THE STUDY OF SCREWS UNDER BENDING FOR CURTAIN WALL HEAD AND SILL ANCHORS APPLICATIONS

by

HUMBERTO MADERO MCENTEE

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Civil Engineering at
The University of Texas at Arlington
May, 2017

Arlington, Texas

Supervising Committee:
Dr. Nur Yazdani, P.h.D., P.E
Dr. Xinbao Yu, P.h.D
Dr. Suyun Ham, P.h.D

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

During my Graduate studies at UTA Dr. Nur Yazdani always welcome me as my advisor teacher to guide me to the best careers goals for my personal aspirations, he was also my teacher on the courses Concrete Bridge Design and Structural Timber Design; his courses where very interesting and rich in knowledge, I enjoy being his student and his classes always had a special touch of creativity and enthusiasm. I thank Dr. Nur Yazdani for all his support during all the phases of developing my thesis, his interest in the subject, his critics, and his concerns; I also thank him for his support on facilitating me the use of the Civil Engineering Laboratory and the fabrication of the test support, I also thank to the Graduate student Timothy Kruzic for helping me in the use of the testing machine in the Civil Engineering Lab.

Special thanks to all my teachers, even that they didn't participated in the thesis I would like to mention them here; thanks to Dr. Yeol Choi for the class of Advance Concrete Design, Mr. Tansil Chris for the class of Advance Steel Design, Dr. Seyed Mohammad Razavi for his class of Advanced Mechanics of Materials, Dr. Abolmaali Seyedali for his class of Introduction to Finite Element, Dr. Yeonho Park for his class of Advanced Structural Analysis and Dr. Xinbao Yu for his class of Foundation Analysis and Design.

DEDICATION

I thanks to my wife Rosario and daughters Andrea and Marian for her support and inspiration during my studies, to my parents Humberto and Eileen to whom I own all what I know and I am, my brothers and relatives; and special thanks to the friends that found on my way, because they represent the voice of god telling me “I love you”.

LIST OF FIGURES

CHAPTER 4 – SCREWS FAILURE

LIST OF TABLES

ABSTRACT

THE STUDY OF SCREWS UNDER BENDING
FOR CURTAIN WALL HEAD AND SILL
ANCHORS APPLICATIONS

Humberto Madero McEntee, MSCE

The University of Texas at Arlington, 2017

Supervising Professor(s): Nur Yazdani

The study of screws under bending is a very important topic for the solution of anchors (connections) of the vertical members of a Curtain Wall or Storefront that connects top and bottom thru Head and Sill anchors. When there are shims that create a gap between the connected anchor and the structure that connects to, the screws connecting the anchor to the structure would be under bending; very few or any tests are available showing the capacity of a screw under bending; this thesis would present tests and theory of screws under bending, and discussion/clarification of the behavior of these screws under bending due to the use of shims.

CHAPTER 1

INTRODUCTION

High rise buildings and mid rise buildings are typically enclosed by what is called a curtain wall facade system as shown on Fig. AA.1

Fig. AA.1 – Curtain Wall

Curtain wall, also called glass facade or glass envelope, refers to the outer covering of the building created to keep the weather forces out. They are composed of light weight material, including aluminum frames with glass and metal panels. The use of glass in curtain wall helps in deeper penetration of light within the building and creation of a pleasant architectural design. The modern day curtain wall uses glass as an exterior facade and offer an advantage of rapid on site assembly, wish significantly reduces construction costs.

Besides looking exquisite, glass curtain walls offer protection against wind, water and other environmental forces that may otherwise spoil the interior of the building.

There is another system called storefront system, and this is typically an aluminum frame that is attached at the top with a head anchor and at the bottom with a sill anchor; the storefront system is typically found at the lower level of a building as shown on Fig. AA.2

Fig. AA.2 – Storefront

A **storefront** or **shopfront** is the facade or entryway of a retail store located on the ground floor or street level of a commercial building, typically including one or more display windows. A storefront functions to attract visual attention to a business and its merchandise.

Before the middle of 19th century, shop fronts did not have large display windows, but often included features such as awnings and bay windows to attract the attention of passersby. Modern storefronts with display windows developed at mid-century after architectural cast iron became widely available and glass manufacturers began producing large panes of glass at a relatively low cost.

The characteristic of a Storefront is that is a unit that is assembled on site, and is anchored at top and bottom with a head and a sill anchors; those anchors are attached to the structure either with self drilling screws when they are anchored into steel or light framing structure, or with concrete screws when they are anchored into concrete structure. The main load that a storefront is designed for is the wind load.

The title presented on this thesis is the Study of screws under bending for Curtain Wall head and sill anchors applications.

The sketch on Fig. A.1 shows a schematic drawing per AAMA 2501-01 of an anchor sill connection, it shows the different substrates to wish it can be connected, our study would concentrate on a steel substrate.

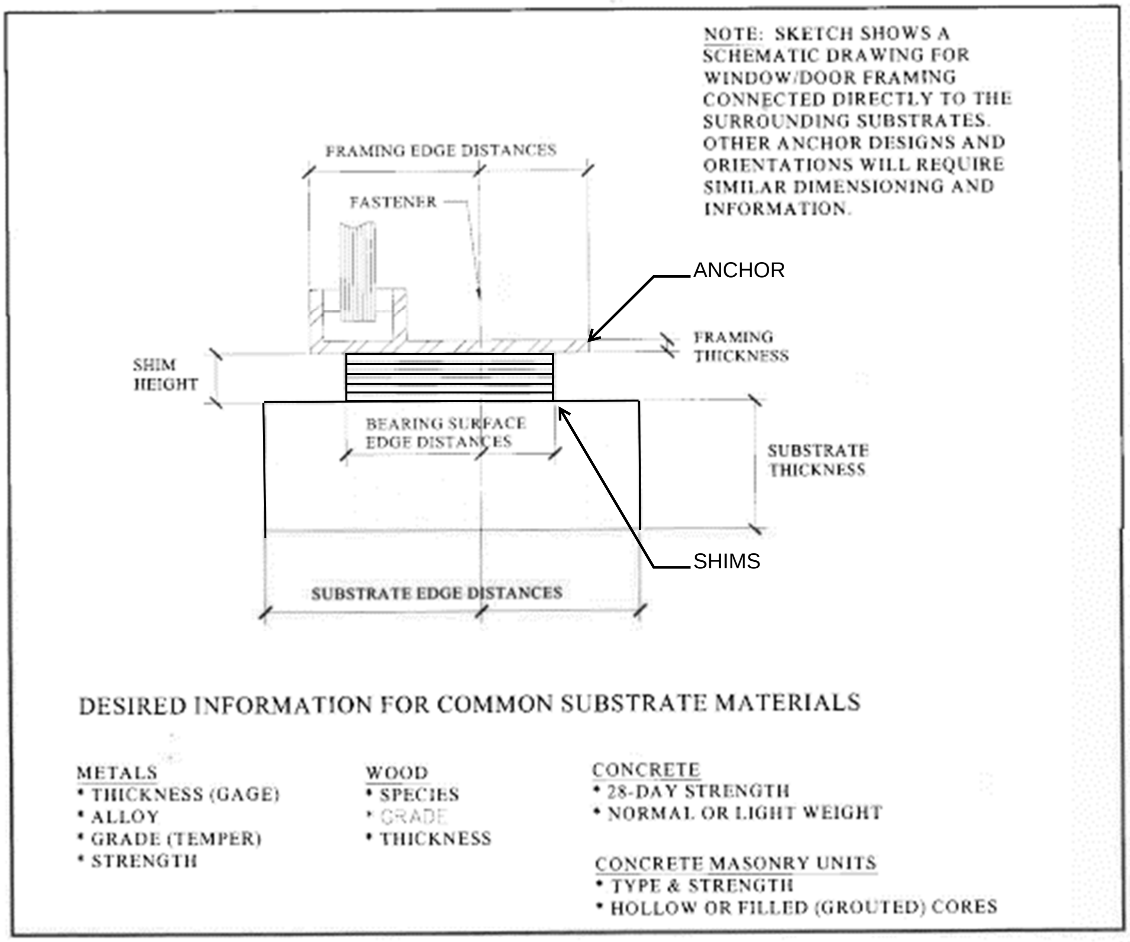


Fig. A.1 – Schematic Connection

This sketch shows a sill connection, it shows the location of the shims and the substrate; it can be noted that to connect the frame, the screws connecting the frame have to go thru the shims and into the substrate, as would be shown on the next examples.

With the use of shims at the anchors connections some eccentricities may create a bending moment on the screws; these screws under bending are typically found at the head anchor and at the sill anchors of the curtain wall or storefront system; as shown on the next pages some examples of head Anchors and sill anchors attaching the aluminum frame structure to a steel structure are shown:

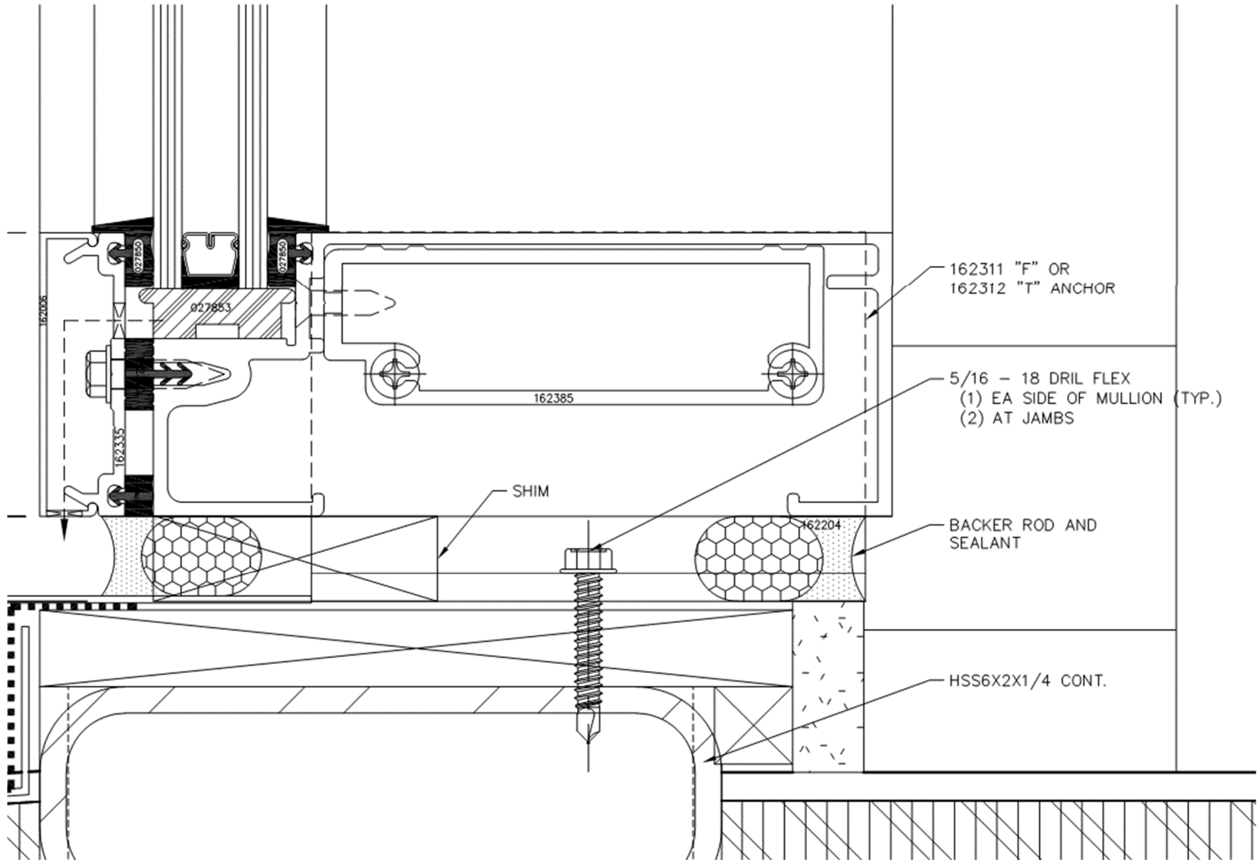


Fig. A.2 - SILL ANCHOR INTO STEEL

On this detail a T anchor is attached to a steel tube with 5/16” screws, and there is a shim of about ¾” in between the steel tube and the T anchor; the screws would be under bending due to the shims.

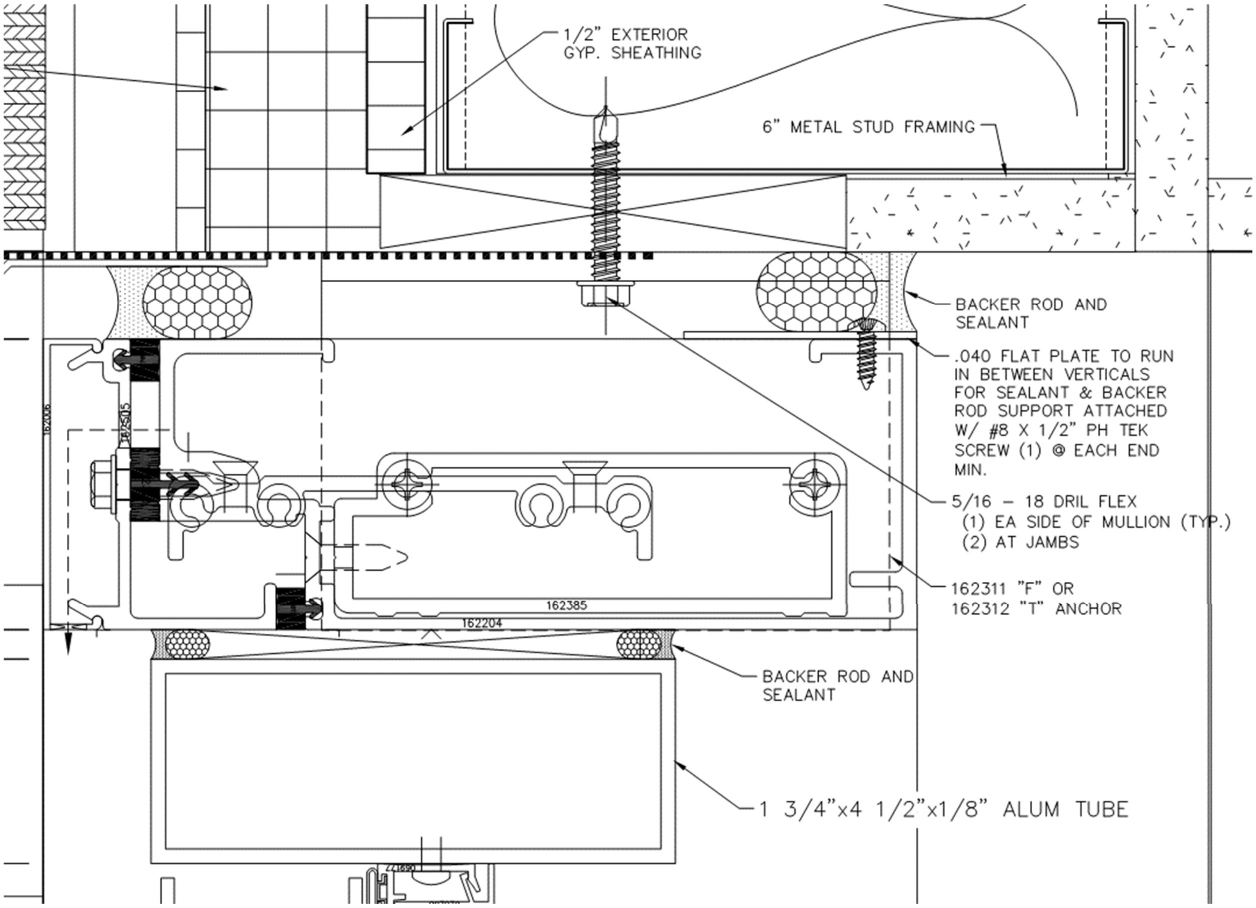


Fig. A.3 - HEAD ANCHOR INTO LIGHT GAGE

This examples shows a head anchor attached with screws to a light gage stud frame; typical the light gage is a 16 Gage, and there is a shim in between the T anchor and the light gage, there is doubt on if these screws are under single bending or under double bending; and also wish diameter of the screw should be used to calculate the section modulus of the screw, either the nominal diameter or the internal thread diameter; the use of the internal thread diameter would be conservative.

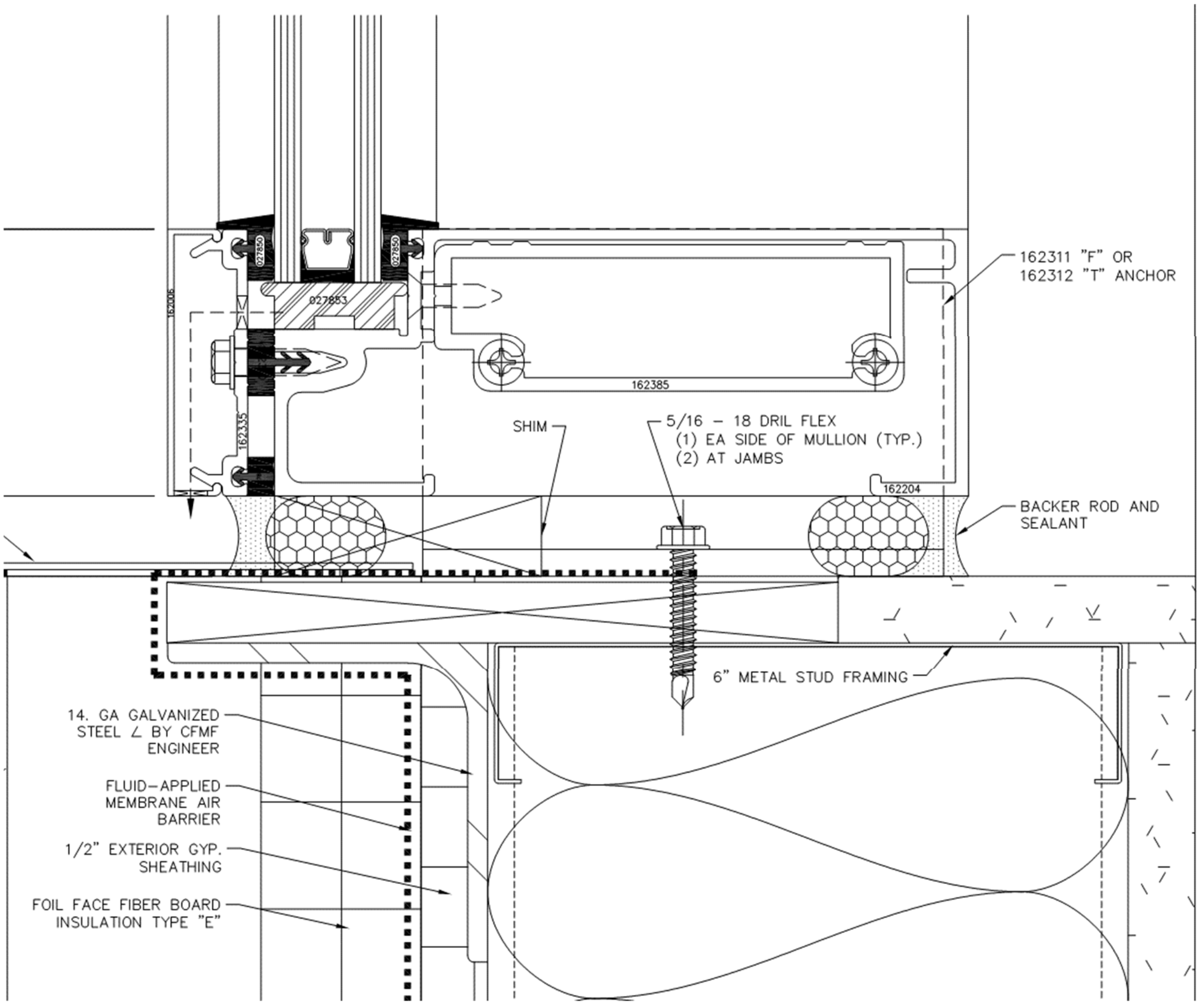


Fig. A.4 - SILL ANCHOR INTO LIGHT GAGE

This is a similar example for a sill anchor condition.

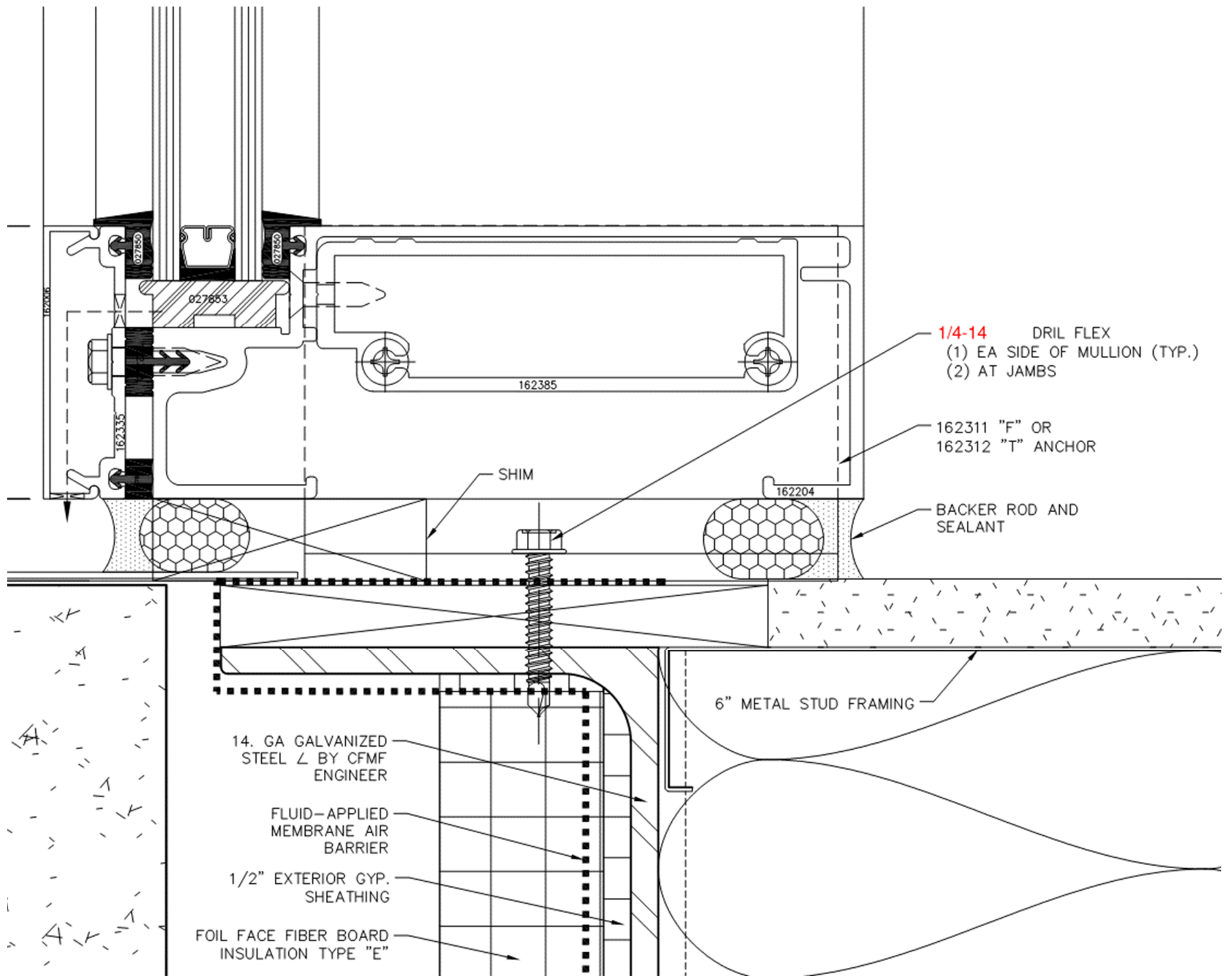


Fig. A.5 - SILL ANCHOR INTO STEEL

This would be the same case as A.1 going into a steel angle instead of a tube; the tests performed in the Civil Engineering Lab would directly apply to this anchor condition.

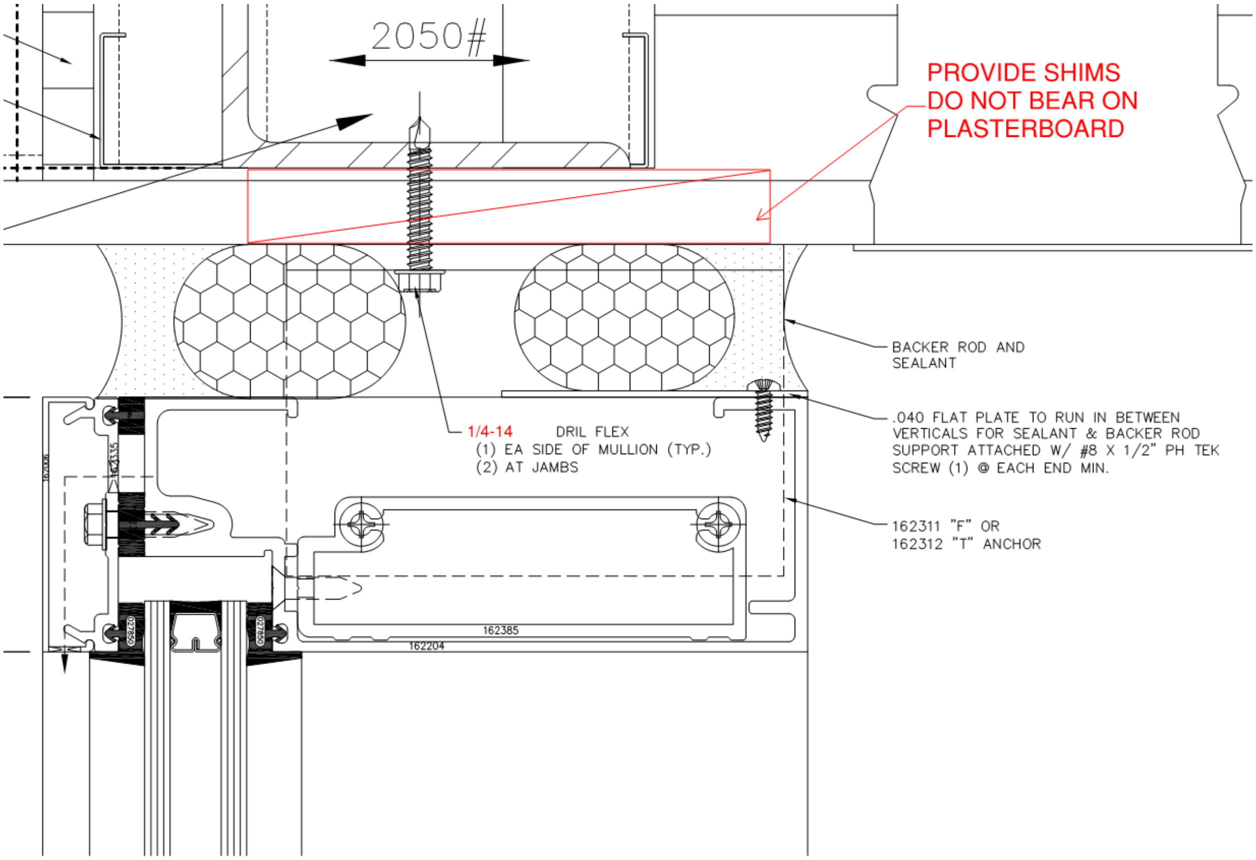


Fig. A.6 - HEAD ANCHOR INTO STEEL

This detail shows the same condition but applied to a head detail; the results from the Laboratory would directly apply to this example.

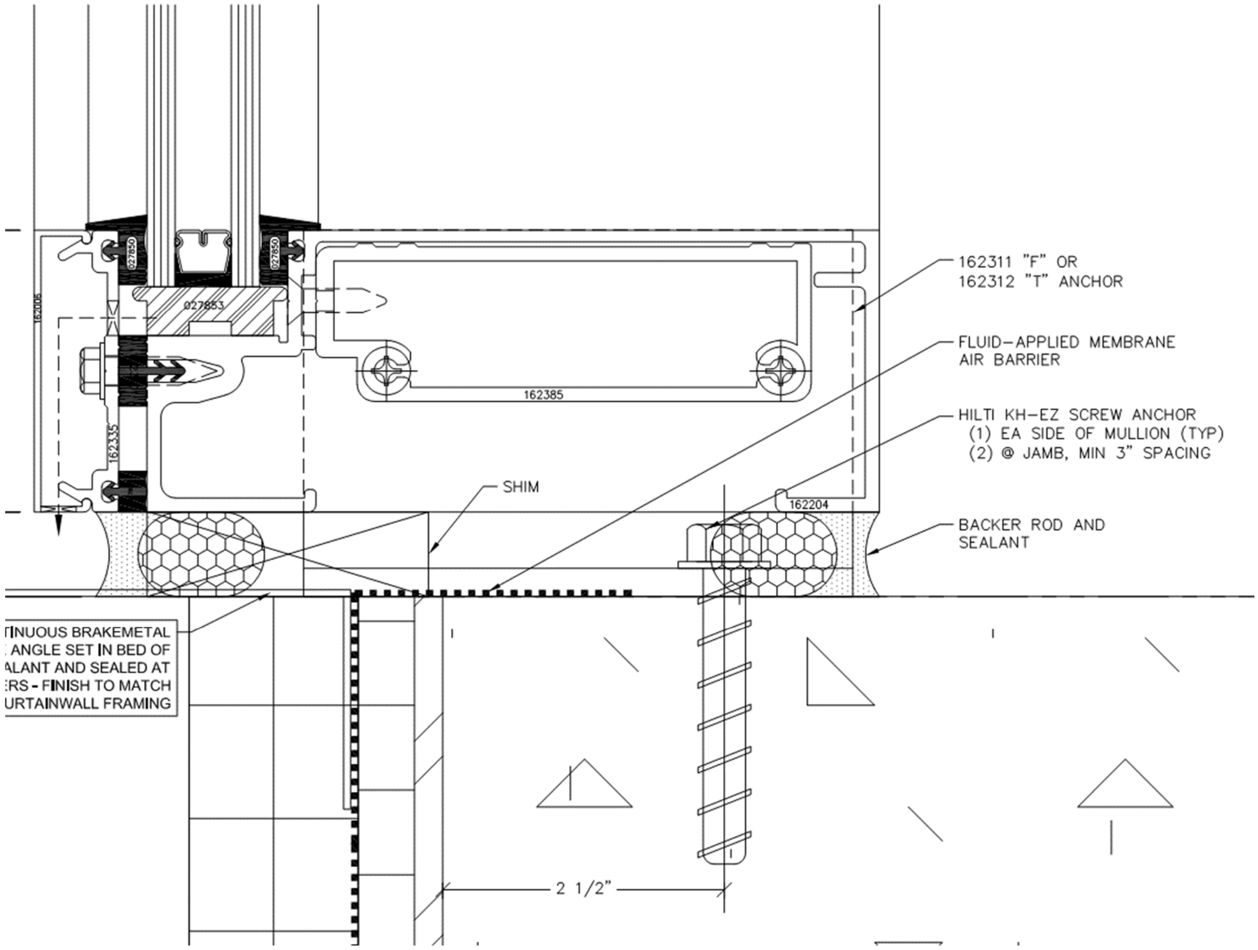


Fig. A.7 - SILL ANCHOR INTO CONCRETE

On this detail is shown that the anchor is attached directly to the concrete without any shims, this would be the case of direct shear with no shims and no bending on the screw.

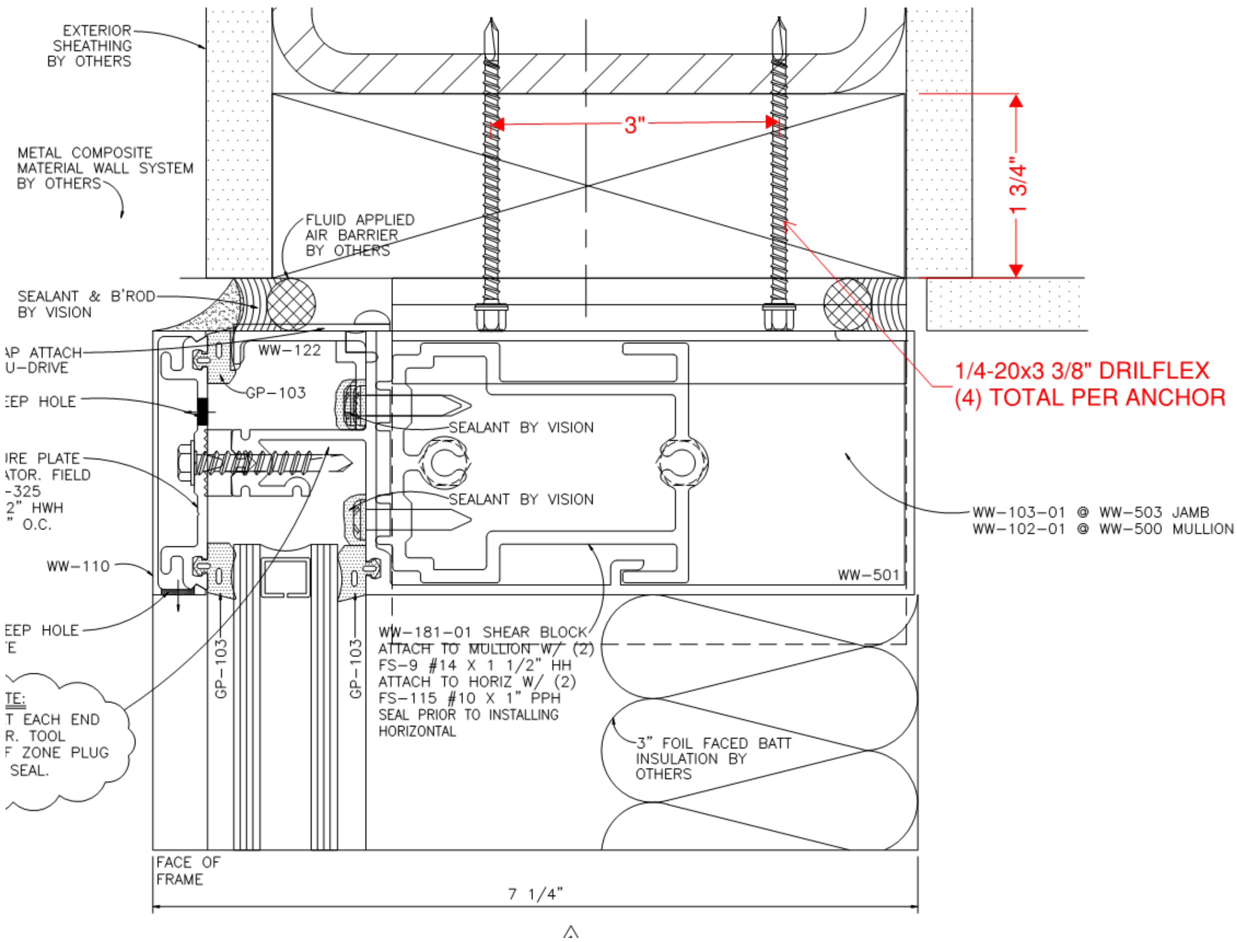


Fig. A.8 - HEAD ANCHOR INTO STEEL

This detail shows an anchor with a wood block, in this case the wood block is considered to be working as a shim, and the screws would have a big bending with 1 ¾” of bending span.

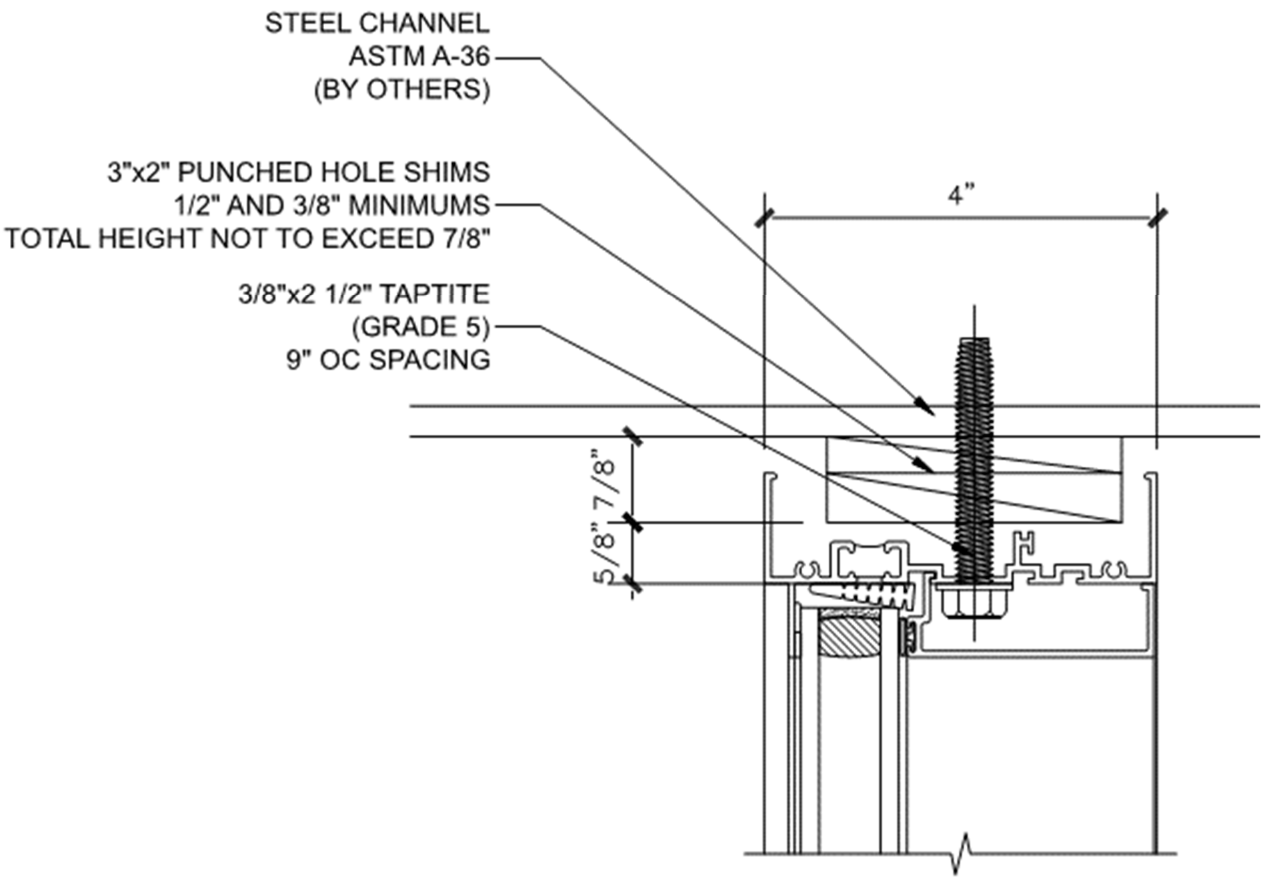


Fig. A.9 - HEAD ANCHOR INTO STEEL

This is another example of a screw under bending, this would be considered a single bending or a cantilever because the material attached to the head of the screw is not capable of bending the head of the screw.

