

1 **Out-of-Plane Behavior of Foundation Inserts of Precast Panels:**
2 **Alternative Connections**

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4 **Abstract:**

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7 **1 INTRODUCTION**

9 **2 TEST DESCRIPTION**

10 **2.1 Alternative Connection Development**

- 11 • Discussion with precast industry, design consultants, and proprietary connection
12 manufacturers

13 **2.2 Test Panel Description**

14 **Table 1: Test panel reinforcement details**

Panel Name	Vert. Reinf		Connection Description	Cover	Insert
	Vert Reinf	Spacing (mm)		behind insert (mm)	
BLT12-C0	HD12	270	Bolted through	0	2
TI12-C0	HD12	270	Threaded insert w/ 0 mm cover	0	2
TI12-C15	HD12	270	Threaded insert w/ 15 mm cover	15	2
TI12-C15-340ST-V135	HD12	135	340 mm headed stud in joint	15	2
TI12-C15-540ST	HD12	270	540 mm headed stud in joint	5	2

TI12-C15-LB-V135	HD12	135	Threaded insert w/ D10 link bar	15	2
TI12-C15-STRP	HD12	270	Threaded insert confined with stirrup at joint	15	2
TI12-C15-STRP-V135	HD12	135	Threaded insert confined with stirrup at joint	15	2
SL12-C50	HD12	270	Single “L” bar	50	1
STI12-C15	HD12	270	Single threaded insert layer w/15 mm cover	15	1
STI12-C15-NA	HD12	270	Single threaded insert layer w/15 mm cover, inserts not aligned w/vert. reinforcement	15	1
STI12-C15-340ST-V135	HD12	135	Single threaded insert layer w/ 340 mm headed stud	15	1
STI12-C15-340ST	HD12	270	Single threaded insert layer w/ 340 mm headed stud	15	1
STI12-C15-540ST	HD12	270	Single threaded insert layer w/ 540 mm headed stud	15	1

^a TI = Threaded Insert

^b All foundation heights are 450 mm tall

^c All connections are made with 4 starter-bars per layer

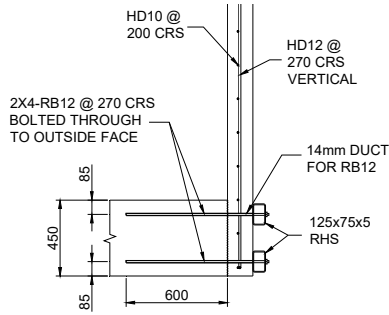
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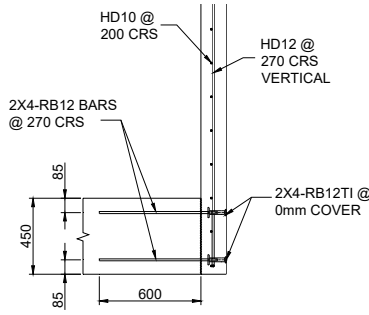
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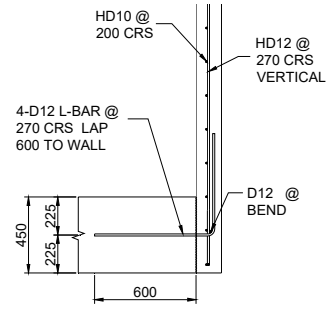
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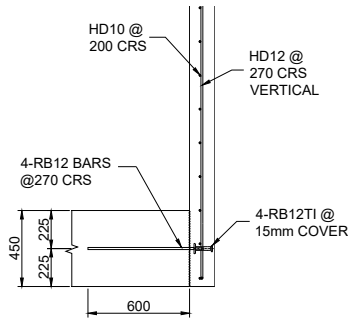
Panel BLT12-C0



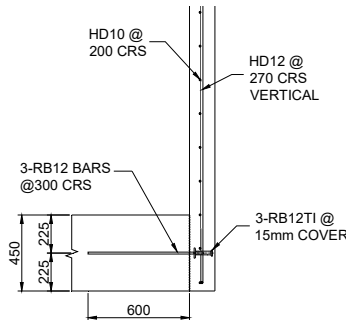
Panel TI12-C0



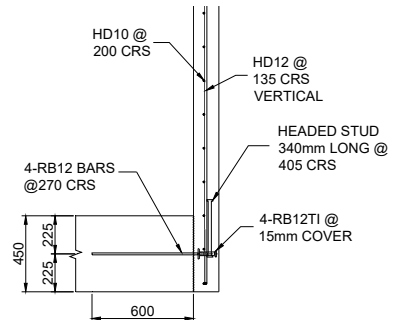
Panel SL12-C50



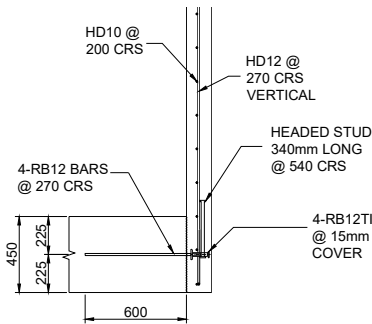
Panel STI12-C15



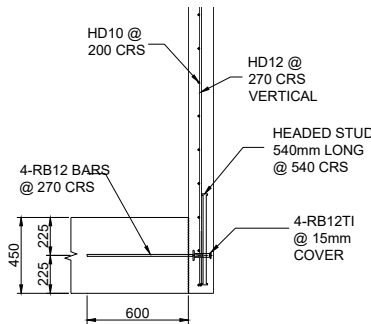
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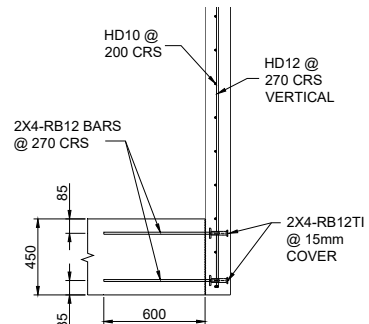
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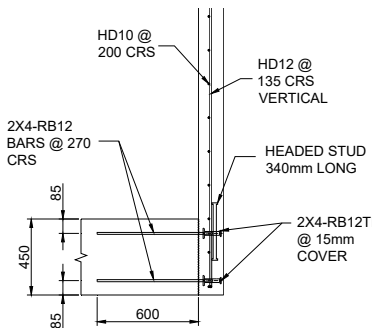
Panel STI12-C15-340ST



