J.B. BYRD ALZHEIMER'S CENTER & RESEARCH INSTITUTE

Raffi Kayat| Structural Option
Faculty Advisor: Dr. Ali M. Memari

Tampa, FL

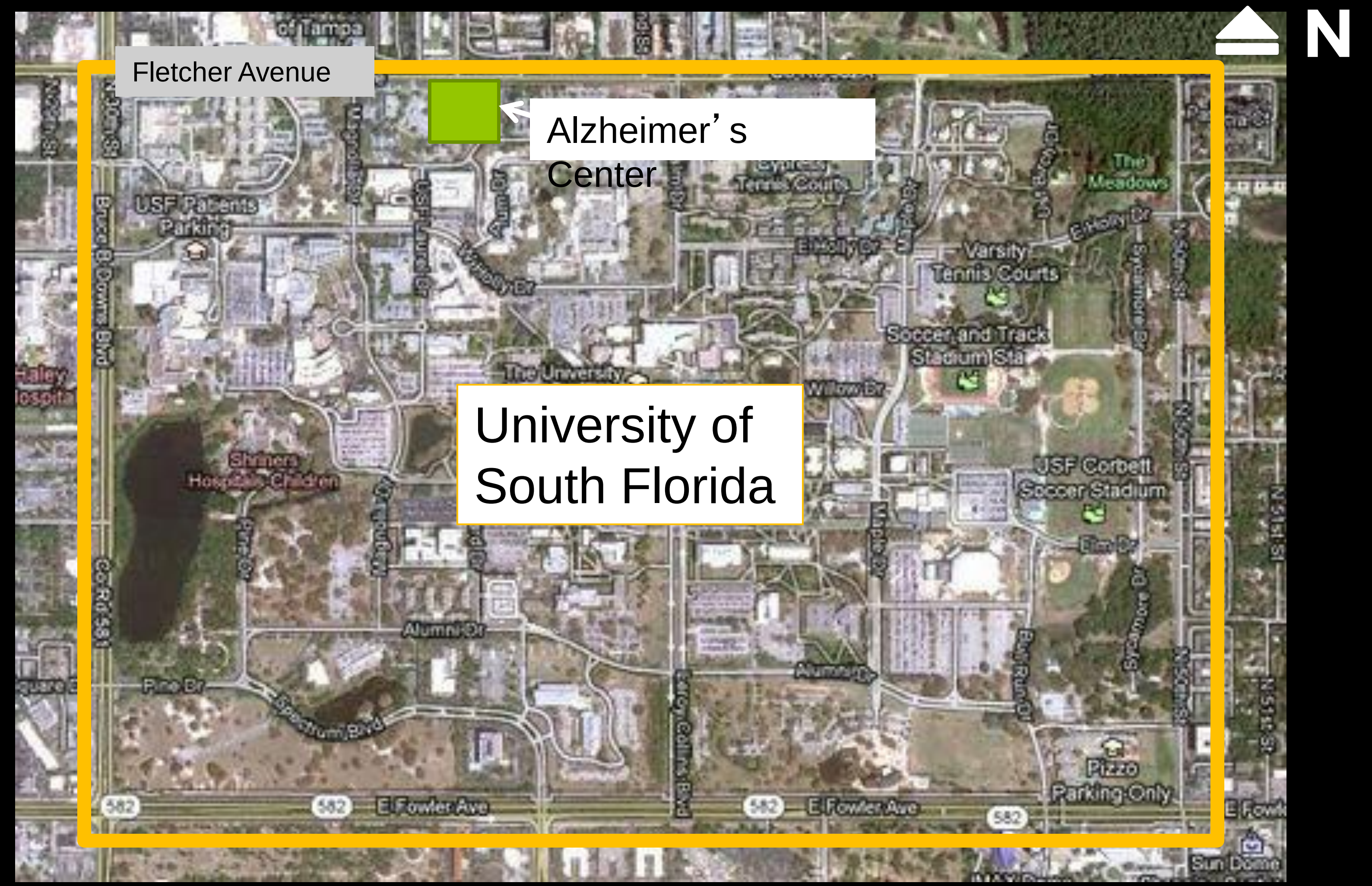
Senior Thesis 2012

J.B. Byrd Alzheimer’s Center

BUILDING INTRODUCTION

- **Building Introduction**
- Existing Structural System
- Problem Statement
- Proposed Solution
- Fixed Base Design
- Base Isolation Design
- Comparison of Designs
- Sustainability Breadth: Viability Study
- Questions/Comments

- **Location**



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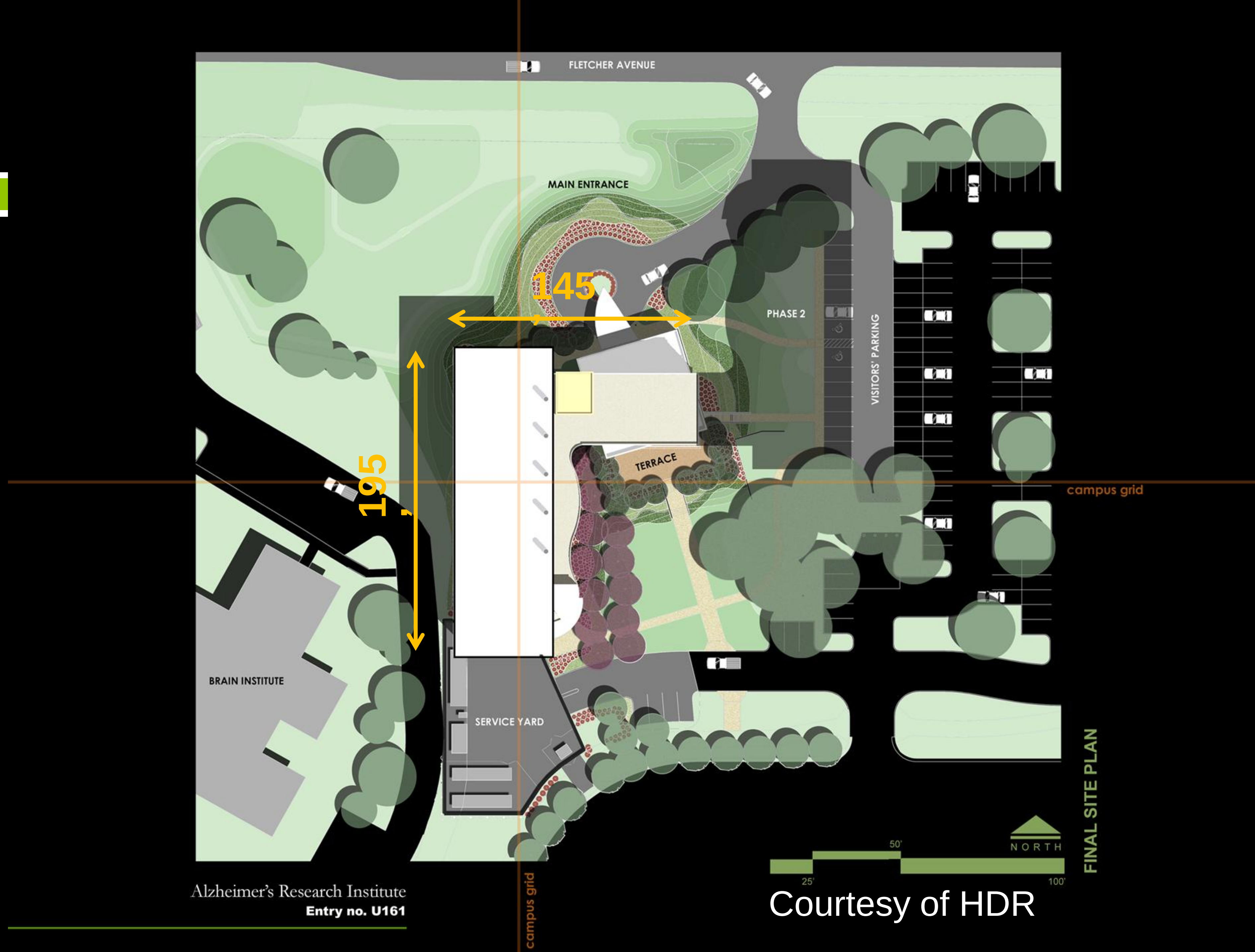
- **Location**
- **Size**
  108,000 SF



Courtesy of HDR

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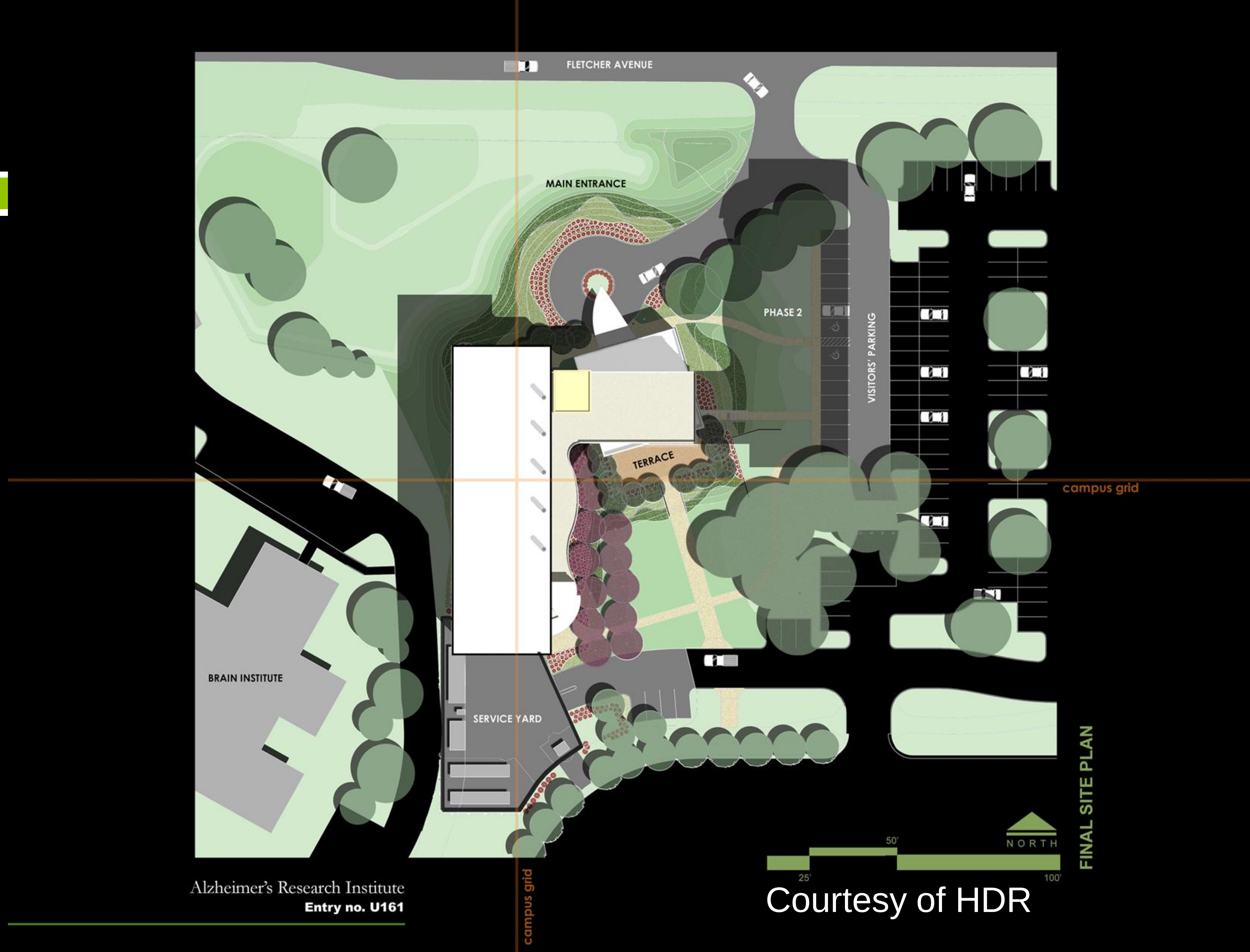
- **Location**
- **Size**
  108,000 SF
- **Total Height**
  116’



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- **Location**
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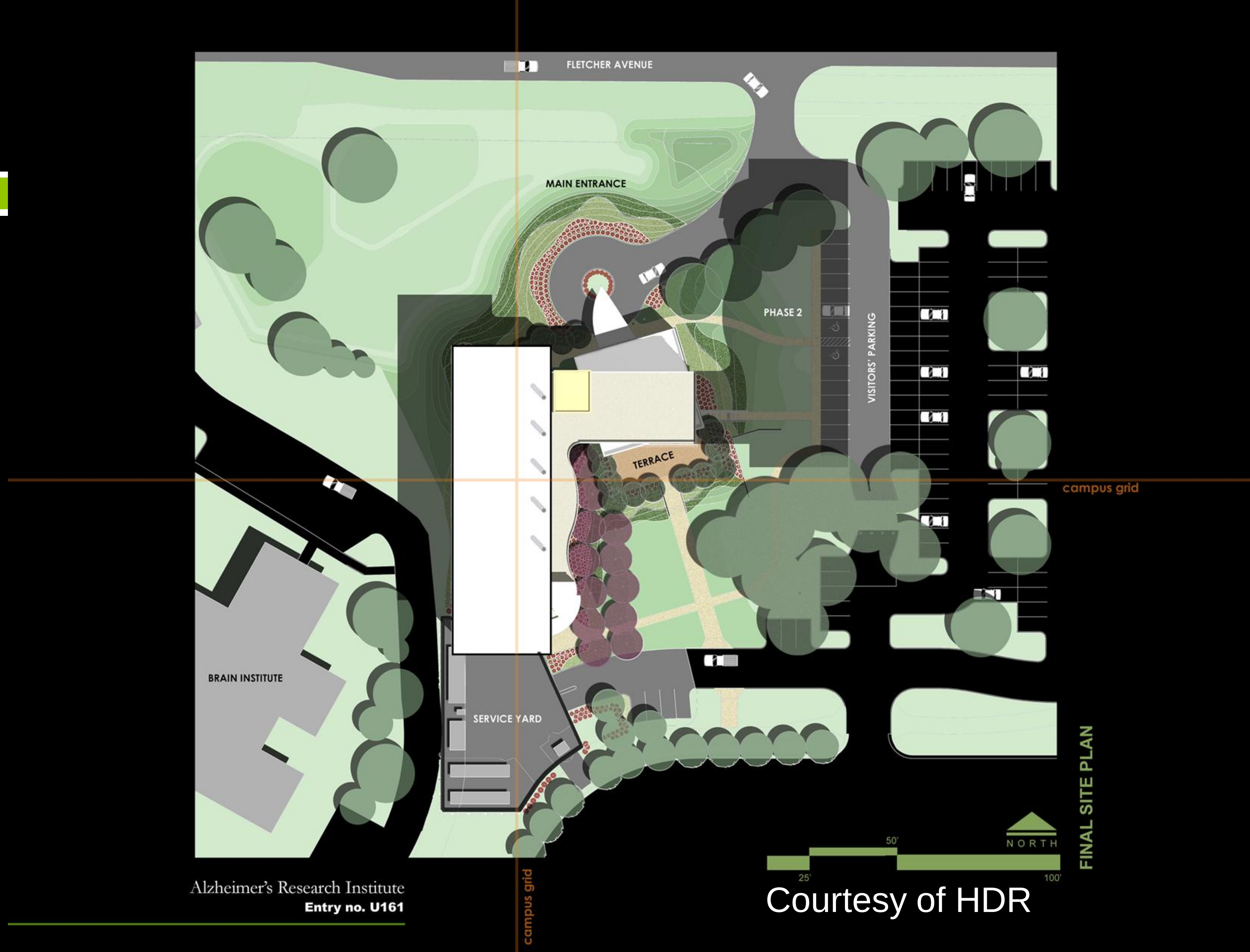
- **Total Height**
  116'
- **Cost**
  $22,000,000



