329 INNOVATION BOULEVARD

PRESENTED BY:
JEREMY R. POWIS

APRIL 15TH, 2008

STRUCTURAL OPTION

PRESENTATION OVERVIEW

I. THESIS GOALS
II. PROJECT INTRODUCTION
   A. LOCATION
   B. BUILDING STATISTICS/BACKGROUND INFO
III. PROPOSAL
IV. STRUCTURAL DEPTH
   A. EXPANSION DESIGN
   B. BRACING DESIGN
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V. BREADTH STUDY: ARCHITECTURE
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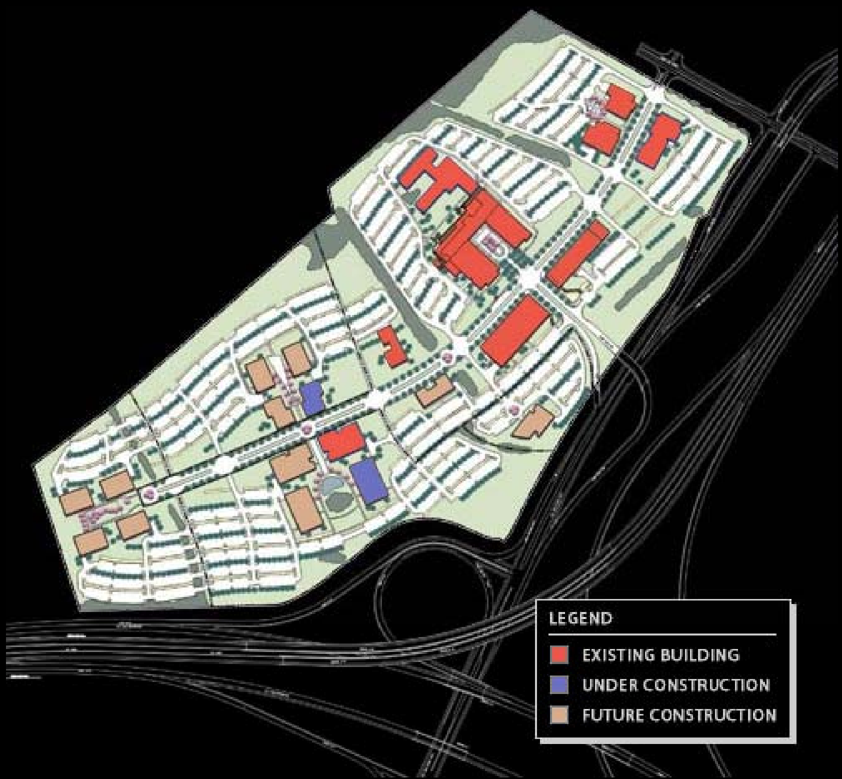
   B. FAÇADE REDESIGN
VI. BREADTH STUDY: MECHANICAL
   A. MECHANICAL DESCRIPTION
   B. MECHANICAL REDESIGN
VII. CONCLUSIONS/RECOMMENDATIONS
VIII. QUESTIONS/COMMENTS

THESIS GOALS

- TO ANALYZE AND REDESIGN THREE NECESSARY SYSTEMS OF 329 INNOVATION BOULEVARD DUE TO A TWO-STORY EXPANSION
  - STRUCTURAL – GRAVITY AND LATERAL MEMBERS
  - ARCHITECTURAL – FAÇADE REDESIGN AND ANALYSIS
  - MECHANICAL – HVAC SYSTEM REDESIGN AND ANALYSIS

SITE LOCATION



I. INNOVATION PARK

   I. ADJACENT TO PSU
   II. PRIME LOCATION FOR BUSINESSES
      I. EASY ACCESS TO RESEARCH AND TECHNOLOGY RESOURCES
   III. IMAGE TO LEFT SHOWS THE EXISITING BUILDINGS. TOPMOST PURPLE BUILDING IS 329 INN. BLVD.

GENERAL ARCHITECTURE

I. MATERIALS
   I. RED BRICK
   II. GLASS WINDOWS
   III. METAL PANELS

II. SURROUNDINGS
   I. THE PENN STATER
   II. 328 INN. BLVD.
      I. SAME DESIGNERS

BUILDING STATISTICS

I. PROJECT TEAM

- I. OWNER: C. B. RICHARD ELLIS
- II. L. ROBERT KIMBALL & ASSOC.
  - I. ARCHITECT
  - II. STRUCTURAL
  - III. ELECTRICAL
  - IV. MECHANICAL

BUILDING STATISTICS

I. GENERAL INFORMATION

I. **BUILDING FUNCTION:** COMMERCIAL OFFICES
II. **SIZE:** 87,000 SQ. FT.
III. **HEIGHT:** 4 STORIES, 58 FT. TALL
IV. **DATES OF CONSTRUCTION:** AUGUST 2007 – LATE 2008
V. **PROJECT COST:** PRIVATE (APPROX. $8,000,000)
VI. **PROJECT DELIVERY METHOD:** DESIGN/BID/BUILD

THESIS PROPOSAL

I. STRUCTURAL DEPTH

- I. TWO-STORY VERTICAL EXPANSION
  - I. WIND ANALYSIS
  - II. SEISMIC ANALYSIS
- II. RE-SIZING OF GRAVITY MEMBERS
- III. LATERAL REDESIGN
  - I. NEW LATERAL SYSTEM
  - II. SIZING OF MEMBERS
  - III. DESIGN OF CONNECTIONS

II. ARCHITECTURAL BREADTH

- I. REDESIGN OF FAÇADE
- II. THERMAL/MOISTURE ANALYSIS

III. MECHANICAL BREADTH

- I. REDESIGN OF MECHANICAL SYSTEM
- II. SIZING APPROPRIATE EQUIPMENT

EXISTING SYSTEM

I. FRAMING SYSTEM

- COMPOSITE SLAB ON METAL DECK WITH BEAMS AND GIRDERS
- LWC 3.5”
- 3” GALV. METAL DECKING
- TYP. BAY IS 30’x33’-3”

