IMPACT OF CLIMATE CHANGE ON STRUCTURAL DESIGN IN BANGLADESH: CHALLENGES, ADAPTATIONS, AND POLICY GAPS

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A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering.



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Dedicated

To

“Our Beloved Parents”

&

“Our Respected Teachers"

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ABSTRACT

Climate change has emerged as a significant challenge to infrastructure development and sustainability in Bangladesh, a country frequently exposed to natural hazards such as cyclones, flooding, salinity intrusion, and temperature extremes. This study investigates the impact of climate change on structural design practices across various climatic zones of Bangladesh, encompassing coastal, urban, and northern regions. A comprehensive methodology was adopted, combining field surveys, expert interviews, focus group discussions, and case studies to assess both physical effects on structures and the adaptation measures adopted by engineers, policymakers, and communities.

Primary data were collected from affected communities, practicing engineers, and institutional representatives, while secondary data were sourced from government agencies, research institutions, and construction industry stakeholders. The findings reveal that climate-induced hazards have already compromised the integrity of various structural elements, particularly in coastal and flood-prone regions. The study also identifies an evolving trend among designers and engineers to incorporate climate resilience in design, yet highlights major gaps in enforcement, policy coherence, and technical guidance.

A SWOT analysis of current disaster-resilient design approaches reveals strengths in local innovations and weaknesses in institutional coordination. The study concludes with practical recommendations for strengthening structural design codes, enhancing institutional capacity, and promoting sustainable construction practices in the face of increasing climate variability.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The effects of climate change are now being felt across nearly every facet of modern life, impacting ecosystems, economies, and human communities on a global scale. With the Earth's temperature rising at an unprecedented rate, driven largely by human activity and greenhouse gas emissions, we are witnessing shifts in global weather patterns, an increase in the frequency and severity of extreme weather events, and a cascade of environmental challenges that threaten both natural systems and human built infrastructure. In particular, climate change has created a pressing need to reassess structural design practices, as buildings and infrastructure must now withstand conditions far more severe and variable than those for which they were originally planned.

Structural design, a discipline traditionally reliant on historical climate data to inform building codes, standards, and materials, faces the challenge of adapting to a future where past climate norms are no longer reliable indicators. Historically, engineers and architects would reference decades of climatic and geological data to determine appropriate safety margins and structural specifications for resilience against wind loads, temperature extremes, and seismic activity. However, with climate models now projecting more extreme events—such as intense storms, heatwaves, flooding, and sea level rise—designers are increasingly tasked with creating infrastructure that can adapt to unprecedented stresses.

This paradigm shift demands innovative strategies that account for uncertainty and variability, integrating adaptive designs, advanced materials, and predictive technologies. It also calls for updated regulatory standards that incorporate dynamic climate projections, ensuring that infrastructure is not only robust against current conditions but resilient to the evolving demands of the future.

In addition to shifts in temperature and precipitation patterns, climate change is reshaping regional conditions, directly influencing the performance requirements of structures in specific geographic areas. Coastal regions, for instance, face heightened risks from rising sea levels, intensified storm surges, and accelerating erosion. Inland areas are increasingly

challenged by severe droughts, which can destabilise soils and compromise foundational integrity. Urban environments, characterised by dense building clusters, are particularly vulnerable, as extreme heat and amplified rainwater runoff exacerbate existing vulnerabilities.

The pressing issue is that much of the existing infrastructure was not engineered to endure the frequency and intensity of extreme weather events now becoming the norm. This necessitates a fundamental reevaluation of approaches to design, material selection, and regulatory standards for new construction. Resilient building practices must prioritise adaptability, ensuring that future infrastructure can withstand the evolving challenges of a changing climate.

Material performance under changing environmental conditions is another critical concern. Extreme heat can cause thermal expansion in steel and concrete, potentially leading to structural instability. Similarly, excessive moisture from prolonged rainfall or flooding can degrade construction materials, while salinity from sea level rise can accelerate the corrosion of metal reinforcements. Designing structures with these challenges in mind requires not only innovative materials but also novel construction techniques and maintenance strategies.

To address these evolving risks, structural design must now integrate adaptive strategies that account for both current and anticipated climate changes. These strategies include the use of more resilient materials, improved drainage systems, energy efficient and heat resistant building techniques, and robust foundations that can withstand soil shifting due to drought or flooding. Furthermore, resilience frameworks emphasise not only building for immediate safety but ensuring longevity under extreme conditions. Advances in materials science, such as high performance concrete, fibre reinforced composites, and biobased materials, offer new possibilities for creating structures capable of enduring the stresses posed by a changing climate.

The adoption of performance based design principles allows for greater flexibility and innovation in how structures are planned and evaluated. Unlike prescriptive design, which adheres to specific regulations and safety codes, performance based design allows engineers and architects to model structural responses to a range of potential climate scenarios. This is particularly important in high risk regions where structures must not only endure but recover quickly from extreme weather events to minimise economic loss and support community

resilience. Furthermore, modern computational tools and climate simulation software allow designers to visualise and test the impact of different climate events on structural performance, offering data driven insights to optimise building resilience.

In this context, understanding the impact of climate change on structural design is essential for developing sustainable and adaptive buildings that can withstand the environmental stresses of a warming world. This paper aims to analyse how evolving climate patterns influence structural design practices, identify emerging challenges, and explore innovative solutions in materials, construction techniques, and design methodologies. By investigating these factors, we hope to contribute to a framework that supports resilient infrastructure development capable of withstanding the environmental pressures of a changing climate.

1.2 Background and Motivations

The design and construction of human built structures have historically been shaped by environmental factors, available materials, and social needs. From ancient stone structures designed to withstand seasonal monsoons to modern skyscrapers built to tolerate high winds and seismic activity, structural design has evolved as a response to the climate and environmental conditions specific to each location. Traditionally, engineers and architects relied on historical climate data to determine acceptable safety margins for structural loads, thermal insulation, and material durability. Building codes and standards developed over decades have been integral to guiding the design, ensuring that structures can withstand typical local conditions and protect occupants.

However, over the past few decades, climate change has introduced a new set of variables that challenge these traditional approaches. Driven largely by anthropogenic activities—especially the burning of fossil fuels, deforestation, and industrial emissions—greenhouse gases like carbon dioxide and methane have accumulated in the Earth's atmosphere, trapping heat and causing global temperatures to rise. According to the Intergovernmental Panel on Climate Change (IPCC), the average global temperature has increased by approximately 1.1°C since the preindustrial period, with projections indicating further increases unless drastic action is taken. This warming has led to significant shifts in weather patterns, with increased frequency and intensity of extreme weather events such as hurricanes, wildfires, heatwaves, and floods.

The impacts of climate change on structural integrity are manifold. As temperatures increase, materials used in construction, like concrete and steel, experience changes in their thermal and mechanical properties. High temperatures can cause thermal expansion, weaken structural connections, and accelerate material degradation. Flooding and sea level rise increase the risk of water intrusion, corrosion of foundations, and erosion, especially in coastal areas. Increased frequency and intensity of hurricanes and storms expose buildings to high wind pressures, which can lead to structural failure if not properly addressed.

In response to these emerging challenges, structural engineering is increasingly emphasizing resilience—a concept that refers to a structure's ability to resist, absorb, recover from, and adapt to adverse events. Resilient design involves selecting materials and structural systems that can endure extreme conditions, implementing redundancies, and designing with recovery and adaptation in mind. This shift in focus also necessitates advancements in building codes, as many current codes are based on historical data that may no longer be applicable in the face of rapid climatic shifts.

1.3 Historical and Current Adaptation Approaches

To manage the risks posed by extreme weather and changing environmental conditions, structural designers have begun to adopt performance based design (PBD) approaches that go beyond prescriptive codes. Performancebased design allows for customised, flexible solutions by evaluating how a structure is likely to perform under various stressors, rather than prescribing specific materials or methods. For instance, PBD enables the simulation of different climate scenarios, assessing how a structure would respond to a projected range of temperatures, moisture levels, and wind loads over its lifetime. This approach aligns with the broader goals of resilience and sustainability in modern engineering.

In addition to PBD, advancements in materials science are playing a crucial role in supporting resilient structural design. Innovative materials like high performance concrete, which is resistant to cracking and weathering, fibre reinforced polymers for lightweight strength, and climate responsive materials that adapt to temperature changes are becoming increasingly vital. Additionally, sustainable materials, such as bamboo composites and recycled steel, support eco-friendly construction while maintaining durability.

Governments and regulatory bodies worldwide have also begun revising building codes and standards to account for climate related risks. For example, the American Society of Civil Engineers (ASCE) has updated its standards to include guidelines for designing structures

that can withstand extreme weather events. Similarly, the European Union has initiated various frameworks to assess climate risks in urban planning, aiming to promote adaptive measures in both new construction and retrofitting projects.

1.4 Objectives of the Study

The primary objective of this study is to investigate the impact of climate change on structural design practices in Bangladesh. The research aims to explore how climate-induced hazards influence both existing structures and the approaches adopted in engineering design and construction. The specific objectives are:

1. To identify the major climate change-induced hazards affecting structural stability in Bangladesh.

This includes hazards such as cyclones, floods, salinity intrusion, extreme rainfall, temperature rise, and droughts that directly or indirectly affect building integrity and performance.

2. To assess the physical and functional effects of these climate hazards on different types of structures.

This involves evaluating damage, degradation, or failure patterns observed in buildings, roads, and bridges across different climatic zones.

3. To examine how structural design practices are adapting to climate change impacts.

This focuses on modifications in design standards, materials used, construction methods, and engineering solutions to enhance structural resilience.

4. To analyze existing policies, building codes, and institutional responses related to climate-resilient construction.

This includes reviewing government strategies, development partner initiatives, and regulatory mechanisms to assess their effectiveness in addressing climate risks.

5. To recommend practical strategies for integrating climate resilience into structural design.

Based on findings, the study will suggest actionable solutions for policymakers, engineers, and the construction industry to reduce climate vulnerability in future infrastructure development.

1.5 Re-Gaps and Emerging Focus Areas

While significant progress has been made in adapting structural design to address climate risks, there remain key areas in need of further research. One major challenge is developing accurate predictive models that can account for future climate variability and uncertainty, which remains a significant obstacle for long term planning. Moreover, understanding how different types of infrastructure (e.g., residential, commercial, industrial) and regions will be differentially affected by climate change remains critical for targeted adaptation strategies.

Furthermore, as urbanisation increases, the vulnerability of densely populated areas to climate impacts grows, emphasising the need for innovative, climate resilient urban infrastructure. Urban heat islands, for example, exacerbate the effects of heatwaves, while high density construction can complicate flood management. Coastal cities face the dual threat of rising sea levels and storm surges, requiring novel approaches to foundation stability and floodproofing.

The goal of this thesis is to address these gaps by exploring how climate change is reshaping the principles of structural design and evaluating the effectiveness of emerging resilience oriented methods. By investigating the effects of climate variability on materials, structural systems, and design methodologies, this seeks to contribute insights that will support the development of adaptive, sustainable infrastructure equipped to withstand the challenges posed by a warming world.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Living beings have inhabited the Earth since the dawn of time. In the early days, humans lived in forests and adapted to their natural surroundings. People lived in different ways—sometimes alone, other times in groups—depending on their needs and environment. During this period, the Earth's weather and atmosphere were generally calm and stable, creating a balanced ecosystem.

However, with the rise of modern civilization, human activities began to exert significant pressure on the environment. Industrialization, urbanisation, and technological advancements, while improving human life in many ways, also initiated destructive practices that disrupted the planet's delicate balance. One of the most harmful consequences of these activities has been the increased concentration of carbon dioxide (CO_2) in the atmosphere.

2.2 Carbon Dioxide and Its Effects[1]

Carbon dioxide, a greenhouse gas, plays a major role in global warming and climate change. It is primarily released through activities such as:

- **Burning Fossil Fuels:** Coal, oil, and natural gas combustion for energy production and transportation.
- **Deforestation:** Cutting down forests reduces the Earth's capacity to absorb CO_2, further exacerbating the problem.
- **Industrial Emissions:** Factories and manufacturing processes release significant amounts of CO_2 and other pollutants.

As CO_2 levels rise, they trap heat in the atmosphere, causing the Earth's temperature to increase—a phenomenon known as the **greenhouse effect**. This leads to a range of adverse impacts, including:

1. Melting Polar Ice Caps: Resulting in rising sea levels and threatening coastal communities.

2. Extreme Weather Events: Increased frequency and intensity of hurricanes, droughts, and floods.

2.3 The Impact of Climate Change on Human and Natural Systems

Climate change is causing significant transformations in the Earth's environment, bringing both direct and indirect consequences for all forms of life. Humans and animals alike are facing devastating challenges. In some regions, floods wreak havoc, while in others, prolonged droughts threaten livelihoods and ecosystems.

One of the most alarming effects of climate change is the rise in the Earth's temperature, driven by increased greenhouse gas emissions. This warming has led to: **Flooding in Low Lying Areas:** Coastal regions and islands are particularly vulnerable, with many areas already experiencing submersion. The rising sea levels and unpredictable weather patterns are just some of the many ways climate change is reshaping our planet.

2.4 Impact on Infrastructure and Modern Habitation [2]

Climate change has a profound influence on the construction and design of buildings, infrastructure, and human made habitats. Modern civilization relies heavily on durable and resilient structures, but changing environmental conditions pose serious challenges.

- **Increased Vulnerability:** Buildings in flood prone or coastal areas face higher risks of damage.
- **Structural Adaptations:** Engineers and architects are now prioritising climate resilience in their designs.

2.5 The Role of Developed Nations [3][4][5]

Developed countries are leading efforts to integrate climate considerations into building designs. Architects and designers are adopting practices such as:

- **EnergyEfficient Buildings:** Incorporating insulation, solar panels, and natural ventilation systems.
- **Flood Resistant Structures:** Elevating building foundations and using water resistant materials.

- **Sustainable Urban Planning:** Creating green spaces and efficient drainage systems to manage stormwater.

These innovations reflect a growing awareness of the critical need to adapt to climate change while reducing environmental impact.

2.6 Climate Resilient Buildings and the Impact of Climate Change on Construction Materials [6][7][8]

To mitigate the effects of climate change, buildings must be designed to be more robust and durable, reducing their susceptibility to damage. Climate Resilient buildings are better equipped to withstand environmental stresses, ensuring long term functionality and safety.

The Impact of Rising Temperatures and Changing Rainfall Patterns

Climate change has led to rising temperatures and shifts in rainfall patterns, which are causing significant challenges for infrastructure:

- **Groundwater Issues:** Fluctuations in groundwater levels, driven by irregular or excessive rainfall, are weakening building foundations.
- **Structural Damage:** Cracks and degradation are becoming more common in buildings, bridges, and other infrastructure, reducing their stability.
- **Deterioration of Construction Materials:** Key materials, such as concrete, are losing quality due to prolonged exposure to high temperatures and increased humidity.

2.7 Features of Climate Resilient Buildings [5][8][9]

To counteract these challenges, buildings are being designed with specific features to enhance their resilience:

- **Enhanced Resistance:** Structures are built to withstand extreme weather events, including storms, floods, and heatwaves.
- **Advanced Materials:** Highquality, climate resistant construction materials, such as improved concrete or nanotechnology based materials, are being utilised.
- **Sustainable Design:** Foundations and structural components are optimised to handle environmental stresses while minimising ecological impact.

2.8 Fundamental Principles of Structural Design

Structural design is a cornerstone of civil engineering, ensuring that structures are safe, reliable, and efficient while serving their intended purposes. It involves a delicate balance between multiple considerations, such as safety, functionality, aesthetics, and environmental impact. The principles of structural design encompass the following key aspects:

1.Safety and Stability

Safety is the foremost priority in structural design. A well designed structure must be capable of withstanding various loads and forces it encounters during its lifetime, including:

Dead Loads: The self weight of the structure.

Live Loads: Loads imposed by occupants, furniture, and temporary uses.

Environmental Loads: Wind, seismic activities, snow, and thermal effects.

Accidental Loads: Rare and extreme events such as explosions or collisions.

Structural stability ensures that the building does not collapse or deform excessively under these forces, even in extreme scenarios like earthquakes or hurricanes. Designers achieve this by applying advanced analytical methods, adhering to building codes, and incorporating safety factors into their calculations.

