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Facade Performance of Mid-rise Affordable Housing in Hot-Humid Climate: Case Study in Jeddah, KSA

Jamil F. Hijazi **Abdullah I. Almahfouz** **Ayad K. Almaimani** **Rahif A. Maddah**

Faculty of Architecture and Planning, King Abdulaziz University, Kingdom of Saudi Arabia.

jhijazi@kau.edu.sa *aalmahfouz0001@stu.kau.edu.sa* *ealmaimani@kau.edu.sa* *rmaddah@kau.edu.sa*

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Abstract: This research aims to evaluate the potential for reducing the long-term financial costs of (AMH) in Saudi Arabia, specifically focusing on the city of Jeddah. The region lacks affordable, energy-efficient housing options, and existing structures exhibit high (EC). The study involves analyzing the historical growth and architectural characteristics of current (AMH), assessing their thermal performance, and developing an optimal facade prototype that can significantly decrease (CEC) in such housing. The research team has devised a model for (AMH), which features EPS pre-insulated clay block walls with a 50 mm layer of EPS insulation and an indoor layer of cement bricks. The findings of this study can potentially enhance the economic and energy efficiency of affordable mid-rise buildings in the future.

Keywords: Affordable Housing, Energy-Efficient, Heat Gain, Hot-Humid Climate, Social Housing, Thermal Performance, Building Façade, Mid-rise Building.

Abbreviations

AH	Affordable Housing	BF	Building Façade
EE	Energy Efficiency	MR	Mid-rise Building
HG	Heat Gain	CEC	Cooling Energy Consumption
HHC	Hot-Humid Climate	AMH	Affordable Mid-rise Housing
SH	Social Housing	EC	Energy Consumption
TP	Thermal Performance		

1. Introduction

As cities worldwide grapple with rapid population growth and heightened housing demands, the imperative of providing energy-efficient housing has gained global significance. Saudi Arabia, in particular, has witnessed an even more accelerated demand for housing due to substantial economic development, population growth, and an expanding foreign workforce. In response, the Saudi government has committed to a policy aimed at establishing mass-produced, affordable housing solutions. However, the combination of population growth and the country's urban development policies, which include demolishing slums, exerts increasing pressure on the existing housing infrastructure. This results in overcrowding, inadequate social amenities, and long-term issues with (EC). Saudi Arabia also grapples with challenges related to the limited availability of affordable housing units, prepared housing, and escalating costs as it strives to meet the housing needs of its rapidly expanding population. With that and the need for regulatory frameworks for resident relocation, the city of Jeddah faces a dual housing crisis: a shortage of affordable, energy-efficient options and excessive (EC) in existing structures. This not only leads to inefficient utilization of the country's financial and natural resources but also imposes a significant financial and time burden on residents who must expend resources on cooling their homes. The city requires a comprehensive strategy to boost the production and availability of affordable housing units with integrated energy-efficient solutions that can lower initial construction costs but result in significant ongoing expenses for residents. Therefore, this research aims to critically evaluate the energy potential of, the current state (AH), while delivering simplified framework models in (HHC), considering the influence of building facades on their thermal performance. And with all that, the research objectives can be summarized in the following matter:

- Identify the historical development and architectural features of (AMH) in Jeddah.
- Evaluate the thermal efficiency of existing (AMH) in Jeddah.
- Create a standardized model representing the thermal characteristics of typical (AMH) facades.
- Develop an optimized facade prototype to reduce (CEC) in (AMH).

2. Literature Review

Affordable housing is of paramount importance in the 21st century, offering a safe and cost-effective choice for individuals and families seeking suitable living arrangements. Affordability is generally defined as the ability of households to acquire or rent a property that meets their needs without subsidies (Soliman S et al.). Without affordable housing, maintaining a stable living situation can be challenging, impacting general welfare and economic stability. Rising inflation, including increasing energy and food prices, can lead to economic insecurity for many middle-class households (Merheim-Eyre, 2022). The Saudi government's 'Vision 2030' plan, unveiled by Deputy Crown Prince Mohammed bin Salman in 2016, aims to reduce the country's reliance on oil income and outlines economic goals across various sectors. Affordable housing is vital for fostering vibrant and diverse communities, promoting cooperation among people from diverse backgrounds, and creating resilient communities. Efficient (EC) in housing can reduce costs and lower energy bills for occupants (International Energy Agency, 2019). Moreover, it reducing reduces greenhouse gas emissions and fossil fuel use (Khajavi, F et al.). Harsh climates, common in the Middle East, present challenges for creating housing that suits the needs of Saudi families. The hot and humid climate necessitates extensive use of air conditioning, accounting for approximately 70% of electricity consumption in residential buildings (Dastbaz M et al, 2017). Research is needed to address these challenges without compromising indoor environmental quality (Mulenga, D et al, 2019). Various factors, such as the building envelope's thermal performance, play a crucial role in cooling load characteristics. Materials with high density and high heat capacities, like bricks, concrete, and tiles, can significantly reduce heating or cooling costs (Jegede, O.E et al.). Efficient (AMH). (AMH) requires the development of assessment methods that offer long-term benefits for both building owners and occupants while reducing environmental impact and operational expenses (Usman, A.M et al, 2022).

In previous studies, it has been observed that there is generally a positive consensus on the majority of long-term goals. These goals typically focus on improving building efficiency and creating a healthier indoor environment. This can be achieved through sustainable air conditioning energy consumption methods such as the study of (et al., 2021) or by meeting established standards set by entities and international organizations specializing in relevant fields, such as (Jegede, O.E et al.). Additionally, other goals pertain to the economic aspect and aim to provide affordable housing for specific groups in society. These goals require targeted intervention mechanisms to ensure economic sustainability.

The methodology used in all research oscillated between using the descriptive survey method such as (Alshahrani, A et al, 2023), which relies on describing and surveying the study problem from a theoretical perspective only, and applying survey studies from the reality of the field by collecting information, some research also utilized the descriptive analytical approach such as (Ali, H.H et al, 2017). This approach involved analyzing the data collected from the field in relation to the agreed-upon standards outlined within each researcher's study objectives. Additionally, certain studies (Wu et al, 2017) incorporated the steps of the experimental method alongside the aforementioned methodologies, albeit as an optional component.

For the study community, studies have been conducted in various Arab countries, such as Egypt and Jordan (Soliman, S et al, 2022), as well as in several Southeast Asian and African countries (Mulenga, D et al.). It was essential to identify the architectural elements that directly impact the building's performance and its relation to the surrounding environment.

When shedding light on the sample, which is considered an example of the study community, it is found that all studies relied on intentionally cropping the sample. This involved classifying relevant and influential variables in relation to the main objectives of the researchers.

influential variables in relation to the main objectives of the researchers.

While the study tools varied in their entirety during the personal interviews, some were not included in the research appendices and may be included as separate documents in scientific journals. These documents would then be kept in the journal's archives independently. Others utilized observation cards to collect information, such as (Masoso, O.T et al.), intending to monitor data related to the research problem and current housing projects, among other things. It was found that certain studies did not limit themselves to using just one tool for data collection (Ali, H.H. et al., 2017). Instead, they sought to enhance the study's level of strength by employing multiple tools. While questionnaires were commonly used as supporting tools in most studies, some relied entirely on questionnaires (Soliman, S et al, 2022).

From the previously reviewed research, it is concluded that although efforts intersected with particular elements, the differences were clearly greater. Therefore, this article aims to present and collect the differences in a single body of work in order to participate in the general knowledge field of affordable energy-efficient residential units.

3. Methodology

1. To accomplish the first objective of this study, the following methods will be employed:

- Collect chronological growth data, including the year of construction and the location of (AMH), from the Ministry of Municipal & Rural Affairs & Housing (MOMRAH).
- Conduct an analytical study using an observation card to identify architectural characteristics related to (CEC). These characteristics include the number of stories, facade area, window-to-wall ratio, average area attached to the facade, facade finishing materials, and building construction materials, which will be compiled in a table for locations across the city of Jeddah.

2. To fulfill the second objective of this study, the following methods will be used:

- Developing a 3D generic model using IDA Ice to measure the thermal properties of the architectural envelope of (AMH).
- 3D generic models of typical residential units in Jeddah using IDA Ice to measure the thermal properties and (CEC) of existing (AMH).

3. To achieve the third objective of this study, the following methods will be employed:

- An analytical comparative study will be conducted to consolidate the collected data and properties of (AMH), classifying them into three types.
- Selecting a baseline generic model based on the results of the comparative study.

4. To meet the fourth objective of this study, the following methods will be used:

- Configure three different material settings in a simulation over the course of one year, representing all four seasons. This simulation aims to identify the optimal material combination.

4. Affordable Housing Historical Time-Line

To accomplish the initial part of the first objective, a chronological study was mandatory to identify the current state of (AH) regarding the city of Jeddah.

