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# Impact of Seawater Sea-Sand Concrete on Concrete Properties - A Comprehensive Review

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**ABSTRACT:** Several intellectuals have recently focused on using Sea sand or seawater to replace conventional concrete, with promising results. Here, we discuss whether Seawater or sea sand impacts concrete properties. In addition to decreasing the setting time of fresh Concrete, SW and SS consume nearly 70% of the natural sand extracted. In global industrial production, concrete finishes 9% of the water. Since concrete has gained significant popularity over the past few centuries, research has examined its properties. It is possible to protect natural resources while improving concrete's mechanical properties using Seawater in Concrete. In this paper, previous findings regarding the impacts of seawater and sea sand on concrete mixtures and structures are evaluated and summarized. Coal bottom ash, copper slag, fly ash, and other supplementary cementitious materials (SCM) are typically added to concrete to increase resistance to seawater. A thorough experimental study, as well as a general direction for marine concrete, is presented in this study.

**KEYWORDS:** Concrete, Durability, Sea-water, Sea-sand, Compressive strength

## I. INTRODUCTION

Freshwater and river sand are consumed in enormous quantities each year, which has triggered widespread concern about seawater consumption in concrete construction. The world has experienced a severe shortage of freshwater for years. As a result of inefficient extraction of river sand for concrete construction, a substantial number of countries experience flooding disasters, which affect the safety of roads and cause flooding during storms. Thus, Seawater and sea sand are natural choices for relieving this dilemma and creating economical materials and constructions, especially in coastal regions and locales. Through nontraditional, modern materials and reused waste materials, fine aggregates have compensated for lacking fine natural aggregates. Construction projects or works often utilize concrete because of its low impact on development, versatility, reliability, and durability. The world's best practices in sustainable development focus on improving citizens' quality of life while reducing the impact on nature.

Concrete as a construction material has become mandatory in recent years, making it nearly impossible to construct a structure without it. Because concrete is lightweight, durable, stable, economical, and moldable, 18 billion tons will be used in construction by 2050. [6]. Due to its weight, stability, ease of moulding, and economy [7], concrete tends to be preferred by prospects. The chloride in seawater sea-sand Concrete (SSSC) causes it to set faster than freshwater or river-sand concrete. Still, its long-term quality is marginally lower due to pollution or sulfate impact than standard and conventional concrete. According to some investigations, Because sea sand concrete contains natural materials or fragile shells, it has a lower compression strength than standard concrete. [8-10].

Due to the integrated presence of impurities or purity with chemical particles, SSSC exhibits various properties. Because of the complex combination of compounds, especially salts, seawater can be very unpleasant on/for structures, even though it can be very complex. It is possible for concrete exposed to the marine water to be weak in strength and degree due to completely different concentrations of salts in it. In estimation, seawater contains 3.5% salts. Salt influences concrete chemically, physically, and mechanically [12]. Sea sand and seawater are used a lot in concrete nowadays. The effects of sea sand on concrete were studied in the 1960s [13, 14], [52], [53], and [54]. Japanese

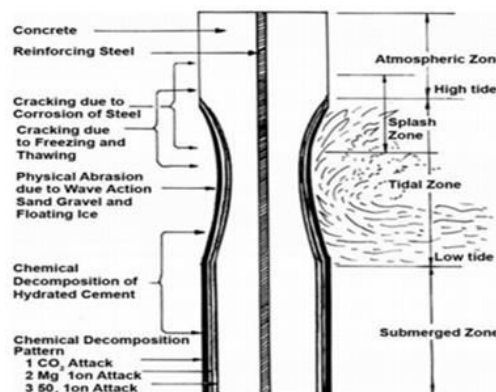
scientists have discovered that desalted sea sand can be used as an aggregate for Concrete [55]. In the Netherlands, South Korea, Hong Kong, Germany, France and Denmark, desalted sea sand is usually used for construction [56].

Because sea sand and seawater contain a high chloride level, according to the current universal code criteria, it must be sluiced with fresh water. It takes additional bureaucracy to obtain the concrete desired when washing sea sands and following the necessary procedures. In addition, for corrosion of steel, modern concrete design codes restrict chloride levels [57]. To overcome these limitations, researchers are studying concrete with sea sand and water without desalination. One structure in Japan was constructed using Sea-water Mixed Concrete (SWC), while another was built with SWC. In figure 1a, concrete breakwater armour is shown as the method for protecting coastal structures from wave loads. The coastal beacon in figure 1b was constructed in 1959 from seawater concrete and is reinforced concrete.

As far as concrete properties are concerned, chloride ions do not affect them, but they slightly affect how fast they set and solidify. Chloride-induced corrosion only affects steel reinforcement, so SS and SW are rarely used in construction because of pollution caused by chlorides. Although used for almost 60 years, (figure 1b) depicts a coastal beacon without significant problems and no corroded concrete or reinforcement. It may be possible to use seawater and unwashed sea sand as part of concrete if designed and manufactured appropriately [57].



**Figure 1:** Shows a breakwater armour made from seawater mixing concrete (a) at Soma Port, Japan, and a lighthouse built in 1959 with reinforced Concrete made from seawater mixing Concrete (b) at Hizen Nagasaki Nao, Ukushima Island, Japan [58].



**Figure 2:** The degradation of the concrete matrix due to seawater exposure [12].

As seen in figure 2, structures under seawater impact undergo dormancy in response to substituting drying and wetting winds, which accelerate the disintegration process. It is also possible for concrete to fail in cold coastal regions due to cracks developed throughout its service life [59].

This study considers raw material properties to determine whether sea-sand and seawater concrete have engineering properties. In addition, an analysis of sea water's chemical composition and SSSC mix proportions is shown in this study, in conjunction with previous studies. Optimal mix compositions are influenced by seawater, including strength, durability, and workability.



II. SEA WATER, SEA SAND IN CONCRETE MIXTURES

2.1 Concrete Mixtures

There is a high level of misuse of concrete around the world [47,48]. Therefore, to systematically develop SSSC with mitigated properties, it is necessary to distinguish sea-sand properties from seawater properties and determine the mixture degree parameters corresponding to concrete structure properties and execution requirements.

According to Yifan Zhao et al. (2021), SWSSC is made of alkali-activated slag (binder), seawater, sea sand, coarse aggregate, and hydrated lime slurry. It contains 35.8% sodium and 46.6% silicon oxide and is activated by sodium metasilicate [15]—Li et al. report on seawater, sodium metasilicate, and sea chemical composition slag. Sand, sea water, sodium metasilicate, and sea slag compositions were ascertained and reported. Furthermore, freshwater and river sand concrete (FWRSC) was examined.

Table 1: Concrete Mixture (kg/m<sup>3</sup>) [49].

CONSTITUENTS	SWSSC	FWRSC
Slag	360	360
Seawater	190	N/A
Freshwater	N/A	190
Sea sand	830	N/A
River sand	N/A	830
Coarse aggregate	1130	1130
Sodium metasilicate	38.4	38.4
Hydrated lime slurry	14.4	14.4

FWRSC: Freshwater and river sand concrete; Swssc: Sea-water and sea sand concrete

Previously, Li et al. [49] reported that slag and solid sodium meta-silicate were mixed in dry conditions before mixing. Both FWRSC and SWSS used the same mixing procedures. It is known that the grading of aggregate can have a slight effect on the strength and workability of concrete [50].

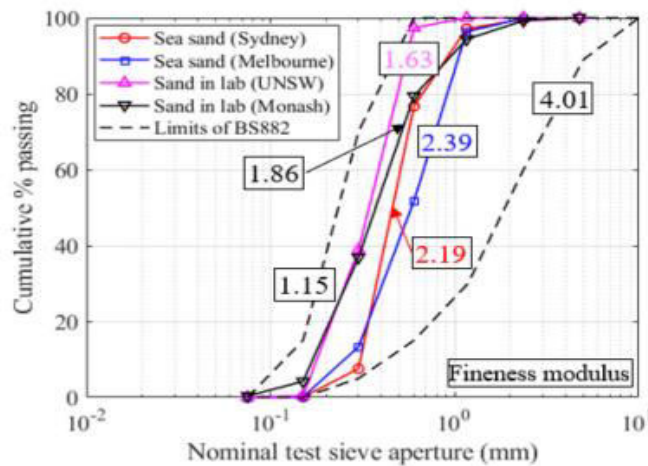


Figure 3: Graphs of sand particle size distributions [49]

Defining particle size distributions of aggregate is essential to ensure concrete quality [51]. A particle size distribution curve for sea sand collected in Sydney and Melbourne, a standard sand sample, and a practical limit of a particle size distribution curve are also included in Figure 3. A sieve with an aperture is less likely to pass through sea sand, so the particles are smaller. The particle size appears uniform in all sand samples collected from different locations. A fineness modulus analysis of sea sand [49] indicates that its grains are rougher or contain more grains than laboratory-derived river sand.

In summary, a number of scholars have characterized concrete as a composite material made up of fine and coarse aggregate joined together with a fluid cement that gradually becomes harder over time. Numerous environmental consequences result from this broad use. By identifying the differences between the characteristics of sea sand and seawater, it is possible to construct SSSC with features that are mitigated. The aforementioned investigations found that



the grading of aggregate had a negligible effect on the strength and workability of concrete. In order to identify the aggregate for FWRSC and SWSSC separately utilizing various mixing experimental research, it is recommended to thoroughly explore these qualities. To comprehend how mixing SW and SS impacts air content in fresh concrete, more research is required.

