FASTENERS
Innovations
LAURUS PER DILIGENTIA

Technical note: AFI/03/012

JOINT DESIGN USING ONESIDE™ STRUCTURAL FASTENER

Dr Saman Fernando
Ajax Fasteners Innovations
76-88 Mills Road
Braeside VIC 3195
AUSTRALIA
Tel: (03) 9580 7012, Fax: (03) 9586 6833
e-mail: sfernando@ajaxfast.com.au
URL: www.ajaxfast.com.au

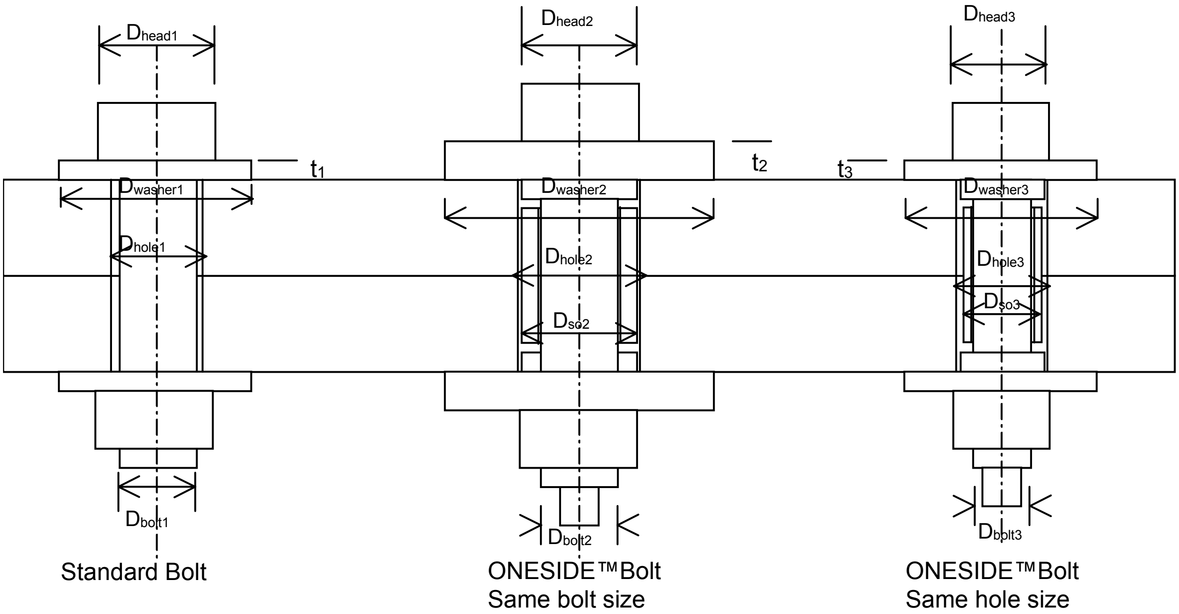
INTRODUCTION

ONESIDE™ is the only truly structural blind fastener in the world. Using **ONESIDE™** the full structural strength of the high strength bolts as per AS4291.1 can be achieved in both shear and tension. **ONESIDE™** can be applied for blind fastening where access to only one side is available. Fastening to hollow members, tanks, pressure vessels, wall cavities can be achieved with structural strength through the use of **ONESIDE™**. With the use of a high tensile sleeve **ONESIDE™** will provide full shear strength correspond to the hole-size.

This paper discusses the similarities and differences of **ONESIDE™** bolts and a standard high tensile bolts. This also describes the use of AS4100 design methods and their limitations and variations.

STRUCTURE OF ONESIDE™ BOLT

The **ONESIDE™** bolt contains a bolt with a circular head, a stepped washer, a split stepped washer, an optional sleeve (for shear) and a standard nut. Figure 1 shows a comparison of components between **ONESIDE™** and a standard bolt in a bolted joint. Two cases, namely, a) the same bolt size and b) the same hole-size are shown.



The bolt head diameter (D_{head}), the hole diameter (D_{hole}), the bolt diameter (D_{bolt}), the washer diameter (D_{washer}) and the washer thickness (t) are the fundamental design parameters of the bolts. The subscripts 1, 2 and 3 represent the cases a) standard bolt b) **ONESIDE™** with the same diameter bolt and c) **ONESIDE™** with the same diameter hole respectively. In the following section the similarities and differences in the three configurations are analysed in the light of Australian Steel Codes AS4100.

