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Research Article

INNOVATION FAÇADE FOR AN ENERGY PERFORMANCE AND THERMAL COMFORT OF BUILDING IN HOT AND DRY CLIMATE

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ABSTRACT

This paper discusses the energy innovation of external facade for existing residential buildings. It consists to taking into account both architectural and thermal aspects for new and old construction. With the use of energy wall systems, it is possible to reduce the heating/cooling demand of energy consumption and evaluate the indicators of energy performance. In doing so, this work can contribute not only to long-term economic growth, but also help address pressing social, including on a wide range impact environmental. We use a dynamic simulation with a structural equation modelling to test the hypothese on a data base of climate of this region. The final part consists technico- economic approach, calculating the investment costs analysis, comfort and energy saving. The results demonstrate its utility in explaining, regarding high systems availables in innovation performance.

Keywords: heating/cooling, hot and dry climate, comfort, coating, investment costs.

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1. INTRODUCTION

As codes change the climate, it is of the highest importance to constantly find innovative ways to improve the quality and efficiency of constructions. A building is no longer just a combination of forms, blocks, and boards; it represents the efforts to reduce energy consumption, our carbon footprint and sustainably. It means providing solutions to ensure green and energy performance construction.

On a global, the buildings are responsible significant amount 30 to 40 % of total energy consumption and $C0_2$ emission. Buildings worldwide still contribute significantly to the high and increasing fossil energy consumption [1].

Obviously, the externals façades are the most essential element considering energy consumption, environmental effects and user's comfort. Consequently, different design strategies are being developed according to different climatic zones for sustainable and high-performance buildings. Today, different systems such as double-wall façades, ventilated – walls and green walls are already being used in building envelopes.

Currently, in face of a large set of choices for innovative curtain façade systems, the main issue is to identify those that prove to be the most effective in the long term and improve the energy performance.

In Algeria, the total demand energy of building is 40% to 55% [16]. Energy consumption in buildings in the southern part of Algeria represents nearly 70 per cent of the total energy use during the summer months, since air conditioning is the only means to ensure thermal comfort for inhabitants.

Therefore, the energy renovation is a discount in state of an existing building with degraded thermal performance at the level of a recent building with high thermal performance [2].

Several studies have been developed in this area, including answering to these challenges.

The study carried out by SAADON Syamimi et al., treating the thermal modeling of a building equipped double photovoltaic façade with naturally ventilated. This system semi-transparent, ventilated PV façade designed for protection and cooling in summer (by natural convection) and heat recovery in winter (by natural ventilation). The air inside the cavity between the two skins of the building (photovoltaic and primary wall) is heated by transmission through the glass sections, and by convective exchange and radiation. He found that the cooling requirements are more prevalent for all the climates considered, but the effect of the facade on the heating needs does not decisive [3].

The work describes by RODLER A, in 2014 a numerical model has been developed to simulate a single room, using a refined spatial three-dimensional description of heat conduction in the envelope but a single air node is considered. The model for environmental conditions that vary over short time-steps and have integrated the projection of solar radiation through a window onto interior walls: the sun patch. This work has confirmed the necessity of representing more accurately the descriptions of the envelope for low energy buildings [4].

Also the thesis realized by C. FLORY CELINI en 2008. aimed at going to proposing a list of measures or studying a few cases and develop a methodology adapted to any building which could give the researcher the opportunity of comparing bioclimatic solutions using the smallest number of simulations. This analysis is a meeting point between building thermal science, architecture and mathematical methods (experience plan, optimization and multiple criteria analysis) that bring something new and different in the methodology [5].

In previous research on innovation construction in hot and dry climate, particularly, the study realized by FIZIOUI N., in 2009, revealed that typology and the choice of building envelope have a notable influence on energy consumption and thermal comfort. A wrong choice can be very costly in the long term with regard to energy expenditure to ensure thermal comfort inside the house. The best measures to improve energy efficiency were insulating the roof and choosing an appropriate material for the external walls. It was concluded that a material should not be considered according to its intrinsic thermal qualities, but by its location in the wall [6].

The study realized by FIZIOUI N., in 2014, treating the thermo physical properties of modern building materials and the results of this study show the impact of inertia on winter consumption, as well as the effectiveness of roof insulation in reducing cooling requirements. The adobe has good properties to improve comfort and energy savings but its stabilization with cement, to improve its mechanical properties decreases its thermal qualities [7].

