

The Office Building Washington, D.C.



Penn State Architectural Engineering Senior Capstone Project
Brett Miller | Construction Option
Advisor: Dr. Ed Gannon

Project Overview



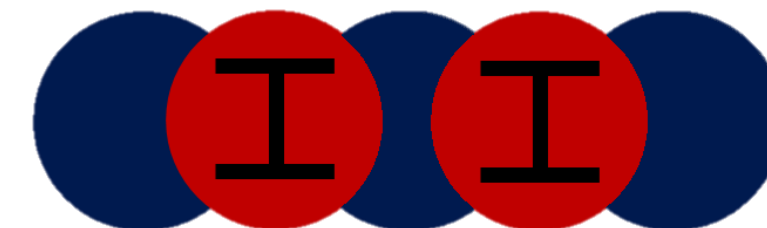
Research| Retaining Structures



Analysis 1 | Foundation Walls



Analysis 2 | Neighboring Foundation Support



Analysis 3 | Value Engineering



Presentation Outline

Project Overview

Research | Retaining Structures

Analysis 1 | Foundation Walls

Cost

Schedule

Conclusion

Analysis 2 | Neighboring Foundation Support

Cost

Schedule

Conclusion

Analysis 3 | Value Engineering

Electrical Breadth | Sizing wire/Busway

Cost

Schedule

Conclusion

Conclusion & Recommendations

Acknowledgements

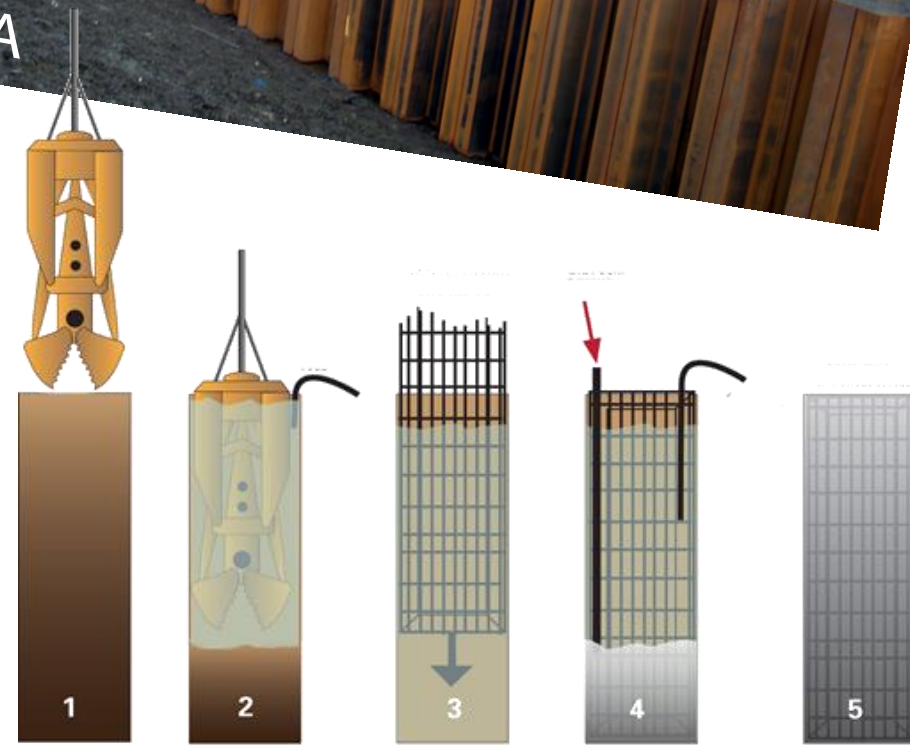


Project Size	108,000 SF
Height Above Grade	9 Stories
Contract Value	\$30.5 million
Dates of Construction	March 2013 – March 2015
Occupant	Undetermined
Primary Use	Office Building
Owner	Mid Atlantic Realty
General Contractor	James G. Davis Construction
Architect	Gensler



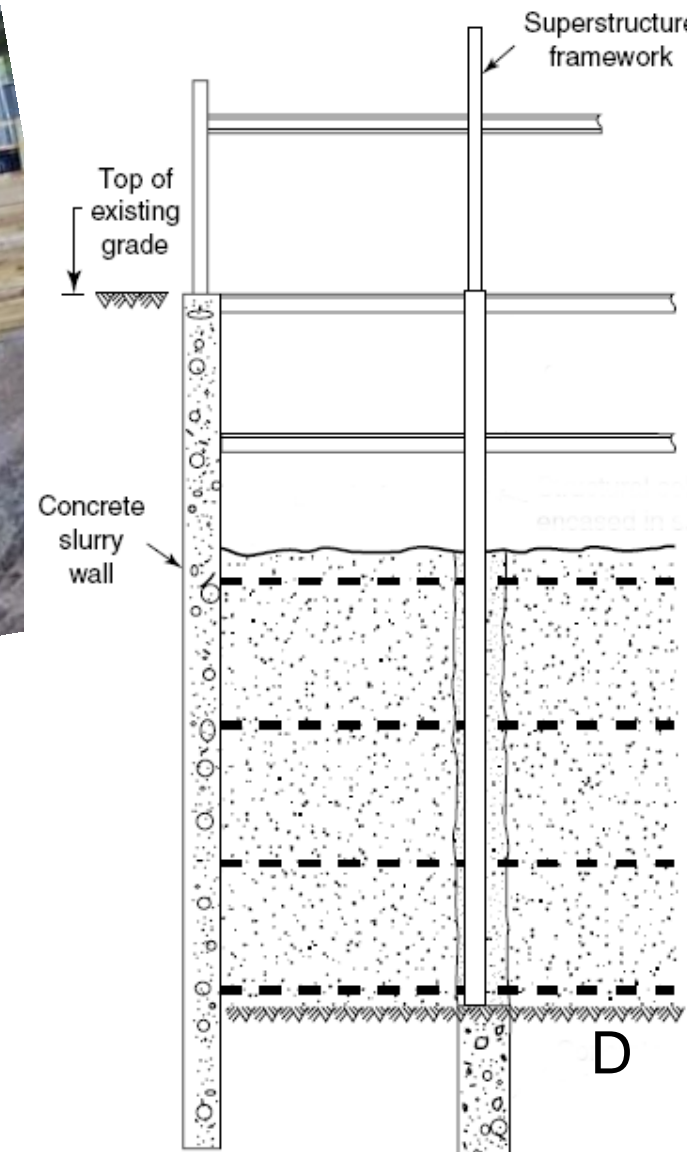
Presentation Outline

- Project Overview
- Research | Retaining Structures**
- Analysis 1 | Foundation Walls
 - Cost
 - Schedule
 - Conclusion
- Analysis 2 | Neighboring Foundation Support
 - Cost
 - Schedule
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C

	Advantages	Disadvantages
Sheet Piling (A)	Watertight Excavation	Costly Time Consuming
Soldier Piles and Lagging (B)	Less Expensive Faster	Loud Installation Not Watertight
Concrete Slurry Walls (C)	Watertight Extreme Depths Foundation Walls	Extremely Costly Time Consuming
Top Down Construction (D)	Fast Ground Stability	Geotech. Considerations



D

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 - Cost
 - Schedule
 - Conclusion
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 - Cost
 - Schedule
 - Conclusion
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 - Schedule
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Problem Identification

- Extensive support of excavation
- 60 Foundation wall box-outs
- Formwork time/cost