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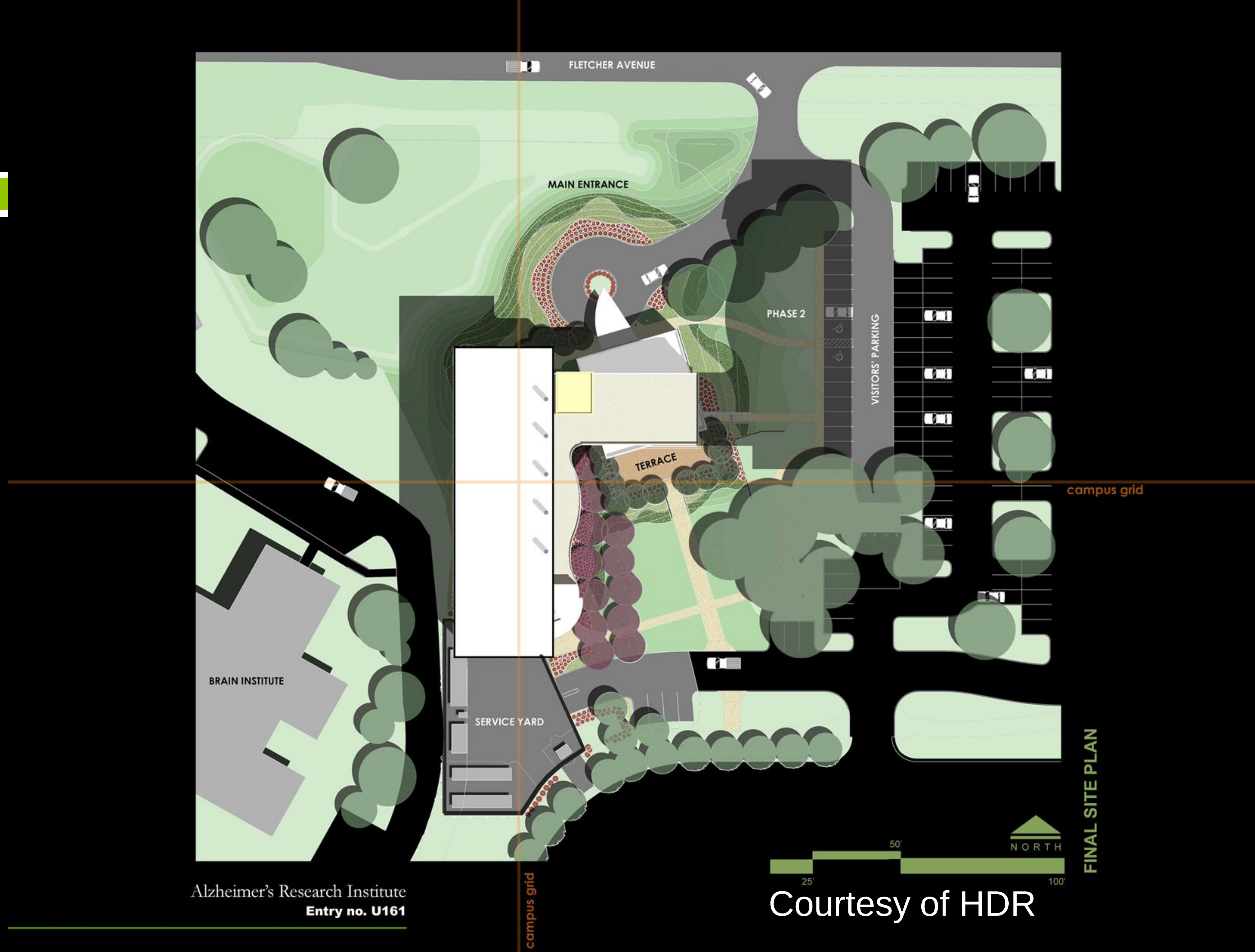
  116’
- **Cost**
  $22,000,000
- **Construction**
  February 2006 to July 2007



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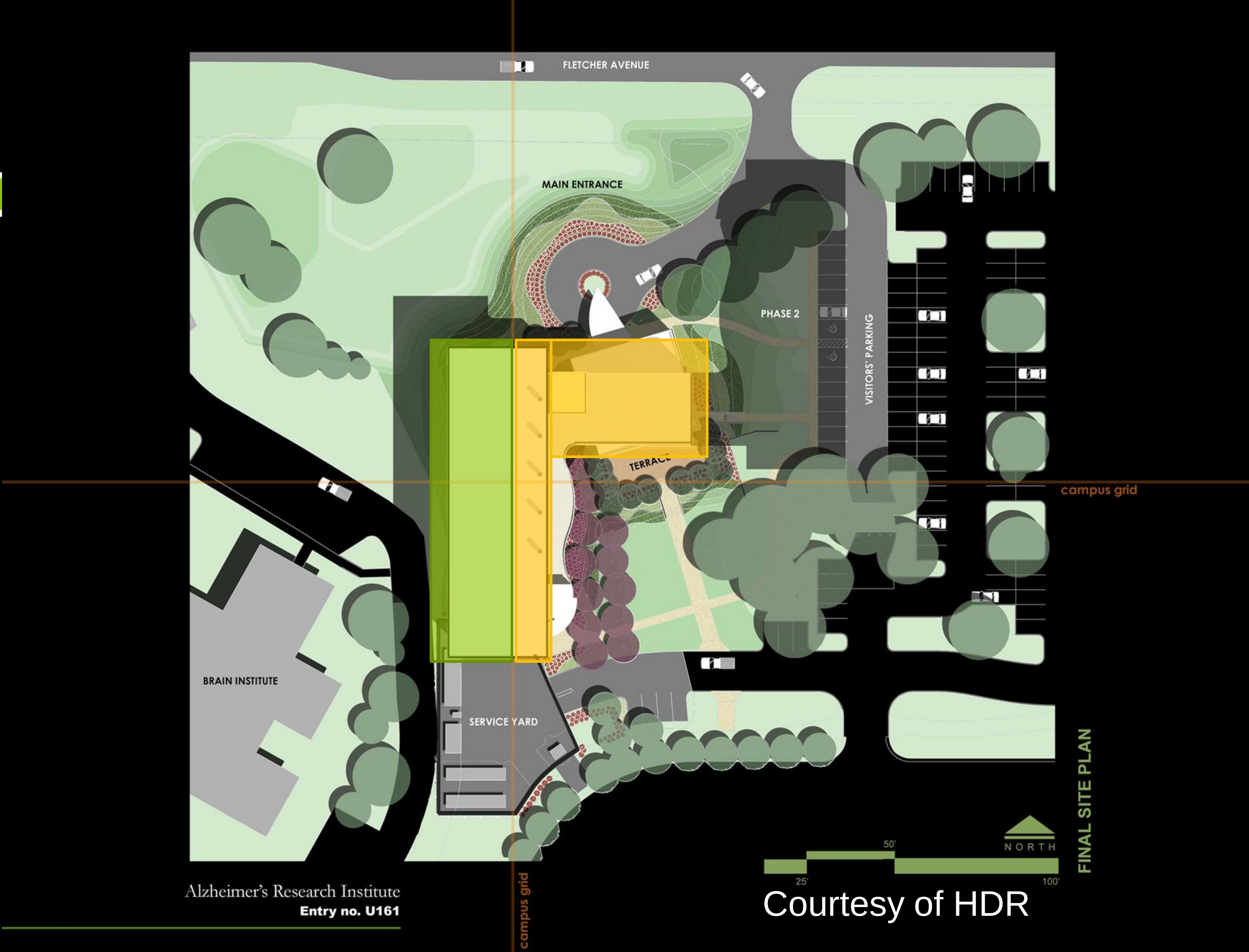
- **Occupancy**
  Business and Research



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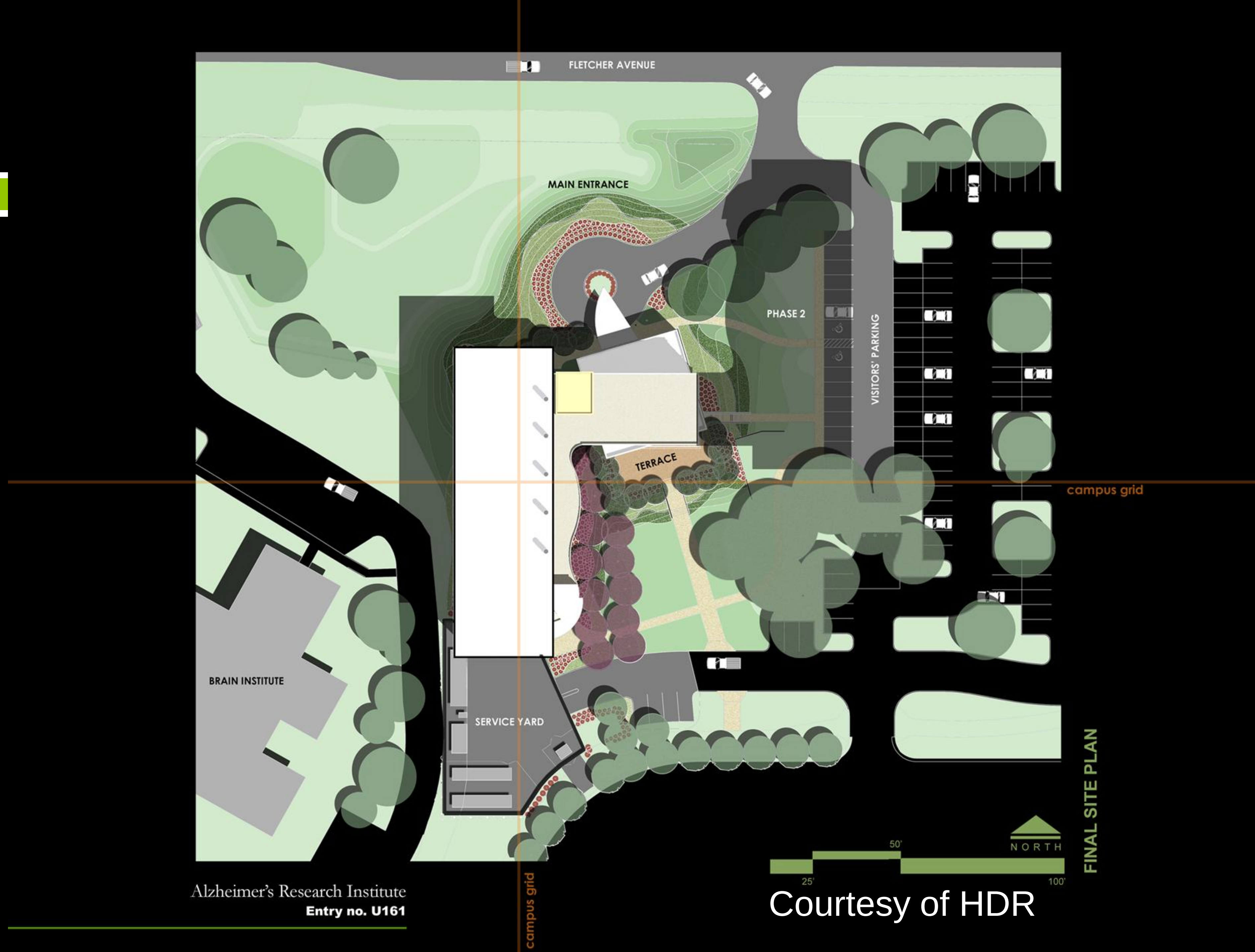
- **LEED Silver**



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PROJECT TEAM

- Building Introduction
- Existing Structural System
- Problem Statement
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- Questions/Comments

Courtesy of HDR

- **Owner**
  J.B. Byrd Alzheimer’s Center
- **General Contractor & Construction Management**
  Turner Construction
- **Architecture**
- **Structural**
- **Mechanical**
- **Electrical**
- **Plumbing**

Turner

HDR

HDR,Inc

EXISTING STRUCTURAL SYSTEM

- Cast-in-place concrete mat-slab foundation

EXISTING STRUCTURAL SYSTEM

- Building Introduction
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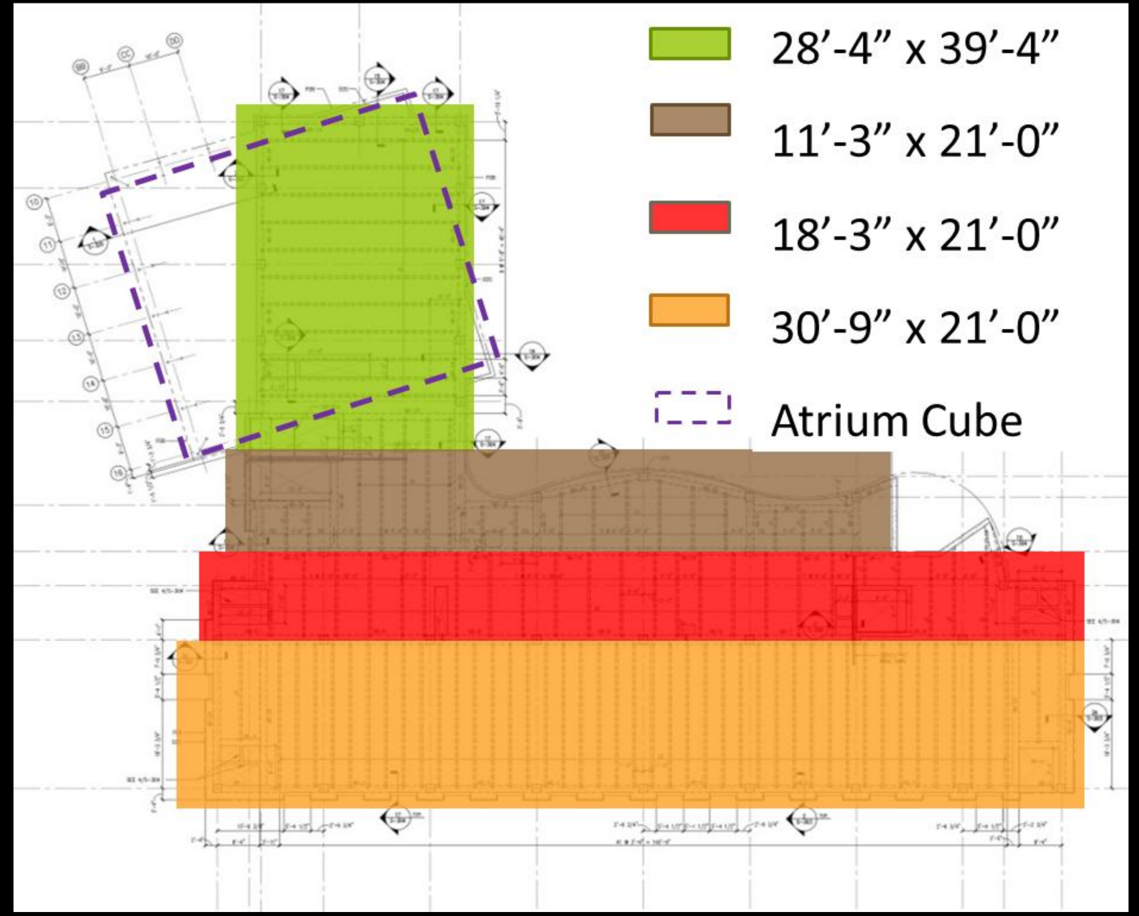
- Cast-in-place concrete mat-slab foundation
- One way slab framing
- Precast Joists and Beam Soffits
- Bay sizes


