Uloga IC termografije pri provođenju energetskih pregleda u svrhu energetskog certificiranja zgrada

The role of IR thermography in energy auditing of buildings in the process of energy certification

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ABSTRACT

Today the building sector is recognized as the biggest individual energy consumer when considering long life cycle of a building and its long and continuous influence on the environment. Therefore the biggest potential of energy and ecology savings is possible in buildings.
Implementation of energy certification in buildings, or grading buildings into classes according to the energy consumption, makes many key changes which will influence quality of construction, refurbishment of pre-existing buildings, reducing maintenance costs, applying innovative technologies and solutions and development of integrated design concept.
To complete the energy certificate an energy audit must be conducted, to determine energy performance of a building and to suggest measures to improve energy efficiency.
Paper shows the role of infrared thermography method in energy audits of new and pre-existing buildings, in analysis of construction and energy characteristics, and essential building characteristics. Through three examples of energy audits of buildings for public purposes; school, elderly nursing home and hospital, the implementation of infrared thermography has been analyzed as an important method in energy certification of buildings.

KEYWORDS
Energy efficiency, energy audits of buildings, energy certificate, infrared thermography, energy performance of buildings

INTRODUCTION

Harmonization of national legislation with European Directives in building sector has resulted in adopting 4 new technical regulations in 2008 and introducing 2 obligatory studies in 2009. New legislation is oriented to classification of new and existing buildings according to energy consumption. Additional analysis of buildings is required by conducting an energy audit and display of results in an energy certificate. Energy audit is a procedure for determining energy characteristics of a building (both building elements and energy systems) and comparison of calculated characteristics of energy consumption to legal values. Energy certificate is a document which shows energy class of a building according to energy characteristics of a building and efficiency of energy systems installed. Calculated data are transposed to referent climate for grading energy consumption in classes from G (highest energy consumption) to A^+ (lowest energy consumption).

ENERGY AUDITS

In an energy audit thermal characteristics of construction elements and characteristics of energy production and consumption systems are analyzed. Measures of energy efficiency are suggested according to three feasibility criteria: energy, ecology and financial savings. Audit is conducted through on site inspection of building and energy systems used and analysis of collected data. Calculated level of energy consumption is compared to legal values, when available. In the first phase of introduction of energy certification only $Q_{h,\,nd}$ (needed yearly heat energy for heating) is used when grading buildings.

Energy audit in new and existing buildings analyzes all energy production and consumption systems. Heating demand is dependent on thermal characteristics of construction elements and climate characteristics of the location of the building. By calculation of transmission ($H_{T'}$, W/K) and ventilation losses ($H_{V'}$, W/K) heating demand is determined. Due to design or construction faults additional heat losses are present, e.g. thermal bridges areas on the building envelope where thermal flow is higher due to change of material, thickness or geometry of building element.

These losses increase total energy consumption and need to be identified and included in EE measures. Measurements are required to determine actual condition of building elements. Visualization of thermal losses by infrared thermography is especially useful in on site inspection and analysis thermal properties of the building's envelope, e.g. construction material is not known or construction faults are suspected. National legislation (in HRN EN 15603:2008, Energy performance of buildings - Overall energy use and definition of energy ratings) recommends infrared thermography in analysis of thermal bridges on building elements. Interpretation of measurements is used to determine measures of energy efficiency for improvement of both thermal and technical characteristics of buildings.

EXAMPLES OF IR THERMOGRAPHY APPLICATION IN ENERGY AUDITS

Use of infrared thermography in energy audits is presented in three examples. In energy audits all building elements and energy systems have been analyzed, calculation of relevant parameters (heat energy needed for space heating), modeling of energy consumption and costs and measurements of thermal losses through external envelope are conducted.

IR thermography measurements are conducted in winter, in early evening (between 6 and 8 p.m.) while heating system was still running. Emissivity factor e=0,95 was used as the material of the external envelope is plaster, brick or concrete. Other parameters are taken according to specific site conditions.

