TREATED WASTEWATER FOR CONCRETE MIXING; A COMPARITIVE STUDY BETWEEN ASTM AND TURKISH STANDARDS

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ABSTRACT:

Water is one of the concrete mixing components that directly affects the workability, durability, and mechanical properties of concrete elements. Generally, potable water which is suitable for human consumption is considered as an appropriate choice as mixing water in hydraulic cement concrete. However, quality of potable water and its physical and biochemical ingredients varies from place to place that indicates need for information from its features before being used in concrete mixing. On the other hand, different standards are considered at different regions to control compositional and performance requirements for water used in concrete mixing. In this study, American Standards for Testing Materials (ASTM; C 1602/C 1602M) and Turkish Standards for specifications of mixing water (TS EN 1008) were compared to determine requirements for water consumption in concrete mixing. As a use case, the required specifications of effluent from Lara wastewater treatment plant, located at Antalya, were analyzed to check whether it meets the standards or not. The examination results showed that physiochemical specifications of the effluent such as pH, color, smell, detergent, sulphate, chloride, density and others meet the standard ranges, so that it can be used in hydraulic cement concrete mixing; however other test are required to determine its effect on the compressive strength of concrete elements.

1. INTRODUCTION

Concrete is one of the mostly used construction material, and water quality is a crucial factor in concrete mixing. Quality of water may influence the performance of fresh concrete as well as its strength and durability after hardened state. Today, water resources management is one of the most important and strategic issues due to the limited available water, particularly in arid and semiarid regions. On the other hand, global warming affects water resources dramatically in such regions. According to World Resources Institute, Turkey is among the countries that face extremely high water stress in 2040 due to climate change [1]. On the other hand, with the growing population/industrialization and consequently increasing water use/demand the country is gradually moving toward water-poor countries. Therefore, further studies on the sustainable water resources management, water saving, and recycling are essentially needed for the future of the country. From the recycling point of view, reuse of water can help to control the use available water resources. Similarly, reuse of treated wastewater (TW) instead of potable water is one of the efficient ways in sustainable water resources management.

Regarding industrial development, Turkey is one of the leader countries in the production of concrete that use a huge amount of potable water every year [2-3]. This brings up the question: do we really need to use potable (drinkable) water in the concrete industry? The answer depends on the type of the concrete and existed standards at each country. There is no doubt that potable water which is treated so that suitable for human drinking is over qualified for concrete mixing/curing. The aim of the present study is to investigate properties of TW and to check if one can use TW instead of potable water in providing concrete mixing. To this end, we compare American Standards for Testing Materials (ASTM; C1602/C1602M) and Turkish Standards for specifications of mixing water (TS-EN1008) for specifications of mixing water. To the best of the author's knowledge, there are only a few studies on this subject. For example, suitability of TW from Reqqa wastewater treatment plant, Kuwait, was investigated by [4]. The authors showed that at early concrete ages (3 and 7 days), the strength of concrete made by preliminary and secondary wastewater was higher than that of concrete made with potable water. In a similar study, [5] showed the suitability of biologically treated domestic wastewater for concrete mixing in Iran. Effect of sea water curing on properties of reinforced cement concrete was investigated in [6]. Different tests conducted are, compressive strength, porosity, chloride penetration rate and capillarity. The result shows that, sea water curing does not affect compressive strength, or the porosity of concrete specimens cast with sulfate resistance cement. However, it increase the chloride concentration at the concrete surface which results hygroscopic effects and lead to water absorption and capillary suction. Chloride penetration coefficients are firstly higher in sea water curing concretes, but as time increases the curve becomes constant.

The quality of the mixing water for production of concrete can influence the setting time, the strength development of concrete and the protection of the reinforcement against corrosion [7]. When assessing the suitability of water of unknown quality for the production of concrete, both the composition of the water and the application of the concrete to be produced should be considered. While the aforementioned studies considered the application of TW in concrete mixing, in the present study, we concentrated on the composition of TW from Lara wastewater treatment plant, located at Antalya, Turkey, to check whether it meets the standards or not. There are different standards available for concrete mixing water around the globe. Here we consider ASTM and TS as mentioned earlier.