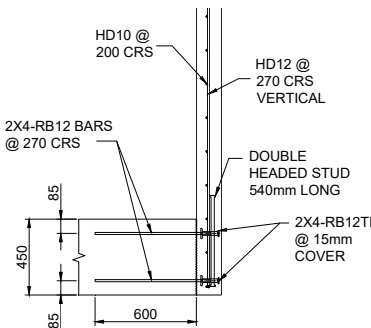
Panel STI12-C15-540ST



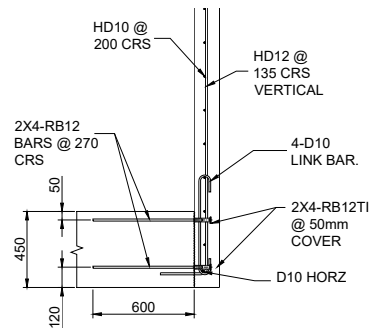
Panel TI12-C15



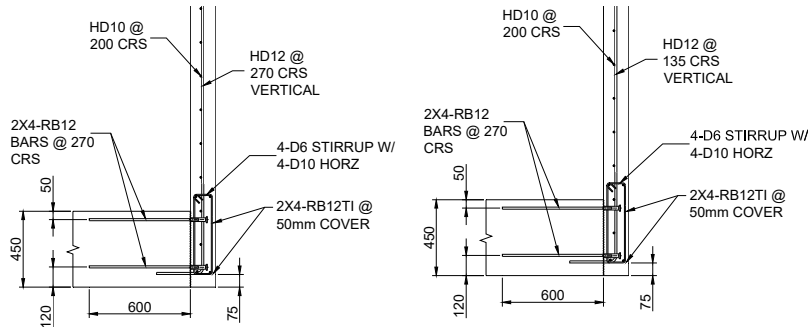
Panel TI12-C15-340ST-V135



Panel TI12-C15-540ST



Panel TI12-C15-LB-V135



Panel TI12-C15-STRP

Panel TI12-C15-STRP-V135

Figure 1: Details of foundation connections tested

2.3 Testing Procedure

- Refer to companion paper for protocol and instrumentation

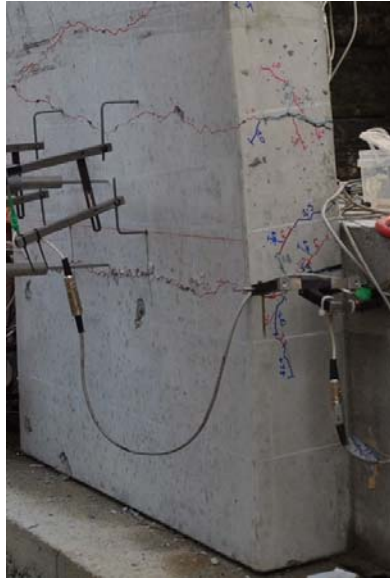
3 TEST RESULTS

- Described in this section are the test results of improved connections
- Data interpretation (i.e. moment-rotation response is the same as the companion paper
- Connection performance is compared to existing connection performance
- Comparisons made for
 - Details with increased embedment depth
 - Strengthening the joint to force damage in the panel
 - Confining the joint
 - Using only a single layer of starter bars to allow for

3.1.1 Details with increased embedment depth 12 mm Starter Bars



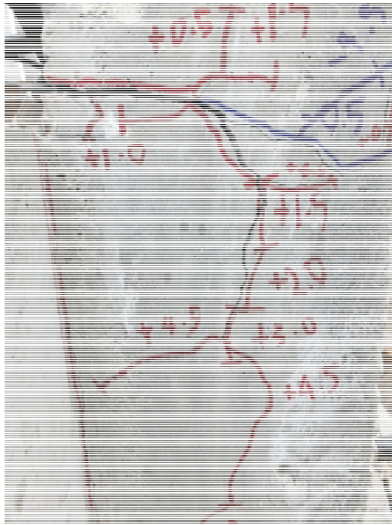
TI12-C0



TI12-C15



BLT12-C0



TI12-C50



TI12-C42

Figure 2: Damage to specimens with increased insert embedment depth compared to existing connections at maximum joint-opening drift

