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Effects of Sugarcane Wastewater Utilization in Concrete Fabrication for Irrigation Channel Coverage

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Abstract

The quality of water can significantly affect concrete properties, including ultimate strength and efficiency. The present work provides a feasibility study of utilizing sugarcane wastewater in the fabrication of concrete for covering irrigation channels. Three other water types, including reverse osmosis (RO) water for the fabrication of the control specimen, tap water, and river water, were employed for comparison purposes. The specimens fabricated using different waste types were maintained within a concrete curing pond for 7, 14, and 28 days. The results showed that the resistance of samples prepared with sugarcane wastewater increased up to 14 days and then decreased resistance by 32%. The use of sugarcane wastewater reduced the efficiency of concrete by up to 75% compared to the use of treated water. Concrete prepared with sugarcane wastewater can be used to fill existing cavities caused by reinforcement in hydraulic structures.

Keywords: Sugarcane Wastewater, Characteristic Strength, Slump, Electrical Conduction.
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Introduction

In light of its extensive agricultural sector, Khuzestan Province, Iran, has numerous irrigation and drainage canals and a large area under cultivation. Most channels are constructed using concrete. Such channels include side concrete structures (e.g., inverted siphons and side weirs) and overpasses. The quality of water used in concrete fabrication can significantly influence concrete properties. Considering the extensive agriculture and the implementation of a 550,000-hectare scheme in Khuzestan Province, the construction of new channels is required. Today, due to water scarcity, the use of renewable water resources and wastewater is of high importance. Drainage systems drain a large amount of unused agricultural wastewater into wetlands and seas every year. Therefore, it is possible to make substantial savings in the consumption of freshwater by utilizing drainage water in the fabrication of concrete, as a large amount of concrete is utilized in the construction of concrete structures and relevant structures in irrigation and drainage networks. Sugarcane is among the most important agricultural products in Khuzestan Province. Sugarcane drainage systems transfer a significant amount of wastewater. It is possible to make considerable savings in water consumption by exploiting sugarcane wastewater for covering channels. Dehkhoda Sugarcane Plantation and Industry Company is among the most important sugarcane production companies in Khuzestan. The present study utilizes the sugarcane wastewater of Dekhoda Sugarcane Plantation and Industry Company to fabricate concrete specimens. A large number of studies

have been conducted on the effects of water quality on concrete properties.
Mostafaeipour (2015) studied the effects of Na_2SO_4-containing water on the strength of concrete used in aquaculture channels and pools. The study concluded that the use of Na_2SO_4-containing water reduced the strength of concrete by up to 25%. Al-Jabri et al. (2011) investigated the effects of wastewater on concrete strength. They evaluated the influence of using wastewater in the fabrication of high-strength concrete. Lawrence (2016) analyzed the impacts of water quality on the compressive strength of concrete and concluded that the specimens fabricated using saltwater and runoff water increased in strength for the initial seven days but then began to reduce in strength. Tiwari et al. (2014) explored the effects of saltwater on the compressive strength of concrete. They fabricated half of the cubic concrete specimens using fresh water and the other half by saltwater. They cured the concrete specimens in the periods of 7, 14, and 28 days before testing them. The results indicated that the strength of the freshwater-fabricated specimens ranged between 27.12-39.12 MPa, while those of the saltwater-fabricated specimens ranged from 28.45 to 41.34 MPa. Mbadike and Elinwa (2011) studied the effects of saltwater in the fabrication of concrete on the compressive and flexural strengths of concrete specimens. They tested concrete specimens with different mix designs and different water-cement ratios. More and Dubey (2014) investigated the impacts of using different water types, including tap water, well water, mineral water, and wastewater, on concrete strength. They employed 15-cm cubic molds and cured the specimens for 7 and 28 days. The results showed that the use of these water types had no significant impacts on the compressive strength of concrete. Olugbenga (2014) evaluated the contents of different elements in water, including Na, Mn, Zn, and Cu, on concrete strength and concluded that a change in the contents of these elements in the water used for concrete fabrication could significantly influence the strength of concrete. Chatveera et al. (2006) analyzed the effects of sludge water on the properties of concrete. They found that the use of sludge water in the fabrication of concrete reduced the strength and slump of concrete. Helali joola (2014) studied the use of industrial wastewater in the fabrication of concrete and reported that wastewater significantly decreased the compressive strength of concrete. Considering that many studies have been done so far on the use of unconventional types of water, including industrial wastewater and sewage in concrete construction, specifically, a comprehensive laboratory study on the use of sugarcane wastewater in concrete construction used in Irrigation canals is not conducted. Therefore, this study, which comparatively examines sugarcane wastewater, river water, (RO) water, and tap water, is of great importance. The present work aims to provide a feasibility study of utilizing sugarcane wastewater in the fabrication of concrete for covering irrigation and drainage channels.

