FINAL DESIGN REPORT

FALL 2014

Design Team: Ana Gouveia, Matthew Laskey, Zach Zavalianos

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PROJECT SUMMARY

Project Summary

Project Riverside is a two-story, steel-framed, office building located in Lowell, MA. GLZ Design has assigned the design team composed by Structural Engineers: Matthew Laskey, Ana Gouveia and Zachary Zavalianos to perform the structural analysis, evaluation and design of this project.

Guided by local regulations, the design team used of the most up to date reference codes, associated to outstanding optimization analysis, along efficient construction practices as the project's design criteria. A more accurate overview of these values can be found in page 7 of this report. Building classifications and initial information can be found in page 8 of this report.

Riverside's design process started through a complete identification of vertical and lateral loads, which were further analyzed by the Load & Resistance Factor Design (LRFD). These initial values were used in the preliminary-sizing of project horizontal and vertical members.

In the second phase of the project, these preliminary members were further evaluated and analyzed. Final framing plans for both first and roof floor were obtained. Two different lateral load resisting systems (LLRS) were designed: a moment-frame resists longitudinal loads, and braced-frames are responsible for transverse loads. Given building risk categories, per code used, ordinary moment-frame and braced-frame were allowed in the design, reducing the project's final budget.

In the project's final phase, composite floor deck, roof joists, girders and diaphragms, and connections were designed. For quality assurance and control, all of the project's information, calculations, analysis and drawings were further back checked. The final results of this project can be found in this report. Calculations, Analysis and Drawings are referred in its respective section on the report and can also be found at this report's appendixes.

GLZ Design appreciates your business and hope to continue serving your Structural Engineering needs in the future.

Sincerely,

Ana Gouveia, EIT

Matt Laskey, EIT

Zac Zavalianos, EIT

GLZ Design

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Design Team

We are pleased to introduce you Riverside's design team:

MATTHEW LASKEY, EIT STRUCTURAL ENGINEER

m.laskey86@gmail.com

Matt continued working as a Structural Engineer at CDM Smith after his summer internship at the firm

Matt has a bachelor's degree in Environmental and Resources Economics from UNH and a Civil Engineering degree from UMass Lowell.

ANA GOUVEIA, EIT STRUCTURAL ENGINEER

acgouveia@live.com

Ana was born in Brazil where she started her college education in Civil Engineering.

As a challenge-seeker, she immigrated to Massachusetts in 2009. Since then studied at Harvard University Extension School, acquired an associate's degree in Engineering from Bunker Hill Community College, a bachelor's degree in Civil Engineering from the University of Massachusetts Lowell.

ZAC ZAVALIANOS, EIT STRUCTURAL ENGINEER

Zachary_Zavalianos@student.uml.edu

Hardworking and enthusiastic structural engineer with experience in design and inspection of bridge structures. Certified in bridge inspection and proficient in inspection databases such as PONTIS and 4-D, as well as MDX and CSI-bridge analysis programs. Seeking to progress career by obtaining a masters degree and working towards a PE license through the upcoming years.

Company Information

GLZ Design

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GLZ Design, LLC

1 University Ave, Lowell, MA

www.glzdesign.com

Design Criteria

Design Criteria and Constraints

The following figure represents the design criteria which guided the team:

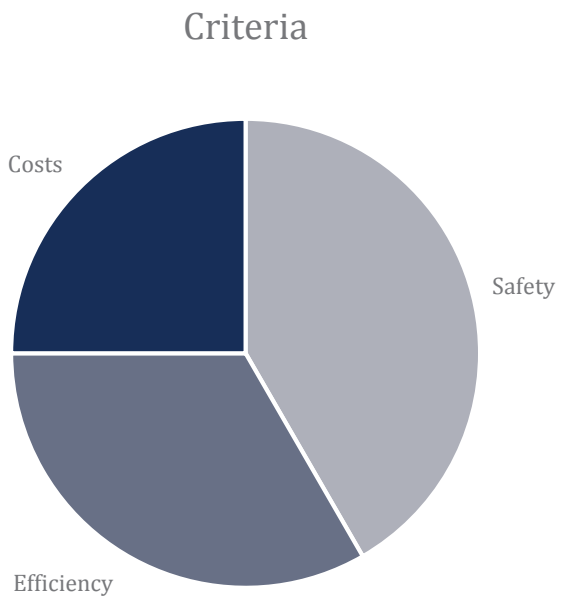


Figure A – Riverside's guiding criteria.