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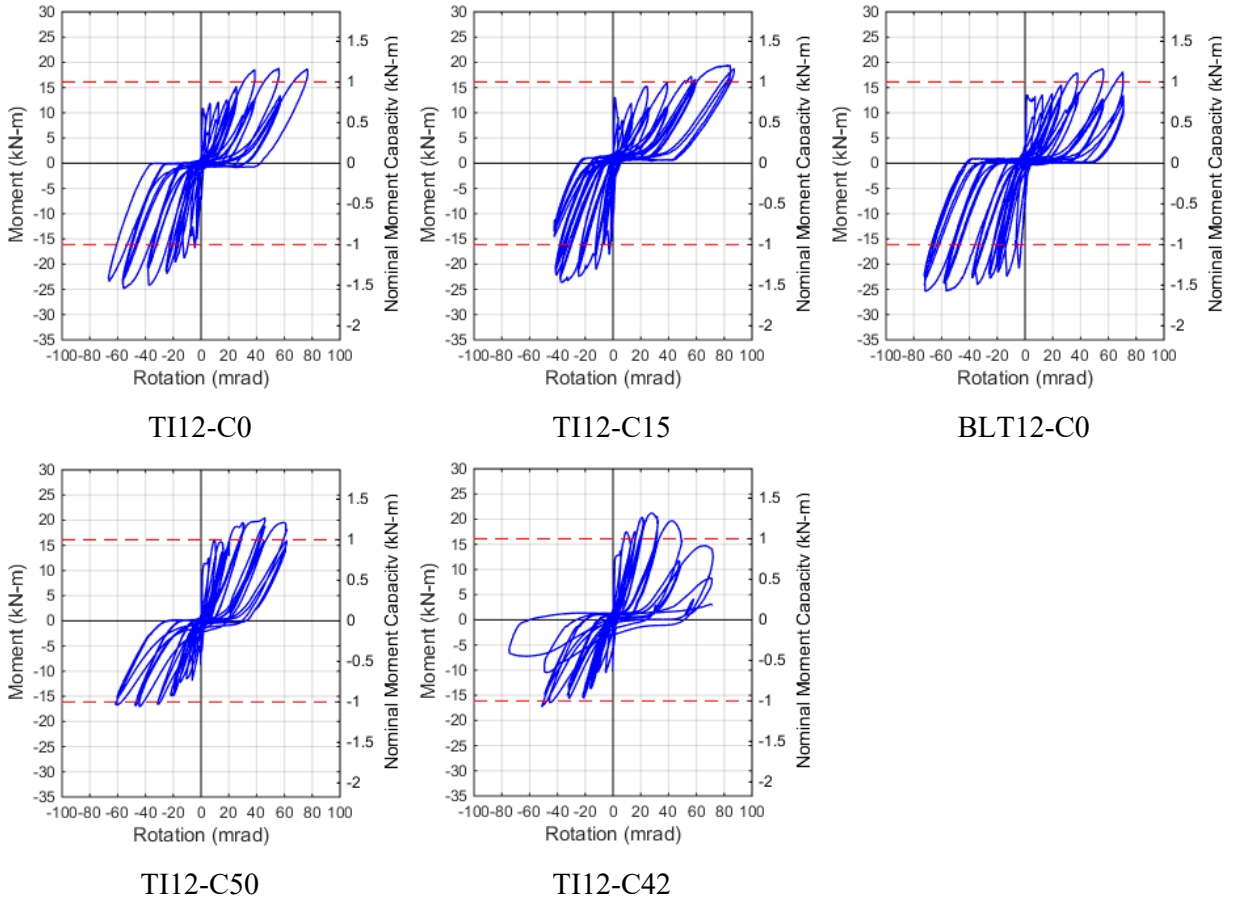
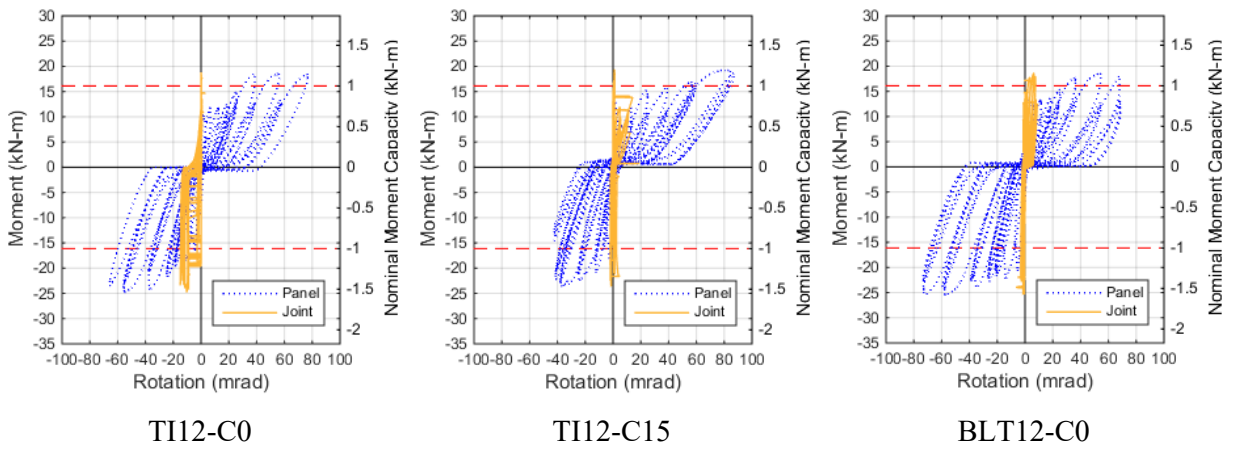
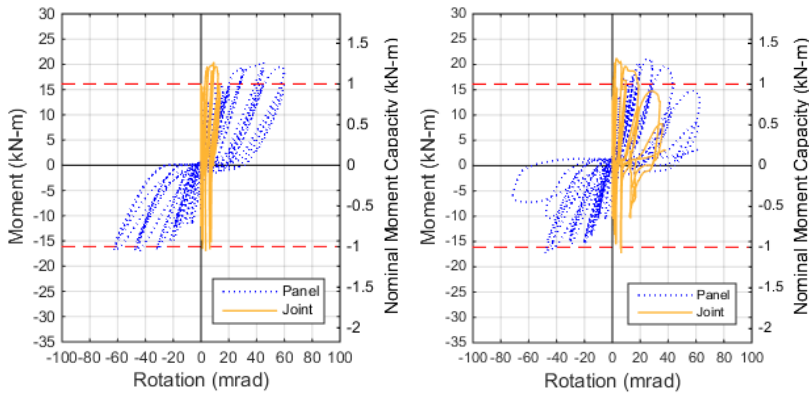


Figure 3: Global moment-rotation behavior of panels with increased insert embedment depth compared to existing connections. Positive values of moment and rotation correspond to joint-opening behavior.