Materials and methods

The present study employed the sugarcane wastewater of the sugarcane drainage of Dehkhoda Sugarcane Plantation and Industry Company. As mentioned, the quality of sugarcane wastewater is not suitable for drinking and agricultural purposes. Electrical conduction (EC) is among the most important parameters representing the quality of water based on the dissolved mineral contents of water. This study employed three other water types with different EC values, including reverse osmosis (RO) water for the fabrication of the control specimen, tap water, and river water (from Karun River), for comparison purposes. Table (1) provides the EC and pH quantities of these water types. It should be noted that specimens were collected in August 2017. Figure (1) illustrates the grading curves of the fine and coarse aggregates used in the present study. To determine the grading curves of fine-grained aggregates, the fineness modulus (FM) was employed. FM is obtained by dividing the total cumulative weight percentage of aggregates on each particular set of sieves by 100. According to the ASTM C33 Standard, the FM of fine-grained aggregates should be in range of 2.3-31 (Tahouni, 2014).

Furthermore, type 2 cement was employed. Figure (2) depicts the aggregates used in the present study.

Table 1- Properties of the Water Types

Specimen	EC (µs⁄cm)	pH
RO water	234	7.70
Tap water	1631	8.00
River water	2730	8.42
Sugarcane wastewater	9160	8.27

