TRADITIONAL ARCHITECTURE IN THE CONTEXT OF CLIMATE CHANGE: STRUCTURAL ADAPTATION STRATEGIES ACROSS THE BLACK SEA, MEDITERRANEAN, AND EASTERN ANATOLIA REGIONS

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Abstract
Climate change has emerged as one of the most critical global challenges, directly influencing building production processes. In this context, traditional architecture provides a significant field of study through structural solutions developed over centuries to adapt to diverse geographical and climatic conditions. The aim of this study is to comparatively examine the structural adaptation strategies of traditional architecture in Turkey's Black Sea, Mediterranean, and Eastern Anatolia regions and to evaluate the extent to which these strategies can serve as guidance in addressing today's climate crisis.
The study first discusses the major impacts of climate change on architecture—rising temperatures, heavy rainfall and flooding, storm- and wind-induced structural damage, and the increasing demand for heating and cooling due to drought and climatic variability. It then analyzes the characteristic architectural features observed in three different climatic zones. In the Black Sea Region, timber-frame construction systems, stone foundations, water-resistant roof forms, and facade solutions developed to withstand high rainfall and humidity are emphasized. In the Mediterranean Region, thick stone walls, whitewashed surfaces, deep eaves, oriels, and courtyards provide passive cooling strategies in response to hot and dry summers. In Eastern Anatolia, harsh continental winters and hot summers have shaped building practices through thick walls, limited window openings, steeply sloped roofs, and the combined use of stone and wood.
Findings demonstrate that local material use, passive climate-control techniques, and typological diversity are the key principles underpinning climate-responsive traditional design. When these principles are integrated with modern sustainability approaches, they can contribute to the design of more resilient and energy-efficient structures. In particular, combining traditional knowledge with contemporary technologies in water management, energy-efficient design, and sustainable material use offers a robust framework for creating environmentally friendly and climate-resilient built environments in the face of the global climate crisis.

Keywords: Traditional architecture, climate change, structural adaptation, passive design, regional typology, sustainable materials.

I. INTRODUCTION

Architecture is an important art and body of knowledge that humanity has developed over centuries to adapt to nature and meet its needs. Climate changes have had significant impacts on architectural designs, deeply affecting regional and cultural differences. In this context, it is essential to understand how climate changes have influenced architectural traditions in different regions of Turkey.

This study examines how traditional architectural designs, shaped by climatic conditions in different climate regions of Turkey due to their climatic diversity, have adapted to climate changes and how these transformations have affected regional architectural identity. Other geographical areas possess unique architectural heritage shaped by their specific climate conditions, material choices, and cultural history. The traditional architectural characteristics of the research area reveal how climate has influenced architectural structures throughout history and how they have adapted to their climate conditions and environmental challenges. This adaptation has formed the foundation of the region's architectural identity.

II. THE RELATIONSHIP BETWEEN CLIMATE CHANGE AND ARCHITECTURE

Today, climate change has become one of our most significant environmental challenges. Climate changes cause ecological problems and seriously threaten economic and social systems. These changes manifest through rising temperatures, sea-level rise, extreme weather events, and many other factors. This situation affects nature and people's ways of living, infrastructure, and architectural designs. At the same time, climate change presents an opportunity for design that addresses environmental sustainability, energy efficiency, and social adaptation.

III. THE EFFECTS OF CLIMATE CHANGE ON ARCHITECTURE

Climate change, by influencing various climatic events globally, significantly impacts the planning and implementation of architectural designs. These changes reveal factors that must be considered in building design, material selection, and urban planning. In this context,

climate change can affect the design processes of architectural projects, particularly under the following five main headings:

3.1. The Impact of Rising Temperatures on Architecture

Today, climate change brings various environmental problems on a global scale. One of these issues is the effects of rising temperatures. In this regard, it has become increasingly important for architectural designs and construction to adapt to increasing temperatures and minimize their environmental impacts. Rising temperatures have a significant effect on building energy efficiency.

3.2. Sea-Level Rise and Coastal Structures

The effects of climate change worldwide are becoming more apparent, with sea-level rise being one of the most prominent changes. This rise in sea levels particularly impacts coastal structures and environmental sustainability.

