

# Full-Scale Testing of PA-EX Series



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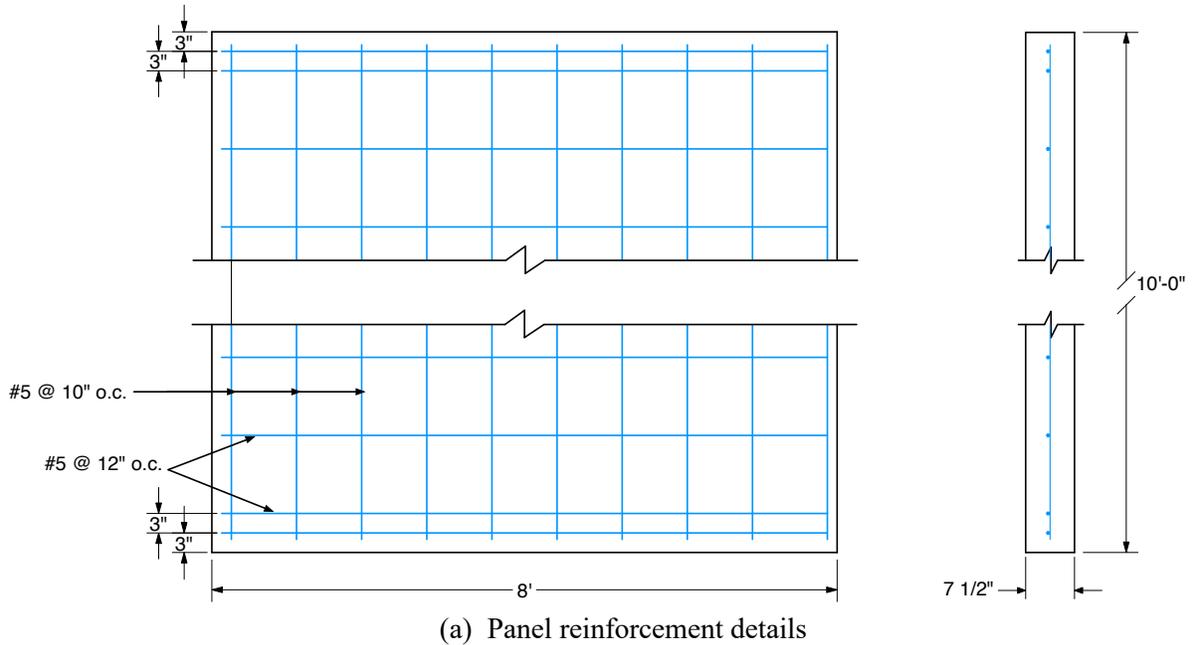
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### 1. Introduction

Three 7.5" thick x 8'-0" wide x 10'-0" tall reinforced concrete panels were cast in order to test a number of AdvanConn devices under various loading configurations. The panels were reinforced with one curtain of No. 5 Gr. 60 reinforcing bars spaced vertically at 10" o.c. and at 12" o.c. horizontally. The reinforcement was placed at mid-thickness. The average 28-day concrete strength was 4,610 psi. Near the ends, where the devices were to be installed, the spacing between the horizontal bars was reduced to 3" based on common practice. The reinforcement layout is illustrated in Figure 1a. The photograph in Figure 1b shows the panel reinforcement and formwork. The panels were designed to allow multiple tests on each panel or three interconnected panels.