2. Strength and Durability [4][5]

The materials used in construction—such as concrete, steel, timber, or composites—must have adequate strength to support the applied loads. However, strength alone is not sufficient; durability is equally critical.

LongTerm Performance: Materials should resist deterioration due to environmental factors such as moisture, temperature changes, corrosion, or UV exposure.

Life Cycle Considerations: Structures are often designed for specific lifespans (e.g., 50100 years), requiring materials and techniques that ensure they remain functional and safe over time.

Advanced Materials: Engineers increasingly use materials like high performance concrete, fibre reinforced composites, or corrosion resistant alloys for improved durability.

3. Serviceability

Beyond safety, a structure must perform well during regular use. Serviceability addresses comfort, functionality, and operational efficiency, focusing on:

Deflection Control: Limiting excessive bending or sagging of structural members.
Vibration Management: Avoiding discomfort or structural damage caused by vibrations from occupants, equipment, or external sources like wind.
Crack Prevention: Ensuring that cracks in structural elements are within acceptable limits to prevent water penetration or long term weakening.
Serviceability ensures the structure remains both functional and pleasant for users, enhancing its usability over time.

4. Economy and Efficiency

Optimal resource use is a vital aspect of structural design, combining cost effectiveness with high performance. This involves:
Efficient Material Use: Reducing material waste while ensuring strength and safety.
Construction Techniques: Utilising modern construction methods like precast systems, modular construction, or 3D printing to save time and labour.
Value Engineering:Evaluating alternative designs and materials to achieve the best balance between cost, performance, and sustainability. Economical design does not compromise safety or quality but aims to achieve maximum output with minimal input.

5. Aesthetics and Functionality

Structural design must harmonise with the architectural intent of the project, ensuring both functionality and visual appeal.
Architectural Integration: Collaborating with architects to create structures that complement the building's design.
Form and Function: Balancing innovative shapes with structural efficiency, as seen in iconic structures like bridges, skyscrapers, and stadiums.
User Experience: Designing spaces that are both practical and inspiring for users. Aesthetic considerations often play a significant role in landmark projects, where design becomes a symbol of cultural or technological achievement.

6. Sustainability

Modern structural design emphasises minimising environmental impact through: Energy Efficiency: Designing structures to reduce energy consumption during both construction and operation.

Renewable Materials: Incorporating materials like bamboo, recycled steel, or low carbon concrete.

Waste Reduction: Using techniques that minimise waste generation and support recycling.

LifeCycle Assessment: Evaluating the environmental impact of a structure throughout its entire lifespan, from construction to demolition.

Sustainability is not just a trend but a necessity, as the construction industry contributes significantly to global carbon emissions.

2.9 Addressing Challenges Posed by Climate Change

Traditional structural design principles are based on historical data and predictable environmental conditions. However, climate change introduces uncertainties and new challenges, necessitating innovative approaches.

1. Increased Frequency of Extreme Weather Events

Rising temperatures and unpredictable weather patterns lead to more frequent hurricanes, floods, and heatwaves. Engineers must design structures with higher resilience to withstand these extreme conditions, often exceeding conventional code requirements.[4][5]

2. Sea Level Rise and Coastal Flooding

Coastal infrastructure faces increased risks due to rising sea levels and storm surges. Adaptive strategies include raising foundation levels, using flood resistant materials, and creating flexible designs for changing environments. [4][10]

3. Material Degradation Under Harsh Conditions

Changes in temperature, humidity, and chemical exposure accelerate wear and tear on traditional materials.Innovations in materials science, such as self healing concrete or advanced coatings, help mitigate these effects. [4][10]

4. Sustainability Under Pressure

As resources become scarcer, sustainable practices like carbonneutral construction and renewable energy integration are critical.

2.10 Key Climate Change Impacts on Structures

1.Temperature Variations:

Rising global temperatures and increased extreme temperature fluctuations significantly impact building materials. Materials like steel, concrete, and glass expand and contract with temperature changes, creating stress at joints and connections, which can lead to cracks and structural instability. [6],[8]

2.Thermal Expansion:

Materials such as steel, concrete, and glass expand and contract with temperature changes. This can cause stress at joints and connections, leading to cracks and weakening of structural integrity. [6],[8]

3.Material Corrosion:

High temperatures accelerate the ageing of materials, reducing their strength and lifespan under extreme heat. Wood and plastics are particularly vulnerable to faster degradation, further compromising structural stability. [4][9]

4.Energy Efficiency Challenges:

The rising temperature and increased thermal stress on buildings make them rely more on cooling systems, which leads to higher energy demand. This creates challenges in maintaining energy efficiency and increases operational costs for buildings.

5.Sea Level Rise and Flooding:

Rising sea levels and increased flooding due to climate change pose significant risks to coastal and low lying structures. Prolonged exposure to water increases corrosion of steel and degradation of concrete in foundations, compromising structural integrity.

6.Erosion and Corrosion:

Prolonged water exposure from flooding or sea level rise accelerates the corrosion of steel and degradation of concrete, especially in foundations. This weakens the structure's stability, leading to potential failure.

7.Inundation Damage:

Floodwater can cause severe damage to foundations, promote mold growth, and compromise structural stability. The effects of water infiltration and prolonged exposure can lead to lasting damage to materials and the overall integrity of buildings.

8.Resilient Design Need:

There is a growing need for elevated structures and waterproofing technology to protect against water infiltration. Re highlights the importance of using materials and designs that can resist water and withstand extreme environmental conditions.

9.Increased Frequency and Intensity of Storms:

Stronger and more frequent hurricanes, tornadoes, and storms have significant implications for building safety. These extreme weather events require structures to be designed to withstand high winds and debris impacts.

10.High Wind Loads:

The increasing frequency of extreme storms demands reinforced structures with strong

anchoring systems. This requires additional considerations in building design to resist high wind loads, especially in vulnerable areas.

11.Debris Impact:

Strong winds and storms carry debris that can cause significant damage to buildings. Materials like tempered glass and impact resistant coatings are necessary to reduce the risk of damage from flying debris.

12.Resilience Standards:

Building codes and standards need to evolve to ensure that structures are capable of withstanding extreme weather. Implementing hurricane straps, storm shutters, and other reinforcement measures helps reduce damage from storms and hurricanes.

13.Droughts and Soil Stability:

Droughts can lead to soil shrinkage, causing foundation shifts and cracks in the structure. Uneven settling of buildings can threaten the stability and integrity of the entire structure.

14.Adaptation for Moisture and Soil Stability:

To address soil shrinkage and moisture loss, moisture stabilizing additives, deep foundations, and moisture managing materials are being used. These techniques help maintain soil stability and structural integrity, even in drought conditions.

These impacts highlight the urgent need for designing structures that are resilient to the effects of climate change. By incorporating sustainable materials, innovative technologies, and adaptive design strategies, buildings can better withstand these challenges.

2.11. Design Adaptations and Innovations in Structural Engineering

As the impacts of climate change become increasingly evident, structural engineering has evolved to integrate innovative strategies that prioritize sustainability, resilience, and adaptability. These design adaptations not only mitigate risks posed by extreme weather events but also contribute to long term environmental stewardship. This section explores three critical areas of innovation: sustainable materials, green building standards, and adaptive building techniques.

2.11.1 Sustainable Materials[11][12]

The use of sustainable and resilient materials has emerged as a cornerstone of climate resilient structural design. These materials are engineered to withstand harsh environmental conditions while reducing the carbon footprint of construction activities.

1. **Reinforced Concrete Enhancements**

   Traditional reinforced concrete, while durable, is susceptible to cracking and corrosion under extreme temperature and moisture variations. To address this, advanced forms like high performance concrete (HPC) and ultrahigh performance concrete (UHPC) have been developed. These materials offer superior strength, reduced permeability, and enhanced durability, making them ideal for structures in flood prone or coastal regions. Additionally, the integration of supplementary cementitious materials (SCMs), such as fly ash and slag, reduces greenhouse gas emissions during production.

2. **Fiber Reinforced Polymers (FRPs)**

   FRPs are increasingly being used for their lightweight, high strength, and corrosion resistant properties. These materials are particularly advantageous in retrofitting existing structures to withstand higher loads or harsh conditions. For example, FRP wraps can reinforce columns and beams in areas prone to earthquakes or hurricanes.

3. **Climate Resistant Composites**

   Innovative composites, such as biobased polymers and grapheneinfused materials, are gaining traction for their adaptability to extreme weather. Biobased materials derived from renewable sources, such as bamboo and recycled plastics, are not only sustainable but also resilient to varying climatic conditions. These materials are ideal for modular and prefabricated construction, especially in regions facing frequent climatic disruptions.

2.11.2 Green Building Standards [13][14]

Green building standards provide a comprehensive framework for designing structures that are both environmentally sustainable and resilient to climate change. Two prominent global standards are LEED and BREEAM.

1. **LEED (Leadership in Energy and Environmental Design)**

   LEED certifications emphasize energy efficiency, water conservation, and the use of sustainable materials. In the context of climate change, LEEDcertified buildings often incorporate passive cooling and heating systems, rainwater harvesting, and renewable energy sources. Structural components in these buildings are designed to reduce energy loads while maintaining indoor comfort during extreme weather events.

2. **BREEAM (Building Re Establishment Environmental Assessment Method)**

   BREEAM focuses on lifecycle sustainability, assessing factors like energy efficiency, pollution, and resilience to climate risks. A key feature is its emphasis on adaptability,

ensuring that buildings can withstand future climatic changes. For example, BREEAM standards encourage the integration of flood defenses, such as permeable pavements and raised foundations, in high risk areas.

3. **Integration of Renewable Materials**

   Both LEED and BREEAM encourage the use of renewable construction materials, such as timber from sustainable forests and recycled steel. These materials not only reduce the embodied carbon of construction but also improve the overall resilience of the structure.

2.11.3 Adaptive Building Techniques[18].

To address the dynamic nature of climate impacts, engineers and architects are increasingly adopting adaptive building techniques. These techniques enhance the capacity of structures to endure and recover from environmental stresses.

1. **Elevated Buildings**

   In flood prone regions, elevating buildings above predicted flood levels is a critical adaptation strategy. Techniques such as stilts, piers, and floating foundations minimize water damage and ensure structural integrity during floods and storm surges. Elevated designs are particularly popular in coastal cities and riverine areas vulnerable to rising sea levels.

2. **Flexible Foundations**

   Flexible foundation systems, such as base isolators and pile foundations, are designed to absorb shocks and adapt to shifting soil conditions. These systems are especially effective in regions prone to earthquakes and landslides, where traditional rigid foundations may fail.

3. **Modular and Prefabricated Construction**

   Modular construction techniques offer versatility and speed while addressing climate resilience. Prefabricated components are manufactured under controlled conditions, ensuring high quality materials that can withstand harsh climates. Additionally, modular buildings can be easily disassembled, relocated, or upgraded, making them ideal for disaster prone regions.

4. **Smart Technologies**

   Adaptive buildings increasingly incorporate smart technologies, such as sensors and automated systems, to monitor and respond to environmental changes. For instance,

smart façades can adjust to solar radiation, optimizing energy efficiency while maintaining internal comfort.

The integration of sustainable materials, adherence to green building standards, and adoption of adaptive techniques represent the cutting edge of structural engineering in the face of climate change. These innovations not only enhance the resilience of infrastructure but also align with global efforts toward sustainability. By leveraging advanced materials, frameworks, and construction techniques, the industry is better equipped to address the evolving challenges posed by a changing climate while contributing to a more sustainable future.

2.12 Case Studies

To understand the practical implementation of climate resilient structural designs, it is essential to examine real world examples. This section explores case studies from around the world, highlighting innovations and adaptations in response to climate change challenges. These examples span different climatic threats, including floods, hurricanes, wildfires, and rising sea levels, and include projects from the Netherlands, the United States, and South Asia (Bangladesh, India, Sri Lanka, and Pakistan).

2.12.1 Flood Resistant Structures in the Netherlands [15]

The Netherlands, a low lying country, has long been at the forefront of flood management and climate resilient infrastructure.

- **Maeslantkering Storm Surge Barrier**: Located near Rotterdam, this massive movable storm surge barrier is part of the Dutch Delta Works, one of the most advanced flood protection systems in the world. The barrier uses innovative sensors and automation to close when storm surges threaten, protecting inland areas.
- **Floating Homes in Amsterdam and Rotterdam**: These amphibious structures, designed to rise and fall with water levels, offer a unique solution to flood risks. Built with lightweight materials and buoyant foundations, they ensure habitability during extreme water level fluctuations.

The Dutch approach emphasizes integrated water management, combining engineering solutions with nature based interventions like wetlands restoration.

2.12.2 Hurricane Resistant Buildings in Florida, USA [16]

Florida faces frequent hurricanes, necessitating robust structural designs to withstand high winds and storm surges.

- **Sand Palace Home in Mexico Beach**: This private residence gained attention after Hurricane Michael in 2018. It survived near total destruction in the area due to reinforced concrete walls, elevated construction, and hurricane resistant windows.
- **MiamiDade County Building Code**: PostHurricane Andrew in 1992, Florida implemented one of the strictest building codes in the world. This requires structures to withstand winds of up to 175 mph, with features like impact resistant glass, reinforced roofs, and storm shutters.

These measures demonstrate how stringent regulations can drive climate resilience in hurricane prone regions.

2.12.3 Wildfire Resistant Designs in California, USA [16]

California's increasing wildfire risks have spurred innovations in fire resistant building materials and designs.

- **Fortified Roofs and Fire Resistant Materials**: Communities like Paradise and Napa Valley have adopted strict building codes mandating fire resistant roofing materials, such as metal and Class A shingles, and ember proof vents.
- **FireResistant Communities**: Projects like Rancho Mirage use defensible space landscaping, separating flammable vegetation from structures to prevent wildfire spread.
- **ReBased Innovations**: The University of California conducts extensive re on fire resilient materials, such as treated timber and concrete infused with fire retardants.

2.12.4 Climate Resilient Design in South Asia

South Asia is one of the most climate vulnerable regions in the world, and countries like Bangladesh, India, Sri Lanka, and Pakistan have implemented innovative strategies to address these challenges.

Bangladesh: Flood Resilient and Cyclone Safe Shelters [17]

- **Multi Purpose Cyclone Shelters**: Bangladesh has built over 12,000 cyclone shelters, doubling as schools or community centers. Elevated above flood levels, these structures use reinforced concrete and are designed to withstand winds of over 250 km/h.
- **Floating Schools and Homes**: In flood prone areas like the Haor regions, floating structures made of bamboo and steel drums allow continuity of life and education during seasonal floods. The Shidhulai Swanirvar Sangstha has pioneered this model.
- **Padma Bridge Project**: Designed to withstand high water flows and seismic activity, this mega infrastructure project exemplifies resilient design in a climate sensitive region.

India: Heat Resistant and Flood Adapted Structures[18]

- **Ahmedabad Heat Action Plan**: With rising temperatures, Ahmedabad has implemented reflective roofing materials and passive cooling techniques to reduce urban heat island effects.
- **Chennai Smart Cities Project**: To combat urban flooding, Chennai has implemented sustainable urban drainage systems (SUDS), including permeable pavements and green roofs.
- **Kerala FloodResilient Housing**: Following the devastating 2018 floods, Kerala introduced elevated and modular housing designs tailored to withstand future flooding.

Sri Lanka: Coastal and Tsunami Resistant Structures [17]

- **Arugam Bay Coastal Buildings**: Post2004 tsunami, Sri Lanka implemented tsunami resilient structures with raised foundations and setback zones. Construction materials like reinforced concrete and cross braced wooden frames are used to enhance stability.
- **Green Infrastructure in Colombo**: Colombo has integrated flood retention systems with green infrastructure, including Beira Lake restoration, to mitigate flooding and heat effects.

Pakistan: Earthquake and Flood Resilient Construction [18]

- **EarthquakeResistant Schools in Balakot**: After the 2005 earthquake, Pakistan adopted earthquake resistant construction techniques, including steel reinforced concrete and lightweight roofs.

- **ClimateResilient Villages**: In Sindh, where rising sea levels and floods are a threat, the Pakistan Poverty Alleviation Fund (PPAF) has introduced raised housing platforms and water resistant materials.
- **Dasu Hydropower Project**: This project incorporates climate resilient hydropower infrastructure designed to manage increased glacial melt and river flow variability.