In the late 1970s, the South Social Housing project was introduced, marking the inception of governmental social housing in Saudi Arabia. This project provided housing for more than 10,000 residents. In the same year, the Al-Sharafyah Social Housing project was completed, comprising 32 residential buildings spanning 17 floors and accommodating around 16,000 residents, including 2,800 families. These initiatives laid the foundation for subsequent affordable housing projects (Al-Harthi, H, 2015). During the 2000s and early 2010s, various strategic plans were executed, including introducing loans and governmental support. These initiatives account for the significant evolution in affordable housing projects during this period (Saudi Real Estate Development Fund, n.d.). The Ministry of Municipal and Rural Affairs of Saudi Arabia is actively committed to expanding housing unit production nationwide. To achieve this goal, it has engaged 653 real estate developers in housing

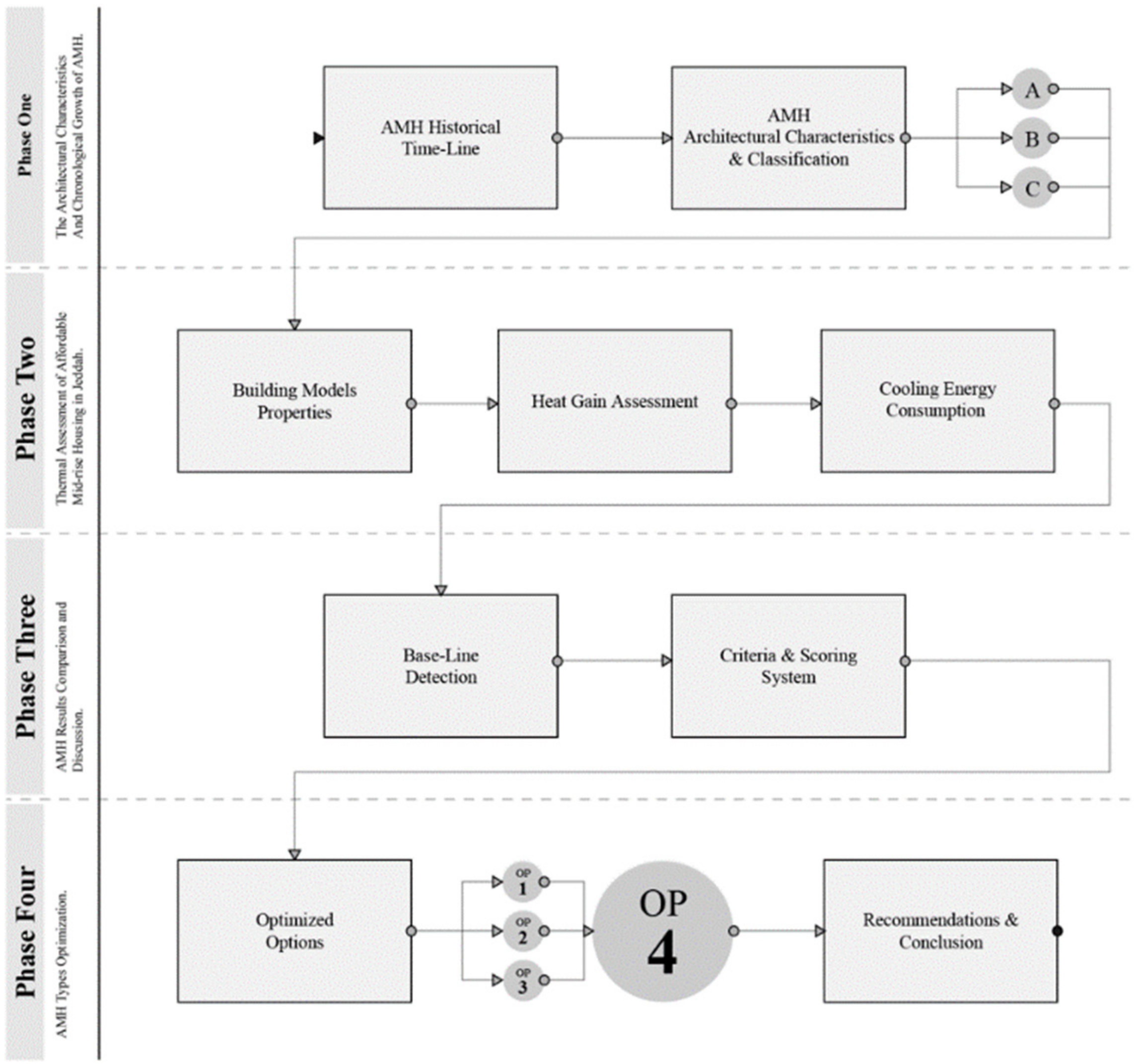


Figure (1). Methodology Flow Diagram

projects to provide affordable options. This endeavor is pivotal in enhancing access to quality, affordable housing for all Saudi citizens (Wafi Platform, n.d.). Turning our attention to the current real estate development efforts in Jeddah, the city is witnessing the implementation of over 15 housing projects between 2019 and 2023, spread across its northern, southern, and eastern areas. Below is a list of the ongoing projects:

1. Rawabi Alhejaz
2. Khayala Suburban
3. Khayala (Al-Muhannadiah) Housing
4. Khayala (Samaa Jeddah) Housing
5. A'aly Jeddah
6. Obhur Park
7. Al-Jawharah
8. Venan Housing
9. Bouvardia City
10. Mojan Village Housing
11. Dari Q Housing
12. Al-Tahlia Gate Housing
13. Jeddah Gardens
14. Mayar Suburb
15. Telal Al-Ghoroub Housing

5. Architectural Characteristics and Classification of (AMH)

5.1 Architectural Characteristics

To fully accomplish the first objective of the study, a field visit was carried out to investigate the architectural features of (AMH), as identified in the earlier stages of the research. The primary objective of this phase was to collect essential data using an observation card to ensure the precision of the simulation. Research tasks encompassed assessing building height and the number of floors, Window Wall Ratio, areas exposed to direct and indirect sunlight, average areas attached to the main facade, building materials, and finishes, and the types of cooling systems in use. This on-site examination was crucial for obtaining real-world insights into the physical attributes of (AMH), providing a solid foundation for accurate simulation outcomes.

5.2 Observation Card Results

After collecting field data, the researchers translated this information into technical data suitable for simulations and further research. The subsequent analysis aimed to evaluate the influence of natural factors in Jeddah on the thermal performance of the (AMH) projects. This comprehensive examination facilitates an assessment of the effectiveness of the outer envelope in mitigating or responding to local environmental conditions. The results of this analysis contribute valuable insights into optimizing thermal efficiency and enhancing the overall performance of these housing projects (Table 1).

Classification

It's mandatory to classify and categorize (AMH) projects in Jeddah based on their current status. This classification is crucial for conducting simulations and generating results applicable to many housing models in the city. The technical details of these projects can also be utilized to forecast future outcomes before implementation. The researchers have classified seven field-surveyed projects into three classes, as outlined in Table 2.

6. Thermal Assessment of (AMH) in Jeddah

6.1 Building Models Properties

After categorizing the projects into A, B, and C classes as shown in Table 3,4, and 5, the subsequent step to complete the initial part of the second objective involves establishing a database for the technical data of each class. This data is the foundation for developing preliminary generic models that observe the amount of heat gain absorbed by the outer envelope. These generic models assist in determining the worst-case scenario for a single unit, serving as the fundamental simulation model in the (CEC) simulation. Analyzing its specifics allows for the measurement of its impact on various factors, including occupants, electrical appliances, and the HVAC system. The outer envelope components will be specifically investigated by the use of three generic models representing (AMH). Additionally, the effects of various building material options available in the markets of Jeddah and Saudi Arabia will be considered.

6.2 Heat Gain Assessment

Following the compilation of technical data from existing classifications, the researchers will embark on the initial stage of the simulation. The primary goal of this simulation is to identify the (AMH) unit within each classification experiencing the highest heat gain through the outer envelope, particularly from direct and indirect sunlight. In theory, excessive heat gain could elevate temperatures within the building throughout the day, posing challenges for HVAC systems to operate optimally. Consequently, these systems may consume more operational energy and run for extended periods.

Table (1). Jeddah city (AMH) Architectural Characteristics

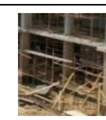
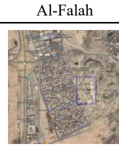
				Architectural Characteristics					
	Project Name	Year	District	Number of Stories	Façade Area	Window to wall ratio	Average Area Attached to the Facade	Facade Finishing Materials	Building Construction Material
1	South Social Housing	1977	 Prince Abdul Majeed	8	Total Area: 1152 m² Floor Area: 144 m²	Solid: 88.01% Void: 11.98% Ratio: 1.2:8.8	Per unit: Total Area: 200 m² Attached Area: 146.19 m²	Count: 2 Material: (Stone Grit/Chips) (Paint)	*N/A*
2	Al-Sharafyah Social Housing	1978	 Al-Sharafyah	17	Total Area: 2448 m² Floor Area: 144 m²	Solid: 84.66% Void: 15.33% Ratio: 1.5:8.4	*N/A*	Count: 2 Material: (Stone Grit/Chips) (Paint)	*N/A*
3	A'aly Jeddah	2023	 Prince Abdul Majeed	7	Total Area: 760 m² Floor Area: 119 m²	Solid: 88.27% Void: 11.72% Ratio: 1.1:8.8	Total Area: 589.9 m² Attached Area: 363.9 m²	Count: 1 Material: (Sand Spray)	 -Cement Block -Cement Plaster
5	Al-Jawharah Residence	2022	 Al-Jawharah Suburban	8	Total Area: 1296 m² Floor Area: 162 m²	Solid: 82.75% Void: 17.24% Ratio: 1.7:8.2	*N/A*	Count: 1 Material: (Sand Spray)	 -Cement Block -Cement Plaster
6	Venan	2021	 Al-Jawharah Suburban	8	Total Area: 579.45 m² Floor Area: 72.43 m²	Solid: 81.44% Void: 18.55% Ratio: 1.8:8.1	Per unit: Total Area: 90 m² Attached Area: 62 m²	Count: 2 Materials: (White Paint) (Wood Alternative)	 -Cement Block -Cement Plaster
7	Bouvardia	2020	 Al-Jawharah Suburban	9	Total Area: 1296 m² Floor Area: 144 m²	Solid: 88.77% Void: 11.22% Ratio: 1.1:8.8	*N/A*	Count: 1 Material: (Sand Spray)	 -Reinforced Precast Concrete Walls
8	Sama'a Jeddah	2021	 Al-Falah	7	Total Area: 756 m² Floor Area: 108 m²	Solid: 87.65% Void: 12.34% Ratio: 1.2:8.7	Per unit: Total Area: 135.24 m² Attached Area: 73 m²	Count: 2 Materials: (Graphito) (Gypsum Ornaments)	*N/A*
10	Rawabi Alhejaz	2019	 Al-Rayan	13	Total Area: 2246.7 m² Floor Area: 172.8 m²	Solid: 74.05% Void: 25.94% Ratio: 2.6:7.4	Per unit: Total Area: 130 m² Attached Area: 111 m²	Count: 1 Material: (Paint) (Gypsum Ornaments)	 -Cast-on-Site Concrete Walls
11	Dari Q	*TBA*	 Al-Salamah	9.5	Total Area: 1701 m² Floor Area: 162 m²	Solid: 55.22% Void: 44.77% Ratio: 4.4:5.5	*N/A*	Count: 2 Materials: (White Paint) (Stone Cladding)	 -Yet to Be Constructed

Table (2). Jeddah city (AMH) Projects Classification

Class	**Class (A):** Pre-cast wall (non-Insulated)			**Class (B):** Pre-cast wall with Polyurethane Foam Insulation	**Class (C):** Cement Block with EPS Insulation		
Project	South Social Housing	Al-Sharafyah Social Housing	Rawabi Alhejaz	Bouvardia	A'aly Jeddah	Al-Jawharah Residence	Venan
Envelop Material	- Fast Co. Applied Precast Concrete Walls		- Cast-on-Site Walls	Reinforced Precast Walls	Cement Block/Cement Plaster		
Façade Finishing	- (Stone Grit/Chips) (Paint)		- (Paint) (Gypsum Ornaments)	(Sand Spray)	(Sand Spray)	(Sand Spray)	(White Paint) (Wood Alternative)

Type (A) Building Model

The absence of insulation and the exclusive reliance on precast walls pose significant obstacles for this model (Table 3).

