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USING SOME TECHNIQUES TO IMPACT ENERGY SAVING FOR BUILDING LOCATED IN HOT CLIMATE (BAGHDAD) / REVIEW STUDY

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Abstract. The built environment is a significant contributor to global energy consumption, with heating, cooling, and lighting accounting for a substantial portion of energy use in buildings. As the demand for energy-efficient structures grows, the integration of advanced design strategies and materials has become critical in reducing energy consumption while maintaining occupant comfort. This article explores the effects of various techniques including building design, material selection, ventilation strategies, cooling load management, insulation, shading, cool paints, glazing, and phase-change materials (PCM) on energy efficiency in buildings. Each factor is analyzed for its impact on reducing energy demand, improving thermal performance, and enhancing sustainability. Building design and orientation play a pivotal role in optimizing natural light and airflow, while material selection influences thermal mass and insulation properties. Ventilation strategies, both natural and mechanical, are examined for their ability to reduce cooling loads, and insulation is evaluated for its effectiveness in minimizing heat transfer. Shading devices and cool paints are discussed for their role in mitigating solar heat gain, while advanced glazing technologies are assessed for their ability to balance day lighting and thermal insulation. Additionally, the use of PCM is highlighted for its potential to store and release thermal energy, thereby stabilizing indoor temperatures. By comparing these factors, this study identifies the most effective strategies for reducing energy consumption in buildings, offering insights for architects, engineers, and policymakers to prioritize solutions that align with sustainability goals.

Keywords: *Energy saiving , insulation , sahding , glazing , PCMs*

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1. INTRODUCTION

Iraq is located near the sun belt, which makes it a country with high solar radiation intensity and high brightness period throughout the year. This leads us to pay attention to this energy resource and exploit it as renewable energy [1]. Therefore, The scope of using renewable energy in the city of Baghdad is wide, especially solar energy, and reducing the demand for using this non-renewable energy [2]. One of the uses of solar energy is for heating during the cold and moderate months in Iraq, specifically the city of Baghdad, where the radiant heating energy for the month of December is 980 MJ [3]. In addition , There are several factors that affect energy consumption in buildings located in areas with very hot and humid climates [4]. It is worth noting saving energy and reducing its consumption is directly linked to sustainability to ensure a better lifestyle in the long term [5]. For example, The International Energy Agency expects the number of air conditioners in India to reach 1144 million tons of refrigeration by 2050 [6]. While, The increase in global heat waves leads to an increase in demand for air conditioning devices, which leads to an increase in energy consumption in buildings. To limit or reduce excessive consumption, we can resort to useful and sustainable technologies [7]. on other side, the performance of any air conditioning system is closely related to the position,heat gained inside the room,the materials of the walls,electrical appliances, and the number of person [8]. This challenge heat gain through the roof, which accounts for 70% of total heat gain [9]. Residential buildings are a significant source of energy consumption and greenhouse gas emissions, making it essential to accurately predict loads to reduce energy consumption [10]. The internal thermal environment and energy performance of a home can be improved by reducing the glazing area [11]. There are many strategies to reduce energy loss, including enclosing insulation in wall structures and on the other hand improve energy saving [12]. It can be said that the relationship between thermal conductivity and the type and thickness of the insulating material, the external temperature, and the relative humidity and their effect on cooling loads and energy consumption [13].

2. ENERGY SAVING TECHNIQUES

There are several ways to reduce energy consumption, mention some common of them:

2.1. EFFECTS OF (BUILDING DESIGN , MATERIALS) ON ENERGY SAVING

G. Manioğlu et al Examined the optimization of courtyard shapes by adjusting width-to-length (W/L) ratios to save energy,analyzed the effects of surrounding building forms [14]. Analyzed four structural materials (steel, wood, concrete, and brick), different opaque enclosures, glazing systems, HVAC options, to determine the best solutions for varying building sizes and climate zones show the steel structures floor area (99m2) and wood (52m2) it is perfect solution for energy saving [15]. S. A. Al-Sanea,compared the heat transfer characteristics of four commercial wall structures, R-values,energy storage,solar radiation, orientation, seasonal changes, and radiative heat exchange alongside standard thermal resistance measurements show that west wall heat gain more than 28 % from south wall [16]. M. Ananin et al Factors such as structural design and materials impact total energy costs. Using materials with low embodied energy result 1287 mj and concrete wall without brick result 562 mj can effectively reduce energy and resource consumption [17].

