University of Massachusetts
UMASS.Lowell

14.508 Practice of Structural Engineering

By: Susan Faraji

2-Story Steel Framed Building

Take Home Exam #2

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Problem 1

In order to determine the typical forces for an earthquake it was necessary to calculate the floor weight per story in the building. Seismic Weight load calculations can be found in Section A-3 in Appendix A of this report. After determining the floor weight, equation 14.10 from Faraji and Connor's Practice of Structural Engineering book was applied in order to determine the building base shear. These values were then further used in order to determine the shear and overturning moment of each individual story studied. Calculations pertaining to this part of the problem can be found in section A-4 of this report. Figures 2-4 on page A-4 in appendix A of this report represent respectively: the force distribution per story, shear and overturning distribution obtained from this initial seismic analysis.

Problem 2

The Portal Method was applied to the N-S and E-W frames in order to determine an estimate of the axial, shear and moment forces of the beams and columns. Results can be found on section A-5 in Appendix A. Figure 5 and 6, show the column moment distribution for members and shear and axial force distribution, respectively for the frame in the N-S direction. Section A-6 and figures 7 and 8 show likewise results for braced frame in the E-W direction.

Problem 3

From the initial values obtained in part 2 of this project, additionally using Equations 11.11 and 11.17 from Faraji and Connor's Practice of Structural Engineering book, brace-forces were estimated and can be found in Tables 1 through 5 appended to part A of this report.

Problem 4

Application of the Muller-Breslau principle can be found in the hand-calculations appended in part B of this report.*

Problem 5

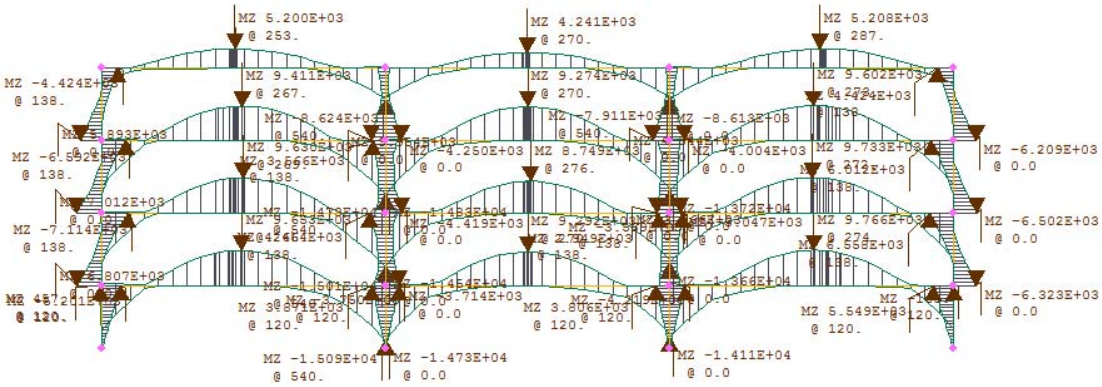

Figure 1. Moment diagram resulting from GTStrudl

Where maximum/minimum values are:

- **For Beams:**

Maximum axial = 71 k

Shear = 170 k

Maximum moment = 1258k.ft

- **For Columns:**

Maximum axial = 972.53k

Shear = 170k

Maximum moment = -587k

Problem 6

Given results above a W21x50 from p.6-89 AISC 14th

Problem 7

Given results above a W10x33 from p.6-89 AISC 14th

Appendix A: Calculations

Calculations used or complimentary to this project are attached to this report in Appendix A.

Appendix B: Hand-Calculations

Hand-Calculations used or complimentary to this project are attached to this report in Appendix B.

Appendix A

Appendix A: Calculations

Calculations used or complimentary to this project are attached to this report in Appendix A.