Simulation Result Data: Figure (5).

Type (B) Building Model

Researchers posit that unit symmetry could mitigate challenges related to orientation and building height, both considered key factors. It was observed that the presence of average-sized windows facing outward may limit the heat acquired through them (Table 4).

Simulation Result Data: Figure (6).

Type (C) Building Model

In the latest model, a disparity in the sizes of housing units has been identified, posing a threat to units located in the western direction due to the length of their sides. Additionally, an increase in the thickness of the building walls has been observed (Table 5).

Simulation Result Data: Figure (7)

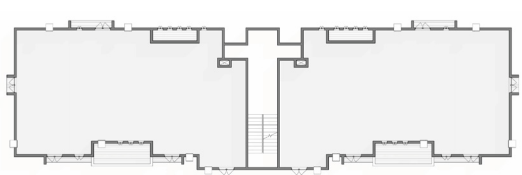


Figure (2). Type (A) Building Outline

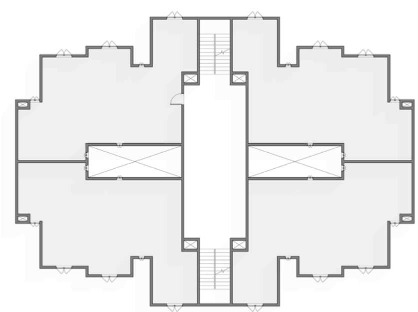


Figure (3). Type (B) Building Outline

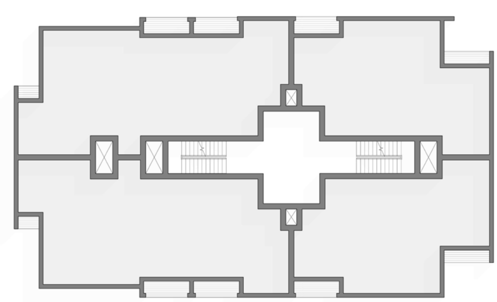


Figure (4). Type (C) Building Outline

After analyzing data for three classifications, researchers determined that units exposed to heat gain were more prevalent on the higher floors of the building. In class A, the eastern unit on the seventh floor exhibited a total (EC) of 17,910.1 kWh, with external walls contributing 7,334.2 kWh (40.9%) and windows contributing 10,575.9 kWh (59.04%). For classification B, the southeastern unit on the eighth floor showed a total (EC) of 9,781.5 kWh, with external walls contributing 4,829.7 kWh

Table (3). Type (A) Model Properties

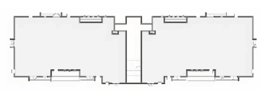
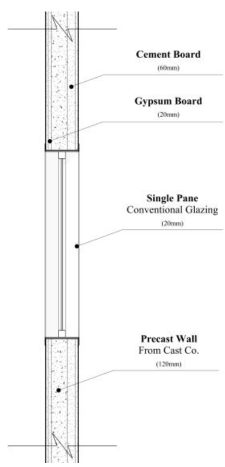
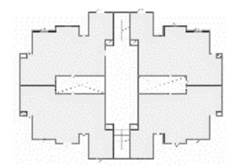
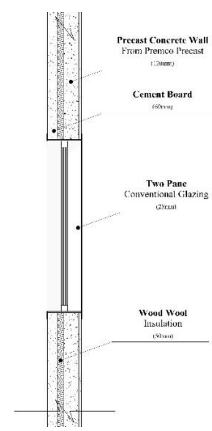
Type	Building Element	Current Construction Layer		Thickness (mm)	U Value (W/m2K)
(A)	Walls (External)	Layer 1	*Cement Board*	60	17.4
		Layer 2	*Concrete Wall*	120	8.7167
		Layer 3	*Gypsum Board*	20	32.5
	Glazing	Layer 4	*Single Pane*	20	5.8
	Wall Finish	Outer Surface	*Beige linoleum*	2	**Sortwave Reflection** 0.504
		Inner Surface	*White Paint (Semi-Glossy)*	2	0.847
	Total			**224**	**4.1478**
	WWR	01:06			
	Façade Alligned Spaces	146.19 m^2			
	Outline Layout				
	Wall Detail				

Table (4). Type (B) Model Properties

Type	Building Element	Current Construction Layer		Thickness (mm)	U Value (W/m2K)
(B)	Walls (External)	Layer 1	*Cement Board*	60	17.4
		Layer 2	*Wood Wool*	50	0.46
		Layer 3	*Concrete Wall*	120	8.71
	Glazing	Layer 4	*Two Pane*	28	2.9
	Wall Finish	Outer Surface	*Beige linoleum*	2	**Sortwave Reflection** 0.504
		Inner Surface	*White Paint (Semi-Glossy)*	2	0.847
			Total	**274**	**0.4263**
	WWR	01:08			
	Façade Alligned Spaces	83.79 m^2			
	Outline Layout				
	Wall Detail				

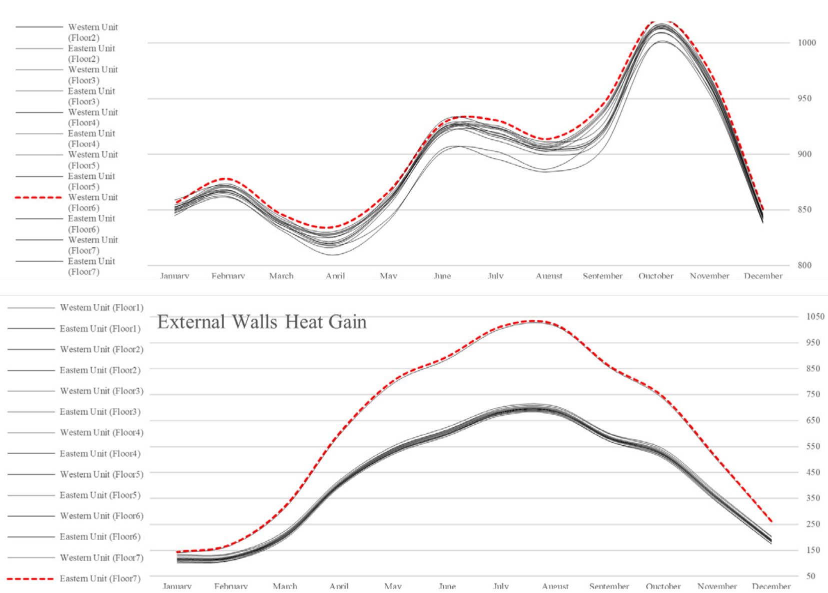


Figure (5). Type (A) Model HG Results

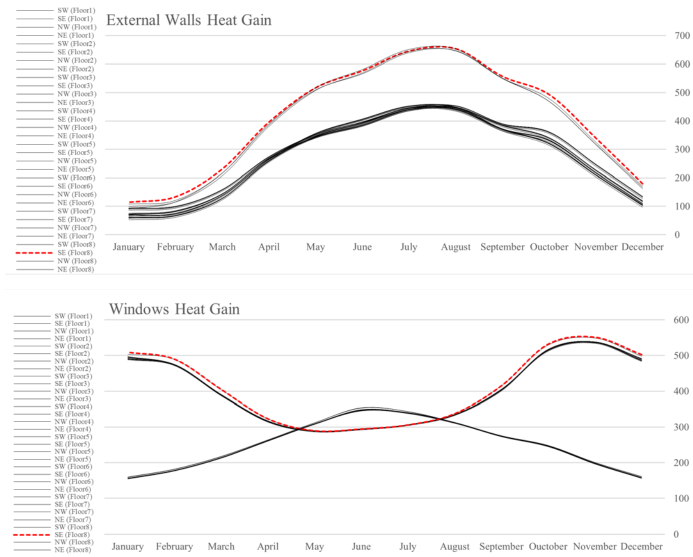
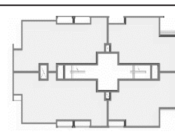
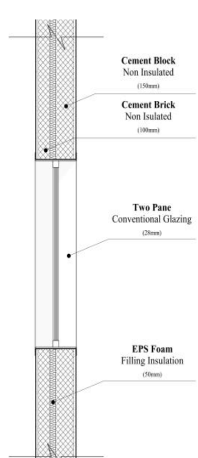


Figure (6). Type (B) Model HG Results

Table (5). Type (C) Model Properties

<table>
<tr><th rowspan="2">Type</th><th rowspan="2">Building Element</th><th colspan="2">Current Construction Layer</th><th>Thickness</th><th>U Value</th></tr>
<tr><th>(mm)</th><th>(W/m2K)</th></tr>
<tr><td rowspan="13">(C)</td><td rowspan="3">Walls (External)</td><td>Layer 1</td><td>Cement Block</td><td>150</td><td>8.66</td></tr>
<tr><td>Layer 2</td><td>EPS Insulation</td><td>50</td><td>0.7</td></tr>
<tr><td>Layer 3</td><td>Cement Brick</td><td>100</td><td>13</td></tr>
<tr><td>Glazing</td><td>Layer 4</td><td>Two Pane</td><td>28</td><td>2.9</td></tr>
<tr><td rowspan="4">Wall Finish</td><td rowspan="2">Outer Surface</td><td rowspan="2">Beige Paint</td><td rowspan="2">2</td><td>Sortwave Reflection</td></tr>
<tr><td>0.504</td></tr>
<tr><td rowspan="2">Inner Surface</td><td>White Paint (Semi-Glossy)</td><td>2</td><td>0.847</td></tr>
<tr><td>Total</td><td>344</td><td>0.6169</td></tr>
<tr><td>WWR</td><td colspan="4">01:05</td></tr>
<tr><td>Façade Alligned Spaces</td><td colspan="4">62 m²</td></tr>
<tr><td>Outline Layout</td><td colspan="4"></td></tr>
<tr><td>Wall Detail</td><td colspan="4">
</td></tr>
</table>

(49.37%) and windows contributing 4,951.8 kWh (50.62%). In classification C, the southwestern residential unit on the eighth floor recorded the highest consumption of 20,104.7 kWh, with external walls contributing 3,690 kWh (18.35%) and windows contributing 16,414.7 kWh (81.64%).