Potential Solutions

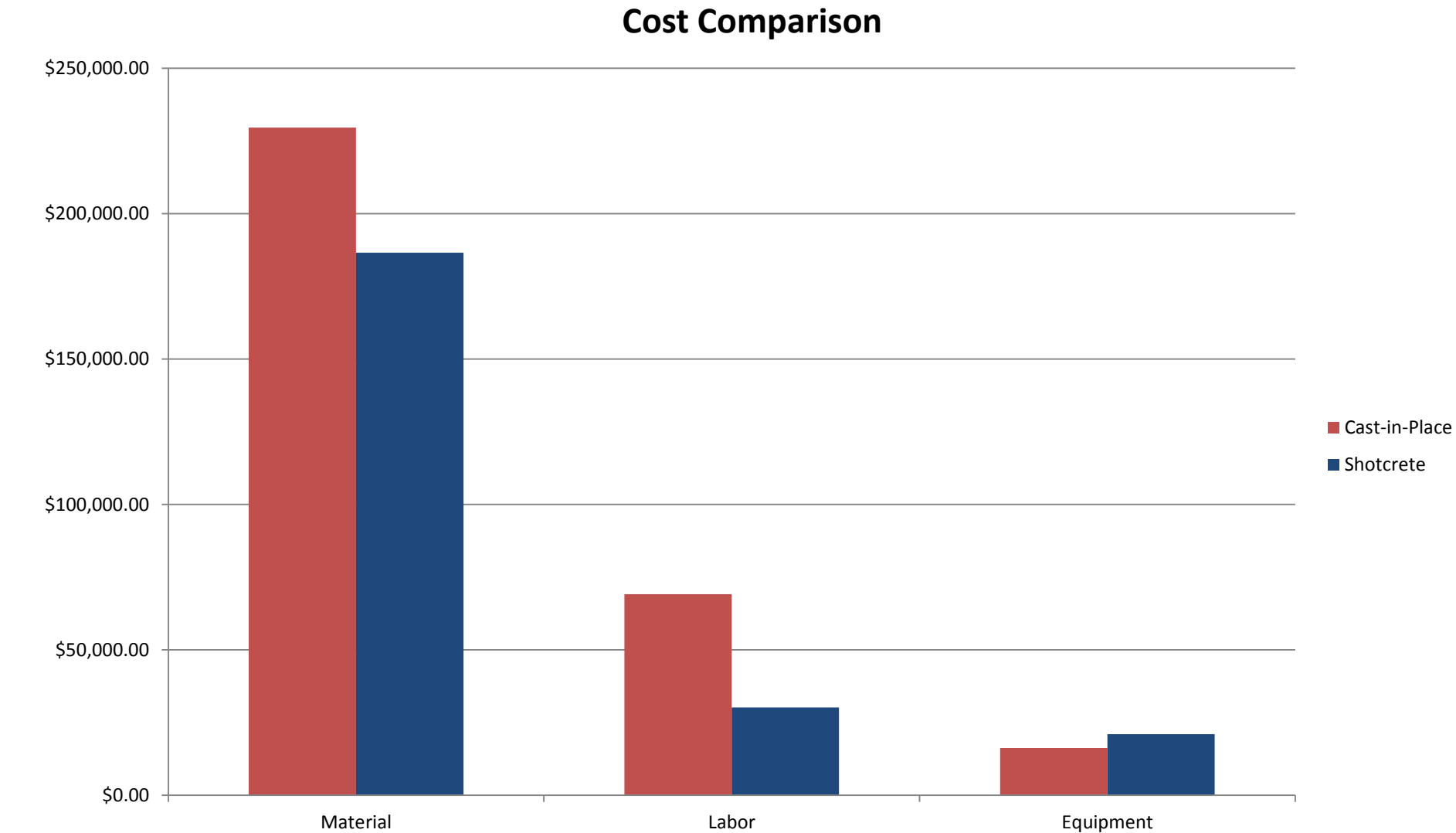
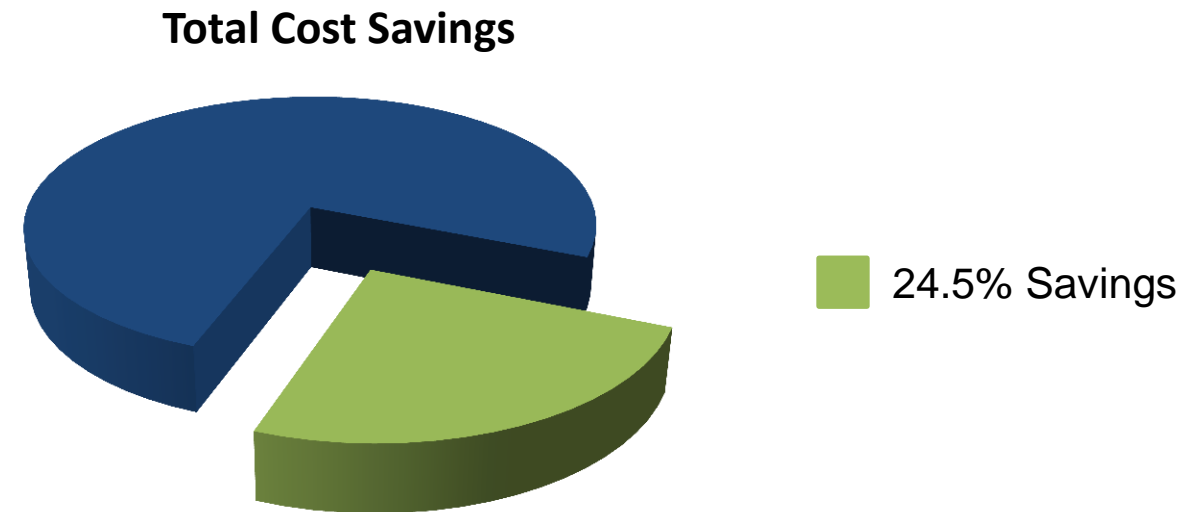
- Replace CIP with shotcrete to reduce formwork

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- Research | Retaining Structures
- Analysis 1 | Foundation Walls
 - Cost**
 - Schedule
 - Conclusion
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 - Cost
 - Schedule
 - Conclusion
- Analysis 3 | Value Engineering
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 - Cost
 - Schedule
 - Conclusion
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Total Cost	
Cast-in-Place	\$314,943.96
Shotcrete	\$237,816.54
Savings	\$77,127.42

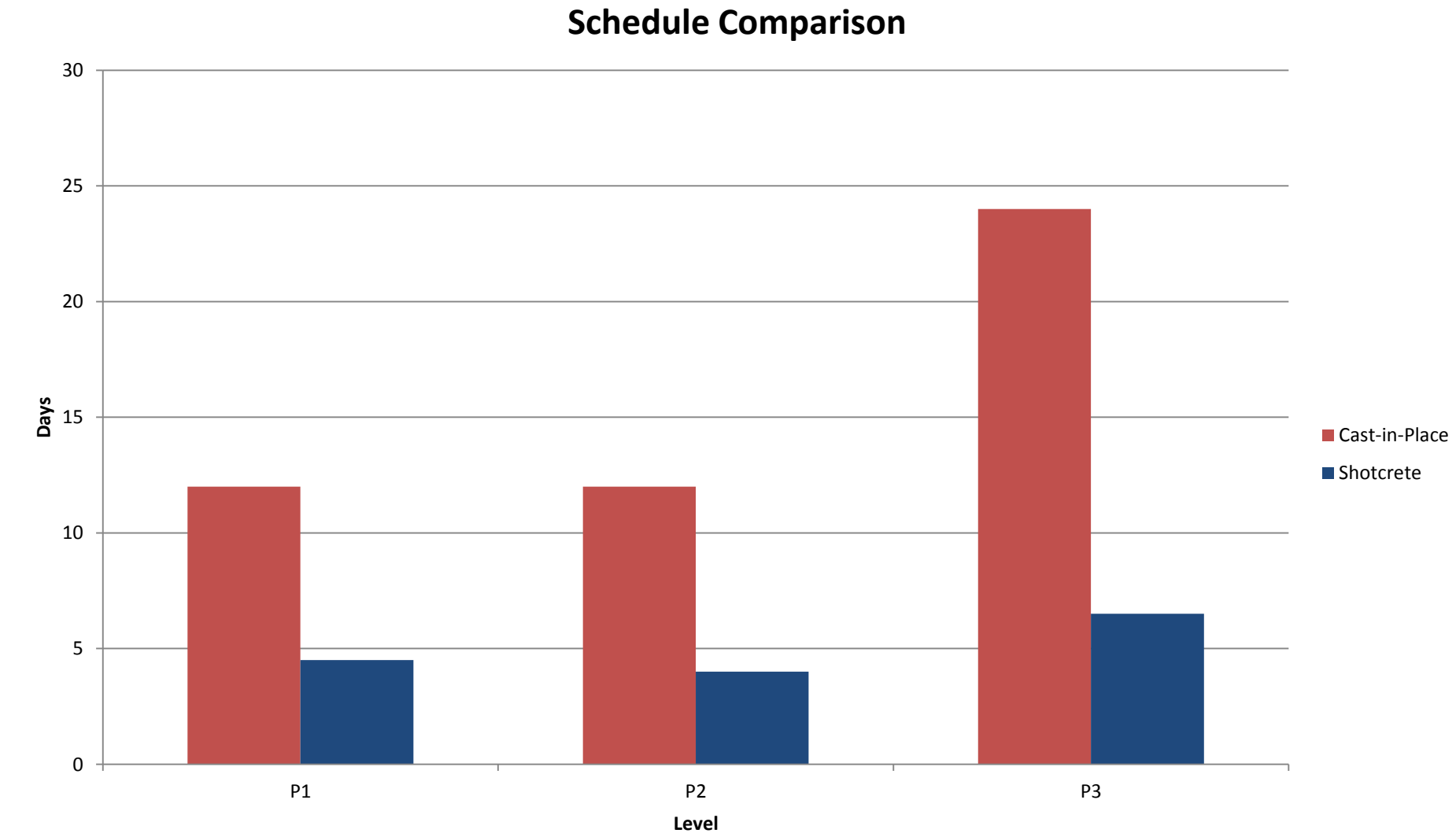
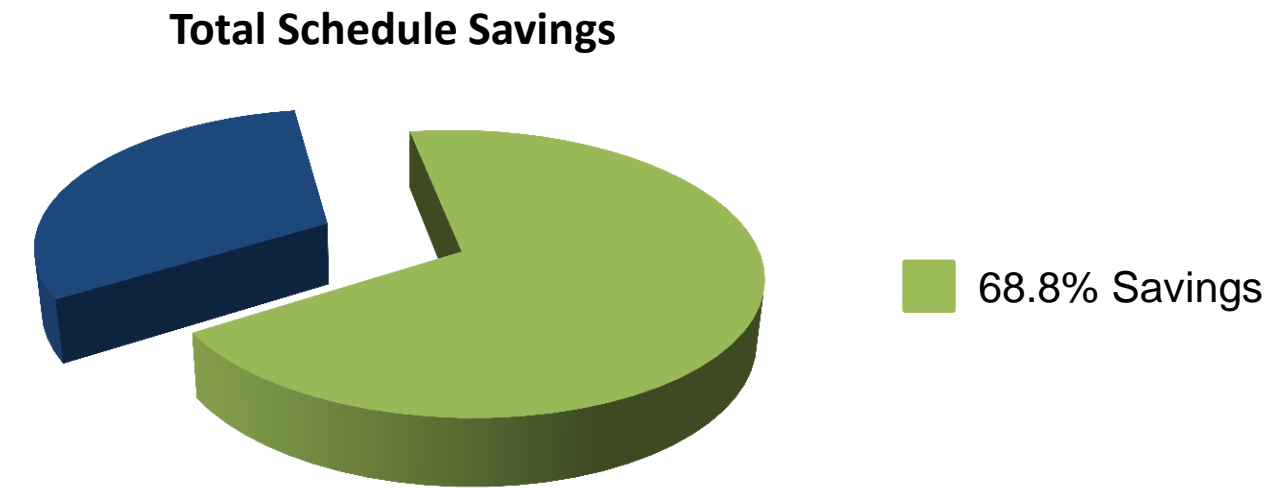


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- Research | Retaining Structures
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 - Cost
 - Schedule**
 - Conclusion
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- Analysis 3 | Value Engineering
 - Electrical Breadth | Sizing wire/Busway
 - Cost
 - Schedule
 - Conclusion
- Conclusion & Recommendations
- Acknowledgements