Sea-level rise is a critical factor that can directly affect structures in coastal regions. It is important to use durable materials and adopt flexible design strategies that can adapt to changes in water levels for coastal structures.

3.3. Damage Caused by Wind and Storms to Structures

Winds and storms can affect buildings in various ways. Strong winds can significantly adversely affect tall buildings and structures in open areas. Damage may include roof dislodgment, window breakage, damage to façade materials, and structural deformations. To mitigate these adverse effects, architectural design strategies are being developed. Examples of these strategies include aerodynamic designs for tall buildings, structural reinforcements, and material selection focused on durability.

3.4. The Impact of Heavy Rainfall and Flooding on Architecture

Climate change and alterations in precipitation patterns increase the frequency and severity of heavy rainfall and flood events. This situation poses a significant risk, particularly for structures located in urban areas and low-lying regions.

Heavy rainfall and floods can severely affect infrastructure and building designs. Strengthening water management systems is crucial to prevent uncontrolled water from damaging buildings. In areas where water may cause soil erosion, landscape architecture, and green infrastructure strategies should be implemented to mitigate these effects.

IV. Architectural Structures Based on Climate Diversity

4.1. Black Sea Architecture

The Black Sea region is located in the north of Turkey. Factors such as climate, geography, culture, and history shape the region's unique architectural characteristics, which contribute to its distinct identity. The architecture of homes in this area is especially notable for blending traditional and functional design elements. Black Sea houses are known for being constructed harmoniously with climatic conditions, local materials, and cultural values.

Black Sea houses are a product of architecture that has achieved harmony with nature, people, and long-term experiences. These houses reflect the synergy between the challenging geography and the resilient people of the Black Sea region [1]. Traditional houses in the Black Sea region are often built using wood from the region's abundant forests. Due to the region's rich forest resources, wood is a preferred building material and is ideal for adapting to the local climate. The wood, processed with traditional craftsmanship, gains an aesthetic appearance. The most suitable tree species for construction are selected based on workability and fiber characteristics. In the Eastern Black Sea region, trees such as pine, spruce, oak, chestnut, alder, and walnut are commonly used, while moving westward, trees like ash, elm, and spruce become more prevalent [2].

Wooden Frame/Timber Construction System:

In contrast to solid wood structures, the process used in the load-bearing elements involves the vertical placement of wooden supports. This method allows all the weight of the building to be transferred to the foundation walls. The section up to the foundation level is generally built with stone masonry, while the upper floors are constructed using a timber frame or solid wood system. A key feature of this construction method is using different load-bearing systems across various floors. Small slats are frequently added between the vertical and horizontal load-bearing pillars in structures built on a foundation layer. These slats are filled with different materials, and plastering is applied afterward.

Solid Wood Construction System:

This technique is used for homes, especially in rural areas, villages, high-altitude settlements, and simple village houses in the Black Sea region. The material typically used is logs stacked on each other, and planks 3-5 cm thick can also be used. No secondary support elements are required in this system, as the wood alone serves as the load-bearing material. The weight of each wooden element is transferred to the one below it and eventually to the ground.

Use of Stone Materials:

Stone, alongside wood, is another important material in the Black Sea region (Figure 1). Using stone in Black Sea architecture reflects the tradition of constructing sustainable and durable structures utilizing the region's natural resources. This material represents the region's efforts to live harmoniously with its surroundings and pass on its architectural heritage to future generations. The foundation of traditional Black Sea houses is often built with stone. The stone enhances the house's durability and helps it adapt to the ground better. Stone is commonly used in the foundation and barn levels of houses in the Black Sea region (Figure 2). Pebbles collected from riverbanks and coastlines are used as extensive filler material in walls, while smaller pebbles are used for ground covering.

