LGSEA

TECHNICAL NOTE $5.00

On Cold-Formed Steel Construction

Light Gauge Steel Engineers Association ● Washington, D.C. ● Toll-Free: 1 (866) 465-4732 ● www.LGSEA.com

POWDER-ACTUATED FASTENERS IN COLD-FORMED STEEL CONSTRUCTION

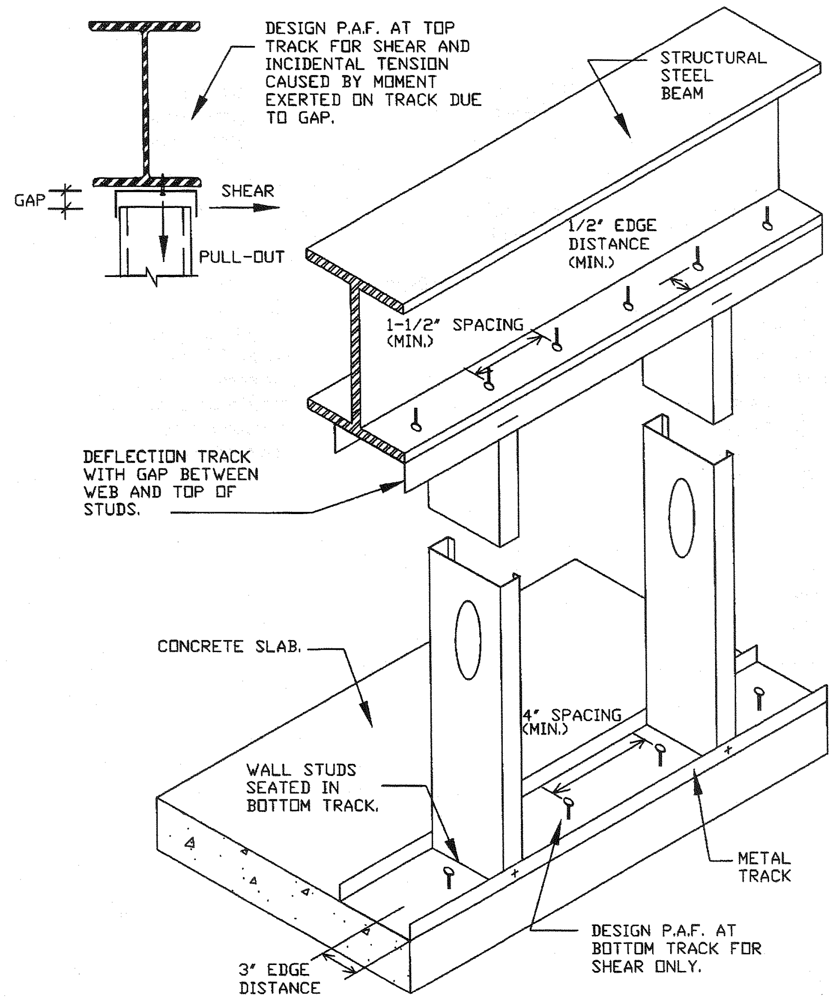
SUMMARY: Powder-actuated (also referred to as low velocity or powder-driven) fasteners are commonly used to attach cold-formed steel framing members, usually a track, to a concrete or structural steel support. Although commonly used, their behavior is less well understood than other fasteners such as screws, bolts and welds. The AISI Cold-Formed Steel Design Manual does not explicitly address powder actuated fasteners. Several guidelines have been put forth in the past but these do not reflect the latest tested data on powder-actuated fasteners. This technical note will explain installation, behavior and good detailing practices. Design values for powder actuated fasteners are also provided.

Introduction:

Powder-actuated fastening is used by virtually all building trades. It is used to attach electrical boxes and conduit, to attach lath, to hang sprinklers and ductwork, to build concrete formwork, and to attach floor and roof decking. The most common application in the cold-formed steel framing trade is the attachment of runner track to concrete or structural steel supports as shown in figure 1. Powder actuated fastening was first developed in the 1920's and has been in widespread use in the United States for decades.