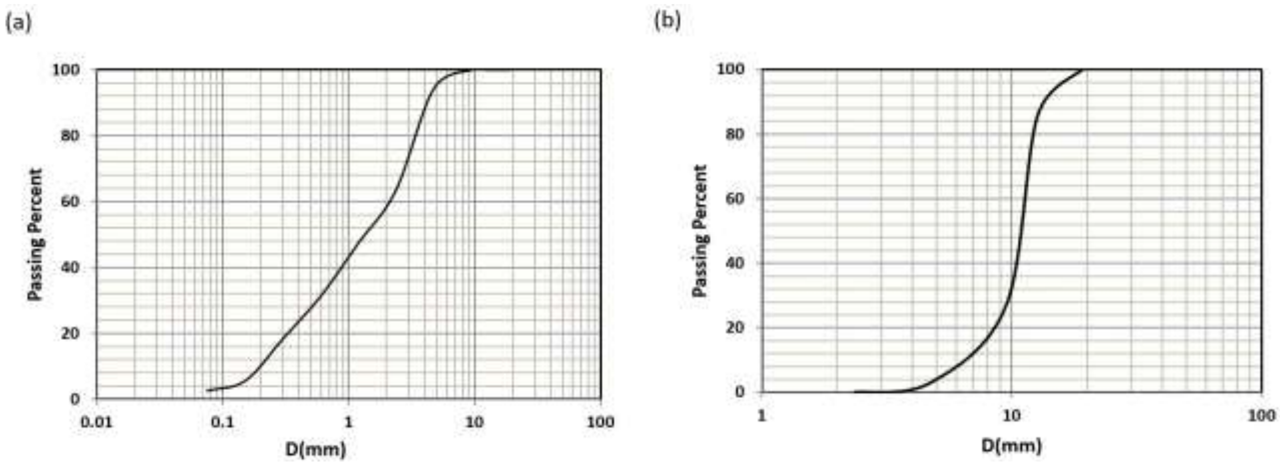

Fig. 1-Granulation curve of (a) Fine-grained and (b) Coarse-grained aggregates

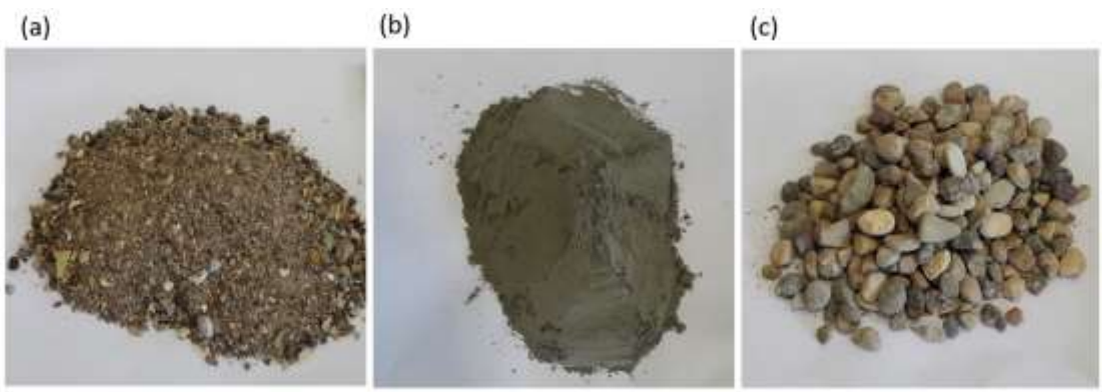

Fig. 2- Materials; (a) Fine-grained aggregates, (b) Type 2 cement, and (c) Coarse-grained aggregates

Table. 2- Mix Design

Material	Gravel	Sand	Cement	Water
Amount (kg/m^3)	950	1050	300	160

Table (2) shows the mix design of the present study. This mix design is based on the mix design used in the fabrication of concrete for covering channels. The cement amount and water-cement ratio of 0.54 were selected based on Code 108 (General Technical Specifications of Irrigation and Drainage Systems, 2013). It should be noted that a mix design is an empirical factor, and the present mix design was selected by receiving consultation from an executor of several plans. The slump test was utilized to determine the efficiency of concrete based on the ASTM C 143.90a Standard. Figure (3-a) demonstrates the slump test setup of the present study.

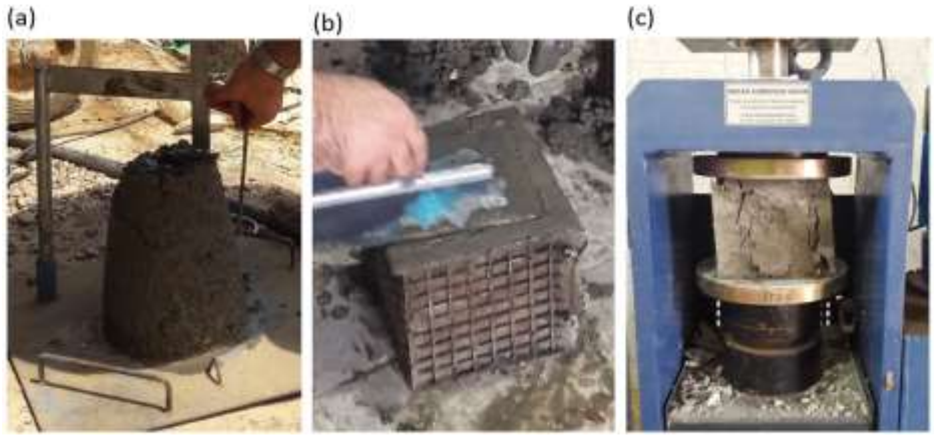

Fig. 3- (a) Slump test setup, (b) Fabrication of specimens in cubic molds, and (c) A concrete specimen under fracture