II. DESIGN LOADS

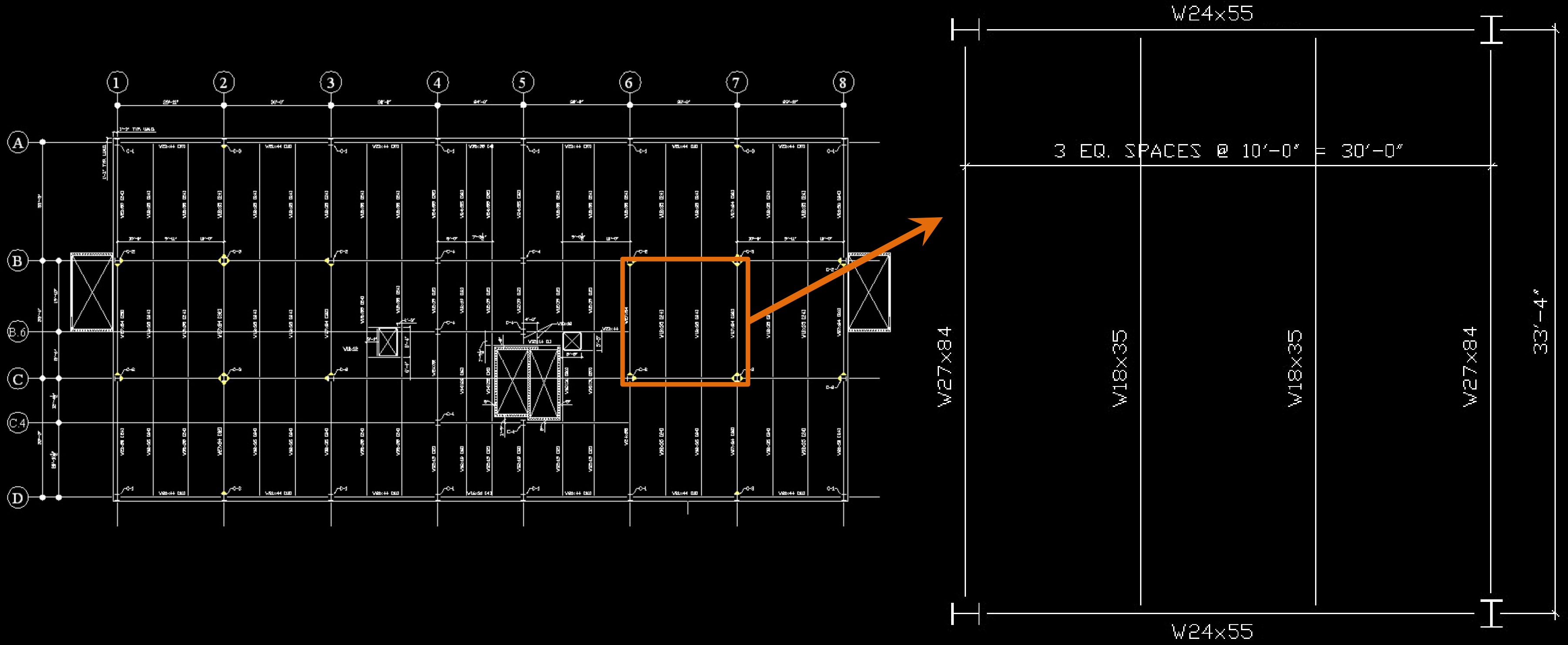
I. LIVE LOADS

I.	CORRIDORS	100 PSF
II.	STAIRS	100 PSF
III.	PUBLIC AREAS	100 PSF
IV.	OPEN OFFICE PLAN	100 PSF

II. DEAD LOADS

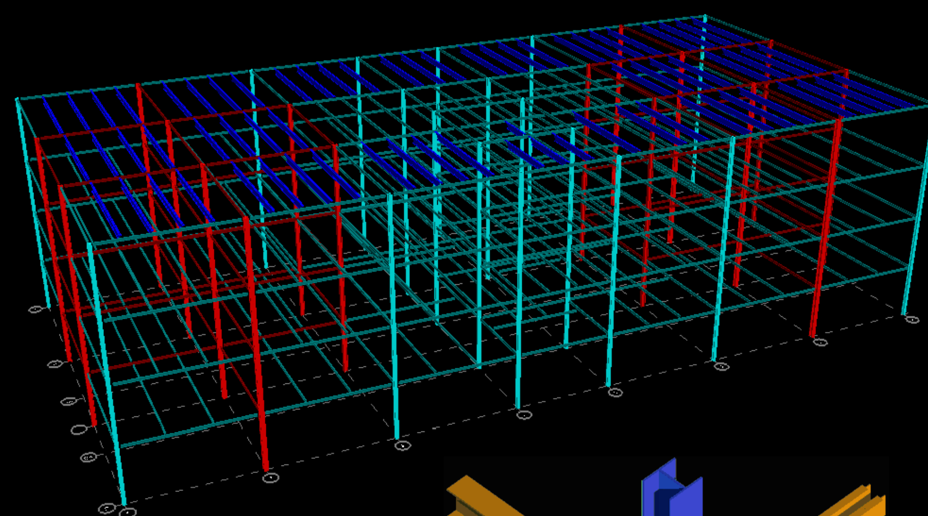
I.	PARTITIONS	20 PSF
II.	LWC	115 PCF
III.	MEP	5 PSF
IV.	METAL DECKING	2-3 PSF

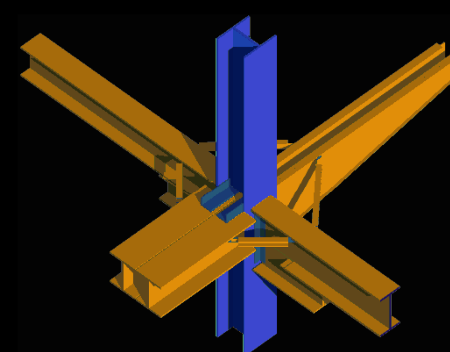
CURRENT TYPICAL FLOOR PLAN



CURRENT FRAMING SYSTEM

I. CURRENT LATERAL RESISTIVE SYSTEM
   I. MOMENT FRAMES
II. OPEN FLOOR PLAN
   I. ALLOWS FOR LARGE OPEN BAYS WITH MINIMAL OBSTRUCTIONS
   II. CREATES MORE TENANT SPACE





EXPANSION PARAMETERS

I. FLOOR PLAN
   I. EXISTING FLOOR PLAN AND CONSTRUCTION USED
      I. SYMMETRIC
      II. EFFICIENT

II. HEIGHTS
   I. TWO-STORY EXPANSION WOULD INCREASE HEIGHT FROM 58’ TO 86’

TWO-STORY EXPANSION

I. NEW LOADS: WIND

II. STORY FORCES

T/ Met. Panel (86')	**88.6 Kips**
Level 6 (60')	**74.9 Kips**
Level 5 (56')	**72.7 Kips**
Level 4 (42')	**60.0 Kips**
Level 3 (28')	**65.0 Kips**
Level 2 (14')	**61.6 Kips**

YIELDS A OVERTURNING MOMENT OF 21,400'^{K}

Wind Loading According to ASCE7-05	
Basic Wind Speed	90 MPH
Exposure Category	C
Enclosure Classification	Enclosed
Building Category	II
Importance Factor	1.0
Internal Pressure Coefficient	0.18