Typical Uses of Powder-Actuated Fasteners

Figure 1



POWDER-ACTUATED FASTENING SYSTEM

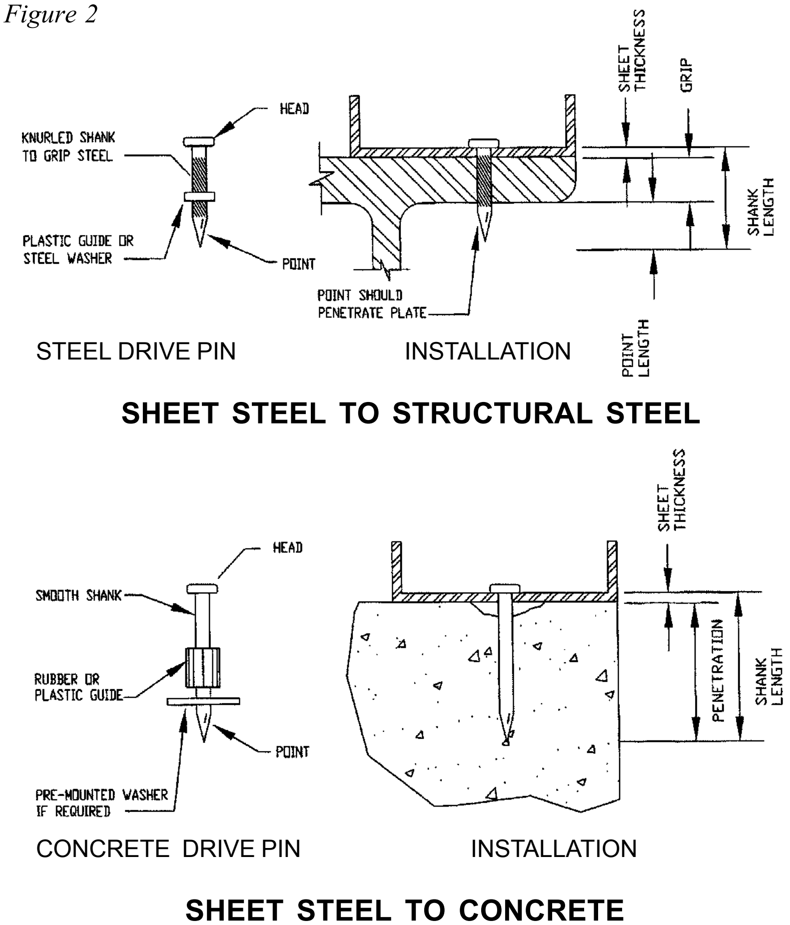
Powder-actuated fastening systems are produced by a number of manufacturers. Although some systems offer special features, all consist of three components: fastener, powder load and powder-actuated tool.

Fasteners

Drive pins and threaded studs are the two main categories of powder-actuated fasteners. Threaded studs allow the attached part to be bolted to the substrate. Drive pins are used for permanent attachments and are the most common type used for

Typical Drive Pins

Figure 2



cold-formed steel framing construction.

Drive pins for attaching to concrete have long, smooth shanks as shown in figure 2. A fluted rubber or molded plastic guide helps hold the pin in the tool and serves to guide the nail during the driving operation while the head prevents the fastener from being over-driven. As the tip of the pin penetrates and displaces concrete, compression caused by the displacement of concrete helps grip the shank of the fastener. During driving, a small amount of spalling may occur near the pin head. This minor spalling is not unusual and should not affect the strength of the fastener. If large amounts of spalling occur, a fastening will be ineffective and another pin should be driven away from the area of spalled concrete. When attaching thin material, using an integral washer may be used to increase pullover resistance of the attached sheet.

