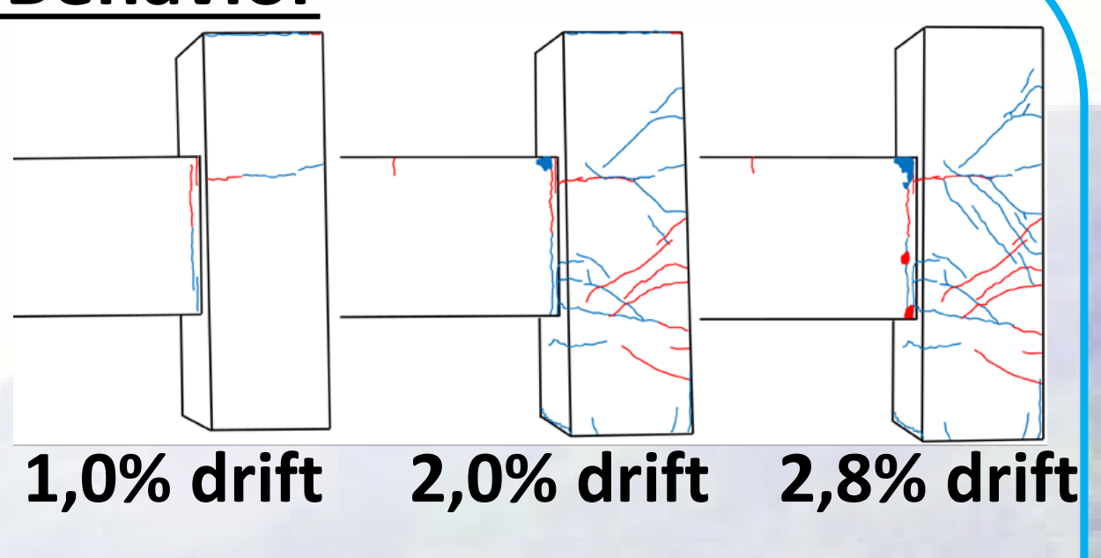

Hybrid joint


PR angle steel connection

Rocking Behavior

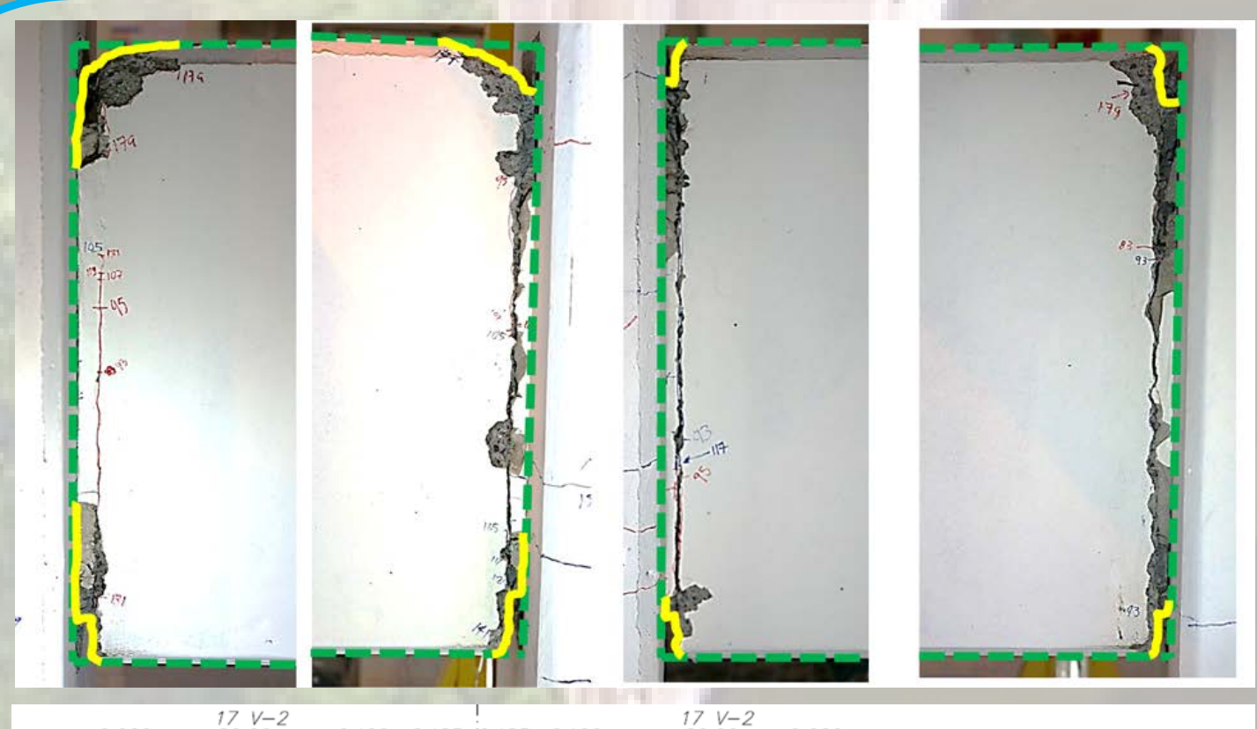
Cracking Behavior

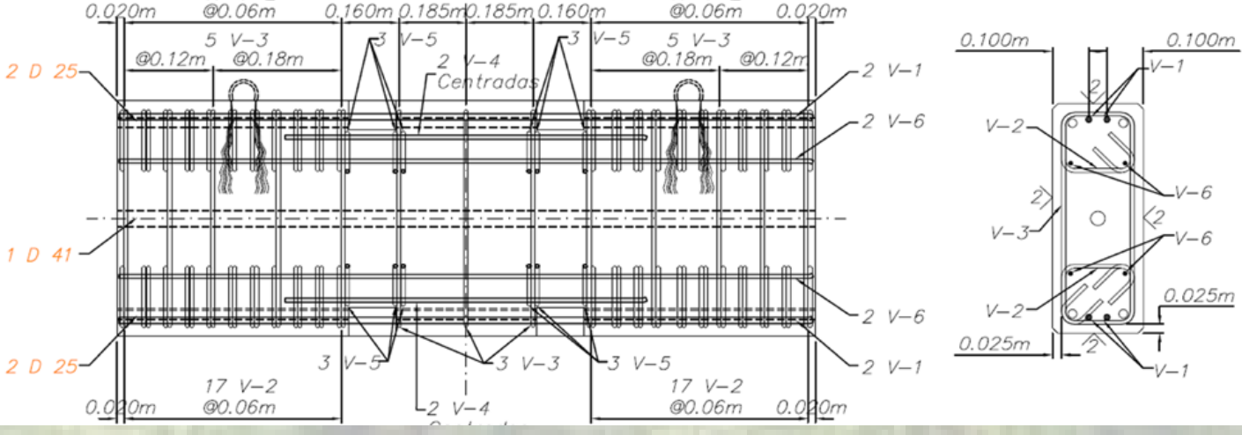

Cracking at the end of the test (2,8 % drift)

