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Façade system analysis: A Critical Review

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Abstract- Façade systems are integrated element of building. They have various functions other than formulating the outer layer of the building. Different types of façade systems show different functions. Besides aesthetics, thermal regulation, efficient day lighting, energy optimization, dehumidification are the different functions for facades. These parameters are highly influenced by the geometry, placement, shading and material used to make that façade.

This paper aims to analyse which façade system is appropriate for what kind of functions, case studies related to different façade systems that emphasizes which system works for what type of climate. This review will help to rate the façade systems based on their functions.

Keywords- Façade systems, Functions, Dehumidification, classification of façade, Building envelope.

I. INTRODUCTION

Building Façade is a non-negotiable element of the building. Besides its main function of creating a barrier each façade systems work as a heat barrier in some way or other. These façade systems are responsible for the control of energy flow, matter from outside to inside. This paper explores different types of facades, their functions and which kind of façade works best for dehumidification based on the literature study.

Facades were a part of enclosed space since the early man era where people use to live in caves. Cave walls acted as the barrier between indoor and outdoor. Traditional facades were based on easily available material like stone, straw, mud. Earlier facades used mud or lime plaster which reduced the indoor temperature. Studies have shown that lime, straw and thatch also helped in dehumidification.

Modern façade systems are versatile. Thought behind modern façade systems is basically based on aesthetics. Changes are seen in materials used, systems and their purpose. Metal, glass had taken forefront in last decade. Research is going on with developing various eco-friendly materials for façade design. If we look at system-based approach curtain walls and double skin façade are widely used. Kinetic façade system is developing based on the function of managing day light and energy efficiency.

These systems can be classified as structural based façade system and advance adaptive façade systems. Structural based façade systems are based on type of structure they use to stand like external wall, curtain wall, fabricated panels, heavy stone-based facades or lightweight facades. Advance adaptive façade systems are thought to use façade for certain regulation purpose, either day-light, energy efficiency or dehumidification. Such façade systems integrate photovoltaic panels, double skin façade, parametric facades or vertical greens.

Further literature studies are done for different types of façade systems in detail and how different façade systems helps in climate adaptive functions are studied.

II. METHODOLOGY

This study uses multiple approaches to systematically classify and evaluate the façade systems. Literature study is the primary source of data for this paper. Detailed study was developed based on architectural journals, different articles, Industry reports and research papers. Initial focus is kept on classification of different types of facades.

2.1 Preparation – Literature study based on existing classification of façade systems.

2.2 Processing- Classification of these façade systems based on their functions.

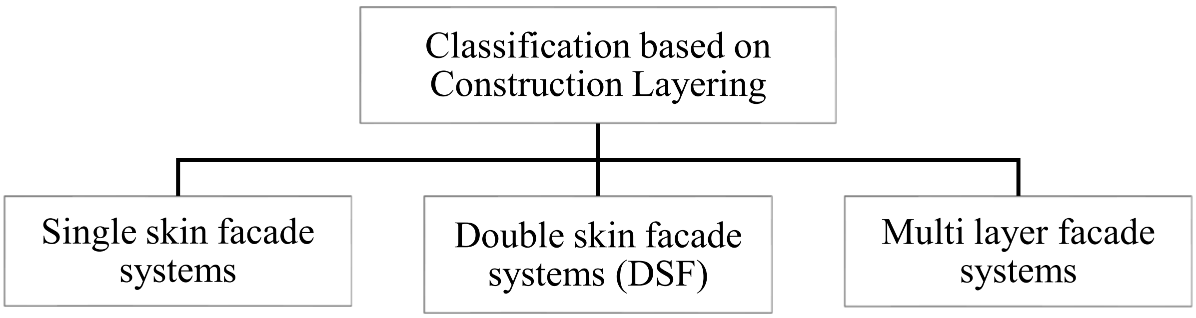
2.3 Comparison adjacency matrix – Develop a classification matrix based on which façade system is effective for its required adaptive purpose.

2.3 Evaluation- Analysis based on all the above studies with different diagrams and literature. This analysis will give a diagrammatic representation of façade system and their usage for helping in easy perception and decision-making process for its actual practical use.