2.2 EFFECTS VENTITATION , INFFILTERATION , LOADS CALCULATIONS ON ENERGY SAVING

Examines ceiling fans operation with air conditioning devices,41% energy saving during peak summer hours [18]. Explores air-conditioning behavior affects energy consumption and presents a Supply-Side Cooling Load Regulation Method (SSRM) where increse ventilation 30 m3/h to 90 m3/h that result increse about 5 degree overall temprature along with an energy consumption [19]. Studied the window's opening area and room temperature this approach to improving indoor thermal conditions [20]. Used the night ventilation and active cooling leadig to a 17% decrease in annual cooling energy consumption and a 3.3% reduction in total annual energy usage [21]. Infiltration from doors or windows can be more important factor of energy use in buildings,While natural ventilation can reduce electricity consumption by up to 3.24% by lowering temperatures through morning window openings, thereby avoiding air conditioning use [22]. Examined the influence of outdoor air pollutant levels, infiltration rates on indoor air quality (IAQ). The effects were assessed through on-site measurements and numerical simulations [23].

Cross-ventilation is an effective method for removing air pollutants and heat from buildings by utilizing natural wind pressure differences [24]. Explored the integration of personal comfort systems (PCS) and natural ventilation (NV) natural ventilation can reduce electricity consumption by up to 3.24% by lowering temperatures through morning window openings to mitigate thermal load imbalances in buildings primarily designed for cooling [25]. Explores the combination of stack ventilation (vertical airflow) and roof channels (horizontal airflow) within buildings, analyzed to determine optimal configurations for one-, two-, and four-story structures [26]. Estimate cooling and heating loads in air-conditioned rooms using the Buckingham-Pi theorem from March to April 2018 [27]. Introduces a framework designed sub-loads by analyzing current and historical total thermal loads. The experiments specifically targeted occupant loads, which are highly relevant to HVAC systems for The experiments specifically targeted occupant loads, improve about 34.9 % sub-load forecasting [28]. Evaluated and contrastd the life cycle costs of a smart HVAC control system building. the smart system resulted in HVAC operational cost savings of 9% to 10% compared to the traditional system [29].

3. ENERGY SAVING BY INSULATION

Installed a thermal insulation sheet on the building's external wall, leading to a decrease in energy consumption by 200 kWh compared to the baseline [30]. The insulation installed polystyrene layers in the ceiling and floor,55% decrease in heating energy demand during winter and an 18% reduction in air conditioning usage in summer [31]. E. Cuce et al assessed a novel insulation plaster (NIP) against traditional insulation plasters varying thicknesses, U-value from 5.5 W/m²K to 47.9%, NIP thickness [32]. Evaluated the optimal insulation thickness for walls, annual savings, and total costs [33]. Examined the transmission load across exterior walls with both external and internal insulation, assessing factors that influence the energy efficiency of each insulation approach [34]. C. Aktemur et al examined the thermal performance of four building materials (Pumice, Hollow Concrete Block , Hollow Red Clay Block , and Reinforced Concrete) and eight insulation materials (Extruded Polystyrene , Expanded Polystyrene, Expanded Polyurethane , Wood Fiber , Hemp Fiber , Linen Fiber , Fiberglass , and Sheep Wool) , Focusing solely on heating efficiency, and life cycle cost analysis to determine optimal insulation thickness, payback periods, and energy savings [35]. Explored the energy-saving of thermal insulating walls made with Super Thin Panel (STP). It assessed the advantages and limitations of the panels' heat