Standard Joint (Subscript 1):

Lets assume the following material properties;

Ultimate tensile stress	f_{u1}
Yield stress	f_{y1}
Ultimate shear stress	$0.62f_{u1}$
Yield shear stress	$0.62f_{y1}$
Effective stress area of thread	A_{s1}

Bolt:

Ultimate tensile strength (F_{u1})	$A_{s1}f_{u1}$
Yield strength (F_{y1})	$A_{s1}f_{y1}$
Ultimate shear strength (F_{us1})	$0.62\ A_{s1}f_{u1}$
Yield shear strength (F_{ys1})	$0.62\ A_{s1}f_{y1}$

The head bearing diameter D_{head1} and the head thickness (T_1)on a standard bolt is designed in such a way that a bearing failure and a shear failure are avoided. Hence;

$$\frac{4F_{u1}}{\pi(D_{head1}^2 - D_{hole1}^2)} < f_{u1}$$

$$\frac{F_{u1}}{\pi T_1 D_{hole1}} < 0.62 f_{u1}$$

Typically D_{hole1} is 2mm larger than the D_{bolt1} for standard bolted joints.

The washer diameter $D_{washer1}$ is selected in such a way;

$$\frac{4F_{u1}}{\pi(D_{washer1}^2 - D_{hole1}^2)} < f_{u1,joint}$$

where, $f_{u1,joint}$ is the ultimate tensile strength of the joint material. Typically, this is smaller than the f_{u1} of the bolt. Hence it requires the use of a high strength washer on either side of the joint in a typical structural bolted joint using high tensile bolts.

F_{u1}, F_{y1}, F_{us1}, F_{ys1} and A_{s1} are the values used in AS4100 for the design of bolted joints.

Design Details for Bolts (Section 9.6 AS4100):

Minimum Pitch and Edge Distance for a bolted joint is specified in the above standard. The minimum pitch is based on the stress distribution within a bolted joint. It has been proven through mathematical modelling and experimentation that a bolt will develop a volume in the joint where stress is distributed. It has been found that a minimum area of not more than 2.5 times the bolt diameter in the joint interface will experience the increased stress due to clamp force [1]. In order to avoid increased stresses due to overlap a minimum distance of 2.5 times the bolt diameter between two bolts is recommended by the AS4100.

The minimum edge distance is calculated to avoid a shear failure. As shown in the table 9.6.2 of the above standard the recommended edge distances vary from 1.25 to 1.75 of the bolt diameter based on the condition of the edge. The effective shear area for tearing is used for this estimation.

ONESIDE™ System with the Same Bolt Size (Subscript 2):

$D_{hole2} > D_{hole1}$
$D_{washer2} > D_{washer1}$
$A_{s2} = A_{s1}$

ONESIDE™ Bolt and Washer have the same strength**:**

Tensile strength	$F_{u2} = F_{u1}$
Yield Strength	$F_{y2} = F_{y1}$
Ultimate shear strength	$0.62\, F_{u2}$
Yield shear strength	$0.62\, F_{y2}$

ONESIDE™ Sleeve (Subscript s)**:**

Tensile strength	f_{us}
Yield Strength	f_{ys}
Ultimate shear strength	$0.62 f_{us}$
Yield shear strength	$0.62 f_{ys}$

Combined Shear strength F_{s2} is given by;

$$F_{s2} \cong 0.62.(f_{u2} A_{s2} + 0.25\pi . f_{us} (D^2_{sleeve2} - D^2_{bolt2})) \\ >> 0.62 f_{u2} A_{s2}$$

and is much larger than the shear strength of just the bolt. **ONESIDE™** is designed to satisfy all the head shear, head bearing and joint bearing requirements. The thickness of **ONESIDE™** washer t_2 is designed such that:

$$\frac{F_{u2}}{\pi t_2 D_{head2}} < 0.62 f_{u2}$$

hence, the assembly is able to carry the full tensile load of the original standard bolt, and a larger shear load. **ONESIDE™** sleeve and washer are also designed to have much lower clearances between the bolt and the washer and the bolt and the sleeve. The shear strength of the **ONESIDE™** assembly is therefore closer to a standard bolt of the same strength that will fit the same hole diameter D_{hole2}.

Minimum Pitch:

As the tensile strength of the bolt is not changed, as per guidelines of AS4100 the minimum pitch to be used with **ONESIDE™** bolt of similar size will still be the 2.5 times the bolt diameter D_{bolt2}. This automatically will avoid interference of **ONESIDE™** oversized washers ($D_{washer2} \approx 1.5 D_{bolt2}$) in the assembly. This will allow a minimum gap of D_{bolt2} between two **ONESIDE™** assemblies.

