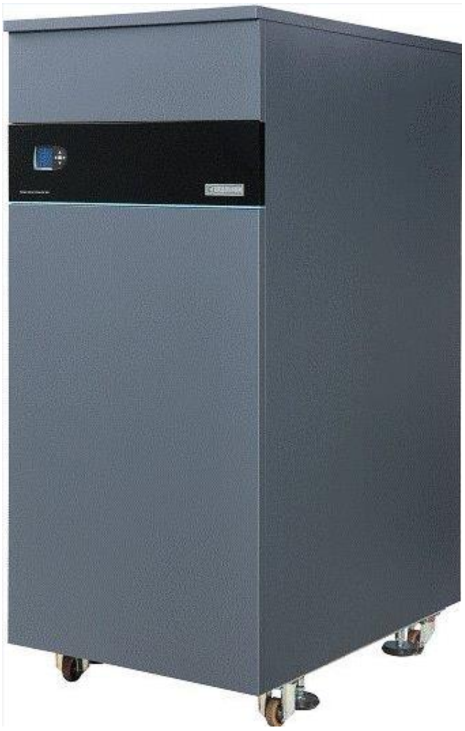
Submittal Documents

Seismic Analysis of the Boiler SVF 750



August 08, 2018

For:
WEIL-McLAIN

Prepared By:
Sam Salissen, ME,PE, Ph.D.

CAE Piping ● 14271 Jeffrey Rd., Irvine, CA 92620 ● Tel: (800) 948-1460

Summary

The scope of this report is the seismic qualification, based on the structural analysis, of the boiler model SVF 750, under the seismic loads for the seismic zone 4 in the United States. The analyses are limited to the load path from the COG of the assembly to the floor and the interior parts of the boiler are not within the scope of this work.

The qualification is in accordance with the seismic design requirements of IBC 2015, ASCE 7-10 and AISC for the seismic zone 4, for non-structural components and based on the seismic parameters used in this report.

The structural analyses carried out on the base frame assembly and based on the safety factors reported in section **5.7**, the minimum safety factor of **1.67**, requirement of AISC, is obtained in all the analyses performed in this report.

It is concluded that the design of the main frame and legs meets the design requirements of IBC 2015, ASCE 7-10 and ASME BPVC and AISC standards. This conclusion is contingence to the accuracy of the SolidWorks model and other input data provided by WEIL-McLAIN (WM) and used to build the FE models and set up the analyses (material, COG,...) appended in Appendix 1.

Revision History

Rev	Date	Scope of the revision	Created by
A	08/06/2018	First Issue	Sam Salissen

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1 Introduction

1.1 Scope

The scope of this report is the seismic qualification, based on the structural analysis, of the boiler, model SVF 750, under the seismic loads for the seismic zone 4 in the states. The analyses are limited to the load path from the COG of the assembly to the floor and the interior parts of the boiler are not within the scope of this work. The qualification is in accordance with the design requirements of IBC 2015, ASCE 7-10 and AISC.

2 Assumptions and open issues

In this chapter, assumptions and open issues are presented in two categories. The definition of each is presented below.

Open issues- Is defined as issues that must be solved, otherwise the analysis cannot be completed.

Key assumption- Is defined as assumptions that may have noticeable impact on the analysis results.

2.1 Open Issues

- No open issues exist.

2.2 Key Assumptions

No fabrication drawing of the parts and assembly were provided and the analyses are based on the SolidWorks model that is provided by WM and no responsibility of the accuracy of the model with respect to the actual assembly will be taken by the author of this report.

- The weight and the location of the center of the gravity of the boiler assembly are estimated and provided by WM, Appendix 1.
- It is assumed that the material of the base frame and the top plate are S235JR and SS316L, respectively.
- It is assumed that the welds have at least the same strength as the base material (Weld strength FEXX=70ksi>54ksi for base material) based on ASME allowable stress in welds under shear and tension is 0.3 *tensile strength =21000psi. In this case it is lower than the allowable stress of the in the members (AISC).

3 Requirements and Prerequisites

3.1 Stress criteria

The seismic loads are calculated based on the IBC 2015 code. The detail of the used parameters and the calculations are as follows. Seismic analyses are performed (using FEM) based on ASD approach of the AISC 14 edition & ASCE 7-10 for the steel parts and LRFD for the anchorage calculations.

