BoltGroup Verification Manual

This following document compares BoltGroup analysis results with the tabulated method provided in AISC. Tables 7-7 through 7-14 employ the instantaneous center of rotation method for the bolt patterns and eccentric conditions indicated, and inclined loads at 0°, 15°, 30°, 45°, 60°, and 75°. The tabulated non-dimensional coefficient, C, represents the number of bolts that are effective in resisting the eccentric shear force.

$\phi R_n = \phi C \times r_n$

where
C = tabular value
r_n = nominal strength per bolt, kip
ϕ = 0.75

Example 1

Determine available strength of bolt group connection with five bolts in each of two vertical rows (2 x 5). Vertical bolt spacing S = 3 inches, horizontal bolt spacing 3 inches, 7/8" diameter A325N bolts are loaded in shear, $\phi_v r_n$ = 21.6 kip (Table 7-1). The in-plane resultant force P = 70 kips is inclined 30° and applied with eccentricity e_x = 10 inches.

a) Using BoltGroup spreadsheet ϕR_n = **83.48 kips**
b) Using AISC table 7-8
C(e_x=10", S=3", n=5) = 3.87
$\phi R_n = \phi C r_n$ = 3.87(21.6) = **83.59 kips**
c) BoltGroup Deviation = (83.59-83.48)/83.59 = **0.13%**

Example 2

Determine available strength of bolt group connection with nine bolts in each of two vertical rows (2 x 9). Vertical bolt spacing S = 6 inches, horizontal bolt spacing 3 inches, 7/8" diameter A325N bolts are loaded in shear, $\phi_v r_n$ = 21.6 kip (Table 7-1). The in-plane resultant force P = 140 kips is inclined 30° and applied with eccentricity e_x = 28 inches.

a) Using BoltGroup spreadsheet ϕR_n = **172.60 kips**
b) Using AISC table 7-8
C(ex=10", S=3", n=5) = 7.99
$\phi R_n = \phi C r_n$ = 7.99(21.6) = **172.58 kips**
c) BoltGroup Deviation = (172.58-172.60)/172.58 = **-0.01%**

COMPANY NAME AND ADDRESS	Project:	BOLTGROUP VERIFICATION MANUAL	Engineer: Date:	YP 12-Apr	Project #
BoltGroup **Copyright © 2007**	Subject:	EXAMPLE 1 2 x 5 PATTERN	Checker: Date:		Page:

ECCENTRICALLY LOADED BOLT GROUP ANALYSIS

The following calculations comply with AISC Manual 13th Edition

Units: US

Applied Forces

Start Location		Direction	Value
X	Y	β	P
in	in	deg	kip
10	0	-120	70

Force Resultant: Total force Pu = 70.00 kip
Px = ΣPcos(β) = -35.00 kip
Py = ΣPsin(β) = -60.62 kip
β = -120.00 deg
Moment about CG , M_{CG} = -606.22 kip-in
Eccentricity to CG, e = M_{CG}/P_u = -8.66 in
Xp = Xc+ e*sin(β) = 7.500 in
Yp = Yc-e*cos(β) = -4.330 in

Bolt Group: Nbolts = 10 (< 100)

Center Gravity (CG)		Instantaneous Center (IC)	
X_C =	0 in	X_{IC} =	-1.71248 in
Y_C =	0 in	Y_{IC} =	1.55371 in