Overall, units on the upper floors experienced higher heat gain due to increased exposure to direct sunlight. Researchers emphasized the need for proper insulation in ceilings to address this issue. Moving forward, researchers will create a database based on standard specifications to simulate internal factors affecting Saudi families and their physiological needs. This database will be utilized during simulations for accurate data collection and analysis.

2.3 (CEC): Having identified the necessary (AMH) units for their study, researchers proceed to examine internal details and factors affecting them. Due to the unique social conditions and physiological needs of Saudi families, various considerations arise. In preparation for the simulation process and in order to fulfill the second objective of the study, a standard specification-based database must be created, incorporating data obtained through field surveys and literature reviews. This database should encompass relevant information regarding leisure time and acceptable usage hours of spaces. Following the completion

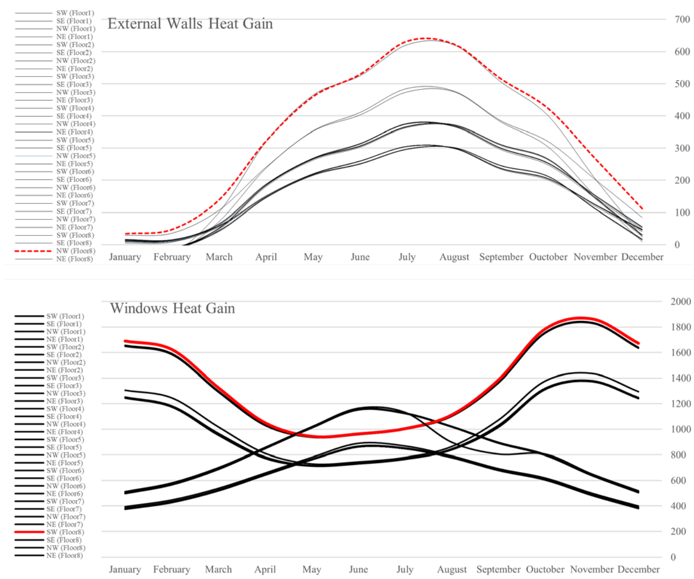


Figure (7). Type (C) Model HG Results

of the database, researchers can proceed with simulations, applying the designated method and utilizing the database as needed.

Appliances Properties: Table (6)

User Profile: Table (7)

Window Scheduling: Table (8)

Table (6). Model Appliances Specifications

Num	Gadget	Location	Emitted Heat per Unit	Scheduling
1	T.V	Living Room	150 W	7-8 17-20 (Everyday) 9-20 (Saturday, Friday and Holidays)
2	Computer	Bedrooms	100 W	7-8 17-20 (Everyday) 9-20 (Saturday, Friday and Holidays)
3	Washer/Dryer	Laundry Room	1140 W	9-11 (Saturday)
5	Clothing Iron	Laundry Room	1100 W	9-11 (Saturday)
6	Stove	Kitchen	3000 W	7-8 17-20 (Everyday)
7	Refrigerator	Kitchen	180 W	Always On

Table (7). Model User Profile Specifications

Num	Space	Occupants	Activity Level	Scheduling
1	Kitchens	1	2.25 MET	7-8 17-20 (Everyday)
2	Living Rooms	4	1.20 MET	6-8 17-20 (Business Days) 9-20 (Holidays and Weekends)
3	Master Bedrooms	2	1.00 MET	0-6 21-24 (Everyday)
4	Regular Bedrooms	2	1.00 MET	0-6 21-24 (Everyday)
5	Guest Rooms	6	1.20 MET	13-19 (Holidays and Weekends)
6	Laundry Rooms	1	2.25 MET	9-11 (Saturday)
7	Dining Room	6	1.20	13-19 (Holidays and Weekends)

Type (A) Unit (CEC)

This model comprises three bedrooms, a kitchen with a living room, a dining room, a guest sitting room, and three bathrooms. It’s noteworthy that Type A receives more sunlight exposure than the other study models.

CEC Percentage:

In August, the CEC increased to 18212 kWh, whereas in February, the (EC) decreased to 7979.3 kWh.

Table (8). Model Window Scheduling Specifications

Num	Space	Fraction Of the total area	U-Value W/m2K	Scheduling
1	Kitchens	0.1	2.0	7-8 17-20 (Everyday)
2	Living Rooms			7-8 17-20 (Business Days) 9-20 (Holidays and Weekends)
3	Master Bedrooms			6-9 17-20 (Everyday) 9-20 (Holidays and Weekends)
4	Regular Bedrooms			
5	Guest Rooms			9-11 (Saturday)
6	Laundry Rooms			
7	Dining Room			

Figure (8). Type (A) Floor Plan

Table (9). Type (A) Model CEC Results

Current Situation		
Month	CEC	Total
1	2021.8 (46%)	4392.4
2	1859.9 (46%)	4019.7
3	2477.2 (51%)	4817.5
4	3637.3 (62%)	5855.3
5	4699.2 (67%)	6993
6	5643.9 (72%)	7863.3
7	5812.2 (72%)	8101.4
8	6388.8 (74%)	8682.7
9	5843.6 (72%)	8060.6
10	5416 (70%)	7713.6
11	3582 (62%)	5801.3
12	2311.3 (50%)	4625
	49693.2 (65%)	76925.8

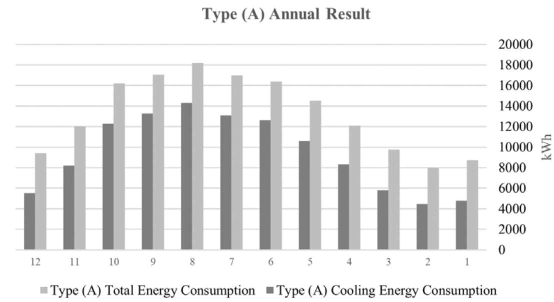


Figure (9). Type (A) Model Annual Results

Type (B) Unit (CEC)

This model comprises two bedrooms, a kitchen, a laundry room, a storage unit, a living area, a guest sitting room, and two bathrooms. However, four dwelling units are on each level, which could reduce sunlight exposure.

Figure (10). Type (B) Floor Plan

CEC Percentage:

The results of Model A and Model B show a noticeable divergence, attributed to the absence of exposed spaces to the facade, the use of wood wool insulation on the walls, and the implementation of double glazing on the windows.

Table (10). Type (B) Model CEC Results

Current Situation		
Month	CEC	Total
1	4793 (55%)	8713
2	4437.3 (56%)	7979.3
3	5822 (60%)	9747
4	8305 (69%)	12089
5	10592 (73%)	14512
6	12621 (77%)	16415
7	13076 (77%)	16993
8	14287 (78%)	18212
9	13284 (78%)	17076
10	12275 (76%)	16197
11	8206 (68%)	12006
12	5515 (58%)	9428
Median	113213.3 (71%)	159367.3

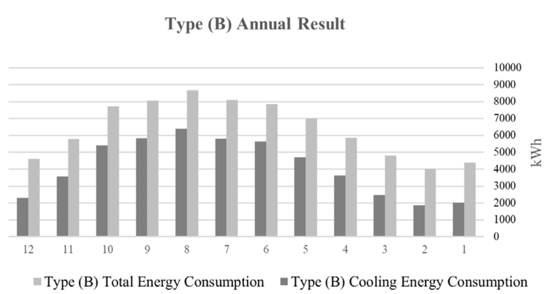


Figure (11). Type (B) Model Annual Results

Type (C) Unit (CEC)

Model C comprises three bedrooms, a maid's room, a kitchen, a laundry room, four bathrooms, a living room, a guest sitting room, and a dining room. Notably, its walls are thicker than those of the other models, owing to the use of double layers of construction materials.

CEC Percentage:

(EC) fluctuated, reaching a peak of 8106.2 kWh in August and a minimum of 4116.2 kWh in February. This variation can be primarily attributed to the effective EPS insulation implemented within the wall, coupled with the use of a coarse sand outer layer spray.

Figure (12). Type (C) Floor Plan

Table (11). Type (C) Model CEC Results

Current Situation		
Month	CEC	Total
1	2044.3 (45%)	4505.5
2	1894.4 (46%)	4116.2
3	2565.9 (51%)	5030.2
4	3693.8 (61%)	6068.5
5	4452.1 (64%)	6916.4
6	5084.4 (68%)	7468.2
7	5386.8 (69%)	7842
8	5641.9 (70%)	8106.2
9	5253.4 (69%)	7631.2
10	5003.1 (67%)	7464.4
11	3581.1 (60%)	5964.9
12	2520.8 (51%)	4976
	47122 (62%)	76089.7