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transfer efficiency, along with the feasibility and potential of utilizing STP as an insulation material [36]. Focused on the impact of various envelope components. examined four AC operation models in adjacent rooms and highlighted the individual contributions of each component. optimizing these envelope elements could reduce average transient heat flows by 16.6% to 65.03%, depending on the operation model. The ceiling showed the greatest potential for energy efficiency, with a reduction ratio of up to 42.8% [37]. Examined the energy usage of a self-sufficient house under two conditions, with and without external insulation, utilized to evaluate the decrease in fuel use and greenhouse gas emissions from the supplementary heating system [38]. Developed a method for determining the ideal insulation thickness by analyzing annual energy balances, across various climate zones [39]. Examined effects homeowners' choices regarding thermal insulation on 160 m² house. Insulated, non-insulated scenarios in three locations, Hourly Analysis Program software and 5 cm of insulation can yield energy savings from 23% to 52% [40]. Used the effectiveness of commonly thermal insulation materials in buildings for noise reduction on different wall thicknesses and type materials [41]. Investigated thermal conductivity of eight widely used building insulation materials (glass wool, rock wool, silica aerogel blanket, expanded polystyrene, extruded polystyrene, phenolic foam, foam ceramic, and foam glass) with temperature (ranging from 20 to 60 °C) and relative humidity (ranging from 0 to 100%). the thermal conductivity increased nearly linearly as temperature rose [42]. Examined the most commonly utilized external wall panels in the construction, lightweight timber-framed panels, light-gauge steel-framed panels, structural insulated panels, cross-laminated timber panels, and precast concrete sandwich panels and evaluates their functional, structural, thermal, and fire performance characteristics [43]. A. M. Saleem et al evaluated the thermal insulation performance of different composite wall and roof configurations to find effective models for energy-efficient building construction in Iraq , weather data from Baghdad on July 21, 2022 for three types of walls and two types of roofs.the second and third wall types reduced heat flux entry by 4% and 10%, respectively, compared to the first wall type, indicating a significant improvement in insulation [44].

4. ENERGY SAVING BY SHADING AND GLAZING

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Examined the impact of shading nets on indoor thermal conditions in buildings during summer. A comparative analysis of two structures one equipped with six-needle black shading nets revealed that these nets reduced solar radiation intensity by approximately 57.86%. peak indoor temperatures in naturally ventilated spaces dropped by 2.3°C, and air conditioning energy use decreased by up to 23% in cooled environments [45]. Implemented shading on opaque facades alone can lead to HVAC energy savings of 8–28%, whereas using cool paints (with a façade value of 0.2) alone can reduce HVAC energy consumption by 10–35%. When shading and cool paints are combined, the energy savings for HVAC systems increase by an additional 2–5% [46]. Examined different dimensions of window glass fenestration and overhang shading devices. So with increasing the dimensions of window overhangs reduces heat gain in buildings. [47]. C. Misiopecki et al Explored the impact of shading on the thermal performance of box-windows, testing two types of shades and three placement options, with a peak 35% reduction in U-value achieved by a roller-shade with low-emissivity , Alternatively, reflective roller-shades placed between window frames led to a 34% improvement in thermal performance without elevating condensation risk [48]. Focused on maintaining thermal comfort and adequate daylight indoors, analyzed energy and daylighting identified appropriate shading systems. The evaluation of these systems on daylight factors and solar heat gains indicated a reduction in cooling hours by up to 4% post-installation [49]. Examined the effects of external shading designs to decrease overall building energy usage while enhancing thermal and visual comfort for occupants. Key shading parameters analyzed include the angle of shading, depth of shading, and the quantity of shading slats [50]. Evaluated and compare the impact of, external blinds, and thermal mass on a building's thermal performance during a heatwave in a temperate climate [51]. Investigated factors window design, such as window-to-wall ratio (WWR), orientation, and glazing materials, to assess energy consumption reduction in Kirkuk, Iraq. A simulation analyzed a typical office building across four WWRs, orientations, and three glazing types (clear, gray, and theoretical) with both single and double glazing, double clear glass on south-facing windows at 100% WWR yields the lowest heating consumption, while double glass on north-facing windows at 25% WWR achieves the lowest cooling consumption [52]. Analyzed and simulated to assess heat balance revealed that 75% of the building's heat gain originated from the lighting system and solar radiation through windows [53]. Investigated the effect of different window glass types on solar heat gain in air-conditioned rooms with a mixing air-distribution system, utilizing ANSYS Fluent and the RNG k-ε turbulence model. single-pane and double-pane clear and tinted glasses with a window-to-wall ratio of 0.33 and varying air change rates (ACH) from 5 to 20.

