Final Report Presentation

April 16th, 2014

Central Ohio Elementary School

Undisclosed Location, Ohio

Raymond Scott Pell, Jr.
Construction Management Option

Advisor: Dr. Robert Leicht

Project Background

The Building

Built: Original Building – 1874

Multiple Renovations

Occupancy: K-5 Grade School

Location: Urban Neighborhood

Closed: 2010 (due to fire damage)

The Project

Size: 28,000 sqft (Renovation) + 18,000 sqft (Addition)

Number of Stories: 3 Stories + Unoccupied Attic

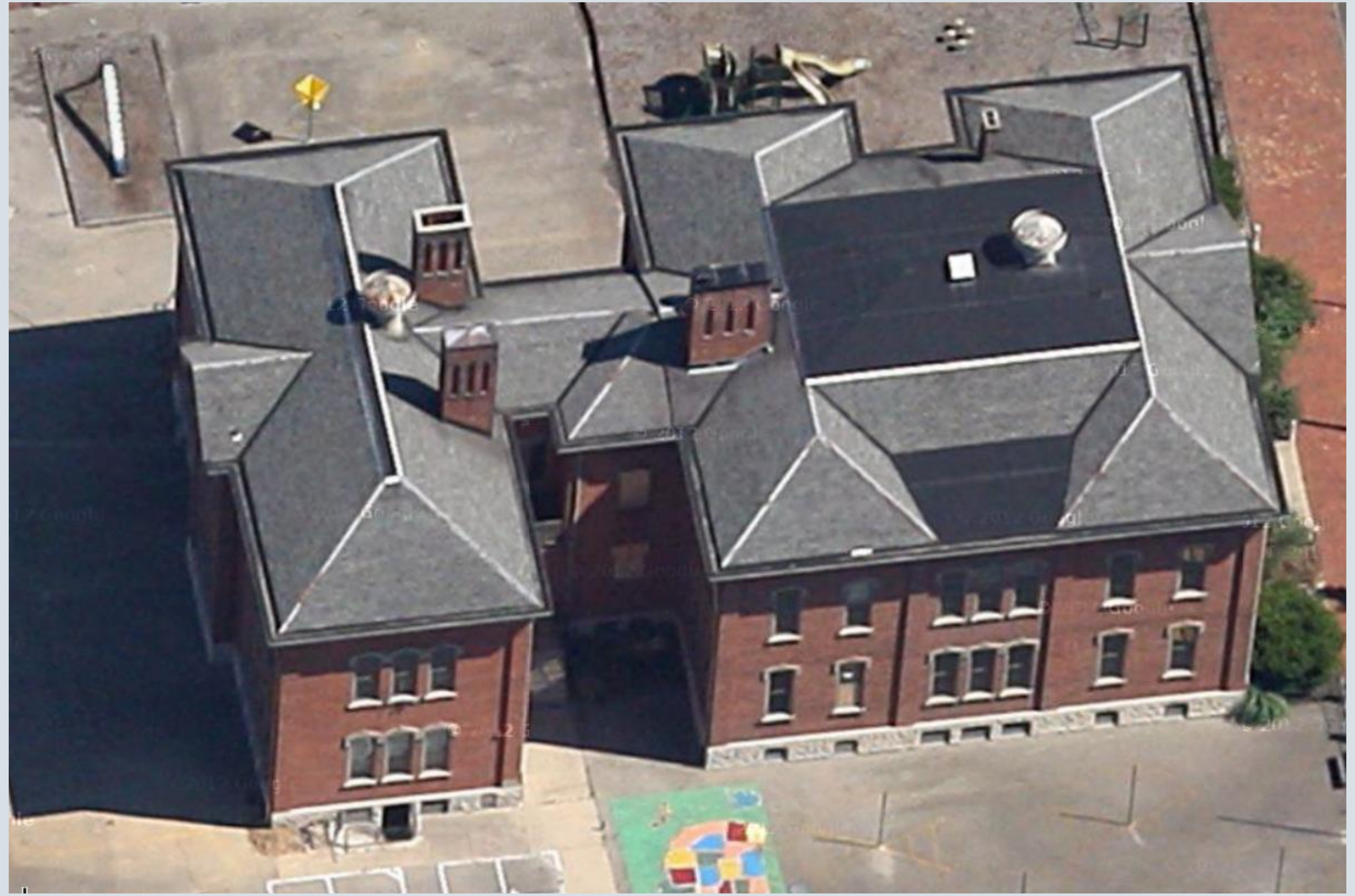
Construction Cost: $9.07 Million

Total Project Cost: $11.2 Million

Construction Start: August 13, 2014

Construction End: January 23, 2015

Project Delivery Method: Single Prime w/ CM Advisor



The Team

Designer: Hardlines Design Company

Project Manager: Smoot Elford Resources

General Contractor: Miles McClellan Construction Co.

SMOOT ELFORD RESOURCE INTERNATIONAL Rii

HARDLINES DESIGN COMPANY

MM MILES•McCLELLAN CONSTRUCTION Columbus

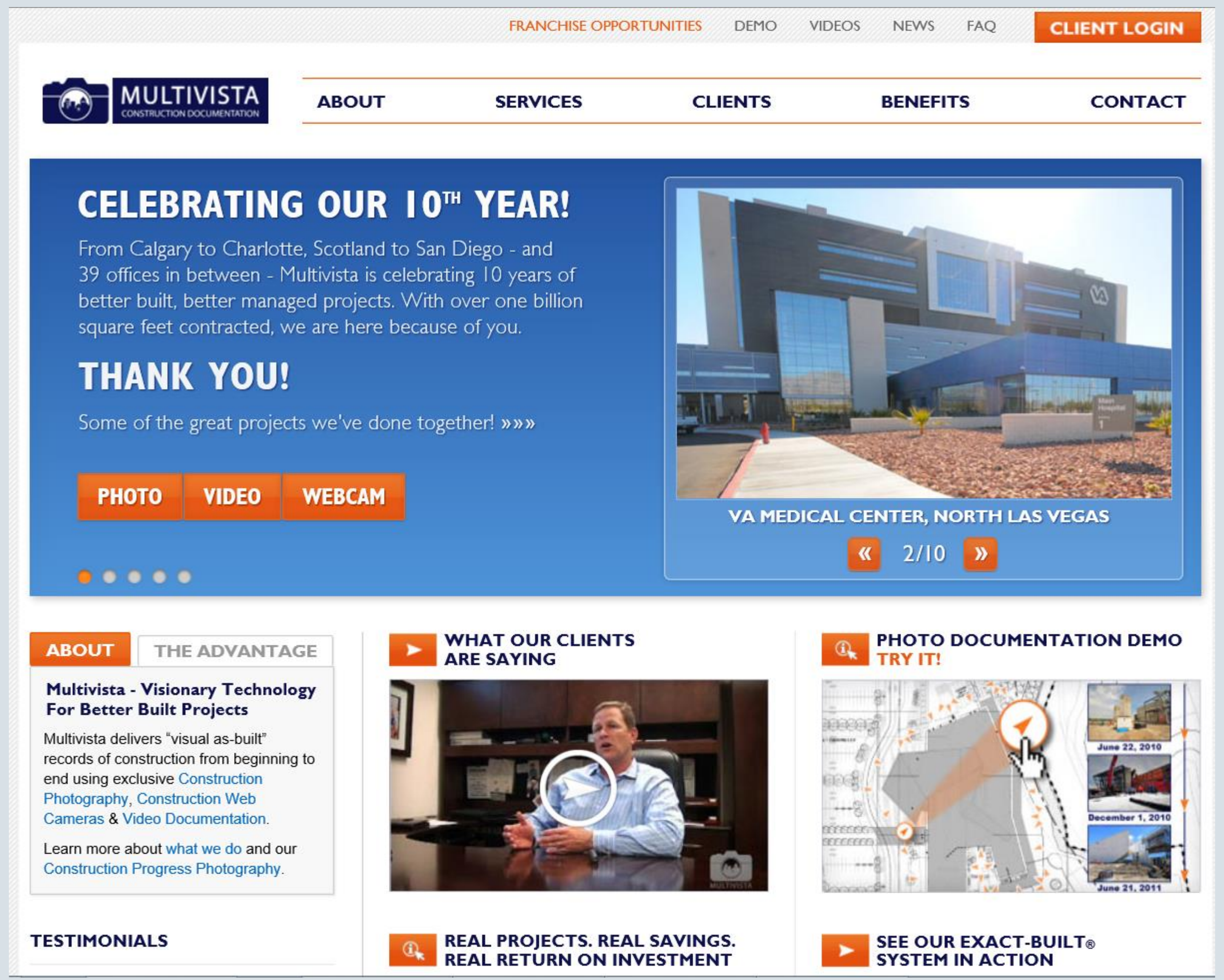
Analysis #1:

Third-Party Photo Documentation

MULTIVISTA
CONSTRUCTION DOCUMENTATION

Background:

- **Multivista Systems, LLC providing service**
- Milestone photography
- Progression photography
- Web-based software



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September 12, 2013

Background:

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October 16, 2013

Background:

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November 20, 2013

Background:

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December 18, 2013

Background:

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January 9, 2014

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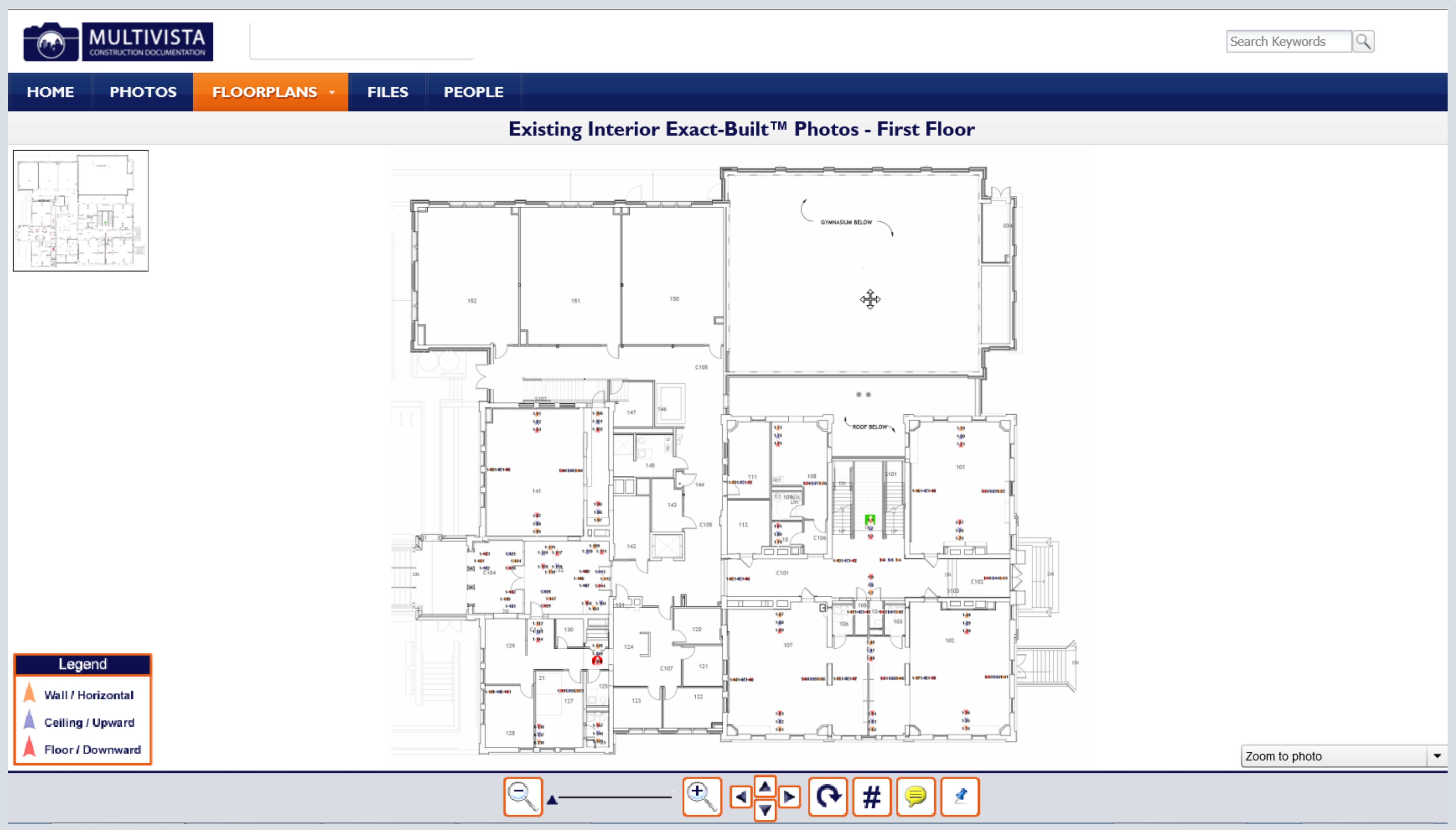

