SlowStop Bollard
IBC 1607.8.3 Testing
2-Aug-2019

Purpose: To confirm conformance to International Building Codes of SlowStop 5" StoreFront Bollard.

Background:

IBC 1607.8.3 states the following:

> **Vehicle barriers.** Vehicle barriers for passenger vehicles shall be designed to resist a concentrated load of 6,000 pounds (26.70 kN) in accordance with Section 4.5.3 of ASCE 7. Garages accommodating trucks and buses shall be designed in accordance with an *approved* method that contains provisions for traffic railings.

ASCE 7 – 4.5.3 states the following:

> Vehicle barrier systems for passenger vehicles shall be designed to resist a single load of 6,000 lb. (26.70 kN) applied horizontally in any direction to the barrier system, and shall have anchorages or attachments capable of transferring this load to the structure. For design of the system, the load shall be assumed to act at heights between 1 ft 6 in. (460 mm) and 2 ft 3 in. (686 mm) above the floor or ramp surface, selected to produce the maximum load effect. The load shall be applied on an area not to exceed 12 in. by 12 in. (305 mm by 305 mm) and located so as to produce the maximum load effects. This load is not required to act concurrently with any handrail or guardrail system loadings specified in Section 4.5.1.Vehicle barrier systems in garages accommodating trucks and buses shall be designed in accordance with *AASHTO LRFD Bridge Design Specifications.*

Experiment Design:

In order to maximize load effects, 27" inches above ground was selected as it produces the maximum moment on the SlowStop rebounding bollard which tilts and absorbs energy with impact. Further, placing a single anchor at maximum distance from the pull direction was determined to produce the maximum tension on the anchor.

Figure 1 - Bollard Initial Condition

A SS5Y-42-SF SlowStop Bollard was installed in 3000 psi concrete using standard 5/8” x 5-1/2” Hilti HUS anchors. A hole was drilled in the bollard pipe to connect rigging to pull (in effect a push due to the connection point on the opposite side) the bollard with 6,000 pounds of force using a lever chain hoist. An S type load cell was rigged in line with the pulling force in order to measure actual force.

A 50,000 pound rated washer type load cell was installed under the head of the worst case anchor in order to read actual force exerted upwards by the bollard base onto the head of the anchor. Concrete used was 3,000 psi, 6”-7” thick parking lot grade. This allowed for five of the anchors to be seated fully as normal. The load cell anchor, however, lost a little over 1” of embedment depth due to the measure device and required structural washers. See Figure 2.

Figure 2 - Loss of Embedment at Load Cell

Results:

Measurements were taken periodically throughout tensioning (and later compared to the 4" bollard testing). See the graph below in Figure 3. The anchor began with approximately 3300 pounds of clamping force. Upon tensioning, the bollard tilted to 20° as designed by compressing the internal rubber elastomer. At that point the bollard became semi-rigid. The base is made of ductile iron with a minimum of 18% elongation. The pipe is standard schedule 40 steel ERW pipe and also subject to some bending, though no noticeable bending occurred. The loading on the washer seems to be linear in two different phases, before and after full tilting, for both models.