III. LITERATURE REVIEW

3.1Classification of façade systems

Different research papers classify facades differently. This paper aims to establish parameters from various papers and formulate the classification according to their function. Authors Katia Gaspar, Miquel Casals and Marta Gangolells in their paper 'Classification systems for facades and anomalies' have studied different residential façade systems for energy optimization. Main parameters which they have considered for classification are number of skins of the façade, Existence of the air cavity, Existence of insulation and types of external wall coverings. These parameters are considered and given a single header of 'classification based on construction layering.'



Single skin façade system consists of masonry wall, monolithic concrete wall, single glazed curtain wall and load bearing facades. Double skin façade systems consist of naturally ventilated façade systems, mechanically ventilated façade systems, hybrid DSF, shaft box DSF, Multi-storey cavity DSF. Multi-layer façade systems consist of ventilated façade, rainscreen façade, Insulated cavity façade and hybrid breathable façade.

Department of architecture from Gazi University had published the article titled 'Different Façade Types and Building Integration in Energy Efficient Building Design Strategies' in which they have classified various energy efficient façade systems as per the climate applicability.

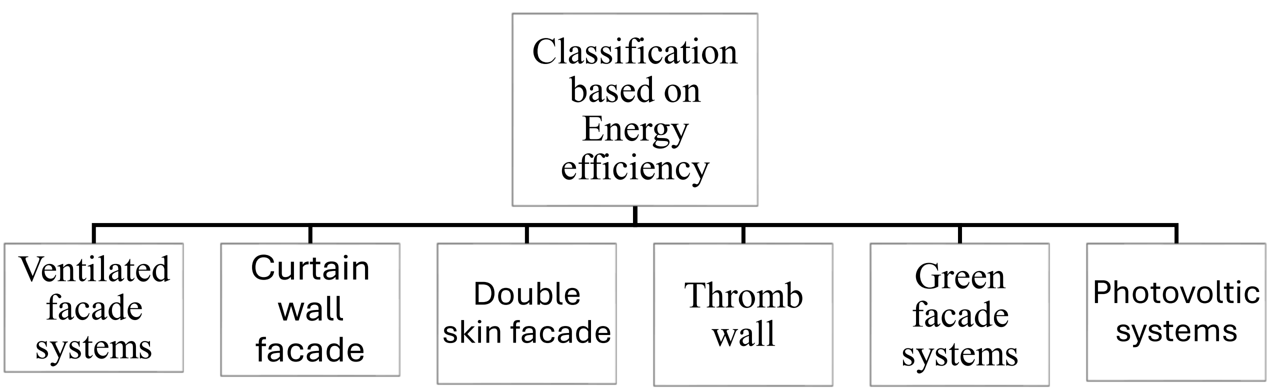
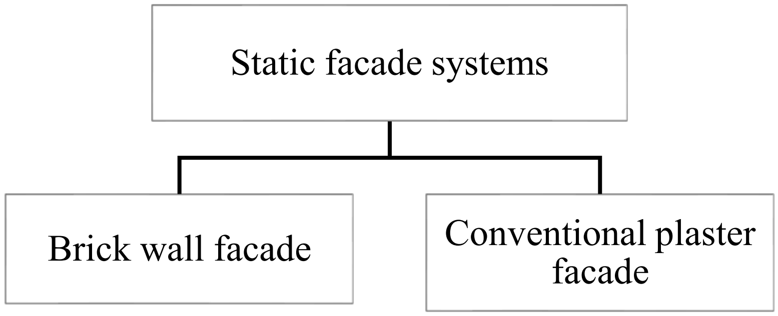
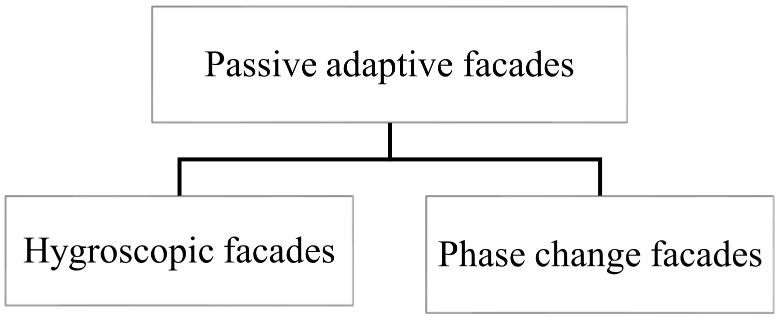
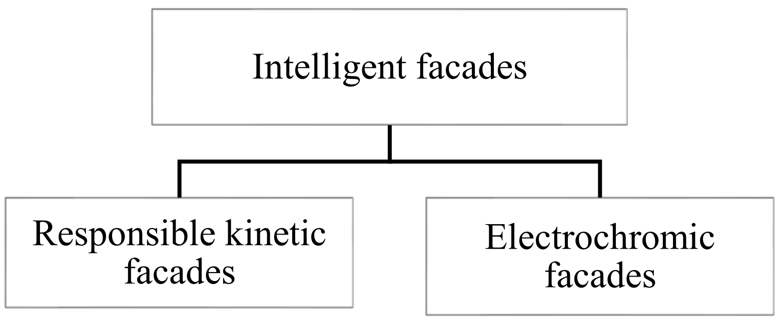