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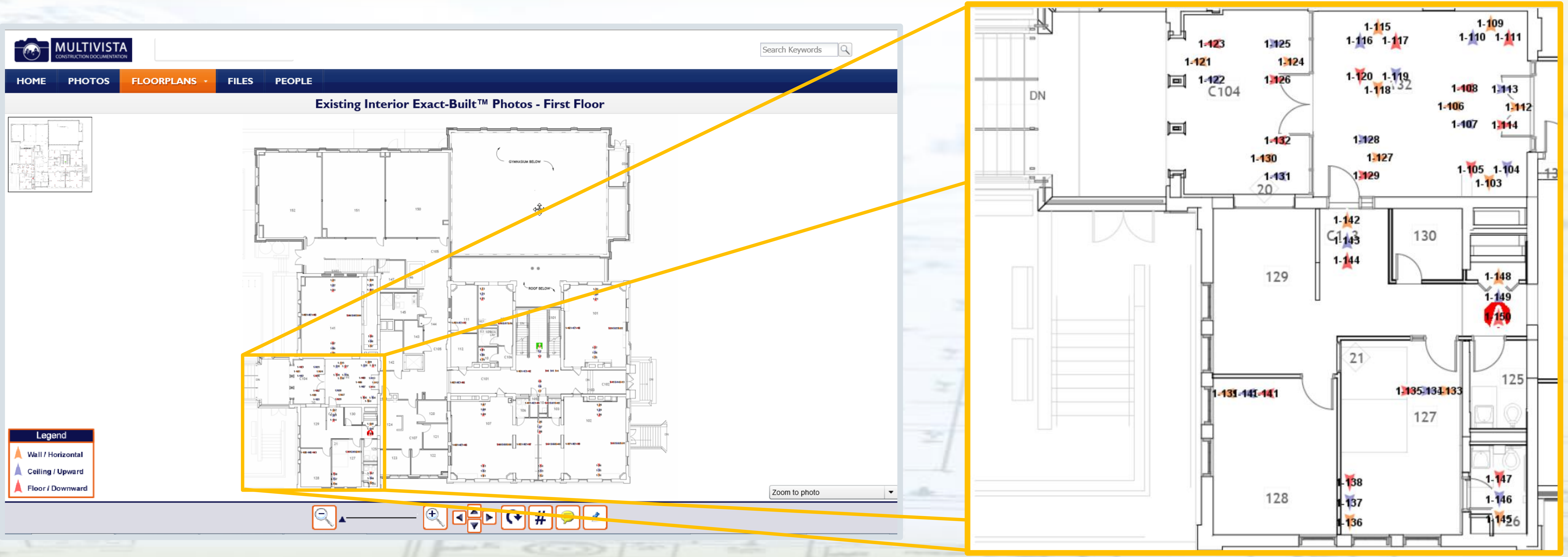

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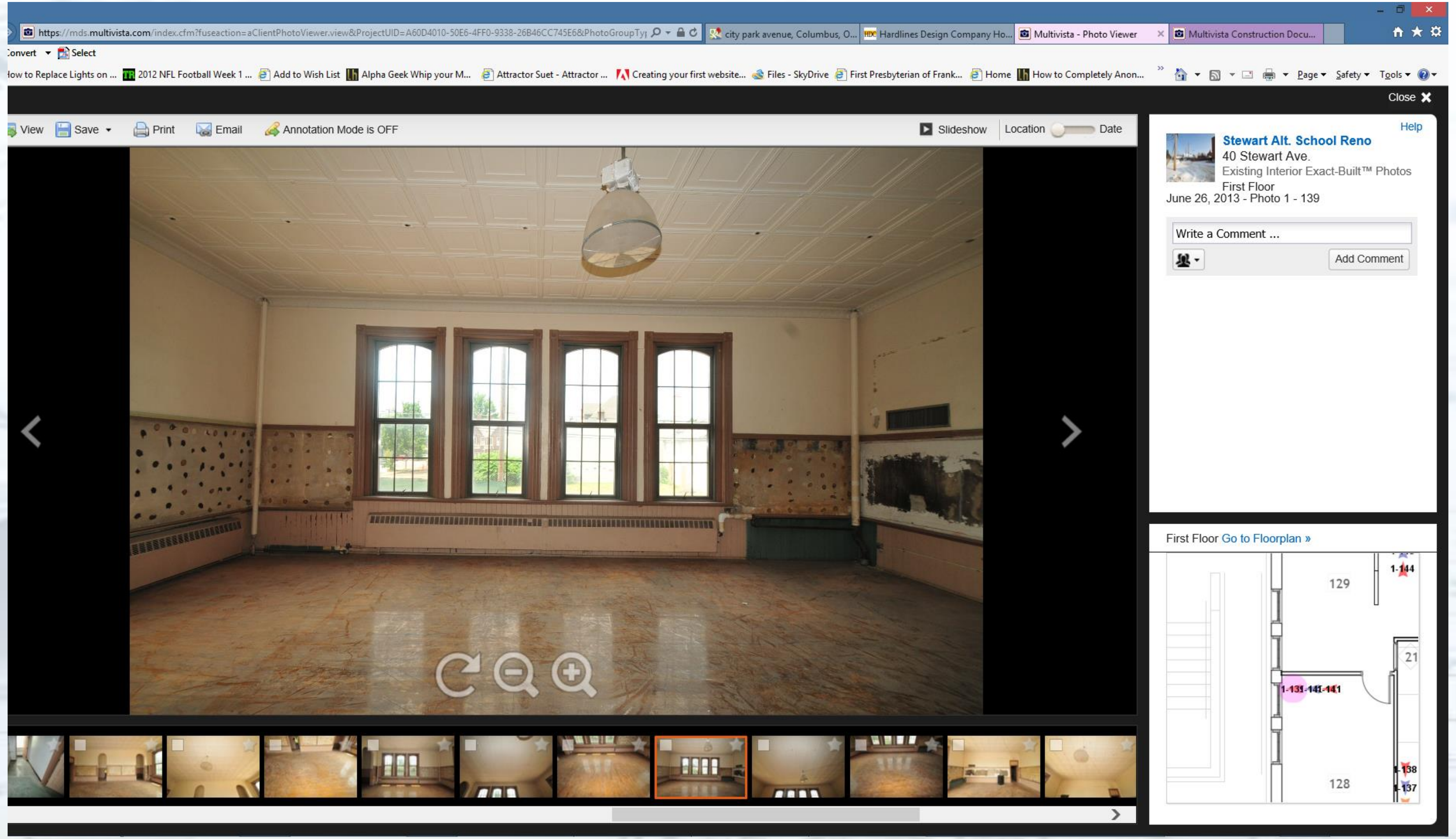

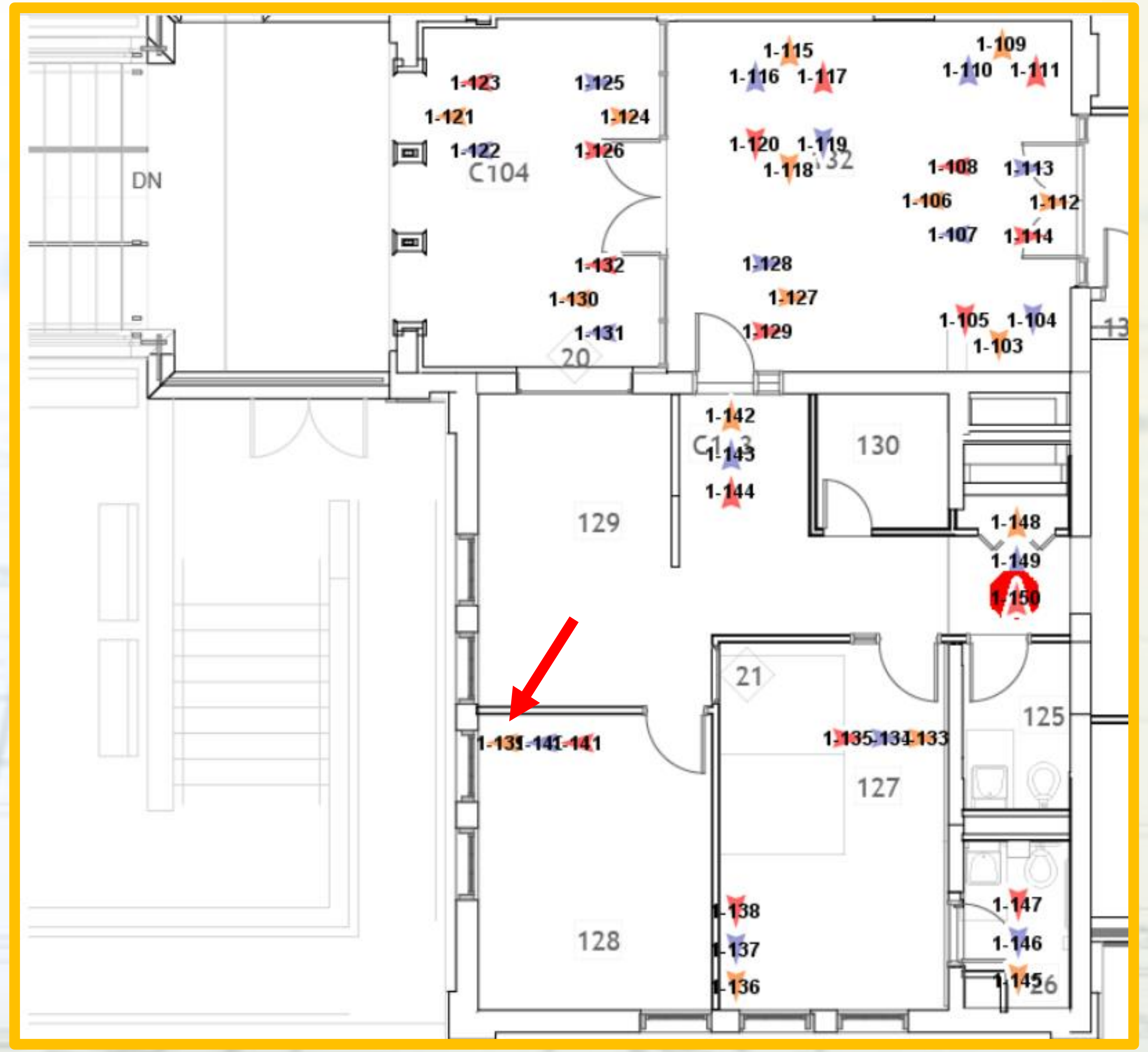

Case Study:

- Newly Constructed Ohio-based Children's Hospital
- ADA handrails in patient bathrooms detached from wall
- Destructive testing found proper support was absent
- 400 bathrooms needed tested
- Referenced MEP Exact-Built® photos
- Only 42 bathrooms needed fixed
- Saved almost $210,000 and 3400 hours

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Cost **without** Photo Documentation				
Activity	Time	Labor	Material	Total
Supervision	1	$84	$0	$84
Destructive Testing	2	$76	$0	$76
Repair	6	$376	$27	$403
Total	9	$536	$27	$563
Total cost for 400 bathrooms				**$225,200**