Minimum Edge Distance:

As the shear capacity of a same bolt size **ONESIDE™** assembly is larger than that of the standard bolt the minimum edge distance need to be calculated by replacing bolt diameter in the AS4100 by the sleeve outside diameter D_{so2}.

ONESIDE™ System with the Same Hole Size (Subscript 3):

$D_{hole3} = D_{hole1}$

$D_{washer3} > D_{washer1}$

$A_{s3} < A_{s1}$ (in order to fit in the same hole size)

ONESIDE™ Bolt and Washer Material Properties

Ultimate tensile stress	$f_{u3} = f_{u1}$
Yield stress	$f_{y3} = f_{y1}$
Ultimate shear stress	$0.62 f_{u3} = 0.62 f_{u1}$
Yield shear stress	$0.62 f_{y3} = 0.62 f_{y1}$

Bolt:

Tensile strength	$F_{u3} = f_{u3}A_{s3} < f_{u1}A_{s1} = F_{u1}$
Yield Strength	$F_{y3} = f_{y3}A_{s3} < f_{y1}A_{s1} = F_{y1}$

Equivalent **ONESIDE™** bolt strength is less than that of the standard bolt due to its smaller size. By moving to a higher grade bolt this difference may be reduced.

Shear strength F_{s3} is given by;

$$\begin{aligned} F_{s3} &\cong 0.62(f_{u3}A_{s3} + 0.25\pi . f_{us}(D^2_{sleeve3} - D^2_{bolt3})) \\ &\leq 0.62 f_{u1}A_{s1} = F_{s1} \end{aligned}$$

and is slightly smaller than the shear strength of the standard bolt in case 1. By choosing a sleeve material of higher strength a matching shear strength to a standard bolt applied in the same hole can be achieved. **ONESIDE™** is designed to satisfy all the head shear, head bearing and joint bearing requirements. The thickness of **ONESIDE™** washer t_3 is designed such that:

$$\frac{F_{u3}}{\pi t_3 D_{head3}} < 0.62 f_{u3}$$

hence, the assembly is able to carry almost the full shear load as the original standard bolt and a smaller tensile load. **ONESIDE™** sleeve and washer are also designed to have much lower clearances between the bolt and the washer and the bolt and the sleeve. Therefore, the shear strength of the **ONESIDE™** assembly is very similar to the standard bolt in case 1.

Minimum Pitch:

As the tensile strength of the bolt is reduced compared to the standard bolt, as per guidelines of AS4100 the minimum pitch to be used with **ONESIDE™** bolt that will fit the same size hole as the standard bolt will still be the 2.5 times the bolt diameter $\mathbf{D_{bolt3}}$. This automatically will avoid interference of **ONESIDE™** oversized washers ($D_{washer3} \approx 1.5 D_{bolt3}$) in the assembly. This will allow a minimum gap of $\mathbf{D_{bolt3}}$ between two **ONESIDE™** assemblies.

Minimum Edge Distance:

As the shear capacity of the same hole-size **ONESIDE™** assembly is similar to that of the standard bolt the minimum edge distance need to be calculated by replacing bolt diameter in the AS4100 by the sleeve outside diameter D_{so3}.

The following table summarizes the above comparison.

	Tensile Strength	Shear Strength	Minimum Pitch Ref. diameter	Min Edge Distance Ref Diameter
Standard Bolt	F_{u1}	F_{s1}	D_{bolt1}	D_{bolt1}
ONESIDE™ with same size bolt	$F_{u2} = F_{u1}$	$F_{s2} >> F_{s1}$	$D_{bolt2} = D_{bolt1}$	$D_{so2} > D_{bolt1}$
ONESIDE™ with same size hole	$F_{u3} < F_{u1}$♥	$F_{s3} \approx F_{s1}$*	$D_{bolt3} < D_{bolt1}$	$D_{so3} \approx D_{bolt1}$

♥ - The difference in tensile strength can be reduced by using a higher strength bolt.
* - This is achieved by using a higher strength sleeve.

Table 1: Relative strengths and minimum pitch and edge requirements for **ONESIDE™** bolts.

