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Engineering Solutions to Address Climate Change Risks in the Construction Sector in the UAE

Saed Alshanti

Independent Researcher, Abu Dhabi, UAE
Email: shantisaed@gmail.com

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Abstract

Climate change is increasing the exposure of the United Arab Emirates (UAE) built environment to extreme heat, coastal and groundwater salinity, intense rainfall, and associated flooding. This narrative literature review examines engineering responses relevant to these risks across materials, building envelopes, urban drainage, coastal protection, and digital monitoring. The review draws on peer-reviewed engineering literature together with authoritative UAE and international institutional publications, with priority given to sources directly addressing hot-arid conditions, durability, climate adaptation, and construction practice. The evidence indicates that no single technology provides a complete response. Established measures such as sulfate-resistant concrete systems, high-performance envelopes, conventional coastal protection, and well-maintained drainage infrastructure can be combined with more emerging options, including geopolymer binders, nanomaterial modification, responsive facades, and digital twins. Their suitability depends on exposure conditions, building function, maintenance capacity, life-cycle cost, and the maturity of supporting standards and field evidence. The review concludes that a risk-based combination of proven and emerging measures offers a more credible pathway to improving the long-term resilience of UAE construction than reliance on individual technologies.

Keywords

Climate Change, UAE Construction Sector, Resilient Engineering, Geopolymer Concrete, Sustainable Drainage Systems, Responsive Facades, Coastal Resilience

1. Introduction

The United Arab Emirates has witnessed an urban and economic boom over the past few decades.

Considering these facts, adhering to traditional construction methods is no longer a sustainable option.

This study is a narrative literature review focused on engineering responses to climate-related risks in the UAE construction sector. Sources were selected through targeted searches of peer-reviewed engineering literature and authoritative institutional publications, including UAE government documents and Intergovernmental Panel on Climate Change (IPCC) assessments. Priority was given to sources addressing hot-arid construction, material durability, coastal and flood exposure, building-envelope performance, and technologies with clear relevance to UAE conditions. Sources were retained when they provided identifiable technical evidence, documented applications, or official regulatory and climate information; unsupported promotional material and claims that could not be verified were excluded.

2. Literature Review and UAE Climate Context

Understanding the dynamic nature of the climate in the United Arab Emirates is a fundamental pillar.

2.1. Current and Future Geographical and Climatic Characteristics

The United Arab Emirates is classified as a region with arid to extremely arid desert climates.

2.2. Coastal Threats and Soil Salinity

The UAE's major urban centers, transport assets, utilities, ports, and desalination infrastructure are strongly concentrated along or near the coast, making coastal exposure a material concern for the built environment. The UAE State of Climate Report identifies buildings, transport links, energy assets, desalination plants, water-supply systems, and sanitation infrastructure among the assets exposed to climate-related risks, including sea-level change, flooding, and changes in seawater salinity (Ministry of Climate Change and Environment [MOCCAE], 2024). The Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change, 2023) likewise identifies increasing risks from sea-level rise and coastal flooding in low-lying coastal areas. In the UAE context, saline groundwater and chloride- and sulfate-rich exposure can accelerate reinforcement corrosion and concrete deterioration; therefore, site-specific geotechnical and groundwater assessment is important when selecting foundation materials and protection systems.

2.3. Extreme Rainfall Patterns and Sandstorms

Recent extreme rainfall events have highlighted the vulnerability of highly urbanized areas to short-duration, high-intensity runoff. Climate assessments also indicate that a warmer climate can intensify heavy precipitation and compound flood risks, although the magnitude and location of change remain regionally variable (Intergovernmental Panel on Climate Change, 2023). In the UAE, these risks interact with extensive paved surfaces, drainage capacity, dust deposition, and local topography. Sand and dust can also contribute to facade weathering and to sediment loading in drainage and permeable-surface systems, reinforcing the need for designs that consider both hydraulic performance and maintenance.