1. BUILDING SPECIFICATIONS:

A. CLASSIFICATIONS:

Occupancy:	B	Office
Construction Type:	II	B
Risk Category:	II	
Seismic Site Class:	C	
Environmental Exposure:	C	

Importance Factor: 1

B. BUILDING LAYOUT

Number Columns:	4				End Clearance:	0 in
Total Area:	8100	ft^2				
Floor Plan:	60	ft	x	135	ft	
Column Grid:	20	ft	x	45	ft	
Total Height:	46	ft				
Individual Height:	11.5	ft			# Stories:	4
Structural Allowance:	-	ft				

C. LATERAL LOAD RESISTING SYSTEMS:

Regular Frame
Lateral Braced Frame

1. BUILDING LOADS AS REQUIRED BY CODE:

Loads are in accordance to:	2012	IBC
Modified by:	Massachusetts Building Code	(CMR780)
Snow	Lowell	MA
Wind	Lowell	MA
Seismic	Lowell	MA
Construction Live Load:	20	psf
Uniform Live Load:	100	psf

2.1 BUILDINGLOADS:

	Roof		All other floors	
2.1. Dead Load (D)		psf	70	psf
2.2. Live Load (L)		psf	80	psf
2.3. Roof Live Load (Lr)		psf		psf
2.4. Snow Load (S)		psf		psf
2.5. Rain Load (R)		psf		psf
2.6. Seismic Load (E)	165.6	psf	125	psf
2.7. Wind Load (W)	8.0	psf	30	psf
Total / Service Load:	173.6		305	psf

2.2 LOAD COMBINATIONS PER LRFD SPECIFICATIONS:

	Roof		All other floors	
1. 1.4D	0.0	psf	98.0	psf
2. 1.2D + 1.6L + .5(Lr or S or R)	0.0	psf	212	psf
3. 1.2D + 1.6(Lr or S or R) + (L or .5W)	4.0	psf	164	psf
4. 1.2D + 1.0W + L + .5(Lr or S or R)	8.0	psf	114	psf
5. 1.2D + 1.0E + L + .2S	165.6	psf	289	psf
6. 0.9D + 1.0W	8.0	psf	93	psf
7. 0.9D + 1.0E	165.6	psf	188	psf
Controlling Load:	165.6	psf	289.0	psf

3.1 BUILDING LATERAL LOAD ON LONGITUDINAL DIRECTION: BRACED-FRAME

	Roof		1st Floor	
2.1. Dead Load (D)		kip		kip
2.2. Live Load (L)		kip		kip
2.3. Roof Live Load (Lr)		kip		kip
2.4. Snow Load (S)		psf		psf
2.5. Rain Load (R)		psf		psf
2.6. Seismic Load (E)		kip		kip
2.7. Wind Load (W)		kip		kip
Total / Service Load:	0.0	psf	0.0	psf

3.2 LOAD COMBINATIONS PER LRFD SPECIFICATIONS:

	Roof		1st Floor	
1. 1.4D	0.0	kip	0.0	kip
2. 1.2D + 1.6L + .5(Lr or S or R)	0.0	kip	0.0	kip
3. 1.2D + 1.6(Lr or S or R) + (L or .5W)	0.0	kip	0.0	kip
4. 1.2D + 1.0W + L + .5(Lr or S or R)	0.0	kip	0.0	kip
5. 1.2D + 1.0E + L + .2S	0.0	kip	0.0	kip
6. 0.9D + 1.0W	0.0	kip	0.0	kip
7. 0.9D + 1.0E	0.0	kip	0.0	kip
Controlling Load:	0.0	kip	0.0	kip

4.1 BUILDING LATERAL LOAD ON TRANSVERSE DIRECTION: MOMENT-FRAME

	Roof			1st Floor		
2.1. Dead Load (D)		kip			kip	
2.2. Live Load (L)		kip			kip	
2.3. Roof Live Load (Lr)		kip			kip	
2.4. Snow Load (S)		kip			kip	
2.5. Rain Load (R)		kip			kip	
2.6. Seismic Load (E)		kip	8.03		kip	7.83
2.7. Wind Load (W)		kip			kip	
Total / Service Load:	0.0	kip		0.0	kip	

