Development of a Simplified Simulation Tool for High Performance K-5 Schools in Hot and Humid Climates

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Outline

- Background
- Purpose and Objectives
- Methodology
- Studies for School Building Shape and Size
- Case Study Building: Calibrated Simulation
- Future Work
- Summary
Background

- High Performance Buildings
  - Designed to
    - Maximize operational **energy savings**.
    - Improve **comfort, health, and safety** of occupants and visitors.
    - **Limit harmful effects** on the environment.
  - Benefits of high performance buildings
    - Energy use reduction of **50% or more**.
    - Reduced **environmental impact**.
    - Increased occupant **comfort and health**.
    - Increased employee **productivity**.
Background

- **High Performance Schools**
  - Energy Efficiency
  - Health and Comfort
  - Indoor Air Quality (IAQ)

- **Motivation**
  - Lack of easy-to-use tools for designing new high performance schools.
  - Currently existing tools still require detailed building information (e.g., building geometry, schedule, HVAC information, etc.)
  - A decision maker can quickly estimate the energy savings by applying high performance features to a new school building in early stage of design phase.
Purpose and Objectives

**Purpose**

- To develop a simplified tool for designing high performance schools in hot and humid climates in early stage of building designing.

**Objectives**

1) A study of school building shapes and common spaces required for K-5 schools.

2) A survey of school shapes in a city in central Texas to identify the most common school shape.

3) Verification of input parameters to drive the building size and other building characteristics.

4) Preliminary results that describe the development of a prototype school geometry for the tool.
Methodology

- Development of a Simplified Simulation Tool
  - Define default input values: survey average school building characteristics (e.g., building shape, building size, type of HVAC systems, etc.).
  - Limited Input Parameters: define minimum input parameters (e.g., # students, building orientation, etc.)
  - Develop a Simulation Input
  - Validation of the tool: comparison between the simplified simulation results with the results from the calibrated simulation of a case study school.
Survey for school building types in hot and humid climates

- **Survey Method**
  - Satellite view from Google Earth
  - School shape classification from “Building Type Basics for Elementary and Secondary Schools (Perkins 2001)”

- **Target schools**: 23 K-12 schools in College Station/Bryan, TX.
Survey for school building types in hot and humid climates

Sample Screenshot for the Survey

<table>
<thead>
<tr>
<th>Building Shape</th>
<th>Classification</th>
<th>Classification Name</th>
<th>DISTNAME</th>
<th>CAMPNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The spine plan</td>
<td></td>
<td>COLLEGE STATION ISD</td>
<td>PEBBLE CREEK EL</td>
</tr>
<tr>
<td></td>
<td>The Centralized resource plan</td>
<td></td>
<td>COLLEGE STATION ISD</td>
<td>SOUTH KNOLL EL</td>
</tr>
<tr>
<td></td>
<td>A classroom -clustering model</td>
<td></td>
<td>COLLEGE STATION ISD</td>
<td>COLLEGE HILLS EL</td>
</tr>
<tr>
<td></td>
<td>The Centralized resource plan</td>
<td></td>
<td>COLLEGE STATION ISD</td>
<td>SOUTHWOOD VALLEY EL</td>
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<tr>
<td></td>
<td>The spine plan</td>
<td></td>
<td>COLLEGE STATION ISD</td>
<td>ROCK PRAIRIE EL</td>
</tr>
</tbody>
</table>
Survey for school building types in hot and humid climates

- Survey Results for Bryan/College Station, TX

<table>
<thead>
<tr>
<th>Plan Description</th>
<th>Shape</th>
<th># Schools in BCS area</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Centralized resource plan</td>
<td>![Centralized Resource Plan]</td>
<td>3</td>
</tr>
<tr>
<td>The dumbbell plan</td>
<td>![Dumbbell Plan]</td>
<td>0</td>
</tr>
<tr>
<td>The spine plan</td>
<td>![Spine Plan]</td>
<td>12</td>
</tr>
<tr>
<td>The courtyard plan</td>
<td>![Courtyard Plan]</td>
<td>2</td>
</tr>
<tr>
<td>A spine with single-loaded classroom wings</td>
<td>![Spine with Single-Loaded Classroom Wings]</td>
<td>2</td>
</tr>
<tr>
<td>A classroom-clustering model</td>
<td>![Classroom Clustering Model]</td>
<td>1</td>
</tr>
<tr>
<td>A courtyard with classroom-clustering plan</td>
<td>![Courtyard with Classroom Clustering Plan]</td>
<td>1</td>
</tr>
<tr>
<td>ETC</td>
<td>![ETC]</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>![Total]</td>
<td>23</td>
</tr>
</tbody>
</table>
Development of High Performance Schools in Hot and Humid Climates