Courtesy of HDR

BAY SIZES



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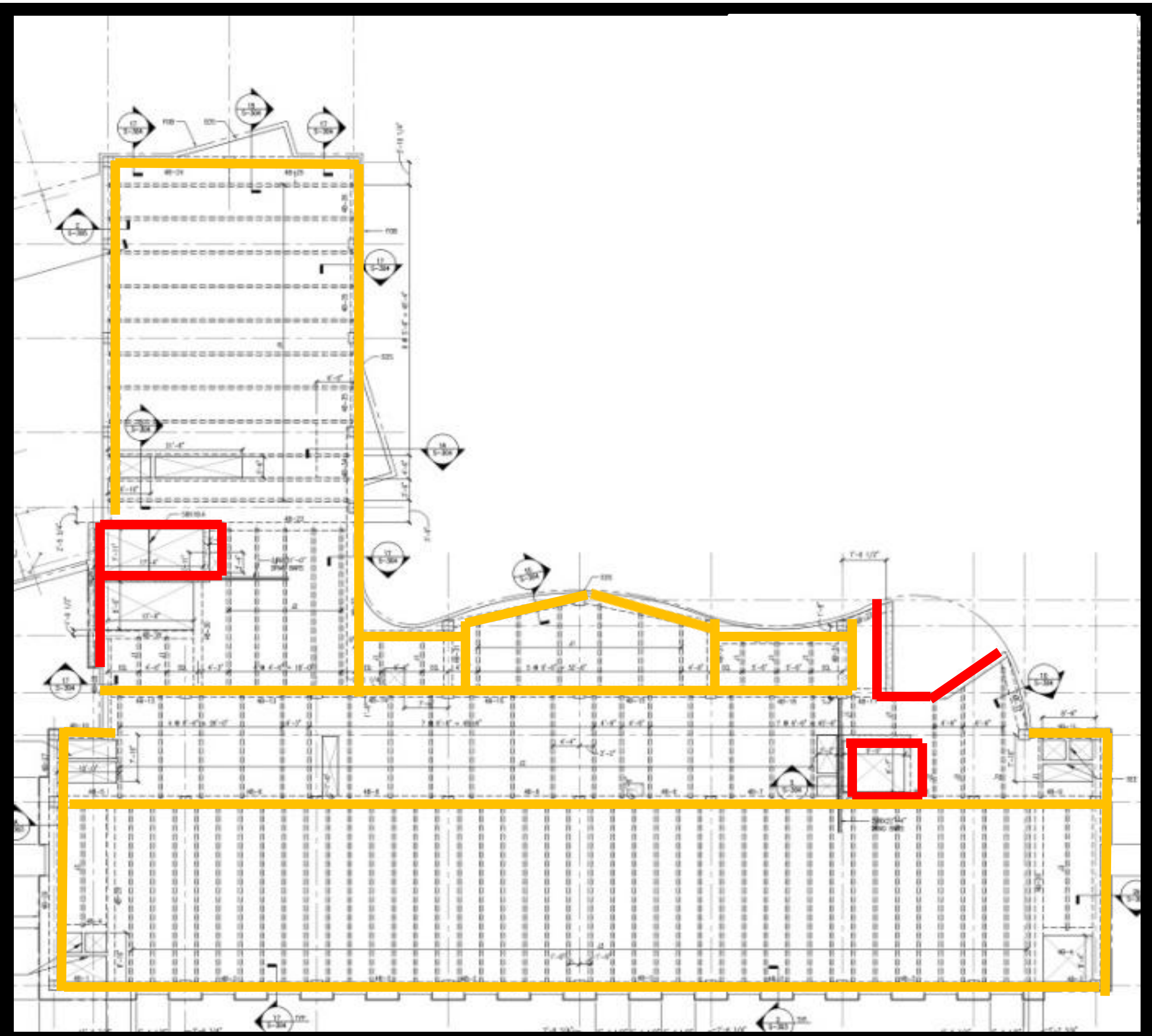
- Cast-in-place concrete mat-slab foundation
- Bay sizes
- One way slab construction
- Precast Joists and Beam Soffits
- Lateral System
  - Concrete Moment frames
  - Concrete Shear Walls

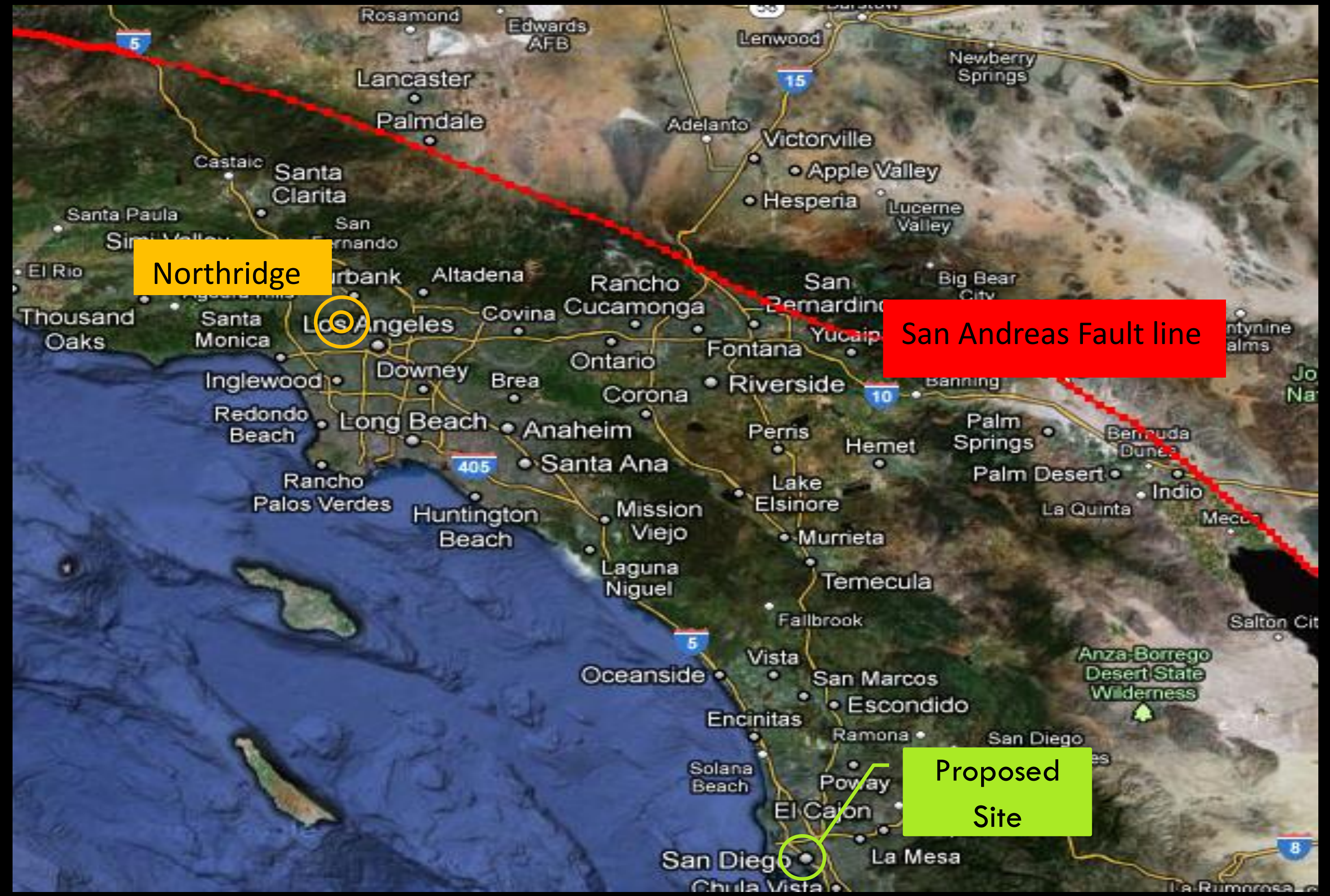
SYSTEM LAYOUT



PROBLEM STATEMENT

- Interest in seismic design
- Scenario Created
  Request for building to be built for University of San Diego (USD)
  Close to Northridge and San Andreas fault line

SAN DIEGO SITE



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- Interest in seismic design
- Scenario Created
  Request for building to be built for University of San Diego (USD)
  Close to Northridge and San Andreas fault line
- Similar site to USF
- Geotechnical report same as original building
- Facility required to meet strict standards

LOCATION ON USD CAMPUS

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GOALS

- Building Introduction
- Existing Structural System
- Problem Statement
- **Proposed Solution**
- Fixed Base Design
- Base Isolation Design
- Comparison of Designs
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- 2 Designs undertaken in concrete
  Fixed Base System in San Diego to meet S-3
  Isolated Base System in California S-3
- Comparison between traditional and high-tech
- Design Goals
  Minimal Impact to Architecture
  Low Cost of Implementation
- MAE Incorporated: Computer Modeling
  Earthquake Design

BASE ISOLATION

Emergency Management Centre of Foligno, Italy

- Load Combination Used

  1.2D+1.0L+1.0E+0.2S

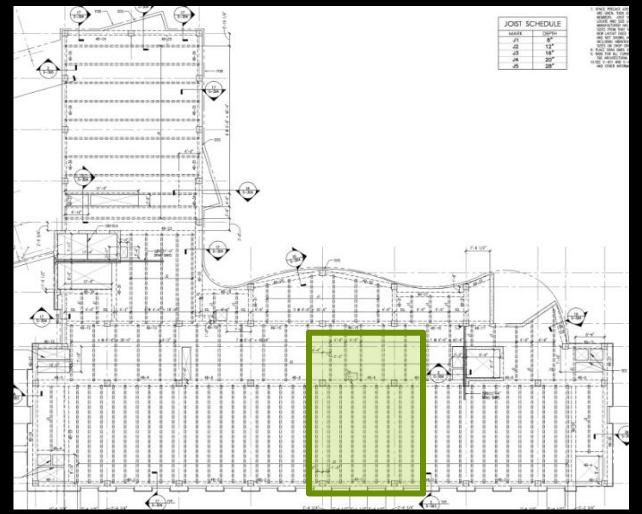
- Modal Response applied to system

Lateral Forces Summary	Tampa,FL		San Diego,CA	
	Base Shear (kips)	Overturning Moment (ft-kips)	Base Shear (kips)	Overturning Moment (ft-kips)
Wind N-S direction	682	36,276	340	18076
Wind E-W direction	892	47,457	448	23811
Seismic N-S direction Seismic E-W direction	193	10,819	2013	169,437

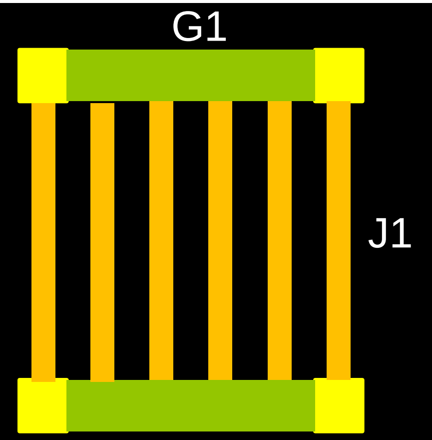
- Reduced Wind
- Higher Seismic
  - Redesign lateral system to resist the higher loads
- Similar Dead and Live Loads
  - Redesign gravity for practicality of construction in California

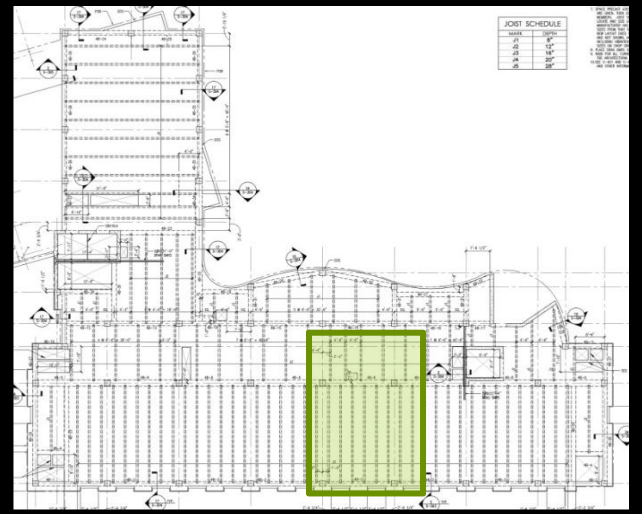
FIXED BASE DESIGN

GRAVITY SYSTEM



Typical Laboratory Bay





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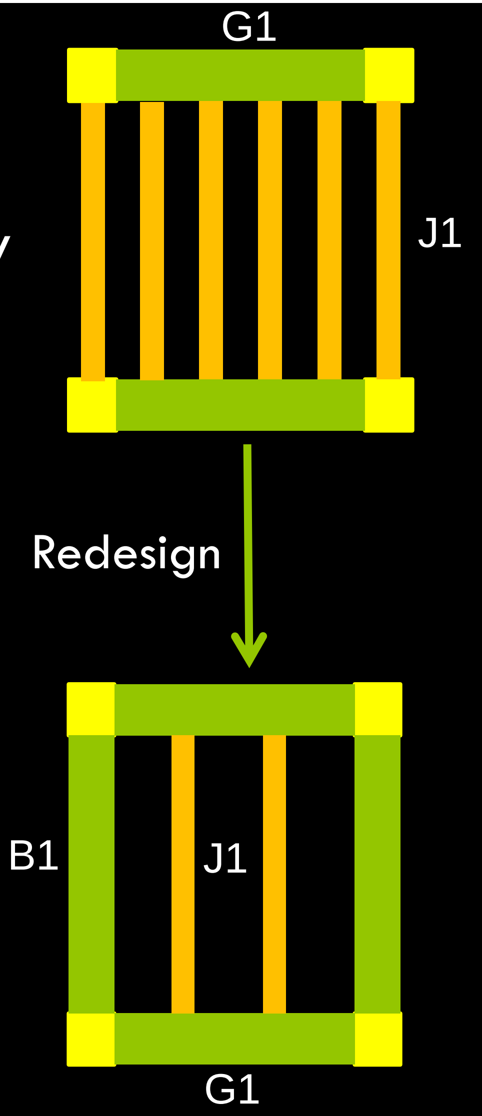
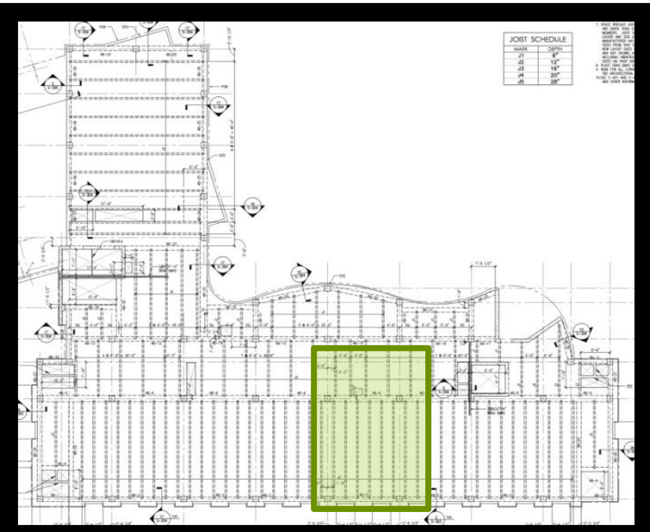


