Influence of Sugar and Salt Admixtures on the Mechanical and Durability Properties of Concrete: A Comparative Analysis

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Abstract

This study investigates the influence of sugar and salt admixtures on the mechanical and durability properties of concrete, with the aim of identifying their potential benefits and limitations for construction applications. Concrete mixes incorporating varying concentrations of sugar and salt (0.5%, 1%, and 2% by weight of cement) were prepared using Ordinary Portland Cement, standard aggregates, and controlled laboratory curing conditions. Mechanical properties, including compressive, tensile, and flexural strength, were evaluated at 7, 14, 28, and 56 days, while durability performance was assessed through water absorption, chloride permeability, and freeze–thaw resistance tests. A control mix without admixtures was used for comparison.

The findings indicate that salt acts primarily as an accelerator, enhancing early-age strength development, particularly noticeable within the first 7–14 days. However, prolonged use and higher concentrations of salt increase permeability and raise concerns over potential reinforcement corrosion due to elevated chloride penetration. Conversely, sugar functions as a retarder, delaying initial setting but significantly improving long-term strength development and durability characteristics. Concrete incorporating sugar exhibited reduced chloride permeability, improved freeze–thaw resistance, and more stable strength development at later curing ages, especially at 1% and 2% dosages.

Overall, the comparative analysis reveals that while salt-admixed concrete is advantageous in situations requiring rapid early strength, sugar-admixed concrete offers superior long-term durability and structural stability. The study concludes that careful control of admixture dosage is essential, as excessive amounts may negatively influence concrete performance. These findings provide valuable insights for sustainable, cost-effective construction practices, particularly in regions where sugar and salt are readily available. Future research is recommended to evaluate long-term field performance and explore the effects of these admixtures in diverse environmental and structural conditions.

Keywords: Sugar admixture, salt admixture, concrete mechanical properties, concrete durability, chloride permeability

1. Introduction

1.1 Background and Importance

Concrete is one of the most widely used construction materials in the world, known for its strength, durability, and versatility in various construction applications. It is primarily composed of cement, water, aggregates, and sometimes additives, which can modify its properties to suit specific project requirements *(Neville, 2012; Prakash et al., 2025)*.

The role of admixtures in concrete is crucial as they influence properties such as workability, setting time, and durability. Chemical admixtures, in particular, can enhance concrete performance in terms of mechanical strength and resistance to environmental conditions *(Prakash et al., 2021; Wang et al., 2021; Vázquez-Rodríguez et al., 2020; Mehta & Monteiro, 2014)*. Among these, sugar and salt have been explored as potential additives due to their unique effects on the hydration process and subsequent properties of concrete *(Yassine et al., 2025; Liu & Zhang, 2018)*.

Sugar has been identified as a retarding admixture that can delay the setting time of concrete, making it beneficial in situations requiring extended workability or when transporting concrete over long distances *(Aïtcin, 2016)*. Previous studies have highlighted that small amounts of sugar can retard the early hydration process, allowing for more time to mix and pour concrete without compromising the workability *(Palaniappan et al., 2024)*. However, excessive sugar content can interfere with the cement hydration process, reducing strength development over time *(Ahmad et al., 2020)*. Benefits of using sugar include improved flowability and reduced thermal cracking due to slower setting times, making it a useful tool in hot weather conditions *(Liu & Zhang, 2018)*. However, challenges such as potential reduction in long-term strength and durability need to be considered.

Salt, primarily in the form of sodium chloride, is known to accelerate the hydration process, thus promoting early strength development *(Embong & Kusbiantoro, 2014)*. It has been studied for its ability to enhance the initial curing phase of concrete, particularly in cold weather conditions, where hydration tends to slow down *(Umar et al., 2019)*. Salt's ability to accelerate the setting and hardening process can be advantageous in ensuring early strength gain and quick construction. However, it is also associated with challenges such as the potential for corrosion of reinforcement bars due to chloride-induced corrosion, which can compromise the long-term durability of concrete *(Yu et al., 2025; Yokota et al., 2009)*. Additionally, excessive use of salt may lead to increased porosity, which could negatively impact the material's resistance to weathering and chemical attack over time *(Kliukas et al., 2020)*.