Solar radiation absorbed by the glass contributes to indoor heat, influencing airflow patterns and temperature distribution. double-pane tinted glass can reduce the air-conditioning load due to heat gain by 55% compared to single-pane clear glass [54]. Movable shading devices are more effective in lowering energy consumption than fixed overhangs. Specifically, the use of interior shades decreased the building's annual energy usage by up to 17.37% compared to the baseline scenario (the same building without any shading) [55].

5. ENERGY SAVING BY USING PCMS

Used phase change materials (PCMs) into roofs to Integrate latent heat storage into building materials significantly contributes to energy conservation in structures, which is a key function of thermal storage systems [56]. Explored strategies for integrating phase change materials (PCMs) , PCM walls can delay heat transfer by 2 hours and reduce temperature variations, while PCM panels in windows can decrease heat transfer by 66%. Combining PCMs with nocturnal radiative cooling can lower interior temperatures by over 13°C, and their use alongside natural ventilation can result in energy savings of up to 90% in hot climates [57]. The properties of phase change materials (PCMs) and ventilation rates, which influence system design, to be feasible, on indoor comfort levels and the indoor air temperature remains mostly below 28°C, the upper threshold for human comfort, on most days [58]. Effect three (PCMs) RT series (RT15, RT18, and RT22) into two common commercial hollow brick walls to improve thermal performance for warmer indoor conditions in cold climates, while the RT22 PCM-filled bricks achieve a 66.79% reduction in average heat flux compared to hollow bricks within the first 24 hours [59].

6. CONCLUSION AND RECOMONDATION

The integration of energy-efficient building design and materials is essential for reducing energy consumption and promoting sustainability. Among the techniques discussed, insulation, shading, and glazing emerge as the most effective factors for minimizing energy use. Insulation provides a strong barrier against heat transfer, shading reduces direct solar gain, and energy-efficient glazing balances day lighting with thermal performance. Additionally, PCMs offer innovative solutions for enhancing thermal comfort and reducing cooling loads. While each technique has its merits, the optimal approach depends on the specific climate, building type, and operational requirements. A holistic strategy that combines multiple techniques such as passive design, high-performance materials, and advanced technologies can achieve the greatest energy savings. By prioritizing these factors, architects, engineers, and policymakers can create buildings that are not only energy-efficient but also comfortable, sustainable, and resilient in the face of climate change.

Recommendations for Better Factors

1. Prioritize Insulation: Invest in high-quality insulation materials to minimize heat transfer and reduce heating and cooling demands.
2. Optimize Shading: Use external shading devices and vegetation to block direct sunlight and lower cooling loads.
3. Adopt Energy-Efficient Glazing: Install double or triple-pane windows with Low-E coatings to balance day lighting and thermal performance.
4. Explore PCMs: Integrate phase change materials into building envelopes to stabilize indoor temperatures and reduce energy consumption.

By focusing on these factors, stakeholders can create buildings that are not only energy-efficient but also environmentally friendly and cost-effective in the long term.

