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Optimizing Concrete Strength: A Case for Sustainable Use of Local Resources

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Abstract:
To improve the sustainability of building materials, this study explores the use of sodium chloride (NaCl) in concrete mixtures as a partial substitute for cement. The study examines the various ways that salt affects concrete, taking into account how it affects durability, long-term structural integrity, and early strength development. Over time, chloride ions from NaCl may seep through the cement matrix and cause embedded steel reinforcement to corrode. However, NaCl can speed up hydration and encourage the production of calcium silicate hydrate (C-S-H) at ideal dosages (usually less than 5% by weight of cement), which improves early-age compressive strength. To maximize the advantages of quicker setting without sacrificing long-term performance, a careful balance is essential when adding salt to concrete. It is crucial to assess the intended use, exposure conditions in the environment, and the existence of reinforcement. Strategies for adding salt that optimize performance while addressing durability issues are still being investigated, especially for non-structural or short-life applications with low corrosion threats.

Key Words: Sodium Chloride; Concrete Mixtures; Durability; Structural Integrity; Compressive Strength; Sustainable Use; Local Resources

Introduction:

Concrete is affected by sodium chloride in a variety of ways, including early strength development, long-term structural integrity, and durability[1]. Over time, the chloride ions that NaCl introduces can reach embedded steel reinforcement through the cement matrix, starting corrosion processes that impair reinforced concrete's structural strength[2]. Because salt affects hydration kinetics and pore distribution, it changes the microstructure of concrete[3]. They ascribe this behavior to the production of more calcium silicate hydrate (C–S–H) and faster hydration[4]. However, the same salt may lead to osmotic effects and the expansion of salt crystals within the pore system[5]. Therefore, using salt as an ingredient in concrete necessitates striking a careful balance between the advantages of quicker setting and the dangers of long-term deterioration[6] [7]. Therefore it is important to consider the intended use, environmental load conditions, and the presence of reinforcements when evaluating the addition of NaCl to concrete mixtures[8]. Research on adding salt that maximizes performance without sacrificing durability is still ongoing [9], especially in applications with short lifespans or non-structural elements where corrosion risk is minimal[10]. In contrast to the use of brine [11], the chloride distribution is evenly distributed upon mixing[12]. Even distribution within the matrix is guaranteed by adding solid NaCl to the dry components[13]. The dosage affects how solid salt affects concrete's mechanical qualities, especially its compressive strength, [14] conditions for cure, and the existence of additional cementitious materials [15].

Background:
Concrete's strength, durability, and adaptability make it a popular building material. To improve early-age strength, researchers have recently looked into adding solid sodium chloride (NaCl) to concrete[16]. Small levels of NaCl can hasten cement's hydration, improving its compressive strength during the early phases of curing. However, the possibility of corrosion in reinforced concrete is raised by the presence of chloride ions [17]. Concrete that has been salt-modified may provide both performance and cost advantages in short-term or non-reinforced applications. The study of NaCl in concrete is accelerating due to rising interest in local material use and sustainable construction.

LITERATURE REVIEW:

Year	Citation	Objective	Methods	Materials	Conclusion
2025	[2]	To investigate how chloride ions are transported and bound in concrete during one-sided salt-freezing cycles.	Chloride ion profiles are measured, and concrete specimens are exposed to salt-freezing cycles as part of an experimental investigation.	Single-sided salt-freezing cycles were applied to the concrete sample.	The transport and binding behavior of chloride ions in concrete are greatly impacted by one-sided salt-freezing cycles.
2025	[18]	To look into the disposal of nuclear waste in salt caverns.	Theoretical analysis and case studies.	Salt caverns for storing radioactive waste.	Long-term disposal of radioactive waste may be possible with salt formations.
2025	[19]	To assess how well concrete mixed with seawater performs in tidal situations.	Laboratory testing and field research.	Concrete mixed with seawater is exposed to tides.	In tidal zones, seawater-mixed concrete shows durability issues.
2025	[20]	To look into how salt affects steel corrosion, water vapor transport, and compressive strength in concrete.	Investigation using concrete samples with different salt contents.	Different concentrations of salt were put into the concrete.	A higher salt content raises the risk of corrosion and decreases compressive strength.
2025	[21]	To comprehend the processes by which concrete materials deteriorate due to salt.	Thorough examination of the chemical degradation pathways in concrete caused by salt.	Cement, water with varying salinity levels, and fine and coarse particles.	Compressive strength rises with low salt concentration and falls with high salt levels.
2025	[22]	To examine how chloride ions affect the durability of concrete over the long run.	Reviews of the literature and case studies.	Concrete in settings with chloride.	Concrete deteriorates due to chloride ions; hence, precautions must be taken.
2024	[23]	To compare the effects of fresh and salt water on concrete.	Concrete samples were cast and cured with both salt and fresh water; mechanical properties were examined.	Cement, aggregates, fresh and salt water.	Use of salt water resulted in slight strength gains; more research is needed to determine the long-term consequences.