2.4. Legislative Frameworks Relevant to Green Building in the UAE

The UAE has established national and emirate-level frameworks that support lower-carbon and more sustainable construction. In Abu Dhabi, the Estidama Pearl Rating System provides sustainability requirements and rating pathways for buildings and other development types (Department of Municipalities and Transport [DMT], 2016). In Dubai, Al Sa'fat - Dubai Green Building System replaced the earlier Green Building Regulations and Specifications in 2020; its current framework includes mandatory requirements for new buildings and higher performance tiers (Dubai Municipality, 2023). At the federal level, Federal Decree-Law No. 11 of 2024 on the Reduction of Climate Change Effects establishes requirements related to mitigation, adaptation, emissions management, and climate-related planning across sources in the State; it entered into force on 30 May 2025 (United Arab Emirates Government, 2024). These instruments provide an important policy context for engineering decisions, while the present review remains focused on technical application rather than regulatory evaluation.

3. Materials Engineering: Development of Flexible and Climate-Resistant Concrete

Concrete is a central structural material in the UAE construction sector and its durability is therefore important under high temperatures, saline exposure, and repeated wetting and drying. This section reviews material strategies intended to improve resistance to thermal and chemical deterioration.

3.1. Geopolymer and Green Concrete

Geopolymer concrete uses aluminosilicate-rich precursors, including fly ash, slag, or metakaolin, activated by alkaline solutions as an alternative to conventional Portland-cement binders. Published life-cycle assessments report substantial potential reductions in carbon emissions, but the magnitude varies with precursor source, activator production, transport, curing, and system boundaries; recent reviews report ranges that can extend from roughly 30% to 80% under particular mix and assessment conditions (Khasawneh, 2025). Geopolymer systems can also provide favorable chemical and thermal resistance, although field performance depends on mix design, curing, material availability, workmanship, and applicable standards. For this reason, geopolymer concrete is treated here as a promising but not universally mature replacement for conventional structural concrete.

3.2. Chemical and Sulfate Resistance

Due to salt seepage and high groundwater salinity in coastal areas, structural foundations are subjected to intense attack from sulfates and chlorides. Sulfates react with calcium hydroxide in concrete to form ettringite, which causes internal expansion leading to concrete disintegration. Chlorides penetrate the concrete, destroying the passive protective layer surrounding the reinforcing steel, causing corrosion and structural failure. The engineering solution lies in using Type V sulfate-resistant cement and reinforcing it with ultra-fine pozzolanic materials such as silica fume. These materials transform the weak calcium hydroxide into a more robust saturated calcium silicate (CSH gel), preventing harmful reactions and extending the lifespan of the foundations.

3.3. Nanotechnology in Concrete and Pore Refinement

The structural weakness of traditional concrete lies in its microscopic porosity, which allows moisture and salts to pass through. Nanoengineering offers a radical solution by incorporating microscopic particles into the concrete mix.

- Nano-silica can refine the pore structure of cementitious materials through filler and pozzolanic effects, which can reduce permeability and improve resistance to moisture and ion ingress. The improvement is dosage- and mix-dependent and should not be interpreted as complete prevention of water or chloride penetration (Muhd Norhasri et al., 2017).
- Carbon nanotubes (CNTs) have been investigated as nanoscale reinforcement capable of modifying mechanical, electrical, and crack-related behavior in cementitious composites. Their use remains comparatively emerging because dispersion, dosage control, cost, health and handling considerations, and large-scale quality control can constrain routine field application.

3.4. Water Management and Recycling at Construction Sites

The scarcity of fresh water in desert environments is directly linked to the efficiency of concrete manufacturing and curing. Chemical curing compounds are used as an alternative to traditional water spraying methods. These compounds form chemical films that prevent the evaporation of the concrete's internal mixing water, ensuring complete cementation without additional water consumption. Furthermore, integrated treatment plants are engineered on construction sites to recycle greywater and truck wash water for use in non-structural mixing and soil stabilization, in line with stringent water stress reduction targets.

