ADMIXTURE EFFICIENCY IN MITIGATING SALINITY EFFECTS ON CONCRETE STRENGTH AND DURABILITY

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ABSTRACT

A significant issue is chloride-related deterioration of concrete structures, especially in marine and coastal environments. Sources of ingress of chloride are external surface water, groundwater, soil and internal sources: aggregates, mixing water, cement and chemical admixtures. Excessive exposure to chloride has negative impacts on hardened cement paste through induction of secondary ettringite, abnormal expansion, internal stress, cracking, high permeability and low structural integrity. The limited availability of potable water in coastal and marine areas to carry out construction usually results in the utilization of saline water that can significantly increase chloride exposure and adversely affect the performance of concrete. To mitigate the adverse impacts of chloride attack and to improve the concrete durability under saline environment, chemical admixtures are usually added to the concrete mix. This study aims at examining the efficiency of Foam-Lub admixture in alleviating the degradation brought by chloride and improving the mechanical qualities of the concrete that is at risk in saltwater. Preparation of concrete specimens was done according to a conventional mix design, and they were subjected to salt concentrations of 0%, 2.5%, 5%, 7.5%, and 10%. Compressive strength, splitting tensile strength and flexural strength were measured after 7, 14 and 28 days of curing in fresh water and salt water and in the presence and absence of Foam-Lub admixture. The findings show that the concrete cured in saltwater without admixtures had less mechanical performance and obtained compressive strength, splitting tensile strength and flexural strength of 27.69 MPa, 4.95 MPa and 5.75 MPa, respectively, in 28 days. The values were enhanced to 28.4 MPa, 5.15 MPa and 6.3 MPa with the addition of Foam-Lub admixture. These results reveal that Foam-Lub admixture is an efficient method of improving the strength and durability of concrete in salinity. Admixture is hence applicable in the construction of concrete in marine and coastal sites.

Keywords: *Salinity effects, concrete durability, compressive strength, flexural and splitting tensile strength.*

1. INTRODUCTION

Concrete is the substance that is utilized for structural and building purposes in all over the world. Identifying an alternative construction material that matches the durability and cost-effectiveness of this material proves to be a challenging task (Qasim & Al-Quraishy, 2018). The quality and quantity of water incorporated in concrete play a vital role in the mixing and curing process (Tiwari et al., 2014). Contaminants in mixing water may influence cement hydration, resulting to the decrease of setting and the decline in the durability and structural strength of concrete. Water chemicals can interact with cement compounds that is why they impact on the hardening, setting, and strength of the substance. A significant proportion of concrete structures are exposed to the extreme salinity of seawater because the oceans cover the majority of the planet's surface, approximately 80% (Qasim et al., 2020). The main components of seawater's chemical makeup are the magnesium, calcium, potassium, sodium, and ions of chloride. The number of significant constituents of salt is 2.3% K_2SO_4, 3.9% $CaSO_4$, 5% $MgSO_4$, 10.5% MgCl, and 78% NaCl and the average total salinity is 3.5% for seawater. (Antonov et al., 2006; Younis et al., 2018).

Concrete initially deteriorates when exposed to a maritime environment, despite its superior durability and straightforward manufacturing. Deterioration of reinforcing steel, along with the following concrete sapling, is the typical traditional condition of degradation. Thus, the choice of materials, the concrete mix design, and the precise detailing of reinforcement are critical factors in ensuring the durability and longevity of concrete framework in marine environments (Emmanuel et al., 2012). The ability of the concrete to withstand shocks and other environmental factors to fulfill its intended purpose is the strength of the concrete that is usually termed as its durability. As a result, chlorides are able to penetrate the concrete quickly, but carbon dioxide can also readily disperse from the atmosphere. Together, these two factors contribute to the corrosion of the reinforcing steel (Nagabhushana et al., 2017). The development of infrastructure is moving in the direction of meeting the annual demand for clean water. The need to examine freshwater conservation efforts is urgent. Additionally, using readily available seawater close to the installation location rather than potable water that must be imported from sources in other locations is more cost-effective. The performance of concrete's durability in plain and saltwater has been studied by a number of researchers in the modern age (Maniyal & Patil, 2015).