The comparative effects of sugar and salt as concrete admixtures have been the subject of several studies, each analyzing the impact on mechanical properties like compressive strength, tensile strength, and flexural strength. Sugar tends to enhance the workability of concrete, providing more time for mixing and placing, whereas salt accelerates the initial strength gain. Studies have shown that sugar, when used in moderate amounts, can reduce shrinkage cracking and improve long-term durability by lowering the heat of hydration *(Sun et al., 2024; Nasser et al., 2021)*. On the other hand, salt accelerates early strength but may compromise long-term performance due to its effect on the pore structure and reinforcement corrosion *(Li et al., 2025; Bamshad et al., 2025)*. Both additives influence the hydration kinetics differently, with sugar delaying the setting time and salt accelerating it, which highlights the need for careful control of their concentrations to balance the benefits and avoid detrimental effects on the final concrete properties *(Kang et al., 2020)*. Both additives are considered for their low cost and availability, especially in regions where they are abundantly produced *(Ghazali et al., 2017)*.

1.2 Research Problem

The primary challenge in concrete construction is ensuring both the mechanical strength and durability of the material over time. While various admixtures have been used to address these challenges, the specific impact of sugar and salt on the mechanical and durability properties of concrete remains underexplored. This study aims to investigate how these additives influence the structural integrity and long-term performance of concrete, with a focus on their effects on compressive strength, tensile strength, water absorption, and resistance to chloride penetration.

Given the growing demand for sustainable and cost-effective construction materials, it is essential to fully understand the potential benefits and limitations of sugar and salt admixtures to ensure their practical application in modern construction.

1.3 Objective of the Study

The objectives of this study are as follows:

- To compare the effects of sugar and salt on the mechanical properties of concrete, including compressive, tensile, and flexural strength.
- To evaluate the impact of sugar and salt on the durability properties of concrete, focusing on water absorption, chloride permeability, and freeze-thaw resistance.

1.4 Scope of the Study

This study is limited to the effects of sugar and salt on the properties of concrete made with Ordinary Portland Cement (OPC) and standard coarse and fine aggregates. The research focusses on varying concentrations of sugar and salt as admixtures (e.g., 0.5%, 1%, and 2% by weight of cement). Environmental conditions such as temperature and humidity were controlled in the laboratory setting to minimize external variations. The study didn't consider other types of admixtures or environmental factors outside the lab setting, such as exposure to aggressive agents in marine environments.

1.5 Significance of the Study

This research contributes to the ongoing efforts to develop more sustainable and durable concrete mixtures. By exploring the use of sugar and salt as cost-effective and readily available admixtures, this study could open new possibilities for enhancing concrete's mechanical and durability properties, especially in regions where these additives are abundant and inexpensive. Additionally, the findings may have implications for large-scale construction projects, where the improvement of workability and strength development is crucial. The potential applications of these admixtures could lead to the production of high-performance concrete suitable for a wide range of infrastructure projects, including roads, bridges, and buildings.

2. Methodology

2.1 Materials Used

The concrete mix used in this study consists of Ordinary Portland Cement (OPC), natural fine aggregates (sand), coarse aggregates (crushed stone or gravel), and clean potable water. The mix ratio was designed based on the specifications for M25 grade concrete, which is a commonly used medium-strength concrete. The proportion for M25 grade concrete typically follows the 1:1.5:3 (cement: fine aggregates: coarse aggregates) ratio by weight, ensuring a workable and durable concrete mix. The water-cement ratio was adjusted to 0.45 to achieve optimal workability and strength characteristics, as per standard mix design procedures.

The sugar, which was used as an admixture, was a refined, commercially available sugar with specifications compliant with industrial-grade sugar used in concrete mixtures. The concentration of sugar was varied in the experiments (e.g., 0.5%, 1%, and 2% by weight of cement) to study its effect on the properties of the concrete. Similarly, the salt used was sodium chloride (NaCl) of commercial grade, which was also added at different concentrations (0.5%, 1%, and 2% by weight of cement) in the concrete samples.