Element		J1	B1	G1
Sizes	Existing	16"x20"	-	16"x24"
	Redesign	16"x24"	20"x24"	20"x24"

- B1 added for potential moment frame addition

FIXED BASE DESIGN



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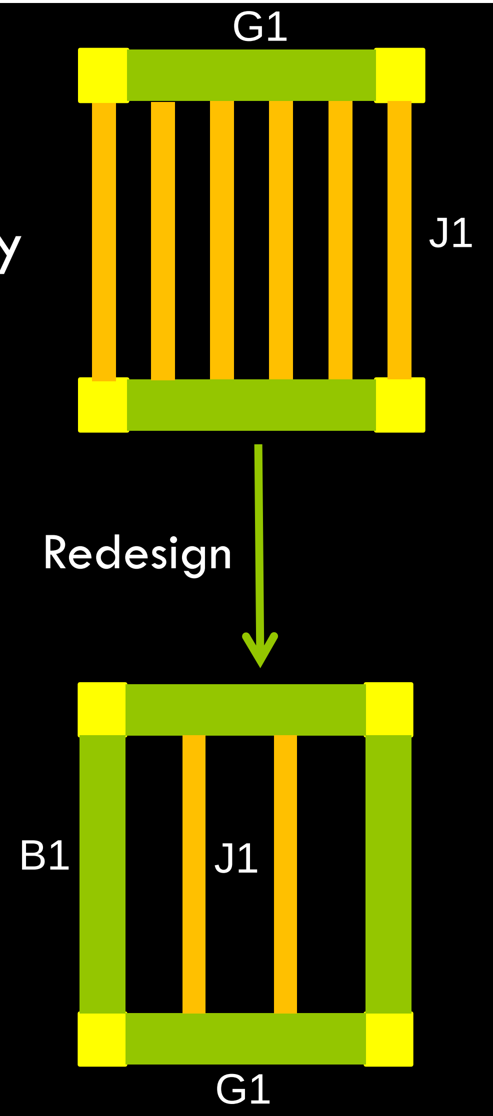

Element		J1	B1	G1
Sizes	Existing	16"x20"	-	16"x24"
	Redesign	16"x24"	20"x24"	20"x24"

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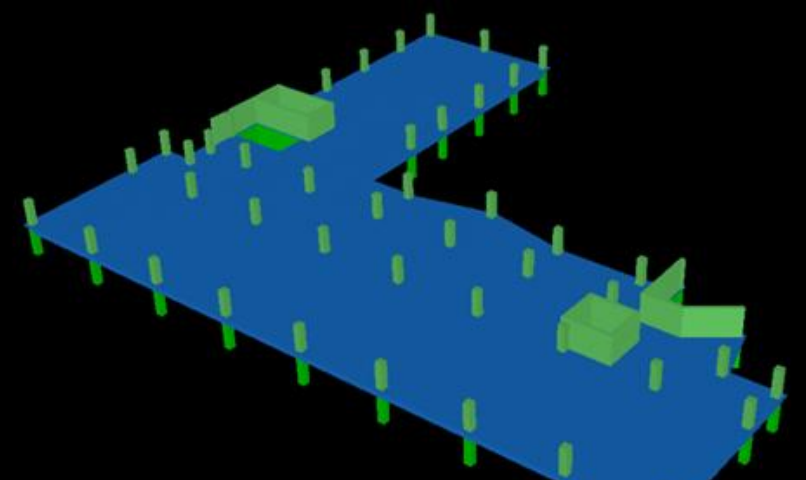
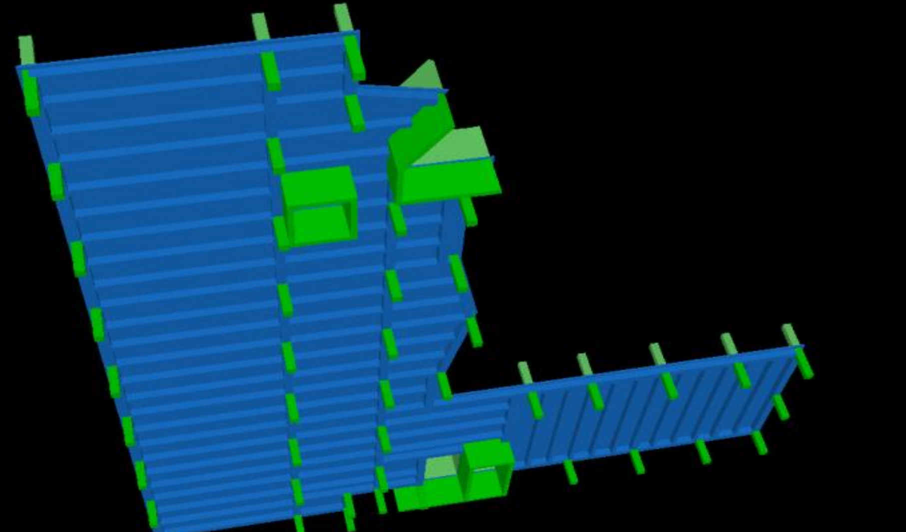
GRAVITY SYSTEM

- Columns kept intact
- Modeled in RAM Concepts
  - Output similar to hand calculations

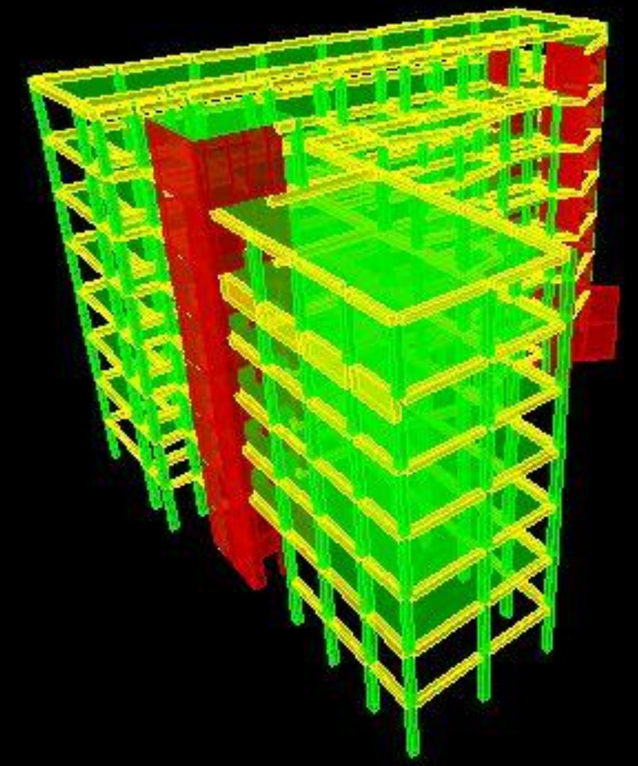


Aerial View



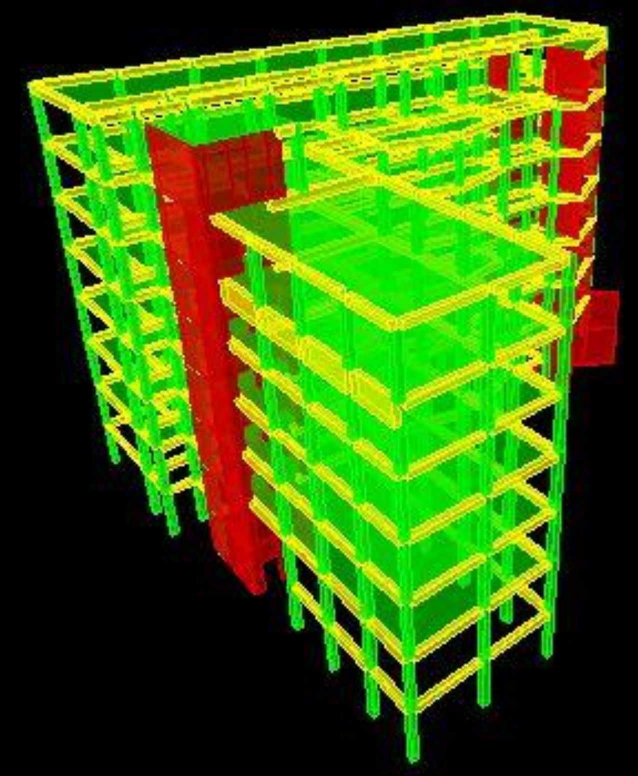
View from below slab

FIXED BASE DESIGN



- Design to overcome
  - Extreme torsional irregularity in the Y-direction
  - Meet code minimum moment frame S-3
  - Minimal Impact to architectural

FIXED BASE DESIGN



- Design to overcome
  - Extreme torsional irregularity in the Y-direction
  - Meet code minimum moment frame S-3
  - Minimal Impact to architectural
- Solution
  - Increase stiffness and reduce torsion in Y-direction
  - Keep same shear walls layout

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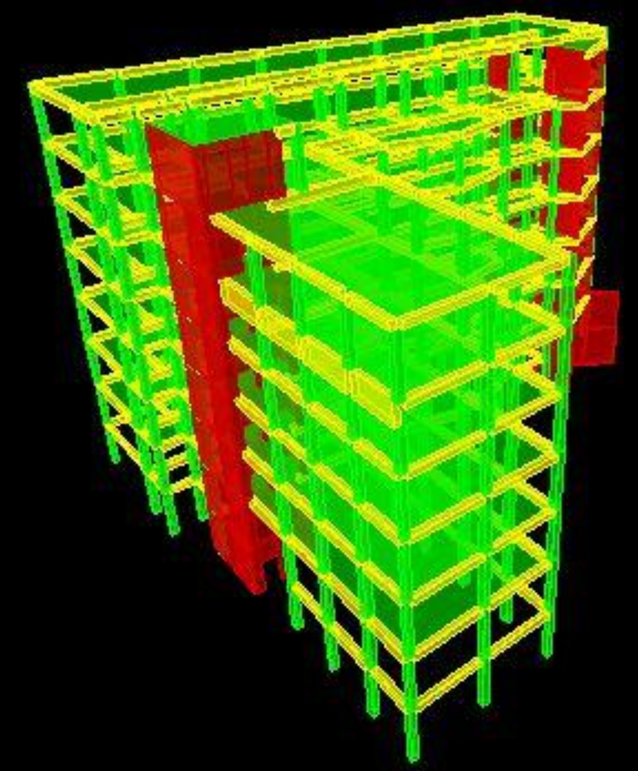
- **Fixed Base Design**
  - Loads
  - Gravity Redesign
  - **Computer modeling**
  - Lateral Redesign



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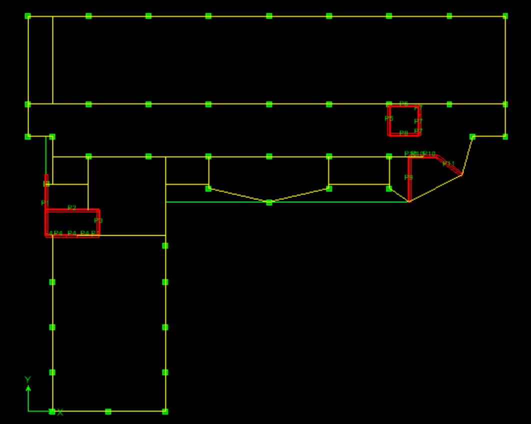
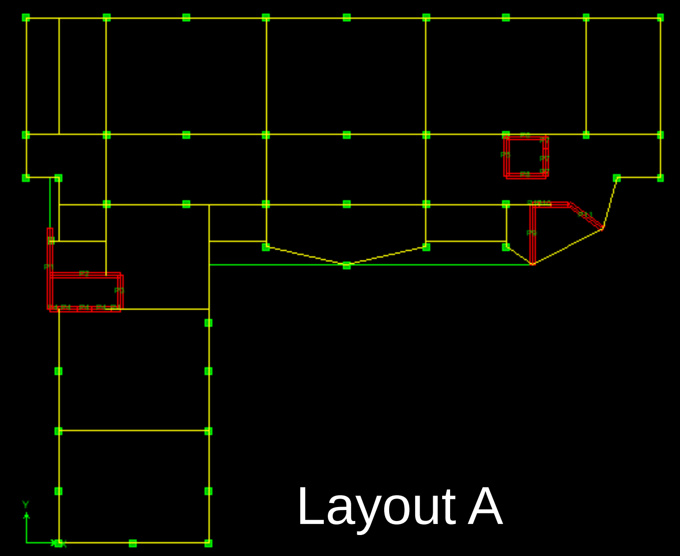
- Design to overcome
  - Extreme torsional irregularity in the Y-direction
  - Meet code minimum moment frame S-3
  - Minimal Impact to architectural
- Solution
  - Increase stiffness and reduce torsion in Y-direction
  - Keep same shear walls layout
- Dual System: Special concrete shear walls with intermediate concrete moment frames R=6.5, Cd=5