The initial report in a United Nations series on the effect of weather condition changes on global water resources estimates that by 2050, nearly five billion people, representing roughly two-thirds of people worldwide, will suffer water deficiency for at least one month every year (Cusick & News, 2022). Whereas seawater hasn't been used for such items because of the requirement for clean water every year, infrastructure development is increasing. There is a crucial need for freshwater preservation research. It is vitally necessary to use seawater, which makes up 97% of all the water on the planet (UN, 2025). The utilization of seawater-mixed concrete can serve as an effective solution for marine and offshore construction, where conventional concrete exhibits poor performance. Several studies suggest that for marine conditions, seawater-mixed concrete demonstrates greater strength than freshwater-based concrete mixtures (Ebead et al., 2022). Seawater has been considered as an alternative mixing water in concrete. Use of seawater is forbidden in concrete mixtures for its high chloride concentrations that accelerate corrosion in reinforcing bars (Younis et al., 2018).

Since the accessible water is influenced by sea salts, there has always been a freshwater shortage in coastal locations. Supplying freshwater for building projects in these locations is so challenging. Additionally, it is more economical to utilize seawater that is already close to the construction area rather than transporting freshwater from remote areas. However, seawater carries large amounts of sea salts. For this reason, sea salts can negatively affect the characteristics of concrete. Numerous studies have been done up to this point on the strength behavior of concrete created with both freshwater and saltwater, as well as concrete exposed to marine conditions (Guo et al., 2018). There is almost 80 percent of the ocean cover on the earth; there are numerous structures that are exposed to salinized seawater either directly or indirectly. As winds carry seawater spray several miles inland from coastal areas, numerous coastal and offshore water constructions are consequently subject to ongoing physical and chemical degradation processes. The difficulty of creating and sustaining long-lasting concrete structures in coastal environments has long been a significant problem for the locals, and this is a fantastic opportunity to comprehend the complexity of concrete durability problems in these places (Melchers, 2020). Hence, the aim of the study is to examine the impact of saltwater and freshwater on the characteristics of concrete (compressive strength, splitting tensile strength, and flexural strength) in the presence and absence of admixtures addition.

2. METHODOLOGY

This chapter presents the materials, experimental methods, characteristics of the constituent materials, mix composition, mix design, curing condition, and specimen preparation.

2.1 Materials

The term "grading" refers to the distribution of different particle sizes within an aggregate. Following ASTM C136, this study employed selected sand from Sylhet, sand FM of 2.81. Coarse aggregate particle sizes are more than 4.75 mm and generally range from 9.5 mm to 38 mm in diameter. For this research, locally sourced crushed stone, known as Sylhet stone, with a size of 20 mm downgrade, was employed.

Cement Coarse aggregate Foam-Lub (admixture) Fine aggregate

Figure 1: Materials used in this study

Foam-Lub (**Figure 1**) is an admixture that helps remove the salinity effect in cement concrete. Foam-Lub is mainly composed of 2, 3, and 4 hydroxy stearate polycarboxylate and competitively grafted emulsified monomers of salts and esters of fatty acids & oils, etc. For very special properties, different ingredients remain in a grafted form with the main polymer chain. It's very slippery, water-soluble, and dispersed when used in cementitious concrete and cement mortar, passing the cementitious reaction process. Foam-Lub is strongly recommended for underground-based concrete such as basements, water-reservoir concrete, cement mortar, ready-mix concrete, lime concrete, roof gardening, swimming pools, waterproofing & damp-proofing plaster, precast faulty basements, ground floors, industrial floors, D.P.C., etc. The optimal amount of Foam-Lub should be determined by experimental trial mixes. As a product guide, a general admixture dosage range of 250 ml to 1000 ml per 100 kg of cement is used. In this study an admixture dosage range of 250 ml per 100 kg of cement is used.

2.2 Materials Mixing, Casting and Curing Procedure

All concrete specimens were prepared following standard mixing procedures. Initially, the coarse aggregate and sand were combined for two minutes to ensure uniformity. Subsequently, cement was incorporated, and the dry mixture was mixed for three minutes until a homogeneous dry blend was achieved. Water was then gradually added throughout the mixing process, which continued until a fully uniform concrete mixture was gained. All specimen preparations were conducted according to **Table 1.** After the full casting process was completed, all specimens were poured into molds and cast for one day, then the samples were unmolded and placed in a water container tank for curing.

