PSU Green Building Internship Final Presentation, 2019: KMC Post-Occupancy Study

Junyoung Lee
Portland State University

Everett Stilley
Portland State University

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Green Building Internship 2019

KMC Post-Occupancy Study

June 24th - September 4th

PSU Capital Projects and Construction

Junyoung Lee + Everett Stilley
B.S. Architecture  B.S. Mechanical Engineering
1. Introduction
2. Previous Studies & Research Goals
3. Data Collection
4. Space Temperature
5. Survey Analysis
6. Air Quality Research
7. Acknowledgements & Recommendations
Karl Miller Center

LEED Platinum Certified
(Oct 11, 2018)

- KMC is the third PSU building to achieve LEED Platinum status
- Mixed-mode building
- Passive Ventilation Design
- Energy Use Intensity (EUI)
  - Pre-renovation EUI = 63 kBtu/gsf/year
  - 2018 EUI = 25 kBtu/gsf/year
  - 2019 EUI calculation in process
Previous Studies

Ky’s Research
(Fall 2017 - Pavilion Classrooms only)

- **Post-Occupancy Survey**
  - 741 responses across 23 classes in 8 Pavilion classrooms

- **Perception & Performance study**
  - 80% of Pavilion responses landed in the comfortable range.
    - 82% comfort level on renovated side (HVAC present)
  - **ASHRAE 55 Standard: Strive for at least 80% of occupants satisfied.**
Previous Studies
Green Building Internship (2018)

- Omar Abu Salaiman & Jocelyn Reynolds
- Post-Occupancy Survey (Renovated classrooms only)
- **No classes held in Pavilion summer 2018**
- Apply ideal comfort range from survey to Pavilion classrooms

**Recommendation**
- No classes after 12pm in certain Pavilion classrooms
Research goals

Investigate Pavilion-side building performance in Summer Classrooms

Survey students taking classes in Pavilion classrooms during summer 2019 term.

Analyze data to update classroom scheduling recommendations.

Initiate long-term monitoring of Indoor air pollutant concentrations in KMC.
Data Collection

Instruments

- **NOAA/NWS**  
  Hourly outdoor temperature

- **Building Automation System (BAS)**  
  Temperature, CO2 and window status for each classroom

- **Kestrel data loggers**  
  Temperature and relative humidity

- **Purple Air particulate concentration sensors**  
  PM1.0, PM2.5, and PM10

- **Deployed Instruments**  
  Kestrel x15  
  Purple Air - x15  
  Weather Station - x1

- **Data set**  
  BAS - 30 minute increments  
  Purple Air - 80 second increments  
  Kestrel - 5 minute increments
Data Collection

Deployment

- **Location**
  - Pavilion-side Classrooms
  - Renovated-side classrooms
  - Outdoor patio
  - Rooftop

- **Strategies**
  - Pairing Classrooms
  - Place based on cardinal direction on patio

Deploying classroom sensors
Pre-design natural ventilation simulation

Classroom simulation with natural Ventilation controls, no heating cooling or mechanical ventilation

Overheating Hours at Various Upper-band Comfort Limits
(Operative Temperature, Occupied Hours Only)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>No Fan</th>
<th>Fan Air Speed 25 fpm</th>
<th>Fan Air Speed 55 fpm</th>
<th>Fan Air Speed 100 fpm</th>
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<td>&gt;80°F</td>
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<tr>
<td>&gt;84°F</td>
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</table>

2015 document simulating natural-ventilation conditions and comfort levels

Behnisch Architekten 2015
Temperature Analysis
Summer 2019 Indoor/Outdoor Pavilion Temperatures

Average, Min and Max Indoor Air Temperature for Pavilion with hourly outdoor air temperature

- AVG
- min
- max
- Outdoor Air Temperature
- Comfort Limit Low
- Comfort Limit High
Warmest week of 2019
Finals week of Spring term 2019

Average, Min and Max Indoor Air Temperature for Pavilion with hourly outdoor air temperature
Temperature Analysis
Summer 2019 Snapshot

Average, Min and Max Indoor Air Temperature for Pavilion with hourly outdoor air temperature
Survey Analysis

Fall 2017 Ky’s Survey Data - Pavilion classrooms only

- A neutral perception of thermal comfort dominates with low numbers at the extremes
- 80% of respondents satisfied
Survey Analysis

Survey Timeline

- 6/26: Prepared Survey Set
  - IRB Approved
  - ASHRAE 55 Guide line

- 7/17-8/1: Conducted First Survey
  - 93 students from 5 classes

- 8/14: Conducted Second Survey

- 8/28: Analysis
  - Compared to previous survey data
  - Identified patterns
Survey Design

Survey Analysis

- Anonymous
- 6 multiple-choice and one open-ended question
- Question #2: Cumulative comfort level over entire term
- Question #3: Comfort level at time of survey
- Question #4: Personal control experience
- Question #5: Air quality perception
- Question #6: Recognition of KMC sustainable features
Survey Analysis

Summer 2019 Survey Results

- 93% of users are satisfied with their comfort level in the Pavilion classrooms.
- 13% Improvement over 2017 survey
  - Building operation improvements in years since construction.

