Importance of Structural Integrity in Precast Connections

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Precast Structure

- A Precast concrete structure is constructed by connecting the different structural elements fabricated in controlled environments using advanced construction materials and techniques.
- This is a faster construction method with enhanced quality control due to its dedicated and fully equipped pre-casting yard.
- Reduction in Material Wastage, Construction Time Span and a Source for the use of alternative construction materials.

Different Types of Connections in Pre-cast Structures

Foundation to Column

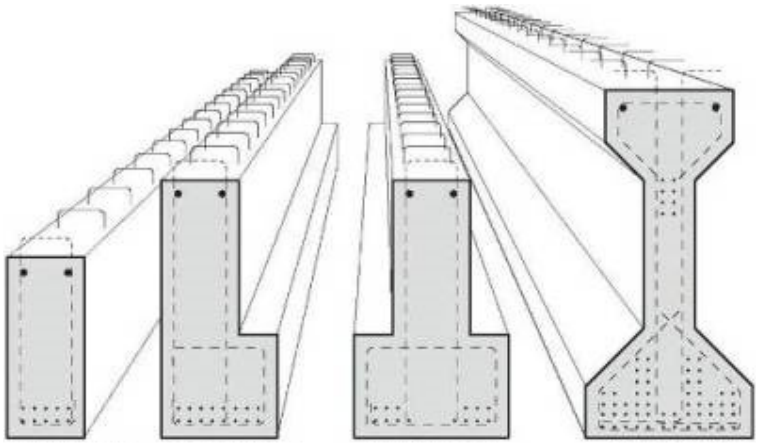
Column to Column

Column to Beam

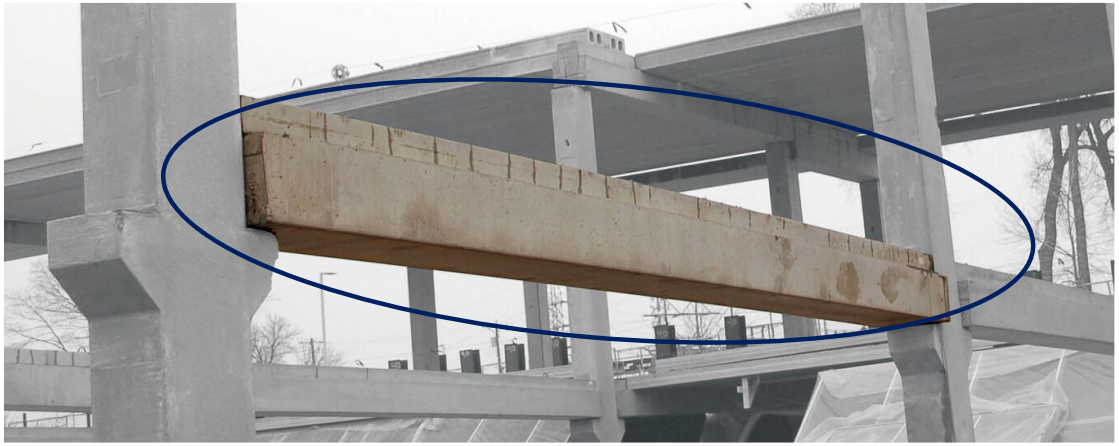
Beam to Slab

Source: constrofacilitator.com

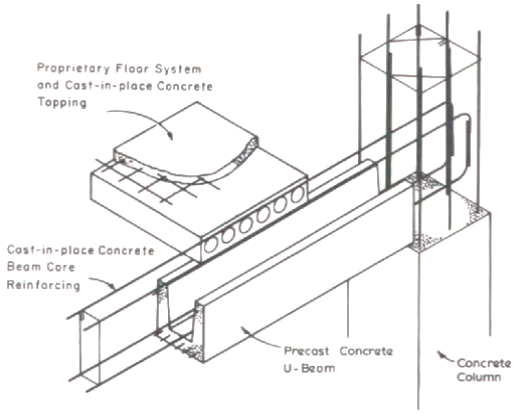
Precast Beams



Different types of precast beams *Source: frontdesk.com*



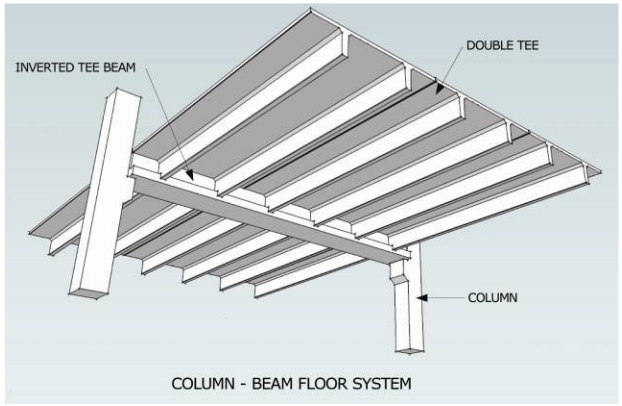
Simply Supported Beam between the Columns *Source: pinterest.com*



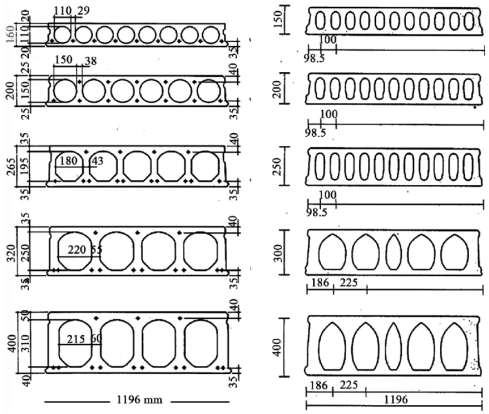
U-shaped precast beams *Source: Park and bull, 1986*

Partial precast beams *Source: Constrofacilitator.com*

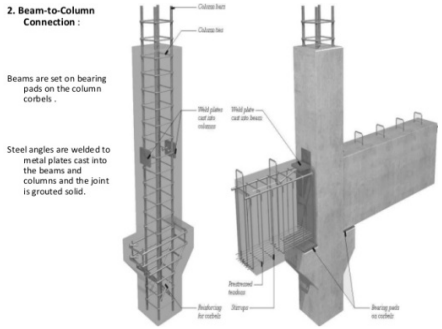
Double T & Single T- Precast Slab



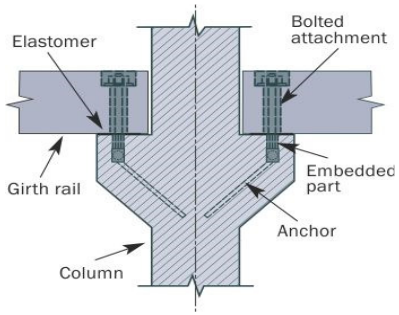
Hollow Core Precast Slab

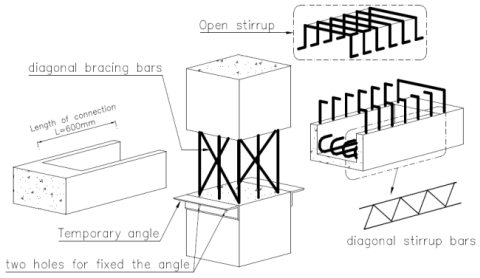


Precast Beam to column connections



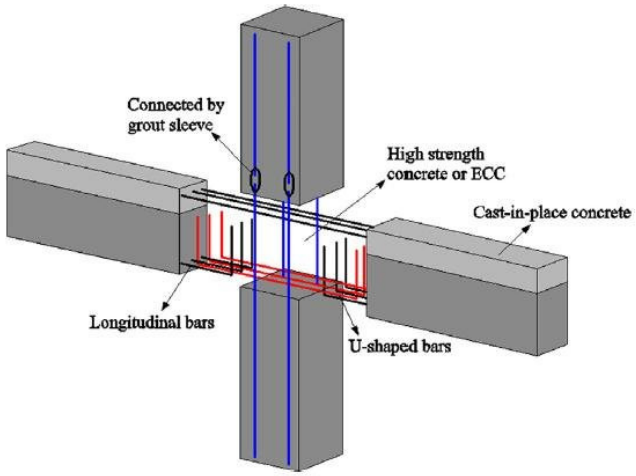
Precast beam-column connection using corbel *Source: fib bulletin 27*



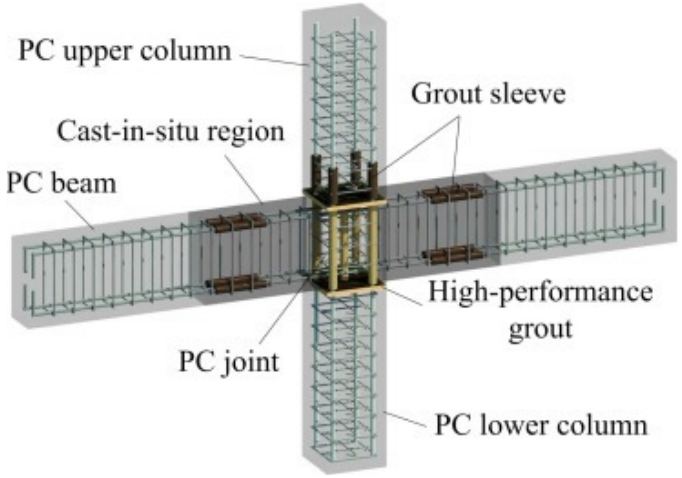


Precast beam-column connection with U-beams

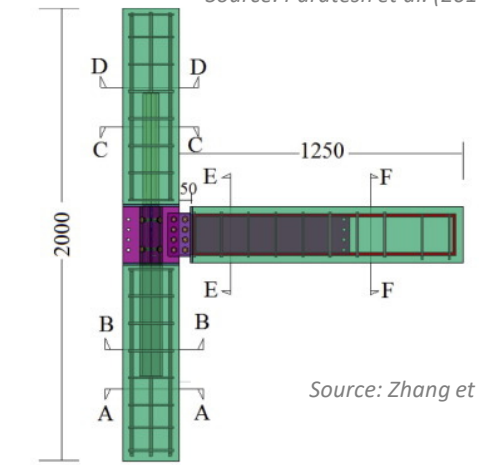
Source: Paratesh et al. (2014)



Precast hybrid beam-column connection *Source: Fallah et al. (2020)*



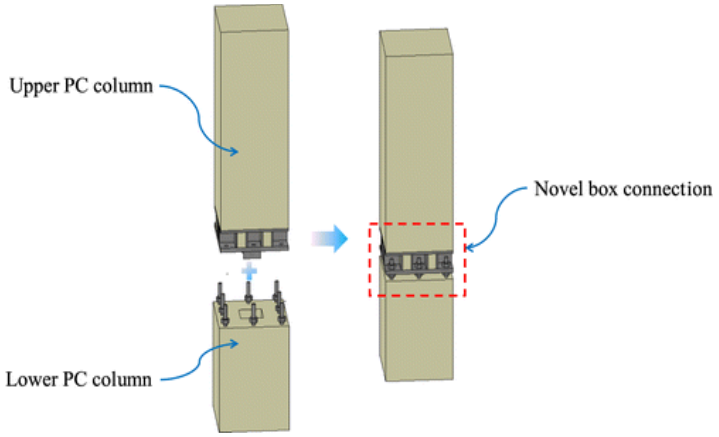
Precast beam-column connections with grouted sleeves *Source: Yan et al. (2018)*