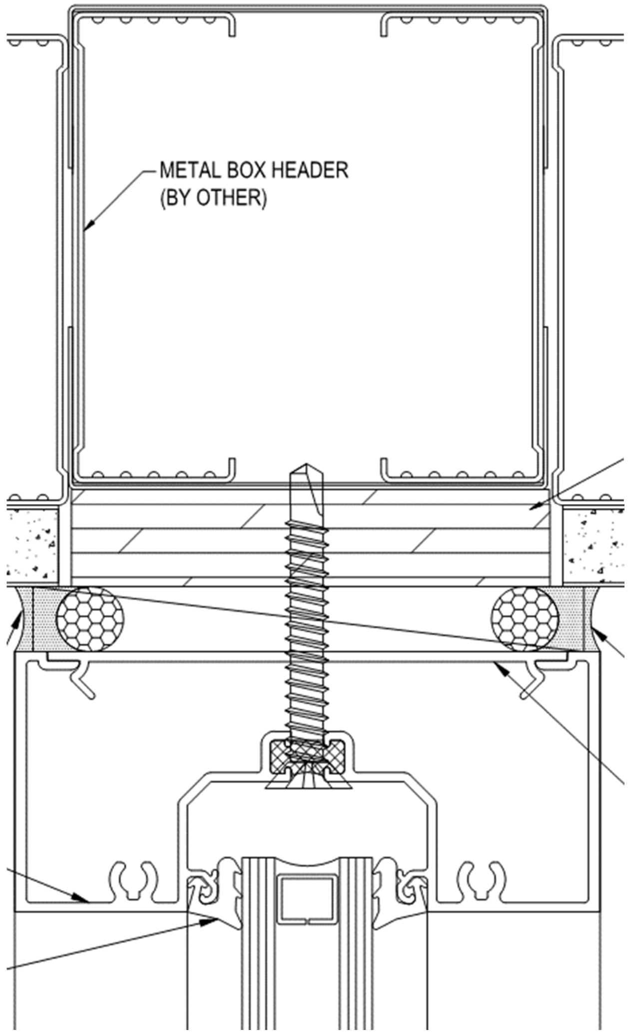


Fig. A.10- HEAD ANCHOR WITH SCREWS UNDER LARGE BENDING

This head anchor has screws under large bending moment going into light gage; this detail has a mistake, the screw is a self-drilling screw going into plywood; self-drilling screws are only for steel or light gage, if the plywood has enough capacity to take the load, instead of using a self-drilling screw, a wood screw or lag screw should be used, if the intention is to attach to the light gage, then a longer screw should be use.

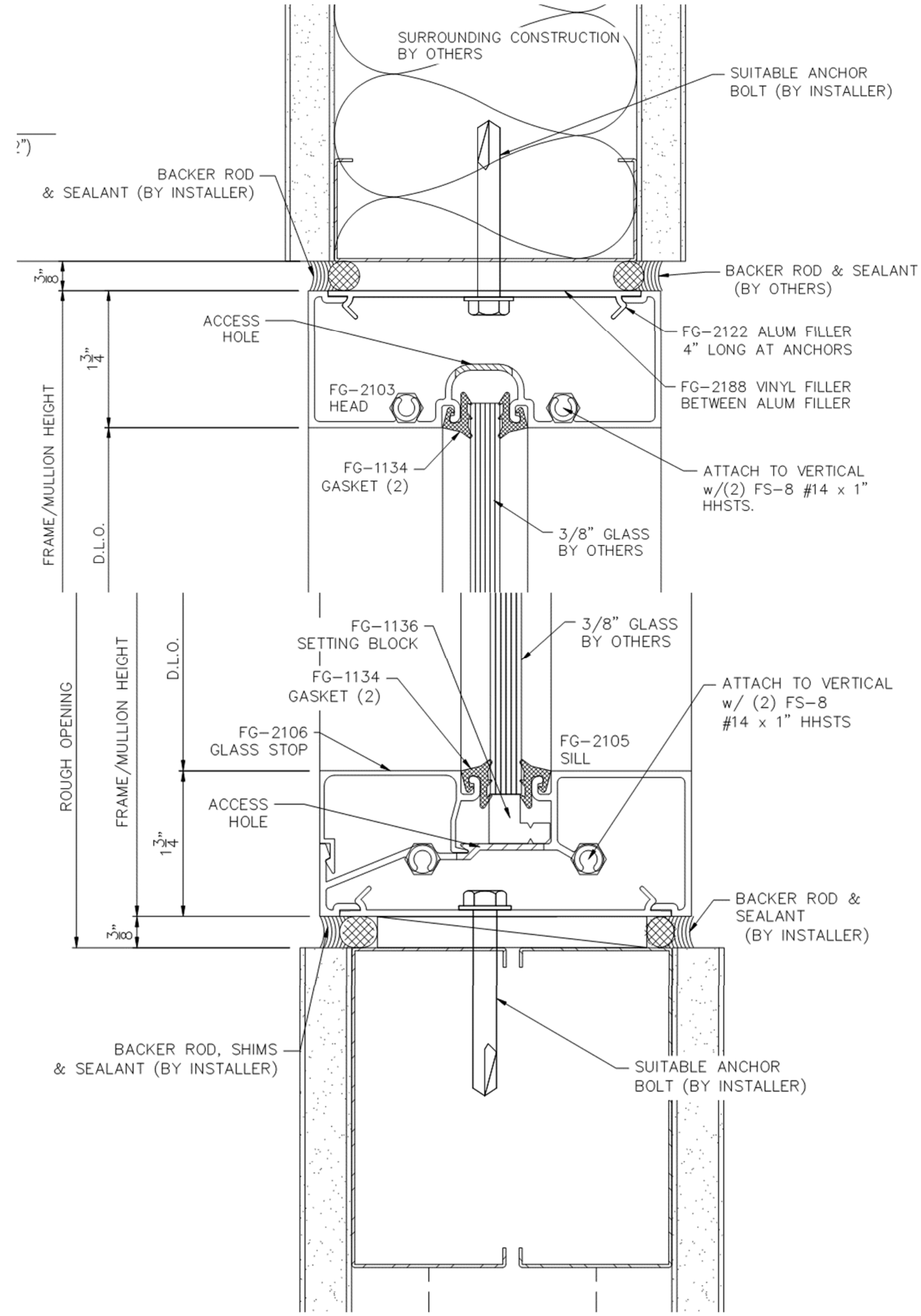


Fig. A.11 - HEAD AND SILL ANCHOR INTO LIGHT GAGE WITH (3/8" PLASTIC SHIM)

On this system there is one or two screws at each side of the vertical element, the screws are under double bending for 3/8" span.

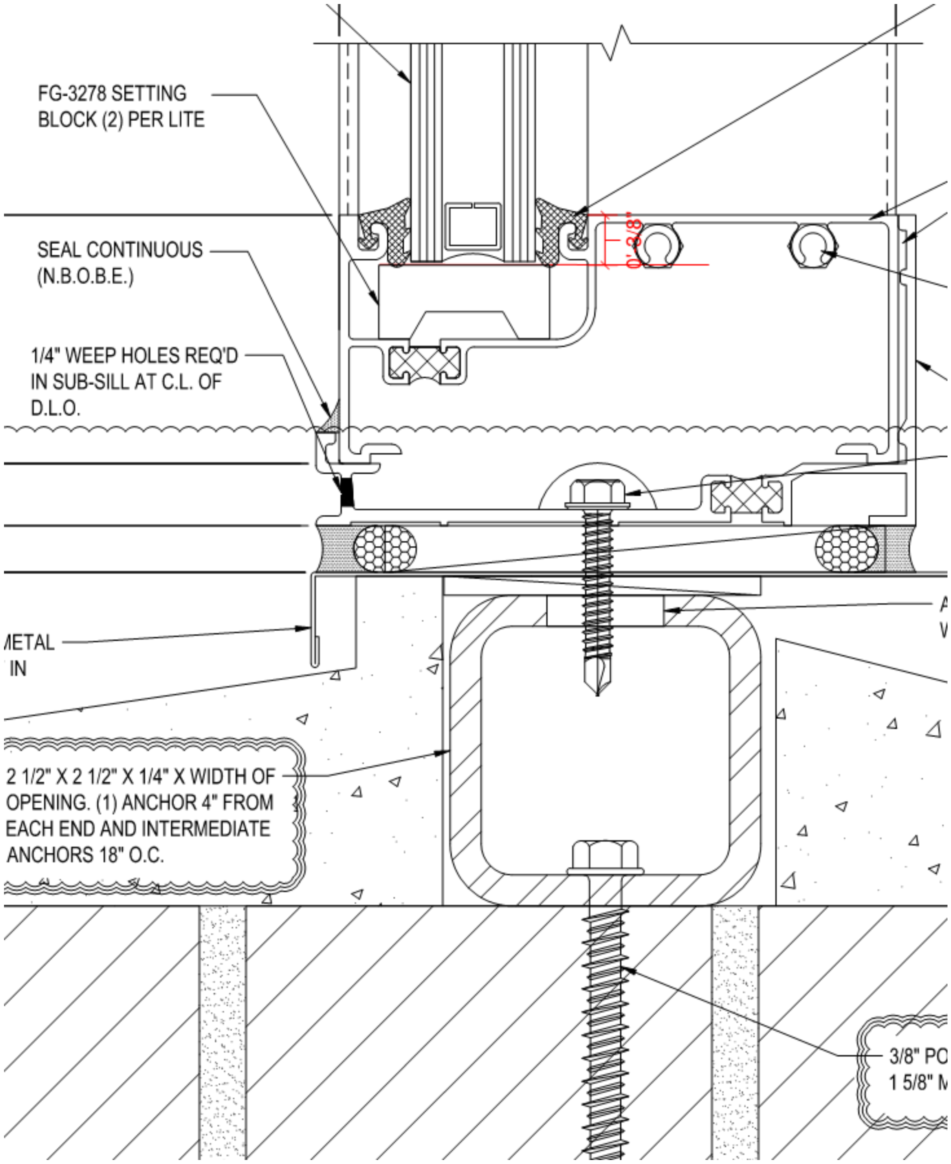


Fig. A.12 - SILL ANCHOR INTO A STEEL TUBE

This anchor shows a screw under double bending going into steel, our tests on the lab apply directly to this test, on this anchor the steel tube is first installed directly over the brick with concrete screws, the window is attached with one or two screws on each side of the vertical element.

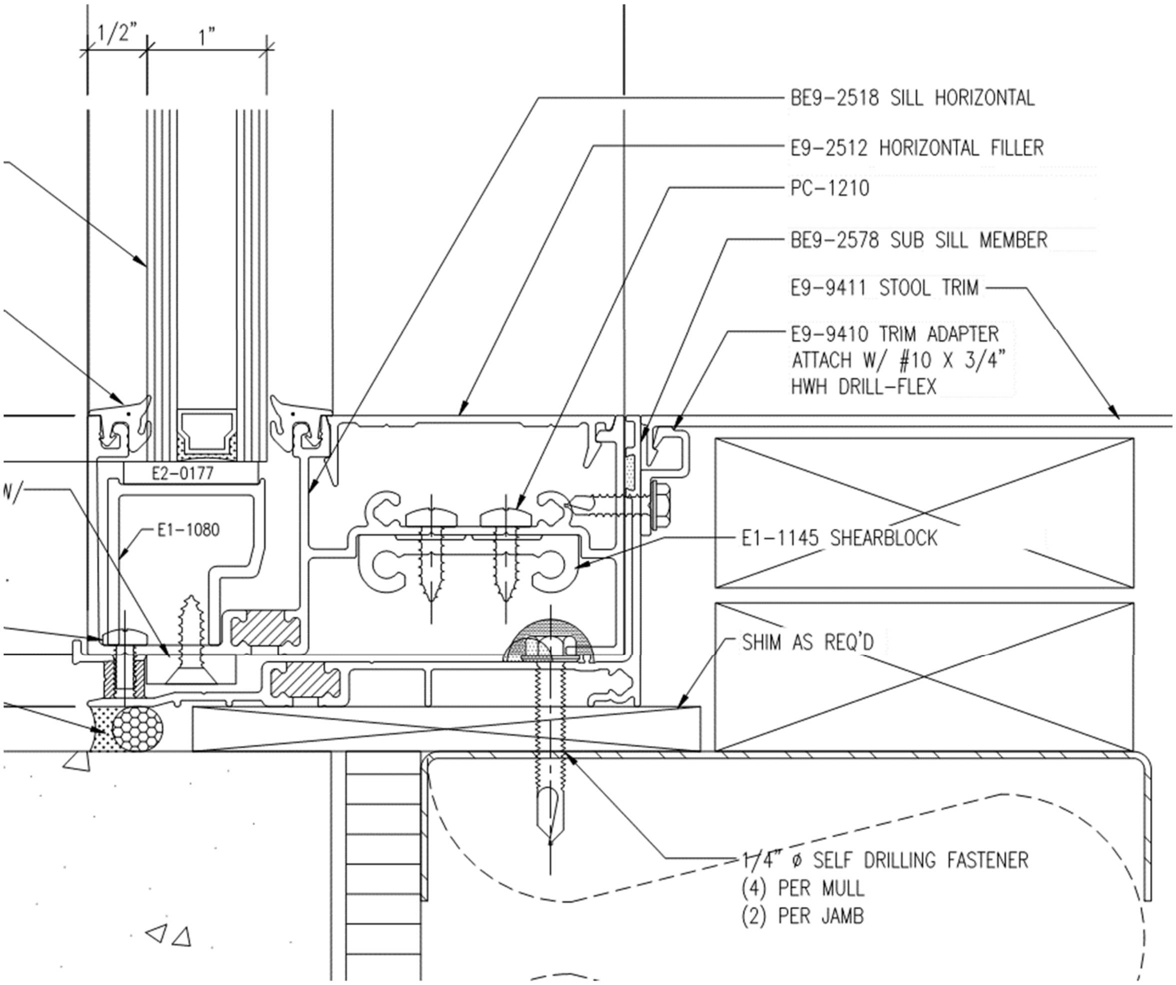
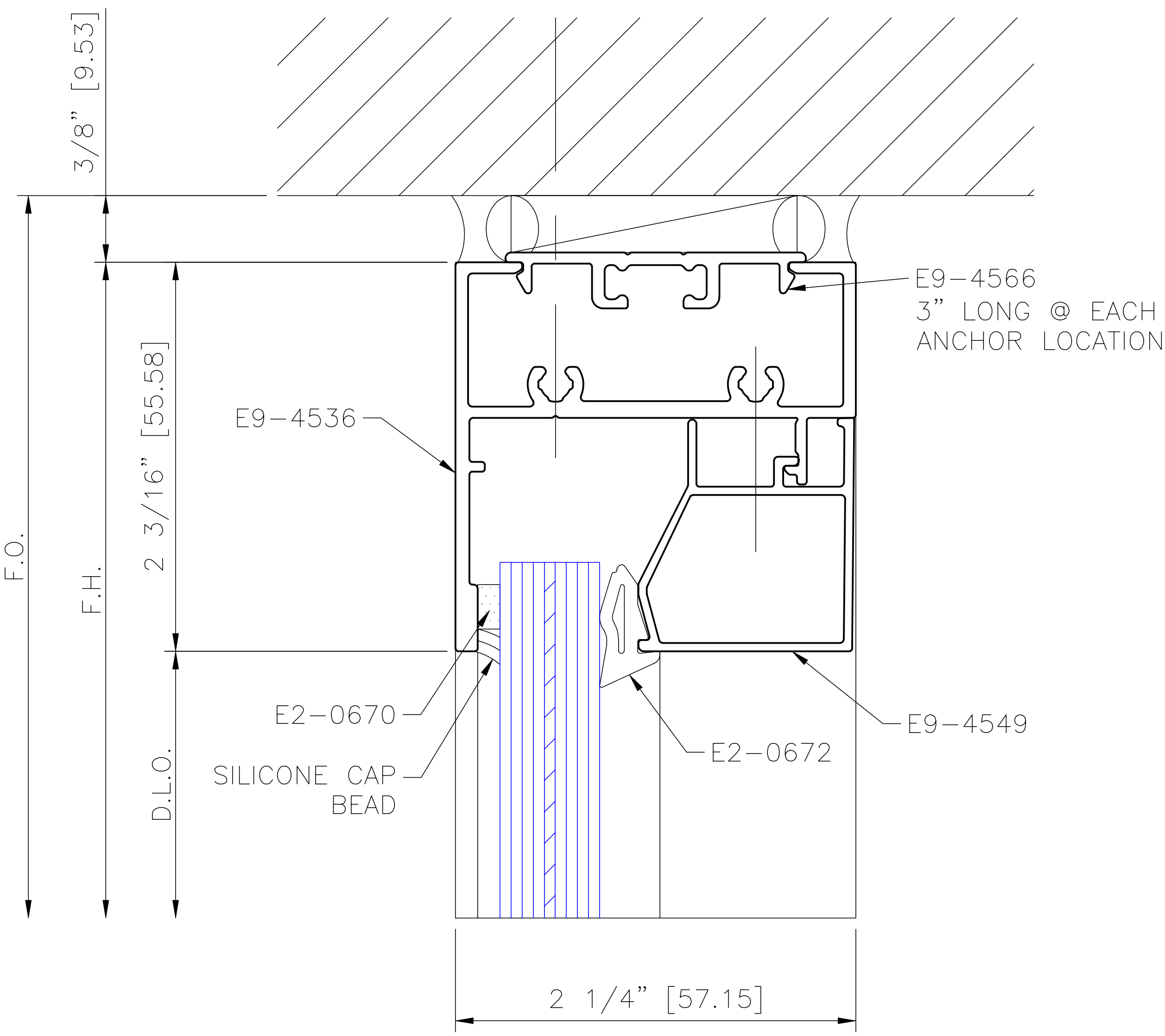
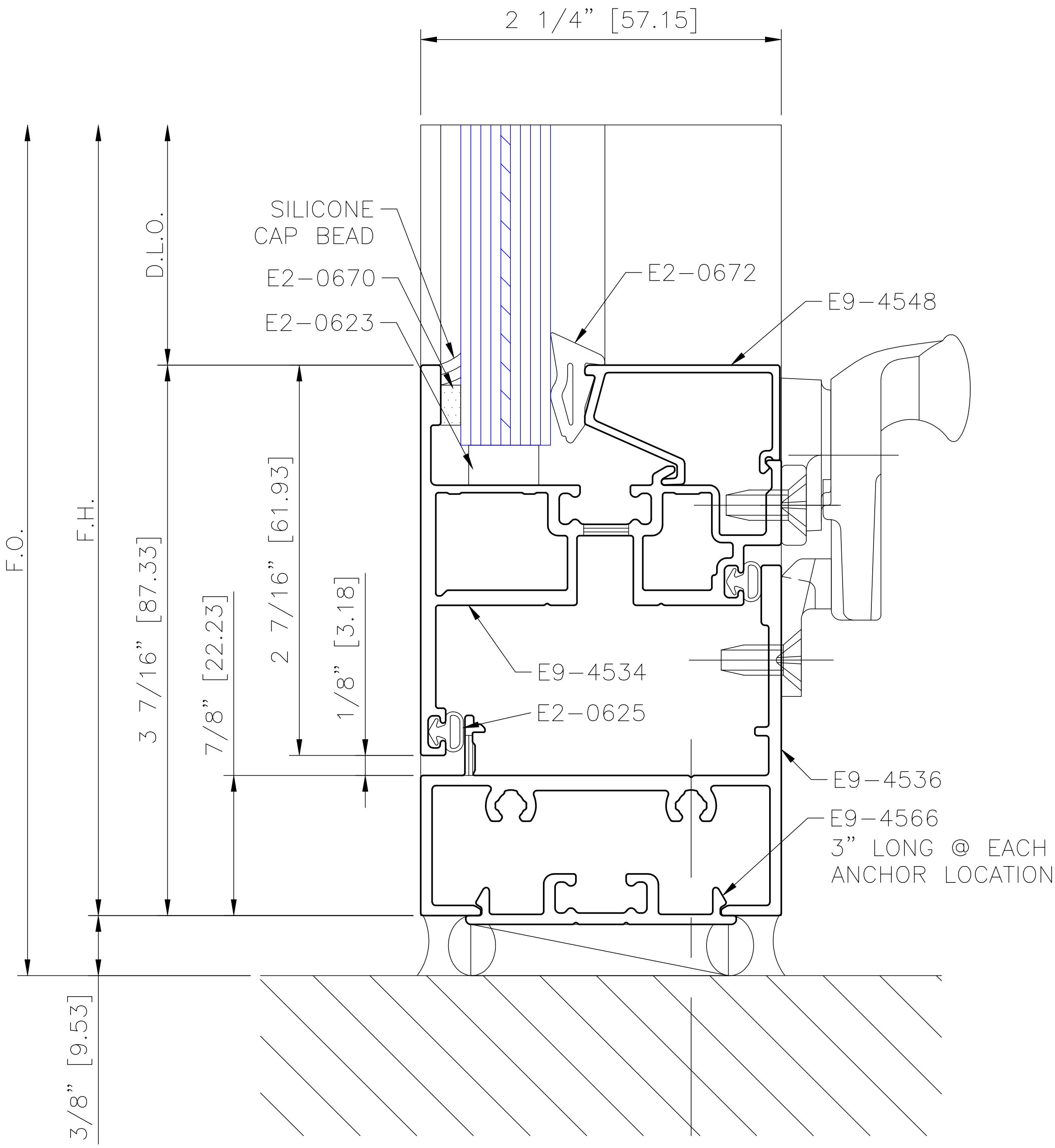


Fig. A.13 - SILL ANCHOR INTO LIGHT GAGE

In this example the screws have a 3/8" shim plus 3/8" void space between the screw head and the shim, making a total of ¾" of eccentricity for bending, in this case if the shim is a hard plastic shim with a close fit hole, the shim would help to reduce the eccentricity.

The next pages would show some other details of a manufacturer called YKK AP showing some of their head and sill connections with shims, and it can be seen with a dashed line the location of the screws to attach thru the shims; these screws would be under bending, applicable to this thesis.


3/8" [9.53]
F.O.
F.H.
2 3/16" [55.58]
D.L.O.
E9-4566
3" LONG @ EACH
ANCHOR LOCATION
E9-4536
E2-0670
SILICONE CAP
BEAD
E2-0672
E9-4549
2 1/4" [57.15]


2 1/4" [57.15]
SILICONE CAP BEAD
E2-0670
E2-0623
E2-0672
E9-4548
D.L.O.
F.O.
F.H.
3 7/16" [87.33]
2 7/16" [61.93]
7/8" [22.23]
1/8" [3.18]
E9-4534
E2-0625
E9-4536
E9-4566
3" LONG @ EACH ANCHOR LOCATION
3/8" [9.53]

This work would mainly benefit curtain wall Engineers, also would benefit Structural Engineers that may find another application of the study on different design of elements that have fasteners under bending, such as steel, wood or concrete connections.

This work would also benefit teachers of the Structural Engineering area to present basic equations applied to real job applications.

The main purpose of the study is to solve the doubt about if the screws when attached into steel, with the use of shims would bend in a single bending or in a double bending condition.

The other purpose is to solve the doubt about the diameter to use for designing of screws under bending, is the nominal diameter can be used, or the internal threads diameter.

SEARCH OF EXISTING STUDIES

Prior to selecting the thesis title, research was made in order to see if other similar studies where available, the following key words where used when doing such research.

Key words:
Bolts with shims – Nothing Found
Screws with shims – Nothing Found
Plates attached with screws – Car Plates Found
Steel Plates attached with screws – Nothing Found
Screws under Bending - Found information, but most of these studies are applied to the medical area, like screws to attach bones, screws for surgical applications, screws for surgical plating for wish our study could be of interest.
Curtain Wall Screws under Bending – Found information related to Curtain Wall installation and a few design procedures, but nothing similar to the planned thesis studies.

Studies Found:
"Modeling Bicortical Screws under a Cantilever Bending Load", By Thomas P. James & Brendon Andrade.
Abstract: As the frictional contact between the plate and the bone is lost, cantilever bending loads are transfer from the plate to the head of the screw.

"Effect of Screw Insertion Torque on Push-Out and Cantilever Bending Properties of Five Angle-Stable Systems", By Alessandro Boero Baroncelli, DVM, PhD
Abstract: Locking plate systems in surgery applications reduce the bending on the screws because the head of the screw locks inside the plate preventing the screw from bending in the thickness of the plate, this study shows that the torque does not makes much difference in the shear capacity of the screw for the different types of lock-plates, then the screws are tested with an eccentricity of 2mm, that is when the plate loses the friction between the bone, small enough to create bending on the screw, wish reduced the screw shear capacity about 20 to 30%.

"Understanding Screw Breakage", By Jim Franklang
This article explains that typically a screw fails in bending, not because over torque; and explains that when a screw is under bending, it´s tensile strength reduces to 40% it´s capacity, but there were no test performed.

“CWCT Curtain Wall Installation Handbook”

Provides some shims description and mentions the bending on screws due to shims, but does not provides any test or example.

“Specifying Metal Curtain Wall Fasteners¨, By Dean Lewis.

Gives a general description of what a curtain wall system is, what kind of loads are resisted by the system, and how these are transferred to the screws, also provides a description of where to find screws properties, but does not show any kind of results of screws under bending.

“CMCT Curtain Wall Installation Handbook”,

Describes the installation procedure, there are few lines that talk about the importance of the design of the maximum shim thickness, but does not provide nothing similar to our study. (The goal of our study is to proof that the actual shim thickness for a screw in bending is much less than the thickness calculated with existing formulas).

SUMMARY

After a good research for similar studies applicable to this thesis, the most close study found was a study of surgical plates attached with screws to the bones for wish studies where performed because apparently is well known by medical history, that when the friction between the bone and the plates is lost or close to zero, then the screws work under bending and sometimes those screws fail, leaving the screw inside the bone as shown on the following picture:

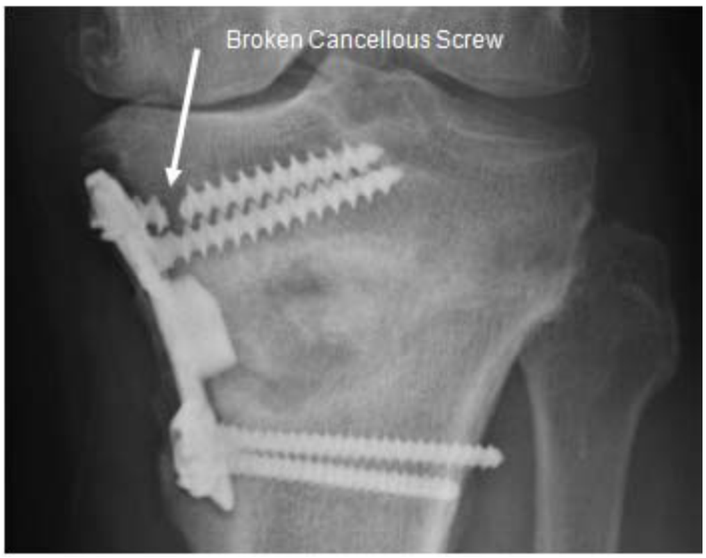


Fig. B – Surgical screw failed in Bending

It was found that surgical plates called lock plates, would hold the head of the screw inside the plate, and some of those screws would also have threads in the head to engage the head in the plate, by doing this the bending is reduced, because now instead of a cantilever is a fixed-fixed condition, and also the friction between the plate and the bone is not zero because the head helps to hold down or lock with more pressure the plate against the bone:

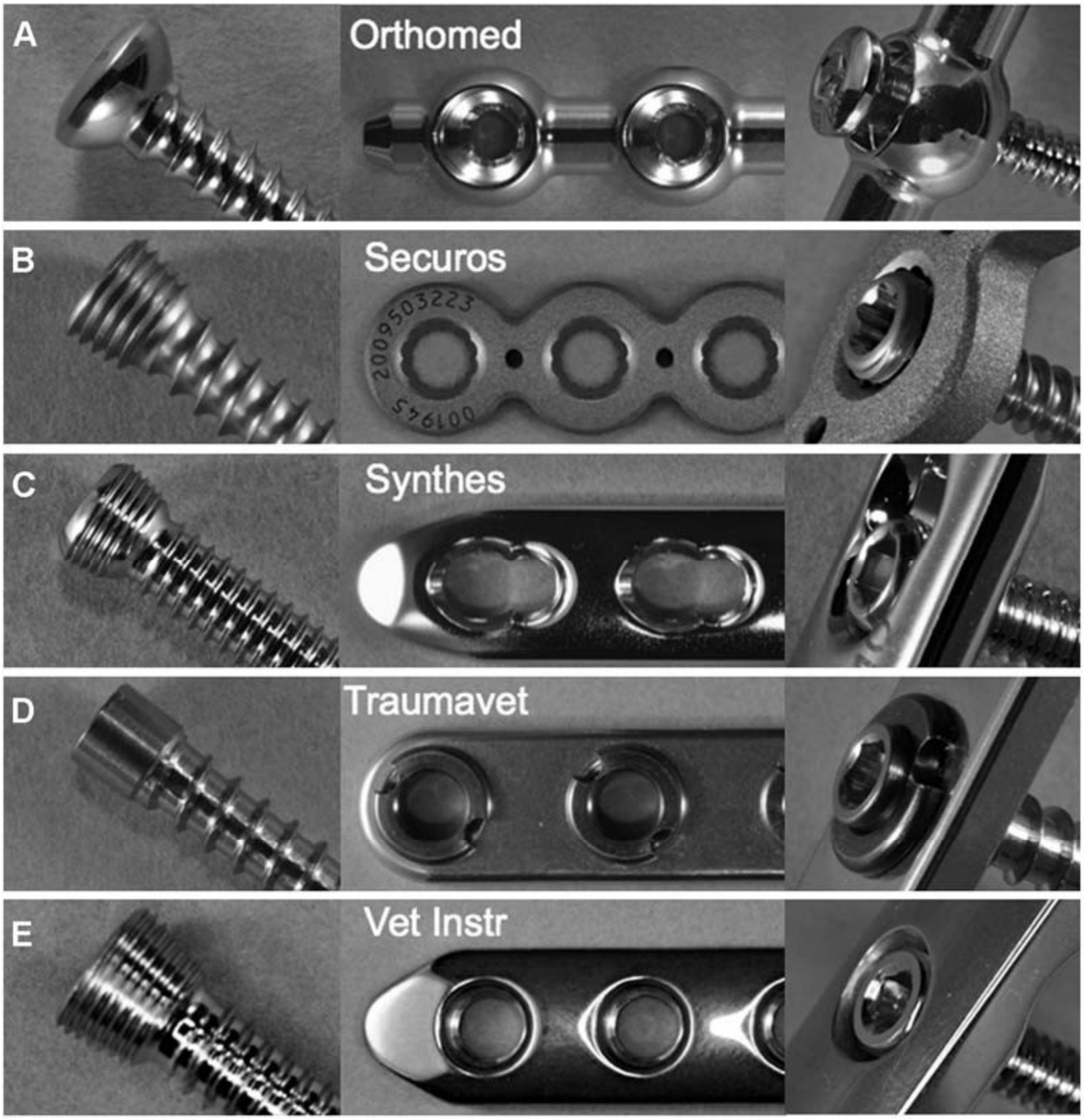


Fig. C – Plates that reduce Bending

This is an advance in medical technology, now lock plates are more often used; this study shows that by locking the head in the plate, the screws resist much more than traditional plates, also they found on this study that the torque would not modify much the screw capacity, but what is controlling is the bending and the capacity of the screw and the plate to create a friction between the bone and the plate.

CHAPTER 2
LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

The title presented in this thesis is “The study of fasteners under bending for curtain wall or storefront head and sill anchors” the study of fasteners is oriented toward the design of curtain wall or storefront connections that may use this fasteners under such condition.

This work would mainly benefit curtain wall Engineers, also would benefit Structural Engineers that may find another application of the study on different design of elements that have fasteners or bolts involved, such as steel, wood or concrete connections.

This work would also benefit Structural Engineering mentors to study basic equations applied to real job applications. The literature that would be used in this work is the following:

AAMA-TIR-A9-14 (American Architectural Manufacturers Association)
This manual provides screws & bolts capacities for different base materials, also provides mechanical properties of different fasteners materials, this manual is fundamental in calculating the screws and bolts capacities by hand.

AISC 14th (American Institute of Steel Construction Manual)
Latest edition of steel manual, this would be useful to get the formulas to calculate the moments of inertia, plastic and section modulus of the screws and also to compare the LRFD method and ASD methods to get the screw capacity as a steel element under bending.

AAMA 2501-06, Voluntary guideline for engineering analysis of window and sliding glass door anchorage system
This literature shows a schematic drawing for window framing connected directly to the surrounding substrates. Shown on Fig. H

YKK AP America Inc. Architectural Products, Design Manual Volume 3
This is a manufacturer manual where it shows all their windows and storefront products and it helps to select the best product available for certain project.

Typically when designing a curtain wall anchor with the use of screws, there are screws tables that show the allowable capacity of the screw under shear and the allowable capacity of the screw under tension; there are different tables depending on the type of screw used, there are tables for grade 5 screws, stainless steel screws, cold work stainless steel, and others; the tables available are the ones shown on the AAMA-TIR-A14, or per the manufacturer tables; on these tables the capacity of the screw under bending is not shown, wish is the case when there are shims creating a bending moment in the screw equal to the shear force times the shim thickness used.

Table A – Fastener Capacity per AAMA TIR-A9-14

SAE Grade 5 Steel for Diameters up thru 9/16" (UNC Threads) ASTM A 449 Steel for Diameters 5/8" and Over (UNC Threads)															
Nominal Fastener Diameter & Threads per Inch	D Nominal Thread Diameter (in)	A(S) Tensile Stress Area (in2)	A(R) Thread Root Area (in2)	Allowable Tension (lbs)	Allowable Shear		Allowable Bearing (lbs)			Minimum Material Thickness (lbs) to Equal Tensile Capacity of Fastener (in)			Maximum Tensile Load (lbs) for Available 3/8" Plate Thickness		
					Single (lbs)	Double (lbs)	1/8" Steel A36	1/8" Aluminum 6063-T5	1/8" Aluminum 6063-T6	A36	6063-T5	6063-T6	3/8" Steel A36	3/8" Aluminum 6063-T5	3/8" Aluminum 6063-T6
#6-32	0.1380	0.0091	0.0078	363	180	360	900	253	345	0.1602	0.3046	0.2268	363	363	363
#8-32	0.1640	0.0140	0.0124	560	286	573	1,070	301	410	0.2079	> 3/8"	0.2953	560	522	560
#10-24	0.1900	0.0175	0.0151	701	350	700	1,240	348	475	0.2246	> 3/8"	0.3001	701	643	701
#12-24	0.2160	0.0242	0.0214	967	493	986	1,409	396	540	0.2594	> 3/8"	0.3619	967	734	967
1/4-20	0.2500	0.0318	0.0280	1,273	$\boxed{646}$	1,291	1,631	458	625	0.2745	> 3/8"	> 3/8"	1,273	865	1,179
5/16-18	0.3125	0.0524	0.0469	2,517	1,299	2,599	2,039	573	781	0.3144	> 3/8"	> 3/8"	2,517	1,303	1,776
3/8-16	0.3750	0.0775	0.0699	3,719	1,937	3,874	2,447	688	938	0.3518	> 3/8"	> 3/8"	3,719	1,572	2,144
7/16-14	0.4375	0.1063	0.0961	5,103	2,664	5,328	2,855	802	1,094	> 3/8"	> 3/8"	> 3/8"	4,937	1,873	2,554
1/2-13	0.5000	0.1419	0.1292	6,811	3,581	7,162	3,263	917	1,250	> 3/8"	> 3/8"	> 3/8"	5,642	2,140	2,918
9/16-12	0.5625	0.1819	0.1664	8,733	4,611	9,222	3,670	1,031	1,406	> 3/8"	> 3/8"	> 3/8"	6,444	2,444	3,333
5/8-11	0.6250	0.2260	0.2071	10,848	5,738	11,477	4,078	1,146	1,563	> 3/8"	> 3/8"	> 3/8"	7,148	2,711	3,697
3/4-10	0.7500	0.3345	0.3091	16,054	8,565	17,130	4,894	1,375	1,875	> 3/8"	> 3/8"	> 3/8"	8,612	3,266	4,454
7/8-9	0.8750	0.4617	0.4285	22,163	11,876	23,753	5,709	1,604	2,188	> 3/8"	> 3/8"	> 3/8"	10,158	3,853	5,254
1-8	1.0000	0.6057	0.5630	29,076	15,601	31,203	6,525	1,833	2,500	> 3/8"	> 3/8"	> 3/8"	11,696	4,437	6,050

SAE Grade 5 Steel (Spaced Threads)															
Nominal Fastener Diameter & Threads per Inch	D Nominal Thread Diameter (in)	K Basic Minor Diameter (in)	A(R) Thread Root Area (in2)	Allowable Tension (lbs)	Allowable Shear		Allowable Bearing (lbs)			Minimum Material Thickness (lbs) to Equal Tensile Capacity of Fastener (in)			Maximum Tensile Load (lbs) for Available 3/8" Plate Thickness		
					Single (lbs)	Double (lbs)	1/8" Steel A36	1/8" Aluminum 6063-T5	1/8" Aluminum 6063-T6	A36	6063-T5	6063-T6	3/8" Steel A36	3/8" Aluminum 6063-T5	3/8" Aluminum 6063-T6
#6-20	0.1380	0.0990	0.0077	308	178	356	900	253	345	0.1358	0.1907	0.1543	308	308	308
#8-18	0.1640	0.1160	0.0106	423	244	488	1,070	301	410	0.1569	0.2175	0.1758	423	423	423
#10-16	0.1900	0.1350	0.0143	573	331	661	1,240	348	475	0.1834	0.2517	0.2028	573	573	573
#12-14	0.2160	0.1570	0.0194	774	447	894	1,409	396	540	0.2182	0.2995	0.2380	774	774	774
1/4-14	0.2500	0.1850	0.0269	1,075	621	1,242	1,631	458	625	0.2617	0.3593	0.2696	1,075	1,075	1,075
5/16-12	0.3125	0.2360	0.0437	2,100	1,212	2,425	2,039	573	781	0.3407	> 3/8"	0.3430	2,100	1,681	2,100
3/8-12	0.3750	0.2990	0.0702	3,370	1,946	3,892	2,447	688	938	> 3/8"	> 3/8"	> 3/8"	2,773	2,017	2,751

	SAE Grade 5 (≤ 9/16")	ASTM A449 (≥ 5/8")	For All Diameters	Effective Area (UNC Threads)	Effective Area (Spaced Threads)
F_U (Min. Ultimate Tensile Strength)	120,000 psi	120,000 psi	$F_T = F_U/SF$	$A(R) = \pi\ (D-1.2269/N)^2 / 4$	$A(R) = \pi K^2/4$
F_T (Allow. Tensile Stress, D≤1/4")	40,000 psi	N/A	Allowable Tension = $F_T[A(S)]$	$A(S) = \pi\ (D-0.9743/N)^2 / 4$	$A(S) = \pi K^2/4$
F_T (Allow. Tensile Stress, D> 1/4")	48,000 psi	48,000 psi	$F_V = Fu / (SF \times sqrt(3))$		
F_V (Allowable Shear Stress, D≤1/4")	23,094 psi	N/A	Allowable Single Shear = $F_V[A(R)]$		
F_V (Allowable Shear Stress, D>1/4")	27,713 psi	27,713 psi			

NOTE 5:

1. Values are taken from AISC, ASTM, IFI, SAE and AA documents. K values for spaced threads are taken as the minimum values in IFI Fast

2. Safety Factor used for fasteners with diameters 1/4" or less is 3.0, Safety Factor used for fasteners with diameters 5/16" or greater is 2.5.