Final result: 6 survey distributions totaling 124 students.
Survey Analysis

Individual thermal comfort at time of survey

Question #3: “Please select the option that best describes your thermal comfort level today”

Outside temperature of 77F, inside 77F

Outside temperature 84F, inside 75F
Survey Analysis

Comparison to indoor and outdoor temperatures at time of survey
# Temperature Analysis

## Determination of Ideal Classrooms

1. Count number of days a given room is over a certain temperature

2. Revise Room Ranking

3. Room 390: 16 days over 78
   4 days over 80

   Room 495: 4 days over 78
   1 day over 80

   Room 295: 2 days over 78
   0 days over 80

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<th>Number of days over a given temperature</th>
<th>Room</th>
<th>75</th>
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Temperature Analysis

Determination of Ideal Classrooms

Summer 2018

Table 1: Average Temperatures of Classrooms by Time of Day (7/15/18 - 8/15/18) per hour (F)

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Average Temperature of Classroom: 72.3°F

Total Seats: 60
Maximum Recommended Occupants: 70

Summer 2019

<table>
<thead>
<tr>
<th>Time</th>
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<th>190</th>
<th>195</th>
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<td>74.3</td>
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</tr>
</tbody>
</table>

Average Temperature of Classroom: 74.1°F

Total Seats: 60
Maximum Recommended Occupants: 70
Air Quality Research

- Initial phase
  - Deployment likely to last one full year
- Comparison of particulate concentrations in naturally ventilated and mechanically ventilated classrooms.
- Summer 2019 outdoor particulate levels very low.
  - Absence of wildfire smoke and other elevated pollution air pollution events.
KMC 495 vs. Outdoor PM 2.5 concentrations

- Levels in KMC are within National Ambient Air Quality Standards (1990 Clean Air Act)
  - 12 micrograms/m3 averaged over 1 year.
Night Purge Effectiveness

Background

- **What is Night Purge?**

Night purging is the removal of heat from a building by bringing in cool night time air without the use of active HVAC cooling and ventilation.
Night Purge Effectiveness

Night Purge Performance on hot week (6/10 - 6/14 Room 495)

- Pavilion finals week performance
  - 6/10 - 6/14
  - Room 495 (Pavilion side)
  - Highest **Outdoor** Temperature: **96.0 F**
  - Highest **Classroom** Temperature: **82.6 F**

- Average Temperature Drop After NP: **0.58 F**

- Outcomes
  1. Overheating causes more temperature drop (Pressure Difference)
  2. Design Intention proposed "NP is more effective with increasing Indoor Air Velocity"
Night Purge Effectiveness

New Night Purge Simulations & Result

- The current setting
  - Operated by temperature
  - No time setting for NP

- 4 different simulations
  - Sample room: Pavilion room 495
  - Operation hours: Midnight ~ 6 AM

Simulation 1 (8/2)
- Ceiling fans off
- Windows open

Simulation 2 (8/5)
- Ceiling fans on
- Windows closed

Simulation 3 (8/22)
- Ceiling fans on
- Windows open

Simulation 4 (8/23)
- Exhaust fan on
- Windows open

<table>
<thead>
<tr>
<th>Simulation(s)</th>
<th>Outside before NP</th>
<th>outside after NP</th>
<th>Outdoor drop</th>
<th>Room before NP</th>
<th>Room after NP</th>
<th>Room drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option1/windows</td>
<td>69</td>
<td>66</td>
<td>3</td>
<td>74.91</td>
<td>75.67</td>
<td>-0.76</td>
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<tr>
<td>Option2(fans)</td>
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<td>6</td>
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<td>Option3(fans&amp;windows)</td>
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<td>58</td>
<td>2</td>
<td>71.6</td>
<td>70.59</td>
<td>1.01</td>
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<tr>
<td>Option4(exhausyt &amp; windows)</td>
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<td>58</td>
<td>3</td>
<td>71.82</td>
<td>69.76</td>
<td>2.06</td>
</tr>
</tbody>
</table>
Night Purge Effectiveness

Findings

- Opening windows only is not effective. The average night purge drop in during Final week was 0.58.
- We assume that opening windows with ceiling fans support or exhaust fan support will bring more temperature down.
- We believe the range of temperature drop-in would more deeper if the outside temperature were higher.
Recommendations

Update of classroom prioritization

Key changes: Emphasize 295,495
Deprioritize 180,185
“Satisfaction with both thermal comfort and air quality increases significantly in buildings that provide people with some means of personal control over their environment, such as thermostats or operable windows”

- CBE Research
Recommendations
Posting Classroom Direction & Informative Poster

How this Classroom Works

This classroom is different from many standard classrooms. Passive design relies on the use of natural forces to save on energy use. Daylight, natural air movement, warmth from the sun, cool morning air, and many other natural forces help this classroom function.

Just like your clothing, it may be necessary to adjust the space. The space may feel uncomfortable. Opening windows and/or turning on the ceiling fans to help cool down the classroom are all possibilities to assist this classroom function.

Thermostat

This building is naturally cooled by night-time ventilation and ceiling fans. With exposed concrete and air movement, research shows that human comfort is extended by 5 degrees.

Ceiling Fan Control

Five speed settings. Beware the upper ranges might blow papers. It is highly recommended that increased air velocity be provided via ceiling fans because it extends the operative temperature comfort range.

Window Control

Hold up or down for desired position. Close windows when it is warmer outside than inside. Ventilation air is provided through motorized windows. Automatic operation controlled by the Building Automation System to moderate natural ventilation flow rates depending upon indoor and outdoor conditions irrespective of space occupancy.

Light Control

Light fixtures adjust automatically with varying daylight. This wall switch has all on/off control and basic settings. High efficiency LED lighting reduces electricity consumption and cooling load.
Recommendations

Design Suggestions

- Sea-Tac Airport Sustainability Advertisement
Acknowledgements

- Capital Projects and Construction
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- Green Building Research Laboratory
- Facilities and Property Management
- PSU School of Business
- Campus Planning Office
- Oregon Department of Environmental Quality
Thank you!

Questions & Comments