PENNSTATE
Department of
Architectural Engineering
Bradley Williams - CM

Taylor Hall
George Mason University

Fairfax, VA

Advisor: Ed Gannon

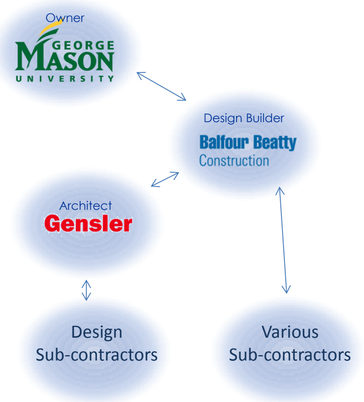
Renderings courtesy of Gensler

PENNSTATE
Department of
Architectural Engineering
Bradley Williams - CM

Taylor Hall – George Mason University

Fairfax, VA

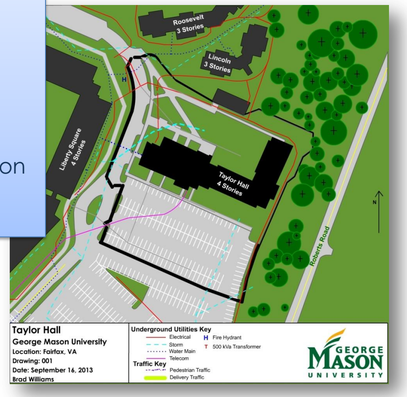
Project Delivery – Design Build



Renderings courtesy of Gensler

Project Statistics:

- 295 Freshman Students
- 70,057 GSF
- ~$16,000,00
- 12 months of construction
- LEED Silver



Investigation Goals

- Investigate new ways to increase job-site safety
- Reduce injury risk for construction workers, future students and maintenance personnel
- Reduce the cost of construction while maintaining quality
- Increase the awareness for sustainable design

Preview of Analyses

Analysis 1: Prevention through Design

Analysis 2: Façade Re-design for Fall Safety
Architectural Breadth: Mechanical Access Points

Analysis 3: Stick-Built construction vs. Infinity System

Analysis 4: Green Roof Addition
Structural Breadth: Green Roof Load incurrence

Current Industry-Wide Issues

- Lack of risk knowledge
- Lack of early collaboration/communication
- Lack of contractual obligation for safety

Balfour Beatty Construction

Prevention through Design

Critical Industry Research

Construction → **Maintenance** → **Decommissioning** → **Disposal / Recycling**

*"…the Center for Disease Control and Prevention (CDC) have pinpointed in recent studies that an abundant **37%** of these work related injuries are **directly caused by poor design**" - CDC.gov*

Ideas for Implementation

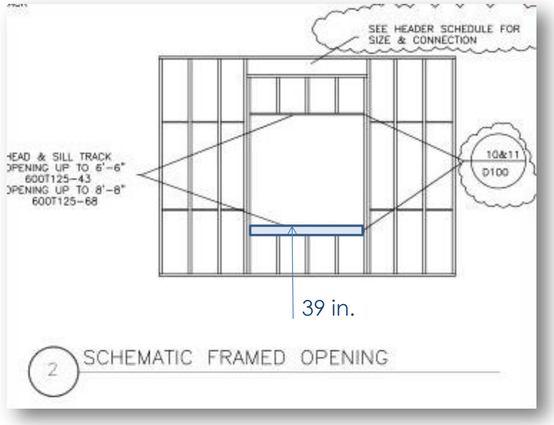
- Raising sill height to 39"
- Prefabrication
- Raising parapet height and using flat roofs
- Lowering mechanical access points
- Using low VOC materials

Results:

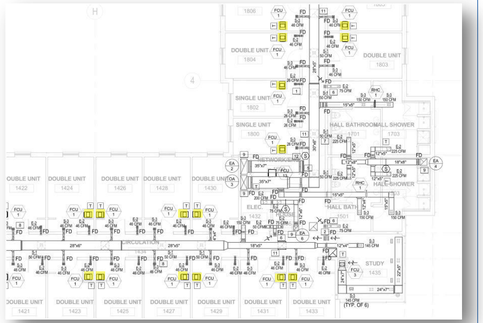
- Increase job site safety
- Prevent student misconduct
- Benefits outweigh cost
- Save cost on temporary fall protection lines

Façade Re-design and Implementation of Prevention through Design

- Logical Safety improvement method given prefab structural system
- Total cost of implementation: **$17,156.40**
- No schedule impact