Figure 1: fdghgfhhjg

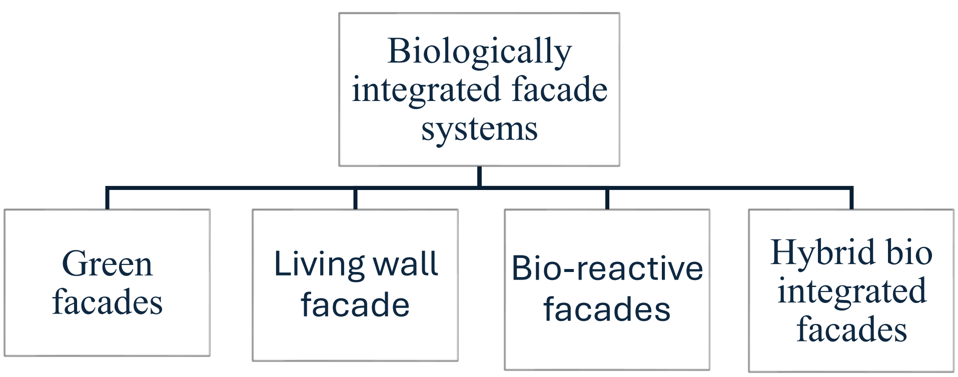
Adaptive façade research (EU COST Action TU1403) had classified the façade systems into 4 main categories.







Façade tectonics institute proposes classification based on biological integration of façade systems



3.2 Functions of façade systems

Above classification of facades are further studied for its primary functions. Details are expressed with sources in the table below. This table helps in holistic understanding of classification of the façade system with its primary function. This data can be used to practically use the façade system for a specific purpose.

FAÇADE SYSTEMS AND ITS FUNCTIONS				
Sr. no.		Façade system type	Primary function	Resources
1.	Structural configuration	Single skin facade	Basic enclosure, thermal separation, weather protection, daylight openings	Gaspar et al. façade classification framework
2.	Structural configuration	Double skin facade	Ventilation cavity airflow, solar buffering, acoustic, Humidity buffer, insulation, thermal regulation	Adaptive façade review (MDPI Buildings Journal)
3.	Structural configuration	Multi-layer façade systems	Rain protection, drying layer separation, insulation improvement, durability enhancement	Façade tectonics multilayer studies
4.	Environmental performance	Ventilated facade	Heat removal via airflow, façade drying, improved thermal stability	Energy-efficient façade system research (IJBES)
5.	Environmental performance	Trombe wall facade	Solar heat storage and delayed heat release	Climate-responsive façade research
6.	Environmental performance	Shading facade	Solar gain control, glare reduction, cooling load reduction	Adaptive façade comparison matrix
7.	Environmental performance	Green Facade	Evaporative cooling, shading improvement, air purification	Bio-integrated façade research
8.	Environmental performance	Photovoltaic facades	Renewable energy generation, façade multifunctionality	Energy façade integration research
9.	Biological integration	Green facades	Cooling through vegetation shading and evapotranspiration	Façade Tectonics Institute bio-façade classification
10.	Biological integration	Living wall facade	Integrated substrate-based vegetation envelope	Living wall façade performance studies
11.	Biological integration	Bio-reactive facade	Micro-climate humidity interaction possible	Bio-reactive façade research

3.3 Comparison adjacency matrix

Comparison matrix is developed to understand which façade system works at what level for different parameters of functions that are discussed above.

