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Investigation on Utilizing Wastewater for Production of Concrete

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***Abstract* - Concrete is the most widely used construction material in the world and is considered one of the largest water consuming industries as approximately 150 liters of water is required per cubic meter of concrete mixture. Recently, population explosion coupled with urbanization has raised the demand for water resulting in its scarcity making water a critical environmental issue that is limiting water supplies and water quality worldwide. On the other hand, with industrialization, the quantity of wastewater generated has soared up warranting appropriate measures for utilization and disposal. An attempt has been made in this direction towards utilization of industrial effluents in construction industry. This study was conducted to investigate the possibility of saving water used in concrete mixtures and make use of produced wastewater domestically and industrially. Nontreated effluents from 7 different factories have been used as mixing water in mortar mixes utilized for preparing 50mm mortar cubes. Effluents had high concentrations of ceramic powder (in case of ceramic factory), marble powder (in case of the stone-pit and marble factory), and sugar (in cases of halva, jam and ice-cream factories). Compressive strength of cubes was tested after 3, 7 and 28 days. Values of compressive strength of control samples (prepared with tap water) have been used for comparison.**

Keywords: Compressive Strength, Mortar, Concrete, Industrial Wastewater

I. INTRODUCTION

In an age of increasing human population and dwindling resources, coupled with the need to curb expenditure in various sectors of the government's budget, attention has been brought to the re-use of resources wherever possible. Perhaps one of the most valuable resources in Egypt and the Middle East in general is water. Therefore, efforts towards wastewater re-use have lately gained worldwide consideration and attention in both the agricultural and industrial fields. Second to water, concrete is of the most widely consumed materials worldwide, with three tons used per person per year (Metcalf and Eddy, 1991). Twice as much concrete is used in construction as all other building materials combined. Concrete is also one of the highest water consuming materials as it requires about 150 liters of water per cubic meter. As demand increases for this fundamental building material, concrete industries have the environmental and societal responsibility to contribute to sustainable development. Accordingly, studies such as the one presented here are carried out in the hope of optimizing the characteristics and properties, ensuring that concrete remains environmentally friendly and affordable. The need of a sustainably developed and environmental friendly concrete industry is aggravated by population growth and scarcity of water (Borger et al., 1994). The world population doubled from 1959 to 1999, increasing from three billion to six billion. According to the United States Census Bureau, the world population is projected to reach nine billion by 2043; or, an increase of 50% relative to 1999. Thus, it is expected that the water demand will have an increasing trend; leading to water scarcity making water reusing, recycling and conservation a necessity. The practice of reuse involves processing used materials into reusable products in order to prevent waste of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy usage, and reduce air pollution and water pollution by reducing the need for conventional waste disposal. Reuse is one of the key components of modern waste management and is an effective method to be applied for the reuse of wastewater in both the agricultural and industrial fields (Sandrolini et al., 2001).

II. METHODOLOGY

In the construction industry, potable water is usually used since it is recommended by most specifications and its chemical composition is known and well regulated. A popular criterion of 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. Currently there are no special tests developed to determine the suitability of mixing water except comparative tests. 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 (Muniandy, 2009). Both concretes should be made with cement proposed to be used in the construction works. In the design codes, it is recommended that the compressive strength of concrete cubes made of untried water not to be less than 90% of cubes made with tap water. In this thesis, mortar cubes were chosen to be used for the comparative tests instead of concrete cubes as this eliminates the risk of aggregates' sizes and strength variability from one cube to another so as not to skew the results. Mortar cubes of dimensions (50mmx50mmx50mm) were prepared according to ASTM (C 109/C 109M – $07^{\varepsilon 1}$) using different industrial wastewater effluents. The cubes

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were then tested and compared to their corresponding control cubes (mortar cubes made by using tap water).