Table 1: Proportions of mix compositions

Batch No	Admixture	Percentage of salt content	Test of strength	Curing days
A	With admixture	2.5%, 5%, 7.5%, and 10%	Compressive	7, 14, and 28
			Split tensile	
B	Without admixture			
			Flexural	14 and 28
C	As a control sample, both with and without admixture at 0% salt content			7, 14, and 28

Casting: Prior to casting, all molds were meticulously cleaned and securely fastened, and their inner surfaces were lightly coated with oil to prevent the hardened concrete from adhering to them. After preparation, concrete was placed into the molds in 3 layers and each layer being compacted using a tamping rod to remove air voids and produce a dense, well-consolidated concrete. This continued until one could no longer see any air bubbles on the surface and the top surface was smoothened so that the surface is smooth.

Curing method: All molds were then covered with plastic sheets after casting in order to minimize evaporation and loss of moisture. This technique encouraged proper curing up to final setting and minimized cracking brought about by shrinkage as a result of loss of water. Uncovered concrete specimens exhibited deplorable conditions such as salt deposition, swelling and a clear weakening of strength (Islam et al., 2025). All the specimens were demolded and marked and cured in a water tank, with 7, 14 or 28 days being used after 24 hours. Different ratios of salt (NaCl), like 0%, 2.5%, 5%, 7.5%, and 10% (w/v), equivalent to 0, 25, 50, 75, and 100 g/L, were adopted, and the specimens were cured in both freshwater and saltwater (**Figure 2**).

Mixing of concrete Molds casting Curing for 0% salt content Salt water curing

Figure 2: Casting and curing of concrete specimens

2.3 Mechanical Testing Procedures

Compressive strength: In this investigation, cube specimens were tested based on the ASTM C109 procedure. The concrete mixed ratio was 1:1.59:2.45, and w/c ratio was 0.48. Cube molds of size 100×100×100 mm. The universal testing machine (UTM) of 1000 KN was used to do compressive strength tests.

Splitting tensile strength: The test was done in accordance with EN 12390-6, ASTM C496, and BS 1881:117. Cube mold sizes were 100×100×100 mm, and splitting tensile strength was determined using the above-mentioned UTM.

Flexural strength: The test was examined in accordance with the ASTM C1018 procedure. Beam molds of size 100×100×400 mm were prepared according to ASTM C348-02 specifications. Beams were tested using UTM after 14 and 28 days of curing, and the average value from three specimens was taken for each testing age.

3. RESULTS AND DISCUSSIONS

3.1 Evaluation of concrete compressive strength

Figures 3 and **4** indicate the influence of concrete with and without admixtures on compressive strength under changing salt levels at curing intervals of 7, 14, and 28 days, representing early, intermediate, and standard ages. The compressive strength of 0% salt content with admixture showed a gradual increase over time. After 7, 14, and 28 days, the strength measured 27.1, 28.4, and 32.1 MPa, respectively. Comparatively, the non-admixture strength specimens were registered at 25.8. 26.3, and 28.7 MPa. The findings reveal that the admixture increases the strength by approximately early, intermediate and standard curing ages gave yields of 5.2%, 8.1% and 11.6%, respectively. The results align with a past experiment which found that concrete is strengthened more cured in fresh water (portable water) enhances its strength more effectively than concrete cured in salt water.(Vishwakarma et al., 2020).

