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AN EXPERIMENTAL STUDY ON EFFECTIVE USE OF EFFLUENT WASTEWATER IN CONCRETE PREPARATION

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Abstract:-

Nowadays fresh water is very limited in Oman and has lack of rain every year. But, concrete industry is still using fresh water to produce their product. This project is to investigate using treated effluent wastewater in concrete preparation as an alternative for using fresh water. The effluent discharge collected from Haya wastewater treatment plant, where the discharged effluent is collected in sewerage pipelines without affecting human and environment. According to this study, to make a value of treated effluent wastewater to be used in the construction industry in concrete casting and curing process. Chemical, physical and biological parameters in wastewater were collected directly from the treatment plant by using LIMS system. The produced concrete has a grade of C30 and the mixture consist of ordinary Portland cement, fine aggregate and coarse aggregate, and prepared by mixing with different water percentages of normal water and treated effluent wastewater. Based on American Concrete Institute requirement, the concrete mix proportions determined. Concrete quality checked with regarding to various tests and performing in the project study which are, slump test, compressive strength test, and split tensile strength test by using UTM. The purpose of these tests is to investigate the hardness and strength of the prepared concrete. The results conform using treated effluent wastewater with 100 % gives higher values in compressive strength and spilt tensile strength than use normal water. Also, heavy metals concentration results are within the limit of other standard effluent discharge standard, hence this test is important for checking the durability of concrete. Based on journals, the results of using treated effluent wastewater in concrete were investigated. The compressive strength and split tensile strength of the concrete is high and achieved the standard requirement. Also, was finding that the usage of acid solution is as removal for the toxic matter in concrete prepared with wastewater. So, usage of treated wastewater gives same normal water performance when added in concrete. However, all output from the literature review would be but into consideration in the project study.

Keywords:- *Treated effluent wastewater, Compressive strength, Split tensile strength, Toxic matter*

1. INTRODUCTION

Oman especially faced a lot of deficit in freshwater due it is hot weather throughout the year where most of the month's weather temperature rise to 50°C, groundwater exploitation, population growth and increase in economic activities which cause to substantial increasing on fresh water. While fresh water is a scare issue nowadays it is important to reduce water consumption in all sectors including the construction industry, by finding an alternative way that could be used in the construction industry like reuse non-drinkable water to decline utilizing freshwater in this part and to create a balance between saving sources of fresh water and demands.

There are different sources of non-freshwater that could be used in building construction, especially in the concrete mixture. In fact, many researchers have studied the effects and feasibility of using seawater and wastewater from treatment plants (Primary and secondary treated wastewater) in various countries such as India, Kuwait, Japan and etc. Is important to check the quality and strength of using these types of water in cement and prepared concrete. Based on those research studies the results were very successful.

However, the present study is coming to follow the previous studies lines to investigate the new technology of feasibility and checking the impact of using treated effluent wastewater in concrete preparation. With considering different percentage of treated effluent wastewater and normal water in concrete properties, study the analysis of used water such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and pH. Also, determination of the compressive strength and split tensile strength to evaluate the concrete strength after 28 days curing by using UTM machine with 1000KN force. Investigating the durability characteristics of prepared concrete C30 grade by conducting toxicity test of Zinc (Zn), Magnesium (Mg) and Copper (Cu). This is for checking the heavy metals present in the concrete prepared with treated effluent wastewater and normal water. So, using treated effluent water for concrete production by this way, it can save and conserve much quantity of fresh water but spreading the awareness is required.

According to Shekararchi et al. (2012), a study of using the biologically treated water in concrete was carried out the main objective of the research is to investigate the feasibility of using biologically treated wastewater in concrete production [3]. Lee et al. (2001), have conducted a study of reusing effluent wastewater in concrete technology was carried using treated effluent in agriculture and industry has successfully developed in some countries [4]. The authors Lakshmi & Gideon (2016), have done investigation on using of effluent water from a secondary treatment plant in concrete production [5]. According to Al-Ghusain & Terro (2003), carrying out the use of treated wastewater for concrete mixing in Kuwait was carried out [6]. Shukla et al. (2010), carried out a study of using the concentrate of membrane filtration of bleach plant effluent in preparation of the bricks was conducted [7].