3. Fasteners with diameters of 5/8" or greater are fabricated from carbon steel complying with ASTM A449 Type

For this thesis study, we are using the most typical screws used in curtain wall wish are the Drilflex screws, these screws are made of a grade 5 material, and Table A is an example of a table for grade 5 screws that shows the capacity of the screw under shear, double shear and tension, it also shows the tension capacity of the screw when the screw is attached to different types of materials, like steel or aluminum. The capacity of the screw varies depending on the material and on the thickness of the material, the maximum capacity of the screw would be the capacity of the screw itself, but before the failure of the screw, the material to wish is attached to could fail first, for example if the screw is attached to a 16Ga. Steel, the allowable tension capacity of the screw is 207lb and the screw capacity is about 1273lb in tension; if the screw is attached to a 3/8" steel material, the screw would control first at 1273lb before the steel capacity in pullout.

The screw that we are studying on this thesis is a 1/4-20 Grade 5 screw (Drilflex), we can see per the table A that the screw itself has an allowable capacity of 646 lb under shear, and an allowable capacity of 1273 lb under tension; but if is attached to a 1/8" steel it shows a capacity of 1631 lb under bearing wish means that the screw would fail first under shear at 646lb and the material would still resist.

We can see that the table has a note where it specifies that the screw has a safety factor equal to 3 to the values on the table, this means that the results we get from the tests in the Engineering lab are ultimate values, and would have to be divided by 3 to have the allowable results and can be comparable to the tables; the only value that can be compared is the test made with no shims, because these results are for direct shear, and can be compared with the allowable shear capacity shown on the table.

The manufacturer of the screws have their own capacities tables that typically are similar to those values shown on the AAMA-TIR-A14 tables, sometimes would differ a little, but the Engineer should be careful on selecting the correct values, because some manufacturers show the ultimate capacity (without the safety factor) instead of the allowable values.

Table B – Fastener Capacity per Manufacturer

Pull-out Tests – Steel: Pull-out values shown are in lbs.

Screw Size	Point Type	Drill Cap.	Steel 18	16	14	12	1/8	3/16	1/4	5/16
10-16	3	.150	396	501	634	1595	1693			
12-14	3	.187	396	527	710	1678	2061	2898		
1/4-14	3	.187	398	530	686	1950	2264	3919		
1/4-20	4	.312		516	649	1912	2296	2928	3561	4488
5/16-18	3	.210				2333	2856			
5/16-24	4	.312				2148	2573	4226	5424	6622
3/8-16	1	.075			1843					

Shear Tests – Steel: Shear values shown are in lbs.

Screw Size	Point Type	Drill Cap.	Steel 18-18 ga.	18-14 ga.	16-16 ga.	14-14 ga.	1/8"-3/16"	3/16"-1/4"	1/4"-12 ga.
10-16	3	.150	1362	1733	1462				
12-14	3	.187	1315	2118	1655	1816			
1/4-14	3	.210	1395	2313	1681	2417	2600		
1/4-20	4	.312	1350	2086	1582	2450	2814	2810	2706
5/16-18	3	.210	1509	2300	1811	3255			
5/16-24	4	.312					5486	5283	4761
3/8-16	1	.075				6750			

NOTE: All performance data shown is based on tests performed under laboratory conditions at independent construction testing facilities. The appropriate safety factor should be applied and code requirements factored into specification and use of these fasteners. A safety factor of 4:1 or 25% of the ultimate average values shown is generally accepted as an appropriate working load. Final determination of the appropriate safety factor and use of these fasteners is the sole responsibility of the user, specifying Engineer, Architect or other responsible person designing the connection. Due to a wide variety of application conditions or intervening factors not under our control, we assume no liability for the use of the information provided in this document.

The ultimate value would greatly differ from the allowable value. An example of a manufacturer table is shown on Table B; by comparing the manufacturer table with the AAMA-TIR-A14 table A we can see that for a 1/8" steel tube wish is comparable to a 3/16" steel tube, the capacity under shear per AAMA-TIR-A14 is 1631 lb, and the shear capacity per the manufacturer table B is 2814 lb, but per table B these are ultimate values and per the note at the bottom it recommends to apply a safety factor of 4, dividing 2814 by 4 we get an allowable shear of 703 lb wish is very similar to the AAMA-TIR-A14 table A results of 646 lb; in a similar manner, the tension allowable capacity per AAMA-TIR-A14 is 1273 lb, and per the manufacturer the tension ultimate capacity is 4488 lb, and divided by 4 is 1122lb wish by comparing we can say that the results are very similar; sometimes there are different sources of screws capacities per different codes, or different associations, but the results should be similar from one table to another; the manufacturer always has their own tables because they make particular tests of their products to proof the capacity of their own products to their possible clients, the Designer, the Engineer or somebody that requests these results, typically they have these results available to the Designer if they request literature or product data of all the products they manufacture.

Table B.2 – Capacities for different thicknesses and substrates

Pull-out Tests – Steel: Pull-out values shown are in lbs.

Screw Size	Point Type	Drill Cap.	Steel 18	16	14	12	1/8	3/16	1/4	5/16
10-16	3	.150	396	501	634	1595	1693			
12-14	3	.187	396	527	710	1678	2061	2898		
1/4-14	3	.187	398	530	686	1950	2264	3919		
1/4-20	4	.312		516	649	1912	2296	2928	3561	4488
5/16-18	3	.210				2333	2856			
5/16-24	4	.312				2148	2573	4226	5424	6622
3/8-16	1	.075			1843					

Pull-out Tests – Aluminum

Screw Size	Point Type	Drill Cap.	Aluminum 6063-T5 1/8"	1/4"	3/8"
10-16	3	.150			
12-14	3	.187	939	2286	
1/4-14	3	.210	1003	2424	
1/4-20	4	.312	897	2075	3683
5/16-18	3	.210	1120	2967	4796
5/16-24	4	.312	1043	2566	

Shear Tests – Steel: Shear values shown are in lbs.

Screw Size	Point Type	Drill Cap.	Steel 18-18 ga.	18-14 ga.	16-16 ga.	14-14 ga.	1/8"-3/16"	3/16"-1/4"	1/4"-12 ga.
10-16	3	.150	1362	1733	1462				
12-14	3	.187	1315	2118	1655	1816			
1/4-14	3	.210	1395	2313	1681	2417	2600		
1/4-20	4	.312	1350	2086	1582	2450	2814	2810	2706
5/16-18	3	.210	1509	2300	1811	3255			
5/16-24	4	.312					5486	5283	4761
3/8-16	1	.075				6750			

Shear Tests – Aluminum

Screw Size	Point Type	Drill Cap.	Aluminum 6063-T5 1/8" - 1/8"	1/8" - 1/4"
10-16	3	.150	1466	
12-14	3	.187	1797	2483
1/4-14	3	.210	1996	2883
1/4-20	4	.312	2006	2926
5/16-18	3	.210	2132	3009
5/16-24	4	.312	1849	2926

NOTE: All test setups and dimensions were as limited and outlined in AISI Test Method for Mechanically Fastened Cold-Formed Steel Connections (CF92-1) document. Performance values listed are ultimate values obtained under laboratory conditions.

The manufacturer has product data available, this is very typical to have available for their market. Another example is Table B.2 wish shows ELCO manufacturer table for different materials and different material thickness. And Table C shows a table that shows both, ultimate tension capacity and allowable tension capacity.

Table C – Ultimate and Allowable Capacities

Ultimate Shear (lbs)

Screw Material Carbon	Stainless
2159	1950

Identification

Carbon steel screw: Elco Flag

Stainless steel screw: "F" above "2"

Pull-Out (lbs)

Single Sheet

Catalog #	Recommended Grip Range	Steel Thickness	Ultimate Tension Load (lbs.)	Allowable Tension Load (lbs.)
EZJ100	.062" & .250"	14 ga.	1100	360
		20 ga.	600	200
		26 ga.	600	200
EZJ120	.250" through .500"	14 ga.	1000	330
		20 ga.	800	260
		26 ga.	600	200
EZJ140	.500" & .750"	14 ga.	1100	360
		20 ga.	800	260
		26 ga.	400	130

1. Allowable load capacities listed are calculated using and applied safety factor of 3.0.

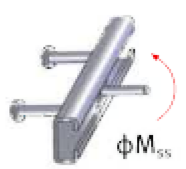
The problem that Engineers typically face is that there are no tables available for screws under bending, the capacity of the screw under bending has to be calculated with formulas.

When the screw has a shim between the material being fastened and the material where the screw is attached to, the screw is under bending; there are some tables that show what is called stand-off; that is when a bolt has double nuts and there is a gap between the nuts as shown on the picture in Table D; this gap would create a bending on the bolt, and some manufacturers of for concrete embeds, would provide capacity values of this stand-off bending moment, there is an example on Table D, this stand-off works as a single bending or cantilever moment.

Table D – Stand-off Capacities

Strength of JORDAHL® T-Bolts due to Bending Moments

T-Bolts Ø		M 6	M 8	M 10	M 12	M 16	M 20	M 24	M 27	M 30
Through hole in attachment part in. (mm)		9/32 (7)	11/32 (9)	15/32 (12)	9/16 (14)	11/16 (18)	7/8 (22)	1 1/32 (26)	1 3/16 (30)	1 19/64 (33)
Factored Bending Strength ϕM_{ss} ft•lb (Nm)	4.6	3 (4)	7 (10)	14 (19)	25 (34)	64 (86)	124 (169)	215 (291)	320 (433)	431 (584)
	8.8	–	14 (20)	29 (39)	50 (68)	127 (173)	249 (337)	430 (582)	–	–



Stand-Off Installation

In the case of stand-off installation, a connection is stressed by a bending moment as well as by tension and shear forces. The design bending moments specified above must be taken into consideration.

> **Note**
> T-Bolt capacity may be limited by the channel bearing. The smaller value is decisive. The specified values are design resistances. For permissible loads divide by 1.5 safety factor.

Stand-off installation

For some concrete embeds there are values for the bolts under bending; but for screws typically the tables do not show values for the screws under bending when there is a gap between the surface and the material being fastened, it would be very useful to have a table that would provide the shear capacity of the screw when is attached with different thicknesses of shims and for different steel thicknesses or materials; because this would vary also, for this thesis a table would be created showing different shear capacities for different shim thicknesses, but only for the case when the screw goes into a 3/16” steel tube; this shear capacity would also be applied to a 1/8” steel tube, since the tension capacity for a 1/8” steel is close to the tension capacity of a 3/16” as shown on Table B.

Tests were also performed for Grade 5 screws in cantilever without shims for different cantilever spans, tests were performed for 1/4”, 1/2”, 3/4”, 1” and 1 1/4” cantilever spans; it was also tested with 0 offset or direct shear with no bending, to compare this result with the shear result from the tables.

The spans for the tests under cantilever where the same shims thicknesses used on the tests; this was made to be able to compare the capacity of a screw on cantilever (fixed free condition), and a screw in a supposed fixed-fixed condition; from the results it was found that the screw with the shim (fixed fixed) didn't only resisted twice the capacity of the screw in cantilever (fixed free), but it resisted much more than twice the capacity; it is assumed that this is because there is another component that is not taken into account, that is the friction between the shims and the attached surfaces, because the shims being in contact with the plate create a tension compression couple, and this couple would create a friction that would help the screw to resist the load; this tension compression couple would vary depending on the material that is being attached to, that is why this tests apply only when the screw is attached to either 3/16” or 1/8” steel material.

For example a screw in cantilever with 1/2” span resisted 401 lb; and two screws with 1/2” horseshoe shims resisted 3547 lb; so the 401 lb multiplied by two for two screws is equal to 802 lb, and multiplied by two for the fixed-fixed condition of the shims with plate is equal to 1604 lb wish is much lower than 3547 lb, what it means that the remaining 3547 – 1604 = 1943 lb is either resisted by the shim in bearing or resisted by a tension compression couple that creates a friction between the steel support and the shims; those 1943lb would vary depending on the material that the screw is being attached to; further analysis would be explained on the Conclusions chapter.

CHAPTER 3
TEST
METHOD

CHAPTER 3

TEST METHOD

Fig. CA.1 Compression Machine

In order to execute the tests of the screws under bending capacity a 60kip compression machine was used in the Civil Engineering Lab, this machine reads the load applied to a sample and plots a graph of load vs deflection, registers the peak load and the peak deflection at the end of the test; it also reads the load rate while running the test; the load rate used for the tests was between 150 and 200lb/sec.

Fig. CA.1 shows the machine used, it is run by a computer, and the procedure is the following:

1. Turn on the computer.
2. Push the black start button shown in the middle between the two handles, rotate the left handle to the left in order for the table to got down to the start position, once the table stops rotate the left handle again but to the right until stops.
3. Install the test on the table (explained later).
4. Run the program.
5. Rotate the right handle slowly to the left, and the table would slowly go up while registering in the computer the load that the sample is resisting.
6. Once the sample fails, push the up button from the machine and another window would pop up asking if it should show the results, click ok and save the test.
7. Rotate the right handle to the right for the table to stop going up.
8. Repeat the steps from point 1 for next tests, at the end push the red End Button.

Fig. CA.2 Compression Machine with arm installed

An arm was installed on the machine to help to perform the tests as shown on Fig. CA.2; this was a perfect item to install on the machine since it has the form of an extruded triangle, perfect to bear on the tests aluminum plate and not interfere with the shims, the machine is shown on the previous picture.

A steel support was fabricated to perform these tests, this support is shown on Fig. E, in order to perform the tests, the drilflex screws with the shims and the aluminum plate where installed on the support as shown on Fig. F; then the support was placed over the machine table and aligned with the vertical arm, this arm was lowered until it lightly touched the aluminum plate as shown on Fig. G.1, then if needed it was leveled with 1/8” shims in order that the aluminum plate was perfectly horizontal with the vertical arm as shown on Fig. G.2

When the sample was ready and installed on the machine table, the machine handle was rotated for the test to start loading in a rate of approximate 200 lb/sec, the machine would move the table up in slow a motion while registering the load that the screws could handle in bending thru the aluminum plate and registering the vertical movement of the table which is the vertical deflection of the screws; once the screws deflected about .3 to .4 inches, the screws failed, and the machine registered the ultimate capacity of those screws as shown on Fig. H.1, and would provide a graph of Load against Deflection as shown on Fig. H.2

After the test was finish, the support was removed from the table, the broken screws where removed from the steel tube, the steel tube was sanded to leave a flat surface again, and another pair of screws with different shims and the aluminum plate where reinstalled to perform the next test.

Fig. E - Tests Support

Fig. F – Sample Installed

Fig. G.1 – Support Mounted

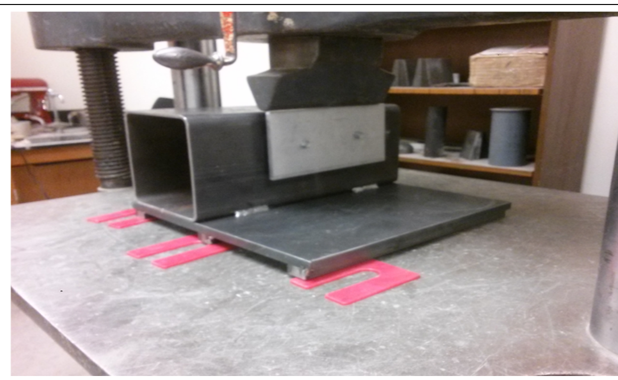


Fig. G.2 – Sample Leveled

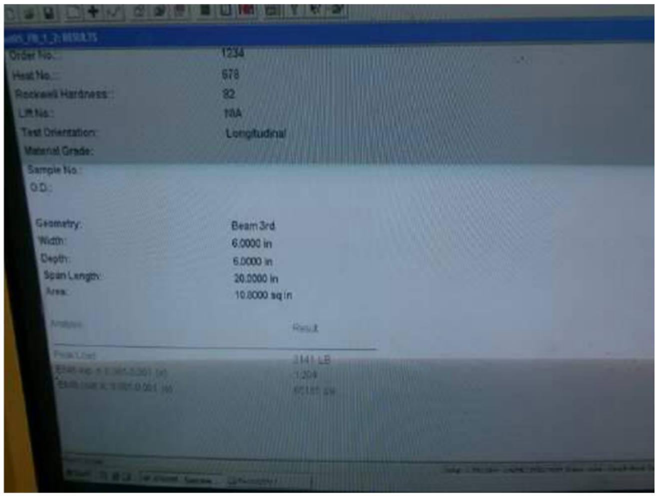
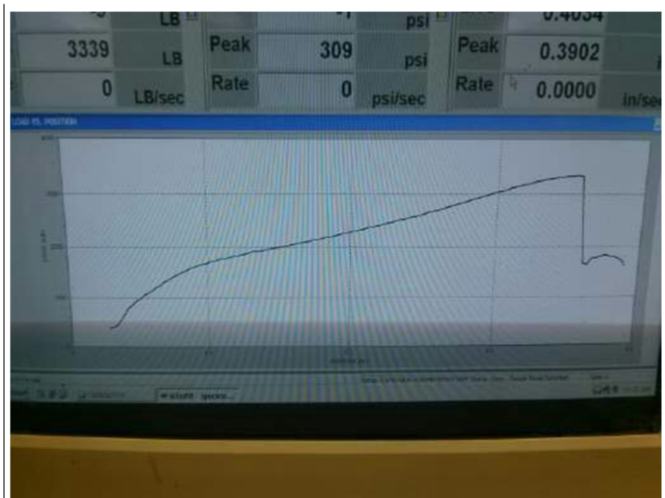
	

Fig. H.1 – Peak Load (Ultimate Load)	**Fig. H.2 – Typical Load vs Defelction Graph**

After each test, the broken screws where removed from the support if it was possible and the tube was sanded to create a flat surface prepared for the next test as shown on Fig. I; this way the shims could be completely flat again and completely in contact with the tube surface, the tube was cleaned with a broom from debris and sand from the previous test; a lot of tests were performed on the same tube, moving the plate to another position for the screw to be able to drill another hole; the screws used are the Drilflex screws wish are self-drilling screws.

Fig. I – Restoring surface for next test

CHAPTER 4
TESTS & RESULTS

CHAPTER 4

TESTS & RESULTS

Tests were performed for different shim thicknesses and different kind of shims; the shims used for these tests are horseshoe shims, these shims have a form of an U shape or as is named it as a horseshoe shape as shown on Fig. K, this shape is intended to be of easy installation, since the U shape is open on one side, it can be installed after the anchor is located and just sliding it in between the anchor plate and the structure; this is better to be used at the Head locations since no weight is over the plate, and shims can be slide in if needed before attaching the screws.

Horseshoe shims are very useful, the come on a variety of sizes and thicknesses, the most typical and used in our study is the 3”x4” size, the thicknesses used are ¼” and 1/8”; the ¼” shims come in color black, and the 1/8” shims come in color red as shown.

Fig. K – 3”x4” Horseshoe Shims

The other kind of shims used at the study are the Full Bearing shims; typically these shims are made of a very strong plastic that can handle compression capacities similar to concrete; the shapes of these shims are typically rectangle, and is a solid rectangle as shown on Fig. L; as different from the Horse shoe shims, these shims can’t be installed after locating the plate, these shims have to have a hole prepared in the same locations as the anchor plate for easy installation, but once the anchor plate is attached, more shims can't be installed; this occurs more at the sill or base of the curtain wall where the weight is there after installing the curtain wall.

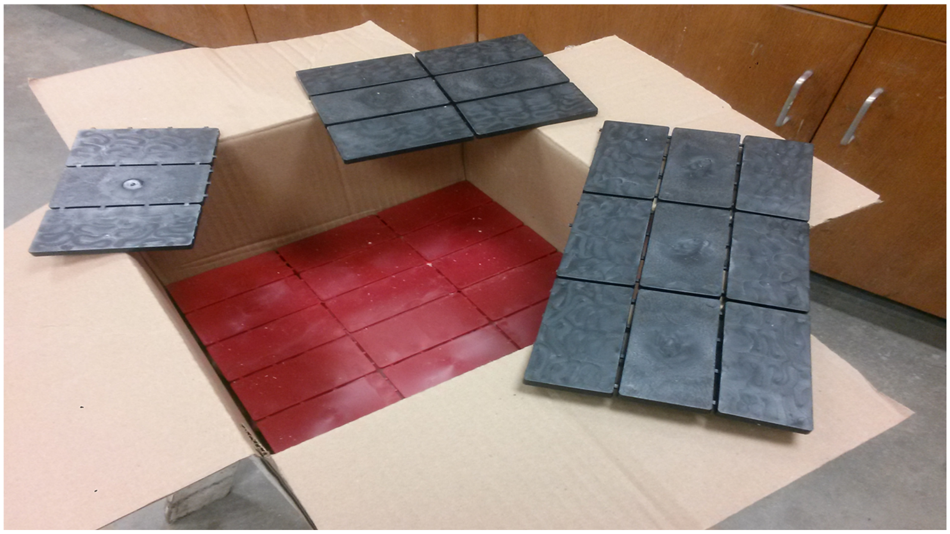


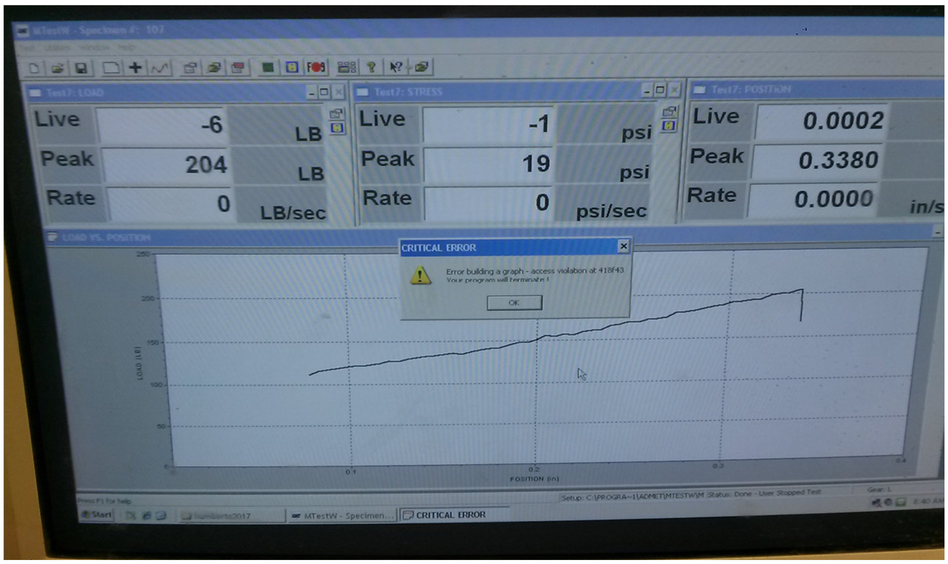
Fig. L – 2"x4" Full Bearing Shims

The shim thickness used in this study is 1/4" (color coded black) wish is the most typical thickness; and only one test was performed with 1/8" shims just to compare the difference in capacity between using (3) 1/4" shims and (6) 1/8" shims. The 1/8" shims are color coded red.

FIRST TESTS

Before the first test was performed, 2 preliminary tests were made to learn to use the machine, the first preliminary test was unsuccessful since the machine broke the screw without giving any results.

After some mistakes and studying the machine, finally the second preliminary test was



successful, and results where plotted.

These results are for ¼" wood shims, showing that one screw broke first, then the second screw continue to handle load until failed, this preliminary test was made with #14 Everbilt screws.

TESTS WITH HORSESHOE SHIMS

TEST: 1/4” HORSESHOE SHIM

The test procedure followed is the same as described on methods, the plate with shims was installed with the aluminum plate and screws as shown on Fig. O.1, then the support was mounted over the table and aligned as shown on Fig. O.2, the test was run, and the maximum resisted load was obtained from the computer as shown on Fig O.3

	
Fig. O.1 Sample Mounted 1/4” Horseshoe Shim	**Fig. O.2 Sample Ready to be Tested**

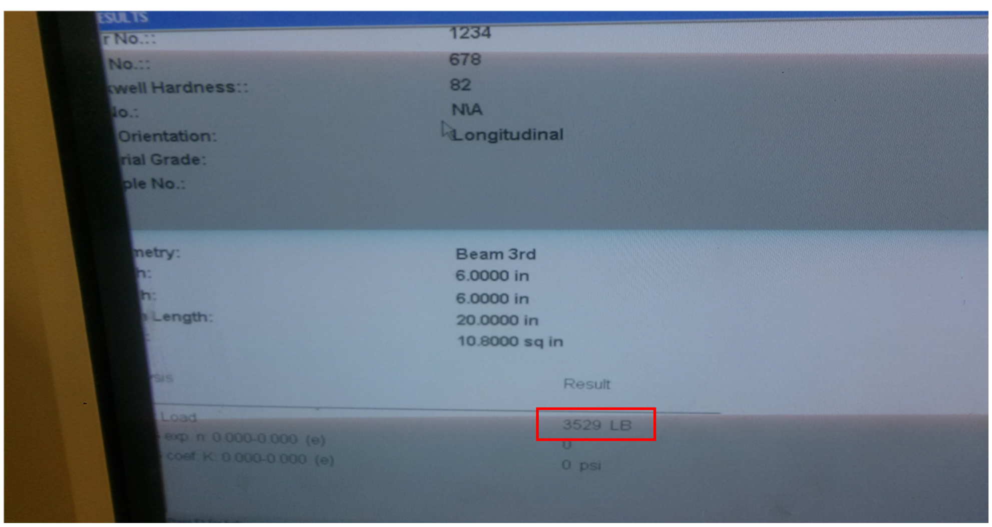


Fig. O.3 Results (3529 #)

TEST: 1/2” HORSESHOE SHIM

The procedure is the same as described on methods, the plate with shims was installed with the aluminum plate and screws as shown on Fig. P.1, then the support was mounted over the table and aligned as shown on Fig. P.2, after letting the machine run, the screws broke and the machine plotted the Load vs. Deflection diagram, registering the peak load and the deflection at the peak load; the peak load was 3300# and the max deflection was .31”

Then the last picture shows the sample tested; when the screws failed.

Fig. P.1 Sample Mounted (2)1/4” Horseshoe Shims

Fig. P.2 – Sample Ready to be Tested

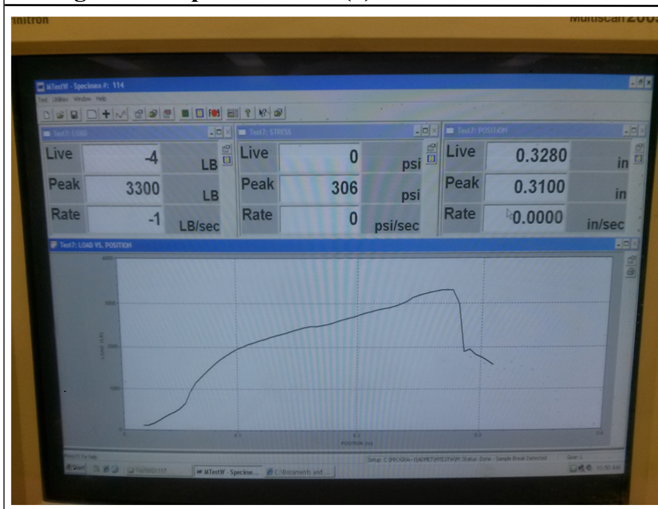


Fig. P.3 – Results (3300#)

Fig. P.4 – Sample Tested

As we can see on the diagram, the screw deflection behaves in a similar way as a steel deflection diagram; first the load deformation is about linear until it reaches the yield strength, then it deflects more than the load increases, like in a almost horizontal line, and at the end the resistance suddenly increases and reaches the ultimate strength point and suddenly fails.

This test was made with the screws snug tight wish means that there was no torque or big force applied to the screws, the screws where only tighten until it barely touched the plate, but no torque was applied; further tests would be made with some torque (Aprox. 5 ft-lb) and greater capacity would be obtained, this would be something to discuss about at the conclusions chapter.

TEST: 3/4" HORSESHOE SHIM

This next test was made in a similar way, with 3 Horseshoe Shims to have a total thickness of 3/4", and similar results or about the same results were obtained.

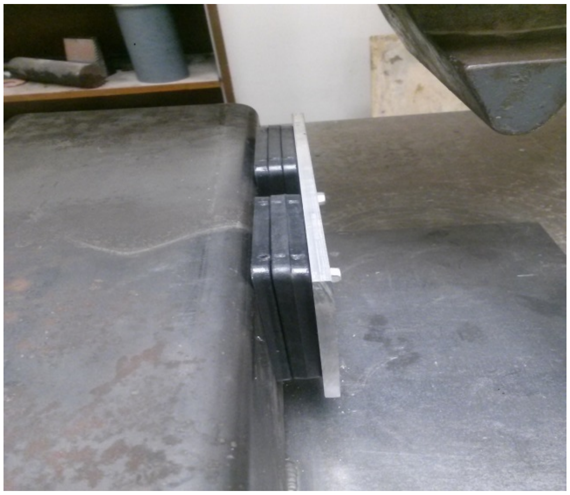


Fig. Q.1 Sample Mounted (3)1/4" Horseshoe Shims

Fig. Q.2 – Sample Ready

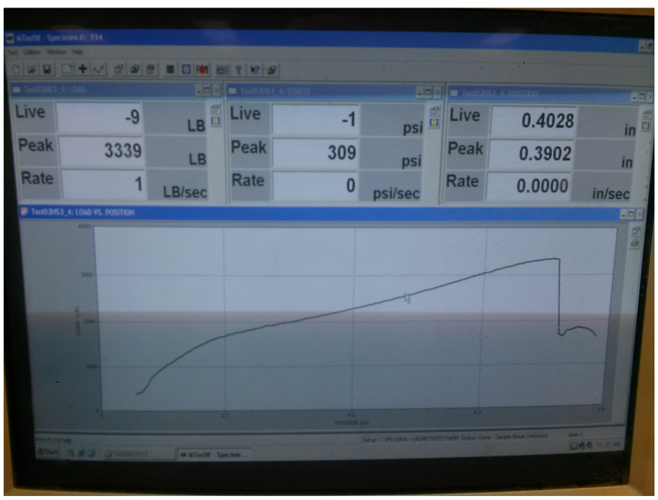


Fig. Q.3 – Results (3339#)

Fig. Q.4 – Sample Tested

This test was also made on a snug tight condition, more tests were performed with a torque of 5ft-lb, and better capacity was obtained, further discussion of this would be made in the Conclusions chapter.

TEST: 1" HORSESHOE SHIM

The next Horseshoe shim test was made the same way, but with (4) four 1/4" Horseshoe shims; the four shims where mounted with the aluminum plate as shown on Fig. R.1, and for the 1" thickness shims the capacity was less than the capacity for 3/4" shims or 1/2" as it was expected in the snug tight condition; more tests where made with some torque and the results where the opposite, this would be discussed on Chapter 4, conclusions section.

Fig. R.1 Sample Mounted (4)1/4" Horseshoe Shims

Fig. R.2 Sample Ready to be Tested

Fig. R.3 – Sample Tested

Fig. R.4 – Screws Bent

Results for the tests can be found at the reference, for the snug tight condition the results where 2417 # (Test #3), and for the typical condition with some torque the results where 3785# (Test #14) and 3839# (Test #23) giving an average of 3812 #.

The sample tested is shown on Fig. P.3; and on Fig. P.4 the shape of the screws after failing is shown, as we can see the screw has a bending at the head and is broken at the bottom, wish it means that it was under bending at the top and also at the bottom, resulting in a fixed-fixed or double bending condition as it would be explained on the screws after fail chapter.

It should be noted that the hole on the plate was made with a ¼” drill, is important that the hole on the aluminum is small (close fit condition) and not too large, this way the aluminum plate would create a prying action on the head screw and perform a bending or a fixed condition on the screw; Fig. P.5 shows a hole on the aluminum plate.

Fig. R.5 – ¼” Holes on Aluminum Plate

TEST: 3/4” HORSESHOE SHIM (6)1/8” HORSESHOE SHIMS

This next test was performed with ¾” of total shim thickness, but instead of using (3)¼” Horseshoe shims, (6)1/8” Horseshoe shims where used, to see the difference on the capacity when using more shims for the same thickness, it is expected that the more shims are used, the less capacity of the screws, this test shows that the capacity was only reduced by 5% when doubling the number of shims in the performed test:

 **Fig. S.1 Sample Mounted (6)1/8” Horseshoe Shims**	 **Fig. S.2 Sample Ready to be Tested**
 **Fig. S.3 – Sample Tested**	 **Fig. P.4 – Screws Bent**

The results for this test is shown at the reference on Test #4.

Fig. P.4 shows the failed screws, it can be seen that the Heads bent and also the screws failed at the base, wish means that the screws resist the load in a double bending condition; it can also be seen at the failure plane that the screws fail on a 40 degree angle and not as a flat surface on the interior threads area, it fails like on an angle approximate to 40 degrees.

TESTS WITH FULL BEARING SHIMS – FREE FIT HOLES

The next set of tests were performed with different kind of shims, these shims are called full bearing shims, on this shims the surface is completely solid as different from a Horseshoe shim, and typically comes on a rectangle form, it has many different sizes, for these tests we would use (2) shims per plate in a size of 2”x3”, one at each screw location; these shims as different from Horseshoe shims would provide more surface of contact between the steel and the shim and the aluminum plate and the shim.

On Fig. T typical Full Bearing shims are presented, the typical thickness used are ¼” in color black and 1/8” in color red.

Fig. T Full Bearing Shims

For these tests Free Fit Holes would be used; these holes are made of a greater size than the screw diameter; a drill of 3/8” diameter was use to make the free fit holes.

TEST: 1/2" FULL BEARING SHIM FREE FIT HOLES

Fig. U.1 Sample Mounted (2)1/4" Full Bearing Free Fit

Fig. U.2 – Sample Tested

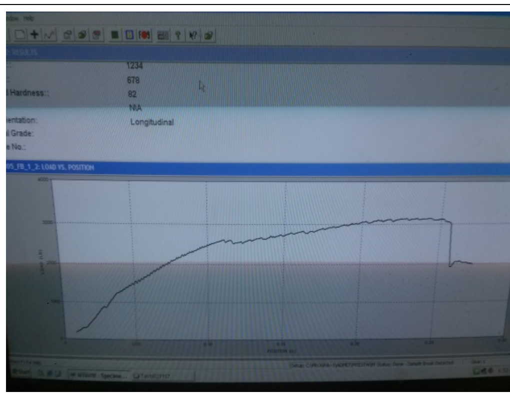


Fig. U.3 – Results (3141 #)

Fig. U.4 – Bent screws

This test was performed with (2)1/4" Full Bearing Shims, and free fit holes (3/8" Diameter) was used; the test was made in a snug tight condition (no torque) and the result obtained was 3141#, this is also shown on Test #5 at the reference; by comparing with the ½" Horseshoe shim snug tight results, that was 3300 #, the results where about the same, this is because the Horseshoe shim acts like a free fit hole condition since is open as a horseshoe shim, and the 5% more capacity obtained with horseshoe shim could be because the horseshoe shim is a little rough compared to the full bearing.

TEST: 3/4" FULL BEARING SHIM FREE FIT HOLES

This next test was made with (3)1/4" Full Bearing Free Fit Holes, with a 3/8" Diameter hole, the results obtained on a snug tight condition was 3294 # also shown on test #6 at reference, this result is very similar to the result of the (3)1/4" Horse shoe shim in a snug tight condition wish was 3339 #.

Fig. V.1 – (3)1/4" Full Bearing Shims Free Fit Holes

Fig. V.2 – Screws Bent

By comparing the Horse shoe shims results with the full bearing free fit shims results, the Horseshoe shims gave a slightly more capacity than the full bearing shim free fit shims; this could be because the Horse shoe shims have a rough surface compared to the solid shims, and because of that rough surface there is more friction between the shim and the steel, and that friction helps the screw to take less load.

TEST: 1” FULL BEARING SHIM FREE FIT HOLES

This test was made from (4)1/4” Full Bearing Shims with free fit holes, Fig. W.1 shows the 4 shims in location before the plate was attached with the Driflex, the screw was inserted in the hole just for the picture, to show that the screw diameter is much smaller than the hole diameter, this is a free fit hole.

Fig. W.2 and W.3 shows the sample ready to be tested on the machine; Fig. W.4 shows the results, it shows that this test resisted 2485# wish is smaller than the previous test with 3294# resisted with ¾” shims, again this test was performed in a snug tight condition, (test #7 at reference); two more tests where made with some torque (test #21 and test #26) just to verify that when there is some torque, the capacity is much greater because friction is generated, this would be discuss in the conclusions chapter.