3.2 Loads

The four load cases consider during the analyses include those specified by the ASCE 7-10. The following parameters are used in calculation of the seismic loads as follows:

1- Load calculation for ASD (used in the analyses of the steel parts)

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JOB NAME: SA-SVF750
CUSTOMER: WEIL-McLAIN

DATE:	PRP. BY.:	CAE PIPING JOB #:
8/3/2018		

SEISMIC CALCULATION WORKSHEET
BUILDING CODE: IBC-2012 / 2015

SEISMIC DESIGN		BLDG. ELEVATION / EQUIP. LOCATION	
S_{ds} =	2		
I_p =	1	h =	40 ft
a_p =	1	**z =	40 ft
R_p =	2.5	** Assume worst case location.	
Ω_o =	2.0		

a_p, R_p, Ω_o per ASCE 7-10

X 40 ft. RF
0 ft. GF or below ground

LOAD COMBINATION: ASD 2012/ 2013
(0.6 DL + 1.75 E)

EQUIPMENT TAG: BOILER SVF 750

EQUIPMENT Information:
W_p = max. operating weight = 1990 lbs.

APPLIED SEISMIC FORCE/ CALCULATIONS: — ANCHORAGE TO CONCRETE — SHT. NUMBER 1 OF 1

F_p / W_p = (0.4 x a_p x S_{ds} x (1 + (2 x (z / h))) / (R_p / I_p) = 0.96

F_p / W_p = 0.96g ; $F_{p,min}$ / W_p = 0.3 x S_{ds} x I_p = 0.60 ; $F_{p,max}$ / W_p = 1.6 x S_{ds} x I_p = 3.20

F_{ph} = Applied Lateral Seismic Force = 1.8 x 0.96g x W_p = 3344 lbs. *WORST CASE

F_{pv} = Vertical component of seismic force = 1.0 x 0.2 x S_{ds} x W_p = 796 lbs. *WORST CASE

2- Load calculation for LRFD (used in the analyses of the anchorage)

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JOB NAME: SA-SVF750
CUSTOMER: WEIL-McLAIN

DATE:	PRP. BY.:	CAE PIPING JOB #:
8/3/2018		

SEISMIC CALCULATION WORKSHEET
BUILDING CODE: IBC-2012 / 2015

SEISMIC DESIGN		BLDG. ELEVATION / EQUIP. LOCATION	
S_{ds} =	2		
I_p =	1	h =	40 ft
a_p =	1	**z =	40 ft
R_p =	2.5	** Assume worst case location.	
Ω_o =	2.0		

a_p, R_p, Ω_o per ASCE 7-10

X 40 ft. RF
0 ft. GF or below ground

LOAD COMBINATION: LRFD 2013
(0.9 DL + 2.50 E)

EQUIPMENT TAG: BOILER SVF 750

EQUIPMENT Information:
W_p = max. operating weight = 1990 lbs.

APPLIED SEISMIC FORCE/ CALCULATIONS: — ANCHORAGE TO CONCRETE — SHT. NUMBER 1 OF 1

F_p / W_p = (0.4 x a_p x S_{ds} x (1 + (2 x (z / h))) / (R_p / I_p) = 0.96

F_p / W_p = 0.96g ; $F_{p,min}$ / W_p = 0.3 x S_{ds} x I_p = 0.60 ; $F_{p,max}$ / W_p = 1.6 x S_{ds} x I_p = 3.20

F_{ph} = Applied Lateral Seismic Force = 2.5 x 0.96g x W_p = 4776 lbs. *WORST CASE

F_{pv} = Vertical component of seismic force = 1.0 x 0.2 x S_{ds} x W_p = 796 lbs. *WORST CASE

5.7 Results Evaluation

Minimum safety factor of **1.72** is obtained in the analyses of the assembly carried out in sections 5.1 to 5.4. The analyses of the joints, welds and bolts, carried out in section 5.5 to 5.6 also show that they meet and exceed the requirement of AISC. However, the stresses reported in section 5 are local stresses and the average stress through the thickness of the members are much lower and that can be shown by stress linearization through the thickness. However, since even the maximum local peak stresses don't exceed the allowable values, the stress linearization work is skipped here.

6 Conclusion

Seismic analysis of the boiler, model SVF 750, is carried out in this report and based on the safety factors reported in section **5.7**, minimum safety factor of **1.72** is obtained in all the analyses performed in this report.

