S. GORDIN STRUCTURAL DESIGN
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(877) 477-4-SGE (4743)

STRUCTURAL ENGINEERING REPORT

Project: Seismic Restraint for Optical Table

Location: Ss=2.484, S1=1.033

Client: Newport Corporation

Code: 2013 CBC, 2012 IBC

SGE Job No. 515.052.369

July 2015

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Date: July 31, 2015

To: Mr. Warren Booth
Vibration Control Product Line Manager
Newport Corporation
1791 Deere Avenue
Irvine, CA 92606
Tel (949) 253-1866

Re: Structural Analysis and Design for
Optical Table Earthquake Restraint

SGE No.: 512.052.369

Dear Mr. Booth,

S. Gordin Structural Design & Engineering Services, Inc. (further referred to as "SGE") completed the engineering work on Structural Analysis and Design for the Earthquake Restraint.

This work was conducted based on Newport Corporation PO # 1421389 dated May 21, 2015.

Please refer to the aforementioned approved proposal for all additional information, including the caveat and limitations.

1. EXISTING DOCUMENTATION

This proposal was developed upon the following documentation (ERS97):

1.1 Drawings by Newport Corporation:

34773K	35712A	35718A
35703A	35715A	37192C
35704B	35716A	37194B
35711A	35717A	37195C
		37255B

1.2 2011 Structural Design by SGE for Earthquake Restraint.

3. STRUCTURAL ANALYSIS BY SGE

3.1 The structural analysis by SGE was based on the following:

3.1.1. Governing design codes:
2012 International Building Code (IBC)
2013 California Building Code (CBC)

ASCE 7-10 (American Society of Civil Engineers)
ACI 318-11 (American Concrete Institute)
Steel Design Manual 14th Edition (American Institute of Steel Construction)
AWS D1.3-2008 Structural Welding Code – Sheet Steel (American Welding Society).

3.1.2 Design assumptions:

Light-gage (13ga) steel	ASTM A570 Grade 50
Structural steel	ASTM A36
Concrete	Normal weight concrete, 3,000 PSI strength in 28 days (minimum for California), 6” minimum uniform thickness
Tributary seismic mass	Per Item 3.2.1 below
Seismic force	Ss=2.484, S1=1.033 (Hayward, CA), ap=1.0;Rp=2.5, Ω=2.5 (Laboratory Equipment, ASCE 7-10 Tbl.13.5-1)
Table location	At the ground floor, mid-height floor, and top floor (roof)
Table configuration	4’x6’ and 4’x20’ (4 isolators, 3 restraints) 4’x20’ (4 isolators, 4 restraints)
Restraint height	29-½” maximum from the floor.

3.1.3 Per request from Newport Corporation, only sleeve-type anchors were considered for the design of anchorage to concrete.

3.2 Commentary on some structural design issues (refer to drawings SD1 and SD2, Appendix A).

3.2.1. Model. The following was assumed for the purposes of this analysis/report:

a. The considered layouts are limited to the three cases presented on drawing SD1.
b. The combined center of gravity of the table and equipment is located within the height and plan limitations outlined by shaded diamond-shaped areas on drawing SD1.
c. Any conditions differing from those reflected on drawing SD1 are subject to additional structural investigation.
d. All tables are supported by vibration isolators (further referred to as “isolators,” 4 per table) and earthquake restraints (or “towers,” 3 or 4 per table). The isolators are assumed to resist vertical downward forces (gravity and seismic) only, while the restrains are capable of resisting only lateral and upward seismic forces.

e. Due to the deformability of the table and connections, the lateral forces on the table were assumed to be resisted by all available restraints.
f. This analysis considered only the resistance of the towers to the seismic forces specified in this report.
g. For the purposes of this analysis, the isolators were assumed as adequate for the resistance to all applicable (vertical/downward) forces at any possible location of the weight resultant force. The analysis of the isolators is beyond the scope of work by SGE.

3.2.2. Codes. The codes per Item 3.1.1 represent the basis for structural design as mandated by the IBC and CBC.

The subject site (Hayward, CA) was chosen by SGE and approved by Newport Corporation to provide seismic forces that are conservative for most of California as well as for most of the continental United States.

3.2.3. Anchors. The seismic restraints experience lateral and vertical (upward only) earthquake forces due to table shifting and overturning (refer to drawings SD1 and SD2). As a result, the concrete anchors in the SGE design are subjected to pullout and shear forces. The tension forces were assumed to be resisted only by anchors along one of the tower faces, while the shear forces were assumed to be resisted by the rest of the anchors.

3.2.4. Light-Gage Steel. The performance of the light-gage steel components under the compression loads (for example, the faces of the 13-gage tower) is addressed in AISC Steel Design Manual. According to that code, only a certain portion of the compressed light-gage component may be considered effective in compressive resistance.

3.2.5. Welding. (1) Similarly to Item 3.2.4, welding of the tower to much thicker structural steel plates is only effective within the aforementioned effective portions of the tower perimeter. For example, for the 13 gage Grade 50 steel, only 3.82” of the 4”-to-10.5” of the tower face width is effective in compression.

(2) The centerlines of the holes for concrete anchors in the bottom plate (baseplate) are located at a distance of 0.75” from the tower. The effective length of the weld at each anchor is limited to the distance equal to 2x0.75”=1.5” which less than the spacing of the anchors.

(3) Welders of the light-gage tower shall be specially certified per AWS D1.3.

3.2.6. Constructability. Due to different tolerances for steel and concrete construction, the baseplate holes for steel-to-concrete connections have diameters that are larger than those for steel-to-steel connections.

3.3 The structural analysis by SGE revealed the following (refer to Appendix A).

3.3.1 The seismic restraint configured per Item 3.2.1 above and drawings SD1 and SD2 is generally adequate for the codes, loads, and assumptions per Item 3.1.2 above.

3.3.2 The resistance of the earthquake assembly appears to be limited by the strength of the anchorage to concrete.

The restraints are anchored to the floor (3,000 PSI minimum 28-day strength, normal weight concrete, minimum uniform thickness 6”) with HILTI HIT HY200 per ICC ESR 3187 (∅0.375” bolts, ∅0.65” HIS-N inserts minimum embedment - 4.38 inches.

3.3.3 Based on the capacity of the assembly, the maximum combined weight of the table and equipment per table shall be evaluated by the following formula:

W0 = 2,710*NR*KX*KZ*KH*KF [LBS]

W0 total maximum combined weight, lbs, of the table **and** of the payload secured on the table;
NR number of restraints per table (**3 or 4**);
KX coefficient for eccentric location of the resultant of the total table and payload weight - along 6' or 20' table dimension;
KZ coefficient for eccentric location of the resultant of the total table and payload weight - along 4' table dimension;
KH coefficient for hazardous payload – for installations involving quantities of toxic or explosive substances sufficient to be dangerous to the public or exceeding quantities per IBC Table 307.1.(2):
- **1.0** for non-hazardous payload
- **0.8** for hazardous payload;

KF coefficient for table location:
- **1.0** ground floor
- **0.5** mid-height floor
- **0.33** roof.

3.3.4 The findings of this report appear applicable for all tables measuring at least 4'x4' and up to 5'x20' with isolator/restraint height of 29 ½" maximum and configurations per Item 3.1.2 above.

3.3.5 Installation on floor slabs constructed over the corrugated decks and/or of the light-weight concrete may considerably limit the capacity of the anchors (to be considered on an individual basis).

3.3.6 The design earthquake was assumed as generated by a site with Ss=2.484 (Hayward CA). For some sites, this high value may be too conservative, meaning that the payload on tables at such sites may be increased (to be considered on an individual basis).

3.3.7 All individual-basis analyses per, and similar to, Items 3.3.5 and 3.3.6, shall be requested from, and conducted by, Newport Corporation and/or SGE.

We appreciate this and any other opportunity to be of service to you. Should you have any questions or need other assistance, please call SGE.

Respectfully submitted,
S. Gordin Structural Design & Engineering Services

REGISTERED PROFESSIONAL ENGINEER
VYACHESLAV "STEVE" GORDIN, Ph.D.
No. S-4311
Exp. 06/30/16
STRUCTURAL
STATE OF CALIFORNIA

Vyacheslav "Steve" Gordin, Ph.D.,
Principal
Registered Structural Engineer
CA License S4311

Appendix A: Schematic Drawings
Appendix B: Structural Calculations

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STRUCTURAL ENGINEERING REPORT

APPENDIX A:

SCHEMATIC DRAWINGS

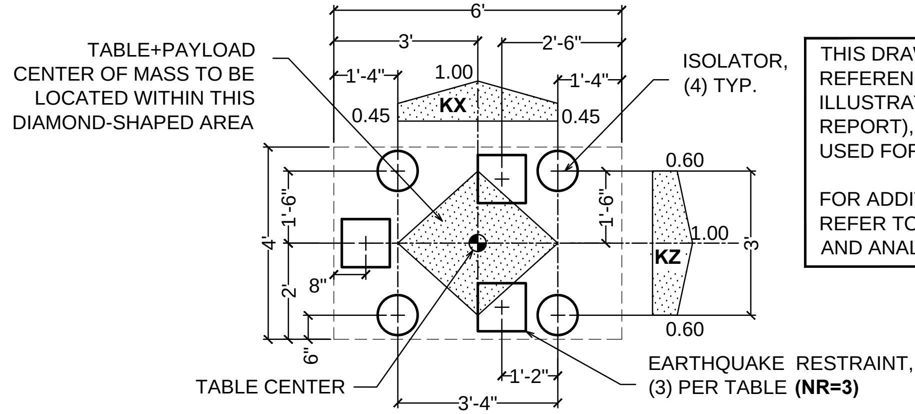
Project: Seismic Restraint for Optical Table