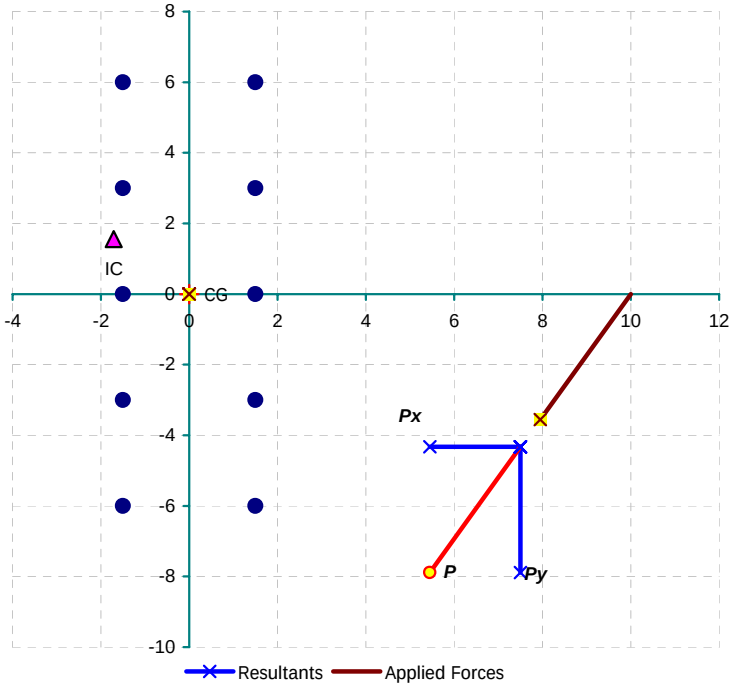
Bolt group shear capacity:

LRFD method: ϕP = **83.48 kip > = 70 OK**
Elastic method: ϕP = **63.22 kip < 70 N.G.** **Solved !**

Add torque = 0 kip-in

Bolt type: A325N SH, 7/8" Dia.
Bolt capacity ϕRn = 21.6 kip

Bolt Location		
Bolt No.	X	Y
(<= 100)	in	in
1	-1.5	6
2	-1.5	3
3	-1.5	0
4	-1.5	-3
5	-1.5	-6
6	1.5	-6
7	1.5	6
8	1.5	3
9	1.5	0
10	1.5	-3



COMPANY NAME AND ADDRESS	Project:	BOLTGROUP VERIFICATION MANUAL	Engineer: Date:	YP 12-Apr	Project #
BoltGroup **Copyright © 2007**	Subject:	EXAMPLE 2 2 x 9 PATTERN	Checker: Date:		Page:

ECCENTRICALLY LOADED BOLT GROUP ANALYSIS

The following calculations comply with AISC Manual 13th Edition

Units: US

Applied Forces

Start Location		Direction	Value
X	Y	β	P
in	in	deg	kip
28	0	-120	140

Force Resultant:

Total force Pu =	140.00	kip
Px = ΣPcos(β) =	-70.00	kip
Py = ΣPsin(β) =	-121.24	kip
β =	-120.00	deg
Moment about CG , M_{CG} =	-3394.82	kip-in
Eccentricity to CG, e = M_{CG}/P_u =	-24.25	in
Xp = Xc+ e*sin(β) =	21.000	in
Yp = Yc-e*cos(β) =	-12.124	in

Bolt Group: Nbolts = 18 (< 100)

Center Gravity (CG)		Instantaneous Center (IC)	
X_C =	0 in	X_{IC} =	-5.96291 in
Y_C =	0 in	Y_{IC} =	6.3331 in

Bolt group shear capacity:

LRFD method: ϕP =	**172.60 kip > = 140 OK**	
Elastic method: ϕP =	**126.43 kip < 140 N.G.**	**Solved !**

Add torque = 0 kip-in

Bolt type: A325N SH, 7/8" Dia.

Bolt capacity ϕRn = 21.6 kip

Bolt Location		
Bolt No. (<= 100)	X in	Y in
1	-1.5	24
2	-1.5	18
3	-1.5	12
4	-1.5	6
5	-1.5	0
6	-1.5	-6
7	-1.5	-12
8	-1.5	-18
9	-1.5	-24
10	1.5	24
11	1.5	18
12	1.5	12
13	1.5	6
14	1.5	0
15	1.5	-6
16	1.5	-12
17	1.5	-18
18	1.5	-24