Introduction

Literature Review

Significance of the Work

Work in Progress

 Common Spaces in K-5 Schools
   4 Major Spaces: Classroom & Library, Admin. Office, Gymnasium, and Dining Area
  - Building Type Basics for Elementary and Secondary Schools (Perkins 2001)
  - 2007 Construction Report (School Planning & Management)

 Size of Each Space: K-5 School Space Profile

 Typical Space Profile (School Planning, NCDPI)

 Space Profile from a case study building

 New Elementary School Prototype (Burleson Independent School District)

Methodology

Development of a Simplified Simulation Tool for High Performance K-5 Schools in Hot and Humid Climates
School Spaces and Size

- **Number of Student & School size**
  (2007 Construction Report (School Planning & Management))
  - Classification of the school size
    - Small School
    - Median School
    - Large School
  - Number of Student vs. School Size (% of each space)
  - Verification
Proposed School Geometry

- Development of Prototype School Geometry
- 4 Major Spaces (Classrooms & Library, Admin. Office, Gymnasium, and Dining Area)
- Floor Area (Default): 88,000 sq.ft. (700 students)
Proposed School Geometry

- Proposed School Geometry

Gymnasium

Dining Area

Admin Office

Classrooms & Library
Determine the size of school and each space based on **number of students**
Introduction

- Purpose of the Case Study
  - To understand the patterns of school building energy uses in hot and humid climates
  - Verify the simplified tool

- Building Description (1)
  - An elementary school in College Station, TX
  - Floor area: 74,000 sq.ft.
  - Window-to-Wall ratio: 10%
  - # students: 600 as of 2006
Case Study School

- Building Description (2)
  - Served by eight AHUs consisting of three different types of AHUs including:
    - four (4) variable air volume (VAV) systems for the classrooms and library
    - three (3) constant volume (CV) systems for a gym, cafeteria, and kitchen
    - one (1) multi zone unit (MZU) for administration offices
  - Two 100 ton air-cooled scroll chillers
  - One hot water boiler
  - Two 100 gallon service water heater.
Data measurement

- Hourly whole building electricity, chiller electricity, and motor control center that were measured from a pre-installed data logger.
- The temperatures (e.g., discharge temp, indoor temp, mixed air, etc.) and RH at the selected points, which were measured using portable loggers.
- Historical monthly utility bills that were obtained from the school district.
- Hourly weather data measured
Calibrated Simulation Steps

1. Actual 2006 weather file with measured solar radiation
2. Lighting & equipment schedule calibrated using AHRAE’s RP-1093 method
3. Scroll chiller performance curve
4. Winkelmann’s method (Winkelmann 1998) for the underground floor (i.e., U-effective value)
5. The HVAC and room setpoint temperature and schedules from the measured data
Case Study School

Results

- Initial Simulation
  (5.6% of MBE & 46% of CV(RMSE))

- Calibrated Simulation
  (1.4% of MBE & 19% of CV(RMSE))
Case Study School

- Changes by Each Calibration Step
  1. Actual 2006 weather file with measured solar radiation
  2. Lighting & equipment schedule calibrated using AHSRAE’s RP-1093 method
  3. Scroll chiller performance curve
  4. Winkelmann’s method (Winkelmann 1998) for the underground floor (i.e., U-effective value)
  5. The HVAC and room setpoint temperature and schedules from the measured data

- MBE and CV(RMSE)

- Changes in BEPS Report
Future Work

- Survey on typical K-5 school building characteristics in hot and humid climates to define the default value.

- Define input parameters for the tool
  - Building location and orientation
  - Number of Students
  - Roof and wall Insulation Level (R-value)
  - Window-to-Wall Ratio
  - Glazing (U-Factor, SHGC, and Shading)
  - Daylighting Option
  - Lighting & Equipment Load
  - Type of HVAC system
  - Chiller and Boiler and SWH efficiency

- Develop the school input file with “Input Macros” command
Summary

- An effort to develop a simplified simulation-based tool for designing K-5 high performance schools in hot and humid climates.
- Prototype Building Shape: Modified spine plan
- 4 main spaces defined: classrooms+library, gymnasium, cafeteria, and admin. office
- Number of students drives the size of a school
- A calibrated simulation of a case study K-5 school
  - To understand the patterns of school building energy uses in hot and humid climates
  - Verify the simplified tool
  - Final Calibrated Simulation gives 1.4% of MBE & 19% of CV(RMSE)
Questions?