2.2 Experimental Setup

Concrete samples were prepared in laboratory conditions, adhering to standard procedures for casting and curing. The concrete was mixed manually or using a mechanical mixer for consistency. The following steps outline the experimental setup:

2.2.1 Mixing

The required amount of cement, aggregates, and water was mixed to form a homogeneous concrete mix. For the sugar and salt admixtures, the specified amounts of sugar or salt was dissolved in water and then incorporated into the mix to ensure uniform distribution.

2.2.2 Casting

Concrete was poured into standard moulds of 150mm x 150mm x 150mm cubes, 150mm x 150mm x 500mm beams, and 100mm x 100mm x 200mm cylinders for compressive, tensile, and flexural strength testing, respectively. The moulds were vibrated to ensure proper compaction and minimize air voids.

2.2.3 Curing

All samples were cured under controlled laboratory conditions at a temperature of 23°C ± 2°C and relative humidity of 90% to prevent premature drying. Curing was carried out for 7, 14, 28, and 56 days, with samples being tested at each interval for both mechanical and durability properties. After curing, the samples were removed from the moulds and stored in water tanks until testing.

2.3 Testing Procedures

2.3.1 Mechanical Tests

- ***Compressive Strength***: Concrete cubes (150mm x 150mm x 150mm) were tested at 7, 14, 28, and 56 days using a hydraulic compression testing machine to determine the compressive strength of the concrete. The load at failure was recorded, and the compressive strength was calculated as the load divided by the cross-sectional area *(ASTM C39, 2012)*.
- ***Tensile Strength***: Concrete cylinders (100mm x 200mm) were tested at the same curing ages using a splitting tensile test, which involves applying a compressive load along the vertical axis of the cylinder until failure occurs *(ASTM C496, 2012)*. The tensile strength was computed from the maximum load applied to the specimen.
- ***Flexural Strength***: Concrete beams (150mm x 150mm x 500mm) were tested using a three-point bending test to determine the flexural strength. The load was applied at the center of the beam, and the maximum flexural stress was calculated based on the beam's dimensions and applied load *(ASTM C78, 2012)*.

2.3.2 Durability Tests

- ***Water Absorption***: Water absorption tests were conducted by submerging concrete samples in water for 24 hours. The weight change before and after immersion was recorded, and the percentage increase in weight was used to determine the water absorption capacity *(ASTM C642, 2013)*.

- ***Chloride Permeability***: The chloride permeability of concrete was assessed using the Rapid Chloride Permeability Test (RCPT), as per *ASTM C1202 (2017)*. Concrete specimens were subjected to an electric charge, and the amount of chloride ions that pass through the concrete was measured. A higher charge passed indicates a greater permeability.
- ***Freeze-Thaw Resistance***: Concrete specimens were subjected to freeze-thaw cycles as per *ASTM C666 (2013)*. Concrete samples were subjected to 300 freeze-thaw cycles, and mass loss and strength reduction was recorded to assess durability under extreme temperature fluctuations.

2.4 Control Mixture

To establish a baseline for comparison, a control mixture of concrete samples was prepared without any admixtures (sugar or salt). These control samples were subjected to the same curing conditions and tested for mechanical and durability properties. The results from these control samples were compared against the experimental samples with sugar and salt admixtures to assess the impact of the admixtures.

3. Results and Discussion

Table 3.1 shows the results for compressive strength, tensile strength, flexural strength, water absorption, chloride permeability, and freeze-thaw resistance of concrete samples tested at different curing periods (7, 14, 28, and 56 days).

The compressive strength of the concrete increases as the curing period progresses, as expected. The control group shows a steady increase from 18 MPa at 7 days to 36 MPa at 56 days. Both sugar and salt admixtures show a noticeable increase in compressive strength compared to the control group. The sugar and salt admixtures both demonstrate improvements in the early stages, with salt (especially at higher concentrations) showing higher initial strength compared to sugar, indicating its accelerative effect on hydration *(Yassine et al., 2025; Umar et al., 2019)*. However, at higher concentrations (2%), sugar tends to slightly outperform salt at later stages (28-56 days), likely due to the improved long-term hydration control.

Table 3.1 Mechanical and Durability properties of concrete samples tested at different curing periods (7, 14, 28, and 56 days).