(a) Panel reinforcement details



(b) Panels before concrete placement

Figure 1. Panel details

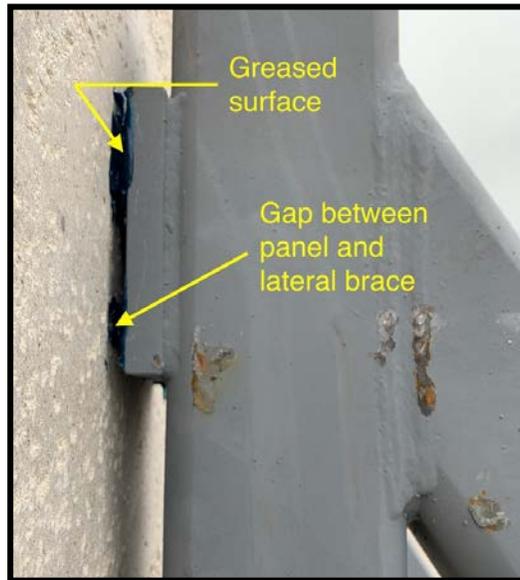
After adequate curing, each panel was tilted upright (Figure 2a) and connected to a 24" wide by 30" deep foundation reinforced with No. 5 Gr. 60 reinforcing bars, and braced as shown in Figure 2b. Approximately 1/8" gap was kept between the panel and lateral braces. The panel at the contact point to the brace was ground and greased (Figure 2c). The combination of having a gap and the greased surfaces eliminated any potential influence of friction between the panel and lateral bracing system on the test results. It should be noted that the tests were conducted without any grout between the panel and foundation.