2024	[24]	To look at the structural soundness of concrete in surroundings with salt.	Assessing the structural integrity of concrete samples exposed to salt.	Chloride salt exposure for the concrete sample.	Concrete that is exposed to salt loses structural integrity and becomes more prone to cracking.
2024	[25]	To investigate how the combination of sugar and salt affects the characteristics of mortar.	Examination of mortar samples experimentally after adding sugar and salt.	Mortar mixtures that have particular proportions of sugar and salt.	Mortar's strength and setting time are influenced by the ratio of sugar to salt.
2023	[26]	To evaluate the resilience of concrete containing nanoparticles to freeze-thaw cycles and chloride penetration.	Laboratory tests assessing the effectiveness of concrete augmented with nanoparticles.	Concrete mixtures that contain nanoparticles are exposed to freeze-thaw cycles and chloride solutions.	The addition of nanoparticles increases concrete's resistance to freeze-thaw degradation and chloride penetration.
2022	[27]	To connect the mechanical characteristics and air-void system to the concrete's ability to withstand salt scaling when made using slag cement.	Tests in the lab on concrete samples exposed to different levels of salt and slag cement.	Slag-cement concrete exposed to salt-scaling conditions.	The resistance of slag cement concrete to salt scaling is greatly influenced by air-void properties.
2021	[28]	To assess how salts affect the internal curing of concrete's strength and durability.	Internal curing concrete with different salt amounts is the subject of an experimental investigation.	Concrete mixes with internal curing agents and added salts.	Salts have an impact on the internal curing of concrete's durability and mechanical qualities.
2021	[29]	To examine the ability of chloride ions to solidify in alkali-activated slag cement when exposed to sodium chloride	Concrete samples were subjected to chloride salts in an experimental setting.	Sodium chloride with alkali-activated slag cement.	Created a prediction model that demonstrates how the composition of the slag affects the ability to bind chloride.
2021	[30]	To evaluate the compound effects of gypsum and sodium chloride on the sulfate resistance and compressive strength of geopolymer concrete made from slag.	Experimental examination of concrete samples with different amounts of gypsum and salt.	Gypsum, sodium chloride, and geopolymer concrete based on slag.	Strength and durability are impacted by mixed additives, which have ramifications for mix design.

The literature emphasizes the substantial impact of salts and chloride ions on the properties and durability of concrete. Research conducted by [2], [19], and [20] indicates that chloride transport, corrosion, and strength are adversely affected by salt exposure, especially in conditions such as seawater and freeze-thaw cycles. Furthermore, references [21] and [22] highlight the enduring impact of chloride ions on the durability of concrete, indicating the necessity for preventive strategies. This research aims to partially substitute cement with salt in conventional concrete, examining the effects of salt on the mechanical properties of concrete. Mixing salt with concrete is one of the best ways to use it in building. It can be added to molds, mixed into the concrete mixture, or cured and adhered to a wall surface. These have the benefits of durability, design freedom, economy, and speed of manufacture in addition to the previously listed design features [31]. Additionally, public-private partnerships in construction projects [32] and the application of artificial intelligence in project management are essential for promoting sustainable concrete practices [33].
Additional studies, including [27] and [28], demonstrate that air-void systems in slag cement and the use of internal curing agents can improve concrete's resistance to salt scaling, thereby supporting the goal of creating alternative materials for optimal thermal mass. Research conducted by [29] and [30] examines alkali-activated slag cement and geopolymer concrete, focusing on their enhanced resistance to chloride and sulfate degradation. The incorporation of agro-industrial waste as supplementary cementitious materials in mortar [34], specifically sugarcane bagasse ash and silica fumes, along with eco-friendly concrete that utilizes fly ash and hemp, promotes sustainable and energy-efficient construction practices [35]. The findings highlight the significance of innovative materials and practices in enhancing concrete performance and sustainability.