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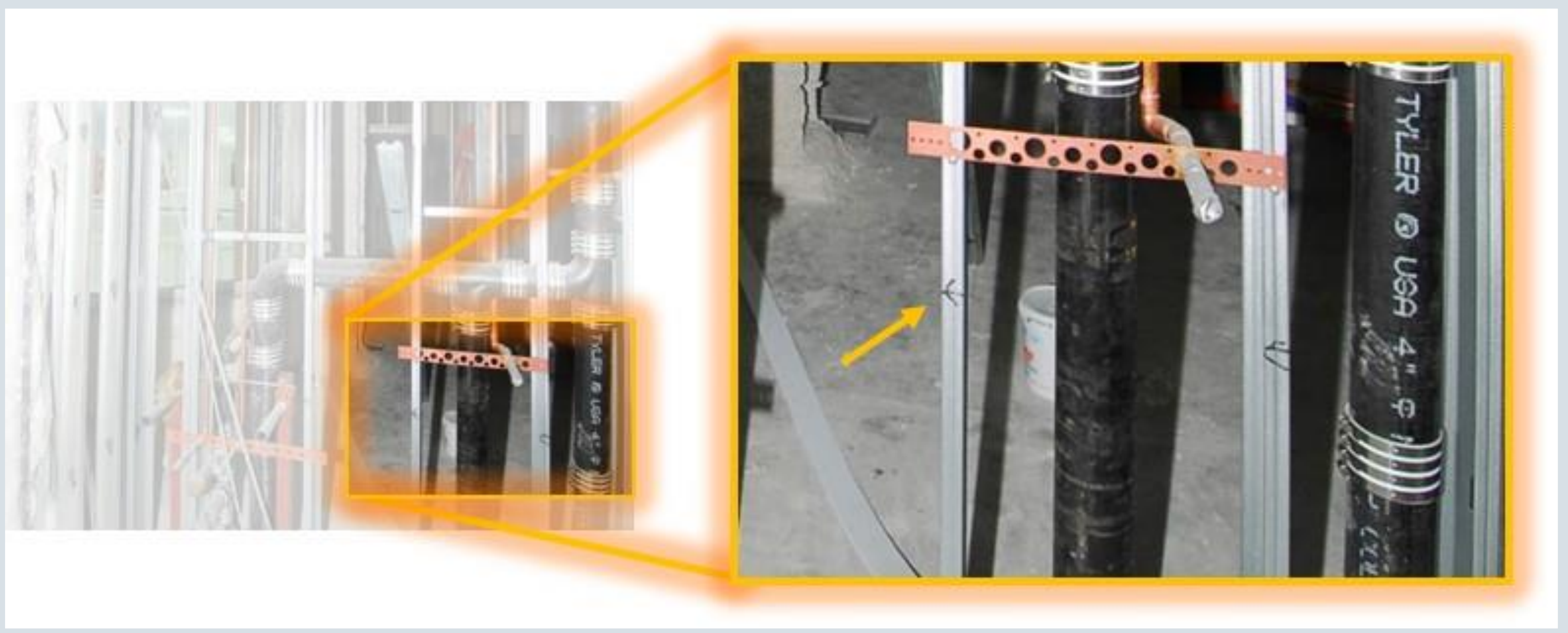

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Cost **with** Photo Documentation

Activity	Time	Labor	Material	Total
Supervision	0.5	$42	$0	$42
Demolition	1	$19	$0	$19
Total	6	$343	$22	$365
Total Cost for 42 Bathrooms				**$15,330**

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Cost **with** Photo Documentation				
Activity	Time	Labor	Material	Total
Supervision	0.5	$42	$0	$42
Demolition	1	$19	$0	$19
Repair	4.5	$282	$22	$304
Total	6	$343	$22	$365
Total Cost for 42 Bathrooms				**$15,330**

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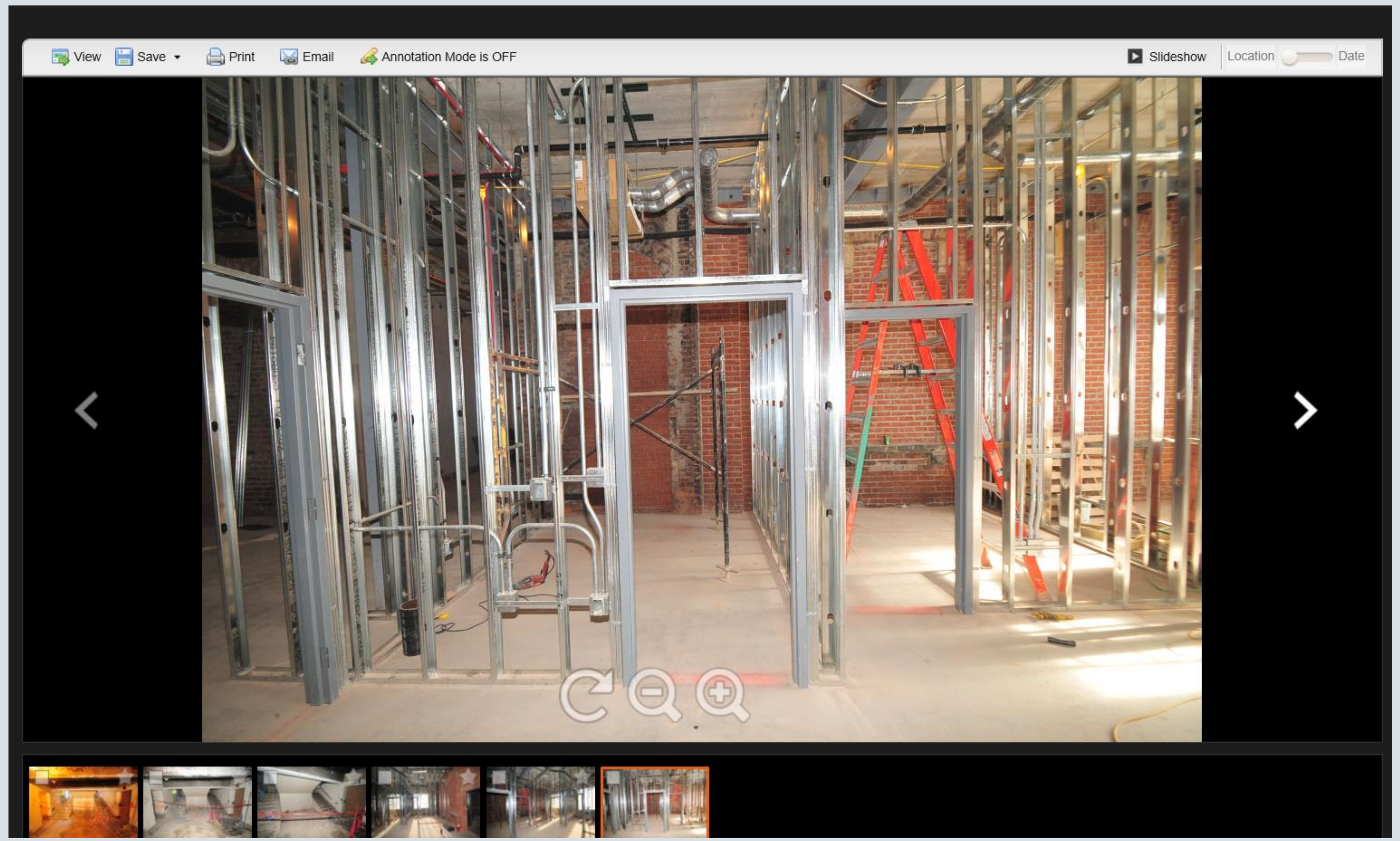
Repair	6	$376	$27	$403
Total	9	$536	$27	$563
Total cost for 400 bathrooms				**$225,200**

$225,200	3600 hrs
-$15,330	-252 hrs
$209,900	**3348 hrs**

Advantages:

- Relieves site superintendent of responsibility
- Photos are immediately available and organized
- Simple to use
- Potential increase in productivity
- Reduces litigation
- "Green" alternative to printed drawings and photos

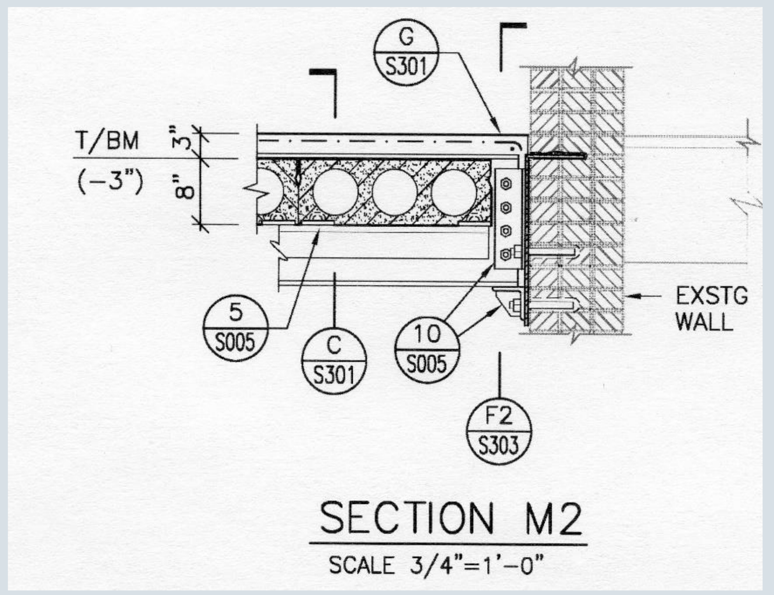


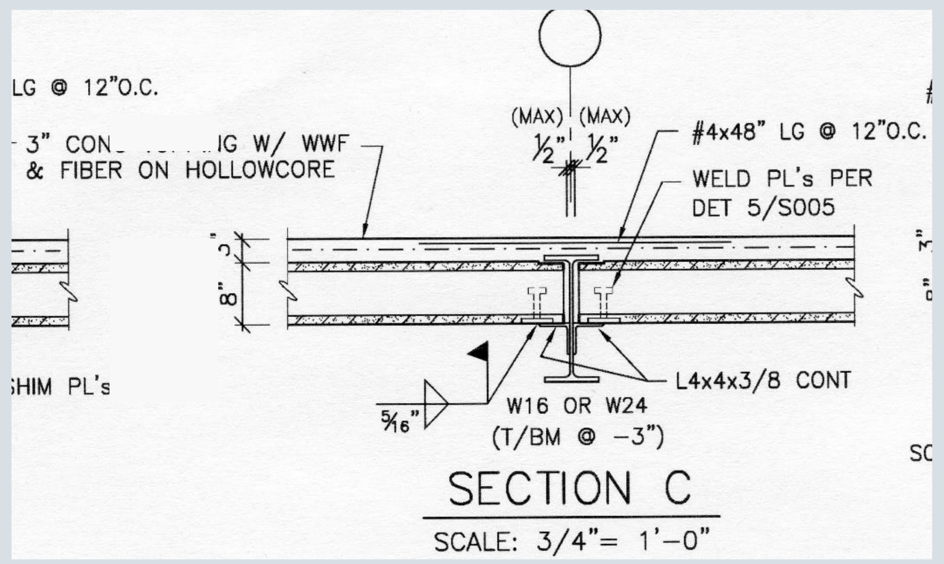
Disadvantages:

- Additional cost
- Doesn't guarantee photographs of everything
- Requires willingness to learn and use

Analysis #2:

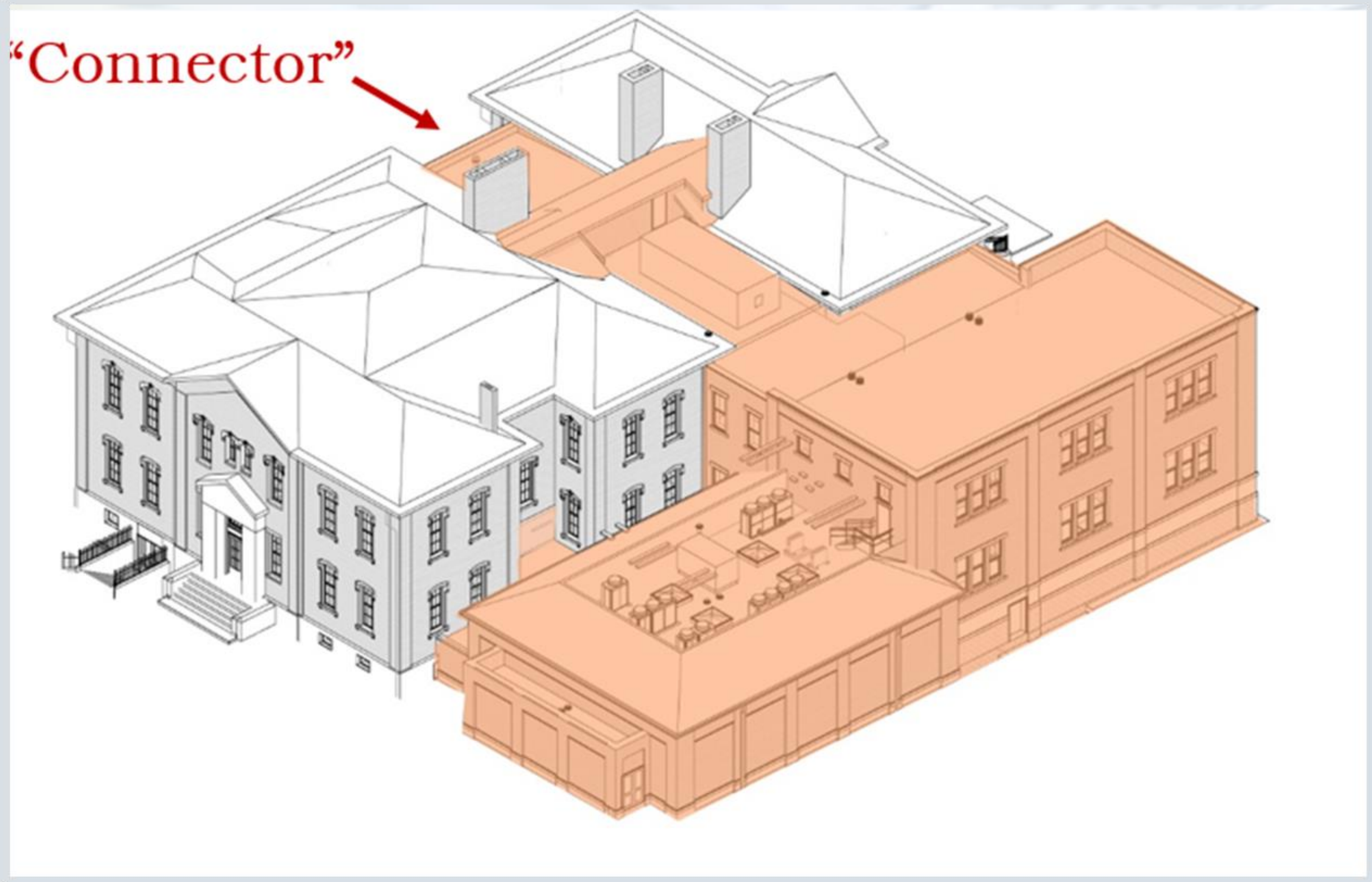
Use of Steel Deck and Cast-in-Place Concrete





Original Design:

- 8" precast hollow core concrete planks
- Steel W-shape beams anchored to existing masonry walls
- 3" concrete top coating
- Welded wire mesh reinforcement

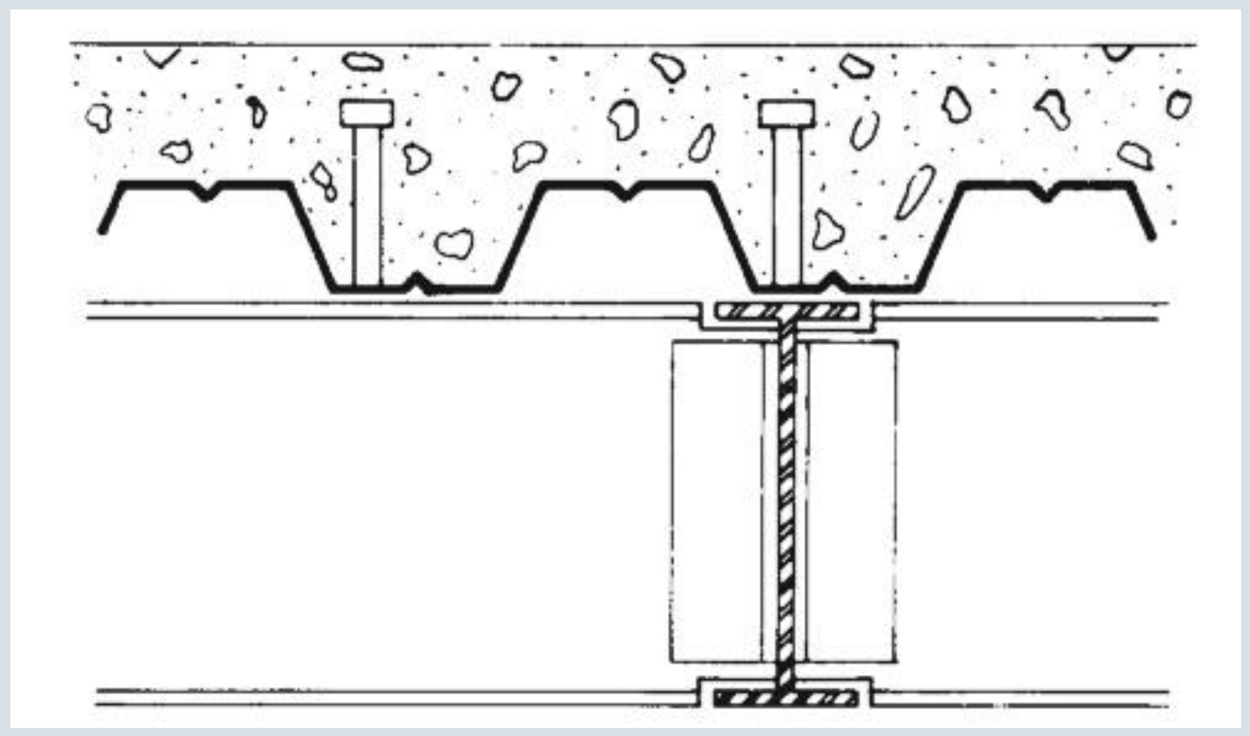


Problem Identification:

- Precast concrete planks require accurate dimensions
- Measurements for "Connector" section proved difficult
- Potential need to move anchor points for steel beams
- Limited access to area
- Changes require re-order of planks
- Limited flexibility for other trades

Alternate Design:

- Composite steel deck
- Cast-in-place concrete
  - 3½" total thickness
  - 2" thickness above steel deck
- Welded wire mesh reinforcement
- Steel W-shape girders anchored to masonry walls
- Steel W-shape joists



Flooring System Estimates

	Description	Qty	Unit	Crew	Daily Output	Bare Material	Bare Labor	Bare Equip.	Bare Total	Total Days	Total Cost
Steel Deck / Cast-in-Placee	W8X10	17.1	L.F.	E2	600	$14.60	$4.68	$2.55	$21.83	0.029	$373
	W8X13	27.5	L.F.	E2	600	$18.98	$4.68	$2.55	$26.21	0.046	$721
	W8X18	91.1	L.F.	E2	600	$26.28	$4.68	$2.55	$33.51	0.152	$3,053
	W8X21	19	L.F.	E2	600	$30.50	$4.68	$2.55	$37.73	0.032	$717
	W8X24	72	L.F.	E2	550	$35.00	$5.10	$2.78	$42.88	0.131	$3,087
	W8X31	57	L.F.	E2	550	$45.00	$5.10	$2.78	$52.88	0.104	$3,014
	W8X35	49.5	L.F.	E2	550	$51.00	$5.10	$2.78	$58.88	0.090	$2,915
	W10X45	50	L.F.	E2	550	$65.70	$5.10	$2.78	$73.58	0.091	$3,679
	W12X50	26	L.F.	E2	750	$73.00	$3.75	$2.04	$78.79	0.035	$2,049
	W12X58	18.5	L.F.	E2	750	$84.50	$3.75	$2.04	$90.29	0.025	$1,670
	W12X65	26.5	L.F.	E2	640	$94.90	$4.39	$2.39	$101.68	0.041	$2,695
	W12X79	45.2	L.F.	E2	640	$115.34	$4.39	$2.39	$122.12	0.071	$5,520
	Vulcraft 1.5VL22	1932	S.F.	E4	3860	$1.86	$0.43	$0.04	$2.33	0.501	$4,502
	6X6 W1.4XW1.4 Wire Mesh	19.32	C.S.F	2 Rodm	35	$14.50	$23.00	$0.00	$37.50	0.552	$725
	3.5" Concrete	1932	S.F.	C8	2613	$1.39	$0.87	$0.27	$2.53	0.739	$4,889
	Steel Deck / Cast-in-Place Flooring System Total									**2.637**	**$39,608**
Precast	W10X33	46.2	L.F.	E2	550	$48.00	$5.10	$2.78	$55.88	0.084	$2,582
	W10X49	18.5	L.F.	E2	550	$71.50	$5.10	$2.78	$79.38	0.034	$1,469
	W16X50	26.5	L.F.	E2	800	$73.00	$3.51	$1.91	$78.42	0.033	$2,078
	W16X67	25	L.F.	E2	760	$97.50	$3.70	$2.01	$103.21	0.033	$2,580
	8" Precast Hollow Core Plank	1932	S.F	C11	3200	$7.10	$1.13	$0.57	$8.80	0.604	$17,004
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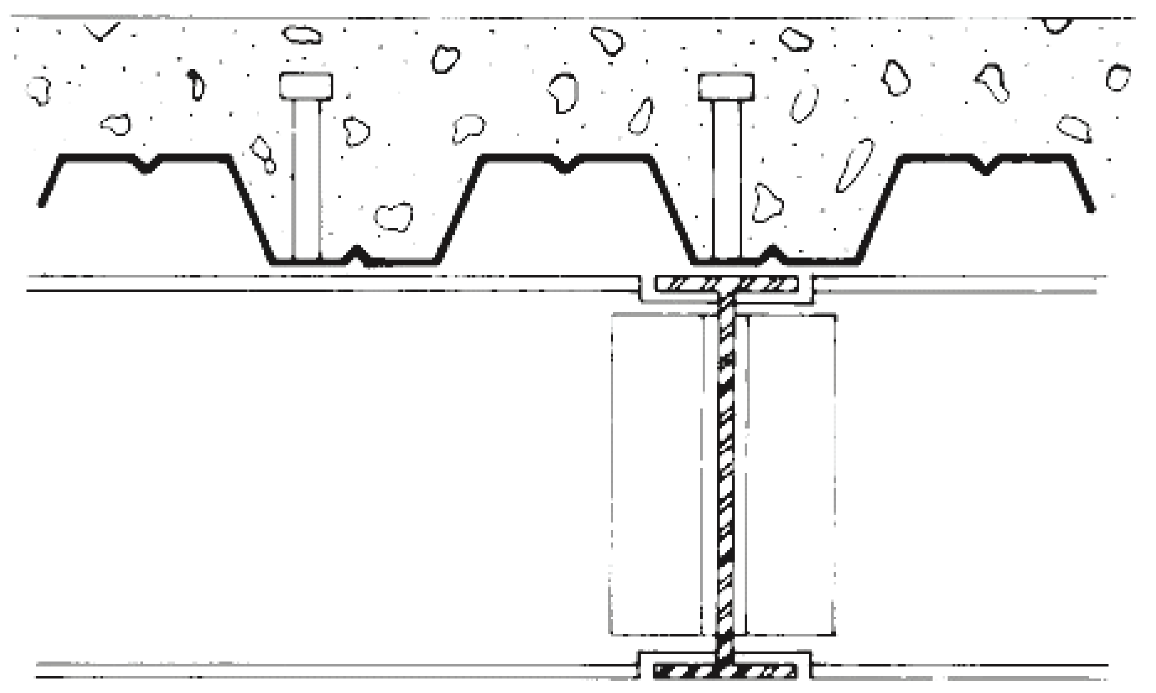
	3" Topcoat Concrete	1932	S.F.	C8	2613	$1.39	$0.87	$0.27	$2.53	0.739	$4,889
	Precast Flooring System Total									**2.079**	**$31,326**