2.12.5 Climate Resilient Designs in Africa

Africa faces a wide range of climate challenges, including desertification, rising temperatures, floods, and cyclones. Several countries have implemented innovative structural designs and policies to mitigate these impacts, blending modern engineering with traditional practices.

1. Great Green Wall Initiative (Sahel Region)[19],[20]

The Great Green Wall is a transformative project involving 20 African countries, aiming to combat desertification across the Sahel region.

- **EcoFriendly Structures**: As part of the initiative, communities build wind resistant and heat reflective buildings using local materials like mud bricks, straw, and clay, reducing energy needs for cooling.
- **Green Urban Planning**: Cities along the initiative's route integrate green roofs and shaded structures, creating cooler microclimates.

  This initiative demonstrates how green infrastructure can provide dual benefits of combating climate change and improving living conditions.

2. Flood Resilient Housing in Mozambique [21]

Mozambique is highly vulnerable to cyclones and floods, as seen during Cyclone Idai in 2019.

- **Elevated Housing in Buzi District**: PostCyclone Idai, raised homes with concrete stilts and sloped roofs were constructed to reduce flood risks.
- **CycloneResilient Materials**: Houses are being built with reinforced cement blocks and wind resistant designs to minimize damage from storms.

  These measures focus on long term resilience to recurring climatic hazards.

3. Climate Resilient Schools in Malawi [22],[23]

Malawi faces frequent floods and droughts, which disrupt education in rural areas.

- **Elevated and Modular Schools**: Floodresilient schools, built with raised platforms and lightweight, sustainable materials, ensure educational continuity during floods.
- **SolarPowered Buildings**: Schools use solar energy for electricity, promoting sustainable infrastructure while reducing dependency on vulnerable energy grids.

4. Sandbag Architecture in South Africa [24],[25]

South Africa has pioneered an innovative sandbag construction method to address both housing shortages and climate challenges.

- **EcoBeams and Sandbags**: EcoBeams (timber frames) are filled with sandbags to create durable, affordable, and insulated homes. These homes are fire resistant, energy efficient, and well suited to the arid climate.
- **Khayelitsha Projects**: In the Khayelitsha township, sandbag homes have been used to provide safe, affordable housing while reducing environmental impact.

5. Coastal Defense and Infrastructure in Senegal [26]

Senegal, particularly the city of SaintLouis, is severely affected by coastal erosion and rising sea levels.

- **SeaWalls and Breakwaters**: Coastal protection projects, such as the construction of breakwaters and elevated seawalls, protect infrastructure from erosion and storm surges.
- **CommunityBased Adaptation**: The city integrates mangrove restoration with structural defenses to enhance climate resilience while preserving biodiversity.

6. Earthquake and Climate Resilient Housing in Ethiopia [27]

Ethiopia experiences both seismic activity and climate induced floods.

BambooBased Construction

- Ethiopia has been promoting **bamboo as a sustainable material** for construction.
- Bamboo is **climate resilient**, flexible, and renewable, making it suitable for areas prone to earthquakes or high winds.
- This approach is particularly beneficial in rural Ethiopia, where it is both affordable and locally available.
- **FloodAdapted Drainage Systems**: Urban areas are redesigning drainage networks to prevent flooding during erratic rainfall patterns caused by climate change.

7. Renewable EnergyIntegrated Buildings in Rwanda [28][29][30]

Rwanda is a leader in integrating renewable energy into climate resilient infrastructure.

- **Green City Kigali Project**: This initiative focuses on constructing energy efficient, climate resilient buildings with rainwater harvesting systems, solar panels, and eco friendly materials.
- **Affordable Housing with Resilience**: The project also includes flood resistant designs and sustainable urban planning to manage water runoff during heavy rains.

African countries have showcased diverse strategies to address their unique climate challenges, ranging from flood resistant housing in Mozambique to sandbag homes in South Africa. These examples highlight the importance of leveraging local materials, community driven approaches, and modern technologies to create structures that not only withstand climatic extremes but also improve living standards. By scaling these innovations, Africa can build a more sustainable and resilient future.

These case studies highlight the diverse approaches adopted globally and in South Asia to enhance climate resilience in structural design. From floating homes in Bangladesh to fire resistant communities in California, these examples illustrate the importance of innovation, policy frameworks, and community based solutions in addressing the multifaceted challenges of climate change. By learning from these successes, engineers and policymakers can develop tailored strategies to protect vulnerable regions and ensure sustainable development.

2.13. Challenges in Implementing Climate Resilient Structural Designs

The shift towards climate resilient structural designs, while essential, is fraught with challenges. These barriers stem from economic, regulatory, and technological factors, which can vary significantly between regions and socioeconomic contexts.

2.13.1 Cost Factors [31] [32]

One of the primary barriers to implementing climate resilient designs is cost.

- **High Initial Investment**: Climate Resilient materials such as advanced composites, energy efficient systems, and reinforced construction often require a higher initial expenditure than traditional options.

- **Limited Funding in LowIncome Regions**: Developing nations often face budget constraints, making it difficult to prioritize climate resilient infrastructure over immediate needs like housing, healthcare, and education.
- **Cost of Retrofitting Existing Structures**: Modifying older buildings to withstand climate threats can be expensive, further straining already limited resources. For example, retrofitting flood prone buildings in Bangladesh often costs more than constructing new, non resilient homes.

2.13.2 Regulatory and Policy Issues[16]

Government policies and regulations play a crucial role in promoting or hindering climate resilient structural designs.

- **Inadequate Building Codes**: Many regions lack modern building codes that address climate risks, leaving structures vulnerable to extreme weather.
- **Enforcement Gaps**: Even where codes exist, poor enforcement, corruption, or lack of technical capacity can undermine their effectiveness.
- **Policy Misalignment**: In some cases, national development policies prioritize rapid urbanization over sustainability, leading to non resilient construction.
  For instance, rapid urban expansion in South Asia and SubSaharan Africa often overlooks flood and heat resilience in informal settlements.

2.13.3 Technological Limitations[33][27]

While technology is advancing, current solutions still face limitations:

- **Material Shortcomings**: Many materials designed to withstand extreme conditions (e.g., ultrahigh performance concrete or climate resistant composites) remain expensive or untested in certain environments.
- **Data Deficiency**: Limited access to localized climate data and predictive modeling tools in developing countries hampers the ability to design region specific solutions.
- **Infrastructure Challenges**: The lack of advanced manufacturing facilities for sustainable materials in low income countries makes it difficult to implement cutting edge solutions.

2.14 Future Directions

Addressing the challenges of climate resilient structural designs requires innovation, interdisciplinary collaboration, and proactive planning. Emerging technologies and integrative approaches offer promising avenues for overcoming these barriers.

2.14.1 Emerging Technologies

The future of structural resilience lies in leveraging advanced technologies:

- **Smart Materials**: Materials like self healing concrete and shape memory alloys can repair minor damage autonomously, extending the lifespan of structures and reducing maintenance costs.[12]
- **Data Driven Designs**: Climate simulation models and AI driven tools enable engineers to predict future risks, optimizing designs for long term resilience. [11]
- **3D Printing and Modular Construction**: These techniques allow for quicker, cost effective construction of climate resilient buildings, particularly in disaster prone regions. For instance, projects in the Middle East are exploring 3d Printed homes that can withstand extreme heat.[11]

2.14.2 Interdisciplinary Approaches[34] [35]

Combining expertise across disciplines is essential for holistic resilience:

- **Climate Science Integration**: Understanding localized climate trends is critical for designing region specific infrastructure.
- **Urban Planning Synergy**: Incorporating climate resilient designs into urban planning ensures that infrastructure, housing, and transportation systems are cohesive and sustainable.
- **Community Participation**: Engaging local communities in the planning process ensures solutions are culturally appropriate and widely adopted.

2.14.3 Policy and Funding Innovations[32][33]

Governments and international organizations must play a proactive role in fostering climate resilience:

- **Green Bonds and Climate Funds**: Expanding access to financial instruments like green bonds can help fund climate resilient projects in low income regions.
- **Adaptive Building Codes**: Developing codes that evolve with climate projections ensures that future infrastructure is adequately prepared for emerging risks.

2.15. Conclusion

The increasing frequency and severity of climate related events underscore the urgent need for climate resilient structural designs. Key themes emerging from the literature include[13][31]:

- The **economic challenges** faced by low income regions in adopting resilient designs.
- The **need for region specific studies** and tailored solutions that consider local climate risks, materials, and cultural factors.
- The role of **emerging technologies** like smart materials, predictive modeling, and 3D printing in transforming the field of structural engineering.

Despite progress, significant gaps remain. Future re must focus on [16]:

- Developing **affordable and scalable resilient materials** to reduce costs.
- Enhancing **government policies and building codes** to address climate risks effectively.
- Exploring **interdisciplinary approaches** that combine engineering, urban planning, and climate science to create holistic solutions.

Ultimately, achieving climate resilience requires a collaborative effort involving engineers, policymakers, communities, and reers. By addressing these challenges head on, structural design can evolve to protect both lives and livelihoods in the face of a changing climate.

CHAPTER 3

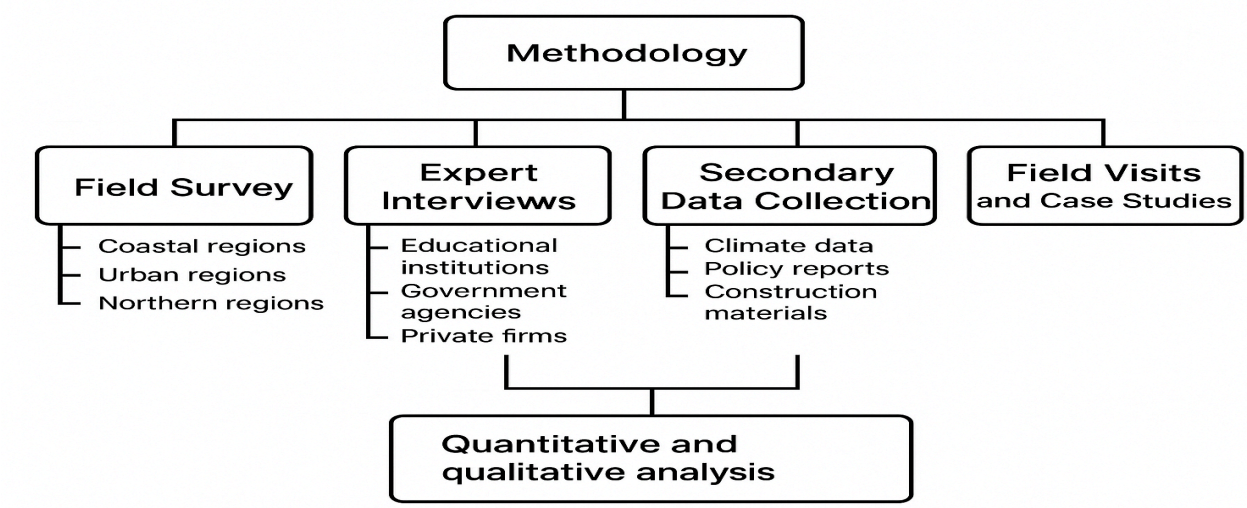
CONCEPTUAL FRAMEWORK AND METHODOLOGY

3.1 Introduction

This chapter describes the methods adopted for collecting and analyzing data to study the impact of climate change on structural design in Bangladesh. A mixed method approach combining qualitative and quantitative techniques was followed to ensure comprehensive and reliable findings.

3.2 Data Collection Methods

Table :3.1 : Flowchart of Methodology



- #### 3.2.1 Field Survey

Primary data were collected through structured surveys conducted among local populations in vulnerable regions. The selected survey areas included:

Coastal Regions: Khulna, Barguna, and Bhola (affected by flooding, cyclones, and salinity).

Urban Regions: Dhaka, Chattogram, and Rajshahi (affected by rapid urbanization and climate induced structural stress).

Northern Regions: Rangpur and Dinajpur (affected by drought and riverbank erosion).

Local cooperation was secured from Upazila offices and NGOs like BRAC, ASA, and Practical Action to facilitate fieldwork.

● 3.2.2 Expert Interviews

In Depth interviews were conducted with experts from educational institutions, government organizations, and private consultancy firms. Institutions included:

Bangladesh University of Engineering and Technology (BUET)

Rajshahi University of Engineering and Technology (RUET)

Department of Environment (DoE)

Bangladesh Water Development Board (BWDB)

Structural Engineers Ltd. (SEL) and others

Experts provided insights into structural vulnerabilities, adaptation techniques, and policy level initiatives.

● 3.2.3 Secondary Data Collection

Secondary data were gathered from reputable sources such as:
Climate Data: Bangladesh Meteorological Department (BMD), Institute of Water Modelling (IWM).
Policy and Government Reports: Planning Ministry, Bangladesh Climate Change Trust (BCCT), and LGED.
Construction Materials: Reports and technical data from BSRM, Seven Rings Cement, and Housing and Building Re Institute (HBRI).
Additionally, international data were referred from IPCC, UNDP, and the World Bank for broader climate related impacts.

● 3.2.4 Field Visits and Case Studies

Targeted field visits and case studies were conducted in specific locations to observe real life structural challenges and resilience strategies, including:

1. Refugee camps in Cox's Bazar

2. Coastal villages near the Sundarbans

3. Slum areas in Dhaka

4. Floodprone haor regions in Sylhet

Observations and case study analyses helped validate the survey findings and provided context specific examples.

● 3.2.5 Data Analysis Techniques

Quantitative Analysis: Survey responses were statistically analyzed to identify trends and correlations between climatic factors and structural performance.

Qualitative Analysis: Expert interviews and case study notes were thematically analyzed to extract key insights regarding adaptive design strategies.

Comparative Analysis: Collected data were compared across different regions to highlight variations in structural impacts based on climatic diversity.

3.3 Ethical Considerations

Prior consent was obtained from all survey participants and interviewees.

Data confidentiality and anonymity were strictly maintained.

The study adhered to the ethical guidelines of academic research.

3.4 Limitations

Accessibility challenges in some remote areas restricted the number of field surveys.

Some secondary data sources were outdated or incomplete, requiring careful validation.

Language barriers in rural areas occasionally required translation support during interviews.

CHAPTER 4

OVERVIEW OF COLLECTED DATA WITH SORT ANALYSIS

4.1 Technical Data (Up to 2024)

4.1.1 Zone 01 (Coastal Area)

4.1.1.1 Climate Trends in Khulna

Temperature: Khulna has experienced increasing temperatures, with daytime temperatures rising by approximately 0.0223°C annually and night time temperatures by about 0.0342°C each year from 1981 to 2020. Notably, in April 2024, Bangladesh faced a severe heatwave, with temperatures soaring up to 42°C, significantly above the average, impacting regions including Khulna.

Rainfall Patterns:There is a declining trend in pre monsoon rainfall, with a decrease of 5.13 mm, while monsoon and post monsoon seasons show slight increases.

Humidity Levels: Overall humidity has decreased, indicating drier conditions over time.

These climatic changes can adversely affect building materials and structural integrity, necessitating adaptations in construction practices.

Structural Performance and Resilience Measures

Bangladesh Water Development Board (BWDB) Initiatives:

To combat climate change impacts, the BWDB is implementing five projects in the Khulna region, with a total budget exceeding Tk 500 crore. These projects aim to protect 728 kilometers of critical riverbanks, re excavate canals, build and repair embankments, and repair regulators. As of early 2025, approximately 46% of the work has been completed. These efforts are expected to mitigate waterlogging, prevent embankment erosion from tidal surges, and protect farmlands and properties from river erosion.

Climate Change Adaptation and Urban Development (CCAUD) Project:

The Khulna City Corporation, in collaboration with the German Development Bank (KfW), is executing the CCAUD project with an estimated cost of Tk 491 crore. Key components include constructing city protection dams and embankments in vulnerable areas, excavating and embanking canals, renovating ponds, and developing drainage systems and roads. These interventions aim to enhance urban resilience against climate induced challenges.



Fig 4.1 Field Survey in Khulna: Assessing Riverfront Construction Materials and Practices

Design Standards: Bangladesh National Building Code (BNBC)

The BNBC serves as the primary regulatory framework for building construction in Bangladesh. Significant updates were made in 2006 and 2020, incorporating enhanced standards for earthquake resistance, fire safety, and energy efficiency. The code outlines requirements in several key areas.

Structural Design: Provides technical specifications for load bearing structures using materials like concrete, steel, and masonry, with special attention to seismic zones.