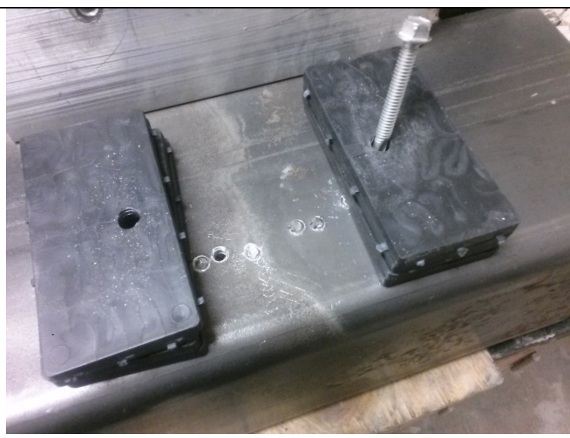


Fig. W.1 (4)1/4” Full Bearing Shims Free Fit Hole

Fig. W.2 Sample ready to be tested

Fig. W.3 Sample ready to be tested

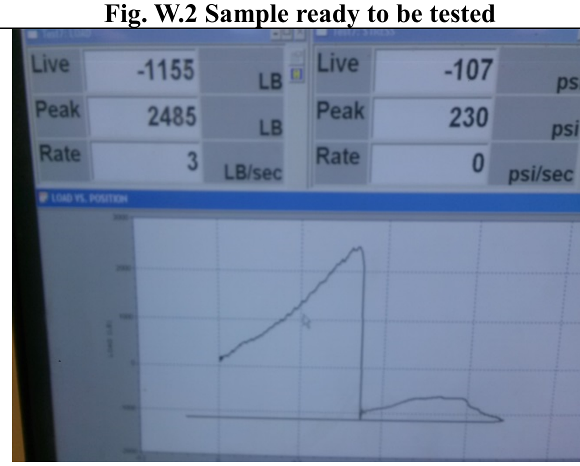


Fig. W.4 Sample ready to be tested

The next pictures Fig. W.5 and W.6 shows the sample with (4)1/4" full bearing shims free fit shims after the test, as is shown on Fig. W.5 one screw failed at the head, and is shown on Fig. W.6 that the other screw failed at the steel tube; with this is shown that the screw is under double bending, and that the bending moment at the head and at the base is about the same, because the screw can either fail at the head or at the base, but never fails in between because at the center the moment is cero as in a fixed-fixed condition moment diagram.

Fig. W.5 Sample tested

Fig. W.6 Sample tested

TESTS WITH FULL BEARING SHIMS – CLOSE FIT HOLES

The next set of tests would be performed with the same Full Bearing Shims, but in this case close fit holes would be used; the close fit holes it means that the holes are small or about the same diameter of the screw, the drill used to do the holes was ¼" wish is the same diameter of the screw, then the screw it self would drill a little bit if necessary to let the screw go thru all the shims;

Fig. X Close Fit Hole

The purpose of the close fit hole is that the shims would bear on the surrounding of the screw, and this bearing action would help the screw to support the load since the screw is not bending, just transferring the shear, and is supposed that the shims would help to take the bending by creating a tension compression couple, but it depends on how strong is the shim material to fail in bearing, with this tests it would be clarified if the shim itself is strong enough to take this bearing and help the screw with the bending.

TEST: 1/2" FULL BEARING SHIM CLOSE FIT HOLES

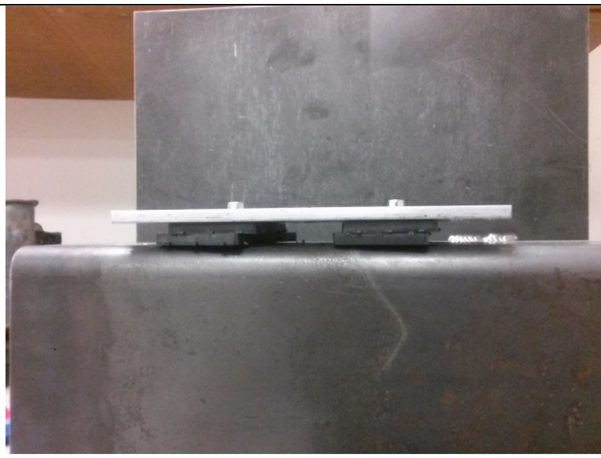


Fig. X.1 Sample Mounted on tube

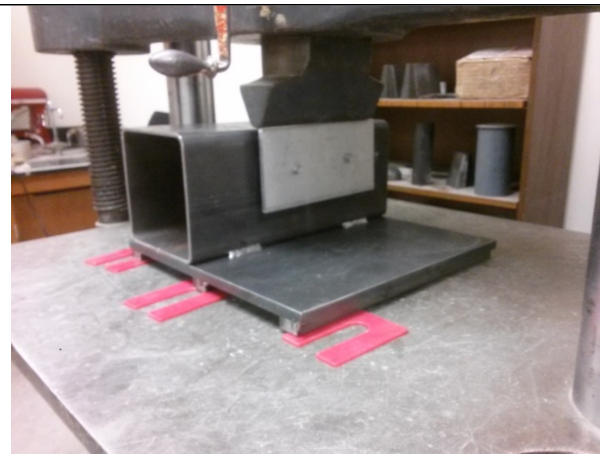


Fig. X.2 Sample ready to be tested

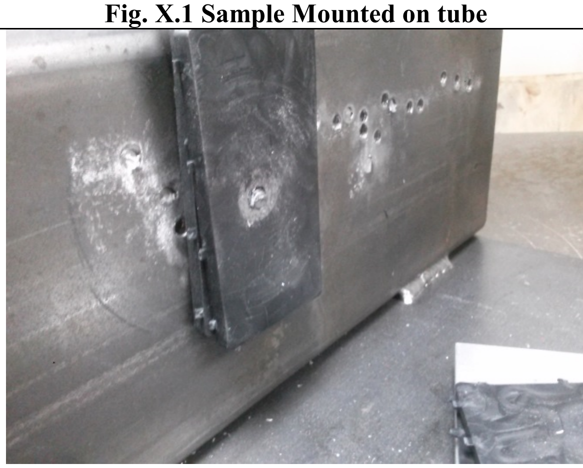


Fig. X.3 Sample tested

Fig. X.4 Sample tested

This test was performed with (2)1/4" Full bearing shims with close fit holes, and the results where 3040# (Test #9 at reference) and with some torque the result was 3630# (Test #11 at reference), by comparing the snug tight result 3040# with the free fit condition for ½" snug tight (3141#) it is shown that there is no difference between using close fit or free fit holes in this case, it might be because the shims are not strong enough to take bearing.

On the other pictures Fig. X.3 and Fig. X.4 it can be seen that one screw failed at the head and the other screw failed at the steel tube, with this is also demonstrated that the screws fail in a double bending or fixed-fixed condition, as it was assumed.

TEST: 3/4" FULL BEARING SHIM CLOSE FIT HOLES

Fig. Y.1 Sample Mounted on tube

Fig. Y.2 Sample Tested

For (3)1/4" Full bearing shims with close fit holes the results where 3478# in the snug tight condition (Test #10 at reference), and by comparing with the ¾" snug tight free fit (3294#) it actually help a 5% this condition, but still about the same to assume that a close tight would not help when the shim thickness is ¾" or ½".

Fig. Y.3 Screw Tested

Picture Y.3 shows the failed screw, even that the screw is also under double bending the body of the screw remains straight wish means that the close fit holes shims actually helped on maintaining the screws straight, but the bearing capacity of the shim material was not enough to prevent the screws from bending.

TEST: 1” FULL BEARING SHIM CLOSE FIT HOLES

 **Fig. Z.1 Sample Mounted and ready to test**	 **Fig. Z.2 Sample Tested**

For this test (4)1/4” full bearing shims with close fit holes, no test was made in a snug tight condition, only two tests were performed with some torque, and the results where 4127# (Test #12) and 4258# (Test #13) for an average of 4192#, this test as opposed to what was expected it had more capacity than the same test with ¾” or ½” of shim thickness; and is when a doubt about a friction factor created by a tension compression force exists, and since 1” has more eccentricity to create this couple, could be a reason to get more capacity than with ¾” or ½”, this would be discussed in the conclusions chapter.

Also by comparing this result 4192# with the average result of 1” free fit test (4213#) it can be concluded again that by comparing close fit with free fit there is no difference, and that close fit does not makes any difference when using plastic shims.

SUMMARY OF TESTS

The next table shows the results of the tests; there are two classifications, typical condition, this is when the screws where torqued with some amount of force (about 5ft-lb), and the snug tight condition, when the screws where only tighten until barely touched the plate, with no force; this where the first tests performed, and then it was found that when the screws where tighten with some force, the capacity would increase, for this reason the results were separated; further discussion would be presented on the conclusions chapter.

Table E – Anchor with shims summary of test performed

			TORQUED	NO TORQUED
TEST PERFORMED:	**1st TEST (LB)**	**2nd TEST (LB)**	**AVG. (LB)**	**SNUG TIGHT**
NO SHIMS (DIRECT SHEAR)	6084	6272	6178	
1/4” HORSESHOE SHIM	4578	4331	4454	3529
1/2” HORSESHOE SHIMS	3547	3467	3507	3300
3/4” HORESESHOE SHIMS (3)SHIMS	3892	3938	3915	3339
1” HORSESHOE SHIMS	3785	3839	3812	2417
1/2” FULL BEARING SHIMS (Free Fit)				3141
3/4” FULL BEARING SHIMS (Free Fit)				3294
1” FULL BEARING SHIM (Free Fit)	4234	4193	4213	2485
1/2” FULL BEARING (Close Fit)	3630		3630	3040
3/4” FULL BEARING (Close Fit)				3478
1” FULL BEARING (Close Fit)	4127	4258	4192	

There are graphs at the reference that the machine created, showing all these numbers

Note: These results are for 2 screws with shims under bending as shown on the Previous pictures.

ONE SCREW UNDER CANTILEVER (Fixed – Pin condition)

In addition to the tests performed of anchor plates with shims; screws in cantilever where tested with different cantilever spans as shown on the pictures of this chapter

The next sketch shows a diagram of the screw when is fixed at the base and with an offset load at the head of the screw, this is a simple representation of the tests performed in the Lab., a cantilever or a fixed free condition with the load P at the farthest point, and the cantilever equal to the different thicknesses of the shims; the load would create a bending at the base and a direct shear, the screw has to resist the shear plus the bending at the base for this cantilever condition.

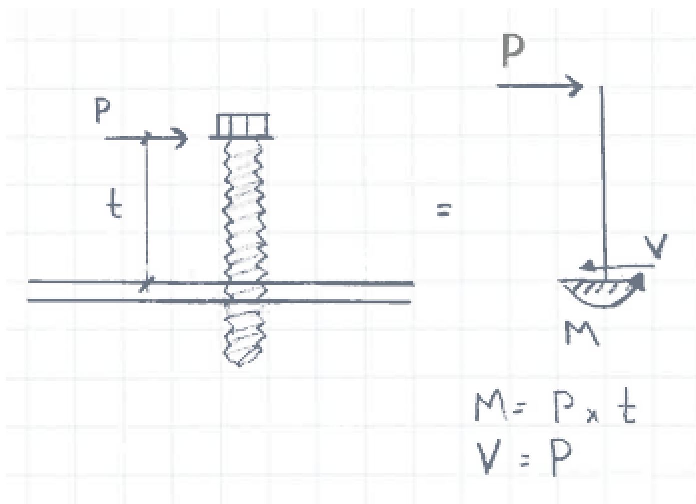


Fig. Z.3 - Sketch of screw tested in cantilever

The cantilevers used where the same thickness of shims tested, 3 tests were performed for each different cantilever, and from the results an average capacity was obtained for each span as shown on Table F.

This information is very useful to directly compare the screw capacity of a screw under single bending obtained with equations with the real capacity obtained from the tests.

When calculating a screw under bending there is doubt of what to use as the screw diameter; if either use the nominal diameter of the screw or the root diameter or internal threads diameter of the screw; from the tests performed it was found that the screw under bending doesn't break horizontally in the inner part of the screw threads as it could be supposed, but is breaks at an approximate 40 degrees angle as shown in Fig. H or I

The surface area that breaks in a 40 degrees angle is greater area than a horizontal area inside a thread; this experiments prove that the area resisting the bending is not the area obtained with the root or internal thread diameter, is a bigger area; from the results of the actual capacity of the screw in bending obtained from the test it can be obtained the percentage of the nominal diameter that would actually give that capacity for different Cantilevers; this reduction factor would be calculated on the Calculations chapter.

With the results of the average load capacity of the 3 tests for each span, calculations would be performed to obtained the real diameter that would give that capacity; this diameter has to be a diameter greater than the root internal thread diameter but smaller than the nominal diameter; and this way a percentage R of the nominal diameter would be experimentally obtained for each span, at the end an average of the percentages can be obtained, and this final percentage can be used as a reduction factor of the nominal diameter of the screw when calculating screws under bending.

The screws where tested in a one by one basis to determine the bending capacity of the screw itself without shims, this way the screw would be under a true fixed pin condition like on a cantilever, then on the next chapter by calculating the capacity of the same screw by hand calculations we can compare the results and calculate a true diameter of failure; since the diameter of failure is not flat on the treaded area, but at 40 degrees, with this the real failure diameter can be determined.

The screw was also tested in direct shear when the screw is fully screwed and the screw head is in contact with the tube as shown on the pictures. Results are presented on next table. The rate of load used on these tests was from 60 to 80 lb/sec.

Table F - Screws in Cantilever summary of tests

CANTI-LEVER	1ST TEST	2ND TEST	3RD TEST	**AVG. (LB)**
1 1/4”	226	180	177	**194**
1”	248	211	225	**228**
3/4”	282	289	279	**283**
1/2”	401	373	386	**386**
1/4”	639	555	706	**633**
0	3228	2114	2548	**2630**

CANTILEVER: 1 1/4”

This first test in cantilever was made for a screw with 1 ¼” of span in cantilever, that is the distance between the steel tube support to the lower part of the head screw as shown on Fig. AB.1, in the same manner as the aluminum anchor plate the screw where tested to determine the ultimate load P that the screw could handle in cantilever, results are show on Fig. AB.4

Fig. AB.1 – 1 ¼” Cantilever

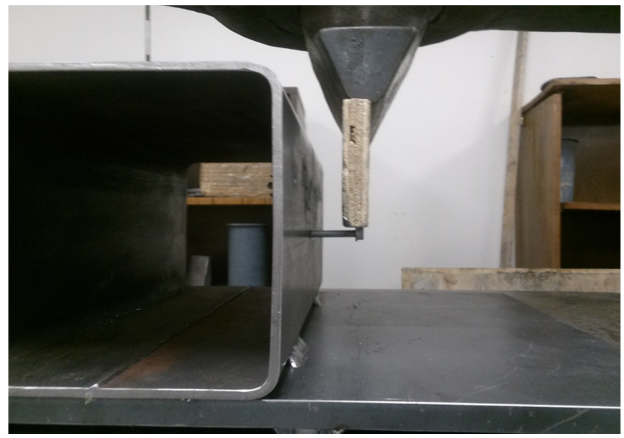


Fig. AB.2 - Ready to test

Fig. AB.3 - Tested

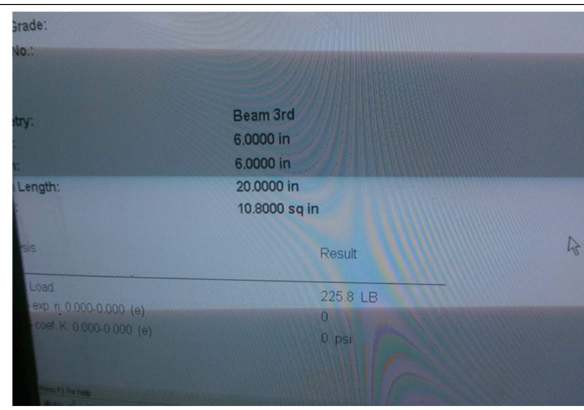


Fig. AB.4 - Results 226 #

Fig. - Screw Tested in Cantilever 1 1/4”

It can be noted on Fig. AB.3 that the screw deformed considerable before losing capacity, this is a yield failure instead of an ultimate failure, this is because the screw material has a big yield strength; the yield strength is 92ksi, the screw deforms a good amount before starting to yield.

The deflection graph can be seen on Test #12.1 it shows that the screw deflects .42” before starting to loose capacity; the graph doesn’t show a smooth curve because when trying to reduce the load rate to 60 to 80lb/sec, the graph would do small jumps.

CANTILEVER: 1"

Fig. AC.1 – 1" Cantilever

Fig. AC.2 - Ready to test

In a similar way 1" span screw was tested, from the results on Appendix B Test #12.2 it can be seen that the screw starts yielding when it reaches .12", then it continues to deform without taking more load until it reaches .42", at that point the capacity increases until reaches the ultimate point load at 248# and .56" when it suddenly reduces the capacity and finally breaks at .83"

CANTILEVER: 3/4” SPAN

Fig. AD.1 – ¾” Cantilever

Fig. AD.2 – Screw tested

Fig. AD.3 – Tested

In a similar way 3/4” span screw was tested, from the results on Appendix B Test #12.3, the machine didn’t started to show results until it almost reached the ultimate strength, it resisted 282#, but there are two more tests with ¾” cantilever, Test #29 and Test #39, both show like an arched graph, it could be that the yield strength (92ksi) and the ultimate strength (120ksi) are very close that when starts yielding suddenly fails.

CANTILEVER: 1/2” SPAN

Fig. AE.1 – 1/2” Cantilever

Fig. AE.2 - Ready to test

Fig. AE.3 - Screw Tested

For ½” the average capacity is 386” and tests graphs are shown on Appendix B Test #12.4, Test #29 and Text #38, same arched graph is shown.

Fig. AF.1 – 1/4” Cantilever

Fig. AF.2 - Ready to test

Fig. AF.3 - Screw Tested

CANTILEVER: 1/4” SPAN

Fig. AG.1 – Direct Shear

Fig. AG.2 - Ready to test

NO CANTILEVER, DIRECT SHEAR

CHAPTER 5
SCREWS
FAILURE

CHAPTER 5

SCREWS FAILURE

On this chapter pictures of screws in failure would be presented, classified in Cantilever, Horseshoe shims, Full bearing shims free fit and Full bearing shims close fit.

CANTILEVERED SCREWS FAILURE:

These screws where tested in Cantilever with no shims, like a fixed free condition and also a single bending condition; the point load is located at the head at the lower part of the head or built in washer; these tests were made in order to determine the capacity of a single screw in bending without the influence of a shim, in this case the screw would be in full single bending without any tension/compression couple and because of these it would not have any friction contribution and it would not have a double bending condition because it has no aluminum plate, from the results it can be seen that the screws resisted much more when they have a plate installed.

Another reason to test the screws in cantilever was to determine thru hand calculations the equivalent diameter that is failing using the results from the test, because there is no knowledge on weather to use the internal thread diameter or the nominal diameter when calculating screws in bending; whit these tests a real diameter can be calculated, this diameter resulted in between the minimum diameter and the nominal diameter; then a reduction factor would be calculated to apply to the nominal diameter to get the capacity obtained in the lab test.

Fig A – Cantilever 1 1/4”

Fig B – Cantilever ”

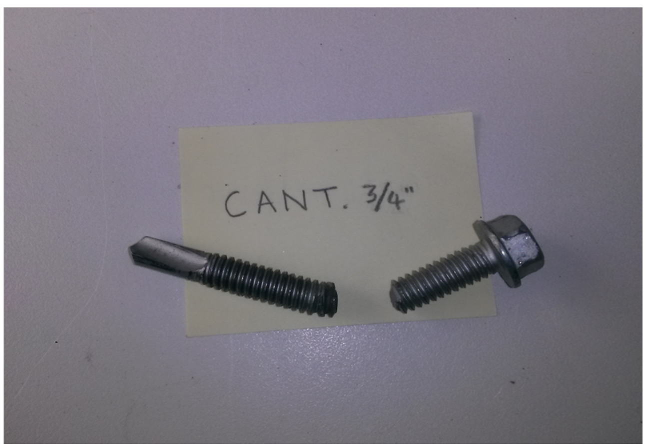


Fig C – Cantilever 3/4”

Fig D – Cantilever 3/4”

Fig E – Cantilever 1/2”

Fig F – Cantilever 1/4”

Fig G – No Shims

SCREWS WITH HORSESHOE SHIMS FAILURE:

The next set of pictures would show the screws in failure that where used to test the aluminum plate anchor with the horseshoe shims, for thicknesses of 1/4” 1/2” 3/4” and 1”.

It is clear to see that the screw is under double bending, as shown on the screws that didn't broke on Fig. J and K, the screw is bent at the Head and is also bent at the bottom, all pictures show the head bent, and in all the picture the failure was at the lower portion or at the steel support wish means that the moment was greater at the base.

Another characteristic that can be seen on the failed screws is that the plane of failure is not on a flat interior thread surface, but the failure is in an angle, close to 40 degree angle, it can be seen that the plane of failure is in an area conformed by 2 to 3 threads; this means that the area of failure in bending it not the internal thread area, is a larger area, but maybe is not as large as the nominal diameter area, more calculations would be made on the next chapter to determine the diameter of failure.

Fig H – Horseshoe shims 1/4”

Fig I – Horseshoe shims 1/2”

Fig J – Horseshoe shims 3/4”

Fig K– Horseshoe shims 1”

SCREWS WITH FULL BEARING SHIMS FAILURE:

For the screws tested with Full Bearing shim, it can be seen that when comparing free fit holes with close fit holes, the screw bent about the same, and in difference with the Horse shoe shims the screws would fail either at the base or at the Head, but more likely at the Head, this could be because the full bearing shim close fit prevents the screw from bending at the base; and it looks like with the close fit holes the screw bents less at the bottom part compared to the free fit holes.

With these shims the screw would also fail in a double bending condition like with the Horseshoe shims; this is when going in to 3/16” steel or the author would say when going into 1/8” steel or 10Ga. Steel (.1”), not know what happens when going into 12 14 or 16Ga. Steel, additional testing would need to be performed.

Fig L – Full Bearing Free Fit shims 1”

Fig M – Full Bearing Free Fit shims 1”

Fig N – Full Bearing Close Fit shims 1”

Fig O – Full Bearing Close Fit shims 1”

SCREWS WITH HORSESHOE SHIMS WHEN GOING INTO 18Ga STEEL:

Typical anchors go into either 16Ga. Studs or 14Ga. Studs; a 18Ga. Stud was donated by Action Gypsum Supply, LP; some tests where made with a 18Ga. Stud, typically the 18Ga stud is used at interior applications because these studs are too thin that do not have any structural capacities, typically designed for 5psf.

Some tests where made with the screws going into 18Ga. Steel, an 18Ga. steel stud was mounted on the steel tube support as shown on Fig. T; and as it was expected it handled much less load than the anchors at the steel tube.

Per the pictures shown the screws failed in single bending, since the screws bent at the Head and failed at the Head, but the lower portion of the screw remained straight, and as shown on Fig. S, the 18Ga. Stud would bend and would fail before the screw could bend at the stud.

Fig P – Horseshoe shims 1/4" into 18Ga

Fig Q – Horseshoe shims 1/2" into 18Ga

 **Fig R – Horseshoe shims 1/2" into 18Ga**	 **Fig S - 18 Gage failure**

Fig T – 18 Gage Stud Mounted on Steel Tube

SCREWS WITH NO SHIMS ONLY THE ALUMINUM PLATE:

The screws where also tested for the case when there was no shims, the failure was in a direct shear, in a straight plane as shown on Fig. V; the capacity of the screws where very high with no shims, it resisted an average of 6178# wish divided by two screws and by the safety factor of 3 (Table 20.3 note 2) it gives a shear capacity of 1029#, much more than the screw shear capacity that comes from table 20.3 shown in Appendix C of 646#; what it is clear to assume that the shear capacity shown on the table it was tested with some offset of maybe 1/8" and with no plate; the plate even without shims create a tension compression couple and a friction; the friction resistance would be the difference of 1029#-646# = 384# are being hold by friction per screw.

Fig U – Plate with No shims

Fig V – Single shear failure

CHAPTER 6
CALCULATIONS

CHAPTER 6

CALCULATIONS

SCREWS IN CANTILEVER

A screw is under bending when a section of the screw body has an applied moment; and the way that moment is created is when the load has an offset from the base of the screw as shown:

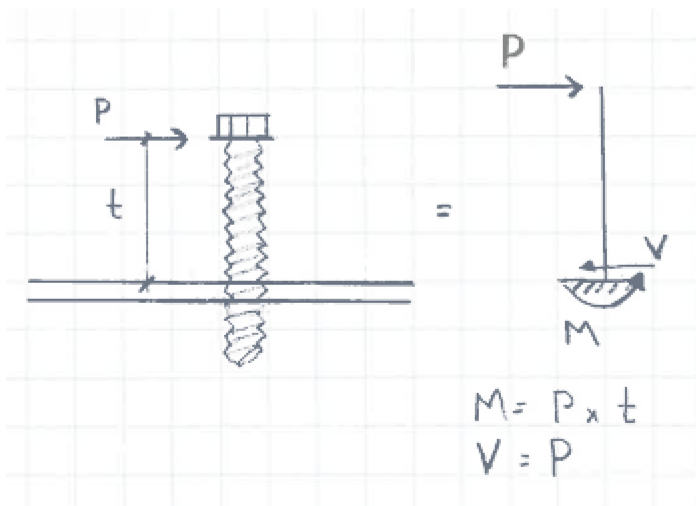


Fig. BA - Sketch of screw tested in cantilever

In this case the screw is on cantilever or fixed free condition, and the moment M would be equal to the load P times the offset of the load, with a moment and a shear at the base of the screw.

The next calculations would be performed to obtain the capacity in bending for screws in cantilever with ¼”, ½”, ¾”, 1” and 1 ¼” cantilevers; and then the results would be tabulated on Table G and compared with the results from Table F, to determine the difference between the hand calculations and the lab tests.

THE NEXT CALCULATIONS ARE THE CAPACITY OBTAINED WITH THE NOMINAL DIAMETER FOR DIFFERENT CANTILEVERS

1/4" CANTILEVER

Section F11 - Flexure, Reactangular Bars and Rounds

Flexure Reduction Factor $\phi_b := .9$

Limit state of yielding:

Nominal Diameter $d := .25in$

Plastic Section Modulus: $Z := \frac{d^3}{6}$ $\quad Z = 0.0026\,in^3$

Yield Strength $F_y := 92ksi$

Nominal Flexural Strength $M_n := F_y \cdot Z$ $\quad M_n = 240\,in \cdot lb$ $\quad < \quad 1.6\ My$

Design Flexural Strength $\phi M_n := \phi_b \cdot M_n$ $\quad \phi M_n = 216\,in \cdot lb$

Section G - Shear:

Shear Reduction Factor $\phi_v := .9$

Area of shear $A_w := \frac{\pi \cdot d^2}{4}$ $\quad A_w = 0.049\,in^2$

Nominal shear strength $V_n := .6 \cdot F_y \cdot A_w$ $\quad V_n = 2710\,lb$

Design shear strength $\phi V_n := \phi_v \cdot V_n$ $\quad \phi V_n = 2439\,lb$

THE LOAD P MANUALLY MODIFIED TO GET INTERACTION CLOSE TO 1

Required Load $V_r := 775lb$ *(load P)*

Cantilever $t := .25in$

Required Flexureal Strength $M_r := V_r \cdot t$ $\quad M_r = 194\,in \cdot lb$

Section H3.2 - Member subject to combined Shear and Flexure:

Interaction $Int := \left(\frac{M_r}{\phi M_n}\right) + \left(\frac{V_r}{\phi V_n}\right)^2$ $\quad Int = 1$

1/2" CANTILEVER

Section F11 - Flexure, Reactangular Bars and Rounds

Flexure Reduction Factor $\phi_b := .9$

Limit state of yielding:

Nominal Diameter $d := .25in$

Plastic Section Modulus: $Z := \frac{d^3}{6}$

Yield Strength $F_y := 92ksi$

Nominal Flexural Strength $M_n := F_y \cdot Z$ $M_n = 240\,in \cdot lb$ < 1.6 My

Design Flexural Strength $\phi M_n := \phi_b \cdot M_n$ $\phi M_n = 216\,in \cdot lb$

Section G - Shear:

Shear Reduction Factor $\phi_v := .9$

Area of shear $A_w := \frac{\pi \cdot d^2}{4}$ $A_w = 0.049\,in^2$

Nominal shear strength $V_n := .6 \cdot F_y \cdot A_w$ $V_n = 2710\,lb$

Design shear strength $\phi V_n := \phi_v \cdot V_n$ $\phi V_n = 2439\,lb$

THE LOAD P MANUALLY MODIFIED TO GET INTERACTION CLOSE TO 1

Required Load $V_r := 420lb$ *(load P)*

Cantilever $t := .5in$

Required Flexureal Strength $M_r := V_r \cdot t$ $M_r = 210\,in \cdot lb$

Section H3.2 - Member subject to combined Shear and Flexure:

Interaction $Int := \left(\frac{M_r}{\phi M_n}\right) + \left(\frac{V_r}{\phi V_n}\right)^2$ $Int = 1.004$

3/4" CANTILEVER

Section F11 - Flexure, Reactangular Bars and Rounds

Flexure Reduction Factor $\phi_b := .9$

Limit state of yielding:

Nominal Diameter $d := .25in$

Plastic Section Modulus: $Z := \frac{d^3}{6}$

Yield Strength $F_y := 92ksi$

Nominal Flexural Strength $M_n := F_y \cdot Z$ $M_n = 240\,in \cdot lb$ $<$ 1.6 My

Design Flexural Strength $\phi M_n := \phi_b \cdot M_n$ $\phi M_n = 216\,in \cdot lb$

Section G - Shear:

Shear Reduction Factor $\phi_v := .9$

Area of shear $A_w := \frac{\pi \cdot d^2}{4}$ $A_w = 0.049\,in^2$

Nominal shear strength $V_n := .6 \cdot F_y \cdot A_w$ $V_n = 2710\,lb$

Design shear strength $\phi V_n := \phi_v \cdot V_n$ $\phi V_n = 2439\,lb$

THE LOAD P MANUALLY MODIFIED TO GET INTERACTION CLOSE TO 1

Required Load $V_r := 284lb$ *(load P)*

Cantilever $t := .75in$

Required Flexureal Strength $M_r := V_r \cdot t$ $M_r = 213\,in \cdot lb$

Section H3.2 - Member subject to combined Shear and Flexure:

Interaction $Int := \left(\frac{M_r}{\phi M_n}\right) + \left(\frac{V_r}{\phi V_n}\right)^2$ $Int = 1.001$

1" CANTILEVER

Section F11 - Flexure, Reactangular Bars and Rounds

Flexure Reduction Factor $\phi_b := .9$

Limit state of yielding:

Nominal Diameter $d := .25in$

Plastic Section Modulus: $Z := \frac{d^3}{6}$

Yield Strength $F_y := 92ksi$

Nominal Flexural Strength $M_n := F_y \cdot Z$ $M_n = 240\,in \cdot lb$ $<$ 1.6 My

Design Flexural Strength $\phi M_n := \phi_b \cdot M_n$ $\phi M_n = 216\,in \cdot lb$

Section G - Shear:

Shear Reduction Factor $\phi_v := .9$

Area of shear $A_w := \frac{\pi \cdot d^2}{4}$ $A_w = 0.049\,in^2$

Nominal shear strength $V_n := .6 \cdot F_y \cdot A_w$ $V_n = 2710\,lb$

Design shear strength $\phi V_n := \phi_v \cdot V_n$ $\phi V_n = 2439\,lb$

THE LOAD P MANUALLY MODIFIED TO GET INTERACTION CLOSE TO 1

Required Load $V_r := 214lb$ *(load P)*

Cantilever $t := 1in$

Required Flexureal Strength $M_r := V_r \cdot t$ $M_r = 214\,in \cdot lb$

Section H3.2 - Member subject to combined Shear and Flexure:

Interaction $Int := \left(\frac{M_r}{\phi M_n}\right) + \left(\frac{V_r}{\phi V_n}\right)^2$ $Int = 1$

1 1/4" CANTILEVER

Section F11 - Flexure, Reactangular Bars and Rounds

Flexure Reduction Factor $\phi_b := .9$

Limit state of yielding:

Nominal Diameter $d := .25\text{in}$

Plastic Section Modulus: $Z := \dfrac{d^3}{6}$

Yield Strength $F_y := 92\text{ksi}$

Nominal Flexural Strength $M_n := F_y \cdot Z$ $M_n = 240\,\text{in}\cdot\text{lb}$ $<$ 1.6 My

Design Flexural Strength $\phi M_n := \phi_b \cdot M_n$ $\phi M_n = 216\,\text{in}\cdot\text{lb}$

Section G - Shear:

Shear Reduction Factor $\phi_v := .9$

Area of shear $A_w := \dfrac{\pi \cdot d^2}{4}$ $A_w = 0.049\,\text{in}^2$

Nominal shear strength $V_n := .6 \cdot F_y \cdot A_w$ $V_n = 2710\,\text{lb}$

Design shear strength $\phi V_n := \phi_v \cdot V_n$ $\phi V_n = 2439\,\text{lb}$

THE LOAD P MANUALLY MODIFIED TO GET INTERACTION CLOSE TO 1

Required Load $V_r := 172\text{lb}$ *(load P)*

Cantilever $t := 1.25\text{in}$

Required Flexureal Strength $M_r := V_r \cdot t$ $M_r = 215\,\text{in}\cdot\text{lb}$

Section H3.2 - Member subject to combined Shear and Flexure:

Interaction $\text{Int} := \left(\dfrac{M_r}{\phi M_n}\right) + \left(\dfrac{V_r}{\phi V_n}\right)^2$ $\text{Int} = 1.002$

Table G – Comparative of hand calculations with lab tests

CANTI-LEVER	**AVG. (LB)**	**HAND CALCS**
1 1/4”	**194**	**172**
1”	**228**	**214**
3/4”	**283**	**284**
1/2”	**386**	**420**
1/4”	**633**	**775**
0	**2630**	**2439**

The hand calculations are very close to the Average of the lab test; note that the 2439# with no cantilever is equal to the Design shear strength.

One of the doubts when designing screws under bending is the diameter to use, sometimes the nominal diameter is used, or sometimes to be very conservative, the internal thread diameter is used; but as shown on the screws failing pictures from chapter 4, the screw it really fails in a slope as shown on pictures H and I from chapter 4, the shear plane is sloped and fails in a thickness of 2 to 3 threads, thus using the internal thread diameter as the diameter of failure is very conservative.

The results obtained with the hand calculations were fairly close to the results obtained from the lab test, and the nominal diameter was used in performing the hand calculations; as a next exercise a reduction factor of the diameter was calculated in order to get the same result from the hand calculation and the lab test; the tests for ¾”, 1” and 1 ¼” would be neglected since the results where about the same; a reduction factor would be calculated for the test with 1/4” cantilever and for 1/2” cantilever, and at the end an average of these 2 reduction factors would be obtained, and this reduction factor of the diameter would be suggested to be used when calculating screws in bending.

CAPACITY OF SCREW IN CANTILEVER PER AISC 14th ED.

1/4" CANTILEVER
633# FROM LAB TEST

Section F11 - Flexure, Reactangular Bars and Rounds

Flexure Reduction Factor $\phi_b := .9$

Limit state of yielding:

Nominal Diameter $d := .25\text{in}$

Reduction Factor of Diameter $RF_d := .93$ *(Modified Manually to get interaction close to 1)*

Reduced diameter $d_r := RF_d \cdot d$ $d_r = 0.233\ \text{in}$

Plastic Section Modulus: $Z := \dfrac{d_r^{\,3}}{6}$

Yield Strength $F_y := 92\text{ksi}$

Nominal Flexural Strength $M_n := F_y \cdot Z$ $M_n = 193\ \text{in}\cdot\text{lb}$ $<$ 1.6 My

Design Flexural Strength $\phi M_n := \phi_b \cdot M_n$ $\phi M_n = 173\ \text{in}\cdot\text{lb}$

Section G - Shear:

Shear Reduction Factor $\phi_v := .9$

Area of shear $A_w := \dfrac{\pi \cdot d_r^{\,2}}{4}$ $A_w = 0.042\ \text{in}^2$

Nominal shear strength $V_n := .6 \cdot F_y \cdot A_w$ $V_n = 2344\ \text{lb}$

Design shear strength $\phi V_n := \phi_v \cdot V_n$ $\phi V_n = 2109\ \text{lb}$

THE LOAD P IS EQUAL TO THE LAB TEST FOR 1/4" SHIM *(From Table F)*

Required Load $V_r := 633\text{lb}$ *(load P)*

Cantilever $t := .25\text{in}$

Required Flexureal Strength $M_r := V_r \cdot t$ $M_r = 158\ \text{in}\cdot\text{lb}$

Section H3.2 - Member subject to combined Shear and Flexure:

Interaction $\text{Int} := \left(\dfrac{M_r}{\phi M_n}\right) + \left(\dfrac{V_r}{\phi V_n}\right)^2$ $\text{Int} = 1.002$

Failure Diameter
93% of Nominal Diameter

THE SAME CALCULATIONS WOULD BE PERFORMED FOR THE DIFFERENT CANTILEVERS

Section F11 - Flexure, Reactangular Bars and Rounds

1/2" CANTILEVER
386# FROM LAB TEST

Flexure Reduction Factor $\phi_b := .9$

Limit state of yielding:

Nominal Diameter $d := .25\text{in}$

Reduction Factor of Diameter $RF_d := .97$ *(Modified Manually to get interaction close to 1)*

Reduced diameter $d_r := RF_d \cdot d$ $d_r = 0.242\text{ in}$

Plastic Section Modulus: $Z := \dfrac{d_r^{\,3}}{6}$

Yield Strength $F_y := 92\text{ksi}$

Nominal Flexural Strength $M_n := F_y \cdot Z$ $M_n = 219\text{ in}\cdot\text{lb}$ $<$ 1.6 My

Design Flexural Strength $\phi M_n := \phi_b \cdot M_n$ $\phi M_n = 197\text{ in}\cdot\text{lb}$

Section G - Shear:

Shear Reduction Factor $\phi_v := .9$

Area of shear $A_w := \dfrac{\pi \cdot d_r^{\,2}}{4}$ $A_w = 0.046\text{ in}^2$

Nominal shear strength $V_n := .6 \cdot F_y \cdot A_w$ $V_n = 2549\text{ lb}$

Design shear strength $\phi V_n := \phi_v \cdot V_n$ $\phi V_n = 2295\text{ lb}$

THE LOAD P IS EQUAL TO THE LAB TEST FOR 1/2" SHIM *(From Table F)*

Required Load $V_r := 386\text{lb}$ *(load P)*

Cantilever $t := .5\text{in}$

Required Flexureal Strength $M_r := V_r \cdot t$ $M_r = 193\text{ in}\cdot\text{lb}$

Section H3.2 - Member subject to combined Shear and Flexure:

Interaction $\text{Int} := \left(\dfrac{M_r}{\phi M_n}\right) + \left(\dfrac{V_r}{\phi V_n}\right)^2$ $\text{Int} = 1.009$

Failure Diameter

97% of Nominal Diameter

From the previous calculations it was found that a reduction factor of .97 of the nominal diameter would give the same results as the lab test for ½" of cantilever, and a reduction factor of .93 of the nominal diameter would give the same results as the lab test for ¼" of cantilever; is not calculated for ¾" because the results where the same, and either for 1" and 1 ¼" because with the nominal diameter it gave even less capacity than the lab test.

The average of the two reduction factors calculated is (.93+.97)/2 = .95

This is the number searched, **95%** of the nominal diameter can be used to calculate screws under bending; but to use the total nominal diameter it would be OK, because for ¾" 1" and 1 ¼" of cantilever even the hand calculations gave little less or the same capacity than the lab tests.