4.2 LOAD COMBINATIONS PER LRFD SPECIFICATIONS:

	Roof		1st Floor	
1. 1.4D	0.0	psf	0.0	psf
2. 1.2D + 1.6L + .5(Lr or S or R)	0.0	psf	0.0	psf
3. 1.2D + 1.6(Lr or S or R) + (L or .5W)	0.0	psf	0.0	psf
4. 1.2D + 1.0W + L + .5(Lr or S or R)	0.0	psf	0.0	psf
5. 1.2D + 1.0E + L + .2S	0.0	psf	0.0	psf
6. 0.9D + 1.0W	0.0	psf	0.0	psf
7. 0.9D + 1.0E	0.0	psf	0.0	psf
Controlling Load:	0.0	psf	0.0	psf

Reference: ASCE 7-10
Section *Eq/Fig/Table/Notes*

DEAD LOAD 3

Floor:	Roof					2nd				
	Item	**Quantity** *(Area)*	**Units**	**Unit Weigh** *(ksf or klf)*	**Weight** *(kip)*	**Item**	**Quantity** *(Area)*	**Units**	**Unit Weight** *(ksf or klf)*	**Weight** *(kip)*
	Dead Load	8140	*sf*	0.070	570	**Dead Load**	*8140*	*sf*	0.070	570
	Steel	540	*lf*	0.6	324	**Steel**	540	*lf*	0.6	324
	Steel W-E	240	*lf*	0.6	144	**Steel W-E**	240	*lf*	0.6	144
										0
										0
										0
Subtotal	*1038*			0.635	1038	*1038*			1.270	1038
Cummulative	*1038*				1038	*2076*				**2076**

***Unit Weights per ASCE 7-10**

ASSUMPTIONS:

Building Frame System: Steel moment-resisting frame

				Reference: Section	ASCE	7-10 *Eq/Fig/Table/Notes*
1. SEISMIC GROUD MOTION VALUES				11.4		
Seismic Site Class:	C			Assumption	11.4.2	
Maximum Considered Earthquake Spectral Response:						
S_a =	0.120	g		Given	Fig	22-1 / 22-4
ke = Sa/g =	0.120					
Seismic Base Shear:				12.8.1		
Seismic Base Shear	415.1	kip		Faraji's Book	Eq	14.10
Vertical Distribution of Seismic Forces:				12.8.3		
Lateral force per level	$F_x = C_{vx}V$			Faraji's Book	Eq	14.11
	$C_{vx} = (w_x h_x^k)/(\Sigma\, w_i h_i^k)$			*Vertical Distribution Factor*		
k =	1.00		0.96	12.8.3		
Horizontal Distribution of Seismic Forces:				12.8.4		
$V_x = \Sigma\, F_i$ =					Eq	12.8-13

Table 1. Building Floor force, shear and overturning moment distribution:

Floor	Height *(ft)*	Weight *(kip)*	$w_x h_x^k$	C_{vx}	F_x *(kip)*	V_x *(kip)*	Overturning Moment *(kip.ft)*	Total Height *(ft)*
Roof	11.5	1038	47739	0.400	166.0	166.0		46
						166.0		46
4th	11.5	1038	35804	0.300	124.5	290.6	1910	34.5
						290.6		34.5
3rd	11.5	1038	23869	0.200	83.0	373.6	5251	23
						373.6		23
2nd	11.5	1038	11935	0.100	41.5	415.1	9548	11.5
						415.1		11.5
First Floor	0	0	0	0	0	415.1	14322	0
SUM	46	4151	119347	1	415.1			0