Hospital for continued nursing in Duga Resa consists of two buildings. In a historic building (built in 1900) external walls being of solid brick display characteristic thermal bridges on IR thermograms (Illustration 1). Although wall thickness represents high thermal mass capacity, total heat energy demand is high. Windows (being considerably thinner) and walls (thickness of 60 cm) connection represents linear thermal bridges. To improve energy efficiency partial application of measures is possible. As historic appearance of the façade can't be changed walls can be thermally insulated from inside. Insulation of ceiling toward unheated attic is also recommended. In a new part of building thermal losses are even higher. Thermal insulation is only used in external walls (thickness of insulation material is 3 cm). Windows of poor thermal characteristics and uninsulated screen boxes have highest influence on heat loses as shown on IR thermograms (Illustration 2). Thermal insulation of all building elements is recommended, external wall with additional 14 cm, ceiling toward attic with 20 cm and ground floor with 10 cm of thermal insulation material. New windows with low coefficient of heat transfer properly positioned to thermal insulation in wall are required to achieve energy economy. By implementation of all energy efficiency measures (for building elements and energy systems) heating energy demand in this building can be lowered by 75 percent.

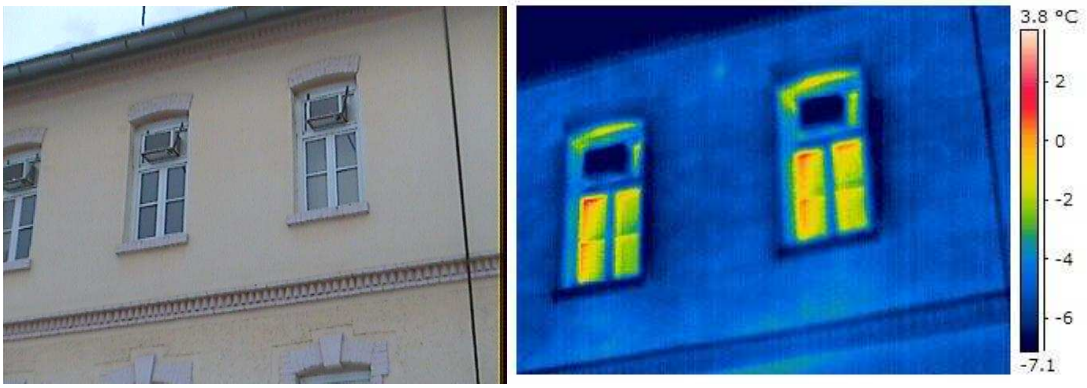

Illustration 1: Photography and thermogram of a historic building (1900)

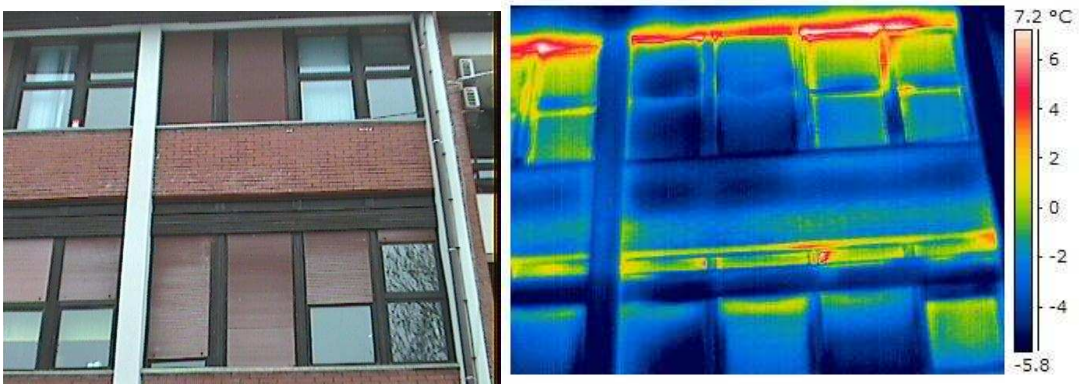

Illustration 2: Photography and thermogram of a new building (1984)

As design documentation of Elderly nursing home in Petrinja (built in two phases, in 1971 and 1981) was not available, IR thermography was used to determine material of external

envelope. IR thermograms showed difference in thermal losses indicating different materials used and no thermal insulation material in the external envelope. Relatively higher thermal losses represent concrete elements of construction, brick elements are represented by relatively lower thermal losses (Illustration 3). Thermal insulation of steel frame windows and panels is poor, displayed by higher emissivity on IR thermogram (Illustration 4). Negative effect of thermal bridges is also displayed on corners of walls, wall and window connection and on cantilevered balcony slabs (Illustration 5). All conclusions from IR thermography analysis were taken into consideration when suggesting energy efficiency measures. Thermal insulation of all building elements is suggested, external walls with 10 cm, ceiling toward unheated attic with 16 cm and change of windows with new ones of good thermal characteristics. Special attention is given to characteristic details of construction in achieving continuity of insulation material to avoid thermal bridges. By all EE measures recommended and specific construction details enclosed total heating energy demand in this building can be lowered by 70 percent.

