

Rutgers University Law School

Building Addition and Renovation

Camden, NJ



Technical Assignment 3

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Structural Option

AE 481W Senior Thesis

The Pennsylvania State University

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Executive Summary

This report is an extension of the first technical report which focused on the existing structural system of the Rutgers University Law School Building Addition. The first report evaluated the gravity load framing system; this report analyzes the lateral load resisting system, frames and foundations, for the project. From the first report, it was determined that wind loading created a more adverse effect on the building; hence, seismic loading was not considered in this report.

The lateral force resisting system used for this building is steel moment frames. This system provides a relatively flexible building; therefore, a majority of the framing members provided have been designed to resist excessive drift rather than excessive loading criteria.

Several computer programs, RAM Structural System and STAAD Pro 2006, were used to create a model of the building and analyze the structure in more detail. The RAM Structural System model was created to develop a three-dimensional interpretation of the building and to fully analyze the wind loading. The two-dimensional model in STAAD was generated to provide a simplified analysis of the forces, moment and axial, on each of the members.

In connection with these computer models, several approximate hand calculations were performed to verify the reliability of the model. While the loads calculated by hand vary slightly from those generated by computer simulation, the values appear to be significantly similar to accept the modeled solution.

As a result of this report, the potential to examine an alternative lateral load system or the development of a combined lateral resisting system in the thesis proposal has become evident. In addition, the method of creating the moment connections may be worth examining in the future thesis work.

Introduction

The Rutgers University Law School Building and Renovation consists of an east building addition, west building renovation and addition, and the development of a connecting bridge which is used to create a student lounge. As the west building additions are minimal, I will concentrate my efforts primarily on the east building addition and will attempt to examine the bridge design project at later date.

The east building consists of two major sections, the primary classroom section, which will be referred to as the primary east addition (4 floors, with basement and penthouse, 75'-0" height) and a student law clinic, which will be referred to as the secondary east addition (2 floors, with basement, 36'-4" height). A majority of the focus in Technical Assignment #3 will be on the typical framing bays located in east addition. as the largest spans and most restrictive framing systems are demanded in this space—resulting in larger frame loads. Connected to the west edge of the primary east addition is the bridge support system. This system creates several complicated analysis procedures which will be investigated in more depth later in this semester and have been neglected in the study of the lateral resisting elements.

This report will review multiple load cases and their effect on the building frame, primarily considering member strength and drift requirements. Computer programs such as STAAD Pro 2006 and RAM Structural System were utilized to develop more a more detailed analysis. Additionally, separate hand calculations were performed to validate the computer simulations.

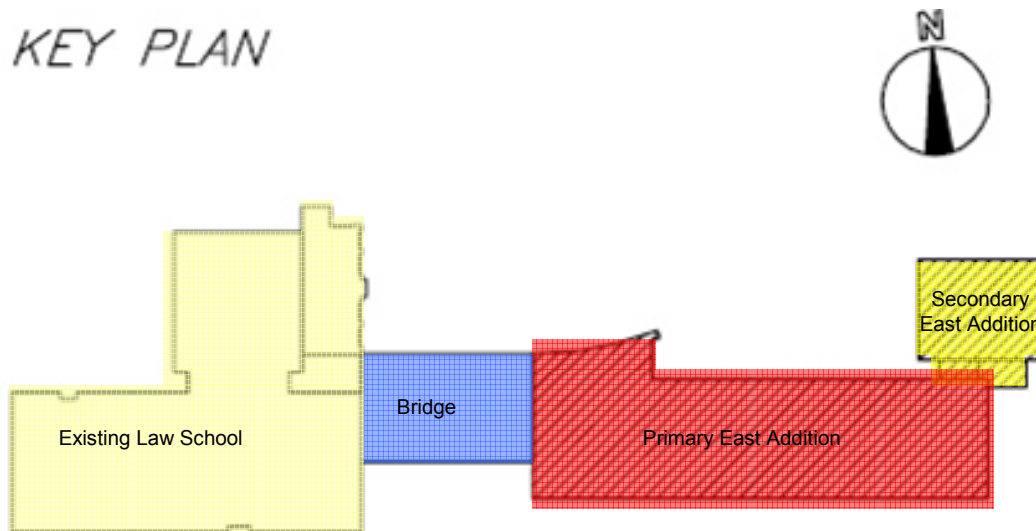


Figure 1: Plan illustrating different building components referenced in this report

Structural System

The following sections will describe the structural elements incorporated in the design of the Rutgers University Law School Building.

Foundation System

The foundation system utilized to support the east building addition incorporates moment-resisting spread foundations, concrete pad foundations, and typical wall footing foundations. The foundation system supporting the bridge designed to cross Fifth Street includes drilled piles with pile caps along with a typical wall footing.

The spread footings supporting the moment frames, designed to resist moments generated by lateral loads, are 11'-0" x 11'-0" x 2'-6" concrete slab, reinforced with No. 8 rebar spaced at 12" on center each way, with a 40" x 40" reinforced pier to 10" below grade. In the smaller, three story section, of the east addition, the moment-resisting foundations are 7'-0" x 7'-0" x 2'-0" spread footings with No. 7 rebar at 7" on center each way. Again, these foundations are supporting a 40" x 40" reinforced pier designed to transfer the moment to the ground. In addition, these spread footings have been designed to be supplemented by the displacement geopier system provided by Geotechnical Structures, Inc. to achieve an allowable bearing capacity of 5000 psf.

The typical wall footings designed around the east addition are 2'-0" wide x 1'-0" deep strip footings reinforced with (3) No. 5 rebar longitudinal and No. 4 rebar spaced at 48" on center transversely. This wall footing is typical around the perimeter of the addition, where not influenced by the bridge system. In locations affected by the bridge assembly, the wall footings increase significantly in size, to 2'-6" x 1'-4" with (3) No. 5 rebar longitudinal and No. 5 rebar at 48" on center.

The final foundation system utilized in the Rutgers University Law School Addition is a drilled pile foundation located below the support of the bridge section of the building. A series of (24) 14" diameter piers are drilled to a depth of 65'-70' below grade, as required by the geotechnical report. In the east addition, the piles are capped with (4) 48" pile caps covering (6) piles each. To top off the pile caps, a grade beam, 2'-0" x 2'-0", has been designed to create a wall footing under the bridge addition.