System Comparison:

Labor: 1 additional day

Cost: additional $16,564



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	Precast Flooring System Total									**2.079**	**$31,326**

System Comparison:

Labor: 1 additional day

Cost: additional $16,564

Advantages:

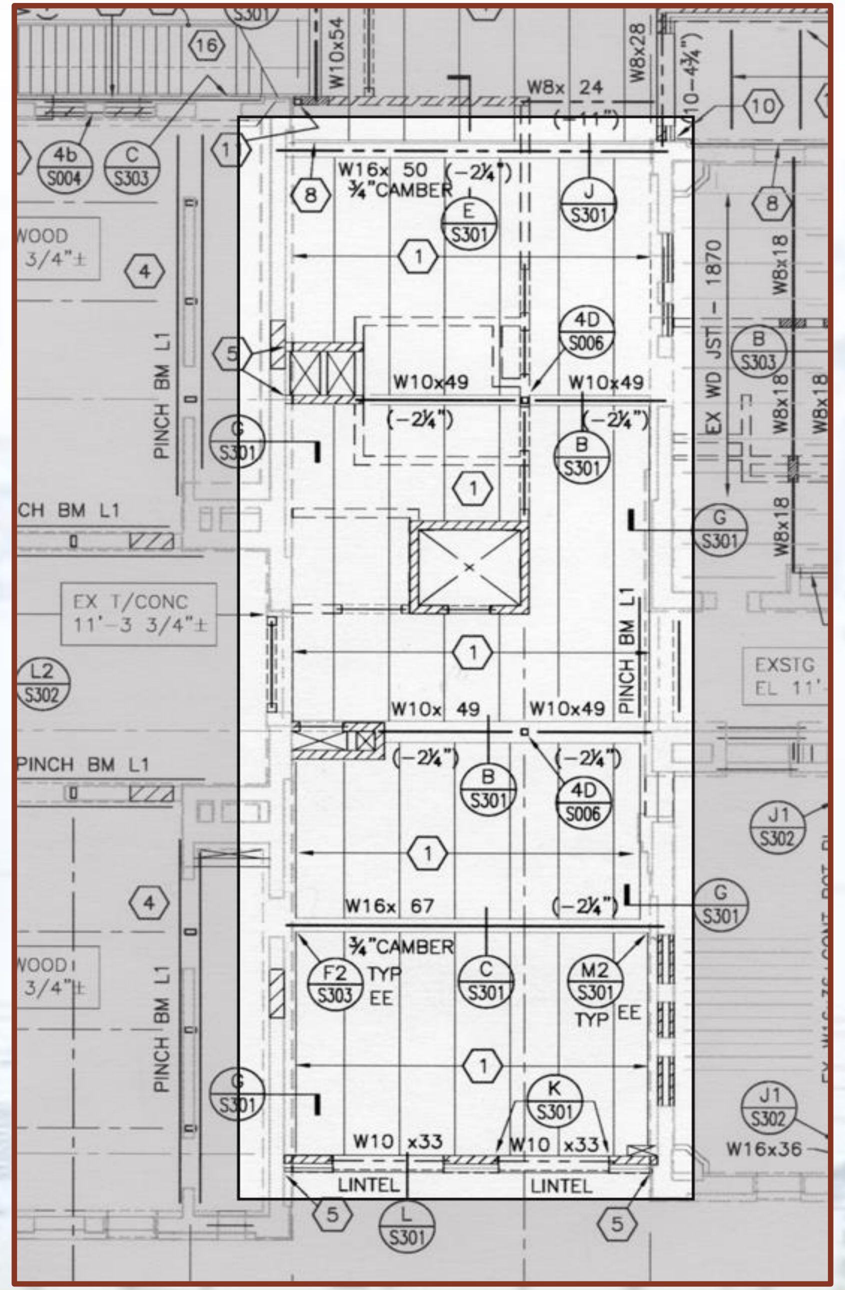
- No accessibility issues
- Onsite adjustability
  - Inaccurate measurements
  - Compromised anchor points
  - Last minute changes
- Can conform to MEP requirements
- No lead time

Structural Breadth:

Design of Steel Deck/Cast-in-Place Flooring System

Design Procedure:

- Identify the joist spacing
- Choose the steel deck and concrete thickness
- Calculate the dead and live loads
- Calculate the shear, moment and moment of inertia
- Choose the beams



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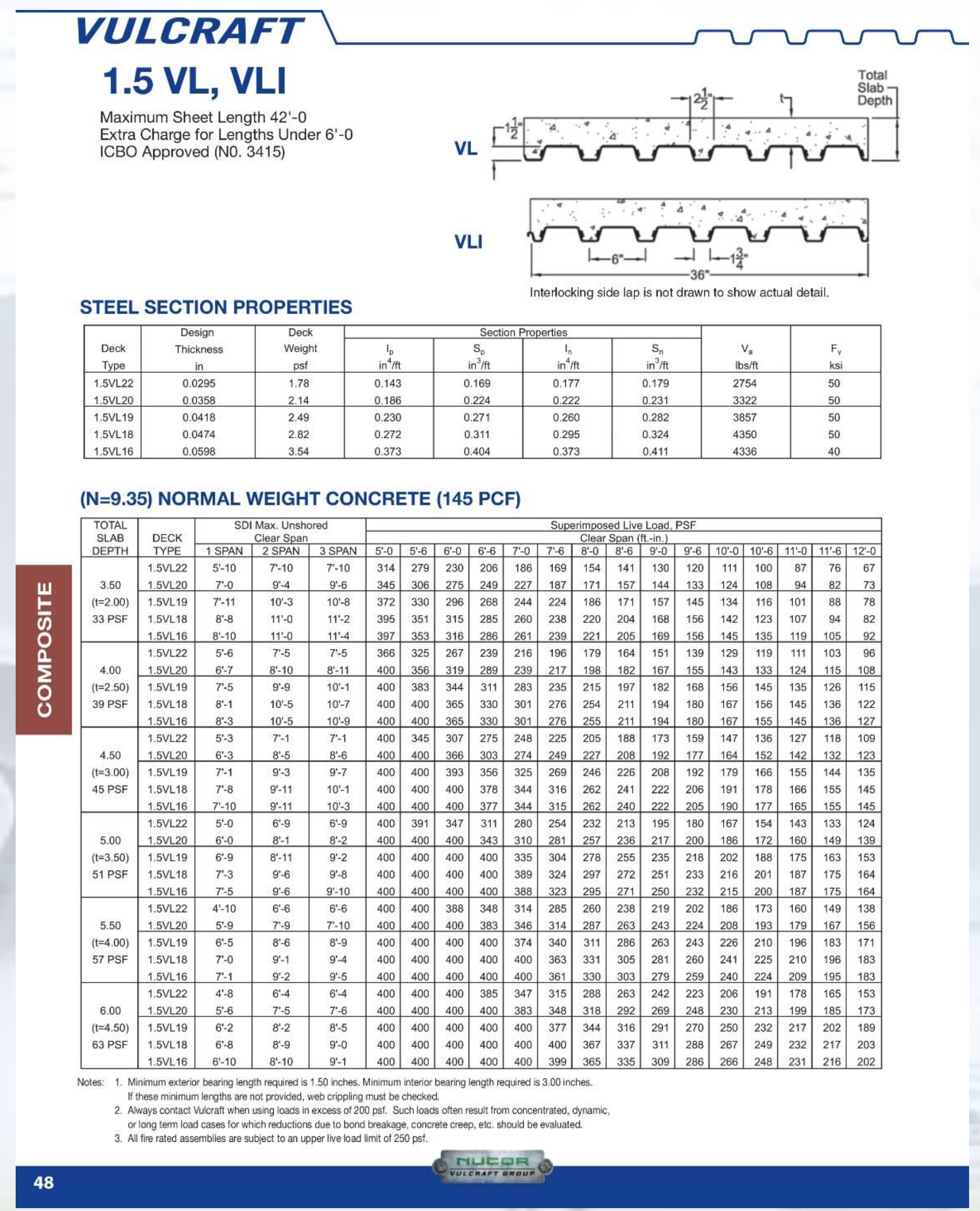

VULCRAFT

1.5 VL, VLI

Maximum Sheet Length 42'-0
Extra Charge for Lengths Under 6'-0
ICBO Approved (N0. 3415)

Interlocking side lap is not drawn to show actual detail.

STEEL SECTION PROPERTIES

Deck Type	Design Thickness in	Deck Weight psf	Section Properties I_p in⁴/ft	S_p in³/ft	I_n in⁴/ft	S_n in³/ft	V_a lbs/ft	F_y ksi
1.5VL22	0.0295	1.78	0.143	0.169	0.177	0.179	2754	50
1.5VL20	0.0358	2.14	0.186	0.224	0.222	0.231	3322	50
1.5VL19	0.0418	2.49	0.230	0.271	0.260	0.282	3857	50
1.5VL18	0.0474	2.82	0.272	0.311	0.295	0.324	4350	50
1.5VL16	0.0598	3.54	0.373	0.404	0.373	0.411	4336	40

COMPOSITE

(N=9.35) NORMAL WEIGHT CONCRETE (145 PCF)

TOTAL SLAB DEPTH	DECK TYPE	SDI Max. Unshored Clear Span			Superimposed Live Load, PSF — Clear Span (ft.-in.)														
		1 SPAN	2 SPAN	3 SPAN	5'-0	5'-6	6'-0	6'-6	7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0
3.50 (t=2.00) 33 PSF	1.5VL22	5'-10	7'-10	7'-10	314	279	230	206	186	169	154	141	130	120	111	100	87	76	67
	1.5VL20	7'-0	9'-4	9'-6	345	306	275	249	227	187	171	157	144	133	124	108	94	82	73
	1.5VL19	7'-11	10'-3	10'-8	372	330	296	268	244	224	186	171	157	145	134	116	101	88	78
	1.5VL18	8'-8	11'-0	11'-2	395	351	315	285	260	238	220	204	168	156	142	123	107	94	82
	1.5VL16	8'-10	11'-0	11'-4	397	353	316	286	261	239	221	205	169	156	145	135	119	105	92
4.00 (t=2.50) 39 PSF	1.5VL22	5'-6	7'-5	7'-5	366	325	267	239	216	196	179	164	151	139	129	119	111	103	96
	1.5VL20	6'-7	8'-10	8'-11	400	356	319	289	239	217	198	182	167	155	143	133	124	115	108
	1.5VL19	7'-5	9'-9	10'-1	400	383	344	311	283	235	215	197	182	168	156	145	135	126	115
	1.5VL18	8'-1	10'-5	10'-7	400	400	365	330	301	276	254	211	194	180	167	156	145	136	122
	1.5VL16	8'-3	10'-5	10'-9	400	400	365	330	301	276	255	211	194	180	167	155	145	136	127
4.50 (t=3.00) 45 PSF	1.5VL22	5'-3	7'-1	7'-1	400	345	307	275	248	225	205	188	173	159	147	136	127	118	109
	1.5VL20	6'-3	8'-5	8'-6	400	400	366	303	274	249	227	208	192	177	164	152	142	132	123
	1.5VL19	7'-1	9'-3	9'-7	400	400	393	356	325	269	246	226	208	192	179	166	155	144	135
	1.5VL18	7'-8	9'-11	10'-1	400	400	400	378	344	316	262	241	222	206	191	178	166	155	145
	1.5VL16	7'-10	9'-11	10'-3	400	400	400	377	344	315	262	240	222	205	190	177	165	155	145
5.00 (t=3.50) 51 PSF	1.5VL22	5'-0	6'-9	6'-9	400	391	347	311	280	254	232	213	195	180	167	154	143	133	124
	1.5VL20	6'-0	8'-1	8'-2	400	400	400	343	310	281	257	236	217	200	186	172	160	149	139
	1.5VL19	6'-9	8'-11	9'-2	400	400	400	400	335	304	278	255	235	218	202	188	175	163	153
	1.5VL18	7'-3	9'-6	9'-8	400	400	400	400	389	324	297	272	251	233	216	201	187	175	164
	1.5VL16	7'-5	9'-6	9'-10	400	400	400	400	388	323	295	271	250	232	215	200	187	175	164
5.50 (t=4.00) 57 PSF	1.5VL22	4'-10	6'-6	6'-6	400	400	388	348	314	285	260	238	219	202	186	173	160	149	138
	1.5VL20	5'-9	7'-9	7'-10	400	400	400	383	346	314	287	263	243	224	208	193	179	167	156
	1.5VL19	6'-5	8'-6	8'-9	400	400	400	400	374	340	311	286	263	243	226	210	196	183	171
	1.5VL18	7'-0	9'-1	9'-4	400	400	400	400	400	363	331	305	281	260	241	225	210	196	183
	1.5VL16	7'-1	9'-2	9'-5	400	400	400	400	400	361	330	303	279	259	240	224	209	195	183
6.00 (t=4.50) 63 PSF	1.5VL22	4'-8	6'-4	6'-4	400	400	400	385	347	315	288	263	242	223	206	191	178	165	153
	1.5VL20	5'-6	7'-5	7'-6	400	400	400	400	383	348	318	292	269	248	230	213	199	185	173
	1.5VL19	6'-2	8'-2	8'-5	400	400	400	400	400	377	344	316	291	270	250	232	217	202	189
	1.5VL18	6'-8	8'-9	9'-0	400	400	400	400	400	400	367	337	311	288	267	249	232	217	203
	1.5VL16	6'-10	8'-10	9'-1	400	400	400	400	400	399	365	335	309	286	266	248	231	216	202