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TI12-C50

TI12-C42

Figure 4: Joint vs panel moment-rotation behavior of panels with increased insert embedment depth compared to existing connections. Positive values of moment and rotation correspond to joint-opening behavior.

3.1.2 Details with strengthened joint



TI12-C15-340ST-V135



TI12-C15-540ST



TI12-C15-LB-V135

Figure 5: Damage to specimens with strengthened joints compared to existing connections at maximum joint-opening drift

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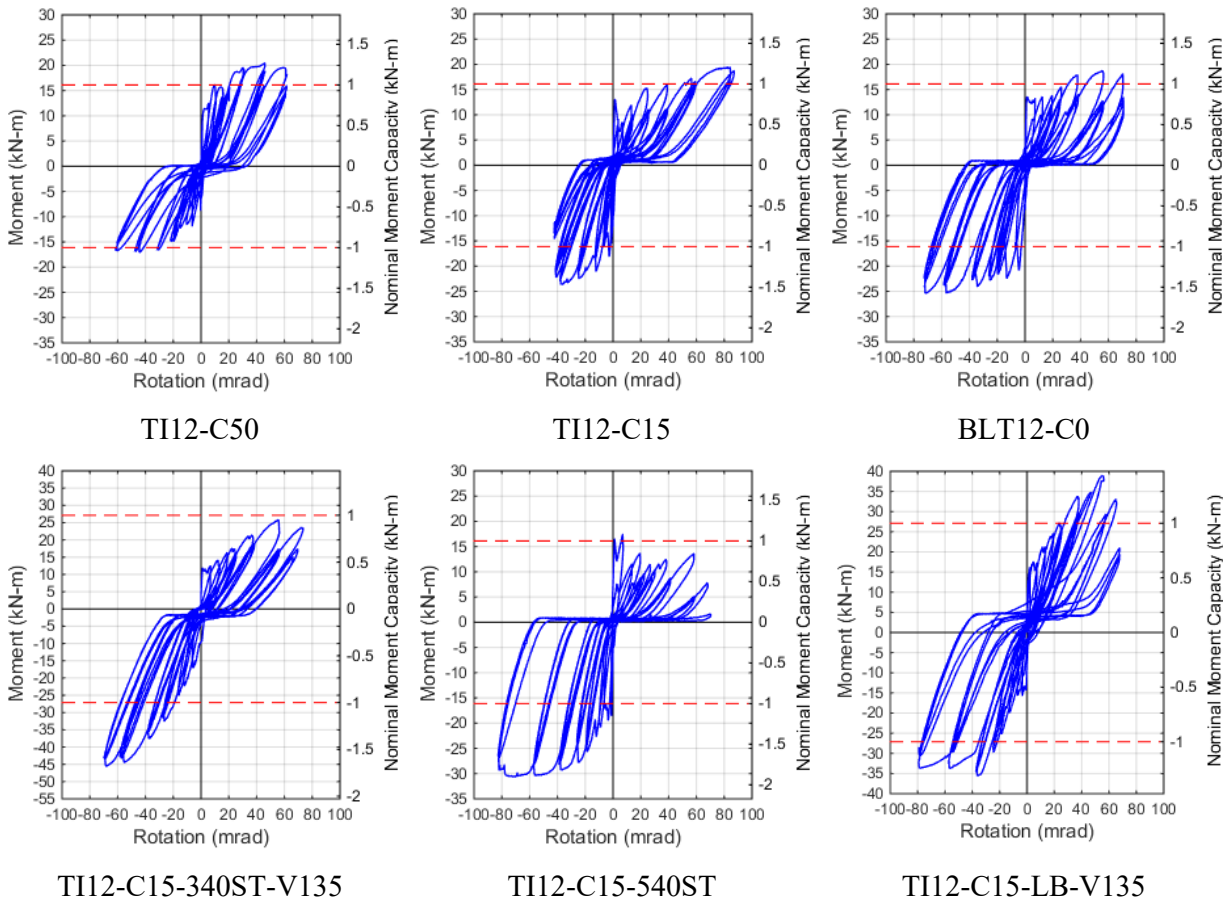


Figure 6: Global moment-rotation behavior of panels with strengthened joints compared to existing connections. Positive values of moment and rotation correspond to joint-opening behavior.

