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Full Length Research Paper

Study the impact of water quality on concrete properties

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This research empirically investigated the impact of mixing water quality on the properties of concrete. The water was collected of different qualities and sources from different locations in the Gaza strip. The TDS concentration in the mixing water was of arranging between 640(mg/l) to 35000(mg/l). 36 concrete cubes were produced at a ratio of 1: cement, 2: sand, 4: aggregate, 0.5: w/c using different TDS concentrations. The cubes were cured and crushed at 7, 14 and 28 days to measure the compressive strength. It was observed that the concrete produced with saltwater had their compressive strengths gradually increased (21.64, 23.18 and 30.35) % of freshwater in (7, 14 and 28 days) respectively. In addition, the setting time is decreasing with increasing the content of TDS. The setting time of seawater decreases by about 23.07% of freshwater. It is noticed that there are no problems to mix the concrete with saltwater with high TDS.

Keywords: Compressive strength, setting time, saltwater, seawater.

INTRODUCTION

Water is the most important component of the concrete mixture, as water has a significant impact on the properties of the concrete mixture. In Gaza Strip, a major problem in the usable water is faced, as the only source of usable water is groundwater. Over the decades the groundwater has been increasing its salinity ratio gradually, due to the large withdrawal of groundwater quantities, the withdrawal is compensated with quantities of seawater. This increased the salinity of groundwater (shomar et al., 2010).

In this research, all types of water quality (fresh-brackish – sea) water was analyzed. Some important elements that will be studied such as calcium, magnesium, hardness and TDS were identified and the effect of these elements on the properties of concrete.

Water has been collected from several different areas in the Gaza Strip to obtain several types of water of different quality.

And, it was found that the increase in concrete strength increased with the degree of salinity, as was found in the following article (Olutoge et al., 2014), and the setting time decreased with increased the degree of salinity.

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EXPERIMENTAL SETUP

Material

- **Ordinary Portland cement**

Portland cement is produced in a plant where raw materials are heated in a rotary kiln. The high heat in the kiln causes a chemical reaction that converts the raw materials to clinker. The clinker is then pulverized to form the cement.

Different types of cement are manufactured to meet different physical requirements and for specific purposes. European cement standard EN 197-1 defines 27 distinct common cement products and their constituents. The standard includes requirements for constituents and performance requirements in terms of mechanical, physical and chemical parameters for all 27 products, which are grouped into five main cement types as, illustrated in a table(1) (EN, T,197-1, Cement-Part1).

Table 1. Five main cement types according to EN 197-1

CEM I	Portland cement (>95% clinker).
CEM II	Portland-composite cement (65-94% clinker).
CEM I III	Blast furnace cement (5-64% clinker).
CEM IV	Pozzolanic cement (45-89% clinker).
CEM V	Composite cement (20-64% clinker).

In this research, Portland-composite cement 42.5 N CEM II/ A-M (SLV) with a trading name of NESHER cement was used for the preparation of the various mixes.

- **Aggregates**

According to ASTM, aggregates passing through the 4.75mm sieve are classified as fine aggregate whereas those retained on the 4.75 mm sieve are classified as coarse aggregates. Natural sand, silt and clay are usually used as fine aggregates while gravel, cobble and boulders are used as coarse aggregates.

The fine and coarse aggregates used in this research selected from the commonly used materials in Gaza Strip. Natural Gaza sand is used as fine aggregates. For coarse aggregates, three sizes of aggregates generally used in Gaza are selected; these are called Folyia, Adasia, and Semsemia, In this research, the coarse aggregate, which passes from sieve 19 mm and remains in sieve 12.5 mm were used, as shown in Figures 1 and 2.

Figure 1. Coarse aggregates

Figure 2. Natural Gaza sand

- **Water analysis**

Chemical analysis for water samples were carried out in the laboratory to determine the quality of water parameters as follows.