(a) Panels before bracing



(b) Panels after installation of lateral braces



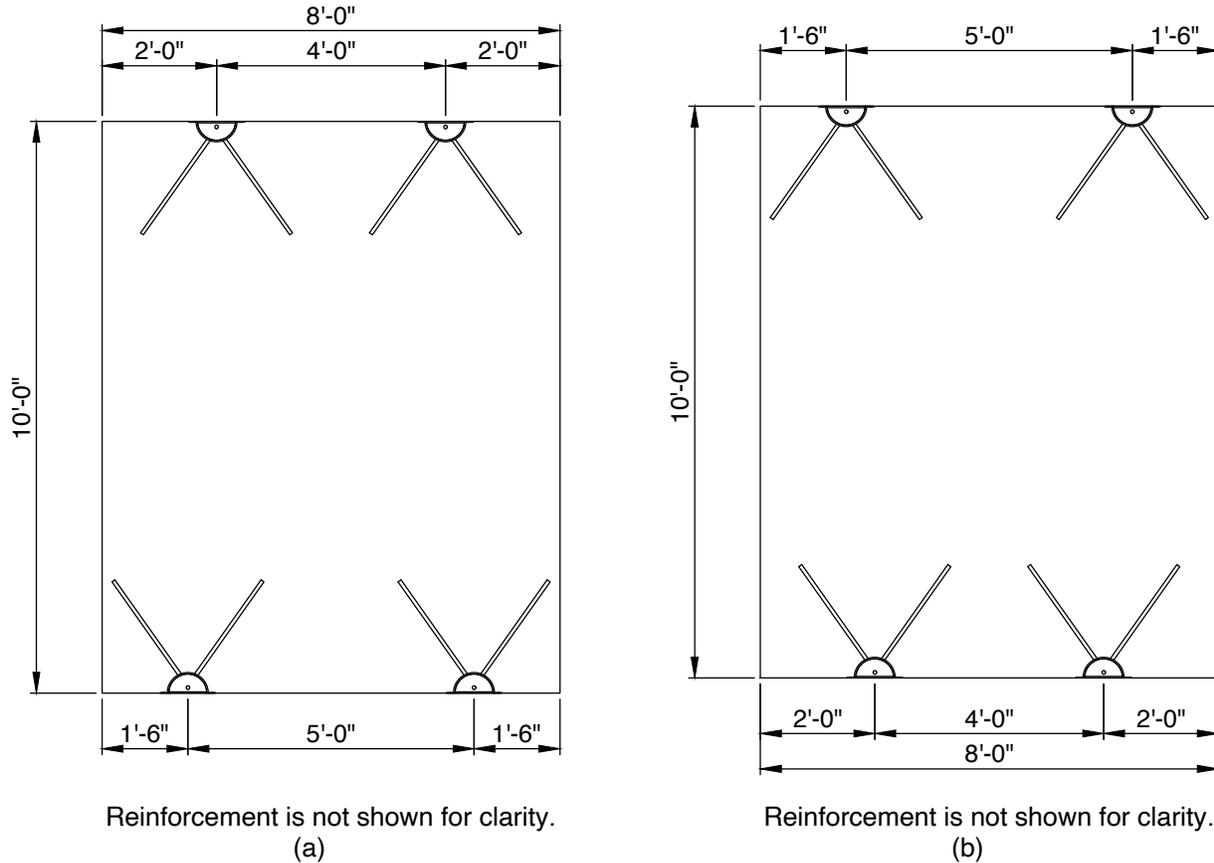
(c) Gap and greased surface

**Figure 2. Overview of test panels and lateral bracing**

The focus of panel 3 was on PA-EX series. At one end of the panel two PA-EX series were placed at 1'-6" from each edge (Figure 3a) while two PA-EX series were placed with 2'-0" edge distance, which is the typical edge practice in practice, at the other end (Figure 3b). The panel was tested according to the loading protocol summarized in Table 1, in which "x" indicates a test was conducted.

**Table 1. Loading protocol**

Configuration and edge distance	Tension	In-plane shear	Out-of-plane shear	Combined in-plane and out-of-plane shear
a 1'-6" (Figure 3a)	x	---	---	---
b 2'-0" (Figure 3b)	---	x	x	x



**Figure 3. Locations of PA-EX devices for test configuration a and b**

## 2. Test setup

Pockets had been cast in the foundation to accommodate hydraulic rams. The locations of these pockets were selected to avoid interaction with the devices that were being tested. The following procedures were followed to load the devices under different loading conditions:

- (a) **Tension test:** A 60-kip hydraulic ram was placed vertically in a pocket in the middle of the panel to apply a vertical uplift force (Figure 4a). The load was transferred to the panel through a bearing plate centered on the panel thickness.
- (b) **In-plane shear test:** The loading device consisted of a longitudinal HSS in the plane of the panel and a transverse HSS that reacted against a pocket cast in the foundation – see Figure 4b. The load was applied by a 60-kip hydraulic ram. The load point, defined as the center of hydraulic ram, was 9.5" (vertically) from the bottom of panel, resulting in tensile/compressive force equal to  $9.5''/48''V = 0.198V$  ( $V$  is the applied in-plane shear force) in the devices for test configuration "b" in addition to the applied in-plane shear.

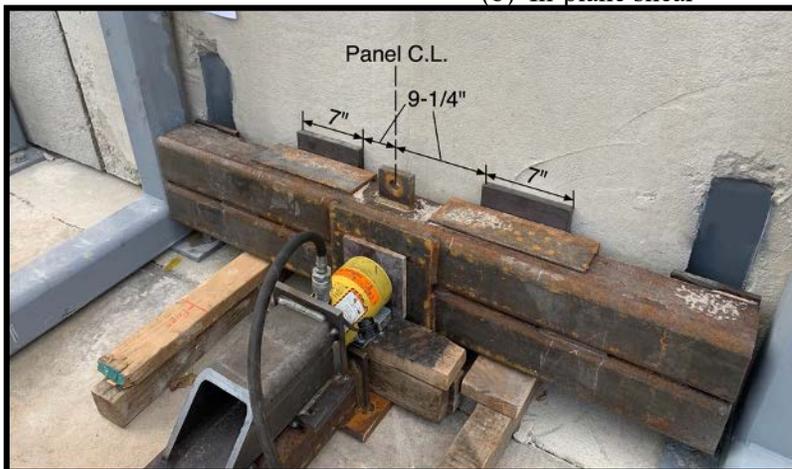
- (c) **Out-of-plane shear test:** The panel was loaded in the out-of-plane direction through a reaction frame that was anchored to the slab on grade in front of the test panel (Figure 4c). The load, applied by a 60-kip ram, was transferred to the test panel through two 7"x7" plates placed at 9-1/4" from the panel centerline. The loading apparatus did not bear against the devices as evident from the gap shown in Figure 4c.
- (d) **Combined in-plane and out-of-plane test:** The panel was loaded in the out-of-plane direction first through the apparatus discussed in (c). After reaching the target shear, the out-of-plane load was maintained by closing a needle valve between the pump and hydraulic ram. The in-plane shear was subsequently applied.