Methodology:
Concrete mixes containing a 1:2:4 ratio of cement, sand, and aggregate were prepared, with 5% sodium chloride (NaCl) by weight replacing some of the cement. The researcher prepared the cement with varying percentages of 2 to 10 percent replaced with sea salt [36]. Cement, sand, and coarse aggregate were dry mixed after the ingredients were meticulously weighed and metered. After that, a salt solution was added to the dry mixture to guarantee even dispersion, and everything was well combined. A universal testing machine was used to measure the concrete's compressive strength after it had been molded into molds and allowed to cure for 7, 14, and 28 days.

Material Selection:
Salt is the sixth most prevalent element in the crust of the Earth is sodium. NaCl speeds up the setting time of concrete by acting as an accelerator, which is advantageous in cold climates. Salt can improve the plasticity and placement ease in trace levels[1]. Concrete may become more susceptible to moisture intrusion due to increased permeability caused by salt. Concrete (1:2:4 mix: cement, sand, and coarse aggregate) can benefit or suffer from the addition of salt (NaCl).

Table 1: Properties of Salt

Sr.	Reference	Property	Value
1.	[37]	Water Absorption	Increases by 5%
2.	[38]	Compressive Strength Reduction	5%
3.	[39]	Specific Gravity of NaCl	2.16
4.	(National Center for Biotechnology Information, 2020)	Bulk density	2.165 g/cm³ at 25 °C
5.	(Las Cuevas 2023)	Porosity	3.8%
	(Berest, Brouard, and Durup 2021; Cosenza et al. 2018)		14%
6.	(Ferguson 2019; National Center for Biotechnology Information 2020)	Melting point	801 °C

43 Grade Cement is used in both residential and low-load commercial buildings because of its outstanding workability and durability. Because of its surplus strength, 43-grade offers sufficient strength without wasting material. After 28 days of curing, 43-grade OPC cement has a minimum compressive strength of 15 MPa. It produces a smooth and closed surface finish and is more resistant to cracking than 33-grade cement. Concretes are easier to work with and apply because of their finer particles.

Table 2: Properties of Cement

Sr.	Reference no.	Property	Value
1.	[31]	Water Absorption	0.6%
2.	[40]	Specific Gravity	3.01
3.	[41]	Fineness (specific surface area)	225 m²/kg
4.	[41]	Initial Setting Time	30 minutes
5.	[41]	Final Setting Time	600 minutes (10 hours)
6.	[42]	Standard Consistency	28%
7.	[43]	Drying Shrinkage	0.15%
8.	[44]	Chloride Content	I.1%

Figure 2: OPC 43 Grade Cement

Figure 1: Salt Crystal

Figure 3: Vicat Apparatus

Coarse aggregate serves as the primary load-bearing component of a 1:2:4 concrete mix, giving the structure the strength and mass it needs. Crushed stone or gravel is typically 20 mm (3/4 inch) in size, but, depending on structural requirements, aggregate sizes ranging from 10 mm to 20 mm may be used. To improve bonding with cement paste, the aggregate is tough, long-lasting, and devoid of dust, clay, or organic contaminants.

