



James Lee

Sorenson Language and  
Communication Center

Patrick B. Murphy

Mechanical Option

AE Senior Thesis Final Report

## TABLE OF CONTENTS

---

SECTION	PAGE
1. ACKNOWLEDGEMENTS .....	1
2. EXECUTIVE SUMMARY .....	2
3. PROJECT BACKGROUND .....	3
3.1. ARCHITECTURE .....	4
3.2. BUILDING SYSTEMS .....	5
4. OVERVIEW OF MECHANICAL SYSTEM .....	7
4.1. DESIGN OBJECTIVES .....	7
4.2. SYSTEM ORIENTATION .....	8
4.3. SYSTEM DESIGN & OPERATION .....	9
5. THESIS DESIGN PROPOSAL .....	16
5.1. GREEN ROOF .....	16
5.2. MECHANICAL SYSTEM .....	16
6. GREEN ROOF DESIGN .....	17
6.1. EXISTING ROOF DESIGN .....	18
6.2. PROPOSED ROOF DESIGN .....	19
6.3. THERMAL PERFORMANCE .....	21
6.4. METHODOLOGY .....	22
6.5. STORMWATER RETENTION .....	26
6.6. URBAN HEAT ISLAND EFFECT .....	30
7. MECHANICAL SYSTEM DESIGN .....	31
7.1. PROPOSED SYSTEM DESIGN .....	31
7.2. VENTILATION STRATEGY .....	35
7.3. ENERGY ANALYSIS METHODOLOGY .....	35
7.4. CASE 1: EXISTING SYSTEM ENERGY ANALYSIS .....	36
7.5. CASE 2: DOAS SYSTEM ENERGY ANALYSIS .....	37
7.6. CASE 3: OVERALL IMPACT OF DOAS, GREEN ROOF LOADS .....	37
7.7. ENERGY COST SAVINGS .....	37



James Lee

Sorenson Language and  
Communication Center

Patrick B. Murphy

Mechanical Option

AE Senior Thesis Final Report

8. STRUCTURAL ANALYSIS .....	38
8.1. EXISTING CONDITIONS .....	38
8.2. STRUCTURAL ANALYSIS METHODOLOGY .....	39
8.3. SAMPLE CALCULATIONS .....	42
8.4. EXISTING STRUCTURE EVALUATION .....	44
8.5. CONCLUSION .....	45
9. ACOUSTIC ANALYSIS .....	46
9.1. ACOUSTIC ANALYSIS METHODOLOGY .....	46
9.2. SAMPLE CALCULATIONS .....	50
9.3. CASE 1: EXISTING CONDITIONS .....	52
9.4. CASE 2: PROPOSED MECHANICAL SYSTEM CONDITIONS .....	53
9.5. CASE 3: GREEN ROOF CONDITIONS .....	54
9.6. CASE 4: OVERALL IMPACT OF PROPOSED DESIGN .....	54
9.7. CONCLUSION .....	55
10. LEED RATING EVALUATION .....	56
10.1. ORIGINAL DESIGN RATING .....	56
10.2. PROPOSED DESIGN RATING .....	60
11. COST ANALYSIS .....	64
11.1. ORIGINAL DESIGN COST .....	64
11.2. PROPOSED DESIGN FIRST COST .....	65
11.3. ENERGY & MAINTENANCE COSTS .....	67
11.4. SIMPLE PAYBACK PERIOD .....	68
12. CONCLUSIONS & RECOMMENDATIONS .....	69
13. REFERENCES .....	70
14. APPENDIX A: GREEN ROOF THERMAL ANALYSIS .....	A
15. APPENDIX B: EXISTING SYSTEM ENERGY ANALYSIS .....	B
16. APPENDIX C: DOAS SYSTEM ENERGY ANALYSIS .....	C
17. APPENDIX D: STRUCTURAL ANALYSIS .....	D
18. APPENDIX E: ACOUSTIC ANALYSIS .....	E