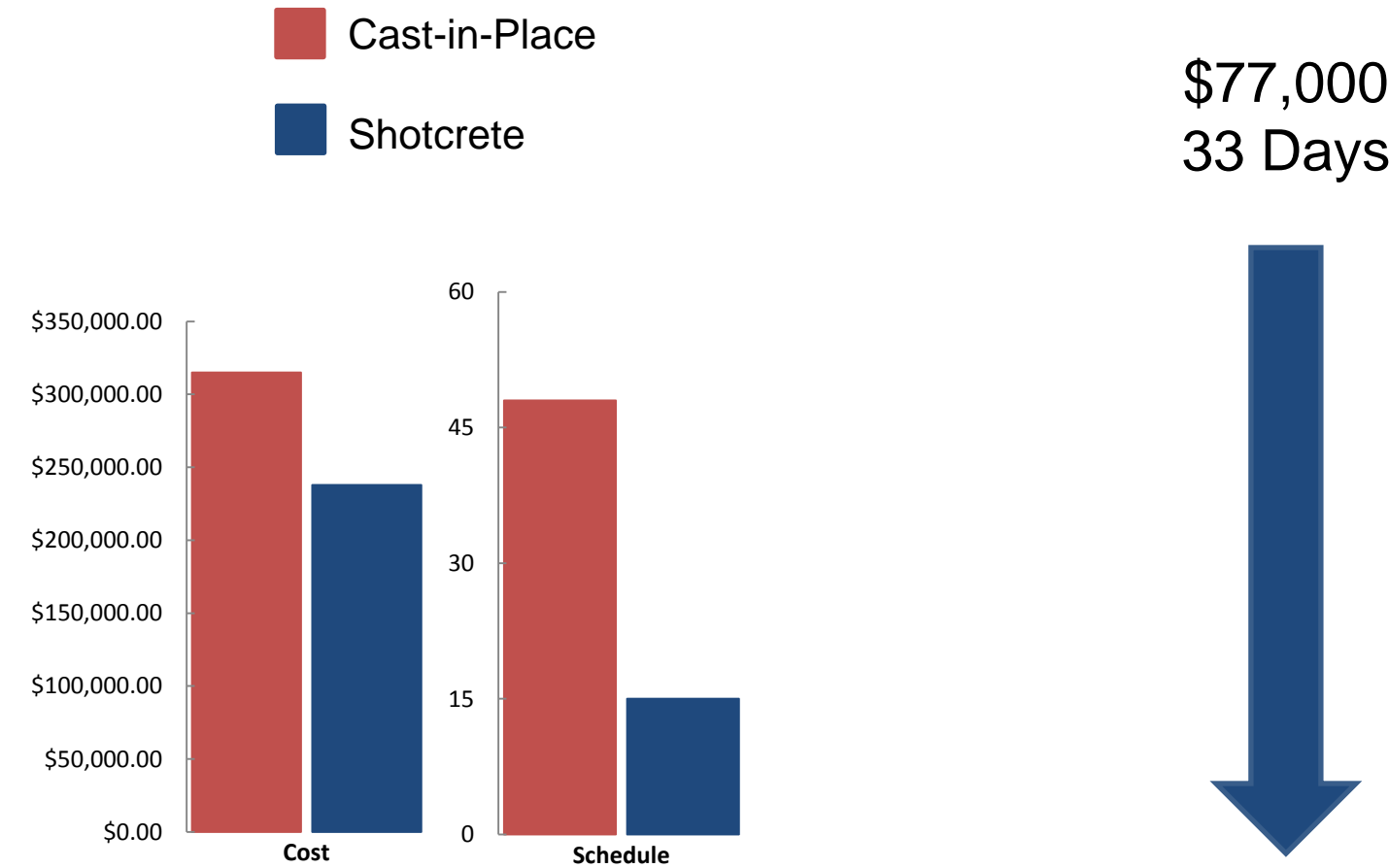


Final Schedule	
Cast-in-Place	48 Days
Shotcrete	15 Days
Savings	33 Days



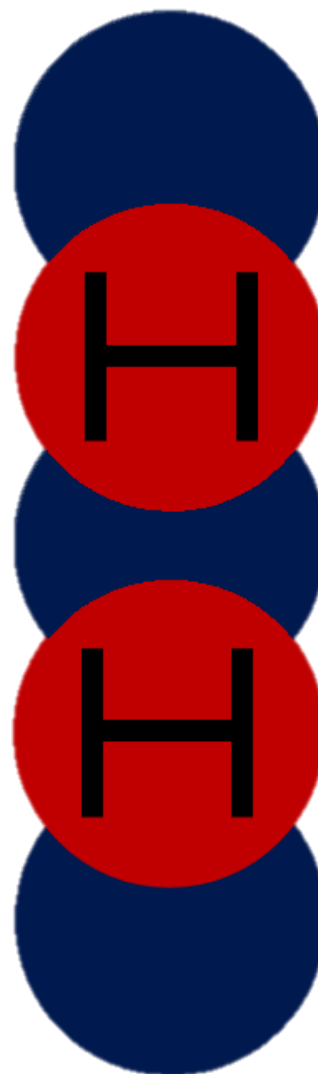
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 - Cost
 - Schedule
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 - Schedule
 - Conclusion
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 - Cost
 - Schedule
 - Conclusion
- Conclusion & Recommendations
- Acknowledgements



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- Project Overview
- Research | Retaining Structures
- Analysis 1 | Foundation Walls
 - Cost
 - Schedule
 - Conclusion
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Problem Identification

- Historic building on West property line
- Foundation needs supported
- Secant Wall duration

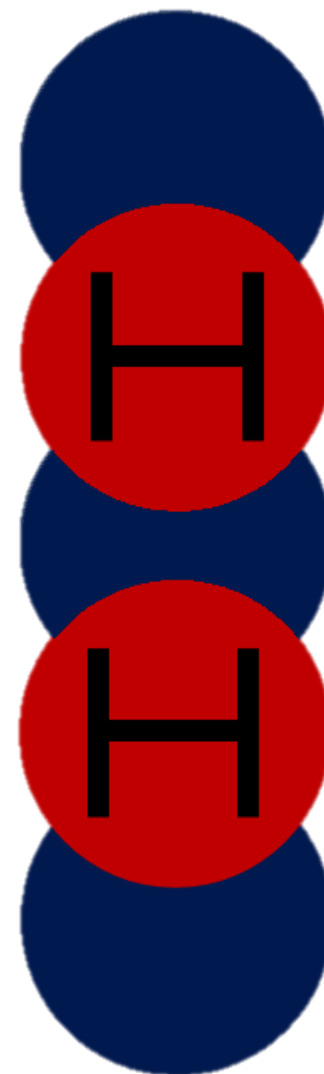
Potential Solutions

- Replace Secant Wall with Slurry Wall

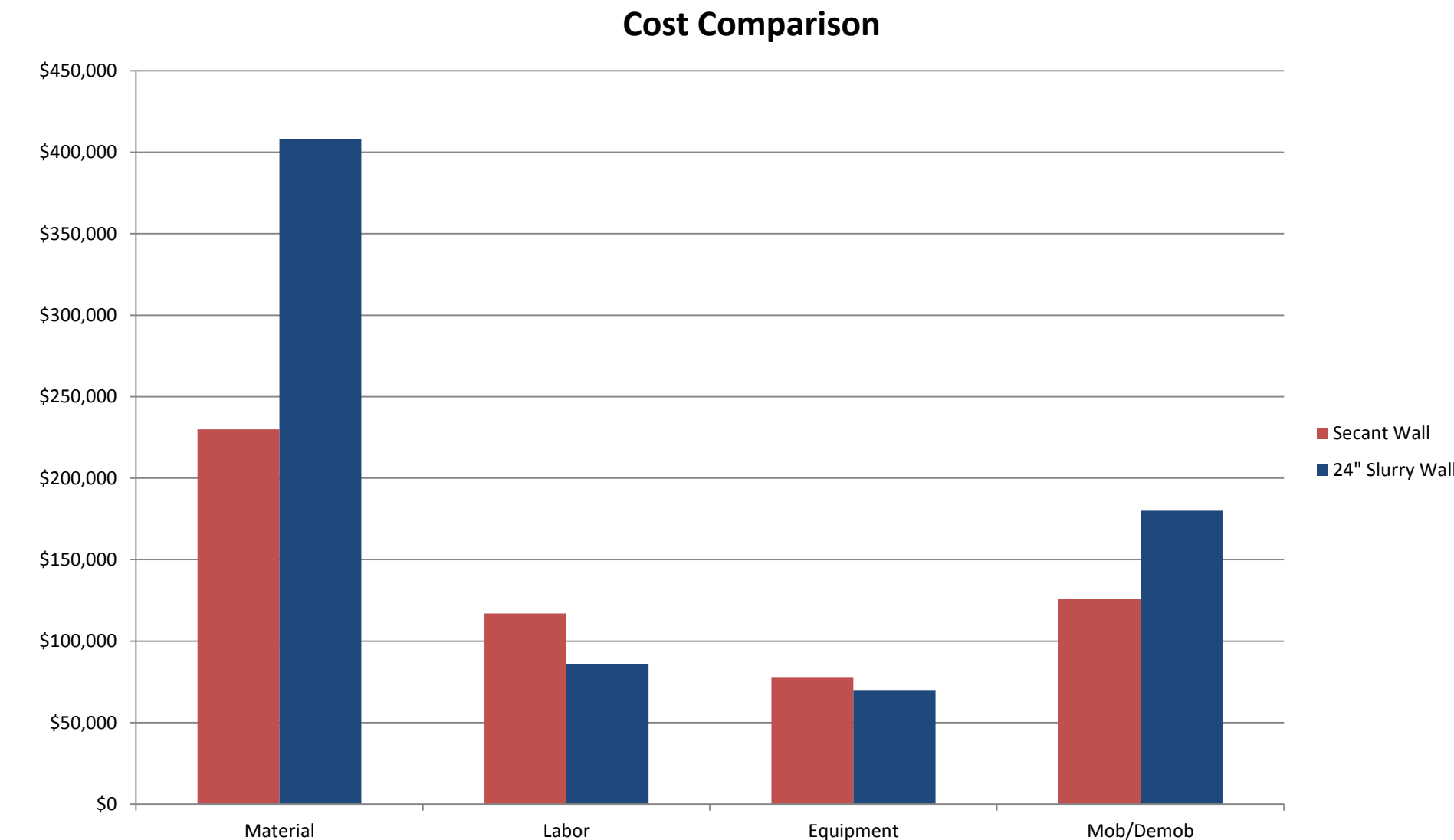
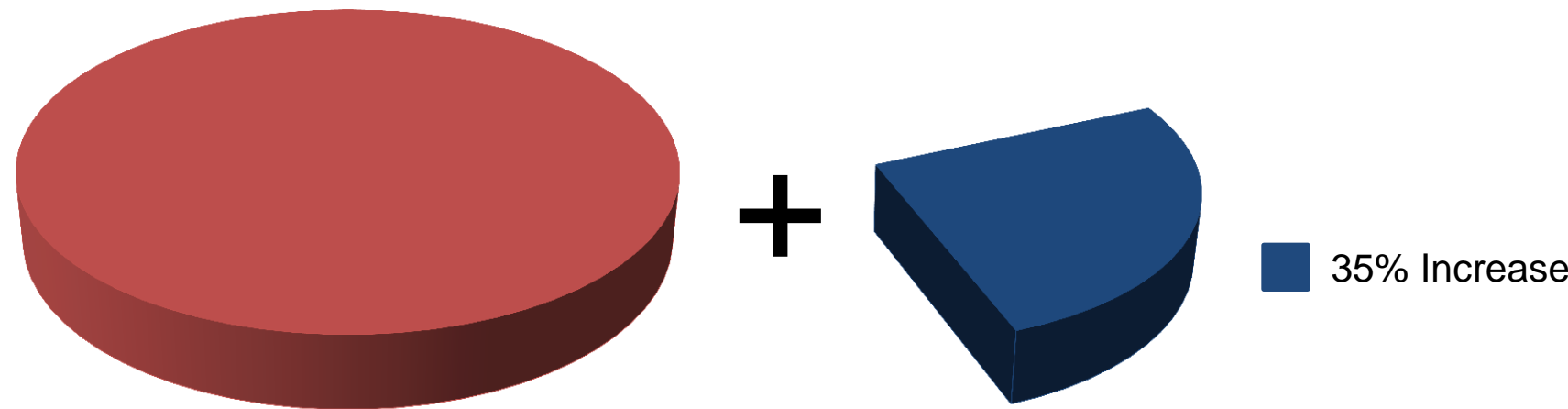