Fire and Life Safety: Includes fire safety codes for commercial and residential buildings, covering emergency exits, fire alarms, sprinkler systems, and evacuation protocols.

Building Services: Regulates electrical systems, HVAC, water supply, sanitation, and plumbing systems.

Environmental and Energy Efficiency: Incorporates provisions for green building practices, such as natural lighting, solar panels, water conservation, and eco friendly materials.

Accessibility: Emphasizes inclusive design, requiring accessible routes, ramps, elevators, and signage to accommodate persons with disabilities.

Construction Materials and Techniques

Climate Resilient Material:

In response to climatic challenges, the use of specific construction materials has been emphasised:

Concrete: Preferred for its durability and resistance to moisture and salinity.

Brick Bonding Techniques: Methods like rattrap bonding reduce material usage while maintaining structural strength.

Partial Lintels and Revolving Windows: Design adaptations that enhance structural performance and reduce costs.

These materials and techniques contribute to the development of low cost, climate resilient housing suitable for vulnerable communities.



Fig: 4.2 A view of LoGIC Project

Community Level Initiatives:

The government is providing climate resilient facilities to two lakh households in seven disaster prone districts, including Khulna. Under the Local Government Initiatives on Climate Change (LoGIC) project, financial support is extended to strengthen the capacity of union parishads and vulnerable communities to address climate change impacts.

4.1.1.2 Climate Trends of Barguna

Temperature: Barguna experiences a tropical monsoon climate Average temperatures range from 15°C in winter to 34°C in summer. Recent data indicates daytime highs reaching up to 33°C, with nighttime lows around 28°C

Rainfall: The district receives substantial rainfall, especially during the monsoon season. However, a 30 year analysis showed no significant change in annual rainfall patterns.

Humidity: Humidity levels are consistently high, averaging between 72% and 87%, contributing to a humid environment throughout the year.

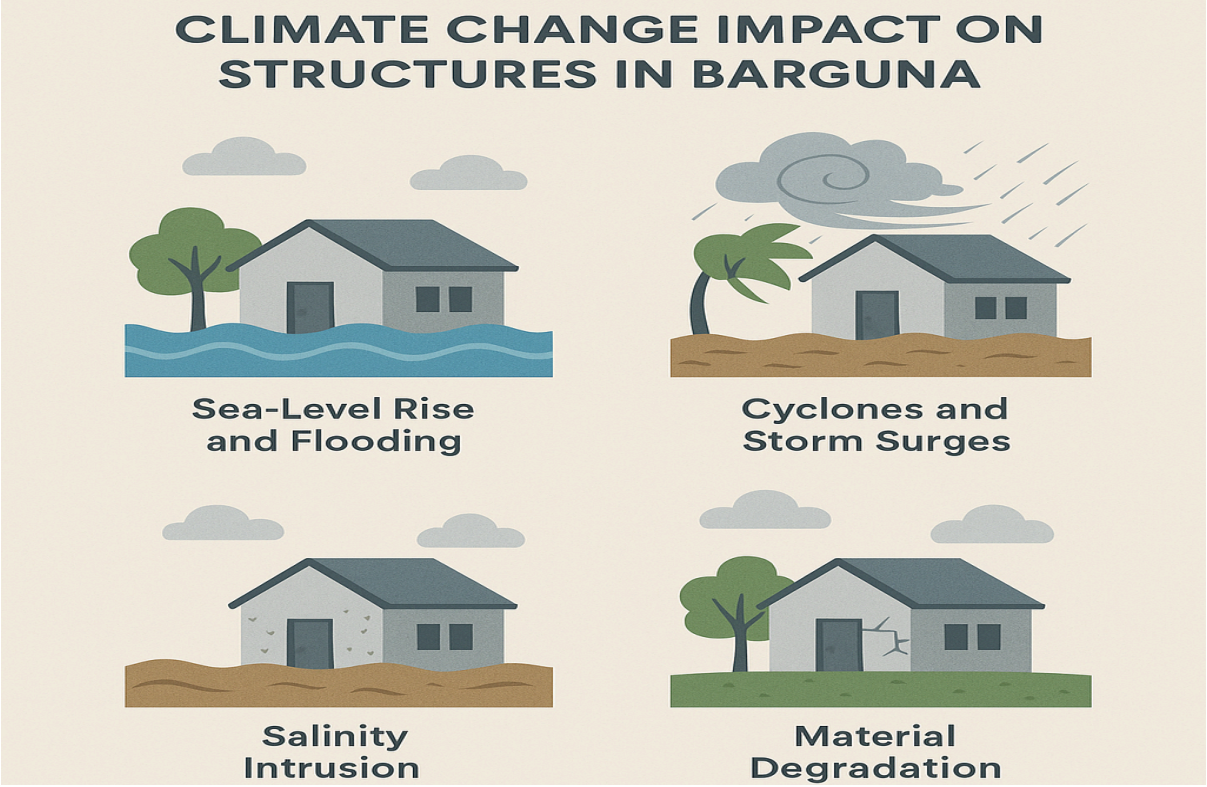


Fig: 4.3 Climate Change impact on structures in Barguna

Structural Performance and Design Standards

Wind and Seismic Loads

Wind Loads Barguna, being a coastal district, is susceptible to cyclonic storms. Design standards must account for high wind speeds, with considerations for exposure categories and importance factors as outlined in the Bangladesh National Building Code (BNBC).

Seismic Considerations While Barguna is not in the highest seismic zone, structures should still be designed to withstand potential seismic activities, adhering to BNBC guideline.

Design Standards

BNBC Guidelines The BNBC provides comprehensive guidelines for structural design, including load calculations, material specifications, and safety factor. It emphasizes the importance of considering environmental loads such as wind and seismic forces in structural design.

Construction Materials

Common Materials:

Bricks: Locally produced bricks are widely used in construction due to their availability and cost effectiveness.

Concrete: Reinforced concrete is standard for structural elements, offering strength and durability.

Steel: Used for reinforcement and structural frameworks, steel must be protected against corrosion, especially in humid and saline environments.



Fig 4.4 Material Inspection and Field Discussion on Construction Practices in Climate-Vulnerable Barguna

Climate Resilient Materials:

Corrosion Resistant Reinforcement: Given the high humidity and proximity to the sea, using corrosion resistant steel or protective coatings can enhance durability.

Elevated Plinths: To mitigate flood risks, structures are often built on raised plinths, a practice supported by local guidelines and historical data.

Prefabricated Components: Utilizing prefabricated elements can expedite construction and ensure quality control, especially beneficial in disaster prone areas.

Additional Considerations

Drainage Infrastructure: Proper drainage systems are crucial to manage heavy rainfall and prevent waterlogging, which can compromise structural integrity.

Maintenance Practices: Regular maintenance, including inspection for corrosion and structural wear, is essential to prolong the lifespan of buildings in Barguna's climate.

4.1.1.3 Climate Trends of Bhola

Location: Coastal district in southern Bangladesh.

Elevation: Low Lying delta region (~23 meters above sea level).

Seismic Zone: Zone 1 (Low seismic risk) — BNBC zone coefficient: Z = 0.12.

Wind Speed: Cyclonic wind speeds can exceed 250 km/h.

Flooding Risk: Very high (regular storm surges and tidal floods).

Salinity: High salinity in both water and soil due to sea intrusion.

Table: 4.1 Structural Performance Data (Design Requirements)

Aspect	Recommendation
Wind Resistance	Design for wind speeds ≥ 250 km/h (cyclone category).
Flood Protection	Plinth levels should be elevated ≥ 1.5 meters above ground.
Foundation	Pile foundations or deep footings to counteract soft soil and water logging.
Corrosion	Use corrosion resistant reinforcement (e.g., galvanized/epoxy coated steel).
Wall Systems	RC frame with confined masonry or reinforced concrete shear walls for robustness.
Drainage	Essential to prevent water accumulation around the structure.

Table: 4.2 Design Standards (Codes & Guidelines)

Standard	Use
BNBC 2020	National design guideline (structural loadings, material specs).
ACI 318	Used for reinforced concrete design (referenced in BNBC).
ASCE 7	Useful for wind and environmental load data.
ISO 13822	For evaluating existing structures under climate impact.
Local PWD Guidelines	For government standard buildings in coastal zones.



Fig 4.5 Field Visit in Bhola: Investigating Building Materials and Construction Methods

Table: 4.3 Construction Materials Used in Bhola

Material	Description
Burnt Clay Bricks	Common, but deteriorates faster in salinity.
Concrete Blocks	Better than clay bricks for durability.
Reinforced Concrete (RC)	Main load bearing material in urban Bhola.
Bamboo/Wood	Still used in rural areas for lightweight structures.
Corrosion Resistant Steel	Needed due to saltwater exposure.
Fly Ash Bricks	Eco Friendly, moisture resistant option.
Waterproof Coatings	Used for protecting concrete/masonry in wet zones.



Fig: 4.6 A Climate-Resilient House in Bhola Constructed with Burnt Clay Bricks and Reinforced Concrete

Table: 4.4 Climate Change Impact Factors in Bhola

Factor	Effect on Structures
Sea Level Rise	Inundation and foundation degradation.
Cyclones	Roof and wall failure due to wind pressure.
Salinity	Corrosion of steel and crumbling of masonry.
Heavy Rainfall	Weakening of soil bearing capacity.
Temperature Variation	Expansion Contraction of materials causing cracks.

4.1.1.4 Climate Trends of Satkhira

1. Structural Performance Data

- Seismic Zone Classification: Satkhira falls under Seismic Zone 1 as per the Bangladesh National Building Code (BNBC) 2020, with a zone coefficient of Z = 0.12, indicating a low earthquake vulnerability.

- Wind Exposure: BNBC 2020 specifies wind load considerations based on regional exposure. While specific wind speed data for Satkhira isn't detailed here, coastal areas like Satkhira are generally subjected to higher wind loads due to cyclonic activities.

- Historical Structural Performance: There is limited publicly available data on the historical durability and performance of local structures in Satkhira during extreme weather events. However, given its coastal location, structures are susceptible to cyclones and flooding, necessitating resilient construction practices.



Fig 4.7 A view of how badly structures were affected by Cyclone Remal in Satkhira in May 2024.

2. Design Standards

- BNBC 2020 Provisions: The BNBC 2020 incorporates updated design parameters to address climate-induced challenges, including:
  - Wind Loads: Adjusted for regional wind speeds, especially pertinent for cyclone-prone areas.
  - Seismic Considerations: Defined seismic zone classifications with corresponding design coefficients.
  - Material Durability: Guidelines for using materials resistant to environmental degradation, such as corrosion due to salinity.

- Impact on Construction Costs: Implementing BNBC 2020 provisions, especially in high wind exposure categories, can increase material requirements and construction costs by up to 22%.

3. Construction Materials

- Material Selection: In coastal regions like Satkhira, construction materials are chosen for their resilience to salinity and moisture. Commonly used materials include:
  - Reinforced Concrete: With corrosion-resistant reinforcement bars.
  - Fiber-Reinforced Concrete: Enhances durability against cracking and environmental stress.
  - Epoxy-Coated Steel: Provides additional protection against corrosion.
  - Geopolymer Cement: Offers improved resistance to chemical attacks and thermal stability.
- Retrofitting Practices: To enhance the resilience of existing structures, retrofitting techniques are employed, such as:
  - Jacketing: Strengthening structural elements by encasing them with additional materials.
  - Fiber-Reinforced Polymer (FRP) Wrapping: Improves load-bearing capacity and ductility.
  - Shear Wall Addition: Enhances lateral strength against wind and seismic forces.
  - Steel Bracing: Provides additional support to resist lateral loads.

4.1.2-Zone-2 (Urban area: Dhaka, Chattogrma, Rajshashi)

4.1.2.1 Structural Performance in Dhaka



Fig 4.8 Urban Housing Survey in Dhaka: Exploring High-Rise Residential Development

Seismic Considerations:

Seismic Zone: Dhaka is classified as Seismic Zone 2 in the Bangladesh National Building Code (BNBC) 2020, indicating moderate seismic risk.

Design Categories: Buildings are assigned seismic design categories B, C, or D based on seismic zone, local site conditions, and importance class .

Environmental Stressors:

Thermal Stress: High ambient temperatures can cause thermal expansion and contraction in building materials, leading to potential structural issues over time.

Saline Exposure: Proximity to coastal areas and high humidity levels can lead to chloride induced corrosion in reinforced concrete structures, compromising durability .

Design Standards (BNBC 2020)

The Bangladesh National Building Code (BNBC) 2020 provides comprehensive guidelines for structural design:

Structural Systems: Defines requirements for various structural systems, including load considerations and material specifications.

Load Considerations: Addresses gravity loads, wind loads, and seismic loads pertinent to Dhaka's environmental conditions.

Material Specifications: Outlines standards for construction materials to ensure safety and durability.

Construction Materials in Dhaka

Cement Type: Portland Composite Cement (PCC) is commonly used.

Standards: Complies with BDS EN 1971:2003, CEM II/BM (SVL), 42.5N standard.

Properties: Contains PFA & slag, offering long term strength development and durability .

Steel Reinforcement

Common Grades: Grade 60: Yield strength of 414 MPa; widely used in residential and commercial buildings.

Grade 500: Yield strength of 500 MPa; increasingly used for highrise and infrastructure projects .

Concrete:- Durability Enhancements: Use of admixtures and supplementary cementitious materials to improve resistance against environmental stressors.

Performance: Designed to withstand thermal stress, saline exposure, and seismic activity, ensuring longevity of structures .



Fig: 4.9 Aerial View of Contrasting Urban Fabric in Dhaka – Informal Settlements beside High-Rise Buildings near Water Bodies

Climate Change Impacts on Structural Integrity

Climate change poses several challenges to structural integrity in Dhaka:

Increased Temperature: Accelerates material degradation and affects thermal comfort.

Sea Level Rise: Heightens the risk of flooding, impacting foundations and lower structural elements.

Extreme Weather Events: Intensifies wind and rain loads, necessitating robust design considerations.

Humidity and Salinity: Promotes corrosion in steel reinforcements, reducing structural lifespan.

4.1.2.2 Rajshahi Climate & Environmental Context

Rajshahi experiences a tropical wet and dry (savanna) climate (Aw), characterized by:

High temperatures: Annual average of 28.5°C, with summer highs often exceeding 35°C.

Moderate rainfall: Approximately 95 mm monthly, with around 128 rainy days per year.

Humidity: Varies seasonally, contributing to material degradation.

These conditions necessitate specific considerations in structural design and material selection to ensure durability and resilience.

Structural Design Standards

Bangladesh National Building Code (BNBC) 2020

The BNBC 2020 is the primary regulatory framework governing building design and construction in Bangladesh, including Rajshahi. Key provisions include:

Structural Design: Guidelines for load calculations, material strengths, and design methodologies.

Seismic Design: Rajshahi falls under Seismic Zone 1, indicating low seismic risk.

Wind Load: Design wind speed for Rajshahi is specified at 180 km/h, requiring structures to withstand significant wind pressures.

Environmental Sustainability: Recommendations for green roofing systems and energy efficient designs to combat urban heat islands and manage stormwater.



Fig 4.10 Site under construction in Rajshahi — captured during our thesis survey.

Common Construction Materials

Concrete

Grades Used: Typically, Grade 20 to Grade 40 concrete is employed, depending on structural requirements.

Durability Measures: Use of waterproofing admixtures and proper curing practices to enhance longevity, especially given the humid climate.

Steel

Types: Commonly used steel includes mild steel (MS) and high strength deformed (HSD) bars.

Corrosion Protection: Application of anticorrosive coatings and regular maintenance to prevent rusting in the humid environment.

Masonry

Bricks: Traditional burnt clay bricks are prevalent, though there's a shift towards concrete blocks for better uniformity and strength.

Mortar: Cementsand mortar with appropriate mix ratios to ensure bonding and durability.

Climate Change Impacts on Structures

Temperature Extremes

Rising temperatures can lead to:

Thermal Expansion: Causing cracks in concrete and masonry.

Material Degradation: Accelerated aging of construction materials.



Fig: 4.11 Wall Cracks Due to Climate-Induced Material Stress in Rajshahi

Increased Rainfall & Flooding

Heavy monsoon rains result in:

Water Ingress: Leading to dampness and potential structural weakening.

Foundation Issues: Soil erosion and settlement affecting building stability.