It is concluded that the design of the structure of the boiler SVF 750 meets the design requirements of AISC, ASCE7-10 and IBC 2012 standards.

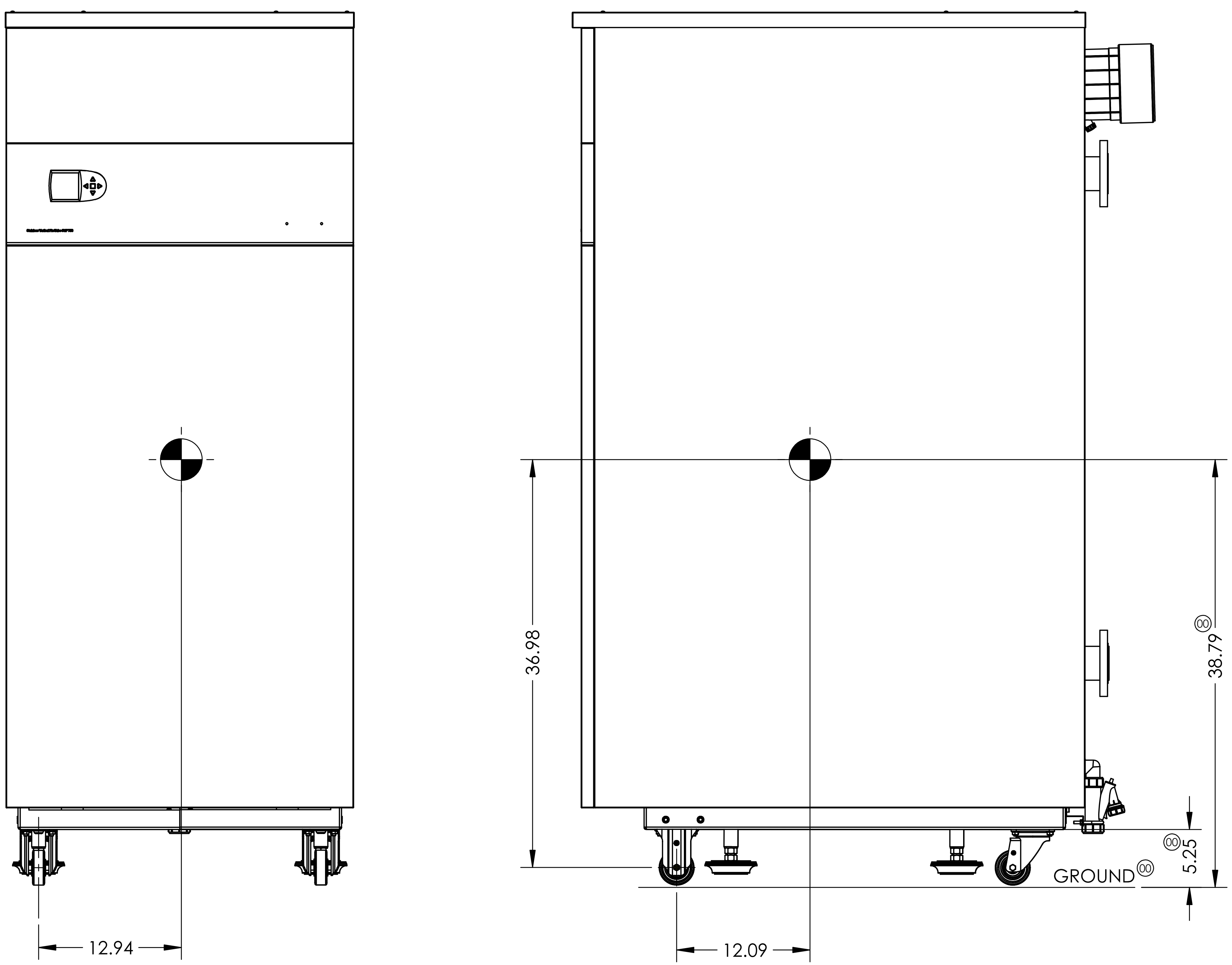
7 References

[1]- IBC 2012.

[2]- AISC 14^{th} Edition.

[3]- ASCE 7-10.