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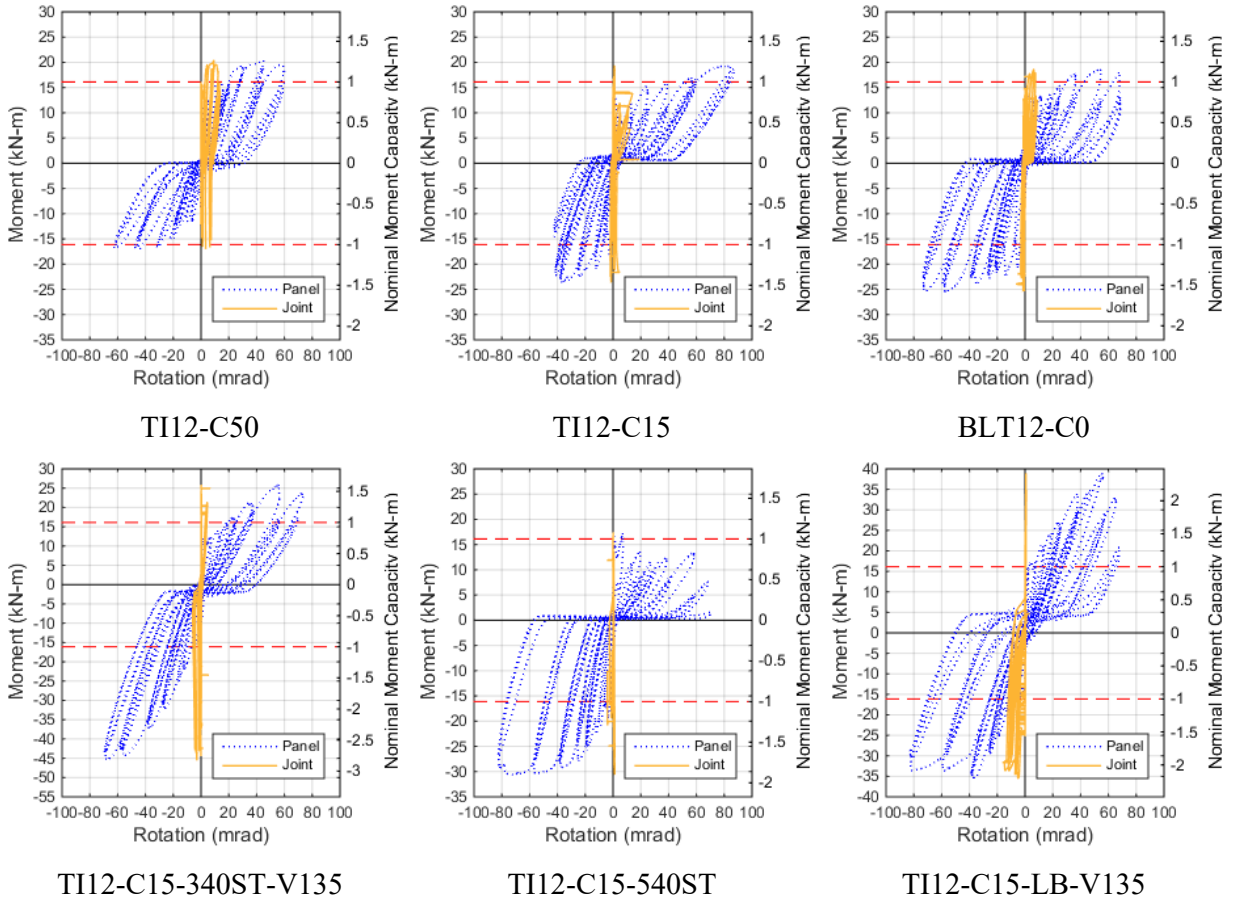


Figure 7: Joint vs panel moment-rotation behavior of panels with strengthened joints compared to existing connections. Positive values of moment and rotation correspond to joint-opening behavior.



TI12-C15-STR



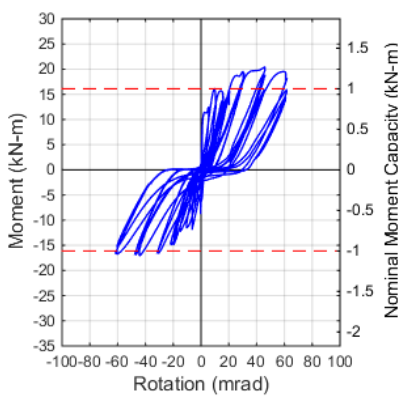
TI12-C15-STRP-V135

Figure 8: Damage to specimens with confined joints compared to existing connections at maximum joint-opening drift

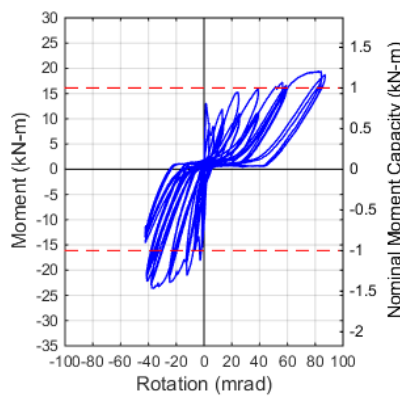
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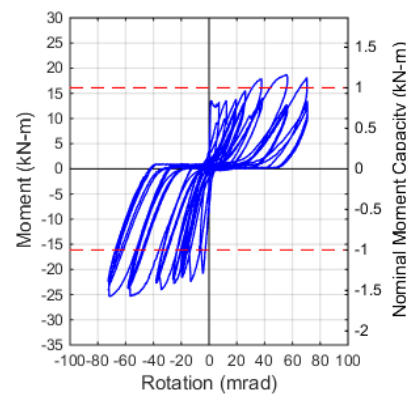
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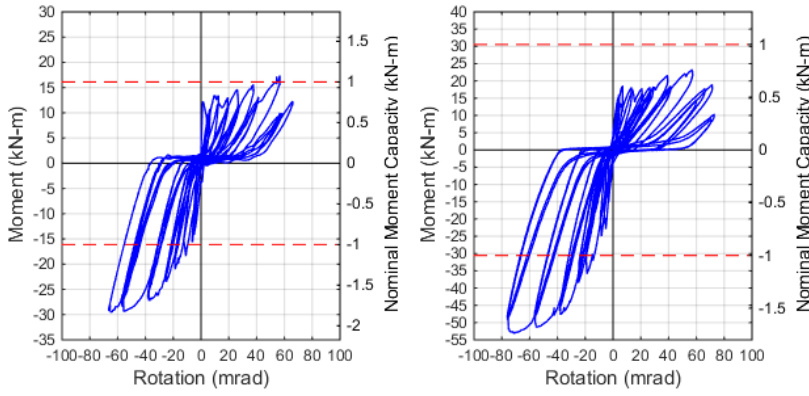
TI12-C50