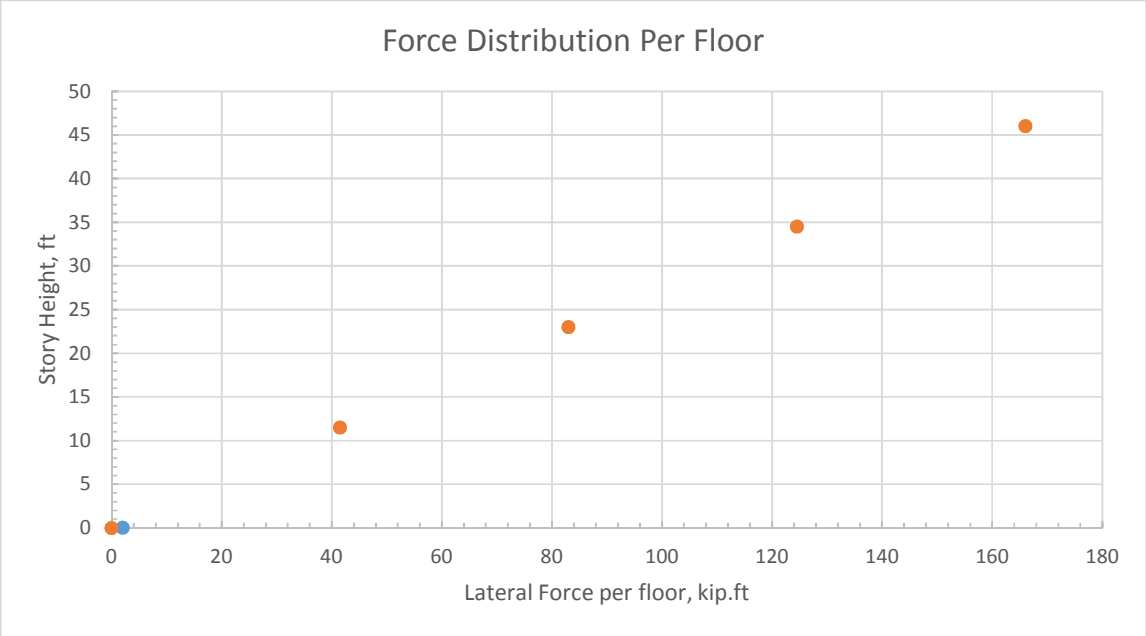

Figure 2. Lateral force per floor

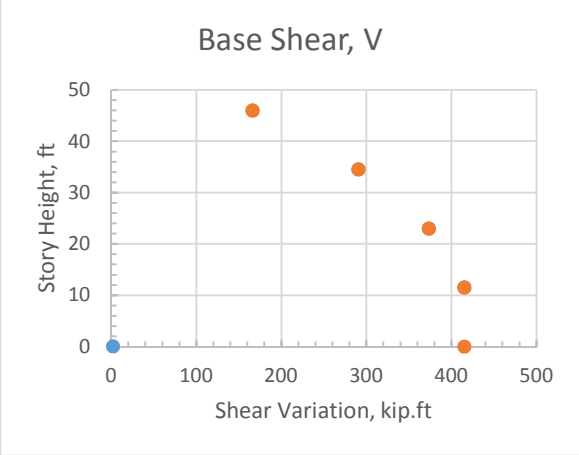

Figure 3. Base shear force variation per story height

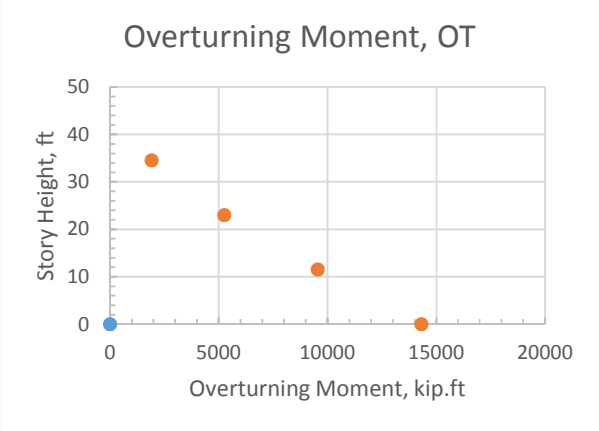

Figure 4. Overturning Moment per story height

ASSUMPTIONS:

Using the Portal Method, assuming Ve=1/2*Vi

Beam Length: 45 ft

Reference: Faraji
Section *Eq/Fig/Table/Notes*

1. N-S FRAME: 11.4

Table 2. Wind and Seismic lateral loading, total story shear and overturning moment.

