7th International Building Physics Conference

IBPC2018

Proceedings

SYRACUSE, NY, USA

September 23 - 26, 2018

Healthy, Intelligent and Resilient Buildings and Urban Environments

ibpc2018.org | #ibpc2018

A Sustainable Approach to the Adaptive Reuse of Historic Brick Buildings: Analysis of Energy Efficiency Strategies for Historic Facade Retrofits

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ABSTRACT

There are many historic brick buildings in downtown areas of the U.S. that are awaiting appropriate strategies for their adaptive reuse and preservation. The adaptive reuse method enables the adaptation of existing, obsolete historic buildings into new, mixed-use developments that will play an essential role in enhancing urban environments. However, many of these buildings have poor energy performance. This paper explores sustainable methods to balance between historic preservation and reduction of peak energy loads, through analyzing design strategies and conducting energy simulations for a building in downtown, Austin, TX. Energy retrofits related to windows, high performance of the facades with added insulation, and passive (spatial) interventions are covered in depth. Four retrofit scenarios were applied and simulated using the energy analysis tool in Revit, a popular BIM program. Analyzing the energy consumption data, we compare an existing building's facade condition to the retrofit scenarios' energy performances and record the energy performance data. This research proposes energy efficient preservation options for historic buildings and ultimately emphasizes potential values such as balancing the integrity of the original design with energy goals. We explore novel solutions for making historic buildings more sustainable through combining the adaptive reuse method with energy retrofit strategies that play up the historic buildings' unique passive potentials. The various solutions are found to be highly dependent on the climate.

KEYWORDS

Energy retrofit, adaptive reuse, historic preservation, facade, peak energy demand reduction

INTRODUCTION

Our research questions start from the growing trend of repurposing historic buildings. Because their original functions have been abandoned or new uses are emerging for them, architects and planners need to consider dealing with historic buildings economically, environmentally, and socially (Orbasli 2008). The act of extending the life of a building through adaptive reuse helps to lower material, transport and energy consumption; significantly contributing to sustainability goals and providing multiple benefits (Bullen and Love 2009).

Restored masonry buildings create vast opportunities for revitalizing communities and promoting cultural value. Instead of destroying the old brick materials and wooden structures, facade retrofits can create spaces that offer new experiences. Such reuse of buildings gives specific opportunities for the public to perceive the value of historic buildings and to make them attractive to neighborhoods and visitors. However, commonly, historic brick buildings are recognized for their poor energy performance with installed single pane glass windows. Therefore, they require a new approach to be adapted with appropriate uses and energy retrofits.

The method of dealing with existing facades comprises a large proportion of the adaptive reuse of old buildings. Because people tend to recognize buildings by the materials and patterns of their facade, facade retrofits can help preserve the historical significance of facades and meet modern energy standards. There are many articles dealing with the advantages of adaptive reuse or retrofits of old buildings, and the improvement of the building envelope, such as insulated roof and window replacements, could significantly reduce heating energy demand, for example, by 52% (Gourlis and Kovacic 2016).

This research addresses four retrofit scenarios for historic brick buildings in downtown Austin, TX. The study presents qualitative and quantitative comparisons of those scenarios, to help architects and planners to understand and apply the appropriate strategies for facade retrofits of old brick buildings in similar areas. The findings demonstrate which strategies are suitable for facade energy retrofits, while balancing energy goals and preserving the cultural value of old brick buildings.

METHODS

Facade retrofit scenarios are analyzed through Revit 2017, using the Energy Analysis for Autodesk Revit Engine. The 3D models represent a building that is 45 feet by 125 feet in plan and 35 feet high, typical for a historic building in downtown Austin. They comprise a ground floor and second floor with a stair opening. Southern and northern facades have four glass doors (7 feet wide by 12 feet high) on the first floor with wood framing and four windows (6 feet wide by 10 feet tall) on the second floor. We set up the input data as retail (building type), Austin (location), and occupancy rate (default of retail facility occupancy: 107.64 SF per person). The 3D models include brick facades and wooden structural systems. We obtain the energy data based on the information and change the specifications of windows and the glass front entry. This paper proposes four types of energy retrofit strategies for historical brick buildings and evaluates them by using the energy consumption data that we obtain from simulation in Revit (see Table 1).

Table 1. Retrofit typologies.