MOMENT FRAME LAYOUT

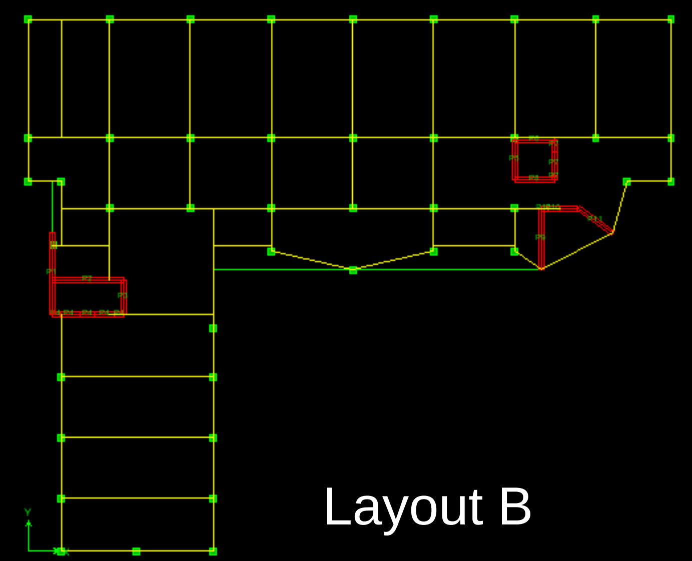
- 2 Moment Frames layouts created



Original



Layout A



Layout B

FIXED BASE DESIGN

LATERAL SYSTEM

- Several iterations done
  - Layout A

Wall size	Beam size	Period (sec)	total drifts in Y (inch)	total drifts in X (inch)	Max drift in Y (inch) between 5-6	Max drift in X (inch) between 3-4	Y-direction		X-direction	
							S5= 2%= 3.48"	S3= 1%= 1.74"	S5= 2%= 3.48"	S3= 1%= 1.74"
12"	20x24	1.737	32.21	26.29	4.686	3.875	NG	NG	NG	NG
	20x28	1.633	28.23	22.97	4.098	3.374	NG	NG	OK	NG
	20x32	1.553	25.25	20.65	3.660	3.022	NG	NG	OK	NG
	20x36	1.489	22.97	18.93	3.324	2.762	OK	NG	OK	NG
16"	20x24	1.622	27.98	23.37	4.072	3.441	NG	NG	OK	NG
	20x28	1.533	24.84	20.65	3.603	3.034	NG	NG	OK	NG
	20x32	1.463	22.42	18.71	3.249	2.742	OK	NG	OK	NG
	20x36	1.406	20.53	17.25	2.971	2.522	OK	NG	OK	NG

- Layout B

Wall size	Beam size	Period (sec)	total drifts in Y (inch)	total drifts in X (inch)	Max drift in Y (inch) between 5-6	Max drift in X (inch) between 3-4	Y-direction		X-direction	
							S5= 2%= 3.48"	S3= 1%= 1.74"	S5= 2%= 3.48"	S3= 1%= 1.74"
12"	20x24	1.687	29.42	26.09	4.271	3.844	NG	NG	NG	NG
	20x28	1.581	25.58	22.77	3.703	3.343	NG	NG	OK	NG
	20x32	1.501	22.78	20.45	3.290	2.992	OK	NG	OK	NG
	20x36	1.439	20.68	18.73	2.980	2.733	OK	NG	OK	NG
16"	20x24	1.582	25.82	23.20	3.744	3.416	NG	NG	OK	NG
	20x28	1.491	22.73	20.48	3.290	3.008	OK	NG	OK	NG
	20x32	1.421	20.42	18.54	2.950	2.716	OK	NG	OK	NG
	20x36	1.366	18.65	17.08	2.690	2.496	OK	NG	OK	NG
20"	20x36	1.307	17.05	15.77	2.460	2.305	OK	NG	OK	NG
24"	20x36	1.258	15.75	14.67	2.272	2.145	OK	NG	OK	NG
	20x42	1.204	14.22	13.40	2.049	1.955	OK	NG	OK	NG
	24x42	1.184	14.22	13.40	2.049	1.955	OK	NG	OK	NG
28"	20x42	1.165	13.291	12.602	1.916	1.839	OK	NG	OK	NG
32"	24x42	1.113	12.808	12.301	1.847	1.794	OK	NG	OK	NG
	24x48	1.077	11.847	11.473	1.708	1.670	OK	OK	OK	OK

FIXED BASE DESIGN

LATERAL SYSTEM

- System chosen to meet S-5 (2% drift)
  Layout B

16"	20x24	1.582	25.82	23.20	3.744	3.416	NG	NG	OK	NG
	20x28	1.491	22.73	20.48	3.290	3.008	OK	NG	OK	NG
	20x32	1.421	20.42	18.54	2.950	2.716	OK	NG	OK	NG
	20x36	1.366	18.65	17.08	2.690	2.496	OK	NG	OK	NG

16"	20x24
	20x28
	20x32
	20x36

- Shear walls: Increase of 4"
  Moment frames: Increase in depth

FIXED BASE DESIGN

LATERAL SYSTEM

- System chosen to meet S-5 (2% drift)

  Layout B

16"	20x24	1.582	25.82	23.20	3.744	3.416	NG	NG	OK	NG
	20x28	1.491	22.73	20.48	3.290	3.008	OK	NG	OK	NG
	20x32	1.421	20.42	18.54	2.950	2.716	OK	NG	OK	NG
	20x36	1.366	18.65	17.08	2.690	2.496	OK	NG	OK	NG

16"	20x24
	20x28
	20x32
	20x36

- Shear walls: Increase of 4"

  Moment frames: Increase in depth

- System chosen to meet S-3 (1% drift)

  Layout B

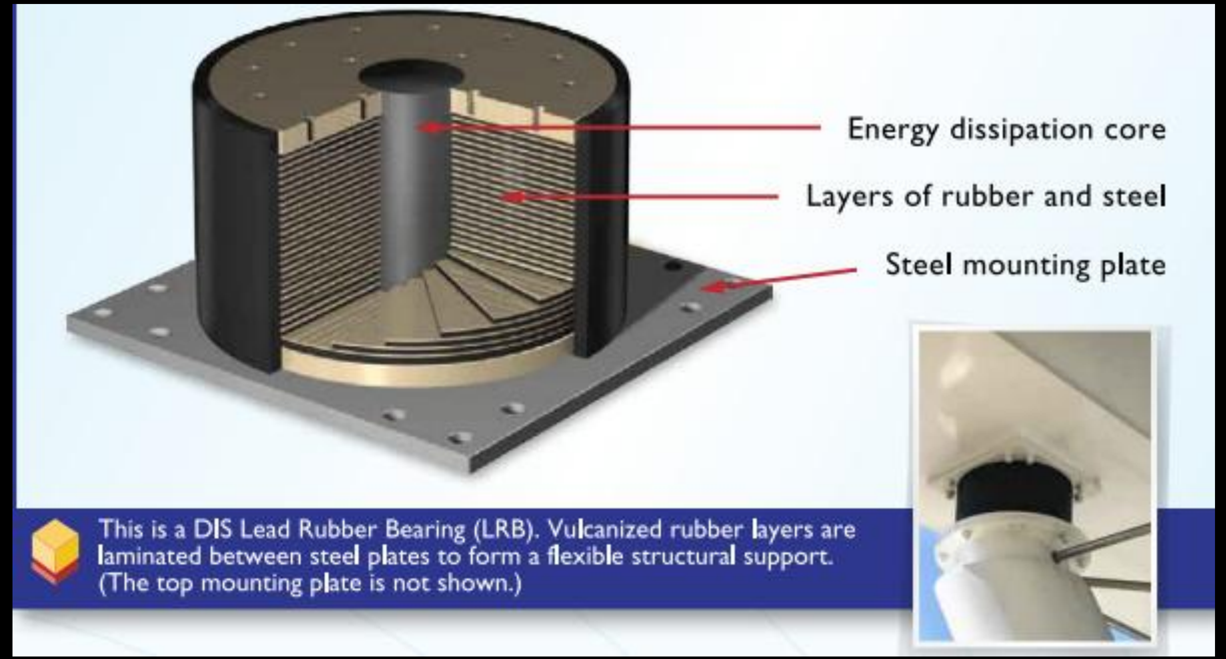
	24x42	1.184	14.22	13.40	2.049	1.955	OK	NG	OK	NG
28"	20x42	1.165	13.291	12.602	1.916	1.839	OK	NG	OK	NG
32"	24x42	1.113	12.808	12.301	1.847	1.794	OK	NG	OK	NG
	24x48	1.077	11.847	11.473	1.708	1.670	OK	OK	OK	OK

28"	20x42
32"	24x42
	24x48

- Impractical design due to plenum space

BASE ISOLATION

- Lead Rubber Base Isolators



Courtesy of Teratec

- Rubber provides flexibility to move and return
- Steel can move horizontally but provide vertical stiffness
- Lead has plastic property
  Kinetic energy is absorbed into heat energy as the lead is deformed

UNIVERSITY SCIENCES BUILDING

- Building Introduction
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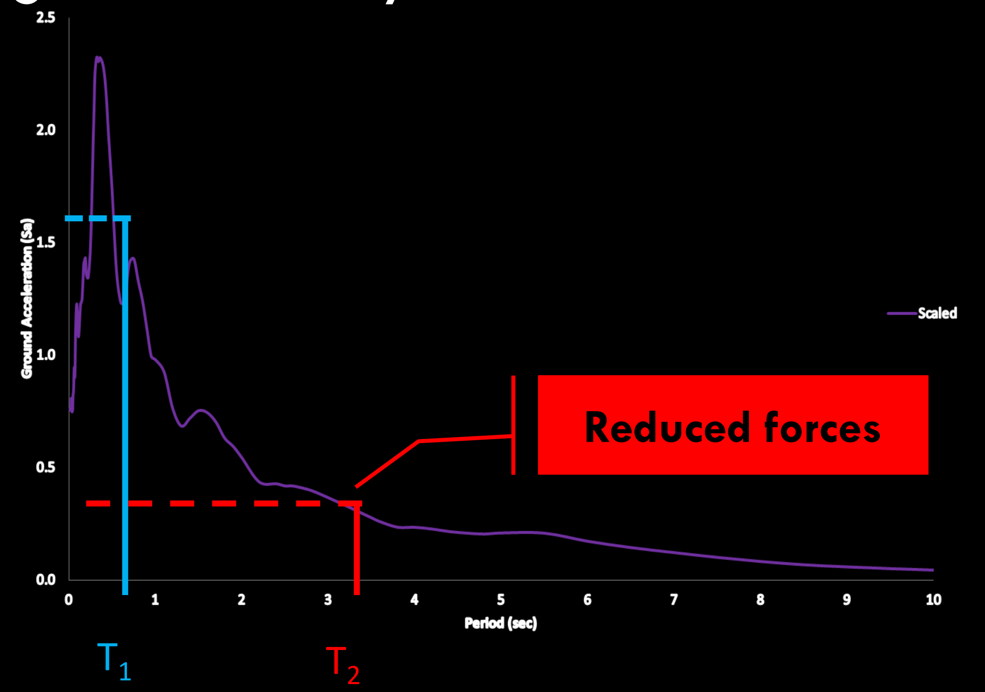
- Problem Statement
- Proposed Solution
- Fixed Base Design
- **Base Isolation Design**
  - **Introduction**
  - Time History
  - Design
  - Results

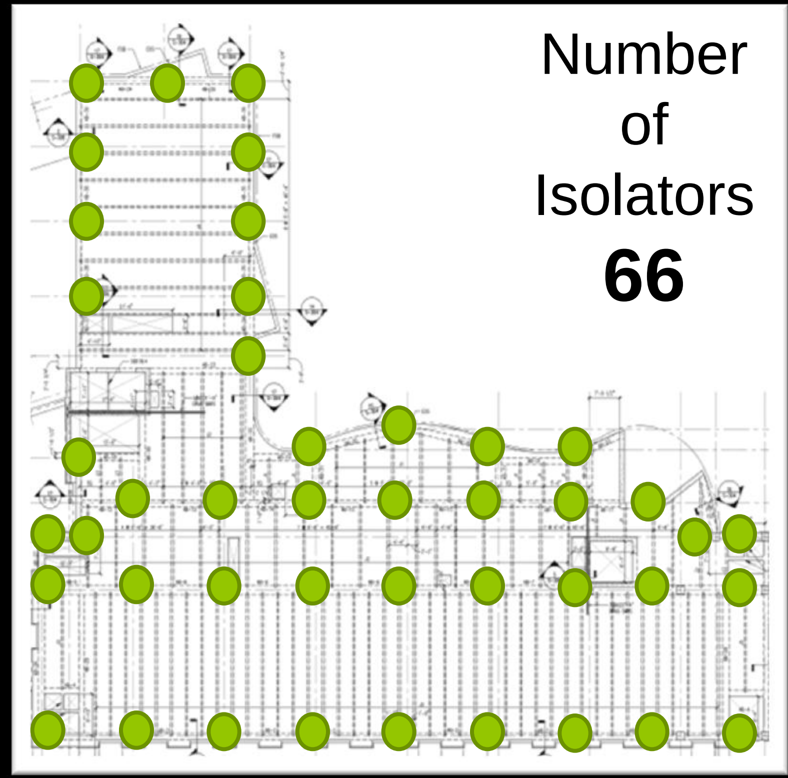
BASE ISOLATION

- Reduce
  Ground movement
  High floor acceleration
  Large inter-story drifts
- Damping



ISOLATORS LAYOUT

- Placed between the structure and the foundation, beneath the ground floor slab



EARTHQUAKES

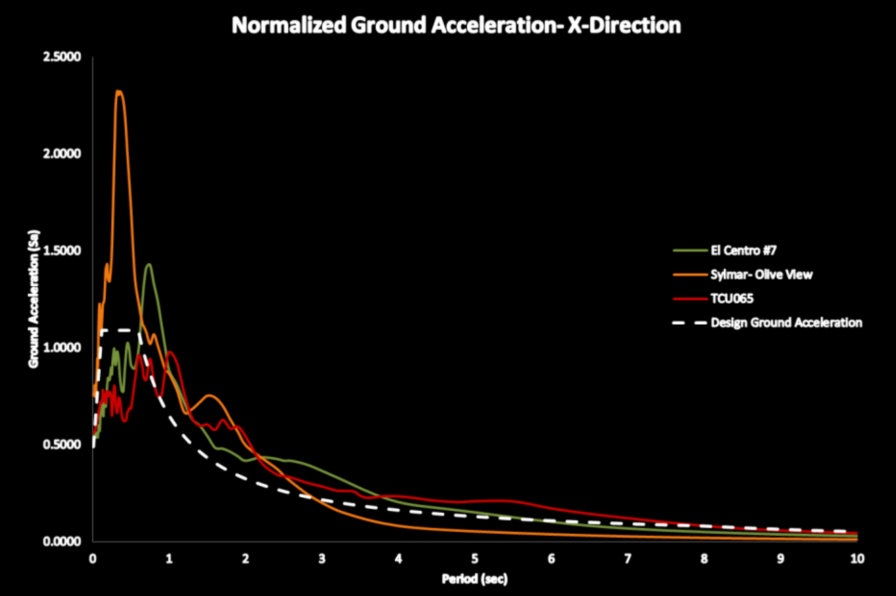
- Recommended records chosen from FEMA P695
- Earthquakes chosen for analysis