Drive pins designed for attaching to structural steel have knurled shanks as shown in figure 2. The knurled shanks are designed to grip the steel substrate. Drive pins with smooth shanks may be used to attach to structural steel, however their pull-out resistance will not be as great. Plastic guides are used to keep the nail straight during driving. As with the concrete drive pins, steel drive pins have heads to prevent over-driving and tips to displace the substrate. When a drive pin is driven in structural steel, small bulges in displaced steel will be formed on each side of the substrate. When attaching to structural steel, it is important that the tip fully penetrate the substrate. If the tip does not fully penetrate, pressure on the tip may push the nail out of the hole, causing a “pop-out.” For this reason, it is important to consider the thickness of the structural steel member, the thickness of the attached sheet and the tip length when selecting the required shank length of the fastener. For applications where the substrate is very thick and the substrate cannot be fully penetrated, the pin manufacturer should be consulted. In some applications, a minimum driving distance can be determined that will provide the required fastener capacity. Integral washers may be used to increase pull-over resistance of the attached sheet. In some fasteners, the integral washers are the same diameter as the pin head and also serve as guides.

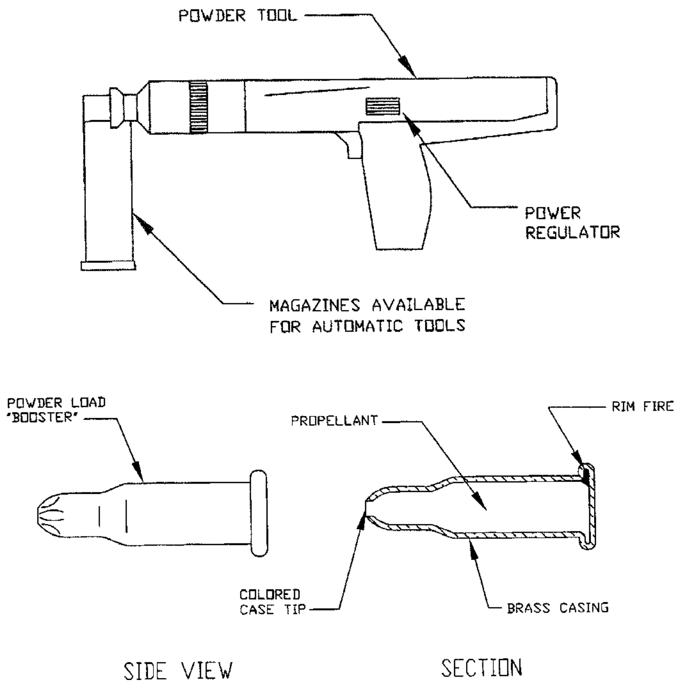
All drive pins are manufactured from steel that has been treated so that it is both hard and ductile. These pins need to be harder than the material that they are penetrating. To test if a substrate is too hard, use a hammer to strike a drive pin against its substrate. If the tip of the drive pin is blunted, the substrate is too hard for the drive pin to penetrate effectively. Also, if the drive pin shatters the material, the substrate may be too brittle for powder actuated fastening.

Powder-Load

Also called the “booster” or “cartridge”, the powder-load is the energy source for the fastening system. Typical powder-loads consist of gunpowder propellant within a brass crimped casing as shown in figure 3. Available calibers range from 0.22 through 0.38. Different power levels are needed depending on the thickness and strength of the substrate and attached sheet. The Powder Actuated Tool Manufacturers Institute uses a standard system for classifying powder-loads. Powder-loads are manufactured in 12 strengths with #1 being the lowest and #12 being the highest. Color codes identify the power level. Power levels #1 through #6 are used for

Powder Actuated Fastening Tool and Booster

Figure 3



low-velocity tools. Higher power levels are used for high-velocity tools, which are seldom used today.

When beginning work, one should always begin using powder loads of a lower level. The power level should be increased until the proper power level is attained and the pins are properly driven. Some tools have a "booster power regulator" which allows the operator to adjust the power delivered by the tool without changing to a different strength load. Powder-loads are available in strips for use in some automatic tools.