A. Materials

- Cement: Portland Cement was used.
- Sand: Graded standard sand was used which is made of natural silica and conforming to the requirements for graded standard sand in Specification C 778.
- Water: Eight different types of water were used for the mixing process of the mortar cubes, which were:
  - Tap Water (Control)
  - Waste Water from a Potato Factory (Starch)
  - Waste Water from a Jam Production Factory (Jam)
  - Waste Water from a Halva Production Factory (Halva)
  - Waste Water from a Stone-Pit (Stone-Pit)
  - Waste Water from a Ceramic Factory (Ceramic)
  - Waste Water from a Marble Factory (Marble)
  - Waste Water from an Ice-Cream and Dairy Products Factory (Ice-Cream)

To simulate the effect of varying concentrations of sugar and starch in the mixing water on the concrete compressive strength, two other waters were prepared.

- Water containing dissolved sugar with different concentrations:
  - 15 g of sugar in 120 g of water (12.5%)
  - 35 g of sugar in 120 g of water (29.17%)
  - 50 g of sugar in 120 g of water (41.67%)
  - 75 g of sugar in 120 g of water (62.5%)
- Water containing dissolved starch with different concentrations:
  - 15 g of starch in 120 g of water (12.5%)
  - 25 g of starch in 120 g of water (20.83%)
  - 35 g of starch in 120 g of water (29.17%)
  - 50 g of starch in 120 g of water (41.67%)

B. Mold

The mold was designed according to the following requirements:

- Its inner dimensions should be 50mmx50mmx50mm
- Its edges should be tight enough not to escape any mortar or water
- Unlocking the bars that separate the cubes from each other should be an easy process
- Its base plate should be stiff to hold all parts of the mold together, and smooth to provide a flat surface for the cubes
- The connection between the separating bars and the base plate should be stiff and firm no to escape mortar or water from the bottom.

First, a sample mold of three cubes was produced so that the design could be tested. After proving its efficiency, the sample mold was up scaled into a mold of twelve cubes. Three molds were produced with the same design and dimensions, having twelve cube partitions each. All molds were produced in the German University in Cairo's workshop.

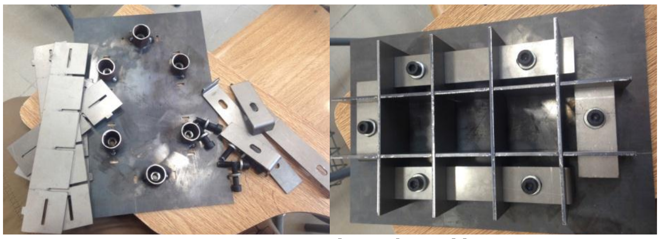

Figure II.1 Sample 3-cube Mold

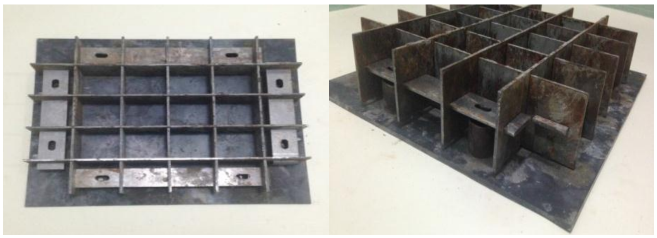

Figure II.2 The 12-cube Mold

C. Equipment

The compressive strength testing machine used for the tests conducted in this thesis is a Zwick/Roell equipment of the model Z100. It was used for the compression testing in room temperature (25°C) as well as in increased temperatures (50°C, 100°C and 150°C).

Figure II.3 The equipment used for the compressive strength testing under room temperature and higher temperatures

III. RESULTS AND INTERPRETATIONS

Visual examination of cube specimens indicated uniformity and suggested that they were satisfactory. This includes cubes made by using tap water, starch wastewater, stone-pit wastewater, marble wastewater, ice-cream wastewater and ceramic wastewater. On the contrary, cubes made by using jam and halva wastewaters experienced serious problems. The halva-made cubes had cracks in them before testing, and a few even split into two parts. Moreover, jam wastewater had a negative effect on the cubes, even worse than halva.

