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Effect of Waste Water Type on Concrete Properties

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Abstract

The scarcity in water resources in Middle East (especially Palestine and Jordan) imposes difficulties and threats to local governments and water authorities to provide fresh water to the people. The rapid development in different industries in the last fifty years has led to the generation of huge amounts of waste water. For example, concrete production, stone cutting and tanning industries consume large quantities of fresh water which is needed for domestic use and generate different types of waste water.

The current research investigates the utilization of 8 types of waste water in concrete mixtures and how they affect some of its properties such as workability, compressive strength, splitting tensile strength and natural water absorption. The results of this study suggest excellent potential for the use of waste water from stone cutting industry in the production of structural concrete and other types of waste water in producing concrete for backfill and non-structural applications. This would allow for the preservation of tremendous amounts of fresh water for domestic use.

Keywords: Waste water, Stone Industry, Sustainable Concrete, Compressive strength.

Introduction

Communities across the world face water supply challenges due to increasing demand, drought, depletion and contamination of ground water. Palestine is among the countries with the scarcest renewable water resources per capita due to both natural and artificial constraints, amounting to only 100 m3 per capita per year. This is far below the per capita available in other countries in the Mediterranean and even in the world. At present water demands exceeds the available water supply. Surface water resources in the West Bank are very limited. The major source of fresh water supply in the West Bank and Gaza Strip is the groundwater. The West Bank has three aquifers: the western, northeastern and eastern. It is estimated that the total renewable groundwater resources in the West Bank is between 590 and 690 MCM/year [1]. A recent report by PCBS [2] showed that the quantity of water consumed in the industrial establishments in the Palestinian territories is about 3,1 MCM/month. In the West Bank about 1,67 MCM/month is consumed, and Gaza Strip consumed about 1,41 MCM/month.

Water reclamation, recycling, and reuse will help in resolving water resources issues by creating new sources of high-quality water supplies. The potential for reuse of treated domestic and industrial waste water is enormous. Part of the treated domestic waste water has been used for long time in agriculture; yet a huge amount of the industrial water across the world is still to be managed and reused.

One of the potential water resources is the utilization and reuse of domestic and industrial waste water for cement and concrete production. A popular criterion as to the suitability of water for mixing concrete is the expression that if water is fit to drink it is suitable for making concrete. Other criteria attempting to ensure the suitability of water for batching fresh concrete require that the water be clean and free from deleterious materials. However these specifications may not be the best basis for evaluation of the suitability of water as mixing water. Some waters which do not meet these criteria have been found to produce concretes of satisfactory quality [3]. Waste water reuse provides a wide range of benefits to communities. One of the most significant benefits of waste water reclamation is the value created by the inclusion of waste water reuse in integrated water resources management to achieve long-term sustainability of our water supplies. All evidence suggests that water recycling and reuse will lay and expanded role in water management in the 21st century especially in semi-arid regions.

Objectives

The main objective of this study is to investigate the potential use of different types of domestic and industrial waste water in cement and concrete production. The effect of waste water on the plastic and hardened properties of concrete was investigated. It is important to compare the performance of concrete made with tap water and different types of waste water. The study is an integration of the world wide trend to the utilization of waste water in cement and concrete production instead of using fresh water. Utilization of industrial and domestic treated waste water will increase the reserve in the countries suffering scarcity of fresh water, and will have good impact on the environment. To the best knowledge of the author, there are limited studies in the literature which investigate the effect of different types of waste water on concrete properties. However, few studies were cited which investigated the effect of one type of waste water on concrete properties.

The study variables consist of 7 types of waste water and the tap water. Three curing time (7, 14 and 28 days), and 5 tests namely slump, compressive strength, splitting tensile strength, absorption and compressive strength for mortar specimens.

Theoretical Framework

So far water is abundantly available almost everywhere, and being freely used for all purposes including the cement and concrete industry. However, construction practice codes routinely recommend the use of potable water for concrete mixing and curing [4].