At admixture of 2.5% salt content, concrete under admixture shows a strength of 26.3, 26.8 and 28.4 MPa after 7, 14 and 28 days of curing respectively. On the contrary, the admixture-free molds record levels of 24.7 MPa, 25.9 MPa and 27.7 MPa within the same curing periods. The admixture enhanced strength and the percentage enhancement was 6.52% in 7 days. In addition, at a salt content of 5%, the strength of concrete with admixture was 26.6, 27, and 28.4 MPa at early, intermediate, and standard curing ages, respectively. The highest strength, 28.4 MPa, was recorded at 28 days, and the lowest value, 26.6 MPa, was at 7 days. In contrast, without admixture, the values are 25.2 MPa, 25.6 MPa, and 26.8 MPa at the same curing ages, respectively. Admixture specimens gain approximately 5.6%, 5.5%, and 6.0% more strength than those without admixture at the same curing intervals. Besides, at 7.5% salt content with admixture the values of the specimen were 25.7 MPa, 27 MPa, and 27.9 MPa at the same curing intervals respectively. Its maximum value was achieved at 28 days with the minimum value of 7 days (25.7 MPa). Comparatively, in the absence of admixtures, the strength of the mold was 25 MPa, 25 MPa and 26.1 MPa at respective curing ages. The admixture made it stronger and the percentage increase was realized to be about 2.8%, 8%, and 6.9% at early, intermediate, and standard age of curing, respectively.

At a salt concentration of 10 percent, a concrete sample that is admixture has the following strengths at an early, middle, and standard curing stage of 23.6 MPa, 24.8 MPa and 27 MPa respectively. Comparatively, concrete molds that are not admixture have a strength of 22.9 MPa, 24.1 MPa, and 25.6 MPa within the same period of curing. The admixture addition enhanced the strength by 3.1%, 2.9% and 5.5% at the respective ages of curing. It exhibits a beneficial impact on concrete performance under saline environment. Increase in the ratio of the saltwater has a negative impact on compressive strength. This degradation takes place due to the fact that aggressive chemical ions enter the material leading to crack development and loss of interfacial bonding. Overall strength is reduced due to the chemical reactions caused by these deleterious agents (Ikponmwosa et al., 2020). It was reported that when admixture is added, the strength increases, but in saltwater conditions, it reduces the strength (Memon et al., 2002).

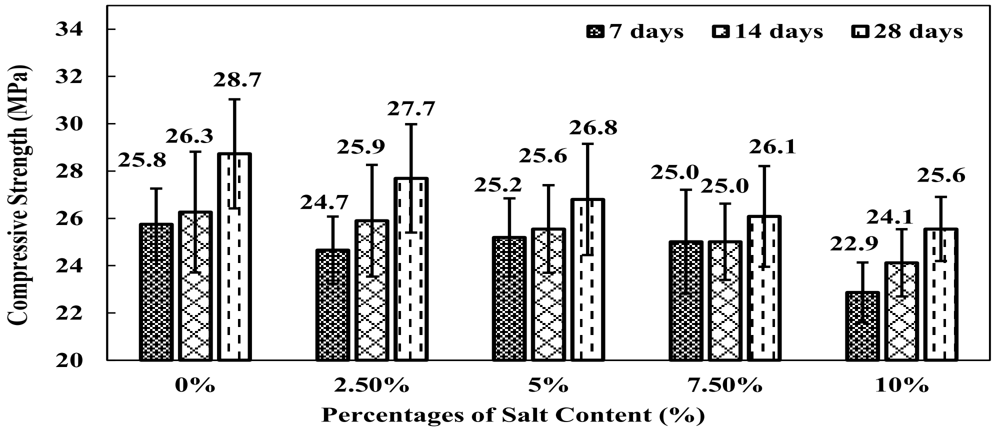


Figure 3: Compressive strength with different salt contents (without admixture)

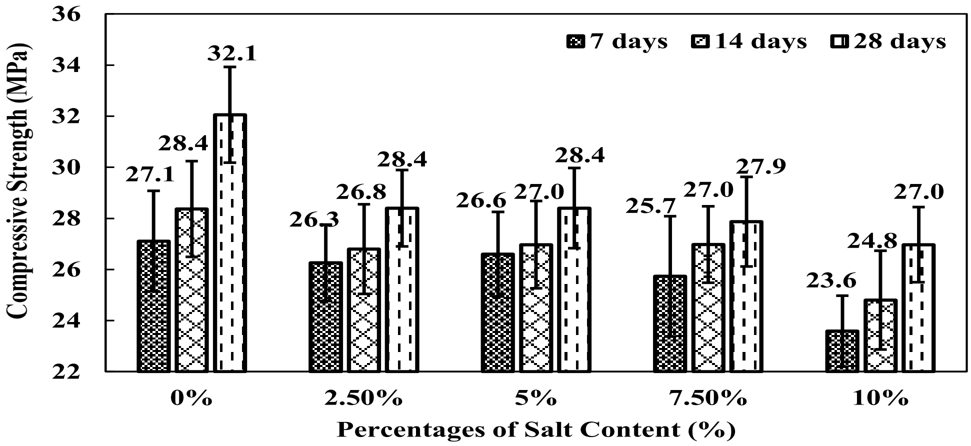


Figure 4: Compressive strength with different salt contents (with admixture)

