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Best Types of Curing for Concrete in Kuwait: A Civil Engineering Review

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Abstract: **The State of Kuwait, situated in the northern part of the Arabian Peninsula, presents one of the most challenging environments for concrete construction in the world. The combination of extreme ambient temperatures exceeding 50°C, intense solar radiation, high wind velocities, and fluctuating relative humidity creates severe conditions that accelerate moisture loss from freshly placed concrete. This rapid evaporation leads to plastic shrinkage cracking, thermal cracking, and long-term durability degradation. Proper curing is therefore not merely a recommendation but a critical engineering necessity to ensure the structural integrity and service life of concrete structures in this region. This paper reviews the climatic challenges specific to Kuwait, examines the fundamental mechanisms of concrete deterioration in hot weather, evaluates various curing methods including water curing, membrane curing compounds, internal curing, and plastic sheeting, and identifies the best practices for hot weather concreting based on established civil engineering standards and empirical research from the Gulf region.**

Keywords: **Concrete curing, Kuwait, hot weather concreting, membrane curing, wet curing, internal curing, ACI 305, durability, Arabian Gulf.**

1. INTRODUCTION

Concrete is the dominant construction material in the Arabian Gulf region, including Kuwait, where virtually all building structures feature a reinforced concrete skeleton [1]. The rapid urbanization and infrastructure development that Kuwait has experienced over the past four decades has placed enormous demands on the construction industry, making the quality and durability of concrete a matter of national importance. However, the harsh environmental conditions of the region pose significant and persistent challenges to concrete durability that are not encountered in more temperate climates.

The process of cement hydration, upon which all concrete strength development depends, is highly sensitive to temperature and moisture availability. The classical law of chemical reactions states that for every 10°C increase in temperature, the rate of chemical reactions approximately doubles [2]. While this initially accelerates early strength gain, the rapid evaporation of mixing water at high temperatures can prematurely halt hydration, leaving a porous and weakened concrete microstructure. When concrete is exposed to high temperatures and low humidity, the rapid evaporation of surface water can arrest hydration, leading to reduced compressive strength and increased susceptibility to aggressive chemical attacks such as chloride and sulfate ingress [3].

Curing is defined as the process of maintaining adequate moisture content and a favorable temperature in concrete during the early period after placement, so that the concrete can develop its designed engineering properties [4]. In temperate climates, standard curing practices are generally sufficient to achieve this goal. However, in hot and arid regions like Kuwait, specialized curing techniques and extended curing durations are essential to mitigate the adverse effects of the climate [5]. This article explores the environmental factors affecting concrete in Kuwait, analyzes the effectiveness of different curing methods, and provides evidence-based recommendations for the optimal curing strategy in this specific geographic context.

2. CLIMATIC CHALLENGES IN KUWAIT

The climate of Kuwait is characterized by extreme heat, intense solar radiation, and significant variations in relative humidity. These factors collectively create a hostile environment for fresh and hardening concrete, and a thorough understanding of these conditions is prerequisite to selecting appropriate curing strategies.

2.1 Temperature and Solar Radiation

Kuwait experiences some of the highest ambient temperatures recorded globally. Ambient temperatures frequently exceed 40°C (104°F) for up to nine hours daily during July and August, and can occasionally surpass 54°C (129°F) in extreme cases [1]. The country receives an average of nine hours of sunshine per day, with approximately 233 days of clear skies annually [6]. The intense solar radiation, which can reach a peak intensity of 1.08 kW/m²/hr during a typical summer day—compared to only 4.83 kW/m²/hr total daily energy in the United Kingdom—significantly raises the temperature of exposed concrete surfaces and accelerates the evaporation of mixing water [6]. This solar loading can raise the surface temperature of concrete slabs far above the ambient air temperature, creating conditions far more severe than those anticipated by standard concreting specifications.

2.2 Humidity and Wind Velocity

While Kuwait is generally classified as an arid environment, its location bordering the Arabian Gulf means that relative humidity can fluctuate dramatically. During a typical summer day, relative humidity may range from as low as 5% to as high as 95% [2]. During periods of low humidity combined with high wind velocities, the rate of evaporation from the concrete surface increases exponentially. The ACI 305 evaporation nomograph is a standard tool used to estimate the rate of surface moisture evaporation; if this rate exceeds 1.0 kg/m²/h, the concrete is at a high risk of developing plastic shrinkage cracks [1]. These cracks form when the surface water evaporates faster than bleed water can migrate to the surface, creating tensile stresses that the immature concrete paste cannot withstand [1].

Dust storms, which are frequent in Kuwait during June and July with an average annual dust fall rate of 119 tons per square kilometer, can also contaminate fresh concrete surfaces and interfere with the formation of curing compound membranes [6].