**2.2 Seawater and sea sand chemical composition**

All but two sea regions and works of literature have very similar seawater salinities, according to several publications about their chemical compositions (Tab. 2) [34]. Sea water in the Baltic Sea has a much lower salinity than the rest of the world because it naturally comes from the rainy, low temperature, cloudy, and foggy climate. Seawater has a much lower salinity than the rest of the ocean, according to Y. Zhao, X. Hu, C. Shi et al. [17]. In several studies, salt in concrete pores has been found to cause damage. For example, Fraternali et al. [18] studied the concrete damage caused by salt hygroscopic behaviour and ions in seawater at higher concentrations. The pH of seawater is generally around 8.2, with an average pH between 7.5 and 8.4 [33, 35].

Many chemical ions are required to manufacture seawater per ASTM D1141-98 [33] based on the saltiness of seawater in various regions. According to Kaushik and Islam [36], the salinity of seawater (which can be increased by five or ten times the typical level) significantly impacts SSSC properties. The primary reactive ions present in Seawater are C1- and Mg2+, which can affect the properties of seawater and threaten the durability of concrete structures. For example, a high concentration of C1- can accelerate steel deterioration, while high concentrations of gypsum and ettringite [37, 38] can accelerate concrete expansion and crack.

By reacting with calcium hydroxide in cement-based materials, magnesium ions form brucite, reducing pores' saltiness and creating a destabilizing C-S-H gel. Chemical ions from seawater can also affect the solid phases of concrete by cooperating with other ions. In concrete, different cation ions, such as sodium, potassium, calcium, and magnesium, affect the microstructure and durability.

**Table 2:** Literature applications of seawater chemical compositions in different regions (unit: mg/l). [15]

References	Water Type	Cl <sup>-</sup>	Na <sup>+</sup>	SO <sub>4</sub> <sup>2-</sup>	Mg <sup>2+</sup>	Ca <sup>2+</sup>	K <sup>+</sup>
Li et al. [16]	Artificial	16,476	11,044	2772	302	53	53
Citizen et al. [17]	Natural	3000	1800	410	240	98	67
Fraternali et al. [18]	Artificial	50,060	31,560	9660	2480	180	180
Nishida et al. [19]	Artificial	19,720	11,111	1325	1319	422	364
Moukwa [20]	Natural	17,035	10,231	2800	1006	327	-
Solution et al.[21]	Natural	19,130	10,750	1890	1370	320	380
Mohammed et al. [22,23]	Artificial	17,087	9290	2378	1167	356	346
Ganjian and Sadeghi[24]	Natural	22,330	11,400	3070	1600	450	397
Province [25]	Artificial	19,753	11,109	2765	1328	422	399
Weerd and Justine [26,27]	Natural	19,400	9500	258	1100	350	350
Huang et al. [28]	Artificial	19,744	11,052	1325	1328	422	369
Rashad et al. [29]	Artificial	21,584	11,993	3601	1458	311	480
Wang et al. [30]	Natural	26,000	15,000	3700	2300	500	520
Cheng et al. [31]	Artificial	19,837	11,032	2765	1314	418	397
Typical Seawater [32]	Natural	18,980	10,556	2649	1262	400	380
Eastern Mediterranean [32]	Natural	21,200	11,800	2950	1403	423	463
Arabian Gulf [32]	Natural	23,000	15,850	3200	1765	500	460
Red sea [32]	Natural	22,219	14,255	3078	742	225	210
ASTM D1141-98 [33]	Artificial	19,837	11,032	2765	1314	418	397

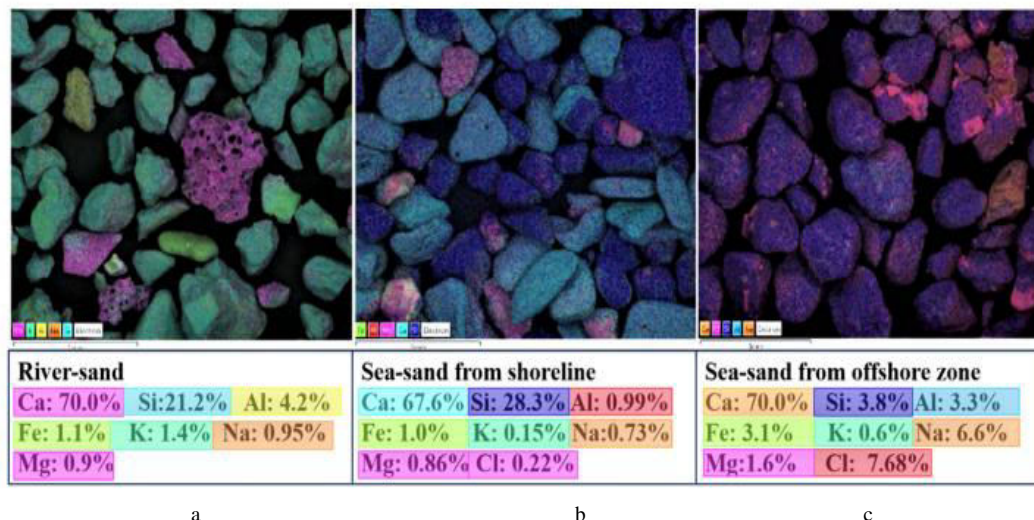


Figure 4: Using SEM, a comparative analysis was conducted on the composition of primary elements in three types of sand tested: (a) river sand, (b) sea sand from shorelines, and (c) sea sand from off-shore zones.

In summary, the aforementioned scholars have investigated how chemical composition affects SSSWC. It has been demonstrated that the microstructure and durability are influenced by several ions, including sodium, potassium, calcium, and magnesium. Additionally, it has been discovered that salt damages concrete pores. An extensive examination of these qualities to discover how resistant SS and SW concrete are against physical (scraped areas, hydration fractures, salt crystallization), chemical, and other assaults (sulfate, chloride, and corrosion). As a result, we suggest using distillation to lessen sea salinity.

### 2.3 Sea Sand

The British spearheaded a desalting process in the 1960s that allowed sea sand to be used in construction applications after decades of construction. The dredged ocean sand could be used in concrete to the extent of 45% [72] as a good total. Even though the sea-sand changes based on diverse climate zones [41, 42], the physical and chemical properties differ dramatically. In particular, the effects are primarily observed at the shoreline, hills, and off-shore zones. [34]. From the above (Fig. 4), it can be seen that off-shore sea sand is higher in salt content and has cubic salt crystals, whereas shoreline sand has an even distribution of salt. Dhondy et al. [34] found that sea sand collected from dunes with greater soil content had lower chloride concentrations and calcium than sea sand collected from shorelines and off-shore regions.

Limeira et al. [43] report a concentration of chloride and fine particles in the surface disposal layer of the off-shore season. Therefore, before being applied to construction, sea sand should be considered for the variations in physical and chemical properties that vary from one climate region to another. Compared to river sand, sea sand contains much more chloride than river sand. Figure 4 shows the primary element composition of river sand and sea sand. Since shells and natural matter differ in substance, the piece of sea sand depends on the amount of silica it contains. Other chemical elements, however, remain the same.

In the hills, calcite ( $\text{CaCO}_3$ ) is significantly higher than in river sand [34, 45]. Sea sand can be washed with fresh water to reduce its salt content to less than 0.015% [34, 44]. Coastal sand contains quartz ( $\text{SiO}_2$ ) and feldspar ((K, Ca, Na)  $(\text{AlSi})_4\text{O}_8$ ) as their primary minerals. A feldspar ((K, Ca, Na)  $(\text{AlSi})_4\text{O}_8$ ) is shown in figure 3. There is no point in using shells and natural components if sea sand is present. The amount of sea sand must be restricted based on grain measurement and the desired concrete quality. Sea sand is unsalted. [15].

In summary, this section explored the shoreline, hills, and off-shore areas while comparing the chemical and physical properties of sea sand. Researchers in this study concluded after conducting multiple experiments that sea sand should be taken into consideration because it contains significantly more chloride than river sand and can be cleansed with fresh water to reduce its salt content by a smaller amount. Then, in order to stress their distinctions, it is advised that future research focus on the chemical diversity of sands from the shoreline, hills, and offshore, as well as freshwater sea sand and seawater.



**2.4 Mechanical Properties of Seawater and Sea Sand of Concrete**

Research conducted on Seawater and sea sand Concrete is summarized in table 3. In the literature, seawater and sea sand have been extensively used in concrete, and a slight increase in compressive strength was observed when applied early. In addition, it has been shown that chloride ions in seawater and sea sand can promote the hydration of cement. In addition to the toughness, tensile strength, impact, and fatigue properties, seawater and sea sand concretes have many other properties that need to be studied and explained.