Location: Ss=2.484, S1=1.033

Client: Newport Corporation

Code: 2013 CBC, 2012 IBC

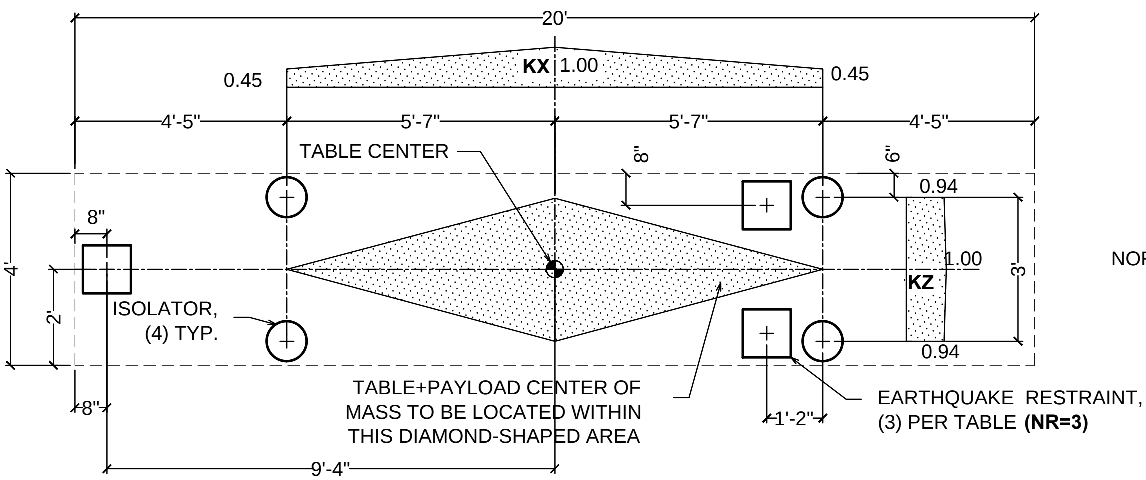
SGE Job No. 515.052.369



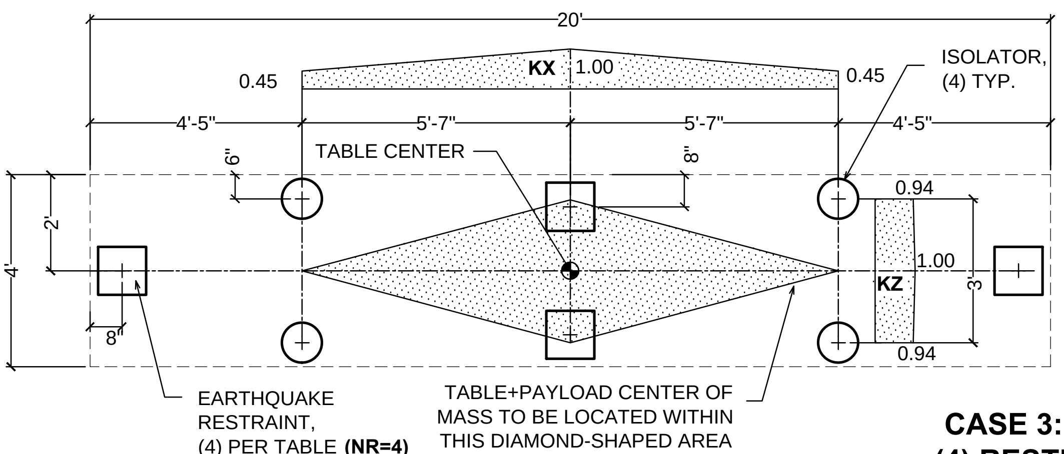
THIS DRAWING IS ISSUED FOR REFERENCE ONLY (AS AN ILLUSTRATION TO THE SGE REPORT), AND SHOULD NOT BE USED FOR MANUFACTURING.

FOR ADDITIONAL INFORMATION REFER TO STRUCTURAL DESIGN AND ANALYSIS REPORT BY SGE

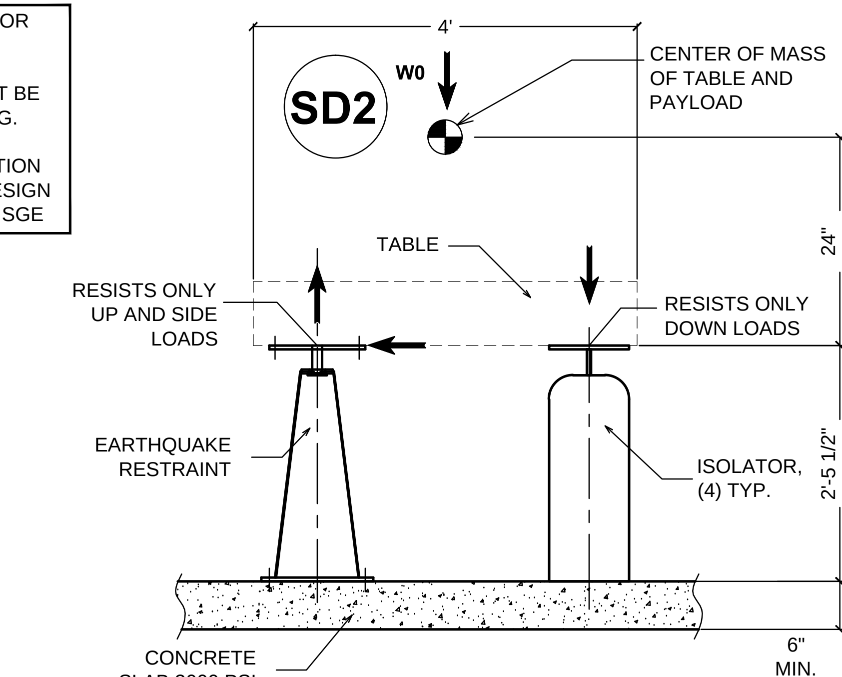
CASE 1:SHORT TABLE - (3) RESTRAINTS, NR=3



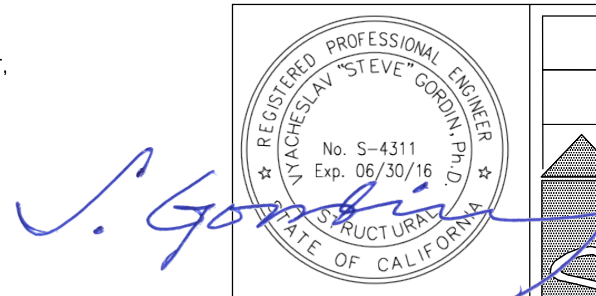
CASE 2: LONG TABLE - (3) RESTRAINTS (NR=3)



CASE 3: LONG TABLE (4) RESTRAINTS (NR=4)



TYPICAL SECTION & LOADING DIAGRAM



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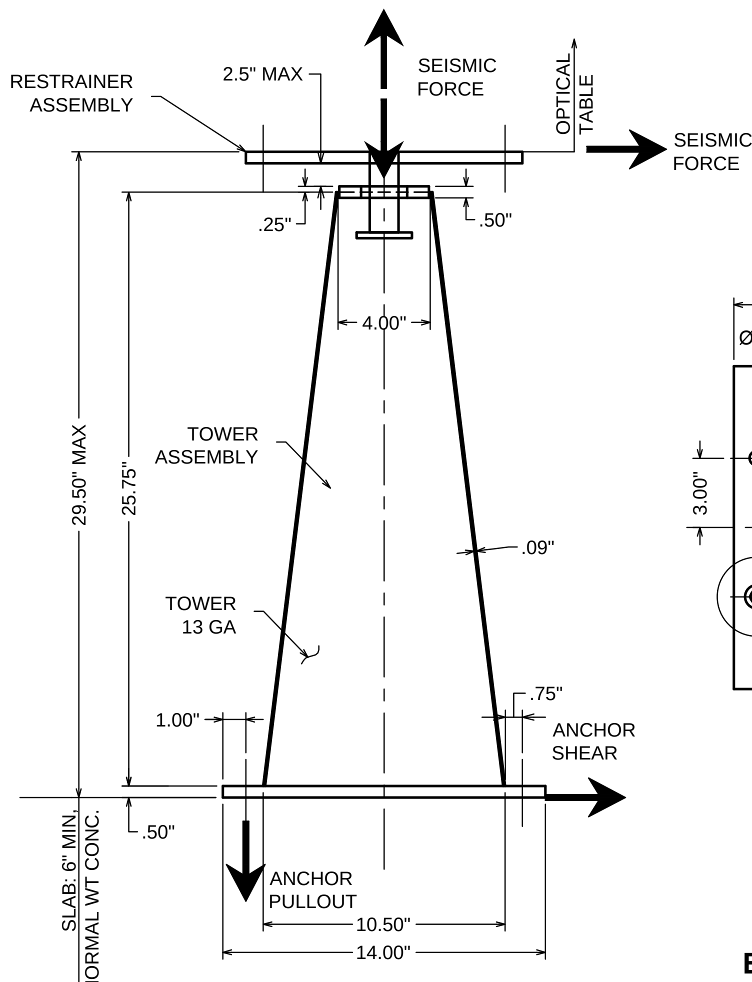
NEWPORT CORPORATION
IRVINE CA

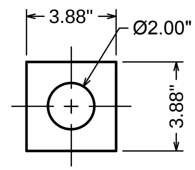
OPTICAL TABLE EARTHQUAKE RESTRAINT

GENERIC LAYOUTS & SECTION

SD1



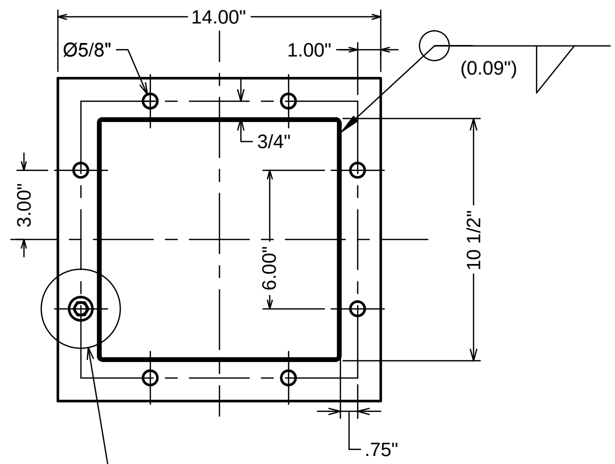
RESTRAINT ASSEMBLY



TOWER ASSEMBLY TOP PLATE

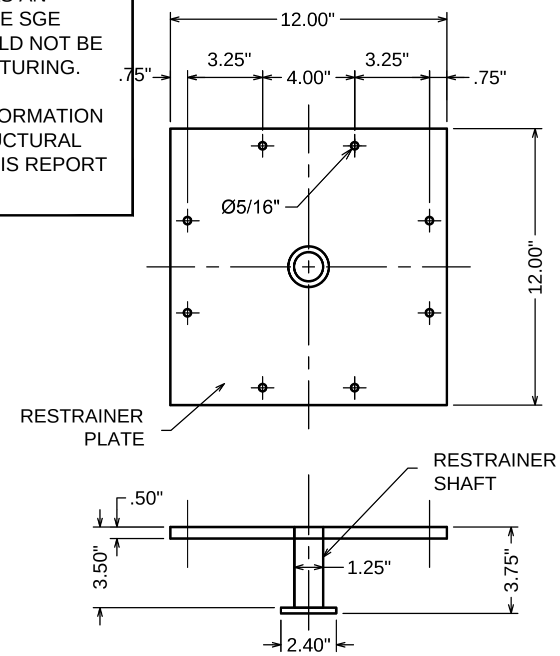
THIS DRAWING IS ISSUED FOR REFERENCE ONLY (AS AN ILLUSTRATION TO THE SGE REPORT), AND SHOULD NOT BE USED FOR MANUFACTURING.