In order to satisfy the above criteria and constraints the following items were used:

References and Regulations

The following literature was used in reference and support of the work done in this project. Please note that names in parentheses are abbreviations commonly cited throughout this project.

- Massachusetts Building Code (CMR 780)
- 2012 International Building Code (2012 IBC)
- Minimum Design Loads for Buildings and Other Structures, (ASCE/SEI 7-10)
- 14th Edition of the Steel Construction Manual (AISC 14th)
- American Concrete Institute Manual (ACI)

DESIGN CRITERIA

- 2007 Steel Deck Institute Design Manual (2007 SDI)
- Vulcraft Joists and Girders (VJG)
- 5th Edition Structural Steel Design, McCormac & Csernak (SSD 5th)

Methods of Design and Analysis

The following methods of design and analysis were thoroughly applied to the different parts of this project.

- Loads: Load & Resistance Factor Design (LRFD) and ASCE 7-10 guidelines.
- Wind Loads: Directional Method (ASCE 7-10)
- Seismic Loads: (ASCE 7-10)
- Preliminary-Sizing: Principles of Structural Engineering Analysis
- Lateral Load Resisting Systems: Direct Analysis Method (DAM) and Effective Length Method (ELM)
- Composite Deck
- Roof Elements
- Connections

Building Information and Requirements

Classifications

- Occupancy: Group B, Office
- Construction: Type IIB
- Risk Category: II
- Seismic Site Class: C
- Environmental Exposure: C

Building Layout

- Total Area = Approx. 17,000 sf (gross)
- Floor Plan: 110 ft. x 74ft
- Column Grid: 36 ft. x 24 ft.

Loads

- The building shall be designed in accordance with 2012 IBC structural provisions and as modified by the Massachusetts Building Code (CMR780).
- Snow, wind, and seismic loads shall be calculated for the Lowell, MA location.

DESIGN CRITERIA

- Minimum Uniform Live Load shall be 100 psf.

Lateral Load Resisting Systems

- Braced Frame in one direction
- Moment Frame in opposite direction
- Rigid Floor and Roof Diaphragms

Floor Systems

- 4,000 psi concrete Floor
- Metal deck
- Composite Steel W-shaped A992 beams
- Steel Girders (W)

Roof Systems

- Single-ply 60 mil EPDM membrane
- 4" rigid insulation
- Metal deck
- Option 1: Open-web steel joists w/ steel girders (W)

Exterior Wall Systems

- Primary Support: 6" Metal stud
- Exterior cladding: 2" Exterior Insulated Finishing Systems
- Fiberglass Batt. Insulation (6")

Scope of Work

Overview

In order to perform this project, GLZ Design determined the criteria and team mentioned in the previous pages.

During Phase 1 of the design process (30% Submittal), members were given the naming convention mentioned in Figures 1-4 below, load evaluations and analysis were done. Calculations can be found within appendix A, Section A-1 to A-10. Preliminary sizes were determined and are catalogued in Calculations Section A-11.

During Phase 2, preliminary sizes were used to determine the building's lateral load resisting system. New member sections were obtained, results catalogued in Calculations Section A-11, and building framing plans and elevations were drafted. Drawings S-2 to S-4 can be found within appendix B. Further, the building composite deck and roof open-web joists and girders were also designed. Calculations can be found in Section A-21 and A-22, respectively.

During Phase 3, connections and other details were designed. Calculations can be found in Sections A-23 to A-24, while final drawings can be found within appendix B.