**Table 3:** Details of concrete specimens from some literature[34].

SW and/ Or SS	Recommendations	Reference
SW	Concrete made with SW decreased by 5-10% after 18 months. Initially, SW's strength was higher, but eventually, it fell by 13% after 28 days.	[77]
SW	In the 10-year exposure test, there were few differences between concrete that had been mixed with SW and Concrete that had been mixed with fresh water.	[85]
SW	A seawater mix concrete after 90 days had a lower compressive strength than conventional concrete owing to its higher compression, tensile, flexural, and bonding strengths. According to the results, SW mixed Concrete's compressive strength decreased significantly after 90 days.	[86]
NaCl	Concrete's strength, Young's modulus, and water loss did not change significantly with a significant increase in chlorine from NaCl.	[79]
SS	25 % of the raw sand was replaced with DMS, which improved the mixes' packing and compressive properties, probably because of grading and changes in the granular skeleton	[69]
SS	conventional Concrete and DMS-based Concrete had similar elastic modulus, compressive strength, tensile strength, and flexural strength	[70]
SS	River sand concrete has the same strength as SSC.	[87]
SS-SW	In both early and late tests, it was found that accelerated alternate wet and dry concrete made from river-sand or freshwater sand was more substantial than concrete made from SWSSC.	[88]
SW and SS	the SWSSC was high and retained its strength over the long term at a high level.	[65]
SW	Compared with fresh water mortar, SW-mixed mortars showed slightly higher compressive strength over a prolonged curing period.	[90]
SS	After 28 days, offshore-sand concrete had lower compression strength than conventional concrete.	[64]



SS	A concrete's strength value can be improved by adding chloride ions	[68]
SW	At an early age, concrete using SW achieved higher compressive strengths than concrete using freshwater or seawater. However, in later periods, both freshwater and seawater produced identical forces.	[67]
SW	Compared with freshwater mixed, SWC's compressive strength was 7–10% lower after 28 days.	[44]
SW	A comparison of the compressive strength of SWC and conventional concrete after 3 and 7 days revealed that the former was firmer by 7.5% and 6%, respectively. After 28 days, both mixtures showed comparable compressive strengths, with the difference decreasing with time.	[13]

The aforementioned researchers concluded that the presence of chloride ions in sea water and sea sand, which accelerate the cement hydration process, results in a little improvement in the compressive strength of concrete when applied at young ages. Even though researchers have conducted a number of experimental investigations on the mechanical properties of saltwater and sea sand in concrete, further research is needed to compare the two materials with mechanically sourced sand and water for concrete makers in the area. is strongly advised. It has been contradictory when it comes to certain characteristics of sea sand and seawater in concrete, such as toughness, tensile strength, impact and fatigue behavior, etc. It takes a lot of work to educate people about these implications.

### III. LITERATURE ON SEA-SAND SEA WATER OF CONCRETE

#### 3.1 The impact of seawater on physical properties

This part presents some studies that have addressed the impact of natural seawater on concrete's durability, fresh-state, physical, and mechanical properties. A study by Mangi et al. (2020) showed that concrete specimen weight increased by 2% after 28 days of mixing with seawater. Since the concrete specimens were cured and mixed with seawater, a minimum level of infiltration was achieved, for example, 25 millimetres. Based on ultra-pulse measurements, concrete models had ultra-pulse speeds between 4.2 and 4.5 km/s, and their density and modulus of elasticity remained unchanged, so they were considered "good".

A higher corrosion current density was found in sea-sand concrete during their studies. However, as coal bottom ash prevents harmful salts from penetrating cement paste and reduces the setting time of cement paste, the weight gained can be maintained by adding cementitious material [61]. Additionally, a study examining the impact of Nigeria's Escravos seawater concluded that an increase in seawater concentration diminishes cement's initial and final setting times [62].

According to an investigation conducted in Nigeria using Escravos seawater for concrete specimen preparation, 115% more strength was achieved in compression. In their view, only Escravos Seawater from the Nigerian delta should be considered when factoring in their findings [94]. Physicochemical characteristics of sea sand samples varied as well, as shown in Figure 5. Most models had steep gradients in particle size distribution curves.



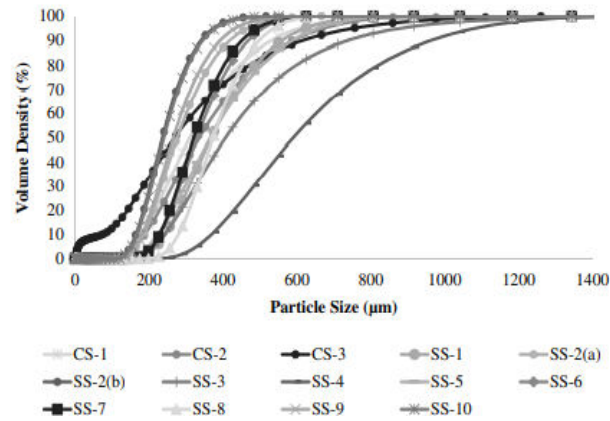


Figure 5: Particle size distribution of the sands tested [63].

Identifying differences in the sand used in concrete is essential to understanding how other physical and chemical properties affect concrete's fresh and hardened state [34]. A particle size distribution for the sands is quantified by the coefficients of uniformity (Cu) and curvature (Cc), which range from 10% to 90% (Figure 6). A visual comparison of the average concrete compressive strength, particle size variations, and surface textures among the sands tested and used is shown in figure 7.

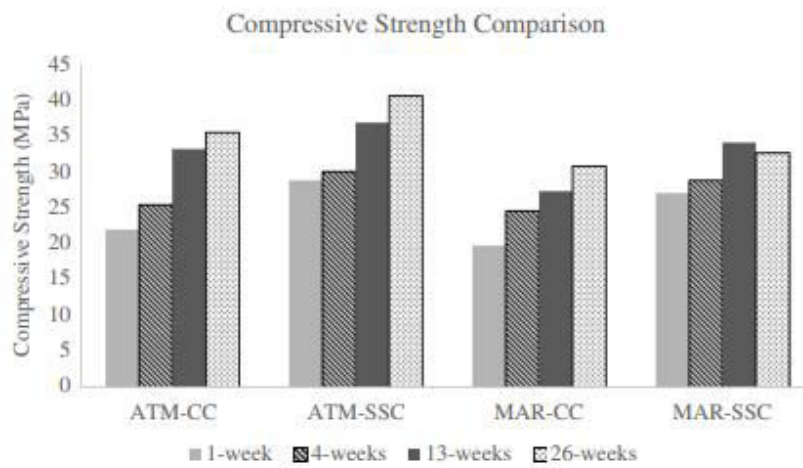


Figure 6: Average concrete compressive strength comparison [63]

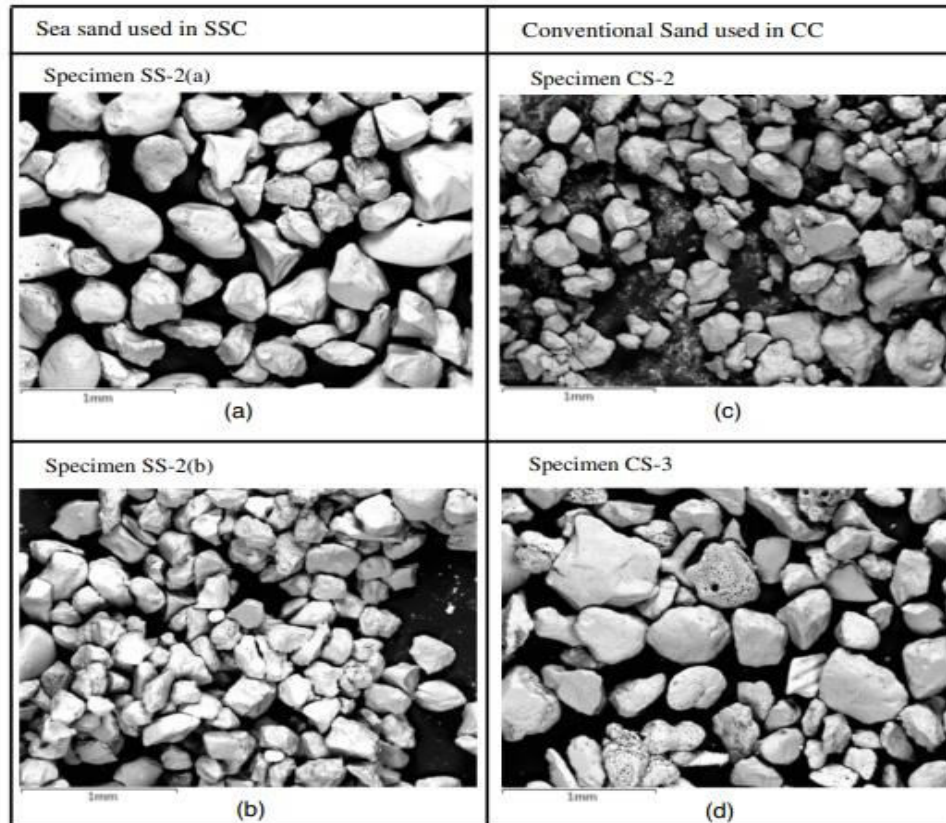


Figure 7: Sand samples were examined visually to determine the variation in particle size and surface texture between (a) sand from the dunes; (b) sand from the shoreline; and (c) sand used in conventional concrete; (d) coarse sand; and (e) fine sand.

In summary, numerous experimental investigations of the SSSWC's physical characteristics have been carried out. Nevertheless, some studies revealed that the weight of the seawater-mixed concrete specimens increased by 2% after 28 days of mixing. Also in other investigations, it was discovered that sea-sand concrete had a larger corrosion current density, which shortens the cement paste's setting time and helps cementitious materials keep the weight obtained. Over 115% strength in compression was attained in study that was carried out in Nigeria using Escravos seawater for concrete specimen preparation. The effects of seawater on physical characteristics are shown by these results. Concrete's many qualities could be enhanced by the use of SCMs. SSSWC with SCMs is therefore strongly advised.

### 3.2 Seawater influence on the workability of concrete

Sea sand (SS) and seawater (SW) have been studied as much as possible for concrete air content. According to [65], [67], and [68], SW affects fresh concrete air content in negligible amounts. To fully understand the workability of concrete mixed with SS and SW, other properties have been examined, including setting times, slumps and spread streams, and air contents. In addition to reducing the first and last setting times, SS and SW in Concrete reduce the slumps and spread streams.