FOR ADDITIONAL INFORMATION REFER TO 2015 STRUCTURAL DESIGN AND ANALYSIS REPORT BY SGE

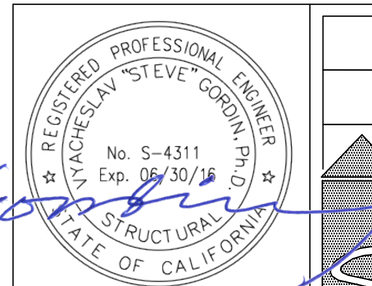


CONCRETE ANCHORS (8) PER RESTRAINT:
HILTI HIT HY 200 PER ICC ESR 3187
Ø3/8" ASTM A307 STEEL BOLT
TYPE N INSERT 4 3/8" MIN. EMBEDMENT
TYPE 1 CIRCULAR WASHER ASTM F436

RESTRAINT ASSEMBLY - BOTTOM PLATE (BASEPLATE)



RESTRAINER ASSEMBLY



W0 TOTAL MAXIMUM COMBINED WEIGHT, LBS, OF THE TABLE **AND** PAYLOAD
NR NUMBER OF RESTRAINTS PER TABLE (**3 OR 4**)
KX COEFFICIENT FOR ECCENTRIC LOCATION OF THE RESULTANT OF THE TOTAL TABLE AND PAYLOAD WEIGHT - ALONG 6' OR 20' TABLE DIMENSION
KZ COEFFICIENT FOR ECCENTRIC LOCATION OF THE RESULTANT OF THE TOTAL TABLE AND PAYLOAD WEIGHT - ALONG 4' TABLE DIMENSION
KH COEFFICIENT FOR HAZARDOUS PAYLOAD
- **1.0** FOR NON-HAZARDOUS PAYLOAD
- **0.8** FOR HAZARDOUS PAYLOAD

KF COEFFICIENT FOR TABLE LOCATION:
- **1.0** GROUND FLOOR
- **0.5** MID-HEIGHT FLOOR
- **0.33** ROOF

SD1

W0 = 2,710*NR*KX*KZ*KH*KF [LBS]

TOTAL MAXIMUM COMBINED WEIGHT (TABLE+PAYLOAD)

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NEWPORT CORPORATION
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OPTICAL TABLE EARTHQUAKE RESTRAINT

GENERIC DETAILS | **SD2**

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STRUCTURAL ENGINEERING REPORT

APPENDIX B:

STRUCTURAL CALCULATIONS

Project:	Seismic Restraint for Optical Table
Location:	Ss=2.484, S1=1.033
Client:	Newport Corporation
Code:	2013 CBC, 2012 IBC
SGE Job No.	515.052.369

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XX - Referenced page number of structural calculations

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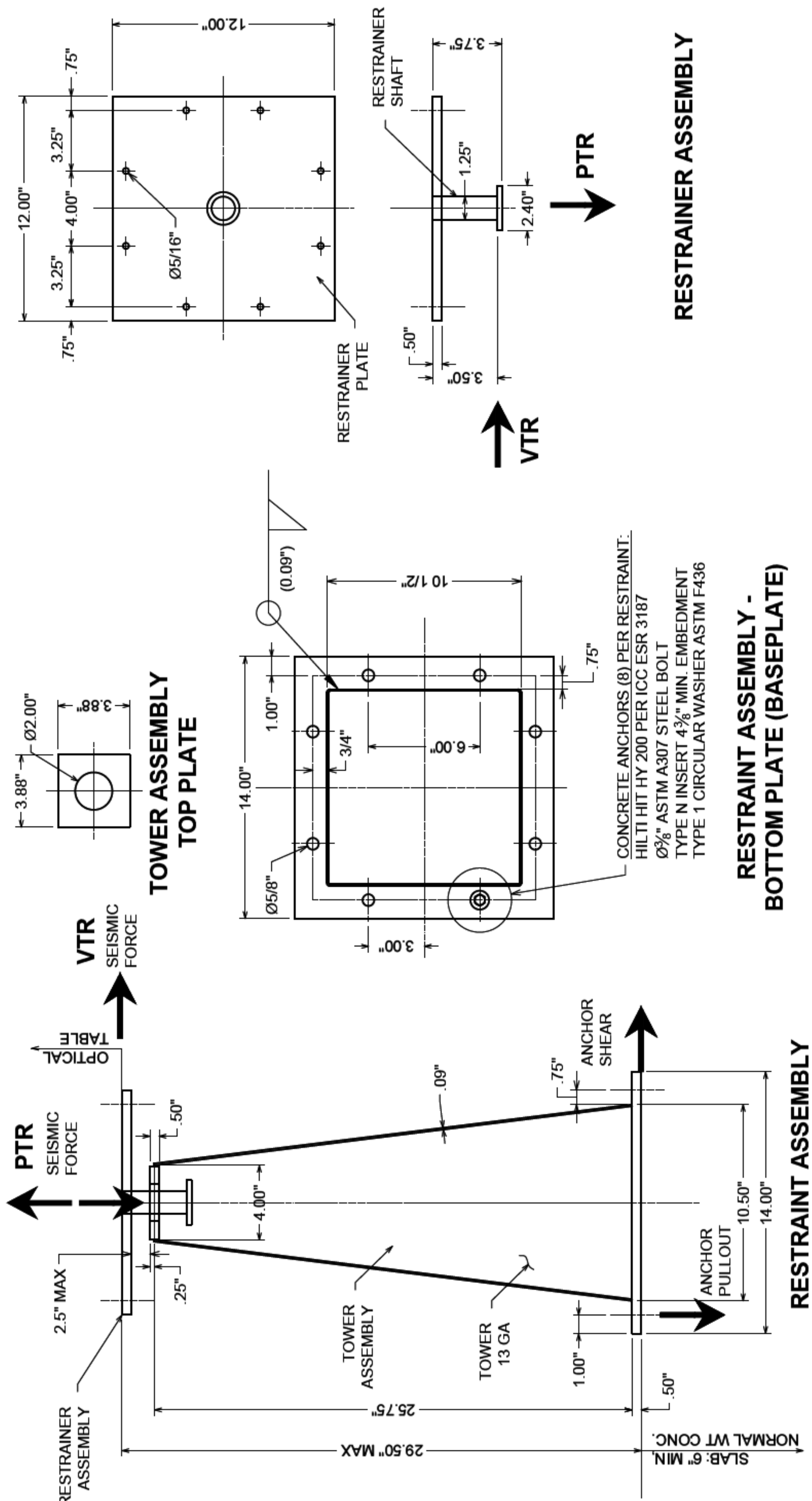
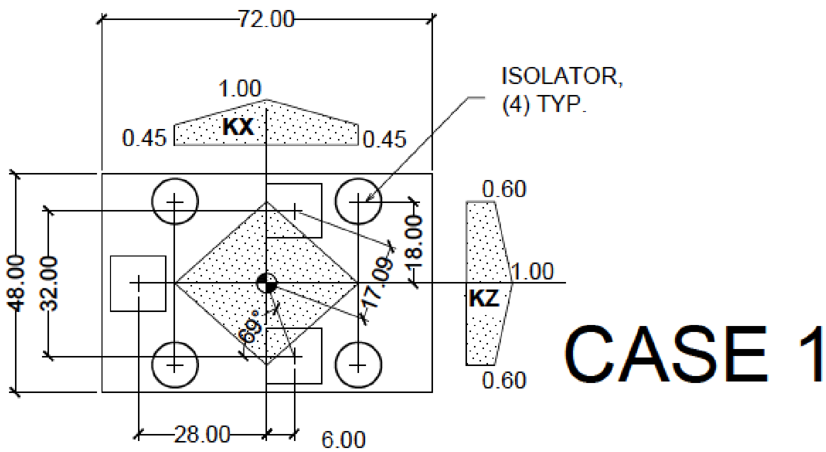
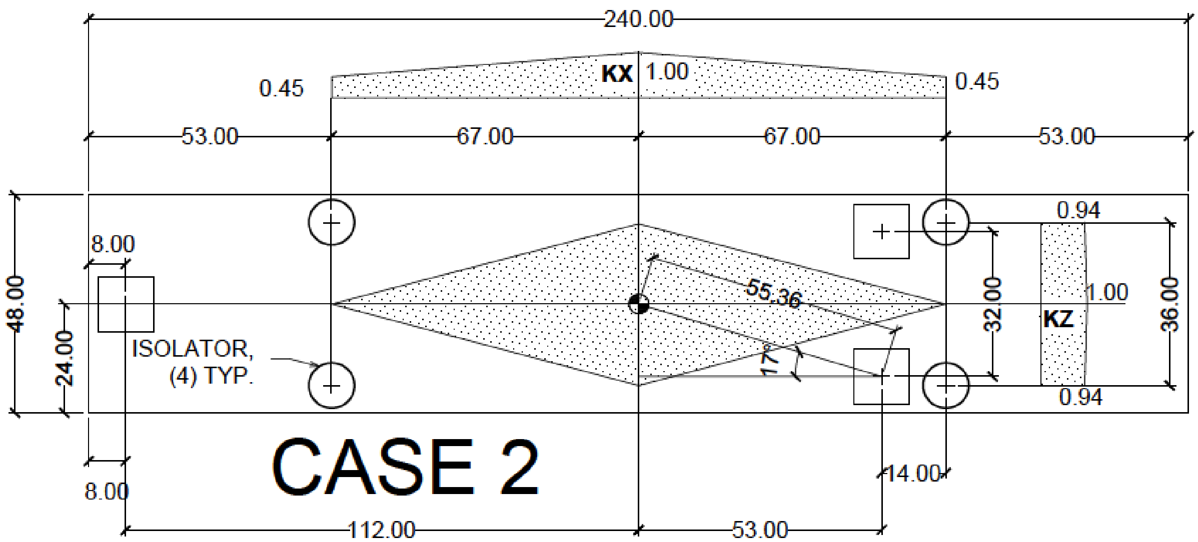
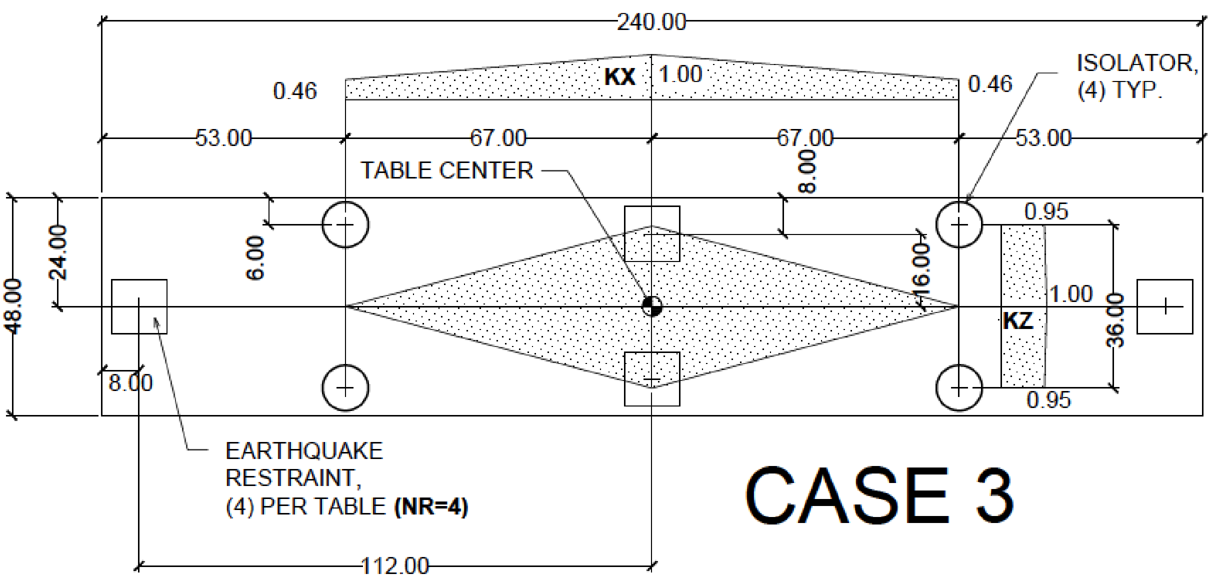
OPTICAL TABLE