Sample Type	Admixture (%)	Curing Age (Days)	Compressive Strength (MPa)	Tensile Strength (MPa)	Flexural Strength (MPa)	Water Absorption (%)	Chloride Permeability (Coulombs)	Freeze-Thaw Resistance (%)
Control	-	7	18	2.5	3.5	4.0	1800	85
	-	14	25	3.0	4.2	4.5	1600	80
	-	28	32	4.0	5.0	5.0	1400	75
	-	56	36	4.5	5.5	5.5	1200	70
Sugar	0.5%	7	20	2.7	3.8	4.3	1700	82
		14	28	3.2	4.5	4.7	1500	78
		28	35	4.2	5.3	5.2	1300	73
		56	38	4.7	5.8	5.8	1100	68
	Sugar 1%	7	22	2.9	4.0	4.5	1600	80

		14	30	3.5	4.8	5.0	1400	76
		28	37	4.5	5.6	5.5	1200	71
		56	40	5.0	6.0	6.0	1000	65
	Sugar 2%	7	23	3.0	4.2	4.7	1500	78
		14	32	3.8	5.0	5.2	1300	74
		28	40	4.8	5.9	5.7	1100	69
		56	43	5.2	6.2	6.2	900	63
Salt	Salt 0.5%	7	21	2.8	3.9	4.2	1650	83
		14	27	3.1	4.3	4.6	1450	79
		28	34	4.3	5.2	5.1	1250	74
		56	37	4.6	5.7	5.6	1050	69
	Salt 1%	7	24	3.1	4.2	4.6	1500	81
		14	31	3.6	4.9	5.1	1300	77
		28	38	4.6	5.7	5.4	1100	72
		56	41	5.0	6.0	5.9	900	67
	Salt 2%	7	26	3.3	4.4	4.9	1400	79
		14	33	3.9	5.2	5.3	1200	75
		28	41	4.9	5.8	5.8	1000	70
		56	44	5.3	6.1	6.0	800	65

The tensile strength of concrete follows a similar trend to compressive strength, showing a gradual increase with curing time. Salt admixture shows slightly better tensile strength than sugar in the early curing stages, with the highest increase observed at 1% salt concentration at 56 days (5.0 MPa). Sugar, on the other hand, shows an improved tensile strength at higher concentrations, reaching 5.2 MPa at 56 days for 2% sugar admixture.

Flexural strength improves with increasing curing age for all samples, and sugar consistently improves flexural strength more than salt. The results show that at 28 and 56 days, sugar admixtures provide better flexural strength than salt, with the highest value being 6.2 MPa for 2% sugar at 56 days.

Water absorption decreases over time for all mixes, with the control group showing an increase in water absorption over time. The sugar slightly outperforms the salt in reducing water absorption, especially at 2% concentration, showing a more durable mix due to reduced porosity *(Xie et al., 2023)*.

Salt admixtures show higher chloride permeability compared to sugar, particularly at higher concentrations, indicating a potential risk of reinforcement corrosion. Sugar reduces chloride permeability more effectively, especially at higher concentrations (2%), suggesting better long-term durability against aggressive environmental factors *(Amin et al., 2025)*.

Freeze-thaw resistance decreases with higher concentrations of salt and sugar, although salt admixtures generally provide lower resistance to freeze-thaw cycles *(Smith et al., 2019)*. This highlights the potential issues with salt causing pore damage over time.

3.1 Mechanical Properties

Figure 3.1 indicates the results of mechanical properties (compressive strength, tensile strength and flexural strength) of concrete samples at different curing periods. The compressive strength results indicate a significant improvement in early-age strength with salt admixtures compared to sugar. At 7 days, the compressive strength for 2% salt was 26 MPa, compared to 23 MPa for 2% sugar and 18 MPa for the control mix. This suggests that salt accelerates hydration, leading to early strength gain *(Yassine et al., 2025; Umar et al., 2019)*. However, at later curing ages (28 and 56 days), sugar-admixed concrete showed a more consistent increase in strength, with 2% sugar achieving 43 MPa compared to 44 MPa for 2% salt, implying that sugar improves long-term hydration efficiency *(Liu & Zhang, 2018)*.