- Electronic conductivity (Ec).
- Total dissolved solids content (TDS).
- pH
- Total hardness content (T.H)
- Calcium hardness content (Ca.H)
- Magnesium hardness content (Mg.H)
- Nitrate content ($NO3^-$)
- Chloride content (CL^-)

Figure 3. Equipment Preparation

Figure 4. Manual mixing

Figure 5. The curing of cubes

Equipment preparation, mixing, casting and curing procedures

- **Equipment preparation**

Before the mixing process is started, and to ensure the optimal efficiency, all the equipment required are prepared and examined beforehand. These include cubic molds, lubricating oil, a standard compacting rod, mixing piles, curing tank. Some of the equipment used are shown in Figure 3 above.

- **Mixing**

The ingredients for each mix are weighted and prepared according to the percentages of concrete components we have prepared are (1:2:4:0.5)
1: cement, 2: sand, 4: agg, 0.5: w/c.
Manual mixing is used to prepare the different concrete mixtures as shown in Figure 4 above (ASTM C192- 16a).

- **Casting**

In this research, BS 1881 standard is followed to prepare the cubical specimens. (10x10x10) cm cubes are used as molds for the various concrete mixtures. Each cube is filled with concrete on two layers; each layer is compacted 25 times using a standard rod. Excess concrete is removed and the surface of the cube is leveled using afloat. The cubes are labeled and placed in room temperature for 24 hours. (BS 1881: Part 116)

- **Curing**

The curing process of cubes and is started immediately after demolding the specimens. All specimens are immersed in a water tank at room temperature until the day of breaking or further testing. Cubical specimens for compressive strength are kept in water for 7, 17 and 28 days. The curing of samples in water is shown in Figure 5 above (ASTM C192- 16a).

Figure 6. Breaking of cubical specimens

Testing procedures

- **Compressive strength of Cubic Specimens**

The Compressive strength test is primarily used to determine whether the concrete mixtures meet the requirements of a specified strength, (fc′) or not. The compressive strength of concrete is the most common performance measure used by engineers in designing buildings and other structures compressive strength is measured by breaking cubic concrete specimens in a compression-testing machine. The compressive strength is calculated from the failure load divided by the cross-sectional area of the specimen (BS 1881: Part 116).

σ_{comp}=P/A

In this research, BS 1881 standard is followed to prepare and test the various mixture specimens. (10x10x10) cm cubes are used as molds for the various concrete mixtures. On the breaking day, the cubes are removed from the water and are left to dry in air temperature. The weight and geometrical dimensions for each cube are measured before they are placed on the breaking machine. Without shock, the load is applied continuously at a nominal rate within the range of (0.2 N/mm2.s to 0.4 N/mm2.s) until no greater load can be sustained and the cube is broken. The breaking process is presented in Figure 6 above.

- **Normal consistency test**

Consistency is the cement's ability to flow. Vicat apparatus is used with a 10mm diameter plunger to perform the test. Standard consistency of cement pasties defined as the w/c% which will permit the plunger to penetrate to a depth of 10±1mm from top of the mold in 30 seconds. The results show that the w/c% for cement which will give 10mm penetration, that is the percentage for normal consistency is 25%.(ASTM C 187).

- **Initial and final time of setting of cement:**

Setting time tests are performed to determine if normal hydration is taking place in the first few hours. These tests are performed using the Vicat apparatus demonstrated in Figure 7. The device consists of a 1 mm needle that is allowed to settle freely into the cement paste. The initial setting time is recorded when the needle penetrates 25 mm into the paste, while the final setting time is recorded when the needle cannot penetrate the pastes. (ASTM C191-82).