Columns

The typical framing system used in the Rutgers University Law School is steel moment frame construction. Typical columns are attached to form a fixed connection to the foundations are A992 Grade 50 W14X159 for the primary east addition creating typical bays of 20'-0" by 46'-8", and A992 Grade 50 W14X82 for the secondary east addition which create 41'-0" by 22'-8" typical bays. Optional column splices have been located above the third floor for value engineering options.

Floor Systems

There are several different types of floor systems used throughout the Law School Building. Each system incorporates a composite floor slab (3/4" X 5" shear studs) with typical A992 Grade 50 steel framing systems.

The floor system used in the primary east addition consist of W21X68 wide flange beams spanning 46'-8", with intermediate beams consisting of W8X18 members spanning the 10'-0" spacing between the beams, which frame into W24X55 girders spanning 20'-0". The typical floor slab consists of 4-1/2" normal weight concrete ($f'_c = 4000$ psi), reinforced with 6X6 W2.9 X W2.9 WWF, on 3"-16ga metal floor decking which spans 10'-0". This floor system is used, with slight variations of beam sizes for all levels of the primary east addition, as well as for the secondary east addition.

In the bridge section of the building, rolled wide flange beams, W21X62, span 43'-0" to W40X235 girders spanning the 67'-4" across Fifth Street. The floor slab consists of 4-1/2" normal weight concrete ($f'_c = 5000$ psi) reinforced with 6X6 W2.9 X W2.9 WWF on 3"-16ga metal floor decking spanning 11'-2" to the W21X62 beams.

Lateral Force Resisting System

The lateral support for the entire east building addition is developed through the use of moment-resisting frames, as an open plan was critical in the architectural design of the building. There are (6) frames spaced at 20'-0" on center for the primary east addition, and (4) frames spaced at 11'-4" on center for the secondary east addition. For the bridge addition, (2) lateral wind resisting frames are required to withstand the load, these frames are spaced at 67'-4" on center. Each of the lateral support frames are created through beam-column moment connections.

The lateral resisting system has been highlighted in the typical framing plan located in the appendix of this report.

Roof Framing System

The roof framing system designed for the entire east building addition and bridge section of the Rutgers University Law School consists of W18 beams spaced at 10'-0" or less on center framing into W18 girders with 3"-18ga galvanized roof decking.

Typical Floor Framing Plan

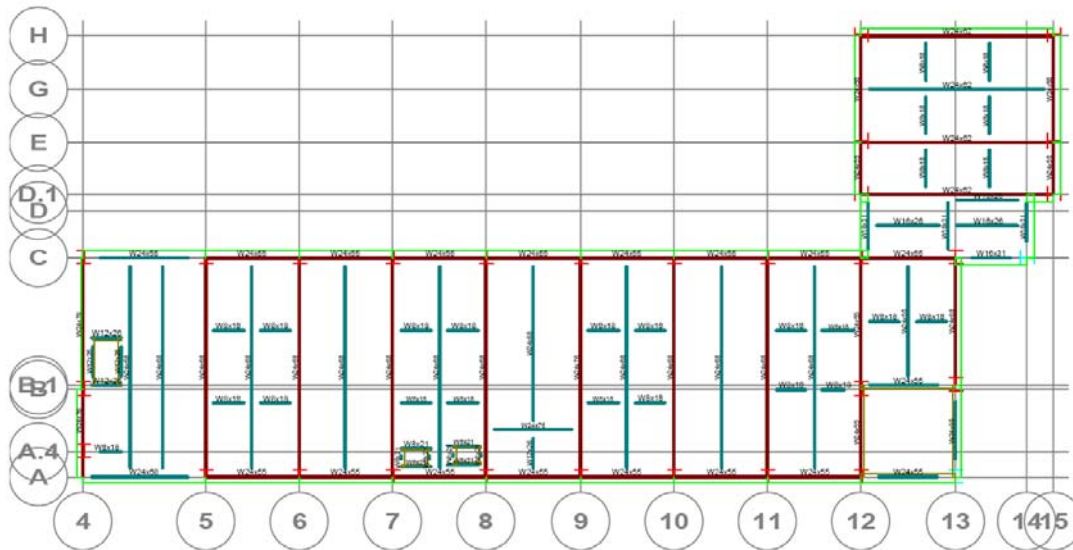


Figure 2: Typical Framing Plan (Lateral Elements Shown in Red)

Building Loads

The following building loads were used for the analysis of the lateral force resisting systems considered in this report. Each loading condition has been described briefly below, while more detailed calculations are available in the appendix of this report. The following load combinations were used to generate the largest loads on the frame.

Load Combinations

1. $1.4D$
2. $1.2D + 1.6L + 0.5L_r$
3. $1.2D + 1.6L_r + L$
4. $1.2D + 1.6W + L + 0.5L_r$
5. $0.9D + 1.6W$

Dead Load

The dead load was calculated for each system through material weights and/or the use of standard charts or tables created by the manufacturer of certain systems. The floor system dead load was found to be 88.5psf, while the roof system dead load was found to be 12psf. In all cases, a superimposed dead load of 15psf was added to account for additional lighting/electrical and mechanical systems, as well as the weight floor finish materials.

Live Load

The live load applied to the floor systems analyzed in this report is 60psf for the STAAD computer model which accounts for the typical classroom occupancy loading, or a combination of 100psf corridor loading and 60psf classroom loading when analyzed with the RAM Structural program. When performing the hand calculations, a live load of 100psf was used as a conservative value for the preliminary design to provide an indication of each system's ability to withstand the large load which will be applied to the center of the clear span in the more detailed computer analysis.

Wind Load

The wind load scenario has been determined to be the controlling lateral load on the Rutgers University Law School from preliminary analysis in Technical Report #1. As a result, only the wind force has been considered in this assignment. Below is a table illustrating the story forces which were applied to the building to determine strength and drift requirements. Additional wind load calculations can be found in the appendix.