The workability properties of concrete are not affected by SS and SW, and previous literature has expressed conflicting opinions. However, several studies have found that salt water reduces slump flow in concrete [68] and increases marine sand consolidation (up to 50%), resulting in significant fluidity losses [69], [70].

Sea-sand Concrete has been emphasized more than seawater concrete regarding its workability; however, no significant changes in either workability have been observed [72]. Curing Concrete mixed with rice husk ash (RHA) was treated with sodium chloride (NaCl) solutions at concentrations of 5% and 10%. RHA pores reduced concrete workability by retaining a large amount of free water [73], resulting in reduced workability. However, [96] and [97] suggest that concrete exposed to seawater may benefit from the addition of supplementary cementitious materials (SCMs). In seawater concrete, SCMs can potentially improve chloride diffusion coefficients.[98, 99].

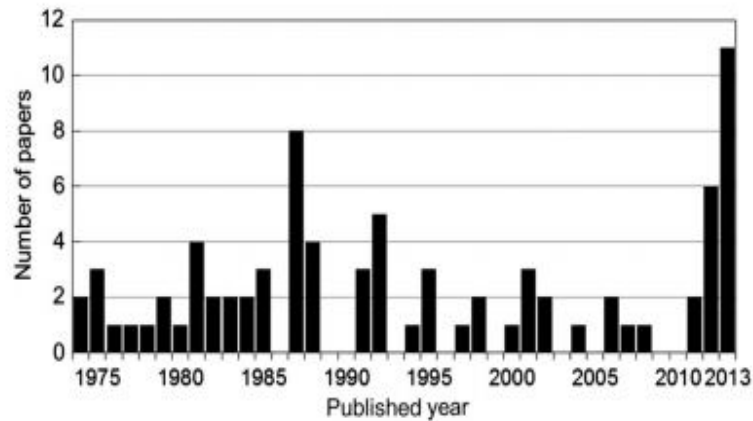


Figure 8: Relationship between Concrete and Seawater: Trends in Publications (1974-2013) [71]

The proposed formulation of SSSC incorporating SCMs does not yet have a widely acknowledged mixing proportion design method [15]. In addition, a cement type can also influence SSSC's deterioration resistance. According to Zhou et al. (2021), applying SCMs with high aluminium phases also enhances corrosion resistance in reinforced SSSCs. After adding 40% GGBS, the density loss ratio of rebar decreased to 0.18% from 0.42% [100], [102], [110]. Throughout history, many scholars have investigated the interaction of Concrete and Seawater. The trend of sweater-related investigations on concrete from 1974 to 2013 is shown in Figure 8.

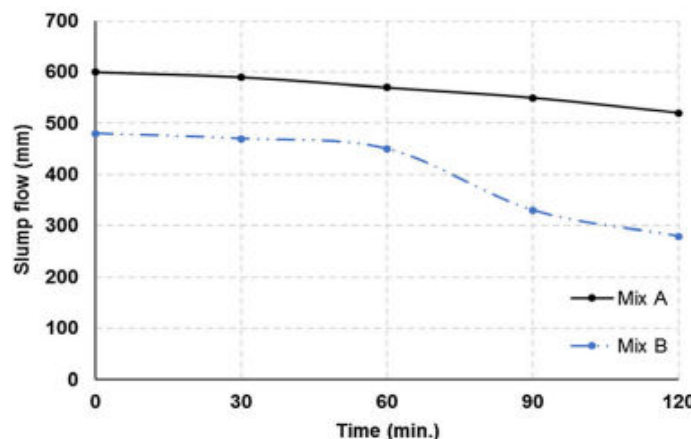


Figure 9: Workability (Slump) of typical and seawater mixed Concrete [72].

There has been no indication that either seawater or freshwater affects the density of the new concrete [67]. According to Figure 9, Younis et al. [68] found similar slump reductions for normal water- and sea-water-prepared concrete. It is necessary to conduct more research on new concrete to understand how mixing SW and SS affects air content.

In summary, investigations on the workability of concrete mixed with SS and SW have previously looked at various features such the initial and last setting time, slump/spread stream, and air content. According to [72], however, neither workability nor a significant impact were found. According to some researchers, SS and SW have little impact on the workability characteristics of concrete. To establish whether SS and SW have an impact on the workability qualities of concrete or not, we advise doing a thorough scientific inquiry because these opinions are not well-defined.

### 3.3 Impacts of Seawater on durability properties

Several factors contribute to concrete durability, including carbonation conduct, freeze-thaw resistance, drying shrinkage, chloride and sulfate diffusion, crawl resistance, and acid resistance in unique environments. Unfortunately, most of the literature on concrete containing SS or SW is in Japanese and Chinese, so few long-term studies have been conducted.



Due to the presence of chlorides [72], sea concrete tends to shrink and resist freeze-thaw action. Furthermore, the study concluded that chlorides hardly impact carbonation [72]. A fly ash ratio of low water-to-fly ash ratio has been proposed to strengthen concrete in marine environments. It has been proposed that SS mortars have nonuniform pores due to ettringite and calcium (OH)<sub>2</sub>. [72,74].

Using off-shore sand, Girish et al. [75] found that chloride ions in concrete ran through the mix twice as much as in cement-filled concrete but still within the ASTM accepted range

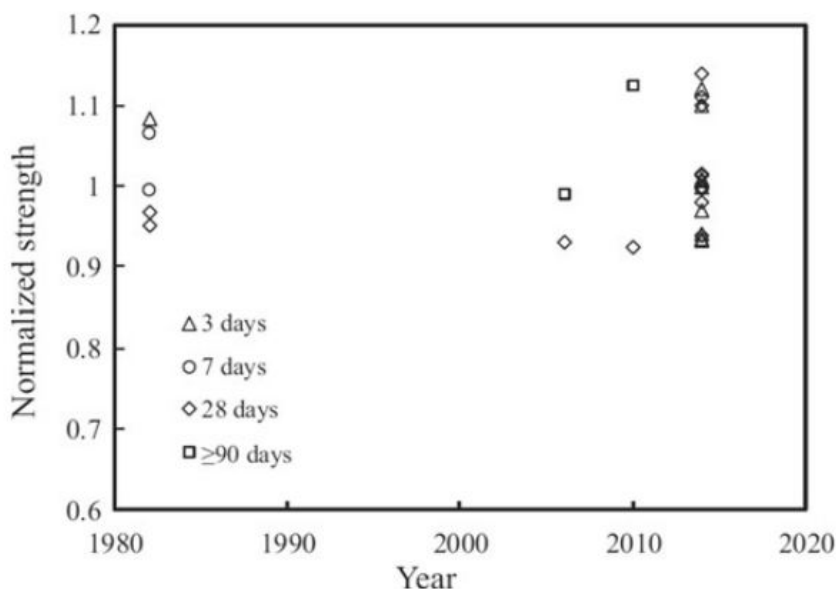


Figure 10: Normalized strength of sea-sand concrete (horizontal axis is the year of publication of the results) [63].

The minimum compressive strength of SSC concrete is higher than that of conventional concrete, as seen in Fig. 10. During the study, researchers examined the relationship between chloride content and permeability. The authors' used river sand splashed with different concentrations of NaCl to produce artificial sea sand of varying chloride contents. According to [72], increasing chloride concentration reduces mortar permeability.

Moreover, Younis et al. [68] examined hardened SWC's permeability performance. The study did not find that mixing Seawater into Concrete significantly affected its chloride aggression, chloride permeability, or water absorption properties. Seawater concrete has a higher chloride binding capacity (103) than ordinary concrete, in addition to its freeze-thaw resistance [103,117]. Sea-sand added to concrete improved chloride diffusion coefficients, according to Xie et al. [108], whereas Bian et al. [107] reported the opposite.

Fig. 11 illustrates that plain concrete prepared with seawater was more substantial than ordinary concrete when equipped with fresh water and seawater. Smaller average pore size was observed for SWC when bottom ash was used as a substitute for cement [93]. This prevented the penetration of corrosive salts into concrete pores and helped fill them [42]. The pore structure results of green artificial reef concrete were the same when cured with seawater and freshwater [64].

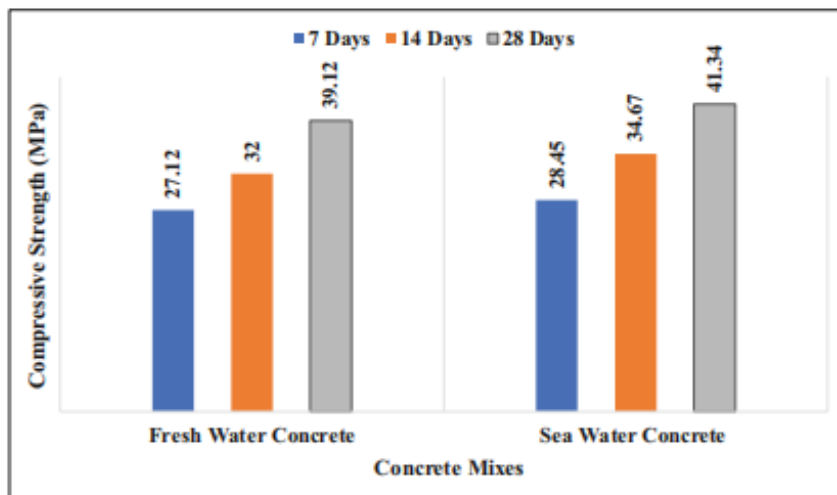
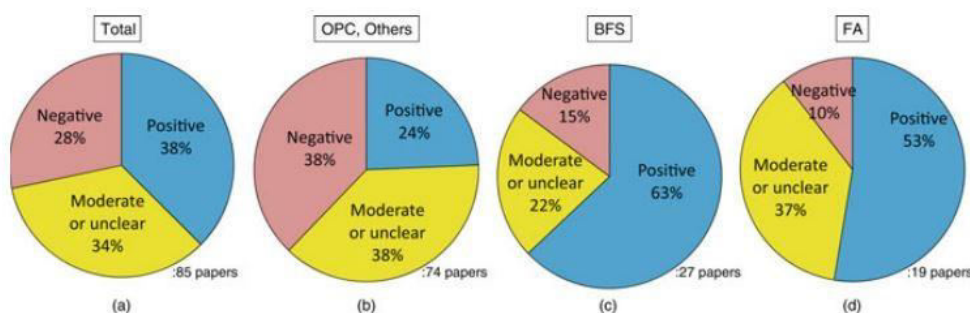


Figure 11: Compressive strength of freshwater Concrete and Seawater concrete [80].