Illustration 3: Difference in thermal losses indicates different materials of building envelope

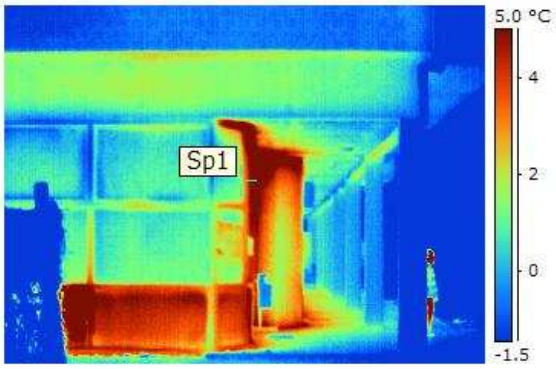

Illustration 4: Low thermal insulation of steel frame windows and panels

Illustration 5: Thermal losses through uninsulated cantilevered balcony slabs and windows

Building crafts high school in Čakovec has low level of thermal protection, all building elements have minimum of thermal insulation material (3-5 cm) in composite wall element. Continuity of insulation material is not achieved and linear thermal bridges are seen on IR thermograms. Wall and ground floor thermal material connection is not achieved and also wall and window connection show thermal bridges (Illustration 6). Due to thermal bridges total heat energy consumption of a building is high (Illustration 7). In an energy audit construction details to avoid thermal bridges are enclosed. Additional thermal insulation is recommended for all building elements, external wall with 12 cm of insulation material, flat roof with 20 cm and change of windows with energy efficient ones with movable shutters to achieve Sun protection. By application of all energy efficiency measures and specific construction details enclosed total heating energy demand in this building can be lowered by 50 percent.

Illustration 6: Linear thermal bridge on ground floor and wall connection

Illustration 7: Characteristic thermal bridges on the corners of a building

ENERGY EFFICIENCY MEASURES INPUT TO ENERGY CERTIFICATION

While energy audit provides information for technically educated personnel, energy certificate communicates to owners and all users of buildings. Energy certificate grades buildings in classes according to energy characteristics calculated in an energy audit: efficiency of energy systems used and quality of thermal characteristics of the external envelope. The class represents in simple way energy consumption of a building, also indicating energy and maintenance costs. Using standard construction principles about 15 percent of energy is used for the construction of a building and 85 percent of energy is used during its lifecycle. Energy efficient buildings have up to 50 percent lower energy demand compared to standard buildings according to legal values. Investing in energy efficiency reduces living/business costs and therefore should be included in planning new and reconstructing existing buildings.

To upgrade energy efficiency, an energy certificate also provides list of measures for improvement of energy systems and building elements and introduces energy management. These measures are divided in two categories, according to complexity of implementation and financial resources needed and can be used in renovation, maintenance and in every day use to achieve energy savings. Simple measures with low financial resources needed and short payback period (up to 3 years and up to 5000 kn/100 m^2) include improvement of deficiencies recognized in on site inspection of the building: improvement of sealing of windows and doors, change of glazing, thermal insulation of ceiling toward unheated attic or pitched attic roof, radiator niches and screen boxes, thermal insulation of heating system distribution pipes and hot water tanks and other measures in heating and electricity consumption system. Most of these measures can be recognized by infrared thermography measurement and interpretation of the results. Improvement of such construction deficiencies or lack of basic maintenance practices can reduce heat energy consumption. These characteristics are very important in energy certification of buildings considering heating demand has highest share of energy consumption, both in residential and non-residential buildings.

Next category are measures with higher financial resources needed and longer pay back period (more than 3 years and more than 5000 kn/100 m^2) and are based on heat energy demand calculation or technical improvement of all technical systems. These measures are recommended when technical and thermal characteristics of building elements and energy systems are poor and total energy demand is much higher than legal value. Infrared thermography analysis can also indicate level of deficiency where change of elements or major improvement of thermal characteristics is required, as shown in previous examples of energy audits.