2. METHODOLOGY AND EXPERIMENTAL SETUP

2.1 General

Concrete is being one of the most construction materials important, easily produced from local materials with different properties. That to achieve a desirable result for fresh or hard concrete properties, which this is depending to the selected mix design code. This chapter provides the required information about the project testing methodology, materials selected, chemical and physical properties that have performed in National University.

2.2 Methodology

Planning properly of the project work is the first stage to carry out the project efficiency. In the following lines the methodology of the project is mentioned in detail:

- Searching for efficient literature reviews that carry out strong research on using treated effluent in concrete preparation and understand the requirement to achieve the project aim.
- Collecting treated effluent wastewater from Haya Water Company [2]. Exactly from Al Ansab treatment plant.
- Investigate the physical, chemical and biological analysis of collected water sample by using (LIMS) system in Haya laboratories.
- Collection of materials used: Ordinary Portland cement, fine and coarse aggregate, normal water and treated effluent wastewater.
- Conducting physical properties of aggregate tests: Sieve analysis and Specific gravity.
- Decide the proportion of water samples to be added in concrete mixture (Treated effluent wastewater and normal water).
- Preparation of cube specimens and cylinders by calculating the mix ratio of C30 concrete for both normal water and effluent wastewater according to American Concrete Institute (ACI) code [1].
- Conduction of performed concrete tests: slump test, compressive strength test and split tensile strength test by Universal Testing Machine (UTM).
- Conduction of toxicological testing on the crushed concrete cast with treated effluent water.

2.3 Materials collection and preliminary tests

For this study, there are different materials used of preparing concrete which are cement, fine aggregate, coarse aggregate and water. Before mixing and casting the concrete, the preliminary tests for the coarse aggregate and fine aggregate should be done such as a sieve analysis and specific gravity. The objectives of these tests are to determine the particle size distribution and fineness modulus of coarse and fine aggregates. Also, to determine the specific gravity of aggregates. In addition, it assists to get ready the mix design of the concrete before mixing and casting process.

Fineness Modulus of fine coarse aggregates using sieve analysis were conducted and gradation curve was plotted. Also, specific gravity on fine aggregates and cements were conducted in the laboratory.

Figure 1. Sieve shaker

Figure 2. Sample of fine aggregate

Figure 3. Specific gravity apparatus

2.4 Treated effluent waste water and normal water

Nowadays, concrete industries are using normal water for preparing the concrete mixture and for building construction. This study is a spot the light to conserve using fresh water. So, after searching and conducting different tests, it found that using treated effluent wastewater can be an alternative way of using fresh water for this purpose. Ministry of Commerce and Industry from General Specifications and Measurements directorate provides the standard and specifications of un-bottled drinking water (OS 8: 2012) that used all in construction industries for a purpose to check the results of this project weather is satisfying the same result or not.

As normal water has a specification and requirements of using it, also treated effluent wastewater it has. Haya Water Company following international specification and Ministry of Environment and Climate Affairs (MECA) requirements. There are regulations of using treated effluent, this study must be achieved their regulation to prove if using treated effluent wastewater satisfying for construction purposes or not. Haya Company provide for this study the specification used for different parameters of treated effluent wastewater. In the appendix, Haya water specification.

Also, based on the Ministry of Environment and Climate Affairs (MECA) regulations (Article 6) of using treated effluent wastewater for any alternative purposes are (Sustainableoman.com, 2019):

- In a buried drip feed system for the irrigation of ornamental trees and shrubs in areas where there should not be public exposure.
- In approved groundwater recharge system in areas where there should not be public exposure. These areas may include open land or wadis.
- Re-use of treated effluent for industrial processes within a closed circuit system where there will not be any dangers to the workers. Full details of such re-use is to be submitted when making application for Permit to Discharge.
- The re-use of treated effluent for flood, hosepipe, sprinkler or spray irrigation shall not be permitted without the prior consent of the Ministry.