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Jam made most of the cubes crack and crumble as soon as they're picked out of the curing tub. This resulted in an insufficient study of the heat effect on the cubes made by using the halva and jam wastewaters.

A. 3-Day Analysis

The compressive strength test after 3 days of curing showed that samples made by using tap water have the highest load sustainability (Fmax: 22919.4 N). Second to tap water were the stone-pit cubes which sustained a maximum force of 20662.65 N. After that was the starch cubes (Fmax: 15940.05 N) and the ceramic cubes (Fmax: 11633.31 N). The cubes that sustained the least loads were those mixed with jam and halva wastewaters. They sustained a maximum force of 110.31 N and 369.1015 N respectively, which were far beyond all other samples made by other wastewaters. The marble factory cubes had an Fmax of 23051.4 N, which exceeds the Fmax of tap water. While the ice-cream factory cubes sustained a maximum force of 13337.27 N. This suggested that the marble factory's wastewater is the only one so far that can be used for concrete mixing, and that jam and halva wastewaters contained a sugar content that acted as a strength reducer, and this drew a preliminary conclusion that those two waters shouldn't be used in the concrete industry.

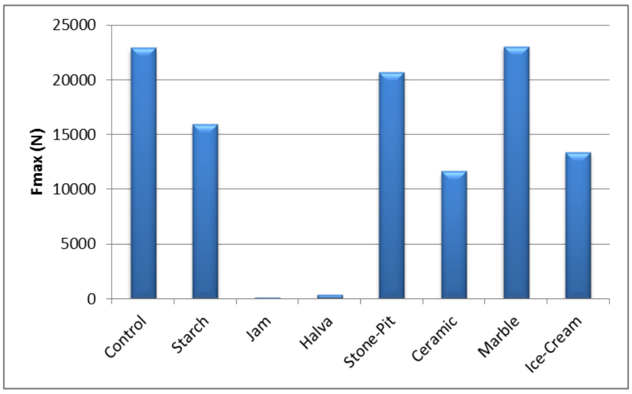

Figure III.1 3-Day Analysis

B. 7-Day Analysis

The compressive strength test after 7 days showed a different pattern other than the 3 days test. After 7 days, it was shown that the cubes made by using stone-pit , marble factory, ice-cream and ceramic wastewaters exceeded the compressive strength of the samples produced by using tap water by about 3% which suggested that those four wastewaters can be used in concrete mixing without having the fear that they might decrease the strength or sustainability. But this wasn't to be confirmed except after the 28 days test as they might strengthen in the early stages but experience a low development in the following stages which negates the theory of using them in concrete production. After 7 days of curing, jam and halva-made cubes remained the least load bearing cubes of all others, with a huge difference between them and other samples having an Fmax of 673.831 and 1056.407 respectively. Starch-made cubes sustained a maximum force of 21381.3 which made it fall beyond the ceramic wastewater-made cubes sustainability. Control, stone-pit, marble, ice-cream and ceramic-made cubes had an Fmax of 32909.7, 33849.5, 33309.7, 32980.2 and 33781 respectively.

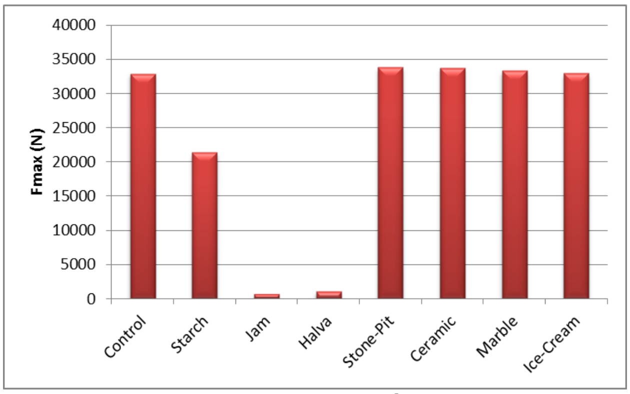

Figure III.2 7-Day Analysis

Water with different starch concentrations was prepared to simulate the variation in compressive strength with increasing the starch content in water and was tested after 7 days of curing. The results showed that increasing the amount of starch dissolved in the water decreases the compressive strength of mortar cubes in the following trend.