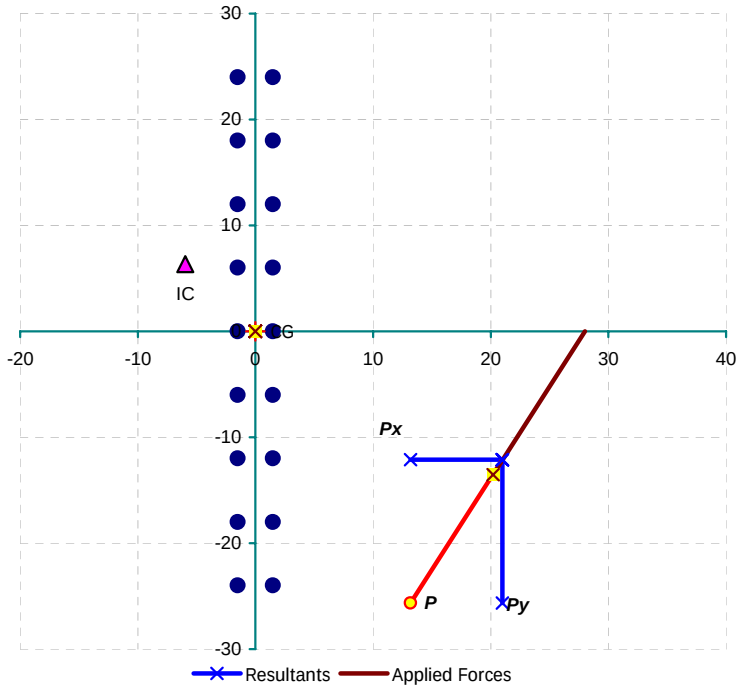


Table 7–8 (continued)
Coefficients *C* for Eccentrically Loaded Bolt Groups
Angle = 30°

Available Strength of a bolt group, ϕR_n or R_n/Ω, is determined with

$$R_n = C \times r_n$$

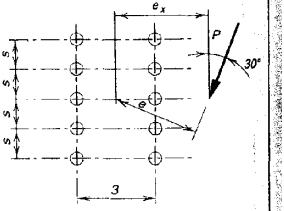
$\phi = 0.75$ $\Omega = 2.00$

or

LRFD	ASD
$C_{min} = \frac{P_u}{\phi r_n}$	$C_{min} = \frac{\Omega P_a}{r_n}$

where

P = required force, P_u or P_a, kips
r_n = nominal strength per bolt, kips
e = eccentricity of P with respect to centroid of bolt group, in. (not tabulated, may be determined by geometry)
e_x = horizontal component of e, in.
s = bolt spacing, in.
C = coefficient tabulated below