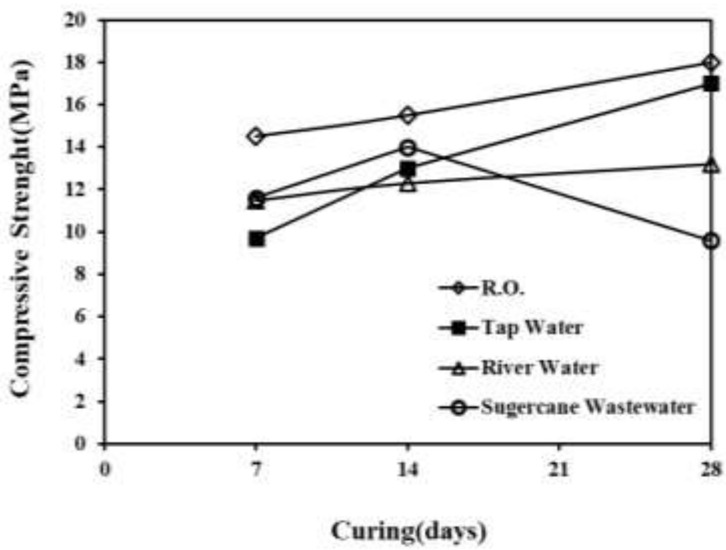

Fig. 4- Compressive strength variations of specimens in the maintenance period

The specimens were fabricated in molds with a size of 15*15*15 cm. The specimens were built in standard conditions and then cured in concrete curing pond for 7, 14, and 28 days. Figure (3-b) illustrates the specimen fabrication process in the present work.

The specimens were loaded based on the BS Standard (1881-1970) (Iranian Concrete Code, 2000). This test was performed by a compressive strength (pressing) machine. This machine increases compression until the entire specimen ruptures. The ultimate compressive strength is the compressive strength of 28-day specimens. Figure (3-c) shows the loading and fracture of a specimen. Since the present study employed cubic molds with a size of 15*15*15 cm for the fabrication of specimens, it was required to multiply the ultimate strength result of the test by 0.93 according to the relevant standards (Keynia, 1997).

Results and Discussion

According to Table (2), the adopted water types had almost the same pH and were slightly alkaline. Figure (4) represents variations in the compressive strength of specimens fabricated by different water types.

As can be seen in Figure. (4), the concrete fabricated using RO water (i.e., the control specimen) had higher strength than the other specimens fabricated by the other water types at all curing ages of 7, 14, and 28 days. The strength of the RO water-fabricated specimens was found to be 14.50, 15.50, and 18 MPa at the ages of 7, 14, and 28 days, respectively. A rise in the maintenance period from 7 to 28 days increased the strength of the RO water-fabricated specimens by nearly 25%. Concerning the other specimens, it was observed that the tap water-fabricated specimen at the age of 7 days had the lowest strength (i.e., 9.70 MPa). However, the river water- and sugarcane wastewater-fabricated specimens had almost the same strength of 11.50 MPa at the age of 7 days. A rise in the curing time to 14 days enhanced the strength of the specimens fabricated by all three other water types; the 14-day strength of the specimens fabricated using tap water, river water, and sugarcane wastewater was found to be 13, 12.30, and 14 MPa, respectively. An increase in the curing time to 28 days increased the strengths of the tap water- and river water-fabricated specimens by 31% and 8% (to 17 and 13.20 MPa), respectively. This implies that the tap water-fabricated specimens had greater strength than river water-fabricated ones. However, the strength of the sugarcane wastewater-fabricated specimen decreased by approximately 32%. As can be seen, a rise in the curing time of the sugarcane wastewater-fabricated specimens to 14 days induced an unstable strength in the specimens, and then the specimens reduced in strength. Since sugarcane wastewater is a questionable resource of water in the fabrication of concrete, based on the ASTM C94 Standard on questionable water resources, the 7- and 28-day strengths of questionable water-fabricated specimens should be at least 90% of the control specimens (the distilled water-fabricated specimens in the present study). According to Fig. 6, 90% of the strengths of the 7- and 28-day control specimens equals 13 and 16.20 MPa, respectively, which are larger than the 7- and 28-day strengths of the sugarcane wastewater-fabricated specimens. Thus, according to this standard, sugarcane wastewater cannot be employed in the fabrication of concrete by the mix design adopted in the present study. Moreover, according to Code 108 (General Technical Specifications of Irrigation and Drainage Systems, 2013), the ultimate strength of concrete used in channel coverage should not be below 16 MPa. Therefore, according to the ultimate strength results of the sugarcane wastewater-fabricated specimens in the present work, this concrete is not suitable for channel coverage. According to Code 108, this concrete can be used only as filler. Figure (5) depicts the slump values of the specimens fabricated in the present study.