Renderings courtesy of Gensler

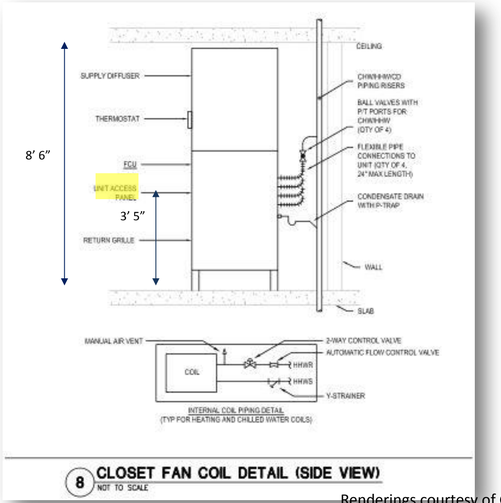


FCU Access points in each unit

Investigation of Mechanical Access Points

Mechanical Access Heights	
Mechanical Room	Floor Mounted Equipment
Unit FCU Access	3’ 5”
Mechanical Penthouse	7’ 8”

- All access points considered safe (except trip hazard in pent house)
- All access points behind locked doors or restricted access
- Considered very “safe” design



Renderings courtesy of Gensler

PENNSTATE
Department of
Architectural Engineering
Bradley Williams - CM

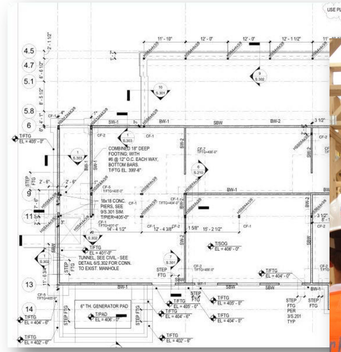
Benefits

- No schedule change with prefabrication
- Fire safe construction
- Experienced craftsmen in D.C. area

Stick-Built Framing vs. Infinity Structural System

Overall Cost of Stick-Built System	
Part of System	Price
Wooden Roof Trusses/Sheathing	$128,240.64
Wooden Framing	$612,998.75
Wooden Joists/Girders	$1,224,596.36
TOTAL COST	$1,965,835.75
Total ($/SF)	$28.06
Location Adjustment Multiplier (78.3)	**$21.97**

- Infinity Structural System estimated at **$23 / SF**
- Total Savings of **$72,158.71**

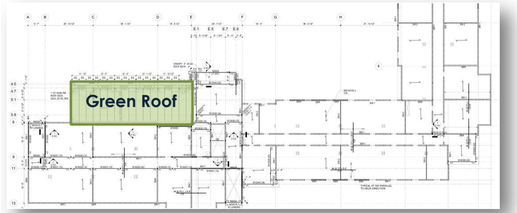


Renderings courtesy of Gensler

Photos courtesy of Brad Williams

PENNSTATE
Department of
Architectural Engineering
Bradley Williams - CM

Multi-purpose Room Green Roof



- **1,310 SF** total
- Omni-Ecosystem comprehensive style green roof for optimum weight
- Can be added post-construction
- Low maintenance, high efficiency

Green Roof Addition

- Installation Cost of **$17,696.63**
- **1 day** installation

50 – year Life Cycle Cost Benefit Analysis ($/SF)	
Initial Cost	$13.51
Maintenance and Replacement	$18.25
Storm Water Reduction Savings	$11.37
Energy Savings	$6.37
CO2 Emission Savings	$2.60
Community Benefits	$30.90
Property Re-sale value premium	$105.93

Fiscal Analysis

- Payback Period: 4.17 - 6.7 years
- Internal Rate of Return*: 4.21%
- Return on Investment*: 196%

* Not including CO2 Emissions, Community Benefits, or Re-Sale Value

Omni-Ecosystems.com

Takeaways

- Significantly longer life than T.P.O.
- Educational opportunities in sustainability
- Lifetime net yield of up to **$182,000** of benefits

Load Comparison

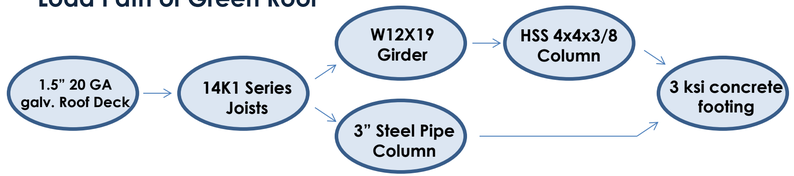
Existing Factored Load: **81 PSF**

Factored Load with Green Roof: **99 PSF**

15 PSF

Structural Evaluation of Potential Green Roof

Load Path of Green Roof



- All structural members can safely accommodate new loading
- No structural changes are necessary