Seismic Activity

While Rajshahi is in a low seismic zone, the risk of earthquakes necessitates:

Reinforced Structural Elements: To absorb and dissipate seismic energy.

Flexible Design Approaches: Allowing structures to withstand ground movements.

Adaptation Strategies

To mitigate climate change effects:

Material Selection: Use of durable, weather resistant materials.

Design Innovations: Incorporation of green roofs, proper drainage systems, and ventilation to manage heat and moisture.

Regular Maintenance: Routine inspections and repairs to address wear and tear promptly.

4.1.2.3 Climate Impact on Structural Performance in Chattogram

Chattogram, as a coastal city, is increasingly vulnerable to climate induced hazards:

Storm Surges and Cyclones: Projections indicate that the 100 year storm tide could intensify from 3.5 m to between 4.9 m and 5.4 m by the end of the 21st century, with the MeghnaNorth Chattogram region being most vulnerable.

Flooding and Heavy Rainfall: There's a strong increasing trend of pre monsoon heavy rainfall days and amounts in Chattogram, contributing to urban flooding and landslides.

Salinity and Corrosion: Being a coastal city, Chattogram faces challenges related to saline prone zones, where the risk of corrosion of steel reinforcements and other materials is relatively high.



Fig: 4.12 Chattogram experienced flooding in 2024.

Design Standards Applicable in Chattogram

Bangladesh National Building Code (BNBC): The BNBC provides technical specifications for load bearing structures using materials like concrete, steel, and masonry. Special attention

is given to seismic zones in the country, particularly in the eastern region, which includes Chattogram.

Seismic Zoning: BNBC categorizes the country into seismic zones, with Chattogram falling into a zone that requires specific design considerations for earthquake resistance.

Material Specifications: BNBC includes special measures for the types of materials (e.g., steel, cement, brick, sand) that should be used in saline prone zones to mitigate corrosion risks.

Common Construction Materials in Chattogram

Cement: Ordinary Portland Cement (OPC) is commonly used, with considerations for sulfate resistance in saline environments.

Steel Reinforcement: High Strength deformed bars are standard, with protective coatings for corrosion resistant alloys recommended in coastal areas.

Bricks: Locally sourced clay bricks are prevalent, though quality control is essential to ensure durability.

Concrete: Mix designs often incorporate admixtures to enhance workability and durability, especially in structures exposed to marine environments.

Waterproofing Materials: Bituminous coatings and membranes are used to protect structures from moisture ingress.

Construction Practices and Considerations

Foundation Design: Given the soft alluvial soils in many parts of Chattogram, pile foundations are commonly employed to achieve the necessary load bearing capacity.

Drainage Systems: Proper drainage design is crucial to manage the high rainfall and prevent waterlogging, which can compromise structural integrity.

Elevated Structures: In flood prone areas, buildings are often elevated on stilts or raised plinths to mitigate flood risks.

4.1.3 Zone-03 (Northern region)

4.1.3.1 Impact of Drought on Structures in Rangpur and Dinajpur



Fig: 4.13 A view of Drought in Rangpur

1. Soil Shrinkage and Foundation Damage

Soil Dryness: Long Term droughts in Rangpur and Dinajpur lead to reduced soil moisture, causing the soil to shrink and crack. This shrinkage undermines the foundations of buildings, roads, and bridges, causing structural instability and potential damage to these structures.

Foundation Movement: In severe drought conditions, moisture loss from the soil causes it to become more compact and dry, which can cause uneven settlement of building foundations. This can lead to cracks in walls, floors, and foundations, making structures unsafe over time.

2. Water Supply Infrastructure Strain

Over Extraction of Groundwater: During droughts, there is heavy reliance on groundwater extraction for drinking and agricultural purposes. The overuse of groundwater leads to the drying up of wells and tube wells, causing potential collapse or malfunction of water supply infrastructure.

Damage to Pipelines: The soil's desiccation can also affect the underground water pipelines. These pipelines can crack or break due to the ground shifting, further disrupting water access.

Impact of Riverbank Erosion on Structures in Rangpur and Dinajpur



Fig 4.14 Riverbank Erosion and Its Impact on Rural Life: Field Observation from Rangpur

1. Loss of Land and Property

Erosion of Riverbanks: Rivers like the Teesta and Jamuna in Rangpur and Dinajpur are prone to severe erosion. As riverbanks erode, they take away valuable agricultural land, homes, and businesses that are situated too close to the water. This erosion results in significant displacement of families and destruction of properties.

Displacement of Communities: Erosion often leads to the displacement of entire communities, forcing people to move further inland. The loss of homes and land leads to both economic and emotional trauma.

2. Damage to Transportation Infrastructure

Erosion of Roads and Bridges: Roads and bridges near the riverbanks are particularly vulnerable to erosion. As the riverbanks collapse, they take out transportation routes, disrupting logistics and connectivity. This leads to the destruction of essential infrastructure, increasing repair costs and making areas harder to access.

3. Compromised Flood Protection Infrastructure

Weakening of Embankments: To protect communities from flooding, embankments and levees are built along riverbanks. However, continuous erosion weakens these structures. As the riverbanks erode, the embankments may break or collapse, leading to increased flooding risks and further loss of infrastructure.

Additional Data and Resources

1. Impact on Housing:

Prolonged droughts and riverbank erosion lead to cracks and eventual collapse of buildings. In many cases, displaced families are forced to build makeshift homes in safer areas, exacerbating their vulnerabilities. Over time, the erosion causes gradual damage to structural foundations, making rebuilding efforts costly.

2. Economic Loss:

The loss of fertile land and infrastructure damages local economies, as agriculture is the primary livelihood in Rangpur and Dinajpur. The destruction of roads, bridges, and water systems leads to higher costs for transportation and repair of public utilities.

3. Health and Safety Risks:

Erosion and drought exacerbate access to safe drinking water, sanitation, and healthcare facilities. This puts both rural and urban populations at risk of waterborne diseases and other health issues due to the destruction of water supply infrastructure.

Both drought and riverbank erosion in Rangpur and Dinajpur significantly affect the built environment. Structures, particularly residential and agricultural buildings, experience foundation instability due to soil shrinkage and shifting, while transportation and water infrastructure are severely impacted by erosion. Efforts to mitigate these effects should include strengthening water management systems, improving flood protection infrastructure, and implementing land use policies to reduce vulnerability to these climate related impacts.

4.2 Economical Data

4.2.1(Zone-01, Coastal areas, Khulna, Satkhira, Barguna, Bhola)

Economic Losses from Climate-Induced Disasters



Fig 4.15 A view of impact of Climate-Induced Disasters on structures in Coastal areas.

Annual Damages from Cyclones and Flooding

A World Bank report indicates that Bangladesh faces annual damages of approximately $570 million due to cyclone-induced flooding, particularly affecting coastal areas. Upazilas such as Amtali (Barguna), Char Fasson (Bhola), and regions in Satkhira and Khulna are among the hardest hit, each incurring yearly damages exceeding $25 million under scenarios of a 0.5-meter sea-level rise .

Impact of Major Cyclones

- Cyclone Amphan (2020): This cyclone caused extensive damage across Khulna and Barisal divisions. In Satkhira, wind speeds peaked, leading to the destruction of over 220,000 homes, with 55,667 completely destroyed, rendering approximately 500,000

people homeless. The total estimated damage in Bangladesh was ৳127 billion (US$1.5 billion).[42]

- Cyclone Sidr (2007): One of the most devastating cyclones, Sidr resulted in damages estimated at ৳196.25 billion (US$2.31 billion), with significant destruction in coastal districts, including Barguna and Khulna.[43]

Household-Level Economic Impacts

A study by the Center for Participatory Research and Development (CPRD) found that families in southern Bangladesh have incurred average losses of ৳462,491 over the past two decades due to natural disasters. In Satkhira, the average loss per family was ৳257,330, encompassing damages to homes, livestock, and croplands.[44]

Adaptation Costs for Climate-Resilient Infrastructure

Climate-Resilient Housing: Organizations like BRAC have been instrumental in constructing climate-resilient houses in coastal districts, including Satkhira, Barguna, and Bhola. These homes are designed to withstand cyclones and flooding, often serving as mini cyclone shelters for 35–40 people. The construction cost for such a house varies between ৳1.3 to 1.4 million (US$13,000–14,000), depending on location and design specifics.[45]

In Satkhira, BRAC built 35 such houses post-Cyclone Amphan, each costing approximately ৳700,000 (US$6,400). These structures not only provide shelter during disasters but also include features like rainwater harvesting systems to ensure access to clean water.[46]

Infrastructure Development Projects

The Coastal Climate Resilient Infrastructure Project (CCRIP) aims to enhance the resilience of infrastructure in 12 coastal districts, including Khulna, Satkhira, Barguna, and Bhola. With a total investment of US$150.05 million, the project focuses on constructing climate-resilient roads, cyclone shelters, and improving market access to bolster the livelihoods of vulnerable communities.[47]

Table 4.5 Summary of Key Figures of Zone 1

Category	Estimated Cost
Annual cyclone-induced damages	$570 million

Cyclone Amphan total damages	৳127 billion (US$1.5 billion)
Cyclone Sidr total damages	৳196.25 billion (US$2.31 billion)
Average household loss (Satkhira)	৳257,330
Climate-resilient house (BRAC)	৳700,000 – 1.4 million (US$6,400–14,000)
CCRIP total investment	US$150.05 million

4.2.2 Zone-02 -Urban areas (Dhaka, Rajshahi, Chattogram)

Economic Losses Due to Climate Change

4.2.2.1 National Overview

- Bangladesh has incurred approximately $3.72 billion in economic losses over the past two decades due to climate change, ranking it fifth globally in such losses. [48]
- Rural households spend nearly $2 billion annually on climate damage repair and prevention, which is double the government's expenditure and over 12 times higher than international financing for rural populations. [49]

4.2.2.2 Urban Centers

- **Dhaka**: Ranked among the top 10 cities globally at high risk from extreme weather and climate change, with a significant concentration of built environments making it particularly vulnerable.
- **Chattogram**: As a coastal city, it faces threats from sea-level rise, cyclones, and flooding, impacting its infrastructure and economy. [50]
- **Rajshahi**: While less exposed to cyclones, it is susceptible to droughts and heatwaves, affecting agriculture and water resources.

4.2.2.3 Adaptation Costs and Initiatives

Climate-Resilient Infrastructure

- **Dhaka**: Architect Rafiq Azam has transformed 31 community parks into green spaces with water-catchment areas, improving drainage and reducing flooding risks. [51]

- **Chattogram**: Efforts are underway to enhance the resilience of its port and coastal infrastructure against sea-level rise and extreme weather events.[52]

4.2.2.4 Housing for Displaced Populations

- **Dhaka hosts approximately 10 million climate-displaced individuals**, with an influx of 2,000 people daily, leading to the expansion of informal settlements lacking basic services.[53]
  - **The Ashrayan Project**: A government initiative providing housing to over 400,000 landless and homeless families, including climate refugees.[54]
  - **Climate Bridge Fund (CBF)**: Established by BRAC in 2019 to support adaptation in urban informal settlements, enhancing livelihoods and resilience to climate-induced migration.[54]

Table 4.6 Summary of Key Figures of Zone 2

Category	Estimated Cost/Impact
National economic losses (20 years)	**$3.72 billion**
Annual rural household climate expenses	**$2 billion**
Dhaka's climate-displaced population	**~10 million**, with 2,000 new arrivals daily
Climate-resilient housing (Ashrayan)	**400,000+ families housed**
Community parks transformed in Dhaka	**31 parks**

4.2.3 Zone-3- Northern Region (Rangpur, Dinajpur)

4.2.3.1 Structural Damage Due to Climate Impacts

1. Flood and Inundation Damage



Fig 4.16 Flood and Its Impact on Rural Life: Field Observation from Rangpur

- Frequent flooding in riverine and *char* areas leads to damage of[55]:
    - Earthen roads, embankments, culverts.
    - Poorly constructed homes (mud, bamboo, tin).
- Entire housing clusters in flood zones are often displaced annually.

2. Drought and Heat Stress on Structures[56]

- Droughts and high temperatures cause cracking in mud-built houses.
- Soil shrinkage undermines foundations of brick and unreinforced structures.
- Public buildings suffer from heat degradation due to lack of ventilation.

4.2.3.2 Structural Adaptation Costs and Efforts

1. Climate-Resilient Housing

- NGOs like BRAC implement[57]:
    - Raised plinth homes (1.5–2.5 ft),
    - Stronger bamboo/concrete frames,
    - Brick/tin structures with better ventilation.
- **Cost per home**: ৳85,000–150,000 (USD 800–1,400)

2. Community-Level Infrastructure

- **Adaptation Initiative for Climate Vulnerable Areas (AICVA)** project[58]:
    - Builds climate-resilient houses,
    - Installs nano-grids and water harvesting systems,

- Focuses on charland and flood-prone regions of Rangpur.

3. Maintenance Costs

- Annual repair costs of flood-affected homes: ৳10,000–15,000
- Includes water-proofing, roof replacement, and wall reinforcement.

Table 4.7 Summary of Key Figures of Zone 3

Impact/Cost Area	Estimate
Annual household structure damage	Up to ৳**20,000**+ per structure
Resilient home construction	**৳85,000 – 150,000**
Community shelter (multi-use)	৳**4.5 million** per structure
Key threats	Floods, drought-induced soil cracking

4.3 Community Feedback on Climate-Induced Structural Challenges

4.3.1 Zone-1 (Coastal areas: Khulna, Satkhira, Barguna, and Bhola):

4.3.1.1 Local Perceptions on Structural Resilience



Fig 4.17 A view of field survey

- **Inadequate Resilience of Existing Buildings**:
  Community members in **Khulna and Satkhira** have expressed concerns that **current**

buildings, including homes and public structures, are not resilient enough to withstand frequent flooding, salinity, and cyclone damage. The majority of houses are built using **mud, bamboo, or tin**, which do not provide sufficient protection during severe weather events such as cyclones and storm surges.

- **Flooding of Residential Areas**:

  In **Barguna** and **Bhola**, many houses are located in low-lying areas that are particularly vulnerable to **tidal flooding**. The existing **embankments** are often unable to fully protect against rising sea levels, which have caused water to breach embankments and flood homes.



Fig 4.18 Life Amid the Flood: A Silent Struggle in Rural Bangladesh- Through Our Team's Lens

- **Lack of Proper Elevation**:

  Many buildings are not elevated, making them more vulnerable to **storm surges** and **sea-level rise**. People have highlighted that **low-lying homes** and structures, which are often built at ground level, are easily inundated during extreme weather events like cyclones.

4.3.1.2 Community Suggestions for Improving Structural Resilience

1. Elevating Buildings

- **Raising Plinths**:
  A common suggestion is to **elevate homes** and other structures by **raising the plinths** to at least 1.5 to 2.5 feet higher than current levels to protect against flooding and tidal surges. People believe that **elevated housing** would reduce the risk of water damage during cyclones and high tides.

2. Strengthening Embankments

- **Upgrading Embankments**:
  Communities in **Khulna** and **Satkhira** suggest **strengthening embankments** by using more durable materials like **concrete** or reinforcing them with **geotextiles** to prevent breaches during heavy storms and rising sea levels.

3. Using Durable Materials for Construction

- **Durable Materials**:
  Residents recommend replacing traditional **mud and bamboo** construction with **stronger, cyclone-resistant materials** like **reinforced concrete, brick, and stone** for more resilient structures. They suggest that **cyclone-proof roofs** and **steel-reinforced walls** could greatly improve structural integrity.

4. Designing Multi-Use Safe Shelters

- **Constructing Multi-Use Shelters**:
  Community members also emphasize the need for **multi-use buildings** that can serve as both **homes** and **emergency shelters** during disasters. They propose **stronger, elevated shelters** built to withstand cyclones, floods, and other extreme weather events. These shelters could be used as **evacuation centers** during storms.



Fig: 4.19 Multipurpose Cyclone Shelter in Coastal Bangladesh

Table 4.8 Summary of Community Feedback

Feedback Area	Community Perception/Suggestion
Current Structure Resilience	Vulnerable to flooding, salinity, and cyclone impacts
Building Elevation	Raise plinths to 1.5–2.5 feet for flood protection
Embankment Strengthening	Upgrade embankments with concrete or geotextiles
Construction Materials	Shift to more durable materials (concrete, steel, brick)
Multi-Use Shelters	Build multi-use cyclone-proof shelters for safety

This feedback indicates a strong desire from local communities for improved infrastructure to withstand climate impacts. Enhancing the durability of buildings and structures through elevation, stronger materials, and better-designed shelters would provide significant protection in this climate-vulnerable region.