North/South Wind Pressure Values

z (ft)	Kz	q_z	$P_{windwardl}$(PSF)	$P_{leeward}$(PSF)	$P_{sidewall}$(PSF)	P_{total}(PSF)
0-15	0.85	14.98	12.84	-8.43	-14.83	21.27
20	0.90	15.86	13.59	-8.43	-14.83	22.02
25	0.95	16.74	14.35	-8.43	-14.83	22.78
30	0.98	17.27	14.80	-8.43	-14.83	23.23
40	1.04	18.33	15.71	-8.43	-14.83	24.14
50	1.09	19.21	16.46	-8.43	-14.83	24.89
60	1.14	20.09	17.22	-8.43	-14.83	25.65
70	1.17	20.62	17.67	-8.43	-14.83	26.10
80	1.21	21.33	18.28	-8.43	-14.83	26.71
90	1.24	21.86	18.73	-8.43	-14.83	27.16

NEW LATERAL RESISTIVING SYSTEM

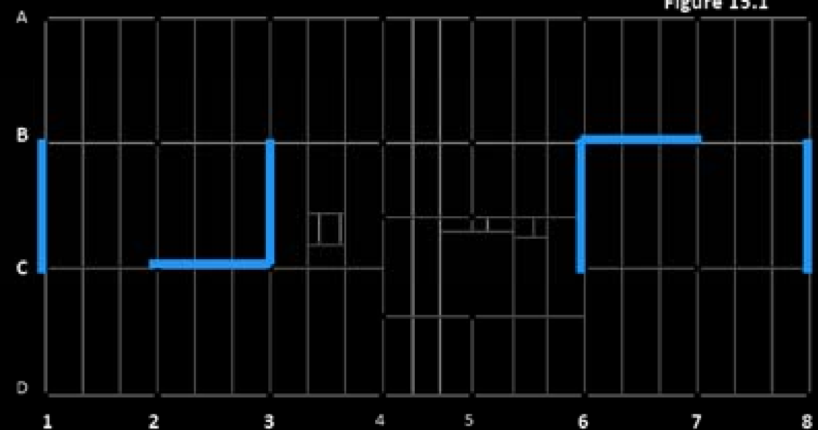
I. BRACED FRAMES

I. NEEDED TO RESIST GREATER LATERAL LOADS
II. CREATE OBSTRUCTIONS IN BAYS

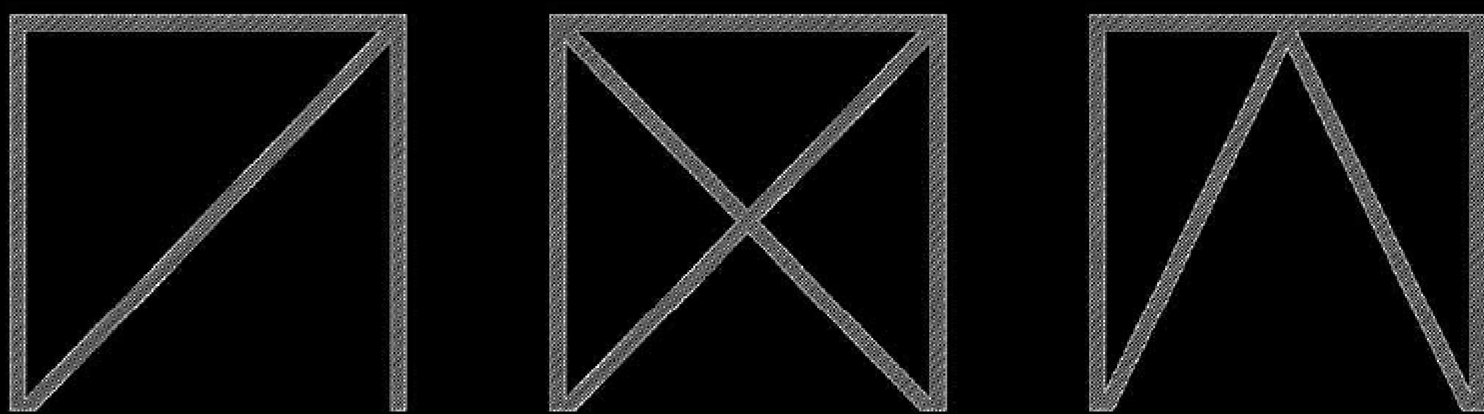
II. PLACEMENT CONSIDERATIONS

I. CENTER OF RIGIDITY/CENTER OF MASS
II. PREVIOUS ARCHITECTURAL ASPECTS
III. POSSIBLE ARCHITECTURAL LAYOUTS WITH BRACED FRAMES