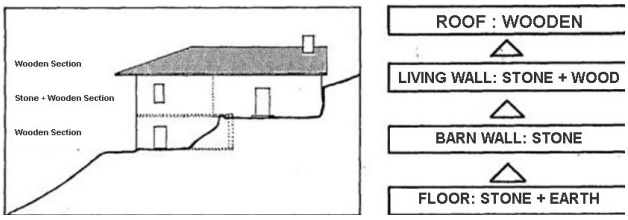

Figure 1. Stone Material Usage in Black Sea Architecture [2]

Figure 2: Stone and Wood Material Usage in Black Sea Architecture [2].

Windows and Doors

In Black Sea architecture, local materials in the region are typically preferred for constructing windows and doors. Wood is the most commonly used material for this purpose. Windows and doors, shaped by traditional craftsmanship and carpentry skills, harmonize with the regional architecture. They are essential details in the architecture of traditional Black Sea houses. Designed to withstand the Black Sea's humid climate and the sea's effects, windows and doors are resistant to strong winds and heavy rainfall. The windows are rectangular and arranged vertically or wingedly based on the same principle (Figure 3).

Figure 3. Black Sea Architecture Window Design [1].

In different parts of the Black Sea region, various types of doors with original forms and decorative features exist. These doors can be simple, ornamental, or embellished, and they are important details that define the architectural identity of the houses. Beyond mere entry points, doors reflect the cultural heritage of the region and enhance the aesthetic value of the house (Figure 4) [1].

Figure 4. Black Sea Architecture [3].

Roof Structure

The roofs of houses in the Black Sea region are generally steeply pitched and extend gently downward from the eaves. This roof design adapts to heavy snowfall and the region's rainy weather. Additionally, the steep angle of the roof reduces the impact of the wind, increasing durability. Traditional reed roof coverings are used in some Black Sea houses, especially in coastal areas. This material effectively drains water and also provides natural insulation.

The region's heavy rainfall has influenced the roof shapes used in its architecture, leading to the development of three basic forms: the gable roof, the three-hipped roof, and the four-hipped roof (Figure 5).

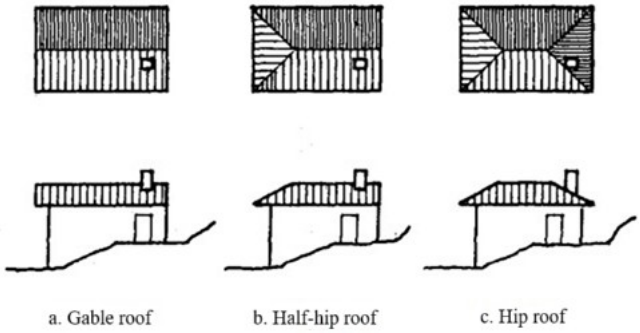

Figure 5. Roof Forms [2].

V. MEDITERRANEAN ARCHITECTURE

The Mediterranean climate is characterized by hot summers, mild winters, and abundant sunshine. This climate type allows architects to design buildings carefully to keep them cool during hot summer days and make the most of the sun during winter. White-colored buildings help reduce indoor temperatures by reflecting sunlight. The wind effect, often felt along the Mediterranean coast, requires architects to protect buildings from this influence. Therefore, design elements such as eaves, awnings, and well-positioned windows create a comfortable indoor climate.

The Mediterranean architecture emphasizes regional materials; stone from local quarries, adobe, wood, and white surfaces are key materials in this style. Wood carving and stone craftsmanship add elegance to architectural details.

Use of Stone Materials

Mediterranean architecture highlights stone's natural beauty and durability, creating a regional architectural character. Stone is an essential architectural element that carries the history and cultural heritage of the Mediterranean to the present day (Figure 6). The Mediterranean region has been home to many civilizations throughout history, and the traces of these civilizations are seen in its stone architecture. Civilizations such as the Romans, Byzantines, and Ottomans have influenced natural stones like limestone, travertine, or basalt use in Mediterranean homes.

Figure 6. Use of Stone Materials in Mediterranean Architecture [4].

Mediterranean architecture typically employs traditional construction techniques used by local craftsmen. Skills such as stone cutting, carving, and masonry create a regional architectural character. Stone's carving and processing capabilities are frequently utilized. Stone craftsmanship, mainly seen in door frames, window edges, and facade decorations, adds elegance to architectural details. These carvings often feature geometric patterns, plant motifs, or figurative elements.