(a) Tension test



(b) In-plane shear



(c) Out-of-plane shear

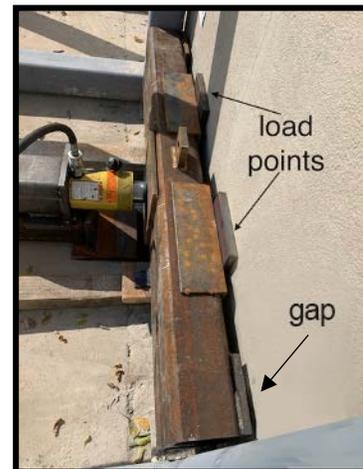


Figure 4. Test setups

### 3. Results and discussion

The maximum load applied for each test is summarized in Table 2. The panel self-weight was taken into account in the reported tension test results.

Tension loading for configuration “a” (1’-6” edge distance instead of the typical 2’-0”) was stopped after reaching 18.6 kips in each device. Additional load could not be applied beyond 18.6 kips due to bending of the device’s plate at the anchor point (Figure 5a), damage on the back face of the wall panel (Figure 5b) caused by bending of the plate, approximately  $\frac{3}{4}$ ” permanent elongation and bending of the anchor bolts (Figure 5c), and to a lesser degree because of slight cracking around the device (Figure 5d). It should be noted the floor slab on the back face of the device, which was not included in the tests, would restrain crack growth behind the device (Figure 5b) and the performance is expected to be better than that reported herein. The maximum applied load corresponds to 1.86 times the nominal design strength of 10 kips.

Each device in configuration “b” (2’-0” edge distance to the device) was subjected to (1) 10.1 kips in-plane shear (2) 10.1 kips out-of-plane shear, and (3) 14.3 kips combined in-plane and out-of-plane shear. Each device was loaded to slightly above the shear resistance of each anchor bolt alone (“resistance of steel”,  $\phi_{sa}V_{sa}$ ), which is 9.89 kips. The concrete around the devices did not crack during any of the shear tests. However, as seen from Figure 6, the device closer to the application of in-plane shear cracked after being subjected to 14.3 kips of combined in-plane and out-of-plane shear, but no cracking was found around the far end device. This behavior is expected as the device closer to the application of in-plane shear was subjected to a tensile force equal to  $0.198V = 0.198*10.1$  kips = 2 kips (where 10.1 kips is the applied in-plane shear) in addition to the combined shear of 14.3 kips. The forces in the far end device consisted of a combined shear of 14.3 kips and a compressive force equal to 2 kips.

**Table 2. Applied loads (kips) in each device**

Configuration and edge distance	Tension	In-plane shear	Out-of-plane shear	Combined in-plane and out-of-plane shear
a 1’-6”	18.6	---	---	---
b 2’-0”	---	10.1	10.1	14.3