Floor/Load	Wind	Seismic	Total	Factored Load	Total Shear	h	Moment
Roof	8	165.6	173.6	165.60	165.60	5.75	952.2
4th	13	124.2	137.2	130.88	296.47	5.75	1704.7
3rd	13	82.8	95.8	91.38	387.86	5.75	2230.2
2nd	12	41.4	53.4	50.94	438.79	11.5	5046.1
1st							
Sum			460	438.79			

*These relationships are based on the portal method: Vt=3Vi

Table 3. Total story shear and overturning moment per column.

Floor/Load	Total Shear	Shear Interior	Shear Exterior	Moment Interior	Moment Exterior	h	Moment Checks
Roof	165.60	55.20	27.60	317.39	158.70	5.75	952.2
4th	296.47	98.82	49.41	568.24	284.12	5.75	1704.7
3rd	387.86	129.29	64.64	743.39	371.70	5.75	2230.2
2nd	438.79	146.26	73.13	1682.04	841.02	11.5	5046.1
1st							
Sum							

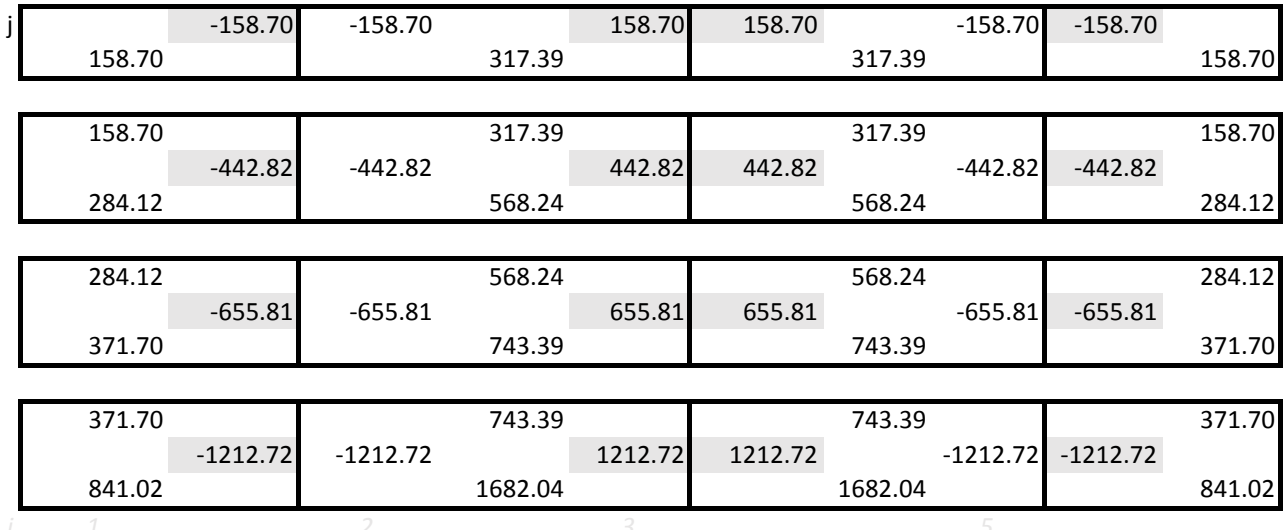

Figure 5. Column Moment Distribution through frame Joints

	7.05	-7.05		7.05	7.05		-7.05	-7.05			
7.05			0.00			0.00			7.05		
7.05			0.00			0.00			7.05		
	-19.68	-19.68		19.68	19.68		-19.68	-19.68			
0.00			3.00			3.00			0.00		
0.00			3.00			3.00			0.00		
	-29.15	-29.15		29.15	29.15		-29.15	-29.15			
0.00			0.00			0.00			0.00		
0.00			0.00			0.00			0.00		
	-53.90	-53.90		-53.90	53.90		-53.90	-53.90			
0.00			0.00			0.00			0.00		
1			*2*			*3*				*5*	

Figure 6. Shear and Axial Force Distribution through frame Joints

ASSUMPTIONS:

Using the Portal Method, assuming Ve=1/2*Vi

Beam Length: 20 ft

Reference: Faraji

Section *Eq/Fig/Table/Notes*

1. E-W FRAME: 11.4

Table 4. Wind and Seismic lateral loading, total story shear and overturning moment.