4.3.2 Zone-2 (Urban Areas: Dhaka, Rajshahi, Chattogram):

4.3.2.1 Community Feedback on Structural Resilience

Dhaka



Fig 4.20 Collecting feedback from residents in the slum areas of Dhaka.

- **Vulnerability of Existing Structures**:

  Residents have raised concerns about the vulnerability of buildings in **Dhaka** to flooding, especially in low-lying areas. Many homes and public structures are not equipped to handle **heavy monsoon rains**.

- **Inadequate Drainage Systems**:

  The drainage infrastructure often becomes overwhelmed during the monsoon season, leading to **waterlogging**. Many community members feel that this results in **further structural stress** on buildings.

Rajshahi



Fig 4.21 Gathering community feedback from residents of Rajshahi.

- **Drought-Induced Structural Stress**:

  In **Rajshahi**, community members suggest that the prolonged dry periods in the region cause **shrinkage** in building foundations, especially in **brick and mud structures**.
- **Erosion Risks**:

  Many residents along the **riverbanks** report that erosion causes foundations to be undermined, leading to **structural instability** in homes and public buildings.

Chattogram

- **Cyclone and Storm Surge Damage**:

  Buildings along the coastal areas of **Chattogram** are highly susceptible to **cyclones and storm surges**. Many of these structures have not been designed to withstand extreme weather.
- **Saltwater Intrusion**:

  Saltwater intrusion into buildings causes **corrosion** of metal structures and degradation of concrete. Community members suggest that this impacts the **long-term durability** of buildings in the area.

4.3.2.2 Community Suggestions for Structural Improvement

Dhaka

- **Elevated Construction**:
  Community members emphasize the need to **elevate buildings** to **1.5-2.5 feet above ground level** to protect against **flooding**.
- **Improved Drainage Systems**:
  Improving the drainage infrastructure to cope with increased water during **heavy monsoons** is another common suggestion.

Rajshahi

- **Moisture-Resistant Materials**:
  Using **moisture-resistant materials** to build homes can reduce the negative impacts of **drought-induced shrinkage**.
- **Erosion Control Measures**:
  Erosion control methods like **planting vegetation** and using **river embankments** are suggested to prevent foundation erosion.

Chattogram

- **Cyclone-Resistant Design**:
  Buildings should be designed to **withstand cyclones**, with **reinforced concrete and steel frames** suggested as materials for improved resilience.
- **Salt-Resistant Materials**:
  To mitigate **saltwater intrusion**, using **salt-resistant materials** is recommended for the construction of both private and public buildings.

Table 4.9 Summary Table of Community feedback of Zone 02

Region	Structural Challenges	Community Suggestions
Dhaka	Flooding, inadequate drainage.	Elevated construction, improved drainage

Rajshahi	Drought-induced shrinkage, erosion.	Moisture-resistant materials, erosion control
Chattogram	Cyclone damage, saltwater intrusion.	Cyclone-resistant design, salt-resistant materials

4.3.3 Zone-03 (Northern Region: Rangpur, Dinajpur):

4.3.3.1 Community Feedback on Structural Resilience

Rangpur

Riverbank Erosion: Communities along the Brahmaputra, Dharla, and Teesta rivers report that **riverbank erosion** undermines building foundations, leading to structural instability.



Fig 4.22 Community Mobilization Against River Threat – Through Our Team's Lens

Drought-Induced Shrinkage: In drought-prone areas, the lack of moisture causes **shrinkage and cracking of building foundations**, particularly in structures built with traditional materials.

Dinajpur

- **Decreasing Rainfall**: Decreasing rainfall patterns in Dinajpur have led to **soil shrinkage**, affecting the stability of buildings.

- **Inadequate Drainage Systems**: The existing drainage infrastructure is often overwhelmed during the monsoon season, leading to **waterlogging** and increased pressure on building foundations.

4.3.3.2 Community Suggestions for Structural Improvement

Rangpur

- **Erosion Control Measures**: Implementing **erosion control measures**, such as planting vegetation along riverbanks and constructing retaining walls, is suggested to protect buildings from river erosion.
- **Use of Moisture-Resistant Materials**: Residents recommend using **moisture-resistant materials** for construction to mitigate the effects of drought-induced shrinkage.



Fig 4.23 Collecting Community Suggestions for Structural Improvement from local residents.

Dinajpur

- **Improved Drainage Systems**: Upgrading and expanding drainage infrastructure to handle increased water flow during heavy rains is a common suggestion to prevent waterlogging and protect building foundations.

Table 4.10 Summary of Community feedback of Zone 3

Region	Structural Challenges	Community Suggestions
Rangpur	Riverbank erosion, drought-induced shrinkage.	Erosion control measures, moisture-resistant materials.
Dinajpur	Decreasing rainfall, inadequate drainage.	Improved drainage systems.

These insights highlight the importance of addressing climate-induced structural challenges in the northern regions of Bangladesh. Implementing community-driven solutions can enhance the resilience of buildings and infrastructure against climate impacts.

4.4 Government Policies & Initiatives for Climate-Resilient Construction

4.4.1 Zone-01(Coastal Areas: Khulna, Satkhira, Barguna, Bhola)

1. Bangladesh National Building Code (BNBC)

The BNBC, updated in 2020, incorporates climate resilience into construction standards, emphasizing disaster-resistant design, energy efficiency, and green building practices. These standards are crucial for ensuring structural safety in cyclone-prone coastal regions. [59]

2. Coastal Climate Resilient Infrastructure Project (CCRIP)

Implemented across 12 coastal districts—including Khulna, Satkhira, Barguna, and Bhola—CCRIP focuses on constructing climate-resilient roads, markets, and cyclone shelters. The project aims to enhance the resilience of rural infrastructure to climate change impacts.[60]

3. Climate Resilient Infrastructure Mainstreaming (CRIM)

Targeting Bhola, Barguna, and Satkhira, CRIM involves building and renovating cyclone shelters, improving critical access roads, and developing urban infrastructure to safeguard vulnerable communities from climate risks. [61]

4. Resilient Homestead and Livelihood (RHL) Project

This initiative focuses on constructing climate-resilient housing for vulnerable coastal populations, particularly in areas like Bhola and Barguna. It also promotes adaptive livelihood options for highly vulnerable and women-headed households.[62]

5. Coastal Embankment Improvement Project (CEIP)

CEIP aims to rehabilitate and upgrade embankments (polders) to protect coastal areas from tidal flooding and storm surges. The project enhances the resilience of coastal infrastructure and supports agricultural productivity by reducing saline water intrusion.[63]

4.4.1.1 Funding & Financial Support Mechanisms

1. Green Climate Fund (GCF)[64]

GCF supports projects like CRIM and RHL, providing financial resources for constructing climate-resilient infrastructure and housing in coastal districts, including Satkhira, Barguna, and Bhola.

2. World Bank Initiatives[65]

- **Coastal Embankment Improvement Project (CEIP):** Funded with $400 million, CEIP enhances coastal protection infrastructure.
- **Multipurpose Disaster Shelter Project (MDSP):** With a $375 million investment, MDSP constructs and rehabilitates multipurpose disaster shelters in coastal areas.

3. Bangladesh Climate Change Trust (BCCT)[66]

Established under the Climate Change Trust Act, 2010, BCCT funds climate adaptation projects, including those focused on resilient infrastructure in coastal regions.

4. Infrastructure Development Company Limited (IDCOL)[67]

A government-owned financial institution, IDCOL provides funding for renewable energy and infrastructure projects, supporting climate-resilient development in urban and rural areas.

5. Bangladesh Infrastructure Finance Fund Limited (BIFFL)[68]

BIFFL finances large-scale infrastructure projects, including those aimed at enhancing climate resilience in coastal zones.

These policies and funding mechanisms collectively aim to strengthen the resilience of coastal infrastructure in Bangladesh, particularly in vulnerable districts like Khulna, Satkhira, Barguna, and Bhola.

4.4.2 Government Policies & Initiatives for Climate-Resilient Urban Construction (Zone -02)

1. Bangladesh National Building Code (BNBC)[59]

The BNBC, updated in 2019, incorporates climate resilience into construction standards, emphasizing disaster-resistant design, energy efficiency, and green building practices. These standards are crucial for ensuring structural safety in urban areas like Dhaka, Chattogram, and Rajshahi.

2. Climate Action Plan – Dhaka South City Corporation (DSCC)[69]

In 2024, DSCC, with support from C40 Cities and ICLEI South Asia, developed a Climate Action Plan focusing on enhancing urban resilience through sustainable infrastructure, improved drainage systems, and green public spaces.

3. Rajshahi Climate Resilient City Action Plan[70]

Rajshahi City Corporation, in collaboration with ICLEI South Asia and UN-Habitat, implemented the Urban-LEDS II project to promote low-emission development strategies, including urban forestry and circular economy initiatives, enhancing the city's resilience to climate impacts.

4. Green Building Initiatives[71]

The Housing and Building Research Institute (HBRI) introduced guidelines for green building codes and developed rating systems like the Building Energy Efficiency and

Environment Rating (BEEER) and Green Affordable Resilience Certification for Habitats (GreenARCH) to promote sustainable construction practices in urban areas.

4.4.2.1 Funding & Financial Support Mechanisms

1. World Bank Financing[71]

- **$900 Million for Urban and Climate Resilience:** In December 2024, the World Bank provided $900 million to Bangladesh to support environmental sustainability and climate-resilient urban infrastructure development.

- **$850 Million for Trade and Social Protection:** In April 2025, Bangladesh and the World Bank signed agreements totaling $850 million, with $650 million allocated for the Bay Terminal Marine Infrastructure Development Project in Chattogram, including climate-resilient infrastructure, and $200 million for social protection programs targeting vulnerable urban populations.

2. Bangladesh Municipal Development Fund (BMDF)[72]

Established in 2002, BMDF provides funding for development and civil work to local governments in urban areas, supporting infrastructure projects that enhance climate resilience.

3. Bangladesh House Building Finance Corporation (BHBFC)[73]

BHBFC offers financing for the construction and renovation of houses and purchasing residential apartments across Bangladesh, including urban areas, facilitating the development of climate-resilient housing.

4. Inclusive Budgeting and Financing for Climate Resilience (IBFCR) Project[74]

Funded by UNDP and implemented by the Finance Division, the IBFCR Project aims to integrate climate resilience into public finance, supporting urban infrastructure projects that address climate risks.

These policies and funding mechanisms collectively aim to strengthen the resilience of urban infrastructure in Bangladesh, particularly in cities like Dhaka, Chattogram, and Rajshahi.

4.4.3 Zone-03 (Northern Region: Rangpur, Dinajpur)

Government Policies & Initiatives for Climate-Resilient Construction

1. National Adaptation Plan (NAP) 2023–2050[75]

The Government of Bangladesh's NAP outlines a strategic framework for enhancing climate resilience across the country, including the northern regions. It emphasizes the development of climate-resilient infrastructure to mitigate the impacts of climate change.

2. Bangladesh Delta Plan 2100 (BDP 2100)[76]: BDP 2100 is a long-term, integrated plan aiming to ensure sustainable development and climate resilience throughout Bangladesh. It includes provisions for infrastructure development in the northern districts to address climate-induced challenges.

3. City Resilience Strategy – Dinajpur Municipality[77]

Dinajpur Municipality, in collaboration with ICLEI South Asia, developed a City Resilience Strategy focusing on climate-resilient urban planning. The strategy addresses infrastructure vulnerabilities and proposes adaptive measures to enhance resilience.

4. Climate Resilient Infrastructure Mainstreaming Project (CRIMP)[78]

Implemented by the Local Government Engineering Department (LGED), CRIMP aims to integrate climate resilience into infrastructure planning and development. It provides tools and guidelines for assessing climate risks and designing resilient structures.

Funding & Financial Support Mechanisms

1. Bangladesh Climate Change Resilience Fund (BCCRF)[79]

BCCRF is a multi-donor trust fund established to support climate adaptation and resilience projects across Bangladesh, including infrastructure development in vulnerable regions like Rangpur and Dinajpur.

2. Green Climate Fund (GCF)[80]

GCF provides financial resources to support climate-resilient infrastructure projects in Bangladesh. It has partnered with various organizations to implement initiatives aimed at enhancing resilience in sectors such as agriculture, water resources, and infrastructure.

3. Asian Development Bank (ADB) Support[81]

ADB has extended financial assistance to Bangladesh for climate resilience initiatives. Notably, it provided a $400 million policy-based loan to support climate priorities, which includes infrastructure development in climate-vulnerable areas.

4. Infrastructure Development Company Limited (IDCOL)

IDCOL, a government-owned financial institution, offers funding for renewable energy and infrastructure projects. It supports initiatives aimed at developing climate-resilient infrastructure in various regions, including the northern districts.

These policies and funding mechanisms collectively aim to strengthen the resilience of infrastructure in Bangladesh's northern regions, particularly in Rangpur and Dinajpur.

4.5 Expert Opinions

4.5.1 Zone 1: Coastal Areas (Khulna, Satkhira, Barguna, Bhola)

Architectural Insight:

Kashef Mahboob Chowdhury, co-founder of the architectural firm Urbana, emphasizes the importance of community-based solutions in flood-prone areas. In the northern district of Gaibandha, his firm developed raised settlements around man made bodies of water to protect homes from flooding while ensuring access to rainwater.[82]

NGO Perspective:

Asif Saleh, Executive Director of BRAC, highlights the pressing issue of salinity affecting 30% of arable land along Bangladesh's coast. He stresses the need for climate adaptation strategies that address immediate challenges faced by communities, advocating for increased climate funding to reach grassroots levels.[83]

4.5.2 Zone 2: Urban Areas (Dhaka, Chattogram, Rajshahi)

Urban Planning Insight:

Bushra Afreen, Chief Heat Officer of Dhaka North, focuses on protecting residents from extreme heat. Her initiatives include planting over 5,000 saplings in vulnerable communities, integrating weather forecast data into the ShobarDhaka App, and collaborating with Dhaka Water Supply and Sewerage Authority to ensure access to clean water for commuters and laborers.[84]

Architectural Perspective:

Rafiq Azam, a prominent architect, has revitalized 31 community parks and playgrounds in Dhaka, converting them into green spaces with water-catchment areas that collect, filter, and store rainwater for drinking. His work aims to mitigate flooding risks and enhance urban resilience.[85]

4.5.3 Zone 3: Northern Region (Rangpur, Dinajpur)

Engineering Insight:

Dr. Imon Chowdhooree, Associate Professor at BRAC University, participated in the UNDP-funded Adaptation Initiative for Climate Vulnerability Offshore Small Islands and Riverine Charland in Bangladesh Project. He contributed to designing climate-resilient housing infrastructure in Gangachara Upazila, Rangpur, through consultation workshops and focus group discussions with beneficiaries.[86]

Urban Planning Perspective:

Dr. Ishrat Islam, Professor at BUET, specializes in urban planning, disaster management, and climate change. Her expertise includes participatory planning and community-based disaster management, contributing to the development of climate-resilient urban strategies in northern regions.[87]

These insights provide a foundational understanding of the diverse approaches and challenges in designing climate-resilient structures across Bangladesh's varied regions.

4.6 CASE STUDY ANALYSIS: CLIMATE ADAPTIVE STRUCTURES IN BANGLADESH

4.6.1 Zone 1: Coastal Areas (Khulna, Satkhira, Barguna, Bhola)

4.6.1.1 Success Case: Raised Plinth Housing in Bhola by BRAC

- **Description**: BRAC constructed elevated homes and community shelters in Bhola on raised plinths to counteract sea level rise and storm surges.
- **Design Features**: Reinforced concrete, locally available materials, cross-ventilation, and elevated water tanks.
- **Impact**: During Cyclone Amphan (2020), these structures experienced minimal damage, protecting both people and livestock.
- **Key Lesson**: Integration of community participation and elevation strategies significantly enhances resilience.

4.6.1.2 Failure Case: Unreinforced Housing in Satkhira

- **Issue**: Many self-built homes used mud or low-quality brick without reinforcement.
- **Outcome**: Collapsed during tidal surges and heavy rainfall (Cyclone Aila, 2009; Cyclone Bulbul, 2019).
- **Reason for Failure**: Lack of structural integrity, poor access to resilient construction knowledge, and no enforcement of building codes.