## TABLE OF FIGURES

FIGURE	DESCRIPTION	PAGE
Figure 3.1:	Rendering of SLCC North Entrance (SmithGroup)	4
Figure 3.2:	Rendering of SLCC Atrium (SmithGroup)	4
Figure 4.1:	Mechanical system zones within the SLCC	8
Figure 4.2:	Airside System Schematic	11
Figure 4.3:	Chilled Water System Schematic	13
Figure 4.4:	Heating Hot Water System Schematic (PRV, HX, Pumps)	14
Figure 4.5:	Heating Hot Water System Schematic (Distribution)	15
Figure 6.1:	Schematic Design Phase proposal for green roof (SmithGroup)	17
Figure 6.2:	Example of a cool roof (fypower.org)	17
Figure 6.3:	Typical material solar absorptivity and emissivity ratios (Gaffin, et al.)	18
Figure 6.4:	Existing roof construction (SmithGroup)	18
Figure 6.5:	Construction of original roof and green roof	19
Figure 6.6:	Scope of proposed green roof	20
Figure 6.7:	Sedum kamtschaticum applied to a green roof project (greenroofplants.com)	20
Figure 6.8:	Energy balance of a green roof (Gaffin, et al.)	21
Figure 6.9:	Average net heat flux into SLCC per hour	25
Figure 6.10:	Average net heat gain histogram through different roof types	25
Figure 6.11:	The SLCC (red dot) is located in the Anacostia Watershed (yellow)	27
Figure 6.12:	Site plan for the SLCC	27
Figure 6.13:	Roof drainage areas 1 (left) and 2 (right)	29
Figure 6.14:	Thermal radiation in the urban Washington, DC environment in 1990(Baumann)	30
Figure 7.1:	Passive chilled beam	31
Figure 7.2:	Proposed reflected ceiling plan for chilled beam system	32
Figure 7.3:	Proposed chilled water system schematic with two (2) CHW loops	33
Figure 7.4:	Typical Heat and Energy Recovery Ventilator (HRV/ERV) (Fantech)	34
Figure 7.5:	Schedule of selected ERVs	34
Figure 8.1:	Typical roof construction detail	38
Figure 8.2:	Plans of typical structural bays studied	41
Figure 8.3:	Free body diagram of a typical girder	41
Figure 8.4:	Free body diagram of a typical joist	41
Figure 8.5:	RAM Model of second floor roof	45
Figure 8.6:	RAM Model of third floor roof	45
Figure 9.1-9.3:	NC performance of original design, VAV system with green roof, and DOAS system with green roof	55
Figure 10.1:	Pervious concrete	62

## TABLES

TABLE	DESCRIPTION	PAGE
Table 4.1:	Design Supply Air Temperatures.....	9
Table 4.2:	Design Room Air Temperature Setpoints .....	9
Table 4.3:	AHU Summary.....	9
Table 6.1:	Monthly average peak instantaneous solar radiation.....	24
Table 6.2:	Monthly average ambient conditions for Washington, DC .....	24
Table 6.3:	Total energy costs savings for green roof compared to cool roof, typical roof.....	26
Table 6.4:	Annual site stormwater runoff.....	28
Table 6.5:	Annual stormwater runoff with green roof and pervious pavement.....	28
Table 6.6:	Roof downspout sizes.....	29
Table 7.1:	Comparison of outdoor and supply air flows for each system.....	35
Table 7.2:	Existing system annual energy cost and use.....	36
Table 7.3:	Annual energy cost and use for the DOAS system.....	37
Table 7.4:	Annual energy cost and use for the DOAS system with a green roof.....	37
Table 8.1:	Expected gravity loads on roof.....	39
Table 8.2:	Joist and beam selections for original, green roofs.....	44
Table 8.3:	Girder selections for original, green roofs.....	44
Table 9.1:	Ambient noise measurements at site.....	46
Table 9.2:	Room noise produced by the original mechanical system.....	52
Table 9.3:	NC levels of combined noise for original roof, VAV system.....	52
Table 9.4:	Room noise produced by the proposed DOAS system. ....	53
Table 9.5:	NC Levels of combined noise for original roof, DOAS system.....	53
Table 9.6:	NC Levels of combined noise for green roof, VAV system.....	54
Table 9.7:	NC levels of combined noise for green roof, DOAS system. ....	54
Table 10.1:	LEED Scorecard for original SLCC design.....	56
Table 10.2:	Sustainable Sites Credit 6.1 calculation for original SLCC design.....	57
Table 10.3:	Energy cost budget for the SLCC.....	58
Table 10.4:	Annual energy costs of regulated, unregulated energy. ....	58
Table 10.5:	LEED-NC v2.1 Energy and Atmosphere Credit 1 calculation for original SLCC design. ....	59
Table 10.6:	LEED Scorecard for SLCC with green roof and DOAS system designs.....	60
Table 10.7:	Summary of energy use in the SLCC for the DOAS system and green roof. ....	61
Table 10.8:	EA Credit 1 points earned with DOAS system and green roof. ....	61
Table 10.9:	Sustainable Sites Credit 6.1 calculation for green roof, pervious parking.....	63
Table 10.10:	Sustainable Sites Credit 6.1 calculation for proposed design and stormwater reuse. ....	63
Table 11.1:	Total project cost estimate (Heery).....	64
Table 11.2:	Itemized cost of proposed changes to SLCC design.....	65
Table 11.3:	Total proposed project cost estimate.....	66
Table 11.4:	Comparison of design first costs. ....	66
Table 11.6:	Additional parallel cooling system cost (green roof). ....	66
Table 11.7:	Original design operation and maintenance costs. ....	67
Table 11.8:	Original design operation and maintenance costs. ....	67
Table 11.9:	Simple payback period for proposed design.....	68