Figure 15.1



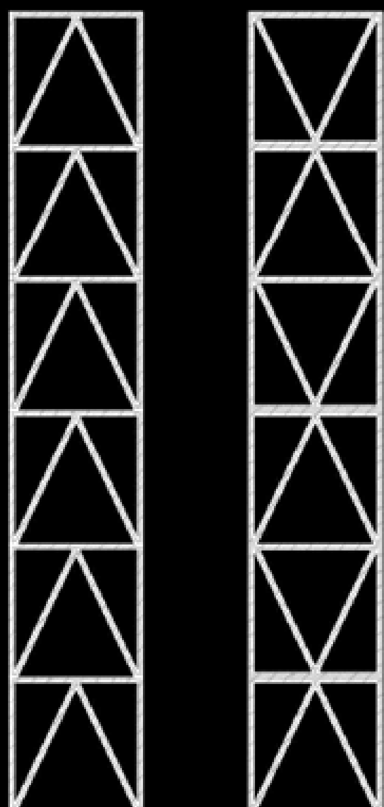
TYPES OF BRACES CONSIDERED



Diagonal Bracing   X-Bracing   Chevron Bracing

HSS SHAPES CHOSEN FOR BRACES

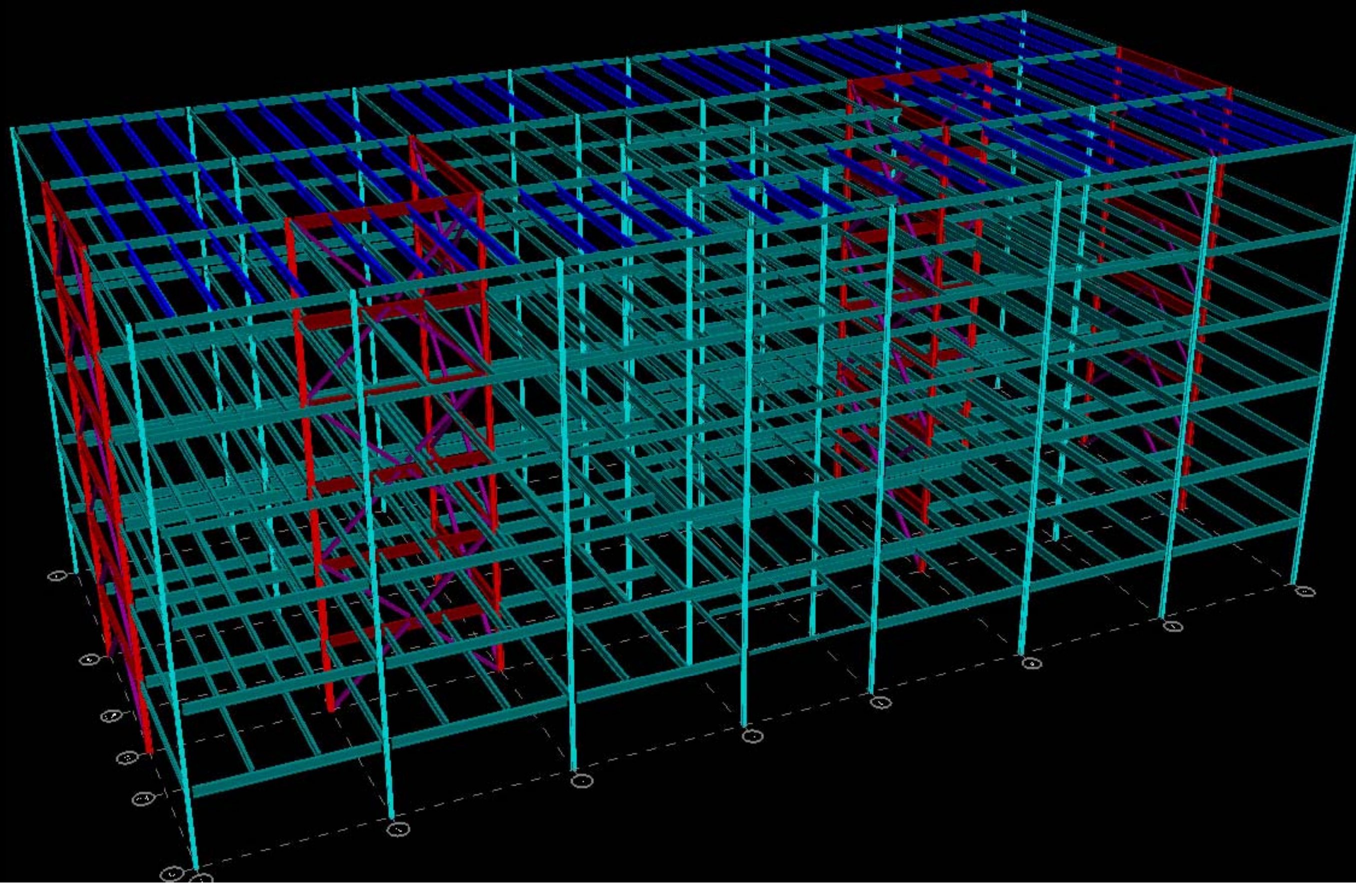
BRACE SCHEMATICS



I. EXTERIOR FRAMES
   I. UTILIZED “INVERTED V” CHEVRON BRACING
   II. CREATED ACCESS TO THE STAIRWELLS USING EXISTING PLAN

II. INTERIOR FRAMES
   I. UTILIZED ALTERNATING “INVERTED V” AND “V” CHEVRON BRACING
   II. CREATED A TWO-STORY “X” BRACE

3D MODEL



DRIFT AND TORSION ANALYSIS

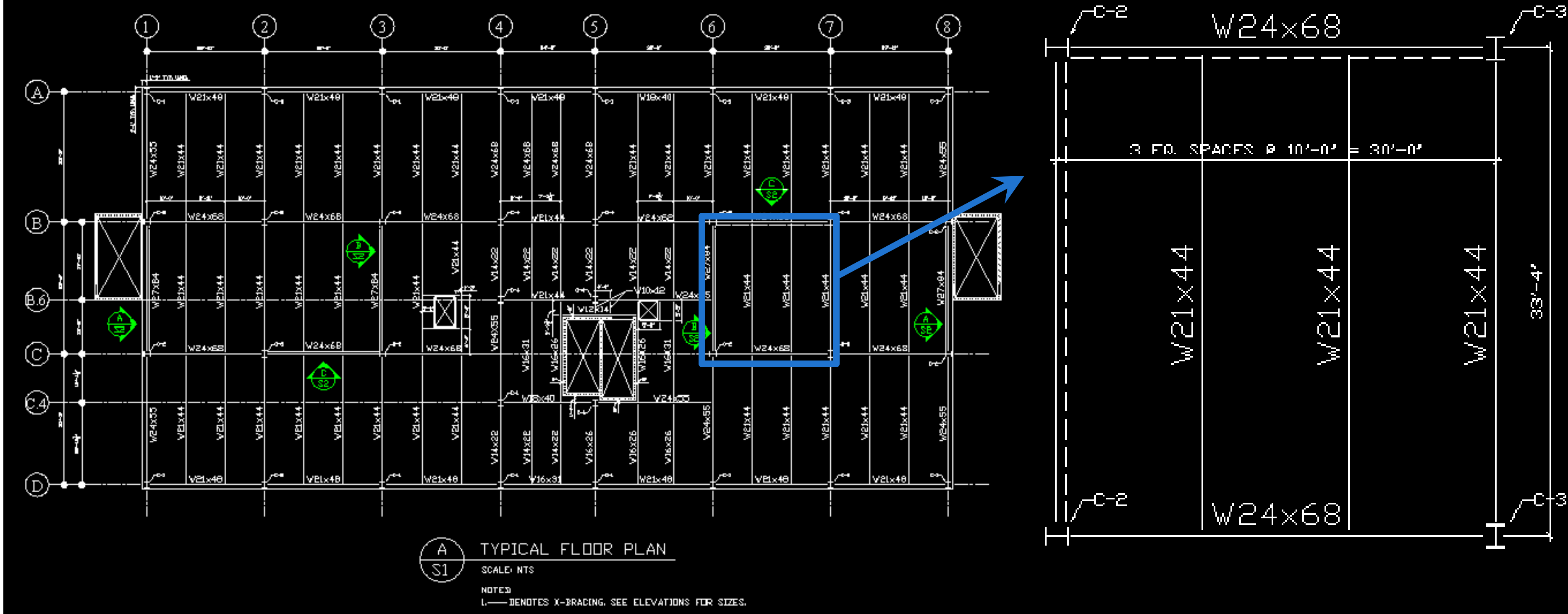
Critical Displacements

Floor	Height (ft.)	FF Height (ft.)	H/400 (in.)	RAM Disp. Values (in.)	RAM Drift Values (in.)	H/400 (in.)
Roof	86	16	2.58	0.59	0.09	0.48
6th Floor	70	14	2.58	0.49	0.10	0.42
5th Floor	56	14	2.58	0.39	0.11	0.42
4th Floor	42	14	2.58	0.29	0.11	0.42
3rd Floor	28	14	2.58	0.18	0.10	0.42
2nd Floor	14	14	2.58	0.08	0.08	0.42
1st Floor	0	N/A	N/A	N/A	N/A	N/A