APPENDIX ***1-*** Drawing with COG markup



Raymond Maddock
Sr. Product Engineer

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This drawing has been prepared according to the established standard uniform practices in ASME Y14.5M-1994. Dimensions are in Imperial units (inches) unless otherwise shown. Printed copies of this document are UN-CONTROLLED unless otherwise controlled, stamped and approved. This may not be the current revision.

TITLE

SVF 750 - CENTER OF GRAVITY LOCATION

TOLERANCES,UNLESS OTHERWISE SPECIFIED
Angular ±
1 Place Decimal ±
2 Place Decimal ±
3 Place Decimal ±

THIRD ANGLE PROJECTION

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SEE LATEST REVISION E.C.O. FOR APPROVALS

ECO NO	ECO-3810	CHECKER	DL
DRAWN	FH	APPROVER	NDB

DRAWING No. SVF-E003-BDOC — REVISION 00

DO NOT SCALE — SIZE B — SHEET: 1 OF 1

ECO NUMBER	REV.	DESCRIPTION	Drawn	Checked	Approve
ECO-3810	00	INITIAL PRODUCTION RELEASE; REVISED TO PRODUCTION REVISION 00 FROM PROTOTYPE REVISION A; ADDED LINE FOR GROUND AND 5.25 AND 38.79 DIMENSIONS.	FH	DL	NDB

REVISIONS

Appendix ***2*** **-**Anchor Bolt Calculation Report

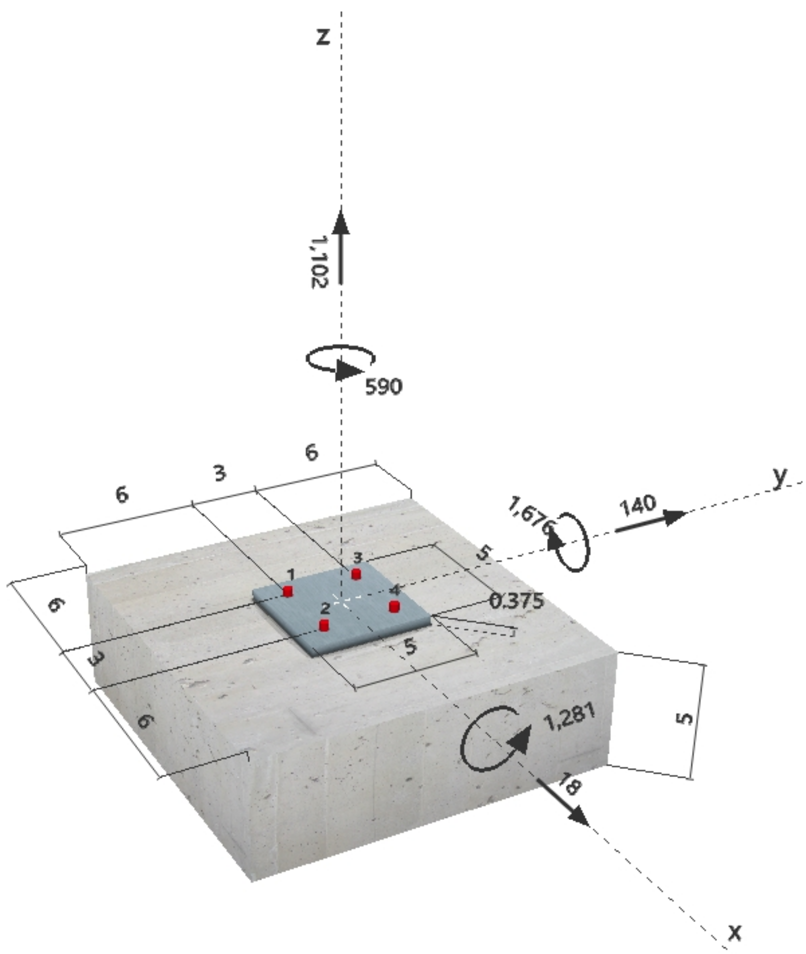
Company:	CAEP	Page:	1
Specifier:	S.S.	Project:	SVF 750
Address:		Sub-Project I Pos. No.:	WM
Phone I Fax:	|	Date:	8/5/2018
E-Mail:			

Specifier's comments:

1 Input data

Anchor type and diameter:	**Kwik Bolt TZ - CS 3/8 (2 3/4)**
Effective embedment depth:	h_{ef} = 2.750 in., h_{nom} = 3.063 in.
Material:	Carbon Steel
Evaluation Service Report:	ESR-1917
Issued I Valid:	6/1/2016 | 5/1/2017
Proof:	Design method ACI 318 / AC193
Stand-off installation:	e_b = 0.000 in. (no stand-off); t = 0.375 in.
Anchor plate:	l_x x l_y x t = 5.000 in. x 5.000 in. x 0.375 in.; (Recommended plate thickness: not calculated
Profile:	no profile
Base material:	cracked concrete, 3000, f_c' = 3000 psi; h = 5.000 in.
Reinforcement:	tension: condition B, shear: condition B; no supplemental splitting reinforcement present
	edge reinforcement: none or < No. 4 bar
Seismic loads (cat. C, D, E, or F)	no

Geometry [in.] & Loading [lb, in.lb]



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Company:	CAEP	Page:	2
Specifier:	S.S.	Project:	SVF 750
Address:		Sub-Project I Pos. No.:	WM
Phone I Fax:	|	Date:	8/5/2018
E-Mail:			

2 Load case/Resulting anchor forces

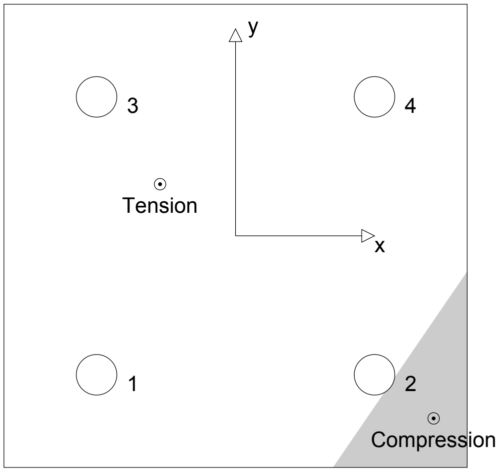
Load case: Design loads

Anchor reactions [lb]

Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	400	56	54	-14
2	29	100	54	84
3	654	47	-45	-14
4	283	95	-45	84

max. concrete compressive strain: 0.12 [‰]
max. concrete compressive stress: 516 [psi]
resulting tension force in (x/y)=(-0.814/0.557): 1366 [lb]
resulting compression force in (x/y)=(2.138/-1.971): 264 [lb]



3 Tension load

	Load N_{ua} [lb]	Capacity ϕ N_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status
Steel Strength*	654	4875	14	OK
Pullout Strength*	654	2246	30	OK
Concrete Breakout Strength**	1366	3776	37	OK

* anchor having the highest loading **anchor group (anchors in tension)

3.1 Steel Strength

N_{sa} = ESR value refer to ICC-ES ESR-1917
$\phi N_{sa} \geq N_{ua}$ ACI 318-08 Eq. (D-1)

Variables

$A_{se,N}$ [in.^{2}]	f_{uta} [psi]
0.05	125000

Calculations

N_{sa} [lb]
6500

Results

N_{sa} [lb]	ϕ_{steel}	ϕN_{sa} [lb]	N_{ua} [lb]
6500	0.750	4875	654

Input data and results must be checked for agreement with the existing conditions and for plausibility!
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Address:		Sub-Project I Pos. No.:	WM
Phone I Fax:	|	Date:	8/5/2018
E-Mail:			

3.2 Pullout Strength

$N_{pn,f'_c} = N_{p,2500} \sqrt{\frac{f'_c}{2500}}$ refer to ICC-ES ESR-1917

$\phi \; N_{pn,f'_c} \geq N_{ua}$ ACI 318-08 Eq. (D-1)

Variables

f'_c [psi]	$N_{p,2500}$ [lb]
3000	3155

Calculations

$\sqrt{\frac{f'_c}{2500}}$
1.095

Results

N_{pn,f'_c} [lb]	$\phi_{concrete}$	$\phi \; N_{pn,f'_c}$ [lb]	N_{ua} [lb]
3456	0.650	2246	654

3.3 Concrete Breakout Strength

$N_{cbg} = \left(\frac{A_{Nc}}{A_{Nc0}}\right) \psi_{ec,N} \; \psi_{ed,N} \; \psi_{c,N} \; \psi_{cp,N} \; N_b$ ACI 318-08 Eq. (D-5)

$\phi \; N_{cbg} \geq N_{ua}$ ACI 318-08 Eq. (D-1)