Sr.	Reference no.	Property	Value
1.	[45]	Moisture Absorption	1%
2.	[46]	Specific Gravity	2.70
3.	[47]	Fineness modulus	4.189
4.	[48]	Aggregate Crushing Value	16.60%
5.	[48]	Aggregate Impact Value	11.01%

Table 3: Properties of Coarse Aggregate

Sieve Size	Weight retained (kg)	Cumulative weight retained (kg)	Cumulative % retained	Cumulative % Passing
19mm	1.519	1.519	30.380	69.620
12.5mm	2.143	3.662	73.240	26.760
9.3mm	1.301	4.963	99.260	0.740
4.75mm	0.037	5	100	0
Total	**5**		**729.64**	

Fineness modulus of Coarse aggregate = 729.64/100 = 7.30

Table 4: Sieve Analysis of Coarse Aggregate

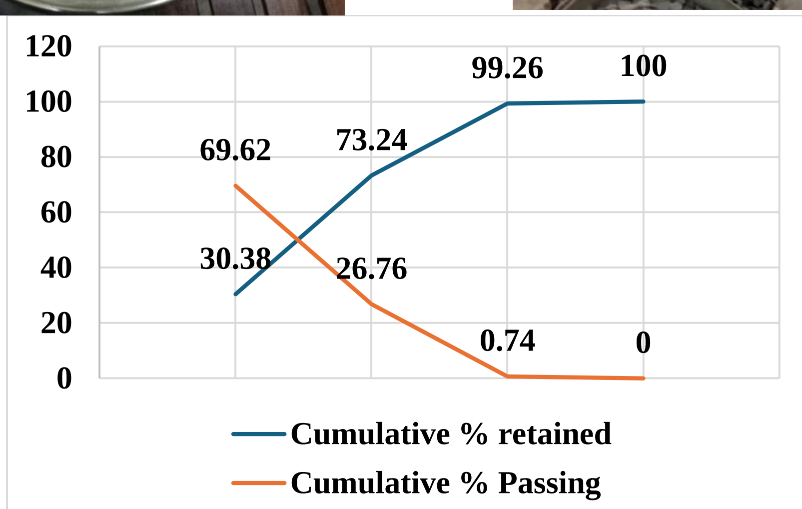

Figure 4: Sieve Analysis of Coarse Aggregate

Sand that is readily available locally is used. Sand, or fine aggregate, is essential to a 1:2:4 concrete mix because it fills in the spaces between coarse aggregates and enhances the mix's cohesiveness and workability. To guarantee a good connection with cement, the sand is clean, well-graded, and devoid of organic matter, silt, clay, and other contaminants.

Sr.	Reference no.	Property	Value
1.	[45]	Moisture Absorption	0.80%
2.	[46]	Specific Gravity	2.61
3.	[47]	Fineness modulus	2.23

Table 5: Properties of Fine Aggregate

Sieve Size	Weight retained (grams)	Cumulative weight retained (grams)	Cumulative % retained	Cumulative % Passing
4.75mm	3	0.3	0.3	99.7
2.36mm	4	0.4	0.7	99.3
1.18mm	82	8.2	8.9	91.1
0.6mm	318	31.8	40.7	59.3

0.425mm	499	49.9	90.6	9.4
0.15mm	68	6.8	97.4	2.6
Total	**1000**		**238.6**	

Fineness modulus of Fine aggregate = 238.6/100 = 2.384

Table 6: Sieve Analysis of Fine Aggregate

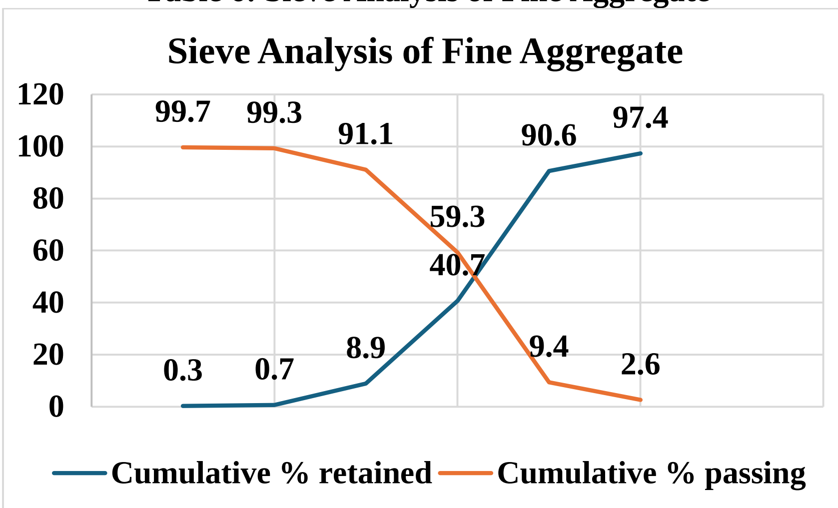

Figure 5: Sand

- Concrete mix ratios (1:2:4 for cement: sand: aggregate) and incrementally replacing a portion of cement with salt NaCl, 5% by weight.
- Cement = 9kg
- Fine Aggregate = 18kg
- Coarse Aggregate = 36kg
- NaCl = 0.45kg
- Water is adjusted with the ratio of 0.6.