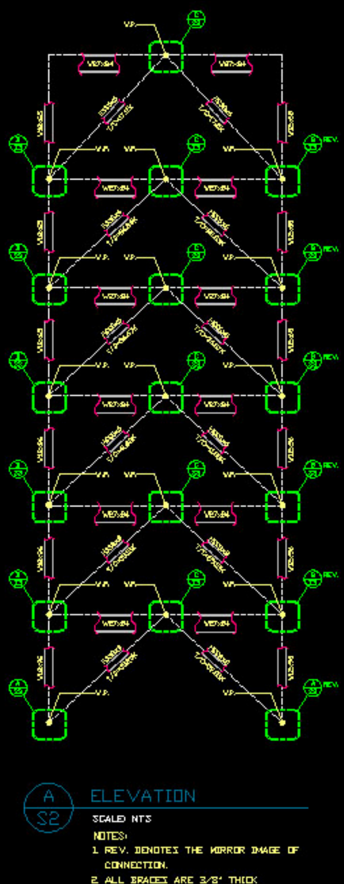
Torsion Values

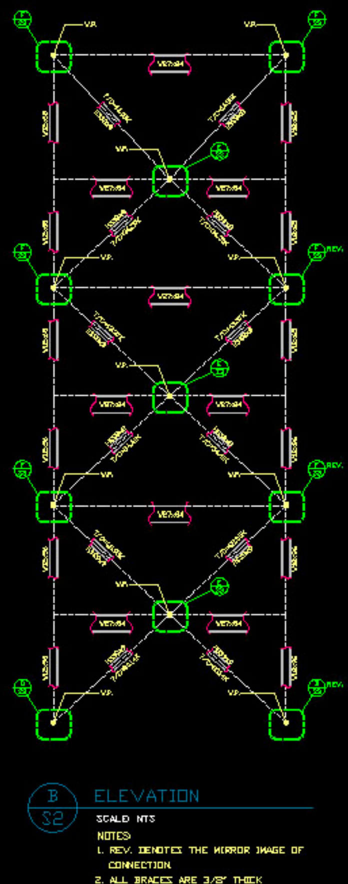
Floor	Centers of Rigidity		Centers of Mass	
	X (Ft.)	Y (Ft.)	X (Ft.)	Y (Ft.)
6th Floor	102.35	49.78	101.96	49.88
5th Floor	102.41	49.81	101.68	50.24
4th Floor	102.50	49.84	101.68	50.25
3rd Floor	102.30	49.88	101.68	50.26
2nd Floor	101.92	49.92	101.68	50.26
1st Floor	101.92	49.91	101.68	50.93