Structural Change

Member	Existing Load	New Load	Allowable
Roof Deck	81 PSF	99 PSF	159 PSF
Joists	329.2 PLF	401.2 PLF	472 PLF
Girder	3.2 kips	3.9 kips	20 kips
Steel Post Column	3.2 kips	3.9 kips	16 kips
HSS Column	9.2 kips	11.3 kips	87 kips
Soil	0.56 KSF	0.71 KSF	2.0 KSF

Renderings courtesy of Gensler

Conclusion

Summary of Results		
Analysis	**Result**	
Prevention through Design	Reduced risk of injury over the building's life	✓
Façade Re-design	More efficient fall safety measures	✓
Stick-Built Construction	Cost effective solution for the D.C. area	✓
Green Roof Addition	Educational opportunities and financial benefits	✓

Renderings courtesy of Gensler

Acknowledgments

- Family and Friends
- John Risley, Contractor Safety Coordinator of PSU OPP
- Professors and Faculty of the Architectural Engineering department

Questions?

Balfour Beatty Construction

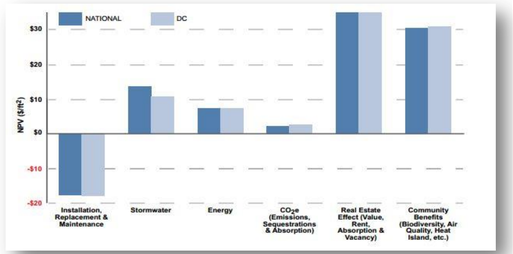
Gensler

George Mason University

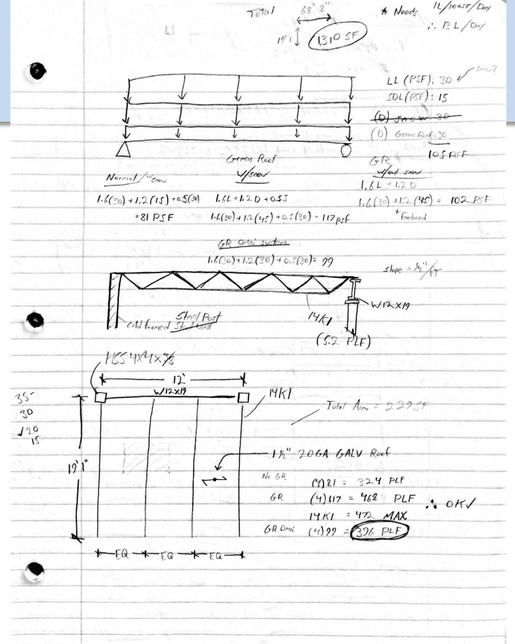
Miller & Long Concrete Construction Established 1947

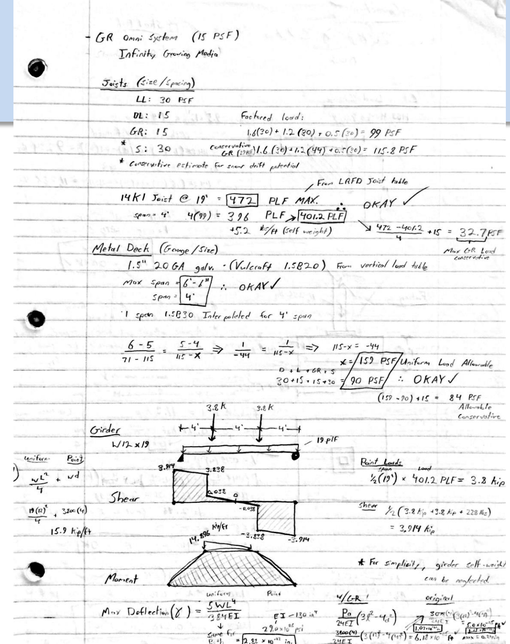
PENNSTATE
Department of
Architectural Engineering
Bradley Williams - CM

Appendix



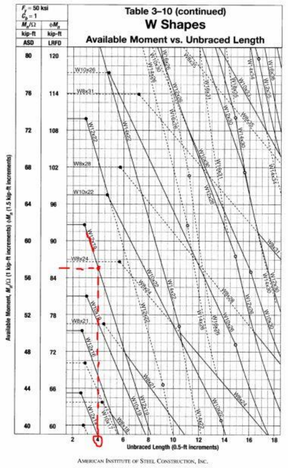
Green Roof Study conducted by the U.S. General Services Administration