3.2 Evaluation of concrete tensile strength

Figures 5 and **6** illustrate the influence of with and without admixtures on the tensile strength of concrete with changing salt contents at curing intervals of 7, 14, and 28 days, representing early, intermediate, and standard ages. The splitting tensile strength of concrete with 0% salt content with admixture had strengths of 3.17 MPa, 4.63 MPa, and 4.87 MPa at early, intermediate, and standard curing ages, respectively. In comparison, the specimens without admixture exhibit values of 2.88, 4.25, and 4.71 MPa at the same curing time. The findings suggest that the admixture addition enhances the strength by 10.1, 8.9 and 3.4 percent at early, intermediate and standard curing ages respectively. This research study proved the positive impact on concrete performance.

At admixture of 2.5 percent salt content, concrete at the early, intermediate and standard curing ages of concrete demonstrates strength of 2.37, 4.54, and 5.15 MPa respectively. The specimens showing no admixture, on the contrary, have the values of 2.17, 4.12 and 4.95 MPa at the same ages of curing. The admixture enhanced strength and the increase of the percentage was around 9.2, 10.2 and 4.0 percent at early, intermediate and standard, curing ages respectively. In addition, at a salt content of 5%, the tensile strength of concrete with admixture was 2.27, 4.13, and 4.95 MPa at early, intermediate, and standard curing ages, respectively. The highest strength, 4.95 MPa, was recorded at

28 days, and the lowest value, 2.27 MPa, was at 7 days. In contrast, without admixture, the values are 1.96, 3.71, and 4.43 MPa at the same curing ages, respectively. Admixture specimens gain approximately 15.8%, 11.3%, and 11.7% more strength than those without admixture at the same curing time. Moreover, for 7.5% salt content with admixture, the specimen value was 2.17, 4.02, and 4.54 MPa at early, intermediate, and standard curing ages, respectively. The highest value was recorded at 28 days, while the lowest value was at 7 days (2.17 MPa). Comparatively, without admixture mold strength, which was 1.45, 3.41 and 4.23 MPa at the indicated curing ages, respectively. The admixture enhanced the strength and the percentage increment was about 49.7, 17.9 and 7.3 percent after 7 days, 14 days, and 28 days respectively.

At 10 percent salt content with admixture, the specimen value was 1.66, 3.81, and 4.13 MPa at early age of curing, intermediate age of curing and at standard age of curing respectively. The highest value was seen at 28 days (4.13 MPa) whereas the lowest at 7 days (1.66 MPa). In comparison, without admixture, it exhibits mold strengths of 1.34, 3.10, and 3.92 MPa at the specified curing ages, respectively. Admixture specimens gain approximately 23.9%, 22.9%, and 5.4% more strength than those without admixture at the specified curing ages. The highest tensile strength was observed for specimens cured in 2.5% salt water, while higher salt concentrations showed decreased strength compared to freshwater curing. Previous studies also reported a decrease in strength with increasing salt content (Wegian, 2010).

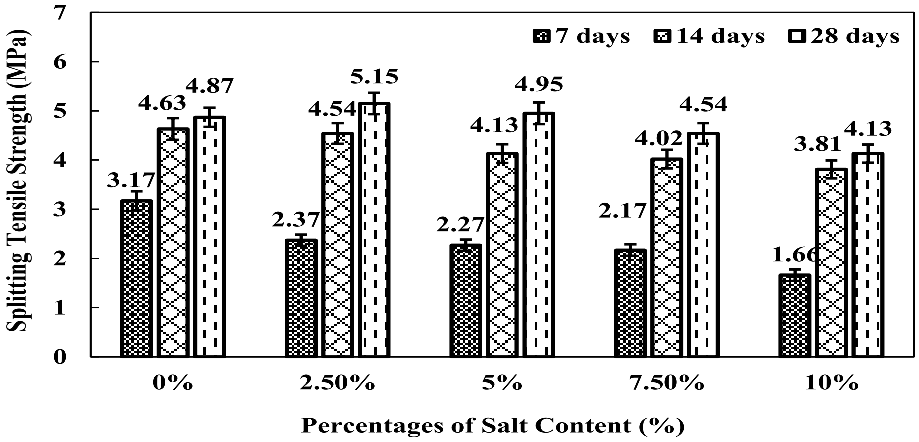


Figure 5: Splitting tensile strength with different salt contents (with admixture)