Façade system	Thermal control	Ventilation support	Daylight control	Energy reduction	Durability	Moisture buffering	Passive dehumidification suitability
Single-skin masonry+ any vernacular plaster	★★★	★★	★★	★★★	★★★★	★★★	★★★
Double skin façade (Naturally ventilated)	★★★★★	★★★★★	★★★★	★★★★★	★★★★	★★★★	★★★★★
Ventilated rainscreen façade	★★★★	★★★★★	★★★	★★★★	★★★★★	★★★★	★★★★★
Multi-layer breathable façade	★★★★★	★★★★	★★★	★★★★★	★★★★★	★★★★★	★★★★★
Curtain wall façade	★★	★★	★★★★★	★★	★★★	★	★
Passive adaptive hygroscopic façade	★★★★	★★★★	★★★	★★★★★	★★★★	★★★★★	★★★★★
Green façade system	★★★★	★★★	★★★★	★★★★	★★★	★★★	★★★
Trombe wall façade	★★★★★	★★	★★	★★★★	★★★★	★★★	★★
Intelligent kinetic façade	★★★★★	★★★★★	★★★★★	★★★★★	★★★	★★★★	★★★★★

IV. RESEARCH GAP AND CRITICAL ANALYSIS

Despite advancements in façade technology, several gaps remain in the understanding and application of dehumidification façades. One of the primary limitations is the lack of empirical data from real-world building applications. Most studies are conducted under controlled laboratory conditions, which may not accurately reflect actual building performance.

There is also a lack of climate-specific design guidelines for façade systems in warm and humid regions. While general principles of moisture control are well established, their application in diverse climatic contexts requires further investigation. The interaction between material properties, façade design, and environmental conditions is complex and not fully understood.

As noted in the base study, there is limited research focusing specifically on moisture regulation through façade systems, particularly in warm and humid climates. Additionally, the integration of simulation tools with experimental validation remains underdeveloped, limiting the ability to predict system performance accurately.

V. DISCUSSION

The integration of dehumidification strategies into façade systems represents a significant advancement in building design. Double skin façades provide a versatile platform for implementing passive moisture control mechanisms, while hygroscopic materials enhance their performance by enabling moisture buffering.

The effectiveness of these systems depends on several factors, including material properties, façade configuration, and environmental conditions. Proper design and operation are essential to ensure optimal performance and avoid issues such as moisture accumulation and reduced airflow efficiency.

Simulation tools offer valuable insights into system behavior, enabling the analysis of complex interactions between heat and moisture transfer. The use of such tools can facilitate the optimization of façade design and improve the accuracy of performance predictions (Hensen & Lamberts, 2011).

VII. CONCLUSION

This study highlights the potential of dehumidification façades as an effective strategy for improving indoor environmental quality in warm and humid climates. The integration of double skin façade systems with hygroscopic materials offers a promising approach to reducing indoor humidity levels and enhancing thermal comfort.

The findings emphasize the importance of adopting a holistic design approach that considers both material properties and façade configuration. While the concept demonstrates significant potential, further research is required to validate its performance in real-world applications and to develop practical design guidelines for implementation.

VII. FUTURE SCOPE

Future research should focus on conducting experimental studies in real buildings to validate theoretical findings and simulation models. The development of climate-specific design guidelines and the integration of advanced modeling tools will be essential for optimizing façade performance. Additionally, interdisciplinary research combining architecture, material science, and environmental engineering can further enhance the effectiveness of dehumidification façade systems.

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