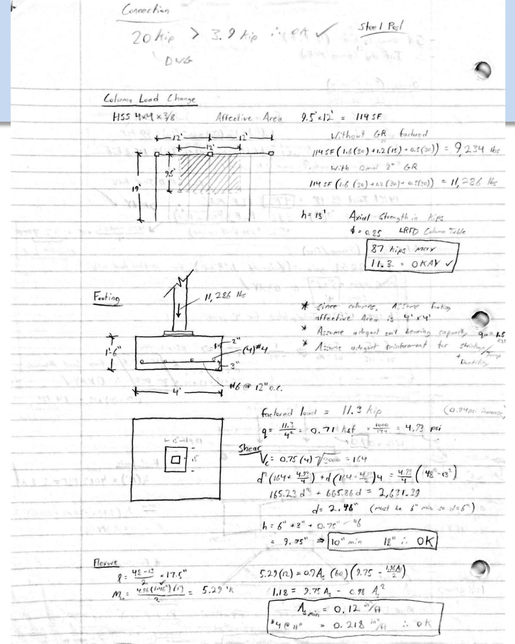


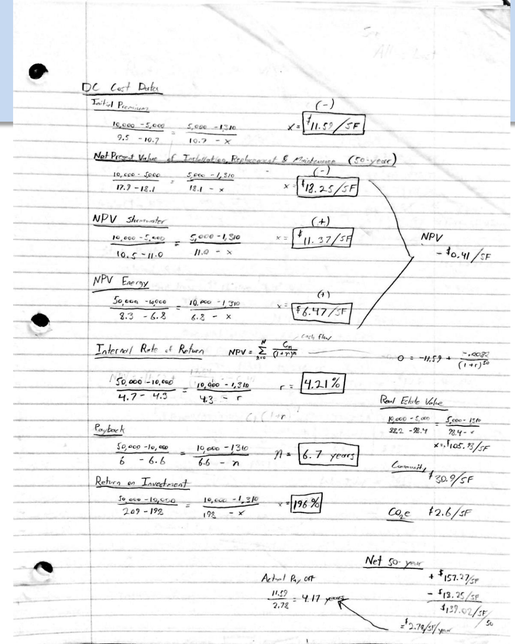


PENNSTATE
Department of
Architectural Engineering
Bradley Williams - CM

Appendix







PENNSTATE
Department of
Architectural Engineering
Bradley Williams - CM

Appendix

VERTICAL LOADS FOR TYPE 1.5B

No. of Spans	Deck Type	Max. SDI Const. Span	Allowable Total (Dead + Live) Uniform Load (PSF) Span (ft.-in.) C. to C. of Support 5'-0	5'-6	6'-0	6'-6	7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0
1	B 24	4'-3	66	52	42	36	30	27	24	21	20	825	825
	B 22	5'-7	91	71	57	47	40	34	30	27	24	22	20
	B 21	6'-0	104	81	64	53	44	38	33	29	26	24	22
	B 20	6'-5	115	89	71	58	48	41	36	31	28	25	23
	B 19	7'-1	139	107	85	69	57	48	41	36	32	29	26
	B 18	7'-8	162	124	98	79	65	55	47	41	36	32	29
	B 16	8'-8	206	157	123	99	81	68	58	50	44	39	34
2	B 24	5'-10	126	104	87	74	64	55	47	41	36	32	29
	B 22	6'-11	102	85	71	61	52	46	40	35	32	28	26
	B 21	7'-4	118	97	82	70	60	52	46	41	36	33	29
	B 20	7'-9	132	109	91	78	67	59	51	46	41	36	33
	B 19	8'-5	154	127	107	91	79	69	60	53	48	43	39
	B 18	9'-1	174	144	121	103	89	78	68	60	54	48	44
	B 16	10'-3	219	181	152	130	112	97	86	76	68	61	55
3	B 24	5'-10	130	100	79	65	54	45	39	34	31	27	25
	B 22	6'-11	128	106	89	76	65	57	50	44	39	34	31
	B 21	7'-4	147	122	102	87	75	65	56	49	42	38	34
	B 20	7'-9	165	136	114	97	84	72	61	53	46	41	36
	B 19	8'-5	193	159	134	114	98	84	71	61	53	47	41
	B 18	9'-1	218	180	151	129	111	96	81	69	60	52	46
	B 16	10'-3	274	226	190	162	140	119	100	85	73	64	56

Notes: 1. Load tables are calculated using sectional properties based on the steel design thickness shown in the Steel Deck Institute (SDI) Design Manual.
2. Loads shown in the shaded areas are governed by the live load deflection not in excess of 1/240 of the span.
3 ** Acoustical Deck is not covered under Factory Mutual
A dead load of 10 PSF has been included.