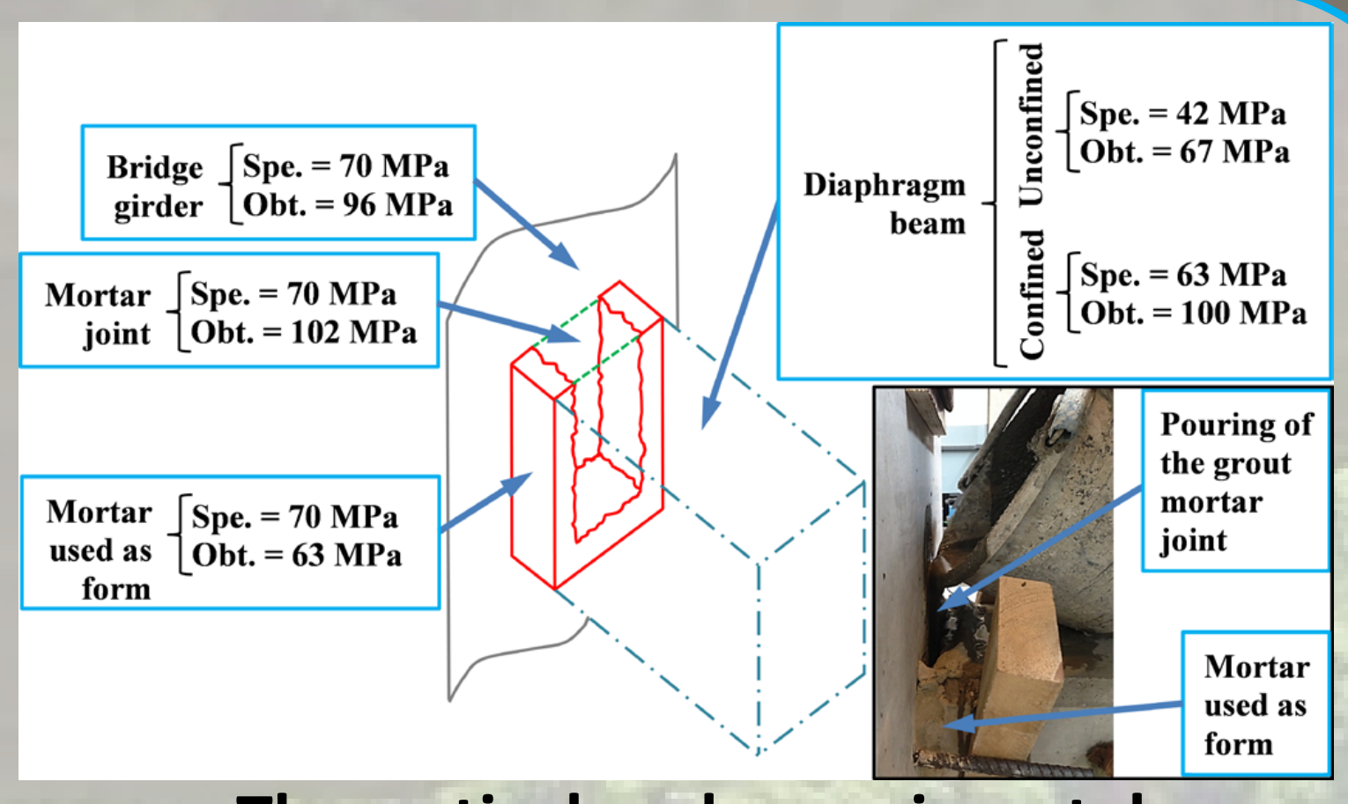

1,0% drift 2,0% drift 2,8% drift

Component	Drift	Máx. Pos.	Máx. Neg.
Girder	1,00%	0,15 mm	0,10 mm
Girder	1,56%	0,18 mm	0,20 mm
Girder	2,24%	0,40 mm	-
Diaphragm	2,00%	-	0,10 mm
Max. residual drift =	0,15 mm (0,10 mm on average)		

Max. crack widths measured


Damages at end sections of diaphragms


Reinforcement details

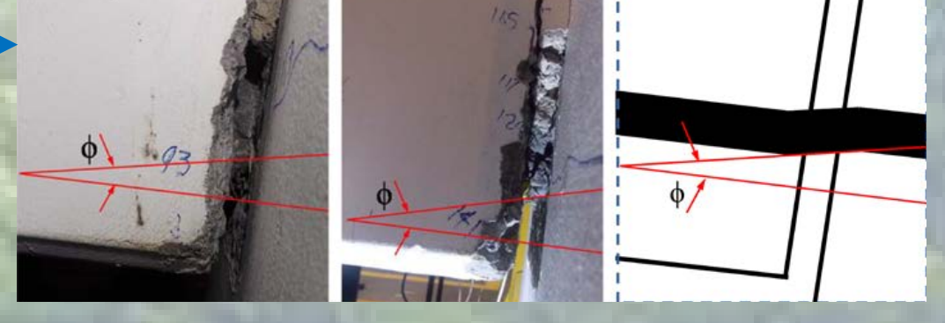


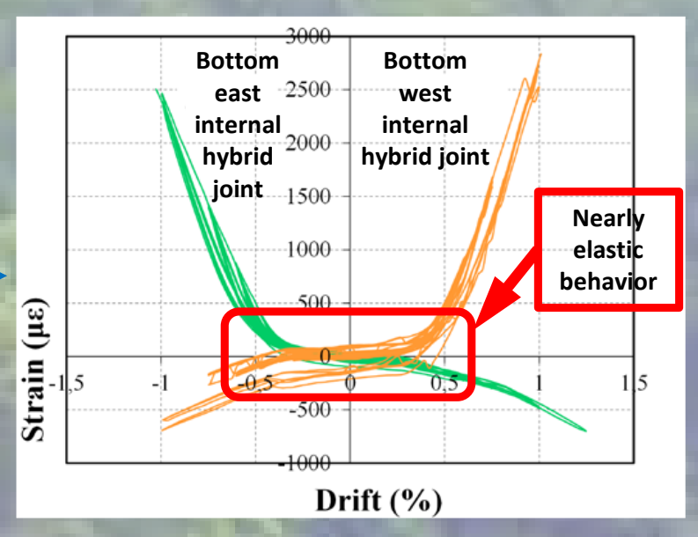
Theoretical and experimental strength hierarchy at end sections of diaphragms

Main Damages

ADDITIONALLY:

- **Loss of mortar inside the metallic ducts at the top of one of the hybrid joints (east internal joint).**
- **Shear displacement and kinking of the reinforcement at the bottom of two of the hybrid joints.**
- **Elastic behavior of the precast/concrete system without evidence of rocking behavior until 0,5% drift.**





CONCLUSIONS AND RECOMENDATIONS

1. **The experimental results demonstrated the proposal to be a viable strategy of seismic behavior improvement for concrete girder bridges, showing adequate resistance, ductility and energy dissipation.**
2. **The causes of the over-strength in the positive direction of load have to be determined, in order to know if it was caused by the interaction between the specimen and the test set up, or it was because an inherent behavior of the system that needs to be improved.**
3. **Diminishing to the minimum the initial elastic behavior showed until 0,5% drift, in order to obtain the rocking mechanism as close as possible to the beginning of the seismic demand, in order to obtain a more ductile behavior and more energy dissipation by making the steel acts sooner. It is expected that improving this aspect, at the same time a higher stiffness could be obtained.**
4. **Using only high strength fiber reinforced grout mortar instead of either regular high resistance grout mortar or a combination of two grout mortars, in order to attain the damage in the confined corners of the end-diaphragm beams and not at the joint, to get a more ductile and controlled result.**

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