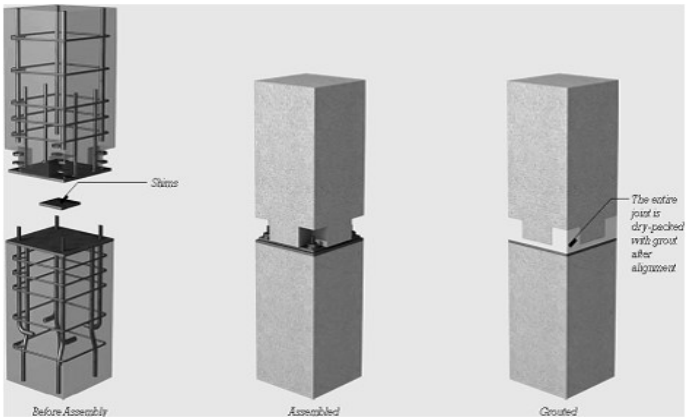
Source: Zhang et al. (2020)

Precast beam-column connections with steel connectors

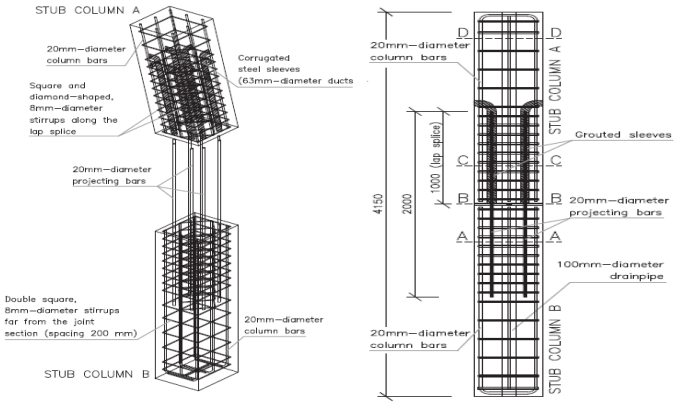
Precast column to column connections



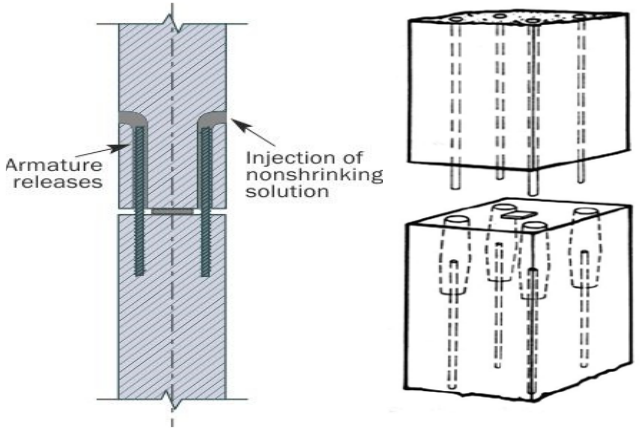
Precast column-column connection using box *Source: Zhang et al. (2020)*



Precast column-column connection using plates *Source: pinterest.com*

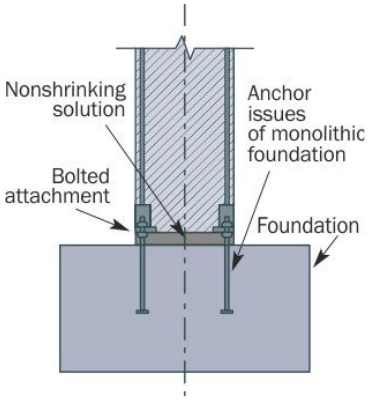


Precast column-column connection using grouted sleeves *Source: Tullini et al. (2016)*

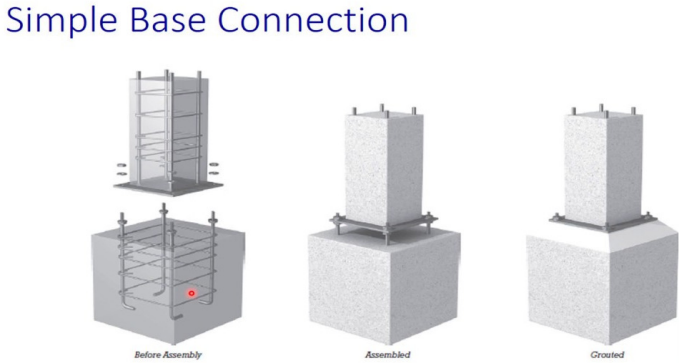


Precast column-column connection using grouted sleeves *Source: http://oberbeton.ua/en/project-department*

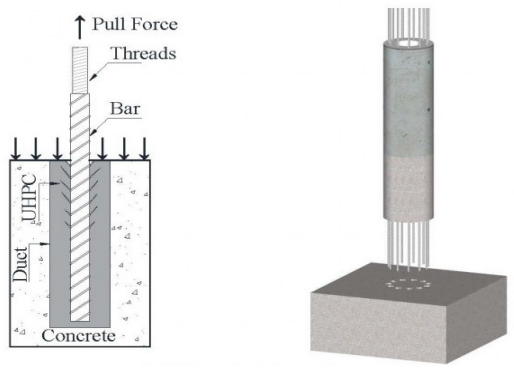
Precast column to Foundation connections



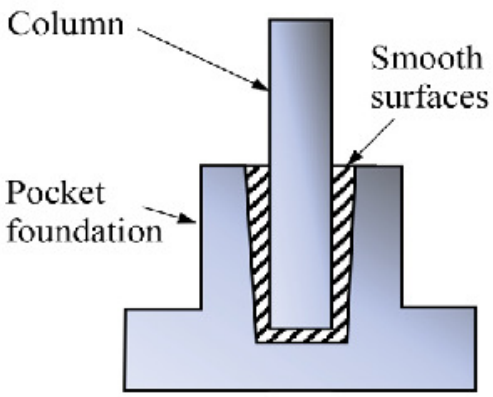
Source: www.pessi.in

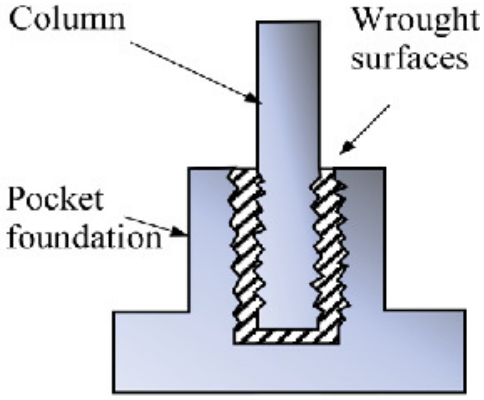


Source: JSP YouTube, 2017

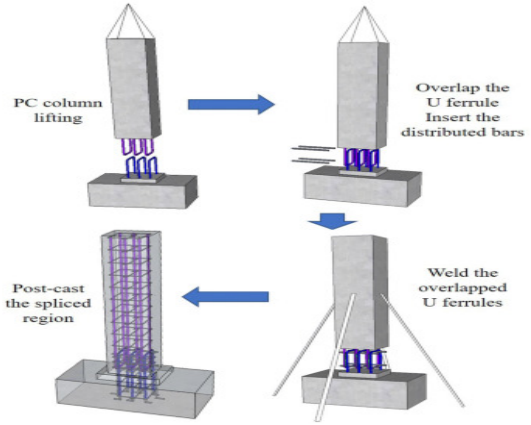


Source: Accelerated bridge construction, 2016





Source: Holly et al., 2020



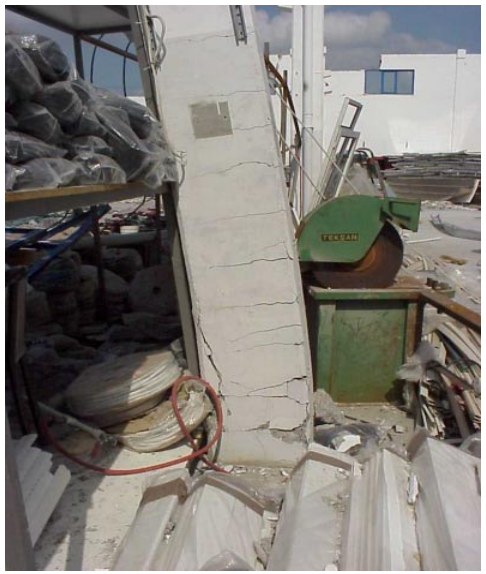
Source: Zhiwu et al., 2019

The 29th May 2012 Emilia Romagna Earthquake

Kocaeli (Turkey) Earthquake of Magnitude 7.4 - August 17, 1999

Large deformation of precast columns in the structure paved the possibility of formation of flexural hinging near the column base making it inefficient to dissipate energy causing the column to fail.

Source : Saatcioglu *et al.,* 2001



Bhuj Earthquake - January 26, 2001

Inadequate connection between the roof panels.

Insufficient seating and anchorage of roof panels over the walls and beam.

These inadequate property led to lack of floor-diaphragm action causing dislodgement of roof panels from the atop of the building.

The adjacent cast-in-situ RC building performed well during the earthquake describing the detrimental effect of connection role in seismic regions.

Source : EERI Special Earthquake Report – April 2001

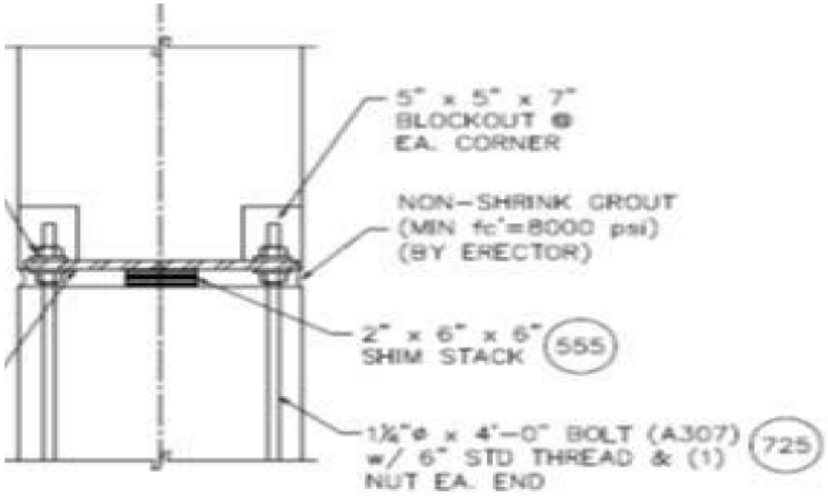
Investigation Of The February 14, 2011 Partial Collapse of a Precast Parking Structure Under Construction In San Antonio, TX

- Flawed construction of contractor to provide proper support for the precast column base plates due to a lack of grout underneath the base plates.
- Uneven displacement of the nuts caused the columns to tilt, resulting in the collapse.