North-South Wind Forces					
Floor	h (ft)	Floor Height	T _{width}	p (psf)	F (k)
2	21.0	21	20.0	21.93	8.25
3	36.3	15.333	20.0	23.75	7.49
4	51.7	15.333	20.0	25.08	7.86
Penthouse	67.0	15.333	20.0	26.15	8.16
Roof	82.3	15.333	20.0	27.06	4.15

East-West Wind Forces					
Floor	h (ft)	Floor Height	T _{width}	p (psf)	F (k)
2	21.0	21	23.5	19.84	8.80
3	36.3	15.333	23.5	21.68	8.06
4	51.7	15.333	23.5	23.03	8.49
Penthouse	67.0	15.333	23.5	24.12	8.86
Roof	82.3	15.333	23.5	25.04	4.51

Distribution

The lateral force resisting system for the Rutgers University Law School Addition is steel moment frames. These frames consist of eight identical frames in the North-South direction, with each frame carrying an equal load from the lateral loading. In the East-West direction, two nearly identical frames resist the lateral forces—as a result, equal distribution was assumed. The secondary east addition to the law school has been neglected in the hand calculations as this addition is less than half the height as the primary addition. Also, the two additions are connected with simply supported beams, allowing each section to have less of an effect on each other. The computer models have been used to illustrate this relationship in more detail—the forces in each model are very similar with or without the addition of the secondary east addition.

Analysis

A computer generated model has been produced in the RAM Structural System program. This program has analyzed the existing framing system with the loadings developed in Technical Assignment #1. The model building code IBC 2003 was used to determine the strength capacity of each member and serviceability criteria associated with lateral wind loading. Based on the model, the lateral elements are significantly larger than necessary for the applied loading, leading to the conclusion that serviceability criteria has governed the design. As steel moment frames are rather flexible structures, it has been determined the member sizes chosen are required to meet the maximum drift requirement of 2.5”.

Additionally, a simplified frame computer model was produced to determine approximate beam and column stresses. This model, developed in STAAD Pro 2006, was used to support the RAM analysis as well as to aid in the hand calculations. This model provided axial loads and moments to simplify portal frame method analysis by hand calculation. Also, this model was used to create an approximate drift calculation which was compared against that created in the RAM model. As these two drift calculations were similar, it has been determined that the lateral system provided for the Rutgers University Law School Addition meets the H/400 requirements.

The final method of analysis performed was hand calculation spot checks of the computer generated models. A portal method analysis was performed on a standard representative frame in each direction. These loads were then compared to the loading generated by the computer programs. As these results were similar to those generated through simulation, it has been determined the approximate analysis is adequate to model the behavior of the steel moment frame system. Also, through hand calculations, the overturning moment has been calculated and its effect on the spread footings has been investigated. The lateral forces creating an overturning moment on the structure were found to have minimal effect on the overall forces in the columns; however, the moments transferred from the column to the foundation were very influential. After analysis, it was determined that the overturning moment transferred to the soil created a bearing capacity force of 4.86ksf, which is less than the allowable bearing capacity of 5.0ksf (calculations

provided in the appendix). As a result, the entire lateral force resisting system has been checked and verified with the existing design.

Conclusion

This technical report builds on Technical Report #1 which analyzed the existing gravity framing system with a very minimal examination of the lateral framing system. The gravity loading cases have been included in this report to determine strength requirements of the lateral analysis. Through previous analysis, wind loading has been determined to control the lateral design requirements; thus, seismic loading has been neglected. It was determined through the first technical assignment that the designed beams and columns were sized larger than necessary to carry the anticipated loadings. As a result, these members were examined much more carefully in this analysis to determine possible reasons for such sizing.

The lateral framing system utilized in the Rutgers University Law School consists of steel moment frames in each direction. These frames act together as a unit in order to provide adequate strength and serviceability limitations. Through the use of structural engineering programs, such as RAM Structural System and STAAD Pro 2006, it has been determined that all the lateral framing members chosen in the design are required to meet current code regulations.

By means of spot checking ground floor columns and beams, the existing framing system was determined to be sized for serviceability criteria rather than strength of the members. The analysis has determined drift to be a major factor in the design, as the moment frame system provides a great deal of flexibility in the structure. In conclusion, the design performed through approximate hand calculations provides support to the analysis reached through the computer simulations.

Appendix A: Building Loads

This section provides a more detailed break down of the loads which have been applied to the Rutgers University Law School Addition.

Dead Load

Building Material Dead Loads:		
Typical Floor System		
	Unit Weight (psf/in)	Total Weight (psf)
16 Ga. Metal Floor Decking	N/A	3.50
4-1/2" Concrete	12.50	56.25
Finish Material Surcharge	5.00	5.00
		64.75
Roofing System		
	Unit Weight (psf/in)	Total Weight (psf)
18 Ga. Roof Decking	N/A	3.00
5/8" Gypsum Board	4.40	2.75
2" Thick Isocyanurate	1.50	3.00
1/2" Gypsum Cover Board	4.40	2.20
0.060 Reinforced FR EPDM	N/A	1.00
		11.95
Wall Systems		
(Assume 30% of wall weight from window)		
	Unit Weight (psf/in)	Total Weight (psf)
8" CMU Wall	N/A	47.00
4" Brick Veneer	N/A	32.00
Glass and Window Openings	N/A	10.00
		55.60
Miscellaneous Loads		
	Unit Weight (psf/in)	Total Weight (psf)
M/E/P Surcharge	N/A	10.00
		10.00

Live Load

Roof Live Load:		
	Design	IBC 2006
Flat roof:	30 psf	20 psf
Floor Live Load:		
	Design	IBC 2006
Typical Room/Office:	60 psf	50 psf
Corridors:	100 psf	100 psf
Corridors above first floor:	100 psf	80 psf
Lobbies:	100 psf	100 psf
Stairwells and exit ways:	100 psf	100 psf
Mechanical Penthouse	150 psf	150 psf

Detailed Wind Load Calculations

Wind Load:		
(Values Calculated from ASCE 7-05)		
V	90 mph	Figure 6-1
Exposure Category	B	
k_d	0.85	Table 6-4
I	1.15	Table 6-1
k_{zt}	1.00	Section 6.5.7
Z_g	1200	Table 6-2
α	7.0	Table 6-2