2.3 Thermal Gradients and Diurnal Temperature Variation

The significant temperature differential between the intensely hot days and the relatively cooler nights in Kuwait induces thermal gradients within concrete elements. These rapid temperature drops can cause thermal cracking, particularly in mass concrete structures such as foundations, retaining walls, and bridge abutments, where the internal heat of hydration further exacerbates the temperature differential between the core and the surface [1]. This phenomenon is especially pronounced in Kuwait, where the combination of high ambient temperatures during placement and cool nights can create temperature differentials that exceed the tensile capacity of the young concrete.

3. MECHANISMS OF CONCRETE DETERIORATION DUE TO INADEQUATE CURING

The failure to implement adequate curing in Kuwait's climate leads to several interconnected forms of concrete deterioration, all of which reduce the service life of structures and increase maintenance costs.

Plastic Shrinkage Cracking is the most immediate consequence of inadequate curing. As described in Section 2.2, rapid moisture loss from the surface of fresh concrete before it has developed sufficient tensile strength leads to the formation of surface cracks, which can be wide enough to compromise the concrete cover over reinforcement.

Reduced Compressive Strength is a direct result of insufficient moisture during hydration. Research has consistently shown that concrete cured at high temperatures without adequate moisture develops a coarser, more porous microstructure than concrete cured under controlled conditions. This results in a lower ultimate compressive strength and a reduced modulus of elasticity [3]. The early strength gain is often deceptively high, masking the long-term strength deficit.

Increased Permeability is perhaps the most consequential long-term effect. A lack of curing leaves the capillary pores within the concrete matrix open and interconnected. This high permeability allows aggressive agents, particularly chloride ions from the saline Arabian Gulf environment and sulfate ions from the soil and groundwater, to penetrate the concrete cover. Chloride-induced corrosion of steel reinforcement is the primary cause of premature structural failure in the Gulf region [2]. Once corrosion initiates, the expansive rust products cause cracking and spalling of the concrete cover, further accelerating deterioration.

Drying Shrinkage over the long term causes the hardened concrete to contract as it loses moisture to the environment. When this shrinkage is restrained by adjacent structural elements or the reinforcement itself, tensile stresses develop that can lead to cracking [7].

4. EVALUATION OF CURING METHODS FOR KUWAIT

To counteract the severe environmental conditions, various curing methods are employed in Kuwait. The effectiveness of each method depends on its ability to retain moisture, control temperature, and maintain these conditions for a sufficient duration. The following sections evaluate the principal methods in the context of Kuwait's specific challenges.

4.1 Water Curing (Wet Curing)

Water curing involves keeping the concrete surface continuously wet through ponding, sprinkling, or covering it with moisture-retaining materials such as wet burlap (hessian) or cotton mats.

Effectiveness: Water curing is universally recognized as the most effective method for promoting cement hydration and developing maximum concrete strength and durability [4]. It not only provides the necessary moisture for continued hydration but also helps cool the concrete surface through evaporative cooling, thereby mitigating thermal gradients and reducing the risk of thermal cracking. Research by Austin and Robins confirmed that wet burlap curing was the most effective method between 7 and 28 days under hot climatic conditions, outperforming air curing significantly [5].

Challenges in Kuwait: The primary limitation of water curing in Kuwait is the scarcity and high cost of desalinated water, which is the only potable water source in the country [6]. The use of desalinated water for concrete curing is both expensive and environmentally unsustainable. Additionally, the extreme heat causes rapid evaporation from the burlap itself, requiring constant supervision and frequent re-wetting to prevent the burlap from drying out. A dry burlap cover can actually draw moisture from the concrete surface, worsening the curing conditions [5].

Recommendations: For critical structural elements, a minimum of 7 days of continuous wet curing is recommended under ACI 308R-16, extending to a minimum of 14 days for concrete containing supplementary cementitious materials (SCMs) such as silica fume, fly ash, or ground granulated blast-furnace slag (GGBFS), which are increasingly used in Kuwait to improve durability [4] [5].

4.2 Membrane Curing Compounds

Curing compounds are liquid membranes applied to the surface of fresh concrete to retard the loss of moisture by forming a physical barrier. They are available in several formulations, each with different performance characteristics:

- **Water-based curing compounds** are the most environmentally friendly but generally provide the lowest moisture retention efficiency.
- **Acrylic-based curing compounds** offer a good balance of performance and workability, providing a clear or white-pigmented membrane.
- **Bitumen-based curing compounds** provide excellent moisture retention due to the impermeability of the bituminous film.
- **Coal tar epoxy compounds** offer superior chemical resistance in addition to moisture retention.