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- Research | Retaining Structures
- Analysis 1 | Foundation Walls
 - Cost
 - Schedule
 - Conclusion
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 - Cost
 - Schedule
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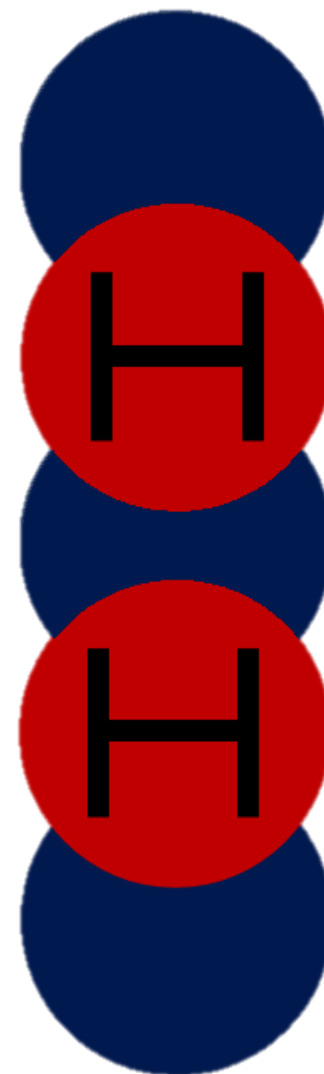


Total Cost	
Secant Wall	\$551,000
24" Slurry Wall	\$744,000
Additional Costs	\$193,000



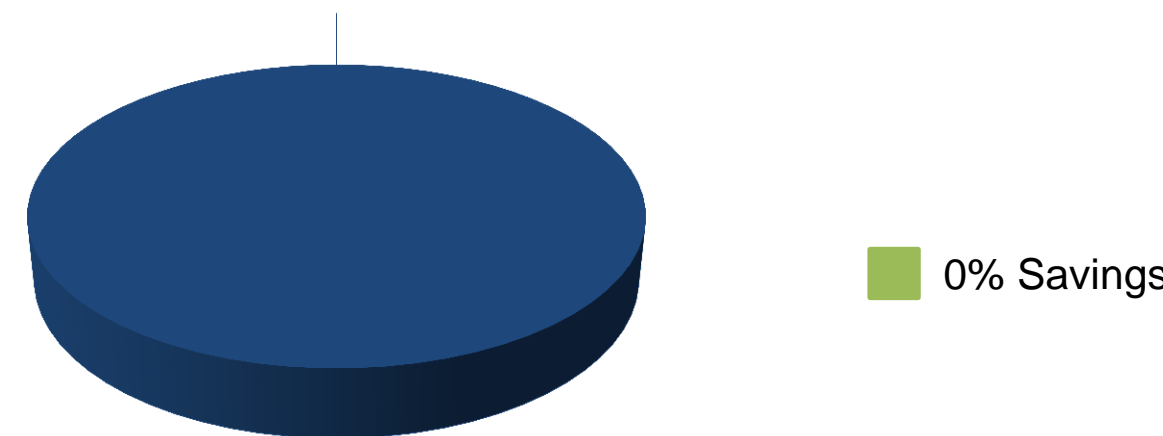
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- Analysis 1 | Foundation Walls
 - Cost
 - Schedule
 - Conclusion
- Analysis 2 | Neighboring Foundation Support
 - Cost
 - Schedule**
 - Conclusion
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 - Electrical Breadth | Sizing wire/Busway
 - Cost
 - Schedule
 - Conclusion
- Conclusion & Recommendations
- Acknowledgements

