Effects of Salinity on Concrete Characteristics

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Abstract:

The worldwide population is growing at an exponential rate, and with it, the need for concrete to build and maintain infrastructure. This has led to a variety of environmental problems. The demand for drinkable water has skyrocketed as a result of this. In order to make dry-area concrete production less harmful to the environment, this study investigates the potential of substituting highly mineralized treated effluent for potable water. We contrasted concrete specimens mixed with distilled water (DW) and those mixed with saline treated wastewater (saline-TWW) to ensure they performed according to the guidelines for water mixing. The results demonstrated that the saline-TWW concrete mixes had higher early strength and equivalent long-term strength to the control mix prepared with DW. Also, the new concrete mixture's workability was unaffected by the addition of saline-TWW, while the curing time of the cement paste was prolonged.To further assess the microstructural characteristics of the hardened concrete, testing for water permeability, scanning electron microscopy (SEM), and X-ray diffraction were used. The results demonstrated that saline-TWW concrete outlasted DW concrete in terms of durability due to its more compacted microstructure and smaller pore sizes.Also, to find out how much corrosion there was, samples of reinforced mortar constructed with saline-TWW and DW were electrochemically tested. Electrochemical testing revealed that concrete mixed with completely saline-TWW significantly increased the rate of corrosion of the embedded steel.

Keywords: Concrete, Saline-TWW Mixing Water, Strength, Chloride, Corrosion

Introduction

Concrete is a great material to use for building projects because of its fresh and hardened qualities [1]. Concrete output therefore surpasses that of all other engineering materials put together, reaching almost 16 billion metric tonnes annually [2]. Many environmental issues on a local, national, and international scale have arisen as a consequence of the massive amounts of water, energy, and materials used in the production of concrete. Consequently, there have been a lot of studies done lately to find ways to make concrete that is more sustainable and long-lasting by using various industrial waste and by-products instead of or in addition to the traditional Portland cement and natural aggregates. Some examples of these materials include fly ash [4], metakaolin [5], recycled aggregates [6], silica fume [3], and so on. However, reducing water use in concrete manufacturing is not given the same level of emphasis. To mix and cure concrete, as well as to wash aggregate and concrete equipment and machinery after usage, water is an essential component [7]. An estimated 16.6 billion cubic metres of water is used every year by the concrete industry, which accounts for almost 18% of the total industrial water consumption worldwide [8]. Regions presently experiencing or projected to experience water shortages may find this demand for water to exacerbate existing management challenges. Consequently, in order to make concrete manufacturing more environmentally friendly, it should be prioritised to develop strategies to decrease the water consumption of the sector. According to reports, cutting down on mixing water is the most effective way to reduce water usage in concrete manufacturing [8]. This is because potable water is often suggested for use due to its regularly tested and well-regulated chemical composition. Accordingly, there are a plethora of water sources that aren't fit for human consumption, including river water, ocean water, wastewater from homes and businesses, and, in rare cases, the grey water from ready-mixed concrete factories [9]. Numerous experimental studies on seawater-produced concrete have shown no significant negative impacts on the strength of the material, either in the short or long term [10, 11]. However, it is now prohibited to mix reinforced concrete with saltwater due to the high chloride concentration of saltwater, which accelerates the corrosion of the reinforcing steel. Concrete from other industrial wastewater sources, including as vehicle washes, the textile sector, heavy industries, and palm oil mills, has been the subject of several further research