Meyer [5] has reported that over ten billion tons of concrete is produced worldwide each year. Such volumes require vast amount of natural resources for aggregate and cement production. In addition, it has been estimated that the production of one ton of Portland cement causes the release of one ton of CO_2 into the atmosphere. Also, the water requirements are enormous and particularly burdensome in the regions of the earth that are not blessed with abundant fresh water. The concrete industry uses over 1 trillion gallons of water worldwide each year, and this does not even include wash water and curing water. In setting strategies for concrete to be used as a green building material, Meyer suggested to reuse wash water for concrete production. The recycling of wash water is readily achieved in practice and already required by law in some countries.

The fresh water is getting scarcer every day. Although there is a lot of water on earth, less than 3% is fresh and most of that is either locked up in fast-melting glaciers and ice caps, or is too deep in the earth to retrieve. In recent press reports, the Indian government expressed deep concern over a future water shortage in the country due to global warming, the Himalayan glaciers, which are the primary source of water in Indian rives, have receded by 30 m (100 ft) during the past 2 years alone. Due to growing agricultural, urban, and industrial needs, available fresh water in every continent is decreasing. Increasing pollution of the rivers, lakes and streams compounds the problem. It has been suggested that with water, as with energy, the only practical, large scale solution is to use what resources we have far more efficiently. Regrettably, we're making the same mistake with water as with energy. We're depleting nonrenewable water resources rapidly and seeking yet more water. As one of the largest industrial consumers of fresh water, it's imperative for the concrete industry to use water more efficiently. In addition to approximately 100 l/m^3 (20 gal/yd^3) wash-water used by the ready-mixed concrete trucks, we're using too much water for concrete mixing [6].

Researchers [7,8] have suggested that the increasing concern of disposal of wash water from ready-mix concrete trucks, need to be addressed. Therefore, they conducted a research project to investigate the potential use of recycled wash waste water in the production of fresh concrete and mortar.

Rakesh and Dubey [9] have investigated 3 types of water beside the tap water for concrete mix, and they found no variation in compressive strength for grade M20 concrete. The types of water used were mineral water, tap water, well water and waste water.

Recent study [10] have reviewed the literature related to the effect of water quality on concrete, the results revealed that the use of impure water for concrete mixing is seen to favorable for strength development at early ages and reduction in long term strength.

The effect of source of water on compressive strength of concrete have been studied by author [11], and results indicated that river water could be considered for mixing where tap water is scarce. However, other properties such as shrinkage and durability should be investigated.

The impact of water quality on strength properties of concrete has been studied [12]. The results showed that Potable water results in good strength properties of concrete when compared to sewage water.

The effect of waste water coming from a medium size ready-mixed concrete plant, in mixing water on concrete and mortar has been studied by other authors [13]. The authors investigated the hysical-mechanical properties and microstructure of concrete as a function of the characteristics of waste water used. The results have shown that mortar and concrete prepared with recycled water exhibit 28-day compressive strength in no way lower that 96% of the reference materials, and in some cases even better. Moreover, the use of wash water in concrete leads to a reduction of the concrete capillary water absorption and mortar micro porosity, which surely improves the durability of the material. This effect can be ascribed to the filling action of the fines present in the wash water and to the slight reduction of the actual water/cement ratio.

The effect of using wash water and underground water on properties of concrete has been reported by some authors [14]. Water used in their study includes tap water, underground water and wash water from mixer washout operations in a ready-mixed concrete plant. The study concluded that, underground water should be considered as mixing water for concrete and wash water be recycled where tap water resources are scarce.

Another study [15] has reported the effect of wash water on concrete properties and durability. The wash water was used as a replacement of fresh water varying from 0% to 100% by weight. The water –to-cement ratios were 0.5, 0.6, and 0.7, respectively. In this study the wash water used was tested and found to have high alkalinity and the total dissolved solids content exceeding the limit of ASTM C94 [16,17], contributing to the more porous and weaker matrix. As a result, when increasing the percentage of wash water in mixing water, the drying shrinkage and weight loss due to acid attacks increased, and the slump and strength decreased. However, the unit weight and temperature of fresh concrete was not affected by the use of wash water.

Recycling waste water in ready-mix concrete production has been addressed in the final report by Chini et al. [18, 19]. The research results showed that both recycled materials wash waste water can be used in concrete production. The results of using waste water from wash water have minute effect on the properties of fresh and hardened concrete.