Figure 7. Vicat apparatus

Table 2. Groundwater quality testes results

Parameter	Ec µS	TDS PPm	PH	T.H as CaCO3 mg/L	Ca.H as CoCA3 mg/L	Mg.H as CaCO3 mg/L	Ca++ mg/L	Mg++ mg/L	NO3- mg/L	CL- mg/L
A/205	1270	640	7.9	200	150	50	60	12	95	190
Prepared On the lap(1)	2900	1460	8.2	590	370	220	148	52.8	48.5	936
shijaa/9	3650	1820	8.2	490	230	260	92	63	131	1200
Prepared On the lap(2)	4460	2240	8.1	1280	900	380	360	91.2	81.8	1740
Prepared On the lap(3)	5270	2700	8.1	1390	770	620	308	148.8	88	2290
D/73	6000	3100	7.8	1700	970	730	388	173	105	2600
R/314	7390	3700	7.8	1790	1160	630	464	150	141	3200
J/32	8790	4390	7.7	1500	650	900	260	216	120	3400
k/21	9260	4640	7.9	2130	840	1290	336	310	67	3990
Seawater	63000	35000	9.17	8600	2100	6500	480	1650	-	20000

RESULTS AND DISCUSSION

- **Water quality results**

Table 2 shows the results of chemical analysis for the samples of water to determine the quality of each sample. The TDS in the groundwater ranges between 640 mg/l to 35000 mg/l.

- **Initial and final setting time**

The cement paste that produced the normally consistent specimen that used to measure the initial and final setting time. Table 3 presents the initial and final setting time results for a different quality of water samples. The results of this research show that the initial setting time is 208 min for freshwater, 196 min for brackish water and 160 min for saltwater. The final sitting time also decreasing for saltwater to reach 242 min. Therefore, it is possible to use seawater in cold areas for decreasing the setting time and have faster hydration process.

Table 3. Setting Time with types of water.

Type of water	TDS (mg/l)	I.S.T (min)	F.S.T (min)
Fresh	640	208	285
Brackish	4640	196	248
Salt (Seawater)	35000	160	242

- **Compressive Strength Test**

Table 4 below presents the results obtained from the compressive strength test of the concrete mixes. One 10-cm cube is tested for each breaking age, which is 7, 14 and 28 days.

Tables 5 and Figures 8, 9 below show that the compressive strength of fresh water mix (with 640 ppm of TDS at 1.83% from seawater content of TDS), increased from **211 KN/cm^2** at 7 days to **279 KN/cm^2** at 28 days with a 24.37% increase. Which are 17.8 and 23.28% less strength than the seawater mix (with 35000 ppm of TDS) at 7 and 28 days respectively.

The results also indicate that the compressive strength value is affected differently with the different types of water. The seawater mix produced the highest compressive strength among all mixes at 28 days. Its compressive strength increased from **257 KN/cm^2** at 7 days to **364 KN/cm^2** at 28 days with a 29.42% increase in comparison with its 7-days compressive strength. The Brackish water (with 4640 ppm of TDS at 13.26% from seawater content of TDS) increased from **183 KN/cm^2** at 7 days to **305 KN/cm^2** at 28 days with a 40% increase. Which are 28.7 and 16.3% less strength than the seawater mix at 7 and 28 days respectively. Whereas it produced 8.52%, more strength than the freshwater mix at 28.

Table 4. Compressive strength of concrete (KN/CM2**)**

			Compressive strength (KN/cm^2)		
Name	**Rang (TDS)**	**Value (mg/L)**	**7 Days**	**14 Days**	**28 Days**
A/205	1000≥	640	211	243	279
Prepared On the lap(1)	1000-1500	1460	214	246	319
Shijaa.9	1500-2000	1820	193	220	273
Prepared On the lap(2)	2000-2500	2240	210	278	306
Prepared On the lap(3)	2500-3000	2700	213	223	312
D/73	3000-3500	3100	215	281	283
R/314	3500-4000	3700	194	262	320
J/32	4000-4500	4390	185	235	290
k/21	4500-5000	4640	183	232	305
Sea Water	-	35000	257	299	364