SCREWS IN ANCHOR PLATE WITH SHIMS

When an anchor plate is attached to a structure with screws, and there are shims between the plate and the structure, the screw would be under bending, and in this case would be under double bending or fixed-fixed condition as shown on Fig. BB, and the bending moment would be equal to the load P times the shim thickness divided by two.

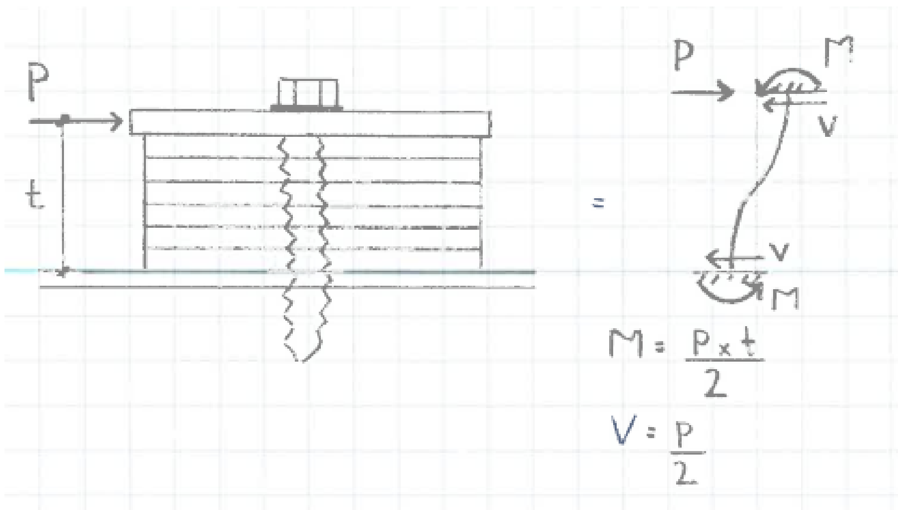


Fig. BB – Anchor with shims, Fixed Fixed condition

Because it was demonstrated from the picture on Chapter 4 that the head of the screw is bent, and also the lower part of the screw is bent, this is a fixed-fixed condition; the aluminum plate when it moves it created a couple in the screw head, and this restriction would bend the screw head, a good example of this can be seen on the pictures K, J, I and on almost every picture with shims, the head is bent.

On the next pages calculations would be performed for an anchor plate with 2 screws under double bending for different shim thicknesses, and the nominal diameter would be used, and the results would be compared with the results shown on Table E, the results from the hand calculations would be compared with the average and the snug tight condition and would be shown on Table H, the results from the hand calculations should be closer to the results from the snug tight condition since in the calculations the friction due to tension/compression couple is neglected.

THE NEXT CALCULATIONS ARE THE CAPACITY OBTAINED WITH THE NOMINAL DIAMETER FOR DIFFERENT SHIM TICKNESSES WITH TWO SCREWS IN DOUBLE BENDING

1/4" SHIM

Number of Screws $N := 2$

Section F11 - Flexure, Reactangular Bars and Rounds

Flexure Reduction Factor $\phi_b := .9$

Limit state of yielding:

Nominal Diameter $d := .25in$

Plastic Section Modulus: $Z := \frac{d^3}{6}$ $Z = 0.0026\,in^3$

Yield Strength $F_y := 92ksi$

Nominal Flexural Strength $M_n := F_y \cdot Z$ $M_n = 240\,in \cdot lb$ $<$ 1.6 My

Design Flexural Strength $\phi M_n := \phi_b \cdot M_n$ $\phi M_n = 216\,in \cdot lb$

Section G - Shear:

Shear Reduction Factor $\phi_v := .9$

Area of shear $A_w := \frac{\pi \cdot d^2}{4}$ $A_w = 0.049\,in^2$

Nominal shear strength $V_n := .6 \cdot F_y \cdot A_w$ $V_n = 2710\,lb$

Design shear strength $\phi V_n := \phi_v \cdot V_n$ $\phi V_n = 2439\,lb$

THE LOAD P MANUALLY MODIFIED TO GET INTERACTION CLOSE TO 1

Required Load $V_r := 2526lb$ ***(load P)*** (Ultimate)

Cantilever $t := .25in$

Required Flexureal Strength $M_r := \frac{V_r \cdot t}{2}$ $M_r = 316\,in \cdot lb$ ***(double bending)***

Section H3.2 - Member subject to combined Shear and Flexure:

Interaction $Int := \left(\frac{M_r}{\phi M_n \cdot N}\right) + \left(\frac{V_r}{\phi V_n \cdot N}\right)^2$ $Int = 1$

Number of Screws $N := 2$

1/2" SHIM

Section F11 - Flexure, Reactangular Bars and Rounds

Flexure Reduction Factor $\phi_b := .9$

Limit state of yielding:

Nominal Diameter $d := .25in$

Plastic Section Modulus: $Z := \frac{d^3}{6}$ $Z = 0.0026\,in^3$

Yield Strength $F_y := 92ksi$

Nominal Flexural Strength $M_n := F_y \cdot Z$ $M_n = 240\,in \cdot lb$ < 1.6 My

Design Flexural Strength $\phi M_n := \phi_b \cdot M_n$ $\phi M_n = 216\,in \cdot lb$

Section G - Shear:

Shear Reduction Factor $\phi_v := .9$

Area of shear $A_w := \frac{\pi \cdot d^2}{4}$ $A_w = 0.049\,in^2$

Nominal shear strength $V_n := .6 \cdot F_y \cdot A_w$ $V_n = 2710\,lb$

Design shear strength $\phi V_n := \phi_v \cdot V_n$ $\phi V_n = 2439\,lb$

THE LOAD P MANUALLY MODIFIED TO GET INTERACTION CLOSE TO 1

Required Load $V_r := 1550lb$ ***(load P)*** (Ultimate)

Cantilever $t := .5in$

Required Flexureal Strength $M_r := \frac{V_r \cdot t}{2}$ $M_r = 388\,in \cdot lb$ ***(double bending)***

Section H3.2 - Member subject to combined Shear and Flexure:

Interaction $Int := \left(\frac{M_r}{\phi M_n \cdot N}\right) + \left(\frac{V_r}{\phi V_n \cdot N}\right)^2$ $Int = 1$

Number of Screws $N := 2$

3/4" SHIM

Section F11 - Flexure, Reactangular Bars and Rounds

Flexure Reduction Factor $\phi_b := .9$

Limit state of yielding:

Nominal Diameter $d := .25in$

Plastic Section Modulus: $Z := \frac{d^3}{6}$ $Z = 0.0026\,in^3$

Yield Strength $F_y := 92ksi$

Nominal Flexural Strength $M_n := F_y \cdot Z$ $M_n = 240\,in \cdot lb$ < 1.6 My

Design Flexural Strength $\phi M_n := \phi_b \cdot M_n$ $\phi M_n = 216\,in \cdot lb$

Section G - Shear:

Shear Reduction Factor $\phi_v := .9$

Area of shear $A_w := \frac{\pi \cdot d^2}{4}$ $A_w = 0.049\,in^2$

Nominal shear strength $V_n := .6 \cdot F_y \cdot A_w$ $V_n = 2710\,lb$

Design shear strength $\phi V_n := \phi_v \cdot V_n$ $\phi V_n = 2439\,lb$

THE LOAD P MANUALLY MODIFIED TO GET INTERACTION CLOSE TO 1

Required Load $V_r := 1092lb$ ***(load P)*** (Ultimate)

Cantilever $t := .75in$

Required Flexureal Strength $M_r := \frac{V_r \cdot t}{2}$ $M_r = 410\,in \cdot lb$ ***(double bending)***

Section H3.2 - Member subject to combined Shear and Flexure:

Interaction $Int := \left(\frac{M_r}{\phi M_n \cdot N}\right) + \left(\frac{V_r}{\phi V_n \cdot N}\right)^2$ $Int = 1$

1" SHIM

Number of Screws $N := 2$

Section F11 - Flexure, Reactangular Bars and Rounds

Flexure Reduction Factor $\phi_b := .9$

Limit state of yielding:

Nominal Diameter $d := .25in$

Plastic Section Modulus: $Z := \frac{d^3}{6}$ $Z = 0.0026\,in^3$

Yield Strength $F_y := 92ksi$

Nominal Flexural Strength $M_n := F_y \cdot Z$ $M_n = 240\,in \cdot lb$ $<$ 1.6 My

Design Flexural Strength $\phi M_n := \phi_b \cdot M_n$ $\phi M_n = 216\,in \cdot lb$

Section G - Shear:

Shear Reduction Factor $\phi_v := .9$

Area of shear $A_w := \frac{\pi \cdot d^2}{4}$ $A_w = 0.049\,in^2$

Nominal shear strength $V_n := .6 \cdot F_y \cdot A_w$ $V_n = 2710\,lb$

Design shear strength $\phi V_n := \phi_v \cdot V_n$ $\phi V_n = 2439\,lb$

THE LOAD P MANUALLY MODIFIED TO GET INTERACTION CLOSE TO 1

Required Load $V_r := 837lb$ ***(load P)*** (Ultimate)

Cantilever $t := 1in$

Required Flexureal Strength $M_r := \frac{V_r \cdot t}{2}$ $M_r = 419\,in \cdot lb$ ***(double bending)***

Section H3.2 - Member subject to combined Shear and Flexure:

Interaction $Int := \left(\frac{M_r}{\phi M_n \cdot N}\right) + \left(\frac{V_r}{\phi V_n \cdot N}\right)^2$ $Int = 1$

Table H - Comparative of hand calculations with lab tests Anchor with shims

	TORQUED	NO TORQUED	
TEST PERFORMED:	**AVG. (LB)**	**SNUG TIGHT**	**HAND CALCS**
NO SHIMS (DIRECT SHEAR)	6178		
1/4” HORSESHOE SHIM	4454	3529	2526
1/2” HORSESHOE SHIMS	3507	3300	1550
3/4” HORESESHOE SHIMS (3)SHIMS	3915	3339	1092
1” HORSESHOE SHIMS	3812	2417	837
1/2” FULL BEARING SHIMS (Free Fit)		3141	1550
3/4” FULL BEARING SHIMS (Free Fit)		3294	1092
1” FULL BEARING SHIM (Free Fit)	4213	2485	837
1/2” FULL BEARING (Close Fit)	3630	3040	1550
3/4” FULL BEARING (Close Fit)		3478	1092
1” FULL BEARING (Close Fit)	4192		837

Per the results obtained, it is clear that the lab tests have more capacity than the hand calculations when shims are used; the hand calculations were performed with the nominal diameter and a fixed-fixed condition, is clear that the use of the nominal diameter and a fixed-fixed condition is a condition that can be used for performing bending calculations on screws; and per the results obtained it can be seen that for example for a typical ¾” shims the capacity is 3339# even on a snug tight condition that is almost the tabulated shear capacity of 642 x 2screws = 1284# x 3 safety factor = 3852#, which means that bending could be neglected when going into steel and when using up to ¾” shim, and just design for shear and tension.

CHAPTER 7
CONCLUSIONS
DISCUSSION

CHAPTER 7

DISCUSSION / CONCLUSIONS

TROUGH THE PRESENT STUDY WORK THE NEXT ITEMS CAN BE DISCUSSED AND DOUBTS ABOUT THE BEHAVIOR OF SCREWS UNDER BENDING WITH SHIMS WHERE CLARIFIED; THE ITEMS OF DISCUSSION / CONCLUSION WOULD BE NUMBERED HERE AND WOULD BE DESCRIBED AFTERWARDS:

1. THE SCREWS UNDER BENDING WITH SHIMS BEHAVE AS A CANTILEVER (FIXED FREE CONDITION) OR AS A DOUBLE BENDING MEMBER (FIXED FIXED)?

After many tests performed, it was found that the screws bent at the Head; the aluminum plate makes a prying action over the Head screw and actually bends the screw, this is correct when the hole at the aluminum is small enough to bend the Head, tests where not performed for when the holes at the aluminum plates are bigger that may not bend the head; but for a ¼" Drilflex, a ¼" Drill was used to make the holes on the aluminum, and with these holes the aluminum plate would bend the head.

The screws where also bent at the base, this is true for a steel tube, the steel tube used at these tests was a 3/16" thickness, strong enough to hold the screw and bend it at the base, this would also be applied to a 1/8" tube, because the pullout capacities are similar.

Sometimes the screw failed at the base, and sometimes it failed at the Head, the times that the screw failed at the Head was typically when using a Full Bearing shim with close fit holes as shown on Fig. N and O, this could be because the shims when bearing in the screw prevent the screw from bending at the base, but the aluminum plate still bends the Head.

Other tests were performed with an 18Ga. Stud, these studs are used on interior application where the wind load is only 5psf, so no much capacity was expected on these screws when going into an 18Ga. Stud; from the tests it was found that the screw would bend at the head, but it didn't bent at the base as shown on Fig. P, Q & R.

In conclusion, the screw bends as a fixed-fixed condition or double bending condition when the screw anchor is attached to a steel tube, 1/8” thk or more; it would bend as a fixed free condition or single bending when the anchor is attached to an 18Ga. Studs; more tests are recommended to be performed for the case when the anchor is attached to a 16Ga. or 14Ga. studs since those are thinner than 1/8” steel but thicker than a 18Ga. stud.

2. THE AREA OF RUPTURE OF THE SCREW IS THE ROOT AREA OR THE TOTAL AREA OF THE SCREW?

From all the tests performed it was shown that the screws failure plane is not a flat horizontal plane at the internal threads of the screw, actually fails in an angle of about 40 degrees, in the wide of about two to three threads as shown for example on Fig. H, I, J K; this plane of failure it has a greater area than the internal thread section cut area.

Because the real diameter of failure is unknown, some Engineers use conservatively the internal threads diameter, other Engineers use the nominal diameter, but the real failure diameter is unknown, and should be a diameter between the internal thread diameter and the nominal diameter of the screw. The tests of the screw in Cantilever from Chapter 3 where used to determine the real diameter of failure by calculating the diameter of failure of the screw for the ultimate capacity obtained.

Table G shows the results for the screws when tested on Cantilever and compares that capacity with the hand calculations; it is shown that the capacities are very similar, some test gave more capacities like for 1 ¼” or 1”, some test gave less capacity like for ½” and ¼” and for the ¾” shim hand calcs and lab tests gave the same capacity. For the tests that gave slightly more capacity we can say that the hand calculation is acceptable when using the nominal diameter (1 ¼”, 1” and ¾” cantilever), for the tests that gave less capacity than the hand calculation (1/2” and ¼” cantilever) a reduction factor of the nominal diameter was calculated and the average was .95, this is a good number to use with the nominal diameter when calculating bending on the screws.

To answer the original question the area of rupture of the screw in bending is not the root area of the screw, is the area obtained by applying a reduction factor of .95 to the nominal diameter; but the total area obtained with the nominal diameter is also acceptable to be used.

3. THE FULL BEARING SHIMS WORK DIFFERENT THAN HORSESHOE SHIMS?

By comparing all the tests performed it can be concluded that no substantial difference is obtained by using Horseshoe shims or Full bearing shims; the results where about the same in a 5% to 10% difference, but sometimes the Horseshoe shims gave better results and sometimes the Full Bearing close fit shims; by taking an average of all the shim thicknesses for Horseshoe shims, Full bearing with free fit and Full bearing with close fit, it can be concluded that the Horseshoe shims and the Full bearing close fit shims would give the same capacity, while the Full bearing free fit holes shims would give about 5% less capacity than Horseshoe shims or Full bearing close fit.

4. CLOSE FIT HOLES IN FULL BEARING SHIMS WOULD IMPROVE THE SCREW CAPACITY?

Yes, this is about the same question as the previous question, the Full Bearing close fit shims would improve the capacity by 5% than using free fit holes.

It should be noted that if using a harder shim, like sometimes a steel plate or an aluminum plate is used as shims, those would have much bigger capacity than the plastic shims, and is expected that the screw resists the total shear capacity of the screw, since it is expected to fail in shear and not in bending, because of the shim bearing very close on the screw, it would prevent the screw from bending.

5. IS THERE A FRICTION BETWEEN THE STEEL AND THE SHIM THAT WOULD IMPROVE THE SCREW CAPACITY?

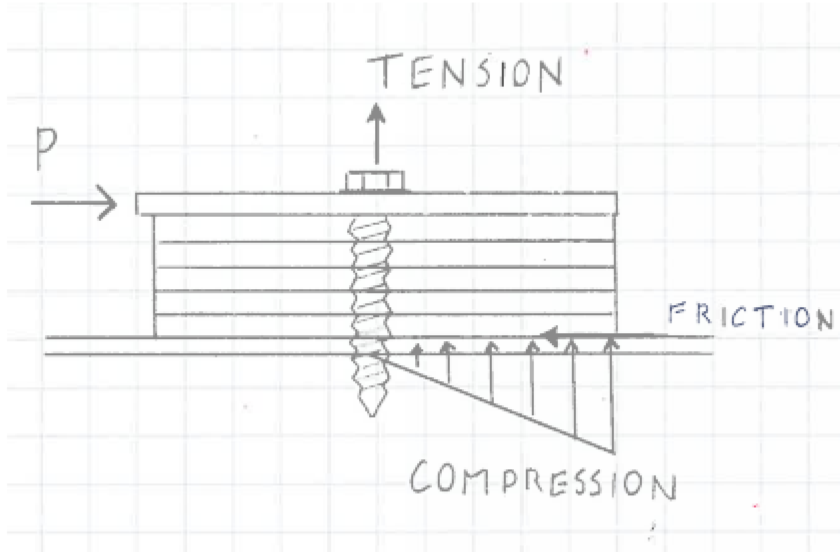
Yes, there is a friction factor that is typically conservatively neglected on the calculations; per table H it was demonstrated in the tests that when the screws where tighten to some torque (5ft.lb), the capacity of the screws would significantly increase, for example the average capacity when using 1” of full bearing shim was 4213# and when the test was made in a snug tight condition (no torque, barely tighten) the capacity was 2485#, this is because the screws create a tension compression couple that create a friction, and this friction would help the anchor to resist more load; and by comparing that capacity in snug tight condition with the hand calculations for 1” wish was only 837#, it means that the remaining 2417-837 = 1580lb is resisted only by friction, because the screws create a tension/compression couple and that compression bearing on the steel and shims would create a good amount of friction that improves the screw capacity.

6. WHEN TESTING A SCREW AS A TRUE CANTILEVER OR FIXED FREE CONDITION WITHOUT SHIMS, ARE THE RESULTS DIFFERENT FROM THE THEORETICAL CAPACITY?

No, as was demonstrated on Table G, the results from hand calculations using the nominal diameter where very similar to the results from the test; a reduction factor of .95 for the nominal diameter was calculated to get more precise results, but is not necessary to be used.

7. ARE THE PHISICAL TESTS OF THE SHIMMED ANCHOR GIVING DIFFERENT RESULTS THAN THE THEORETICAL CAPACITY OF THE SCREW UNDER BENDING?

Yes, as per Table H the lab test gave much more capacity than the Hand Calculations, even that for the hand calculations the nominal diameter was used and a fixed-fixed condition was assumed; when using shims in between the anchor plate and the connected substrate the capacity of the screw in bending increases considerably, and this is because the shims create a tension/compression couple as shown on the next sketch, that creates friction between the shims and the substrate and anchor plate.



For a direct shear it also gave more capacity, the Design shear strength per the calculations was 2439# times 2 for 2 screws is 4878#, and per the lab test the capacity was 6178#, what is means that also the flat plate against the tube creates some tension/compression couple and friction; because when a single screw was tested with no shims as shown on Table G, the capacity was 2630# wish is very similar to the design shear calculated of 2439# because there was no plate and shims, and no tension/compression couple and no friction.

SUGGESTED ADDITIONAL TESTS

This thesis demonstrated that when calculating screws under bending using shims, the Engineer can be more confident on using the nominal diameter for design, and a fixed fixed condition for calculating the bending moment.

The additional tests that can be performed are the same tests with shims but using a 16Ga. stud and a 14Ga. stud as backup material as shown on Fig. T, this figure shows a 18Ga. stud, the results with 18Ga was 1410lb and 1561lb as shown on tests #33 & #34 on Appendix A.

Additional tests can be performed measuring the torque on the screws and using different torque loads to determine the optimum torque that can be used for the different material thicknesses, elaborate a table similar to Table H showing the capacities for different shim thicknesses for different torque load increases, and elaborate one table for 1/8” Steel, 10Ga., 12Ga., 14Ga., 16Ga. and 18 Ga. steel Backup.

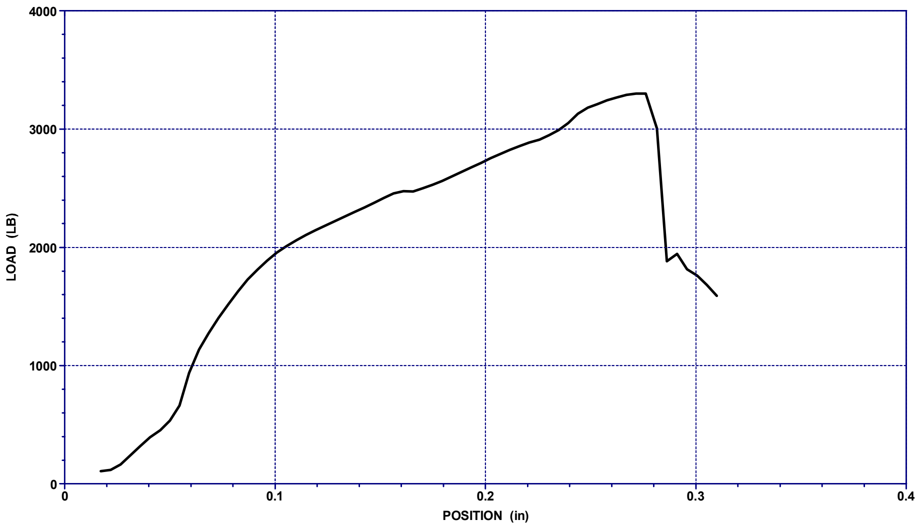
APPENDIX A
GRAPHS
TESTS WITH SHIMS

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Test #01 - 1/2" Horseshoe shim
SNUG TIGHT

Date: 12/05/06 **Time: 10:49:40**



Peak Load	**3300 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

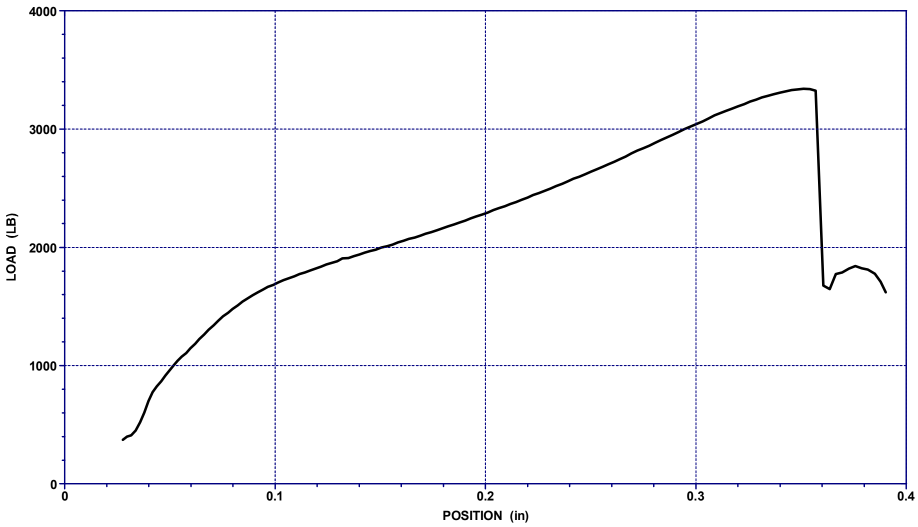
MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Test #02 - 3/4" Horseshoe shim

SNUG TIGHT

Date: 12/05/06 **Time: 11:35:42**



Peak Load	**3339 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

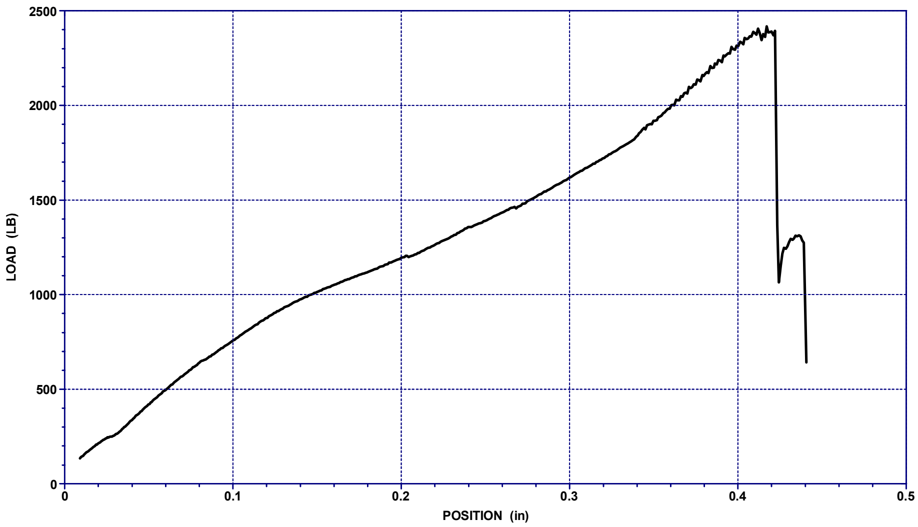
MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #03 - 1" Horseshoe shim

SNUG TIGHT

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 12/05/06 **Time: 12:15:13**



Peak Load	**2417 LB**
E646 exp. n: 0.001-0.001 (e)	**0.632**
E646 coef. K: 0.001-0.001 (e)	**887.9 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

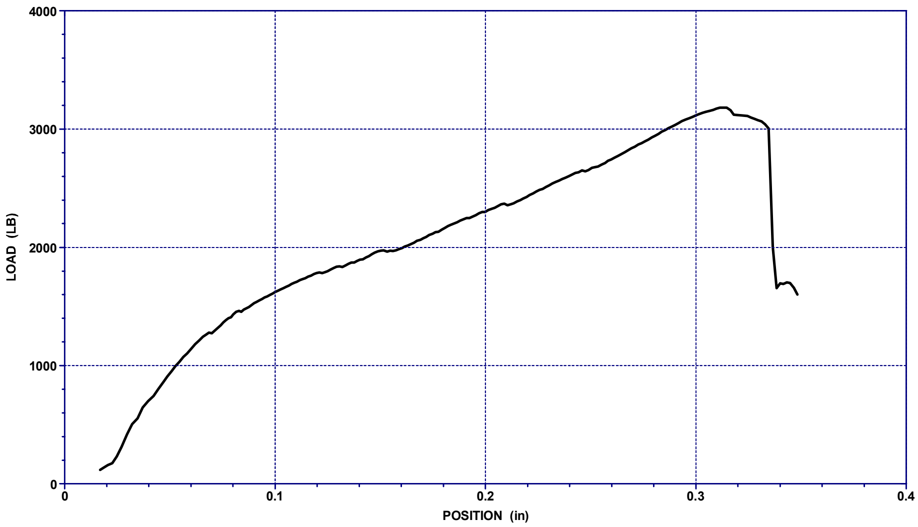
Specimen #:	114
Operator:	JCS
Order No.::	1234
Heat No.::	678
Rockwell Hardness::	82
Lift No.:	N\A
Test Orientation:	Longitudinal
Material Grade:	
Sample No.:	
O.D.:	

Test #04 - 3/4" Horseshoe shim (6)Shims

SNUG TIGHT

Geometry:	Beam 3rd
Width:	6.0000 in
Depth:	6.0000 in
Span Length:	20.0000 in
Area:	10.8000 sq in

Date: 12/05/06 Time: 12:53:03



Peak Load	3180 LB
E646 exp. n: 0.000-0.000 (e)	0
E646 coef. K: 0.000-0.000 (e)	0 psi

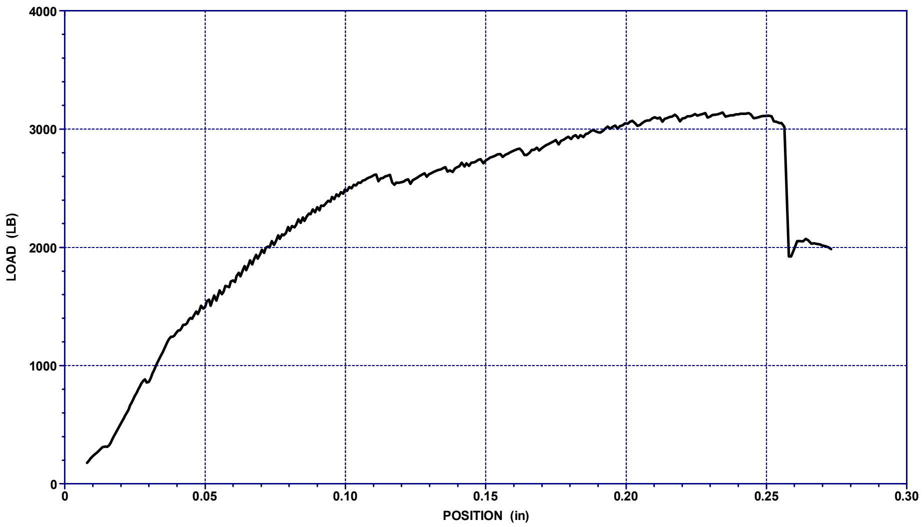
MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #05 - 1/2" Full Bearing shim

SNUG TIGHT

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 12/13/06 **Time: 06:49:33**



Peak Load	**3141 LB**
E646 exp. n: 0.001-0.001 (e)	**1.204**
E646 coef. K: 0.001-0.001 (e)	**65185 psi**

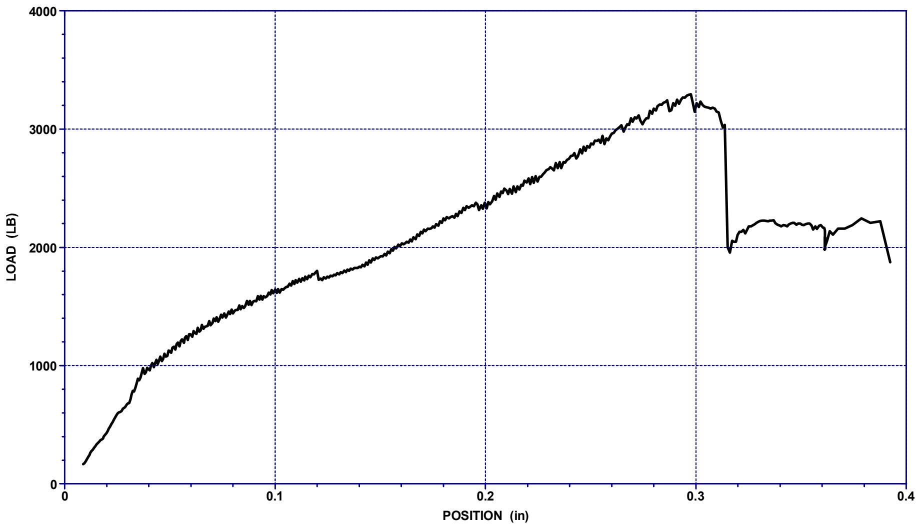
MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Test #06 - 3/4" Full Bearing shim

SNUG TIGHT

Date: 12/13/06 **Time: 07:30:16**



Peak Load	**3294 LB**
E646 exp. n: 0.001-0.001 (e)	**1.254**
E646 coef. K: 0.001-0.001 (e)	**74769 psi**

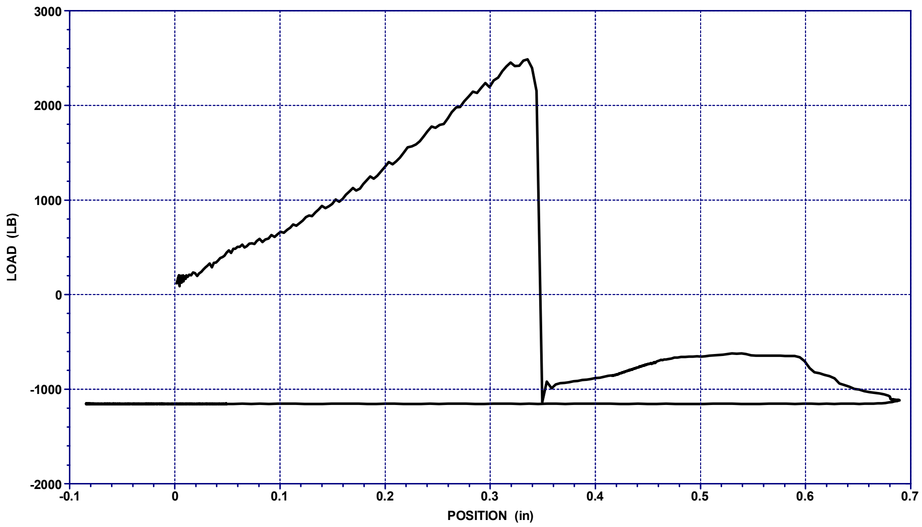
MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Test #07 - 1" Full Bearing shim

SNUG TIGHT

Date: 12/26/06 **Time: 08:20:27**



Peak Load	**2485 LB**
E646 exp. n: 0.000-0.001 (e)	**0.0681**
E646 coef. K: 0.000-0.001 (e)	**24.41 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

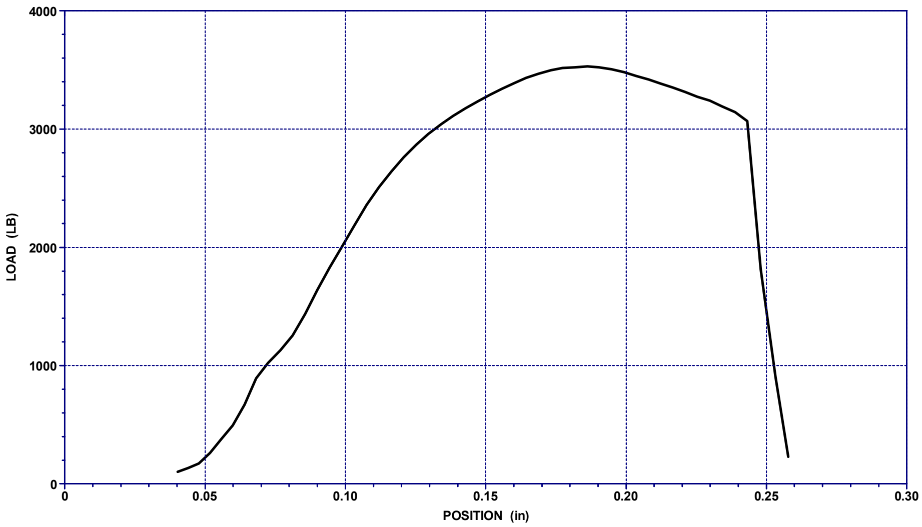
Test #08 - 1/4" Horseshoe shim

SNUG TIGHT

Specimen #:	114
Operator:	JCS
Order No.::	1234
Heat No.::	678
Rockwell Hardness::	82
Lift No.:	N\A
Test Orientation:	Longitudinal
Material Grade:	
Sample No.:	
O.D.:	

Geometry:	Beam 3rd
Width:	6.0000 in
Depth:	6.0000 in
Span Length:	20.0000 in
Area:	10.8000 sq in

Date: 12/26/06 Time: 08:47:33



Peak Load	3529 LB
E646 exp. n: 0.000-0.000 (e)	0
E646 coef. K: 0.000-0.000 (e)	0 psi

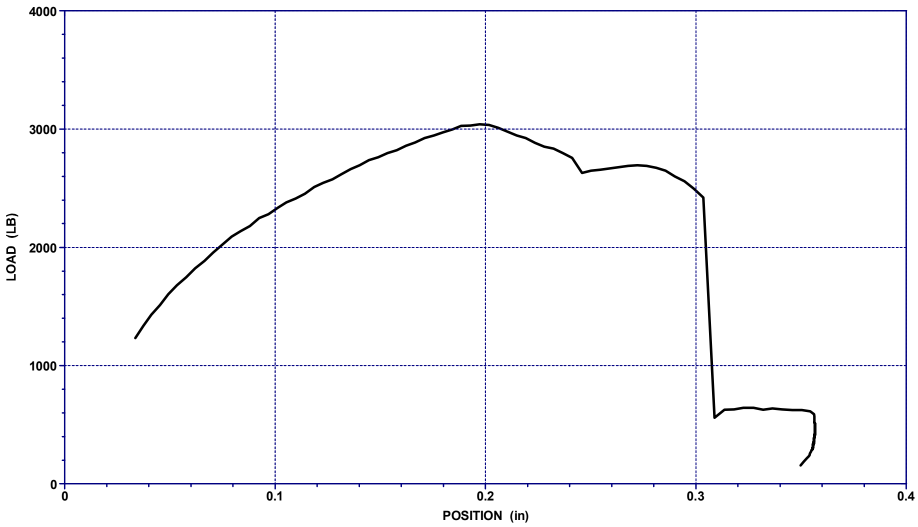
MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #09 - 1/2" Full Bearing close fit shim

SNUG TIGHT

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/02/07 **Time: 07:15:53**



Peak Load	**3040 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

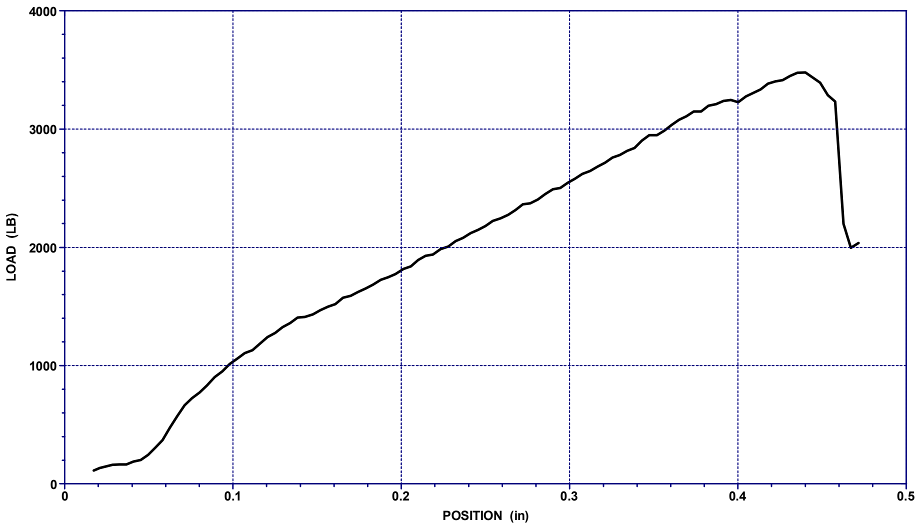
Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	