TI12-C15



BLT12-C0

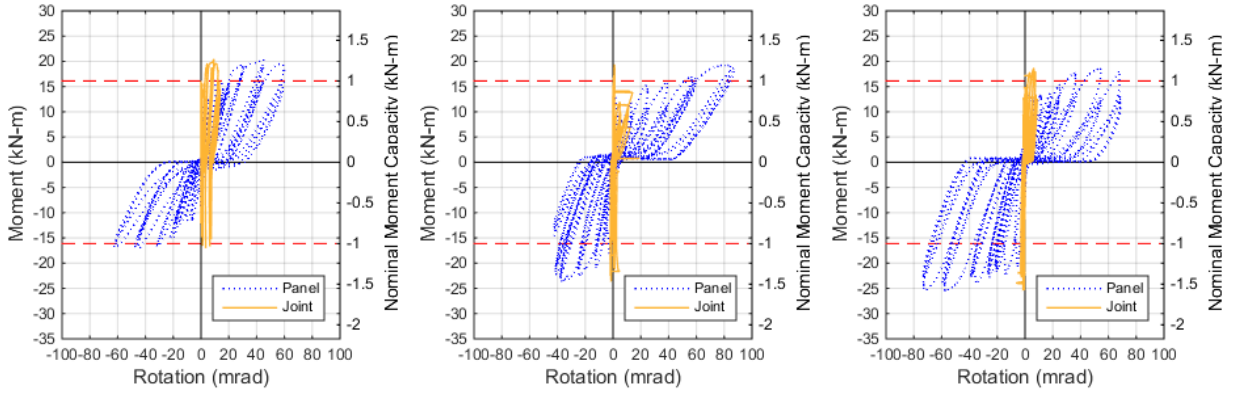


TI12-C15-STR

TI12-C15-STRP-V135

Figure 9: Global moment-rotation behavior of panels with confined joints compared to existing connections. Positive values of moment and rotation correspond to joint-opening behavior.

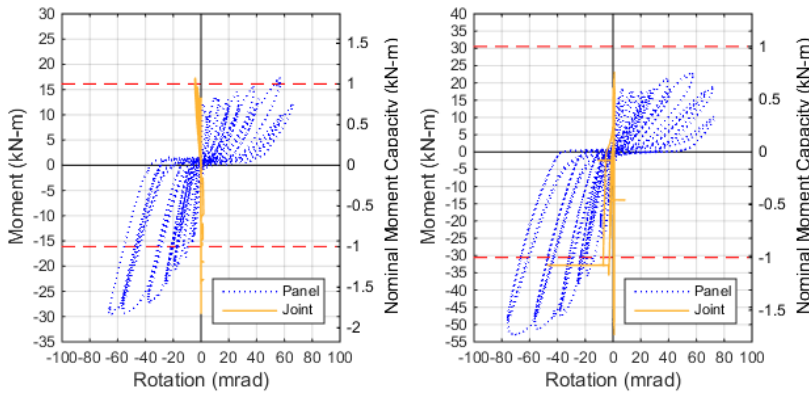
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TI12-C50

TI12-C15

BLT12-C0



TI12-C15-STR

TI12-C15-STRP-V135

Figure 10: Joint vs panel moment-rotation behavior of panels with confined joints compared to existing connections. Positive values of moment and rotation correspond to joint-opening behavior.

50 **3.1.4 Details with a single layer of 12 mm starter bars**

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SL12-C50



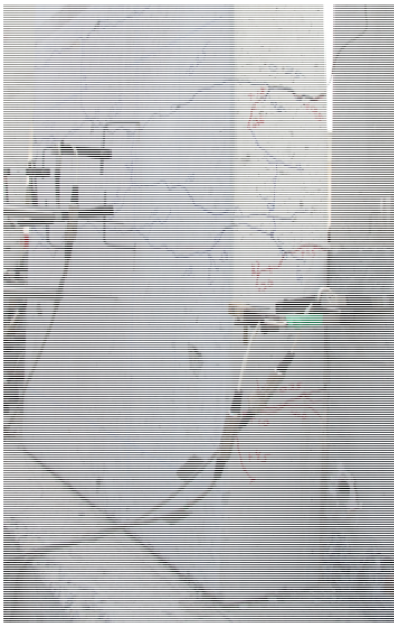
STI12-C15



STI12-C15-NA



STI12-C15-340ST-V135



STI12-C15-340ST

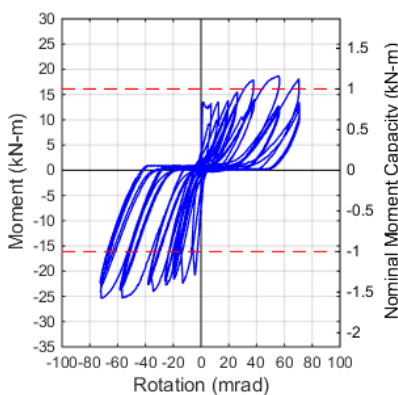


STI12-C15-540ST

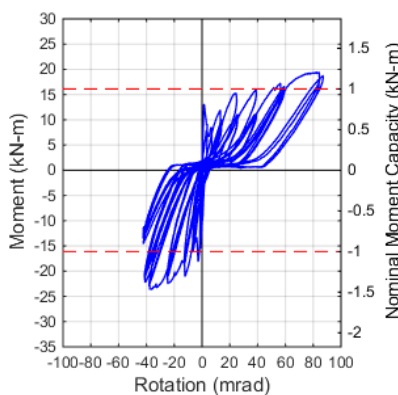
Figure 11: Damage to specimens with single layer of starter bars compared to existing connections at maximum joint-opening drift

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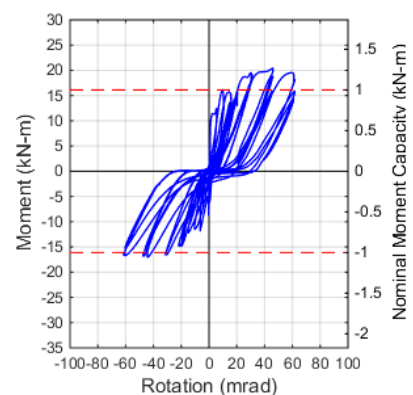
- SL12-C50: cracking at top of hook extension as well as at level of starter bar. Significant opening (10 mm) at foundation interface
- STI12-C15: Significant opening (5 mm) at foundation interface. Crack at insert level. Large flexural crack for joint-closing direction
- STI12-C15-NA: Significant opening (5 mm) at foundation interface. Crack at insert level with vertical cracking. Large flexural crack for joint-closing direction
- STI12-C15-340ST-V135: crack at insert and 5 mm opening at foundation level. Appears to have crushing failure at large opening. Diagonal cracking at toe initiates at around 3.0%
- STI12-C15-340ST: Same large gap at foundation interface (5-10 mm). crack at top of stud and at insert level
- STI12-C15-540ST: opening (3 mm) at foundation interface. Large flexural crack for joint-closing direction. Slight cracking at insert level Joint stayed in good condition