4.6.2 Zone 2: Urban Areas (Dhaka, Chattogram, Rajshahi)

4.6.2.1 Success Case: Water-Integrated Parks in Dhaka by Rafiq Azam

- **Description**: 31 parks and playgrounds were redesigned with water-catchment systems, shaded tree canopies, and flood-friendly landscaping.
- **Design Features**: Stormwater storage, green infrastructure, and public accessibility.
- **Impact**: Helped reduce urban heat, improved groundwater recharge, and mitigated flash floods during monsoon seasons.
- **Key Lesson**: Nature-based solutions in dense urban areas can offer multi-benefit outcomes if integrated with urban planning.

4.6.2.2 Failure Case: Unplanned Urban Drainage in Chattogram

- **Issue**: Infrastructure built without considering increasing rainfall intensity or drainage capacity.
- **Outcome**: Frequent waterlogging, foundation erosion, and damage to low-rise buildings during monsoons.
- **Reason for Failure**: Lack of coordination between urban development and hydrological planning; poor maintenance of canals and drainage.

4.6.3 Zone 3: Northern Region (Rangpur, Dinajpur)

4.6.3.1 Success Case: Climate-Resilient Char Settlements in Gaibandha (with UNDP/BUET)

- **Description**: Raised housing clusters on embankments to protect against river flooding and erosion.
- **Design Features**: RCC frame structures, raised tube wells, community cyclone shelters.
- **Impact**: Protected hundreds of families during annual floods without major damage.
- **Key Lesson**: Long-term investment in elevation, sanitation, and durable materials offers strong flood resilience.

4.6.3.2 Failure Case: Tin-Shed Schools in Dinajpur Floodplain

- **Issue**: School buildings made of bamboo and tin, located in seasonal flood zones.
- **Outcome**: Washed away or badly damaged every 1–2 years, disrupting education and incurring repetitive costs.
- **Reason for Failure**: Inappropriate site selection, low-cost temporary materials, and absence of long-term planning.

4.7 Comparative Analysis: Coastal vs. Inland Areas

Table 4.11 Comparative Analysis: Coastal vs. Inland Areas

Criteria	Coastal Areas	Urban Areas	Northern Areas
Primary Threats	Cyclones, salinity, tidal surges	Heatwaves, flooding, drainage failures	River floods, erosion

Successful Strategies	Elevated plinths, reinforced homes	Green infrastructure, stormwater harvesting	Raised settlements, reinforced community shelters
Common Failures	Use of non-durable materials in informal housing	Unplanned development, drainage mismanagement	Temporary shelters in high-risk flood zones
Adaptation Drivers	NGO-led, community-inclusive	Architect/Planner-led + gov. support (e.g., Dhaka)	Research-led + donor-funded
Weaknesses	Economic constraints, weak code enforcement	Rapid growth, weak maintenance	Rebuilding focus instead of prevention

4.8 Key Takeaways:

- **Community involvement** and **local material use** lead to more sustainable, accepted designs in rural/coastal zones.
- **Urban success** depends on integrating climate adaptation into city planning — not treating it as an add-on.

- **Failures often stem from** short-term thinking, lack of enforcement, or disconnect between design and local context.

CHAPTER 5

DATA ANALYSIS AND FINDINGS

This chapter presents the analysis and interpretation of data collected through a comprehensive and multi-tiered methodology to investigate the impact of climate change on structural design in Bangladesh. Data were obtained from structured field surveys across vulnerable coastal areas, urban centers, and northern regions, along with semistructured interviews conducted with experts from academic, governmental, and private sectors. Additionally, secondary data were sourced from credible organizations involved in climate monitoring, policy planning, and construction industries.

The analysis has been organized to systematically address the objectives, focusing on both the effects and impacts of climate change on structures. Quantitative data collected through surveys have been statistically analyzed to identify patterns, trends, and correlations related to structural vulnerabilities under various climatic stresses such as cyclones, salinity, flooding, drought, and rapid urbanization. Qualitative data from interviews, field observations, and case studies have been thematically analyzed to explore deeper insights into adaptive strategies, technical challenges, and community level resilience practices.

The findings are structured in multiple sections: first, examining the types of climate induced hazards and their direct impact on structural integrity; second, evaluating the broader effects on urban and rural built environments; third, assessing professional and community responses to structural vulnerabilities; and finally, analyzing existing policies, identifying gaps, and proposing recommendations for enhancing climate resilience structural designs.

Throughout the analysis, ethical standards were maintained, ensuring the confidentiality of respondents and the integrity of the data collected. This comprehensive approach ensures that the findings reflect the complex realities of Bangladesh's exposure to climate change and its implications for future structural design practices.

5.1 Hazards and Their Impact on Structural Design

5.1.1 Major Hazards Identified

Field surveys, expert interviews, and secondary data review (BMD, IWM reports) revealed that Bangladesh faces multiple climate induced hazards that significantly impact structural

design.

The major hazards identified include:

- **Cyclones** (coastal zones: Khulna, Satkhira, Barguna, Bhola)
- **Salinity intrusion** (southwest coastal belts)
- **River and urban flooding** (Dhaka, Chattogram, Sylhet)
- **Droughts** (northern districts: Rangpur, Dinajpur)
- **Heat waves** (urban areas: Dhaka, Rajshahi)

Each hazard has specific implications for building safety, longevity, and design standards.

5.1.2 Effects on Structures

Cyclones:

- High wind speeds cause roof blow offs, window failures, and sometimes complete structural collapse.
- Weak foundation and poor roofing systems fail under cyclone pressures.
- Cyclone Shelters built with reinforced concrete perform significantly better compared to traditional dwellings.

Salinity Intrusion:

- Saline water corroding steel reinforcement inside concrete structures.
- Cracks and spalling in concrete structures due to chemical reactions (sulfate attack).
- Accelerated deterioration of building materials like cement, steel, and brick.

Flooding (River and Urban):

- Basement inundation leading to weakening of foundations.
- Uplift pressure on slab foundations in urban settings (e.g., Dhaka).
- Soil erosion undermines structural stability in riverbank regions.

Droughts:

- Drying and shrinking of clayey soils causing settlement cracks in foundations and walls.
- Structural instability in low moisture soil areas unless deep foundations are used.

Heat Waves:

- Increased thermal stress causing expansion and contraction of building materials.
- Degradation of concrete and asphalt surfaces.
- Rising energy demand influences the design of ventilation and insulation systems.

Table 5.1 Regional Hazard Severity (Based on Field Data)

Region	Major Hazard	Impact on Structures
Khulna, Satkhira	Cyclones, Salinity	Roof damages, concrete corrosion
Dhaka	Urban Flooding, Heat	Basement flooding, material degradation
Rajshahi	Heat Waves, Drought	Soil shrinkage, cracks in foundations
Rangpur, Dinajpur	Drought	Ground instability, settlement issues
Bhola, Patuakhali	Cyclones, Flooding	Structural collapse, uplift failures

5.2 Regional Vulnerability Analysis

5.2.1 Coastal Zones (Khulna, Satkhira, Barguna, Bhola)

Field survey findings reveal that coastal areas are extremely vulnerable to climate induced hazards, especially cyclones, tidal surges, and salinity intrusion.

- **Structural Vulnerabilities:**
    - Traditional houses made of wood and tin easily collapse during high wind events.
    - Reinforced concrete (RC) structures are more resilient but still suffer corrosion due to high salinity levels.
    - Foundation failures are common in saline affected soils.

- **Observed Cases:**
- In Satkhira and Khulna, multiple cyclone shelter buildings show signs of reinforcement corrosion within 10–15 years of construction.



Fig 5.1 View of observed case

Adaptation Measures:

- Elevated plinths.
- Use of corrosion resistant construction materials (e.g., coated steel).
- Cycloneresistant roofing systems.

5.2.2 Urban Centers (Dhaka, Chattogram, Rajshahi)

Urban areas experience frequent urban flooding, waterlogging, heat waves, and infrastructure stress due to rapid urbanization and climate change.

- **Structural Vulnerabilities:**
    - Poor drainage leads to foundation waterlogging and settlement issues.
    - Increased temperature accelerates material fatigue (especially concrete surfaces).
    - Overcrowding limits possibilities for climate resilient designs.

Observed Cases:



Fig 5.2 Climate-Induced Urban Flooding in Dhaka City: A Real-Time Snapshot

- Water seepage in underground parking basements in Dhaka (e.g., Dhanmondi Gulshan, Motijheel).
- Cracking and surface distress on asphalt roads during peak summer.

Adaptation Measures:

- Sustainable Urban Drainage Systems (SUDS).
- Improved heat resilient construction materials (e.g., white roofs, green buildings).
- Vertical urban expansion with resilient designs.

5.2.3 Northern Region (Rangpur, Dinajpur)

Northern Bangladesh is highly prone to droughts and seasonal flooding.

- **Structural Vulnerabilities:**
  - Shrinking soils lead to foundation subsidence and wall cracks.
  - Poor construction materials make buildings highly sensitive to temperature variations.
- **Observed Cases:**

  - In Dinajpur, several rural schools reported foundation cracking after severe dry seasons.

Adaptation Measures:

- Deep pile foundations.
- Soil moisture management around building footprints.
- Use of flexible joints in structures.

5.3 SWOT Analysis of Current Structural Practices

A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis has been conducted to evaluate the current structural design and construction practices in Bangladesh. This analysis is based on data collected from field surveys, expert interviews, and secondary sources.

5.3.1 Strengths

- **Established Guidelines and Codes:**
  Bangladesh has structured regulatory frameworks like the Bangladesh National Building Code (BNBC) and Bangladesh Standards (BDS), which define design standards clearly.
- **Skilled Engineering Workforce:**
  Graduates and professionals from leading universities such as BUET, RUET, and CU possess international level expertise in structural engineering.
- **Adoption of Advanced Technologies:**
  Major projects are increasingly incorporating seismic resilient, cyclone resistant, and green building technologies.
- **Active Role of NGOs and Government Organizations:**
  Organizations like BRAC and Practical Action, along with government bodies, are working to promote resilient construction practices.

5.3.2 Weaknesses

- **Poor Enforcement of Regulations:**
  Although BNBC guidelines are mandatory, compliance is often lacking, especially in small and medium sized projects.
- **Inadequate Supervision:**
  There is insufficient quality control and monitoring during the construction process.

- **Use of Substandard Materials:**
  In many cases, counterfeit steel, low quality cement, and improper construction materials weaken structural integrity.
- **Skill Gaps in Labor Force:**
  Many workers and small contractors, particularly in rural or semi urban areas, lack knowledge of modern construction methods.

5.3.3 Opportunities

- **Growing Trend of Sustainable Construction:**
  There is a rising trend towards eco friendly and climate resilient structural designs.
- **International Collaboration and Funding:**
  Bangladesh is receiving significant international support, such as from the Green Climate Fund and World Bank, to improve resilience.
- **Introduction of New Construction Technologies:**
  Technologies like prefabricated structures, fiber reinforced concrete, and corrosion resistant steel are becoming more accessible.

5.3.4 Threats

- **Increased Disaster Risk:**
  Climate change is leading to more frequent and severe events like cyclones, floods, and heatwaves, posing greater threats to structures.
- **Unpredictable Climate Change Impacts:**
  Emerging risks, such as increased salinity intrusion in new areas, could challenge future structural designs.
- **Economic Constraints:**
  Low Income communities often cannot afford resilient construction, continuing the cycle of vulnerability through poorly built structures.

5.4 Coping Strategies and Adaptation Mechanisms

This section discusses the coping strategies and adaptation mechanisms adopted by both local communities and authorities in Bangladesh to address the impact of climate change on

structural resilience. The analysis is based on field observations, interviews, and secondary data reviews.

5.4.1 Community Level Coping Strategies

- **Use of Indigenous Knowledge:**
  Local communities, especially in coastal and flood prone areas, have been applying traditional building methods, such as raising plinth levels and using flexible materials like bamboo and wood that can better withstand cyclones and floods.
- **Elevated Housing and Raised Platforms:**
  In coastal regions such as Barguna and Bhola, people are building houses on stilts or raised platforms to minimize flood damage.
- **Use of SalinityResistant Materials:**
  In areas affected by salinity intrusion, such as Satkhira, builders are adapting by using construction materials more resistant to corrosion.
- **Community Shelters:**
  The establishment of multipurpose cyclone shelters by local communities has become a common coping mechanism during disasters.

5.4.2 Authority Led Adaptation Mechanisms

- **Cyclone Resilient Infrastructure Development:**
  Government agencies, supported by NGOs, have been constructing cyclone resilient schools, hospitals, and shelters following stricter building codes.
- **Flood Control Measures:**
  Initiatives such as embankment construction, improved drainage systems, and river training works are being implemented by organizations like BWDB (Bangladesh Water Development Board).
- **Urban Resilience Projects:**
  In urban areas like Dhaka and Chattogram, city corporations are introducing climate resilient urban planning, improving drainage systems, and promoting green infrastructure.
- **Policy Initiatives:**
  The government has introduced plans like the National Adaptation Plan (NAP) and

Bangladesh Delta Plan 2100 to integrate resilience into national development planning.

5.4.3 Private Sector and NGO Contributions

- **Promotion of DisasterResilient Housing:**
  NGOs like Practical Action and BRAC are promoting low cost, disaster resilient housing models for vulnerable communities.
- **Capacity Building and Training Programs:**
  Several NGOs and private organizations conduct training programs for masons, contractors, and engineers to improve knowledge of climate resilient construction.
- **Innovation and Re:**
  Private construction firms and re institutions are investing in developing new technologies and design solutions suitable for the changing climate.

5.5 Government Policies and Initiatives

In this section, we will analyze existing government policies and initiatives aimed at addressing the impact of climate change on structural design and infrastructure in Bangladesh. The review is based on governmental reports, policy documents, and expert interviews to assess the strengths and gaps in these policies.

5.5.1 Overview of Key Government Policies

- **National Adaptation Programme of Action (NAPA):**
  The NAPA, introduced by the Ministry of Environment, Forest and Climate Change, identifies the most vulnerable sectors and proposes adaptation measures, particularly in the coastal regions and flood prone areas. It focuses on the integration of climate change adaptation into development planning, including structural resilience in housing and infrastructure.
- **Bangladesh Climate Change Strategy and Action Plan (BCCSAP):**
  Launched by the Ministry of Environment, this comprehensive policy document outlines the steps needed for adaptation to climate change, focusing on sectors such as water resources, agriculture, and disaster management. The plan also addresses the need for enhancing the resilience of infrastructure against climate induced hazards.

- **Bangladesh Delta Plan 2100:**

  This long term development strategy aims to integrate climate change adaptation into Bangladesh's overall development agenda. It includes measures for flood management, river training, and enhancing the structural resilience of coastal and urban infrastructure.
- **National Building Code (BNBC):**

  The BNBC is a set of regulations aimed at improving construction quality and safety. While it includes aspects of structural design for disaster resilience, further revisions are needed to incorporate climate change impacts, especially in vulnerable regions.

5.5.2 Government Initiatives in Disaster Resilience

- **Disaster Management Act and National Disaster Management Policy:**

  The Disaster Management Act provides a framework for reducing vulnerability and managing disaster risks. The policy emphasizes disaster resilient infrastructure development, including retrofitting existing buildings and constructing new buildings to withstand extreme weather events.
- **Cyclone Shelter Program:**

  The government has invested in cyclone shelters, particularly in coastal areas, to protect people and infrastructure during cyclones. These shelters are designed to withstand severe weather conditions and are an essential part of the country's disaster management plan.
- **Flood Protection Measures:**

  The government is working with the Bangladesh Water Development Board (BWDB) to implement flood control measures, including the construction of embankments, sluice gates, and drainage systems, to mitigate the impacts of rising flood risks in urban and rural areas.

5.5.3 Challenges and Policy Gaps

- **Lack of Enforcement and Compliance:**

  While policies such as the BNBC exist, the enforcement and monitoring of these policies are often inadequate, particularly in the private construction sector and smaller projects. This results in the use of substandard materials and the construction of buildings that are not resilient to climate change impacts.

