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Energy Intensity of a Historical Downtown: Estimating the Energy Demand of a Budapest District

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***Abstract*—**The dense urban fabric of the 7th district of Budapest - known as the former Jewish Quarter-, contains mainly historical style, multi-story tenement houses with courtyards. The high population density and the unsatisfactory energetic state of the buildings result high energy consumption. As a preliminary survey of a complex rehabilitation plan, the authors aim to determine the energy demand of the area. The energy demand was calculated by analyzing the structure and the energy consumption of each building by using Geographic Information System (GIS) methods. The carbon dioxide emission was also calculated, to assess the potential of reducing the present state value by complex structural and energetic rehabilitation. As a main focus of the survey, an energy intensity map has been created about the area.

***Keywords*—**Carbon dioxide, energy intensity map, geographic information system, GIS, Hungary, Jewish quarter, rehabilitation.

I. Introduction

THE climate change is one of today's most crucial topics, which is on several points linked to the built environment. The building sector is one of the most influential energy consumers in Europe, where the energy utilization of buildings has been constantly increasing in the last 20 years. In most European Union countries, the buildings are responsible for more than 40% of the total primary energy consumption. In order to decrease the import dependency of the European Union, the European Parliament accepted various action plans and directives, aiming to reduce the energy demand and the carbon dioxide emission [1]. At the same time, the renewable energy sources are to be increased in each country's energy mix. In Hungary, the renewable energy ratio is around 9% of the total energy consumption. The Hungarian Government aims to reach the 14.85% ratio until 2020 [2].

The development of historical downtowns was analogical until the Industrial Revolution across Europe, which resulted in a dense, sometimes organic inner city surrounded by a newer, looser urban fabric. Parallel to the development, the microclimate of the settlements has changed, resulting in a rising temperature, which is called the Urban Heat Island Effect (UHI). The change in the microclimate has negative impact on either the residents, and on constructions - the densely built-in inner city areas have high population density, particularly elderly people are sensitive to the changes of microclimate.

Reducing the UHI is especially complicated in case of historical inner areas, where the fabric, the landscape and the buildings are protected for their historical and architectural values (Fig. 1).

Fig. 1 Densely built-in urban fabric in Budapest; Photo is courtesy of Yuta Nagai Architect MSc

Significant part of the historical houses of Budapest downtown is in a run-down condition, due to the lack of maintenance [3]. Their characteristics are not sufficient for today's health, economical or ecological requirements, their value decreased by their poor state.

In case of contemporary buildings, the sustainability and energy saving aspects are becoming more and more important, although their number is insignificant compared to the energetically inefficient buildings.

As the buildings built before 1960 are responsible for substantial amount of the final energy consumption in Europe, consequently it is obvious to consider the ageing building stock when researching energy efficiency measures.

The characteristic turn of the century apartment houses of Budapest downtown has distinctive, sculptural façade, which cannot be insulated by using the most common insulation technologies, also the renewable energy utilization has its own boundaries in case of dense urban fabric. Their problem however requires solution because of the large quantity of the building stock.

II. Budapest Housing Stock

The vast majority of the inner city housing stock rehabilitation was built in three main construction eras:

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The first period ended with the World War I, around 1920. This is the era of the apartment buildings with enclosed courtyards (Fig. 2). During this period, the housing constructions reached their highest pace in Budapest's overall history. The two peaks were in the middle of the 1890s, and in 1913. The majority of the houses waiting for renovation were built in this era.

Fig. 2 An apartment house of the 1900's with enclosed courtyard

In Budapest, the characteristic apartment house with enclosed courtyard spread from the beginning of the 19th century (first construction era), however majority of the buildings built later also have similar form. Two significant types are: Classicism style apartment building organized around a large square courtyard, or the originally single-story cotter slots later developed into two-story buildings, on narrow, deep slots with flats opening to the hanging corridor.

The inner courtyards in the blocks particularly in the first period had minor functional role. The valuable rooms of the apartment houses were facing the streets; the less important functions (or later less valuable flats) were oriented to the courtyard.

The second era started in 1920 and lasted until 1944, with a peak in 1936. Condominiums appeared around this time. Larger territories were built in simultaneously parallel to urban planning and regulation actions [4].

The third era followed the Word War II and ended in 1988. This is the time of the mass house constructions, using sandwich panel structures. The peak was in 1975. The housing estates were often placed as an isolated neighborhood in the existing urban fabric [4].

III. Characteristic Structures of the Apartment Buildings

The development of construction technologies in Hungary can be demonstrated easily through the residential houses. The traditional buildings are mostly one-story family houses. Their walls are mainly built from solid brick, adobe or stone, the upper slab is mostly timber.

In Budapest and other major towns, the eclectic (historical) style multi-story buildings have the same building materials and structures. They were mainly built before the World War II.