Design of Bolted Joints to AS4100 (Clause 9.3) using ONESIDE™:

Bolt Strength Limit State (Clause 9.3.2)

Bolt in Shear (Clause 9.3.2.1)

V_f = Nominal Shear Capacity of bolt (single shear plane) x number of shear planes
= **ONESIDE™** Shear Breaking load as per Tables 3 and 4 x number of shear planes

Except for bolted lap connections where a reduction factor of kr to be used as per table 9.3.2.1 of AS4100.

Bolt in Tension (Clause 9.3.2.2)

N_{tf} = Nominal tensile capacity of the bolt
= **ONESIDE™** Tensile breaking loads as per Tables 3 and 4 below.

Bolt Subject to Combined Shear and Tension (Clause 9.3.2.3)

In this case the effect of the sleeve need not be taken into consideration, as it does not undergo tension. For combined shear and tension on the bolt, the nominal shear and tensile capacities of the same size standard bolt (Table 2) may be used.

V_f = Nominal Shear Capacity of bolt (single shear plane) x number of shear planes
= **ONESIDE™** bolts -the nominal shear capacity of a standard bolt (Table 2) having the same size as the **ONESIDE™** bolt (Tables 3 and 4) x number of shear planes

N_{tf} = Nominal tensile capacity of the bolt
= **ONESIDE™** Tensile breaking load as per Tables 3 and 4 below.

Minimum pitch and edge distances as given in Tables 3 and 4 should be used when using the corresponding **ONESIDE™** bolt system.

Friction Type (TF) Joints

For friction type joint designs the sleeve can be neglected and the design should be carried out as per a standard bolt having the same size as the **ONESIDE™** bolt. Tensile breaking loads given in Tables 3 and 4 should be used for this case. The shear capacity to be determined as per AS4100 clause 9.3.3.

Standard Bolt											AS4100	
Bolt Size	Tensile Stress Area of Thread	Hole Diameter	PC 8.8 Tensile		PC8.8 Shear		PC 10.9 Tensile		PC 10.9 Shear		Minimum Pitch	Min Edge Distance Ref Diameter
			Proof Load(kN)	Breaking Load(kN)	Proof Load(kN)	Breaking Load(kN)	Proof Load(kN)	Breaking Load(kN)	Proof Load(kN)	Breaking Load(kN)		
6	20.1	7	11.6	16.1	7.2	10.0	16.7	20.9	10.4	13.0	15	6
8	36.6	9	21.2	29.2	13.1	18.1	30.4	38.1	18.8	23.6	20	8
10	58	11	33.7	46.4	20.9	28.8	48.1	60.3	29.8	37.4	25	10
12	84.3	13	48.9	67.4	30.3	41.8	70	87.7	43.4	54.4	30	12
14	115	16	66.7	92	41.4	57.0	95.5	120	59.2	74.4	35	14
16	157	18	91	125	56.4	77.5	130	163	81	101	40	16
18	192	20	115	159	71	99	159	200	99	124	45	18
20	245	22	147	203	91	126	203	255	126	158	50	20
22	303	24	182	252	113	156	252	315	156	195	55	22
24	353	26	212	293	131	182	293	367	182	228	60	24
27	459	29	275	381	171	236	381	477	236	296	67.5	27
30	561	32	337	466	209	289	466	583	289	361	75	30
33	694	35	416	576	258	357	570	722	353	448	82.5	33
36	817	38	490	678	304	420	678	850	420	527	90	36
39	976	41	586	810	363	502	810	1020	502	632	97.5	39