RESTRAINER ASSEMBLY
RESTRAINER PLATE
RESTRAINER SHAFT
Ø5/16"
PTR
VTR
TOWER ASSEMBLY TOP PLATE
Ø2.00"
RESTRAINT ASSEMBLY - BOTTOM PLATE (BASEPLATE)
CONCRETE ANCHORS (8) PER RESTRAINT:
HILTI HIT HY 200 PER ICC ESR 3187
Ø3/8" ASTM A307 STEEL BOLT
TYPE N INSERT 4 3/8" MIN. EMBEDMENT
TYPE 1 CIRCULAR WASHER ASTM F436
Ø5/8"
RESTRAINT ASSEMBLY
PTR SEISMIC FORCE
VTR SEISMIC FORCE
OPTICAL TABLE
2.5" MAX
TOWER ASSEMBLY
TOWER 13 GA
ANCHOR SHEAR
ANCHOR PULLOUT
29.50" MAX
25.75"
SLAB: 6" MIN. NORMAL WT CONC.


72.00
1.00
KX
0.45
0.45
ISOLATOR,
(4) TYP.
0.60
1.00
KZ
0.60
48.00
32.00
18.00
17.09
69°
28.00
6.00
CASE 1


240.00
0.45
KX
1.00
0.45
53.00
67.00
67.00
53.00
0.94
1.00
KZ
0.94
8.00
55.36
48.00
24.00
ISOLATOR,
(4) TYP.
17°
32.00
36.00
CASE 2
8.00
14.00
112.00
53.00


240.00
0.46
KX
1.00
0.46
ISOLATOR,
(4) TYP.
53.00
67.00
67.00
53.00
TABLE CENTER
8.00
0.95
6.00
16.00
1.00
KZ
36.00
0.95
48.00
24.00
8.00
EARTHQUAKE
RESTRAINT,
(4) PER TABLE **(NR=4)**
CASE 3
112.00

USGS Design Maps Summary Report

User–Specified Input

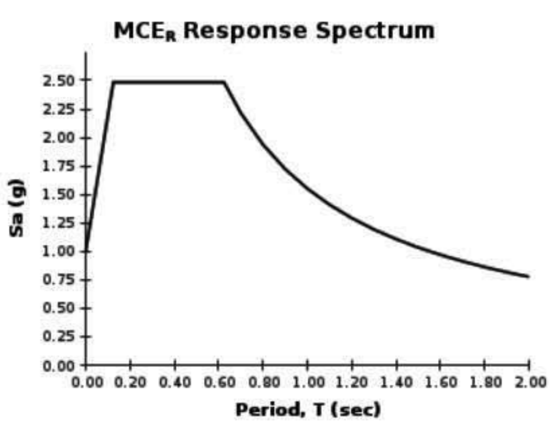
Report Title	NEWPORT ERS Fri June 5, 2015 23:03:46 UTC
Building Code Reference Document	2012 International Building Code (which utilizes USGS hazard data available in 2008)
Site Coordinates	37.6699°N, 122.0799°W
Site Soil Classification	Site Class D – "Stiff Soil"
Risk Category	I/II/III

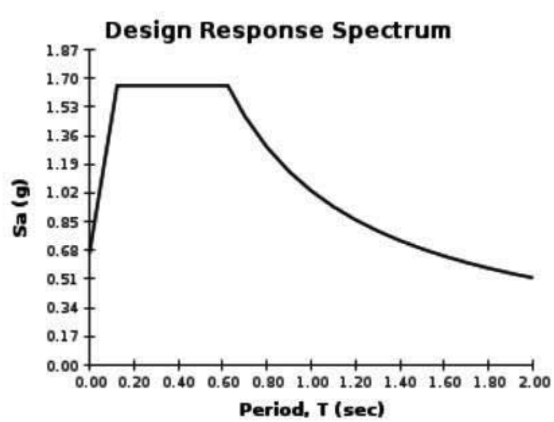
USGS–Provided Output

S_S = 2.484 g S_{MS} = 2.484 g S_{DS} = 1.656 g

S_1 = 1.033 g S_{M1} = 1.550 g S_{D1} = 1.033 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.





APPLICABILITY OF THE CODE ASCE 7-10

WEIGHT OF THE OPTICAL TABLE (NON-BUILDING STRUCTURE) <25% OF THE COMBINED WEIGHT OF THE TABLE AND SUPPORTING STRUCTURE (I.E. BUILDING) ∴ DESIGN SHOULD BE CONDUCTED PER CHAPTER 13. AS FOR "LAB EQUIP"

4

SEISMIC LATERAL FORCE ON TRIBUTARY WEIGHT

ASCE 7-10
13.3-1

$$VS = FP = \frac{0.4(ap)(SDS)W0*\left(1+\frac{2Z}{h}\right)*\Omega}{Rp/Ip}$$

AP = 1.0 RP=2 ½ Ω = 2 ½ SDS = 1.656G

VS=K1*(IP)*(W0)

GROUND FLOOR: Z/H = 0 → K1=0.6624

MID HEIGHT FLOOR: Z/H = ½ → K1=1.3248

TOP FLOOR (ROOF): Z/H = 1 → K1= 1.9872

FACTOR KF (INSTALLATION FLOOR)

KF =0.6624/0.6624 = 1.0
=0.6624/1.3248 = 0.5
=0.6624/1.9872 = 0.33

IP = 1.0 (NON HAZARDOUS)

IP = 1.25 (HAZARDOUS)

FACTOR KH (HAZARDOUS CONDITION)

KH =1/1.0 = 1.0 (NON-HAZARDOUS)
=1/1.25 = 0.8 (HAZARDOUS)

ADDITIONAL VERTICAL FORCE DUE TO VERTICAL SEISMIC ACCELERATION

TOTAL:

ASCE 7-10
12.14-6

EV = ±0.2(SDS)(D)
=±(0.2)(1.656)(IP)(W0) = ±0.331(IP)(W0)=K2(IP)(W0) TOTAL

PER RESTRAINT

TVS =EV/NR=K2(IP)(W0)/NR

K2 =0.331

UPLIFT ON RESTRAINTS DUE TO OVERTURNING

2

3

WEIGHT/MASS TRIBUTARY TO EACH RESTRAINT:

WTR= W0/NR (NR = # OF RESTRAINTS PER TABLE)

NR =3 (CASE 1, 2)

=4 (CASE 3)

LATERAL SEISMIC FORCE, TOTAL

V0 = K1*KF*(IP)*(W0)

LATERAL SEISMIC FORCE, TRIBUTARY TO, AND APPLIED ON TOP OF, EACH RESTRAINT:

VTR=K1*(IP)*(W0)/NR

ADDITIONAL UPLIFT ON ANCHORS DUE TO OVERALL OVERTURNING OF THE TABLE:

TOT=VTR*H/(R*NRT)

H =53.5” HEIGHT OF CENTER OF MASS ABOVE FLOOR, TYP

R = 34” DESIGN DISTANCE BETWEEN RESTRAINTS AND ISOLATOR

NRT = 1 #OF RESTRAINTS PARTICIPATING IN OVERTURNING RESISTANCE

TOT = K1*W0*H*IP/(NR*R*NRT) =

= K1*W0*(53.5”)*IP/[NR*(34”)*1] =1.574*K1(IP)*(W0)/NR

=0.35*K1*(IP)*(W0) CASE 1, 2 (NR=3)

=0.26*K1*(IP)*(W0) CASE 3 (NR=4)

TVS =K2*(IP)(W0)/NR

=0.110*(IP)*(W0) CASE 1, 2 (NR=3)

=0.083*(IP)*(W0) CASE 3 (NR=4)

RESTRAINT STRENGTH BASED ON ANCHOR CAPACITY:

PA = MTR/LE + PTR/N ≤ 8.0 KS

MTR	= VTR*HR, IN-K	MOMENT AT BOTTOM OF EACH RESTRAINT = V*HR
	=6.514*K1*(IP)*(W0)	CASE 1, 2 (NR=3)
	=4.885*K1*(IP)*(W0)	CASE 3 (NR=4)
PTR	=TOT+TVS	TOTAL UPLIFT ON RESTRAINT
	=0.46*K1*(IP)*(W0)	CASE 1, 2 (NR=3), GROUND FLOOR
HR	= 29.5"	HEIGHT OF RESTRAINT
LE	= 7.5"	EFFECTIVE MOMENT ARM FOR ANCHORS
N	= 4	# OF ANCHORS PER SIDE (ANCHOR GROUPS)
		(2) ANCHORS PER SIDE = (1) ANCHOR GROUP
8K		LRFD CAPACITY OF ANCHOR GROUP IN TENSION