s, in.	e_x, in.	Number of Bolts in One Vertical Row, *n*											
		1	2	3	4	5	6	7	8	9	10	11	12
3	2	0.97	2.60	4.52	6.54	8.59	10.6	12.7	14.7	16.7	18.8	20.8	22.8
	3	0.75	2.12	3.83	5.71	7.71	9.75	11.8	13.9	15.9	18.0	20.0	22.1
	4	0.62	1.78	3.29	4.99	6.88	8.87	10.9	13.0	15.1	17.1	19.2	21.3
	5	0.52	1.53	2.85	4.39	6.16	8.06	10.0	12.1	14.1	16.2	18.3	20.4
	6	0.45	1.34	2.51	3.89	5.54	7.33	9.23	11.2	13.2	15.3	17.3	19.4
	7	0.40	1.19	2.23	3.48	5.01	6.70	8.51	10.4	12.4	14.4	16.4	18.5
	8	0.36	1.07	2.00	3.15	4.57	6.14	7.86	9.68	11.6	13.6	15.6	17.6
	9	0.32	0.97	1.81	2.87	4.19	5.66	7.28	9.02	10.9	12.8	14.7	16.7
	10	0.30	0.88	1.66	2.64	3.87	5.24	6.77	8.43	10.2	12.0	13.9	15.9
	12	0.25	0.75	1.41	2.27	3.34	4.54	5.92	7.43	9.04	10.8	12.5	14.4
	14	0.22	0.65	1.23	1.98	2.93	3.99	5.24	6.61	8.09	9.67	11.4	13.1
	16	0.19	0.58	1.08	1.76	2.60	3.56	4.69	5.94	7.30	8.77	10.3	12.0
	18	0.17	0.52	0.97	1.58	2.34	3.21	4.24	5.38	6.64	8.0	9.45	11.0
	20	0.16	0.47	0.88	1.43	2.12	2.92	3.87	4.92	6.08	7.3	8.70	10.1
	24	0.13	0.39	0.74	1.21	1.79	2.48	3.29	4.18	5.19	6.3	7.48	8.75
	28	0.12	0.34	0.64	1.04	1.55	2.14	2.85	3.63	4.52	5.5	6.54	7.68
	32	0.10	0.30	0.56	0.92	1.36	1.89	2.51	3.21	4.00	4.9	5.81	6.83
	36	0.09	0.26	0.50	0.82	1.21	1.69	2.25	2.87	3.59	4.4	5.22	6.15
6	2	0.97	3.20	5.31	7.37	9.39	11.4	13.4	15.4	17.4	19.4	21.3	23.3
	3	0.75	2.75	4.86	6.95	9.01	11.1	13.1	15.1	17.1	19.1	21.1	23.1
	4	0.62	2.39	4.42	6.49	8.57	10.6	12.7	14.7	16.8	18.8	20.8	22.8
	5	0.52	2.10	4.02	6.04	8.11	10.2	12.3	14.3	16.4	18.4	20.4	22.5
	6	0.45	1.87	3.67	5.61	7.66	9.73	11.8	13.9	16.0	18.0	20.1	22.1
	7	0.40	1.69	3.36	5.21	7.21	9.27	11.4	13.4	15.5	17.6	19.6	21.7
	8	0.36	1.53	3.08	4.84	6.79	8.82	10.9	13.0	15.1	17.1	19.2	21.3
	9	0.32	1.40	2.84	4.51	6.40	8.39	10.4	12.5	14.6	16.7	18.7	20.8
	10	0.30	1.29	2.63	4.21	6.04	7.98	9.99	12.0	14.1	16.2	18.3	20.4
	12	0.25	1.12	2.28	3.70	5.39	7.23	9.16	11.2	13.2	15.3	17.3	19.4
	14	0.22	0.98	2.00	3.29	4.86	6.57	8.41	10.3	12.3	14.4	16.4	18.5
	16	0.19	0.87	1.78	2.95	4.40	6.01	7.75	9.6	11.5	13.5	15.5	17.6
	18	0.17	0.79	1.60	2.68	4.02	5.52	7.17	8.9	10.8	12.7	14.7	16.7
	20	0.16	0.71	1.45	2.45	3.70	5.09	6.65	8.3	10.1	12.0	13.9	15.9
	24	0.13	0.60	1.23	2.08	3.17	4.39	5.79	7.3	8.95	10.7	12.5	14.4
	28	0.12	0.52	1.06	1.82	2.77	3.85	5.11	6.5	7.99	9.59	11.3	13.0
	32	0.10	0.46	0.93	1.61	2.45	3.42	4.56	5.8	7.20	8.68	10.3	11.9
	36	0.09	0.41	0.83	1.44	2.20	3.08	4.12	5.3	6.53	7.91	9.37	10.9

Example 3

Determine available strength of bolt group connection with three bolts in each of three vertical rows (3 x 3). Vertical bolt spacing S = 6 inches, horizontal bolt spacing 6 inches, 7/8" diameter A325N bolts are loaded in shear, $\phi_v r_n$ = 21.6 kip (Table 7-1). The in-plane resultant force P = 100 kips is inclined 75° and applied with eccentricity e_x = 20 inches.

a) Using BoltGroup spreadsheet ϕR_n = 132.85 kips
b) Using AISC table 7-12
$C(e_x$=20", S=6", n=3) = 6.15
$\phi R_n = \phi C r_n$ = 6.15(21.6) = 132.84 kips
c) BoltGroup Deviation = -0.0075%

COMPANY NAME AND ADDRESS	Project:	BOLTGROUP VERIFICATION MANUAL	Engineer: Date:	YP 12-Apr	Project #
BoltGroup Copyright © 2007	Subject:	EXAMPLE 3 3 x 3 PATTERN	Checker: Date:		Page:

ECCENTRICALLY LOADED BOLT GROUP ANALYSIS

The following calculations comply with AISC Manual 13th Edition

Units: US

Applied Forces

Start Location		Direction	Value
X	Y	β	P
in	in	deg	kip
20	0	-165	80

Force Resultant: Total force Pu = 80.00 kip
Px = ΣPcos(β) = -77.27 kip
Py = ΣPsin(β) = -20.71 kip
β = -165.00 deg
Moment about CG , M_{CG} = -414.11 kip-in
Eccentricity to CG, e = M_{CG}/P_u = -5.18 in
Xp = Xc+ e*sin(β) = 1.340 in
Yp = Yc-e*cos(β) = -5.000 in