Researchers from Kuwait [20] have investigated the suitability of using treated waste water for mixing concrete. In their study, they used different types of waste water from Regga wastewater treatment plant in Kuwait. The results revealed that all waste water used did not affect the concrete slump and density. However, setting times were found to increase with deteriorating water quality. They concluded that tertiary treated wastewater produced from wastewater treatment plant in Kuwait, is suitable for mixing concrete with no adverse effects.

Another study [21] reported results on the effect of water quality on the strength of flowable fill mixtures. They used about 9 types of ground and production waste water. The results indicated that the use of non-fresh water will produce lower compressive strength in comparison with tap water. However, all water types would still generate an acceptable 28-day strength requirement of 350-3500 kPa for flowable fills. With the exception of a few mixes, flowable fill blends prepared using brackish groundwater gave higher strength than mixes prepared using oily production water. Generally, there was no appreciable difference in slump values for most of the mixes.

The effect of used engine oil on properties of fresh and hardened concrete has been studied by some authors [22]. The results showed that used engine oil increased the slump and percentage of entrained air of the fresh concrete mix, and did not adversely affect the strength properties of hardened concrete.

In Palestine, the stone cutting industry uses large volume of water for cooling purposes and produces large volume of sludge. The estimated volume of water used by the stone cutting industry (only) is about 570 m3 per day which is necessary for domestic uses. The moisture content (waste water) of the stone slurry is about 62%, [23].

The disposal of both the waste water and the stone slurry waste in the disposal site, sewerage net work or open agricultural lands is costly and environmentally unacceptable. A limited number (30-40%) of the stone industry companies, in the West Bank have recycled waste water from stone slurry by means of special pressing machines which cost about $50,000. The rest of the stone industry companies do not have pressing machines and therefore, get red of the stone slurry waste in open dumping sites and sewerage systems.

Stone slurry waste has been characterized and reused in various processes. The stone powder from stone slurry has been incorporated in concrete industry up to 25% replacement of fine materials. The recycled water has been reused in stone industry several times, before they get red of it the sewage network, because it contains heavy metals and can't be used for agriculture or other purposes.

Some scientist believed that the yearly global mixing water requirement can be cut in half by better aggregate grading and by greatly expanding the use of mineral admixtures and super plasticizers. Moreover, why should the industry use municipal, drinking water for mixing concrete? Most recycled industrial waters or even brackish natural waters are suitable for making concrete, unless proven otherwise by testing. This is even true for wash-water and curing water.

Materials and Methods

A. Water used

Eight types of waste water were used in this study, the tap water, salty water (5% and 10% of salt by weight), oily water (5% and 10 by weight), primary treated sewerage water, water from stone slurry waste and waste water from tanning industry. The salty and oily waters were prepared by adding 5% and 10% by weight, salt and lube oil (engine oil) to the tap water. All types of water were analyzed for pH, salinity, electrical conductivity (EC) and total dissolved solids (TDS). The tests results are presented in Table (1).

TABLE 1. Properties of Waste Water Used

Type of Water	TDS* (g/L)	EC* (mS/cm)	Salinity (%)	pH
Tap	0.342	0.703	0.3	6.76
5% Salt	44.7	68	47.2	6.80
10% Salt	80.5	124.1	84	6.62
5% Oil	0.274	0.565	0.3	7.57
10% Oil	0.148	0.308	0.1	7.47
Treated Waste	1.641	3.2	1.7	7.49
Stone Slurry	0.68	1.37	0.7	8.31
Tanning	51.7	95.1	53	0.98

B. Concrete Mixtures

The concrete mixture was designed to achieve a nominal 28 days concrete compressive strength of 250 kg/cm2, by using the ordinary tap water. Other mixtures were prepared with the same W/C ratio, by changing the type of mixing water in each batch. No admixtures were used in the concrete mixtures. The research variables are seven types of waste water in addition to the tap water, and curing time (7, 14 and 28 days).

C. *Testing*

There are no special tests developed to determine the suitability of mixing water except comparative tests (Pierce, 1994). Generally, comparative tests require that, if the quality of water is not known, the strength of the concrete made with water in question should be compared with the strength of concrete made with water of known suitability. Both concretes should be made with cement proposed to be used in the construction works.