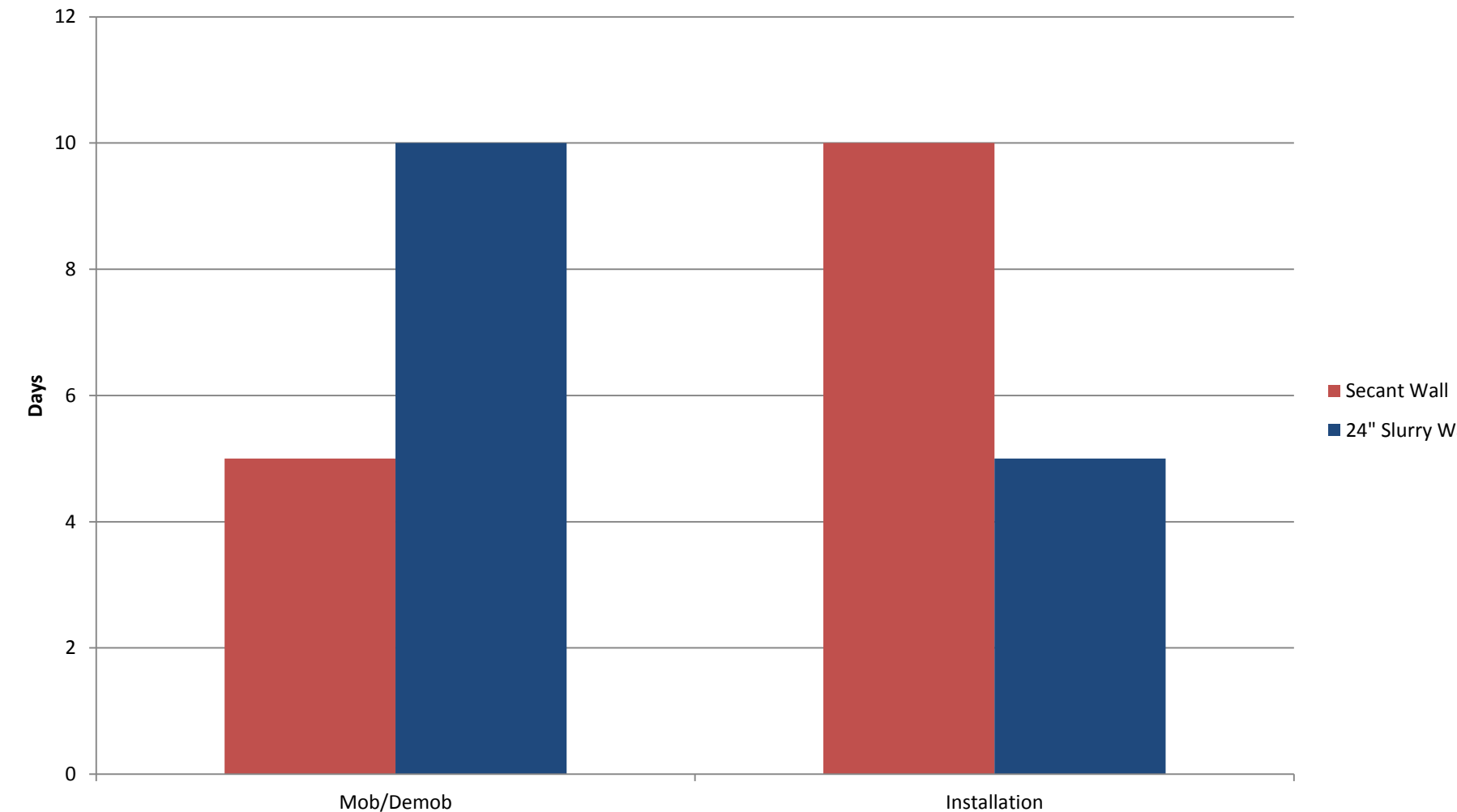


Final Schedule	
Secant Wall	15 Days
Slurry Wall	15 Days
Savings	0 Days

Total Schedule Savings

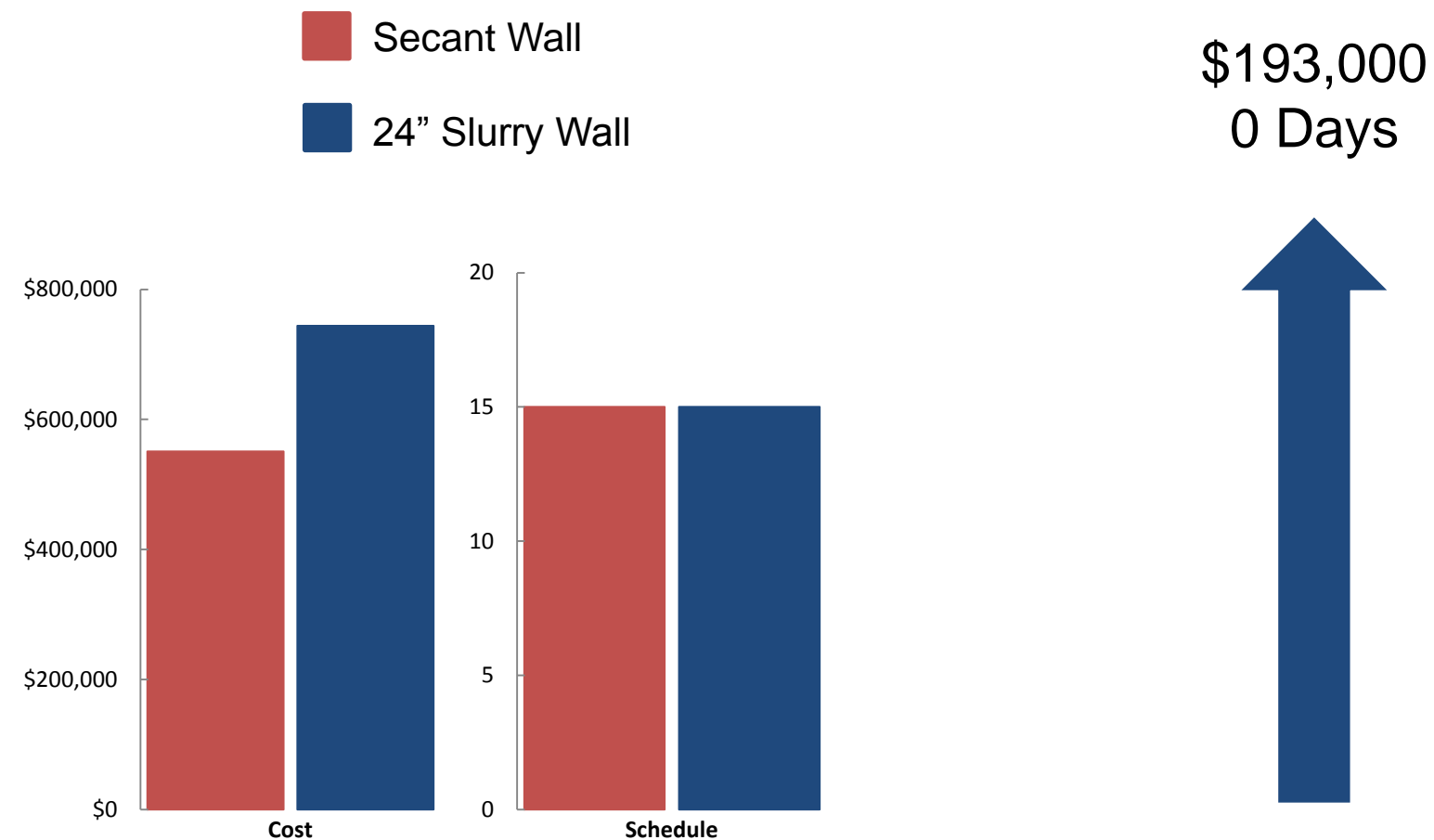
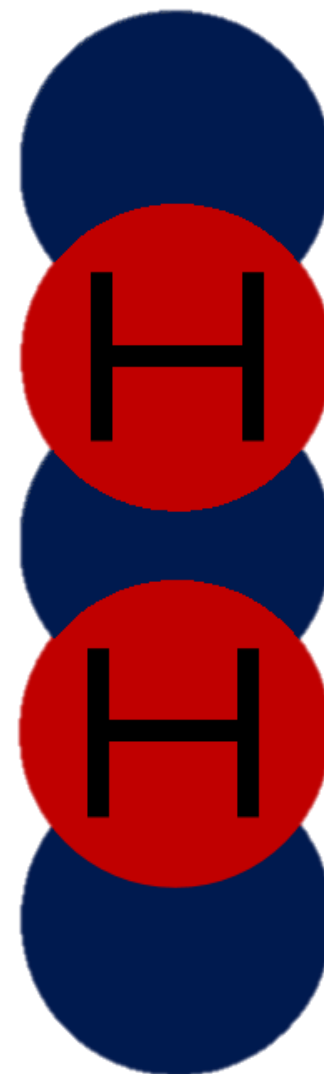


Schedule Comparison



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- Analysis 1 | Foundation Walls
 - Cost
 - Schedule
 - Conclusion
- Analysis 2 | Neighboring Foundation Support
 - Cost
 - Schedule
 - Conclusion**
- Analysis 3 | Value Engineering
 - Electrical Breadth | Sizing wire/Busway
 - Cost
 - Schedule
 - Conclusion
- Conclusion & Recommendations
- Acknowledgements



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 - Cost
 - Schedule
 - Conclusion
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 - Schedule
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 - Schedule
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Problem Identification

- Unforeseen costs
- Over budget
- Expensive copper feeder

Potential Solutions

- Replace copper wiring with less expensive system



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 - Cost
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 - Cost
 - Schedule
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 - Cost
 - Schedule
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Sizing Aluminum Wiring

2500 A Load per Switchboard

Table 310.15 (B)(16)

↳ 500 *kcmil* → 310 A

$$\frac{2500 A}{310 A} = 8.06 \rightarrow 9 \text{ Sets} * 310 A = 2790 A$$

Table 250 – 66

↳ 500 *kcmil*_{AL} → 1/0 AWG_{AL}

Table C.1

↳ (4)500 *kcmil* + (1) 1/0 → 4" Conduit

Sizing Aluminum Busway

2500 A Load per Switchboard

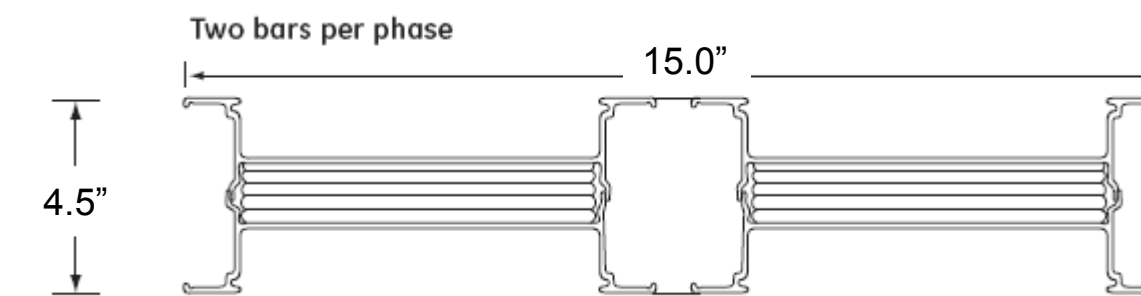
GE Spectra Series Busway

Table 8.1

↳ (2) bars → 1 1/8" Thick per Phase & Neutral

Table 11.1

↳ 4.5" × 15.0"



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 - Cost
 - Schedule
 - Conclusion
- Analysis 2 | Neighboring Foundation Support
 - Cost
 - Schedule
 - Conclusion
- Analysis 3 | Value Engineering
 - Electrical Breadth | Sizing wire/Busway
 - Cost**
 - Schedule
 - Conclusion
- Conclusion & Recommendations
- Acknowledgements

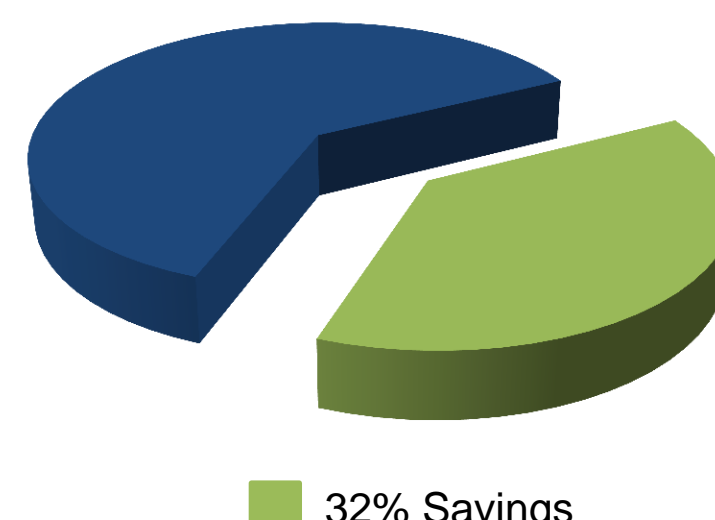


Total Cost	
Copper Wiring	\$330,436.85
Aluminum Wiring	\$313,076.71
Aluminum Busway	\$225,346.06