A_{Nc} see ACI 318-08, Part D.5.2.1, Fig. RD.5.2.1(b)

$A_{Nc0} = 9 \; h_{ef}^2$ ACI 318-08 Eq. (D-6)

$\psi_{ec,N} = \left(\frac{1}{1 + \frac{2 \; e'_N}{3 \; h_{ef}}}\right) \leq 1.0$ ACI 318-08 Eq. (D-9)

$\psi_{ed,N} = 0.7 + 0.3 \left(\frac{c_{a,min}}{1.5h_{ef}}\right) \leq 1.0$ ACI 318-08 Eq. (D-11)

$\psi_{cp,N} = \text{MAX}\left(\frac{c_{a,min}}{c_{ac}}, \frac{1.5h_{ef}}{c_{ac}}\right) \leq 1.0$ ACI 318-08 Eq. (D-13)

$N_b = k_c \; \lambda \; \sqrt{f'_c} \; h_{ef}^{1.5}$ ACI 318-08 Eq. (D-7)

Variables

h_{ef} [in.]	$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	$c_{a,min}$ [in.]	$\psi_{c,N}$
2.750	0.814	0.557	6.000	1.000

c_{ac} [in.]	k_c	λ	f'_c [psi]
4.125	17	1	3000

Calculations

A_{Nc} [in.^{2}]	A_{Nc0} [in.^{2}]	$\psi_{ec1,N}$	$\psi_{ec2,N}$	$\psi_{ed,N}$	$\psi_{cp,N}$	N_b [lb]
126.56	68.06	0.835	0.881	1.000	1.000	4246

Results

N_{cbg} [lb]	$\phi_{concrete}$	$\phi \; N_{cbg}$ [lb]	N_{ua} [lb]
5809	0.650	3776	1366

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4 Shear load

	Load V_{ua} [lb]	Capacity ϕV_n [lb]	Utilization $\beta_V = V_{ua}/\phi V_n$	Status
Steel Strength*	100	2337	5	OK
Steel failure (with lever arm)*	N/A	N/A	N/A	N/A
Pryout Strength*	100	2764	4	OK
Concrete edge failure in direction y+**	200	1846	11	OK

* anchor having the highest loading **anchor group (relevant anchors)

4.1 Steel Strength

V_{sa} = ESR value refer to ICC-ES ESR-1917

$\phi V_{steel} \geq V_{ua}$ ACI 318-08 Eq. (D-2)

Variables

$A_{se,V}$ [in.^{2}]	f_{uta} [psi]
0.05	125000

Calculations

V_{sa} [lb]
3595

Results

V_{sa} [lb]	ϕ_{steel}	ϕV_{sa} [lb]	V_{ua} [lb]
3595	0.650	2337	100

4.2 Pryout Strength

$V_{cp} = k_{cp}\left[\left(\frac{A_{Nc}}{A_{Nc0}}\right)\psi_{ed,N}\,\psi_{c,N}\,\psi_{cp,N}\,N_b\right]$ ACI 318-08 Eq. (D-30)

$\phi V_{cp} \geq V_{ua}$ ACI 318-08 Eq. (D-2)

A_{Nc} see ACI 318-08, Part D.5.2.1, Fig. RD.5.2.1(b)

$A_{Nc0} = 9\,h_{ef}^2$ ACI 318-08 Eq. (D-6)

$\psi_{ec,N} = \left(\frac{1}{1+\frac{2\,e_N'}{3\,h_{ef}}}\right) \leq 1.0$ ACI 318-08 Eq. (D-9)

$\psi_{ed,N} = 0.7 + 0.3\left(\frac{c_{a,min}}{1.5h_{ef}}\right) \leq 1.0$ ACI 318-08 Eq. (D-11)

$\psi_{cp,N} = \text{MAX}\left(\frac{c_{a,min}}{c_{ac}}, \frac{1.5h_{ef}}{c_{ac}}\right) \leq 1.0$ ACI 318-08 Eq. (D-13)

$N_b = k_c\,\lambda\,\sqrt{f_c'}\,h_{ef}^{1.5}$ ACI 318-08 Eq. (D-7)

Variables

k_{cp}	h_{ef} [in.]	$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	$c_{a,min}$ [in.]
2	2.750	0.000	0.000	6.000