Notes:
1. Minimum exterior bearing length required is 1.50 inches. Minimum interior bearing length required is 3.00 inches. If these minimum lengths are not provided, web crippling must be checked.
2. Always contact Vulcraft when using loads in excess of 200 psf. Such loads often result from concentrated, dynamic, or long term load cases for which reductions due to bond breakage, concrete creep, etc. should be evaluated.
3. All fire rated assemblies are subject to an upper live load limit of 250 psf.

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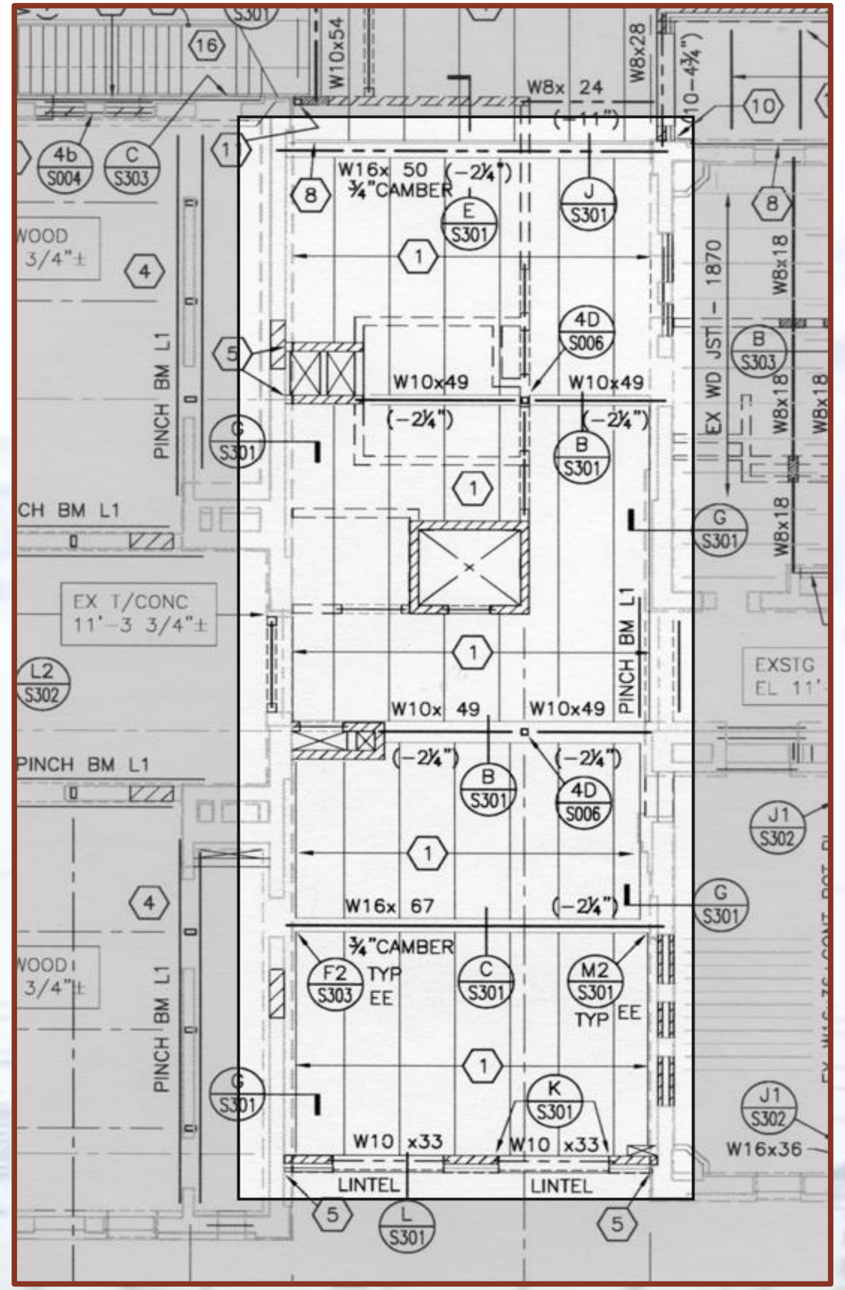


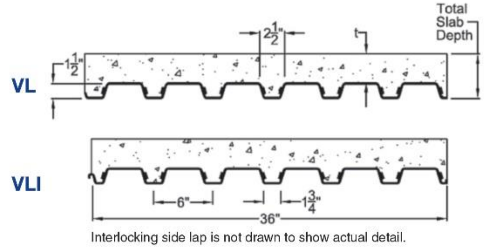
Design Procedure:

- Identify the joist spacing
- Choose the steel deck and concrete thickness
- Calculate the dead and live loads
- Calculate the shear, moment and moment of inertia
- Choose the beams

VULCRAFT

1.5 VL, VLI

Maximum Sheet Length 42'-0
Extra Charge for Lengths Under 6'-0
ICBO Approved (N0. 3415)



Interlocking side lap is not drawn to show actual detail.

STEEL SECTION PROPERTIES

Deck Type	Design Thickness in	Deck Weight psf	Section Properties I_p in⁴/ft	S_p in³/ft	I_n in⁴/ft	S_n in³/ft	V_a lbs/ft	F_y ksi
1.5VL22	0.0295	1.78	0.143	0.169	0.177	0.179	2754	50
1.5VL20	0.0358	2.14	0.186	0.224	0.222	0.231	3322	50
1.5VL19	0.0418	2.49	0.230	0.271	0.260	0.282	3857	50
1.5VL18	0.0474	2.82	0.272	0.311	0.295	0.324	4350	50
1.5VL16	0.0598	3.54	0.373	0.404	0.373	0.411	4336	40

(N=9.35) NORMAL WEIGHT CONCRETE (145 PCF)

TOTAL SLAB DEPTH	DECK TYPE	SDI Max. Unshored Clear Span			Superimposed Live Load, PSF Clear Span (ft.-in.)														
		1 SPAN	2 SPAN	3 SPAN	5'-0	5'-6	6'-0	6'-6	7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0
3.50 (t=2.00) 33 PSF	1.5VL22	5'-10	7'-10	7'-10	314	279	230	206	186	169	154	141	130	120	111	100	87	76	67
	1.5VL20	7'-0	9'-4	9'-6	345	306	275	249	227	187	171	157	144	133	124	108	94	82	73
	1.5VL19	7'-11	10'-3	10'-8	372	330	296	268	244	224	186	171	157	145	134	116	101	88	78
	1.5VL18	8'-8	11'-0	11'-2	395	351	315	285	260	238	220	204	168	156	142	123	107	94	82
	1.5VL16	8'-10	11'-0	11'-4	397	353	316	286	261	239	221	205	169	156	145	135	119	105	92
4.00 (t=2.50) 39 PSF	1.5VL22	5'-6	7'-5	7'-5	366	325	267	239	216	196	179	164	151	139	129	119	111	103	96
	1.5VL20	6'-7	8'-10	8'-11	400	356	319	289	239	217	198	182	167	155	143	133	124	115	108
	1.5VL19	7'-5	9'-9	10'-1	400	383	344	311	283	235	215	197	182	168	156	145	135	126	115
	1.5VL18	8'-1	10'-5	10'-7	400	400	365	330	301	276	254	211	194	180	167	156	145	136	122
	1.5VL16	8'-3	10'-5	10'-9	400	400	365	330	301	276	255	211	194	180	167	155	145	136	127
4.50 (t=3.00) 45 PSF	1.5VL22	5'-3	7'-1	7'-1	400	345	307	275	248	225	205	188	173	159	147	136	127	118	109
	1.5VL20	6'-3	8'-5	8'-6	400	400	366	303	274	249	227	208	192	177	164	152	142	132	123
	1.5VL19	7'-1	9'-3	9'-7	400	400	393	356	325	269	246	226	208	192	179	166	155	144	135
	1.5VL18	7'-8	9'-11	10'-1	400	400	400	378	344	316	262	241	222	206	191	178	166	155	145
	1.5VL16	7'-10	9'-11	10'-3	400	400	400	377	344	315	262	240	222	205	190	177	165	155	145
5.00 (t=3.50) 51 PSF	1.5VL22	5'-0	6'-9	6'-9	400	391	347	311	280	254	232	213	195	180	167	154	143	133	124
	1.5VL20	6'-0	8'-1	8'-2	400	400	400	343	310	281	257	236	217	200	186	172	160	149	139
	1.5VL19	6'-9	8'-11	9'-2	400	400	400	400	335	304	278	255	235	218	202	188	175	163	153
	1.5VL18	7'-3	9'-6	9'-8	400	400	400	400	389	324	297	272	251	233	216	201	187	175	164
	1.5VL16	7'-5	9'-6	9'-10	400	400	400	400	388	323	295	271	250	232	215	200	187	175	164
5.50 (t=4.00) 57 PSF	1.5VL22	4'-10	6'-6	6'-6	400	400	388	348	314	285	260	238	219	202	186	173	160	149	138
	1.5VL20	5'-9	7'-9	7'-10	400	400	400	383	346	314	287	263	243	224	208	193	179	167	156
	1.5VL19	6'-5	8'-6	8'-9	400	400	400	400	374	340	311	286	263	243	226	210	196	183	171
	1.5VL18	7'-0	9'-1	9'-4	400	400	400	400	400	363	331	305	281	260	241	225	210	196	183
	1.5VL16	7'-1	9'-2	9'-5	400	400	400	400	400	361	330	303	279	259	240	224	209	195	183
6.00 (t=4.50) 63 PSF	1.5VL22	4'-8	6'-4	6'-4	400	400	400	385	347	315	288	263	242	223	206	191	178	165	153
	1.5VL20	5'-6	7'-5	7'-6	400	400	400	400	383	348	318	292	269	248	230	213	199	185	173
	1.5VL19	6'-2	8'-2	8'-5	400	400	400	400	400	377	344	316	291	270	250	232	217	202	189
	1.5VL18	6'-8	8'-9	9'-0	400	400	400	400	400	400	367	337	311	288	267	249	232	217	203
	1.5VL16	6'-10	8'-10	9'-1	400	400	400	400	400	399	365	335	309	286	266	248	231	216	202

Notes:
1. Minimum exterior bearing length required is 1.50 inches. Minimum interior bearing length required is 3.00 inches. If these minimum lengths are not provided, web crippling must be checked.
2. Always contact Vulcraft when using loads in excess of 200 psf. Such loads often result from concentrated, dynamic, or long term load cases for which reductions due to bond breakage, concrete creep, etc. should be evaluated.
3. All fire rated assemblies are subject to an upper live load limit of 250 psf.