After the post-war reconstruction period, in order to alleviate the average housing shortage, the industrialized building technologies gained popularity. This process started with the large-block technology, and then the prefabricated sandwich panels appeared.

After the end of Communism in Hungary, the energy crisis influenced the building industry via increased energy prices. The previously used solid bricks were replaced by hollow ceramic blocks with insulation layer in order to reduce heat losses.

The condominiums were built with monolith reinforced concrete frame and hollow brick infilling walls [5]. Since then, the ever-stricter building energetic requirements prescribe thicker insulation on façades, attics and basements, at the same time prescribing airtight insulated fenestrations and encourage the renewable energy utilization.

IV. Buildings and Energy Usage

Buildings have a key role in our life. Their architectural solutions, for example geometry, space, material, as well as their look and technical properties affect not only our health, mood and productivity, but also the energy consumption of the building. These properties define the energy demand of heating, cooling and ventilation required for a pleasant environment. Buildings are responsible for significant amount of energy consumption as well as greenhouse gas emission in the form or carbon dioxide, altering the planet's climate. By the highly efficient renovation of these buildings, our living conditions can be improved, and significant amount of energy can be saved at the same time.

The mixture of historical and modern buildings characterizes the European building stock - offering opportunities and challenges at the same time. Presently, the official policies are aiming to reduce the energy consumption of the building stock [6].

The energy efficiency of a building depends on many factors, such as the efficiency of the built-in heating system, the building envelope, the function, the climatic conditions. The heating energy consumption databases concluded that the greatest energy saving potential is within the older building stock. Interesting fact that in some cases, the buildings constructed in the 1960's have worse conditions than the older buildings, which have significantly thicker walls and slabs. The buildings of the 1960's have thinner enveloping structures, however the insulation materials were still not sufficient at the time (or were not used frequently) [6].

V. Building Energy Typologies

The Tabula Episcope international project [5] is an initiative to create typologies of the national building stocks. Different groups were created by considering the age and size of buildings, and then characteristic building materials and engineering solutions were assigned to them (based on statistical data). However, the database is not separating buildings built before 1944 into sub-groups, which causes some limitations in terms of accuracy in case of surveying the downtown building stock. The methodology is however applicable to more refined cases.

In the project, renovation scenarios had been created for each type, thus the possible energy saving potentials and costs can be assumed for each building type. However, these scenarios do not give special instructions for the monuments, or protected buildings, where the structural and surface adjustments may be severely restricted.

The National Building Energetics Strategy - similarly to the TABULA – defines 15 different residential building types. The majority of the downtown area buildings in question belong to the type Nr. 10. The characteristics of the group are: Built before 1945, brick or stone walls, more than ten flats in an apartment house (Fig. 3). According to the typology, 15.3% of the buildings are in a run-down condition, 50.1% are satisfactory. Almost 95% are heated by gas; nearly none of them has secondary heating option. Vast majority of them is situated in urban areas, 88.3% in Budapest. The value of the flats is above the national average [7].

Two renovation scenarios were created for every type, based on valid national Decrees: the cost-optimal and the deep renovation options. The Decrees prescribe various strict requirements for the structures and energy utilization. The deep renovation scenario contains at least 25% renewable energy utilization commitment, to be considered as a so-called “nearly-zero energy” consumption building [8].

It is also prescribed that in case of public buildings, it is particularly necessary to examine the possibility of creating green roof or green façade, considering the technical characteristics and the load bearing capacity of the structures.

When renovating monuments and protected buildings, the monumental values should not be damaged. The characteristics of the historical building should always be taken into account, as the preservation of its fundamental values is the most significant requirement [7].

As an example of the Tabula project, a condominium built before 1944 was examined. In case of cost-optimal refurbishment, the external, enveloping structures - walls, slabs and attic - are insulated; the aged fenestration is also exchanged. The heating system is modernized by installing modern condensation gas heaters. The deep renovation also contains the insulation and fenestration exchange. The engineering modernization is completed with solar collectors. With these measures, total primary energy demand for heating and domestic hot water decreases by 51% in case of cost-optimal, and 61% in case of deep renovation. The carbon-dioxide emission for heating and domestic hot water is also decreased by 50% in case of cost-optimal and 60% in case of deep renovation [5].

Fig. 3 A characteristic example for residential house type Nr 10.

VI. Case Study Area- Budapest Old Jewish Quarter

The development in this part of Budapest, known as Belső-Erzsébetváros (or Inner-Elizabethtown), began spontaneously in the 18th century, as the population of Pest started to outgrow the city walls of the middle age, and lasted for a hundred years.

The Great Flood of River Danube in 1838 destroyed half of the buildings of the district, which this time has already been the densest and most populated area of Pest. As replacement for the demolished one-story buildings, urbanized, two- or three-story, L or U shaped houses were built in an unbroken row along the streets (Fig. 4).