According to the study of RODRIGUEZ G an architectonic approach, it validated the performance of the shape of the house as an effective response to environmental constraints. To do this, he analyzes the vernacular habitat in search of the motivations that shaped it. The relationships between geographic and climatic circumstances can determine the shapes of these houses. These relationships of influences are modeled on the basis of qualitative functions, allows automatic reasoning to be carried out, based on the knowledge collected on the geo-climatic environment. In this study, the evaluation of the performance of the form of new constructions and the structuring of a housing design approach adapted to a local context [8].

VERBEEK 2005, ENKVIST 2007, EEK 2013 studies have shown that the most effective solution for controlling energy consumption in the construction sector (old and new buildings) is to reduce energy loss by improving the external insulation installed [9].

Today, there is a major interest in the use of super-insulating materials, like aerogels; which has unique properties and proves to be very interesting in the new construction rules. Their optical transparency and their very low thermal conductivity, aerogels can be used in the insulation of opaque facades and glazed parts [9].

In the scope of our research, these enhancement solutions will be assessed in terms of energy-saving potential, summer comfort and also energy efficiency. Thus, making it possible to suggest recommendations on the best solutions to reduce the effects linked to summer comfort and energy consumption.

The objective of this work is to explore innovative solutions for energy retrofitting of old and new systems of existing buildings. Towards, this work conducts on advanced materials and solutions for enhancing the safety, energy and resource efficiency of facade. The challenge needs to be addressed the cost, sustainability and durability with the recommendations for future research activities towards sustainable buildings retrofitting. For that, a novel approach technico-economic and environmental impact expected from such system is preliminary assessed. To achieve this study, we will compare these systems with proposing an optimal hybrid structural-plus-energy retrofitting solution based on innovative lightweight materials for envelopes, aiming to simultaneously increase their thermal comfort and energy performance.

1.1. The externals facades innovatives

In order to increasing requirements of energy, a series of bioclimatic energy strategies is, being implemented in construction. Coming from vernacular traditions or new technological developments, these systems promise to reduce the energy needs of buildings. Some examples are Trombe walls, solar cooling, solar chimneys, phase change materials, green roofs and reflective roofs [10].

Today, different systems such as double-wall façades, ventilated walls, solar and green walls are already being used in building envelopes. The first priority of these systems is decreasing energy consumption by utilization of natural ventilation and solar energy.

1.2. Innovative local facades (inspired by vernacular architecture)

Used for centuries of the planet, passive strategies distributed both economic and logical responses adapted to the environment. They take into account temperature, orientation and winds. It is also possible to take advantage of the local orography to ensure the thermal regulation of the interiors or to make use of materials offering a high thermal mass or high quality of insulation [11].

Algeria has an outstanding treasure in terms of typologies and vernacular forms, especially in extreme climate (South Algeria) presented by Ksour are generally erected on rocky soils for self-defense purposes and also for the preservation of water resources and fertile soils. The Ksour is found in the Algerian desert from east to west and from the north of the Sahara to the far south. They do not present uniform typological characterizations [12].

For example, The Ksar of Kenadsa is considered among the most important old cities of the south-west region of Algeria by its cultural and religious dimensions. This traditional architecture has been built to achieve the comfort in hot season.

In the South of Algeria, the new building of construction has been built following the north architectural design neglecting the very harsh climate of this area, characterized by very hot and dry climate. For this effect, the traditional architecture has been built to achieve the comfort in hot season. These vernacular constructions, called Ksour, characterize by simple forms adapted to their sociocultural and geo-climatic context. This habitat, which has resulted from the long term, is sustainable, and the geographical and climate have been considered to determine the shape of houses [7,29].

This study aims to place the vernacular architectural approach at the center of the sustainable conception. For this, a various example of technical construction;

a. Massive Inert Facades

Massive Inert Facades are of high thermal inertia to capture and store heat during the day, to restore it at night. In summer providing atmospheres close to comfort but hardly heated in winter. Choose a high inertia of the materials of a thermal mass which makes it possible to phase and absorb the external heat contributions; this mass can act as an accumulator in the heart of the building.

A Raw Brick Facade, made from the most clayey soils (Toub).