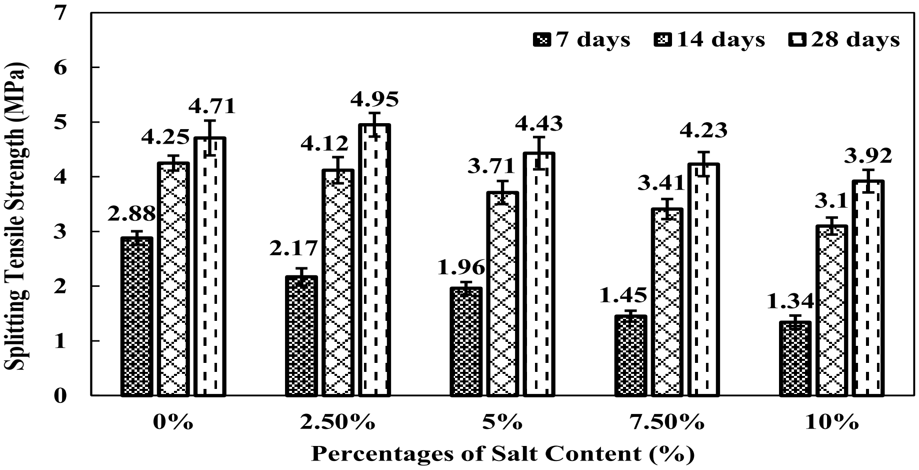


Figure 6: Tensile strength with different salt contents (without admixture)

3.3 Evaluation of concrete flexural strength

Figures 7 and **8** illustrate the influence of with and without admixtures on the flexural strength of concrete with changing salt contents at curing periods of 14 and 28 days. The flexural tensile strength of concrete with 0% salt content was evaluated with and without Foam-lub admixture over designated curing periods (14 and 28 days). For specimens with Foam-lub, the strength was 6.26 and 6.95 MPa at 14 and 28 days, respectively. In comparison, specimens without Foam-lub showed strength values of 5.70 and 6.70 MPa. The results indicate that incorporating a foam-lub admixture enhances the flexural strength by approximately 9.8% and 3.7% at the specified curing ages, respectively.

The strength of concrete with 2.5% salt content was evaluated with and without Foam-lub admixture over designated curing periods (14 and 28 days). For specimens with admixture, the strength was 5.79 and 6.30 MPa at 14 and 28 days, respectively. Comparatively, the Foam-lub-lacks showed strength values of 5.33 and 5.75 MPa. The findings show that the introduction of a foam-lub admixture increases flexural strength by about 8.6 and 9.6 percentages at the curing ages targeted respectively. In addition, flexural strength of concrete admixture concrete strength was 5.26 and 6.07 MPa at 14 and 28 days respectively at salt content of 5%. The maximum strength of 6.07 MPa was found at 28 days and the minimum strength of 5.26 MPa was found at 14days. However, in absence of admixture, the values are 5.16 and 5.32 MPa respectively at the same curing ages. The admixture specimens acquire about 1.9 and 14.1 percent of additional strengths compared to the non-admixtures at the same time of curing. Moreover, at a salt content of 7.5%, it was evaluated with and without Foam-lub admixture over designated curing periods (14 and 28 days). The strength of concrete with admixture was 5.26 and 5.86 MPa at the specified curing ages, respectively. The highest strength, 5.86 MPa, was recorded at 28 days, and the lowest value, 5.26 MPa, was at 14 days. In contrast, without admixture, the values are 5.08 and 5.24 MPa at the same curing ages, respectively. Admixture specimens increased approximately 3.5% and 11.8% more in strength than those without admixture at the same curing time.