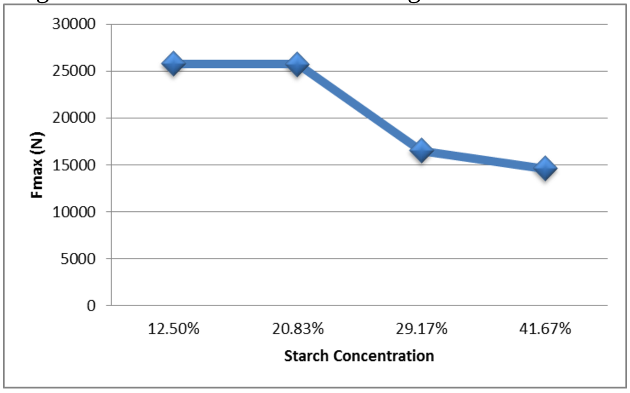

Figure III.3 Trend of Fmax Variation with Different Starch Concentrations

C. 28-Day Analysis

After 28 days of curing, ceramic wastewater based cubes had the highest ultimate strength among all other cubes. It sustained a maximum force of 51183.98 N, which exceeds the strength of control cubes that are made by using tap water by 42% which can be considered a great privilege for ceramic factories that they can now sell their wastewater to concrete producers without paying for any treatment of their wastewater. Second to ceramic were the stone-pit cubes with Fmax of 36870.25 N. Jam and halva based cubes remained the least load bearing waters sustaining an Fmax of 1495.2 N and 1987.14 N respectively. Cubes mixed with starch wastewater sustained a maximum force of 33464.7 N which is a little below the strength of the tap water cubes (Fmax 36014.65 N) but falls within the acceptable range, as according to researchers the strength of the cubes made by another water than tap water shouldn't have less than 90% percent of the strength of the tap water cubes. And in our case, starch wastewater cubes have 92.9% of the control cubes which make them satisfactory and appropriate for use in concrete production.

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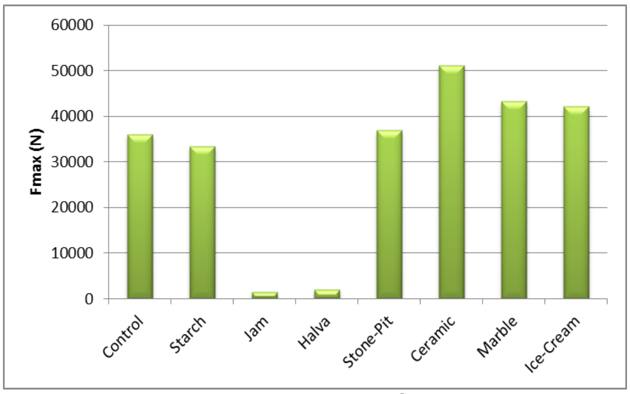

Figure III.4 28-Day Analysis

To simulate the effect of sugar content on the compressive strength of cubes, water having variable sugar concentrations was prepared and tested for compression after 28 days of curing. The results demonstrated that the compressive strength of cubes increased with increasing the sugar concentration as shown in the following figure.