	Retrofit Option	Description	U-value (Btu/(h·ft^2·°F))	R-value ((h·ft^2·°F) Btu)
Existing	Single pane glass	8-inch masonry	1.18	0.85
		1/4-inch single pane glass with 3/8-inch cavity	0.50	1.98
Alt-1	Double glazed low-e	8-inch masonry	1.18	0.85
		1/4-inch double glazed glass (clear, low-e (e=0.05))	0.35	2.86
Alt-2	Wall insulation	3-inch thermal/Air layer + metal stud + gypsum wall board on interior of exterior wall	0.02	50
		1/4-inch double glazed glass (clear, low-e (e=0.05))	0.35	2.86
Alt-3	Secondary glazed windows	Alt-2	0.35	2.86
		Secondary windows system	0.35	2.86
Alt-4	Double skin (glass)	Alt-2	0.35	2.86
		Glass covered facade (system panel; 1/4-inch double glazed glass (blue-green, low-e (e=0.05))	0.35	2.86

Through conducting the energy analysis in Revit, we obtained the data including annual energy consumption, monthly peak demands, and monthly cooling/heating load. This paper selects ‘peak demands’ representing peak cooling/heating load for comparing an existing building to four facade retrofit scenarios. A growing number of retrofit interventions have started to take place around the world. All of them represent unique characteristics and respond to specific budgets, contexts, and functions. We re-classify those interventions into four categories of facade retrofit based on Martinez's table (Martinez 2013) (e.g. single pane glass, double glazed low-e, wall insulation applied to the interior of the exterior facade wall, secondary glazed windows, and double skin). Based on the proposed typologies, we create 3D models in Revit and run energy analyses in order to better understand how those strategies deal with energy improvements.

It should be noted that the simulated data would be different with measured results in an actual building because of orientation, climate condition, surroundings, and accuracy of simulation models. However, through modeling, this paper addresses facade retrofit typologies based quantitative and qualitative analysis of the simulation data, ultimately including the cultural value of the brick material, the design, and aesthetics. Thomas describes that successful sustainability should be evaluated by qualitative and quantifiable criteria simultaneously (Thomas 2004), which is why we chose to also value the aesthetic impact of retrofit measures - keeping our interventions as visually subtle as possible.

RESULTS

Five 3D models were designed in Revit for energy analysis based on the narrow rectangular type commercial building in downtown Austin. We gathered energy data to compare sustainable solutions for the adaptive reuse of historic brick buildings. Nagy explains that window replacement alone is able to reduce heating energy consumption by 12%, according to measured and simulated data for a building in Zurich, Switzerland (Nagy et al. 2014). Considering the total peak energy demands of an existing brick building in Austin, TX, which has a different climate and occupancy, the replacement of single pane glass with double low-e glass (low emissivity) enables the reduction of the peak energy demand by 0.70% (see Table 2).

Table 2. Comparison of energy simulation data. (1Btu=0.293Wh)

Retrofit Option	Floor Area (ft^2)	Peak Cooling total load (Btu/h)	Peak Heating total load (Btu/h)	Total Load (Btu/h)	WRT Single Pane Glass
Single pane glass	11,035	531,657.30	326,727.40	858,384.70	100.00%
Double glazed low-e	11,035	526,012.30	326,283.70	852,296.00	99.29%
Wall insulation	10,454	154,253.40	24,268.00	178,521.40	20.80%
Secondary glazed windows	10,194	130,663.10	14,465.70	145,128.80	16.91%
Double skin (glass)	11,084	188,675.40	32,413.10	221,088.50	25.76%

Table 2 illustrates peak energy demands of five typologies. 'Improvement of the wall insulation' resulted in approximately 80% total peak energy demands reduction as compared to the existing brick model, 'Single pane glass'. The 'secondary glazed windows' option allows for a reduction of 19% peak energy demand compared to 'improvement of insulation'.

According to Figure 1, the 'double skin scenario' reduces the peak energy demand less than the improvement of wall insulation. Rather, total peak energy demands are increased as compared to insulation improvement.

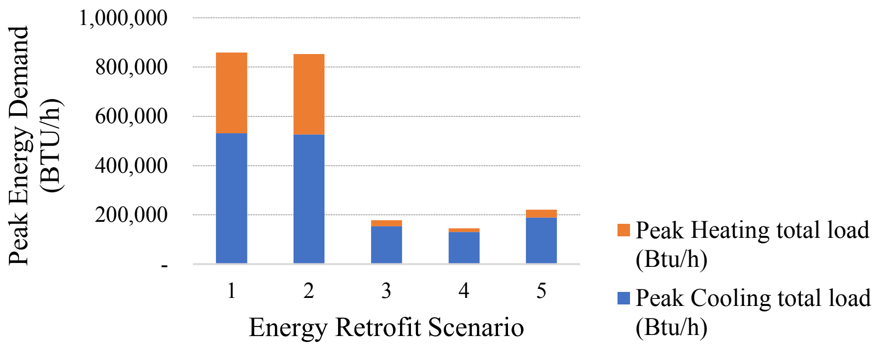


Figure 1. Peak energy demand comparison. (1-Single pane glass, 2-Double glazed low-e, 3-Wall insulation, 4-Secondary glazed windows, 5-Double skin (glass))

Table 3 shows the energy analysis models, plans, and section drawings. The double skin type has an additional seven feet wide corridor at the southern facade. Comparing facade visualization of five scenarios, the double skin option is only changed by layering the old brick material with glass (see Table 4). However, all the typologies enable the preservation of the brick material and its facade elements.