Members

The members in the project were labeled as shown in the figures below:

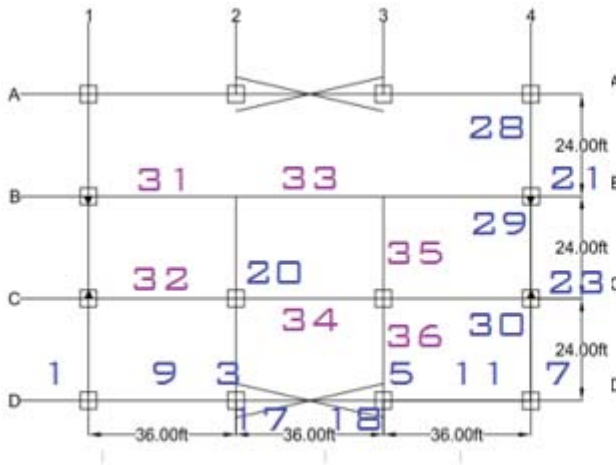


Figure 1 - First Floor Plan

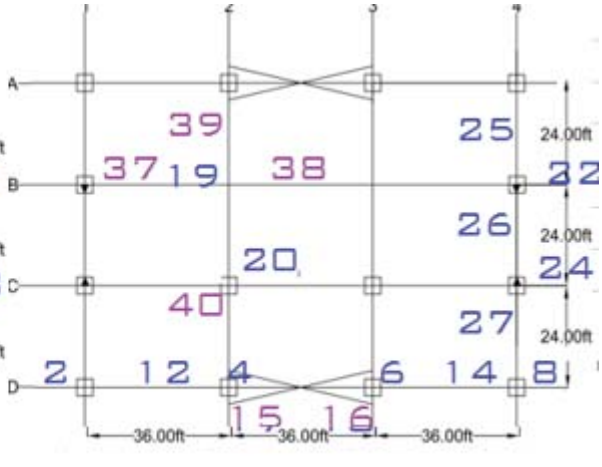


Figure 2 - Roof Floor Plan

SCOPE OF WORK

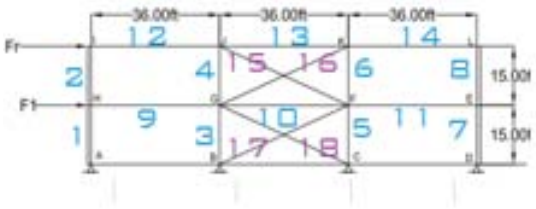


Figure 3 - Braced-Elevation

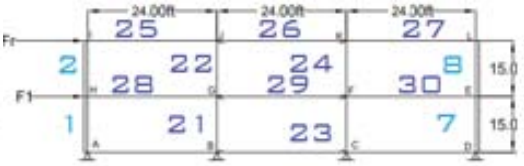


Figure 4 - Moment Frame - Elevation

Lateral Load Resisting Systems

The design team designed two different lateral frame systems. Longitudinally a braced frame can be found, while transversely the project uses of a moment frame. The designed connections calculations can be found within Appendix A, section A-30.

Connections

The designed connections calculations can be found within Appendix A, section A-40.

Composite Deck & Roof Design

Using a parallel panels to the girders the buildings composite floor consists of 6" of concrete poured in 18" g.a. steel sheets. Calculations are found in appendix A. Further, GLZ Design team determined and used of open-web joists and girders for the roof. Calculations are found in appendix A, section A-50 Additional Details.

Schedule

The project was completed within schedule.

Cost Estimate

Attached in Appendix C.

Appendix A: Calculations

1. BUILDING SPECIFICATIONS:

A. CLASSIFICATIONS:

Occupancy:	B	Office				
Construction Type:	II	B				
Risk Category:	II					
Seismic Site Class:	C				Importance Factor:	1
Environmental Exposure:	C					

B. BUILDING LAYOUT

Number Columns:	3					End Clearance:	2 in
Total Area:	8140	ft^2					
Floor Plan:	110	ft	x	74	ft		
Column Grid:	36	ft	x	24	ft		
Total Height:	30	ft					
Finish Floor to Fin. Floor Height:	15	ft				# Stories:	2
Structural Allowance:	4	ft					

C. LATERAL LOAD RESISTING SYSTEMS:

D. FLOOR SYSTEMS:

Concrete Floor Strength:	4	ksi	γ =	0.15	kcf
Concrete Floor Thickness:	6	in			
Metal Deck					
Composite Steel Beams:	W		Type:	A992	
Steel Girders:	W				