North-South Gust Factor	
G_f	0.822
I_z	0.281
Q	0.818
g_r	5.682
g_q, g_v	3.4
R	0.031
z bar	49.32 ft
c	0.3
B	166.0 ft
L	94.2 ft
h	82.2 ft
L_z	365.9
f	320
ϵ	0.333
n_1	0.664
β	1.00
N1	3.70
Vz	65.68
b bar	0.45
α bar	0.25
E	1.00
R_n	0.061
R_h	0.227
R_B	0.121
R_L	0.066
η_{Rh}	3.824
η_{Rb}	7.723
η_{RL}	14.67

East-West Gust Factor	
G_f	0.838
I_z	0.281
Q	0.846
g_r	5.682
g_q, g_v	3.4
R	0.039
z bar	49.32 ft
c	0.3
B	94.2 ft
L	166.0 ft
h	82.2 ft
L_z	365.9
f	320
ϵ	0.333
n_1	0.664
β	1.00
N1	3.70
Vz	65.68
b bar	0.45
α bar	0.25
E	1.00
R_n	0.061
R_h	0.227
R_B	0.202
R_L	0.038
η_{Rh}	3.824
η_{Rb}	4.383
η_{RL}	25.86

North-South Direction	
L	94.2 ft
B	166.0 ft
h	82.2 ft
L/B	0.567
Wall Pressures	
	C_p
Windward	0.8
Leeward	-0.5
Side	-0.7

East-West Direction	
L	166 ft
B	94.2 ft
h	82.2 ft
L/B	1.762
Wall Pressures	
	C_p
Windward	0.8
Leeward	-0.348
Side	-0.7

North-South Wind Pressures						
Floor	h (ft)	Floor Height	k_z	q_z	p	
					Windward	Leeward
1	21.0	21	0.633	12.82	10.74	-11.19
2	36.3	15.3	0.740	15.00	12.56	-11.19
3	51.6	15.3	0.818	16.58	13.89	-11.19
4	66.9	15.3	0.881	17.86	14.96	-11.19
Penthouse	82.2	15.3	0.934	18.94	15.86	-11.19

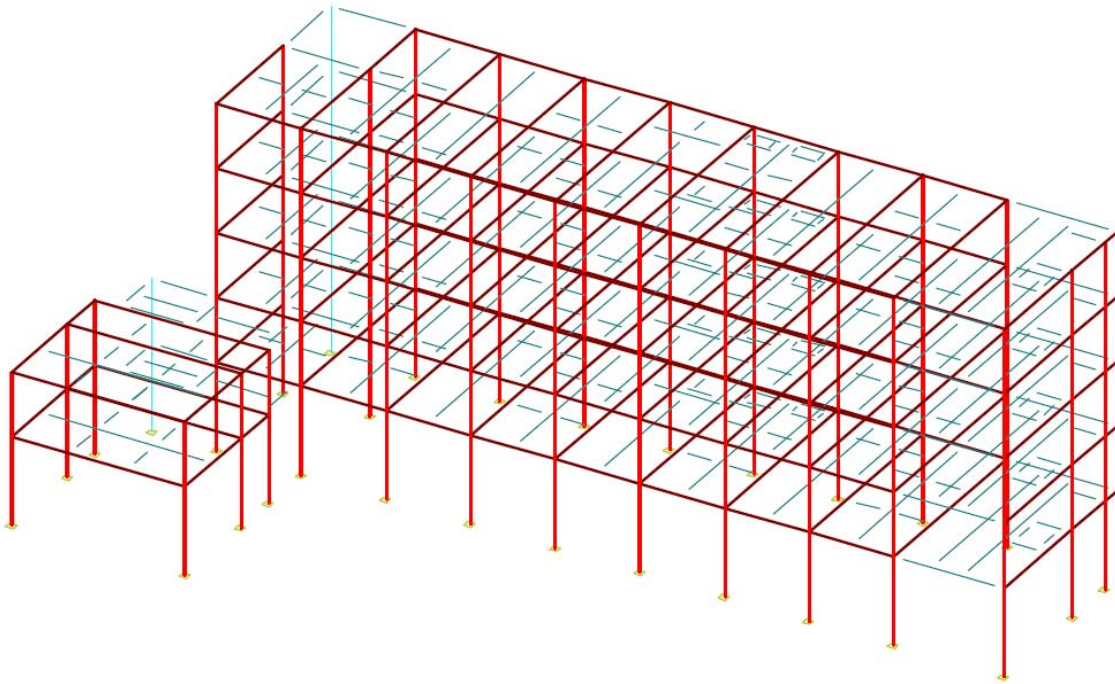
East-West Wind Pressures						
Floor	h above grade(ft)	Floor Height (ft)	k_z	q_z	p (psf)	
					Windward	Leeward
1	21.0	21	0.633	12.82	10.91	-8.93
2	36.3	15.3	0.740	15.00	12.75	-8.93
3	51.6	15.3	0.818	16.58	14.10	-8.93
4	66.9	15.3	0.881	17.86	15.19	-8.93
Penthouse	82.2	15.3	0.934	18.94	16.11	-8.93

Overturing Moment:

Level	Height (ft)	h_{total}	North-South Direction			East-West Direction		
			Width (ft)	Area (sf)	M_o (ft*k)	Width (ft)	Area (sf)	M_o (ft*k)
Roof	7.6	82.2	166	1261.6	2274.7	46.7	354.9	578.7
Penthouse	15.3	67.0	166	2539.8	4041.9	46.7	714.5	1038.0
4th Floor	15.3	51.6	166	2539.8	3286.9	46.7	714.5	849.1
3rd Floor	15.3	36.3	166	2539.8	2410.9	46.7	714.5	625.5
2nd Floor	18.2	21.0	166	3021.2	1716.6	46.7	849.9	446.9
1st Floor	10.5	0.0	166	1743.0	0.0	46.7	490.4	0.0
					<u>13731.1</u>			<u>3538.2</u>

Appendix B: RAM Analysis

This section provides documentation of the RAM Structural/Frame model which was generated and analyzed for the Rutgers University Law School Addition.