Connection Failures

Investigation of The October 10, 2012 Parking Garage Collapse During Construction at Miami Dade College, Doral, FL6

- Poor grouting placed between the column and the footing.
- The increased load on the interior column exceeded the anchor bolts and shim plates capacity.
- When the interior column collapsed, a cascade effect was initiated that led to other columns, inverted tee beams, and double tees to collapse.
- Precast structural members were not adequately supported by welding and bracing (29 CFR 1926.704(a)). These deficiencies added to the structural instability.



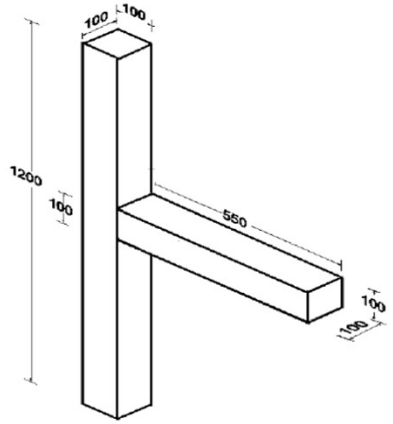
Improper Grouting

Structural Integrity

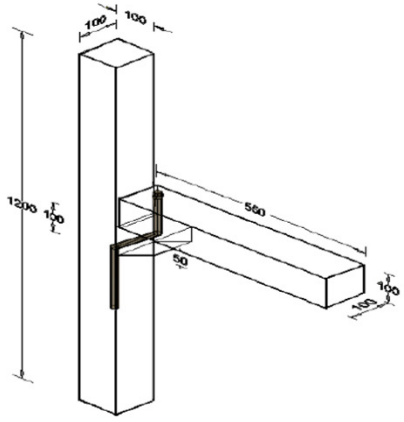
This is the ability of a structure to offer unceasing stress paths to transfer the design forces and to provide better resistance to the seismic force without sudden collapse. The integrity of a structure not only resists the force also ensure proper ductility and better energy dissipation.

Importance of structural Integrity in precast elements

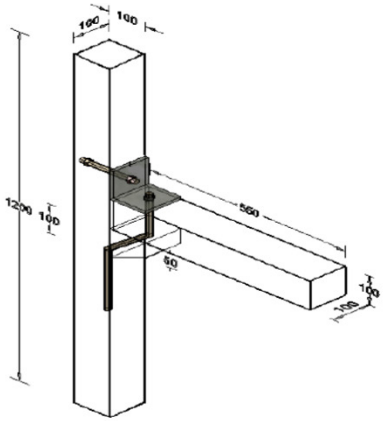
Vidjeapriya et al. (2012) studied the performance of pre-cast beam-column joints with dowel connections under cyclic loading.



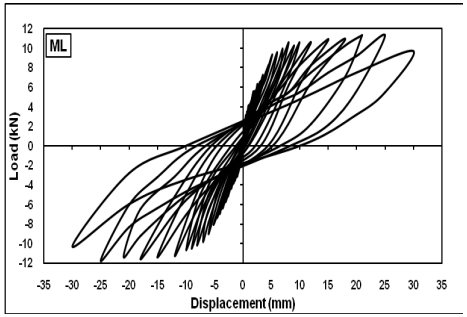
a)Specimen ML

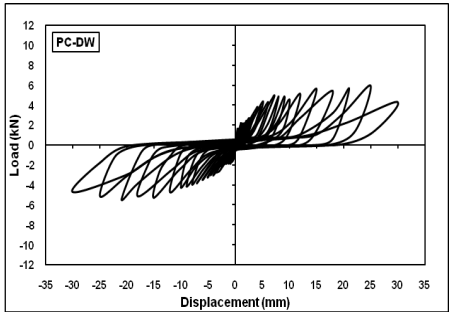


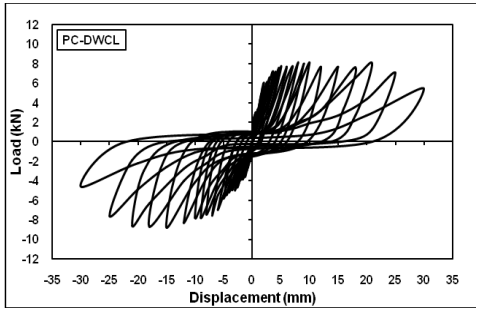
b)Specimen PC-DW



c)Specimen PC-DWCL

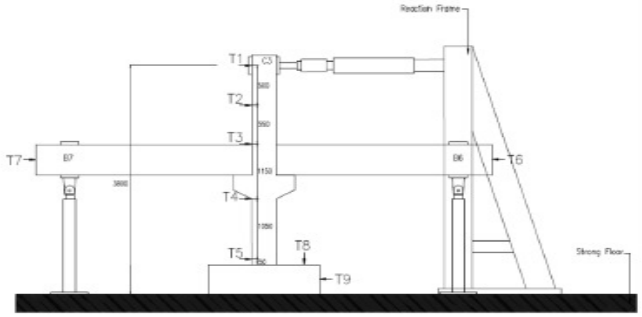


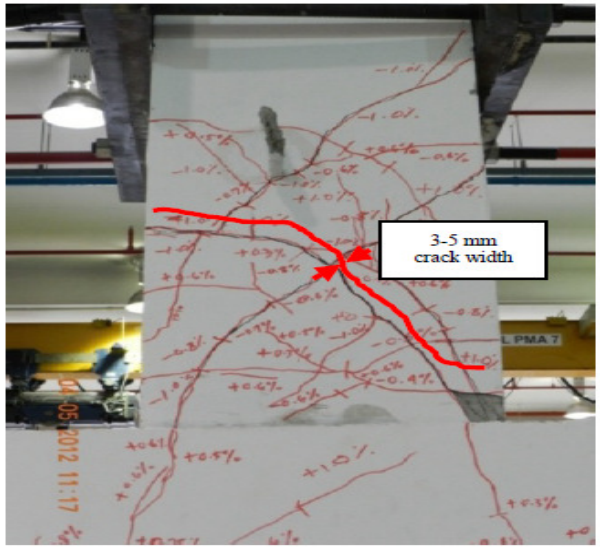


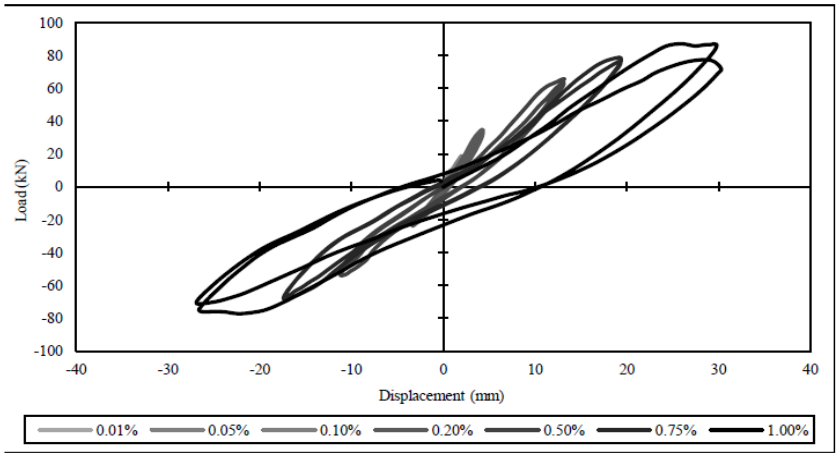


Precast beam column joints with dowel connections

Ghani et al. (2013) examined the interior beam column joint with corbel mechanism under cyclic loading.

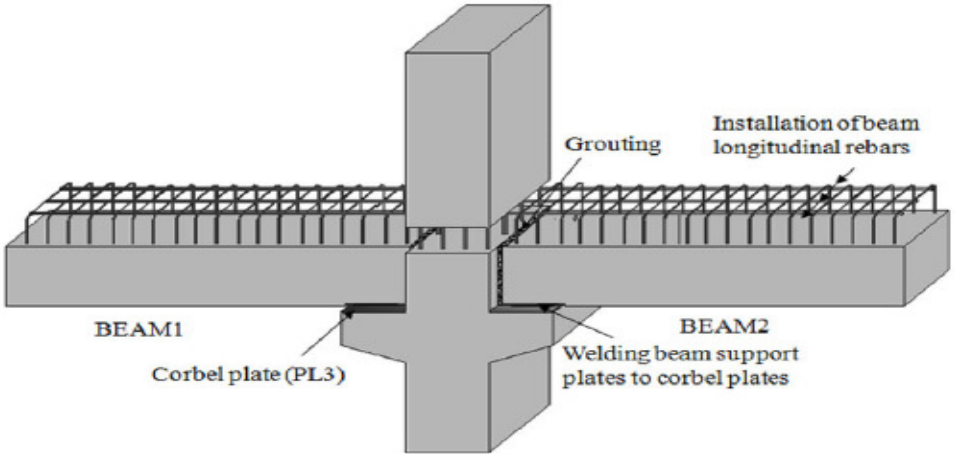






Test Setup and Hysteretic Loop

- **Sadik et al (2017) investigated the behavior of precast hybrid (emulative-welded) beam-column connections with welded components under cyclic loading.**
- **Strength, stiffness and energy dissipation capacities of test specimens were investigated with respect to welding coefficient and unbonded length of rebar connected with the plate as the main test variables.**



Precast joint with emulative-welding technique

(a)

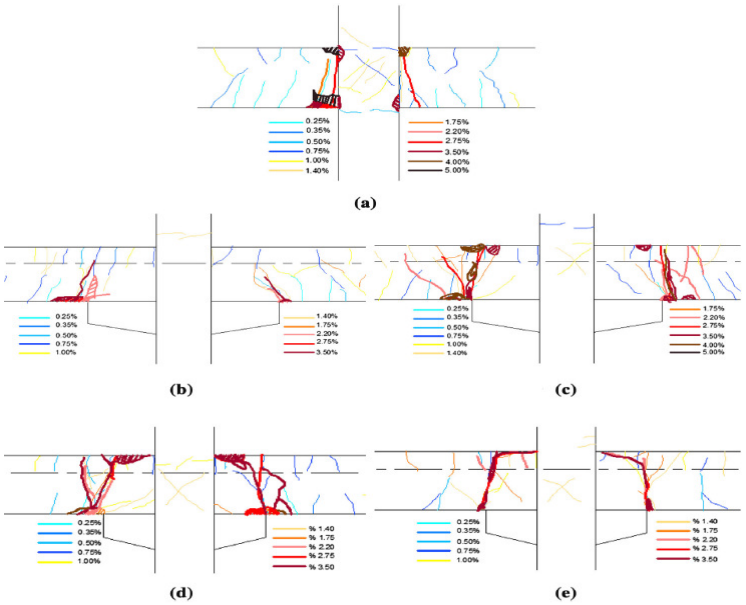
(b)