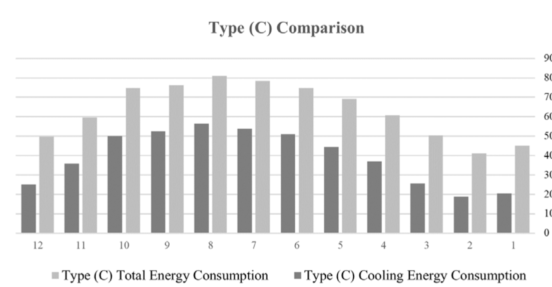


Figure (13). Type (C) Model Annual Results

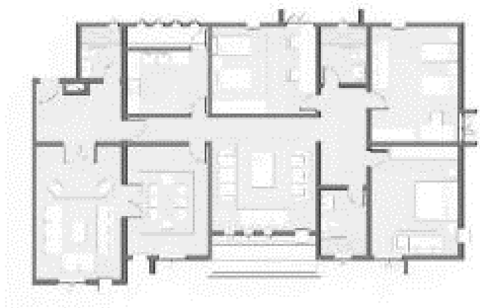


Figure (14). Type (A) Floor Plan

Figure (15). Type (B) Floor Plan

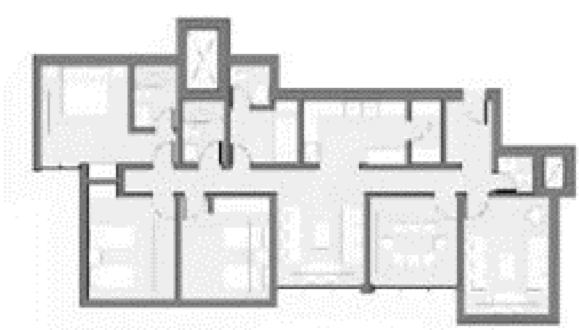


Figure (16). Type (C) Floor Plan

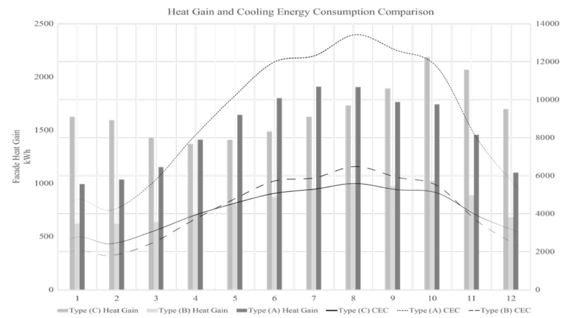


Figure (17). HG and CEC Comparison

In the process of achieving the third objective of the study, and after analyzing all the findings, we have concluded that heat gain and (EC) for cooling are positively correlated. As the building absorbs more heat, the air conditioning units must work harder and consume more energy to maintain a comfortable indoor environment for human occupancy. Keeping this in mind, our team will construct various models that accurately reflect the existing conditions of mid-rise affordable housing projects. Our goal is to provide enhanced specifications that will improve the energy efficiency of these structures, ultimately reducing overall (EC). After comparing the previous results, researchers should propose solutions based on the current situation. These proposals should primarily address thermal performance. To obtain models that accurately depict reality, researchers must rely on specific research determinants. These determinants contribute to the process of sorting and arranging proposals, as follows:

Scoring Mechanism:

Table (12). Current Situation Comparison

Unit	**Area**	**Parameter**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Annually (kWh)**	**/ Area (kWh)/ m²**
Type (A)	208 m²	Electric Cooling	*4688*	*4330.1*	*5680*	*7984*	*10074*	*11868*	*12199*	*13269*	*12479*	*11631*	*7931*	*5388*	**107‚521**	**516.92**
Type (B)	121 m²	Electric Cooling	*2038.9*	*1876.9*	*2497.2*	*3655.3*	*4719.2*	*5662.9*	*5834.2*	*6409.8*	*5866.6*	*5440*	*3608*	*2332.3*	**49‚941.3**	**412.73**
Type (C)	170 m²	Electric Cooling	*2691.4*	*2473.5*	*3078*	*3881.9*	*4508.3*	*5030.6*	*5253.9*	*5537.1*	*5227.5*	*5059.3*	*3892.3*	*3057.9*	**49‚691.7**	**292.3**

(AMH) Comparison:

Table (13). Scoring System Mechanism

Num	Criteria	Discerption	Measuring Unit	Low	Below-Med	Medium	Above-Med	High
1	Availability	An initial survey of the labor market is conducted to determine the availability of materials used locally, and the possibility of providing them from external sources is evaluated based on repetitions.	(%)	0% - 20%	21% - 40%	41% - 60%	61% - 80%	81% - 100%
2	Initial Cost	Examples of local companies that implement these systems are seen at a certain price for packages that include a comprehensive implementation plan.	(SAR/m^2)	0 - 200	201 - 400	401 - 600	601 - 800	801 - 1000
3	Installation	The time required for implementation and the ease of including systems in the general framework of projects are studied.	(Hours/m^2)	0 - 4	4.1 - 8	8.1 - 12	12.1 - 16	16.1- 20
4	Durability	The study determines how well materials can withstand external and internal factors over time, as the life span of projects may vary.	(Years)	1 - 20	21 - 40	41 - 60	61 - 80	81 - 100
5	Wall Thickness	The proposed options' effect on the quality of the architectural space is measured. Increasing wall thickness reduces the available interior space.	(mm)	100 - 150	151- 200	201 - 250	251 - 300	301 - 350
6	U-Value	Finally, thermal performance significantly affects the quality and sustainability of buildings over time, ultimately influencing the quality of life for Saudi families and society as a whole.	(m^2*K)	0 – 0.30	0.31 – 0.60	0.61 – 0.90	0.91 – 1.2	1.21 - 3

7.Results

To fulfil the final objective of the study, it was mandatory to showcase the simulation results.

7.1 Option 1: A traditional Exterior Wall, as shown in Type (C) (Table 5), was used and insulated by an Infiltration Cavity with a width of 50mm, while the traditional Cement Block was replaced with a Clay Block.

Properties: Table 14

Simulation Result (Comparison): Table 15, 16

Data Analysis: Figure 18

In this option (as shown in the figure below), the total (EC) decreased by 31%, amounting to 23279 kWh. (CEC) accounted for 23912.4 kWh, leading to a 17% reduction in the (CEC) percentage from the current consumption situation.

Observation:

Using clay blocks introduces infiltration gaps that play a vital role in reducing heat transmission through conduction and hindering radiant heat. Incorporating EPS insulation within the inner gap extends the duration for heat to travel from the inner facade to the building's interior. While an infiltration barrier can be implemented between the inner and outer layers to accommodate plumbing and electrical systems, it may also lead to an expansion of wall thickness. This factor should be carefully considered during the architectural design process. Implementing an inner layer of cement bricks may deter a significant amount of

Table (14). Option 1 Specifications

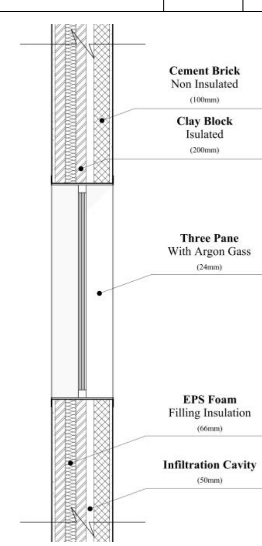
Building Element	Current Construction Layer		Thickness (mm)	Value (W/m2K)
Walls (External)	Layer 1	Insulated Clay Block	150	0.62
	Layer 2	Infiltration Cavity	50	1.2
	Layer 3	Cement Brick	100	13
Glazing	Layer 4	Three Pane *with Argon Gas*	24	1
Wall Finish	Outer Surface	White Paint (Matt)	2	**Sortwave Reflection** 0.892
	Inner Surface	White Paint (Semi-Glossy)	2	0.847
Total			**304 mm**	**0.3322 W/m2K**
Wall Detail				

Table (15). Option 1 Optimization Summary

Current Situation		Optimized Trail	
CEC	Total	CEC	Total
2044.3 (45%)	4505.5	1243.9 (34%)	3699.1
1894.4 (46%)	4116.2	1129.1 (34%)	3345.9
2565.9 (51%)	5030.2	1444.7 (37%)	3903
3693.8 (61%)	6068.5	1882.9 (44%)	4252.6
4452.1 (64%)	6916.4	2282.4 (48%)	4740.7
5084.4 (68%)	7468.2	2422.6 (50%)	4800.4
5386.8 (69%)	7842	2786.2 (53%)	5235.4
5641.9 (70%)	8106.2	2735.8 (53%)	5194.1
5253.4 (69%)	7631.2	2390.2 (50%)	4762
5003.1 (67%)	7464.4	2367.9 (49%)	4823.1
3581.1 (60%)	5964.9	1794.4 (43%)	4172.2
2520.8 (51%)	4976	1432.3 (37%)	3881.5
47122 (62%)	**76089.7**	**23912.4 (45%)**	**52810**

Table (16). Option 1 Optimization Comparison

	Current	Optimized	Reduction	Percentage
Total Energy Reduction	76089.7	52810	*23279.7*	31 %
CEC Reduction	47122	23912.4	*23209.6*	17 %

heat, as cement has the ability to absorb and hold it for extended periods, releasing it at night when it poses no issue. Overall, these optimized envelope components have positive impacts, protecting the indoor space and enhancing the performance of the AC system. This ultimately minimizes the compressor's operating time to maintain ideal temperatures, satisfying user comfort.

Criteria Fitting:

In 2023, SmallProjects.org compiled a list of clay and cement block manufacturers in Saudi Arabia, revealing over 20 specialized factories. The highest concentration is in the Mecca region, constituting 30% of the total, with six factories currently operating. Jeddah has four factories, accounting for 20% of the total, indicating a high demand for this construction material that caters to various customer preferences.

To construct a one-square-meter wall using 12.5 insulated clay blocks and cement blocks, the cost of clay blocks must adhere to Ministry of Commerce regulations, priced at least 2600 SR per 1000 blocks, equivalent to 2.6 SR per block. A one-square-meter wall using clay blocks would cost approximately 32.5 SR, excluding additional labor costs. Alternatively, a cement brick costs around 1.35 SR per block, resulting in a one-square-meter wall cost of roughly 16.875 SR. Therefore, the total cost for option 1 would amount to 49.375 SR for a one-square-meter wall without additional labor costs.

Buildingmaterials.co.uk reports that a construction worker can lay approximately 500 blocks per day. Constructing a one-square-meter area consisting of two layers of clay and cement blocks would require approximately 1.2 hours per worker.

According to JUWO Proton, structures built with clay blocks usually last for an average lifespan of 100 years while requiring minimal maintenance, thereby lowering upkeep costs.

Table 14 indicates that this particular option has a total wall thickness of 304mm.