ONLY (2) ANCHORS OUT OF (8) CONSIDERED
EFFECTIVE FOR MOMENT RESISTANCE
SHEAR IS RESISTED BY THE REST OF THE
ANCHORS (IN COMPRESSION ZONE)

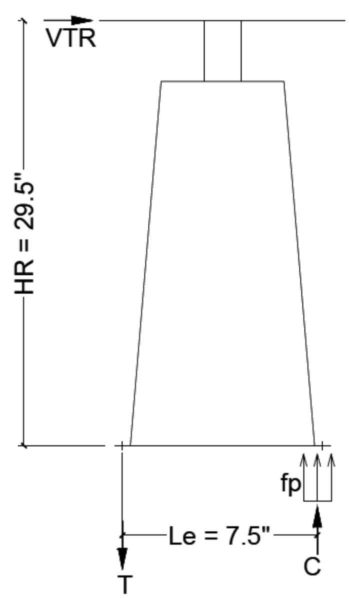
P_A = 6.514*(IP)*(W0)/7.5" + 0.46*(IP)*(W0)/4 ≤ 8 K

IP = 1 (NON-HAZARDOUS) ,

NR =3

W0 ≤ 8.14 K, OR

WTRA = W0/NR = 2.71 K



2
8
9

SUMMARY

ANALYSIS - CENTERED FORCE

NA=number of anchors in group
TA=Total number of anchors
WTRA= weight per restraint anchor prespective
WTRS=weight per restraint from steel perspective
WTRW= weight per restraint from weld perspective
W TBL = total max weight of table and load

TOT=tension from overturning
P=Tension from Vertical Seismic and Overturning consideration
V=Shear on restraint
M=Moment on restraint
$vw=\sqrt{(P^2+V^2)}$ weld shear

	CASE	IP	R	H	HR	NR	K1	K2	TOT/(W0*IP)	P/(W0*IP)	V/(W0*IP)	M/(W0*IP)	VW
			IN	IN	IN				K	K	K	IN-K	K
GROUND FLOOR	1, 2	1.00	34.00	53.50	29.50	3.00	0.6624	0.331	0.35	0.46	0.221	6.514	0.508
MID-HEIGHT FLOOR	1, 2	1.00	34.00	53.50	29.50	3.00	1.3248	0.331	0.69	0.81	0.442	13.027	0.918
TOP FLOOR	1, 2	1.00	34.00	53.50	29.50	3.00	1.9872	0.331	1.04	1.15	0.662	19.541	1.329

(TOT/(W0*IP) through VW: PER RESTRAINT)

RETAIN SHAFT

TTR=P VTR=V

	CASE	NA	TA	WTRA	WTRS	WTRW	WTR (MIN)	W TBL	TTR	VTR
			K	K	K	K	K	K	K	K
GROUND FLOOR	1, 2	2.000	8.00	2.71	14.39	5.86	**2.71**	**8.14**	1.24	1.80
MID-HEIGHT FLOOR	1, 2	2.000	8.00	1.38	7.20	2.98	**1.38**	**4.13**	1.11	1.82
TOP FLOOR	1, 2	2.000	8.00	0.92	4.80	2.00	**0.92**	**2.76**	1.06	1.83

	CASE	IP	R	H	HR	NR	K1	K2	TOT/(W0*IP)	P/(W0*IP)	V/(W0*IP)	M/(W0*IP)	VW
			IN	IN	IN				K	K	K	IN-K	K
GROUND FLOOR	3	1.00	34.00	53.50	29.50	4.00	0.6624	0.331	0.26	0.34	0.166	4.885	0.381
MID-HEIGHT FLOOR	3	1.00	34.00	53.50	29.50	4.00	1.3248	0.331	0.52	0.60	0.331	9.770	0.689
TOP FLOOR	3	1.00	34.00	53.50	29.50	4.00	1.9872	0.331	0.78	0.86	0.497	14.656	0.997

(TOT/(W0*IP) through VW: PER RESTRAINT)

RETAIN SHAFT

	CASE	NA	TA	WTRA	WTRS	WTRW	WTR (MIN)	W TBL	TTR	VTR
			K	K	K	K	K	K	K	K
GROUND FLOOR	3	2.000	8.00	2.71	14.39	5.86	**2.71**	**10.85**	0.93	1.80
MID-HEIGHT FLOOR	3	2.000	8.00	1.38	7.20	2.98	**1.38**	**5.50**	0.83	1.82
TOP FLOOR	3	2.000	8.00	0.92	4.80	2.00	**0.92**	**3.69**	0.80	1.83

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ANCHORAGE TO CONCRETE ~ EPOXY ANCHOR ~ HILTI HIT-HY 200

REFERENCES		
	C	IBC 2012 (2009 OK), CBC 2013 (2010 OK)
	D	ACI 318-11 (08 OK), INCL APP D
	E	ICC ESR 3187

DESIGN PARAMETER	NAME	FORMULA OR SWITCH	VALUE	UNIT	?	COMMENT	REFERENCE
FORCES & CONDITIONS							
FACTORED PULLOUT FORCE	Nn1		8.00	K			7
FACTORED SHEAR FORCE	Vn1		0.00	K			
OPTIONAL FORCE FACTOR	KF		*1.00*				
TEMPERATURE (ºF) AND TEMPERATURE RANGE	T		130			HILTI LETTER 11/21/14	E TBL 14
DESIGN PULLOUT FORCE	Nan	Nn1*KF	***8.00***	K			
DESIGN SHEAR FORCE	Vn	Vn1*KF	***0.00***	K			
SEISMIC COEFF (TENSION, CONCRETE ONLY)	ksdc		***0.75***			SDC C-F	D D.3.3.4.4
DUCTILE FAILURE IN THE STRUCTURE Y/N		N					D D.3.3.4.3(d)
FACTOR DESIGN FORCES BY **Ω** Y/N	Ω	N	***1.00***		OK		
CONCRETE STRENGTH (NWC)	f'c		***3,000***	PSI			
INSTALLATION CONDITION		DRY = "D"; WET/SATURATED="W"	D				D D.6.1.3
GROUT PADS (SHEAR STEEL ONLY)	kg	N	***1.00***				
CRACKED CONCRETE Y/N		N					
GEOMETRY							
# OF ANCHORS IN THE GROUP, EFFECTIVE							
STEEL & CONCRETE, TENSION	nt		***2.00***			<=4	
CONCRETE, SHEAR	nv		***2.00***				
STEEL, SHEAR	ns		***2.00***				
ALONG LOADED EDGE	NALE		***2.00***				
DIAMETER							
ANCHOR	da		***0.375***	IN			
INSERT	d		***0.650***	IN			
SPECIFIED STRENGTH OF STEEL							
ANCHOR, TENSILE	fut		***75***	KSI		CARBON GR 55 OR SIM	
ANCHOR, YIELD	fy		***55***	KSI	OK		
fyt<=125,000 PSI; fyt<=1.9fy		1.9fy	105	KSI			
	futa		75	KSI			
INSERT, TENSILE	fut		***75***	KSI			
ANCHOR, YIELD	fy		***55***	KSI			
INSERT/ANCHOR(S) EMBEDMENT, ASSUMED	hef		***4.33***	IN	OK		
INSERT/ANCHOR EMBEDMENT, MINIMUM	hef min		2.38	IN			E TBL 14
PAD THICKNESS, MINIMUM	tp*		5.63	IN			E TBL 12
PAD THICKNESS, ASSUMED	tp		***6.00***	IN	OK		
ACTUAL SPACING							
DIRECTION 1 (MINIMUM)	s1		***6.00***	IN			
DIRECTION 2 (MAXIMUM)	s2		***12.00***	IN			
ALONG LOADED EDGE	SL		***6.00***	IN			
MIN. ANCHOR SPACING	smin		1.88	IN	OK		E TBL 12
		3hef	12.99	IN			
AVAIL. WIDTH OF HALF-PYRAMID BASE	wpa		***12.00***	FT			
ANCHOR EDGE DISTANCE							
DIRECTION 1	c11		***12.00***	IN	OK		
	c12		***12.00***	IN	OK		
DIRECTION 2	c21		***12.00***	IN	OK		
	c22		***12.00***	IN	OK		
		1.5hef	**6.50**	IN			
ACROSS SHEAR FORCE	C1A		***12.00***	IN			
	C2A		***12.00***	IN			
PARALLEL TO (ALONG) SHEAR FORCE	c1		***12.00***	IN			
MIN. EDGE DIST	cmin	6*d	2.25	IN	OK		D.8.3, D.8.4