Emulative-welding technique

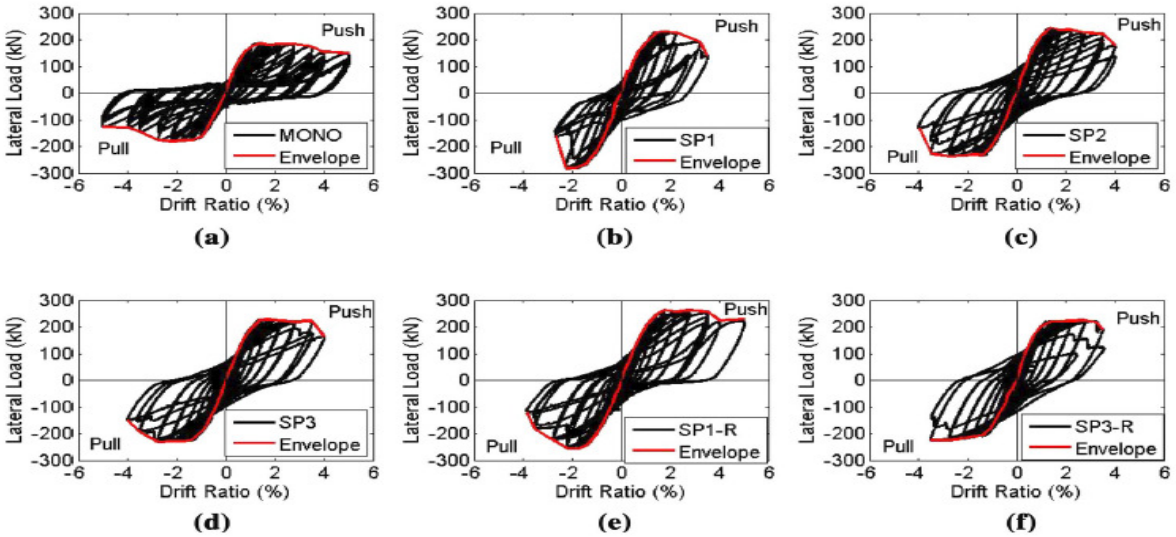
(c)

(d)

Source: Sadik et al (2017)



Crack patterns of specimens

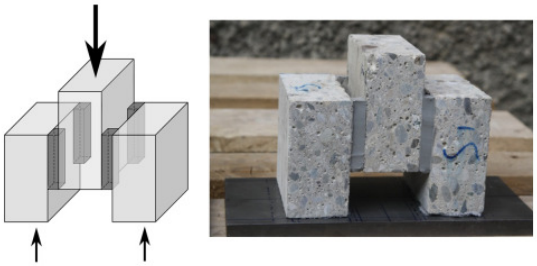


Hysteresis behavior

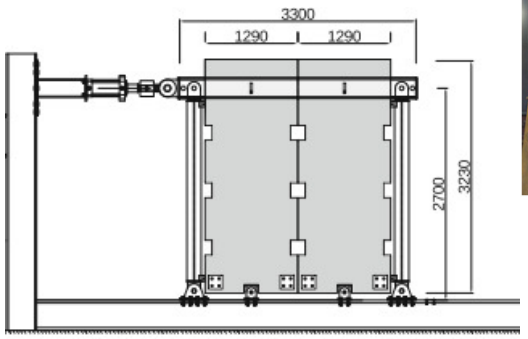
- **The specimen's unbounded length showed higher ductility than the monolithic specimen, but showed severe pinching due to shear failures.**

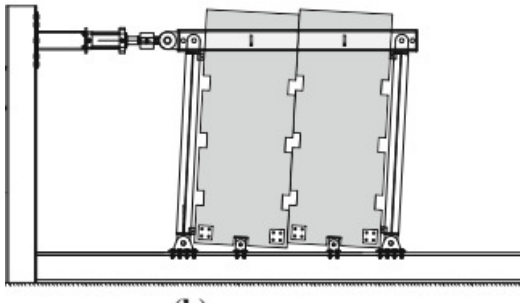
- **The specimens with higher unbounded lengths showed an improved seismic behavior and the additional ties to prevent early buckling of longitudinal bars .**

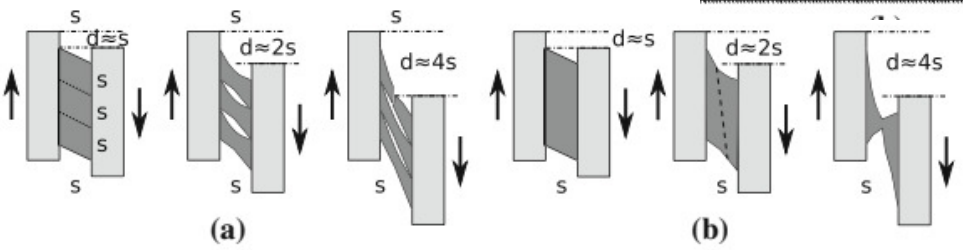
Dal Lago et al (2017); silicone sealant placed in between cladding panels of precast frame structures can influence the seismic performance at the serviceability limit state and increase the load demand on the panel connections.

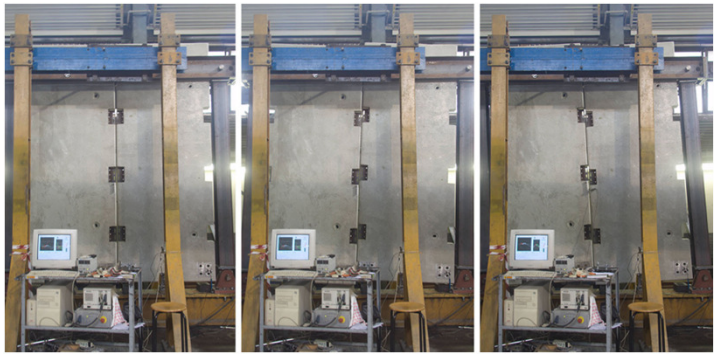


Monotonic testing on assembled specimen

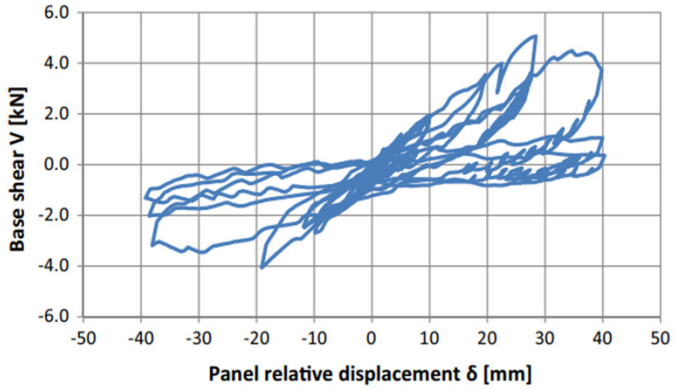






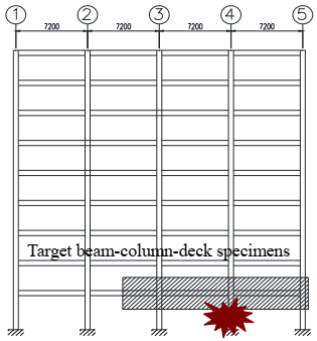


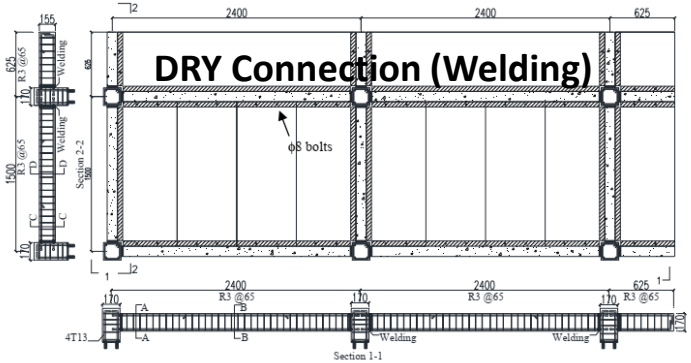
Cyclic testing on assembled panels at different drift ratios



Hysteresis behavior

Kai Qian[1]; Bing Li[2]; and Yi Liu[3] 2016





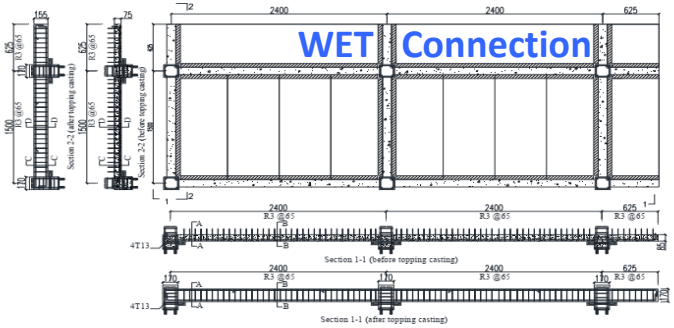
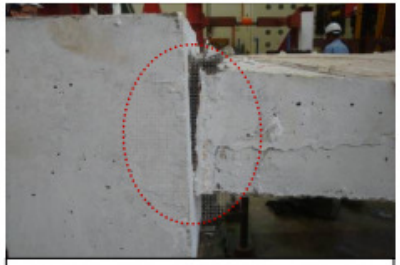
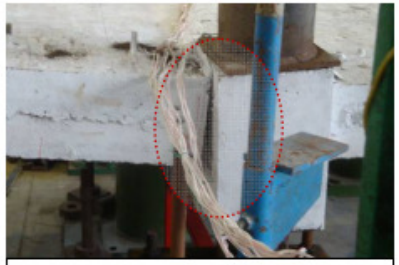