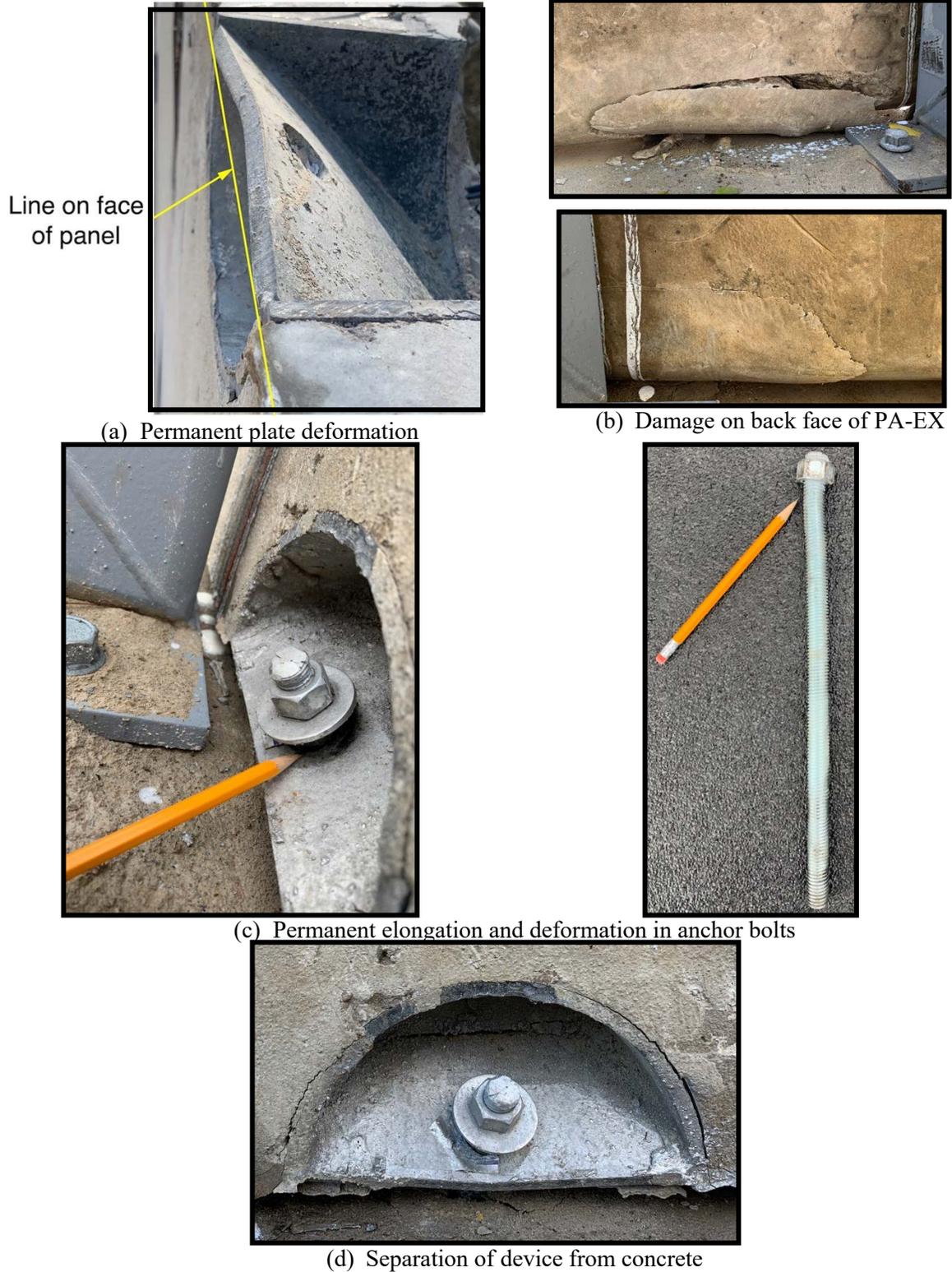


Figure 5. Cracking and damage after applying 18.6 kips tension in each device



(a) PA-EX away from the application of in-plane shear

(b) PA-EX close to the application of in-plane shear

**Figure 6. Status of the devices applying 14.3 kips combined in-plane and out-of-plane shear in each device**

#### 4. Summary and observations

Two PA-EX devices were subjected to (1) tension, (2) in-plane shear, (3) out-of-plane shear, and (4) combined in-plane and out-of-plane shear. The devices did not experience any brittle failure during any of the tests.

Each PA-EX could resist 1.86 times the nominal design strength in tension even though the edge distance was 1'-6" instead of 2'-0" commonly used in practice. The devices could not resist additional loads beyond 1.86 times the nominal design strength in each PA-EX primarily due to a combination of (a) excessive bending of plate through which the device is anchored, (b) damage to the concrete behind the device, and (c) major elongation and bending of the anchor bolts. The presence of floor slab on the back face of the device, which was not simulated in the tests, would restrain growth of cracks behind the device and should enhance the performance. The reported load carried by each device accounted for the self-weight of the panel. Additional superimposed dead load and live loads were, however, not simulated in the tests. Clearly, such gravity loads would enhance the performance of PA-EX device.

Each device could resist at least the shear capacity of the anchor bolt alone, so called "shear resistance of steel", for all the three types of shear tests (in-plane, out-of-plane, and combined in-plane and out-of-plane). The concrete around both PA-EX devices remained uncracked.