Table 3. Energy simulation models, plans, and southern facade section drawings in Revit.

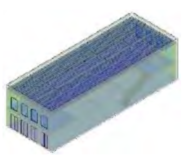
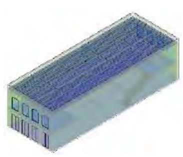
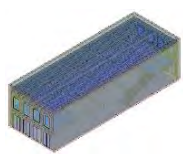
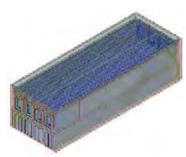
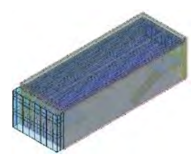
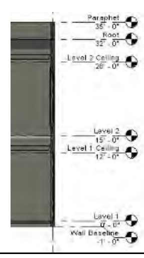
	Single Pane glass	Double Glazed low-e	Wall insulation	Secondary glazed windows	Double skin (glass)
Energy model					
Section					

Table 4. Comparison of external facade visualization.

	Single pane glass ~ alt-4	Double skin (glass)
Southern facade render		

DISCUSSIONS

The building type analyzed is typical as part of downtown Austin's grid, planned by Edwin Waller in 1839. In general, most of the narrow rectangular type buildings face north and south, and are surrounded on the sides with adjacent buildings. Window to wall ratios are already low in such historic buildings, so replacement of the glass will not have as much of an impact as it would in buildings with larger windows. As seen in the second scenario, replacement of windows by low-e, the peak demand reduction is smaller than we expected, when looking at similar retrofit studies elsewhere. Moreover, as the occupancy is retail/commercial, and a narrow rectangular building facing south, it will not benefit as much from window replacement because there are more internal heat loads from the greater number of occupants, while the west and east facades are insulated by attached buildings.

The energy consumption significantly depends on building types or internal thermal loads, such as human activities. Replacing old single pane glass in this case helps to reduce peak cooling total loads more than peak heating loads. Improving specifications of facade wall type have positive effects on peak energy demand reduction. Upgrading old windows and doors to meet modern standards should be adopted into old buildings in Austin, with improving energy performance of the wall. These interventions are also visually unobtrusive to the original design.

Keeping old facades and preserving historic districts can produce social benefits to visitors and neighborhoods. The adaptive reuse and retrofit strategies for old buildings are produced by various decision makers. However, social aspects and the aesthetic value of historic brick buildings should also be considered as a positive solution for urban sustainability, and are not found to be in conflict with energy saving measures, according to our study. Moreover, a double skin type might be possible solution for harmony with modern goals while also preserving the historic brick material, but would most visually alter the facade and would also perform better in a climate less prone to overheating.

CONCLUSIONS

Austin, Texas has a humid subtropical climate, which requires a consideration to reduce cooling load from May to September. This study focuses on peak energy demand reduction for historic brick buildings, with retrofit alternatives evaluated and predicted with energy consumption data in balance with aesthetic impacts important for historic preservation. The best solution that balances the energy performance and aesthetic of the historic building is the option of adding an additional layer of glass on the interior side of the historic single pane windows (secondary glazed windows) in addition to better insulation. This totally preserves the character of the building from the outside, including the original window appearance, while greatly improving the energy performance with only a slight reduction of interior space.

This paper deals with balancing energy retrofit strategies and social-cultural value. Symbiotic strategies need to be considered in the early design phase of energy retrofit projects (Eliopoulou and Mantziou 2017). Unless the simulated data might be different with measured data in actual buildings, this paper proposes potential methods for the development of energy retrofits for historic buildings. Historic buildings are often limited in their energy retrofit options because of preservation requirements (Zagorskas et al. 2013). Therefore, this study does not cover shading options that would greatly alter the external appearance of the facade. However, it has been argued that the interaction between building regeneration, economic development and social renewal enables planners to make cities creative places (Sepe 2013). For this reason, balancing between historic preservation and energy retrofit strategies proves a significant step for architects and planners to make cities more sustainable.

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