- ***A Wet Earth Facade***, kneaded and molded, is then dried in the sun, and sometimes added straw to the dough to give it more cohesion and solidity.
- ***Thermal Mass Wall***, allow to capture and store heat during the day, to restore it at night. In summer providing a comfort but hardly heated in winter. Choose a high thermal mass of the materials makes it possible to phase and absorb the external heat contributions; this mass can act as an accumulator in the heart of the building. For example:
- ***Terracotta wall***, made from the made in clay soils (Toub).
- ***External Walls Dressed Stone Blocks***, the building is formed by stones blocks. petri, molded, and to dried in the sun, and sometimes added straw to the dough to give it more cohesion and solidity.

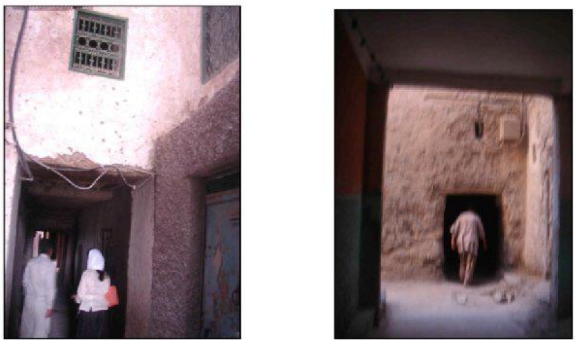

Fig.1. The residential walls of Ksar (South-West of Algeria) [15]

- ***Baked Stone Facade***: The use of a baked stone wall with great thermal inertia and great thickness makes it possible to phase and absorb the external heat inputs; this density can act as an accumulator in the heart of the building. The role of thermal inertia is often associated with nocturnal periods by its ability to store excess intakes during the day and to return them later when it is colder at night by using ventilation [13].

- ***Stone Facade***

The facades are cut from stone and traditional plaster preserving the listed buildings. The use of a baked stone wall with great thermal inertia and great thickness makes it possible to phase and absorb the external heat inputs; this density can act as an accumulator in the heart of the building. The role of thermal inertia is often associated with nocturnal periods by its property of storing excess intakes during the day and returning them later when it is colder at night by using ventilation [13].

b. Living Wall Systems By Vegetal Fibers

The vernacular construction of the Ksour once used exclusively local materials which determined a coherent and comfortable construction: they allowed the use of such a technique and the combination of original architectural elements. Among these strategies, walls that constitute natural materials such as palm fibers to increase the resistance of the construction. For desert regions, the thickness of the walls depends on the phase shift to be ensured, and on the types of materials used. It varies 30 and 60cm, using raw stones or bricks (local material) with a coating made of a mixture of lime or clay and sometimes palm fibers [16].

c. The Ventilated Facade

The facade composed by two opaque skins with a distance between the wall and the added cladding which creates a ventilated cavity in a natural way "chimney effect" , or mechanical [14].

d. Double-Skin Glazing Facades “Day Lighting”

To improve energy performance, it will have ventilated double-skin facades and most of the offices will benefit from natural day lighting. The design principle of the ventilated façade lies in the static autonomy of each single facing slab as well as in elimination of fixing mortar.

The double skin facade was exploited for multiple reasons and different functions including the aesthetic and technical aspect. It is used to improve natural lighting, optimize thermal and acoustic comfort, provide natural ventilation and minimize energy consumption [18]

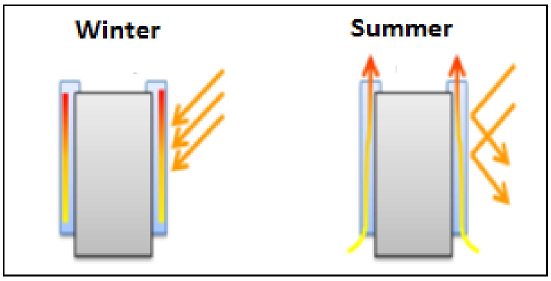

Fig.2. Thermal principle of operation of a double skin glazed façade [14]

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2. RESEARCH FRAMWORK

This study was conducted the characterization of household and then through the evaluation of energy performance indicators. Firstly, we carried out to characterize the variants of systems retrofots. Secondly, a series of simulation of the variants of systems walls has been realized by TRNSYS and database of climate of Bechar (In practice, an annual simulation with an hourly time step are carried out in order to obtain an overall assessment of the building. The classic indicator for estimating energy performance is the energy requirement in kWh / m^2. year [17].