E. ROOF SYSTEM

Single-ply 60 mil EPDM membrane		
Rigid Insulation Thickness:	4	in
Metal Deck		
Option 1:	Open-web steel joists w/ steel girders (W)	

F. EXTERNAL WALL SYSTEM

Primary Suport:	Metal Stud	Thickness:	4	in
Insulation:	Fiberglass Batt. Insulation	Thickness:	6	in
Exterior Cladding:	Ex. Insulated Finishing Systems	Thickness:	2	in

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 BUILDING VERTICAL LOADS:

	Roof		1st Floor	
2.1. Dead Load (D)	26.0	psf	128	psf
2.2. Live Load (L)		psf	100	psf
2.3. Roof Live Load (Lr)	20.0	psf		psf
2.4. Snow Load (S)	41.0	psf		psf
2.5. Rain Load (R)		psf		psf
2.6. Seismic Load (E)		psf		psf
2.7. Wind Load (W)	-23.0	psf		psf
Total / Service Load:	64.0	psf	228	psf

2.2 LOAD COMBINATIONS PER LRFD SPECIFICATIONS:

	Roof		1st Floor	
1. 1.4D	36.4	psf	179.2	psf
2. 1.2D + 1.6L + .5(Lr or S or R)	51.7	psf	313.6	psf
3. 1.2D + 1.6(Lr or S or R) + (L or .5W)	85.2	psf	253.6	psf
4. 1.2D + 1.0W + L + .5(Lr or S or R)	28.7	psf	153.6	psf
5. 1.2D + 1.0E + L + .2S	39.4	psf	253.6	psf
6. 0.9D + 1.0W	0.4	psf	115.2	psf
7. 0.9D + 1.0E	23.4	psf	115.2	psf
Controlling Load:	85.2	psf	313.6	psf

3.1 BUILDING LATERAL LOAD ON LONGITUDINAL DIRECTION: BRACED-FRAME

	Roof		1st Floor	
2.1. Dead Load (D)		psf		psf
2.2. Live Load (L)		psf		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)	20.8	psf	20.4	psf
2.7. Wind Load (W)	6.4	psf	12.9	psf
Total / Service Load:	27.2	psf	33.3	psf

3.2 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)	3.2	psf	6.4	psf
4. 1.2D + 1.0W + L + .5(Lr or S or R)	6.4	psf	12.9	psf
5. 1.2D + 1.0E + L + .2S	20.8	psf	20.4	psf
6. 0.9D + 1.0W	6.4	psf	12.9	psf
7. 0.9D + 1.0E	20.8	psf	20.4	psf
Controlling Load:	20.8	psf	20.4	psf

4.1 BUILDING LATERAL LOAD ON TRANSVERSE DIRECTION: MOMENT-FRAME

	Roof		1st Floor	
2.1. Dead Load (D)		psf		psf
2.2. Live Load (L)		psf		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)	17.6	psf	17.0	psf
2.7. Wind Load (W)	9.8	psf	19.6	psf
Total / Service Load:	27.3	psf	36.6	psf

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)	4.9	psf	9.8	psf
4. 1.2D + 1.0W + L + .5(Lr or S or R)	9.8	psf	19.6	psf
5. 1.2D + 1.0E + L + .2S	17.6	psf	17.0	psf
6. 0.9D + 1.0W	9.8	psf	19.6	psf
7. 0.9D + 1.0E	17.6	psf	17.0	psf
Controlling Load:	17.6	psf	19.6	psf

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

DEAD LOAD

3

Floor:	Roof					2nd				
	Item	Quantity *(Area)*	Units	Unit Weight *(ksf or klf)*	Weight *(kip)*	Item	Quantity *(Area)*	Units	Unit Weight *(ksf or klf)*	Weight *(kip)*
	Metal Deck	7776	*sf*	0.014	109	Concrete Slab	7776	*sf*	0.075	583
	EPDM Membrane	7776	*sf*	0.001	8	Metal Deck 18 g.a	7776	*sf*	0.014	109
	Insulation	7776	*sf*	0.006	47	Cladding	7776	*sf*	0.01	78
	Mechanical Equipment	7776	*sf*	0.005	39	Partitions	7776	*sf*	0.01	78
						Mechanical Equipment	7776	*sf*	0.007	54
						Steel Structure	7776	*sf*	0.012	93
Subtotal	*202*			0.026	202	*995*			0.128	995
Cummulative	*202*				202	*1198*				**1198**