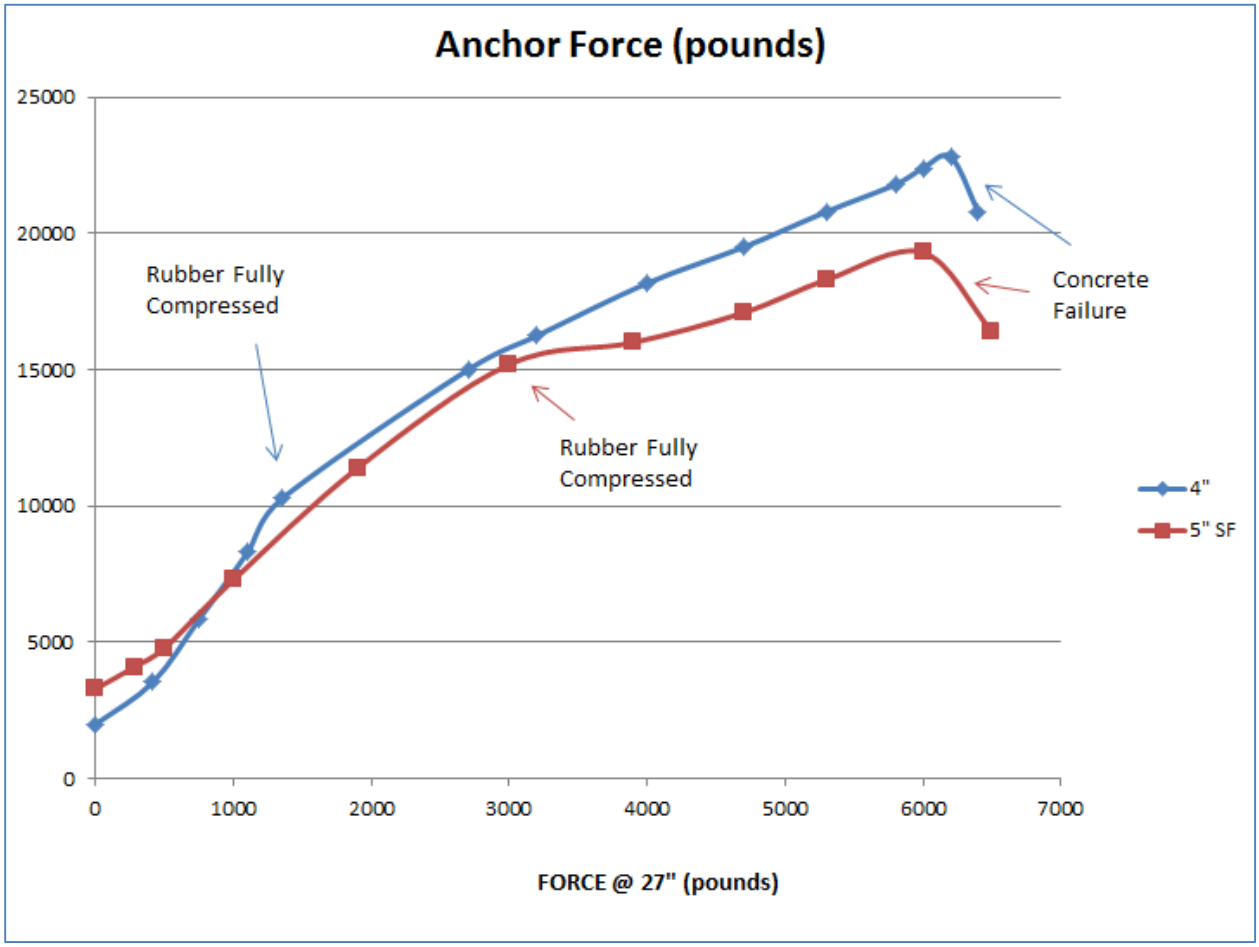


Figure 3 - Load Forces

At 6,000 pounds of force on the bollard, the system held in steady state, with approximately 19,300 pounds of tension on the anchor. The system was tensioned further to explore failure point. At approximately 6,500 pounds of force, the concrete under the worst case anchor began to spall. See Figure 4.

Figure 4 - Spalled Concrete

Because the worst case anchor lost 1” of embedment depth, it is logical to assume that the concrete would have failed later had there been full embedment.

Calculation Back-Check:

Figure 5 - 27" Above Ground Level Force

Appendix A shows basic static calculations to determine expected vertical tension on the worst case bolt. Calculations agree with measured data within 2%.

See APPENDIX B to this report for Load Cell Calibration Certificates.

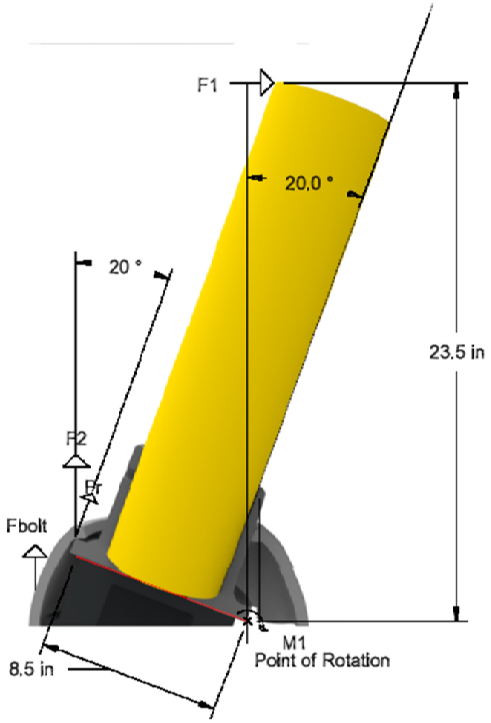
Conclusion:

Given proper foundation and anchorage design, the SlowStop bollard conforms to IBC 1607.8.3 and ASCE 7 – 4.5.3 and is an appropriate product selection for parking garages. For thinner decks, backing plates anchor designs may be necessary to contain the load.

APPENDIX A– Static Calculations

Forces	Analytical	Experimental
F1	6000 lbs	6000 lbs
F2	18893 lbs	19300 lbs
Fbolt	18893 lbs	19300 lbs

F1 = Axial Force from Hoist
F2 = Vertical Force from Adapter to Pedestal
Fbolt = Vertical Force on Bolt from Pedestal
Fbolt = F2 ; Summation of Forces in the Y Direction



Sum of x Forces
F1=6000

Moment around Point of Rotation
M1= 6000 * 23.5 = 141,000 lb-in

Reaction Force
Fr = M1 / 8.5 = 16588 lbs

Sum of y Forces
F2 = Fbolt = Fr * cos(20) = 16588 * .940 = 15576 lbs

Total load
Fbolt total = F2 + Preload = 15593 + 3300 = 18893 lbs
Fbolt total = 18893 lbs

4955 STOUT DR. · SAN ANTONIO, TX 78219 · (800) 736-5256

SIZE	PART NO.	DWG.	REV
A			
SCALE	SLOWSTOP GUARDING SYSTEMS, LLC	DATE	

APPENDIX B – Load Cell Calibration Certificates

S-Type Pull Force

OMEGA ENGINEERING INC.