DESIGN PARAMETER	NAME	FORMULA OR SWITCH	VALUE	UNIT	?	COMMENT	REFERENCE
STEEL STRENGTH, TENSION			**ANCHOR**			**INSERT**	
THREADS PER INCH	nt		16.00			11	
EFFECTIVE AREA	Ase=	π/4(d0-.9743/nt)^2	0.0775	IN^2		0.2476	NET AREAS
NOM. STRENGTH OF ANCHOR GROUP - STEEL	Ns	nt*(Ase)futa	**11.62**	K		37.13	
STEEL STRENGTH REDUCTION FACTOR	ϕ***S***		0.75			0.75	D 9.2
DESIGN STRENGTH, STEEL		ϕ***S*Ns***	8.72	K		27.85	
	NS1		**8.72**	K			
	NS2	1.2NS1	**13.95**	K			
CONCRETE BREAKOUT STRENGTH, TENSION							
PROJ. AREA OF TENSION FAILURE SURFACE FOR ANCHOR GROUP							
nt=1 CLOSE TO EDGE	AN1c	(c1+1.5hef)(2*1.5hef)	-	IN^2		c1<1.5hef	D D.5.2
nt=1 AWAY FROM EDGE	AN0	9hef^2	169	IN^2		c1>1.5hef	
nt=2 CLOSE TO EDGE	AN2c	(c1+s1+1.5hef)(2*1.5hef)	-	IN^2		c1<1.5hef, s1<3hef	
nt=2 AWAY FROM EDGE	AN2a	(s1+3*hef)(3*hef)	247			c1>1.5hef, s1<3hef	
nt=4 CLOSE TO EDGE	AN4c	(c1+s1+1.5hef)* *(c2+s2+2*1.5hef)	-	IN^2		c2<1.5hef, s1<3hef, s2<3hef	
nt=4 AWAY FROM EDGE	AN4a	(s1+3*hef)(s2+3*hef)	-	IN^2		c1>1.5hef, c2>1.5hef, s1<3hef. s2<3hef	
		n*AN0	337				
	AN	<=n*AN0	**172**	IN^2			
	kc		**24**			UNCRACKED	E TBL 12
BASIC BREAKOUT STRENGTH IN CONCRETE	Nb	kc*(f'c)$^{1/2}$*(hef)$^{3/2}$	**11.84**	K			D D-6
ECCENTRICITY OF PULLOUT FORCE	e'N1		***0.00***	IN			
	e'N2		***0.00***	IN			
MODIFICATION FACTOR FOR ECCENTRICITY	$\Psi 11$	[1+2e'N/(3hef)]$^{-1}$	1.00				D D-8
	$\Psi 12$	[1+2e'N/(3hef)]$^{-1}$	1.00				
	$\Psi 1$	$\Psi 11 * \Psi 12$	1.00				
MODIFICATION FACTOR FOR EDGE EFFECT			1.00			c1>=1.5hef	D D-9
			-			c1<1.5hef	D D-10
	$\Psi 2$		1.00				
MODIF FACTOR FOR CRACKED TENSION ZONE	$\Psi 3$	IF (f_t < f_r) = 1.25, 1.00	1.25			NO TENSION CRACKS	
NOMINAL CONCRETE BREAKOUT STRENGTH							
FOR SINGLE ANCHOR	Ncb	(AN/AN0) ($\Psi 2$)($\Psi 3$)Nb	**14.81**	K			D D-3
FOR GROUP OF ANCHORS	Ncbg	(AN/AN0) (Ψ**1**) ($\Psi 2$)($\Psi 3$)Nb	**15.09**	K			D D-4
STRENGTH REDUCTION FACTOR	ϕ***C1***		0.75				D D.4.3(a)
DESIGN BREAKOUT STRENGTH		ϕ***C1*Ncbg***	**11.32**	K			
CONCRETE PULLOUT STRENGTH, TENSION							
BOND STRENGTH IN CONCRETE	$\tau 1$		**1,600**	PSI		UNCRACKED	E TBL 12
MIN. EMBEDMENT	hefm		**3**	IN			E TBL 12
MINIMUM SPACING	smin		**1.88**	IN			E TBL 12
	$\tau 3$	<=24*(hef*f'c)$^{1/2}$/(π*d)	**1,340**	PSI			E 4.1.10.2
	kcc	MAX(3.1-0.7h/hef; 1.4)	2.13				E 4.1.10.2
CRITICAL EDGE DISTANCE	cac	hef*($\tau 3$/1,160)$^{0.4}$*kcc	4.59	IN			E 4.1.10.2
	cna	10da*(τ *uncr* /1,100)$^{0.5}$	8.49533	IN			D D-21
	cc1	MIN(cac, cna)	**4.59**	IN			
MODIFICATION FACTORS FOR:							
POST INSTALLED ANCHORS	Ψ_{CPNA}		**1.00**			cmin≥cc1	D D-26
		cmin/cc1	**-**			cmin<cc1	D D-27
EDGE EFFECTS	Ψ_{EDNA}		**1**			cmin≥cc1	D D-24
		0.7+0.3*cmin/cc1	**N/A**			cmin<cc1	D D-25
FOR ECCENTRICITY	Ψ_{ECNA}		1.00			NO ECCENTRICITY	D D-23
STRENGTH REDUCTION FACTORS:							
FOR BOND IN SEIS. CATEGORIES C-F	α_{NS}		**0.80**				E TBL 14
STRENGTH REDUCTION FACTOR	$\phi 1$		**0.65**				E TBL 14

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DESIGN PARAMETER	NAME	FORMULA OR SWITCH	VALUE	UNIT	?	COMMENT	REFERENCE
							PULLOUT, CONTINUED
PROJ. AREA OF PULLOUT FAILURE SURFACE FOR ANCHOR GROUP							
nt=1 CLOSE TO EDGE	AN1c 1	(c11+c12)(c21+c22)	-	IN^2		c1<cc1	D D.5.5.1
nt=1 AWAY FROM EDGE	AN0 1	$(2*cac)^2$	84	IN^2		c1>cc1	
nt=2 CLOSE TO EDGE	AN2c 1	(c11+s1+c12)(c21+c22)	-	IN^2		c1<cc1; s1<2cc1	
nt=2 AWAY FROM EDGE	AN2a 1		391	IN^2		c1>cc1; s1<2cc1	
nt=4 CLOSE TO EDGE	AN4c 1	(c11+s1+c12)(c21+s2+c22)	-	IN^2		c1<cc1; c2<cc1; s1<2cc1; s2<2cc1	
nt=4 AWAY FROM EDGE	AN4a 1		-	IN^2		c1>cc1; c2>cc1; s1<2cc1; s2<2cc1	
		n*AN0	168	IN^2			
	AN 1	<=n*AN0 1	**391**	IN^2			
	Na0	$\tau 1 * \pi$ *d*hef*α_{NS}	11.3	K			D D-22
NOMINAL STATIC PULLOUT (BOND) STRENGTH							
FOR SINGLE ANCHOR	Na	(AN1/AN01)* Ψ_{EDNA}*Ψ_{CPNA}*Na0	**11.3**	K			D D-18
FOR GROUP OF ANCHORS	Ncbg	(AN1/AN01)* Ψ_{EDNA}*Ψ_{ECNA}*Ψ_{CPNA}*Na0	**52.5**	K			D D-19
DESIGN PULLOUT STRENGTH		ϕ**1 * Ncbg**	**34.2**	K			
ANCHOR GROUP TENSION STRENGTH							
STEEL Ns			***8.7***	K			
CONCRETE Nc			***11.3***	K			
DUCTILE STEEL ANCHOR Y/N		Y					
STEEL STRENGTH GOVERNS Y/N		**Y**					
CONSERV., NO SUPPL REINF. , COND B, Y/N		Y					
FACT'D TENSILE STRENGTH, ANCHOR GROUP		***MIN(Ns, Nc*ksds)***	***8.49***	K	**OK**		

DESIGN PARAMETER	NAME	FORMULA OR SWITCH	VALUE	UNIT	?	COMMENT	REFERENCE
SHEAR							
STEEL STRENGTH IN SHEAR	Vs	ns*kg*n*0.6*Ase*fut	**13.95**	K			D D-29
REDUCTION FOR SEISMIC SHEAR	α_{VS}		0.70				E TBL 11
STRENGTH REDUCTION FACTOR							
STEEL	ϕs		0.60				E TBL 11
CONCRETE	ϕc		0.70				E TBL 12
CONCRETE BREAKOUT STRENGTH (SHEAR)							
SHEAR FORCE PARALLEL TO EDGE Y/N	ksd	N	1.00				
SHEAR FORCE ECCENTRICITY	e'V		*0.00*		**OK**		
MODIFICATION FACTORS FOR SHEAR STRENGTH:							
FOR ECCENTRICITY	Ψ_{ECV}	$[1+2*e'v/(3*C1)]^{-1} \le 1$	1.00			NO ECC	D D-36
EDGE EFFECTS	Ψ_{EDV}		-			ca2/ca1≥1.5	D D-37
		0.7+0.3*cmin/cc1	**0.90**			ca2/ca1<1.5	D D-38
FOR TENSION IN THE ANCHORING ZONE							
CRACKING IN THE TENSION ZONE		**N**					
SUPPLEMENTARY REBAR >=#4		Y					
	Ψ_{CV}		1.40				D D.6.2.7
			-			ha/c1≥1.5	
	Ψ_{HV}		1.73			ha/c1<1.5	D D-39
			1.73				
LOAD BEARING ANCHOR LENGTH, SHEAR	Le		4.33	IN		L<=8d0	
	1.5c1		18.00	IN			
PAD THICKNESS	tp		6.00	IN			
DEPTH OF SHEAR FAILURE HALF-PYRAMID BASE	dp	MIN(1.5c1,tp)	6.00	IN			
ANCHOR SPACING ALONG LOADED EDGE	SL		6.00	IN			
	cef						
EDGE DISTANCE ACROSS SHEAR FORCE	CA		12.00	IN			
	cd	MIN(1.5c1,c2)	12.00	IN			
BASIC BREAKOUT STRENGTH, SINGLE ANCHOR	Vb	$7(Le/d)^{0.2}(d)^{1/2}(f'c)^{1/2}(c1)^{1.5}$	18.776	K			D D-33
		$9(f'c)^{1/2}(c1)^{1.5}$	20.49	K			D D-34
			18.78	K			
# OF ANCHORS ALONG LOADED EDGE	NALE		2.00				

DESIGN PARAMETER	NAME	FORMULA OR SWITCH	VALUE	UNIT	?	COMMENT	REFERENCE
							SHEAR, CONTINUED
WIDTH OF SHEAR FAILURE HALF-PYRAMID BASE							
GROUP	wp	2*1.5c1+(NALE-1)*SL	42.00	IN			
		c1a+1.5c1+(NALE-1)*SL	36.00	IN			
		c1a+c2+(NALE-1)*SL	30.00	IN			
			30.00	IN			
SINGLE	wp1	MIN [wp, 3c1,(c1a+c2a)]	24.00	IN			
DESIGN WIDTH OF HALF-PYRAMID BASE GROUP	wpd	MIN(wpa,wp)	**30.00**	IN			
AREA OF SHEAR FAILURE HALF-PYRAMID BASE							
ACTUAL	AV	dp*wpd	180	IN^2			
SINGLE, DEEP CONCRETE AWAY FROM EDGES	AV0	$4.5(ca1)^2$	648	IN^2			D D-32
NOMINAL CONCRETE BREAKOUT STRENGTH							
		$AV/AV0(\Psi_{EDV}*\Psi_{ECV}*\Psi_{HV})Vb$	11.38	K			D D-30
ANCHOR GROUP		$AV/AV0(\Psi_{EDV}*\Psi_{ECV}*\Psi_{HV}*\Psi_{HV})Vb$	**11.38**	K			D D-31
CONCRETE PRYOUT STRENGTH IN SHEAR							D D.6.3
	kcp		***2.00***			hef>=2.5 IN	D D-40
PRYOUT STRENGTH, SINGLE ANCHOR	Vcp	kcp*Ncb	**29.61**	K			D D-41
PRYOUT STRENGTH, ANCHOR GROUP	Vcpg	kcp*Ncbg	**30.18**	K			
ANCHOR GROUP NOMINAL STRENGTH, SHEAR							
STEEL Vs		***ϕs*Vs*αvs***	***5.86***	K			
CONCRETE Vc		***ϕc*Vc*αvc***	***5.58***	K			
DUCTILE STEEL ANCHOR Y/N		*Y*					
STEEL STRENGTH GOVERNS Y/N		***Y***					
CONSERV., NO SUPPL REINF. , COND B, Y/N		*Y*					
FACTORED SHEAR STRENGTH, GROUP	***ϕV***	***MIN(Ns, Nc)***	***5.58***	K	OK		