BLT12-C0



TI12-C15



TI12-C50

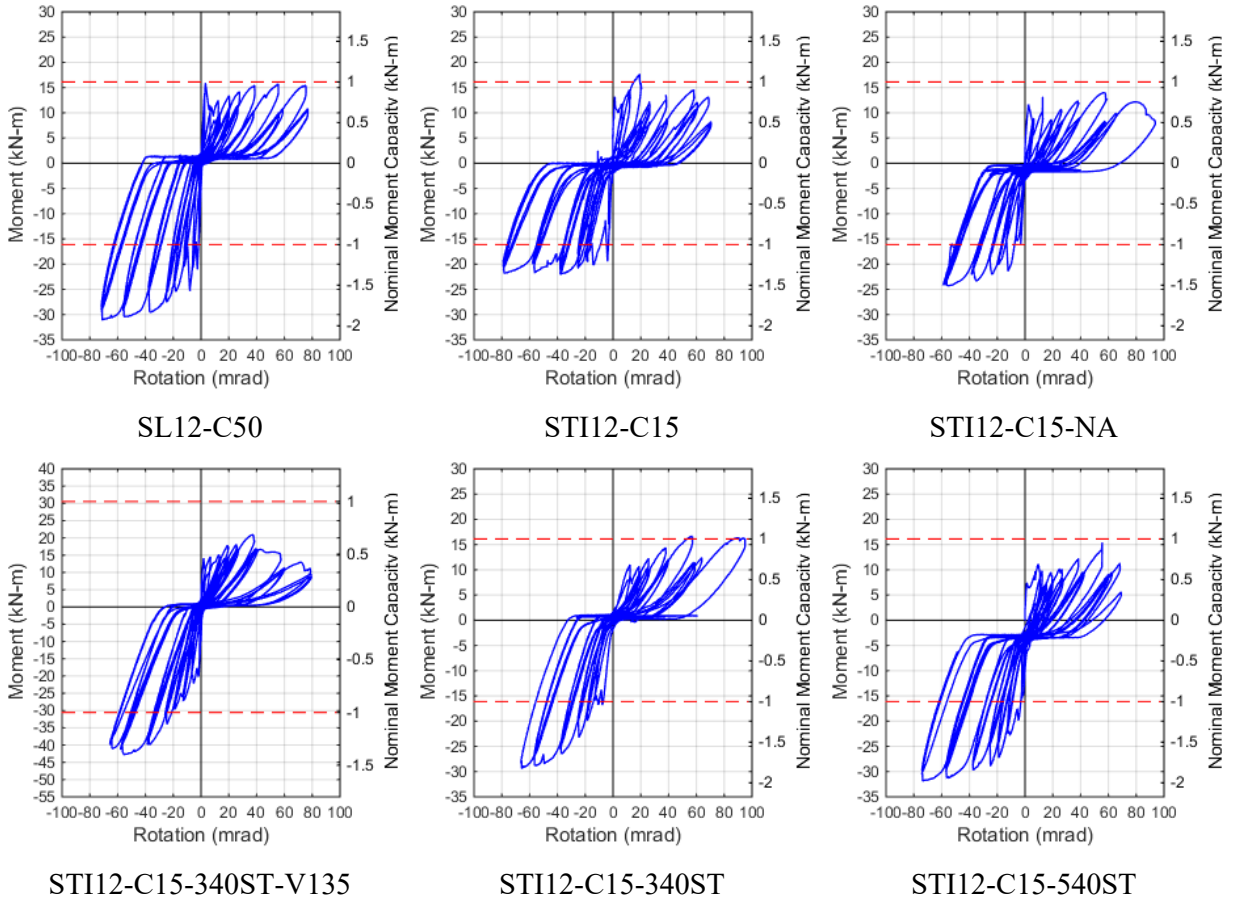
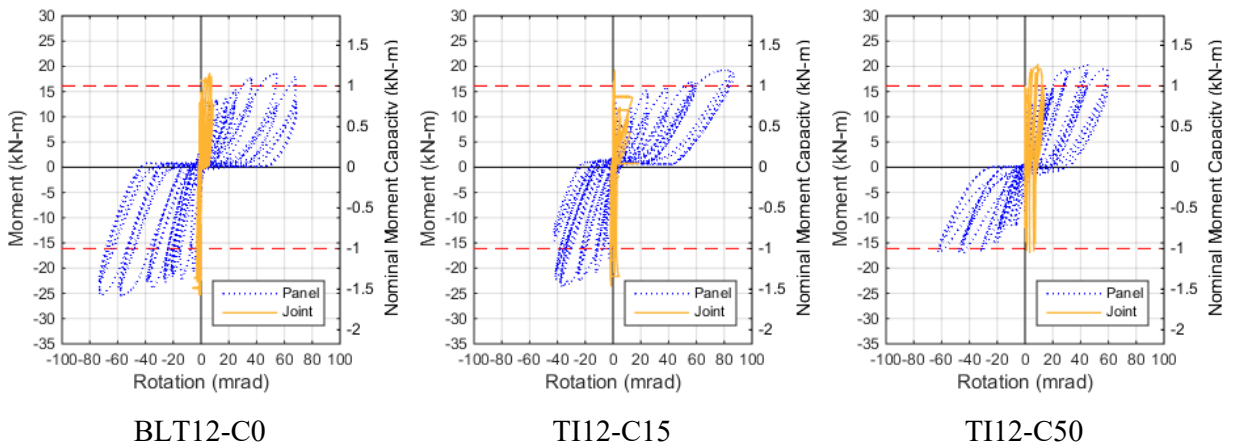


Figure 12: Global moment-rotation behavior of panels with single layer of starter bars compared to existing connections. Positive values of moment and rotation correspond to joint-opening behavior.