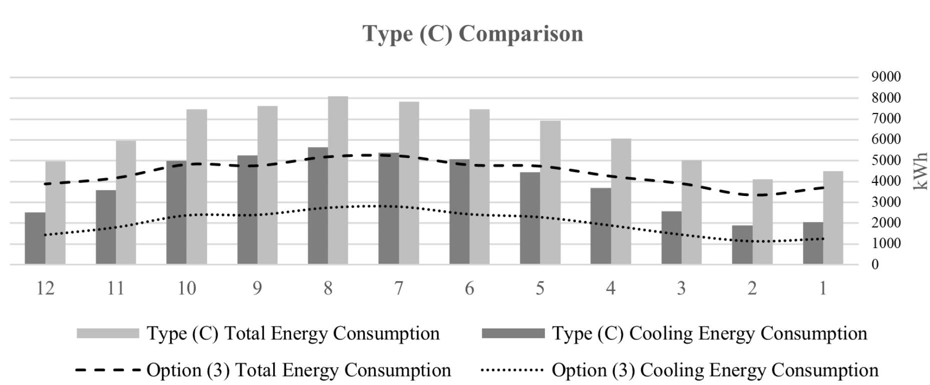


Figure (18). Type (C) Comparison Chart

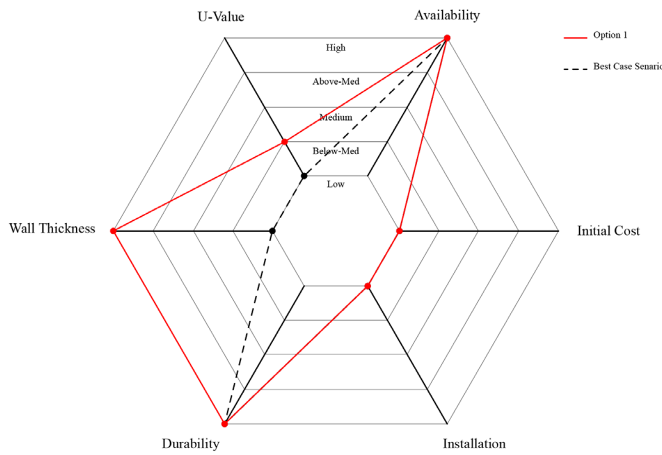


Figure (19). Option 1 Criteria Radar Chart

7.2 Option 2: A traditional Precast Wall as showed in Type (A) was replaced by RapidWall cast-on-site walls from Sakann SA, and was insulated with a filling of 20MPa Concrete with a thickness of 94mm.

Properties: Table 17

Simulation Data: Table 18

Comparison: Table 19, Figure 20

In this option (as shown in the figure below), the total (EC) decreased by 23%, totaling 36142.8 kWh, with (CEC) accounting for 76477.5 kWh. This led to a 9% reduction in the (CEC) percentage compared to the current situation consumption.

Table (17). Option 2 Specifications

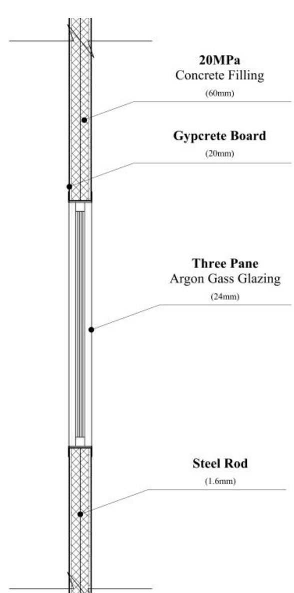
Building Element	**Current Construction Layer**		**Thickness** *(mm)*	**U Value** *(W/m2K)*
Walls (External)	Layer 1	*Gypcrete*	15	0.72
	Layer 2	*20MPa Concrete*	94	1.66
	Layer 3	*Gypcrete*	15	0.72
Glazing	Layer 4	Three Pane *with Argon Gas*	24	1
Wall Finish	Outer Surface	*White Paint (Matt)*	2	**Sortwave Reflection** 0.892
	Inner Surface	*White Paint (Semi-Glossy)*	2	0.847
Total			**128 mm**	**2.7777 W/m2K**
Wall Detail				

Table (18). Option 2 Optimization Summary

Current Situation		**Optimized Trail**	
CEC	Total	CEC	Total
4793 (55%)	8713	3282.7 (45%)	7252.7
4437.3 (56%)	7979.3	3021.5 (46%)	6609.5
5822 (60%)	9747	4063.1 (51%)	8039.1
8305 (69%)	12089	5767 (60%)	9599
10592 (73%)	14512	7364.9 (65%)	11334.9
12621 (77%)	16415	8393.5 (69%)	12236.5
13076 (77%)	16993	9009.5 (69%)	12976.5
14287 (78%)	18212	9579 (71%)	13555
13284 (78%)	17076	8519.9 (69%)	12360.9
12275 (76%)	16197	8032.6 (67%)	12005.6
8206 (68%)	12006	5610 (59%)	9459
5515 (58%)	9428	3833.8 (49%)	7795.8
113213.3 (71%)	**159367.3**	**76477.5 (62%)**	**123224.5**

Table (19). Option 2 Optimization Comparison

	Current	**Optimized**	**Reduction**	**Percentage**
Total Energy Reduction	159367.3	123224.5	*36142.8*	23
CEC Reduction	113213.3	76477.5	*36735.8*	9

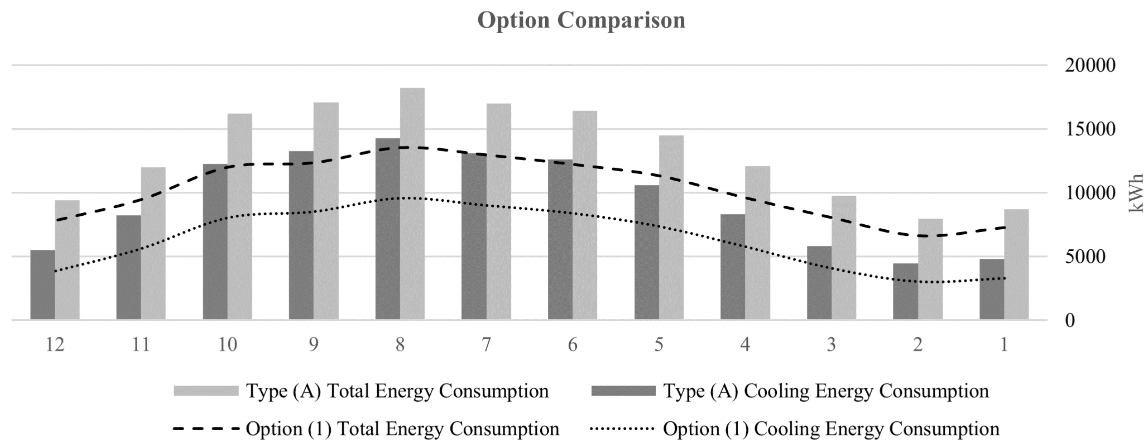


Figure (20). Type (A) Comparison Chart

Data Analysis: Figure 20

Observation:

The researcher suggests considering Rapid Wall as an alternative to the current precast system, given its increasing popularity in the construction industry. Rapid Wall's gypcrete vessel exhibits a lower energy embodiment by 61.5% compared to traditional precast panels, making it more heat-resistant. Additionally, it reduces cement usage by 50.8% and features an inner chamber that can serve as an infiltration barrier for plumbing and electrical systems.

The incorporation of insulation into the panels further improves thermal performance, reducing heat gain. The use of Rapid Wall has the potential to cut costs in various areas. However, the availability of manufacturers may pose a challenge as it is a growing industry. Overall, Rapid Wall holds promise for making mid-rise affordable housing more cost-efficient while ensuring comfortable indoor temperatures.

Criteria Fitting:

During the research process, obtaining Rapid Wall within the city of Jeddah proved challenging, with more than three providers, including Sakann SA, Rapid Building Construction CO, and Modern Maj Contracting Est., not found.

Sakann SA stated that the initial cost for a 143 m2 unit would be 26,800 USD, equivalent to 100,500 in Saudi riyals. Therefore, the initial cost

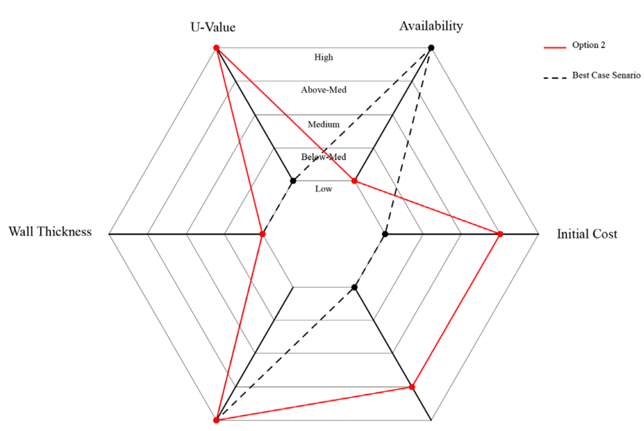


Figure (21). Option 2 Criteria Radar Chart

per square meter would be 702 SR.

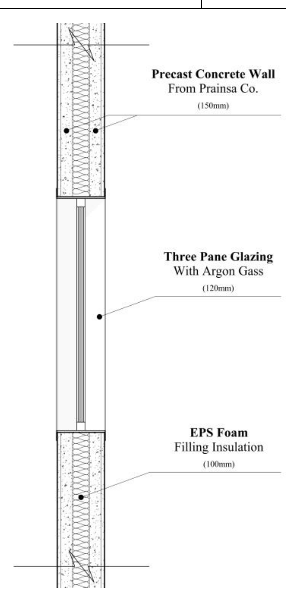
According to Sakann SA, construction of a 143 m2 unit could take up to 21 days, with a single square meter of the building portion requiring up to 14.6 hours. Though the process includes various stages, the price would be significantly higher.

The durability of structures built with RapidWall from Sakann SA may vary as the materials used are a composition of various materials. The GFRG (Gypcrete) panels used to hold the concrete have an average lifespan between 80 - 85 years without deteriorating based on previous structures.

Table 17 indicates that the total wall thickness for this particular option is 128mm.

7.3 Option 3: A wood wool insulated Precast Exterior Wall as showed in Type (B) was replaced by a two 70mm precast walls and insulated with a filling of EPS (Expanded Polystyrene) with a thickness of 50mm of EPS from Prainsa Co. Saudi Arabia.