COMPOSITE

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$$Concrete = 33\ {}^{lb}/_{ft^2} \quad Steel\ Deck = 1.78\ {}^{lb}/_{ft^2} \quad Misc. = 10\ {}^{lb}/_{ft^2}$$

$$Dead\ Load_{Joist} = Concrete + Deck + Misc = 33 + 1.78 + 10 = 44.8 \approx 45\ {}^{lb}/_{ft^2}$$

$$Dead\ Load_{Girder} = Concrete + Deck + Misc. + Joist \approx 45\ {}^{lb}/_{ft^2} + Joist$$

$$Live\ Load = 100\ {}^{lb}/_{ft^2}$$

$$W_{dead} = Dead\ Load_{Joist} \times Tributary\ Width = 45 \times 3.25 = 146.25\ {}^{lb}/_{ft}$$

$$W_{live} = Live\ Load \times Tributary\ Width = 100 \times 3.25 = 325\ {}^{lb}/_{ft}$$

Design Procedure:

- Identify the joist spacing
- Choose the steel deck and concrete thickness
- Calculate the dead and live loads
- Calculate the shear, moment and moment of inertia
- Choose the beams

$$V_{dead} = \frac{W_{dead}L_{beam}}{2(1000\,{}^{lb}/_{k})} = \frac{(146.25)(17)}{2(1000\,{}^{lb}/_{k})} = 1.24\ kips$$

$$V_{live} = \frac{W_{live}L_{beam}}{2(1000\,{}^{lb}/_{k})} = \frac{(325)(17)}{2(1000\,{}^{lb}/_{k})} = 2.76\ kips$$

$$V_u = 1.2V_{dead} + 1.6V_{live} = 1.2(1.24) + 1.6(2.76) = 5.91k \cdot ft$$

$$M_{dead} = \frac{W_{dead}L_{beam}{}^2}{8(1000\,{}^{lb}/_{k})} = \frac{(146.25\,{}^{lb}/_{ft})(17ft)^2}{8(1000\,{}^{lb}/_{k})} = 5.28\ k \cdot ft$$

$$M_{live} = \frac{W_{dead}L_{beam}{}^2}{8(1000\,{}^{lb}/_{k})} = \frac{(325\,{}^{lb}/_{ft})(17ft)^2}{8(1000\,{}^{lb}/_{k})} = 11.74\ k \cdot ft$$

$$M_u = 1.2M_{dead} + 1.6M_{live} = 1.2(5.28) + 1.6(11.74) = 25.12k \cdot ft$$

$$\Delta_{allow} = \frac{L_{beam}(12\,{}^{in}/_{ft})}{360} = \frac{17(12)}{360} = 0.57in.$$

$$I = \frac{5W_{live}L_{beam}{}^4(12\,{}^{in}/_{ft})^4}{384(29,000,000)(\Delta_{allow})(12\,{}^{in}/_{ft})} = \frac{5(325)(17)^4(12)^4}{384(29,000,000)(0.57)(12)} = 37.17in^4$$

$$Concrete = 33\,{}^{lb}/_{ft^2} \quad Steel\ Deck = 1.78\,{}^{lb}/_{ft^2} \quad Misc. = 10\,{}^{lb}/_{ft^2}$$

$$Dead\ Load_{Joist} = Concrete + Deck + Misc = 33 + 1.78 + 10 = 44.8 \approx 45\,{}^{lb}/_{ft^2}$$

$$Dead\ Load_{Girder} = Concrete + Deck + Misc. + Joist \approx 45\,{}^{lb}/_{ft^2} + Joist$$

$$Live\ Load = 100\,{}^{lb}/_{ft^2}$$

$$W_{dead} = Dead\ Load_{Joist} \times Tributary\ Width = 45 \times 3.25 = 146.25\,{}^{lb}/_{ft}$$

$$W_{live} = Live\ Load \times Tributary\ Width = 100 \times 3.25 = 325\,{}^{lb}/_{ft}$$

Design Procedure:

- Identify the joist spacing
- Choose the steel deck and concrete thickness
- Calculate the dead and live loads
- Calculate the shear, moment and moment of inertia
- Choose the beams

$$V_{dead} = \frac{W_{dead}L_{beam}}{2(1000\,{}^{lb}/_{k})} = \frac{(146.25)(17)}{2(1000\,{}^{lb}/_{k})} = 1.24\ kips$$

$$V_{live} = \frac{W_{live}L_{beam}}{2(1000\,{}^{lb}/_{k})} = \frac{(325)(17)}{2(1000\,{}^{lb}/_{k})} = 2.76\ kips$$

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$$M_{live} = \frac{W_{dead}L_{beam}{}^2}{8(1000\,{}^{lb}/_{k})} = \frac{(325\,{}^{lb}/_{ft})(17ft)^2}{8(1000\,{}^{lb}/_{k})} = 11.74\ k \cdot ft$$

$$M_u = 1.2M_{dead} + 1.6M_{live} = 1.2(5.28) + 1.6(11.74) = 25.12k \cdot ft$$

$$\Delta_{allow} = \frac{L_{beam}(12\,{}^{in}/_{ft})}{360} = \frac{17(12)}{360} = 0.57in.$$

$$I = \frac{5W_{live}L_{beam}{}^4(12\,{}^{in}/_{ft})^4}{384(29,000,000)(\Delta_{allow})(12\,{}^{in}/_{ft})} = \frac{5(325)(17)^4(12)^4}{384(29,000,000)(0.57)(12)} = 37.17in^4$$