A consequence of the hydration process is increased permeability and strength fall of the concrete matrix due to expansive products from hydration [12] and [59]. Moreover, SW is less resistant to sulphate attack than CC [72]. SW also increases shrinkage when dried [67], [68], [78], [79].

Comparing seawater mixing to freshwater blending [76], Seawater mixing improved concrete's carbonation resistance over the short and long term (25 years). Nevertheless, some studies claimed that freshwater and seawater concretes did not differ significantly in carbonation depth improvement [58,77].

Effects of Seawater and Sea-Sand on Concrete Properties ...



BFS refers to all slags of blast furnace (i.e. BFS, GBFS and GGBS)

Figure 12: Researcher's opinions about concrete mixed with Sea-water before 2015 [58].

Figure 12 shows that Nishida et al. [71] reviewed 85 publications on concrete mixed with SW. One-fourth of these 85 papers favoured SW in Concrete combined with SMCs. Islam et al. posit that the drying shrinkage deformation of sea-sand seawater concrete was lower when compared to concrete with cement powder [81], while Zhang et al. concluded that sea-sand seawater concrete followed the same direction as that of cement powder [81]. Fly ash might pose a challenge when using seawater concrete because drying shrinkage might be an issue, so applying sea sand to the concrete would have an impact. When seawater is used to produce Concrete, Amusan et al. report that gel pores enhance shrinkage resulting in concrete shrinking [104]. Fly ash in concrete can retard the strength loss resulting from seawater concrete mixtures [95].

In conclusion, various academics have determined that the effects of seawater on durability attributes are brought on by carbonation conduct, freeze-thaw resistance, drying shrinkage, chloride and sulfate diffusion, crawl resistance, and acid resistance in particular conditions. Other research indicates that marine concrete has a propensity to contract

and withstand freeze-thaw activity. Since drying shrinkage may be a problem and fly ash can delay the strength loss brought on by seawater concrete mixtures, fly ash may also present a challenge when used with seawater concrete. Given the increased demand for infrastructure, it is advised that all these elements, which appear to reduce concrete's durability, be taken into consideration. This will make it essential for the building sector to apply the best strategy to maintain existing structures.

### 3.4 Effect of Sea-water on the strength of concrete

Prior studies have demonstrated that seawater is an excellent solvent for curing and mixing concrete. In [92], bottom ash at a 10% permutation level is suggested as sand for fixing and mixing self-compacting concrete exposed to seawater. Concrete showed an increase in compression strength at an early age, but by 90 days after curing, the strength gains were gradually reduced. Seawater curing increases concrete's tensile strength by 10–20 percent. Still, there is no significant difference in the flexural strength of concrete beams prepared with fresh water and concrete beams prepared with seawater. [60].

During their investigation, researchers found that 5% NaCl cured concrete best. The strength of concrete initially increased with water with NaCl solutions but was then reduced by heat of hydration. [82].

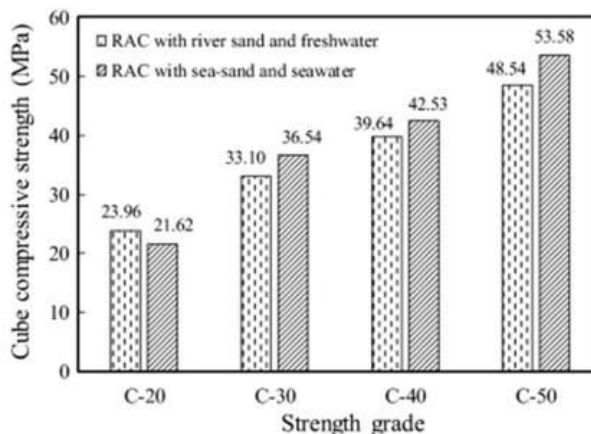


Figure 13: Compressive strength of control RAC and seawater sea-sand RAC [72].

In (Fig. 13), it can be seen that the use of sea-sand and its properties harm sea-sand seawater compressive strength. Furthermore, several studies [81,84] show that concrete made from sea sand usually has a reduced compressive strength due to organic soils, not delicate seashells.

Despite this, it was possible to measure the compressive strength of concrete with seashells and organic soil removed from the seawater, or with sea sand dosages ranging from 25% to 50%, or a mass ratio of sea sand to fine aggregate, after seashells and organic soil had been removed. Furthermore, due to its low fineness and low fineness on the surface, sea sand also improves its compressive strength to a certain extent [45].

As shown in Figure 14, sea-sand dosages and characteristics influence SSSC's compressive strength. It has been demonstrated that using sea sand containing seashells and clay can reduce the compression strength of concrete.

A strength degradation factor can be calculated mathematically by expressing the impact of sea sand and seawater on the compressive strength of concrete as follows:

$$SDF = (\sigma / \sigma_R - 1) \times 100 \tag{1}$$

Accordingly, sea sand and concrete have equal compressive strength (MPa)  $\sigma$  and  $\sigma_R$  comparable at the time of curing for the same curing condition and mixture proportions. Seawater also degrades steel reinforcement in concrete, increasing seawater concentration [91].

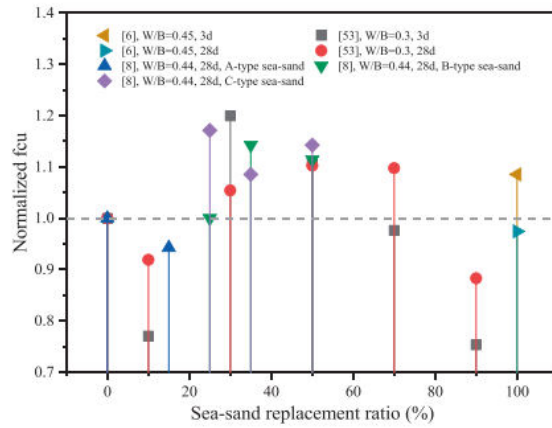


Figure14: An analysis of the effectiveness of sea-sand dosage and properties on compressive strength of sea-sand concrete. Y. Zhao et al. (2021).

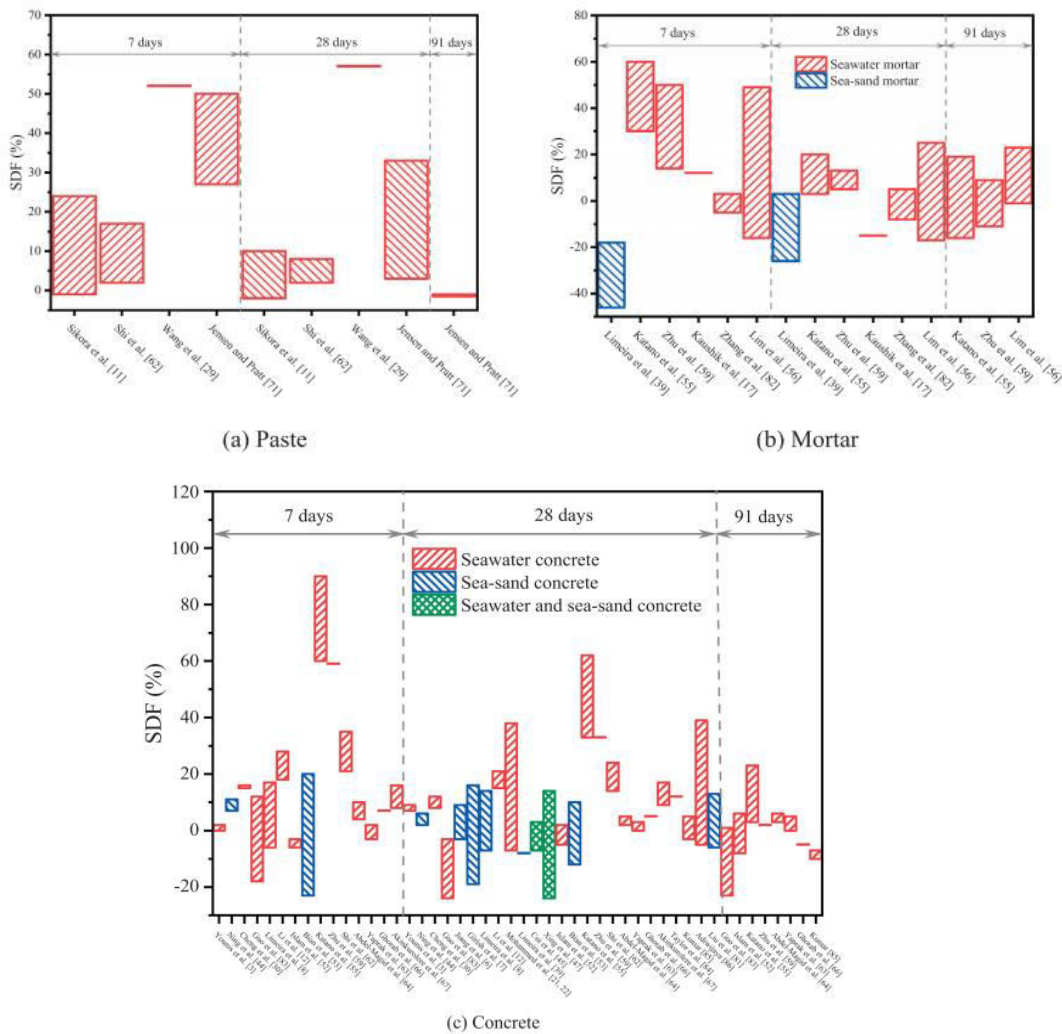


Figure 15: (a), (b), and (c) Strength of Concrete when exposed to seawater and sea sand [Y. Zhao, X. Hu, C. Shi et al.]