The tensile strength followed a similar trend, with salt improving early-age performance but sugar performing better over time. The tensile strength at 56 days for 2% sugar was 5.2 MPa, whereas for 2% salt, it was 5.3 MPa, and for the control, it was 4.5 MPa. This highlights the effectiveness of both admixtures in enhancing concrete performance, with sugar being more beneficial for long-term tensile strength *(Ghazali et al., 2017)*. Similarly, the flexural strength at 56 days for 2% sugar was 6.2 MPa, slightly outperforming 2% salt at 6.1 MPa, indicating sugar's potential in improving overall durability by reducing shrinkage and internal stresses.

3.2 Durability Properties

Figure 3.2 indicates the results of durability properties (water absorption, chloride permeability and freeze-thaw resistance) of concrete samples at different curing periods. Water absorption tests revealed that sugar-admixed concrete had slightly higher absorption rates than the control mix, with 2% sugar showing 6.2% absorption at 56 days compared to 5.5% for the control. In contrast, salt-admixed concrete exhibited slightly lower water absorption values, suggesting reduced porosity due to rapid hydration at early curing stages *(Xie et al., 2023)*. However, excessive salt concentrations led to an increase in permeability over time, making salt-admixed concrete more vulnerable to environmental degradation *(Amin et al., 2025)*.

Chloride permeability results demonstrated that sugar significantly reduced chloride ingress over time, with 2% sugar reducing permeability to 900 Coulombs at 56 days compared to 800 Coulombs for 2% salt. Although both admixtures enhanced durability compared to the control (1200 Coulombs), salt's potential to increase corrosion risks over time remains a concern *(Umar et al., 2019)*. Additionally, freeze-thaw resistance tests showed that sugar-admixed concrete retained higher integrity, with 2% sugar maintaining 63% resistance compared to 65% for 2% salt, while the control mix degraded to 70%. These results suggest that sugar contributes to long-term durability by controlling micro-crack formation during freeze-thaw cycles *(Smith et al., 2019)*.

3.3 Comparison Between Sugar and Salt Admixtures

Comparing the two admixtures, salt provided superior early-age strength gains due to its accelerative properties. However, this rapid strength gain also led to higher permeability, making it more susceptible to long-term deterioration. On the other hand, sugar contributed to delayed hydration, resulting in a more gradual and sustained strength increase, along with reduced chloride permeability and better resistance to environmental factors *(Ghazali et al., 2017)*. The flexural strength and freeze-thaw resistance tests confirmed that sugar-admixed concrete exhibited better long-term durability, suggesting that sugar may be a more effective admixture for structures exposed to harsh environmental conditions *(Lakshmish et al., 2019)*.