LOAD CELL
FINAL CALIBRATION

0.00 - 10000.00 LBS
Excitation 10.000 Vdc

Job: WHM0030957 Serial: 381452
Model: LCCD-10K Tested By: ED
Date: 5/22/2019 Temperature Range: +0 to +150 F
Calibrated: 0.00 - 10000.00 LBS Specfile: LCCD

Force LBS	Unit Data mVdc	Normalized Data
0.00	- 0.070	0.000
5000.00	14.939	15.009
10000.00	29.950	30.020
5000.00	14.947	15.017
0.00	- 0.070	0.000

Balance	- 0.070	mVdc
Sensitivity	30.020	mVdc
In Resist	447.00	Ohms
Out Resist	352.30	Ohms
59K Shunt	14.913	mVdc

Change at 0.00 LBS (-INPUT to -OUTPUT)

Calibration Factors:
Sensitivity = 3.002 mV/V 59K Shunt = 1.491 mV/V

ELECTRICAL LEAKAGE: PASS
ELECTRICAL WIRING/CONNECTOR: RED = +EXCITATION
BLACK = -EXCITATION
GREEN = +OUTPUT
WHITE = -OUTPUT

This Calibration was performed using Instruments and Standards that are traceable to the United States National Institute of Standards Technology.

S/N	Description	Range	Reference	Cal Cert
177438-A	20K LB LOAD STD TEN	0 - 10000.00 LBS	C-2740	C-2740
3146A20228	34401A DMM UUT	Unit Under Test	C-2404	WCS44931L
US36107898	34401A DMM STD	Pressure Monitor	C-3006	WCS41717L

Q.A. Representative : *Ed Suchman Jr.* Date: 5/22/2019

This transducer is tested to & meets published specifications. After final calibration our products are stored in a controlled stock room & considered in bonded storage. Depending on environment & severity of use factory calibration is recommended every one to three years after initial service installation date.
COMMENTS: FINAL TEST IN TENSION.

Omega Engineering Inc., 800 Connecticut Ave., Norwalk, CT 06854
http://www.omega.com email: info@omega.com phone (800) 826-6342

Washer Type Anchor Force

OMEGA ENGINEERING INC.

LOAD CELL
FINAL CALIBRATION

0.00 - 50000.00 LBS
Excitation 10.000 Vdc

Job: WHM0031001 Serial: 399034
Model: LCWD-50K Tested By: ED
Date: 5/31/2019 Temperature Range: +60 to +160 F
Calibrated: 0.00 - 50000.00 LBS Specfile: LCWD+20K

Force LBS	Unit Data mVdc	Normalized Data
0.00	- 0.148	0.000
25000.00	8.854	9.002
50000.00	18.143	18.291
0.00	- 0.147	0.001

Balance	- 0.148	mVdc
Sensitivity	18.291	mVdc
In Resist	752.20	Ohms
Out Resist	703.50	Ohms
200K Shunt	8.774	mVdc

Change at 0.00 LBS (-INPUT to -OUTPUT)

Calibration Factors:
Sensitivity = 1.829 mV/V 200K Shunt = 0.877 mV/V

ELECTRICAL LEAKAGE: PASS
ELECTRICAL WIRING/CONNECTOR: RED = +INPUT (EXC)
BLACK = -INPUT (EXC)
GREEN = +OUTPUT
WHITE = -OUTPUT

This Calibration was performed using Instruments and Standards that are traceable to the United States National Institute of Standards Technology.

S/N	Description		Range	Reference	Cal Cert
326425A	300K LB LOAD STD		0 - 50000.00 LBS	C-3008	C-3008
US36037962	HP 34401A DMM	UUT	Unit Under Test	C-2451	N/A
US36121869	HP 34401A DMM	STD	Pressure Monitor	C-2461	WCS44922L1

Q.A. Representative : *Ed Euchman Jr* Date: 5/31/2019

This transducer is tested to & meets published specifications. After final calibration our products are stored in a controlled stock room & considered in bonded storage. Depending on environment & severity of use factory calibration is recommended every one to three years after initial service installation date.
COMMENTS: FINAL TEST.

Omega Engineering Inc., 800 Connecticut Ave., Norwalk, CT 06854
http://www.omega.com email: info@omega.com phone (800) 826-6342