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

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

SNOW LOAD

7

Exposure Factor	C_e =	0.90		Table	7-2
Thermal Factor	C_t =	1.00		Table	7-3
Importance Factor	I_s =	1.00		Table	1.5-2
Ground Snow Load	ρ_g =	65.00	psf	CMR	780
Flat Roof Snow Load	ρ_f =	40.95	psf	Eq	7.3-1
				Reference: ASCE	7-10

	Section	*Eq/Fig/Table/Notes*
SEISMIC LOAD	12	

Number of Floors: 2

Floor:	**Roof**					**2nd**				
	Item	**Quantity** *(Area)*	**Units**	**Unit Weight** *(ksf or klf)*	**Weight** *(kip)*	**Item**	**Quantity** *(Area)*	**Units**	**Unit Weight** *(ksf or klf)*	**Weight** *(kip)*
						Concrete Slab	7776	*sf*	0.075	583
	Metal Deck	7776	*sf*	0.014	109	**Metal Deck**	7776	*sf*	0.014	109
	EPDM Membrane	7776	*sf*	0.001	8	**Cladding**	7776	*sf*	0.01	78
	Insulation	7776	*sf*	0.006	47	**Partitions**	7776	*sf*	0.01	78
	Mechanical Equipment	7776	*sf*	0.005	39	**Mechanical Equipment**	7776	*sf*	0.007	54
	Snow	7776	*sf*	0.04095	318	**Steel Structure**	7776	*sf*	0.012	93
Subtotal	*521*				**521**	*995*				**995**
Cummulative	*521*				**521**	*1516*				**1516**
Mass (kip*s^2/ft)					107					58

WIND LOAD ANALYSIS

				Reference: Section	ASCE 7-10 *Eq/Fig/Table/Notes*	
1. BUILDING INFORMATION RELATED TO WIND LOAD ANALYSIS				26/27/28		
Mean roof height	H_{roof} =	30	ft	*Height of heighest level of structure*		
Floor-Floor Height	h_n =	15	ft			
Building Length	L =	112	ft			
Building Width	W =	76	ft			
Number of Braces/Level		2				
Number of Moment Frames/ Level		2				
2. WIND EXPOSURE, ROUGHNESS AND OCCUPANCY CATEGORY				26.4		
Occupancy Category:		B			Table	1-1
Ground Surface Roughness:		B				26.7.2
Exposure Category:		C				26.7.2
3. ENVIRONMENTAL CHARACTERISTICS AND FACTORS				26.5		
Wind Speed	V =	120	mph	26.5	Figure	26.5-1A
Zone A	P_{s30} =	22.8	psf		Figure	28.6-1
Zone C	P_{s30} =	15.1	psf		Figure	28.6-1
	a_1 =	7.6	ft	*.1*W*		
	a_2 =	12	ft	*.4*H_{roof}*		
	a =	7.6	ft	*Min Value*		
	2.a =	15.2	ft			
Weighted Average for P_{s30}:						
Longitudinal		16.1	psf			
Transverse		16.6	psf			
4. DESIGN WIND PRESSURE				26.8		
Adjustment Factor	λ =	1.4			Figure	28.6-1
	K_{zt} =	1		*26.8*		
Design wind pressure,	$P_{s\text{-longitudinal}}$ =	22.6	kip			
Design wind pressure,	$P_{s\text{-transverse}}$ =	23.3	kip			
5. LOAD APPLIED TO EACH LEVEL				26.8		
Roof	$F_{u\text{-longitudinal}}$ =	12.9	kip		Figure	28.6-1
	$F_{u\text{-transverse}}$ =	19.6	kip	*26.8*		

Level 1	$F_{u\text{-longitudinal}} =$	25.8	kip
	$F_{u\text{-transverse}} =$	39.1	kip

6. LATERAL LOAD APPLIED TO BRACED AND MOMENT FRAME

		Roof	Level 1	
Braced Frame	(Longitudinal)	6.44	12.88	kip
Moment Frame	(Transverse)	9.78	19.57	kip