STRENGTH DESIGN INTERACTION SUMMARY

					D D.7
KN	(Nu/FNn)<=1.0	**0.94**		OK	D D.7.1
KV	(Vu/FVn)<=1.0	**0.00**		OK	D D.7.2
	$(Nu/FNn)^{5/3}+(Vu/FVn)^{5/3}\leq 1$	-		OK	RD 7

DUCTILE STEEL TO GOVERN

PER ANCHOR GROUP (na ≥ 1)						
NOMINAL SHEAR STRENGTH, STEEL	VS		**13.95**	K		
NOMINAL SHEAR STRENGTH, CONCRETE	VC		**11.38**	K		
SHEAR DEMAND	V		**0.00**	K		
NOMINAL TENSILE STRENGTH						
STEEL	TSU		**13.95**	K		D D.3.3.4.3a1
CONCRETE, BREAKOUT	TCU1		15.09	K		
CONCRETE, PULLOUT	TCU2		21.77	K		
CONCRETE, MIN	TCU		**15.09**	K		
TENSILE DEMAND	T		**8.00**	K		

UTILIZATION (DEMAND-TO-CAPACITY RATIOS)

SHEAR, STEEL	kvs	V/VS	**0.000**			D RD.3.3.4.3
SHEAR, CONCRETE	kvc	V/VC	**0.000**			
TENSION, STEEL	kts	T/TS	**0.574**			
TENSION, CONCRETE	ktc	T/TC	**0.530**			
TOTAL, STEEL	KS	kvs+kts	**0.574**			
TOTAL, CONCRETE	KC	kvc+ktc	**0.530**	OK	STEEL GOVERNS	

RESTRAINT STRENGTH BASED ON TOWER CAPACITY

BY INSPECTION, COMPRESSION GOVERNS OVER TENSION

2

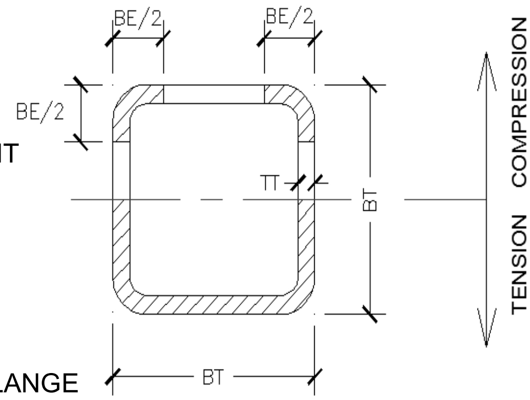
EFFECTIVE PROPERTIES OF RESTRAINT TOWER

BTT/TT = 10.5”/0.09” = 116

$\sqrt{\frac{E}{FY}} = \sqrt{\frac{29E3}{50}}$ = 24 @

1.40*24 = 33 << 116 → SLENDER ELEMENT

BE =1.92*0.09*24*[1-(0.38*24)/116] =
=3.82” <10.5” O.K.

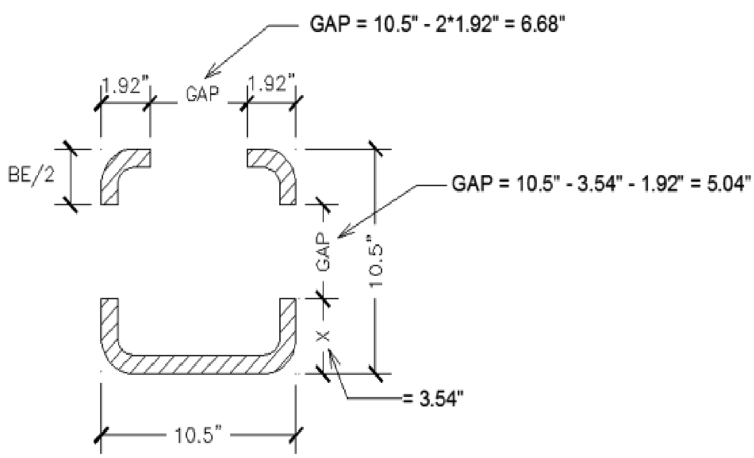


AISC 14TH
TBL B4.1-17

AISC 14TH
P.16.1-13

EFFECTIVE WIDTH OF COMPRESSIVE FLANGE

BE/2 = 1.92”



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Built-Up Section Properties

restraint 2011.ecw:Calculations

Description TOWER BTTM

General Information

	Type...					X cg	Y cg
#1	Rectangular	Height	0.0900 in	Width	10.5000 in	5.2500 in	0.0000 in
#2	Rectangular	Height	3.5400 in	Width	0.0900 in	0.0000 in	1.7700 in
#3	Rectangular	Height	3.5400 in	Width	0.0900 in	10.5000 in	1.7700 in
#4	Rectangular	Height	1.9200 in	Width	0.0900 in	0.0000 in	9.5400 in
#5	Rectangular	Height	1.9200 in	Width	0.0900 in	10.5000 in	9.5400 in
#6	Rectangular	Height	0.0900 in	Width	1.9200 in	0.9600 in	10.5000 in
#7	Rectangular	Height	0.0900 in	Width	1.9200 in	9.5400 in	10.5000 in

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Summary

Total Area	2.2734 in2	Ixx	43.794 in4	r xx	4.3890 in
		Iyy	42.238 in4	r yy	4.3104 in
X cg Dist.	5.2500 in	Edge Distances from CG...			
Y cg Dist.	3.5426 in	+X	5.2950 in	S left	7.9769 in3
		-X	-5.2950 in	S right	7.9769 in3
		+Y	7.0024 in	S top	6.2541 in3
		-Y	-3.5876 in	S bottom	12.2072 in3

S MIN, AS EFFECTIVE IN COMPRESSION

STEEL STRENGTH OF FULLY EFFECTIVE PORTION OF TOWER WALL, LRFD

MTR/SEFF ≤ 0.9*50 KSI = 45 KSI

SEFF = 6.25 IN^3

FOR GROUND FLOOR, CASE 1: NR = 3,

MTR = 6.514 (IP)*(W0) = 14.39 K

WTRA = 2.71 K < WTRS = 14.39 K ∴ ANCHOR-BASED CAPACITY GOVERNS

RESTRAINT STRENGTH BASED ON WELD CAPACITY

CAPACITY BASED ON OVERALL WELD STRENGTH, LRFD

AW = 2.27 IN^2

SW = 6.25 IN^3 (MIN)

TW = 0.09 IN FILLET WELD LEG & EFFECTIVE THROAT, LIGHT-GAGE STEEL

$\frac{\sqrt{PTR^2+VTR^2}}{Aw} + \frac{MTR}{Sw} \leq 0.75*0.6*70$ KSI=31.5 KSI

5 6 8

FOR GROUND FLOOR, CASE 1:

NR = 3, MTR = 6.514 (IP)*(W0), PTR = 0.46(IP)*(W0), VTR = 0.221(IP)*(W0)

1.27 (IP)*(W0) ≤ 31.5 KSI

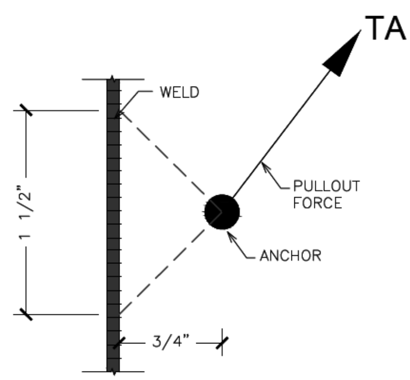
W0 = 24.80 K

WEIGHT TRIBUTARY TO EACH PER RESTRAINT BASED ON WELD STRENGTH

WTRW = W0/NR = 8.27 K >WTRA = 2.71 K ∴ ANCHOR-BASED CAPACITY GOVERNS

CAPACITY BASED ON EFFECTIVE WELD AT EACH ANCHOR

EFFECTIVE WELD – TENSION



2 3

LW = 2*0.75" = 1.5" PER ANCHOR

TW =0.09"

IP =1

NA = 2 # OF ANCHORS PER SIDE/ ANCHOR GROUP

N =4 # OF ANCHOR GROUPS

TENSION FORCE, PER ANCHOR, CASE 1, GROUND FLOOR

TA = 6.514 (IP)*(W0)/(7.5"*2) + 0.46*(IP)*(W0)/(4*2) = 0.49*(IP)*(W0)

fw = TA/(LW*TW) ≤ 31.5 KSI,

WWA ≤ 8.67 K

WTRA ≤ 2.71 K < WWA =8.67 K∴ ANCHOR-BASED CAPACITY GOVERNS

RESTRAINT STRENGTH BASED ON BASEPLATE CAPACITY

MAXIMUM (GOVERNING) ANCHOR FORCE:

TA =8K /2=4K (LRFD) 2

MPL =4K*0.75"=3 IN-K PER ANCHOR

ZPL =1.5"*TPL^2/4=0.375TPL^2 7

fb =MPL/ZPL≤0.9*36 KSI

TPL ≥0.5", ∴½" PLATE O.K.