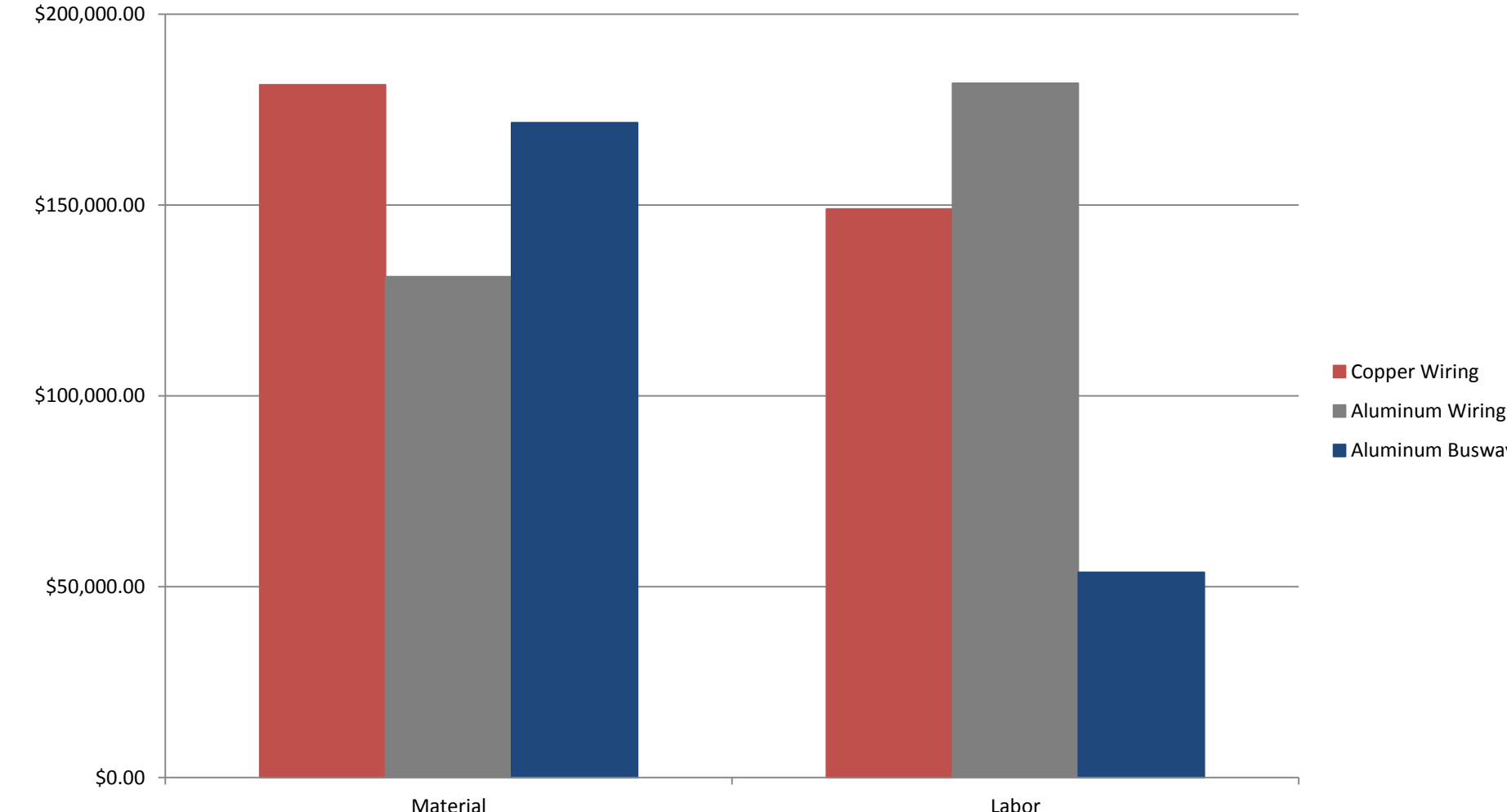
Aluminum Wiring Cost Savings



Aluminum Busway Cost Savings



Cost Comparison



Presentation Outline

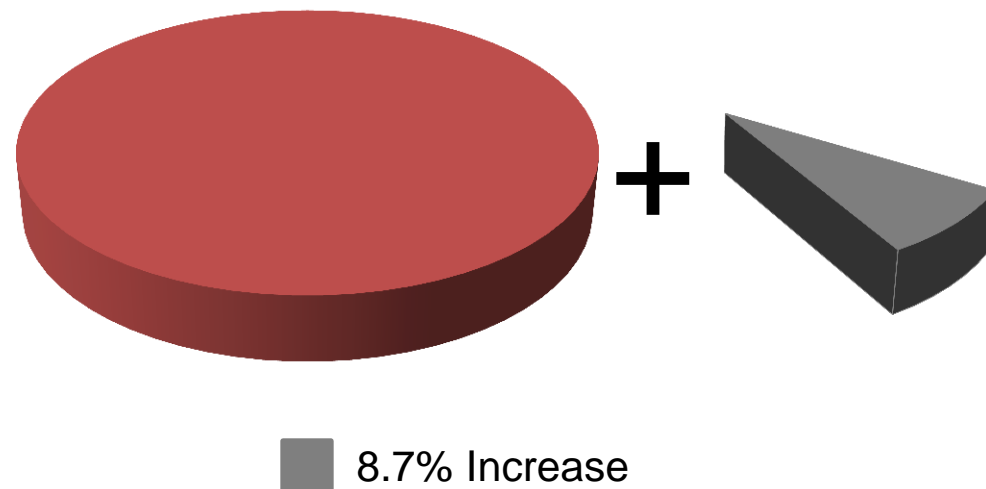
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- Research | Retaining Structures
- Analysis 1 | Foundation Walls
 - Cost
 - Schedule
 - Conclusion
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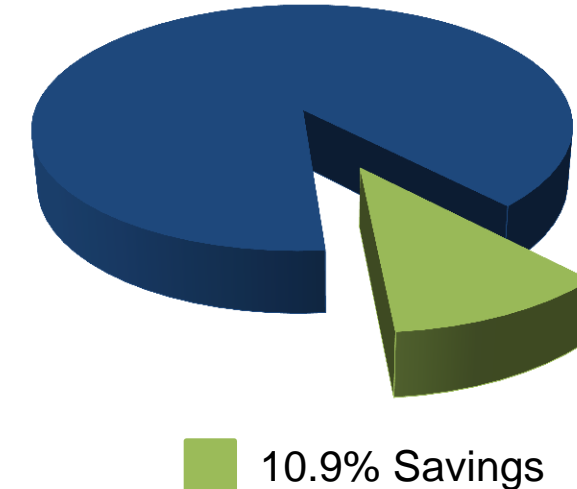
Final Schedule