Bolt Group: Nbolts = 9 (< 100)

Center Gravity (CG)		Instantaneous Center (IC)	
X_C =	0 in	X_{IC} =	-2.11599 in
Y_C =	0 in	Y_{IC} =	7.67525 in

Bolt group shear capacity:

LRFD method: ϕP = **132.85 kip > = 80 OK**
Elastic method: ϕP = **105.08 kip > = 80 OK** **Solved !**

Add torque = 0 kip-in

Bolt type: A325N SH, 7/8" Dia.
Bolt capacity ϕRn = 21.6 kip

Bolt Location		
Bolt No. (<= 100)	X in	Y in
1	-6	6
2	-6	0
3	-6	-6
4	0	6
5	0	0
6	0	-6
7	6	6
8	6	0
9	6	-6

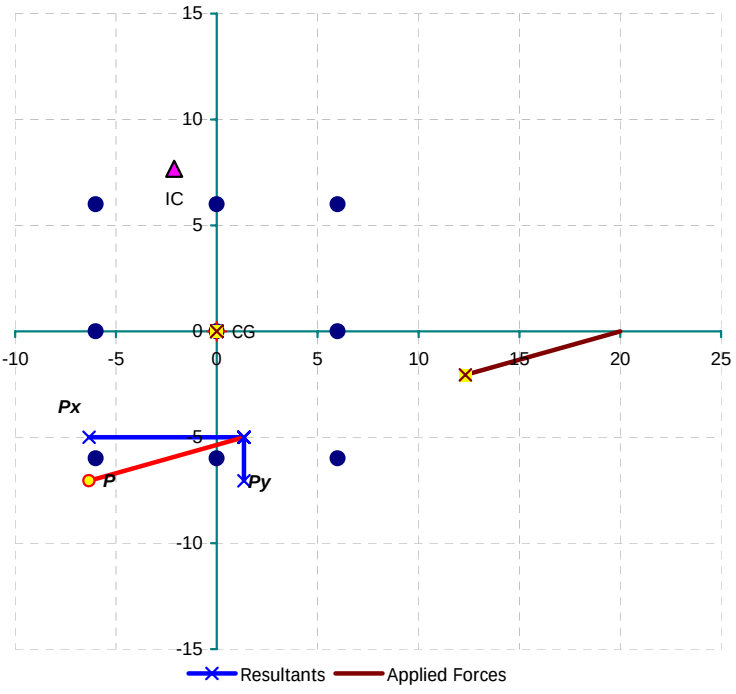


Table 7–12 (continued)
Coefficients C for Eccentrically Loaded Bolt Groups
Angle = 75°

Available Strength of a bolt group, ϕR_n or R_n/Ω, is determined with

$$R_n = C \times r_n$$

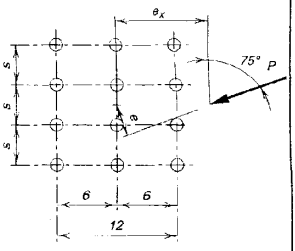
$\phi = 0.75$ $\Omega = 2.00$

or

LRFD	ASD
$C_{min} = \frac{P_u}{\phi r_n}$	$C_{min} = \frac{\Omega P_a}{r_n}$

where

P = required force, P_u or P_a, kips
r_n = nominal strength per bolt, kips
e = eccentricity of P with respect to centroid of bolt group, in. (not tabulated, may be determined by geometry)
e_x = horizontal component of e, in.
s = bolt spacing, in.
C = coefficient tabulated below