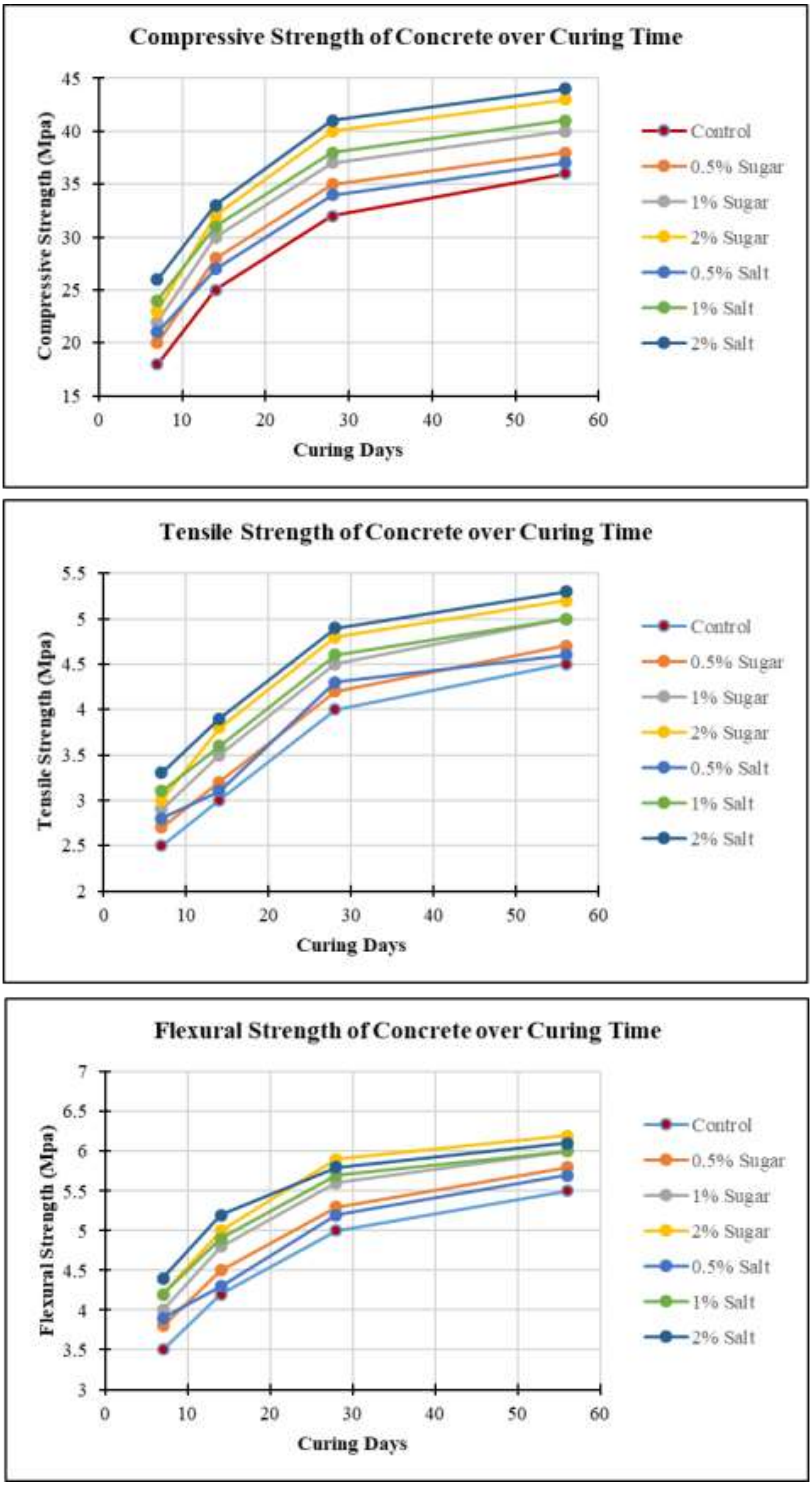
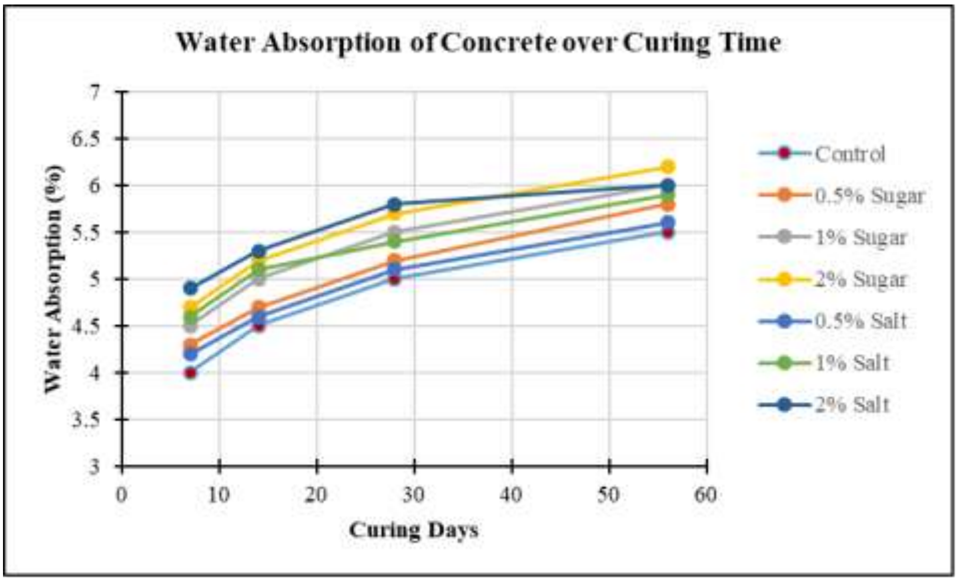
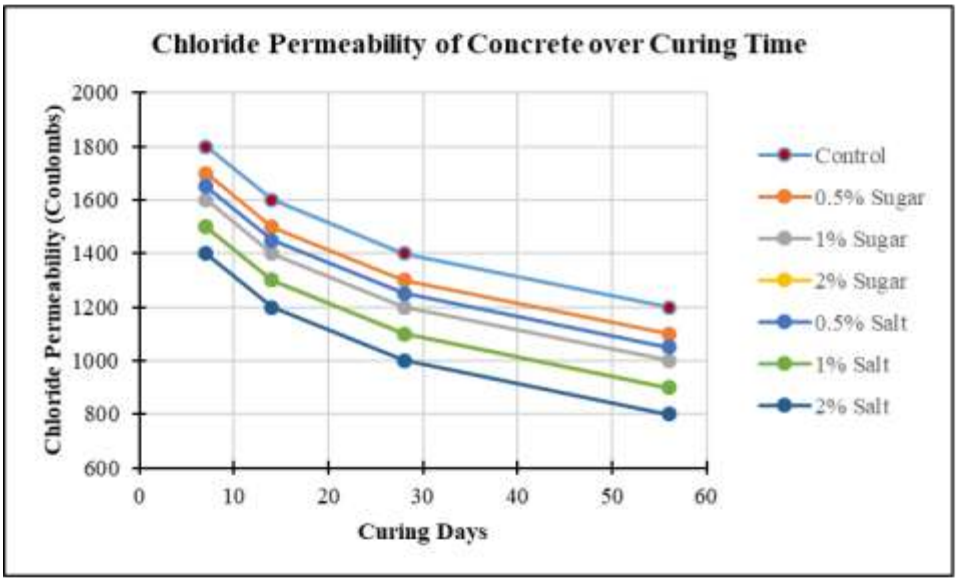