Powder-Actuated Tool

Powder actuated tools are used to set the drive pins using the booster as an energy source. Older models of tools were often the "direct-acting" type in which the expanding gas of the booster acts directly on the fastener. This method is similar to the workings of a pistol and is considered a "high velocity" tool, driving the pin at average speeds in excess of 150 meters per second. Although some "direct-acting" tools may still be in use, they are not recommended. Modern powder actuated tools are "indirect-acting" type in which the expanding gas from the booster acts on a piston which drives the pin. These are usually classified as "low-velocity" tools, using the same amount of energy but driving the pin at speeds less than 100 meters per second.

Less-expensive powder actuated tools are hammer-actuated. The tool is held like a chisel, and a blow to the handle with a hammer triggers the booster. The majority of tools in use today are trigger operated as shown in figure 3. These tools are easy to handle and to fire. Tools are designed so that they should not discharge when dropped. They are also designed to fire only when pressure is exerted on the work surface. Still, the operator should be trained in the proper use of the particular tool being used. This training should include operation, safety and tool care. Such training is required by OSHA and may also be required by local laws.

Tools now come equipped with many useful accessories. As mentioned earlier, many tools now have a built in power regulator. This allows the operator to adjust the amount of energy delivered to a pin without changing the power level of the booster used. Many tools may be equipped with magazines that allow automatic firing for higher production rates. Pole attachments are available, which allow the operator to attach pins overhead without the use of a ladder. Some models can be fitted with a spall-stop, which helps reduce the amount of spalling which occurs when fastening to concrete.

DESIGN CONSIDERATIONS

Fastener selection is an important part of the design of cold-formed steel framing systems. First, the designer must identify those connections that should use powder actuated fasteners. Second, a connection must be designed in which the proper fastener, edge distance, spacing and strength is selected.

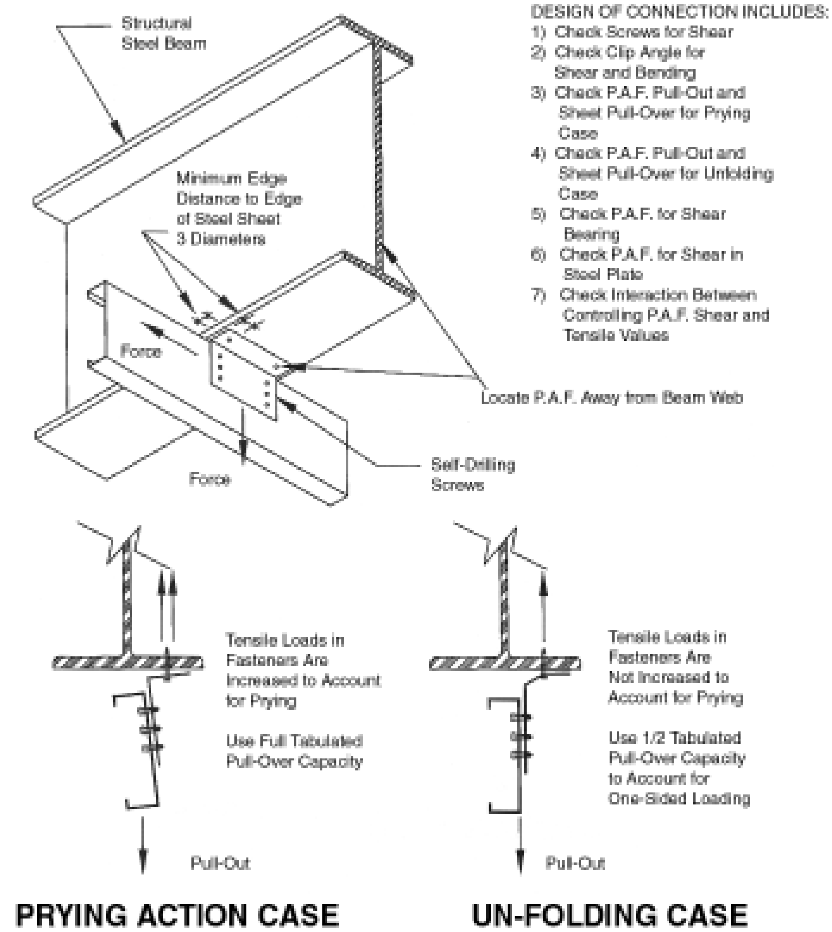
Choosing Powder Actuated Fasteners Over Other Connectors