RESTRAINT STRENGTH BASED ON RETAINING SHAFT CAPACITY

BASED ON ANCHOR CAPACITY, KH=KF=1, CASE 1, 2 (NR=3), GROUND FLOOR

WTR =W0/NR= 2.71K

VTR =K1*(IP)*(W0)/NR=0.6624*(1)*(2.71) =1.80K (LRFD) 8

PTR =1.24K

2

MMAX = 1.8K * 3" = 5.4K

D =1.25" SHAFT DIAMETER 7

Z $=1.25^3/6 = 0.33\ IN^2$ $A = 1.23\ IN^2$

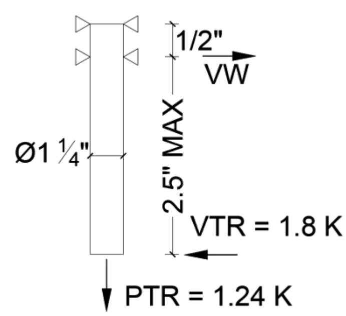
f $= 5.4\ IN\text{-}K/(0.33\ IN^3)+1.24K/(1.23\ IN^2) = 17.4\ KSI<0.9\ (36\ KSI) = 32.4\ KSI$ ∴O.K

WELD

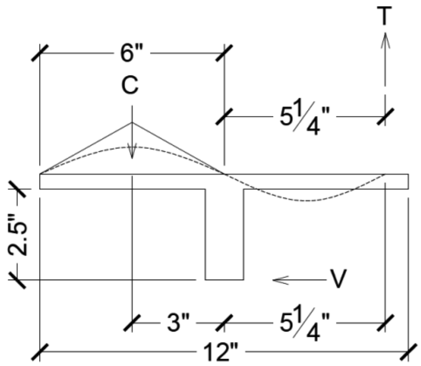
VW = 1.8K*3"/0.5" = 10.8 K MAX. REACTION AT WELD

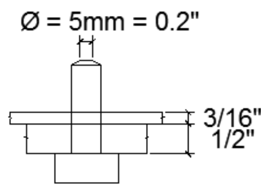
AW $= 0.7071 * (1.25"+0.25")*3.14*0.25"=0.83\ IN^2$

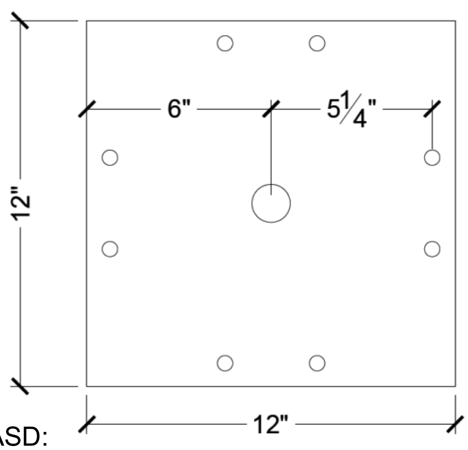
fw $= \frac{\sqrt{10.8^2+1.24^2}}{0.833} = 13.1\ KSI < 31.5\ KSI$, ∴ ¼" WELD OK



RETAINING PLATE DESIGN







2

16

8

ASD:

V = VTR/1.4 = 1.8K/1.4 = 1.23K

PTR =1.24K/1.4=0.89K

T = 1.23K* 2.5" /(3" + 5.25") + 0.89K/(4 SIDES) = 0.37K+0.22K=0.59K

PER SIDE - (2) ANCHORS

FS =33 KSI (ASSUMED)

DM =0.2" (5mm)

L =3T/(3.14*DM*FS) = 3*0.59K/[3.14*(0.2")*(33KSI)] = 0.07" < 3/16" ∴ PLATE OK

FASTENER DESIGN MANUAL, NASA PUBL. 1228, 0. 21

ANCHOR STRESS

V = 1.23K/8 = 0.15K

T = 0.59K/2 = 0.30K (2) ANCHORS IN TENSION

A = 0.2^2*3.14/4 = 0.03 IN^2

f = (0.15K + 0.30K)/0.031 = 14.5 KSI – ANCHORS OK

ECCENTRIC POSITION OF RESULTANT OF LATERAL FORCE
CAUSING TRANSLATION AND ROTATION IN THE PLANE OF THE TABLE

CASE 1

RESTRAINTS EFFECTIVE ***3 of 3***

3

EX

i			1	2	3	4
Ai		IN	28	17.09	17.09	0
$\sum AI^2$				1368		
EX		IN	20	20	20	
L		IN		6	6	
B		IN		32	32	
α	ATAN(B/2/L)	RAD	0	1.212	1.212	
		DEG		69.4	69.4	
M	E*(V0=1)	IN-#	20	20	20	
RM	M*Ai/∑Ai		0.409	0.250	0.250	
RMX	RM*SIN α		0.000	0.234	0.234	
RVX	1/3		0.000	0.000	0.000	
RX	**RMX+RVX**	#	**0.000**	**0.234**	**0.234**	
RMZ	RM*COS α		0.409	0.088	0.088	
RVZ	1/3		0.330	0.330	0.330	
RZ	RMZ+RVZ		**0.739**	**0.418**	**0.418**	
R0	**$(RX^2+RZ^2)^{0.5}$**		**0.739**	**0.479**	**0.479**	
KX	**V0/(3*R0)**		**0.45**	**0.69**	**0.69**	
KX MIN (@ ±EX)				**0.45**		

EZ

i			1	2	3	4
Ai		IN	28	17.09	17.09	0
$\sum AI^2$				1368		
EZ		IN	18	18	18	
L		IN		6	6	
B		IN		32	32	
α	ATAN(B/2/L)	RAD	0	1.212	1.212	
		DEG		69.4	69.4	
M	E*(V0=1)	IN-#	18	18	18	
RM	M*Ai/∑Ai		0.368	0.225	0.225	
RMX	RM*SIN α		0.000	0.211	0.211	
RVX	1/3		0.333	0.333	0.333	
RX	**RMX+RVX**	#	**0.333**	**0.544**	**0.544**	
RMZ	RM*COS α		0.368	0.079	0.079	
RVZ	1/3		0.000	0.000	0.000	
RZ	RMZ+RVZ		**0.368**	**0.079**	**0.079**	
R0	**$(RX^2+RZ^2)^{0.5}$**		**0.497**	**0.549**	**0.549**	
KZ	**V0/(3*R0)**		**0.66**	**0.60**	**0.60**	
KZ MIN (@ ±EZ)				**0.60**		

ECCENTRIC POSITION OF RESULTANT OF LATERAL FORCE
CAUSING TRANSLATION AND ROTATION IN THE PLANE OF THE TABLE

CASE 2

RESTRAINTS EFFECTIVE ***3 of 3***

3

EX

i			1	2	3	4
Ai		IN	112	55.36	55.36	0
$\sum AI^2$				18673		
EX		IN	67	67	67	
L		IN		53	53	
B		IN		32	32	
α	ATAN(B/2/L)	RAD	0	0.293	0.293	
		DEG		16.8	16.8	
M	E*(V0=1)	IN-#	67	67	67	
RM	M*Ai/∑Ai		0.402	0.199	0.199	
RMX	RM*SIN α		0.000	0.057	0.057	
RVX	1/3		0.000	0.000	0.000	
RX	**RMX+RVX**	#	**0.000**	**0.057**	**0.057**	
RMZ	RM*COS α		0.402	0.190	0.190	
RVZ	1/3		0.330	0.330	0.330	
RZ	RMZ+RVZ		**0.732**	**0.520**	**0.520**	
R0	**$(RX^2+RZ^2)^{0.5}$**		**0.732**	**0.523**	**0.523**	
KX	**V0/(3*R0)**		**0.45**	**0.63**	**0.63**	
KX MIN (@ ±EX)				**0.45**		

EZ

i			1	2	3	4
Ai		IN	112	55.36	55.36	0
$\sum AI^2$				18673		
EZ		IN	18	18	18	
L		IN		53	53	
B		IN		32	32	
α	ATAN(B/2/L)	RAD	0	0.293	0.293	
		DEG		16.8	16.8	
M	E*(V0=1)	IN-#	18	18	18	
RM	M*Ai/∑Ai		0.108	0.053	0.053	
RMX	RM*SIN α		0.000	0.015	0.015	
RVX	1/3		0.333	0.333	0.333	
RX	**RMX+RVX**	#	**0.333**	**0.348**	**0.348**	
RMZ	RM*COS α		0.108	0.051	0.051	
RVZ	1/3		0.000	0.000	0.000	
RZ	RMZ+RVZ		**0.108**	**0.051**	**0.051**	
R0	**$(RX^2+RZ^2)^{0.5}$**		**0.350**	**0.352**	**0.352**	
KZ	**V0/(3*R0)**		**0.94**	**0.94**	**0.94**	
KZ MIN (@ ±EZ)				**0.94**		

ECCENTRIC POSITION OF RESULTANT OF LATERAL FORCE
CAUSING TRANSLATION AND ROTATION IN THE PLANE OF THE TABLE

CASE 3

RESTRAINTS EFFECTIVE ***4 of 4***

3

	i			1	2	3	4
EX	Ai		IN	112	112	16	16
	$\sum AI^2$				25600		
	EX		IN	67	67	67	67
	L		IN		0	0	0
	B		IN		32	32	32
	α	ATAN(B/2/L)	RAD	0	0.000	1.570	1.57
			DEG		0.0	90.0	90.0
	M	E*(V0=1)	IN-#	67	67	67	67
	RM	M*Ai/∑Ai		0.293	0.293	0.042	0.042
	RMX	RM*SIN α		0.000	0.000	0.042	0.042
	RVX	1/4		0.000	0.000	0.000	0.000
	RX	**RMX+RVX**	#	**0.000**	**0.000**	**0.042**	**0.042**
	RMZ	RM*COS α		0.293	0.293	0.000	0.000
	RVZ	1/4		0.250	0.250	0.250	0.250
	RZ	RMZ+RVZ		**0.543**	**0.543**	**0.250**	**0.250**
	R0	$(RX^2+RZ^2)^{0.5}$		**0.543**	**0.543**	**0.254**	**0.254**
	KX	**V0/(4*R0)**		**0.46**	**0.46**	**0.99**	**0.99**
	KX MIN (@ ±EX)				**0.46**		

	i			1	2	3	4
EZ	Ai		IN	112	112	16	16
	$\sum AI^2$				25600		
	EZ		IN	18	18	18	18
	L		IN		0	0	0
	B		IN		32	32	32
	α	ATAN(B/2/L)	RAD	0	0.000	1.570	1.570
			DEG		0.0	90.0	90.0
	M	E*(V0=1)	IN-#	18	18	18	18
	RM	M*Ai/∑Ai		0.079	0.079	0.011	0.011
	RMX	RM*SIN α		0.000	0.000	0.011	0.011
	RVX	1/4		0.250	0.250	0.250	0.250
	RX	**RMX+RVX**	#	**0.250**	**0.250**	**0.261**	**0.261**
	RMZ	RM*COS α		0.079	0.079	0.000	0.000
	RVZ	1/4		0.000	0.000	0.000	0.000
	RZ	RMZ+RVZ		**0.079**	**0.079**	**0.000**	**0.000**
	R0	$(RX^2+RZ^2)^{0.5}$		**0.262**	**0.262**	**0.261**	**0.261**
	KZ	**V0/(4*R0)**		**0.95**	**0.95**	**0.96**	**0.96**
	KZ MIN (@ ±EZ)				**0.95**		