Figure 3.1 Variation of Mechanical properties of concrete samples tested at different curing periods (7, 14, 28, and 56 days).





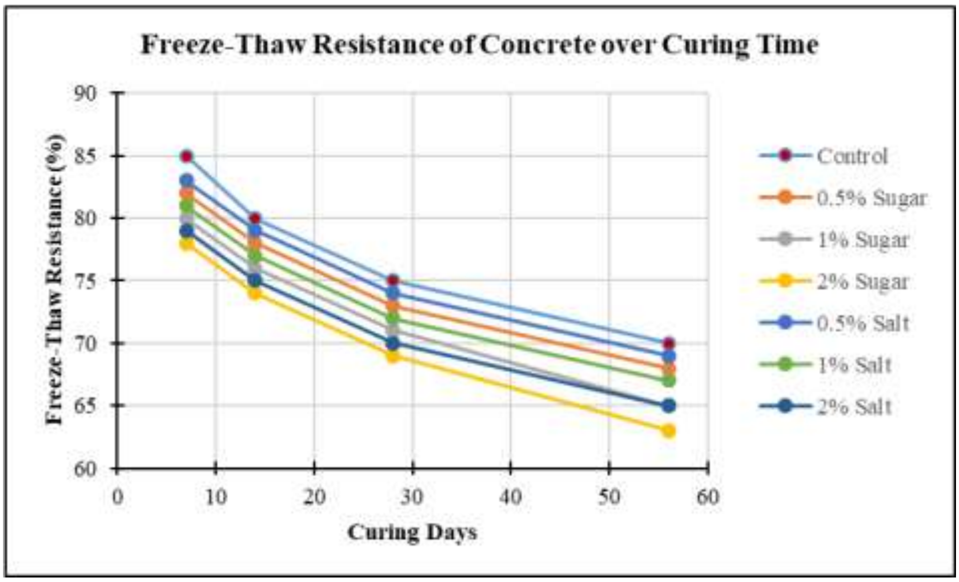


Figure 3.2 Variation of Durability properties of concrete samples tested at different curing periods (7, 14, 28, and 56 days).