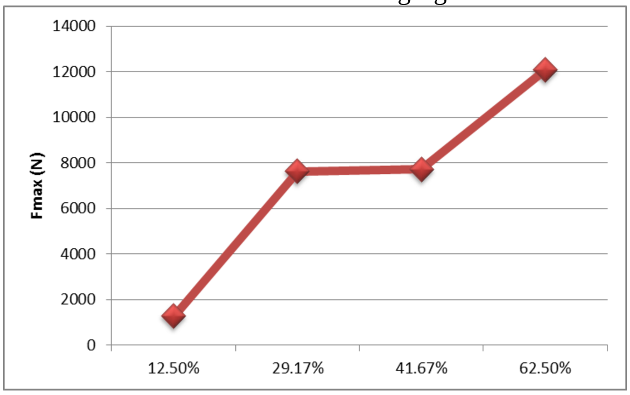

Figure III.5 Trend of Fmax Variation with Different Sugar Concentrations

D. Strength Variation with Temperature

Cubes made with all waters were tested after 28 days of curing for compressive strength under an increasing temperature. The test was conducted using three different temperatures (50°C, 100°C, and 150°C) and comparing the strength obtained under these temperatures with the cubes tested in room temperature (25°C). Control cubes showed the best behavior under increasing heat and developed its strength in an increasing manner. All other wastewater-based cubes' compressive strength decreased as the temperature rose up. Starch wastewater-based cubes' strength decreased to 52% of their strength in room temperature when the temperature rose to 150°C. Stone-pit cubes sustained an Fmax of 16219.5 N in 150°C which represents only 44% of its original strength. While ceramic-based cubes decreased to 57% of its former strength before increasing the temperature. Due to the cracks and crumbling of the jam and halva cubes, there were no sufficient cubes to perform the compressive strength test under variable temperatures, but it would have been of no use as both waters can never be used in concrete production because of their very low strength and sustainability that was realized among the 3, 7 and 28 days tests.

IV. CONCLUSION AND RECOMMENDATIONS

An approach towards decreasing the demand on potable water used in the concrete industry as well as efficiently using industrial wastewater generated from factories without the need for expensively recycling or treating it was presented in this study. Wastewater effluents from seven different factories were collected and used in mixing hydraulic cement mortar cubes of dimensions (50mmx50mmx50mm). Factories had different natures, four of which were of food industry type, and the other three were of ceramics, stone and marble type. The food industry factories were a potatoes production factory, a jam factory, a halva factory and a dairy products and ice-cream factory. Mortar cubes of all wastewaters were tested for compressive strength after 3, 7 and 28 days of curing and compared to control samples prepared with tap water. Cubes were tested for compressive strength in four different temperatures (25°C, 50°C, 100°C and 150°C).

The results of the compressive strength test showed that marble factory, stone-pit and ceramic factory had higher strength than control samples with about 42% difference which is a big difference and suggests that these wastewaters can be used in concrete production. In the second place comes the dairy products and ice-cream factory whose strength values were almost like the strength values of the control samples, which means that it can be used in concrete production as well. On the other hand, jam and halva factories' effluents significantly decreased the strength of mortar cubes to the extent that they only sustained about 4% of the force that control samples sustained. This indicates that these two waters can never be used in such an industry as concrete production.

The cubes prepared with the potatoes factory wastewater sustained a maximum force of about 92% of the force sustained by the control samples which, according to literature and previous researches, falls within permissible ranges (90% - 100%).

The strength variation with time was also analyzed throughout the testing days (3,7 and 28 days). It was shown that ceramic wastewater cubes had the highest rate of strength development among all other cubes. After that was ice-cream wastewater cubes having a strength development rate higher than that of control samples with a significant difference. Stone-pit, marble and control cubes almost had the same rate of strength development from 3 to 28 days with a little increase in the stone-pit's rate. Potatoes factory wastewater cubes had a lower strength development rate than that of control cubes while jam and halva cubes had the least strength development rate and the least sustainability compared to all other samples.

Increasing the temperature during compressive strength testing showed that almost all cubes reacted differently than how control samples reacted to the temperature increase. The control samples hardened and sustained more load with the increasing temperature, while all other cubes prepared with different wastewaters sustained less loads as temperature rose up except for the stone-pit cubes which increased with temperature but with a slightly less rate than that of the control samples.