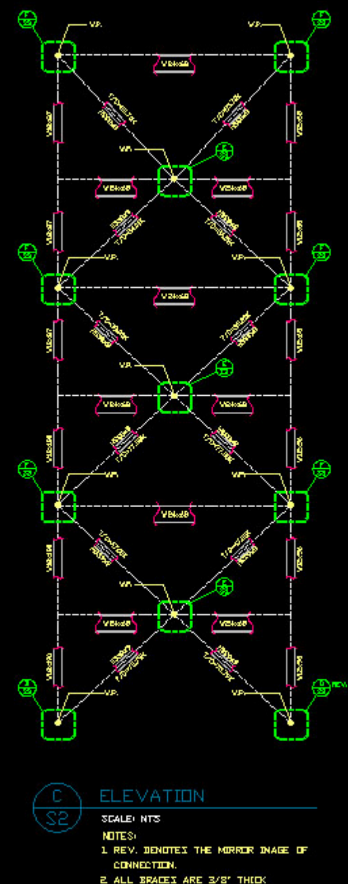
NEW TYPICAL FLOOR PLAN

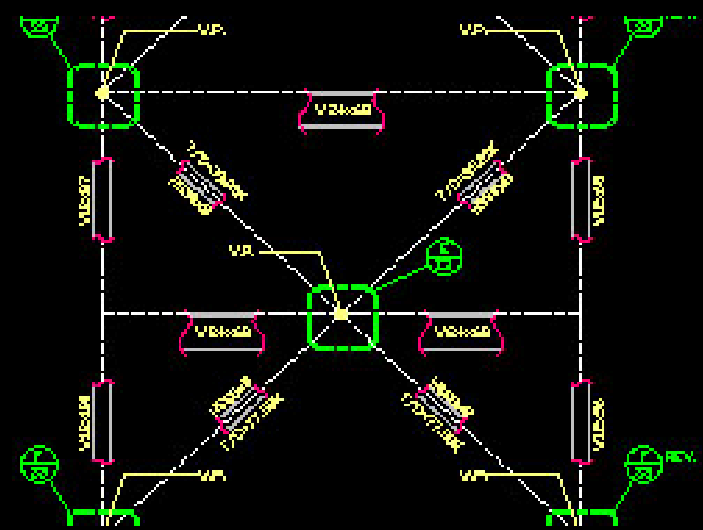


ELEVATIONS



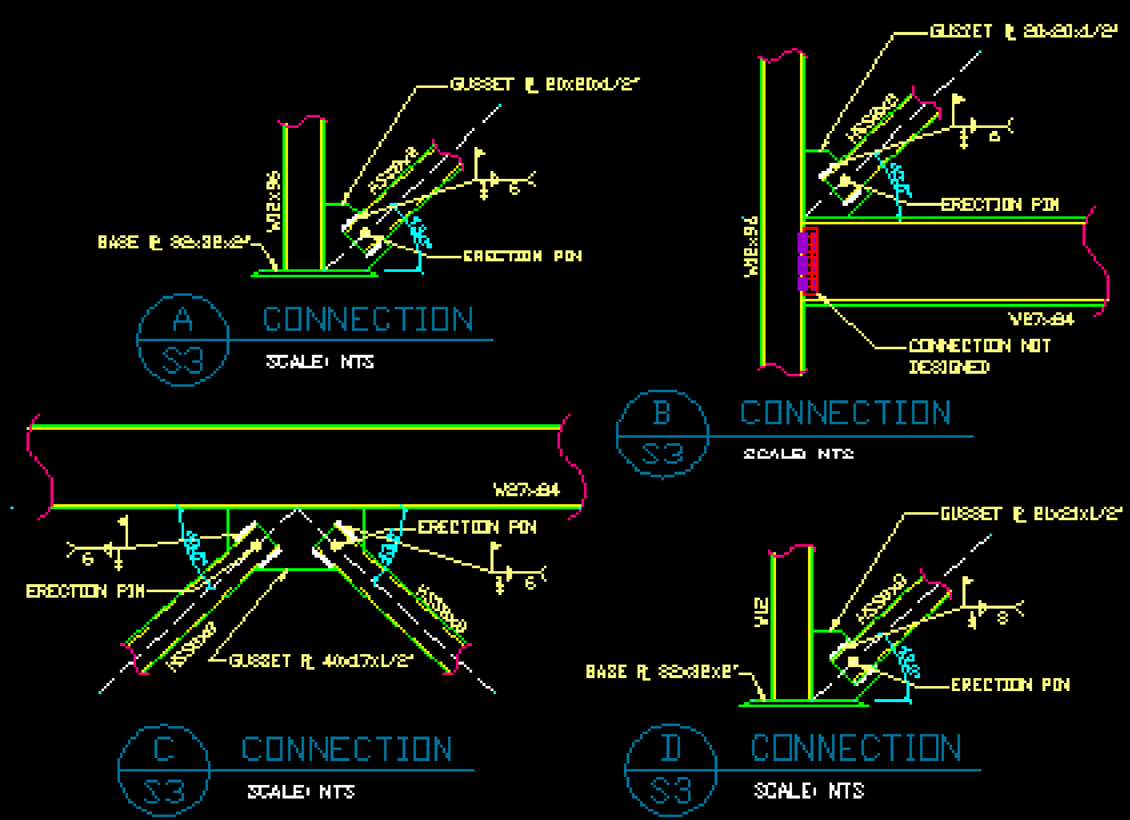






REFER TO PAGES 28-29 OF REPORT

CONNECTIONS



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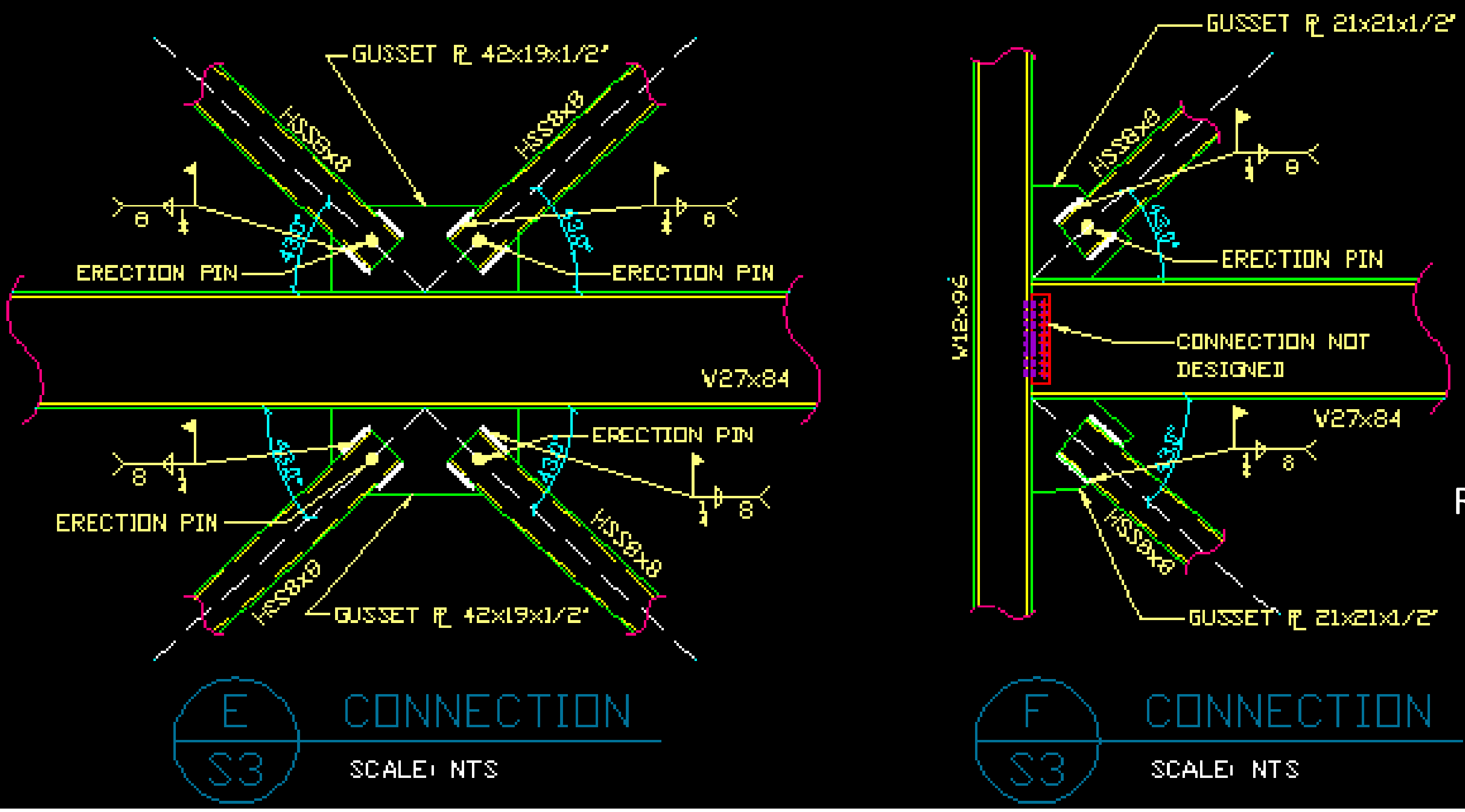
OF REPORT

CONNECTIONS



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COST ANALYSIS

Moment Connection Costs

Material	Cost/Unit	Unit/Connection	# of Connections Per Floor	# of Floors	Total Cost ($)
Bolts	$10/bolt	18	36	6	38880.00
Welds	$35/lb	4	36	6	30240.00
Plates				(+ 10%)	6912.00
Total					**76032.00**

I. COSTS OF RAW MATERIALS

II. RESULTS

- BOTH CONNECTION COSTS BEING ESTIMATES, THE MOMENT CONNECTIONS AT $76,000 EASILY DOUBLES THAT OF THE BRACED CONNECTIONS ($32,000)

Braced Connection Costs

Material	Cost/Unit	Size	Tons/Member	Quantity	Total Cost ($)
		HSS9x9x3/8	0.439	16	4916.8
HSS	$700/ton	HSS8x8x3/8	0.386	40	10808
		HSS6x6x3/8	0.281	16	3147.2
		Connection Type	**SF of Plare/Connection**		
		A	2.80	4	274.40
		B	2.80	20	1372.00
Plates	$24.50/SF	C	4.70	12	1381.80
		D	3.00	8	588.00
		E	11.10	12	3263.40
		F	6.10	24	3586.80
		Connection Type	**Pounds/Connection**		
		A	0.334	4	50.77
		B	0.334	20	253.84
Welds	$35/lb	C	0.668	12	304.61
		D	0.444	8	134.98
		E	1.777	12	810.31
		F	0.889	24	810.77
Total					**31703.67**