[12]. Using wash water from concrete batching plants and mixer trucks as mixing water has also been studied, however thus far, there have been no notable impacts on the mechanical characteristics, corrosion resistance, fresh concrete qualities, or resistance to sulphate attack [13–14]. By decreasing the concrete's porosity and water absorption, the findings demonstrated that wash fluids with a high concentration of fine particulates improve the material's durability [14]. Contrarily, it has been shown that additive efficacy and concrete resistance to acid attack are both diminished when wash waters with more than 50,000 ppm total solids are used in concrete mixes [15]. Also, experiments have shown that treated household wastewater may be used to mix and cure concrete. The setting time and compressive strength of concrete were not negatively affected by treated household wastewater whether utilised in part or in whole as mixing or curing water, according to research by Tay and Yip [16]. In terms of fresh characteristics, compressive strength, durability, and corrosion potential of steel, Al-Gussain and Terro [17] discovered that concrete mixed with tertiary-TWW was indistinguishable from that made with tap water. Preliminary and secondary-TWW-made concrete, on the other hand, had a greater impact on setting times and exhibited lesser strength. The variation in dissolved organic compounds across preliminary, secondary, and tertiary-TWW may explain these findings. Additionally, Ghrair and Al-Mashaqbeh [18] found that using primary-TWW as mixing water increased the initial setting time of PPC cement by 30 minutes and significantly decreased the long-term compressive strength of concrete due to the quantity of chemical oxygen demand (COD) in the water. The COD concentrations in the TWW prior to chlorination reduced the 28-day compressive strength of concrete by 6% and increased the setting periods of OPC cement, according to Asadollahfardi et al. [19]. When using tertiary-TWW as a curing and mixing water, Meena and Luhar [20] found that it increased abrasion resistance and lowered resistance to chloride ion and carbonation penetration. According to Hassani et al. [21], when the water-to-cement ratio is high, the chloride ions penetrate deeper into the TWW due to the high COD content. There was no discernible change in the fracture toughness of concrete when mixed and cured with TWW that had a modest level of COD, according to Peighambarzadeh et al. [22]. Based on the literature research, it can be concluded that the chemical components of the water used to mix impure concrete have an impact on the mechanical and physical attributes of the finished product. Particularly in water-scarce areas of the globe, there is a pressing need for further research into the safe use of different kinds of dirty water in concrete mixing [7]. Take, for instance, the paucity of research into how highly mineralized treated wastewater affects different concrete characteristics (both plain and reinforced). Consequently, this experimental research aims to examine the feasibility of mixing concrete with saline-TWW that is derived from the Saïd-Otba wastewater treatment facility in Ouargla province. Located in the dry southern parts of Algeria, Ouargla relies on brackish groundwater for its freshwater source. Consequently, saline-TWW might be a valuable alternative to potable water in this dry area, saving money and reducing environmental effect when mixed with concrete. This water is often desalinated.

2 Experimental program

2.1 Materials and mixture proportions of concrete

This investigation used two different kinds of mixing water: distilled water (DW) and saline-treated wastewater (saline-TWW).

The CEMI 42.5N 197-1 sulfate-resistant cement, which complies with EN standards, was used in the making of the concrete. The oxide components of the cement are shown in Table 1. With a density of 2.61 g/cm3 and a fineness modulus of 2.48, the fine aggregate was manufactured from locally available river sand. The coarse aggregate consisted of three sized pieces of crushed limestone gravel with a density of 2.62 g/cm3. In Figure 1 we can see the aggregates' grain-size distributions that were employed for this study. There was a maximum chloride level of 0.003% in the fine aggregates and 0.005% in the coarse aggregates.Table 1 Chemical composition of sulfate resisting cement

Composition	Amount (wt %)
SiO_2	16.74
Al_2O_3	4.02
Fe_2O_3	2.88
CaO	63.35
K_2O	0.54
MgO	1.68
Na_2O	0.07
SO_3	2.16
Cl	0.02
C_3S	63.61
C_3A	5.78
C_4AF	12.23
Insoluble residual	0.81
Loss on ignition	0.81

Preparation of concrete and reinforced mortar testspecimens

Casting concrete cylinders (Ø15 cm × H30 cm) under similar conditions with each of the four concrete mixes allowed us to examine the compressive strength after varying curing durations.