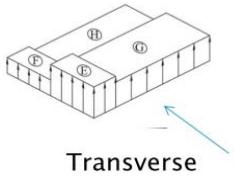
7. VERTICAL UPLIFT PRESSURES ON ROOF

Zone E	P_{s30}	-27.4	psf	Figure 28.6-1
Zone F	P_{s30}	-15.6	psf	Figure 28.6-1
Zone G	P_{s30}	-19.1	psf	Figure 28.6-1
Zone H	P_{s30}	-12.1	psf	Figure 28.6-1

Design wind pressure Zone E,	P_s	-38.36	psf
Design wind pressure Zone F,	P_s	-21.84	psf
Design wind pressure Zone G,	P_s	-26.74	psf
Design wind pressure Zone H,	P_s	-16.94	psf

7. UPLIFT PRESSURE (TRANSVERSE LOADING)

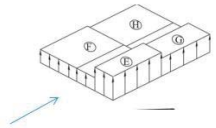
Area, Zone E	577.6	ft^2
Area, Zone F	577.6	ft^2
Area, Zone G	3678.4	ft^2
Area, Zone H	3678.4	ft^2
Total Roof Area	8512	ft^2



Weighted Uplift Pressure from Transverse Wind Load: -22.96 psf

8. UPLIFT PRESSURE (LONGITUDINAL LOADING)

Area, Zone E	851.2	ft^2
Area, Zone F	851.2	ft^2
Area, Zone G	3404.8	ft^2
Area, Zone H	3404.8	ft^2
Total Roof Area	8512	ft^2



Longitudinal

Weighted Uplift Pressure from Longitudinal Wind Load	-23.49	psf

9. MAXIMUM UPLIFT PRESSURE

Controlling Uplift Pressure	-23.49	psf	Largest Absolute Value

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		11.4.2	*Soil Properties / Ch. 20*	
Maximum Considered Earthquake Spectral Response:					
S_s =	0.250		11.4.1	Fig	22-1 / 22-4
S_1 =	0.077		11.4.1	Fig	22-1 / 22-4
Adjusted MCE Spectral Response:					
F_a =	1.200		11.4.3	Table	11.4-1
F_v =	1.700		11.4.3	Table	11.4-2
$S_{MS} = F_a S_s$ =	0.3		11.4.3	Eq	11.4-1
$S_{M1} = F_v S_1$ =	0.131		11.4.3	Eq	11.4-2
Design Spectral Response Acceleration Parameters:					
$S_{DS} = 2/3\ S_{MS}$ =	0.2		11.4.4	Eq	11.4-3
$S_{D1} = 2/3\ S_{M1}$ =	0.087		11.4.4	Eq	11.4-4
Design Response Spectrum:					
$T_O = 0.2\ S_{D1}/S_{DS}$ =		s	11.4.5		
$T_S = S_{D1}/S_{DS}$ =	0.436	s	11.4.5		
Long Period Transition T_L=	6	s	11.4.5	Fig	22-15
T =	0.60	s	*Fundamental Period of Structure*		
S_a = if $T < T_O : S_{DS}(0.4+0.6T/T_O)$ =			11.4.5	Eq	11.4-5
if $T_O < T < T_S : S_{DS}$ =			11.4.5		
if $T_S < T < T_L : S_{D1}/T$ =	0.147		11.4.5	Eq	11.4-6
if $T > T_L : S_{D1}*T_L/T^2$=			11.4.5	Eq	11.4-7
2. IMPORTANCE FACTOR AND OCCUPANCY CATEGORY			11.5		
Occupancy Category:	II			Table	1-1
Importance Factor:	1			Table	11.5-1
3. SEISMIC DESIGN CATEGORY			11.6		
SDC based on short period:	B			Table	11.6-1
SDS based on 1-s period:	B			Table	11.6-2
SDC =	**B**		*Maximum from values above*		
4. EQUIVALENT LATERAL FORCE PROCEDURE			12.8		
R =	8		12.8.1	Table	12.2-1
Ω_O =	3		12.8.1	Table	12.2-1
C_D =	3		12.8.1	Table	12.2-1