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Quantifying Thermal Bridge Effects and Assessing Retrofit Solutions in a Greek Residential Building

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Abstract

Material and component performances are blunt instruments for appraising the thermal performance of structures. A certain amount of consumed energy is attributable to the interaction of building fabric components, where thermal bridges occur. This paper analyses the thermal bridging effect and provides a number of modelled, cost-effective retrofit approaches in Greek single family houses, in order to address thermal bridges and improve the building's energy performance. The impact of thermal bridging on the overall annual heating load was estimated at 13%. The investigated retrofit solutions achieved a decrease of the annual heating energy requirement of 4-10%. The sunspace achieved the highest energy reduction of 10%, offering 'free' solar heating at a reasonable payback period.

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Keywords: Thermal bridges; Heat loss; Building thermal simulation; TRNSYS; THERM; Retrofit.; Cost-Benefit Analysis.

1. Introduction

The 1970s energy crises forced the building community to investigate and implement strategies to minimise the buildings' energy losses. At a national level, European countries established legislative actions to face the explosion in oil prices by decreasing the energy demand of buildings. However, thermal bridging effect was never broadly considered until 1995 when the European ISO 10211-1:1995[1] provided an acceptable way of calculating the heat flows through the building fabric due to thermal bridging and setting surface temperature limitations[1].

Thermal bridges or coldbridges are described in different studies as localised areas of the building fabric, with significantly lower thermal insulation protection, where the thermal barrier of the building envelope is interrupted

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and substantial heat flows occur[2,3].

Thermal bridging effects are created where two materials with noticeably different thermal conductivity are used in combination on the building fabric and when there are discontinuities in the uniform thermal insulation layer (due to structural or geometrical requirements or defects)[4]. Thermal bridges can be classified into two types: the linear and point ones[2]. Linear bridges have a uniform cross-section along one dimension. They are characterized by a linear thermal transmittance (ψ-value or psi value W/m*K) and are always calculated as they significantly affect the thermal performance of the envelope[2]. The linear transmittance or the ψ-value expresses the effect of all the linear thermal bridges of a building envelope.

Table 1 summarises results from studies that investigated the contribution of thermal bridges to the total building heat losses in different locations and climates. Around 1984, in Washington DC, Fang *et al.* studied the impact of thermal bridges on the energy demand of three office buildings using in situ thermography and laboratory based estimations and found that could account for up to 21% of the building's heat losses[3]. In Germany, a study for two family houses, with insulated bricks, triple, low emissivity glazing and insulation on the roof and slabs, revealed that approximately 11 kWh/m^2 per year could be saved[5].

Lahmidi & Leguillon also concur that 15% is the primary energy reduction for a concrete family house in Paris when using thermal breaks and insulation on floor and ceiling[6]. In a case study building in Northern France (Trappes) Gao *et al.* investigated the contribution of thermal bridges (up to14% of the total heat losses) for a single zone building by using a simplified model in TRNSYS[7].

In Czech Republic, a study for an existing 70's brick residential building with wooden windows indicates that the relative influence of thermal bridges on the total heat loss balance is 7%, while this could reach 17% when an insulation layer is added[8]. On the other hand, a Polish research calculated the thermal bridge contribution on the energy consumption of a typical two storey house at only 6%(All cited in[9]). Two cases with different levels of thermal bridging correction for a terraced and a semi-detached house were examined in an Italian study and calculated 25% and 18% reduction of the primary energy for the terraced and semi-detached house respectively[2].

Table 1. The thermal bridges relative influence on the total heat losses of various building types. Literature review summarized.

Source	Building type	Location	Climate*	Th. br. as % of heat losses	Method**
3	Office	Washington	Cfb	21%	Tr.
5	Family houses ‘high thermal performance’	Germany	Cfb	15%	M
6	Family house	Paris	Cfb	15%	M
7	Single zone building	Trappes, France	Cfb	14%	Tr.
8	70's residential house, uninsulated	Czech Republic	Cfb	7%	SS
8	70's residential house, insulated	Czech Republic	Cfb	15%	SS
9	Two storey house	Poland	Cfb	6%	SS
2	Terraced house	Italy	Csa	25% (winter)	Tr./SS
2	Semi-detached house	Italy	Csa	18% (winter)	Tr./SS
10	Detached, 2-storey house	Greece	Csa	16% (winter)	Tr.

*Climate C:Temperate ($-3<T_{min}<18$), f: fully humid, b: Warm summer (T<22= and T>10 at least 4 months), s: Dry summer, a: Hot summer ($T_{max}>22$) Climate data taken from [11]. **Method: Tr.=Transient simulation; SS=Steady state calculation; M=Measured.

In Greece, 40% of the residential building stock was constructed between 1980 and 2010, during the validity period of the Regulation of Thermal Insulation[12]. However, the majority of them do not comply with the regulation[12]. An insulating layer on the load bearing parts has been introduced only in the last few years of the 30 year timescale[12]. The double wall construction which includes an insulation layer was and continues to be a common practice. Familiar features of the residential buildings in the Mediterranean region, such as cantilevers, overhangs, semi-open spaces, ground floor open parking spaces (pilotis) and flat roofs, mostly address the climatic and social need for immediate access to the outdoors. Typically partially insulated, they are responsible for substantial unwanted thermal flows[10,13]. In the ‘Mediterranean research area’, Theodosiou and Papadopoulos investigated the effect of thermal bridges for a multi-family building in Thessaloniki, Northern Greece, for 4 characteristic insulation configuration scenarios, using TRNSYS and energy data typical for the region and found it to be 16% of the heating demand[10].

The aim of the present paper is to investigate the impact of thermal bridges on the energy performance of a

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