THERMAL COMFORT IN JORDANIAN HOUSING: AN OVERVIEW

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ABSTRACT

As people spend majority of their time indoors, their satisfaction with the internal thermal environment is a vital requirement and a significant determinant of healthy buildings. However, thermal discomfort in Jordanian housing is a common issue, which has resulted in serious health concerns and deterioration in occupants' well-being and productivity. Poor thermal insulation in building envelope and lack of indoor temperature control, are major causes of these circumstances and contributors to Sick Building Syndrome (SBS) prevalence. Moreover, these conditions generate high energy consumption, in a country that imports most of its' needed energy. In this paper: thermal comfort in Jordanian housing was examined, the underlying reasons and consequences of thermal discomfort were analysed and local relevant building codes and housing structures in Jordan were studied. Based on the review process, more enforcement of local building codes and more awareness of thermal insulation's significance are required. Updating old codes and seeking healthier and cost-efficient heating and cooling tools are essential to meet optimal thermal comfort conditions.

KEYWORDS _ *Thermal comfort, housing, Sick Building Syndrome, Jordan*

INTRODUCTION

A healthy indoor environment is vital to promote occupants' well-being and performance. Several factors impact the Indoor Environmental Quality (IEQ) of buildings, and key factors include thermal comfort and Indoor Air Quality (IAQ). Thermal comfort is evaluated by the subjective assessment, which describes the satisfaction of people with their surrounding thermal environment (ASHRAE,2013). Based on their conditions, thermal comfort and IAQ directly impact residents' health and performance. Research demonstrates that occupants' perception of thermal discomfort indoors, i.e. feeling too warm or too cold and lack of temperature control, correlated with an increase in Sick Building Syndrome (SBS) symptoms (Jaakkola et al., 1989). SBS term, is used to describe a set of symptoms, which are experienced by building occupants, and are linked to the time spent indoors, with no clear cause or a specific illness (U.S. Environmental Protection Agency [EPA], 1991). SBS is directly influenced by IAQ conditions and originated from the evolution of building construction in the last decades, which was accompanied by using detrimental materials to indoor environments. The presence of medical symptoms e.g. fatigue, headache, respiratory issues, and impaired concentration between dwelling residents (Redlich et al., 1997) and that's confinement to indoor exposure time, was the first indicator to discover SBS issue. The inappropriate levels of indoor physical variables e.g. temperature and humidity and the presence of indoor air pollutants e.g. Volatile Organic Compounds (VOCs) like paints and formaldehyde; and Bioaerosols e.g. fungi and moulds, were major contributors to SBS cases (Redlich et al., 1997). Using adequate building materials may resolve the problem, but due to cost considerations, this might be not feasible. However, occupants' overall comfort perception indoors, is affected by the interaction between thermal comfort, IAQ and ventilation rates (Jia et al., 2021). Therefore, ventilation is the most practical and cost-effective solution to eliminate indoor toxins (Almomani and Ali,2008). Hence, buildings characterized with inadequate ventilation e.g. office buildings, are more susceptible to SBS symptoms. Examination of these circumstances requires an analysis of several building variables e.g. age, design, construction, furniture, and residents of the building (Figure 1). In addition to climate conditions (Spaul, 1994) and outdoor site elements e.g. sky, pavement, greenery, and neighbourhood buildings, which have a direct influence on indoor thermal comfort and percentage of pollutants inside (Lin, Y et al., 2023). Furthermore, building envelope including thermal insulation quality, significantly impacts occupants' thermal comfort perception (Younis et al.,2020).