Test #10 - 3/4" Full Bearing Close Fit shim

SNUG TIGHT

Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/02/07 **Time: 08:09:01**



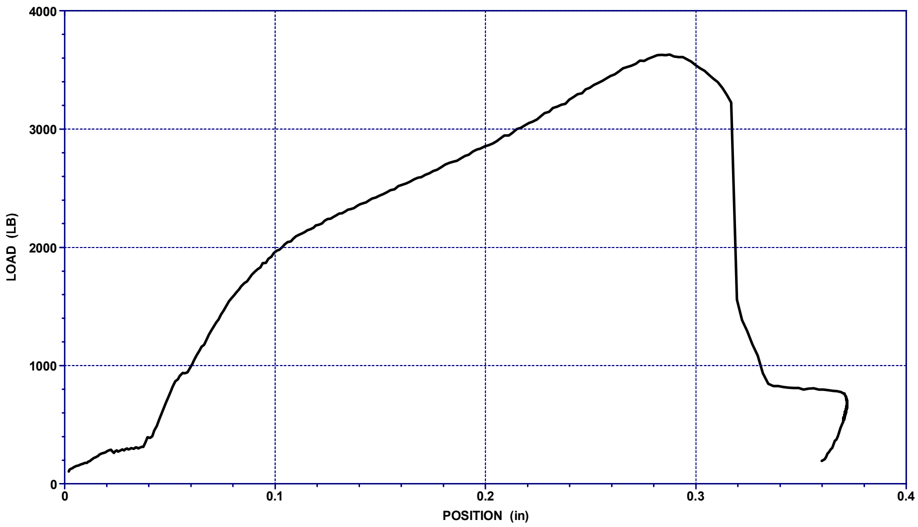
Peak Load	**3478 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Test #11 - 1/2" Full Bearing close fit shim

Date: 01/02/07 **Time: 09:31:16**



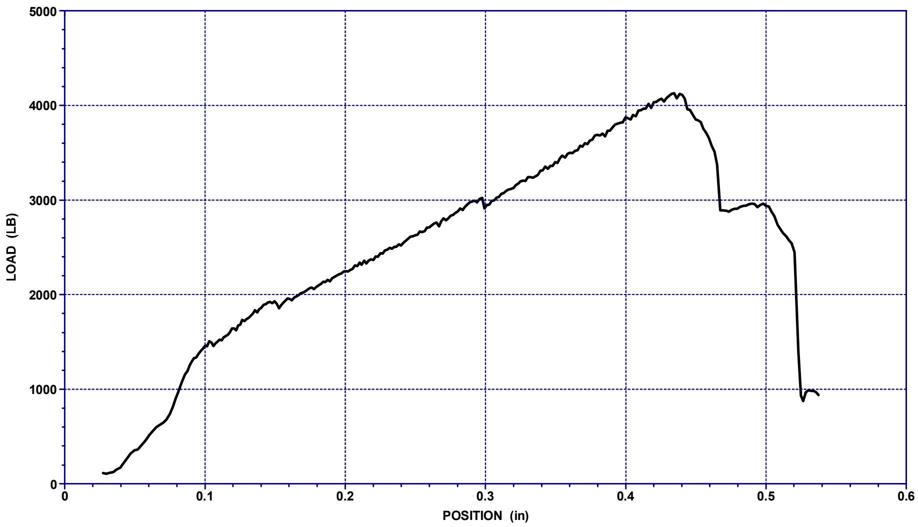
Peak Load	**3630 LB**
E646 exp. n: 0.000-0.001 (e)	**0.270**
E646 coef. K: 0.000-0.001 (e)	**98.03 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Specimen #:	114
Operator:	JCS
Order No.::	1234
Heat No.::	678
Rockwell Hardness::	82
Lift No.:	N\A
Test Orientation:	Longitudinal
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	Beam 3rd
Width:	6.0000 in
Depth:	6.0000 in
Span Length:	20.0000 in
Area:	10.8000 sq in

Test #12 - 1" Full Bearing close fit shim

Date: 01/02/07 Time: 11:22:57



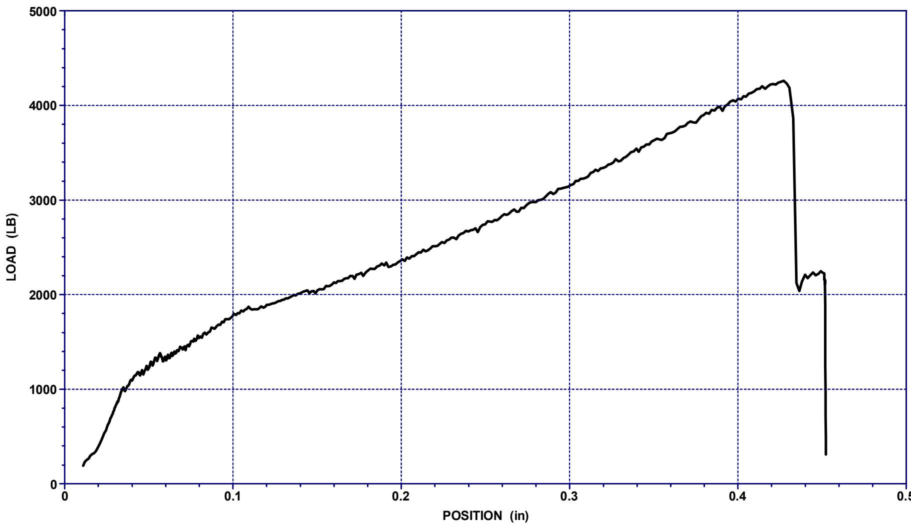
Peak Load	4127 LB
E646 exp. n: 0.000-0.000 (e)	0
E646 coef. K: 0.000-0.000 (e)	0 psi

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #13 - 1" Full Bearing close fit shim

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/09/07 **Time: 09:15:29**



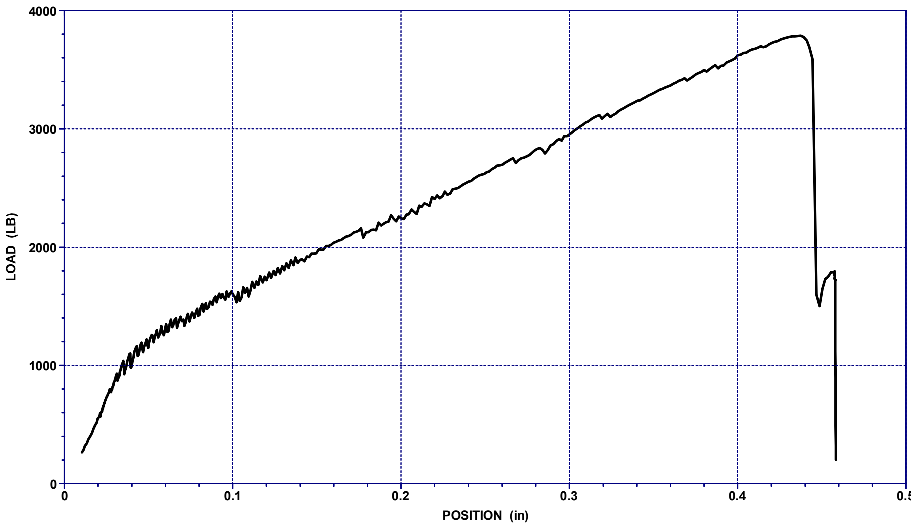
Peak Load	**4258 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Test #14 - 1" Horseshoe shim

Date: 01/09/07 **Time: 10:02:48**



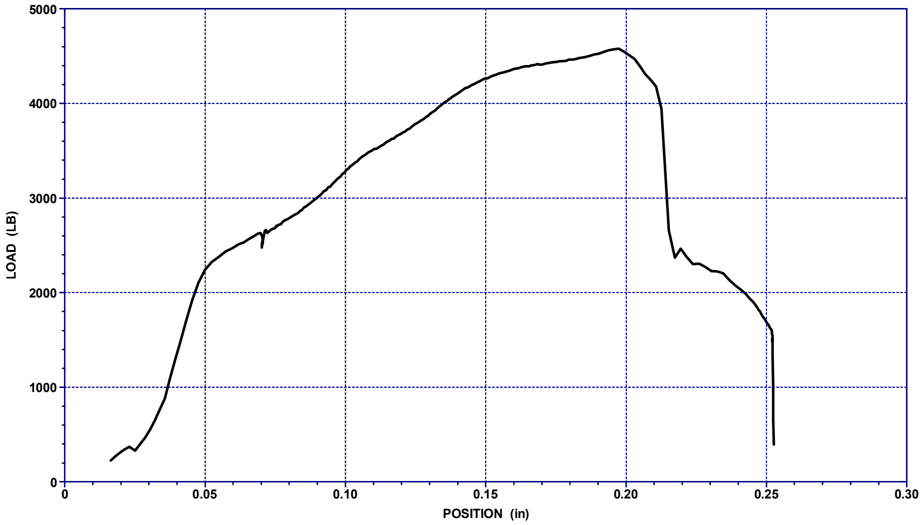
Peak Load	**3785 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #15 - 1/4" Horseshoe shim

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/09/07 **Time: 10:28:44**



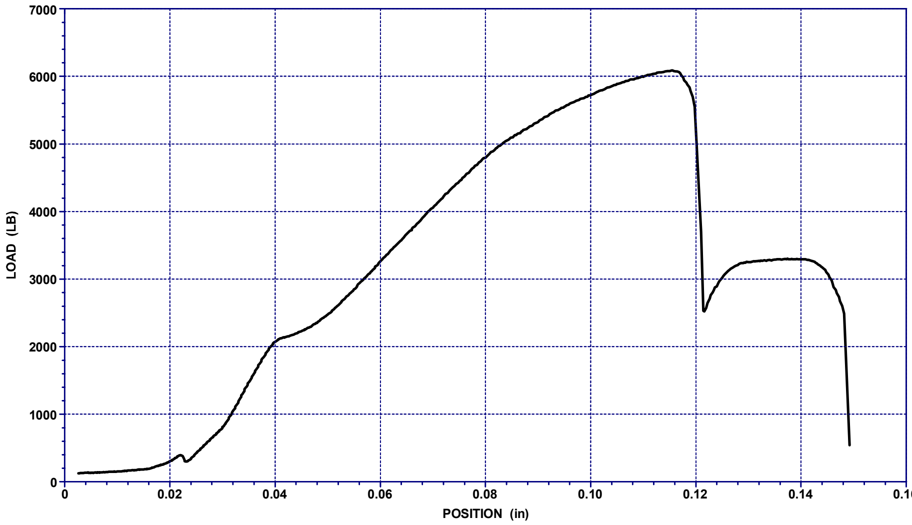
Peak Load	**4578 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Specimen #:	114
Operator:	JCS
Order No.::	1234
Heat No.::	678
Rockwell Hardness::	82
Lift No.:	N\A
Test Orientation:	Longitudinal
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	Beam 3rd
Width:	6.0000 in
Depth:	6.0000 in
Span Length:	20.0000 in
Area:	10.8000 sq in

Test #16 - Plate without shim

Date: 01/09/07 Time: 10:50:49



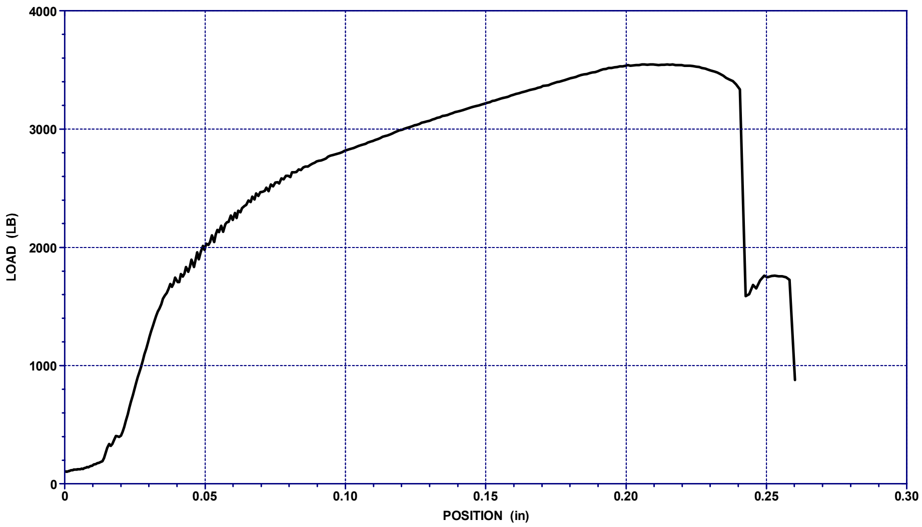
Peak Load	6084 LB
E646 exp. n: 0.000-0.001 (e)	0.134
E646 coef. K: 0.000-0.001 (e)	33.30 psi

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #17 - 1/2" Horseshoe shim

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/09/07 **Time: 11:23:15**



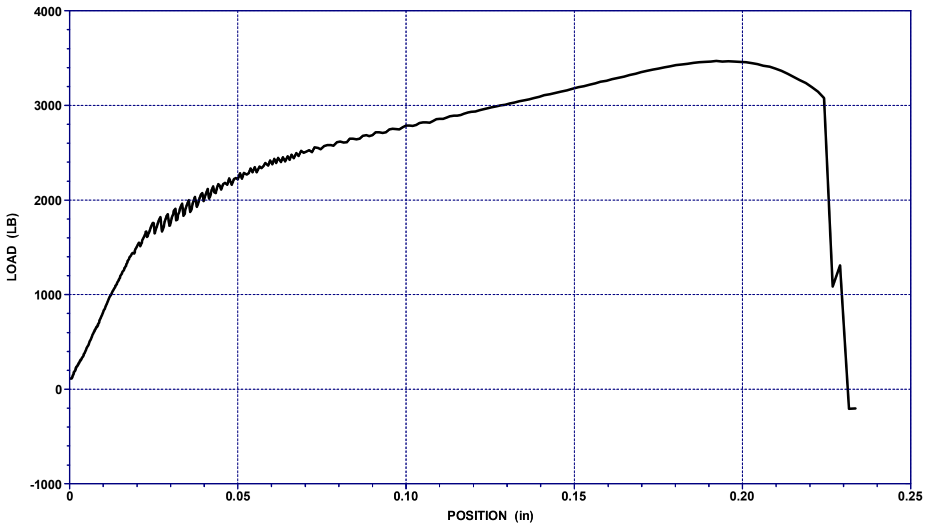
Peak Load	**3547 LB**
E646 exp. n: 0.000-0.001 (e)	**0.192**
E646 coef. K: 0.000-0.001 (e)	**47.93 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Specimen #:	114
Operator:	JCS
Order No.::	1234
Heat No.::	678
Rockwell Hardness::	82
Lift No.:	N\A
Test Orientation:	Longitudinal
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	Beam 3rd
Width:	6.0000 in
Depth:	6.0000 in
Span Length:	20.0000 in
Area:	10.8000 sq in

Test #18 - 1/2" Horseshoe shim

Date: 01/09/07 **Time: 11:36:07**



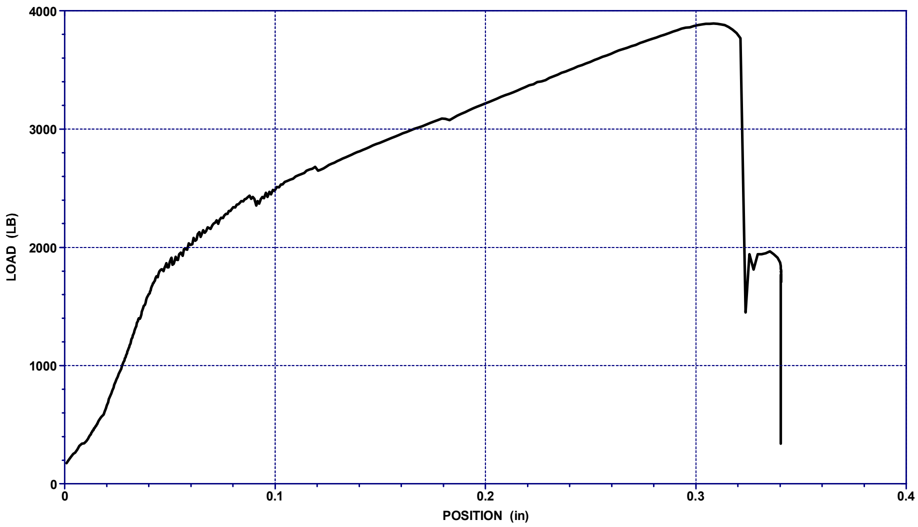
Peak Load	3467 LB
E646 exp. n: 0.000-0.001 (e)	0.825
E646 coef. K: 0.000-0.001 (e)	17597 psi

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #19 - 3/4" Horseshoe shim

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/09/07 **Time: 12:01:08**



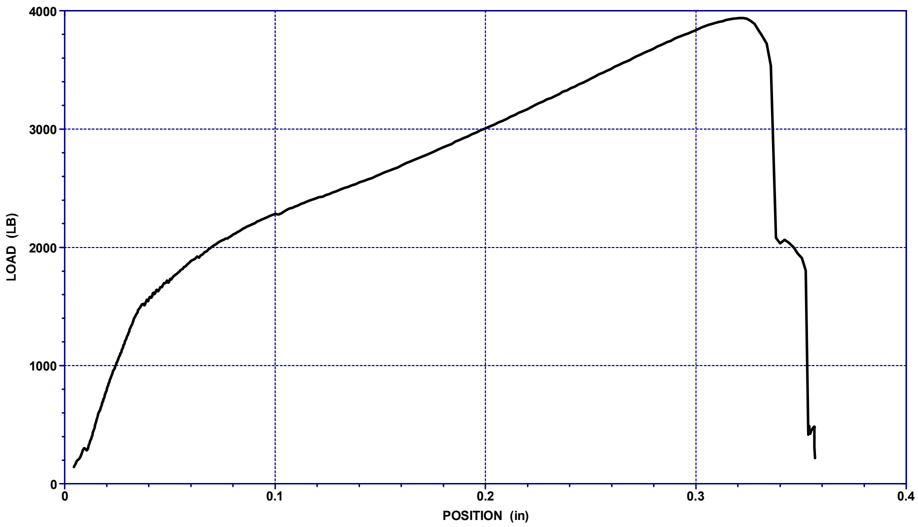
Peak Load	**3892 LB**
E646 exp. n: 0.000-0.001 (e)	**0.386**
E646 coef. K: 0.000-0.001 (e)	**431.4 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #20 - 3/4" Horseshoe shim

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/09/07 **Time: 12:13:02**



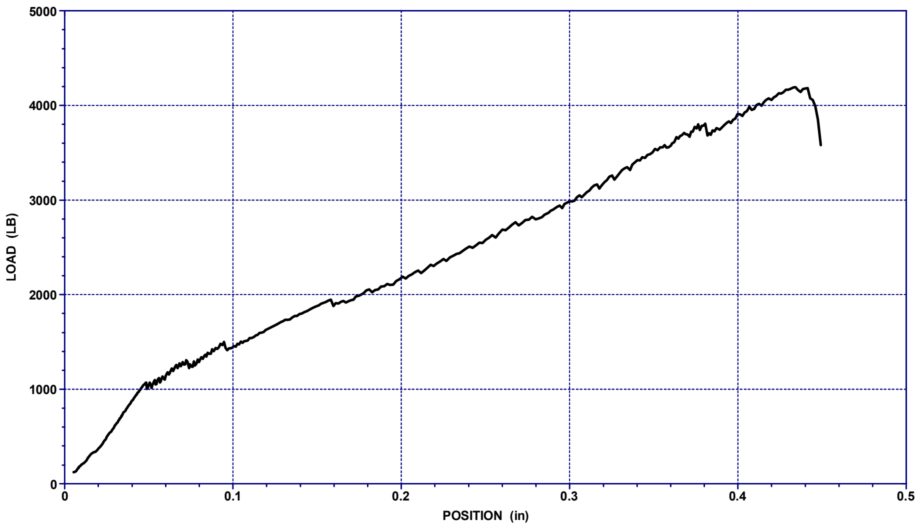
Peak Load	**3938 LB**
E646 exp. n: 0.001-0.001 (e)	**0.899**
E646 coef. K: 0.001-0.001 (e)	**11197 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Specimen #:	114
Operator:	JCS
Order No.::	1234
Heat No.::	678
Rockwell Hardness::	82
Lift No.:	N\A
Test Orientation:	Longitudinal
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	Beam 3rd
Width:	6.0000 in
Depth:	6.0000 in
Span Length:	20.0000 in
Area:	10.8000 sq in

Test #21 - 1" Full Bearing free fit shim

Date: 01/23/07 Time: 04:12:49



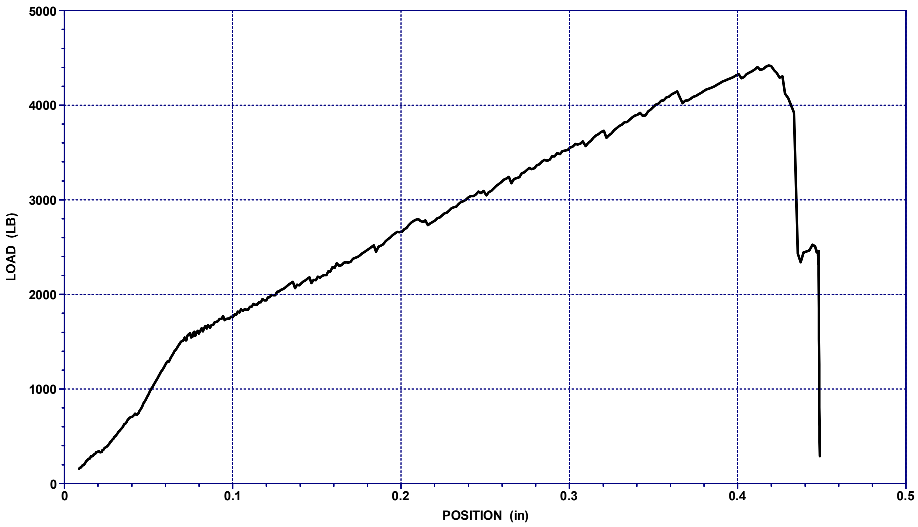
Peak Load	4193 LB
E646 exp. n: 0.001-0.001 (e)	0.883
E646 coef. K: 0.001-0.001 (e)	6592 psi

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #22 - 1" Full Bearing free fit shim

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 04:28:10**



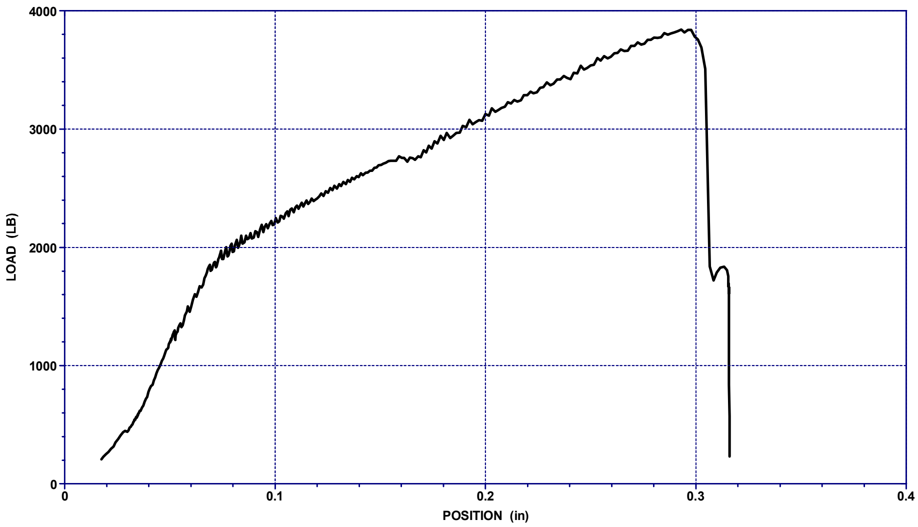
Peak Load	**4418 LB**
E646 exp. n: 0.001-0.001 (e)	**0.889**
E646 coef. K: 0.001-0.001 (e)	**6086 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #23 - 1" Horseshoe shim

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 04:38:52**



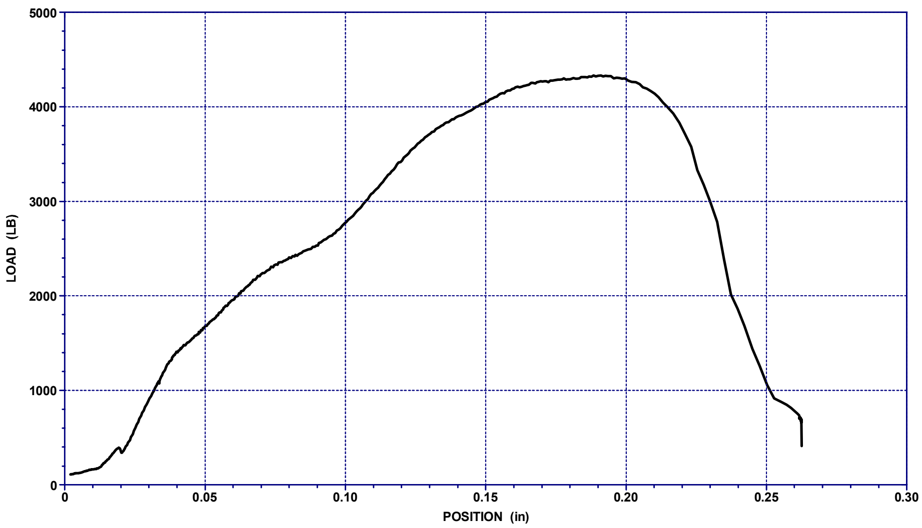
Peak Load	**3839 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #24 - 1/4" Horseshoe shim

Specimen #:	114
Operator:	JCS
Order No.::	1234
Heat No.::	678
Rockwell Hardness::	82
Lift No.:	N\A
Test Orientation:	Longitudinal
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	Beam 3rd
Width:	6.0000 in
Depth:	6.0000 in
Span Length:	20.0000 in
Area:	10.8000 sq in

Date: 01/23/07 Time: 05:00:31



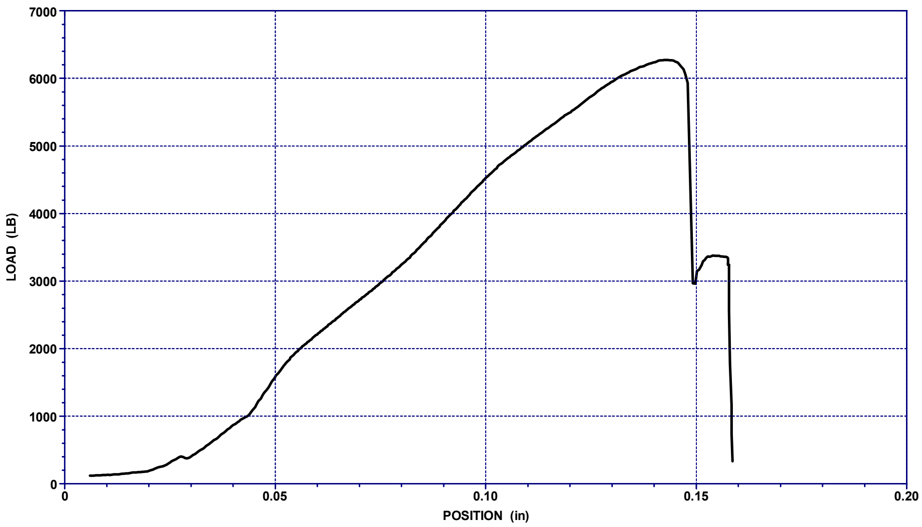
Peak Load	4331 LB
E646 exp. n: 0.000-0.001 (e)	0.275
E646 coef. K: 0.000-0.001 (e)	90.66 psi

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #25 - No shim

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 05:10:15**



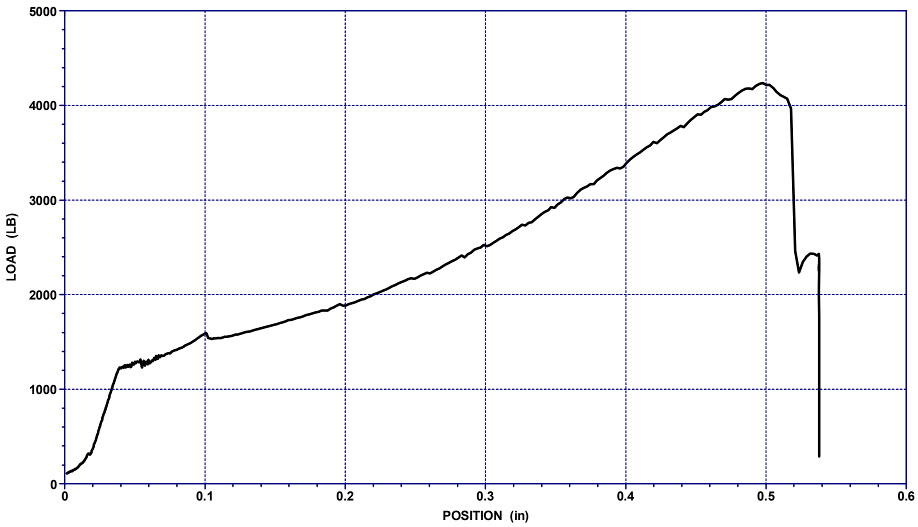
Peak Load	**6272 LB**
E646 exp. n: 0.001-0.001 (e)	**0.201**
E646 coef. K: 0.001-0.001 (e)	**46.34 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #26 - 1" Full Bearing free fit shim

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 05:38:52**



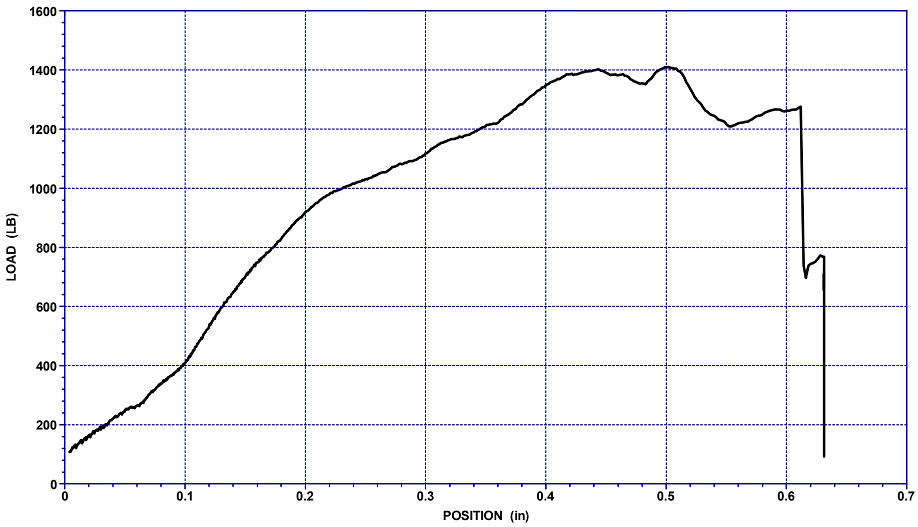
Peak Load	**4234 LB**
E646 exp. n: 0.000-0.001 (e)	**0.293**
E646 coef. K: 0.000-0.001 (e)	**110.6 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #33 - 1/2" Horseshoe shim - 18Ga.

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 08:34:08**



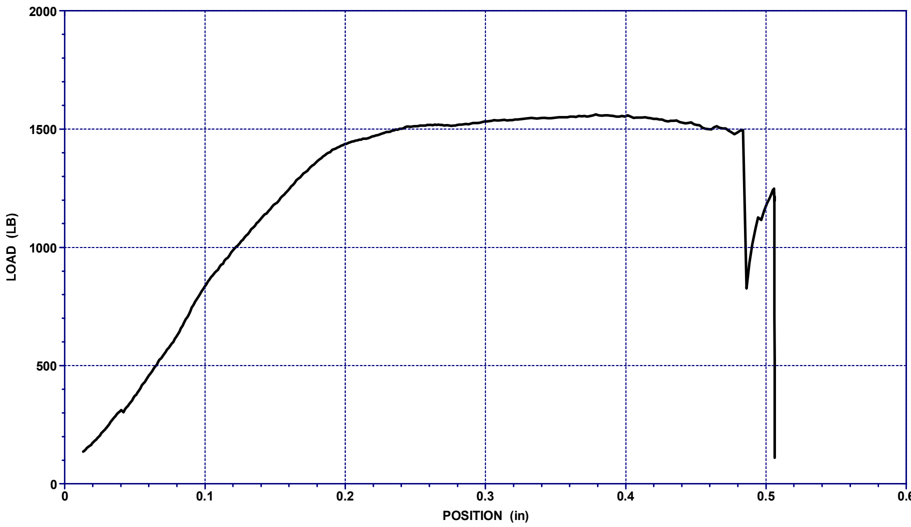
Peak Load	**1410 LB**
E646 exp. n: 0.000-0.001 (e)	**0.213**
E646 coef. K: 0.000-0.001 (e)	**49.87 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #34 - 1/4" Horseshoe shim - 18Ga.

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 08:48:02**



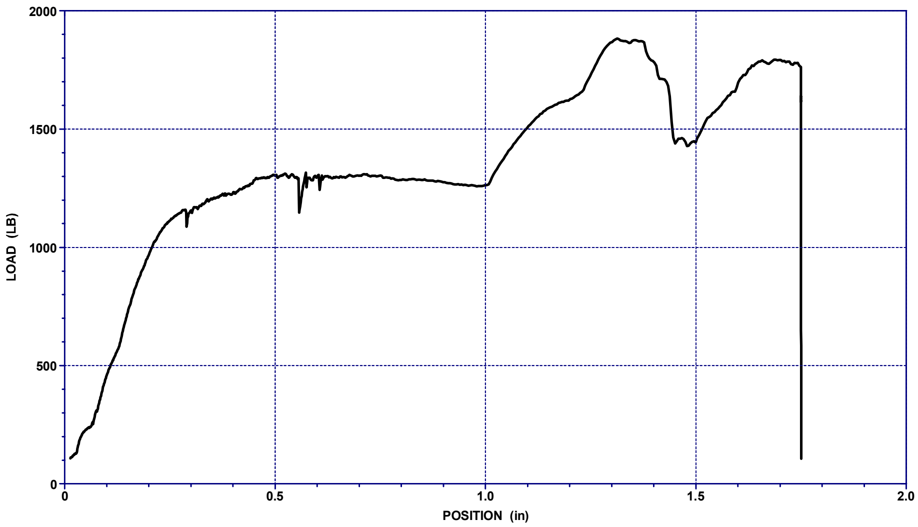
Peak Load	**1561 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Test #35 - 1/4" No shim - 18Ga.

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 08:59:18**



Peak Load	**1882 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

APPENDIX B

GRAPHS

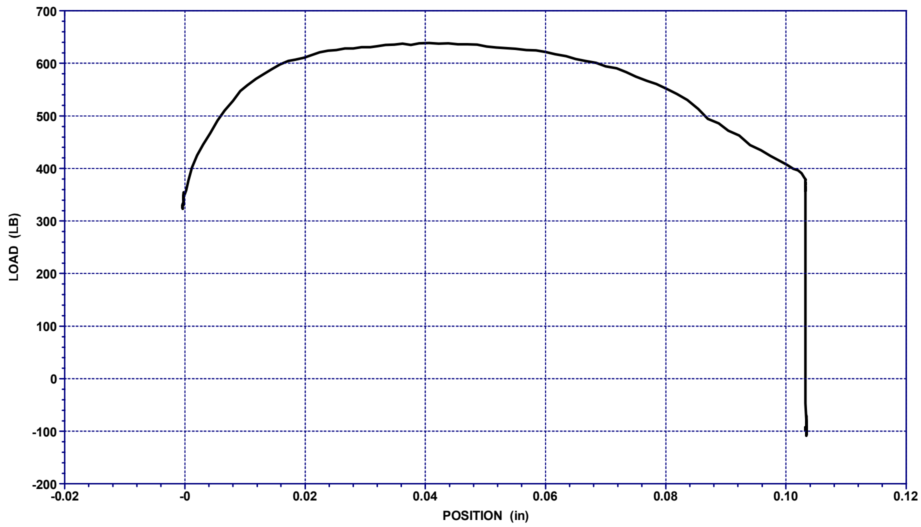
TESTS IN CANTILEVER

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 1/4"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/09/07 **Time: 07:12:10**



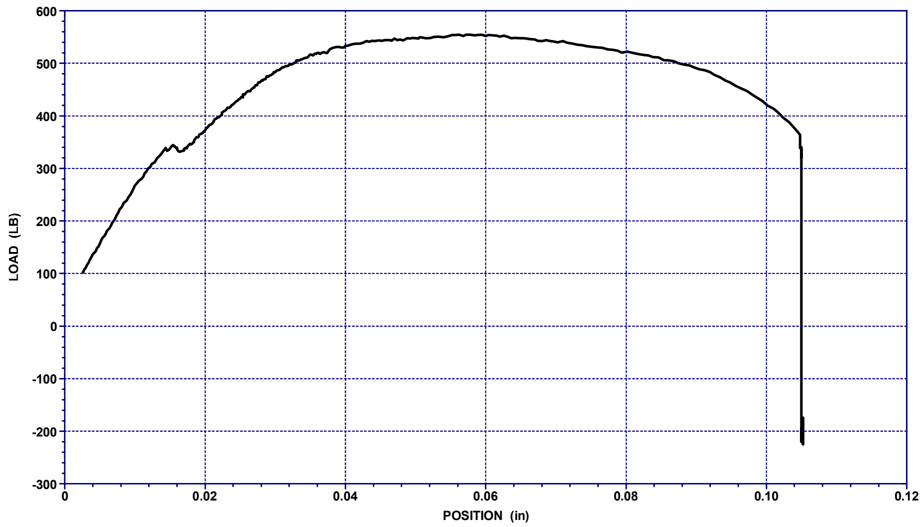
Peak Load	**638.7 LB**
E646 exp. n: 0.000-0.001 (e)	**0.186**
E646 coef. K: 0.000-0.001 (e)	**176.4 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 1/4"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 06:54:59**



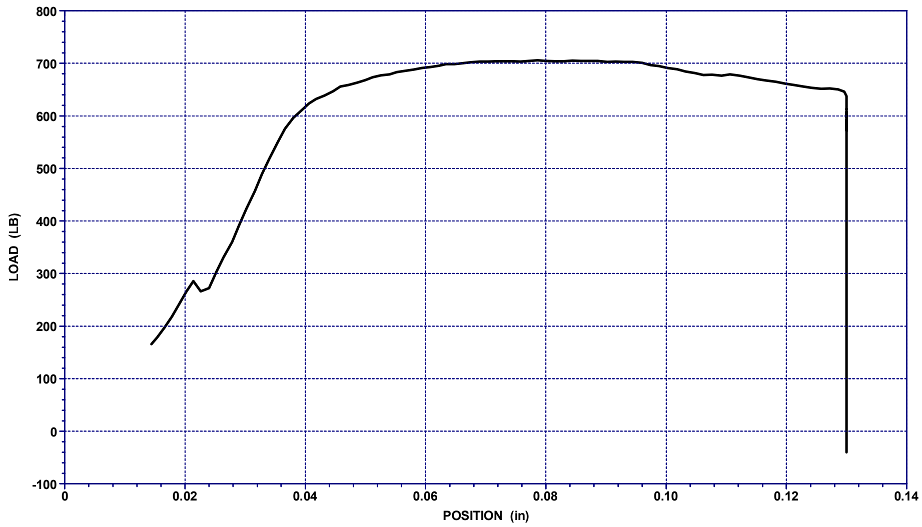
Peak Load	**554.6 LB**
E646 exp. n: 0.000-0.001 (e)	**0.719**
E646 coef. K: 0.000-0.001 (e)	**2894 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

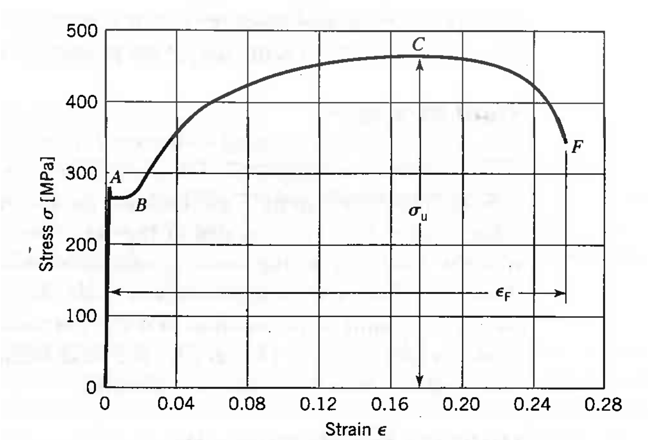
CANTILEVER - 1/4"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 09:55:49**



Peak Load	**705.7 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**



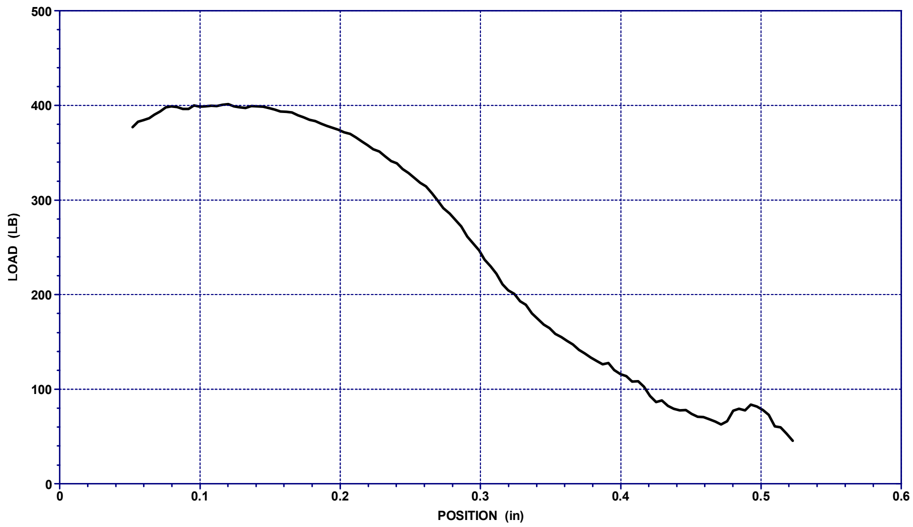
This diagram shows the stress-strain diagram for a tension specimen of structural steel, it can be seen the similarity with the upper diagram of the screw in bending; Engineers use stress-strain diagrams to define certain properties of the material.