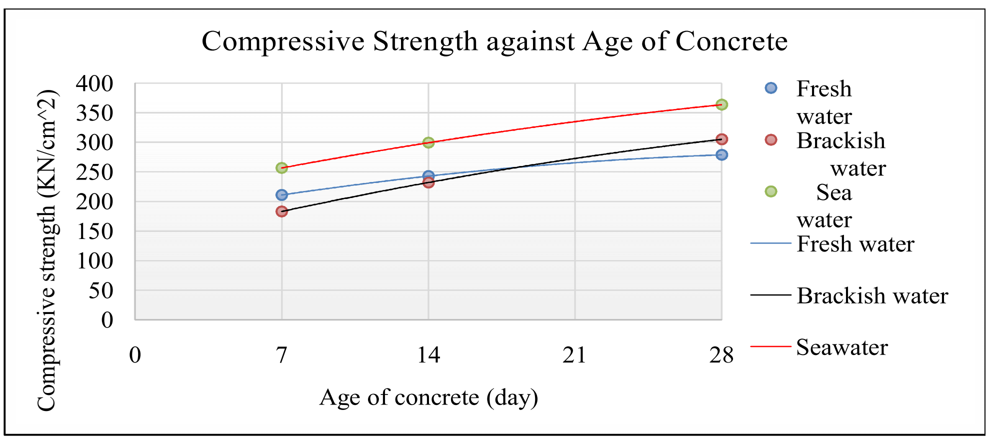

Figure 8. Compressive Strength against Age of Concrete for different types of water

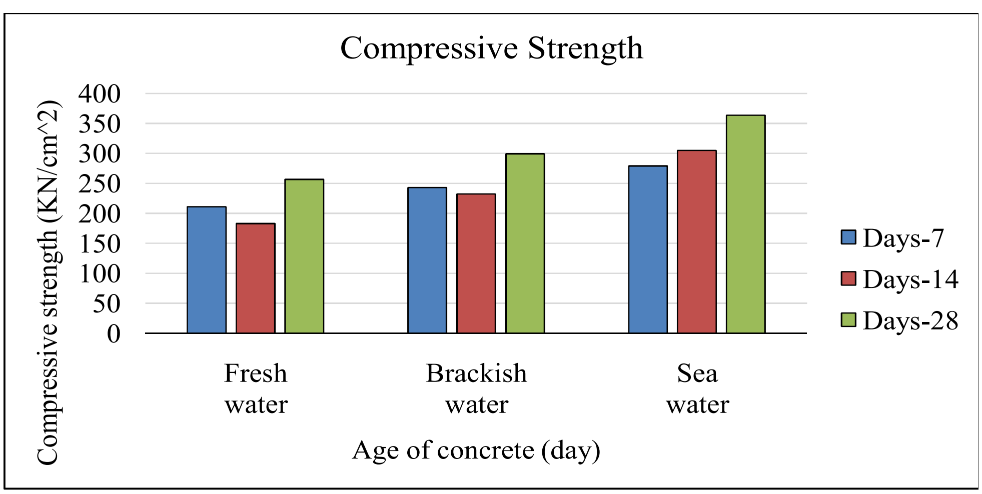

Figure 9. Compressive strength with different types of water for different types of water

Table 5. Compressive strength with different types of water.

Age of concrete (day)	Compressive strength (KN/cm^2)		
	Fresh water	Brackish water	Sea water
7	211	183	257
14	243	232	299
28	279	305	364

CONCLUSION

It can be concluded that:

1. The strength of concrete is different depending on the type of water, as is evident in this research, the strength increases as water salinity increases.The strength of the concrete prepared by seawater increases by about 30.35% of the concrete prepared by freshwater.
2. The seawater may include other components and chemicals may lead to an increase in the strength of concrete such as TDS, calcium and hardness.
3. The compressive strength of specimens having TDS more than 3500, showed in the early age (7 and 14) days a decrease in strength concerning the results of the reference. However, these specimens showed a higher strength at (28) days age.
4. The setting time certainly decreases with increases the content of (TDS ppm). This decreases the initial and final setting time of paste cement mixers, which can be explained due to the accelerated reaction of high concentration of TDS in water.
5. The setting time of the concrete prepared with seawater decreases by about 23.07% of the concrete of freshwater.

RECOMMENDATIONS

Based on the findings from this research, the followings can be recommended:

- The use of saltwater should be used for casting of concrete during construction most especially in the coastal environment.
- Further research should be carried to investigate the relation of other chemicals in seawater and the strength of concrete in addition to durability properties of concrete.

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