Powder actuated fasteners are typically used for track attachment to slabs or structural steel beams. Their advantage is that they can be placed quickly into these hard substrates and have high shear capacities. Other types of fasteners may be used to attach to these substrates but typically involve more labor. Concrete screws or expansion bolts require predrilling, for example. Welding may be used to attach track to structural steel, but most framing crews do not have qualified welders. Also, welding equipment is less portable than a powder-actuated tool and may not be used in wet weather.

There are certain drawbacks to powder-actuated fastening. For example, screws or welding may be more appropriate for a hospital renovation where the firing of the powder-actuated tool may disturb patients. Powder-actuating fasteners are subject occasional problems during installation. If a fastener causes a large spall, the operator must drive a new pin away from the spalled area. If a connection must be confined to a small area of concrete, a fastener less prone to spalling may be appropriate. Because powder-actuated fasteners resist pullout primarily through friction, a designer may choose a mechanical connection such as an expansion bolt for tension connections or connections subject to fatigue. If there is a possibility of damaging post-tensioned strands, or if voids in precast hollow-core planks are present, the designer should consider welding the cold-formed steel framing system to embed plates rather than risk damaging the substrate with drive pins.

Clip Angle Using Powder-Actuated Fasteners

Figure 4



Once the designer has decided to use powder actuated fasteners, he or she must properly detail spacings and edge distances and determine whether the connection capacity is adequate for the given application. Minimum spacings and edge distances as shown in figure 1 must be maintained in order for the fastener to be driven without damaging the substrate. The capacity of the connection is based on the failure of the connected sheet or on the capacity of the pin within the substrate. Both the steel sheet and the substrate must be investigated. The design capacity is determined by the lower value.

Strength of attached sheet

The strength of a drive pin connection may be limited by the strength of the attached sheet. Although the AISI *Specification for Cold-Formed Steel* does not specifically address sheet failure of powder-actuated fasteners, it may be reasonable to assume that published values for screw attachment can be applied. A minimum edge distance of three diameters should be maintained to the end of the attached sheet.

When subjected to a shear load, the connected sheet(s) may experience a bearing failure mode. Because there are no recognized design equations to predict the bearing capacity of a powder-actuated fastener in a bearing connection, it is recommended that equation E4.3.1-2 and 3 from the AISI *Specification* be used. This recommendation is based on engineering judgment and limited proprietary testing. Allowable bearing values for typical drive pin shank diameters are given in table 1.

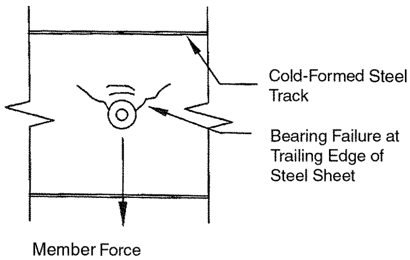
When subjected to tensile load, the connected sheet(s) may experience a pull-over failure mode. Because there are no recognized design equations to predict the pull-over capacity of a power actuated fastener in a connection, it is recommended that equation E4.4.2-1 from the AISI *Specification* be used. This recommendation is based on engineering judgment. Allowable pull-over values for typical drive pin head diameters and washer diameters are given in table 2.

Strength in Concrete

The strength of drive pins themselves has been determined by tests. Manufacturers publish technical data showing allowable loads for many styles of fasteners attached to different substrates. Drive pin strength in concrete is a function of drive pin diameter and length as well as concrete strength

Bearing Capacity of Steel Sheet Allowable Loads (lbs.)