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 1/2"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/09/07 **Time: 07:02:52**



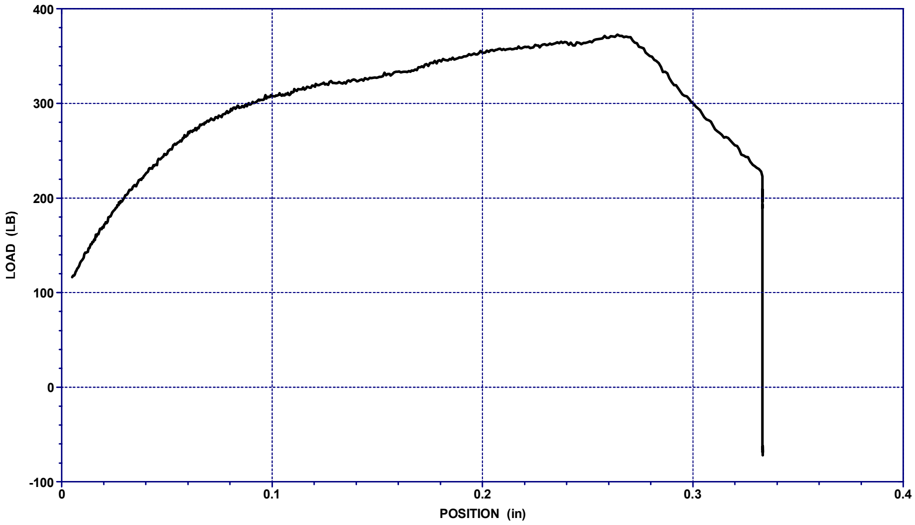
Peak Load	**401.2 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

CANTILEVER - 1/2"

Date: 01/23/07 **Time: 06:33:54**



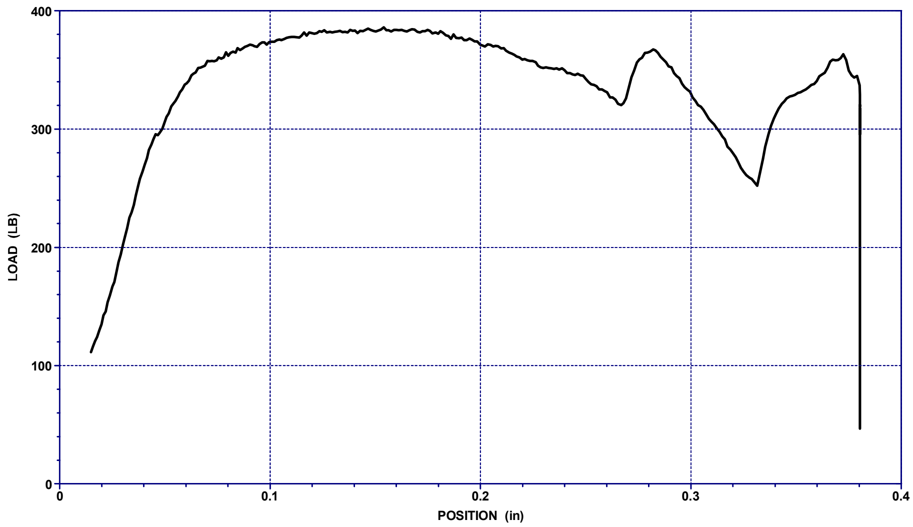
Peak Load	**372.8 LB**
E646 exp. n: 0.001-0.001 (e)	**0.232**
E646 coef. K: 0.001-0.001 (e)	**58.48 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 1/2"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 10:00:35**



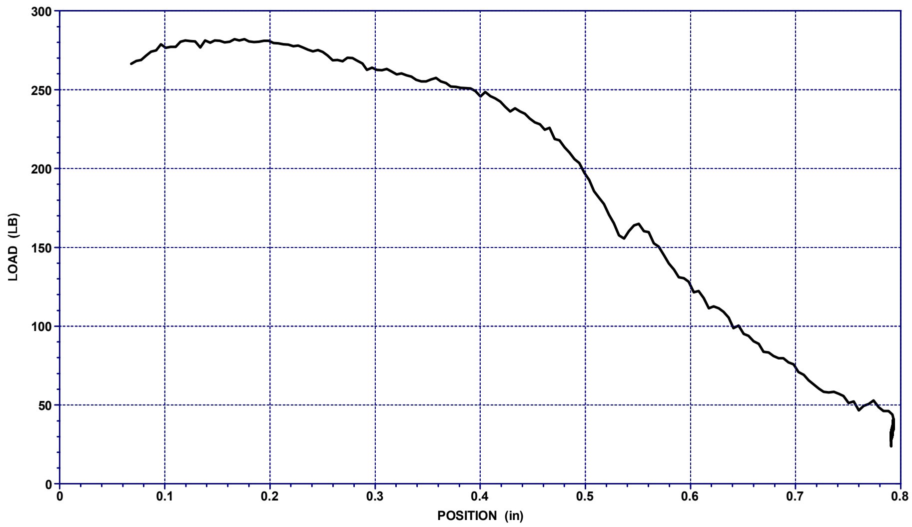
Peak Load	**385.9 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 3/4"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/09/07 **Time: 06:42:07**



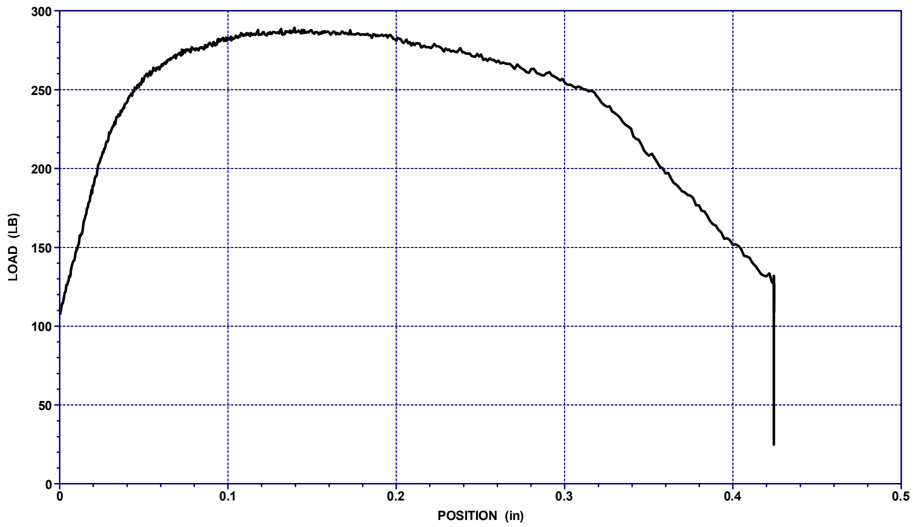
Peak Load	**282.0 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 3/4"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 06:29:03**



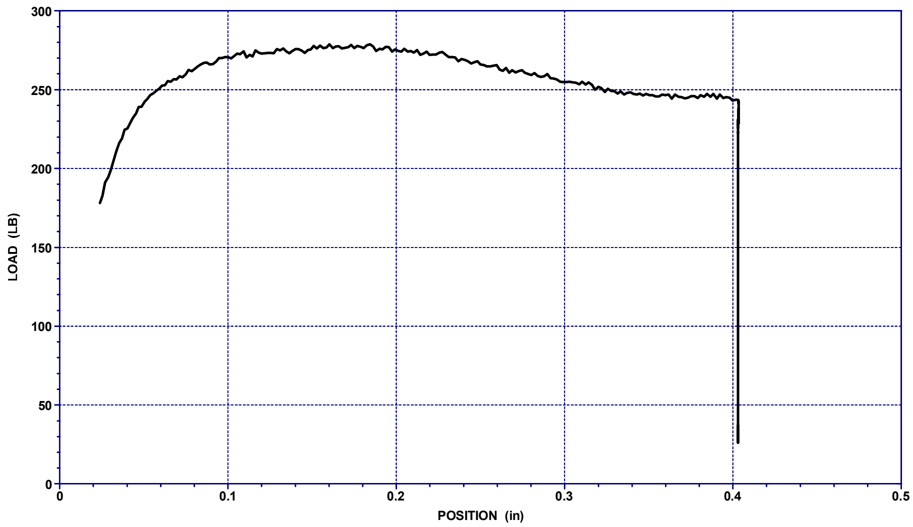
Peak Load	**289.3 LB**
E646 exp. n: 0.000-0.001 (e)	**0.165**
E646 coef. K: 0.000-0.001 (e)	**40.57 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 3/4"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 10:04:35**



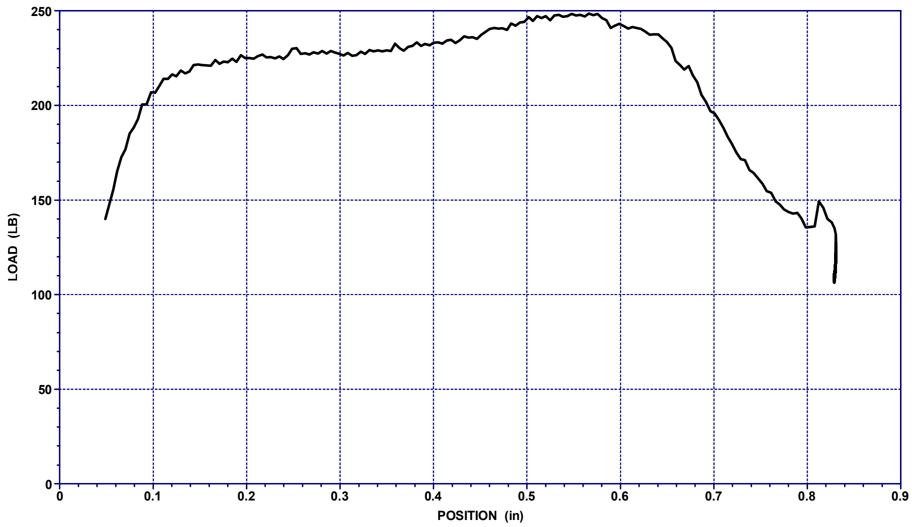
Peak Load	**278.7 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 1"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/02/07 **Time: 10:47:14**



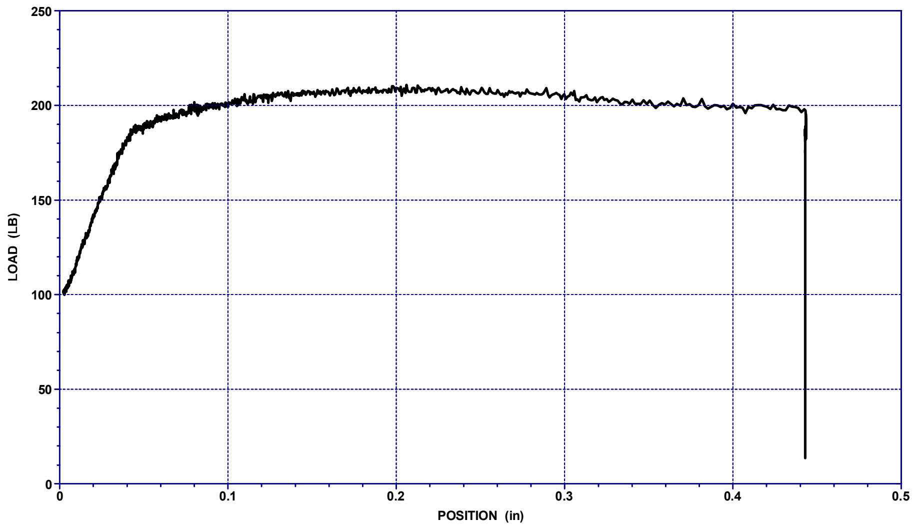
Peak Load	**248.5 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 1"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 06:15:42**



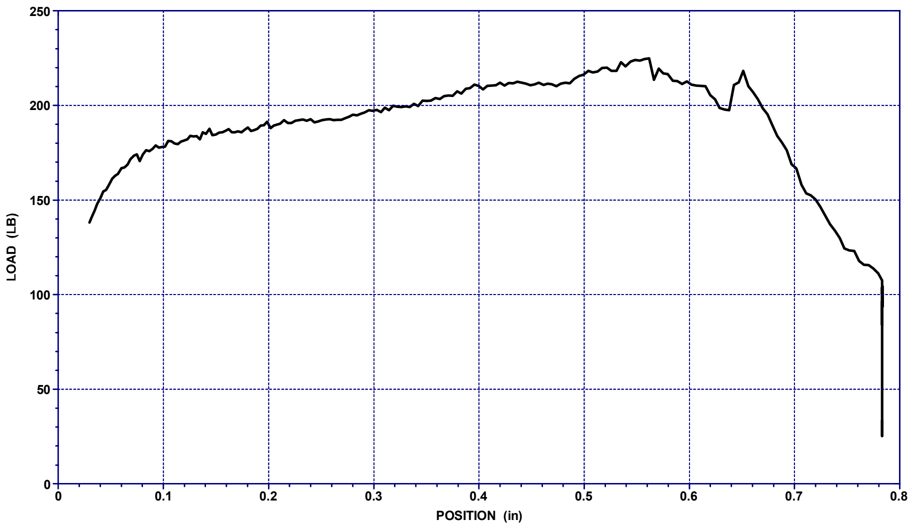
Peak Load	**210.7 LB**
E646 exp. n: 0.000-0.001 (e)	**0.0980**
E646 coef. K: 0.000-0.001 (e)	**20.26 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 1"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 09:47:09**



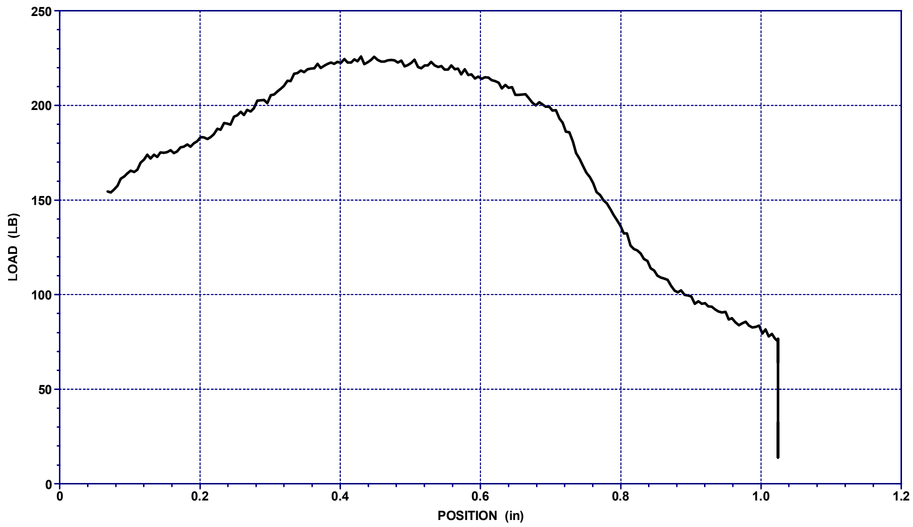
Peak Load	**224.8 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 1 1/4"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/02/07 **Time: 10:33:37**



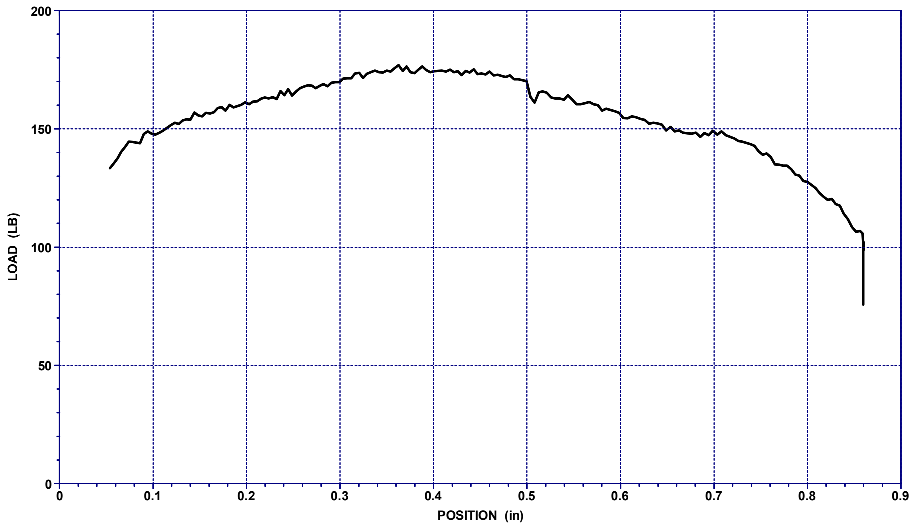
Peak Load	**225.8 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 1 1/4"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 10:13:27**



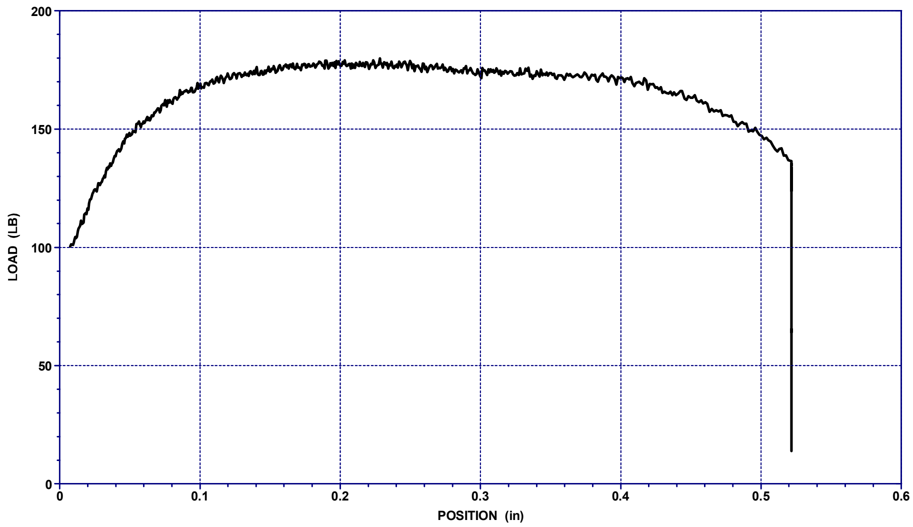
Peak Load	**176.8 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

CANTILEVER - 1 1/4"

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 06:19:25**



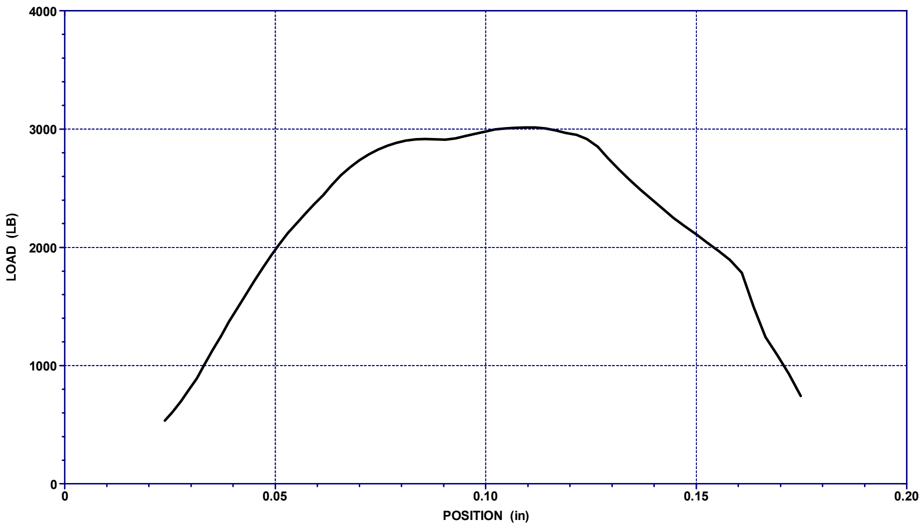
Peak Load	**179.8 LB**
E646 exp. n: 0.001-0.001 (e)	**0.0388**
E646 coef. K: 0.001-0.001 (e)	**12.19 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

NO SHIM

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/09/07 **Time: 07:35:19**



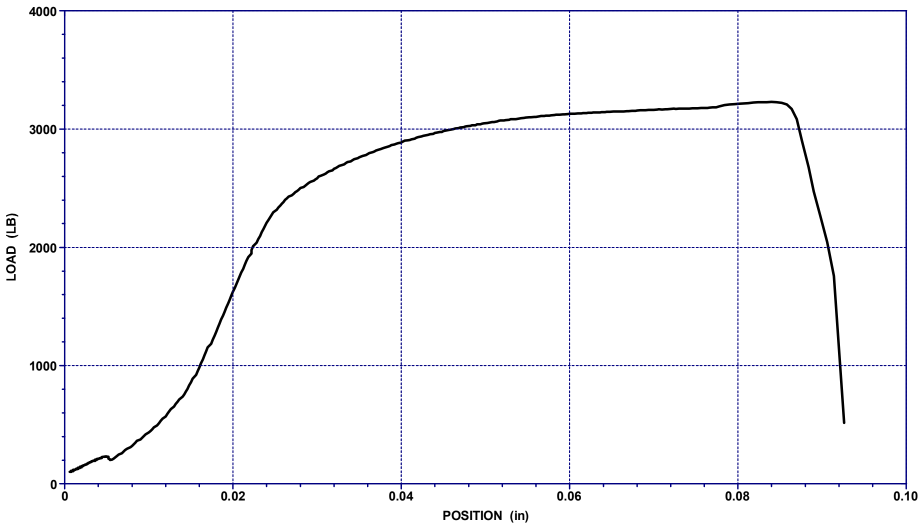
Peak Load	**3013 LB**
E646 exp. n: 0.000-0.000 (e)	**0**
E646 coef. K: 0.000-0.000 (e)	**0 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

NO SHIM

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/09/07 **Time: 07:50:30**



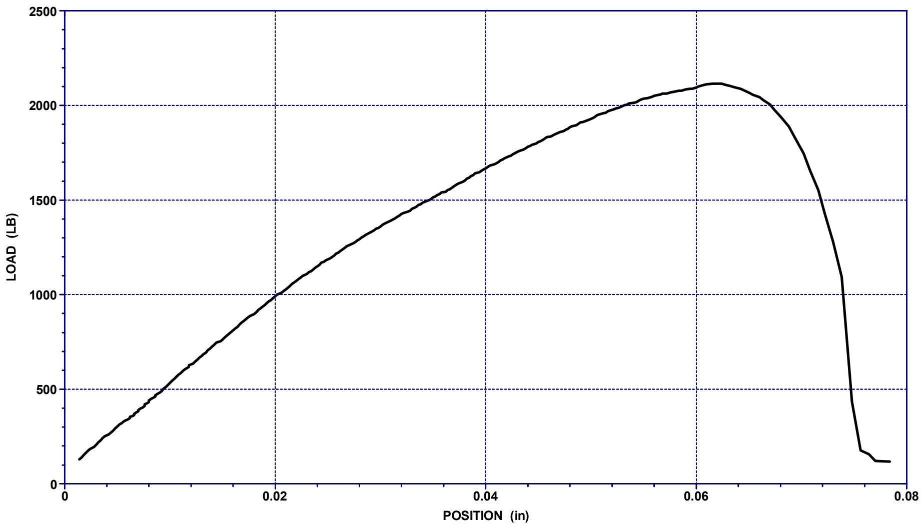
Peak Load	**3228 LB**
E646 exp. n: 0.000-0.001 (e)	**0.573**
E646 coef. K: 0.000-0.001 (e)	**1486 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

NO SHIM

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 06:57:50**



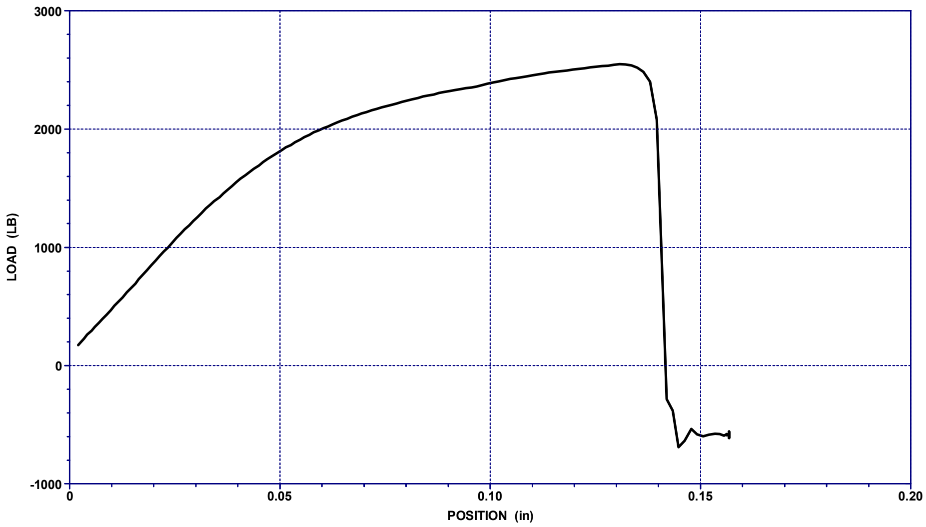
Peak Load	**2114 LB**
E646 exp. n: 0.000-0.001 (e)	**0.747**
E646 coef. K: 0.000-0.001 (e)	**6843 psi**

MTESTWindows Materials Testing System
Customer name:DANA
Customer reqirements:
Minimum Yield-
Minimum Tensile Strength-
Minimum % Elongation-
Minimum Hardness-
Trial#:
Claim#:
Lab Report#:

NO SHIM

Specimen #:	**114**
Operator:	**JCS**
Order No.::	**1234**
Heat No.::	**678**
Rockwell Hardness::	**82**
Lift No.:	**N\A**
Test Orientation:	**Longitudinal**
Material Grade:	
Sample No.:	
O.D.:	
Geometry:	**Beam 3rd**
Width:	**6.0000 in**
Depth:	**6.0000 in**
Span Length:	**20.0000 in**
Area:	**10.8000 sq in**

Date: 01/23/07 **Time: 09:42:15**



Peak Load	**2548 LB**
E646 exp. n: 0.000-0.001 (e)	**0.671**
E646 coef. K: 0.000-0.001 (e)	**3767 psi**

APPENDIX C
TABLES
CAPACITIES OF SCREWS

TABLE 20.3: Fastener Capacity

SAE Grade 5 Steel for Diameters up thru 9/16" (UNC Threads) ASTM A 449 Steel for Diameters 5/8" and Over (UNC Threads)																
Nominal Fastener Diameter & Threads per Inch	D Nominal Thread Diameter (in)	A(S) Tensile Stress Area (in2)	A(R) Thread Root Area (in2)	Allow able Tension (lbs)	Allow able Shear		Allow able Bearing (lbs)			Minimum Material Thickness (lbs) to Equal Tensile Capacity of Fastener (in)			Maximum Tensile Load (lbs) for Available 3/8" Plate Thickness		
					Single (lbs)	Double (lbs)	1/8" Steel A36	1/8" Aluminum 6063-T5	1/8" Aluminum 6063-T6	A36	6063-T5	6063-T6	3/8" Steel A36	3/8" Aluminum 6063-T5	3/8" Aluminum 6063-T6
#6-32	0.1380	0.0091	0.0078	363	180	360	900	253	345	0.1602	0.3046	0.2268	363	363	363
#8-32	0.1640	0.0140	0.0124	560	286	573	1,070	301	410	0.2079	> 3/8"	0.2953	560	522	560
#10-24	0.1900	0.0175	0.0151	701	350	700	1,240	348	475	0.2246	> 3/8"	0.3001	701	643	701
#12-24	0.2160	0.0242	0.0214	967	493	986	1,409	396	540	0.2594	> 3/8"	0.3619	967	734	967
1/4-20	0.2500	0.0318	0.0280	1,273	646	1,291	1,631	458	625	0.2745	> 3/8"	> 3/8"	1,273	865	1,179
5/16-18	0.3125	0.0524	0.0469	2,517	1,299	2,599	2,039	573	781	0.3144	> 3/8"	> 3/8"	2,517	1,303	1,776
3/8-16	0.3750	0.0775	0.0699	3,719	1,937	3,874	2,447	688	938	0.3518	> 3/8"	> 3/8"	3,719	1,572	2,144
7/16-14	0.4375	0.1063	0.0961	5,103	2,664	5,328	2,855	802	1,094	> 3/8"	> 3/8"	> 3/8"	4,937	1,873	2,554
1/2-13	0.5000	0.1419	0.1292	6,811	3,581	7,162	3,263	917	1,250	> 3/8"	> 3/8"	> 3/8"	5,642	2,140	2,918
9/16-12	0.5625	0.1819	0.1664	8,733	4,611	9,222	3,670	1,031	1,406	> 3/8"	> 3/8"	> 3/8"	6,444	2,444	3,333
5/8-11	0.6250	0.2260	0.2071	10,848	5,738	11,477	4,078	1,146	1,563	> 3/8"	> 3/8"	> 3/8"	7,148	2,711	3,697
3/4-10	0.7500	0.3345	0.3091	16,054	8,565	17,130	4,894	1,375	1,875	> 3/8"	> 3/8"	> 3/8"	8,612	3,266	4,454
7/8-9	0.8750	0.4617	0.4285	22,163	11,876	23,753	5,709	1,604	2,188	> 3/8"	> 3/8"	> 3/8"	10,158	3,853	5,254
1-8	1.0000	0.6057	0.5630	29,076	15,601	31,203	6,525	1,833	2,500	> 3/8"	> 3/8"	> 3/8"	11,696	4,437	6,050

SAE Grade 5 Steel (Spaced Threads)																
Nominal Fastener Diameter & Threads per Inch	D Nominal Thread Diameter (in)	K Basic Minor Diameter (in)	A(R) Thread Root Area (in2)	Allow able Tension (lbs)	Allow able Shear		Allow able Bearing (lbs)			Minimum Material Thickness (lbs) to Equal Tensile Capacity of Fastener (in)			Maximum Tensile Load (lbs) for Available 3/8" Plate Thickness		
					Single (lbs)	Double (lbs)	1/8" Steel A36	1/8" Aluminum 6063-T5	1/8" Aluminum 6063-T6	A36	6063-T5	6063-T6	3/8" Steel A36	3/8" Aluminum 6063-T5	3/8" Aluminum 6063-T6
#6-20	0.1380	0.0990	0.0077	308	178	356	900	253	345	0.1358	0.1907	0.1543	308	308	308
#8-18	0.1640	0.1160	0.0106	423	244	488	1,070	301	410	0.1569	0.2175	0.1758	423	423	423
#10-16	0.1900	0.1350	0.0143	573	331	661	1,240	348	475	0.1834	0.2517	0.2028	573	573	573
#12-14	0.2160	0.1570	0.0194	774	447	894	1,409	396	540	0.2182	0.2995	0.2380	774	774	774
1/4-14	0.2500	0.1850	0.0269	1,075	621	1,242	1,631	458	625	0.2617	0.3593	0.2696	1,075	1,075	1,075
5/16-12	0.3125	0.2360	0.0437	2,100	1,212	2,425	2,039	573	781	0.3407	> 3/8"	0.3430	2,100	1,681	2,100
3/8-12	0.3750	0.2990	0.0702	3,370	1,946	3,892	2,447	688	938	> 3/8"	> 3/8"	> 3/8"	2,773	2,017	2,751

	SAE Grade 5 (≤ 9/16")	ASTM A449 (≥ 5/8")	For All Diameters	Effective Area (UNC Threads)	Effective Area (Spaced Threads)
F_U (Min. Ultimate Tensile Strength)	120,000 psi	120,000 psi	$F_T = F_U/SF$	$A(R) = \pi\ (D-1.2269/N)^2 / 4$	$A(R) = \pi K^2/4$
F_T (Allow. Tensile Stress, D≤1/4")	40,000 psi	N/A	Allow able Tension = $F_T[A(S)]$	$A(S) = \pi\ (D-0.9743/N)^2 / 4$	$A(S) = \pi K^2/4$
F_T (Allow. Tensile Stress, D> 1/4")	48,000 psi	48,000 psi	$F_V = Fu / (SF \times sq\,rt(3))$		
F_V (Allowable Shear Stress, D≤1/4")	23,094 psi	N/A	Allowable Single Shear $= F_V[A(R)]$		
F_V (Allowable Shear Stress, D>1/4")	27,713 psi	27,713 psi			

NOTE 5:

1. *Values are taken from AISC, ASTM, IFI, SAE and AA documents. K values for spaced threads are taken as the minimum values in IFI Fastener Handbook, 6th Ed.*
2. *Safety Factor used for fasteners with diameters 1/4" or less is 3.0, Safety Factor used for fasteners with diameters 5/16" or greater is 2.5.*
3. *Fasteners with diameters of 5/8" or greater are fabricated from carbon steel complying with ASTM A449 Type*

Dril-Flex® Structural Drill Screws

Virtually immune to delayed embrittlement failures

Dual heat treated drill screws provide the strength, ductility and resistance to embrittlement required for critical applications.

Specifications

- Diameters: #10 to 3/8"
- Lengths: 3/4" to 4"
- Head/Drive Styles: Hex washer and phillips pan, wafer and undercut flat
- Point Types: #3, #4 and #5
- Material: Alloy steel
- Heat Treat: Grade 5
- Finish: Silver Stalgard® or Stalgard SUB coating

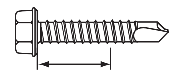
Features & Benefits

- Stalgard SUB coating (Hex washer product only) provides 2000 hours of salt spray resistance (per ASTM B117)
- High-hardness points and lead threads for drilling and tapping with lower-hardness in load-bearing threads for ductility
- Virtually immune to delayed embrittlement failures

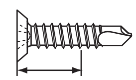
Catalog No.	Description	Pt.	Load-Bearing Area	Finish	Carton Quantity	Carton Weight
#10 Diameter, 5/16" Hex Washer Head						
EAF430	10-16 x 3/4"	#3	.380"	Stalgard SUB	6,000	48
EAF460	10-16 x 1-1/2"	#3	1.25"	Stalgard SUB	2,500	30
EAF470	10-16 x 2"	#3	1.50"	Stalgard SUB	2,000	28
EAF480	10-16 x 2-1/2"	#3	2.25"	Stalgard SUB	1,500	25
#10 Diameter, #2 Phillips Pan Head						
EDX445	10-16 x 3/4"	#2	.380"	Stalgard	6,000	36
#10 Diameter, #2 Phillips Wafer Head						
EBL530	10-24 x 1-1/4"	#3	.750"	Stalgard	5,000	44
#12 Diameter, 5/16" Hex Washer Head						
EAF621*	12-14 x 7/8"	#3	.380"	Stalgard SUB	5,000	54
EAF641	12-14 x 1"	#3	.500"	Stalgard SUB	4,000	44
EAF681	12-14 x 1-1/2"	#3	1.00"	Stalgard SUB	2,500	38
EAF690	12-14 x 2"	#3	1.50"	Stalgard SUB	2,000	37
EAF715	12-14 x 3"	#2	2.35"	Stalgard SUB	1,000	27
#12 Diameter, #3 Phillips Undercut Flat Head						
EBL215	12-14 x 1"	#3	.500"	Stalgard	4,000	36
EBL223	12-14 x 1-1/2	#3	1.00"	Stalgard	2,500	26
1/4" Diameter, 3/8" Hex Washer Head						
EAF816	1/4-14 x 1"	#3	.450"	Stalgard SUB	3,000	54
EAF841	1/4-14 x 1-1/2"	#3	.950"	Stalgard SUB	2,000	45
EAF876	1/4-20 x 1-1/2"	#4	.830"	Stalgard SUB	2,000	48
EAF846	1/4-14 x 2"	#3	1.45"	Stalgard SUB	1,500	41
EAF886	1/4-20 x 2"	#4	1.33"	Stalgard SUB	1,500	45
EAF865	1/4-20 x 1-1/8"	#4	.500"	Stalgard SUB	2,500	51
EAF888	1/4-20 x 1-3/4"	#5	.800"	Stalgard SUB	1,000	27
EAF890	1/4-20 x 2-1/2"	#4	1.83"	Stalgard SUB	1,000	45
EAF900	1/4-20 x 3-3/8"	#4	2.70"	Stalgard SUB	500	22
EAF910	1/4-20 x 4"	#4	3.50"	Stalgard SUB	500	23
1/4" Diameter, #3 Phillips Undercut Flat Head						
EBL330	1/4-20 x 3"	#4	2.50"	Stalgard	500	20
EBL340	1/4-20 x 4"	#4	3.50"	Stalgard	500	23
5/16" Diameter, 3/8" Hex Washer Head						
EAF940	5/16-18 x 1-1/2"	#3	.800"	Stalgard SUB	1,000	37
EAF960	5/16-24 x 1-1/2"	#4	.800"	Stalgard SUB	1,000	40
EAF970	5/16-24 x 2"	#4	1.25"	Stalgard SUB	1,000	49
3/8" Diameter, 3/8" Hex Washer Head						
EAF310	3/8-16 x 1-3/4"	#1	.850"	Stalgard SUB	500	18

* for aluminum applications only.