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Figure and tables

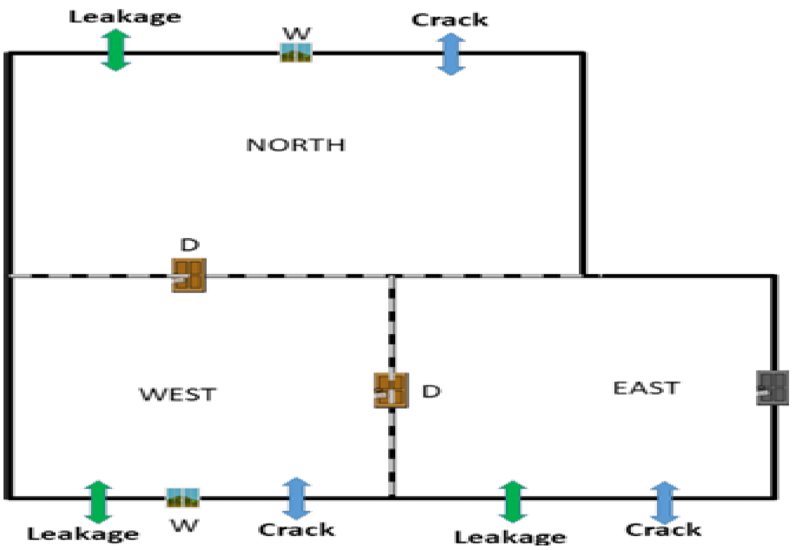

Fig. 1 Leakage and cracks in walls and windows [22]

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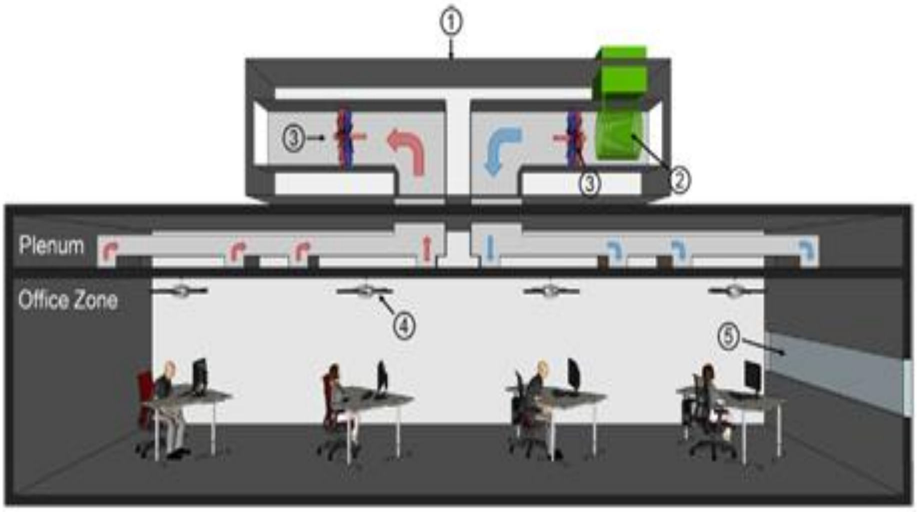

Fig. 2 Office zone with hvac system [25]

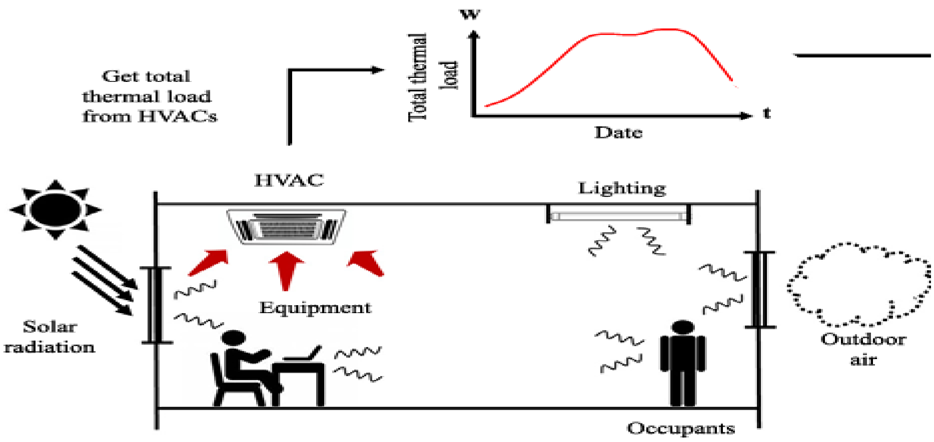

Fig. 3 External , internal load sources [28]