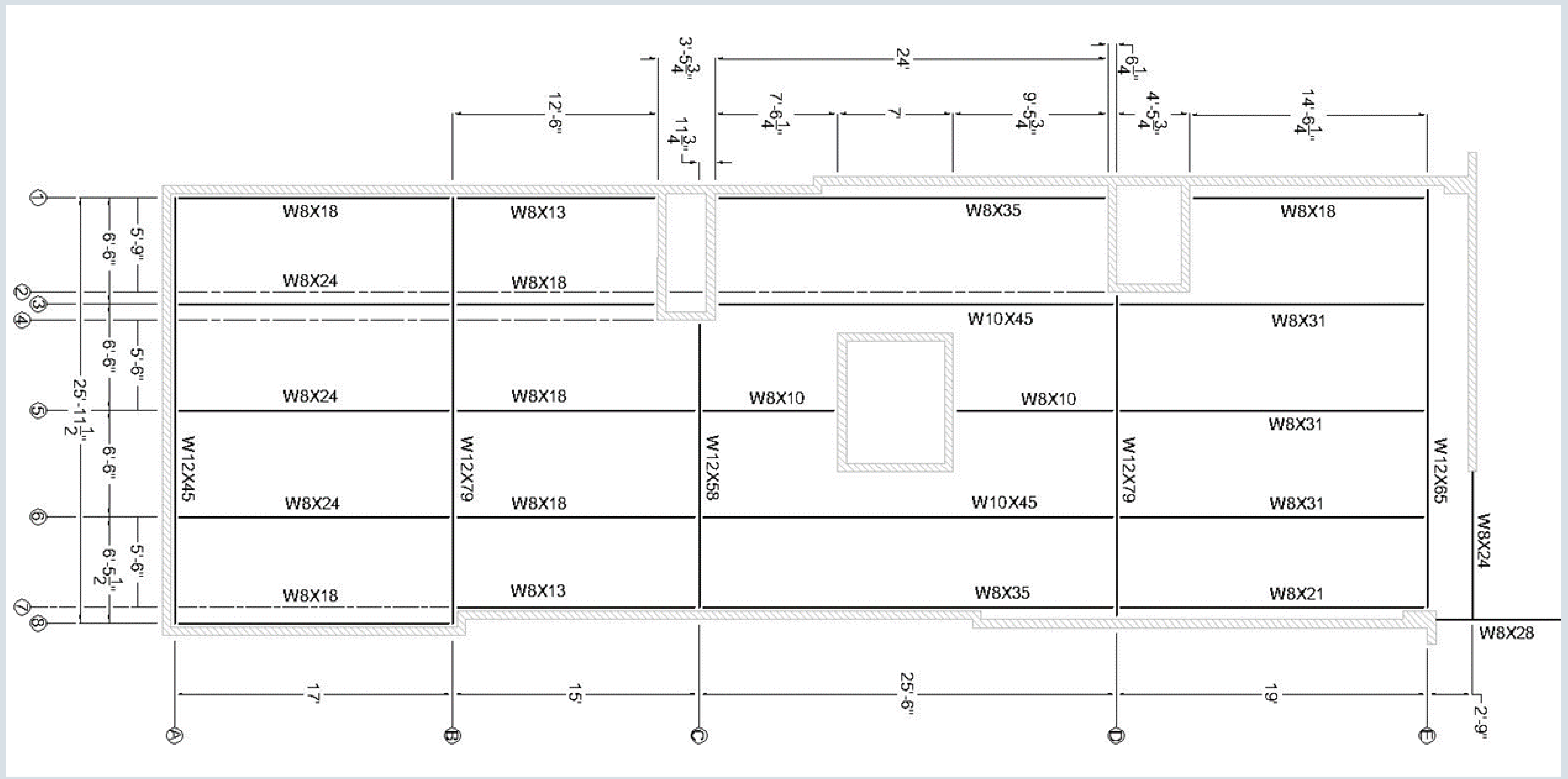
Steel Beam Calculation Spreadsheet

	Beam	Tributary Width (ft)	Beam Length (ft)	Dead Load (psf)		Live Load (psf)	W_D (lb/ft)	W_L (lb/ft)	M_D (k·ft)	M_L (k·ft)	**M_U (k·ft)**	V_D (kips)	V_L (kips)	**V_U (kips)**	Δ_{allow} (in.)	**I ($in.^4$)**	Beam Shape	Beam Wt. (lb.)
				Deck	Joists													
Joists	AB 1	3.25	17.0	45.0		100.0	146.25	325.00	5.28	11.74	**25.12**	1.24	2.76	**5.91**	0.57	**37.17**	w8x 18	306.00
	AB 2	6.50	17.0	45.0		100.0	292.50	650.00	10.57	23.48	**50.25**	2.49	5.53	**11.82**	0.57	**74.33**	w8x 24	408.00
	AB 3	6.50	17.0	45.0		100.0	292.50	650.00	10.57	23.48	**50.25**	2.49	5.53	**11.82**	0.57	**74.33**	w8x 24	408.00
	AB 4	6.48	17.0	45.0		100.0	291.56	647.92	10.53	23.41	**50.09**	2.48	5.51	**11.79**	0.57	**74.09**	w8x 24	408.00
	AB 5	3.23	17.0	45.0		100.0	145.31	322.92	5.25	11.67	**24.96**	1.24	2.74	**5.87**	0.57	**36.93**	w8x 18	306.00
	BC 1	3.25	12.5	45.0		100.0	146.25	325.00	2.86	6.35	**13.58**	0.91	2.03	**4.35**	0.42	**14.77**	w8x 13	162.50
	BC 2	6.50	12.5	45.0		100.0	292.50	650.00	5.71	12.70	**27.17**	1.83	4.06	**8.69**	0.42	**29.55**	w8x 18	225.00
	BC 3	6.50	15.0	45.0		100.0	292.50	650.00	8.23	18.28	**39.12**	2.19	4.88	**10.43**	0.50	**51.06**	w8x 18	270.00
	BC 4	6.00	15.0	45.0		100.0	270.00	600.00	7.59	16.88	**36.11**	2.03	4.50	**9.63**	0.50	**47.13**	w8x 18	270.00
	BC 5	2.75	15.0	45.0		100.0	123.75	275.00	3.48	7.73	**16.55**	0.93	2.06	**4.41**	0.50	**21.60**	w8x 13	195.00
	CD 1	3.75	24.0	45.0		100.0	168.75	375.00	12.15	27.00	**57.78**	2.03	4.50	**9.63**	0.80	**120.66**	w8x 35	840.00
	CD 2	6.50	24.5	45.0		100.0	292.50	650.00	21.95	48.77	**104.37**	3.58	7.96	**17.04**	0.82	**222.49**	w10x 45	1102.50
	CD 3.1	6.50	7.5	45.0		100.0	292.50	650.00	2.06	4.57	**9.78**	1.10	2.44	**5.22**	0.25	**6.38**	w8x 10	75.00
	CD 3.2	6.50	9.6	45.0		100.0	292.50	650.00	3.37	7.49	**16.02**	1.40	3.12	**6.68**	0.32	**13.39**	w8x 10	96.00
	CD 4	6.00	25.5	45.0		100.0	270.00	600.00	21.95	48.77	**104.37**	3.44	7.65	**16.37**	0.85	**231.57**	w10x 45	1147.50
	CD 5	3.25	25.5	45.0		100.0	146.25	325.00	11.89	26.42	**56.53**	1.86	4.14	**8.87**	0.85	**125.43**	w8x 35	892.50
	DE 1	3.75	14.6	45.0		100.0	168.75	375.00	4.50	9.99	**21.38**	1.23	2.74	**5.86**	0.49	**27.16**	w8x 18	262.80
	DE 2	6.50	19.0	45.0		100.0	292.50	650.00	13.20	29.33	**62.77**	2.78	6.18	**13.21**	0.63	**103.77**	w8x 31	589.00
	DE 3	6.50	19.0	45.0		100.0	292.50	650.00	13.20	29.33	**62.77**	2.78	6.18	**13.21**	0.63	**103.77**	w8x 31	589.00
	DE 4	6.00	19.0	45.0		100.0	270.00	600.00	12.18	27.08	**57.94**	2.57	5.70	**12.20**	0.63	**95.79**	w8x 31	589.00
	DE 5	3.25	19.0	45.0		100.0	146.25	325.00	6.60	14.67	**31.38**	1.39	3.09	**6.61**	0.63	**51.89**	w8x 21	399.00
Girders	A 18	8.50	26.0	45.0	4.2	100.0	417.78	850.00	35.19	71.59	**156.78**	5.42	11.03	**24.16**	0.87	**346.06**	w12x 50	1297.92
	B 17	16.00	25.0	45.0	7.3	100.0	836.96	1600.00	65.39	125.00	**278.47**	10.46	20.00	**44.55**	0.83	**581.90**	w12x 79	1975.00
	C 47	20.25	18.5	45.0	7.1	100.0	1055.63	2025.00	44.96	86.24	**191.94**	9.74	18.69	**41.59**	0.62	**296.42**	w12x 58	1070.58
	D 37	22.25	20.2	45.0	12.1	100.0	1270.48	2225.00	64.85	113.58	**259.55**	12.84	22.48	**51.38**	0.67	**427.39**	w12x 79	1596.46
	E 18	10.88	26.5	45.0	5.8	100.0	552.67	1087.50	48.51	95.46	**210.96**	7.32	14.41	**31.84**	0.88	**471.06**	w12x 65	1722.50

denotes beams whose size is controlled by I_x.

Design Procedure:

- Identify the joist spacing
- Choose the steel deck and concrete thickness
- Calculate the dead and live loads
- Calculate the shear, moment and moment of inertia
- Choose the beams



Analysis #3:

Use of PEX Tubing for Domestic Plumbing System

Original Design:

- Copper pipe – sizes 3” to ½”
- Soldered joints
- Cold, hot and hot water return lines
- Trunk and branch layout

Problem Identification:

- Copper is expensive
- Soldering joints is labor intensive
- High risk of theft

Alternate Design:

- Cross-linked polyethylene tubing (PEX) – 2” to ½” (larger pipes to remain copper)
- Clamped joints
- No 90° elbows in ½”, ¾” or 1” pipe
- Cold, hot and hot water return lines
- Trunk and branch layout

Advantages:

- Less Expensive (50%)
- Faster Install (67%)
- No Open Flames
- Fewer Fittings
- No "dry fit" joints
- Corrosion resistant

Disadvantages:

- Special equipment
- Learning curve
- Unknown longevity
- Not bacteriostatic
- Not UV resistant
- Not fireproof

Total Costs

Category	PEX			Copper		
	Materials	Labor	Mat.+Labor	Materials	Labor	Mat.+Labor
Pipe	$7,305.51	$6,818.93	$14,124.44	$10,172.20	$9,352.69	$19,524.89
90º	$1,290.80	$417.50	$1,708.30	$975.71	$12,157.68	$13,133.39
Tee	$1,032.10	$654.55	$15,832.74	$664.18	$2,890.53	$32,658.28
Insulation	$7,305.00		$7,305.00	$12,595.00		$12,595.00
Totals			**$38,970.48**			**$77,911.56**

Plumbing Breadth:

Compare Friction Loss in PEX System to that in Copper System

Procedure:

- Determine design velocity – 4ft/s
- Calculate flow
- Calculate friction loss
- Calculate total equivalent length
- Calculate total friction loss

Procedure:

- Determine design velocity – 4ft/s
- Calculate flow
- Calculate friction loss
- Calculate total equivalent length
- Calculate total friction loss

$$velocity\left({}^{ft}/_{s}\right) \times area(ft^2) \times 7.48\,{}^{gal}/_{ft^3} \times 60\,{}^{s}/_{min} = flow({}^{gal}/_{min})$$

$$4\,{}^{ft}/_{s} \times 3.09in^2 \times \frac{1ft^2}{144in^2} \times 7.48\,{}^{gal}/_{ft^3} \times 60\,{}^{s}/_{min} = 38.53\,{}^{gal}/_{min}$$

Procedure:

- Determine design velocity – 4ft/s
- Calculate flow
- Calculate friction loss
- Calculate total equivalent length
- Calculate total friction loss

$$velocity\left(\frac{ft}{s}\right) \times area(ft^2) \times 7.48\,\frac{gal}{ft^3} \times 60\,\frac{s}{min} = flow\left(\frac{gal}{min}\right)$$

$$4\,\frac{ft}{s} \times 3.09in^2 \times \frac{1ft^2}{144in^2} \times 7.48\,\frac{gal}{ft^3} \times 60\,\frac{s}{min} = 38.53\,\frac{gal}{min}$$

$$P = \frac{4.52 \times Q^{1.85}}{C^{1.85} \times d^{4.87}}$$ *(Hazen-Williams formula)*

$$P = \frac{4.52 \times 38.53^{1.85}}{130^{1.85} \times 1.985^{4.87}} = 0.0169\,\frac{psi}{ft}$$

Pipe Size (in)	Velocity (ft/s)	Flow (gal/min)	Friction Loss (psi/ft)	System Components	Equivalent Length of Component	Number of Components	Total Equivalent Length (ft)	Total Friction Loss (psi)
2				Straight Pipe	89.00	1	89.00	
				90° Elbow	5.50	5	27.50	
				Tee	0.50	1	0.50	
	4.00	38.53	0.0169				117.00	1.9769

Procedure:

- Determine design velocity – 4ft/s
- Calculate flow
- Calculate friction loss
- Calculate total equivalent length
- Calculate total friction loss

$$velocity\left({}^{ft}/_{s}\right) \times area(ft^2) \times 7.48\, {}^{gal}/_{ft^3} \times 60\, {}^{s}/_{min} = flow\left({}^{gal}/_{min}\right)$$

$$4\, {}^{ft}/_{s} \times 3.09 in^2 \times \frac{1ft^2}{144in^2} \times 7.48\, {}^{gal}/_{ft^3} \times 60\, {}^{s}/_{min} = 38.53\, {}^{gal}/_{min}$$

$$P = \frac{4.52 \times Q^{1.85}}{C^{1.85} \times d^{4.87}} \quad \textit{(Hazen-Williams formula)}$$

$$P = \frac{4.52 \times 38.53^{1.85}}{130^{1.85} \times 1.985^{4.87}} = 0.0169\, {}^{psi}/_{ft}$$

Friction Loss to Most Distant Fixture (Copper)

Pipe Size (in)	Velocity (ft/s)	Flow (gal/min)	Friction Loss (psi/ft)	System Components	Equivalent Length of Component	Number of Components	Total Equivalent Length (ft)	Total Friction Loss (psi)
2				Straight Pipe	89.00	1	89.00	
				90° Elbow	5.50	5	27.50	
				Tee	0.50	1	0.50	
	4.00	38.53	0.0169				117.00	1.9769
1½				Straight Pipe	321.00	1	321.00	
				90° Elbow	4.00	8	32.00	
				Tee	0.50	7	3.50	
	4.00	22.19	0.0235				356.50	8.3599
1¼				Straight Pipe	80.00	1	80.00	
				90° Elbow	3.00	2	6.00	
				Tee (Branch)	0.50	1	0.50	
	4.00	15.71	0.0288				86.50	2.4946
1				Straight Pipe	103.00	1	103.00	
				90° Elbow	2.50	4	10.00	
				Tee (Branch)	4.50	5	22.50	
	4.00	10.29	0.0367				135.50	4.9729
¾				Straight Pipe	64.00	1	64.00	
				90° Elbow	2.00		0.00	
				Tee	3.00	1	3.00	
	4.00	6.03	0.0502				67.00	3.3613
½				Straight Pipe	15.00	1	15.00	
				90° Elbow	1.00	8	8.00	
				Tee	2.00	2	4.00	
	4.00	2.90	0.0767				27.00	2.0711
Total Friction Loss to Most Distant Fixture								**23.2366**

Procedure:

- Determine design velocity – 4ft/s
- Calculate flow
- Calculate friction loss
- Calculate total equivalent length
- Calculate total friction loss

24.45 psi
-23.24 psi
1.21 psi

Friction Loss to Most Distant Fixture (PEX)

Pipe Size (in)	Velocity (ft/s)	Flow (gal/min)	Friction Loss (psi/ft)	System Components	Equivalent Length of Component	Number of Components	Total Equivalent Length (ft)	Total Friction Loss (psi)
2				Straight Pipe	89.00	1	89.00	
				90° Elbow	11.29	5	56.45	
				Tee (Branch)	1.56	1	1.56	
	4.00	25.99	0.0170				147.01	2.4992
1½				Straight Pipe	321.00	1	321.00	
				90° Elbow	10.85	8	86.80	
				Tee (Branch)	2.07	7	14.49	
	4.00	15.16	0.0237				422.29	10.0083
1¼				Straight Pipe	80.00	1	80.00	
				90° Elbow	9.61	2	19.22	
				Tee (Thru)	1.64	1	1.64	
	4.00	10.88	0.0290				100.86	2.9249
1				Straight Pipe	103.00	1	103.00	
				90° Elbow	3.40	0	0.00	
				Tee (Thru)	2.00	5	10.00	
	4.00	7.28	0.0373				113.00	4.2149
¾				Straight Pipe	64.00	1	64.00	
				90° Elbow	2.20	0	0.00	
				Tee (Thru)	0.80	1	0.80	
	4.00	4.41	0.0510				64.80	3.3048
½				Straight Pipe	15.00	1	15.00	
				90° Elbow	3.00	0	0.00	
				Tee (Branch)	2.00	2	4.00	
	4.00	2.21	0.0787				19.00	1.4953
Total Friction Loss to Most Distant Fixture								**24.4474**

Conclusion

Analysis #1: 3rd-Party Photo Documentation

- $0.20 - $0.60 / sqft
- Reliable
- Organized and accessible photos
- Reduces litigation
- Increases productivity
- "Green"

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- Flexibility during installation
- Easy coordination of penetrations
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Analysis #3: PEX Domestic Water System

- 50% savings in material cost
- 67% savings in installation time
- Fewer fittings = fewer leaks
- No corrosion
- Low risk of theft

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Questions?