The Jewish settlers came here permanently in the 19th century, when the Law of 1840 at last permitted them to own real estate.

The uniqueness of this so-called Old Jewish Quarter of Pest is that the early, 19th citizen houses of Pest can be found coherently and in exceptionally large number. On the other hand, since the Jewish commercial life flourished here, some rare apartment house type can also be observed, for example: passage houses, tenement houses built together with synagogues or small factories.

Fig. 4 Orczy House, one of the most significant tenement houses in the Old Jewish Quarter of Pest, already demolished [9]

During the World War II, this traditional Jewish Quarter of Pest became a ghetto. When the post-war renovations occurred, some the buildings damaged by bombs were demolished. Ever since the War, the area could not regain its original status.

At the beginning of the eighties, a short development started when the first block rehabilitations were launched, unfortunately, only to be halted after finishing three blocks [10].

According to the research done by Dr. Béla Nagy, the creator of the currently valid regulation plan, out of the 486 slot and 623 building of the area, the renovated ratio is only 19%, while the remaining 81% requires renovation. Urgent repair would be needed in case of 58.000 m^2 of flats and 24.000 m^2 of other estate [3].

VII. Case of District Survey with Geographical Information System (GIS) Methodology

A. Field Research, Collection of Building Data

As a first step of an extensive building-by-building database, the history of each slot and building were explored with special emphasis on constructions, reconstructions, additions and demolitions.

During field research, every building was photo documented. The main geometrical data (footprint, height, courtyard area, glazing ratio, relevant building materials and structures) were recorded [11]. In case of inaccessible area, for example: Roof geometry, enclosed spaces, Google and Apple map applications were used for minor corrections.

The collected data are directly linked to maps for illustrate the results: On Fig. 5 the number of stories of each building is shown – the lower buildings with lighter shade, the taller ones are darker. It can be concluded that alongside the main roads, the buildings are higher, and the side streets contain lower buildings. The exception is the Király Street (bordering the area from north-west side), which on contrary of its main street role, contain lower buildings. The development of the area started alongside the Király Street [10], which is why these buildings are in average older then in case of other streets. The newer block averagely contains taller buildings, especially alongside Károly körút (on the south-west border of the area), which is a result of a significant regulation plan and reconstruction, when the original fabric was demolished to make place for a large-scale building complex known as Madách-házak. It can be also concluded that the newer buildings, in vast majority, have more stories than the older buildings, continuously increasing the built-in intensity of the area.

For later energetic calculation purposes the position of the buildings were also examined. Five types were distinguished: the most characteristic "unbroken row type", "corner type", "unbroken row type adjacent to empty slot", "empty slot", and "other type" (Figs. 5, 6). These positions are significant form energetics point of view, since the „corner type", or the "unbroken row type adjacent to empty slot" buildings have larger ratio of their façades connected with outside environment, while the "unbroken row type" buildings have a significant ratio of their enveloping surfaces connected to another building – decreasing the heat losses, which are higher if the surface is not covered.

Fig. 5 Number of stories in case of each building: The higher the buildings are marked with darker shade, based on [3]

Fig. 6 Different positions in case study area: 1. unbroken row type, 2. corner type, 3. unbroken row type adjacent to empty slot, 4. empty slot

Fig. 6 Position of buildings. The lighter shaded buildings are "unbroken row types", the darker are "corner type". The black marked slots are empty

B. Calculations

The energy intensity map (Fig. 7) was created by calculating each building's heating energy demand. For the calculation, the previously measured geometrical data were used. For simplification reasons, the buildings were divided into subgroups based on footprint and height data. To these subgroups, characteristic energy demand values were assigned. These characteristic energetic values were created statistically, by calculating various buildings' energy demand, chosen from each subgroup. The values were calculated by using the standard energy demand calculation of the European Union Energy Performance of Buildings Directive [Hungarian adaptation: 8].

Fig. 7 Energy intensity map of the case study area. The darker buildings consume more eating energy

It can be concluded that the older buildings consume more heating energy. They characteristically contain a larger, enclosed courtyard, thus the façade surface ratio is larger. On the other hand, the newer buildings can be marked on the energy intensity map, which have more ideal geometry and structure.

VIII. Conclusion

Currently, it is unavoidable to systematically survey the downtown area building stock, due to its large quantity and the variously restricted rehabilitation possibilities. These apartment buildings can be modernized structurally and energetically within certain limits. The limits contain many aspects, for example the densely built in fabric resulting many architectural and engineering problems.

The ever stricter energetic demands and also the question of sustainability call for complex energetic rehabilitation plans.

The preliminary typology-based calculations concluded that around 50% of the primary energy consumption could be saved by renovating these buildings.

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