Mix Preparation:

Salt content is a crucial variable in experimental concrete mixes, which are made to maximize qualities including strength, thermal performance, and moisture regulation. The amount of NaCl added to standard mixes is carefully regulated and never exceeds 5% of the cement weight. In their dry form, cement, sand, and coarse aggregate are first thoroughly mixed in a 1:2:4 ratio. These dry components are then gently mixed with a salt solution while being constantly stirred to ensure that the chloride ions are evenly distributed throughout the mixture. Two to three minutes are needed for this mixing to reach a uniform consistency.

Experimental mixes are created with salt concentration to determine the optimal balance of properties like strength, thermal performance, and moisture regulation. In sample casting, molds—usually 6x6—are prepared and filled with the concrete mixture. The samples are demolded after a day to allow for adequate hydration and strength development. After that, these samples are cured in water for the allotted 7, 14, and 28 days.

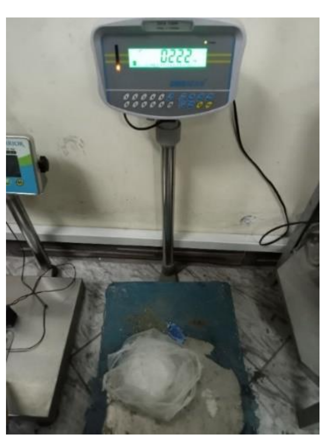

Figure 6: Digital Weighting Balance


Figure7: Mixing Dry Ingredients

Figure 8: Addition of Salt

Figure 9: Final Mixing


Figure 10: Application of oil before pouring concrete

Figure 11: Water Tank

TESTING AND ANALYSIS:

Using a universal testing machine (UTM), the compressive strength test is the main test that is carried out. This test is essential for figuring out how much weight the salt-admixed concrete can support. The UTM model is "T10P02" to identify particular mix variants. By applying controlled force to the concrete samples, the UTM determines their strength quantitatively by determining when they fail under compression. Researchers are able to comprehend the effects of salt content on the finished concrete product through this thorough testing and analysis

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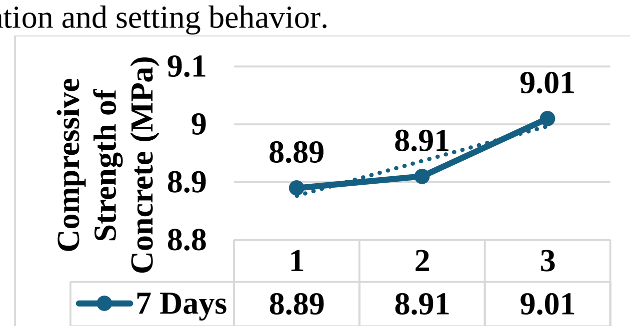
Figure 126: Model of UTM **Figure 13: Universal Testing Machine**

Figure 14: Before Compressive Test

Figure 15: After Compressive Test

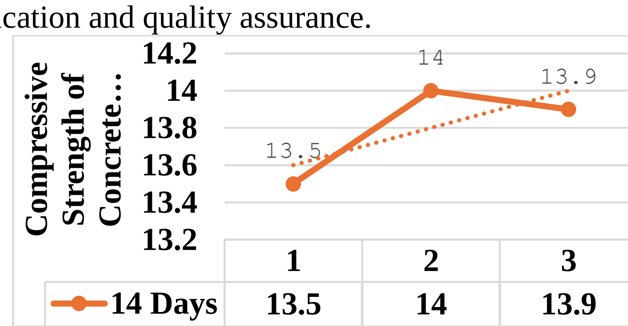
RESULTS

To track the rate of strength development over time, the concrete's compressive strength was routinely assessed at 7, 14, and 28-day curing intervals. Approximately 59.33% of the 28-day design target strength of 15 MPa is represented by this early-age strength. For handling and formwork removal decisions in real-world applications, this strength rise at this point is a sign of appropriate early hydration and setting behavior.