Based on relevant literature, (figure 15) illustrates SDF values after seven days, 28 days, and 91 days. Due to the reinforced microstructure of seawater, cement paste can increase its compression strength to 57%, thereby increasing its

maximum SDF value. Studies indicate that concrete and mortar compression strengths increase and decrease over time. Compression strength for concrete varies between 24 percent and 90 percent, whereas that for cement mortar varies between 46 percent and 60 percent. SDF values fluctuate less with increasing curing age, suggesting the compressive strength of SSSC becomes more erogenous when mixture proportions are raised at an early stage with rising sea sand to seawater ratios.

At twenty-eight (28) days, Zhao et al. (Fig. 14) show a reduction of 9% of the SDF (from 16 to 7) and an increase of 0.45 to 0.55 in the W/B ratio. The authors of [109] suggest that, at 28 curing days, seawater water has a 67% higher ettringite content than freshwater. In addition to compressive strength, SSSC's W/B ratio is influenced by its microstructure. The authors observed a stepwise reduction in chloride ingress after exposure to seawater. Concrete resistance to wetting and drying cycles influenced by W/B ratios was studied in [105].

In summary, scholars found that seawater is a great solvent for curing and mixing concrete in their research. According to other reports, concrete initially exhibited an increase in compression strength, but 90 days after curing, the strength improvements steadily decreased. With increasing curing age, SDF values also change less, indicating that the compressive strength of SSSC becomes more erogenous when combination proportions are enhanced early on with rising sea sand to saltwater ratios. Studies show that the compressive strengths of mortar and concrete change over time. Sea sand also enhances its compressive strength to some extent because of its low fineness and low fineness on the surface. However, concrete constructed from sea sand often has a lower compressive strength.

#### IV. CONCLUSION

This paper examines the available literature on the impacts of seawater and sea sand on concrete. Contradictory conclusions exist regarding how natural seawater affects concrete properties, such as tensile strength, workability, volume, density, compressive strength, colour, water absorption, bond strength, micro-structural behaviour, etc. Different regions may have other seawater properties, and geographical factors may play a role here. Climate differences also affect concrete infrastructures, which increases carbonation rates due to temperature variances and rising sea levels that alter marine exposure conditions. In this session, we discussed the following impacts on SSSC: physical properties, durability properties, workability, concrete strength, and the effect of seawater. Therefore, seawater is detrimental to the concrete structures constructed in marine environments in the long term, as it only negatively impacts concrete strength during its early stages. There is still work to be done to understand how substantial seawater can benefit each other. The influence gained cannot be maintained in such a relationship.

#### REFERENCES

- [1] J. Xiao, Q. Zhang, P. Zhang, L. Shen, C. Qiang, Mechanical behaviour of concrete using Sea-water and sea-sand with recycled coarse aggregates, *Struct. Concr.*1 (2019) 1–13.
- [2] A.F. Velegrakis, A. Ballay, S. Poulos, R. Radzevicius, F. Manso, European marine aggregates resources: origins, usage, prospecting and dredging techniques, *J. Coastal Res.* 51 (6) (2010) 1–15.
- [3] A. Younis, U. Ebead, P. Suraneni, A. Nanni, Fresh and hardened properties of seawater-mixed Concrete, *Constr. Build. Mater.* 190 (2018) 276–286.
- [4] Mangi SA, Wan Ibrahim MH, Jamaluddin N, Arshad MF, Ramadhansyah PJ (2019) Effects of ground coal bottom ash on the properties of concrete. *J EngSciTechnol* 14(1):338–350
- [5] Ali MF, Memon NA, Memon BA, Memon MA, Memon AN (2019) The effect of textile on compressive strength of concrete. *Quest Res J* 17(2):21–26
- [6] Jatoi MA, Solangi GS, Shaikh FA, Khan S, Ahmed S (2019) Effect of lakhra fly ash as partial replacement of cement in traditional concrete. *MehranUniv Res J EngTechnol* 38(4):1045–1057 <https://doi.org/10.22581/muet1982.1904.16>
- [7] Mangi SA, Wan Ibrahim MH, Jamaluddin N, Arshad MF, Memon FA, Jaya PR, & Shahidan S (2018) A review on potential use of coal bottom ash as supplementary cementing material in sustainable concrete construction. *Int J IntegrEng* 10(9):127–135
- [8] YT Li, L. Zhou, M. Jiang, Y. Zhang, J. Shao, Experimental study on the concrete mechanical property based on seawater and sea sand, *Adv. Mater. Res.* 641– 642 (2013) 574–577.
- [9] Y. Jiang, J. Liu, W. Sun, C. Zheng, S. Wu, Study on the properties of sea sand concrete with fly ash, *Adv. Mater. Res.* 1065–1069 (2015) 1854–1857.



- [10] CG Girish, D. Tensing, KL Priya, et al., Dredged off-shore sand as a replacement for fine aggregate in Concrete, *Int. J. Eng. Sci. Emerg. Technol.* 8 (3) (2015) 88–95
- [11] Islam M, Islam S, Mondal BC, Islam MR (2010) Strength behaviour of mortar using slag with cement in seawater environment. *J CivEng* 38(2):129–140
- [12] Islam MS, Islam MM, Mondal BC (2010) Effect of freeze-thaw action on marine concrete's physical and mechanical behaviour. *J InstEng Malaysia* 71(1):53–64
- [13] Ahn N (2005) Effects of C3A and mineral admixtures on the sulfate attack using ASTM C 1012. *J ASTM Int* 2(2):1–20. <https://doi.org/10.1520/JAI12472>.
- [14] Chapman GP (1968) The sea-dredged sand and gravel industry of Great Britain. In: *Proceedings of the symposium: sea-dredged aggregates for concrete, sand and gravel association Great Britain Buckinghamshire, UK*
- [15] Newman K (1968) Sea-dredged aggregates for concrete. In: *Proceedings of the symposium: sea-dredged aggregates for concrete, sand and gravel association Great Britain Buckinghamshire, UK.*
- [16] Yifan Zhao, Xiang Hu, Caijun Shi, Zuhua Zhang, Deju Zhu, A review on seawater sea-sand Concrete: Mixture proportion, hydration, microstructure and properties, <https://doi.org/10.1016/j.conbuildmat.2021.123602>
- [17] H. Li, N. Farzadnia, C. Shi, The role of Sea-water in the interaction of slag and silica fume with cement in low water-to-binder ratio pastes at the early age of hydration, *Constr. Build. Mater.* 185 (2018) 508–518.
- [18] A. Cwirzen, P. Sztarmer, D. Sc, Effect of Baltic Seawater and binder type on frost durability of Concrete, *J. Mater. Civ. Eng.* 26 (2) (2014) 283–287.
- [19] F. Fraternali, S. Spadea, V.P. Berardi, Effects of recycled PET fibres on the mechanical properties and seawater curing of Portland cement-based concrete, *Constr. Build. Mater.* 61 (2014) 293–302.
- [20] T. Nishida, N. Otsuki, H. Ohara, Z.M. Garba-Say, T. Nagata, Some Considerations for applicability of Sea-water as mixing water in Concrete, *J. Mater. Civil. Eng.* 27 (7) (2015) B4014004.
- [21] M. Moukwa, Deterioration of Concrete in cold sea waters, *Cem. Concr. Res.* 20 (3) (1990) 439–446
- [22] P. Solution, M. In, SEA Water, Alkali-silica reaction and pore solution composition in mortars in seawater, *Cem. Concr. Res.* 26 (12) (1996) 1809–1819.
- [23] T.U. Mohammed, H. Hamada, Long-term performance of alumina cement concrete mixed with tap water and Sea-water, *ACI Mater. J.* 101 (3) (2004) 226–232.
- [24] TU. Mohammed, H. Hamada, T. Yamaji, Performance of seawater-mixed Concrete in the tidal environment, *Cem. Concr. Res.* 34 (4) (2004) 593–601.
- [25] E. Ganjian, H. Sadeghi, Effect of magnesium and sulfate ions on the durability of silica fume blended mixes exposed to the seawater tidal zone, *Cem. Concr. Res.* 35 (7) (2005) 1332–1343
- [26] A. Province, Viscosity and anti washout properties of cement Mortar at low-temperature seawater environment, *Asian J. Chem.* 26 (6) (2014) 1595–1598.
- [27] K. De Weerd, H. Justness, M.R. Geiker, Changes in the phase assemblage of concrete exposed to seawater, *Cem. Concr. Compos.* 47 (2014) 53–63.
- [28] K. De Weerd, H. Justness, The effect of seawater on the phase assemblage of hydrated cement paste, *Cem. Concr. Compos.* 55 (2015) 215–222.
- [29] Y. Huang, X. He, Q. Wang, Y. Sun, Mechanical properties of sea sand recycled aggregate concrete under axial compression, *Constr. Build. Mater.* 175 (2018) 55–63.
- [30] A.M. Rashad, A.S. Ouda, D.M. Sadek, Behavior of alkali-activated metakaolin paste blended with quartz powder exposed to seawater attack, *J. Mater. Civ. Eng* 30 (8) (2018) 1–8.
- [31] J. Wang, E. Liu, L. Li, Multiscale investigations on hydration mechanisms in Seawater OPC paste, *Constr. Build. Mater.* 191 (2018) 891–903.
- [32] S. Cheng, Z. Shui, T. Sun, Y. Huang, K. Liu, Effects of Seawater and supplementary cementitious materials on the durability and microstructure of lightweight aggregate Concrete, *Constr. Build. Mater.* 190 (2018) 1081–1090.
- [33] J.A. Cotruvo, Water desalinization processes and associated health and environmental issues, *Water Condition. Purif.* 47 (1) (2005) 13–17.
- [34] A. D1141–98, Standard Practice for the Preparation of Substitute Ocean Water, ASTM International, West Conshohocken, PA, USA, 2013, p. 2013.
- [35] T. Dhondy, A. Remennikov, M. ASCE, M. Neaz Sheikh, Properties and application of sea sand in sea sand-seawater Concrete, *J. Mater. Civ. Eng.* 32 (12) (2020) 04020392.
- [36] E.D. Goldberg, *Marine Geochem.:Annu. Rev. Phys. Chem.* 12 (1) (2003) 29–48