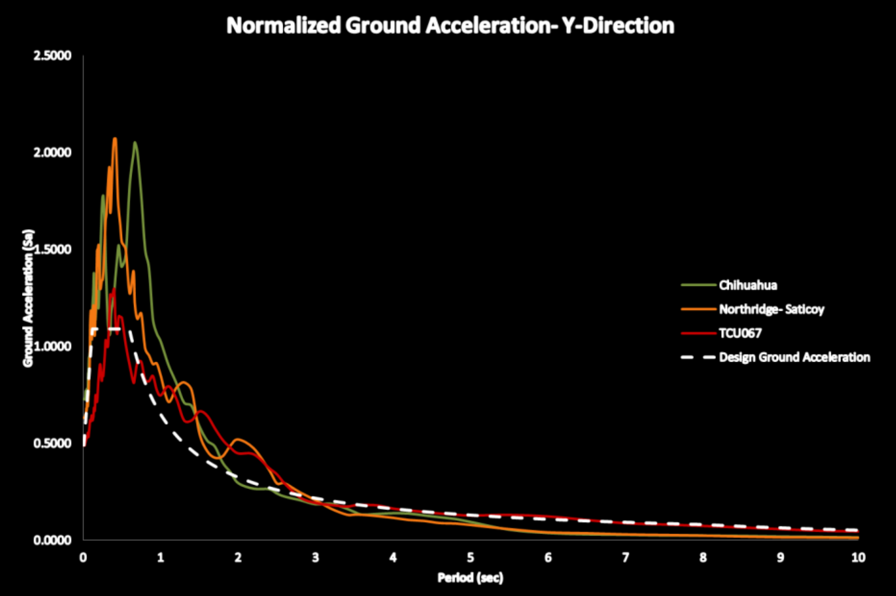
Direction of Earthquake	Earthquake	Station	Magnitude
X-Direction	Imperial Valley	El centro 7	6.5
	Northridge-01	Sylmar - Olive View	6.7
	Chi Chi, Taiwan	TCU065	7.6
Y-Direction	Imperial Valley	Chihuahua	6.5
	Northridge-01	Northridge - Saticoy	6.7
	Chi Chi, Taiwan	TCU067	7.6

- FEMA= Federal Emergency Management Agency
- P695=Quantification of Building Seismic Performance Factors

TIME HISTORY

- Response spectrum and scaling factors were taken from PEER NGA for the proposed solution

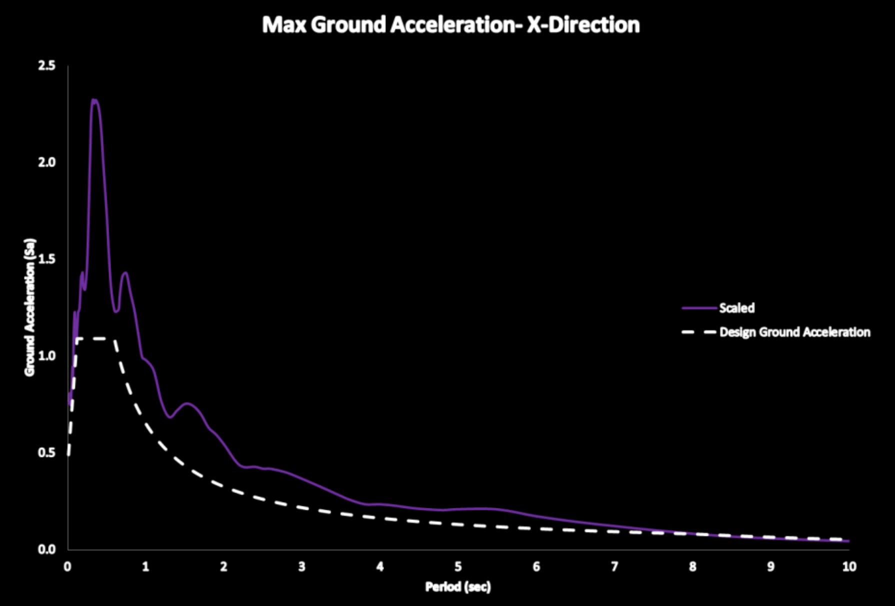


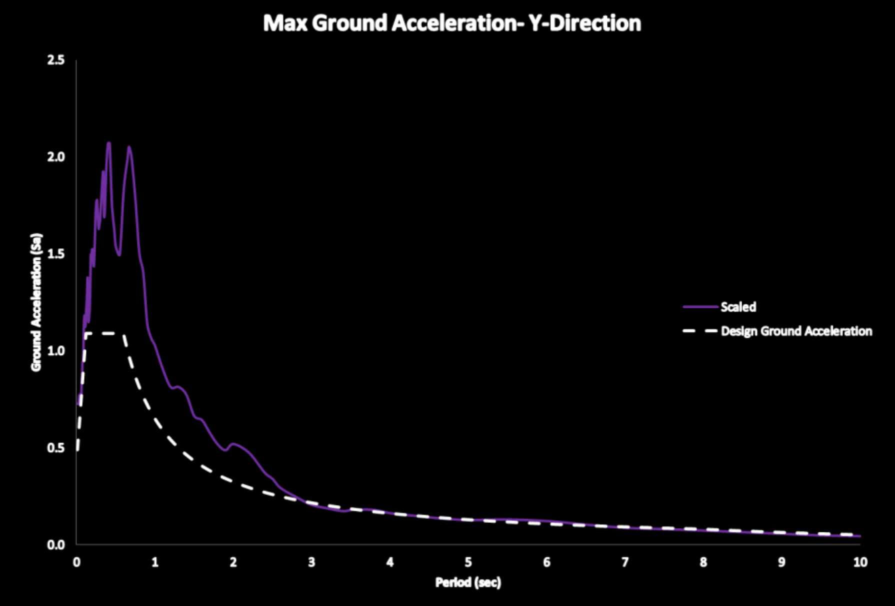


- PEER= Pacific Earthquake Engineering Research Center of the University of California at Berkeley

TIME HISTORY

- Response spectrum were taken from PEER NGA for the proposed solution then scaled accordingly
- Maximum Envelope of the ground motion history





DESIGN METHOD

- Time histories applied to fixed base design S-3
  - Recorded max displacements & interstory drifts for each earthquake

DESIGN METHOD

SIZING (ASCE 7-05)

- Time histories applied to fixed base design S-3
- Time histories applied to isolated structure CA S-3
  - Hysteresis curve could no be obtained
  - Preliminary sizing for base isolators was done following ASCE 7-05
  - Recorded max displacements & interstory drifts for each earthquake

- Minimum lateral displacement in each direction

Design Displacement:	
$D_D =$	$\frac{gS_{D1}T_D}{4\pi^2 B_D}$
$D_D =$	34.92 in.

Maximum Displacement:	
$D_M =$	$\frac{gS_{M1}T_M}{4\pi^2 B_M}$
$D_M =$	30.46 in.

- Minimum with actual and accidental torsion

Total Displacement:		
$D_{TD} = D_D\left[1 + y\frac{12e}{b^2+d^2}\right]$	49.3	in.
$D_{TM} = D_M\left[1 + y\frac{12e}{b^2+d^2}\right]$	43.0	in.

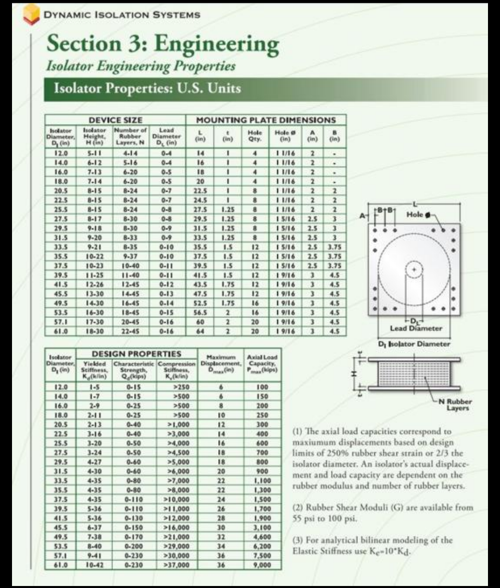
Minimum axial capacity of 1,300 kips

DESIGN METHOD

- Time histories applied to fixed base design S-3
- Time histories applied to isolated structure CA S-3
- Further iterations done
  - Size base isolator
  - Optimize structure by reducing strength and stiffness

BASE ISOLATOR

- Isolator chosen for optimized system from manufacturer cut sheet



- Diameter: 37.5”
- Maximum displacement: 24”
- Axial Capacity: 1,500 kips
- Unit Cost: $14,250

- Link element modeled in ETABS using cut sheet

Isolator Properties	
Linear Properties	
Effective Stiffness (k/in)	4
Effective Damping	0.15
Nonlinear Properties	
Stiffness (k/in)	40
Yield Strength (kips)	110
Post Yield Stiffness Ratio	0.2

OPTIMIZED SYSTEM

- Dual system:

  12" special shear walls

  20"x28" intermediate moment frames

  using Layout A

- Period of the structure

  T = 4.04 seconds

- Displacement / Interstory drifts / Controlling EQ

Direction of Earthquake	Earthquake	Station	Scale Factor	Magnitude	Peak time in X (sec)	Peak time in Y (sec)	Max Displacement (inch)	
							X	Y
X-Direction	Imperial Valley	El centro 7	525	6.5	5.48	11.27	16.38	1.88
	Northridge-01	Sylmar - Olive View	441	6.7	4.82	14.60	21.22	1.76
	Chi Chi, Taiwan	TCU065	312	7.6	5.42	12.37	9.20	1.50
Y-Direction	Imperial Valley	Chihuahua	1018	6.5	32.41	14.91	1.51	9.23
	Northridge-01	Northridge - Saticoy	579	6.7	7.31	4.07	1.22	16.56
	Chi Chi, Taiwan	TCU067	451	7.6	44.27	30.94	1.57	18.74

Direction of Earthquake	Earthquake	Magnitude	Max interstory drift		Max interstory drift location	S5= 2%= 3.48"		S3= 1%= 1.74"	
			X	Y		X	Y	X	Y
X-Direction	Imperial Valley	6.5	1.458	0.334	Story 1-Story 2	OK	OK	OK	OK
	Northridge-01	6.7	1.729	0.789	Story 1-Story 2	OK	OK	OK	OK
	Chi Chi, Taiwan	7.6	1.032	0.277	Story 1-Story 2	OK	OK	OK	OK
Y-Direction	Imperial Valley	6.5	0.164	0.734	Story 1-Story 2	OK	OK	OK	OK
	Northridge-01	6.7	0.161	1.321	Story 1-Story 2	OK	OK	OK	OK
	Chi Chi, Taiwan	7.6	0.177	1.493	Story 1-Story 2	OK	OK	OK	OK

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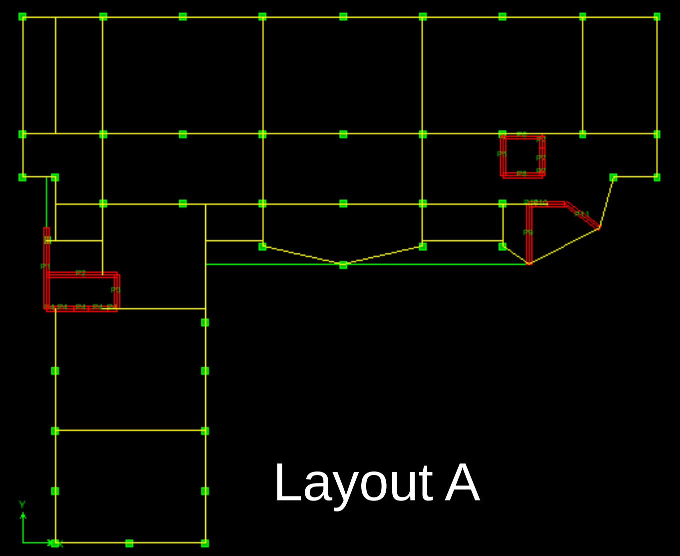
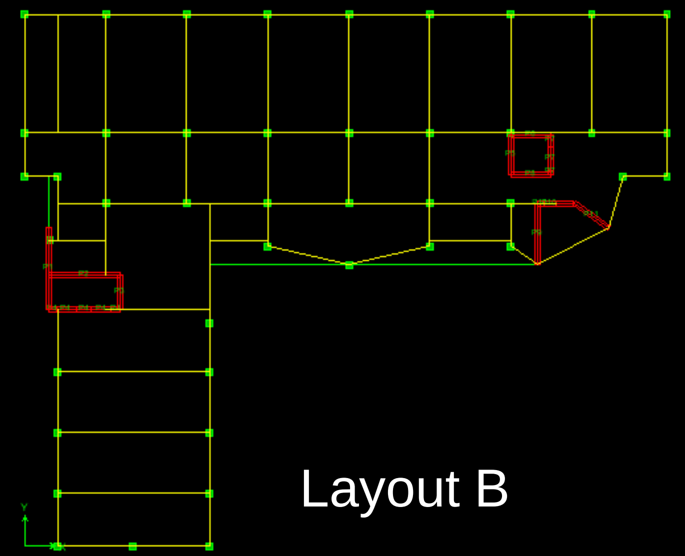
SUMMARY

CONSTRUCTION MANAGEMENT

- Structure

Requirement	S-3 (1% Drift)	
Structure	Fixed	Isolated
Moment frames	Layout B	Layout A
	24x48	20x28
Shear Walls	32"	12"


Layout A


Layout B

- Cost

	Original	Fixed CA-S3	Isolated CA-S3
Superstructure	$2,890,802	$2,656,186	$2,302,165
Isolators	$0	$0	$985,820
Total Cost	$21,620,193	$22,091,880	$22,683,679
Difference to original	-	+ $471,687	+ $1,063,486

- Schedule

Schedule Summary		
System	# days	Extra to original
Original design	324	-
One way cast-in-place	380	56
Isolated one way cast-in-place	391	67

INTRODUCTION

- Building Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Fixed Base Design
- Base Isolation Design
- Comparison of Designs
- **Sustainability Breadth: Viability Study**
- Questions/Comments

- Feasibility of Integrated photovoltaic curtain wall
  - Life Cycle Assessment
  - Payback Period
  - Additional LEED points earned
- Solar study for California site
- BISEM Inc.
  - Panel size 33"x33"
    72 Watt Monocrystalline silicon
    Efficiency of 30-40%

Example of BIPV curtain wall

GOOGLE SKETCHUP

- Building Introduction
- Existing Structural System
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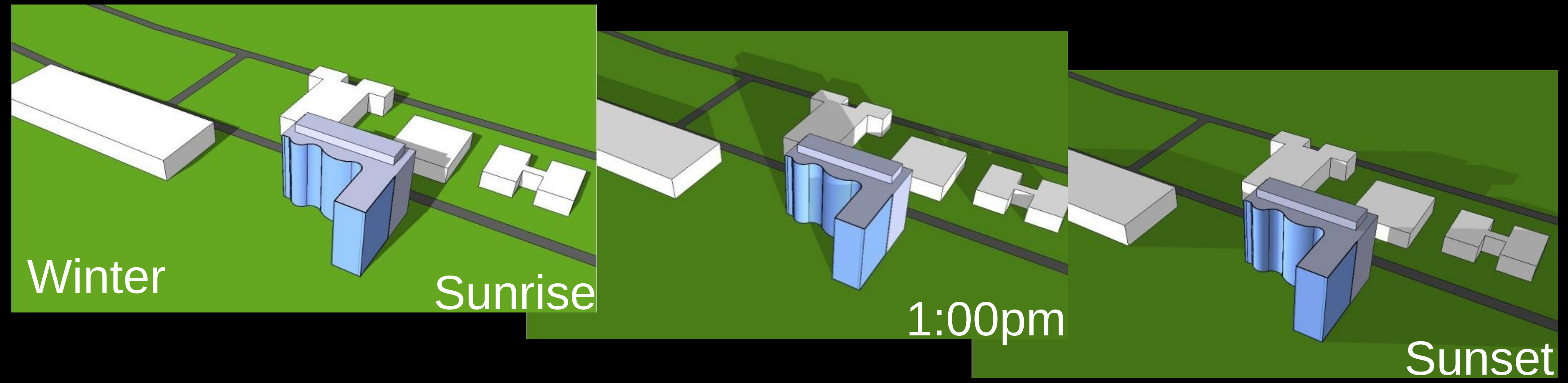
- Critical Days
  - Winter Solstice, Summer Solstice, and Equinox
- Critical Times
  - Sunrise, Sunset, and 1:00 PM (peak hour)