Use of Wood Materials

Another frequently encountered element in the architectural features of the Mediterranean region is wood. Wood is a natural insulation material well-suited to the warm Mediterranean climate. Wooden structures remain cool in hot weather and contribute to energy efficiency, helping the homes in the region provide a comfortable and sustainable living environment.

Facade Features

The southern facade of Mediterranean houses is generally dominant in views, and the front facade is often defined by the outer walls of the central sofa on the ground floor and the central sofa on the living floor. Due to the function of the ground floor, the number of windows opening to the outside is limited. In some examples, the bay windows decorating the front facade are connected to the roof covering with triangular pediments. Variations in window design and roof covering are frequently observed, with deviations from traditional window types and various forms standing out. Key elements in the facade layout include stone walls with wooden buttons, increased windows on the living floor, and wooden-clad wall surfaces. A simple and minimalist approach is adopted in the facade design, with interior aesthetics and details not typically reflected on the outer facade. The oriel sections on the living floor also showcase beautiful wood craftsmanship, with window grilles decorated with various motifs (Figure 7).

Figure 7. Mediterranean Architecture Window Grille Example [5].

Doors and Windows

Street doors are usually made of wood and can be single or double-leafed. In some houses, iron or wooden grated openings above the doors are present to allow light and air (Figure 8). Traditional house doors stand out with their richly carved decorations [6]. Iron doors are also sometimes seen at entry points.

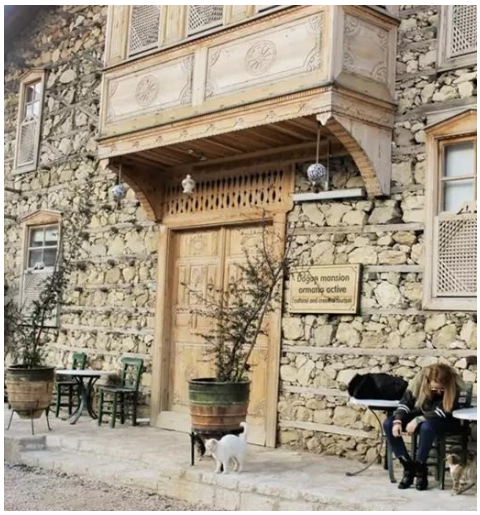

Figure 9. Mediterranean Architecture Street Door [5].

Courtyard doors are generally double-leafed and quite broad, with designs that emphasize simplicity. Most are made of wood and operate on a mirrored system, though some examples feature a batten door style. Rarely are courtyard doors made with panels, which are usually plain and undecorated. The upper sections of courtyard doors are typically covered with a barrel roof [4].

Windows are designed in various forms depending on the construction, but their dimensions and sizes are usually similar. Arranged from the outside to the inside, windows consist of two-sided wooden shutters, wooden grilles or iron bars, and glass double-leaf panels. The windows in Antakya houses are often referred to as "Taka" and are adorned with small windows known as "bird takes" [6]. Window grilles

are made of either wood or iron with different pattern applications and are used as decorative elements (Figure 9).

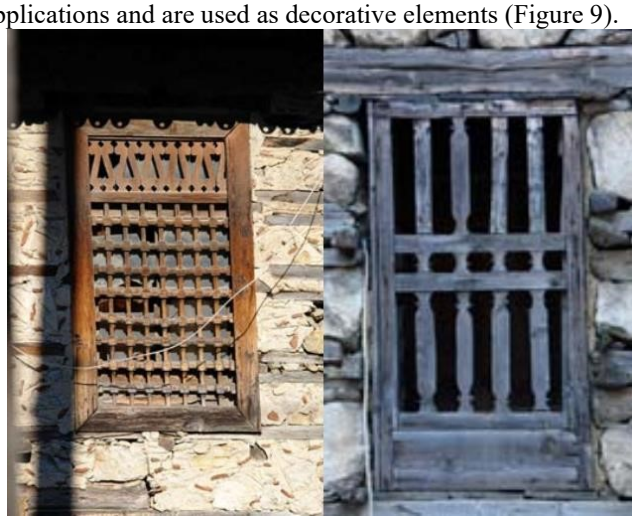

Figure 9. Mediterranean Architecture Window Grilles [4].