Workability of fresh concrete was investigated by slump test according to ASTM C143 / C143M. Compressive strength measurements were carried out on concrete samples of standard size (10x10x10 cm), cured at room temperature for 7, 14 and 28 days, according to ASTM C39. The splitting tensile strength was conducted on specimens (15 cm diameter and 30 heights) cured for 7 and 28 days, according to ASTM C496. The natural absorption test was carried out on cubes cured for 28 days in water, oven dried and immersed in water for 2 days.

In order to investigate the effect of waste water quality on the material microstructure without taking into account the contribution of coarse aggregate, compressive strength tests on mortar specimens, were conducted after 7 days curing.

Experimental Results

Table (2) summarizes all test results. The results showed that when salty and oily water were used in the concrete mixtures, the slump was higher compared with tap water and other types of waste water used. The maximum slump was obtained when 10% salty and oily water were used. The minimum slump observed when stone slurry water was used in concrete mixture. This is because the stone slurry water Contains a large amount of sediments in the forms of solids and fine particles, which tend to increase the amount of water to be adsorbed at the surface and absorbed into the particle, and consequently lower the concrete slump.

TABLE.2. Summary of Experimental Tests Results

	Compressive Strength (kg/cm2)			**Split. Tensile Strength (kg/cm2)**		**Comp. Str. (Mortar) (kg/cm2)**	**Natural Absorption (%)**	**Slump, (cm)**
	Curing days)			Curing (days)		Curing (days)		
	7	14	28	7	28	7	28	28
Tap Water	179	240	262	6	13	140	4.53	3
Salty Water, 5%	150	226	272	5.5	10.4	178	4.03	10
Salty Water, 10%	184	252	274	7.1	10.4	247	4.01	20
Oily Water, 5%	131	147	170	6.2	6.5	219	4.88	12
Oily Water, 10%	127	169	212	6.4	6.6	151	4.01	14
Treated Waste Water	157	217	233	6.1	10.3	129	4.35	7
Stone Slurry Water	179	204	313	8.2	14.4	157	4.26	1
Tanning Water	168	214	239	6.6	10.8	131	4.47	3

A. Compressive Strength of Concrete (ASTM C39)

It is noticed that, when 5% salty water was used in concrete mixtures, the early age compressive strengths (after 7 days curing) was 84% of that made with tap water. The early age strength of concrete made with 10% salty water was 103% of that made with tap water. The compressive strength of concrete made with 5% and 10% salty water was higher than that for concrete made with tap water after 28 days curing. Thus, one could argue that beyond 21 days curing, the compressive strength of concrete made with 5% and 10% salty water will not be less than 100% of the compressive strength of concrete made with tap water (Figure 1).

On the contrary, when oily water was used in concrete mixtures, the compressive strength after 7 days curing was almost 73% of that made with tap water, for both types of waste water (5% and 10% oily). However, after 28 days curing, the compressive strength of concrete made with 10% oily water was higher than that made with 5% oily water, but well below the strength of concrete made with tap water for both types of oily water (Figure 2).

The compressive strength of concrete made with primary treated domestic waste water was about 88% of that made with tap water, at all ages (Figure 3).

Concrete specimens made with stone slurry waste water exhibited the optimum compressive strength after 28 days. The gain of strength was slow at early ages, but after 28 days the compressive strength was 19% higher than that of concrete made with tap water (Figure 4). Using the tanning waste water in concrete mixtures led to reduction in compressive strength of 7% after 28 days curing (Figure 5).

B. Splitting Tensile Strength of Concrete (ASTM C496)

The splitting tensile strength is carried out by applying a compressive force along the diameter of cylindrical concrete specimens (15 cm diameter and 30 cm height). This loading induces tensile stresses on the plane containing the applied load. The maximum splitting tensile strength was attained when stone slurry water was used as mixing water. The strength after 28 days curing was 14.4 kg/cm2, this value represents 4.6% of the compressive strength of the same concrete batch, and was about 11% higher than the splitting tensile strength of concrete specimens made with tap water.