However, water quality is dependent on its constituents, which can be divided into organic and inorganic substances. Given the wide range of natural and synthetic compounds which exist, an analysis of the individual constituents is not a practical proposition and, in any case, a complex affair. In practice, in order to arrive at significant milestones which will permit an evaluation of water quality, rapid methods of analysis are used which consider groups of parameters, rather than the individual parameters themselves for a specific time as well. So, for the study were analyzed different parameters of treated effluent wastewater in Haya Water Company by using Laboratory Information Management System (LIMS). The system is directly connected to the treated effluent wastewater. This software gives the constituents of the parameters with

drawing the graphs to show the variations. This study was selected different parameters to check their concentration during the period of collected water where is between 1/1/2019 to 3/2/2019, the table is shows treated effluent parameters.

Table 1: Treated effluent wastewater parameters

Physical	Chemical	Biological
pH	Chlorides (Cl) Sulphate (SO_4) Calcium (Ca)	Biological Oxygen Demand (BOD) Chemical Oxygen Demand (COD)

2.5 Mix Design Calculation by ACI Method

2. 6 Mix Description Table 2: Mix Description

SI. No.	Description of Mix	Normal Water	Treated Effluent Water	No. of Cubes	No. of Cylinders	Components
1	M1 (Control mix)	100%	0%	3	2	OPC, normal water, fine aggregate (FA) & coarse aggregate (CA)
2	M2	75%	25%	3	2	OPC, normal water, treated effluent water, FA & CA
3	M3	50%	50%	3	2	OPC, normal water, treated effluent water, FA & CA
4	M4	25%	75%	3	2	OPC, normal water, treated effluent water, FA & CA
5	M5	0%	100%	3	2	OPC, treated effluent water, FA & CA

Mix design was done for C30 concrete based to American Concrete Institute (ACI). It is important to know and to find the combinations of ingredient that will give the concrete properties are complying with confirm the specification. However, the concrete mix ratio is 1:
1.7: 2.34 with water cement ratio = 0.5

2.7 Quantity calculation, casting and curing

The total amount of concrete mix samples is provided in below table. Slump tests were conducted on fresh concrete. Three cubes of two cylinders were cast in each test sample. The dimension of each cube is (150 mm × 150 mm × 150 mm) and each cylinder has a dimension of (150 mm diameter and 300 mm length). At first, it must clean the cube and cylinder inside the mould surface properly with oil and brush. After that, preparing the concrete mixture. After, fill each mould (cube or cylinder) with 3 equal layers, each layer is compacted 25 times by tamping rod. This is used to reduce any air gaps. After that kept in the curing tank for the period of 28 days.

Table 3: Total amount for all mixes

Mix	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Normal Water (lit)	Treated effluent wastewater (lit)
M1 (Control mix)	4.86	9.17	12.63	2.43	0
M2	4.86	9.17	12.63	1.822	0.608
M3	4.86	9.17	12.63	1.215	1.215
M4	4.86	9.17	12.63	0.608	1.822
M5	4.86	9.17	12.63	0	2.43