Floor/Load	Wind	Seismic	Total	Factored Load	Total Shear	h	Moment
Roof	18	165.6	183.6	183.60	183.60	5.75	1055.7
4th	30	124.2	154.2	154.20	337.80	5.75	1942.4
3rd	30	82.8	112.8	112.80	450.60	5.75	2591.0
2nd	27	41.4	68.4	68.40	519.00	11.5	5968.5
Sum			519	519.00			

*These relationships are based on the portal method: Vt=3Vi

Brace forces can be obtained by applying the coefficient obtained with Mathcad to the total force found above.

$h := 11.5\ ft \quad bx := 20\ ft \quad E := 29 \cdot 10^3\ ksi \quad \theta := \operatorname{atan}\left(2 \cdot \frac{h}{bx}\right) = 0.855$

Assumptions:

Assuming W21x93 $Ib := 2070\ in^4$

Assuming W10x45 $Ic := 248\ in^4$

Using a L shaped brace, with Area: L8x4x $A := 6.45\ in^2$

Assuming Hinged Support for the braced frame, applying EQ. chapter 11:

Upper Stories Sub-Element:

$ke := 6 \cdot E \cdot \frac{Ic}{h^3} = 2.837 \times 10^4$

$ki := 8 \cdot E \cdot \frac{Ic}{h^3} = 3.783 \times 10^4$

$kframeup := 1(2 \cdot ke + 2 \cdot ki) = 1.324 \times 10^5$

For base story:

$kex := 2 \cdot E \cdot \frac{Ic}{h^3} = 9.458 \times 10^3$

$kib := 2.4 \cdot E \cdot \frac{Ic}{h^3} = 1.135 \times 10^4$

$kframeb := 2 \cdot ke + 2 \cdot ki = 1.324 \times 10^5$

$kframe := kframeup + kframeb = 2.648 \times 10^5$

Finally, we have kbrace:

$kbrace := 2 \cdot A \cdot E \cdot \frac{\left[\sin(\theta) \cdot (\cos(\theta))^2\right]}{h} = 1.057 \times 10^4$

kr= 0.04

Therefore the force per brace can be obtained by iterating the equation below through the different forces estimated through the different building stories, ie:

$Pbrace := P \cdot \frac{kbrace}{kframe}$

Table 5. Total story shear and overturning moment per column.

Floor/Load	Total Shear	Shear Interior	Shear Exterior	Brace Forces	Moment Interior	Moment Exterior	h	Moment Checks
Roof	183.60	61.20	30.60	7.34	351.90	175.95	5.75	1055.7
4th	337.80	112.60	56.30	6.17	647.45	323.73	5.75	1942.4
3rd	450.60	150.20	75.10	4.51	863.65	431.83	5.75	2591.0
2nd	519.00	173.00	86.50	2.74	1989.50	994.75	11.5	5968.5
1st								
Sum								