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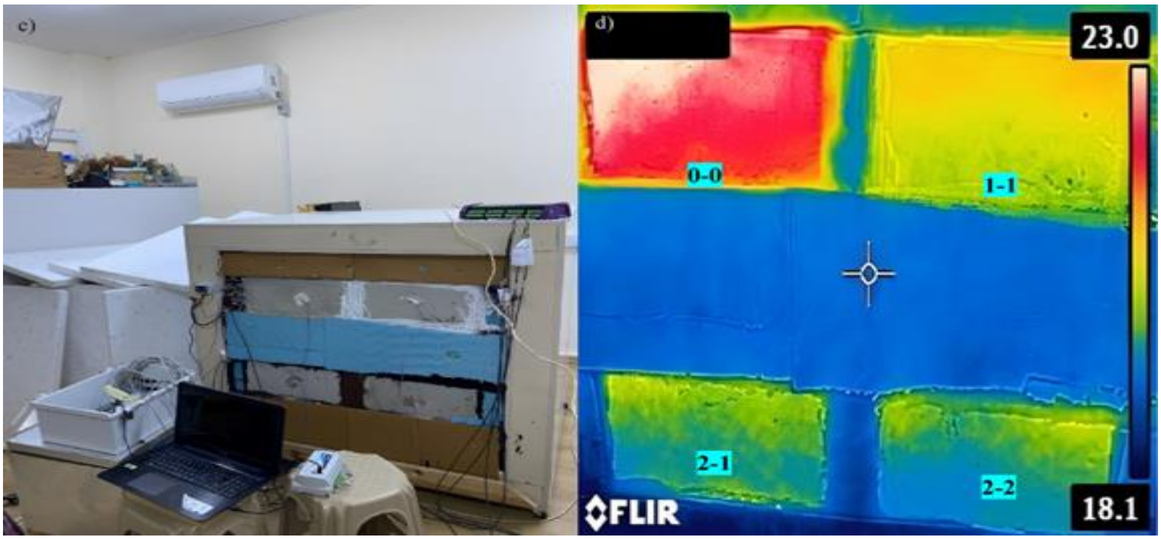

Fig. 5 Novel insulation plaster (NIP) [38]

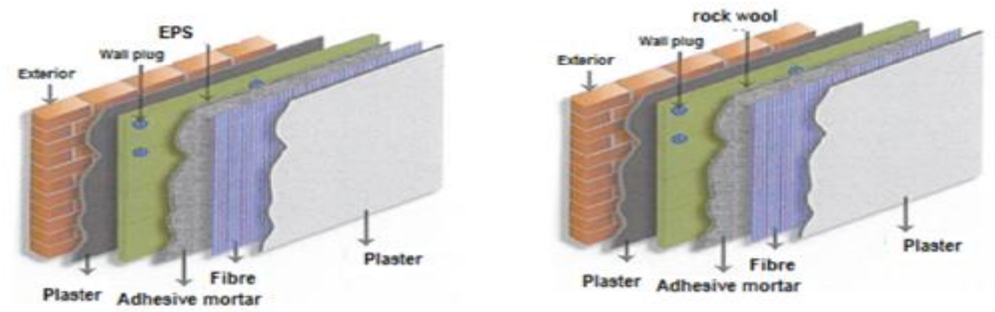

Fig. 6 Wall noise insulation layers [41]