Table 1: Construction deficiencies recognized by infrared thermography in presented examples

Building	Year of construction	Construction deficiencies recognized by infrared thermography	Energy efficiency measures	Expenses
Hospital for continued nursing in Duga Resa	Old building in 1900, new building in 1984	Low level of thermal insulation on new building Uninsulated screen boxes Widows of poor thermal and technical characteristics	Thermal insulation of external envelope, change of windows	More than 5000 kn/100 m^2
Erderly nursing home in Petrinja	Old building in 1971, new building in 1981	Linear thermal bridges on cantilevered balcony slabs Uninsulated external envelope Widows of poor thermal and technical characteristics	Thermal insulation of external envelope, change of windows	More than 5000 kn/100 m^2
Building crafts high school in Čakovec	1975	Low thermal protection of the external envelope Linear thermal bridges on wall and ground floor connection Widows of poor thermal and technical characteristics	Thermal insulation of external envelope, change of windows	More than 5000 kn/100 m^2

Market value of a building will be influenced by an energy certificate for it shows energy consumption according to actual energy characteristics and gives list of measures required to improve living comfort and reduce energy costs. Starting from September 2009 energy certificate display will be obligatory for all public buildings and when selling, leasing or renting buildings or single units of a building. Presentation of energy characteristics of buildings will stimulate implementation of contemporary construction principles and building elements to reduce energy consumption. To achieve this goal cooperation and contribution of all participants in construction process is required, starting from design idea. Engineers trained in energy efficiency and conducting energy measurements are new members of design team responsible for improvement, harmonization and feasibility of basic design and technical solutions.

CONCLUSION

Examples of energy audits show importance of measurements to assess energy characteristics of buildings and detect possible construction deficiencies. Thermal characteristics of the building's envelope influence energy demand for heating and cooling i.e. highest share of energy consumption. These characteristics need to be calculated, measured and evaluated on site and in design documentation. For measurement of thermal losses a non destructive and easily interpreted method of infrared thermography is used. Thermograms visualize thermal losses of building elements and indicate state and possible deficiencies of building elements and energy systems.. Highest potential for energy saving in Croatia is in building sector for mostly they were built in the period from 1960 to 1980 using no thermal insulation. These buildings need to be renovated not only to reduce energy consumption but also to improve other technical characteristics. When suggesting measures of energy efficiency, actual condition of building elements and energy systems must be evaluated to achieve not only energy economy and thermal protection but also include other essential characteristics of a building, upgrading hygiene, health, indoor comfort and environmental conditions Assessment of current energy characteristics of a building and calculations for energy efficiency improvement conducted in an energy audit provide energy, financial and ecology feasibility of investment. For this reason an energy audit is necessary in reconstruction of existing buildings and in planning new buildings. Also, calculation of energy characteristics of a building provides input data for energy certification. Energy audits and energy certification are new obligatory technical documents of buildings. In a very near period experienced, specifically trained and certified engineers are required for provision of these documents.

SAŽETAK

Sektor zgradarstva danas je prepoznat kao najveći pojedinačni potrošač energije, koji zbog dugog životnog vijeka zgrada, ima dug i kontinuiran utjecaj na okoliš. Također je prepoznato da se upravo u zgradama krije najveći potencijal energetskih i ekoloških ušteda. Uvođenje energetske certifikacije zgrada odnosno podjele zgrada u razrede prema energetskoj potrošnji, donosi niz ključnih promjena koje će utjecati na podizanje kvalitete gradnje, osuvremenjivanje postojećih zgrada, smanjenje troškova održavanja, primjenu inovativnih tehnologija i rješenja, te razvoj integralnog pristupa projektiranju. Za izdavanje energetskog certifikata potrebno je provesti energetski pregled, kojim se utvrđuju energetska svojstva zgrade te predlažu mjere za povećanje energetske učinkovitosti.
U radu je prikazana uloga metode IC termografije pri provođenju energetskih pregleda novih i postojećih zgrada kod analize građevinskih i energetskih karakteristika, te općenito

utvrđivanja bitnih svojstava građevine. Kroz tri primjera provedenih energetskih pregleda zgrada javne namjene, škole, doma za starije i nemoćne osobe, te bolnice, analizira se primjena termografije kao nezaobilazne metode pri energetskom certificiranju zgrada.

KLJUČNE RIJEČI
energetska učinkovitost, energetski pregledi zgrada, energetski certifikat, IC termografija, energetska svojstva zgrada

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