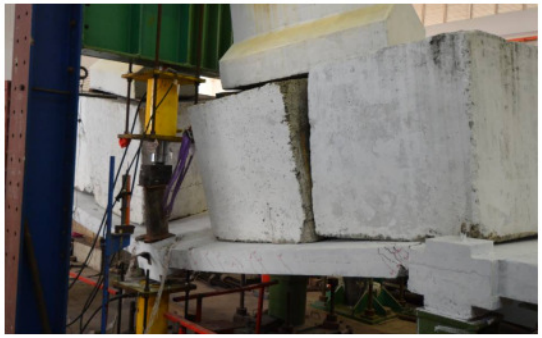
Fig. 9: Failure mode of Specimen PC1

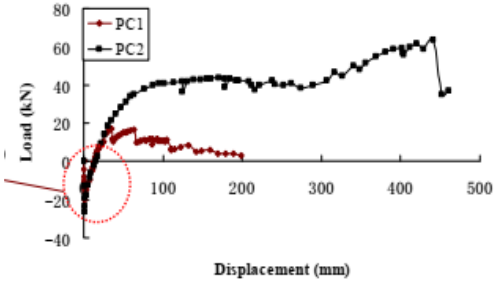


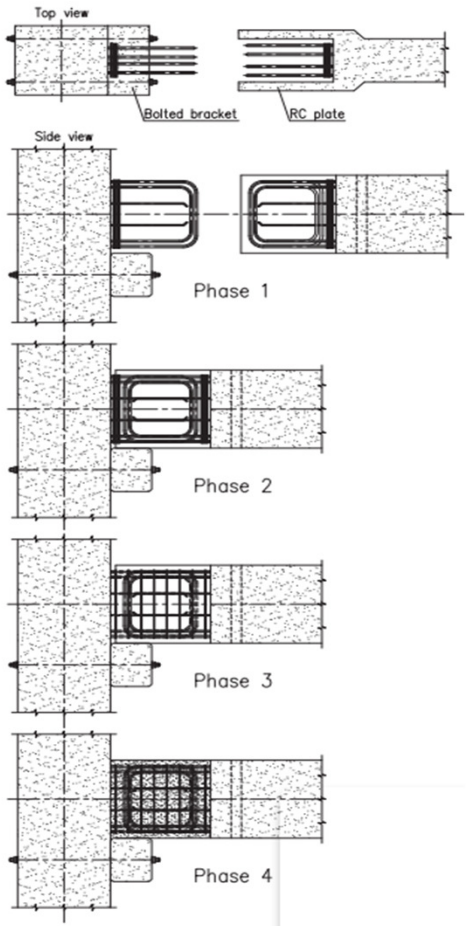
Welding Broken between Headed Stud Steel Anchor and Steel Plate

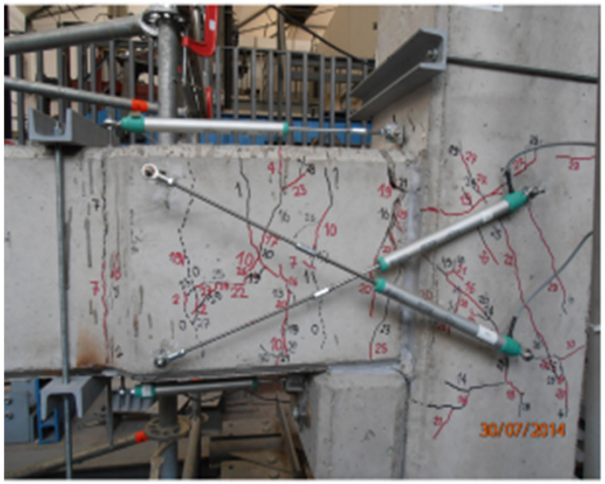


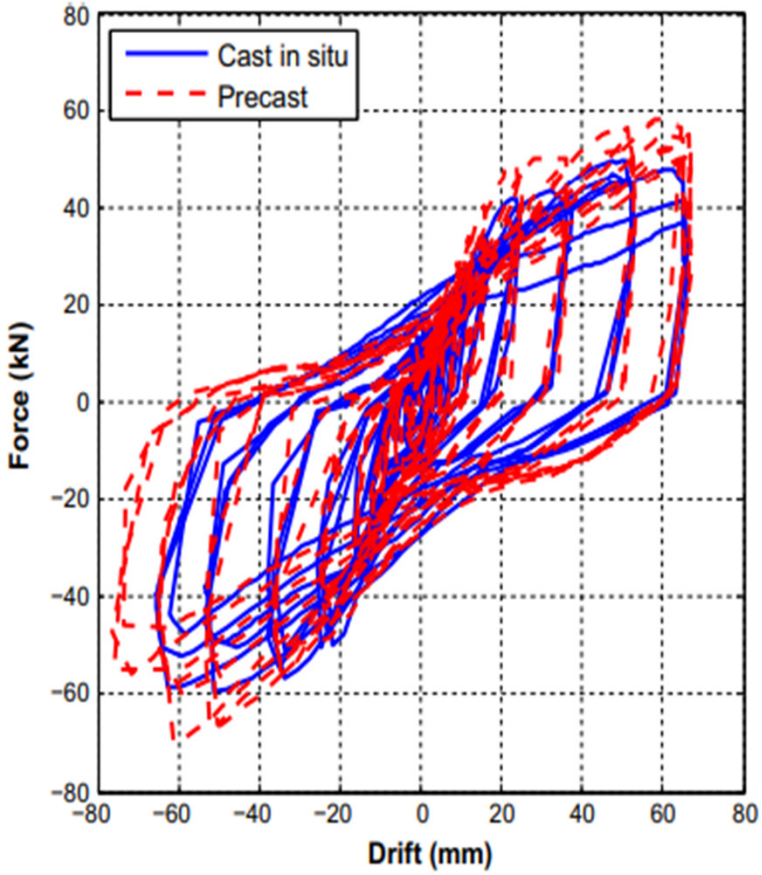
Welding Broken between Headed Stud Steel Anchor and Steel Plate



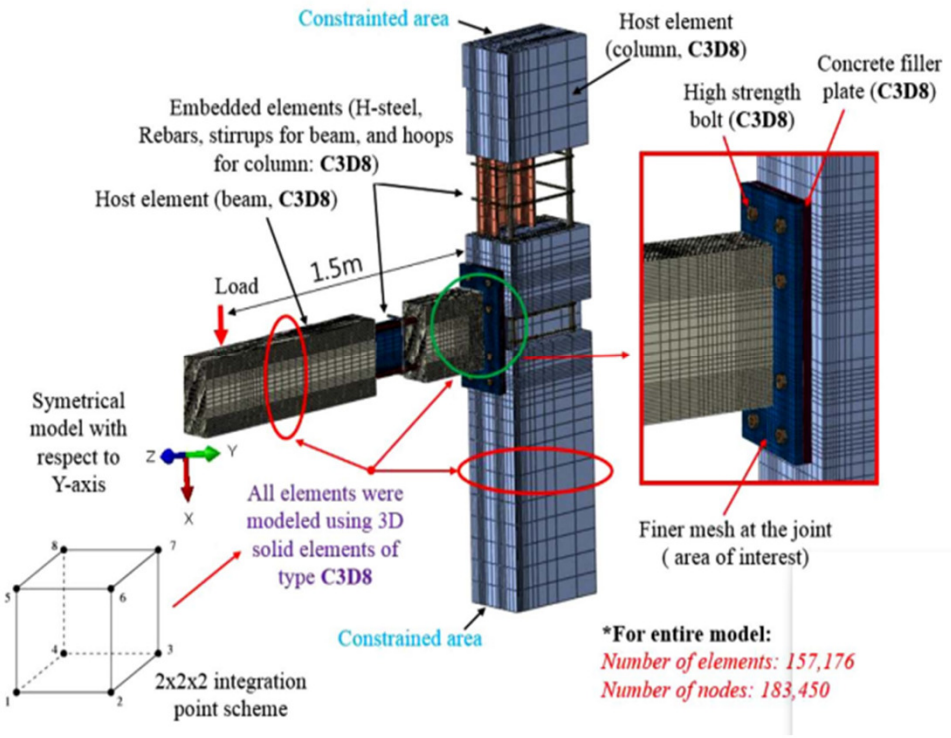


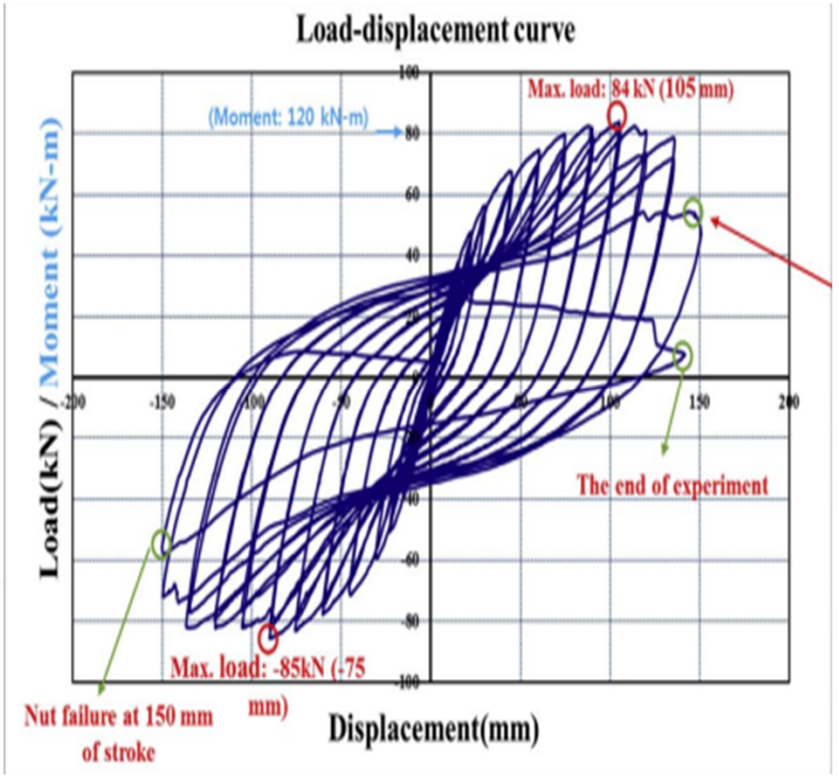




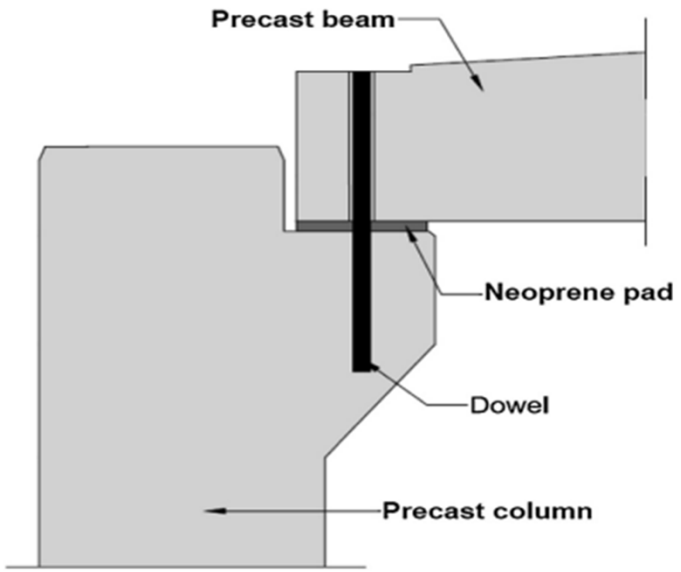


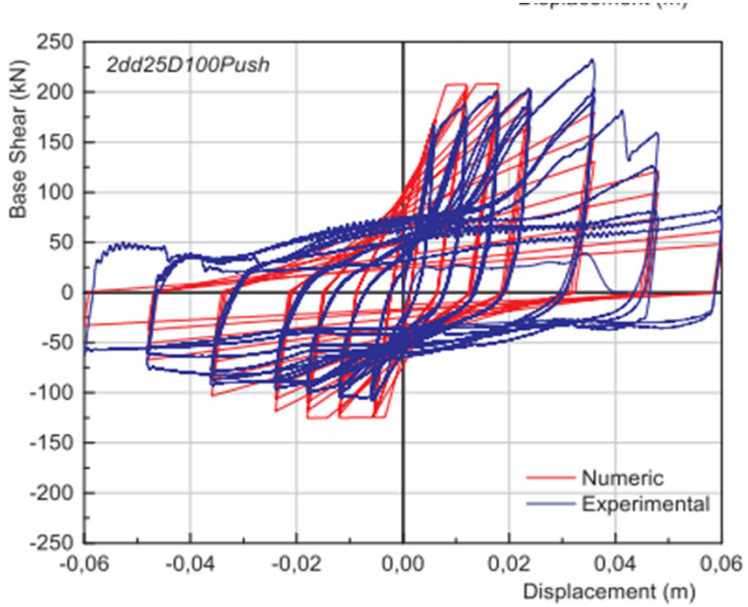
M. Breccolotti et al. (2016) proposed a wet joint Beam-Column connection in which the experimental results confirmed its good structural performances in terms of strength and ductility.