Table1. Description of the systems walls, materials, thickness and U-value coefficient [26]

Facades	Composition	thickness (m)	U-Value (W/m2K)
Vegetal Facade	Plaste exterior	0.02	0.29
	Finish coat	0.02	
	Insulation plate with natural fibres	0.05	
	Red brick	0.20	
	Plaster	0.02	
Facade with stone bricks	Red brick	0.20	0.69
	Blade of air	0.02	
	Hollow Brick	0.10	
	Gypsum plasters	0.02	
Double skin glazing	Cement plaster	0.02	0.22
	Brick concrete	0.2	
	Insulating plate expanded polystyrene solid	0.08	
	Cavity	0.02	
	Glass window (doubl glazing)	0.02	
	External rolling blind	0.02	
	Concrete blocks	0.10	

In this study, the multi-family housing complex selected as the representative type of existing residential building located in south-west Algeria. The key energy sources mainly used in residential buildings are electricity, which is used for home appliances, lighting, and cooling. The gas source is used for domestic heating, water heating and cooking [30].

The first priority of these systems is decreasing energy consumption by utilization of natural ventilation and solar energy. Today, different systems such as double-wall façades, ventilated windows, solar and green walls are already being used in building envelopes [24,25].

3. RESULTS AND DISCUSSION

3.1. Evaluation of the Energy Performance of system Wall

As has been discussed, with simulation in this study to calculate IPS, during hottest week of summer that we exploited in this work [32].

The table 2 explaine the analysis of the maximum and average temperatures for each improvement system is a very important parameter to know the best solution. In Figure 3, the concept of a typical day is generally applied (21 July, 10 january).

Table 2. Comfort IPS of each system facade

Facades	T ° initial	T ° with fibres	T ° doubl skin glazing	T ° stone bricks
T° max	37.54	32.50	29.86	30.23
Δ T° Max	-	6.04	6.68	7.31
T° Moyenne	32.50	30.85	30.34	31.57
Δ T° moyenne	-	0.65	2.16	0.93
T confort	26	26	26	26
Discomfort	100	40	29.5	41.5
IPS	-	0.46	0.75	0.65

Regardless evaluation of temperature of each system, it has been shown that the double skin glazed facade has two different effects on the energy performance of the building. As expected, it allows a value of 0.75 of IPS (summer comfort) and a reduction in the building's discomfort rate about 29.5% compared to the configuration of the basic building.

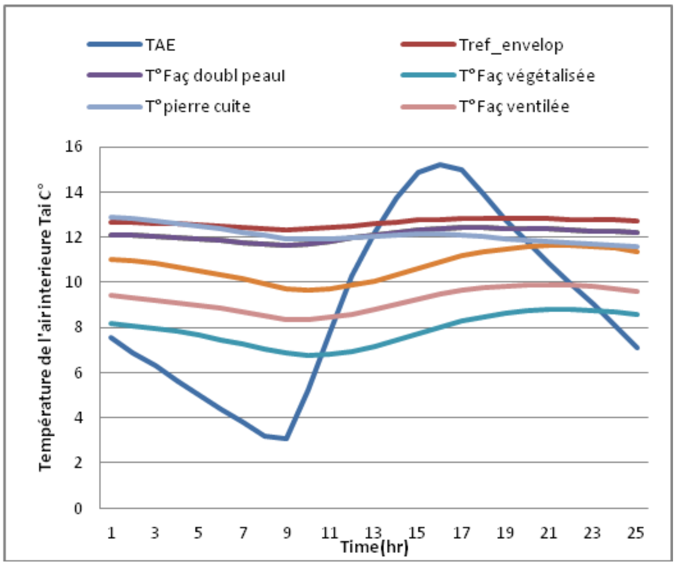

Fig.3. Variation of temperature for each system wall (10 january 2019]

As a result, by using three different compositions of facades based on local materials, that the performance of double skin fall has a higher of IPS 0.76 and the maximum temperature until 29.86°C (because it has a fable U Value 0.22 W/m2 k and larger thickness 0.45m). The consequences on the durability of envelopes in these regions are significant, which appeals to the necessity in a consideration the risks caused by geo-climatic conditions during the design of construction [19,20].