LRFD

STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown in Pounds per Linear Foot (plf)

Joist Designation	8K1	10K1	12K1	12K3	12K5	14K1	14K3	14K4	14K6	16K2	16K3	16K4	16K5	16K6	16K7	16K9
Depth (in.)	8	10	12	12	12	14	14	14	14	16	16	16	16	16	16	16
Approx. Wt (lbs./ft.)	5.1	5.0	5.0	5.7	7.1	5.2	6.0	6.7	7.7	5.5	6.3	7.0	7.5	8.1	8.6	10.0
Span (ft.) 8	825 550															
9	825 530															
10	825 480	825 550														
11	798 377	825 545														
12	666 288	825 455	825 550	825 550	825 550											
13	565 223	718 363	825 510	825 510	825 510											
14	486 179	618 289	750 426	825 483	825 483	825 550	825 550	825 550	825 550							
15	421 145	537 234	651 344	814 428	825 434	766 475	825 507	825 507	825 507							
16	369 119	469 192	570 282	714 391	825 396	672 467	825 467	825 467	825 467	825 590	825 590	825 590	825 590	825 590	825 590	825 590
17		415 159	504 234	630 291	825 366	592 424	742 443	825 443	825 443	768 488	825 526	825 526	825 526	825 526	825 526	825 526
18		369 134	448 197	561 245	760 317	528 272	661 339	795 397	825 408	684 409	762 485	825 490	825 490	825 490	825 490	825 490
19		331 113	402 167	502 207	681 269	472 230	592 287	712 336	825 383	612 357	682 386	820 452	825 455	825 455	825 455	825 455
20		298 97	361 142	453 177	613 230	426 197	534 246	642 287	787 347	552 297	615 330	739 388	825 426	825 426	825 426	825 426
21			327 123	409 153	555 198	385 170	483 212	582 248	712 299	499 255	556 285	670 333	754 399	822 426	825 426	825 426
22			298 106	373 132	505 172	351 147	439 184	529 215	648 259	454 222	505 247	609 289	687 323	747 351	825 385	825 385
23			271 93	340 116	462 150	321 128	402 160	483 188	592 226	415 194	462 216	556 252	627 282	682 307	760 339	825 363
24			249 81	312 101	423 132	294 113	367 141	442 165	543 199	381 170	424 189	510 221	576 248	627 269	697 298	825 346
25						270 100	339 124	408 145	501 175	351 156	390 174	469 195	529 219	576 238	642 263	771 311
26						249 88	313 110	376 129	462 156	324 133	360 148	433 173	489 194	532 211	592 235	711 278
27						231 79	289 98	349 115	427 139	300 119	334 132	402 155	453 173	493 188	549 208	658 246
28						214 70	270 88	324 103	397 124	279 106	310 118	373 138	421 155	459 166	510 186	612 220
29										259 93	289 106	348 124	391 139	427 151	475 167	570 198
30										241 86	270 96	324 112	366 126	399 137	444 151	532 178
31										226 78	252 87	304 101	342 114	373 124	415 137	498 161
32										213 71	237 79	285 92	321 103	349 112	388 124	466 147

LRFD Columns Square HSS

Design Axial Strength in kips (ϕ=0.85)