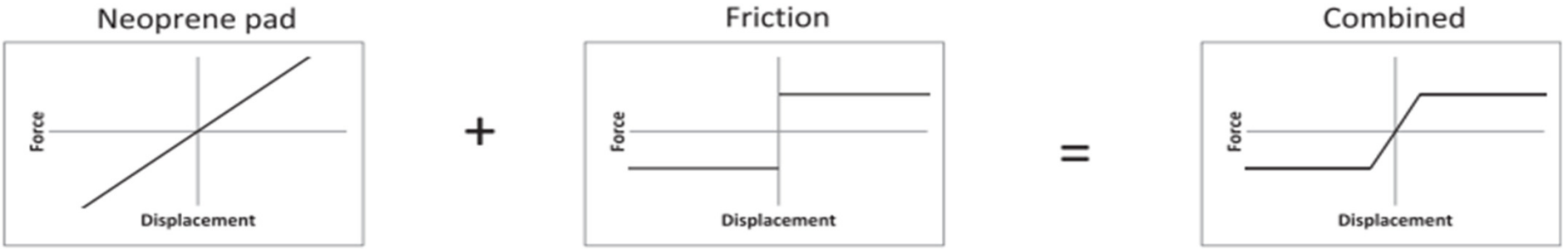




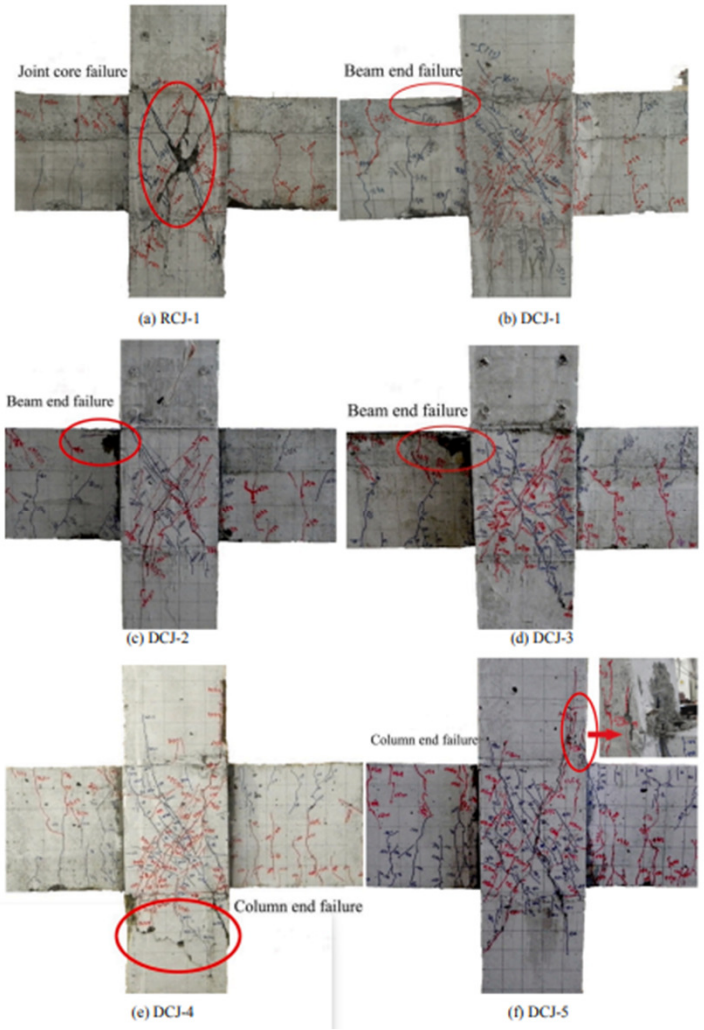
J.D. Nzabonimpa et al. (2018) showed that the steel-concrete precast beam-column joints with concrete filler plates offered sufficient structural capability in transferring loadings from beams to columns.

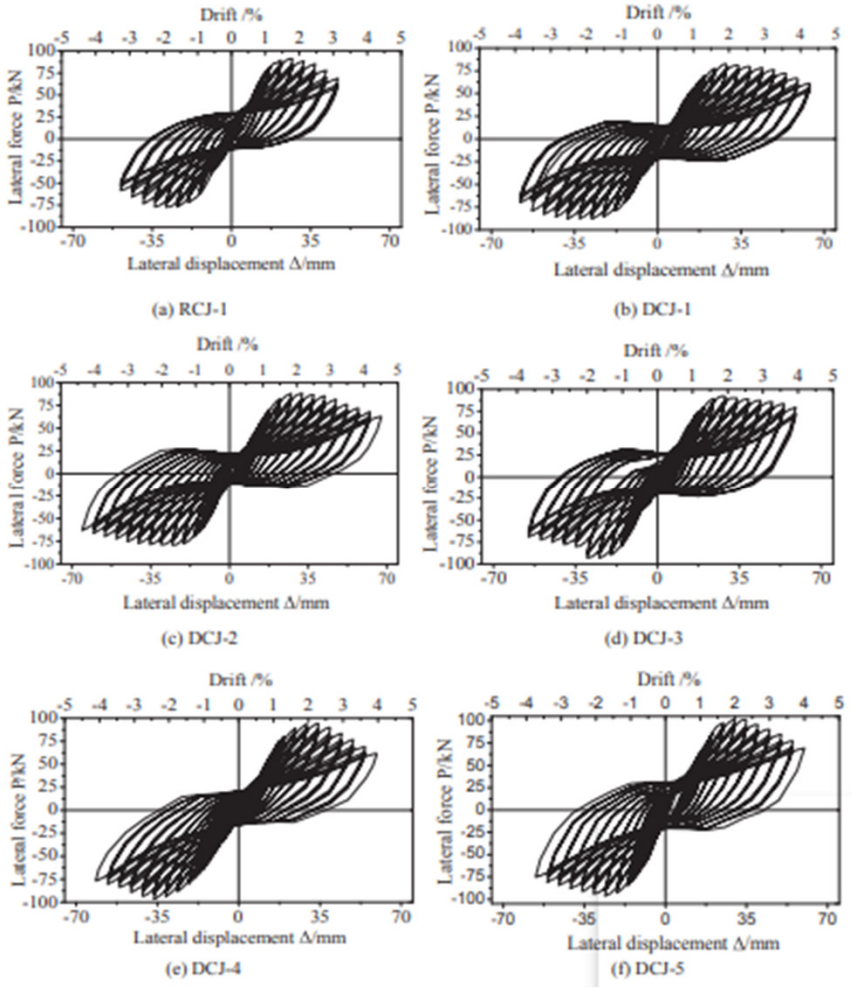






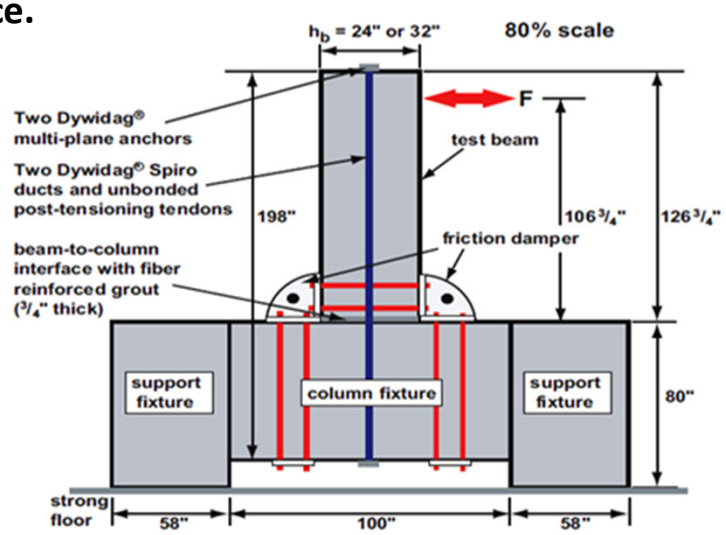
R. Sousa, et al.(2020) highlights the important contribution of the dowels for the total lateral strength, as well as the need to incorporate the friction component in order to obtain a reliable estimate of the energy dissipation of a connection system .