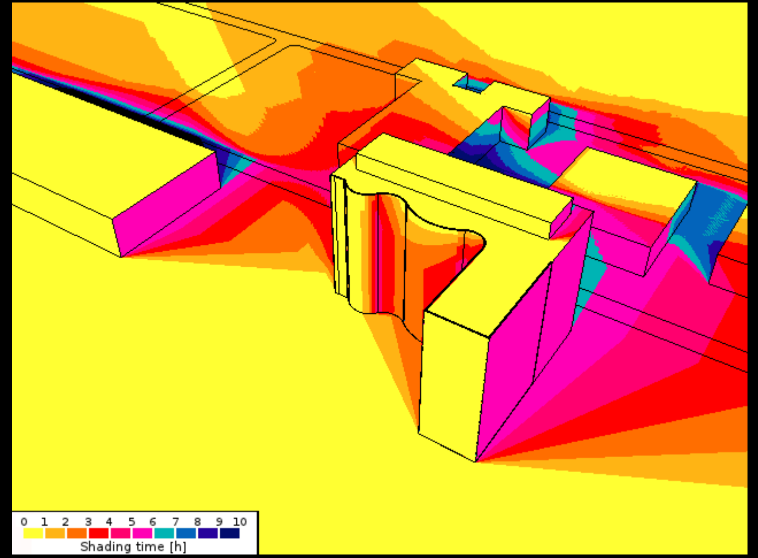


Courtesy of HDR

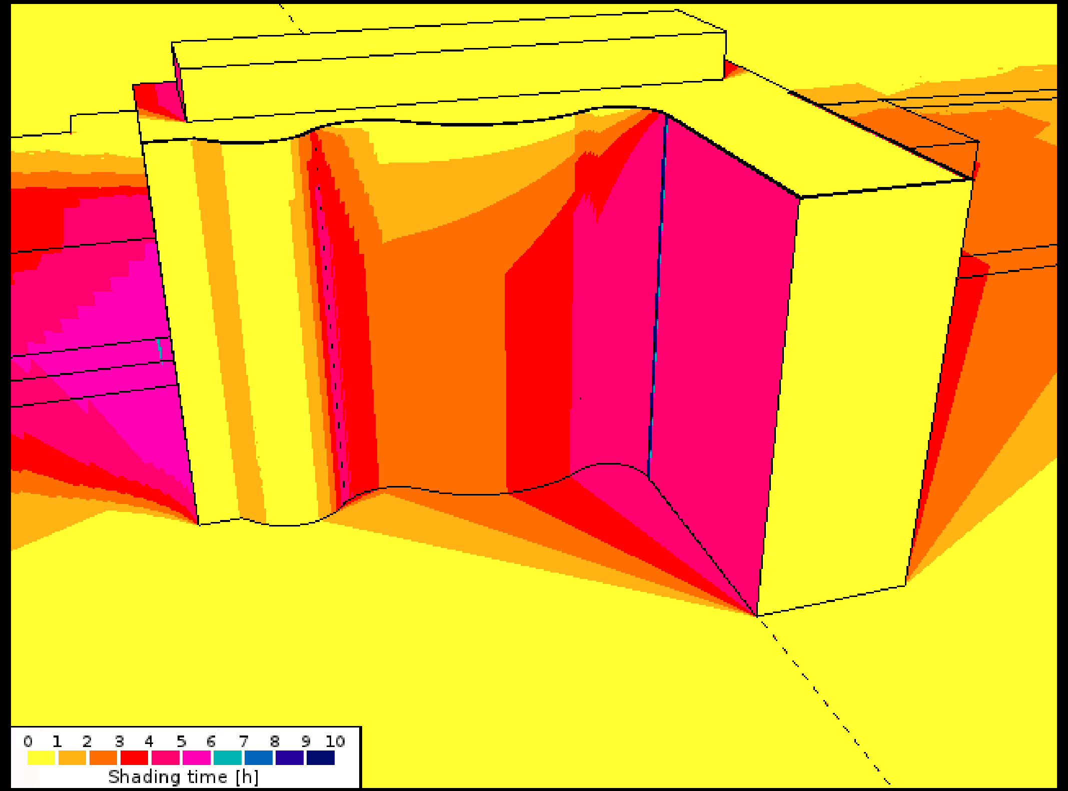
SHADOW ANALYSIS

- Building Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Fixed Base Design
- Base Isolation Design
- Comparison of Designs
- **Sustainability Breadth: Viability Study**
- Questions/Comments

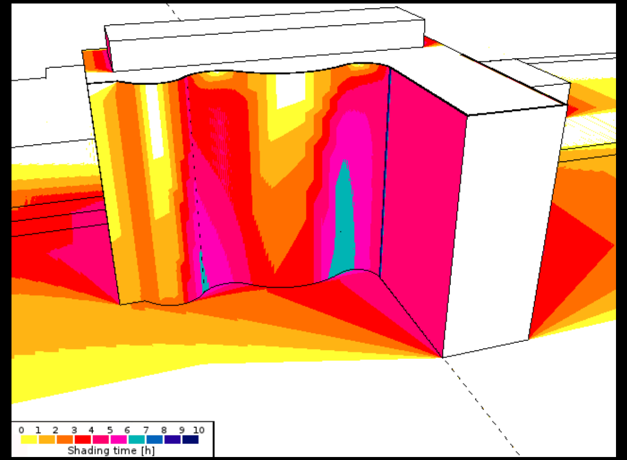
- An improved analysis using Shadow Analysis



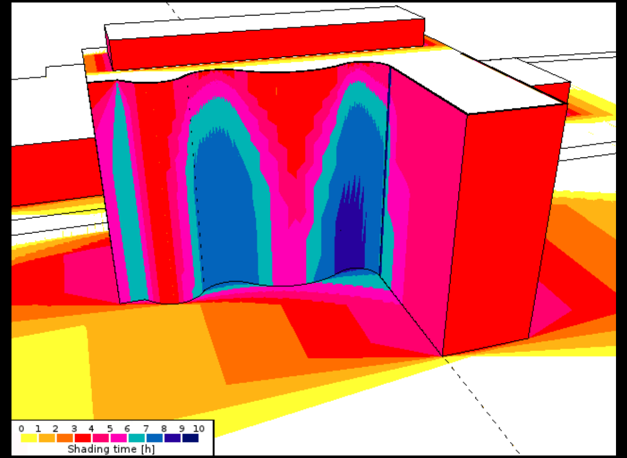
Legend:



Winter Solstice



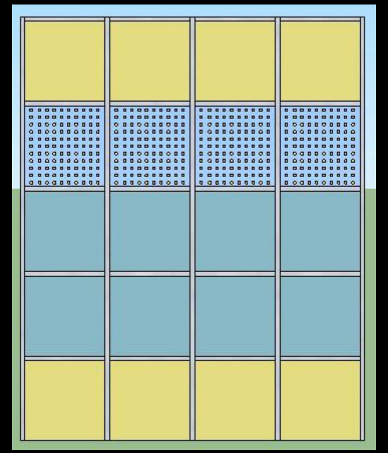
Equinox



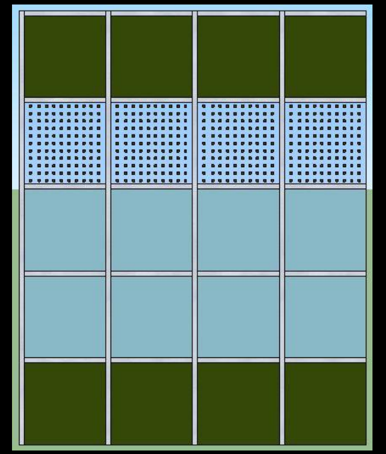
Summer Solstice

ARCHITECTURE

- Impact on exterior aesthetic
- Model



Existing



Proposed

- Actual

Existing

Proposed

- Minimal Impact to exterior architecture

J.B. Byrd Alzheimer's Center

COST

- Building Introduction
- Existing Structural System
- Problem Statement
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- Questions/Comments

- Items considered

Description	Total	$/sf
PV Design	$ 198,090	$ 15.00
Electrical Design	$ 198,090	$ 15.00
Curtain Wall Design	$ 198,090	$ 15.00
Curtain Wall Aluminun	$ 264,120	$ 20.00
Vision Glass	$ 39,618	$ 3.00
Thin Film at Spandrel	$ 726,330	$ 55.00
Inverters & Monitoring	$ 158,472	$ 12.00
Wiring	$ 198,090	$ 15.00
Fabrication	$ 264,120	$ 20.00
Installation	$ 264,120	$ 20.00
Total	$ 2,509,140	$ 190.00

- Existing panel price at $78/sq.ft

Total BIPV curtain wall	Exisiting Panels	Addition for BiPV
$2,469,522	$1,030,068	$1,479,072

J.B. Byrd Alzheimer's Center

- Building Introduction
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Total BIPV curtain wall	Exisiting Panels	Addition for BiPV
$2,469,522	$1,030,068	$1,479,072

PAYBACK PERIOD

- PV surface area is 46% of curtain wall
- Federal tax credit is 30% in the first year
- State and federal calculated using the Modified Accelerated Cost Recovery System (MACRS)
- Watts generated decrease for 90° tilt
- 1 credit received for LEED certification

J.B. Byrd Alzheimer's Center

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PAYBACK PERIOD

95% Payback in 36 Months

Assumption: South, East & West Elevation of the curtain wall is 13,206 square feet. The federal tax credit for the BIPV curtain wall is 30% in the first year. There is also a state and federal accelerated depriciation, MACRS. This allows the BIPV curtain wall to be deducted over 5 years, rather than 30 years. So, by the end of the second year, you will have paid for the premium for the BIPV thinfilm addition. The next three years of accelerated depriciation become an ROI.

			Cost		
Standard Curtain Wall:	13,206	$ 78	$1,030,068		
BiPV Curtain Wall Premium:	13,206	$ 112	$1,479,072		
Total Taxable BiPV:			$2,509,140		
Federal Tax Credit 30% of total BiPV in First Year:			$ 740,857		
MACRS Depreciation Year One:			$ 189,758		
Local Utility Rebate:			$ 94,925	=	$18,925 per year for 5 years
MACRS Depreciation Federal/State Year Two:			$ 189,758		
MACRS Depreciation Federal/State Year Three:			$ 189,758	95%	Payback 36 Months
MACRS Depreciation Federal/State Year Four:			$ 189,758	13%	ROI
MACRS Depreciation Federal/State Year Five:			$ 189,758	13%	ROI

RESULTS

- LEED – systems are the same
- All other analyses favor BIPV retrofit

ACKNOWLEDGMENTS

- HDR Architecture, Inc. for providing the project and the owner permission form, specially
  - Michael Paczack
- BISEM, Inc. for providing BIPV information and guidance
- Entire AE faculty
  - Dr. Ali Memari
  - Prof. Kevin Parfitt
  - Prof. Robert Holland
- Special thanks to my family and friends for their support

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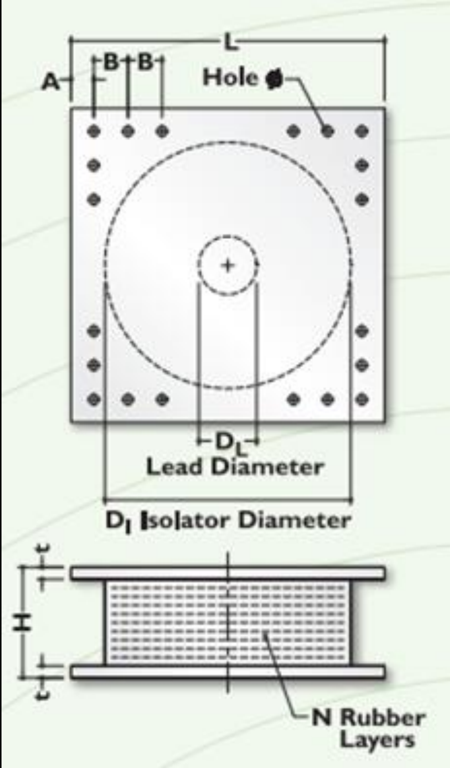
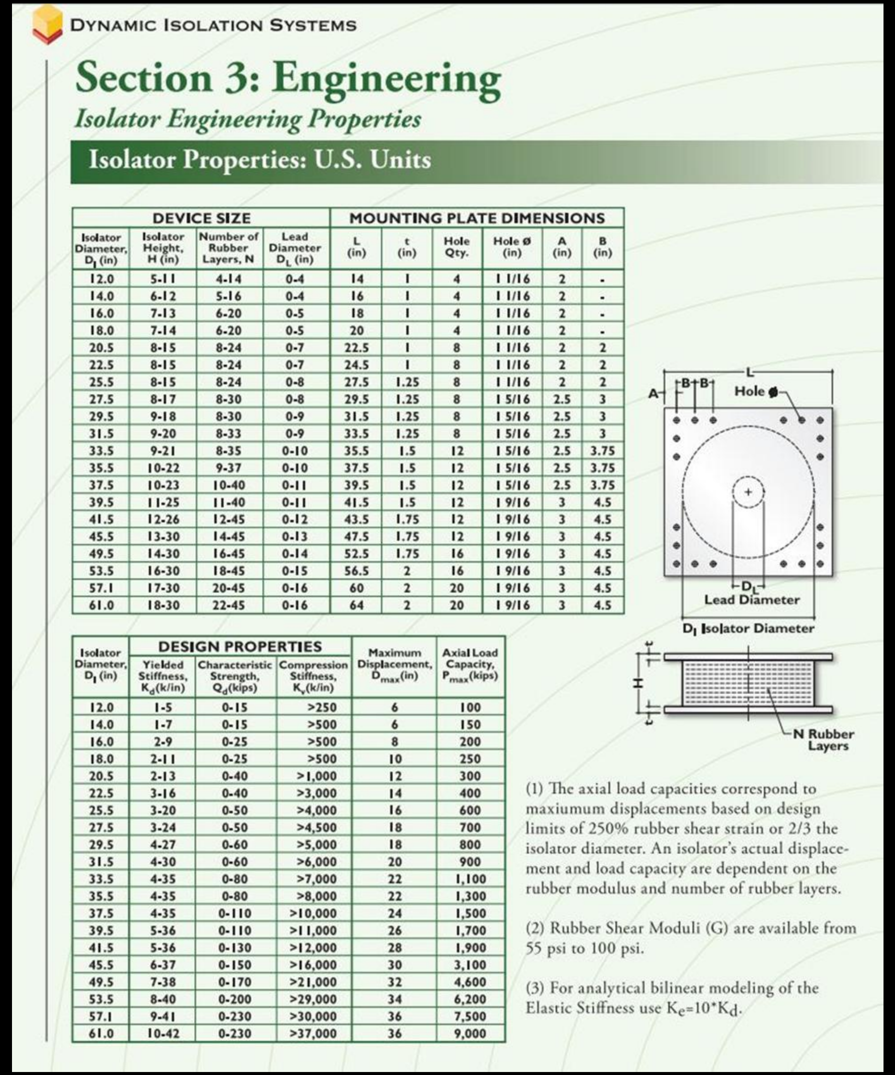
QUESTIONS?