- **Insufficient Integration of Climate Change into Local Planning:**

  While national level policies address climate change adaptation, local governments often lack the capacity and resources to implement these measures effectively. There is a need for better integration of climate change adaptation into local urban and rural planning.
- **Financial Constraints:**

  Many of the proposed adaptation measures require significant investment. While international funding is available, there is still a lack of sufficient domestic funding and technical capacity to carry out these initiatives, particularly in poorer regions.
- **Limited Public Awareness:**

  There is limited public awareness regarding climate change impacts on structural design. People often rely on traditional construction methods without understanding the need for climate resilient designs.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study aimed to understand the multifaceted impact of climate change on structural design in Bangladesh—a country highly vulnerable to climatic hazards due to its geographic location, socio-economic challenges, and rapid urbanization. Drawing upon a combination of primary and secondary data—including field surveys, expert interviews, and institutional records—the research has demonstrated how both natural and human-induced climatic changes are reshaping the principles and practices of structural design across diverse regions.

The data revealed that **coastal regions**, such as Bhola, Khulna, and Satkhira, face severe threats from rising sea levels, salinity intrusion, storm surges, and cyclonic winds. Structures in these areas often suffer from early deterioration due to corrosion of reinforcement, water logging, and substandard foundation stability. Many buildings are not built to withstand the increasing intensity of storms or resist saline water damage. Traditional building methods and materials remain dominant, especially in rural areas, lacking sufficient engineering input or climate adaptation features.

In contrast, **urban centers** like Dhaka and Chattogram face challenges of heat stress, unplanned vertical expansion, poor drainage, and flooding, exacerbated by climate variability. Interviews with professionals highlighted a critical lack of integration between climate risk assessments and structural planning, especially for informal settlements and small-scale infrastructure projects.

The **northern zones**, including Rangpur and Dinajpur, experience irregular rainfall and prolonged droughts, influencing soil stability and structural integrity. There is little awareness or practice of modifying structural designs based on these changing environmental loads. Engineers in these regions often follow generic national codes without localization, making many structures vulnerable.

Expert insights from BUET, RUET, structural consultants, and government officials point to a significant gap in climate-adaptive design practices. While there is awareness among leading professionals, the transition from theory to practice remains slow. Limitations include

outdated building codes, insufficient field-level monitoring, low awareness in local construction sectors, and limited institutional coordination.

Policy reviews further exposed weaknesses in **implementation**, with the Bangladesh National Building Code (BNBC) still lacking region-specific guidance or enforceable climate-resilience clauses. Coordination between climate research bodies, design institutions, and local government engineering departments remains fragmented.

In summary, the findings indicate that **climate change is not only a future threat but a current structural challenge** for Bangladesh. Without proactive, localized, and forward-looking reforms in structural design and construction practices, the built environment—especially in high-risk zones—will remain highly vulnerable. The study highlights the need for urgent intervention, capacity building, and policy innovation to ensure the safety, durability, and sustainability of infrastructure in a changing climate.

6.2 Recommendations

1. Update Building Codes for Climate Resilience
   National structural design codes (like BNBC) should be revised to integrate region-specific climate risks such as wind speed, salinity, flood load, and temperature fluctuations.
2. Establish Regional Structural Guidelines
   Develop area-based structural design frameworks especially for coastal zones, including Bhola, where salinity and cyclones demand reinforced concrete, corrosion-resistant materials, and elevated foundation design.
3. Strengthen Professional Training
   Conduct regular workshops for engineers, architects, and builders on climate-resilient structural techniques, materials, and adaptive construction practices.
4. Promote Climate-Resilient Materials
   Encourage the use of materials that are less vulnerable to salinity and temperature-related degradation, such as fiber-reinforced concrete, epoxy-coated steel, or geopolymer cement.
5. Enhance Institutional Collaboration
   Improve coordination between LGED, DoE, BMD, and academic institutions like BUET and RUET to develop shared data systems and structural assessment tools.

6. Policy Integration and Implementation

   Integrate structural resilience with national development and disaster management plans. Ensure local governments have the technical capacity and funding to enforce building standards.

7. Support for Vulnerable Communities

   Introduce subsidy or incentive programs to help low-income groups in vulnerable areas build safer, climate-resilient homes and shelters.

8. Monitoring and Evaluation Frameworks

   Develop a national monitoring mechanism to assess the performance of structures over time under climate stress and update policies accordingly.

9. Promoting Public Private Partnerships:

   The government should promote public private partnerships to finance climate resilient infrastructure projects, leveraging both domestic and international funding sources.

10. Increasing Public Awareness:

    There should be campaigns to educate the public about climate resilient construction and the benefits of adopting these practices in vulnerable areas.

6.2.1 Final Thoughts

The need for climate resilient structural design in Bangladesh has never been more urgent. As climate change continues to escalate, the vulnerability of the country's infrastructure will increase unless comprehensive measures are taken to enhance resilience. By implementing the recommendations outlined above, Bangladesh can improve the durability of its structures, protect its people from climate induced disasters, and ensure sustainable development for future generations.

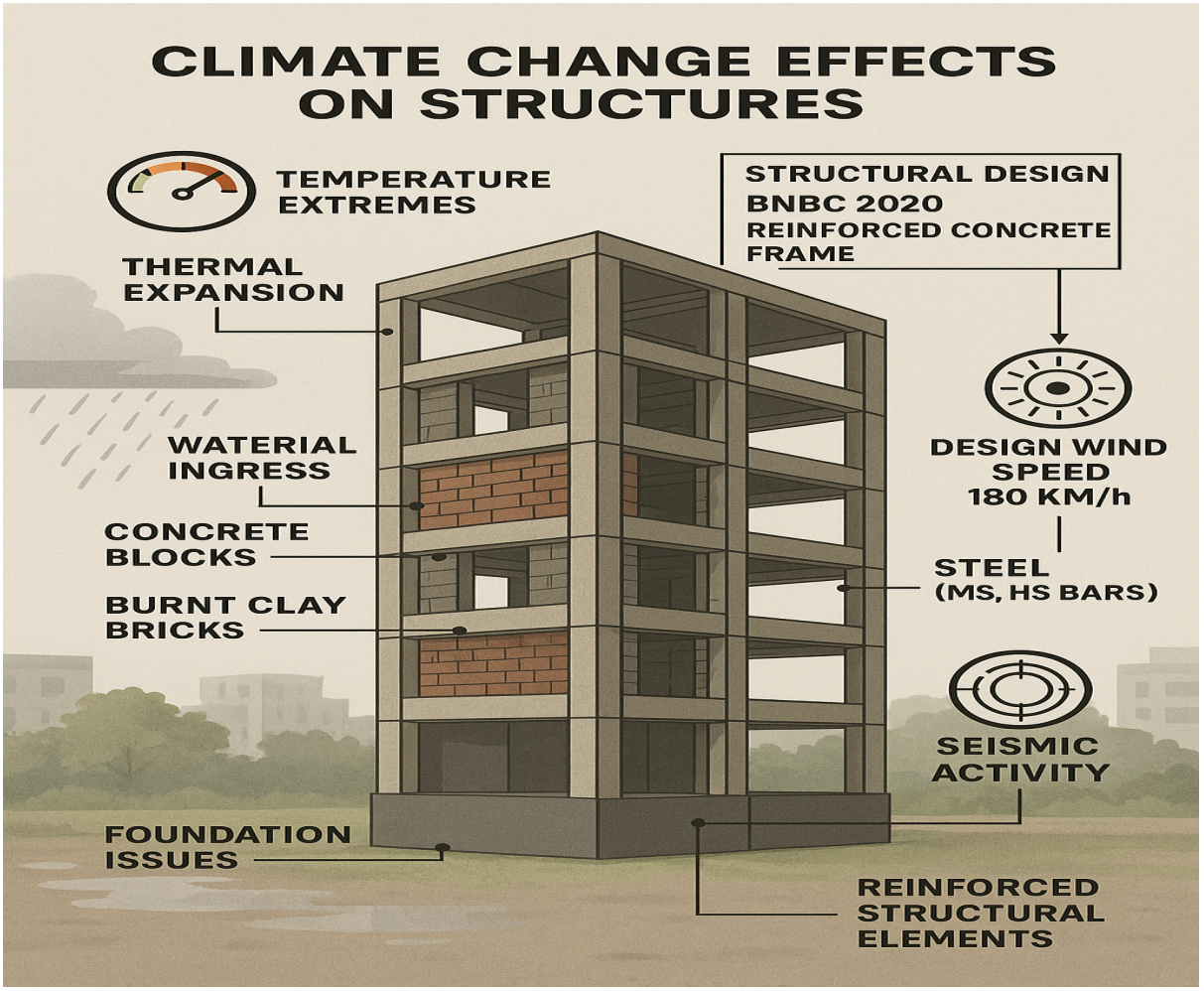


Fig 6.1 Climate Change Effects on Structures

6.3 Limitations

1. Geographical Constraints

Although the study covered several regions including coastal, urban, and northern areas, it was not feasible to cover all vulnerable regions of Bangladesh due to time and resource limitations. Therefore, some critical zones with unique climatic challenges may not have been adequately represented.

2. Time Constraints

The data collection and field visits were conducted within a limited timeframe, which restricted the depth of long-term observation, seasonal variation analysis, and post-disaster structural performance evaluation.

3. Access to Experts and Institutions

While attempts were made to include insights from professionals and agencies (like BUET, Department of Environment, etc.), not all relevant stakeholders could be reached due to scheduling conflicts or lack of availability, potentially limiting the diversity of expert opinions.

4. **Dependence on Secondary Data**

A portion of the study relied on secondary data from various organizations. The accuracy and timeliness of such data could not be independently verified and may have influenced the findings.

5. Respondent Bias

In survey and interview responses, some local residents or officials may have underreported or overemphasized certain impacts based on perception, recent experiences, or expectations, which may introduce response bias.

6. Technical Complexity

Detailed structural analysis under projected climate scenarios (e.g., simulation under high wind speed or increased flood load) was beyond the scope of this study due to lack of computational tools and engineering software access.

7. Policy and Legal Limitations

Lack of access to some unpublished or restricted government documents on structural policies or climate plans created limitations in policy gap analysis.

8. **Organizational and Administrative Constraints**

In certain regions, local administration or organizational cooperation was limited, which may have caused delays in data collection or resulted in the absence of some crucial information.

9. **Diversity of Mentalities and Needs in Different Areas**

People in different regions of Bangladesh have varied perceptions and needs, which may affect structural projects. This diversity was not fully addressed, as there were limited opportunities to conduct an in-depth analysis of local realities.

10. Limitations in Data Comparison and Analysis

In some cases, the data obtained was incomplete or insufficient, which made it challenging to perform comparisons or comprehensive analysis of certain findings.

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APPENDIX

The following questionnaire was administered to local residents to gather their insights:

Title: Community Impact of Climate Change on Local Structures and Living Conditions

Purpose: To understand how local communities in Bangladesh perceive the impact of climate change on their homes, infrastructure, and daily lives.

Section 1: General Information

1. Name (Optional):

2. Age:

3. Gender: □ Male □ Female □ Other

4. Occupation: □ Farmer □ Laborer □ Student □ Homemaker □ Business Owner □ Other (Please specify): _____

Section 2: Experiences with Climate Change

5. Have you noticed any changes in weather patterns in your area over the last 5–10 years?

□ Yes □ No □ Not Sure

6. What types of extreme weather events have you observed in your area recently? (Select all that apply):

□ Floods □ Heavy Rainfall □ Drought □ Cyclones □ Storms □ Other (Please specify): _____

7. How often do these extreme weather events occur in your area?

□ Frequently (Every year) □ Occasionally (Every few years) □ Rarely (Once in many years) □ Never

8. Have these extreme weather events caused any damage to your home or property? □ Yes □ No □ Not Sure If yes, please describe the damage: (Open-Ended) _____

Section 3: Impact on Structures and Infrastructure

9. Have you experienced any of the following damages to local infrastructure due to climate change? (Select all that apply):

□ Cracked walls or foundations □ Roof damage or leakage □ Damaged roads or bridges □ Flooding or waterlogging in streets □ Loss of agricultural land □ Other (Please specify): _____

10. Do you think the houses and buildings in your area are built to withstand extreme weather conditions?

□ Yes □ No □ Somewhat

11. Have you or your neighbors made any changes to your homes to protect them from climate-related damages (e.g., strengthening roofs, raising foundations, etc.)?

□ Yes □ No If yes, what changes have you made? (Open-Ended)

Section 4: Awareness and Adaptation

12. Do you feel that climate change is affecting your community?

□ Yes □ No □ Not Sure

13. Are you aware of any government or local initiatives to help communities adapt to climate change?

□ Yes □ No If yes, what initiatives have you heard about? (Open-Ended)

_____

14. What do you think should be done to help your community better cope with climate change? (Open-Ended)

_____

15. Would you be interested in participating in programs or workshops that teach how to protect homes from climate-related damage? □ Yes □ No Section

Section 5: Suggestions and Feedback

16. Do you have any suggestions for improving the resilience of local infrastructure or homes against climate change? (Open-Ended)

_____

17. Any additional comments or experiences you would like to share about climate change and its impact on your community? (Open-Ended)

_____

Understanding Structural Vulnerabilities and Climate Adaptation Needs: Insights from Field Experts:

Survey Questionnaire

Title: *Impact of Climate Change on Structural Design in Bangladesh*
Purpose: To understand how climate change affects the durability of structures and to explore necessary strategies for climate-resilient design.
Respondent Types: Engineers, architects, construction experts, policymakers, and relevant professionals.

Section 1: General Information

Name (optional):

Profession:

□ Civil Engineer

□ Architect

□ Contractor

□ Climate Scientist

□ Policymaker

□ Others (please specify): _____

Work Experience:

□ 0–5 years

□ 6–10 years

□ More than 10 years

1. **Work Area (tick where applicable):**
    - □ Coastal region
    - □ Flood-prone region
    - □ Urban area
    - □ Others (please specify): _____

Section 2: Impact of Climate Change on Structures

5. **In your experience, which aspects of climate change most affect the durability of structures? (Select all that apply):**
    - □ Heavy rainfall
    - □ Cyclones / Storm surges
    - □ High humidity
    - □ Rising temperature
    - □ Flooding
    - □ Others (please specify): _____

6. **What types of structural damage have you observed due to climate change? (Select all that apply):**
    - □ Cracks in walls or foundations

- □ Corrosion of steel rods
- □ Weakening of structural joints
- □ Waterlogging-related damage
- □ Others (please specify): _____

7. **Which type of structures are most vulnerable to climate change in your area?**
   - □ Residential buildings
   - □ Commercial buildings
   - □ Bridges and flyovers
   - □ Roads
   - □ Others (please specify): _____

8. **In your opinion, are the current structures in your area sufficiently capable of handling climate-related challenges?**
   - □ Yes
   - □ No
   - □ Partially

Section 3: Adaptation Strategies

9. **Which materials do you consider most effective in adapting to the effects of climate change? (Select all that apply):**

- □ Corrosion-resistant steel
- □ High-quality concrete
- □ Environment-friendly construction materials
- □ Flood-resistant foundations
- □ Others (please specify): _____

10. **What design strategies would you recommend for climate-resilient structures?**

- □ Elevated foundations
- □ Improved drainage systems
- □ Green roofing or shaded systems
- □ Wind-resistant designs
- □ Others (please specify): _____

11. **What challenges have you faced in implementing climate-resilient design in your projects? (Select all that apply):**

- □ Lack of awareness
- □ High cost of materials
- □ Lack of technology
- □ Lack of policy support

- □ Others (please specify): _____

Section 4: Local Codes and Standards

12. **Do you follow the Bangladesh National Building Code (BNBC) for climate-resilient design?**

- □ Yes
- □ No
- □ Partially

13. **In your opinion, does the BNBC provide adequate guidelines for addressing the impact of climate change on structures?**

- □ Yes
- □ No
- □ Partially
- □ Not sure

14. **What improvements or additions would you suggest regarding climate resilience in the BNBC?**
    (Open-ended):

Section 5: Recommendations and Suggestions

15. **What actions should policymakers take to reduce the damage to climate-vulnerable structures?**
    (Open-ended):

16. **If you know of any successful climate-resilient project or case study in Bangladesh, please briefly mention it.**
    (Open-ended):

Final Section

17. **Would you like to receive updates about the findings of this research?**

- □ Yes (please provide your email): _____
- □ No

18. **Any additional comments or suggestions (if any):**
    (Open-ended):

Documentation from Our Field Survey


















Structures Affected by Climate Disasters — Captured Through Our Lens


















Survey Stories: Captured Moments