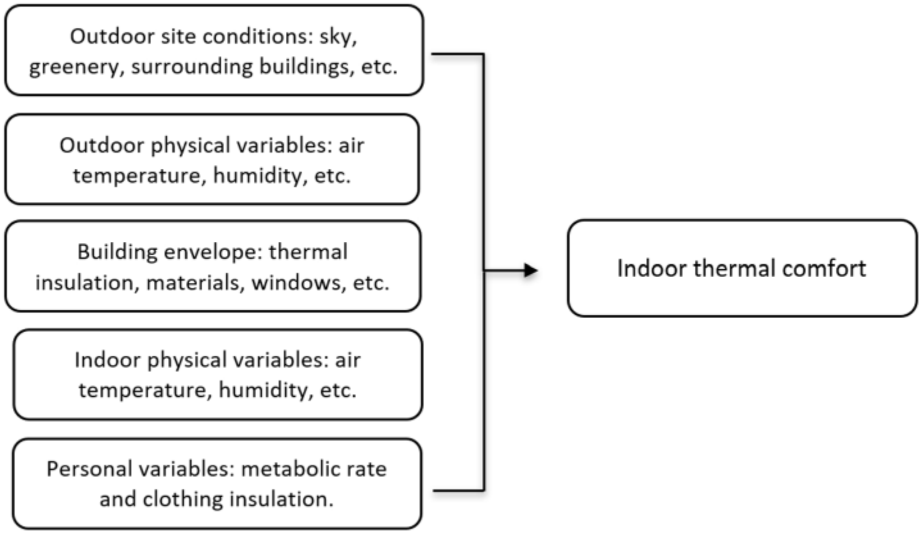

Figure 1: Factors impacting Indoor thermal comfort, source: authors,2025.

THERMAL COMFORT AND SBS IN JORDANIAN HOUSING

Despite that several studies proved prevalence of SBS symptoms in Jordanian housing; it is not officially addressed in local building codes, and they only include requirements for indoor contaminants' levels (Almomani and Ali,2008). In (Freihat and Al-kurdi,2023) study on IAQ conditions in residential buildings in Zarqa city, Jordan, they found that Particulate Matter (PM2.5) and indoor air pollutants e.g. VOCs, formaldehyde (HCHO) in the studied sample, surpassed the recommended values and SBS symptoms were linked to Total Volatile Organic Compounds (TVOC) indoors. Moreover, in another study on residential buildings in three cities of Jordan: Amman, Irbid, and Zarqa, (Almomani and Ali, 2008) found a prevalence of SBS symptoms in 93% of the studied sample of forty apartment buildings. This correlated with poor ventilation and lack of temperature control and led to performance decline. The study also emphasized that building's external envelope e.g. window size; apartment location and orientation, were also influencing variables. Moreover, poor IAQ was more prevalent in the densest city i.e. Zarqa. Furthermore, the connection between poor thermal comfort and SBS in Jordanian houses, was studied in (Younis et al.,2020) research on low-middle income apartment buildings in Amman, Jordan. The study concluded that 50% of 106 studied occupants, experienced asthma in winter. Additionally, 75% of them were living in poor thermally insulated buildings, with high U-value (thermal transmittance coefficient) levels. This situation resulted in 39% and 89% of them, using unfluted kerosene and Liquefied Petroleum Gas (LPG) portable heating devices, respectively, which generated poor indoor air quality in these buildings. The paper emphasized that residential buildings in Jordan are thermally inefficient, and that contributes to SBS occurrence. In summary, previous literature shows that thermal discomfort in Jordanian housing, due to poor thermal insulation and lack of temperature control, is a significant risk factor. It triggers unhealthy indoor environments and SBS occurrence, due to thermal discomfort perception and occupants' use of unhealthy devices (Figure 2).