$\psi_{c,N}$	c_{ac} [in.]	k_c	λ	f_c' [psi]
1.000	4.125	17	1	3000

Calculations

A_{Nc} [in.^{2}]	A_{Nc0} [in.^{2}]	$\psi_{ec1,N}$	$\psi_{ec2,N}$	$\psi_{ed,N}$	$\psi_{cp,N}$	N_b [lb]
31.64	68.06	1.000	1.000	1.000	1.000	4246

Results

V_{cp} [lb]	$\phi_{concrete}$	ϕV_{cp} [lb]	V_{ua} [lb]
3948	0.700	2764	100

Input data and results must be checked for agreement with the existing conditions and for plausibility!
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4.3 Concrete edge failure in direction y+

$V_{cbg} = \left(\frac{A_{Vc}}{A_{Vc0}}\right) \psi_{ec,V}\ \psi_{ed,V}\ \psi_{c,V}\ \psi_{h,V}\ \psi_{parallel,V}\ V_b$ ACI 318-08 Eq. (D-22)

$\phi\ V_{cbg} \geq V_{ua}$ ACI 318-08 Eq. (D-2)

A_{Vc} see ACI 318-08, Part D.6.2.1, Fig. RD.6.2.1(b)

$A_{Vc0} = 4.5\ c_{a1}^2$ ACI 318-08 Eq. (D-23)

$\psi_{ec,V} = \left(\frac{1}{1 + \frac{2e_V'}{3c_{a1}}}\right) \leq 1.0$ ACI 318-08 Eq. (D-26)

$\psi_{ed,V} = 0.7 + 0.3\left(\frac{c_{a2}}{1.5c_{a1}}\right) \leq 1.0$ ACI 318-08 Eq. (D-28)

$\psi_{h,V} = \sqrt{\frac{1.5c_{a1}}{h_a}} \geq 1.0$ ACI 318-08 Eq. (D-29)

$V_b = \left(7\left(\frac{l_e}{d_a}\right)^{0.2} \sqrt{d_a}\right) \lambda \sqrt{f_c'}\ c_{a1}^{1.5}$ ACI 318-08 Eq. (D-24)

Variables

c_{a1} [in.]	c_{a2} [in.]	e_{cV} [in.]	$\psi_{c,V}$	h_a [in.]
4.000	6.000	1.265	1.000	5.000

l_e [in.]	λ	d_a [in.]	f_c' [psi]	$\psi_{parallel,V}$
2.750	1.000	0.375	3000	1.000

Calculations

A_{Vc} [in.^{2}]	A_{Vc0} [in.^{2}]	$\psi_{ec,V}$	$\psi_{ed,V}$	$\psi_{h,V}$	V_b [lb]
75.00	72.00	0.826	1.000	1.095	2798

Results

V_{cbg} [lb]	$\phi_{concrete}$	$\phi\ V_{cbg}$ [lb]	V_{ua} [lb]
2637	0.700	1846	200

5 Combined tension and shear loads

β_N	β_V	ζ	Utilization $\beta_{N,V}$ [%]	Status
0.362	0.108	5/3	21	OK

$\beta_{NV} = \beta_N^{\zeta} + \beta_V^{\zeta} <= 1$

6 Warnings

- Load re-distributions on the anchors due to elastic deformations of the anchor plate are not considered. The anchor plate is assumed to be sufficiently stiff, in order not to be deformed when subjected to the loading! Input data and results must be checked for agreement with the existing conditions and for plausibility!
- Condition A applies when supplementary reinforcement is used. The Φ factor is increased for non-steel Design Strengths except Pullout Strength and Pryout strength. Condition B applies when supplementary reinforcement is not used and for Pullout Strength and Pryout Strength. Refer to your local standard.
- Refer to the manufacturer's product literature for cleaning and installation instructions.
- Checking the transfer of loads into the base material and the shear resistance are required in accordance with ACI 318 or the relevant standard!

Fastening meets the design criteria!