The splitting tensile strength of concrete made with salty water (5% and 10% by weight) was 10.4 kg/cm2, this value represent about 4% of the compressive strength of the same concrete after 28 days curing. The minimum splitting tensile strength values were attained when oily water was used as mixing water. The tensile strength varied between 6.2 to 6.6 kg/cm^2 after 7 and 28 days curing, respectively.

C. *Compressive Strength of Mortar (ASTM C109)*

This test provides a means of determining the compressive strength of hydraulic cement and other mortars. The compressive strength of mortar cube (5x5x5 cm3) was determined after 7 days curing. The results varied between 135 and 158 kg/cm2 (Table 3). The minor variation in compressive strength of mortar, suggest that waste water has a minute effect the overall strength of concrete after 7 days curing. However, using stone slurry water and the 5% salty water has increased the compressive strength of mortar about 12% and 13% respectively. The 10% salty water produced mortar specimens with compressive strength 5% higher than that made with tap water. The compressive strength of mortar specimens made with other types of waste water varied between 95% and 97% of that mixed with tap water. These values conform to the American Standard ASTM C 94, which requires that the age of 28 days mortar strengths made with test water to be a minimum of 90% of the strength of cubes made with tap water.

D. Absorption of Concrete

Absorption tests of concrete specimens were conducted after 28 days curing. The concrete cubes were cured in the normal procedure for 28 days, then removed from the curing chamber and oven dried for 24 hours at 110 Co. The specimens immersed in water for 2 days before the natural absorption was computed from the difference in dry and wet weights. Changing the type of waste water in concrete mixtures did not affect the natural absorption significantly (Table 3). However, using salt water in concrete mixtures reduced natural absorption about 0.5%. Stone slurry waste water also, reduced absorption by 0.27%. These data suggest that precipitation of fine suspended particle in the water can act as fine fillers in the hardened concrete.