s, in.	e_x, in.	Number of Bolts in One Vertical Row, n											
		1	2	3	4	5	6	7	8	9	10	11	12
3	2	2.92	5.83	8.73	11.6	14.5	17.4	20.3	23.1	26.0	28.9	31.8	34.7
	3	2.89	5.77	8.63	11.5	14.3	17.2	20.0	22.8	25.7	28.5	31.4	34.2
	4	2.86	5.70	8.51	11.3	14.1	16.9	19.7	22.5	25.3	28.1	30.9	33.7
	5	2.82	5.61	8.38	11.1	13.9	16.6	19.4	22.1	24.9	27.7	30.5	33.3
	6	2.77	5.51	8.23	10.9	13.6	16.3	19.0	21.8	24.5	27.2	30.0	32.8
	7	2.72	5.40	8.06	10.7	13.4	16.0	18.7	21.4	24.1	26.8	29.6	32.3
	8	2.66	5.29	7.89	10.5	13.1	15.7	18.3	21.0	23.7	26.4	29.1	31.9
	9	2.60	5.16	7.71	10.3	12.8	15.4	18.0	20.6	23.3	26.0	28.7	31.4
	10	2.53	5.04	7.53	10.0	12.6	15.1	17.7	20.3	22.9	25.6	28.3	31.0
	12	2.40	4.78	7.16	9.57	12.0	14.5	17.0	19.6	22.1	24.8	27.4	30.1
	14	2.26	4.52	6.80	9.12	11.5	13.9	16.4	18.9	21.4	24.0	26.6	29.3
	16	2.13	4.27	6.45	8.68	11.0	13.3	15.8	18.2	20.7	23.3	25.9	28.5
	18	2.00	4.03	6.12	8.27	10.5	12.8	15.2	17.6	20.1	22.6	25.1	27.7
	20	1.89	3.81	5.80	7.88	10.1	12.3	14.6	17.0	19.4	21.9	24.4	27.0
	24	1.67	3.41	5.24	7.18	9.22	11.4	13.6	15.9	18.2	20.7	23.1	25.6
	28	1.49	3.06	4.75	6.56	8.49	10.5	12.6	14.9	17.1	19.5	21.9	24.3
	32	1.34	2.77	4.33	6.02	7.84	9.77	11.8	13.9	16.1	18.4	20.7	23.1
	36	1.21	2.52	3.97	5.56	7.27	9.10	11.1	13.1	15.2	17.4	19.7	22.0
6	2	2.92	5.82	8.71	11.6	14.5	17.4	20.3	23.5	26.4	29.3	32.3	35.2
	3	2.89	5.76	8.60	11.4	14.3	17.1	20.0	22.9	25.8	28.7	31.7	34.6
	4	2.86	5.68	8.47	11.3	14.1	16.9	19.8	22.6	25.5	28.4	31.3	34.2
	5	2.82	5.59	8.34	11.1	13.9	16.7	19.5	22.4	25.2	28.1	31.0	33.9
	6	2.77	5.49	8.19	10.9	13.7	16.4	19.2	22.1	24.9	27.8	30.7	33.6
	7	2.72	5.39	8.04	10.7	13.4	16.2	19.0	21.8	24.6	27.5	30.4	33.3
	8	2.66	5.27	7.89	10.5	13.2	16.0	18.8	21.6	24.4	27.2	30.1	33.0
	9	2.60	5.16	7.74	10.4	13.0	15.8	18.5	21.3	24.1	27.0	29.8	32.7
	10	2.53	5.04	7.58	10.2	12.8	15.5	18.3	21.0	23.9	26.7	29.5	32.4
	12	2.40	4.81	7.27	9.81	12.4	15.1	17.8	20.6	23.3	26.2	29.0	31.8
	14	2.26	4.57	6.97	9.47	12.0	14.7	17.4	20.1	22.9	25.6	28.4	31.3
	16	2.13	4.35	6.69	9.13	11.7	14.3	16.9	19.6	22.4	25.1	27.9	30.7
	18	2.00	4.13	6.41	8.82	11.3	13.9	16.5	19.2	21.9	24.7	27.4	30.2
	20	1.89	3.93	6.15	8.51	11.0	13.5	16.1	18.8	21.5	24.2	27.0	29.8
	24	1.67	3.57	5.67	7.95	10.4	12.9	15.4	18.0	20.7	23.4	26.1	28.8
	28	1.49	3.25	5.25	7.44	9.77	12.2	14.7	17.3	19.9	22.6	25.3	28.0
	32	1.34	2.97	4.87	6.98	9.23	11.6	14.1	16.6	19.2	21.8	24.5	27.2
	36	1.21	2.73	4.54	6.56	8.74	11.1	13.5	16.0	18.5	21.1	23.7	26.4