3.2. Calculate Indictor of Economical « IECO »

Generally, it is considered that the larger the Heating/Cooling consumption is calculated by TRNSYS in kWh. We can calculate the Ieco in the following relation:

IECO = (Cep heating -Ref – Cep heating-Sys) + (Cep cooling-Ref - Cepc-Sys cooling)

equation [21]

Accordingly, the observation in Table 3 shows that the systems studied are economical in terms of energy consumption. It a lower energy consumption, which has validated the choices in improvement systems with the saving of energy consumption.

Table3. Values of the Ieco according to each improvement system walls

	initial	*double skin glazing*	*stone brick*	*With fibres*
Cheating	277.71	60.44	100.12	112,95
Ccooling	51.73	47.25	41.25	48,67
TOTAL	329.44	107.69	141.37	161,62
IECO	-	221.75	188.07	167.82
Réduction %	-	67.31	57.08	50,94

3.3. Calculate Cost Investments and TR

To address this challenge, it is necessary to establish the economic evaluation, cost-investment. The table below presents the economic data of all the technical systems in the form of investment costs, electricity consumption, savings achieved and payback time [22,23].

In other word, we can appreciate that the best solution from an energy, economic and comfort point of view is for the ventilated double skin facade with a return time of 5 years.

Table 4. The economic data and the payback time on the investment of the facades studied

Systèmes	***Coast investem ent DA/m2***	***Coast electricity/ years***	***Simple payback (years)***	***Annual saving (DA)***	***Return on investment***
Initial building	-	103773.6	-	-	-
Facade double skin glazing	400	65577.35	5.20	58195.25	5 years
Facade with stone	210	70011.9	2.85	33761.7	2years and 8 months
Facade with naturel fibre	240	33948.95	2.45	19824.65	2years and 4months

However, this study conducted a comparative analysis between doubl-skin walls, living walls and wall with stone bricks. By having these over base cases, the initial building will be able to payback the initial investment resulted from construction cost saving in around 5.20 years if is used the doubl skin glazing.

4. CONCLUSION

The present research focuses on facades innovation in hot and dry climate. For this, we have simulated three systems of exterior facade.

As has been discussed, this study examined the implementation of building energy performance. It has been shown that the three system walls of construction can allow energy consumption and evaluate comfort. Generally, it is considered that the larger low energy consumption is the higher of saving energy [27,28].

This work describes also the systems of vernacular construction with and new technology that has adapted in a hot and dry climate. Therefore, this study analyzed the indicators of energy performance: IPS, Ieco and TR. Based on the analysis result, this study aimed to develop a new systems energy walls for the buildings from two perspectives: (i) establishment of reasonable criteria for the building energy performance, and (ii) establishment of comparatives to encourage the use of system of construction inspired of vernacular architecture.

Based on this act, it was concluded the performance of double skin facade is carried out in hot and dry climate, with two transparent surfaces separated by a cavity. The extra skin can reduce cooling demand in summer and heating demand in winter (70%).

It is concluded that in arid climate, the wall with stone can perform better that living wall in summer. The hot thermal mass of stone allows capturing and storing heat during the day, to restore it at night. In summer providing a comfort but hardly heated in winter. An exposed brick wall absorbs more heat than smooth plastered walls. About the same as a brick wall, so the cost is pretty.

- Thermal losses are reduced in winter, and in summer, it reduces heat input from the walls. It is the high thermal inertia which acts mainly in summer, marks a phase shift in our hot climate, brings benefits in summer as in winter. The higher the inertia, the more effective the improvements in the three indices.
- The vegetal facade structured by a stainless contributes in reducing the building's thermal loads 32% and also in reducing the effects of urban heat in hardly environment.
- We can see that the best solution and the most economical in energy consumption is achieved by the double skin glazed facade, with a reduction of 70%, and 50% for the raw brick facade. Also, the ventilated facade has a 50.94% reduction. The green facade allows a reduction of 32% in summer only.

The innovation performance of extertior facades in the hot and dry climate, shows that there is a clear distribution of intellectual property rights in the innovation energy to facilitate the participation of residential building and, more generally, to identify good policy practices and proposed different initiatives retrofits improved innovation performance with local materials appropriate to this region.

In this work, we examine how knowledge systems of innovation performance within biotechnology facades. The innovation performance takes an in-depth look at a range important factors that anableand promote innovation performance including economic structure, and relevant law, policies and instruments.

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