2.8 Hardened concrete tests

It is a test for determining strength of concrete cube after 28 days curing that based to British standard. It is a test for determining cylinder specimen tensile splitting strength of hardened concrete after 28 days curing that based to British standard. Splitting tensile strength test on the concrete cylinder is a very important and basic method to determine the tensile strength and properties of concrete. The concrete is very weak in tension compared to its compressive strength

because it is brittle in nature and not expected to resist the direct tension. Splitting tensile important to determine the tensile forces and load which the concrete member may crack. After completed the cylinders curing in 28 days, removed from the curing tank. Then, the cylinders placed to dry under room temperature for one day. The cylinders have size 150 mm diameter × 300 mm height. The cylinder must be placed horizontally with strips steel and plywood on both the upper and lower of the cylinder due to distributed on the load uniformly a long length of the cylinder. Pressed green button until the two plates top and bottom touché the surface of the cylinder. Next, start the test with written all detailed on software. Wait until the show in the graph the load strength was flown of the cylinder. After tested the cylinder, was removed and appears as a crack on the surface of the cylinder.

$$\text{Splitting tensile strength} = F_t = \frac{2P}{\pi DL}$$

Where:
P = Compressive Load at Failure (N)
L = Length of cylinder (mm)
D = Diameter of cylinder (mm)

2.9 Toxicological test

Is to analyze the leaching of heavy metals in prepared concrete by mixed with acidic solution and normal water. Concrete prepared with treated effluent wastewater and normal water. Apparatus and materials required for this tests are, Sulfuric acid, Nitric acid, 2 volumetric flasks with size of 500 ml, Shaker with 20 RPM speed, Filter paper and Atomic Absorption Spectrometer (AAS) machine.

Figure 4. Atomic Absorption Spectrometer (AAS) machine

2.9.1 Procedure

In the following the procedure of toxic test to check the heavy metals in prepared concrete:

- Firstly, Crush the concrete that after 28 days curing to become like powder.
- Prepare 10 samples of powder concrete all the samples have same weight of 10 grams (5 samples will be used with chemical and 5 samples will add with normal water only).
- Preparing the chemical solution for first 5 samples as the following:
- Prepare 0.3 ml of sulfuric acid and 0.2 ml of nitric acid (0.5 ml solution)
- Take prepared solution to 500 ml of volumetric flask and then fill it with water.
- Shake the liquid in volumetric flask to be the water will mix with the solution.
- The solution is ready.
- Take 5 concrete samples and added with 100 ml chemical liquid, other 5 concrete samples add with 100 ml normal water.
- Keep the samples in the shaker with speed 20 RPM for 18 – 24 hours.
- After, filter the samples by using filter paper, take the weight of suspended solid after filtrating the samples.
- Take pH reading by using pH matter device.
- Finally, do the analysis of heavy metals (Cu, Zn, Mg) for the samples were prepared of acid leachate and normal water leachate, this implanted by using Atomic Absorption Spectrometer (AAS) machine.

Figure 5. Preparing acid

Figure 6. Concrete sample collection solution

Figure 7. Acid and normal leachate during filtration

3. RESULTS AND DISCUSSION

3.1 Analyzing treated effluent waste water

Haya water company lab using Laboratory Information Management System (LIMS) for analyzing the treated effluent wastewater parameters as annually, monthly or daily. The system is connected directly to the treatement plant.This technology depending on the parameters after how much time it will appear, which this system gives an exact values of concentration of these parameters in treated effluent water. However, the result is showing as:

a. Physical analysis:

pH analysis: During the selected period from 1/1/2019 to 3/2/2019, there are four reading of pH value of treated effluent water that is arranging between the values of 7. These results are satisfying with un-bottled drinking water standard specification of Oman.

b. Chemical analysis:

Calcium, Chloride and Sulphate analysis: There are only one value reading of this analysis which takes only one time in each month. Where the results are also matching to un-bottled drinking water standard requirement.

c. Biological analysis:

Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD): Daily reading is taking of biological parameters; this is very important to maintain amount of oxygen in treated effluent water and to be suitable work as in normal water.