- [36] SK Kaushik, S. Islam, Suitability of seawater for mixing structural concrete exposed to a marine environment, *Cem. Concr. Compos.* 17 (3) (1995) 177–185.
- [37] F.M. Wegian, Effect of Sea-water for mixing and curing on structural Concrete, *IES, J. Part A Civ. Struct. Eng.* 3 (4) (2010) 235–243.
- [38] L. Shi, J. Liu, J.P. Liu, X.L. Gao, W.N. Zhang, Q. Jiang, Transmission and binding behaviour of chloride ion in concrete under sulfate ion coupling effect in the marine environment, *Concrete* 348 (10) (2018) 67–71.
- [39] O.S.B. Al-Amoudi, Rasheeduzzafar, M. Maslehuddin, S.N. Abduljawwad, Influence of chloride ions on sulphate deterioration in plain and blended cement, *Mag. Concr. Res.* 46 (167) (1994) 113–123.
- [40] M. Frias, S. Goñi, R. García, R.V. De La Villa, Seawater effect on durability of ternary cements. Synergy of chloride and sulphate ions, *Compos. Part B* 46 (2013) 173–178.
- [41] S. Wang, X. Liu, D. Dai, X. Li, H. Chen, Distribution characteristic of marine aggregate resources and potential prospect in China, *Mar. Geol. Quat. Geol.* 23 (3) (2003) 83–89 (in Chinese).
- [42] M. Etxeberria, J.M. Fernandez, J. Limeira, Secondary aggregates and seawater employment for sustainable concrete dyke blocks production: case study, *Constr. Build. Mater.* 113 (2016) 586–595.
- [43] J. Limeira, L. Agullo, M. Etxeberria, Dredged marine sand in concrete: an experimental section of a harbour pavement, *Constr. Build. Mater.* 24 (6) (2010) 863–870.
- [44] W. Sun, J.Z. Liu, J.L. Yan, Y.H. Dai, Study on the influence of chloride ions content on the sea sand concrete performance, *Am. J. Civ. Eng.* 4 (2) (2016) 50–54.
- [45] J. Limeira, M. Etxeberria, L. Agulló, D. Molina, Mechanical and durability properties of concrete made with dredged marine sand, *Constr. Build. Mater.* 25 (11) (2011) 4165–4174.
- [46] W. Liu, H. Cui, Z. Dong, F. Xing, H. Zhang, T.Y. Lo, Carbonation of Concrete made with dredged marine sand and its effect on chloride binding, *Constr. Build. Mater.* 120 (2016) 1–9
- [47] P.J.M. Monteiro, S.A. Miller, A. Horvath, Towards sustainable Concrete, *Nat. Mater.* 22 (2017) 698–699, <https://doi.org/10.1038/nmat4930>.
- [48] F.U.A. Shaikh, Mechanical and durability properties of fly ash geopolymer concrete containing recycled coarse aggregates, *Int. J. Sustainable Built Environ* 5 (2016) 277–287, <https://doi.org/10.1016/j.ijbsbe.2016.05.009>
- [49] Li YL, Zhao XL, Singh Raman RK, et al. (2018c) Thermal and mechanical properties of alkali-activated slag paste, mortar and concrete utilizing seawater and sea sand. *Construction and Building Materials* 159: 704–724.
- [50] Mehta PK and Monteiro PJM (2006) *Concrete: Microstructure, Properties, and Materials*. 3rd ed. New York: McGraw-Hill.
- [51] ASTM C33/C33M (2018) Standard specification for concrete aggregates.
- [52] Roeder AR (1968) Some technical data on sea-dredged aggregates. In: *Proceedings of the symposium: sea-dredged aggregates for concrete, sand and gravel association Great Britain Buckinghamshire, UK*.
- [53] Shacklock BW (1968) Durability of Concrete made with sea-dredged aggregate. In: *Proceedings of the symposium: sea-dredged aggregates for concrete, sand and gravel association Great Britain Buckinghamshire, UK*.
- [54] Griffin DF, Henry RL (1964) The effect of salt in concrete on compressive strength, water vapour transmission, and corrosion of reinforcing steel. *Port Hueneme, California*.
- [55] Yamazaki K (1974) Viewpoints on using sea sand in concrete as fine aggregates in Japan. *Concr J* 12(10):72–76.
- [56] Garel E, Bonne W, Collins MB (2009) Off-shore sand and gravel mining. In: Steele JH (ed) *Encyclopedia of ocean sciences*, 2nd edn. Academic Press, Oxford.
- [57] C. M. Wang et al. (eds.), EASEC16, Lecture Notes in Civil Engineering 101, [https://doi.org/10.1007/978-981-15-8079-6\\_187](https://doi.org/10.1007/978-981-15-8079-6_187).
- [58] Otsuki N, Hamada H, Takeda N, Imamoto K.-I, Yamaji T, Habuchi T, Nishida T (2014) Technical Committee on the use of seawater in concrete.
- [59] Islam S, Kaushik SK, Islam M (2005) Physical and mechanical behaviour of concrete in seawater under high hydrostatic pressure. *JInstEng Malaysia* 66(2):46–52.
- [60] Isam AMT, Mahgoub OO, Haider IO, Tarig MR, Osman HS, Abdel-Hafiz BA (2016) Influence of Sea-water in strengths of concrete mix design when used in mixing and curing. *Key Eng Mater* 711:382–389. <https://doi.org/10.4028/www.scientific.net/KEM.711.382>.
- [61] Mangi SA, Wan Ibrahim MH, Jamaluddin N, Arshad MF, Shahidan S (2019) Performances of Concrete containing coal bottom ash with different fineness as a supplementary cementitious material exposed to seawater. *EngSciTechnolInt J* 22(3):929–938. <https://doi.org/10.1016/j.jestch.2019.01.011>.