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Two more waters were prepared to simulate the variation in strength of mortar cubes with increasing the concentrations of starch and sugar dissolved in mixing water. Starch and sugar contents were specifically chosen to confirm the results of jam, potatoes, halva and dairy products and ice-cream factories' effluents. Testing of cubes prepared with these two waters showed that the compressive strength of cubes decrease with increasing the starch content dissolved in water, while the sugar content increase increases the strength of the mortar cubes and accordingly, increases the strength of concrete cubes.

Due to the tight time offered for this project, some questions were left unanswered in the hope that in future researches an answer could be found. For further researches, it is recommended that the waters used in this project undergo a complete chemical analysis to be able to figure out their composition so that we can interpret why those results presented in this were achieved. Another thing that might be helpful is that other w/c ratios than the one maintained in this study shall be experimented. Some waters might sustain high forces with lower w/c ratio and not defect any other property of concrete which can be another useful discovery. Also, it might be useful if we take this study as a first step towards using non-treated wastewater effluents and test other types of wastewaters from different and diverse industries. The most important thing is that the waters used in this study should be utilized in concrete production to confirm the trends and comparisons obtained from testing mortar cubes and comparing them to control samples.

REFERENCES

[1] Metcalf and Eddy, Inc. (1991). Wastewater Engineering: Treatment, Disposal and Reuse. Third Edition, McGrawHill.

[2] Borger, J., R.L. Carrasquillo, and D.W. Fowler (1994). Use of recycled wash water and returned plastic concrete in the production of fresh concrete. Advanced Cement Based Materials. 1(6): p. 267-274.

[3] Sandrolini, F. and E. Franzoni (2001). Waste wash water recycling in ready mixed concrete plants. Cement and Concrete Research. 31(3): p. 485-489. Sethuraman, P. (2006). "Water reuse and recycling - a solution to manage a precious resource?" <http://www.frost.com/prod/servlet/market-insighttop.pag?docid=90081832> (Sep. 21, 2009).

[4] Muniandy, T.A. (2009). Reusing of Treated Wastewater in Concrete Production. Malaysia.

[5] Taha R, Al-Harthy AS, and Al-Jabri KS (2010). Use of production and brackish water in concrete. Proceedings International Engineering Conference on Hot Arid Regions (IECHAR 2010) March 1-2, Al Ahsa, Kingdom of Saudi Arabia, pp. 127-132.

[6] Cebeci OZ, and Saatci AM (1989). Domestic sewage as mixing water in concrete, ACI Materials Journal. 86(5), pp. 503-506.

[7] El-Nawawy OA, and Ahmad S (1991). Use of treated effluent in concrete mixing in an arid climate. Cement and Concrete Composites. 13(2), pp. 137-141.

[8] Mujahed FS (1989). Properties of concrete mixed with red sea water and its effects on steel corrosion. Unpublished M.S.Thesis, Jordan University of Science and Technology, Jordan.

[9] Ficcadenti, S.J., Effects of Cement Type and Water to Cement Ratio on Concrete Expansion Caused by Sulfate Attack Structural Engineering, Mechanics and Computation, A. Zingoni, Editor. 2001, Elsevier Science: Oxford. p. 1607-1613.

[10] Yigiter, H., H. Yazici, and S. Aydin (2007). Effects of cement type, water/cement ratio and cement content on sea water resistance of concrete. Building and Environment. 42(4): p. 1770-1776.

[11] WASAMED (2004). Water Saving in Mediterranean agriculture. "Non-Conventional Water Use". Egypt.

[12] Standard Test Method for Compressive Strength of Hydraulic Cement Mortars(Using 2-in. or [50-mm] Cube Specimens) <http://compass.astm.org/Standards/HISTORICAL/C109C109M-05.htm>

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