Copper Wiring	46 Days
Aluminum Wiring	50 Days
Aluminum Busway	41 Days

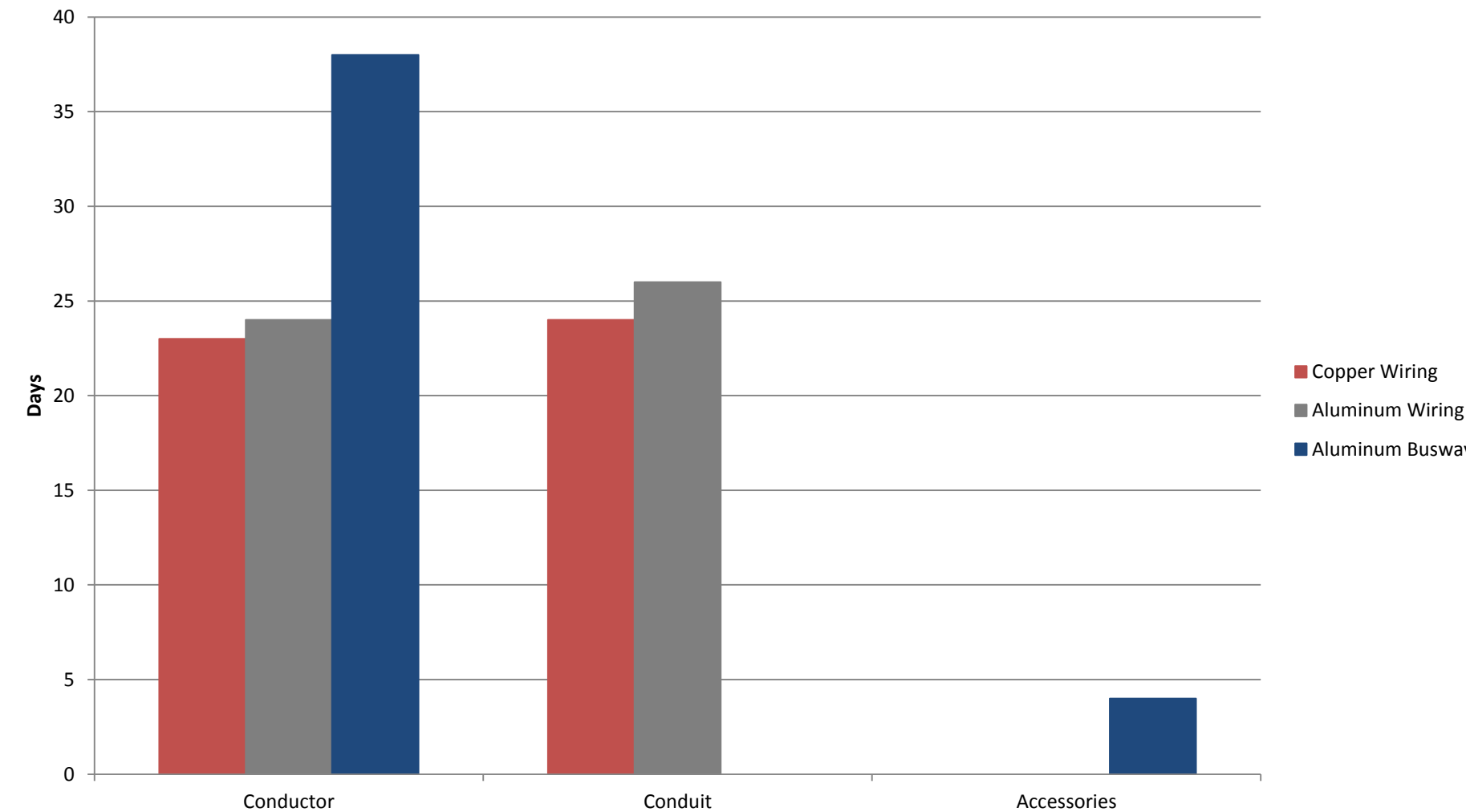
Aluminum Wiring Schedule Increase



Aluminum Busway Schedule Savings

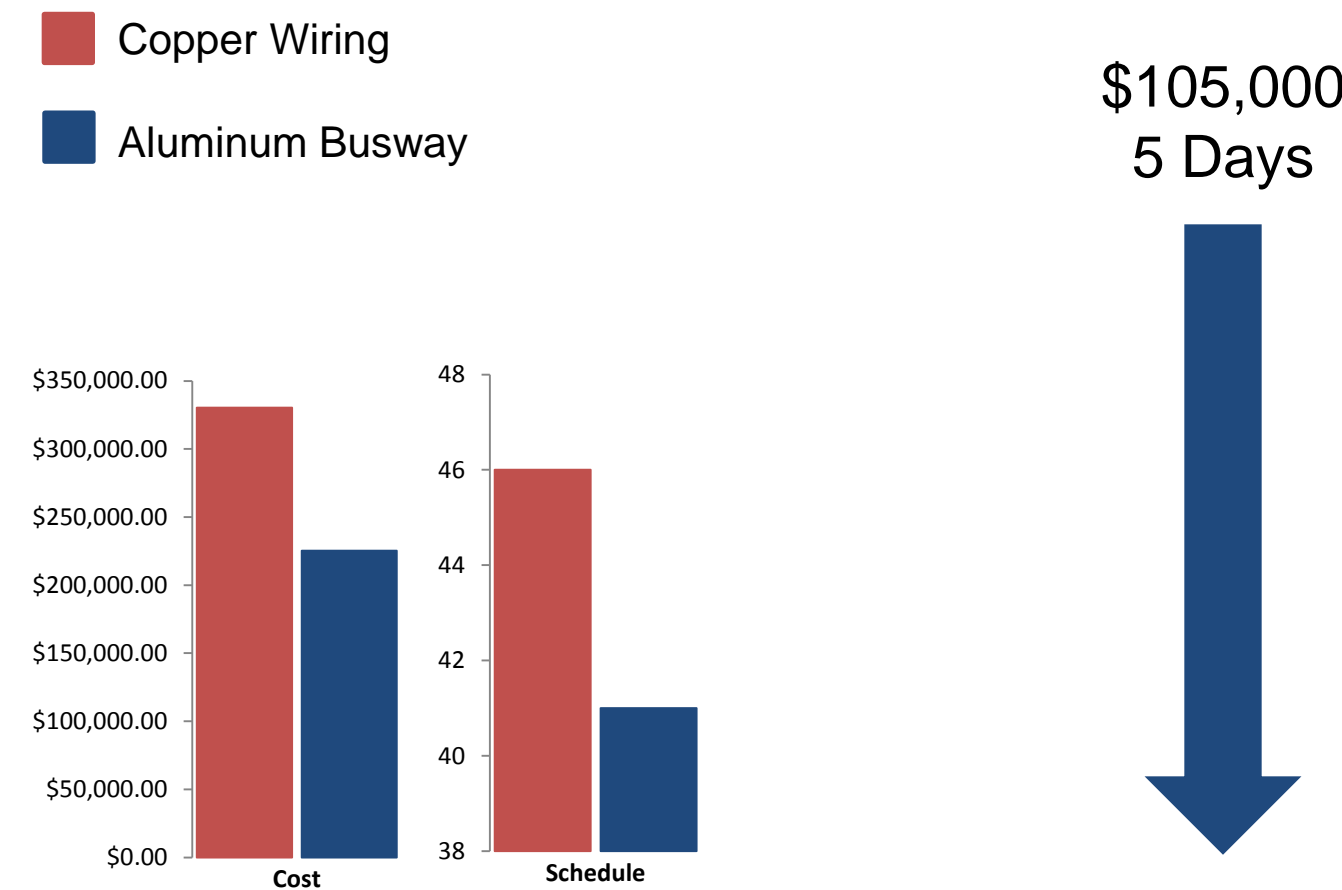
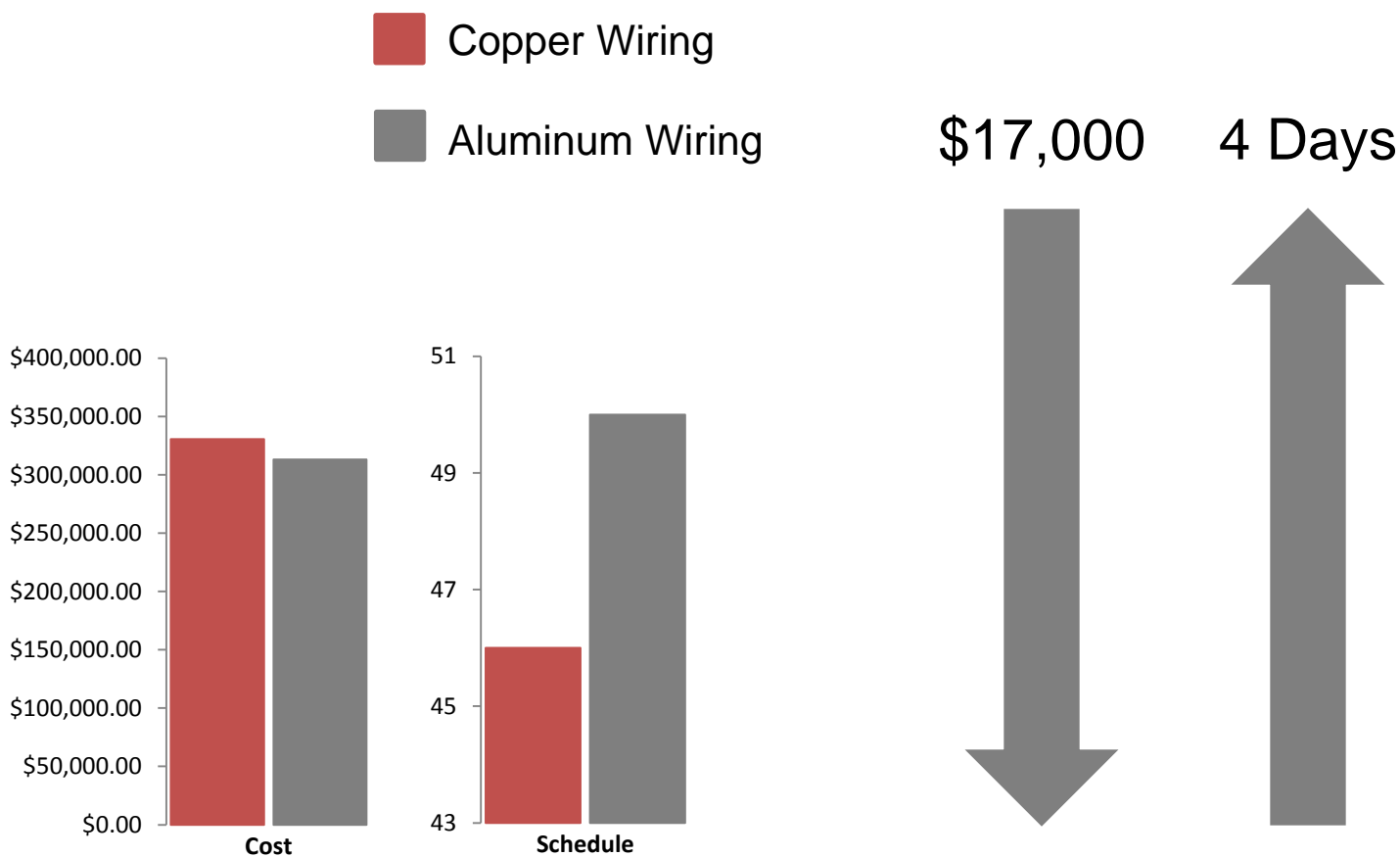


Schedule Comparison



Presentation Outline

- Project Overview
- Research | Retaining Structures
- Analysis 1 | Foundation Walls
 - Cost
 - Schedule
 - Conclusion
- Analysis 2 | Neighboring Foundation Support
 - Cost
 - Schedule
 - Conclusion
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 - Cost
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- Project Overview
- Research | Retaining Structures
- Analysis 1 | Foundation Walls
 - Cost
 - Schedule
 - Conclusion
- Analysis 2 | Neighboring Foundation Support
 - Cost
 - Schedule
 - Conclusion
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 - Cost
 - Schedule
 - Conclusion
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Total Savings

\$182,000

38 Days

Analysis 1 | Foundation Walls

Cost Impact: Save \$77,000

Schedule: Save 33 Days

Recommendation: Select Shotcrete

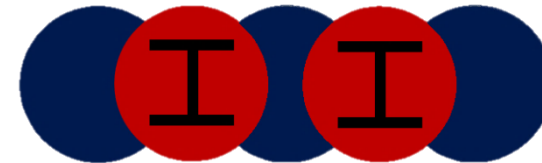


Analysis 2 | Neighboring Foundation Support

Cost Impact: \$193,000 More Expensive

Schedule: No Advantage

Recommendation: Select Secant Wall



Analysis 3 | Value Engineering

Cost Impact: Aluminum Wire Saves \$17,000

Aluminum Busway Saves \$105,000

Schedule: Aluminum Wire Takes 4 More Days

Aluminum Busway Saves 5 Days

Recommendation: Select Aluminum Busway



Academic Acknowledgements

Dr. Ed Gannon
Dr. Robert Leicht
Dr. Craig Dubler

Industry Acknowledgements

MRP | REALTY



DAVIS

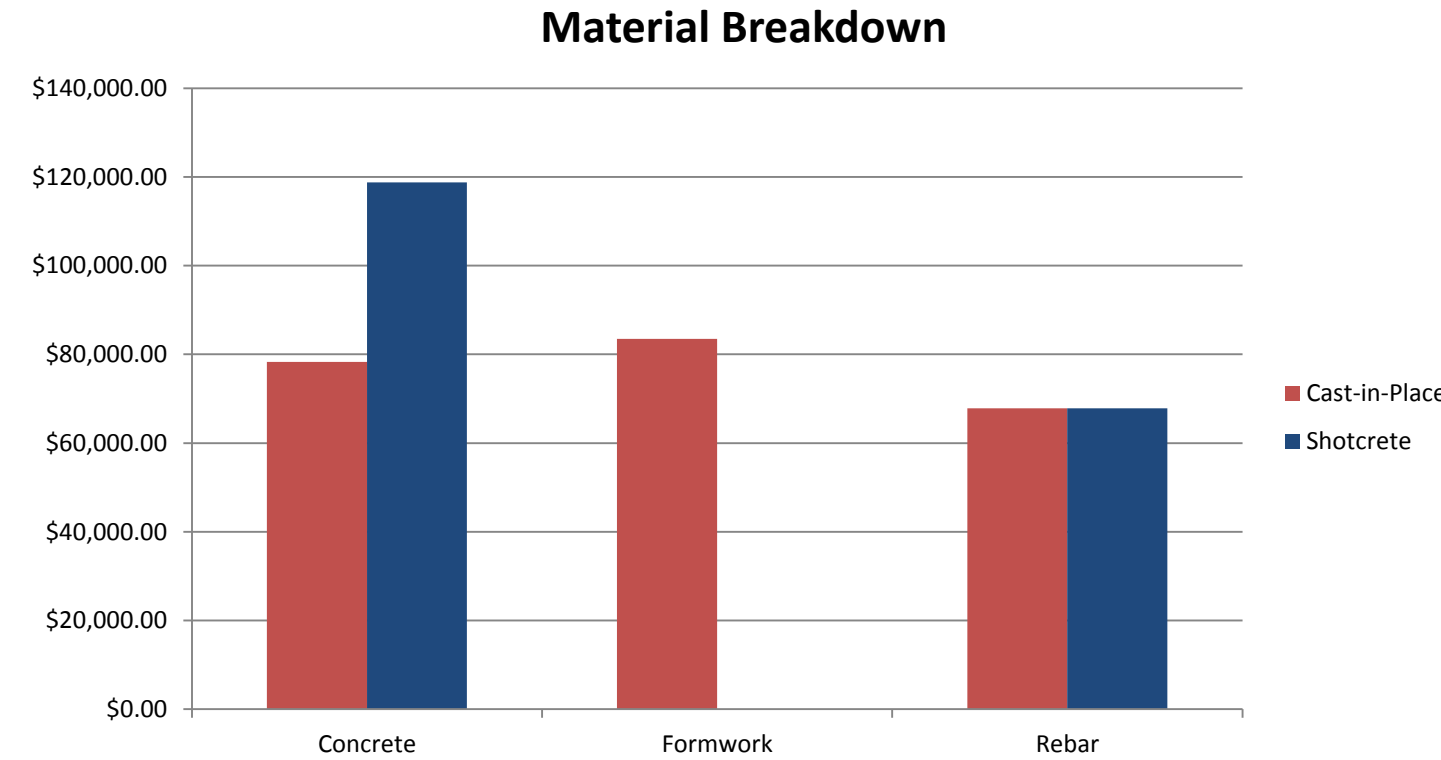


Gensler

Special Thanks

The DAVIS Project Team
Will Cox – DAVIS Project Manager
Drew Heilman – DAVIS Project Engineer
Rebecca Nordby – Balfour Beatty Project Executive
PACE Industry Members
Friends and Family