Table (20). Option 3 Specifications

Building Element	Current Construction Layer		Thickness (mm)	U Value (W/m2K)
Walls (External)	Layer 1	*Precsast Concrete Wall*	70	14.94
	Layer 2	*EPS Insulation*	100	0.35
	Layer 3	*Precsast Concrete Wall*	70	14.94
Glazing	Layer 4	Three Pane *with Argon Gass*	24	1
Wall Finish	Outer Surface	*White Paint (Matt)*	2	**Sortwave Reflection** 0.892
	Inner Surface	*White Paint (Semi-Glossy)*	2	0.847
Total			**284 mm**	**0.3301 W/m2K**
Wall Detail				

Properties: Table 20

Simulation Data: Table 21

Comparison: Table 22, Figure 22

In this option (as shown in the figure below), the total (EC) decreased by 22%, totaling 16702.8 kWh, with (CEC) accounting for 33126.3

Table (21). Option 3 Optimization Summary

Current Situation		Optimized Trail	
CEC	Total	CEC	Total
2021.8 (46%)	4392.4	1621.8 (41%)	3950.1
1859.9 (46%)	4019.7	1481.7 (41%)	3593.8
2477.2 (51%)	4817.5	1915.4 (45%)	4229
3637.3 (62%)	5855.3	2547.9 (53%)	4764.2
4699.2 (67%)	6993	3114.2 (58%)	5407.9
5643.9 (72%)	7863.3	3522.6 (61%)	5741.9
5812.2 (72%)	8101.4	3637.8 (61%)	5926.9
6388.8 (74%)	8682.7	3896.1 (63%)	6189.9
5843.6 (72%)	8060.6	3596.4 (62%)	5813.2
5416 (70%)	7713.6	3432.6 (60%)	5727.5
3582 (62%)	5801.3	2523.5 (53%)	4742.7
2311.3 (50%)	4625	1836.3 (44%)	4135.9
49693.2 (65%)	76925.8	33126.3 (55%)	60223

Table (22). Option 3 Optimization Comparison

	Current	Optimized	Reduction	Percentage
Total Energy Reduction	76925.8	60223	*16702.8*	22
CEC Reduction	49693.2	33126.3	*16566.9*	10

kWh. This led to a 10% reduction in the (CEC) percentage compared to the current situation consumption.

Observation:

Utilizing a precast wall system from Prainsa Co that incorporates insulation made of either polystyrene or polyurethane, depending on the required thermal resistance value (R-Value), can significantly enhance a building's thermal performance. Polystyrene is particularly effective in humid areas due to its high resistance to temperature fluctuations, low moisture absorption, and closed, uniform cell structure.

This system also features thin layers of concrete that prevent heat transmission by radiation, trapping heat within the molecules for extended

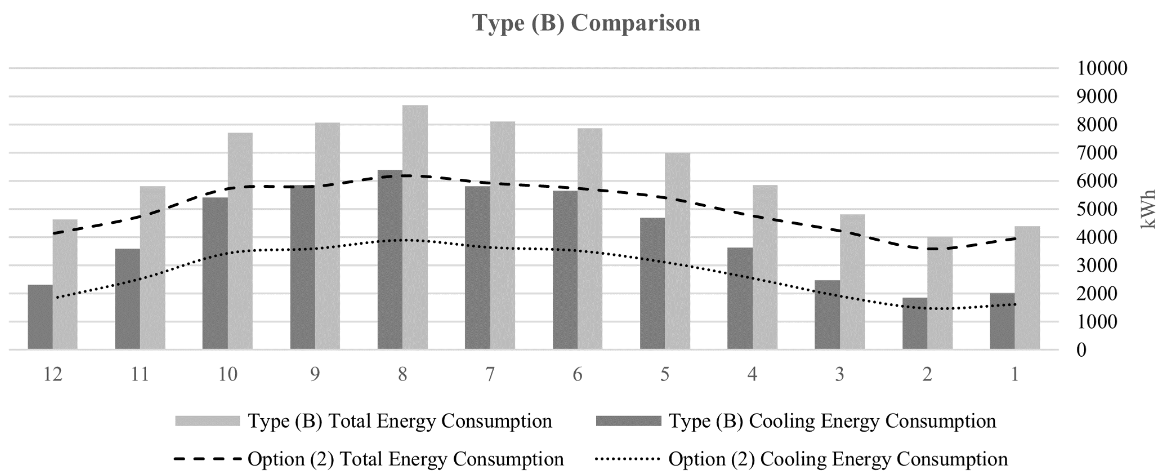


Figure (22). Type (B) Comparison Chart

periods and allowing the EPS layer to counteract against heat. Overall, these advantages make it a highly effective local solution for insulated precast walls, creating a comfortable indoor environment and optimizing the performance of the AC system by reducing the compressor's workload throughout the day.

Criteria Fitting:

Regarding availability, two options exist. The first is to source the exact wall panels from PrainSA, based in Dammam city, which may incur additional costs for transportation, potentially defeating the purpose of relying on local availability. The second is to consider similar options from local providers such as Saudi Building Material Company in Jeddah.

According to Maplebuilding.au, the initial costs for a traditional pre-cast concrete wall can range from $160 to $250 per m2, equivalent to 600-937.5 SR, depending on various factors including panel number, size, thickness, and application. This makes it most suited for mass-produced buildings rather than individual ones.

According to Med-state Concrete Industries, in an article published on January 15, 2019, the

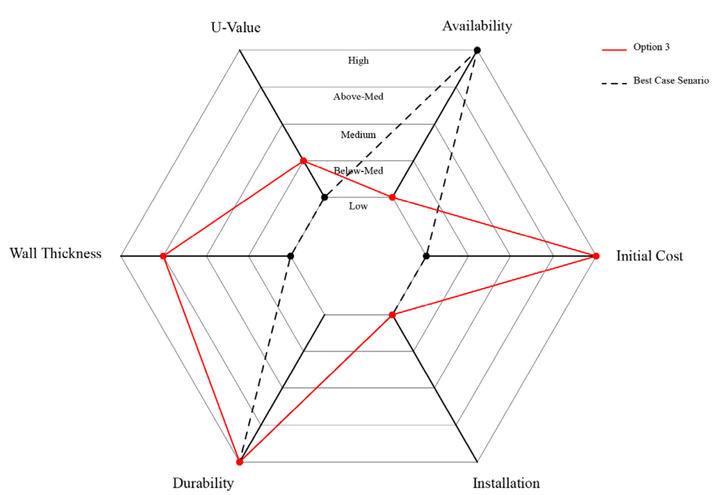


Figure (23). Option 3 Criteria Radar Chart

installation time for an 8,424 m2 residential apartment building was estimated to be 84 days, with a 1 m2 building portion taking around 20 minutes based on project variables.

Based on the National Precast Concrete Association N.P.C.A, precast wall panels are incredibly durable and can last up to 50-100 years when well-maintained. Precast load-bearing wall mix can withstand up to 6,000 psi of compressive strength for a full 28 days. In comparison, an average human being exerts an average of 16 psi, making them one of the most enduring construction materials around.

Based on Table 22, the total wall thickness of this particular option is 284mm.

7.4 Option 4: A traditional Exterior Wall as showed in Type (C) was modified and insulated by a 50mm of EPS (Expanded Polystyrene), while replacing the traditional Cement Block into Clay Block with additional embedded EPS Filling.

Table (23). Option 4 Specifications

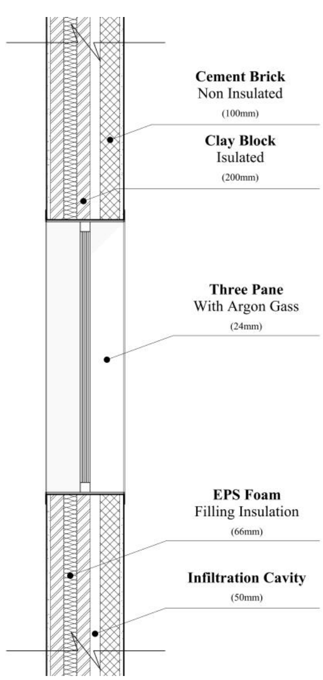
Building Element	Current Construction Layer		Thickness (mm)	U Value (W/m2K)
Walls (External)	Layer 1	Insulated Clay Block	150	0.62
	Layer 2	EPS Insulation	50	0.7
	Layer 3	Cement Brick	100	13
Glazing	Layer 4	Three Pane *with Argon Gas*	24	1
Wall Finish	Outer Surface	White Paint (Matt)	2	Sortwave Reflection 0.892
	Inner Surface	White Paint (Semi-Glossy)	2	0.847
Total			**304**	**0.2774**
Wall Detail				

Table (24). Option 4 Optimization Summary

Current Situation		Optimized Trail	
CEC	Total	CEC	Total
2044.3 (45%)	4505.5	1048.3 (30%)	3509.5
1894.4 (46%)	4116.2	1098.4 (35%)	3120.2
2565.9 (51%)	5030.2	1422.4 (47%)	3032.2
3693.8 (61%)	6068.5	1692.8 (42%)	4067.5
4452.1 (64%)	6916.4	2449.1 (50%)	4913.4
5084.4 (68%)	7468.2	2080.4 (47%)	4464.2
5386.8 (69%)	7842	2382.8 (41%)	5838
5641.9 (70%)	8106.2	2638 (52%)	5102.3
5253.4 (69%)	7631.2	2250.4 (49%)	4628.2
5003.1 (67%)	7464.4	2003.1 (45%)	4464.4
3581.1 (60%)	5964.9	1582.1 (32%)	4965.9
2520.8 (51%)	4976	1524.8 (38%)	3980
47122 (62%)	**76089.7**	**22172.6 (43%)**	**52085.8**

Table (25). Option 4 Optimization Comparison

	Current	Optimized	Reduction	Percentage
Total Energy Reduction	76089.7	52085.8	*24003.9*	32
CEC Reduction	47122	22172.6	*24949.4*	19

Properties: Table 23

Simulation Data: Table 24

Comparison: Table 25, Figur 24

In this option (as shown in the figure below), the total (EC) decreased by 32%, totaling 24003.9 kWh, with (CEC) accounting for 22172.6 kWh. This led to a 19% reduction in the (CEC) percentage compared to the current situation consumption.

Observation:

In Option 1, the researcher took specific actions. Additionally, the infiltration barrier was replaced with a 5cm thick EPS layer, combining the benefits of the models used in Option 3 and Option 1. The study found that the EPS layer was slightly more effective than the previous infiltration barrier and could potentially save up to 724.5 kWh of total (EC) per year.

Overall, the Extruded Polystyrene layer proved to have long-term benefits as an excellent thermal insulator. It had the lowest U-value out of all four options, and the researcher suggests that it could be integrated as an element into more advanced wall formulas.