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Company:	CAEP	Page:	6
Specifier:	S.S.	Project:	SVF 750
Address:		Sub-Project I Pos. No.:	WM
Phone I Fax:	|	Date:	8/5/2018
E-Mail:			

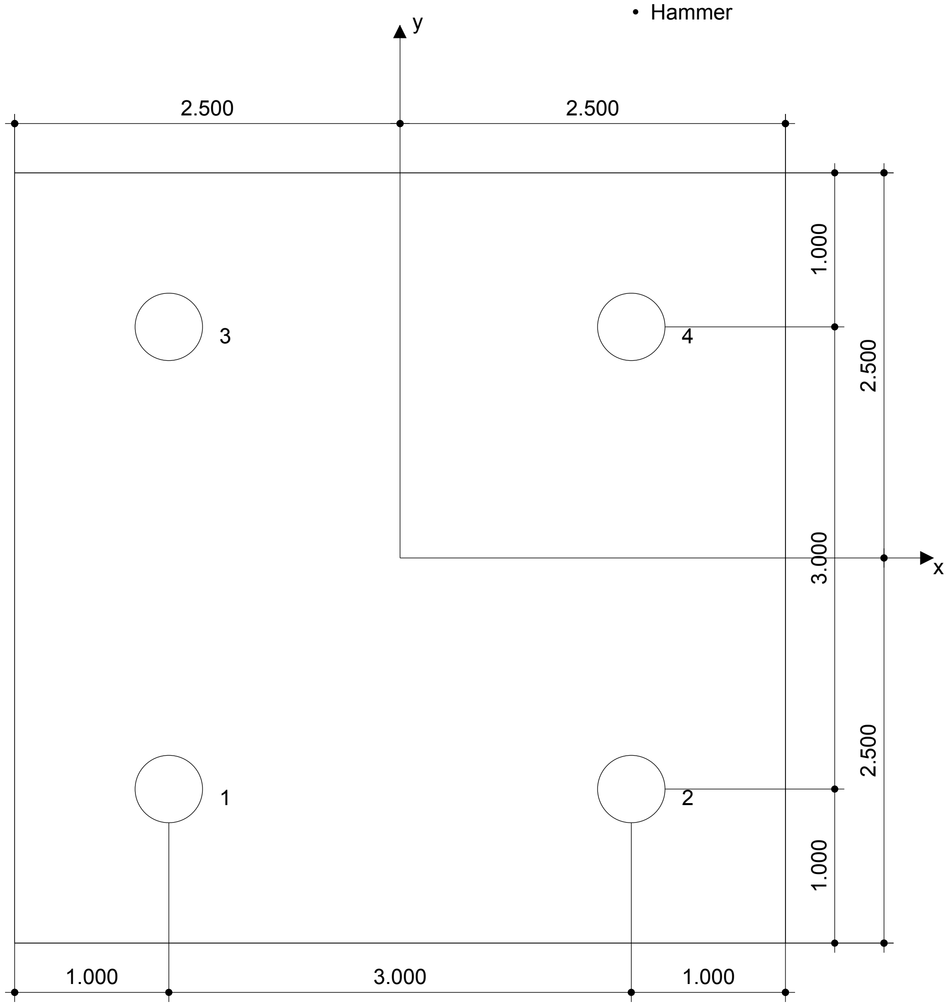
7 Installation data

Anchor plate, steel: -
Profile: no profile
Hole diameter in the fixture: d_f = 0.438 in.
Plate thickness (input): 0.375 in.
Recommended plate thickness: not calculated
Drilling method: Hammer drilled
Cleaning: Manual cleaning of the drilled hole according to instructions for use is required.

Anchor type and diameter: Kwik Bolt TZ - CS 3/8 (2 3/4)
Installation torque: 300.000 in.lb
Hole diameter in the base material: 0.375 in.
Hole depth in the base material: 3.375 in.
Minimum thickness of the base material: 5.000 in.

7.1 Recommended accessories

Drilling	Cleaning	Setting
• Suitable Rotary Hammer	• Manual blow-out pump	• Torque wrench
• Properly sized drill bit		• Hammer



Coordinates Anchor in.

Anchor	x	y	c_{-x}	c_{+x}	c_{-y}	c_{+y}
1	-1.500	-1.500	6.000	9.000	6.000	9.000
2	1.500	-1.500	9.000	6.000	6.000	9.000
3	-1.500	1.500	6.000	9.000	9.000	6.000
4	1.500	1.500	9.000	6.000	9.000	6.000

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Company:	CAEP	Page:	7
Specifier:	S.S.	Project:	SVF 750
Address:		Sub-Project I Pos. No.:	WM
Phone I Fax:	|	Date:	8/5/2018
E-Mail:			

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