Projections

In traditional Mediterranean homes, projections are essential structural elements shaped according to how the house is positioned on the plot and the formation of the street (Figure 10). Open projections are usually called balconies, while closed projections are known as bay windows. Projections are preferred for their functions, such as providing views and access to the street, allowing sufficient light and air, creating larger spaces on upper floors, protecting the entrance floor from weather conditions, and observing activities on the street [4].

Figure 10. Mediterranean Architecture House Projections [4].

Roof Structure

Traditional Mediterranean architecture includes architectural designs planned to create a relaxing atmosphere, keep interiors cool, and reduce the effects of the sun, all influenced by the warm and sunny climate. Roofs are typically covered with durable and cooling tiles. The colorful tiles give the buildings a traditional appearance. Roof slopes allow rainwater to flow and reduce the effects of the sun.

VI. EASTERN ANATOLIAN ARCHITECTURE

The Eastern Anatolia Region stands out with its rich cultural heritage, historical texture, and distinctive climatic features. The architecture of this region has been shaped by various civilizations throughout history, resulting in a unique character. Traditional Eastern Anatolian architecture consists of original structures designed by the region's climate, geographical features, and local culture. The cold winters, hot summers, and generally rural character of Eastern Anatolia influence its architecture. As a result, traditional Eastern Anatolian houses are typically built using wood and stone. Wood is commonly preferred due to the abundance of forests in the area, while stone is valued for its durability and strength.

Use of Materials

Various building materials are used in traditional Eastern Anatolian houses. Rubble stones are generally used for the facade, while cut stones are preferred for the corners of load-bearing walls, fireplace fronts, door and window edges, and lintels. Bricks are made by mixing clay, loamy soil, and silt, shaping them, and then firing them. Bricks are essential in various structures, used in walls, domes, vaults, floor coverings, chimneys, and as infill in wooden frameworks. Wood is the most widely used construction material in Eastern Anatolian houses. It is utilized for doors, windows, shelves, cupboards, bath alcoves, granaries, floor coverings in rooms, ceiling coverings, the upper coverings of tandır (traditional clay ovens) houses, and other units, the binding elements called "hatıl," interior and exterior stairs, and the beams supporting roofs. Metal materials include door and window hinges, nails, window protection bars, and door knockers [7].

Doors and Windows

The main door on the exterior facade of Eastern Anatolian houses and the semicircular windows above the stone lintels stand out as a departure from traditional standards. Doors are typically designed as single or double-leaf, serving as both main entrance and room doors. In exterior doors, carved knife-pattern designs and large-headed forged nails holding the door panels, along with door knockers, play an essential role in the decorative elements of Eastern Anatolian houses. The door knockers come in geometric, human hand, animal, and plant forms and are categorized by gender as children's, women's, and men's knockers (Figure 11).

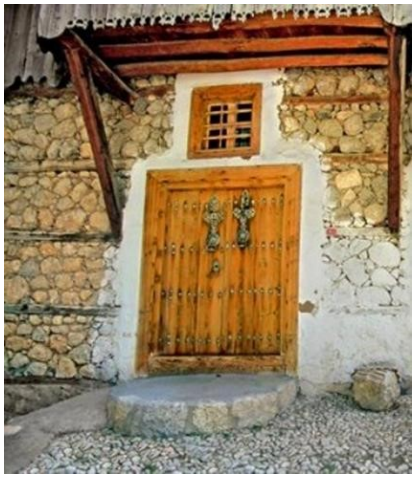

Figure 11. Eastern Anatolian Architecture Street Door [8].

Windows are generally small, and the thick walls are expanded inward like an arrow slit. Frames are positioned close to the exterior, with iron bars added between the inner and outer layers. Window shutters have three pairs of openings; the inner shutters open inward, while the outer ones open outward (Figure 12).