CONCLUSIONS

I. IMPACT OF EXPANSION

I. REQ'D REDESIGN OF GRAVITY AND LATERAL MEMBERS
II. CREATED TWICE THE OVERTURNING MOMENT

II. LATERAL RESISTIVE SYSTEM

I. HSS CHEVRON BRACING UTILIZED
II. SIZES RANGED FROM HSS6x6x3/8 TO HSS9x9x3/8

III. CONNECTIONS

I. SIMPLIER CONNECTIONS ARE NEEDED FOR BRACING
II. ¼" WELDS USED WITH ½" PLATES
III. WELDS RANGED FROM 6-8" LONG

IV. OVERALL

I. EXTREMELY RIGID SYSTEM
II. ADVANTAGES IN COSTS OVER MOMENT CONNECTIONS
III. MINIMAL CHANGES TO GRAVITY MEMBERS

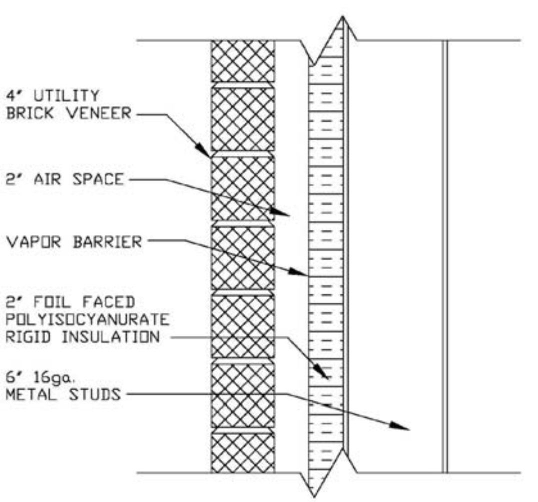
ARCHITECTURE BREADTH

FAÇADE STUDY

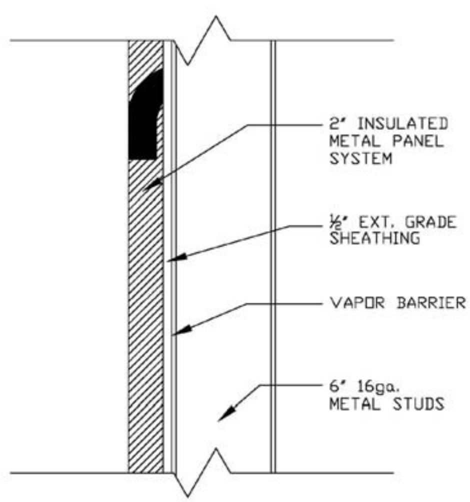
I. FAÇADE STUDY OF INNOVATION PARK

"NEW-LOOK" 329 INN. BLVD.

THERMAL ANALYSIS



BRICK VENEER SECTION



METAL PANEL SECTION

Material	R-Value		U-Value
	Per Inch	Per Thickness	
Polyisocyanurate (Foil Faced)	7.20	14.40	0.0694
Brick 4" Common		0.80	1.2500
1/2" Fiberboard Shething		1.32	0.7576
ABP Wall Panel		16.00	0.0625
5500 ISOWEB Window Type F		5.41	0.1850

$$ETTV = 12(1-WWR)U_W + 3.4(WWR)U_F + 211(WWR)(CF)(SC) \quad \text{(Metric)}$$

$$ETTV < 50\ W/m^2$$

THERMAL ANALYSIS

North/ South Direction (English)

Material	Area (ft^2)	R-Value	U-Value	A*U
Opaque Wall				
Polyisocyanurate	9418	14.40		
Brick	9418	0.80		
Total		**15.20**	**0.0658**	**619.61**
Fiberboard	3928	1.32		
Wall Panel	3928	16.00		
Total		**17.32**	**0.0577**	**226.79**
Fenestration				
Window	4414	5.41	0.1850	816.59
Total				**816.59**

North/ South Direction (Metric)

Material	Area (m^2)	R-Value	U-Value	A*U
Opaque Wall				
Polyisocyanurate	875	2.52		
Brick	875	0.14		
Total		**2.66**	**0.3757**	**328.70**
Fiberboard	365	0.23		
Wall Panel	365	2.80		
Total		**3.03**	**0.3297**	**120.33**
Fenestration				
Window	410	0.95	1.0564	433.10
Total				**433.10**

$$ETTV = 12((328.7 + 120.33)/1650) + 3.4(433.1/1650) + 211(433.1/1650)(0.80)(1.00)$$

$$ETTV = 48.5\ W/m^2 < 50\ W/m^2$$

MOISTURE ANALYSIS

Inside Surface Film C-Value From ASHRAE: C = 8.3

$R_{surface\ film}$ = 1/8.3 = 0.1205

Surface Temperature Index,

$Ti_{surface}$ = $R_{surface\ film}/R_{total}$
= 0.1205/(0.1205 + 0.95)

= 0.114

$T_{Dewpoint,\ Interior} < T_{Int} - Ti_{surface}\ (T_{int} - T_{Ext})$

Design Values:

T_{Int} = 70 °F

Average Temperatures: **Winter (Low):** **T_{Ext} = 18 °F**

Summer (High): **T_{Ext} = 81 °F**

Winter: **$T_{Dewpoint,\ Interior}$** < 70 + 0.114(70 – 18)

< 76 °F

Summer: **$T_{Dewpoint,\ Interior}$** < 70 - 0.114(70 – 81)

< 68 °F

THE INTERIOR TEMPERATURE SHOULD NOT > 76 °F IN THE WINTER AND SHOULD NOT < 68 °F IN THE SUMMER

CONCLUSIONS

I. "NEW-LOOK" FAÇADE

- I. INTENDED TO FIT THE MOLD OF IP
  - I. SUBJECTIVE
  - II. UTILIZES THEMES FROM PARK

II. THERMAL ANALYSIS

- I. DICTATED:
  - I. SIZE OF WINDOWS
  - II. TYPE OF WINDOWS
- II. ACHIEVED THERMAL COMFORT LEVEL

III. MOISTURE ANALYSIS

- I. PERFORMED TO AVOID CONDENSATION
- II. PRODUCED DESIGN PARAMETERS FOR MECHANICAL SYSTEM

IV. OVERALL

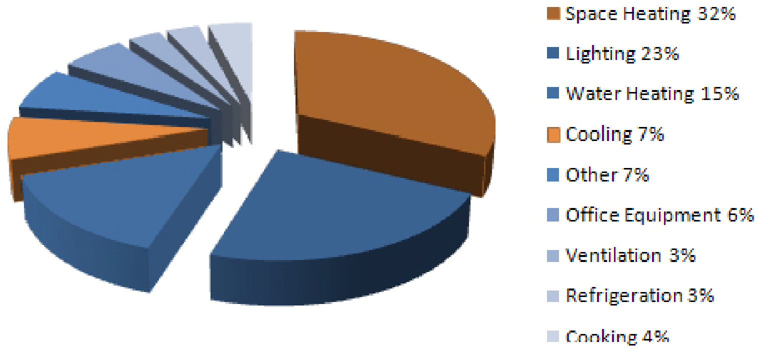
- I. COSTLY MATERIALS
- II. THERMAL COMFORT LEVEL ACHIEVED
- III. CONDENSATION NOT ALWAYS BAD