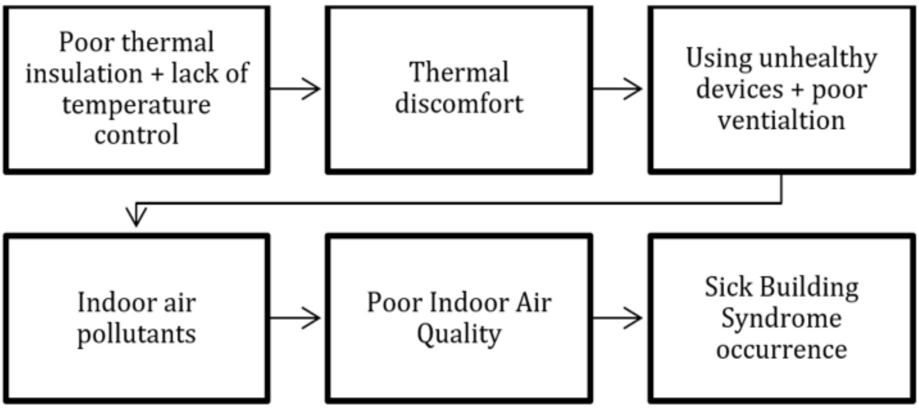

Figure 2: The relation between thermal discomfort, poor ventilation, poor Indoor Air Quality and Sick Building Syndrome in Jordanian housing, source: authors,2025.

HOUSING STRUCTURE IN JORDAN

The typical external wall envelope of a Jordanian building consists of stone cladding, hollow concrete blocks, poured concrete, insulation, and plaster (Figure 3). However, external walls may vary in their components, number of layers, thickness, and cladding materials. They are of four types: uninsulated solid walls, uninsulated cavity walls with stone cladding, uninsulated cavity walls without stone cladding and insulated walls as shown in (Table 1).

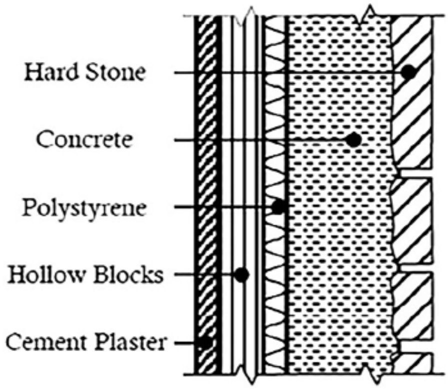

Figure 3: Typical insulated external wall envelope of a Jordanian building, source: Alsaad & Hammad, 2016, as cited in: Abdel-Fattah et al., 2022.

Table 1: Most common wall structures in Jordanian housing and their thermal performance, adapted from: Shammout and Khurissat,2018.

Wall Type	**Layers (from outside to inside)**	**Total Thickness (mm)**	**U-value (W/m²K)**
Wall Type 1: Uninsulated solid wall	Stone cladding (60 mm) + Cast in site concrete (80 mm) +Hollow concrete blocks (100 mm) + Cement plastering (20 mm).	260 mm	2.55 W/m²K
Wall Type2: Uninsulated cavity walls with stone cladding	Stone cladding (60 mm) + Cast in site concrete (80 mm) + Air gap (50 mm) + Hollow concrete blocks (100 mm) + Cement plastering (20 mm).	310 mm	1.99 W/m²K
Wall Type3: Uninsulated cavity walls without stone cladding	Plaster (20 mm) + Hollow concrete blocks (100 mm) + Air gap (50 mm) + Hollow concrete blocks (100 mm) + Cement plastering (20 mm).	290 mm	1.27 W/m²K
Wall Type 4: Insulated walls	Stone cladding (60 mm) + Cast in site concrete (80 mm) + Extruded Polystyrene (30 mm) + Hollow concrete blocks (100 mm) + Cement plastering (20 mm).	290 mm	0.75 W/m²K

Additionally, windows are commonly made of single pane glass with hollow aluminium frames, with a total U-value of 5.7 W/m²K (Awadallah et al., 2009), leading to high heat loss. Moreover, common external roofs of Jordanian buildings are of two types: uninsulated flat roofs with tiles, consisted of ceramic tiles, cement mortar, sand and gravel, waterproofing, light weight concrete, reinforced concrete and cement plaster, with a total thickness of 522 mm and U-value of 0.80 W/m²K; uninsulated flat roofs without tiles, composed of waterproofing, light weight concrete ,reinforced concrete and cement plaster with a total thickness of 424 mm and U-value of 1.02 W/m²K (Shammout and Khurissat, 2018).