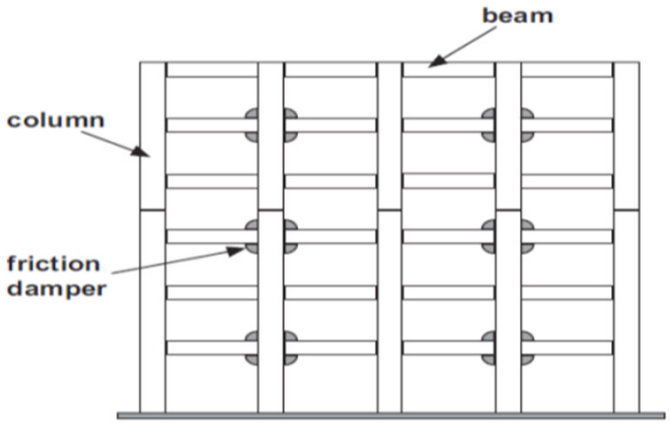


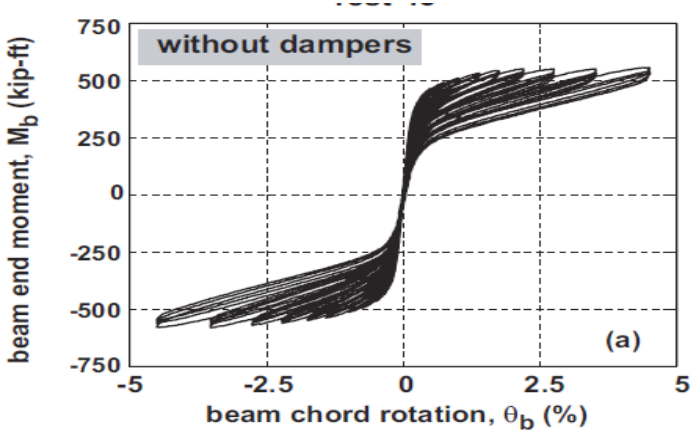


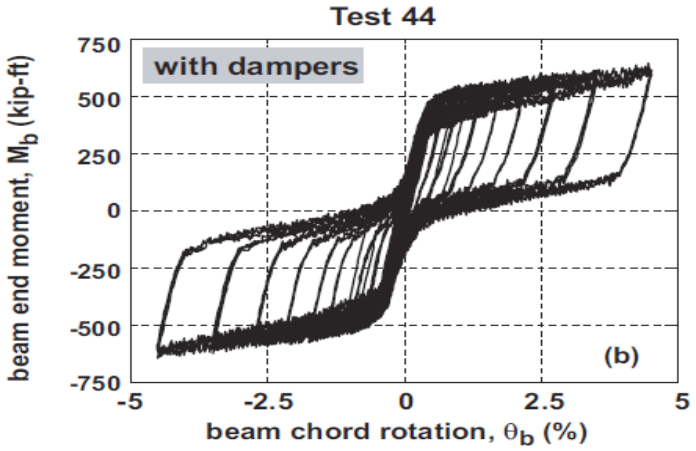
M. Deng, et al. (2020) finds that the application of HDC in joints significantly enhances the shear capacity and damage-tolerance capacity of joints and changes the joint shear failure to beam end failure.

Brian et al. (2004) developed a friction damper for post-tensioned precast concrete beam-to-column joints. This dampers are placed at the connection region through which the energy dissipation during earthquake will take place.

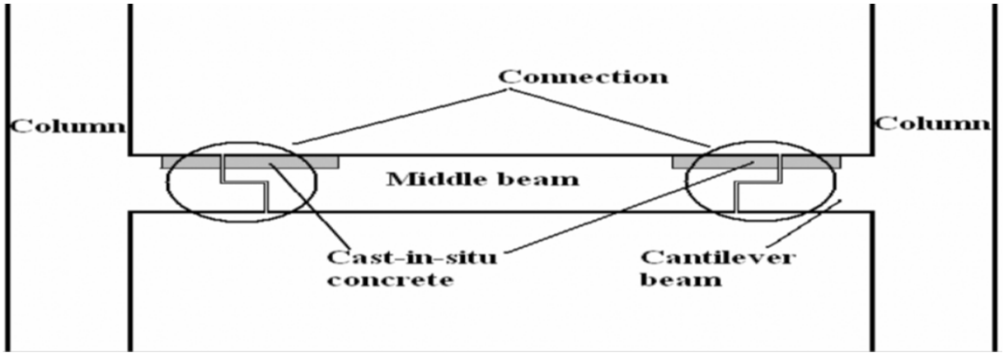


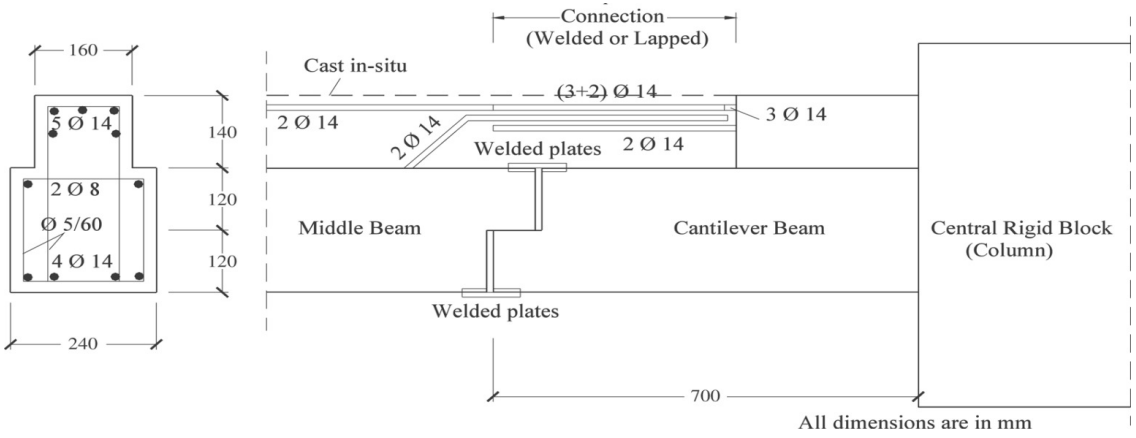


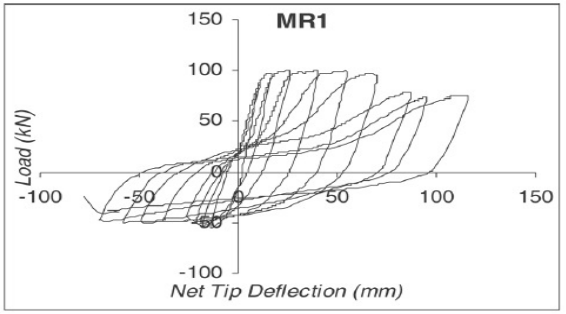


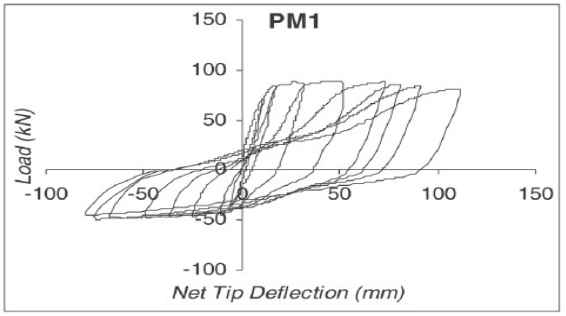


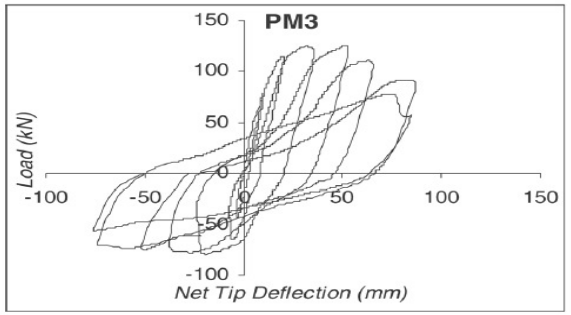
Hasan et al.(2005) did investigation on the cyclic performance of precast concrete beam-to-beam connection by use of conventional and welding techniques and did comparisons with a monolithically cast specimen.







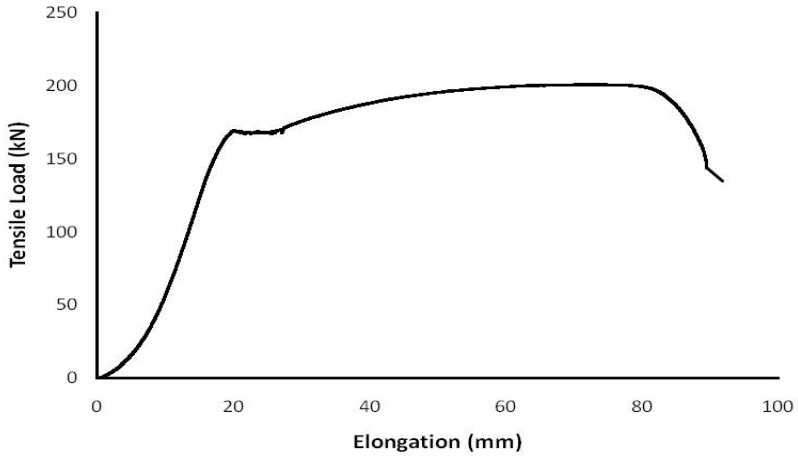




Precast Column – Foundation Connection Study at CSIR-CBRI Roorkee

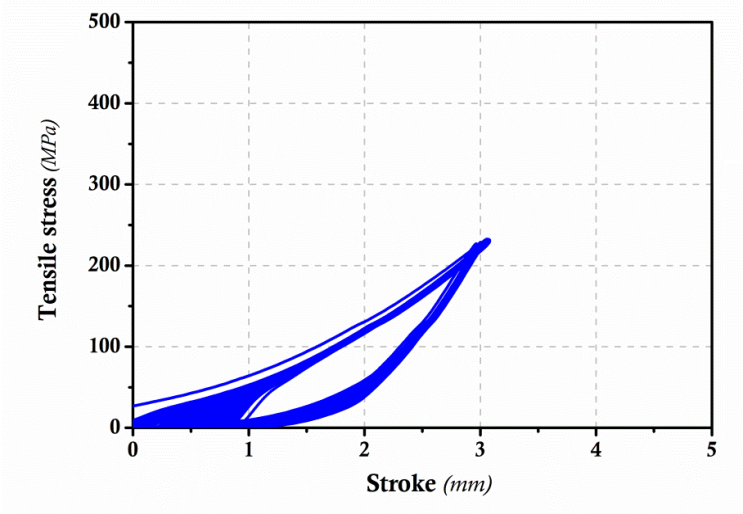
COUPLER FOR CONNECTION

- Rebar Coupler is the primary source to connect the adjacent rebars. In particular this connection is proposed in the hinge region. Hence this has to connect the rebars and able to dissipate energy under cyclic loading.
- Hybrid rebar coupler for various diameter bars have been fabricated and tested under tension to estimate the connection tensile strength and failure behavior.
- Based on the test results, modifications in the couplers have been made and second stage specimens have been prepared.

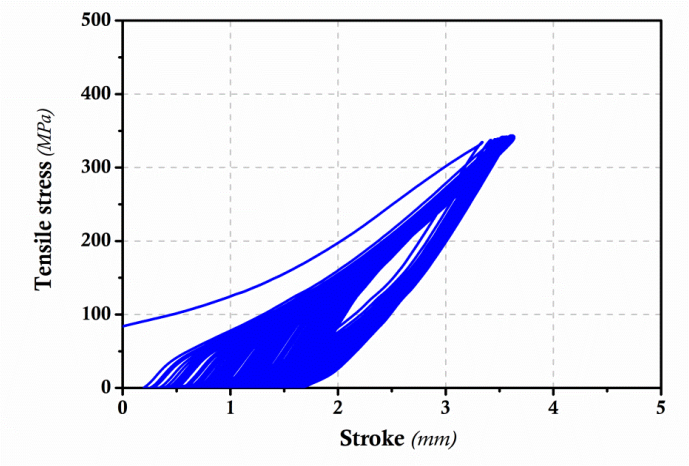


Tensile Behavior of Rebar with Coupler (20 mm dia.)