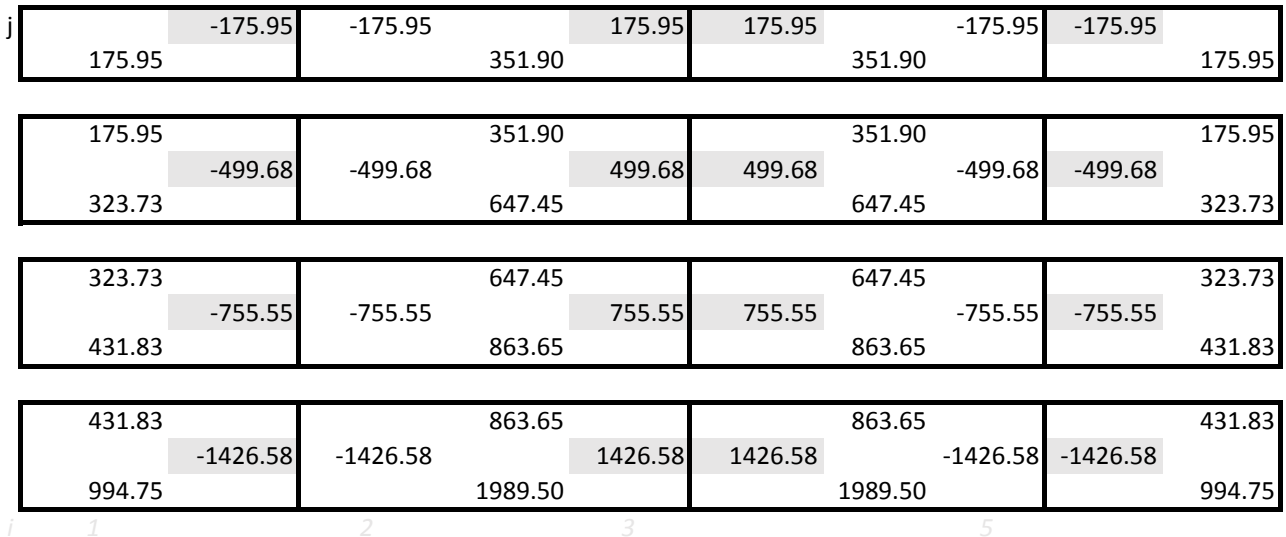

Figure 7. Column Moment Distribution through braced-frame Joints

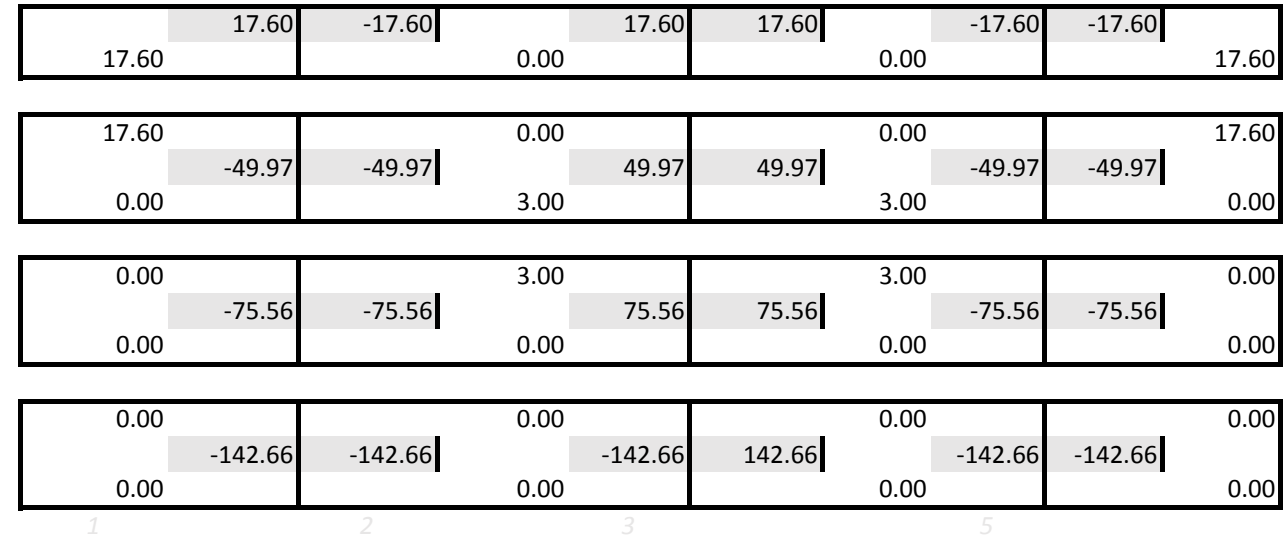

Figure 8. Shear and Axial Force Distribution through braced-frame Joints

Appendix B

Appendix B: Hand-Calculations.

Hand-Calculations used or complimentary to this project are attached to this report in Appendix B.

References:

Connor, Jerome J. and Faraji, Susan, “Introduction to Structural Engineering.”