System	P1	P2	P3	Total
Cast-in-Place	12	12	24	48
Shotcrete	4.5	4	6.5	15
Savings	19.5	8	5.5	33



System	Material	Labor	Equipment	Total
Cast-in-Place	\$229,583.19	\$69,120.00	\$16,240.77	\$314,943.96
Shotcrete	\$186,587.54	\$30,240.00	\$20,989.00	\$237,816.54
Savings	\$42,995.65	\$38,880.00	-\$4,748.23	\$77,127.42

Brett Miller Construction

Appendix A | Foundation Walls

The Office Building Washington, D.C.

Cast-in-Place Concrete Cost Breakdown

Floor	Volume (cu yd)	Concrete Unit Cost (\$/cu yd)	Concrete Cost	Formwork Unit Cost (\$/ft)	Formwork Cost	Rebar Cost	Total Material Cost	Labor Unit Cost (\$/Day)	Labor Cost	Equipment Unit Cost (\$/cu yd)	Equipment Cost	Total
P3	205	118.41	\$24,274.05	\$78.37	\$25,901.29	\$21,021.39	\$71,196.73	\$1,440.00	\$34,560.00	24.57	5036.85	\$110,793.58
P2	188	118.41	\$22,261.08	\$78.37	\$23,746.11	\$18,987.06	\$64,994.25	\$1,440.00	\$17,280.00	24.57	4619.16	\$86,893.41
P1	268	118.41	\$31,733.88	\$78.37	\$33,855.84	\$27,802.49	\$93,392.21	\$1,440.00	\$17,280.00	24.57	6584.76	\$117,256.97
Total:			\$78,269.01		\$83,503.24	\$67,810.94	\$229,583.19		\$69,120.00		\$16,240.77	\$314,943.96

CIP Schedule Breakdown

Floor	Wall Length (ft)	Duration (Day)
P3	330.5	24
P2	303.0	12
P1	432.0	12
Total	1066	48

Shotcrete Cost Breakdown

Floor	Volume (cu yd)	Concrete Unit Cost (\$/cu yd)	Concrete Cost	Rebar Cost	Total Material Cost	Labor Unit Cost (\$/Day)	Labor Cost	Equipment Unit Cost (\$/cu yd)	Equipment Cost	Total
P3	234	\$157.32	\$36,812.88	\$21,021.39	\$57,834.27	\$2,016.00	\$9,072.00	\$27.80	\$6,505.20	\$73,411.47
P2	216	\$157.32	\$33,981.12	\$18,987.06	\$52,968.18	\$2,016.00	\$8,064.00	\$27.80	\$6,004.80	\$67,036.98
P1	305	\$157.32	\$47,982.60	\$27,802.49	\$75,785.09	\$2,016.00	\$13,104.00	\$27.80	\$8,479.00	\$97,368.09
Total	755		\$118,776.60	\$67,810.94	\$186,587.54		\$30,240.00		\$20,989.00	\$237,816.54

Shotcrete Schedule Breakdown

Floor	Volume (cu yd)	Duration (Day)
P3	234	4.5
P2	216	4
P1	305	6.5
Total	755	15

Cost Comparison					
System	Material	Labor / Manpower	Equipment	Transportation / Mobilization	Grand Total
Secant Wall System	\$230,000	\$117,000	\$78,000	\$126,000	\$551,000
24" thick Slurry Wall	\$408,000	\$86,000	\$70,000	\$180,000	\$744,000
Savings	-\$178,000	\$31,000	\$8,000	-\$54,000	-\$193,000

Schedule Comparison		
System	Duration	
Secant Wall System	Mob/demob	1 Week
	Wall	2 Weeks
24" thick Slurry Wall	Mob/demob	2 Weeks
	Wall	1 Week

Table 310.15(B)(16) (formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).]						Size AWG or kcmil
	60°C (140°F)		75°C (167°F)		90°C (194°F)		
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, ML, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	14	—	—	—	—
16	—	—	18	—	—	—	—
14**	15	20	25	—	—	—	—
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	330	370	230	270	300	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).
**Refer to 240.4(D) for conductor overcurrent protection limitations.

Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems

Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum
2 or smaller	1/0 or smaller	8	6
1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250	4	2
Over 3/0 through 350	Over 250 through 500	2	1/0
Over 350 through 600	Over 500 through 900	1/0	3/0
Over 600 through 1100	Over 900 through 1750	2/0	4/0
Over 1100	Over 1750	3/0	250

Tubing (EMT) (Based on Table 1, Chapter 9)

Type	Conductor Size (AWG kcmil)	Metric Designator (Trade Size)									
		16 (½)	21 (¾)	27 (1)	35 (1¼)	41 (1½)	53 (2)	63 (2½)	78 (3)	91 (3½)	103 (4)
RHH, RHW, RHW-2	14	4	7	11	20	27	46	80	120	157	201
	12	3	6	9	17	23	38	66	100	131	167
	10	2	5	8	13	18	30	53	81	105	135
	8	1	2	4	7	9	16	28	42	55	70
	6	1	1	3	5	8	13	22	34	44	56
	4	1	1	2	4	6	10	17	26	34	44
	3	1	1	1	4	5	9	15	23	30	38
	2	1	1	1	3	4	7	13	20	26	33
	1	0	1	1	1	3	5	9	13	17	22
	1/0	0	1	1	1	2	4	7	11	15	19
	2/0	0	1	1	1	2	4	6	10	13	17
	3/0	0	0	1	1	1	3	5	8	11	14
	4/0	0	0	1	1	1	3	5	7	9	12
	250	0	0	0	1	1	1	3	5	7	9
	300	0	0	0	1	1	1	3	5	6	8
	350	0	0	0	1	1	1	3	4	6	7
	400	0	0	0	1	1	1	2	4	5	7
	500	0	0	0	0	1	1	2	3	4	6
	600	0	0	0	0	1	1	1	3	4	5
	700	0	0	0	0	0	1	1	2	3	4
	750	0	0	0	0	0	1	1	2	3	4
	800	0	0	0	0	0	1	1	2	3	4
	900	0	0	0	0	0	1	1	1	3	3
	1000	0	0	0	0	0	1	1	1	2	3
	1250	0	0	0	0	0	0	1	1	1	2
	1500	0	0	0	0	0	0	1	1	1	1
	1750	0	0	0	0	0	0	1	1	1	1
	2000	0	0	0	0	0	0	1	1	1	1

Copper Wiring Breakdown

Master Format Code	Description	Unit	Length	Material Unit Cost	Total Material	Labor Unit Cost	Total Labor	Total	Crew	# of Crews	Labor Hours	Duration (hrs)
260519900490	500 kcmil Copper Conductor	CLF	96.46	\$1,186.75	\$114,473.91	\$833.04	\$80,355.04	\$194,828.94	3 Elec	3	5	161
260519900260	1/0 kcmil Copper Grounding Conductor	CLF	24.115	\$253.51	\$6,113.39	\$402.48	\$9,705.81	\$15,819.20	2 Elec	3	2.424	20
260533131140	4" Diameter Metal Conduit	LF	2411.5	\$25.25	\$60,890.38	\$38.07	\$91,805.81	\$152,696.18	2 Elec	3	0.229	185
Total					\$181,477.67		\$148,959.18	\$330,436.85				366

Aluminum Wiring Breakdown

Master Format Code	Description	Unit	Length	Material Unit Cost	Total Material	Labor Unit Cost	Total Labor	Total	Crew	# of Crews	Labor Hours	Duration (hrs)
260519900800	500 kcmil Aluminum Conductor	C.L.F.	124.02	\$398.95	\$49,477.78	\$221.52	\$27,472.91	\$76,950.69	3 Elec	3	4	166
260519900620	1/0 Aluminum Grounding Conductor	C.L.F.	31.005	\$111.10	\$3,444.66	\$111.28	\$3,450.24	\$6,894.89	2 Elec	3	2	21
260533131140	4" Diameter Metal Conduit	L.F.	3100.5	\$25.25	\$78,287.63	\$38.07	\$118,036.04	\$196,323.66	2 Elec	3	0.2	207
Total					\$131,210.06		\$181,866.65	\$313,076.71				394

Aluminum Busway Breakdown

Master Format Code	Description	Unit	Length	Material Unit Cost	Total Material	Labor Unit Cost	Total Labor	Total	Crew	# of Crews	Labor Hours	Duration (hrs)
262513104620	Feeder Al Busway 2500 amp	L.F	200.5	\$484.80	\$97,202.40	\$147.68	\$29,609.84	\$126,812.24	2 Elec	2	1.333	134
262513100330	Plug-in Al Busway 2500 amp	L.F	144	\$398.95	\$57,448.80	\$126.88	\$18,270.72	\$75,719.52	2 Elec	2	1.143	83
262513106470	Busway End Box 2500 amp	Ea.	2	\$1,136.25	\$2,272.50	\$738.40	\$1,476.80	\$3,749.30	2 Elec	1	13.333	27
262513105520	Busway Elbow 2500 amp	Ea.	10	\$1,464.50	\$14,645.00	\$442.00	\$4,420.00	\$19,065.00	2 Elec	1	8	80
Total					\$171,568.70		\$53,777.36	\$225,346.06				324