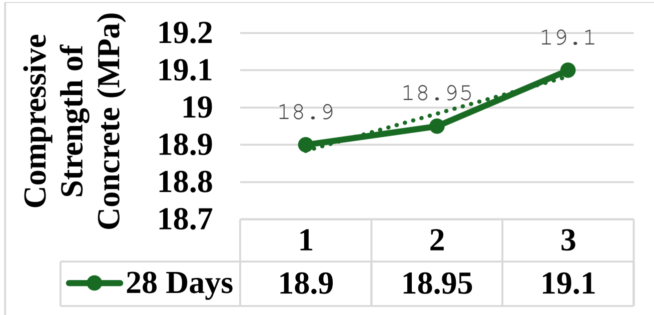
Graph 1: Compressive Strength at 7 Days

The compressive strength reached 90% of the goal strength by the fourteenth day. This steady rise indicates that the mix design and curing conditions are favorable for strength development and are a reflection of ongoing hydration. Additionally, the strength rise over 7–14 days offers a useful standard for site modification and quality assurance.



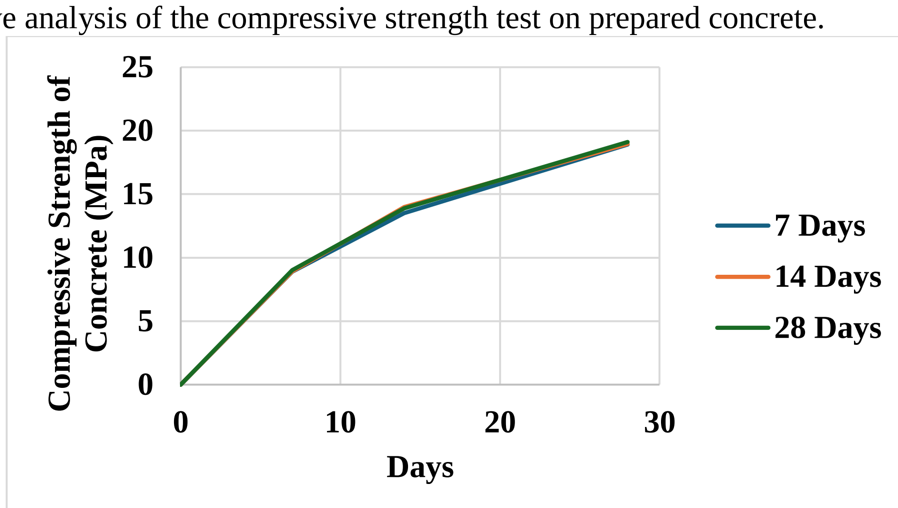
Graph 2: Compressive Strength at 14 Days

The concrete reached above 100% of the desired strength at the end of the typical 28-day curing time. This attests to the mix's compliance with structural application performance requirements. All things considered, the compressive strength data show a steady and predictable pattern of strength growth, which is in line with what is generally expected for regular Portland cement-based concrete under usual curing conditions.



Graph 3: Compressive Strength at 28 Days

The collective analysis of the compressive strength test on prepared concrete.