Effectiveness: Studies conducted under field conditions in the Arabian Gulf have demonstrated that curing compounds can be highly effective when applied correctly and at the right time. Research by Ibrahim et al. (2013), conducted specifically to evaluate curing methods under hot weather field conditions, demonstrated that the strength and durability of concrete specimens cured with specific compounds were similar to or better than those cured with wet burlap [5]. The effectiveness of a membrane curing compound is critically dependent on the time of application; it must be applied immediately after finishing to minimize the period of unprotected evaporation.

Comparative Performance: Among the different compound types evaluated by Ibrahim et al. (2013), bitumen-based compounds exhibited the best overall performance in hot weather, followed by coal tar epoxy, acrylic-based, and water-based compounds [5]. The superior moisture retention of bitumen-based compounds is a significant advantage; however, their dark color absorbs solar radiation, which can raise the concrete surface temperature. For this reason, white-pigmented acrylic compounds may be preferred for exposed horizontal surfaces in Kuwait, as their reflectivity helps to mitigate solar heating.

Recommendations: Curing compounds are highly recommended in Kuwait as a practical and water-efficient curing method. Their effectiveness is significantly enhanced when preceded by an initial period of wet curing (1 to 3 days), which ensures early hydration and provides the initial cooling effect [5]. The compound should be applied in two coats at right angles to each other to ensure complete coverage and eliminate pinholes.

4.3 Internal Curing and Self-Curing Admixtures

Internal curing represents an advanced approach in which materials are incorporated into the concrete mix itself to provide a reservoir of water that is released internally as hydration proceeds and the internal relative humidity of the concrete drops.

Superabsorbent Polymers (SAPs): SAPs are cross-linked polymer networks capable of absorbing and retaining large quantities of water relative to their own mass. When incorporated into the concrete mix in a pre-saturated state, they release this stored water into the cement paste as the internal relative humidity decreases during hydration, providing a continuous internal source of curing water [8]. Research has demonstrated that SAPs can significantly reduce autogenous shrinkage and improve the hydration of low water-to-cement ratio mixes, which are commonly used in Kuwait to reduce permeability.

Self-Curing Admixtures: Chemical admixtures such as polyethylene glycol (PEG) function by reducing the vapor pressure of the pore solution within the concrete, thereby reducing the rate of evaporation from the surface. Research by Rizzuto et al. (2020) demonstrated that self-curing (SC) concrete outperformed normal conventional concrete (NC) under hot weather conditions in terms of compressive strength, splitting tensile strength, and flexural strength [9]. This is a particularly promising finding for the Gulf region.

Application in Kuwait: These advanced methods are particularly promising for Kuwait and the broader Gulf region as they fundamentally reduce the reliance on external water sources and mitigate the risks associated with inadequate external curing practices [2]. They are especially suitable for high-performance concrete mixes with low water-to-binder ratios, which are increasingly specified for aggressive exposure conditions.

4.4 Plastic Sheeting and Impervious Covers

Covering the concrete with impervious polyethylene plastic sheeting prevents moisture loss by creating a sealed environment over the concrete surface.

Effectiveness: Plastic sheeting is highly effective at retaining moisture and can achieve moisture retention comparable to wet curing when properly applied. However, it carries a significant risk in Kuwait's climate: the sheeting can create a greenhouse effect, trapping solar radiation and significantly raising the temperature of the concrete surface, which is highly detrimental to long-term strength development and durability [4].

Recommendations: If plastic sheeting is used in Kuwait, it must be white or highly reflective to minimize solar heat absorption. It must be applied immediately after finishing, secured at the edges to prevent wind from lifting it, and maintained in contact with the concrete surface throughout the curing period [10].

5. BEST PRACTICES AND APPLICABLE STANDARDS FOR KUWAIT

Based on the environmental challenges and the evaluation of curing methods, the following best practices are recommended for concrete construction in Kuwait. These recommendations align with the international standards referenced by the Kuwaiti Code for the Design of Reinforced Concrete Structures.

5.1 Applicable Standards and Codes

The Kuwaiti Code for the Design of Reinforced Concrete Structures adopts the American Concrete Institute (ACI) framework as its primary reference [11]. The following standards are directly applicable to hot weather concreting and curing in Kuwait:

Standard	Title	Key Relevance
ACI 305R-20	Guide to Hot Weather Concreting	Temperature limits, evaporation control, curing duration
ACI 308R-16	Guide to External Curing of Concrete	Curing methods, duration, and performance criteria
ACI 308.1-11	Specification for Curing Concrete	Prescriptive requirements for curing methods
ACI 318-19	Building Code Requirements for Structural Concrete	Minimum curing requirements for structural elements
ASTM C1064	Temperature of Freshly Mixed Hydraulic-Cement Concrete	Maximum placement temperature (32°C)
BS EN 13670	Execution of Concrete Structures	European standard for concrete construction practice

5.2 Temperature Control at Placement

According to ASTM C1064 and ACI 305R-20, the maximum recommended temperature of fresh concrete at the time of placement should not exceed 32°C (90°F) [10]. To achieve this in Kuwait's summer conditions, contractors must employ a combination of cooling techniques, including the use of chilled mixing water, replacing a portion of the mixing water with flaked ice, shading aggregate stockpiles from direct sunlight, and pre-cooling the formwork by wetting it before placement [1].