MECHANICAL BREADTH

REASONS FOR CHANGE

I. CURRENT MECH. SYSTEM
   I. HEAT PUMPS
      I. 14 INDOOR UNITS
      II. 4 ROOFTOP UNITS
      III. PROVIDES 28,000 CFM WHICH YIELDS 0.33 CFM/SF
   II. TEMPORARYY
      I. DUCTWORK LABELED WITH TEMPORARY GRILLES

II. OFFICE BUILDING ENERGY USAGE BREAKDOWN



HEAT PUMPS VS. VAV SYSTEM

Heat Pump Advantages
1 Even temperatures
2 Comfortable humidity levels in winter
3 Less noise and odor
4 No pilot light or vent
5 No seasonable change-over
6 Only one fuel bill
7 May supply hot water w/ excess heat

Heat Pump Disadvantages
1 Unable to operate at low temperatures, which requires a back-up system
2 People find the air supplied to be "cold" during the winter

VAV Advantages
1 Produces minimal margin of error from the specified desired temperature
2 Contributes significantly to the efficiency of the system
3 Individually controlled zones (as small as individual rooms)
4 Little cost added to operational cost to run the system
5 Requires minimal maintenance

VAV Disadvantages
1 Latent heat may cause issues in auditoriums and conference rooms
2 Minimum outside air requirements must be met
3 Decreased air temperature may lead to poor dispersion of the tempered air
4 Little control over pressurization
5 Equipment located just above the ceiling can create noise

I. VAV CHOSEN

- VAV BECOMING A TREND IN OFFICES OVER THE PAST 5 YEARS
- MANY DISADV. DON'T APPLY TO OFFICE SPACES
- ZONES ALLOW MORE CONTROL FOR TENANTS

TRACE® 700 DESIGN OUTPUT

SYSTEM SUMMARY

DESIGN AIRFLOW QUANTITIES

By PSUAE

		MAIN SYSTEM						
		Outside	Cooling	Heating	Return	Exhaust	Auxiliary System Supply	Room Exhaust
		Airflow	Airflow	Airflow	Airflow	Airflow	Airflow	Airflow
System Description	System Type	cfm	cfm	cfm	cfm	cfm	cfm	cfm
System - 001	Variable Volume Reheat	17,622	145,609	43,891	145,609	17,622	0	0
Totals	(30% Min Flow Default)	17,622	145,609	43,891	145,609	17,622	0	0

Note: **Airflows on this report are not additive because they are each taken at the time of their respective peaks.**
To view the balanced system design airflows, see the appropriate Checksums report (Airflows section).

Project Name: 329 Innovation Boulevard — TRACE® 700 v4.1

Dataset Name: P:\Thesis\Research\Mechanical Breadth\329 Inn Boul System.trc — Alternative - 1 Design Airflow Quantities report page 1

EQUIPMENT SIZING

VAV BOX SIZING

 # VAV Boxes = 145,609 cfm/(2 Zones)(6 Floors)(3,000 cfm/box)
= **4.04**

Try 5 Boxes Per Zone:

VAV Box Size (CFM) = 145,609 cfm/(2 Zones)(6 Floors)(5 Boxes/Zone)
= 2,430 CFM

Krueger KQFP Ultra-Quiet VAV units will be used (Total CFM = 2960 > 2430 CFM). The unit size is 7, and the inlet size is 16.

VAV DUCT SIZING

Ductulator Method:

Air Volume: 2,430 CFM

Friction Per 100 Feet of Duct: 0.25

Ductulator Checks: Rectangular Duct Possibilities:

15”x15”
18”x12”
16”x14

Other Ductulator Value: Velocity = 1700 FPM

CONCLUSIONS

I. EXISTING SYSTEM

I. TEMPORARY AND WOULD NEED REDESIGN ANYWAY.

II. VAV SYSTEM

I. EACH ZONE CAN CONTROL TEMP.
II. MORE COSTLY UPFRONT
III. CHEAPER MAINTENANCE AND OPERATIONAL COSTS
IV. SHIFT TO VAV SYSTEMS IN OFFICES

III. EQUIPMENT SIZES

I. MULTIPLE DUCT SIZES
II. VAV BOX NUMBER ABLE TO INCREASE OR DECREASE
III. ONE AHU WAS UTILIZED TO ALLEVIATE COORDINATION PROBLEMS

IV. OVERALL

I. MORE COST EFFICIENT
II. PROVIDES MORE CFM/SF
III. ABIDES TO ASHRAE STANDARD 62.1-2007

FINAL CONCLUSIONS/RECOMMENDATIONS

I. STRUCTURAL SYSTEM

I. BRACED FRAMES CREATED AN EXTREMELY RIGID BUILDING
II. MINIMAL CHANGES IN GRAVITY MEMBER SIZES IMPLICATE SAVINGS DUE TO TIME TO REDESIGN
III. THE COST OF RAW MATERIALS IS MUCH LESS FOR BRACED CONNECTIONS THAN MOMENT CONNECTIONS

II. ARCHITECTURAL SYSTEM

I. NEW FAÇADE STILL STICKS TO IP MOLD
II. THERMAL ANALYSIS DICTATED SELECTION OF MATERIALS
III. SAVINGS FROM STRUCTURAL ABSORBED BY MAT. COSTS
IV. EXTISTING FAÇADE SUFFICIENT

III. MECHANICAL SYSTEM

I. NEEDED REDESIGN REGARDLESS
II. VAV SYSTEM SEES LONG-TERM BENEFITS

IV. OVERALL

I. AN EXPANSION = MORE WORK
II. ALL OF THE NEW SYSTEMS FEASIBLE

ACKNOWLEDGEMENTS

CHRIS BOWERS, OF L. ROBERT KIMBALL & ASSOCIATES

PROFESSOR M. KEVIN PARFITT

THE AE FACULTY

MY FAMILY

AND LAST, BUT NOT LEAST

MY FELLOW AE'S

Any Questions/Comments?