Given a solution of 10 percent salt, a concrete sample with admixture will have strengths of 5.08 and 5.57 MPa at the given ages of curing, respectively. In comparison, concrete molds without admixture exhibit strengths of 4.78 and 5.06 MPa at the same curing intervals. The addition of the admixture increased strength approximately 6.3% and 10.1% at 14 and 28 days, respectively. It shows a positive effect on concrete performance under saline conditions. The admixture enhances flexural strength in saline conditions by improving the microstructure and permeability of the concrete, which mitigates salt intrusion and improves binder cohesion (Ray et al., 2025). A previous study similarly reported a strength increase in seawater-mixed concrete using chemical admixtures without serious deterioration (Memon et al., 2002).

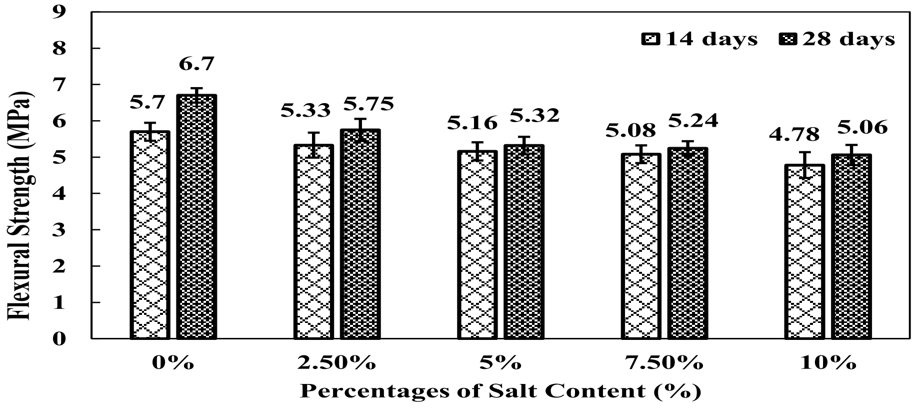


Figure 7: Flexural strength with different salt contents (without admixture)