2. METHODS

2.1. ASTM AND TS-EN1008 FOR CONCRETE MIXING WATER

The ASTM C 1602/C 1602M standard covers the compositional and performance requirements for water used as mixing water in hydraulic cement concrete. It defines sources of water and provides requirements and testing frequencies for qualifying individual or combined water sources. In any case where the requirements of the purchaser differ from these in this specification, the purchaser's specification shall govern. According to ASTM, potable water is permitted to be used as mixing water in concrete without testing for conformance with the requirements of this specification. Also, non-potable water that have no apparent taste or smell can be used in concrete mixing. Water shall be tested for compliance with Table 1 before the first use and thereafter every three months or more often when there is reason to believe that a change has occurred in the characteristics of the source.

Table 1: Concrete performance requirements for mixing water

	Limits	Test Methods
Compressive strength, min % control at 7 days	90	C 31/C 31M, C39/C 39M
Time of set, deviation from control, h: min	From 1 early to 1:30 later	C 403/C 403M

Based on TS EN 1008, all potable waters are suitable for concrete mixing water without testing. Water from underground sources must be tested before and after testing periodically to ensure meets the standards. The quality of the mixing water for production of concrete can influence the setting time, the strength development of concrete and the protection of the reinforcement against corrosion. When assessing the suitability of water of unknown quality for the production of concrete, both the composition of the water and the application of the concrete to be produced should be considered. Seawaters and lake waters are suitable for the concrete which does not have reinforcement or any embedded metals. Nevertheless, these waters cannot be used in reinforced or pre-stressed concrete.

- Based on TS EN 1008 for sources of non-potable mixing water proposed for use as mixing water, the following chemical, physical and biological tests shall apply to the total combined mixing water.
- Oils and fats: As provided by TS EN 1008, there must be no more than visible trace in water. All water samples were complied with this prescription.
- Detergents: Any foam should disappear within 2 minutes according to TS EN 1008. However, not any single foam was formed during sample preparation process.
- Color and odor: The color shall be assessed qualitatively as pale yellow or paler. TS EN 1008 allows no smell, except the odor allowed for potable water. No smell of hydrogen sulphide after addition of hydrochloric acid. In this water samples, there were no sensible odor.
- Suspended matter: TS EN 1008 allows maximum 4 ml. sediment. Nevertheless, not any sedimentation was observed in all water samples.
- Sulphate: Sulphate content in concrete mixing water cause reaction between concrete and cement paste. Sulphates also cause expansion in concrete and leads to fall on concrete surface. For the concrete which exposes sulphates, sulphate resistant concrete must be used. Sulphate resistant concretes are low in C_3a content. By this property, sulphates do not react with cement paste. The standard method for measuring sulphates is Gravimetric analysis. In gravimetric analysis, water treated with hydrochloric acid and precipitated with $BaCl_2$. Precipitated sulphates filtered and then fired. Using precise scales, precipitated sulphates are measured (TS EN 196-2, 2010). According to TS EN 1008 standard, sulphates are limited with 2000 ppm (mg/L). Especially sea water, lake waters, industrial wastewaters and some underground and surface waters have high sulphate content. Standards signifies that sulphate test must be applied at least 6 monthly periods. This periodical test time may extent if waters' chemical properties are stable.
- Chloride: Chloride content is critical because it can corrode the reinforcements in concrete. Corrosion is degradation of materials' properties due to interactions with their environments, and corrosion of most metals (and many materials for that matter) is inevitable [8]. This deterioration causes decrease in strenght of concrete. Therefore, chloride content is vital for reinforced concretes, pre-stressed concrete and grout. According to "TS EN 1008, 2003" chloride contents are limited for restressed concretes 500 ppm (mg/L), reinforced concretes 1000 ppm (mg/L), unreinforced concrete 4500 ppm (mg/L). Unless chloride content is reached up to 20000 ppm (mg/L), does not have detrimental effect on cement hydration. It is observed that in high chloride concentrations, long term strength of concrete decreased up to 30%. In concrete mixing waters, chloride content is measured by manual titration method. This method is also known as Volhard

method and it uses a back titration with potassium thiocyanate to determine the concentration of chloride ions in a solution [8].