Table 1: Design Parameters for a Standard Bolt

ONESIDE™ Same Size Bolt																		AS4100	
Bolt Size	Bolt Head Diameter	Head Thickness	Washer		Sleeve		Hole Diameter	PC 8.8 Tensile		PC 8.8 Shear		PC 10.9 Tensile		PC 10.9 Shear		Min Pitch	Min Edge Distance Ref D
			Dwo	Dwi	Outside Diameter	Inside Diameter		Proof Load(kN)	Breaking Load(kN)	Proof Load(kN)	Breaking Load(kN)	Proof Load(kN)	Breaking Load(kN)	Proof Load(kN)	Breaking Load(kN)		
6	9	6	12	6.5	9	6	10	11.6	16.1	14.6	20.3	16.7	20.9	17.8	23.3	15	9
8	12	6	13	8.5	12	8	13	21.2	29.2	26.3	36.5	30.4	38.1	32.0	41.9	20	12
10	15	6	21	10.5	15	10	16	33.7	46.4	41.5	57.4	48.1	60.3	50.4	66.0	25	15
12	17	7	25	13	17	12	18	48.9	67.4	54.2	75.0	70	87.7	67.3	87.5	30	17
14	20	8	29	15	20	14	21	66.7	92.0	75.0	103.7	95.5	120.0	92.8	120.8	35	20
16	23	9	32	17	23	16	24	91.0	125.0	101.4	140.4	130.0	163.0	125.8	163.7	40	23
18	26	10	36	19	26	18	27	115.0	159.0	129.4	179.4	159.0	200.0	156.8	204.4	45	26
20	29	11	42	21	29	20	30	147.0	203.0	163.8	227.0	203.0	255.0	198.7	258.9	50	29
22	32	12	46	23	32	22	33	182.0	252.0	201.7	279.5	252.0	315.0	244.9	319.0	55	32
24	34	13	51	25	34	24	35	212.0	293.0	226.9	314.4	293.0	367.0	277.2	360.4	60	34
27	39	15	59	28	39	27	40	275.0	381.0	301.3	417.5	381.0	477.0	366.7	477.2	67.5	39
30	43	16	65	31	43	30	44	337.0	466.0	365.1	505.9	466.0	583.0	445.1	578.9	75	43
33	47	18	72	34	47	33	48	416.0	576.0	442.7	613.5	570.0	722.0	541.7	703.8	82.5	47
36	51	20	78	37	51	36	52	490.0	678.0	519.0	719.1	678.0	850.0	635.5	825.5	90	51
39	56	21	86	40	56	39	57	586.0	810.0	629.2	871.9	810.0	1020.0	768.4	998.9	97.5	56

Table 2: Design Parameters for **ONESIDE™** bolt with the bolt diameter same as the standard bolt

Note: Sleeve is made of Machine Tube with a minimum tensile strength of 470MPa and proof strength of 338MPa. Optional higher strengths may be achieved by using heat-treated sleeves.

Standard Bolt		ONESIDE™ Same Size Hole																		AS4100	
Bolt Size	Hole Size	Bolt Size	Hole Size	Bolt Head Dia	Head Thick	Washer		Sleeve		PC 8.8 Tensile		PC8.8 Shear		PC 10.9 Tensile		PC 10.9 Shear		Minimum Pitch	Min Edge Distance Ref Dia.
						Dwo	Dwi	Outside Diar	Inside Dia	Proof Load(kN)	Breaking Load(kN)	Proof Load(kN)	Breaking Load(kN)	Proof Load(kN)	Breaking Load(kN)	Proof Load(kN)	Breaking Load(kN)		
10	11	6	10	9	6	12	6.5	9	6	11.6	16.1	14.6	20.3	16.7	20.9	17.8	23.3	15	9
12	13	8	13	12	6	13	8.5	12	8	21.2	29.2	26.3	36.5	30.4	38.1	32.0	41.9	20	12
14	16	10	16	15	6	21	10.5	15	10	33.7	46.4	41.5	57.4	48.1	60.3	50.4	66.0	25	15
16	18	12	18	17	7	25	13	17	12	48.9	67.4	54.2	75.0	70	87.7	67.3	87.5	30	17
20	22	14	21	20	8	29	15	20	14	66.7	92.0	75.0	103.7	95.5	120	92.8	120.8	35	20
22	24	16	24	23	9	32	17	23	16	91.0	125.0	101.4	140.4	130.0	163.0	125.8	163.7	40	23
24	26	18	27*	26	10	36	19	26	18	115.0	159.0	129.4	179.4	159.0	200.0	156.8	204.4	45	26
27	29	20	30*	29	11	42	21	29	20	147.0	203.0	163.8	227.0	203.0	255.0	198.7	258.9	50	29
30	32	22	33	32	12	46	23	32	22	182.0	252.0	201.7	279.5	252.0	315.0	244.9	319.0	55	32
33	35	24	35	34	13	51	25	34	24	212.0	293.0	226.9	314.4	293.0	367.0	277.2	360.4	60	34
36	38	27	40	39	15	59	28	39	27	275.0	381.0	301.3	417.5	381.0	477.0	366.7	477.2	67.5	39

*- **ONESIDE™** requires a marginally larger hole.

Table 3: Design Parameters for **ONESIDE™** which uses the same hole size as a standard bolt.

Note: Sleeve is made of Machine Tube with a minimum tensile strength of 470MPa and proof strength of 338MPa. Optional higher strengths may be achieved by using heat-treated sleeves.