ENERGY CONSUMPTION OF HOUSING IN JORDAN

High housing stock in Jordanian cities, driven by urban expansion and population growth, has resulted in high energy demands, in a country that is known for its' poor energy resources (Alkurdi et al., 2012). Housing sector accounts for 40% of total energy consumption of the country (Alasmar et al.,2024) and 49.4% of the total electrical consumption (Abdel-Fattah et al., 2022). Moreover, the wasted energy for heating purposes, constitutes 61% of the total wasted energy in Jordanian houses. Various variables control the consumed heating energy in these buildings, e.g. the quality of insulation, building design, variations in local weather, and family size and income. Additionally, the most common used energy resources for heating locally are: Liquid Petroleum Gas (LPG), Kerosene, Diesel, and electricity (Figure 4). In the forms of portable liquified petroleum gas (LPG), Kerosene and electrical heaters, in addition to radiators and air conditioning split units in winter, compared to cooling fans and air conditioners in summer. Due to cost considerations, portable LPG and Kerosene heaters are the most widely used tools for heating purposes in winter, in compared to cooling fans in summer. However, these heaters encompass LPG and Kerosene combustion, and generate toxic elements like Carbon dioxide (CO_2) and Carbon monoxide (CO), particularly when combined with inadequate ventilation, which promotes SBS symptoms and risky indoor conditions (Younis et al.,2020) and increases the need for healthier heating tools inside buildings (Hussein et al., 2022).

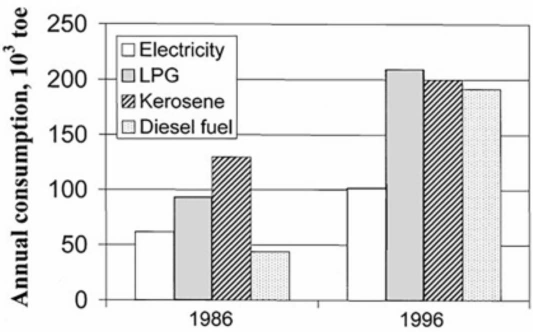

Figure 4: Annual household consumption in Jordan according to the type of energy, source: Jaber and Probert, 2001.

LOCAL BUILDING CODES IN JORDAN

Despite that local Energy Efficient Building Code (2010), and Thermal Insulation Code (2009), are present in Jordan and provide mandatory requirements for thermal insulation and energy requirements in buildings (Table 2), they are not completely enforced nor checked for their implementation (Shammout and Khurissat,2018; Daher, 2011). For example, a local thermal insulation code is present with penalties, however, 77% of houses in Jordan lack insulation (Al-Hinti and Al-Sallami,2017). Furthermore, only 5% of Jordanian residential stock have wall insulation (Jaber, 2002). Additionally, most common used building envelopes in buildings, exceeds the maximum limit of the required U-value by the local building codes. The implementation costs and unawareness of building insulation's importance, contribute to absence of thermal insulation in residential buildings (Alkhalidi et al., 2021). Additionally, negligence of thermal bridges issue, and lack of technical experience in applying thermal insulation, hinders thermal its' effectiveness. For instance, confusion between thermal and water insulation, inappropriate thickness of insulation materials, discontinuity of thermal insulation and thermal insulation's distortion by poured concrete (Shammout and Khurissat,2018; Abdel-Fattah et al., 2022;), are common deficiencies of thermal insulation implementation in Jordan, which rise the need for proficient installation.

Table 2: Maximum elemental U-value (W/m2K) in Jordanian Building Envelope, adapted from: Awadallah et al., 2009.

External opaque walls	Exposed roofs	Slabs between floors	Exposed floors
0.57 W/m²K	0.55 W/m²K	1.2 W/m²K	1.8 W/m²K

CONCLUSIONS

Poor thermal comfort in Jordanian housing is a recurring challenge, which is driven by poor thermal insulation and lack of temperature control. It significantly hinders the occupants' comfort and increases energy consumption rates. Moreover, it generates poor IAQ and SBS prevalence in these buildings. Despite that relevant codes are present in Jordan, there is a necessity for new regulations and more awareness of the issue. Additionally, enforcing local building codes and retrofitting existing buildings are essential steps. Moreover, it is important to look for healthier and cost-effective tools for heating and cooling purposes, to enhance thermal comfort in Jordanian houses.

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