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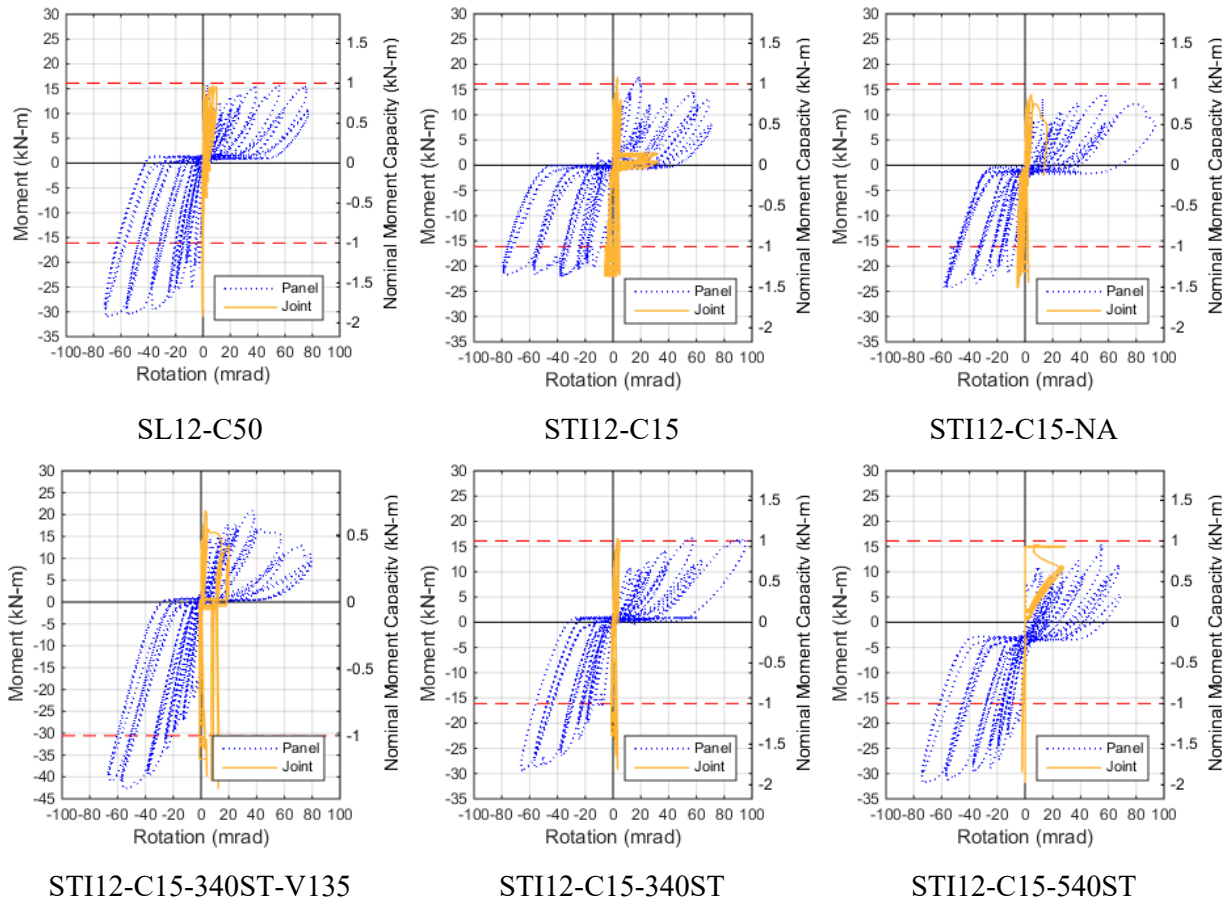


Figure 13: Joint vs panel moment-rotation behavior of panels with single layer of starter bars compared to existing connections. Positive values of moment and rotation correspond to joint-opening behavior.

4 CONCLUSIONS & FUTURE WORK

In order to assess the out-of-plane seismic performance of dowel type precast panels, fourteen precast panel connections were subjected to out of plane loading. The panel connections

represented typical dowel type connections used in the precast industry and included both threaded inserts and conventional starter bars. The majority of panels displayed asymmetric hysteretic behavior between joint-opening and joint-closing directions. In the joint-closing direction the panels were able to develop the full nominal moment capacity of the panel, but in the joint-opening direction, the panel shear force at the foundation level introduced an additional moment into the foundation connection thereby reducing the strength and stiffness of the joint-opening direction. Due to this additional joint moment introduced in the joint-opening direction, the joint performance was found to be dependent upon the relative strengths between the panel and foundation connection.

Panels that utilized conventional starter bars tended to perform better than those panels with threaded inserts, which developed cracking behind the insert head as was predicted from strut-and-tie analysis. This improved performance was attributed to either over reinforcing the joint in the case of “L” starter bars or more efficient transfer of load between panel reinforcement and starter bars for the “U” bar connections. Due to the poor performance but prevalence of the threaded insert connections, an additional study was performed to develop connections connection details that utilized threaded inserts but avoided the loss of load path behind the insert head. This study is detailed in a companion paper entitled: *Out-of-Plane Behavior of Foundation Inserts of Precast Panels: Existing Connections*.

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102 **5 REFERENCES**

103