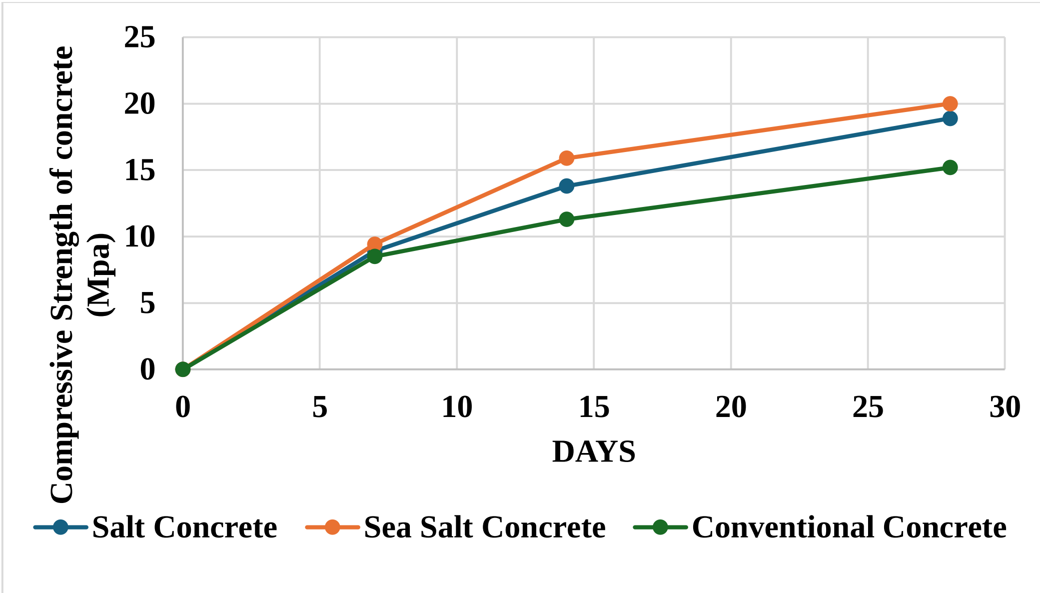
Graph 4: Compressive strength of concrete

DISCUSSION

Adding sodium chloride (NaCl) to a 1:2:4 concrete mix up to 5% by weight of cement had a major impact on the development of compressive strength[1]. The salt-concrete samples demonstrated that early hydration was successfully increased without sacrificing final strength, achieving 59.33% at 7 days, 90% at 14 days, and above 100% at 28 days. When compared to sea salt, the salt concrete's compressive strength was lower[21]. The fact that their physical and chemical makeups differed. Sea salt, which is naturally produced when seawater evaporates, is rich in trace minerals. Sulfates, potassium, calcium, and magnesium all help to alter the cement hydration process[49]. Industrial-grade sodium chloride, the salt employed in the experiment, typically lacks these extra substances and contains undesirable contaminants that obstruct hydration reactions or increase the porosity of the concrete matrix[50]. Between the two sources, there may be notable differences in the salt's particle size distribution, rate of solubility, and interaction with cementitious materials. The experimental salt concrete's relatively poor performance was caused by the lack of advantageous mineral admixtures.

Concrete Type	7 Days		14 Days		28 Days	
	Av. Wt. of cube (Kg)	Av. Conc. Strength (MPa)	Av. Wt. of cube (Kg)	Av. Conc. Strength (MPa)	Av. Wt. of cube (Kg)	Av. Conc. Strength (MPa)
NaCl	7.82	8.9	7.90	13.8	8.50	18.9
Sea Salt	7.85	9.43	8.110	15.9	8.55	20
Nominal Mix Design	7.68	8.502	8.0	11.3	8.1	15.2

Table 7: Result of Average Compressive Strength of Nominal Mix Design Concrete



Graph 5: Compressive Strength of Sea Salt concrete, Salt concrete, and M15 Grade Concrete

Although the strength results are encouraging, the study is constrained by its exclusive focus on short-term mechanical properties and unreinforced concrete. Long-term durability concerns like freeze-thaw resistance, possible alkali-silica interactions, and corrosion caused by chloride in reinforced structures are not covered[51]. Furthermore, no change in environmental exposure or additional cementitious materials was examined; only one salt dosage of 5% was. Thus, without additional testing on permeability, shrinkage, and microstructural integrity, the results might not apply to reinforced structural applications or extreme climatic conditions[4].

