SlowStop Bollard
IBC 1607.8.3 Testing
19-JUN-2019

Purpose: To confirm conformance to International Building Codes of SlowStop 4" 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, using fixed plate analysis, it was determined that impact at 45° to the squared base produces maximum tension on the anchor which is farthest from impact.

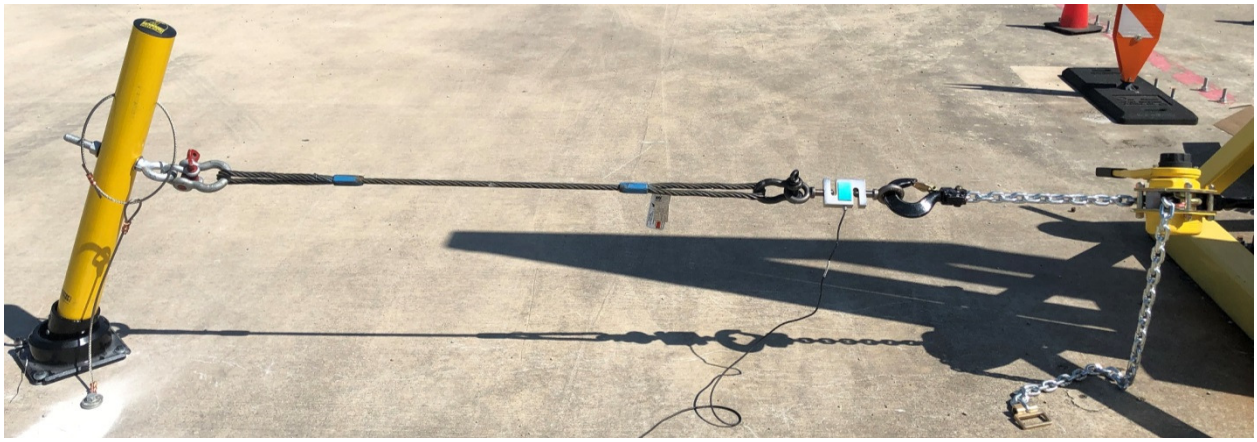


Figure 1 - Bollard at Maximum Force

A production SS4Y-42 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 three 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. See the graph below in Figure 3. The anchor began with approximately 2000 pounds of clamping force. Upon tensioning, the bollard tilted to 20º 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.

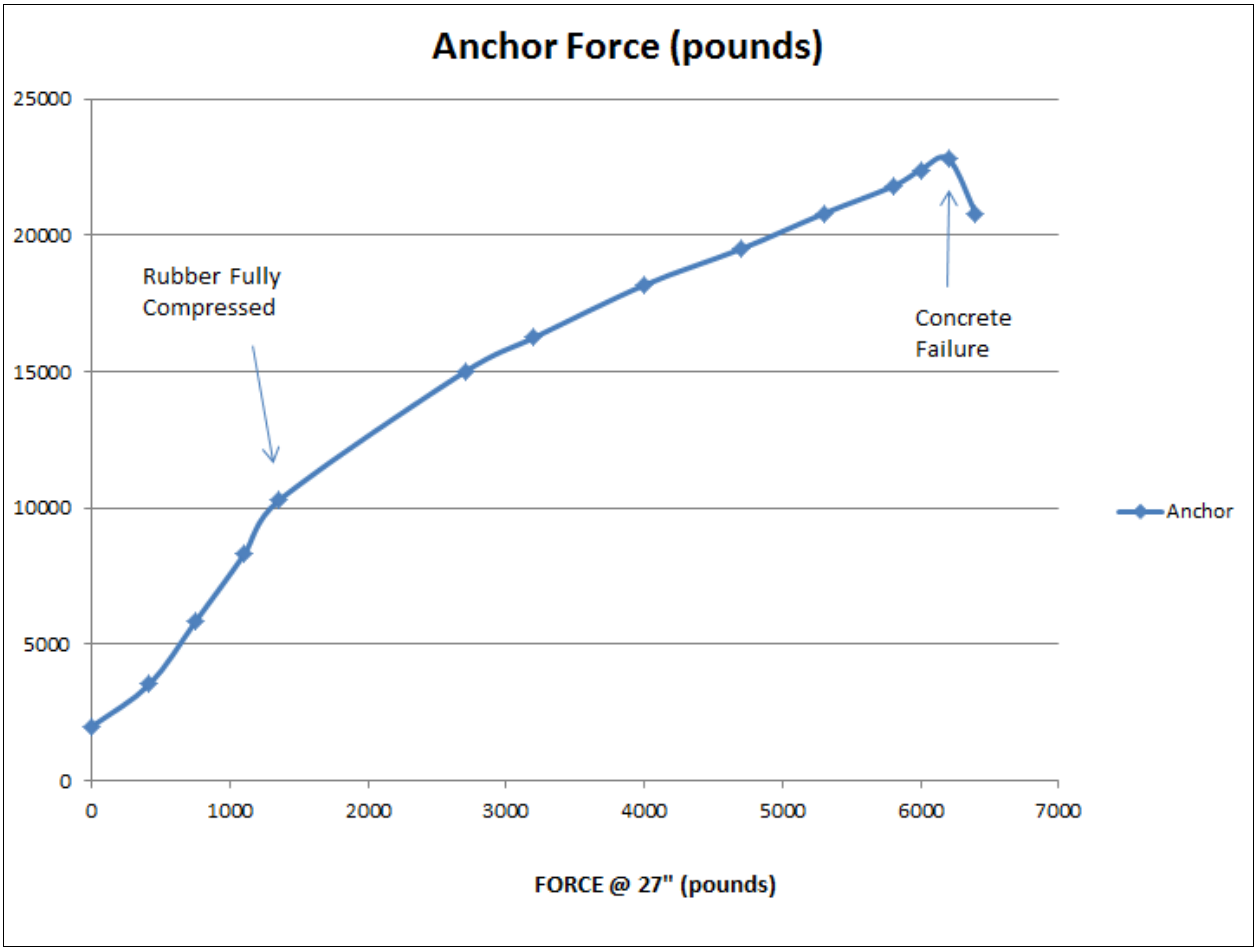


Figure 3 - Load Forces

At 6,000 pounds of force on the bollard, the system held in steady state, with approximately 22,400 pounds of tension on the anchor. The system was tensioned further to explore failure point. At approximately 6,200 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.