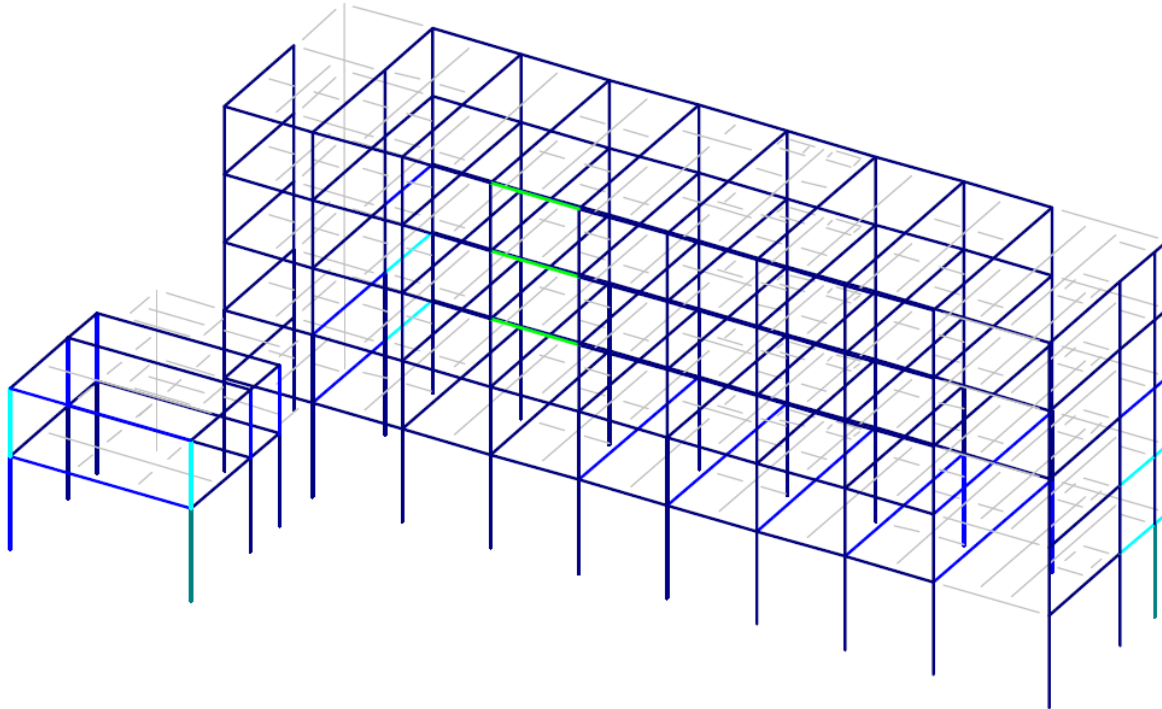


3D Model



Typical Framing Plan

RAM Frame V11.0 - AISC LRFD
DataBase: Tech 3 Model 12/02/07 02:12:19
Code Check - Standard Provisions
<0.40 .40-.50 .50-.60 .60-.70 .70-.80 .80-.90 .90-.95 .95-1.00 >1.00



Stress Calculations for Lateral Framing Members
(Illustrates framing member sizes required for drift control)

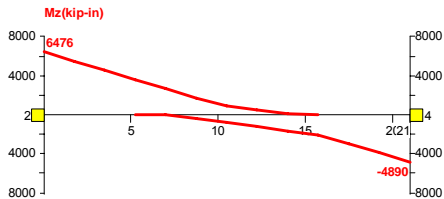
Story Drift
Displacement (in)
2.74
2.40
2.22
2.16
2.14
1.70
2.10
2.07
2.31
2.53

The story drift listed has been determined from column drift at the top of each column. When acting together, the total story drift will be less than the limit of $H/400$ or 2.5". At this time, a more complete detail of story drift performed by RAM Structural System is not available.

Appendix C: STAAD Analysis

This section provides documentation of the STAAD Pro 2006 model which was generated and analyzed for the Rutgers University Law School Addition.

Diagram 1: Column Moment Envelope



Story Drift			
Floor	Displacement		
	x (in)	y(in)	Total (in)
Roof Level	3.251	-0.179	3.256
Penthouse	3.030	-0.174	3.035
4	2.605	-0.152	2.609
3	1.903	-0.119	1.906
2	1.029	-0.076	1.031