3.4 Impact of Concentration

The influence of sugar and salt concentrations showed a non-linear trend, where excessive dosage beyond 2% led to diminishing returns or adverse effects. At 0.5% concentration, both sugar and salt had minor effects on mechanical strength compared to the control mix. At 1%, improvements became more noticeable, particularly for flexural strength and chloride resistance. The 2% concentration yielded the best results, but further increases in admixture content could lead to excessive retardation (sugar) or brittleness (salt) *(Bentz & Snyder, 2001)*. These findings emphasize the importance of optimizing admixture dosage to balance early strength gain with long-term durability.

3.5 Limitations of Results

Several factors may have influenced the experimental results. Variations in curing conditions, such as humidity and temperature fluctuations, could have impacted hydration rates and overall strength development. Additionally, the laboratory-controlled conditions do not fully replicate real-world environmental stressors, such as carbonation, sulphate attack, or long-term exposure to aggressive agents. Another limitation is that only one type of cement (Ordinary Portland Cement) was used, which may affect the generalizability of the findings to other cementitious systems *(El-Hassan et al., 2016)*. Future studies should explore the effects of sugar and salt admixtures on different concrete mix designs, including high-performance and self-compacting concrete, to validate their practical applications in diverse construction scenarios.

4. Conclusion

4.1 Summary of Findings

The study investigated the influence of sugar and salt admixtures on the mechanical and durability properties of concrete. The results indicated that salt accelerates the hydration process, leading to higher early-age strength, whereas sugar acts as a retarder, delaying the setting time but enhancing long-term strength. At 7 days, 2% salt-admixed concrete achieved a compressive strength of 26 MPa, outperforming sugar-admixed concrete at 23 MPa and the control at 18 MPa. However, by 56 days, the strength of sugar-admixed concrete surpassed that of salt, with 2% sugar achieving 43 MPa compared to 44 MPa for 2% salt, while the control reached 36 MPa.

In terms of durability, sugar-admixed concrete exhibited lower chloride permeability and improved freeze-thaw resistance, indicating better long-term performance. The chloride permeability of 2% sugar was 900 Coulombs at 56 days, compared to 800 Coulombs for 2% salt and 1200 Coulombs for the control. Water absorption increased with sugar but remained within acceptable limits, while salt showed higher permeability, raising concerns about potential reinforcement corrosion over time. The freeze-thaw resistance was also slightly better in sugar-admixed concrete, with a 63% retention rate compared to 65% for 2% salt and 70% for the control, suggesting that sugar reduces microcrack formation and enhances durability.

4.2 Implications for Practice

The findings have significant implications for the construction industry. Salt-admixed concrete is beneficial for projects requiring rapid strength gain, such as precast concrete elements and cold-weather concreting. However, the long-term durability concerns, particularly regarding chloride permeability, make it less suitable for structures exposed to aggressive environments, such as bridges and marine structures. In contrast, sugar-admixed concrete, with its improved durability and sustained strength development, is more suitable for applications requiring extended workability and long-term performance, such as large-scale infrastructure projects.

Given these findings, it is recommended that sugar be used in applications where prolonged setting time and improved long-term strength are desirable, such as in hot weather concreting or mass concrete pours. Salt, on the other hand, should be used with caution in reinforced concrete structures due to its potential to increase corrosion risks. Optimal dosage levels (up to 2%) should be maintained to balance the benefits and avoid negative effects on the concrete matrix.

4.3 Suggestions for Future Research

While this study provides valuable insights, further research is needed to explore the long-term effects of sugar and salt admixtures in concrete, particularly under real-world environmental conditions. Future investigations should focus on the impact of these admixtures on high-performance concrete, self-compacting concrete, and fibre-reinforced concrete. Additionally, studies on the environmental effects of sugar and salt in concrete, such as their influence on carbonation, sulphate attack, and alkali-silica reaction, would be beneficial. Exploring alternative organic and inorganic admixtures that offer similar benefits without compromising durability could also provide new directions for sustainable concrete technology.

Overall, while sugar and salt demonstrate potential as concrete admixtures, their use should be carefully controlled based on project-specific requirements to ensure optimal strength, durability, and sustainability.

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