many times. The testing specimens were prepared according to EN 12390-2 [25]. After the concrete was mixed using a pan-type mixer, it was compressed using a vibrating table. After 24 hours of casting, the concrete specimens were demoded and allowed to cure in a humid environment with a temperature of 23°C and a humidity level of 95% for the length of the relevant test ages. In order to conduct electrochemical testing, cylindrical shapes with reinforced mortar in the centre (Ø45mm x H113mm) were produced in accordance with EN 480-14 [26]. By use of a steel rod with a diameter of 6 millimetres. To make the cylinders, we used regular mortar combined with DW and saline-TWW. Following the removal of oxide scale from the steel specimens using SiC abrasive sheets ranging from P60 to P240 grit, a 70 mm exposure length, or 13.47 cm2 of exposed surface, remained. Following this, the specimens were epoxy-coated. A humid chamber was maintained for 120 days after demolding of reinforced mortar sample.

The world over, people rely on concrete as a structural and building element. It is challenging to find installation replacement materials that are both long-lasting and affordable [1]. The amount of water is an important factor in the making of concrete. The cement's setting and, maybe, its strength qualities could be negatively impacted by contaminants in the water supply.

The combination's hardening, setting, and strength progression characteristics may be affected by chemical reactions between the water's constituents. Given that water makes up around 80% of the Earth's surface, a lot of structures are in direct contact with the ocean's very saline water. The durability of concrete is greatly affected by the quality of the water used [2]. The most common chemical elements found in seawater are ions of chloride, potassium, calcium, sodium, and magnesium. The potassium chloride, magnesium chloride, calcium chloride, potassium, sodium, and magnesium chlorides make up an important portion of the salt.

Concrete may degrade more quickly in coastal environments, despite its superior basic construction and durability. In the normal conventional degrading condition, the steel reinforcement corrodes at the same time as the succeeding concrete seedling. So, while making concrete for a marine structure that will survive, the three most critical things to think about are mix design, reinforcing detail, and material selection [3]. The durability of concrete is its capacity to endure impacts and environmental variables while still performing its intended purpose. This facilitates the entry of chlorides into the concrete, but atmospheric carbon dioxide might also seep in and corrode the reinforcing steel [4].

Over the course of a building's useful life, concrete will deteriorate due to the cumulative effects of chemical and physical attacks from the environment. Improving infrastructure is becoming more important, and that includes providing enough clean water each year. Examination of Freshwater conservation is highly important. It is also more economical to use saltwater that is already on site for the installation rather than to bring potable water from farther away. To far, a number of research have looked at how well concrete built with either freshwater or saltwater holds up over time [5, 6].

Hardened concrete has many wonderful qualities, but its compressive strength is paramount (Grundy, 1981). Thus, in order to make conclusions about the effect of salt on concrete strength, this study utilises compressive strength as its dependent variable.

To support the rapid growth of cities and industry, more land is required. In order to meet this requirement, efforts have been made to reclaim and use places that are unsuitable or have suffered ecological degradation. A large portion of these regions are situated around coastlines. Building erection teams, and civil and structural engineers in particular, will profit substantially from this study's conclusions. In particular, their findings will illuminate how salt affects the durability of concrete basements situated in coastal areas.

Conclusion

The focus of this research is on how salt affects the tensile and compressive strengths of ordinary concrete. For as long as 120 days, the unreinforced beam, cylinder, and cube specimens were cured using a range of curing fluids. The specimens underwent evaluation at different curing ages that were predetermined. Both the Unilag tap water and the lagoon water had their physical and chemical properties, workability, compressive, split tensile, and flexural strengths measured. To replicate lagoon water with chloride concentrations five times (5×) and ten times (10×) greater, respectively, two curing mediums were utilised: salt water I and salt water II. Curing concrete samples in lagoon water resulted in weaker structural strengths than curing in salt water I, but stronger development than curing in salt water II. The decline in structural strengths was more pronounced when moving from lagoon water to salt water II; after 28 days, compressive strengths had fallen by 29.35%, tensile strengths by 17.67%, and flexural strengths by 33.65%. Predictions of structural strengths made using mathematical models developed using the Modified Regression Approach were in good agreement with the experimental results.

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