Allowable Drift: $H/400 = 2.5''$

Diagram 2: Column Axial Load

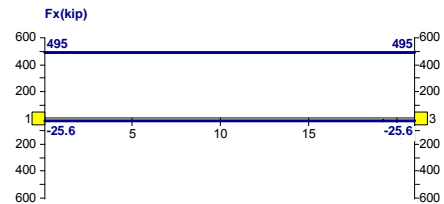


Diagram 3: Beam Moment Envelope

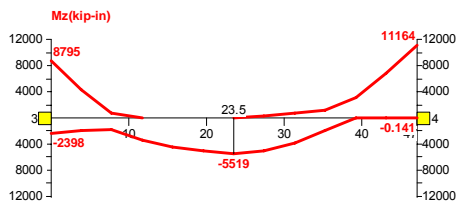
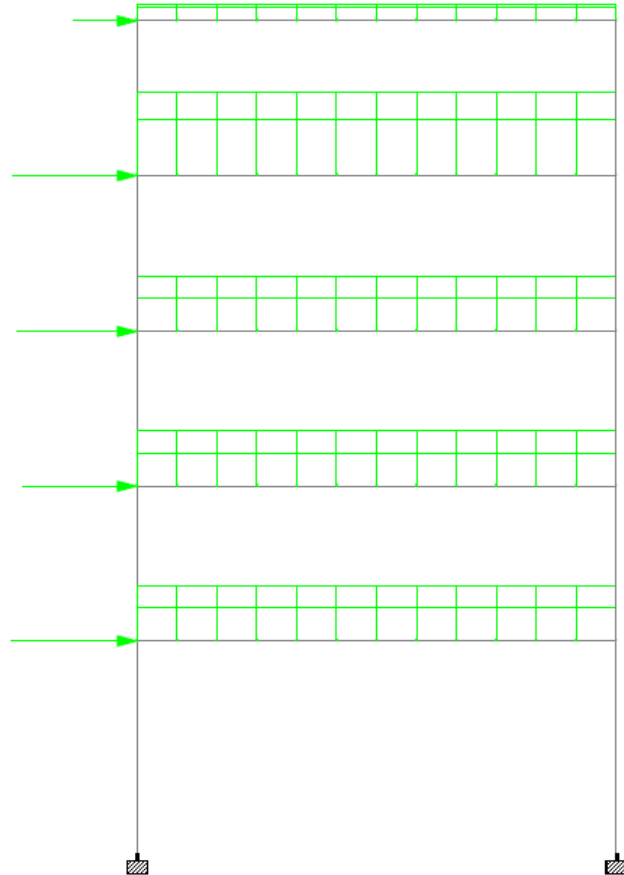
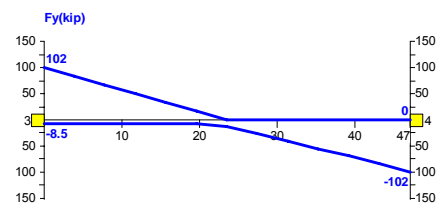
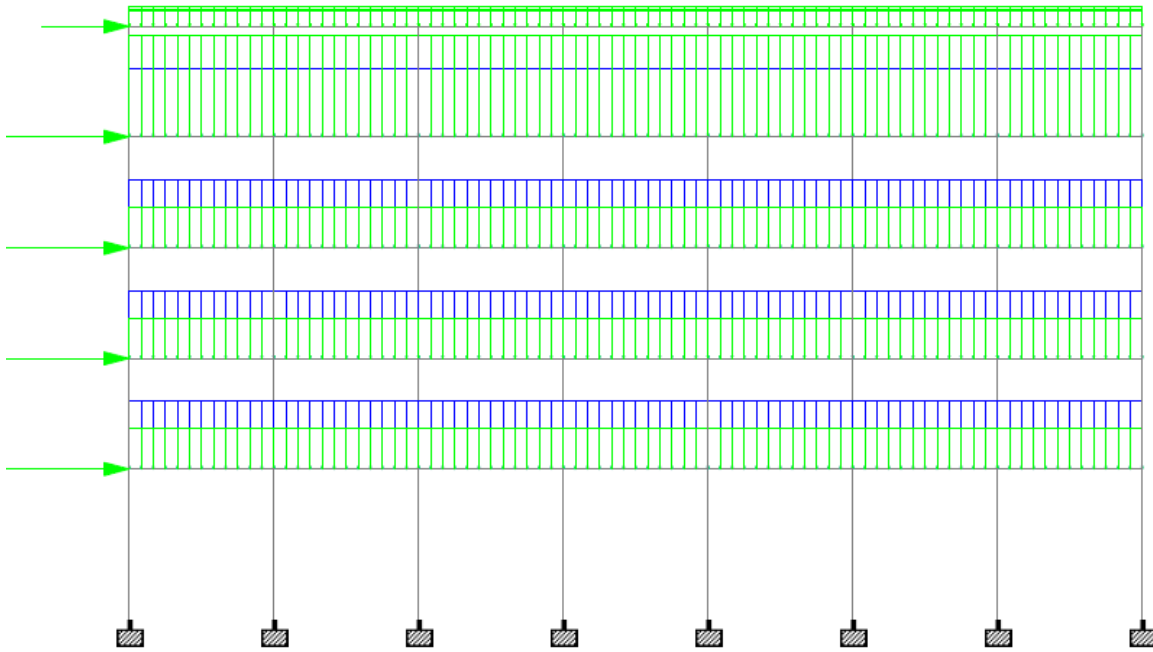


Diagram 4: Column Shear Envelope



Typical North-South Frame



Typical East-West Frame

Diagram 5: Interior Column Moment Envelope

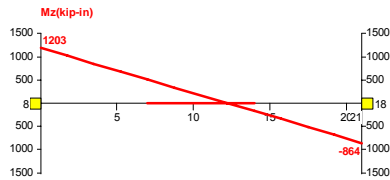


Diagram 6: Exterior Column Moment Envelope

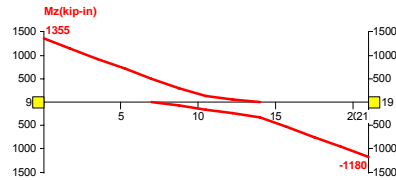


Diagram 7: Interior Column Axial Load

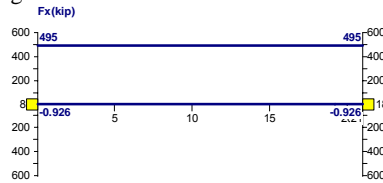


Diagram 8: Exterior Column Axial Load

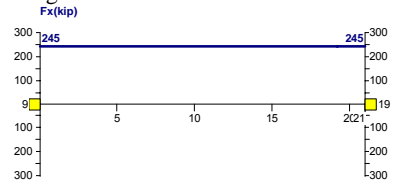
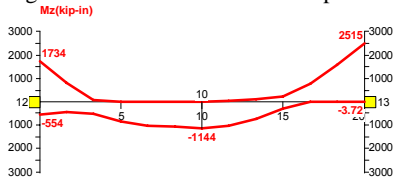