Confirmation of Data:

Figure 5 - 27" Above Ground Level Force

Figure 5 shows the location of the connection point to the force applied, confirming 27” above ground. Load applied over the area of the backing washer, obviously less than 12” x 12”.

Hilti PROFIS software was used to back-check the data obtained. As PROFIS models perfectly rigid, calculations are being used to confirm realism. PROFIS predicts load capacity of 14,432 pounds of concrete breakout strength for the anchor group for 3000 psi, 7” concrete with a 0.75 safety factor, for an actual 19,242 concrete failure point. Given that concrete PSI ratings are generally wide and this concrete was fully cured, it’s likely that failure at ~22,800 pounds is plausible.

PROFIS software predicted a load of 19,431 pounds for the anchor group of a rigid bollard of similar configuration at a point near the worst case anchor. Given that actual load was measured at 22,400 pounds, this is also confirmed.

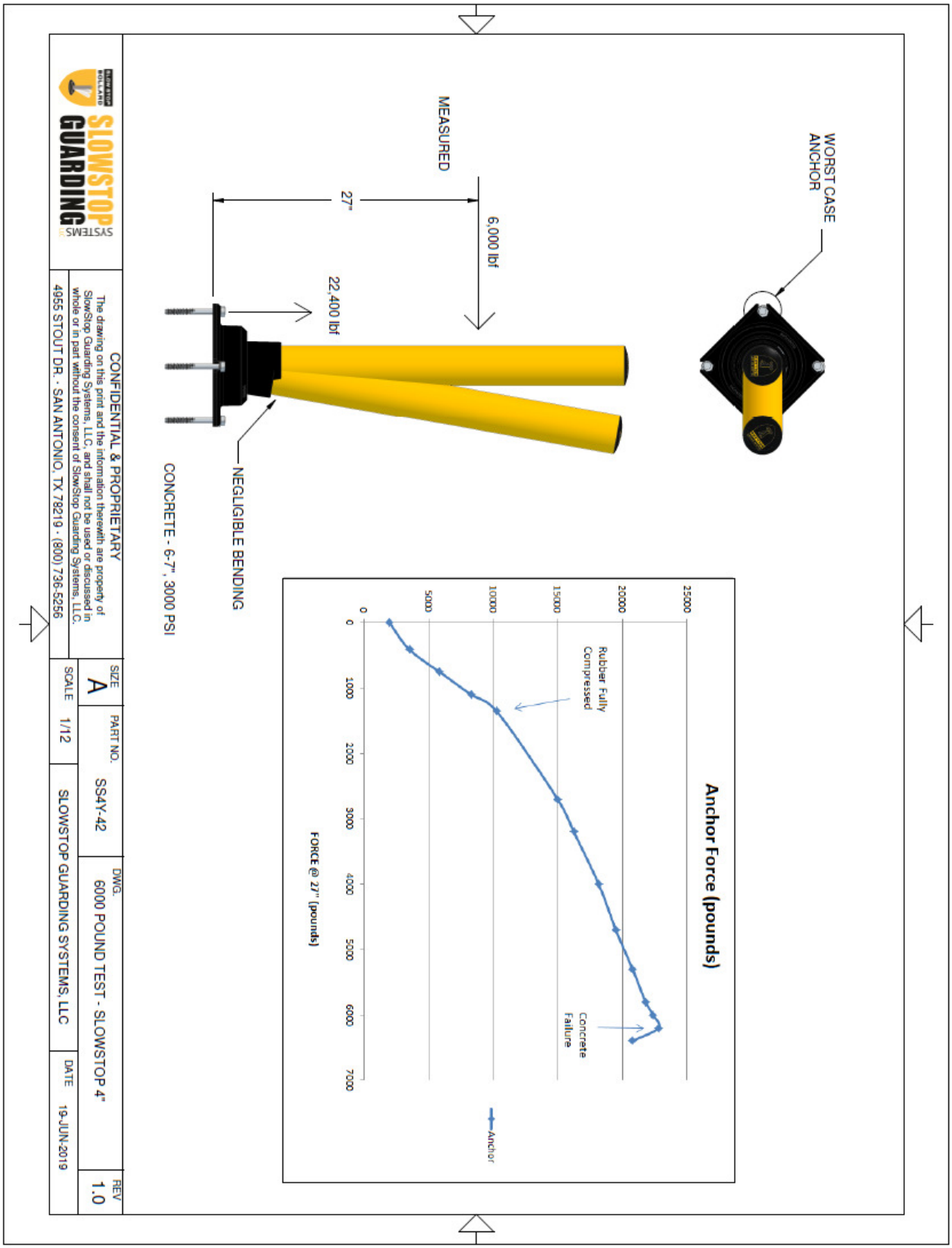
The PROFIS report is available as an addendum to this report.

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– Test Rig Drawing and Results



SLOWSTOP GUARDING SYSTEMS

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

SIZE	PART NO.	DWG.	REV
A	SS4Y-42	6000 POUND TEST - SLOWSTOP 4"	1.0
SCALE 1/12	SLOWSTOP GUARDING SYSTEMS, LLC	DATE 19-JUN-2019	

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