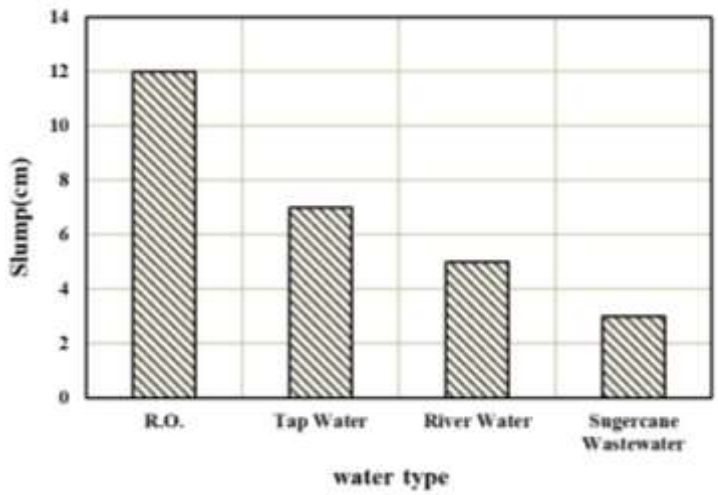

Fig. 5- Slump results of the concrete specimens

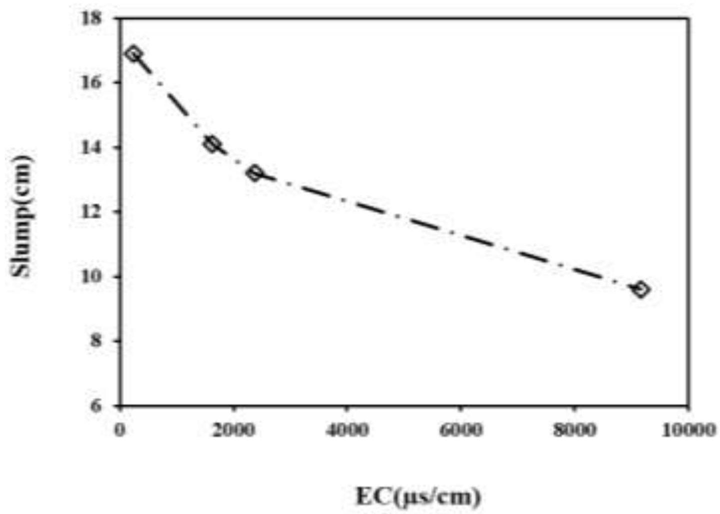

Fig. 6- Slump versus EC

As can be seen, the sugarcane wastewater-fabricated specimens had the smallest slump results (i.e., 3 cm), while the RO water-fabricated specimens had the largest slump results (i.e., 12 cm). Figure 6 plots the slump versus EC.

According to Figure (6), a variation in EC substantially influenced the slump. A rise in the EC of the water used in concrete fabrication from 234 to 1631 µs/cm reduced the concrete slump by 42% - the slump of the tap water-fabricated specimen reached 7 cm. Then, a 28% reduction in the slump occurred, with the slump of the river water-fabricated concrete becoming 5 cm. Finally, the slump of the sugarcane wastewater-fabricated concrete underwent a 40% reduction and became 3 cm.

Conclusion

The present work provided a feasibility study of utilizing sugarcane wastewater in the fabrication of concrete for covering water transfer channels. To this end, the efficiency and ultimate strength of sugarcane waste-fabricated concrete specimens at the ages of 7, 14, and 28 days were measured. Moreover, other water types with different EC values, including RO water, tap water, river water (of Karun River), were employed for comparison purposes. The results indicated that the strength of OR water- and tap water-fabricated specimens linearly increased in the curing period. Furthermore, the strength of river water-fabricated specimens linearly enhanced in the curing period but was finally found to be lower than those of the RO water- and tap water-fabricated specimens. The ultimate strength of the sugarcane wastewater-fabricated specimens at the age of 7 days was observed to be almost equal to the initial strength of the other specimens. At the age of 14 days, the sugarcane wastewater-fabricated specimen underwent an unstable 21% rise in strength and experienced a substantial decline by 32% at the age of 28 days, reaching an ultimate strength of 9.60 MPa. On the other hand, the efficiency of the sugarcane wastewater-fabricated specimens was determined to be nearly 3 cm. Since sugarcane wastewater is a questionable resource of water in concrete fabrication, it cannot be employed for fabricating concrete, according to the ASTM C94 Standard. In addition, according to Code 108, the ultimate strength of the sugarcane wastewater-fabricated concrete in the adopted mix design demonstrated that this concrete type is unsuitable for covering channels. According to Code 108, sugarcane wastewater-fabricated concrete can be employed only as filler.

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