- [62] Abalaka AE, Babalaga AD (2011) Effects of sodium chloride solutions on compressive strength development of concrete containing rice husk ash. *ATBU J Environ Technol* 4(1):33–40.
- [63] T. Dhondy1; A. Remennikov, M.ASCE2; and M. Neaz Sheikh3 Properties and Application of Sea Sand in Sea Sand–Sea-water Concrete DOI:10.1061/(ASCE)MT.1943- 5533.0003475. © 2020 American Society of Civil Engineers.
- [64] Zheng X, Easa SM, Ye Y J (2018) Evaluating the feasibility of using seawater curing for green artificial reef concrete: *Constr Build Mater* 187:545-552. <https://doi.org/10.1016/j.conbuildmat.2018.07.140>
- [65] Katano K, Takeda N, Ishizeki Y, Iriya K (2013) Properties and application of concrete made with seawater and un-washed sea sand. In: Third international conference on sustainable construction materials and technologies. Kyoto, Japan.
- [66] Thomas K, Lisk WEA (1970) Effect of seawater from tropical areas on cement setting times. *Mater Struct* 3(14):101–105.
- [67] Khatibmasjed M (2018) sustainable Concrete using seawater and glass fibre reinforced polymer Bars. Doctor of Philosophy, University of Miami.
- [68] Younis A, Ebead U, Suraneni P, Nanni A (2018) Fresh and hardened properties of seawater-mixed concrete. *Constr Build Mater* 190:276–286.
- [69] Limeira J, Agulló L, Etxeberria M (2012) Dredged marine sand as a new source for construction materials. *J Materiales de Construcción* 62(305):7–18
- [70] Limeira J, Agulló L, Etxeberria M (2012) Dredged marine sand as construction material. *Eur J Environ CivEng* 16(8):906–918.
- [71] Nishida T, Otsuki N, Ohara H, Garba-Say ZM, Nagata T (2015) Some considerations for applicability of Sea-water as mixing water in concrete. *J Mater CivEng* 27(7):1–7. [https://doi.org/10.1061/\(ASCE\)MT.1943-5533.0001006](https://doi.org/10.1061/(ASCE)MT.1943-5533.0001006)
- [72] Xiao J, Qiang C, Nanni A, Zhang K (2017) Use of sea-sand and Sea-water in concrete construction: Current status and future opportunities. *Constr Build Mater* 155:1101–1111. <https://doi.org/10.1016/j.conbuildmat.2017.08.130>
- [73] Abalaka AE, Babalaga AD (2011) Effects of sodium chloride solutions on compressive strength development of concrete containing rice husk ash. *ATBU J Environ Technol* 4(1):33–40.
- [74] Chalee W, Jaturapitakkul C, Chindaprasirt P (2009) Predicting the chloride penetration of fly ash concrete in seawater. *Mar Struct* 22(3):341–353. <https://doi.org/10.1016/j.marstruc.2008.12.001>.
- [75] Girish CG, Tensing D, Priya KL (2015) Dredged off-shore sand as a replacement for fine aggregate in concrete. *Int J EngSciEmergTechnol* 8(3):88–95.
- [76] Adiwijaya (2015) A fundamental study on seawater-mixed concrete related to strength, carbonation and alkali-silica reaction. Doctor of Engineering, Kyushu University
- [77] Kaushik SK, Islam S (1995) Suitability of seawater for mixing structural concrete exposed to a marine environment. *CemConcr Compos* 17(3):177–185
- [78] Modupeola AG, Olutoge FA (2014) The effect of Sea-water on shrinkage properties of concrete. *Int J Res Eng. Technol* 2(10):1–12.
- [79] Park SS, Kwon S-J, Song H-W (2011) Analysis technique for restrained shrinkage of concrete containing chlorides. *Mater Struct* 44(2):475–486
- [80] Tiwari P, Chandak R, Yadav RK (2014) Effect of salt water on compressive strength of concrete. *Int J Eng. Res Appl* 4(4):38–42
- [81] Zhang Z, Sang Z, Zhang L, Ma Z, Zhang Y (2013) Experimental research on the durability of concrete made by Sea-water and sea sand. *Adv Mater Res* 641–642:385–388
- [82] Sukhavasi P, Patnaikuni CK, Venugopal NVS (2014) Variations of water absorption and compressive strengths for RHA concrete exposed to NaCl medium. *Int J Innov Res Sci Eng. Technol* 03(09):16257–16264. <https://doi.org/10.15680/ijirset.2014.0309064>.
- [83] W. Liu, Y.J. Xie, B.Q. Dong, F. Xing, Study on the characteristics of dredged marine sand and the mechanical properties of concrete made with dredged marine sand, *Bull. Chin. Ceram. Soc.* 33 (1) (2014) 15–22 (in Chinese).
- [84] U.G. Eziefula, J.C. Ezech, B.I. Eziefula, Properties of seashell aggregate concrete: a review, *Constr. Build. Mater.* 192 (2018) 287–300.
- [85] Mori Y et al. (1981) 10 years exposure test of concrete mixed with Sea-water under marine environment. *J CemAssoc* 35:341–344

- [86] Wegian FM (2010) Effect of Sea-water for mixing and curing on structural concrete. *IES J Part ACivStruct Eng.* 3(4):235–243.
- [87] Hong C, Fan Y, Zhang R, Wu H (2013) Research on the properties of sea sand concrete. *ApplMech Mater* 405–408:2899–2902.
- [88] Li YT, Zhou L, Jiang M, Zhang Y, Shao J (2013) Experimental study on the concrete mechanical property based on seawater and sea sand. *Adv Mater Res* 641–642:574–577.
- [89] Lim ED, Roxas CL, Gallardo R, Nishida T, Otsuki N (2015) Strength and corrosion behaviour of mortar mixed and cured with Sea-water with various fly ash replacement ratios. *Asian JCiv Eng.* 16(6):835–849.
- [90] Sun W, Liu J, Dai Y, Yan J (2016) Study on the influence of chloride ions content on the sea sand concrete performance. *American Journal of Civil Engineering* 4(2):50–54
- [91] Emmanuel AO, Oladipo FA (2012) Investigation of salinity effect on compressive strength of reinforced concrete. *J Sustain Dev* 5(6): 74–82. <https://doi.org/10.5539/jsd.v5n6p74>.
- [92] Wan Ibrahim MH, Hamzah AF, Jamaluddin N, Mangi SA, Ramadhansyah PJ (2020) Influence of bottom ash as a sand replacement material on the durability of self-compacting concrete exposed to seawater. *J Eng. SciTechnol* 15(1):555–571.
- [93] Mangi SA, Wan Ibrahim MH, Jamaluddin N, Arshad MF, Memon SA, Shahida S, Jaya RP (2019) Coal bottom ash as a sustainable supplementary cementitious material for the concrete exposed to seawater. In: *AIP Conference Proceedings*, vol 2119, no. July, pp 1–8. <https://doi.org/10.1063/1.5115361>.
- [94] Osuji S, Nwankwo E (2015) Marine water effect on compressive strength of Concrete: A case study of Escravos area of Nigerian Delta. *Niger J Technol* 34(2):240–244. <https://doi.org/10.4314/njt.v34i2.4>.
- [95] Ramesh Kumar GB, Mohamed Muzammil VR (2020) Fly ash in concrete using seawater A review. *Mater Today Proc* 22:890893. <https://doi.org/10.1016/j.matpr.2019.11.097>.
- [96] Mather B (1964) Effect of seawater on concrete
- [97] Jaya RP, Bakar BHA, Johari MAM, Ibrahim MHW, Hainin MR, Jayanti DS (2014) Strength and microstructure analysis of concrete containing rice husk ash under seawater attack by wetting and drying cycles. *AdvCem Res* 26(3):145–154. <https://doi.org/10.1680/ adcr.13.00010>.
- [98] Z. Shi, Z. Shui, Q. Li, H. Geng, Combined effect of metakaolin and sea water on performance and microstructures of Concrete, *Constr. Build. Mater.* 74 (2015)57–64.
- [99] T.I. Abdel-Magid, O.M. Osman, O.H. Ibrahim, R.T. Mohammed, S.O. Hassan, A.A.H. Bakkab, Influence of Sea-water in strengths of concrete mix design when used in mixing and curing, *Key Eng. Mater.* 711 (2016) 382–389.
- [100] X.M. Zhou, J.P. Li, C.L. Wang, Research on laws of sea sand on concrete durability performance impact, *Archit. Technol.* 48 (10) (2017) 1065–1066 (in Chinese).
- [101] O.O. Akinkulore, C. Jiang, O.M. Shobola, The influence of salt water on the compressive strength of Concrete, *J. Eng. Appl. Sci.* 2 (2) (2007) 412–415.
- [102] Q. Huang, X. Xiao, Y. Li, S. An, C. Chang, J. Wen, J. Dong, Research on the properties of magnesium oxychloride cement prepared with simulated Sea-water, *Adv. Cem. Res.* 30 (7) (2018) 1–8.
- [103] F. Xing, J. Liu, B.Q. Dong, Y. Huo, Combination procedure and mechanism of sea-sand type chlorine ions with cement materials, *J. Southeast Univ. (Engl.Ed.)* 36 (2006) 167–172 (in Chinese).
- [104] G.M. Amusan, A.O. Festus, The effect of Sea-water on shrinkage properties of Concrete, *Int. J. Res. Eng. Technol.* 2 (10) (2014) 1–12.
- [105] A. Dasar, D. Patah, H. Hamada, Y. Sagawa, D. Yamamoto, Applicability of Seawater as a mixing and curing agent in 4-year-old Concrete, *Constr. Build. Mater.* 259 (2020) 119692.
- [106] F. Selicato, M. Moro, L. Bertolini, A. Nanni, Towards sustainability of concrete without chloride limits, *ACI Spec. Publ.* 305 (2015) 1–10.
- [107] L. Bian, SM Song, F. Li, Research on the durability of sea sand concrete, China,
- [108] *Concr. Cem. Prod.* (2) (2012) 11–14 (in Chinese).
- [109] C.L. Xie, Y. Zhang, X.X. Hu, Experimental research on concrete preparation with sea sand, *World Build. Mater.* 5 (2015) 20–23.
- [110] P. Li, W. Li, T. Yu, F. Qu, V.W.Y. Tam, Investigation on early-age hydration, mechanical properties and microstructure of seawater sea sand cement mortar, *Constr. Build. Mater.* 249 (2020) 118776.
- [111] K.S. Nguyen, A.T. Nguyen-Phung, H.T. Le, et al., Chloride binding ability and anti-corrosion properties of super sulfated cement in sea-water/sand mixing concrete, *Congrès International De Géotechnique - Ouvrages – Structures*, Springer, Singapore (2017).



- [112]Y. Cao, C. Gehlen, U. Angst, L. Wang, Z. Wang, Y. Yao, Critical chloride content in reinforced concrete - an updated review considering Chinese experience. *Concr. Res.* 117 (5) (2009) 58–68.
- [113]H.Y. Ghorab, MS Hilal, A. Antar, Effect of mixing and curing waters on the behaviour of cement pastes and substantial part 2: microstructure of cement pastes, *Cem. Concr. Res.* 19 (6) (1990) 868–878.



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