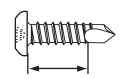
Load-Bearing Area:



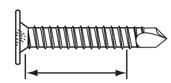
Hex Washer Head



Undercut Head



Pan Head



Wafer Head

Dril-Flex® Structural Drill Screws

Technical Information

Pull-out Tests – Steel: Pull-out values shown are in lbs.

Screw Size	Point Type	Drill Cap.	Steel 18	16	14	12	1/8	3/16	1/4	5/16
10-16	3	.150	396	501	634	1595	1693			
12-14	3	.187	396	527	710	1678	2061	2898		
1/4-14	3	.187	398	530	686	1950	2264	3919		
1/4-20	4	.312		516	649	1912	2296	2928	3561	4488
5/16-18	3	.210				2333	2856			
5/16-24	4	.312				2148	2573	4226	5424	6622
3/8-16	1	.075			1843					

Pull-out Tests – Aluminum

Screw Size	Point Type	Drill Cap.	Aluminum 6063-T5 1/8"	1/4"	3/8"
10-16	3	.150			
12-14	3	.187	939	2286	
1/4-14	3	.210	1003	2424	
1/4-20	4	.312	897	2075	3683
5/16-18	3	.210	1120	2967	4796
5/16-24	4	.312	1043	2566	

Shear Tests – Steel: Shear values shown are in lbs.

Screw Size	Point Type	Drill Cap.	Steel 18-18 ga.	18-14 ga.	16-16 ga.	14-14 ga.	1/8"-3/16"	3/16"-1/4"	1/4"-12 ga.
10-16	3	.150	1362	1733	1462				
12-14	3	.187	1315	2118	1655	1816			
1/4-14	3	.210	1395	2313	1681	2417	2600		
1/4-20	4	.312	1350	2086	1582	2450	2814	2810	2706
5/16-18	3	.210	1509	2300	1811	3255			
5/16-24	4	.312					5486	5283	4761
3/8-16	1	.075				6750			

Shear Tests – Aluminum

Screw Size	Point Type	Drill Cap.	Aluminum 6063-T5 1/8" - 1/8"	1/8" - 1/4"
10-16	3	.150	1466	
12-14	3	.187	1797	2483
1/4-14	3	.210	1996	2883
1/4-20	4	.312	2006	2926
5/16-18	3	.210	2132	3009
5/16-24	4	.312	1849	2926

NOTE: All test setups and dimensions were as limited and outlined in AISI Test Method for Mechanically Fastened Cold-Formed Steel Connections (CF92-1) document. Performance values listed are ultimate values obtained under laboratory conditions.

Comparison to Stainless Steel Screws

300 series stainless steel fasteners provide high resistance to hydrogen embrittlement failures. However, stainless steel is galvanically incompatible with aluminum or steel panels. In this case, stainless steel fasteners trigger a sacrificial action, which can lead to degradation of the panel and loosening of the fastener.

A dual-hardening process allows Dril-Flex® fasteners to provide high strength and resistance to hydrogen embrittlement failures. Their Stalgard® finish provides corrosion resistance several times greater than other commonly-used finishes. If an environment is corrosive enough to significantly affect the Stalgard finish, the potential for significant degradation of the aluminum/stainless steel assembly would also exist.

Galvanic Series

Anodic End	
Metal/Alloy	*EMF(v)*
Magnesium	-1.60
Zinc	-1.10
Alum (5000, 6000, 7000)	-.75
Iron, Low Alloy Steels	-.70
Alum (2000)	-.60
Lead	-.55
18% Chromium Steel	-.35
Naval Brass	-.30
Brass, Bronze	-.25
Austenitic Stainless (300 Series)	-.20
Nickel	-.15
Silver	0
Gold	+15
Cathodic End	

Embrittlement Tests

Embrittlement testing of Dril-Flex screws was performed in accordance to ASTM F1624-06. Fastener lots were tested to determine their Threshold Stress Limits for both Internal Hydrogen Embrittlement and Environmental Hydrogen Embrittlement. Threshold Stress Limit is the stress level below which no time-dependent cracking will occur. Above this level, subcritical cracking that leads to time-delayed fracture or embrittlement may occur if the fastener is exposed to a hydrogen environment.

Embrittlement Test Results

- Dril-Flex fasteners have a hardness range of HRC 28 – 34, which is roughly equivalent to a SAE Grade 5 fastener (HRC 25 – 34).
- Dril-Flex fasteners showed resistance to the effect of hydrogen-assisted cracking when loaded to 75% of their tensile strength. This is within accepted industry guidelines for in-service loading conditions.
- Dril-Flex fasteners showed no degradation or failures in tensile strength below their ultimate tensile strength.

Identification

(hex washer head shown)

NOTE: All performance data shown is based on tests performed under laboratory conditions at independent construction testing facilities. The appropriate safety factor should be applied and code requirements factored into specification and use of these fasteners. A safety factor of 4:1 or 25% of the ultimate average values shown is generally accepted as an appropriate working load. Final determination of the appropriate safety factor and use of these fasteners is the sole responsibility of the user, specifying Engineer, Architect or other responsible person designing the connection. Due to a wide variety of application conditions or intervening factors not under our control, we assume no liability for the use of the information provided in this document.

For additional product information and technical assistance, please contact Elco directly at 1-800-435-7213.

MADE IN THE USA WITH GLOBAL MATERIALS

Drill Screws

Technical Information

Ultimate Strength Values†

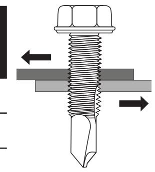
Carbon Steel, Case Hardened Product

Size	Tensile Lbs. Min.	Shear Avg. Lbs. Ult.	Torque Min. In-Lbs.
8-18	1,615	1,100	42
8-32	1,890	1,228	48
10-16	2,200	1,470	61
10-24	2,362	1,535	65
12-14	2,950	1,960	92
12-24	3,400	2,275	100
1/4-14	3,850	2,580	150
1/4-20	4,276	2,860	168
5/16-12	7,650	5,100	250
5/16-18	8,903	5,247	438
11/32-12	8,550	5,700	400
23/64-12	9,150	6,100	425

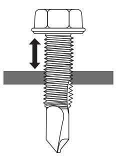
Shear Values†

(Average Lbs. Ultimate)

Desc.	Pt.	Gauge 26	24	22	20	18	16	14	12	0.125 (1/8")
8-18	2	301	500	542	742	1,049	—	—	—	—
10-16	1	403	585	673	883	1,330	—	—	—	—
10-16	3	—	461	524	731	1,254	1,524	1,674	—	—
12-14	1	437	718	763	1,030	1,548	—	—	—	—
12-14	2	370	607	622	860	1,360	1,690	2,112	2,212	—
12-14	3	—	—	—	775	1,361	1,624	1,974	1,993	—
12-24	4	—	—	—	—	—	1,430	1,930	2,455	2,573
12-24	4.5	—	—	—	—	—	1,389	1,920	2,174	2,257
12-24	5	—	—	—	—	—	1,351	1,825	2,152	2,226
1/4-14	1	519	863	892	1,301	1,771	—	—	—	—
1/4-14	3	—	—	—	930	1,447	2,102	2,584	2,650	—
1/4-20	5	—	—	—	—	—	1,655	2,277	—	3,210



Shear



Ultimate Average Fastener Pull-Out Values† (Lbs.)

Descrip.	Point Type	Material Thickness 26 Ga.	24 ga.	22 Ga.	20 Ga.	18 Ga.	16 Ga.	14 Ga.	12 Ga.	.120"	3/16"	1/4"	5/16"	3/8"
8-18	2	120	197	268	301	494	702	961	1,615	—	—	—	—	—
10-16	1	151	242	315	361	565	826	1,092	1,791	—	—	—	—	—
10-16	3	130	206	272	303	498	702	970	1,495	—	—	—	—	—
12-14	1	161	260	332	394	640	920	1,262	1,940	—	—	—	—	—
12-14	2	154	247	286	379	609	852	1,186	1,863	2,345	—	—	—	—
12-14	3	142	214	296	349	580	767	1,078	1,553	1,956	—	—	—	—
12-24	5	—	—	—	311	452	1,060	1,288	1,844	2,205	3,237	—	—	—
1/4-14	1	228	342	432	571	801	1,169	—	—	—	—	—	—	—
1/4-14	3	150	238	301	340	702	891	1,162	1,798	2,120	—	—	—	—
1/4-20	3	—	—	—	337	571	1,232	1,525	2,212	2,447	4,066	—	—	—
1/4-20	5	—	—	—	—	—	—	—	—	3,431	4,801	5,261	—	—
5/16-12	3 (.260 dia.)	—	—	—	491	706	1,609	1,707	2,831	2,915	3,745	—	—	—
5/16-18	3 (.290 dia.)	—	—	—	457	568	1,209	1,712	2,422	2,601	3,716	5,122	5,288	—
14-10 SS	A	270	363	426	459	657	1,194	1,368	—	—	—	—	—	—
1/4-14 SS	B	216	344	383	411	571	686	983	1,698	2,242	2,693	3,695	3,746	3,484

NOTE: SS = Stainless Steel; CS = Carbon Steel

†**NOTE:** Test values shown are ultimate average values obtained under laboratory conditions and apply to fasteners manufactured by Elco Construction Products only.

NOTE: All performance data shown is based on tests performed under laboratory conditions at independent construction testing facilities. The appropriate safety factor should be applied and code requirements factored into specification and use of these fasteners. A safety factor of 4:1 or 25% of the ultimate average values shown is generally accepted as an appropriate working load. Final determination of the appropriate safety factor and use of these fasteners is the sole responsibility of the user, specifying Engineer, Architect or other responsible person designing the connection. Due to a wide variety of application conditions or intervening factors not under our control, we assume no liability for the use of the information provided in this document.

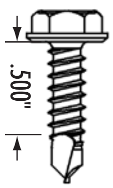
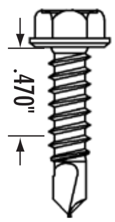
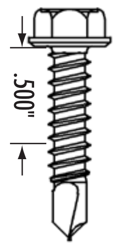
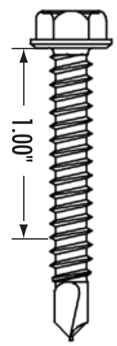
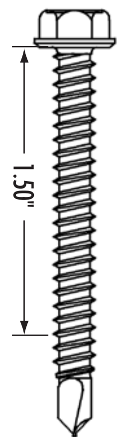
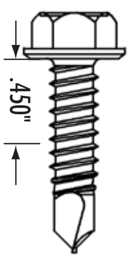
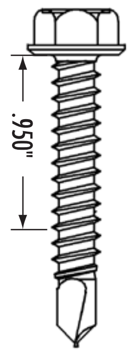
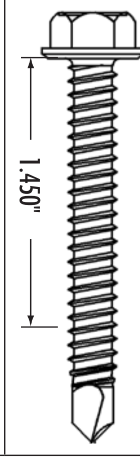
For additional product information and technical assistance, please contact Elco directly at 1-800-435-7213.

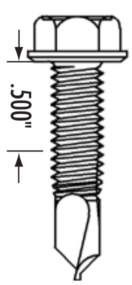
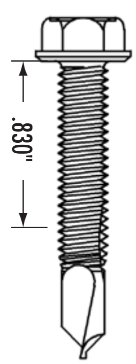
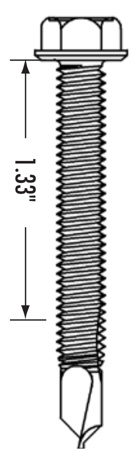
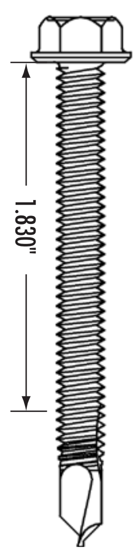
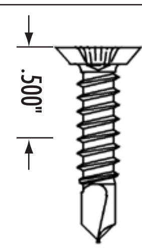
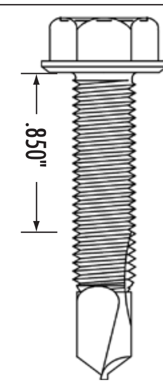
MADE IN THE USA WITH GLOBAL MATERIALS

APPENDIX D
MISCELANEOUS

Dril-Flex® Structural Fasteners

SELECTION GUIDE*

Size	10-16	12-14	12-14	12-14	12-14	1/4-14	1/4-14	1/4-14
Length	3/4"	7/8"	1"	1-1/2"	2"	1"	1-1/2"	2"
Head Style	HWH #3	HWH #3	HWH #3	HWH #3	HWH #3	HWH #3	HWH #3	HWH #3
Application Use	steel and aluminum	aluminum only	steel and aluminum	steel and aluminum	steel and aluminum	steel and aluminum	steel and aluminum	steel and aluminum
Drilling Capacity	.150"	.187"	.187"	.187"	.187"	.210"	.210"	.210"
Catalog Number	AF 430	AF 621	AF 641	AF 681	AF 690	AF 816	AF 841	AF846
Maximum Load-Bearing Area** Indicated By Arrows								

Size	1/4-20	1/4-20	1/4-20	1/4-20	12-14	5/16-24
Length	1-1/8"	1-1/2"	2"	2-1/2"	1"	1-1/2"
Head Style	HWH #4	HWH #4	HWH #4	HWH #4	Undercut Flat Head #3	HWH #4
Application Use	steel and aluminum	steel and aluminum	steel and aluminum	steel and aluminum	steel and aluminum	steel and aluminum
Drilling Capacity	.210" to .312"	.210" to .312"	.210" to .312"	.210" to .312"	.187"	steel: 0.187" aluminum: 0.25"
Catalog Number	AF 865	AF 876	AF 886	AF 890	BL 215	AF960
Maximum Load-Bearing Area** Indicated By Arrows			 SCREW USED IN TESTS			

* Fasteners shown are in-stock. Other head styles, threads, lengths and drilling capabilities can be produced to meet specific application needs.

** IMPORTANT: to ensure proper performance, only the load-bearing area should be engaged in the material being fastened.

Tap-Flex™
Structural Fasteners

ELCO®

Tap-Flex™ Thread-Forming Structural Screws

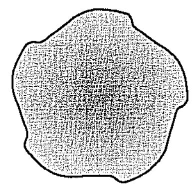
Increased thread engagement with strength and ductility

Elco Construction Products has utilized its 25 years of experience in construction fasteners manufacturing to create the new Tap-Flex structural fasteners. These thread-forming screws are dual heat treated, self-tapping fasteners that provide the strength, ductility, and resistance to embrittlement failures required in critical curtain wall and dissimilar metal applications. Tap-Flex fasteners are engineered to replace nut and bolt assemblies and Taptite® fasteners commonly used in building construction.

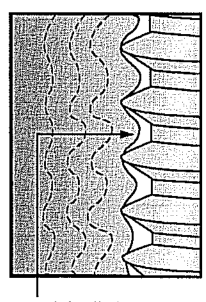
Enhanced Thread Design

Tap-Flex screws are threadformers with the patent-pending E-form® segmented thread profile. This design improves both installation and in-place performance:

- Decreases thread-forming torque, easing starting and placement
- Overcomes friction build-up and reduces drive torque
- Increases thread engagement, so it resists back-out and loosening caused by vibration or thermal changes



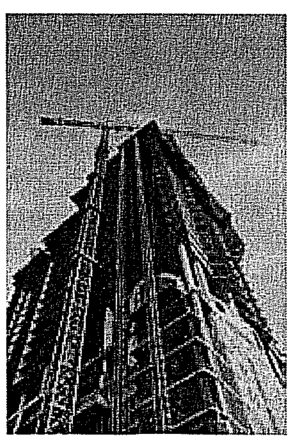
E-Form® Profile



material rolls in to fill space, increasing thread engagement

Exclusive Flex Technology® Process

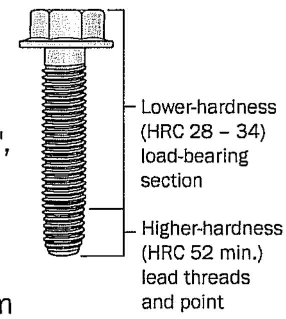
Tap-Flex fasteners undergo the unique Flex Technology dual hardening process. The lead tapping threads are selectively hardened to a minimum of HRC 52, easing installation. The load-bearing portion of the fastener is held at or below the critical HRC 34 level. This reduced hardness level also **meets Grade 5 ASTM A449** strength and ductility standards. This helps prevent embrittlement and other structural failures, providing long life high performance in the field.



Made in the U.S.A.

Specifications

- Diameters: 3/8", 1/2", and 5/8"
- Lengths: 1-1/2", 2" and 2-1/2"
- Head Style: Hex washer
- Threads: E-Form five-lobe thread forming
- Material: Alloy steel
- Finish: Silver Stalgard® GB coating
- Grade 5: meets ASTM A449 specifications (120 ksi strength)



Features and Benefits

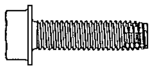
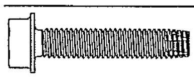
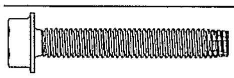
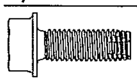
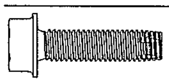
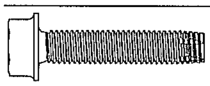
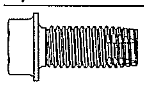
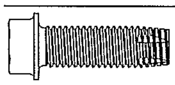
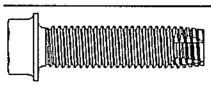
- Eliminates thread-tapping operations
- E-Form configuration overcomes friction build-up and reduces drive torque
- Roll forms own work-hardened thread to resist loosening cause by vibration or thermal changes
- Provides enhanced pull-out performance
- Well-suited for metal applications such as steel and aluminum
- Flex Technology heat treat provides required strength and ductility
- Virtually immune to delayed embrittlement failures
- Stalgard GB coating provides 1000 hours of salt spray resistance (per ASTM B117)
- Accept standard nuts and washers if required

AutoCAD® drawings available to ease design and specification. Contact gmelvin@infastech.com.

Tap-Flex™ Thread-Forming Structural Screws

Tap-Flex. Structural Fasteners

Selection Guide & Performance Data

	Size	Head/Drive	Catalog No.	Finish	Load-Bearing Length	KSI*
3/8" Diameter						
	3/8-16 x 1-1/2	HWH	ESU310	Stalgard GB	1.00"	120 KSI min.
	3/8-16 x 2	HWH	ESU320	Stalgard GB	1.49"	
	3/8-16 x 2-1/2	HWH	ESU330	Stalgard GB	1.99"	
1/2" Diameter						
	1/2-13 x 1-1/2	HWH	ESU410	Stalgard GB	0.875"	120 KSI min.
	1/2-13 x 2	HWH	ESU420	Stalgard GB	1.365"	
	1/2-13 x 2-1/2	HWH	ESU430	Stalgard GB	1.865"	
5/8" Diameter						
	5/8-11 x 1-1/2	HWH	ESU510	Stalgard GB	0.800"	120 KSI min.
	5/8-11 x 2	HWH	ESU520	Stalgard GB	1.24"	
	5/8-11 x 2-1/2	HWH	ESU530	Stalgard GB	1.74"	

* Per ASTM A449.

Identification

Elco flag in a raised circle

Elco Construction Products
1304 Kerr Drive • Decorah, IA 52101
1.800.435.7213 • Fax: 563.387.3540
www.elcoconstruction.com

infastech™ Our Technology, Your Success

Avdel® iForm™

ConFlex® Large Diameter Masonry Screws

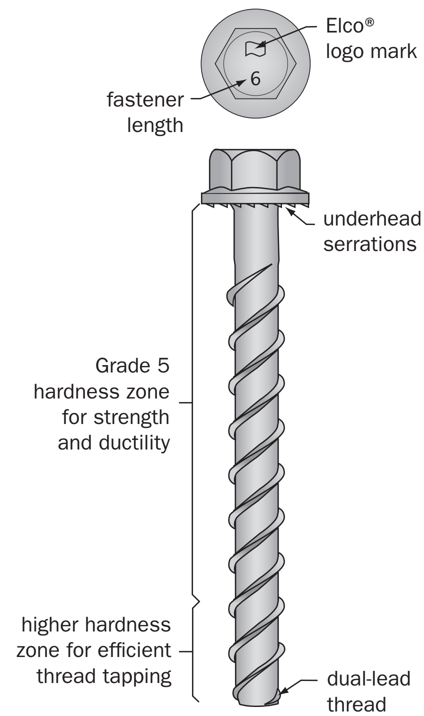
Conflex® fasteners are a new generation of masonry screws from Elco Construction Products. The design combines our 25 years of experience in manufacturing the highest quality masonry screws with our unique Flex Technology® heat treat process used in our Dril-Flex® drill screws. The result is a large diameter masonry screw that is virtually immune to brittle failures, allowing use in exterior applications.

High Performance

The major feature of the ConFlex® design is the Flex Technology® heat treatment, which provides dual hardness zones on the screw shank:

- The lead threads are extremely hard for more efficient and effective thread tapping
- The lower hardness of the rest of the fastener renders it virtually immune to brittle failures

Brittle failures occur when high hardness fasteners, under high loads (including that from installation torque), are used in applications where moisture is present. The chance of failure is greatly enhanced when aluminum is in contact with such a fastener. This type of metallurgical reaction is usually referred to as Hydrogen-Assisted Stress Corrosion Cracking (HASCC).



Other Features and Benefits

- Installs using standard ANSI masonry drill bits
  - 3/8" masonry drill bit for 3/8" Conflex® fastener
  - 7/16" masonry drill bit for 1/2" Conflex® fastener
- Silver Stalgard® finish provides exceptional corrosion resistance (800 to 1,000 hours without red rust in salt spray testing per ASTM B117)
- Double-lead threads allow rapid fastener advancement into the pilot hole – twice as fast as a standard single-lead thread
- Locking serrations under the head provide back-out resistance
- Provides high pull-out and shear values
- Low installation torque
- Head markings allow easy inspection

Specifications

Sizes: 3/8" and 1/2" diameters
Actual thread O.D. is greater than nominal screw anchor diameter designation (see thread diameter information on following page)

Material: Alloy steel

Mechanical Properties

Tensile Yield:	92,000 KSI min. (Grade 5)
Tensile Ultimate:	120,000 KSI min. (Grade 5)

Finish: Silver Stalgard® corrosion-resistant coating

Corrosion Resistance: 800 to 1,000 hours in salt spray testing without red rust (per ASTM B117)

Applications

- Curtain wall and glazing
- Blast- and impact-resistant window systems
- Accordion and pull-down hurricane shutter tracks
- Racking and shelving
- Maintenance and repairs
- Window and door frames
- Fencing
- Mudsills and ledgers
- Material handling
- Pool enclosures

STAFDA ASSOCIATE

ConFlex® Large Diameter Masonry Screws

ConFlex® Selection Guide

3/8" Diameter				1/2" Diameter			
Length	Thread Length	Part No.	Quantity Per Box	Length	Thread Length	Part No.	Quantity Per Box
2-1/2"	2-1/4"	EMR215	50	2-1/2"	2-1/4"	EMR320	50
3"	2-1/4"	EMR235	50	3"	2-1/4"	EMR340	50
4"	3-1/2"	EMR255	50	4"	3-1/2"	EMR360	50
5"	3-1/2"	EMR265	25	5"	3-1/2"	EMR370	25
7-1/2"	3-1/2"	EMR295	25	6"	3-1/2"	EMR380	25
Recommended min. embedment: 2"				Recommended min. embedment: 2"			
Installation: • Standard 3/8" ANSI masonry drill bit (.398" +.000"/-.010") • Recommended functional masonry drill bit length: minimum 1" more than fastener length				Installation: • Standard 7/16" ANSI masonry drill bit (.468" +.000"/-.010") • Recommended functional masonry drill bit length: minimum 1" more than fastener length			

Dimensional Properties

3/8" Diameter	1/2" Diameter
Drive system: 9/16" hex	Drive system: 3/4" hex
Washer diameter: 11/16"	Washer diameter: 1.0"
Thread O.D.: .430"	Thread O.D.: .525"
Thread root: .345"	Thread root: .405"
Unthreaded shank dia.: .360"	Unthreaded shank dia.: .426"
Head mark: Elco® logo mark and length in inches	Head mark: Elco® logo mark and length in inches

† Note: Indicated pull-out and shear values listed are ultimate values and were obtained in tests conducted by HETI/ Miami, FL, an independent test lab. These figures are offered only as a guide and are not guaranteed in any way by Elco Construction Products. A safety factor of 4:1 or 25% of ultimate values are generally accepted as a safe working load.

Testing was done per ASTM E 488 - 96. Additional technical data is available upon request.

For more information, please contact:

Elco Construction Products

5110 Falcon Road · Rockford, IL 61109

1.800.435.7213 or 815.391.5500

Fax: 815.397.8986

www.fastenersforconstruction.com

Distributed By:

ConFlex® Performance Data†

Ultimate Value (Lbs) in Concrete

1,819 PSI				
Dia .	Edge Distance	Embedment	Pull-out	Shear
3/8"	1-7/8" (5d)	1-1/2	1,364	X
		2	2,995	X
		2-1/2	3,226	1,534
		3-1/2	5,379	2,170
	2-5/8"	1-1/2	X	X
		2	X	X
		2-1/2	3,620	2,459
		3-1/2	6,070	3,902
	3-3/4" (10d)	1-1/2	1,232	4,766
		2	3,296	5,658
		2-1/2	3,936	6,419
		3-1/2	6,493	7,047
1/2"	2	1-3/4	X	X
		2	X	X
		3	X	X
		4	X	X
	2-1/2" (5d)	1-3/4	2,266	X
		2	2,706	X
		3	4,666	4,549
		4	7,058	6,960
	3-1/2"	1-3/4	X	X
		2	X	X
		3	5,483	5,739
		4	8,656	8,028
	4	1-3/4	X	X
		2	X	X
		3	X	X
		4	X	X
	5" (10d)	1 3/4	2,090	6,081
		2	2,875	7,167
		3	6,042	9,148
		4	8,732	9,631
4,510 PSI				
Dia.	Edge Distance	Embedment	Pull-out	Shear
3/8"	1-7/8" (5d)	1-1/2	2,497	X
		2	3,169	X
		2-1/2	5,063	2,111
		3-1/2	9,288	2,732
	2-5/8"	1-1/2		
		2		
		2-1/2	5,111	2,667
		3-1/2	8,438	4,046
	3-1/2"	1-1/2	2,055	X
		2	X	5,810
		2-1/2	4,778	X
		3-1/2	X	X
	3-3/4" (10d)	1-1/2	2,055	3,414
		2	X	5,810
		2-1/2	5,111	7,309
		3-1/2	9,508	8,339
1/2"	2"	1-3/4	3,515	X
		2	4,388	X
		3	6,719	2,229
		4	11,076	3,860
	3" (6d)	1-3/4	X	X
		2	X	X
		3	X	X
		4	X	X
	3-1/2"	1-3/4	X	X
		2	X	X
		3	7,646	X
		4	10,234	X
	4"	1-3/4	2,887	6,787
		2	4,310	6,678
		3	8,169	8,489
		4	11,111	10,942
	5" (10d)	1-3/4	X	X
		2	X	X
		3	X	X
		4	X	X

Aggre-Gator®
300 Series Stainless Steel
Threaded Concrete Anchors

ELCO®

Aggre-Gator® Bi-Metal Fasteners: The corrosion resistance of 300 series stainless steel in a threaded concrete anchor

Owners, architects and, design engineers expect longer life cycles from buildings. Extended warranties and use of more sustainable materials add up to greater expectations for performance – from structural integrity to the purely aesthetic – of all building components.

The Solution:
Aggre-Gator Bi-Metal Threaded Concrete Anchors

- Made of 300 series (18-8) stainless steel alloy to provide unmatched corrosion resistance in your toughest applications
- Fused and hardened steel tapping threads make installations easy and hold tight in block and poured concrete
- Coated with silver-colored Stalgard® GB, a Galvanic Barrier to protect aluminum components from accelerated corrosion when in contact with 300 series stainless steel
- Gimlet point provides quick starts, and makes Aggre-Gator anchors an ideal choice for treated, wood-to-wood applications

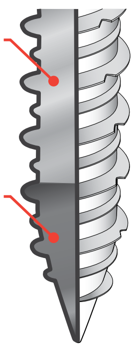
Applications

- Exposed anchoring/coastal/wet areas
- Aluminum enclosures
- Hurricane shutters/windows/awnings/thresholds
- Curtain wall & window wall support anchors
- Stone facade support anchors
- ACQ-treated wood

You won't find a better, easier-to-install or more reliable 300 series stainless steel anchor for your toughest construction applications than Aggre-Gator bi-metal concrete anchors.

Features

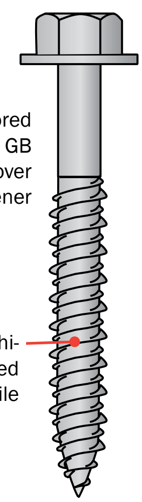
- Bi-metal technology – 300 (18-8) stainless steel head and shank
- Fused and hardened steel tapping threads and gimlet point
- Alternating, hi-low notched thread profile
- Silver-colored Stalgard GB coating



- Hex washer head and TrimFit® flat head designs

Benefits

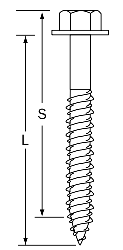
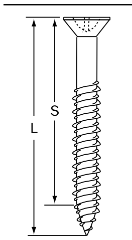
- Outstanding corrosion resistance
- Long service life
- High strength and ductility
- Offers greater galvanic compatibility in dissimilar metal applications involving aluminum
- Thread profile provides quick cutting and stability during installations
- High in-place value over life of structures



Aggre-Gator®
300 Series Stainless Steel
Threaded Concrete Anchors

ELCO®

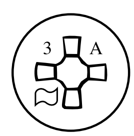
Selection Guide

	Dia.	L Length	Length Code†	Drive System	Head Style	Drill Bit Size* (Carbide)	S 300 Series (18-8) Stainless Steel Length	ECP Catalog Number*	Pieces Per Box	Pieces Per ¼ Keg
Hex Washer Head										
	1/4"	1-3/4"	A	5/16" hex	hex washer	3/16" X 3-1/2"	1-1/4"	EML315	50	2000
		2-1/4"	B			3/16" X 4-1/2"	1-3/4"	EML325	50	1500
		2-3/4"	C			3/16" X 4-1/2"	2-1/4"	EML335	50	1000
		3-1/4"	D			3/16" X 5-1/2"	2-3/4"	EML345	50	1000
		4"	F			3/16" X 5-1/2"	3-1/2"	EML365	50	500
TrimFit® Flat Head Fasteners										
	1/4"	1-3/4"	A	#3 phillips	TrimFit® flat head	3/16" X 3-1/2"	1-1/4"	EMM310	50	2500
		2-1/4"	B			3/16" X 4-1/2"	1-3/4"	EMM320	50	1500
		2-3/4"	C			3/16" X 4-1/2"	2-1/4"	EMM330	50	1000
		3-1/4"	D			3/16" X 5-1/2"	2-3/4"	EMM340	50	1000
		4"	F			3/16" X 5-1/2"	3-1/2"	EMM360	50	500

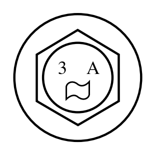
† Length code is marked on top of fastener head (see Identification section).

Identification

The head markings consists of the number “3”, the length code, and the Elco® logo as shown to the right.



TrimFit® head



hex washer head

The Ideal Solution

- Unmatched, multi-level corrosion resistance
- Quick and easy installs into concrete or masonry
- Perfect choice for exposed/wet areas/aggressive environments, such as coastal areas
- High performance for your most critical applications

Aggre-Gator®
300 Series Stainless Steel
Threaded Concrete Anchors

ELCO®

Miami-Dade County Product Control Approved-NOA No. 08-0813.06
High Velocity Hurricane Zone

Performance Data

Substrate: 2220 psi Concrete

Anchor Dia.	Min. Edge Dist.	Min. Spacing	Min. Embedment	Allowable Tension (lbs)
1/4"	1.25"	3.0"	1.000"	118
	2.50"	1.5"	1.000"	195
	1.25"	3.0"	1.375"	289
	2.50"	1.5"	1.375"	343
	1.25"	3.0"	1.750"	517
	2.50"	1.5"	1.750"	465

Anchor Dia.	Min. Edge Dist.	Min. Spacing	Min. Embedment	Allowable Shear (lbs)
1/4"	1.50"	3.0"	1.000"	204
	3.00"	1.5"	1.000"	259
	1.50"	3.0"	1.375"	259
	3.00"	1.5"	1.375"	413
	1.50"	3.0"	1.750"	318
	3.00"	1.5"	1.750"	488

Substrate: 3275 PSI Concrete

Anchor Dia.	Min. Edge Dist.	Min. Spacing	Min. Embedment	Allowable Tension (lbs)
1/4"	1.25"	3.0"	1.000"	248
	2.50"	1.5"	1.000"	263
	1.25"	3.0"	1.375"	389
	2.50"	1.5"	1.375"	251
	1.25"	3.0"	1.750"	295
	2.50"	1.5"	1.750"	319

Anchor Dia.	Min. Edge Dist.	Min. Spacing	Min. Embedment	Allowable Shear (lbs)
1/4"	1.50"	3.0"	1.000"	255
	3.00"	1.5"	1.000"	226
	1.50"	3.0"	1.375"	319
	3.00"	1.5"	1.375"	511
	1.50"	3.0"	1.750"	306
	3.00"	1.5"	1.750"	515

Substrate: 1x4 (3/4" Thick) Treated No. 2 SYP attached to 2220 psi Concrete

Anchor Dia.	Min. Edge Dist.	Min. Spacing	Min. Embedment	Allowable Shear (lbs)
1/4"	2.50"	3.0"	1.5"	200

Substrate: 2x4 (1-1/2" Thick) Treated No. 2 SYP attached to 2220 psi Concrete

Anchor Dia.	Min. Edge Dist.	Min. Spacing	Min. Embedment	Allowable Shear (lbs)
1/4"	2.50"	3.0"	1.75"	199

Substrate: Concrete Masonry Hollow Block

Anchor Dia.	Min. Edge Dist.	Min. Spacing	Min. Embedment	Allowable Tension (lbs)
1/4"	2.00"	3.0"	1.250"	195
	4.00"	3.0"	1.250"	221

Anchor Dia.	Min. Edge Dist.	Min. Spacing	Min. Embedment	Allowable Shear (lbs)
1/4"	2.00"	3.0"	1.250"	234
	4.00"	3.0"	1.250"	264

Substrate: Grout-Filled Concrete Block

Anchor Dia.	Min. Edge Dist.	Min. Spacing	Min. Embedment	Allowable Tension (lbs)
1/4"	2.00"	3.0"	1.250"	208
	4.00"	1.5"	1.250"	186
	2.00"	3.0"	2.00"	407
	4.00"	1.5"	2.00"	504

Anchor Dia.	Min. Edge Dist.	Min. Spacing	Min. Embedment	Allowable Shear (lbs)
1/4"	2.00"	3.0"	1.250"	259
	4.00"	1.5"	1.250"	352
	2.00"	3.0"	2.00"	591
	4.00"	1.5"	2.00"	597

NOTES

1. Edge distances denoted herein shall be measured from the center of the anchor to the edge of the substrate in the direction of, as well as perpendicular to, the direction of the load. Spacing between anchors denoted herein shall be measured center-to-center of anchors.
2. Allowable loads suggested herein are only valid when both the minimum anchor center-to-center spacing and the minimum edge distances are complied with.
3. Allowable loads suggested herein equal 25% of the average ultimate laboratory test values obtained during testing performed as part of the requirements to obtain this NOA. Final determination of the appropriate working/design loads to be used in a specific project are the sole responsibility of the engineer of record or of the architect of record specifying the use of the product.
4. No increase in allowable stress has been incorporated into the values provided in the tables contained herein.
5. Anchors approved under this product approval document have not been tested for use under combined loading.
6. The concrete substrate into which these anchors will be attached shall conform to ACI 301 specifications with strength properties as specified herein.
7. The hollow and grout-filled concrete block substrate into which these anchors will be attached shall be medium weight or normal weight concrete block conforming to ASTM C-90.
8. Combination wood and concrete substrate shall consist of 1 x 4 nominal (3/4" thick) treated No. 2 Southern Yellow Pine attached to concrete substrate conforming to ACI 301 specifications with strength properties as specified herein, or 2 x 4 nominal (1-1/2" thick) treated No. 2 Southern Yellow Pine attached to concrete substrate conforming to ACI 301 specifications with strength properties as specified herein.

For more information, contact Elco Construction Products or your distributor.

Elco Construction Products
1304 Kerr Drive • Decorah, IA 52101
Phone: 1.800.435.7213 (USA & Canada)
Fax: 563-387-3540
www.elcoconstruction.com

Distributed By:

Our Technology, Your Success

Rev.03/11

REFERENCES

REFERENCES

AAMA TIR-A9-14, Design Guide for Metal Cladding Fasteners

AISC 360-10, Specification for Structural Steel Buildings

AAMA 2501-06, Voluntary Guideline For Engineering Analysis of Window and Sliding Glass Door Anchorage System

YKK AP America Inc. Architectural Products, Design Manual Volume 3

Arthur P. Boresi, Richard J. Schmidt (2013), Advanced Mechanical of Materials; p. 9-12