The addition of sodium chloride (NaCl) to concrete mixtures had a significant impact on the development of compressive strength when compared to the Nominal mix design concrete of M15 OPC 43 grade cement. While 43 grade cement normally reaches strengths of 56.68% at 7 days, 75.33% at 14 days, and 100% at 28 days[52]. Salt-modified concrete samples achieved 59.33%, 90% and 26% greater than the target strength of these respective benchmarks. As the mix design ratio chosen is 1:2:4 using NaCl 5% replacement of cement, the compressive strength of M15 OPC 43 Grade Nominal mix design concrete is greater than the limit of 15MPa. It manufactures the M15 grade nominal mix design concrete[53]. It is recommended for low-load construction such as residential concrete work, flooring, etc. Industrial-grade NaCl's capacity to promote hydration reactions is limited since, in contrast to sea salt, it lacks advantageous trace components. Although minerals like calcium, magnesium, potassium, and sulfates that are frequently present in natural sea salt can improve long-term performance and early hydration, their lack in the studied salt concrete probably resulted in increased porosity and broken cementitious bonding[21].

For certain engineering applications where early strength gain, cost-effectiveness, or local material use are important considerations, such as temporary structures, rural pavements, or precast elements in arid areas, salt-modified concrete shows significant promise[54]. Using NaCl as a setting accelerator can shorten building times and increase workability in areas with restricted access to sophisticated additives. To reduce the risk of corrosion, its application must be limited to elements that have a short service life or are not strengthened. To prevent localized weakening or crystal growth, field implementation should also provide enough salt dissolving and uniform distribution[55].

From a scientific standpoint, this study advances our knowledge of ion-driven changes in cement hydration chemistry[55]. It encourages more research into the dual function of chloride ions as agents of deterioration and performance enhancement. Alternative accelerator formulations, heat regulation research, and sustainable binder systems are all made possible by the controlled usage of NaCl. Additionally, the findings enhance the material science database on salt by informing prediction modeling for microstructural development and chloride transport in cementitious matrices[37].

CONCLUSION

1. The development of compressive strength is greatly impacted when sodium chloride (NaCl) at a weight percentage of up to 5% of cement is added to 1:2:4 ratio concrete. The compressive strength is 26% greater than the nominal mix design of M15 concrete using OPC 43 grade cement with the ratio of 1:2:4. It manufactures the M15 grade nominal mix design concrete. It is recommended for low-load construction such as residential concrete work, flooring, etc.

2. The influence of sodium chloride on the cement hydration process is the main reason for the increased compressive strength seen in concrete with a 5% addition of NaCl as opposed to the nominal mix. In particular, NaCl promotes a quicker and more thorough hydration of the cement by acting as an accelerator. The primary binding agent that gives concrete its strength, calcium silicate hydrate (C-S-H), is produced in greater quantities as a result of this faster hydration. As a result, compared to the nominal mix design concrete, the NaCl-modified concrete achieves a higher compressive strength through more efficient strength development.
3. The Salt concrete achieved 94.5% compared to the addition of Sea Salt in a 1:2:4 mix design at a weight percentage of 5% of cement. However, because of their different physical and chemical compositions, the salt concrete compressive strength was lower than that of sea salt concrete but greater than the nominal mix design of M15 concrete. The strength results are promising, using NaCl in concrete necessitates striking a careful balance between the possibility of long-term durability and rapid setting.

LIMITATIONS AND FUTURE RESEARCH:

The short-term mechanical characteristics of unreinforced concrete are the main focus of this investigation. Long-term durability issues, such as chloride-induced corrosion in reinforced structures, possible alkali-silica interactions, and freeze-thaw resistance, are not addressed. Another limitation of the study is that it only looks at one dosage of salt (5%) and excludes changes in exposure to the environment and the use of other cementitious materials. Therefore, without additional testing on permeability, shrinkage, and microstructural integrity, the results might not be immediately relevant to reinforced structural applications or extreme climatic conditions.

To completely comprehend the effects of adding sodium chloride to concrete, more investigation is required. Long-term durability studies, salt dose optimization for different concrete mixes and environmental circumstances, and the assessment of salt-modified concrete in particular applications such as temporary structures or non-reinforced elements should all be part of this. To avoid localized weakening or crystal development, more research could examine ways to guarantee sufficient salt dissolving and uniform dispersion in field implementation. From a scientific standpoint, future studies should focus on developing the salt-C-S-H material science database and assisting in the development of predictive models for chloride transport and microstructural evolution in cementitious matrices.

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