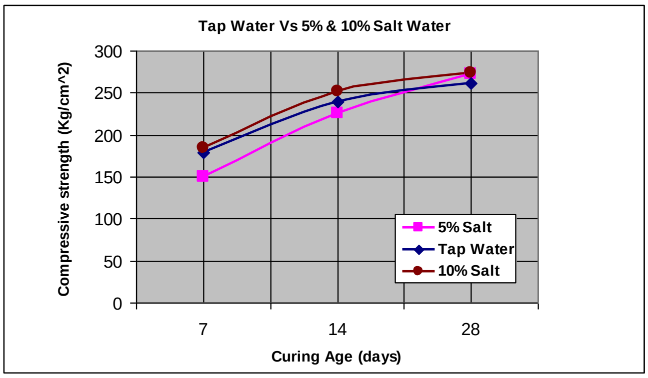

Fig.1.Compressive Strength of Concrete With Tap Water and 5%, 10% Salt Water

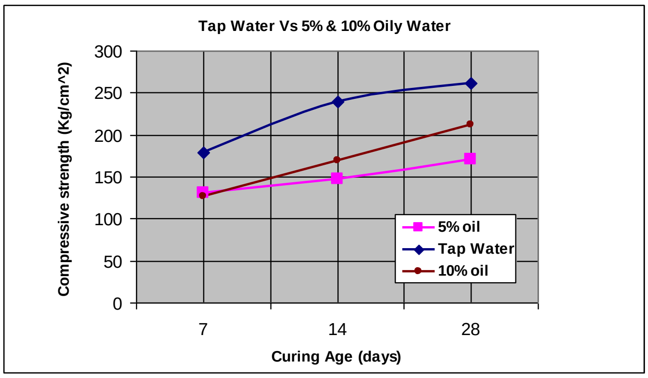

Fig.2.Compressive Strength of Concrete With Tap Water And 5%, 10% Oil Water

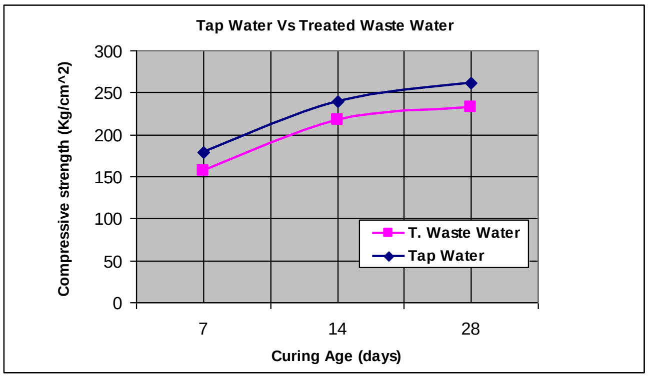

Fig.3.Compressive Strength of Concrete With Tap Water And Treated Waste Water

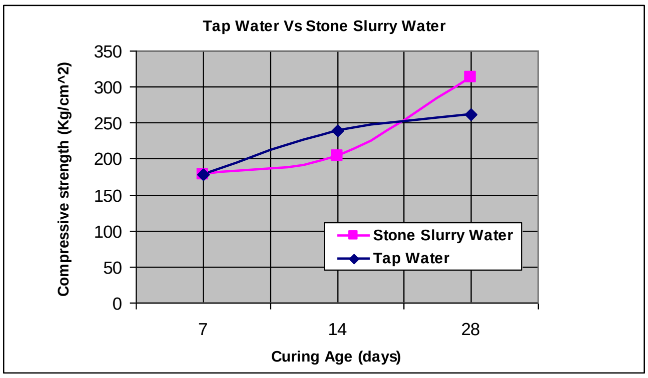

Fig.4.Compressive Strength of Concrete With Tap Water and Stone Slurry Water

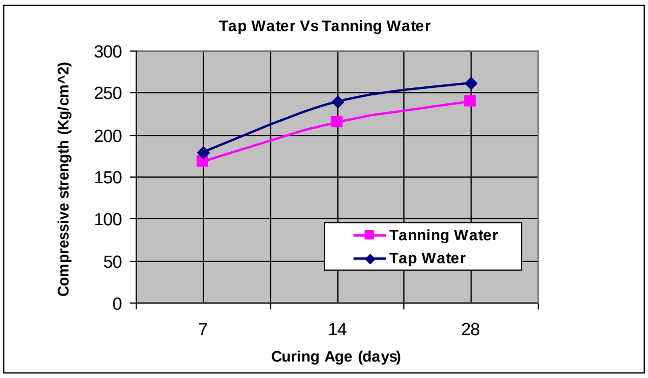

Fig.5.Compressive Strength of Concrete With Tap Water and Tanning Water

TABLE 3. Compressive Strength of Mortar After 7 Days Curing, And Natural Absorption of Concrete After 28 Days

Type of Water	Comp. Strength of Mortar after 7 days (kg/cm2)	Absorption Of Conc. after 28 days (%)
Tap Water	140.3	4.53
5% Salt	158.2	4.03
10% Salt	147.5	4.01
5% Oil	141	4.78
10% Oil	135	4.01
Treated Waste Water	137.3	4.35
Stone Slurry	157	4.26
Tanning	139.5	4.47

Conclusion Remarks

Based on the experimental results reported in this study for concrete and mortar specimens, it can be argued that using stone slurry waste water in concrete mixtures improved the workability, compressive strength, splitting tensile strength and natural absorption. Compressive strength and splitting tensile strength were increased by 20% and 11% respectively. Therefore, stone slurry water is recommended to be used as mixing water in the production of structural concrete; the treated domestic waste water and salty water slightly influenced the compressive strength of concrete after 28 days, therefore, they can be used in the production of non-structural concrete, such as flowable fill or controlled low strength concrete which used primarily as a backfill.

Oily water and tanning waste water reduced the compressive and splitting tensile strengths of concrete at all ages, therefore, they are not recommended to be used in concrete production before primary treatment and further investigation.

Utilization of stone slurry waste water in concrete production will help in securing substantial amounts of fresh water for domestic use in Palestine. Also, using the treated domestic waste water in stone cutting industry for saw cooling will secure additional amounts of fresh water.

Recommendation

1) Classification of reusable domestic and industrial waste water should be based on their chemical composition.
2) The effect of waste water quality on other concrete properties such as durability, shrinkage and long term strength need to be investigated.
3) The effect of waste water quality on corrosion of steel reinforcement, need to be investigated.
4) Reclamation and reuse of waste water should be legislated and enforced for the production of structural and non structural concrete.

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