5.3 Timing of Concrete Placement

To avoid the peak temperatures and highest evaporation rates, concrete placement should be scheduled during the cooler parts of the day, specifically late afternoon, evening, or night [1]. This practice, while operationally challenging, is widely adopted on major construction projects in Kuwait and the broader Gulf region and is one of the most effective measures for managing hot weather concreting risks.

5.4 The Recommended Hybrid Curing Strategy

Based on the research reviewed, the most effective and practically feasible curing strategy for Kuwait involves a systematic hybrid approach, implemented in three sequential stages:

1. **Stage 1 — Immediate Evaporation Control:** Immediately after finishing and before the concrete has set, protect the surface from evaporation using an evaporation retarder (monomolecular film) or fog misting if the evaporation rate, as determined from the ACI 305 nomograph, exceeds 1.0 kg/m²/h [1].
2. **Stage 2 — Initial Wet Curing:** Apply continuous wet curing using wet burlap or hessian for the first 1 to 3 days. This critical initial period ensures early cement hydration, provides evaporative cooling to the concrete surface, and establishes the foundation for long-term strength development [5].
3. **Stage 3 — Membrane Curing Compound:** Following the initial wet curing period, apply a high-quality, high-solids curing compound—preferably acrylic-based (white pigmented for horizontal surfaces) or bitumen-based (for elements not exposed to view)—to maintain moisture for the remainder of the required curing period, which should be a minimum of 7 days for OPC concrete and 14 days for concrete containing SCMs [5] [4].

The table below summarizes the comparative evaluation of the principal curing methods in the context of Kuwait:

Curing Method	Advantages in Kuwait	Disadvantages in Kuwait	Recommended Application
Continuous Wet Curing (Burlap/Hessian)	Maximum strength and durability; provides evaporative cooling.	High water cost; requires constant supervision; rapid drying in heat.	First 1–3 days for all critical structures; minimum 7 days for OPC.
Membrane Curing Compounds (Acrylic/Bitumen)	Conserves water; less labor-intensive; effective moisture retention.	Effectiveness depends on application timing; dark compounds absorb heat.	Apply after initial wet curing; use white acrylic for exposed surfaces.
Internal/Self-Curing Admixtures (SAP/PEG)	Eliminates need for external water; reduces autogenous shrinkage.	Higher material cost; requires precise mix design and quality control.	High-performance, low w/c concrete; remote or inaccessible locations.
White Plastic Sheeting	Excellent moisture retention; readily available.	Greenhouse effect risk if not reflective; must be secured against wind.	Secondary option; use only white, reflective sheeting with tight sealing.

6. CONCLUSION

The extreme hot and arid climate of Kuwait demands a level of rigor in concrete curing practices that far exceeds the requirements of temperate climates. The failure to properly cure concrete in this environment leads to rapid and severe deterioration, compromising both the safety and the economic value of structures. The research reviewed in this paper consistently demonstrates that inadequate curing in hot weather results in reduced compressive strength, increased permeability, and accelerated deterioration through chloride and sulfate attack.

While continuous water curing remains the gold standard for cement hydration, the practical constraints of water scarcity, high desalinated water costs, and the rapid evaporation of moisture from burlap covers make it challenging to implement effectively for the full required curing duration. The evidence strongly supports a **hybrid curing strategy** as the optimal approach for Kuwait: an initial period of wet curing for the first critical days to manage surface temperature and promote early hydration, followed by the application of high-quality, high-solids membrane curing compounds to retain moisture through the remainder of the curing period.

Furthermore, the integration of internal curing agents, particularly superabsorbent polymers and self-curing admixtures, represents a sustainable and technically superior future direction for the region. These technologies address the root cause of curing deficiency by providing water from within the concrete matrix itself, independent of the quality of external curing operations. As Kuwait continues to develop its infrastructure and as climate change further intensifies the already extreme conditions, the adoption of these advanced curing technologies will become increasingly important.

By strictly adhering to hot weather concreting standards—principally ACI 305R-20 and ACI 308R-16—and by implementing the optimized hybrid curing strategies described in this paper, civil engineers and contractors in Kuwait can ensure the durability, resilience, and longevity of concrete structures in one of the world's most demanding construction environments.

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