4. Structural & Architectural Design

This section focuses on advanced engineering and architectural solutions for the building envelope, with the aim of insulating and protecting the structural framework from extreme thermal changes and reducing the operational carbon footprint resulting from cooling buildings in the UAE environment.

4.1. High-Performance Thermal Insulation and Smart Materials

The building envelope strongly influences solar heat gain and cooling demand in the UAE. High-performance options include aerogel-based insulation and phase-change materials (PCMs). Aerogels can provide very low thermal conductivity in relatively thin assemblies, while PCMs can moderate temperature fluctuations by storing and releasing latent heat. Their actual benefit depends on assembly design, orientation, installation quality, durability, fire and moisture requirements, and life-cycle cost; they reduce heat transfer rather than eliminating it.

4.2. Kinetic and Climate-Responsive Envelopes

Dynamic shading systems can respond to solar position and reduce direct solar exposure. The Al Bahar Towers in Abu Dhabi provide a documented regional example: published project information reports that the responsive external screen can reduce solar gain by more than 50% under the project's design conditions. This figure should be understood as project-specific rather than a general performance value for all kinetic facades. Wider application also requires consideration of controls, moving components, maintenance, wind exposure, commissioning, and whole-life cost.

4.3. Advanced Thermal Modeling, BIM, and Digital Twins

Building Information Modeling (BIM) and simulation tools can integrate climate assumptions with thermal, energy, and asset information during design. Digital twins extend this concept by linking digital models with operational data, potentially supporting condition monitoring and preventive maintenance. However, digital-twin applications for climate-resilient buildings remain an emerging practice whose effectiveness depends on sensor quality, data interoperability, cybersecurity, model calibration, staff capability, and long-term system maintenance.

4.4. Reinterpreting Traditional Passive-Cooling Techniques

Traditional Gulf passive-design principles, including windcatchers (Barjeel), can be reinterpreted using contemporary geometry, materials, and ventilation analysis. Where climate, orientation, air quality, and building use are suitable, these strategies can reduce part of the mechanical-cooling demand, but they generally complement rather than replace mechanical cooling in modern UAE buildings.

5. Infrastructure & Coastal Engineering

This section focuses on engineering solutions to protect cities and infrastructure in the UAE from two major and growing risks: flash floods resulting from extreme rainfall, and flooding and chemical erosion resulting from rising sea levels in coastal areas.

5.1. Sustainable Drainage Systems (SuDS) and Urban Network Re-Engineering

Recent extreme rainfall has strengthened the case for evaluating drainage systems against high-intensity events and for combining conventional networks with distributed Sustainable Drainage Systems (SuDS) where site conditions permit. Relevant measures include:

- Permeable Pavements: Porous or permeable surfaces can reduce and delay surface runoff by allowing temporary storage, infiltration, or controlled drainage. Their performance can decline when pores become clogged by sediment, so inspection and cleaning are necessary to retain hydraulic function (Sousa et al., 2024).
- Underground Stormwater Storage: Tunnels, tanks, and reservoirs can temporarily store peak runoff and release or reuse it after the event, reducing pressure on surface networks where land availability and project economics justify such infrastructure.
- Bioretention and Swales: Vegetated or engineered channels can slow and filter runoff and direct it toward storage, treatment, or controlled discharge. In UAE applications, plant selection, irrigation demand, saline or shallow groundwater, soil infiltration capacity, and available urban space require site-specific assessment.

UAE-specific SuDS considerations: SuDS performance should not be assumed to transfer directly from wetter climates. Shallow or saline groundwater can limit infiltration and affect planting or subsurface materials; fine dust and sediment can accelerate clogging of permeable surfaces; dense urban areas may restrict the land available for swales or detention features; and long dry periods can increase maintenance demands. Accordingly, UAE applications should include pretreatment where appropriate, accessible cleaning and inspection provisions, overflow routes for extreme events, and monitoring of infiltration performance over time.