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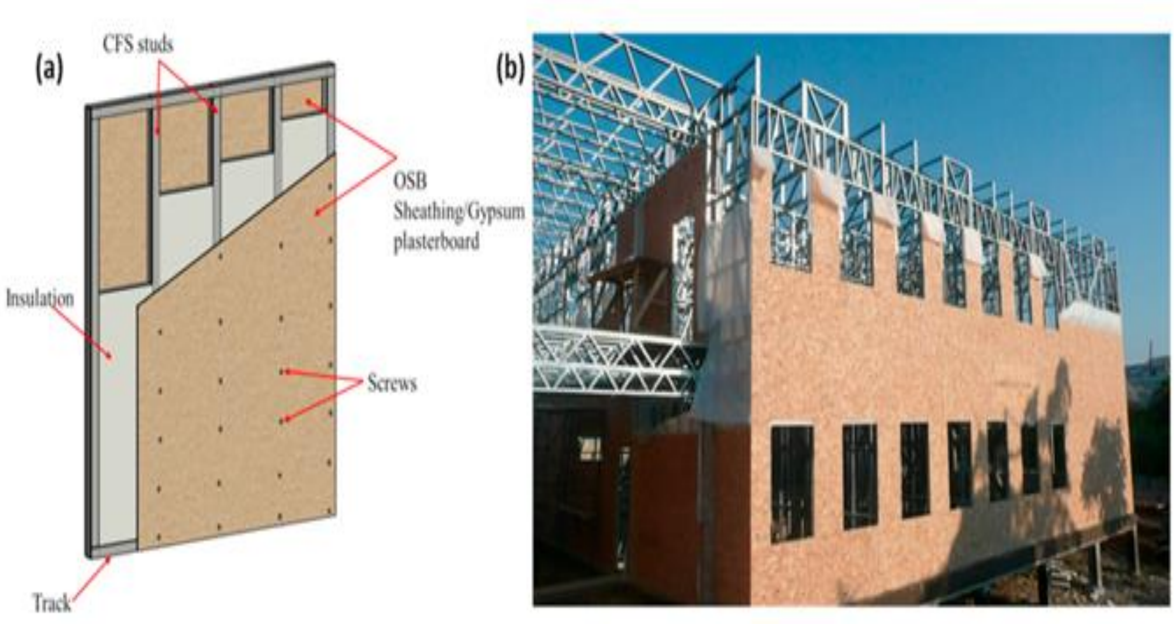

Fig. 7 Insulation panel [43]

Layer	Thermal conductivity (W/m.°C)	Density (kg/m^3)	Specific heat (kJ/kg.°C)	Resistance (m^2.°C/W)
Cement mortar	1.08	2105	0.85	0.018
Brick	0.54	1570	0.93	0.444
Gypsum	0.72	1416	1.006	0.027
Plaster	0.32	1068	1.115	0.006
Air	0.025	1.205	1.005	2
Sheathing timber	0.115	500	1.6	0.043
Reinforced concrete	1.25	2290	0.92	0.16
Precast concrete flag	1.22	2270	0.896	0.04
River sand	0.78	1500	0.82	0.128
Tar	0.24	1070	1.47	0.083

Fig. 8 Roof, wall and floor material specifications [44]

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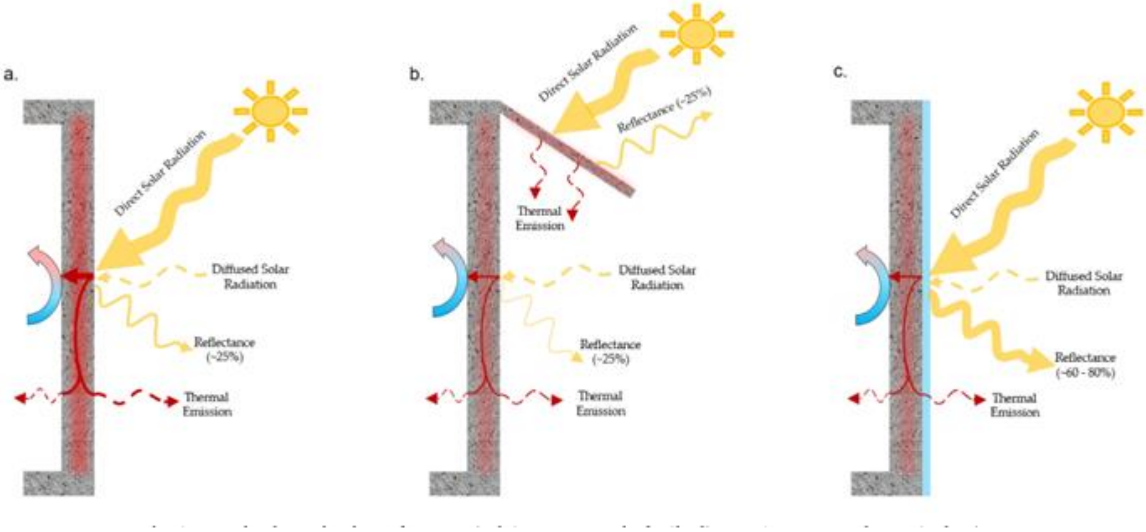

Fig. 9 shading mode with opaque facade [46]

Fig . 10 Roof pcm models [56]