Table 1



Design Sheet Thickness	Minimum Delivered Thickness	Drive Pin Shank Diameter		
		0.14"	0.17"	0.205"
0.0346 in.	33 mil.	196	238	287
0.0451 in.	43 mil.	256	311	374
0.0566 in.	54 mil.	321	390	470
0.0713 in.	68 mil.	404	491	592
0.1017 in.	97 mil.	577	700	844

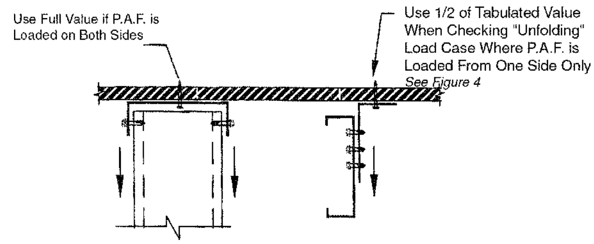
Notes: Based on ASTM A653 steel, Fy = 33ksi (Fu = 45ksi). For Fy = 40ksi (Fu = 55ksi), multiply tabulated values by 1.22. For Fy = 50ksi (Fu = 65ksi), multiply tabulated values by 1.44.

Values based on Equation E4.3.1-2 and 3 of the AISI *Specification for the Design of Cold-Formed Steel Structural Members*, 1996: P_{ns} = 2.7(t)(d)Fu

Based on a factor of safety of 3.

Pull-Over Capacity of Steel Sheet Allowable Loads (lbs.)

Table 2



Design Sheet Thickness	Minimum Delivered Thickness	Drive Pin Head or Washer Diameter			
		0.3"	5/16"	3/8"	1"
0.0346 in.	33 mil.	234	242	292	779
0.0451 in.	43 mil.	304	317	381	1015
0.0566 in.	54 mil.	382	397	478	1274
0.0713 in.	68 mil.	481	501	602	1604
0.1017 in.	97 mil.	686	715	858	2288

Notes: Based on ASTM A653 steel, Fy = 33ksi (Fu = 45ksi). For Fy = 40ksi (Fu = 55ksi), multiply tabulated values by 1.22. For Fy = 50ksi (Fu = 65ksi), multiply tabulated values by 1.44.

Values based on Equation E4.4.2.1 of the AISI *Specification for the Design of Cold-Formed Steel Structural Members*, 1996: P_{nov} = 1.5(t)(dw)Fu

Based on a factor of safety of 3.

and weight. A summary of allowable loads for drive pins in concrete is given in table 3. These values are based on tested strengths from three major manufacturers' ICBO reports of drive pins available at the time of this printing.

Strength in Structural Steel

Drive pin strength in structural steel is a function of pin diameter as well as plate thickness and grade. As noted earlier, drive pin length should be sufficient to fully penetrate the steel plate. A summary of allowable loads for drive pins in structural steel is given in table 4. These values are based on tested strengths from three major manufacturers' ICBO reports available at the time of this printing.

Strength in Concrete Masonry Unit Construction

Data on drive pin strength in CMU construction is more limited that that for other substrates. Drive pin strength in CMU construction is a function of whether the wall is grouted or not, and whether the pin is fastened to the face of the CMU or to the mortar joint. Ideal placement is within the horizontal mortar joint. Allowable loads for drive pins in CMU construction are given in table 5. These values are based on tested strengths from the one manufacturers' ICBO report that contains published values at the time of this printing.

Note on Allowable Fastener Loads

The allowable loads published in tables 3,4 and 5 were compiled based on the lowest ICBO published values from three major manufacturers. These tables are presented to aid the designer who wishes to specify a fastener by diameter, penetration, washer size, and shank type only. In this case, the contractor could select the manufacturer of the fastener. Alternately, the designer may wish to specify a particular manufacturer's fastener. In this case, the designer may often find larger allowable loads in that manufacture's ICBO report. Some fasteners, although similar to others, have unique advantages that result in larger allowable loads. In other cases, values for some manufacturer's fasteners may benefit from a lower factor of safety due to a larger test sampling size or a lower coefficient of variation of test results.

Connection Design

Figures 1 and 4 show some typical uses of powder actuated fasteners. Once the capacity of an individual fastener and

Capacity of Drive Pins in Concrete Allowable Loads (lbs.)