Appendices



Isolator Dimensions	
DI (in)	37.5
H (in)	23
N	40
DL (in)	11
L (in)	39.5
t (in)	1.5
Hole Qty	12
Hole D (in)	1 5/16
A (in)	2.5
B (in)	3.75



DYNAMIC ISOLATION SYSTEMS

Section 3: Engineering

Isolator Engineering Properties

Isolator Properties: U.S. Units

DEVICE SIZE				MOUNTING PLATE DIMENSIONS					
Isolator Diameter, D_I (in)	Isolator Height, H (in)	Number of Rubber Layers, N	Lead Diameter D_L (in)	L (in)	t (in)	Hole Qty.	Hole Ø (in)	A (in)	B (in)
12.0	5-11	4-14	0-4	14	1	4	1 1/16	2	-
14.0	6-12	5-16	0-4	16	1	4	1 1/16	2	-
16.0	7-13	6-20	0-5	18	1	4	1 1/16	2	-
18.0	7-14	6-20	0-5	20	1	4	1 1/16	2	-
20.5	8-15	8-24	0-7	22.5	1	8	1 1/16	2	2
22.5	8-15	8-24	0-7	24.5	1	8	1 1/16	2	2
25.5	8-15	8-24	0-8	27.5	1.25	8	1 1/16	2	2
27.5	8-17	8-30	0-8	29.5	1.25	8	1 5/16	2.5	3
29.5	9-18	8-30	0-9	31.5	1.25	8	1 5/16	2.5	3
31.5	9-20	8-33	0-9	33.5	1.25	8	1 5/16	2.5	3
33.5	9-21	8-35	0-10	35.5	1.5	12	1 5/16	2.5	3.75
35.5	10-22	9-37	0-10	37.5	1.5	12	1 5/16	2.5	3.75
37.5	10-23	10-40	0-11	39.5	1.5	12	1 5/16	2.5	3.75
39.5	11-25	11-40	0-11	41.5	1.5	12	1 9/16	3	4.5
41.5	12-26	12-45	0-12	43.5	1.75	12	1 9/16	3	4.5
45.5	13-30	14-45	0-13	47.5	1.75	12	1 9/16	3	4.5
49.5	14-30	16-45	0-14	52.5	1.75	16	1 9/16	3	4.5
53.5	16-30	18-45	0-15	56.5	2	16	1 9/16	3	4.5
57.1	17-30	20-45	0-16	60	2	20	1 9/16	3	4.5
61.0	18-30	22-45	0-16	64	2	20	1 9/16	3	4.5

Isolator Diameter, D_I (in)	DESIGN PROPERTIES			Maximum Displacement, D_{max} (in)	Axial Load Capacity, P_{max} (kips)
	Yielded Stiffness, K_d (k/in)	Characteristic Strength, Q_d (kips)	Compression Stiffness, K_v (k/in)		
12.0	1-5	0-15	>250	6	100
14.0	1-7	0-15	>500	6	150
16.0	2-9	0-25	>500	8	200
18.0	2-11	0-25	>500	10	250
20.5	2-13	0-40	>1,000	12	300
22.5	3-16	0-40	>3,000	14	400
25.5	3-20	0-50	>4,000	16	600
27.5	3-24	0-50	>4,500	18	700
29.5	4-27	0-60	>5,000	18	800
31.5	4-30	0-60	>6,000	20	900
33.5	4-35	0-80	>7,000	22	1,100
35.5	4-35	0-80	>8,000	22	1,300
37.5	4-35	0-110	>10,000	24	1,500
39.5	5-36	0-110	>11,000	26	1,700
41.5	5-36	0-130	>12,000	28	1,900
45.5	6-37	0-150	>16,000	30	3,100
49.5	7-38	0-170	>21,000	32	4,600
53.5	8-40	0-200	>29,000	34	6,200
57.1	9-41	0-230	>30,000	36	7,500
61.0	10-42	0-230	>37,000	36	9,000

(1) The axial load capacities correspond to maxiumum displacements based on design limits of 250% rubber shear strain or 2/3 the isolator diameter. An isolator's actual displacement and load capacity are dependent on the rubber modulus and number of rubber layers.

(2) Rubber Shear Moduli (G) are available from 55 psi to 100 psi.

(3) For analytical bilinear modeling of the Elastic Stiffness use $K_e=10*K_d$.

Appendices

Geo tech: Nodarse & Associates, Inc.

S_S =	1.636		d =	195	ft
S_1 =	0.646		e =	20.8	ft (with 5% accidental torsion)
S_{M1} =	0.49		g =	386.4	in./sec^2
S_{D1} =	0.646		$T_{str.}$ =	1.491	
R =	6.5		T_D =	7.455	sec.
W =	20,000	kips	T_M =	8.6	sec.
b =	145	ft	Damping =	15%	
Variation =	10%	(Variation in stiffness from the mean stiffness values of the isolators is considered			

Effective Period of Design Displacement:

$$T_D = 2\pi\sqrt{\frac{W}{k_{D,MIN}\,g}}$$

$k_{D,MIN}$ = 36.8 k/in.

Effective Period at Maximum Displacement:

$$T_M = 2\pi\sqrt{\frac{W}{k_{M,MIN}\,g}}$$

$k_{M,MIN}$ = 27.8 k/in.

Design Effective Damping in the System:

$$\beta_D = \frac{1}{2\pi}\left[\frac{\text{total area of hysteresis loop}}{K_{D,MAX}\,D^2}\right]$$

$k_{D,MAX}$ = 44.9 k/in.

Maximum Effective Damping in the System:

$$\beta_M = \frac{1}{2\pi}\left[\frac{\text{total area of hysteresis loop}}{K_{M,MAX}\,D^2}\right]$$

$k_{D,MAX}$ = 34.0 k/in.

B_D =	1.35	(Table 17.5-1 Damping Coefficient)
B_M =	1.35	*Assumed same level of damping assigned to both directions

Design Displacement:

$$D_D = \frac{g S_{D1} T_D}{4\pi^2 B_D}$$

D_D = 34.92 in.

Maximum Displacement:

$$D_M = \frac{g S_{M1} T_M}{4\pi^2 B_M}$$

D_M = 30.46 in.

Total Displacement:

$$D_{TD} = D_D\left[1 + y\frac{12e}{b^2 + d^2}\right]$$ 49.3 in.

$$D_{TM} = D_M\left[1 + y\frac{12e}{b^2 + d^2}\right]$$ 43.0 in.

Minimum Lateral Forces: (Isolation System and Structural Elements below the Isolation System

$V_b = k_{D,MAX} D_D$ 1569 kips

Structure Elements Above the Isolation System:

$$V_s = \frac{k_{D,MAX} D_D}{R_I}$$ 784.5 kips

R_I = (3/8)R = 2.438 1.0 ≤ R_I ≤2.0 ∴ 2.0

Appendices

Federal Investment Tax Credit 30% of total BiPV until 2017:		$ (740,857)	30%	740,857
MACRS Depreciation Value:		$ 2,469,522		
Depreciation Schedule Per Year:	yr 1	$ 493,904		167,927
	yr 2	$ 493,904		167,927
	yr 3	$ 493,904		167,927
	yr 4	$ 493,904		167,927
	yr 5	$ 493,904		167,927
State Depreciation: (10 Year Straight Line)		$ 246,952.20	10%	21,831

TAX SAVINGS

YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	$ 1,479,072
908,784										
	167,927									
		167,927								
			167,927							
				167,927						
21,831	21,831	21,831	21,831	21,831	21,831	21,831	21,831	21,831	21,831	
930,615	189,758	189,758	189,758	189,758	21,831	21,831	21,831	21,831	21,831	$ 1,798,800
63%	13%	13%	13%	13%	NET OUT OF POCKET COSTS					$ (319,728)

95% Return in 36 months

Actual 13% posetive return on investment per year for two years

Break Even Point

PV performance	13.47	kWh/SF/YR
No Pv SD EUI	5.53	(KWh/SF/YR)
Floor Plate	12934	SF
Story height	14.5	ft

	South Façade PV Coverage	PV GEN (kWh/YR)	West Façade PV Coverage	PV GEN (kWh/YR)	East Façade PV Coverage	PV GEN (kWh/YR)	TOTAL PV GEN (kWh/YR)	Consumption (kWh/YR)	Net Consumption
Façade Length	140		80		80				
PV (KWh/SF/YR)	11.43		11.33		11.53				
80% performance	9.144		9.064		9.224				
Story 8	46%	8,539	46%	4,837	46%	4,922	18,297	71,525	53,228
7	46%	8,539	46%	4,837	46%	4,922	18,297	71,525	53,228
6	46%	8,539	46%	4,837	46%	4,922	18,297	71,525	53,228
5	46%	8,539	46%	4,837	46%	4,922	18,297	71,525	53,228
4	46%	8,539	46%	4,837	46%	4,922	18,297	71,525	53,228
3	46%	8,539	46%	4,837	46%	4,922	18,297	71,525	53,228
2	46%	8,539	46%	4,837	46%	4,922	18,297	71,525	53,228
1	46%	8,539	46%	4,837	46%	4,922	18,297	71,525	53,228
	Σ	68,309	Σ	38,692	Σ	39,375	146,377	572,200	425,823

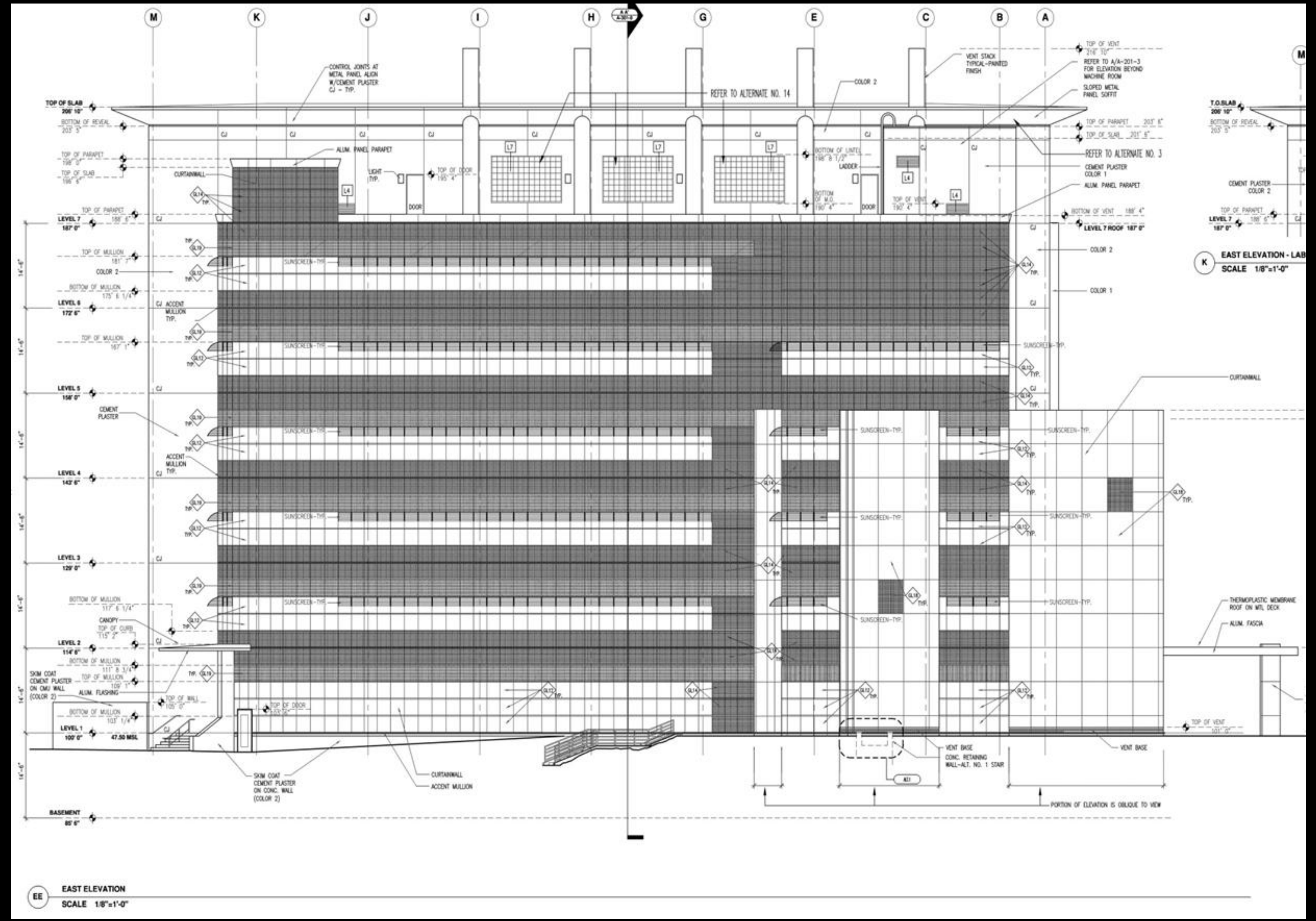
Total PV Offset (%) = 25.58%

x

0.1297 $/kWh

Total Savings= $18,985

Appendices



Element		J1			B1			G1		
Reinforcement	Hand Calculation	(2)#9	(3)#9	(4)#9	(2)#9	(3)#9	(4)#9	(4)#9	(2)#9	(4)#9
	RAM Concept	(4)#7	(5)#7	(4)#9	(4)#7	(5)#7	(4)#9	(4)#9	(4)#7	(4)#9

Direction	Earthquake Name / Recording Station	Scale factor from PEER
X	Imperial Valley-06/ El Centro #7	1.3587
	Northridge-01 / Sylmar - Olive View	1.1408
	Chi Chi, Taiwan / TCU065	0.8084
Y	Imperial Valley-06/ Chihuahua	2.6337
	Northridge-01 / Northridge - Saticoy	1.498
	Chi Chi, Taiwan / TCU067	1.1668

S_s=	164%	1.636
S_1=	65%	0.646

F_a=	1.0
F_v=	1.5

S_{ms}=	$Fa.S_s$=	1.6
S_{m1}=	$Fv.S_1$=	0.969

Category=	II	SDS = D
S_{DS}=	D	
S_{D1}=	D	

S_{DS}=	$2/3\ S_{MS}$	1.091
S_{D1}=	$2/3\ S_{M1}$	0.646

Cs=	$S_{DS}/(R/I)$	0.16779487	≤	Cs=	$S_{D1}/(T.(R/I))$	0.1067	
			>	Cs=	$0.5S_1/(R/I)$	0.049692308	Cs= 0.1067

C_u=	1.4	T_a=	$C_T.h_n^x$=	0.67
		T=	$C_u.T_a$ =	0.93