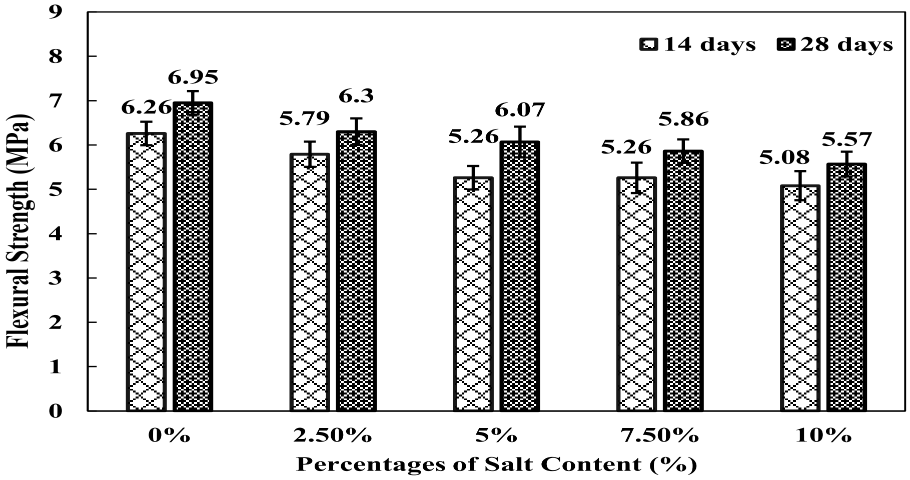
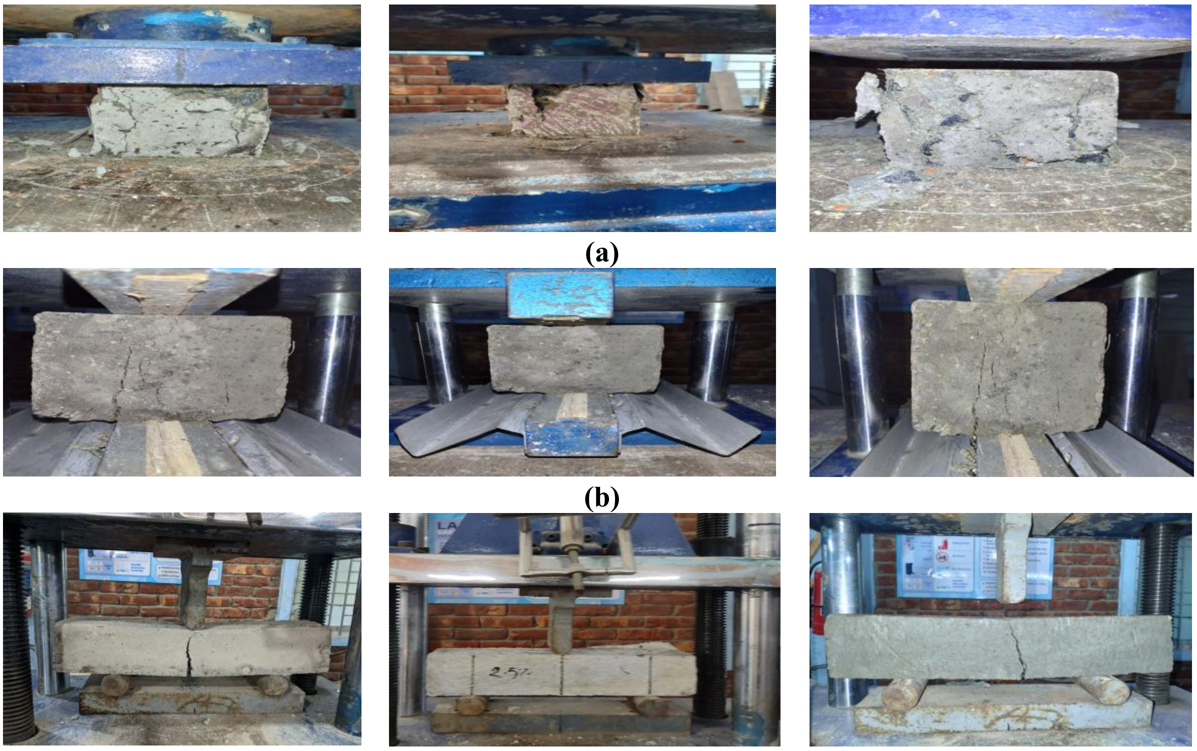


Figure 8: Flexural strength with different salt contents (with admixture)

3.4 Specimen failure modes

Figure 9 presents the different failure patterns observed in the concrete cube specimens. Compression specimens exhibit vertical cracking followed by crushing and edge spalling. Cracks developed gradually, and failure was brittle, and the failure mode was semi-explosive (Ahamed et al., 2024). Tensile test specimens are cleanly split along the loading axis, occurring without fragmentation or sudden collapse and in a non-explosive failure mode. Flexural specimens developed mid-span cracking and gradual rupture, and the failure mode was semi-explosive. Flexural tests also produced transverse cracks across the beam width as a result of bending stresses from the applied loads (Younis et al., 2020).


(a)

(b)

(c)

Figure 9: Concrete specimen (a) compressive, (b) tensile, and (c) flexural failure modes

4. CONCLUSIONS

Based on the findings, the study draws the following conclusions:

- Results show the use of admixture consistently enhances the strength of concrete across all salt contents and curing ages. The highest improvement was observed with 0 to 5% salt content and longer (28 days) curing duration.
- The findings show that for 14 days of curing with 0% salt content, specimens with admixture exhibit increases of 8.1% in compressive strength, 8.9% in splitting tensile strength, and 9.8% in flexural strength and increase compressive, tensile and flexural strength by 11.65%, 3.4% and 3.7%, respectively, after 28 days compared to specimens without admixture.
- The incorporation of admixtures consistently enhances the compressive, tensile and flexural strength of concrete at any curing age. The results demonstrated that this admixture is used to accelerate the development of strength in 7, 14 and 28 days, even in saline conditions.
- The increase in salt content resulted in a progressive decrease in compressive, tensile and flexural strength, which means that salt content has a negative effect on the work of concrete; however, the admixtures mitigated the negative effects of salinity by enhancing the durability and bonding between the interfaces.

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