Diagram 9: Beam Moment Envelope



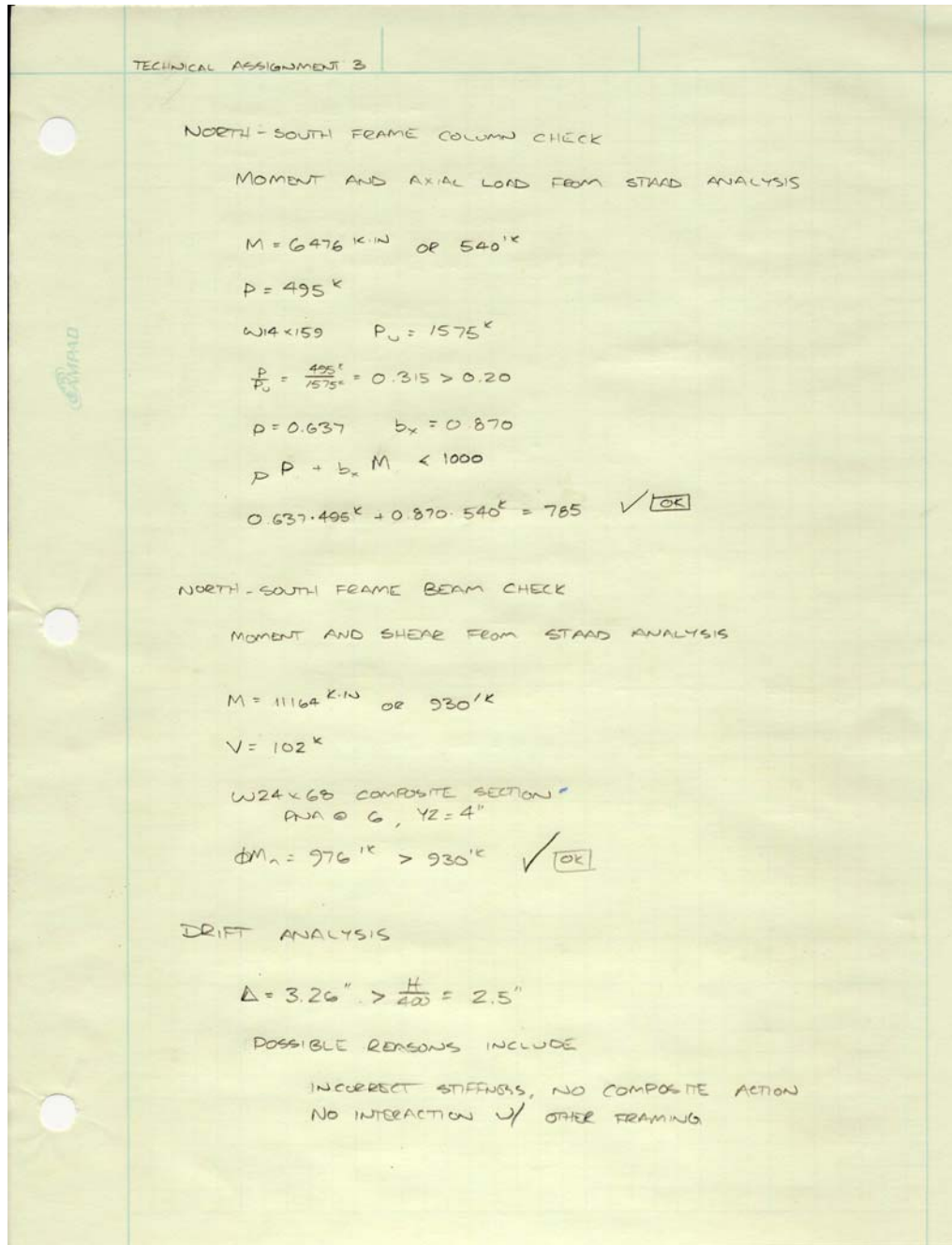
Story Drift			
Floor	Displacement		
	x (in)	y (in)	Total (in)
Roof Level	0.465	-0.088	0.473
Penthouse	0.462	-0.085	0.489
4	0.413	-0.075	0.419
3	0.319	-0.059	0.324
2	0.199	-0.037	0.202

Allowable Drift: $H/400 = 2.5''$

Appendix D: Spot Checks

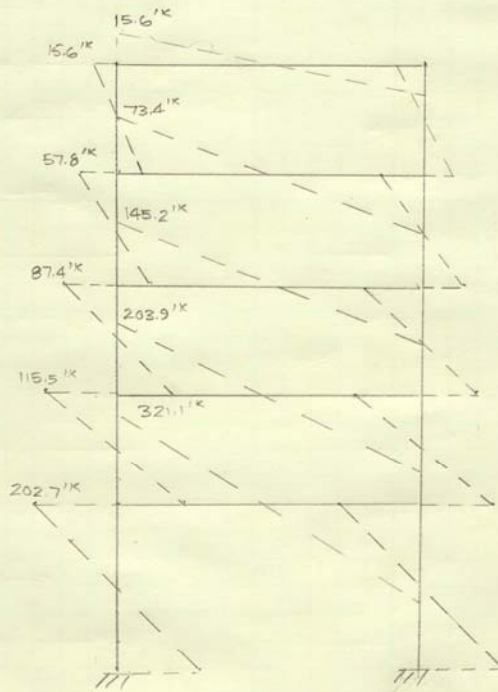
This section provides documentation of the hand calculations performed on the lateral resisting system, as well as spot checks developed in connection with the computer models which for the Rutgers University Law School Addition.

North-South Frame



TECHNICAL ASSIGNMENT #1 | LATERAL SYSTEM CHECK | NATE REYNOLDS

PORTAL FRAME MOMENTS OF TYPICAL NORTH-SOUTH FRAME



TECHNICAL ASSIGNMENT #1	LATERAL SYSTEM CHECK	NATE REYNOLDS
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COLUMN LOAD (FIRST FLOOR LATERAL LOAD)

$$1.2D + 1.6W + L + 0.5S$$

$D = 147.76^k$ FROM PREVIOUS CALCULATION

$L = 126.9^k$ FROM PREVIOUS CALCULATION

$S = 23.1 \text{ PSF} \cdot 470 \text{ SF} = 10.9^k$

$W = 32.6^k$ FROM PORTAL METHOD

$= 202.7^k$ FROM PORTAL METHOD

$L_{\text{mom}} = 90.8^k$ FROM BEAM CONNECTION

$$P = 1.2(147.76^k) + 1.6(32.6^k) + 126.9^k + 0.5(10.9^k)$$
$$P = 361.8^k$$
$$M = 90.8^k + 1.6(202.7^k) = 415.1^k$$
$$P_{\text{fact}} = 361.8^k + \frac{2.4}{1.4}(415.1^k) = 1074^k$$