5.2. Coastal Engineering Defenses and Resilience to Sea-Level Rise

Given the concentration of vital facilities and major investment projects on the UAE coasts, coastal engineering requires dynamic solutions to cope with increasing sea tides and port storms:

- **Advanced hydraulic breakwaters:** The use of engineered concrete blocks with special geometric shapes (such as Xblocs or Tetrapods) designed to efficiently disperse the energy of high waves and reduce erosion forces on developed beaches.
- **Adaptive electromechanical seawalls:** Designing coastal walls that can be adjusted and heightened in the future based on tide monitoring sensors, ensuring the protection of investments without distorting the visual appearance of tour-

ist cities.

- **Beach Nourishment:** Engineering operations involving the periodic pumping of sand and its stabilization using underwater structures to prevent shoreline retreat and protect the foundations of nearby hotels and facilities.
- Deep Foundations Engineering: In saline groundwater, durability strategies may include low-permeability concrete, appropriate cementitious systems, increased cover, protective barriers or jackets, corrosion-resistant reinforcement, and cathodic protection where technically justified. Such measures can reduce chloride ingress and corrosion risk, but no single barrier should be described as absolute. Service-life targets, including very long design lives, depend on exposure classification, material properties, detailing, construction quality, inspection, maintenance, and verified service-life design rather than on one protection measure alone.

Selection of engineering measures should be risk-based rather than technology-led. Project teams should first identify the dominant exposure—such as heat, chloride/sulfate attack, pluvial flooding, or coastal inundation—then consider the building or infrastructure function, required service life, constructability, inspection access, maintenance capability, and life-cycle cost. Mature solutions with established standards and field experience are generally preferable for safety-critical functions. Emerging measures can be appropriate where they provide a clear performance advantage and where pilot evidence, specialist expertise, monitoring, and contingency measures are available.

Measure	Maturity	UAE applicability	Initial cost	Maintenance	Main limitation
Sulfate-resistant/ low-permeability concrete	Mature	High for saline exposure	Low-Medium	Routine	Mix, cover, curing, workmanship
High-performance insulation	Mature	High for heat reduction	Medium	Low-Routine	Detailing and installation quality
Permeable pavement/SuDS	Established; site-dependent	Selective	Medium	Regular	Clogging, groundwater, space
Geopolymer concrete	Developing	Potentially high	Medium-High	Project QA	Activators, variability, standards
CNT-modified concrete	Emerging	Specialized	High	Specialist QA	Dispersion, dosage, cost, scale-up
Kinetic facade	Established in selected applications	Project-specific	High	High	Moving parts, controls, commissioning
Digital twin	Emerging for resilience management	Potentially high	Medium-High	Continuous	Data, calibration, cybersecurity, skills
Conventional coastal protection	Mature	High where justified	High	Periodic	Site impacts and long-term adaptation
Adaptive seawall concepts	Emerging/ project-specific	Potential future option	High	Specialist	Complexity and limited field evidence

6. Engineering Challenges & Future Outlook

Although the reviewed measures can improve resilience to climate-related risks, their practical value depends on technical maturity, project economics, construction quality, maintenance capability, and compatibility with applicable standards.

6.1. Economic and Financial Considerations

- Initial cost: Advanced materials and responsive systems can have higher procurement, specialist-design, commissioning, or installation costs than conventional alternatives. Their use should therefore be justified against expected durability, energy performance, risk reduction, and life-cycle cost.
- Life-cycle value: Economic assessment should consider not only initial capital cost but also inspection, maintenance, replacement, energy use, downtime, and the consequences of premature deterioration. The preferred option will vary by asset type and exposure.

6.2. Technical Knowledge and Skills

- Specialist capability: BIM-based simulation, digital twins, kinetic systems, and nanomaterial-modified concrete require appropriate design, commissioning, quality-control, and maintenance expertise. Capability requirements should be considered during technology selection.
- Constructability and training: Some emerging materials and systems require unfamiliar mixing, curing, installation, or commissioning procedures. Training, method statements, mock-ups, and quality assurance can reduce implementation risk, particularly under hot-weather construction conditions.