Criteria Fitting:

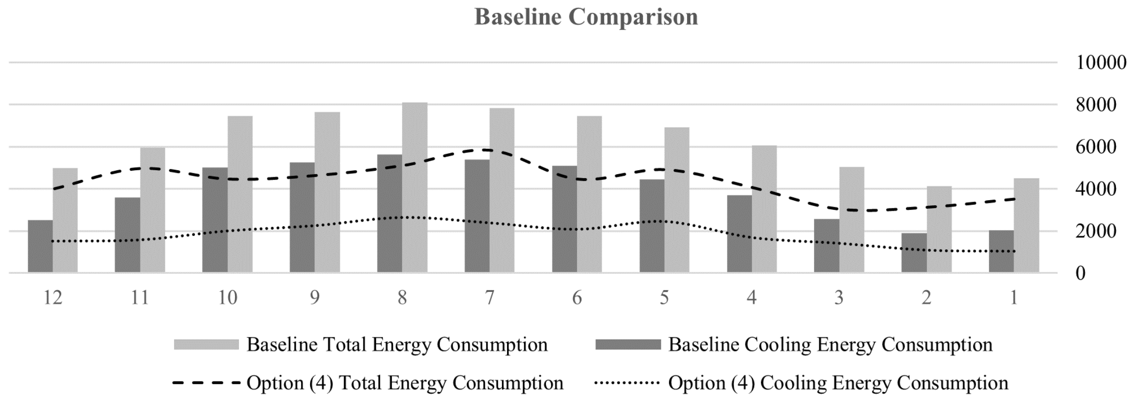


Figure (24). Type (C) Comparison Chart

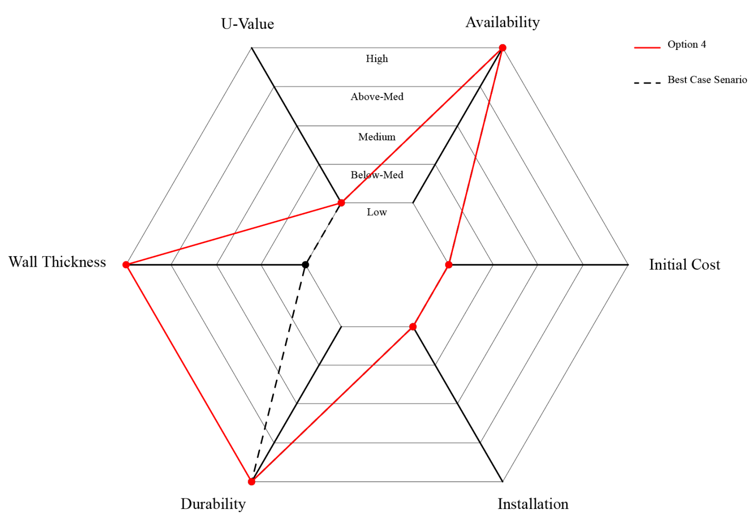


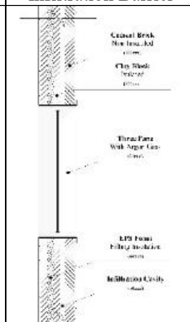
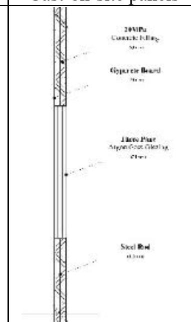
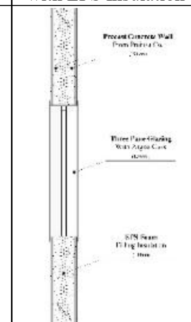
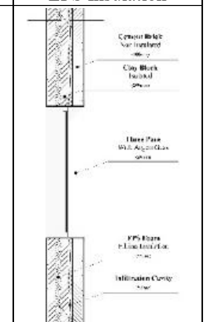
Figure (25). Option 4 Criteria Radar Chart

After assessing the previous options against the previously discussed criteria, researchers discovered that Options 1 and 4 bear a strong resemblance. The similarity between these options is noteworthy, considering the varying prices of EPS insulation boards dependent on their type and quantity, as outlined by Al-Rashed Polystyrene. For every square meter, the cost of insulation panels ranges from 1 riyal to 54 riyals based on the required quantity. The average price is 27.5 riyals. Additionally, the first option, detailed in the previous stage, incurs a cost of 49.375 riyals per meter, resulting in a total expected price of 76.875 riyals. It's pertinent to note that the wall thickness remained the same, with the infiltration barrier being substituted with thermal insulation panels.

Options Summary:

Upon completion of the optimization stage and after conclusion, the study aim represented to critically evaluate the energy potential of the current state (AH) while delivering simplified framework models in (HHC), considering the influence of building facades on their thermal performance. distinctions among the proposed

Table (26). Options Comparison

Measuring		Values				Result
Measuring Unit	System	*Option 1* Clay Block with Infiltration Barrier	*Option 2* Rapid Wall Cast-on-site panels	*Option 3* Precast Concrete with EPS Insulation	*Option 4* Clay Block with EPS Insulation	
	Details					
(%)	**Availability**	100%	20%	20%	100%	*Option 1,4*
(SAR/ per m^2)	**Initial Cost**	49.375	702	600	76.875	*Option 1*
(Hours per m^2)	**Installation**	1.2	14.6	0.25	1.2	*Option 3*
(Years)	**Durability**	100	85	100	100	*Option 1,2,3*
(Mm)	**Thickness**	304	128	284	304	*Option 2*
(m^2*K)	**U-Value**	0.3322	2.7777	0.3301	0.2774	*Option 4*

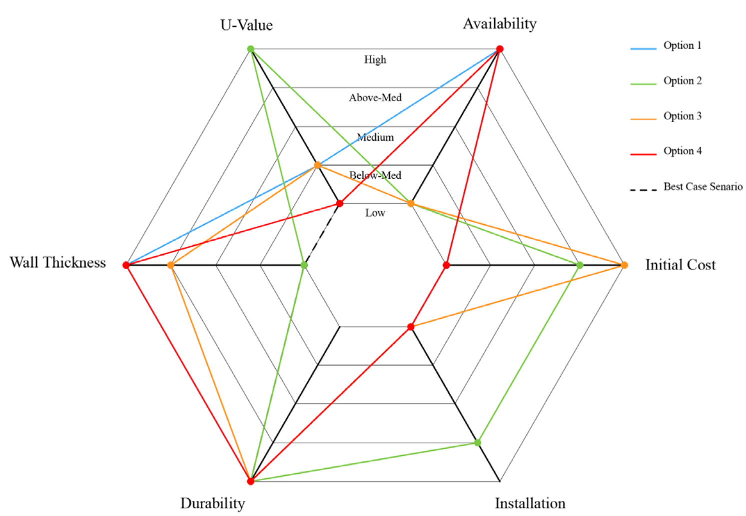


Figure (26). Options Criteria Radar Chart

options, all grounded in the same current situation, became apparent. We systematically summarized and compared these options, scrutinizing their effectiveness and alignment with previously identified determinants. Through this meticulous process, we pinpointed the optimal choice, striking a balance across most determinants. Researchers assert that this choice will curtail (EC) for cooling devices, enhance building efficiency, and, in turn, diminish long-term economic costs. Such an outcome holds particular significance for advancing (AMH) units.

8. Conclusion

was to critically evaluate the energy potential of the current state (AH) while delivering simplified framework models in (HHC), considering the influence of building facades on their thermal performance. The study's objectives include identifying the architectural characteristics of existing (AMH) in Jeddah, evaluating their thermal performance, creating a baseline generic model reflecting thermal properties, and devising an optimal facade prototype for low (CEC). The methodology involved data accumulation from the Ministry of Municipal & Rural Affairs & Housing, 3D model development for thermal property measurement, and a comparative study integrating collected data and housing properties. The examination of facade-attached spaces in (AMH) highlighted areas requiring improvement. A generic model based on identified architectural characteristics was developed, and subsequent simulation models were assessed (EC) for cooling. The proposed model, featuring cement block walls insulated with a 50 mm layer of EPS, demonstrated a consumption rate of 292.3 kWh per square meter, emerging as the most suitable option from the current situation models. The researchers posit that this study holds the potential to contribute significantly to the enhancement of economics and energy efficiency in future affordable mid-rise buildings.

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أداء الواجهات المعمارية لمباني الاسكان الميسر في المناخ الحار الرطب: دراسة حالة مدينة جدة بالمملكة العربية السعودية

جميل فريد حجازي عبدالله إبراهيم المحفوظ إياد خالد الميمني راهف عبد القادر مداح

كلية العمارة والتخطيط، جامعة الملك عبد العزيز، المملكة العربية السعودية.

rmaddah@kau.edu.sa ealmaimani@gmail.com aalmahfouz0001@kau.edu.sa jhijazi@kau.edu.sa

قدم للنشر في ١٢/ ٦/ ١٤٤٥ هـ ؛ وقبل للنشر في ١٢/ ١٠/ ١٤٤٥ هـ.

ملخص البحث. يهدف هذا البحث إلى تقييم إمكانية خفض التكلفة المالية طويلة المدى للمساكن الميسرة متوسطة الارتفاع في المملكة العربية السعودية، ولا سيما في مدينة جدة، حيث يوجد نقص في الخيارات الموفرة للطاقة بأسعار في متناول اليد، والاستهلاك العالي للطاقة في المباني القائمة. تحدد الدراسة النمو الزمني والخصائص المعمارية للمساكن الميسرة متوسطة الارتفاع الحالية، وتقيِّم أداءها الحراري، وتطور نموذجاً أولياً مثالياً لواجهاتها المعمارية تناسب الاستهلاك المنخفض لطاقة التبريد للمساكن الميسرة متوسطة الارتفاع. توصل البحث إلى نموذج لمساكن متوسطة الارتفاع ميسورة التكلفة تشتمل على جدران من الطوب الطيني المعزول مسبقاً بطبقة EPS معزولة بطبقة ٥٠ مم من EPS مع طبقة داخلية من الطوب الإسمنتي، ويشير إلى أن هذه الدراسة قد تساهم في تعزيز الاقتصاد وكفاءة الطاقة لمباني الإسكان الميسر متوسطة الارتفاع في المستقبل.

الكلمات المفتاحية: الإسكان الميسر، كفاءة استهلاك الطاقة، الاكتساب الحراري، المناخ الحار الرطب، الإسكان الاجتماعي، الأداء الحراري، واجهات المباني، المباني متوسطة الارتفاع.