Nominal Size	4 x 4						3 1/2 x 3 1/2				
Wall Thickness	1/2	3/8	5/16	1/4	3/16	1/8	3/8	5/16	1/4	3/16	1/8
Weight Per Foot	21.63	17.27	14.83	12.21	9.42	6.46	14.72	12.70	10.51	8.15	5.61
Design Wall Thickness	0.465	0.349	0.291	0.233	0.174	0.116	0.349	0.291	0.233	0.174	0.116
						F_y = 46 ksi					
Effective length KL in feet 0	235	187	160	132	101	69	160	138	114	88	60
2	231	184	158	130	99	68	156	134	111	86	59
3	225	179	154	127	97	67	151	131	108	83	57
4	218	174	150	123	95	65	145	125	104	80	55
5	208	167	144	119	91	63	137	119	99	77	53
6	198	159	137	113	87	60	128	112	93	72	50
7	185	150	129	107	83	57	119	103	87	68	47
8	172	140	121	101	78	54	108	95	80	62	43
9	159	129	113	94	73	51	98	86	73	57	40
10	145	119	104	87	67	47	87	77	65	51	36
11	131	108	95	79	62	43	76	68	58	46	32
12	117	97	86	72	56	40	66	60	51	41	29
13	103	87	77	65	51	36	57	51	44	36	25
14	90	77	68	58	46	32	49	44	38	31	22
15	79	67	60	51	41	29	43	39	33	27	19
16	69	59	53	45	36	26	38	34	29	24	17
17	61	52	47	40	32	23	33	30	26	21	15
18	55	47	42	36	28	20	30	27	23	19	13
19	49	42	37	32	25	18	27	24	21	17	12
20	44	38	34	29	23	16	24	22	19	15	11
21	40	34	31	26	21	15	22	20	17	14	10
22	37	31	28	24	19	14			16	12	9
23	34	29	25	22	17	12					
24		26	23	20	16	11					
25				18	15	10					
26						10					
27											

Appendix

Load Bearing Capacity of Standard Steel Pipe Columns
(36 KSI Yield)

Nominal Dia. (in.)	Outside Dia. (in.)	Wall Thickness (in.)	Weight (lb./ft.)	Allowable Load in Thousands of Pounds Unsupported Column Length (ft.)* 6	8	10	12	14
3	3.50	0.216	7.58	38	34	28	22	16
3-1/2	4.00	0.226	9.11	48	44	38	32	25
4	4.50	0.237	10.79	59	54	49	43	36
5	5.563	0.258	14.62	83	78	73	68	61
6	6.625	0.280	18.97	110	106	101	95	89

* The above loads are the allowable loads for a column in which the load acts downward along the longitudinal axis of the column. For other designs, such as a column with a side load consult with an engineer for the proper size. When in doubt consult with an engineer.

SOIL BEARING CAPACITY

TABLE 1804.2
ALLOWABLE FOUNDATION AND LATERAL PRESSURE

Class of Materials	Allowable Foundation Pressure (psf)[d]	Lateral Bearing (psf/f below natural grade)[d]	Lateral Sliding	
			Coefficient of friction[a]	Resistance (psf)[b]
1. Crystalline bedrock	12,000	1,200	0.70	—
2. Sedimentary and foliated rock	4,000	400	0.35	—
3. Sandy gravel and/or gravel (GW and GP)	3,000	200	0.35	—
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000	150	0.25	—
5. Clay, sandy clay, silty clay, clayey silt, silt and sand silt (CL, ML, MH and CH)	1,500[c]	100	—	130

PENNSTATE
Department of
Architectural Engineering
Bradley Williams - CM

Appendix

Roof: Stick-Built VS. Infinity System

From Tech II

	$/SF
Total $1,086,434.97	$15.50
RS Means	$19.98
Infinity	$23.00
Original from BBC	$30.00

TOTAL
Roof = $128,240.64
Int. Frame = $612,998.75
Joists/Girders = $1,224,596.36
$1,965,835.75
= $28.06/SF × Fairfax, VA factor (78.3) Wood work
= $21.97/SF
∴ Saving $72,158.71

Stick Built
- Wood Roof
Wood truss 5" 12 slope, 24" O.C. (Assumed)
- 44' to 60' span
span is 45' 10.5" + 4' lip → 49' 10.5"

Materials	Instalation	Total
4.43	2.61	7.04

Slope pitch multiplier (5 in 12) = 1.083
Roof Area (flat) = 16,820 SF
(pitch) = 18,216 SF
Sub-Total = $128,240.64

- Wood Partitions
5/8" Drywall / Res. channel / 2×4 @ 16" O.C. / Res. chanel / 5/8" Drywall | -½" fiberglass

Materials	Instalation	Total
2.10	6.65	8.75

Floor Area (Net) = 70,057
Sub-Total = $612,998.75

- Joists/Girders

	SDL	LL	
Residential Load =	20	40	= 60 / Majority
Stairs (Mer) =	20	100	= 120

Sub-Total = $1,224,596.36

* Assume 15' × 15' Bay
Superimposed Load = 75 PSF; Girder 8×16 4×16; Joists 2×8 @16; Total Load 90
Floor Area (Net) = 70,057

Materials	Installation	Total
12.60	4.88	17.48