6.3. Regulatory and Standards Alignment

- Regulatory and standards alignment should focus on translating climate-risk evidence into project-level design, material selection, commissioning, and maintenance decisions. Existing frameworks such as Estidama, Al Sa'fat, and Federal Decree-Law No. 11 of 2024 provide relevant sustainability and climate-policy context. For emerging technologies, performance-based validation, field evidence, recognized testing methods, and compatibility with applicable building and structural standards are preferable to prescribing specific material dosages before sufficient evidence and standardization are available.

6.4. Future Outlook and Opportunities

- **Self-reliance in local manufacturing:** The UAE is moving towards localizing advanced technology industries. This approach opens the door to establishing local factories for the production of pozzolanic materials, green concrete, and nanomaterials, which contributes to reducing their logistical costs and makes them accessible to all projects.
- Artificial Intelligence and the Internet of Things (AI and IoT): Greater integration of sensing, analytics, and automated controls may support condition monitoring and adaptive building operation. These systems should be treated as enabling tools rather than guaranteed solutions, with attention to data qual-

ity, interoperability, cybersecurity, commissioning, and maintenance.

- Knowledge transfer: Experience gained from applying and evaluating climate-resilient engineering measures in the UAE may provide useful evidence for other hot-arid and coastal cities facing comparable exposure conditions. The value of such transfer will depend on transparent performance data and adaptation to local environmental, economic, and regulatory contexts.

7. Conclusion

This review indicates that the UAE construction sector is exposed to a combination of heat, saline conditions, coastal hazards, and intense rainfall that can affect material durability, building performance, and infrastructure reliability. These risks support a shift from isolated technical responses toward risk-based design and maintenance strategies that consider present exposure together with plausible future climate conditions.

The evidence supports an integrated response across three connected scales: durable material systems, climate-responsive building envelopes, and resilient drainage and coastal infrastructure. Established measures should form the baseline where their performance is well understood, while emerging options such as geopolymer binders, nanomaterial modification, kinetic systems, and digital twins should be adopted selectively where project-specific evidence, expertise, maintenance capacity, and standards support their use.

In conclusion, climate-resilient engineering should be evaluated as a life-cycle investment rather than solely as an increase in initial construction cost. The most appropriate solution will vary by exposure, building or infrastructure function, required service life, maintenance capability, and available evidence. A balanced combination of proven measures and carefully validated emerging technologies can improve long-term resilience while avoiding claims of universal or guaranteed performance.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

Department of Municipalities and Transport (2016). *The Pearl Rating System for Estidama: Public Realm Rating System—Design & Construction* (Version 1.0). Government of Abu Dhabi.

Dubai Municipality (2023). *Al Sa'fat—Dubai Green Building System* (2nd ed.).

Intergovernmental Panel on Climate Change (2023). *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*.

Khasawneh, M. A. (2025). Geopolymer Concrete in Construction Projects: A Review. *Discover Civil Engineering, 2,* Article No. 124. https://doi.org/10.1007/s44290-025-00281-1

Ministry of Climate Change and Environment (2024). *The UAE State of Climate Report*.

Muhd Norhasri, M. S., Hamidah, M. S., & Mohd Fadzil, A. (2017). Applications of Using

Nano Material in Concrete: A Review. *Construction and Building Materials, 133,* 91-97. https://doi.org/10.1016/j.conbuildmat.2016.12.005

Sousa, M., Almeida, M. D., Fael, C., & Bentes, I. (2024). Permeable Asphalt Pavements (PAP): Benefits, Clogging Factors and Methods for Evaluation and Maintenance—A Review. *Materials, 17,* Article 6063. https://doi.org/10.3390/ma17246063

United Arab Emirates Government (2024). *Federal Decree-Law No. 11 of 2024 on the Reduction of Climate Change Effects*.