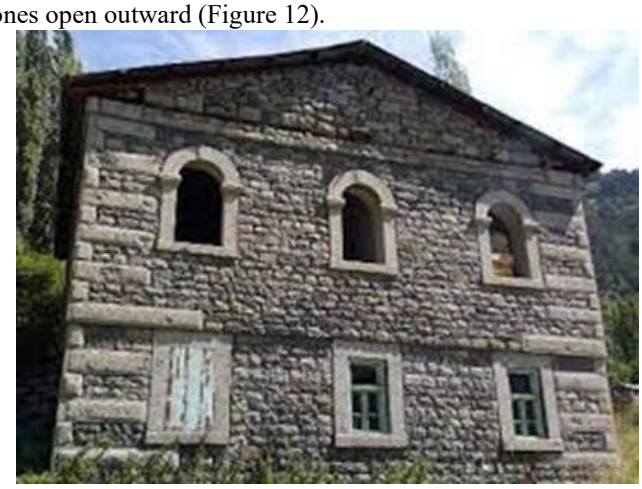

Figure 12: Eastern Anatolian Architecture Windows [8].

Protrusions and Balconies

The facades of Eastern Anatolian houses include various types of protrusions. These elements include floor projections, angled projections, bracketed projections, cantilevered projections, and open cantilevered projections. Floor and angled projections are created by extending the load-bearing beams outward, usually adding an aesthetic touch to the first floors of houses. In bracketed projections, the angled projections are supported by brackets and are used to correct the irregularity of the ground floor, especially when the plot is narrow. Cantilevered projections are made by extending the beams of the first floor, typically providing an aesthetic contribution to a single room or the entire facade. In open cantilevered projections, some of the beams supporting the projection are left exposed, creating a distinct appearance [9].

Balconies in Eastern Anatolian houses are usually symmetrically placed at the second-floor level, directly above the main entrance door, serving as significant facade elements. The balcony architecture contributes to the exterior aesthetics with arches created by wooden posts resting on wooden beams (Figure 13).

Figure 13. Wooden Balcony in Eastern Anatolian Architecture [10].

Roof Structure

In traditional houses across Anatolia, roofs protect against atmospheric precipitation. These are generally gable roofs supported by wooden posts and sloped in two directions. To shield from harsh weather conditions, the roofs are extended outward and covered with sheet metal [8].

CONCLUSION AND RECOMMENDATIONS

Turkey's Black Sea, Mediterranean, and Eastern Anatolia regions exhibit significant differences in traditional architecture due to their rich cultural heritage and climatic diversity. Each region's distinct architectural tradition is shaped by its climatic conditions, local material use, and cultural characteristics. By comparing the strategies and traditional architectural features used to cope with climate changes in each region, the findings and recommendations are as follows:

The Black Sea Region is characterized by heavy rainfall and high humidity. Traditional architecture emphasizes water drainage systems and waterproofing. Wooden roofs, durable materials, and water-resistant door and window designs are prominent solutions for the region's climate. The modernization of drainage systems and the broader use of water-resistant materials could enhance the adaptability of traditional architecture to climate change.

The Mediterranean Region experiences hot and dry summers. Traditional architecture includes flat or slightly sloped roofs, wide eaves, and surfaces suitable for solar panels. The eaves' protective function against rain is essential in this region. It is suggested that wide eaves and solar panels be promoted to cope with climate change.

Eastern Anatolia has a continental climate with cold, snowy winters and hot, dry summers. Traditional architecture in this region adapts to these harsh conditions with thick walls, steeply sloped roofs, and the use of durable wood. Climate change, particularly rising temperatures and dryness,

may require more effective insulation and energy-saving solutions. Increasing the use of solar energy and adopting sustainable materials can help modernize Eastern Anatolia's architecture.

General Findings and Recommendations:

Traditional architecture, shaped by the climatic conditions of each region, should be reinforced with local material use, energy efficiency, and sustainable design principles to adapt to climate changes.

Innovations in material use, energy-efficient designs, and water management improvements can make traditional architecture more resilient to climate change.

Engaging communities and combining traditional knowledge with modern solutions can help develop unique and sustainable architectural solutions regionally.

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