Table 3

Shank Diameter	Minimum Penetration	Loading Type	Concrete Compressive Strength 2000 psi	3000 psi	4000 psi
0.14"	3/4"	Pullout	45	70	80
		Shear	90	95	95
0.14"	1-1/4"	Pullout	110	155	185
		Shear	155	165	165
0.17"	1-7/16"	Pullout	135	145	200
		Shear	225	240	260
0.205"	1-1/4"	Pullout	165	165	200
		Shear	220	220	320

NOTES:
1. Based on lowest published values for three major manufacturers. Reference ICBO reports #2388 (1995), #1639 (1995), #5330 (1999), and #4546 (2001).
2. Values based on low-velocity shot in stone aggregate.
3. Minimum spacing is 4", minimum edge distance is 3".
4. Values used for design may not exceed the capacity of the attached steel sheet in bearing and pull-over.
5. Use concrete strength at time of installation.
6. Concrete thickness must be three times as long as the fastener, minimum.
7. Based on a minimum factor of safety of 5.

connected sheet are known, the designer must carefully assess all loads acting on a connector group. Bottom track connections, as shown in figure 1, carry shear loads only. In this case, a required spacing may be determined by dividing the fastener capacity by the uniform load along the base of the wall. The top deflection track carries shear as well as a small amount of tension. Where shear and tension act on a fastener, interaction should be checked as shown below as recommended in the *Acceptance Criteria for Powder-Driven Fasteners in Concrete, Steel and Masonry Elements*, ICBO Report AC70:

$$(P/P_a)+(V/V_a) < 1$$

Where
P and P_a are the applied and allowable tension loads
and
V and V_a are the applied and allowable shear loads.

Capacity of Drive Pins in Structural Steel Allowable Loads (lbs.)

Table 4

Shank Diameter	Shank Type	Loading Type	Steel Plate Thickness 1/8"	3/16"	1/4"	3/8"	1/2"
0.14"	Smooth	Pullout	75	80	125	285	375
		Shear	420	395	575	250	690
0.14"	Knurled	Pullout	55(70)	130(165)	240(265)	370(300)	440(325)
		Shear	110(270)	285(365)	460(465)	680(660)	605(725)
0.17"	Smooth	Pullout	115	85	180	330(320)	280(340)
		Shear	540	740	625	780(745)	810(990)
0.17"	Knurled	Pullout	350	165	210	340	515
		Shear	295	585	585	295	995
0.205"	Knurled	Pullout	---	200	265	550	445
		Shear	---	750	1500	1540	1100

NOTES:
1. Based on lowest published values for three major manufacturers. Reference ICBO reports #2388 (1995), #1639 (1995), #4546 (2001), and #5330 (1999).
2. Minimum spacing is 1-1/2", minimum edge distance is 1/2".
3. Based on A36 steel substrate. Values in ( ) are for ICBO report #2388 (1995) values for A572 Gr50 steel substrate
4. Values used for design may not exceed the capacity of the attached steel sheet in bearing and pull-over.
5. Based on a minimum factor of safety of 5.