CHOOSE W14x120 USING LINE LOAD REDUCTION

BEAM MOMENT (SECOND FLOOR FRAMING)

$$M = 1.2D + L + 1.6W$$
$$M = 1.2(136.1^k) + 181^k + 1.6 \cdot 321.1^k = 858^k$$

REQUIRE W24x62 BEAM $\phi M_n = 831^k$

East-West Frame

TECHNICAL ASSIGNMENT 3

EAST - WEST FRAME COLUMN CHECK

MOMENT AND AXIAL LOAD FROM STAAD ANALYSIS

$M = 1355 \text{ k}\cdot\text{ft}$ OR 112 k

$P = 495 \text{ k}$

W14 x 159 EFFECTIVE LENGTH: $1.6 \overset{r_x/r_y}{(21')} = 34'$

$\phi P_n = 983 \text{ k}$

$\frac{P_u}{\phi P_n} = \frac{495}{983} = 0.504 > 0.2$

$\rho = 1.02 \quad b_x = 0.949$

$\rho P + b_x M = 1.02(495) + 0.949(112) = 611 < 1000 \checkmark \text{OK}$

EAST - WEST FRAME BEAM CHECK

MOMENT AND SHEAR FROM STAAD ANALYSIS

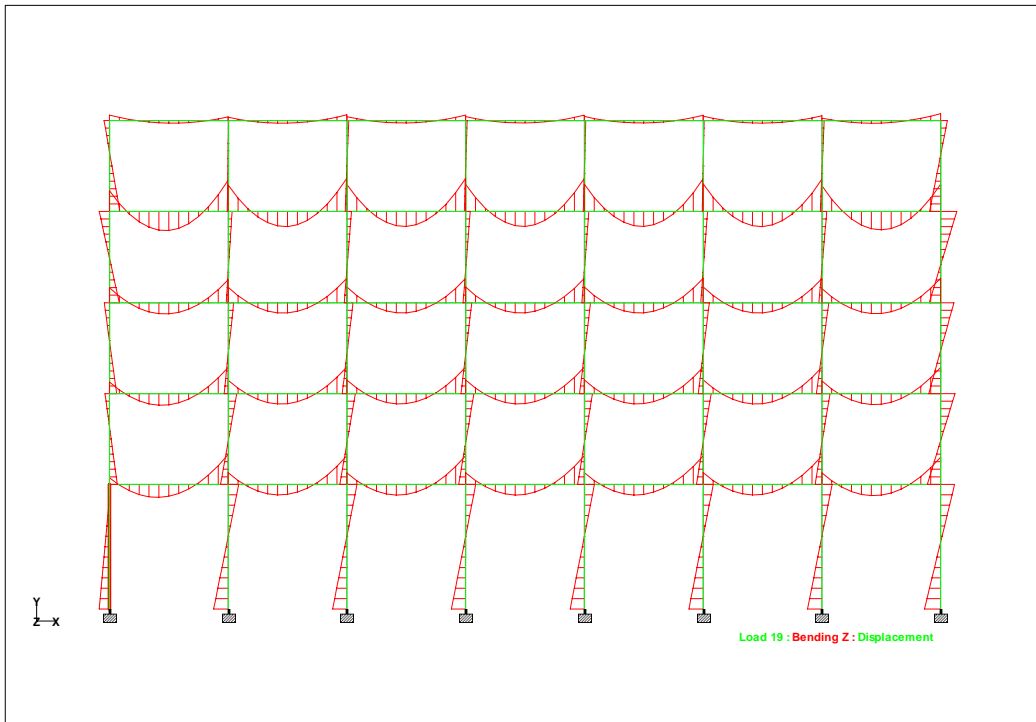
$M = 2515 \text{ k}\cdot\text{ft}$ OR 209 k

W24 x 55 BRACED @ 10'

$\phi M_n = 380 \text{ k} > M_u = 209 \text{ k} \quad \checkmark \text{OK}$

DRIFT ANALYSIS

$\Delta = 0.465'' < H/400 = 2.5''$



East-West Frame Moment Diagram

Overturning Calculation

OVERTURNING MOMENT

$$M_0 = 13731 \text{ }^1\text{k} \text{ (N-S DIRECTION)} \text{ OR } \frac{13731 \text{ }^1\text{k}}{10 \text{ FRAMES}} = 1373 \text{ }^1\text{k} / \text{FRAME}$$
$$M_0 = 3538.2 \text{ }^1\text{k} \text{ (E-W DIRECTION)} \text{ OR } \frac{3538.2}{2} = 1769 \text{ }^1\text{k} / \text{FRAME}$$

AS ONLY ONE BAY IN THE NORTH-SOUTH DIRECTION,
THIS FRAME SHALL BE INVESTIGATED

$$M = 1373 \text{ }^1\text{k} \quad P = 362 \text{ }^1\text{k}$$
$$11' \times 11' \times 2'-6'' \text{ FTG} \quad Q_s = 5000 \text{ PSF}$$
$$\frac{1373 \text{ }^1\text{k}}{47'} = 29.2 \text{ }^1\text{k} \Rightarrow \text{NEGLECTIBLE EFFECT FROM WIND LOADING}$$

OVERTURNING DUE TO MOMENT IN COLUMN

$$M = 415 \text{ }^1\text{k} \quad P_u = 362 \text{ }^1\text{k}$$
$$B = 11'-0'' \quad e = \frac{415 \text{ }^1\text{k}}{362 \text{ }^1\text{k}} = 1.15' < B/6 \text{ USE CASE 1}$$
$$L = 11'-0''$$
$$B/6 = 11'/6 = 1.83'$$
$$q_{\max} = \frac{P}{A} + \frac{M}{S} = \frac{P}{BL} + \frac{M \cdot 6}{B^2 L} = \frac{362 \text{ }^1\text{k}}{(11')^2} + \frac{415 \text{ }^1\text{k}(6)}{(11')^3}$$
$$q_{\max} = 4.86 \text{ KSF} < 5 \text{ KSF} \quad \checkmark \text{ OK}$$
$$q_{\min} = \frac{P}{BL} - \frac{M \cdot 6}{B^2 L} = 1.12 \text{ KSF} \quad \checkmark \text{ OK}$$

Comparison