3.2 Compressive strength test

Each Mix samples have a different compressive strength result and the average compressive strength of all cubes casted are presented in the following chart:

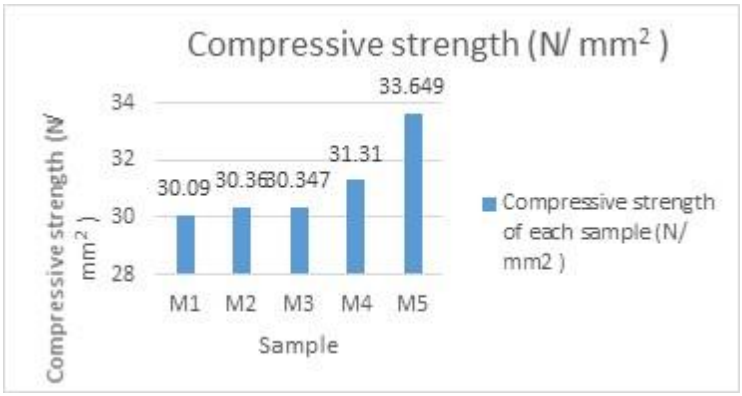

Chart 1: Result of Compressive strength

In this part the discussion on the results of cube compressive strength of C30 grade. A total number of cube were cast is 15 and test their strength after 28 days curing are showing in above tables. The results indicate that till M3 (50 % of normal water and 50 % treated effluent water) there is no much effect of increasing the strength, but after M3 there is a significantly increase of strength by 0.846 %. From the chart, the compressive strength results are in increasing and the difference between M1 to M4 is take around 3.89 %. Finally, to compare the result of 100 % of normal water and 100% of treated effluent water is gives using treated effluent wastewater in concrete mixture will gives additional increase of strength by 11.82 which is not high. So to conclude the result discussion of compressive strength test, using treated effluent wastewater will help to increase strength of the concrete cube, which M5 result is equal to 33.64 N/mm^3. Also, The compressive strength of concrete with normal water and treated effluent water is not affected. It may affect the concrete in long term.

Figure 5. Compressive Strength Test

Figure 6. Split Tensile Strength Test

However, in some trails of concrete mixture results it found lesser value than the required C30 grade in compressive strength that because of various error, which like:

- The cubes have surface cracks while handling the cube.
- The cube has air voids that means while making the cube the compaction was not done well.
- Types of aggregate, quality of aggregate that will effect to the result of compressive strength.
- Quality or type of cement used.

3.3 Split tensile strength test

Each mix samples have a different split tensile strength result, as shows in chart:

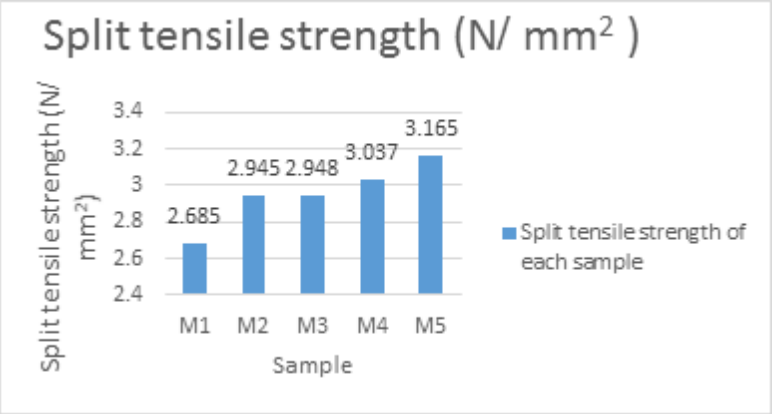

Chart 2: Result of split tensile strength

10 numbers of 150 mm × 300mm size cylinders were cast for M1, M2, M3, M4, and M5 concrete mix. The mix is similar to cubes mixture, where preparing concrete of C30 grade by using different water percentage (normal water and treated effluent wastewater). The cylinder samples were tested by split tensile strength test after 28 days curing. The average split tensile strength results provided in the table 4.19. The graphs are representing the average value results also. However, from the result values in the graph, it shows that M5 has the maximum value of strength, which was equal to 3.165 N/mm^3 and it is within BS standard of spilt tensile strength test. By comparing the strength results between M1 and M5 it was representing the difference is reaching to 17. 877% which is not high. Where in M1 are mixed with 100% of normal water and M5 is mixed with 100% of treated effluent wastewater which is not affected. It may affect the concrete in long term. Also, in a mix of M2 only the strength start increasing which is reaching to 9.683% with comparing with control mix M1. However, in both M2 and M3, there is significantly increasing which is reaching to 0.102%. Finally, from provided result is indicating that with the addition of 100% of treated effluent wastewater is getting the highest strength results from others. So, that is mean using treated effluent wastewater in the concrete is satisfying the condition of the test.

3.4 Toxicological test

To discuss the leachability test of heavy elements by using AAS machine, the results from tables it showed. All elements are within acceptable limits. In Zinc element the result higher concentration than other elements. Magnesium element results are non-detectable which that means it is very less appearance in the test. Also, Copper, Zinc, and Magnesium elements have higher concentration compared to normal water. Heavy metals concentration in concrete made from wastewater all most similar to the concrete made with normal water. Where there is no specific standard for using wastewater in concrete production. However, heavy metals concentration obtained are within the limit of other standard effluent discharge standard. While using acetic acid is like a solution to dissociated organic matters.

Table 4: Analyzing the elements for Leachate testing

Mix	**Mix in) percentage (Water mix, %**	**Acidic water leachate, (mg/l)**			**Normal water leachate, (mg/l)**		
		Parameters			**Parameters**		
		Cu	**Zn**	**Mg**	**Cu**	**Zn**	**Mg**
M1 (control mix)	100% NW,0% TEW	0.339	0.926	ND*	0.325	0.633	ND
M2	75% NW,25% TEW	0.390	0.103	ND	0.385	0.839	ND
M3	50% NW,50% TEW	0.320	1.125	ND	0.316	1.024	ND
M4	25% NW,75% TEW	0.478	1.339	ND	0.420	1.305	ND
M5	0% NW, 100% TEW	0.466	1.526	ND	0.450	1.349	ND

*ND - Non Detectable

4. CONCLUSION

The following conclusions were made based on the experimental work and corresponding results.

- Preliminary tests such as sieve analysis and specific gravity tests were conducted on concrete to determine the physical properties of concrete. Based on the sieve analysis tests, the fineness modulus of fine aggregate is 3.65, which means it is within the range of BS limit (2 – 4), and the shape of curve is 'S-gradient curve'.
- Specific gravity of fine and coarse aggregate results are same and the value is 2.7. It is within the range of fine and coarse aggregate. That is means it is suitable aggregate used for making concrete.
- Using LIMS system for analyzing treated effluent wastewater parameters, the results it shows is within Haya treatment effluent water requirement and normal water requirement.
- Slump tests were conducted to determine the workability of fresh concrete. The highest result of slump test was 28 mm, which for concrete made of 100 % of treated effluent wastewater.
- 28 days maximum compressive strength of concrete cube is 33.649 N mm^2, for concrete made of 100 % of treated effluent wastewater.
- Using treated effluent of wastewater in concrete production gives 11.83% difference between the results of M5 (concrete with 100% effluent) and control mix in compressive strength test.
- The highest result of split tensile strength was 3.165 N /mm^2. Split tensile strength test results indicates, concrete with 100% treated effluent wastewater (M5) result is greater than normal water (M1). The difference between M1 and M5 is 17.88 %.
- Result of analyzing the elements for leachate testing indicates that acidic water leachate gives higher results than normal water leachate in toxicity test for prepared concrete.
- In this project study was implemented different tests were required for checking the concrete strength and it is durability. Investigating the possibility of using treated effluent wastewater as a replacement than normal water in concrete mixture. Where the results concluded that use 100 % of treated effluent wastewater for concrete mixing it shows the higher results of strengthen the concrete after 28 days curing.

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