- Total alkali content: Importance of sodium oxide and potassium oxide content, which defined as alkali, is that they can give undesired reactions with aggregates in concrete. Alkali aggregate reaction causes harmful expansions and cracks in concrete. The pH test is applied to determine acidic or alkaline degree of water sample. Concrete is an alkaline product due to the elements used in preparing cement. For this reason, water used in concrete must be alkaline. According to "TS EN 1008" standards, concrete mixing water pH value must be higher than 4. pH value is determining by pH test.

3. CASE STUDY

Lara wastewater treatment plant is a domestic sewage treatment facility consists of physical treatment (pre-treatment units), biological treatment units and sludge dewatering units. In the first stage of treatment, untreated wastewater passes through screens and grates, sand, gravel, and other substances are removed. In the second stage of treatment, Bardenpho system is applied to remove nitrogen by means of complete nitrification and denitrification and to remove phosphorus in anaerobic and aerobic ponds. Finally, the sludge digesting, 3% of the sludge is removed from the sludge digester by the action of microorganisms in sludge digestion tanks and sludge mixed with polyelectrolyte is dewatered in decanters. The resulting sludge cake is sent to the treatment sludge thermal drying and co-generation facility. Figure 1 shows different parts of the plant.

Figure 2. Lara wastewater treatment plant: a) physical treatment unit, b) anaerobic Reactor, and c) final settling pools

Lara wastewater treatment plant is maintained and operated by Antalya Water and Wastewater Administration (ASAT) Lara Wastewater Treatment Plant. The wastewater has domestic source and after treatment is discharged to the Mediterranean Sea. The TW samples used in this study were provided by ASAT at March 2019. To perform the relevant analysis, we prepared samples in four categories: (i): 100% TW, (ii): 75% TW with 25% Potable water, (iii) 50% TW with 50% Potable water, and (iv) 25% TW with 75% Potable water. Figure 2 shows preparation of TW in different mixing ratios.

Figure 3. Preparation of TW samples at different ratios.

4. RESULTS

Concerning the desired standards and different mixing ratios of TW samples, the relevant tests were accomplished in Environmental Engineering Laboratory of Akdeniz University and the results are tabulated in Table 2.

Table 2: Chemical features of TW at different mixing ratioes and their required ranges in TS and ASTM Standards

Test Parameter	To	TW				Standards Range	
	Potable Water	100%	75%	50%	25%	TS	ASTM
SO_4^{-2} (Sulphate)	38	87-88	LLM*	LLM	LLM	2000 (mg/L)	3000 ppm
Cl^-(Chloride)	23	LLM	LLM	LLM	LLM	1000 (mg/L)	1000 ppm
Alkali	21	320-420	LLM	LLM	LLM	1500 (mg/L)	600ppm
pH	7.4	7.56	7.48	7.46	7.41	≥4	≥4
Density	0.99	0.971	0.982	0.983	0.985	<1.01	<1.01
Conductivity(µS/cm)	565	890	815	736	655	---	---

*: Less than minimum

Table 2 indicates that sulphate content is under detectable limit in combined water samples. However, it is mostly presented in 100% TW, but it is still way below for TS and ASTM. According to TS-EN 1008, chloride contents are limited for restressed concretes 500 ppm (mg/L), reinforced concretes 1000 ppm (mg/L), and unreinforced concrete 4500 ppm (mg/L). The chloride content is in safe range for TS and ASTM. The color shall be assessed qualitatively as pale yellow or paler. Water samples were exactly like described and it can be seen in *Figure 2*.

5. CONCLUSION

Impurities present in water are reacting differently with different constituent of concrete. These reactions may affect the setting time, compressive strength and may also cause straining of concrete surface. To ensure that non-potable water sources are suitable for concrete mixing, the ASTM and TS was considered in the present study. Our results showed that the TW from Lara waste water treatment plant meet the requirements of both ASTM and TS. Therefore, it is suitable for using as concrete mixing water. Some parameters are not specified in ASTM, thus it can be also concluded that TS is clearer in this context.

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