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COMPARISON BETWEEN CONVENTIONAL DESIGN AND INTEGRATED SIMULATION-BASED OPTIMAL DESIGN FOR AN OFFICE BUILDING

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ABSTRACT

It is widely acknowledged that optimal building design can be well achieved by selecting appropriate design options at each design stage (conceptual design, preliminary design, final design), e.g. orientation, shape → building envelopes → HVAC, controls. This sequential optimal design approach is conventional and is strongly recommended for architectural design practice. In contrast, an integrated optimal design approach exists where all design parameters are optimized simultaneously. In this paper, the aforementioned two design approaches are compared for a given office building in terms of selected optimal design variables and thermal load (kWh/m^2.yr). EnergyPlus, a dynamic building energy simulation tool developed by U.S. DOE, was used. It is found that the integrated optimal design approach could allow more design options and better energy-efficient outcome than the conventional approach. For further study, the impact of decision making at each design stage on the gap between the two design approaches will be investigated.

1 INTRODUCTION

It has been widely accepted that the building performance simulation tools must be invoked at each design stage, e.g. from conceptual design, preliminary design to final design. Building form (orientation and width-to-depth ratio), envelopes (opaque, transparent), and other design parameters are determined sequentially through the design stages. However, the design decisions in early design stages are made on incomplete information and many assumptions and lack the ‘dynamic view’ of all design activities, and therefore can cause negative impacts on ‘downstream alternative designs’ (IBPSA proceedings 1987-2019). With this in mind, this study aims to analyze two optimal design approaches for a target building: one is sequential optimal design and the other is integrated optimal design. The former can be regarded as a conventional design approach as mentioned above (Case 1), while the latter is an ‘ideal’ approach (Case 2).

2 METHODOLOGY

The authors selected a typical office building represented in an EnergyPlus building model that was developed by U.S. DOE (2020). It is assumed that for Case 1, the orientation and shape of the building are determined heuristically by a designer’s intuition and expertise (true south facing & width/depth=1.0). Then, the building envelope (window-to-wall ratio, thermal properties of walls & windows) was optimized using genetic algorithm. According to the conventional design practice, the thermal properties of all facades (S, N, E, W) are assumed identical. For Case 2, the aforementioned design parameters (orientation, shape, envelopes) are optimized simultaneously where building envelopes for S, N, E, W can have different thermal properties. In contrast to Case 1, Case 2 was purposefully to designed to show the degree of the design improvement (gap) when complete information/data are provided for decision making. The overall process is illustrated in Figure 1.

3 RESULTS AND CONCLUSION

It is found that optimal design obtained from the conventional approach (Case 1) could be improved when the integrated approach (Case 2) is taken, by 13.6% (=[1−**51.6**/**59.7**]×100) in terms of thermal load (kWh/m^2·yr). It is noteworthy that the densities of the South and East side walls were selected as being lightweight. It can be inferred that having lightweight walls (ρ = **83**, **53** kg/m^3) would be helpful for stored heat during daytime in summer to be released to outdoor air during nighttime, leading to a reduction in cooling energy. Having lightweight walls is *unlikely* to be reached when the conventional approach is employed. For further study, HVAC, lighting, controls, and other parameters will be considered during the design process. In addition, the causes of the gap between the two design approaches will be investigated.

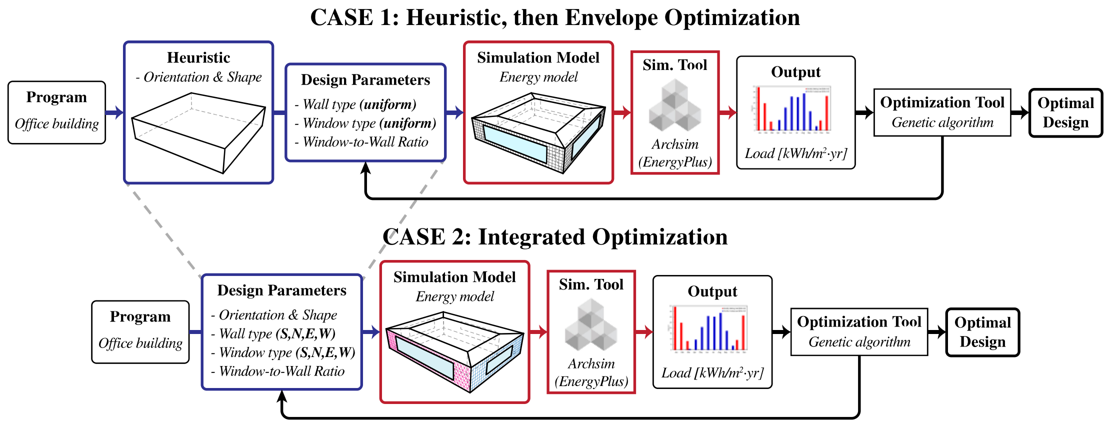

Figure 1: Conventional vs. integrated simulation-based optimal design for an office building.

Table 1: Design parameters and thermal Load of the optimal designs.

Design Process	**Form**		**Opaque Walls**															
			South				**East**				**North**				**West**			
	Orient-ation	**W/D Ratio**	**k**	**ρ**	**Cp**	**t**	**k**	**ρ**	**Cp**	**t**	**k**	**ρ**	**Cp**	**t**	**k**	**ρ**	**Cp**	**t**
Case 1	0.00	1.00	0.05	579	1290	0.50	(Same as South)				(Same as South)				(Same as South)			
Case 2	-3.74	4.00	0.05	83	1520	0.50	0.05	53	2448	0.46	0.05	300	1041	0.50	0.05	248	1547	0.48

Design Process	**Windows**																**Objective**
	Window to Wall Ratio				**South**			**East**			**North**			**West**			**Load**
	South	**East**	**North**	**West**	**SHGC**	**Uval**	**Tvis**	**SHGC**	**Uval**	**Tvis**	**SHGC**	**Uval**	**Tvis**	**SHGC**	**Uval**	**Tvis**	
Case 1	0.74	0.44	0.40	0.40	0.10	1.20	0.80	(Same as South)			(Same as South)			(Same as South)			**59.7**
Case 2	0.40	0.40	0.40	0.40	0.17	1.20	0.80	0.10	1.20	0.80	0.10	1.20	0.80	0.10	1.20	0.80	**51.6**

k: Conductivity(W/m·K), **ρ**: Density(kg/m^3), **Cp**: Specific heat(J/kg·K), **t**: Thickness(m), **Uval**: U-value(W/m^2·K), **Tvis**: Visible Transmittance

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