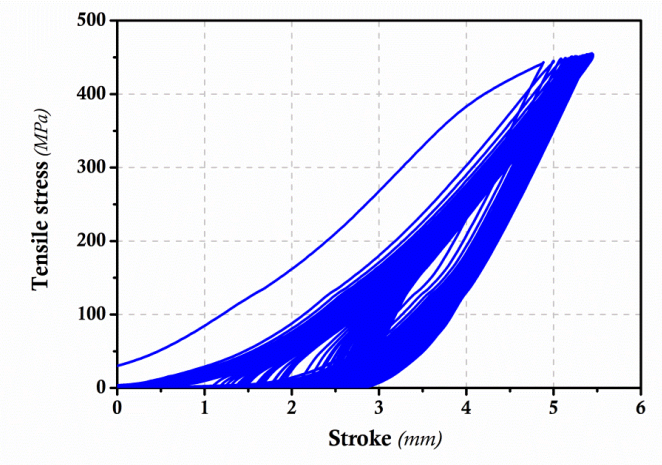
Cyclic (100 Cycles) Tension @ 0.4 f_y, 0.6 f_y and 0.8 f_y



S-S 0.4 f_y

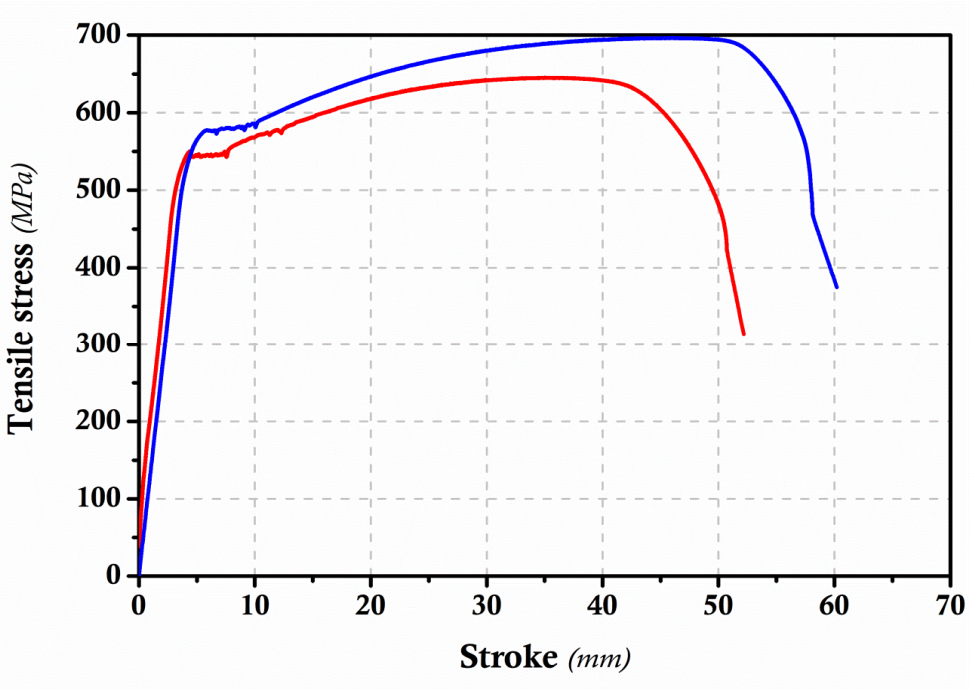


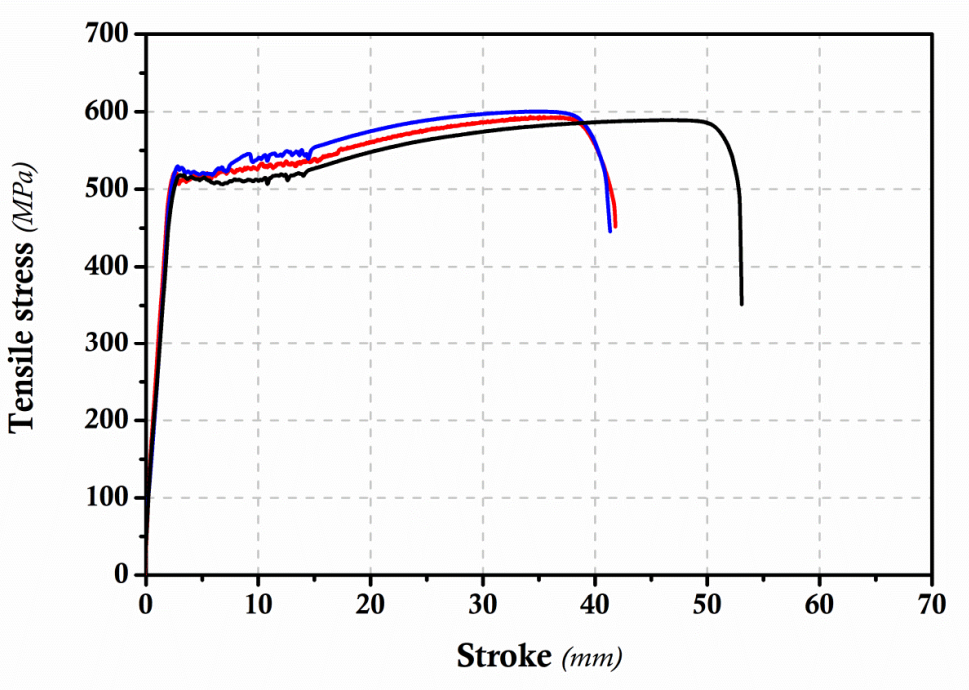
S-S 0.6 f_y



S-S 0.8 f_y

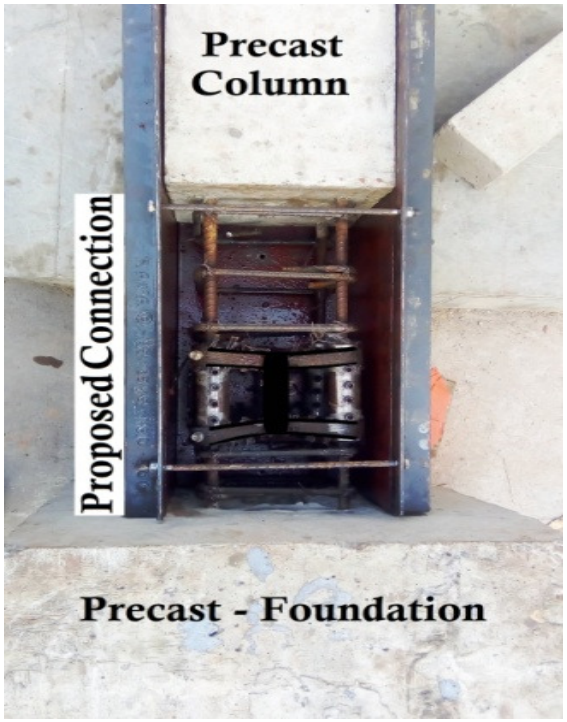
Tensile Behavior of Rebar with Coupler



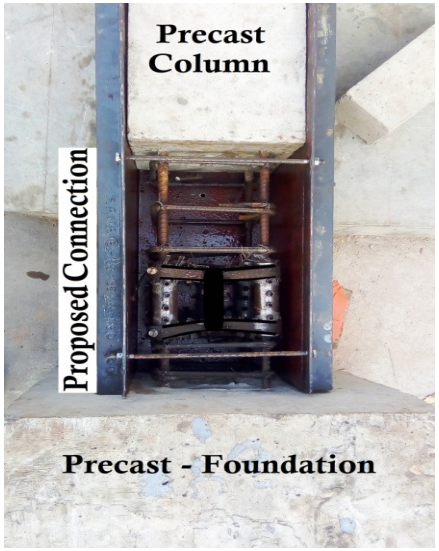


PRECAST COLUMN WITH HOLLOW CORE PROVISION

PRECAST COLUMN WITH HOLLOW CORE PROVISION



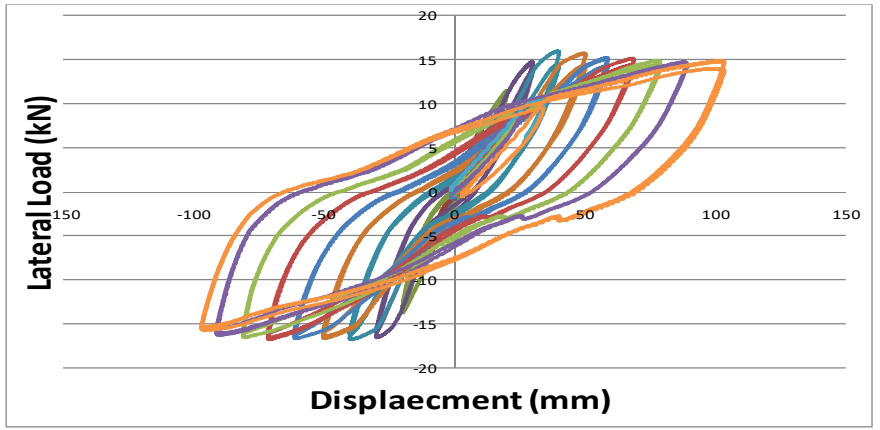
PRECAST COLUMN to FOUNDATION CONNECTION WITH THE DEVELOPED HYBRID COUPLER UNDER CYCLIC LOADING



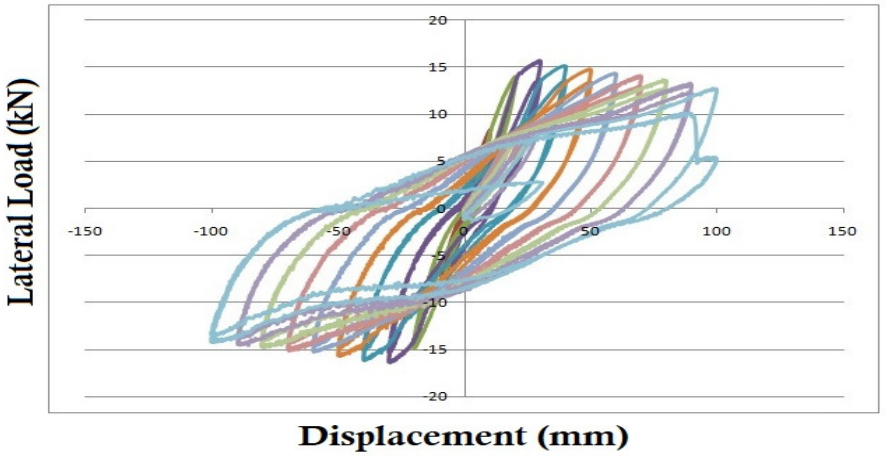
Coupler Connection (12mm dia.)

Cyclic Test Setup

Cracks at the Hinge



Hysteresis Curve




Typical Precast Moment Resistant Frame Model Structure

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Thank You