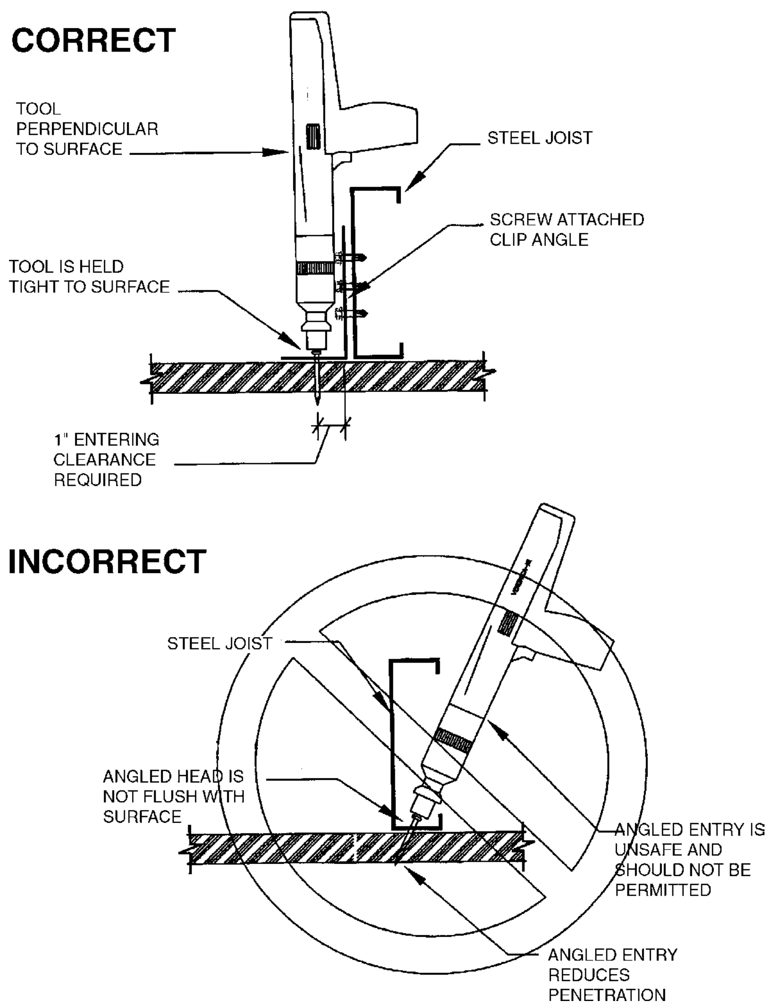
Shear and tension also act on the fasteners shown in figure 4. However, the one-sided loading in this clip angle connection requires checking two failure mechanisms. In one check, "prying action" magnifies the tensile load in the fasteners and the full pull-over capacity of the steel sheet is assumed. In the second check, "unfolding action" does not increase the tensile load in the fasteners, but only half of the sheet pull-over capacity is assumed. Allowable loads should not be increased for short-term loading. Connections should be designed to permit proper entering clearances for the powder-actuated tool as shown on figure 5. Angled entry of fasteners is unsafe for the tool operator and will result in lower fastener strength.

Capacity of Drive Pins in Concrete Masonry Units
Allowable Loads (lbs.)
Table 5

Shank Diameter	Minimum Penetration	Loading Type	Hollow CMU		Grouted CMU	
			Face	Mortar Joint	Face	Mortar Joint
0.145"	1"	Pullout	35	45	90	150
		Shear	65	70	130	115

1. Based on lowest published values for one manufacturer. Reference ICBO report #2388 (1995).
2. Values used for design may not exceed the capacity of the attached steel sheet in bearing and pull-over.
3. Based on ASTM C90 grade N masonry and type M mortar.
4. No more than one fastener may be installed in an individual cell.
5. Face shell thickness shall be a minimum of 1-1/4".
6. Based on a minimum factor of safety of 5.

Tool Entering Clearance
Figure 5



References

1. *Acceptance Criteria for Powder-Driven Fasteners in Concrete, Steel and Masonry Elements*, ICBO Report AC70, September 1995, Effective April 1, 1996.
2. *Fasteners for Residential Steel Framing*. American Iron & Steel Institute Publication RG-933, June 1993
3. ICBO Report 2388, ICBO Evaluation Services, Reissued November 1, 1995.
4. *Powder Actuated Fastening Systems Basic Training Manual*. Powder Actuated Tool Manufacturers' Institute Inc. 1991.
5. ICBO Report 5330, ICBO Evaluation Services, Reissued October 1, 1999.
6. ICBO Report 1639, ICBO Evaluation Services, Reissued December 1, 1995.
7. *Specification for the Design of Cold-Formed Steel Structural Members*. The American Iron and Steel Institute, 1996.
8. ICBO Report 4546, ICBO Evaluation Services, Issued April 1, 2001.

Author of this Tech Note: John C. Lyons, P.E., Associate
Walter P. Moore and Associates