Comparative study of concrete constructed using wastewater and potable water

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Abstract. 80% of the water supplied, normally comes out as wastewater either domestic or industrial. The utilization of wastewater in concrete will reduce potable water usage in the construction industry. Approximately 150 litres of water are required for 1m\(^3\) of concrete without considering other applications of water in the concrete industry. This research study has investigated the performance of concrete using wastewater. 60 total number of concrete cubes have been designed and constructed using 10%, 20%, 30% and 100% of wastewater. The experimental data indicated that 30% of wastewater content in the concrete mix have increased 18% of the concrete strength compared with the control sample. Meanwhile, the result of the X-Ray Fluorescence Test (XRF) test for the concrete sample recorded that the CA is higher than the 30% concrete sample.

1. Introduction

Construction industry is a crucial sector for developed country. The main challenges in construction industry are the environment issues such as efficient resources usage especially water, it effects to the climate change and accidental risk. 97 percent of water are from oceans, only remaining 3 percent is clean water [1]. It became worst when approximately 150 litres water is required for 1m\(^3\) of concrete exclude other applications of water at the construction site. The shortage of clean water shall be overcome in order to minimise the social and environmental impact in future. The usage of wastewater seems to be more useful in solving this matter. In Malaysia, about 2.97 billion cubic meters of wastewater production have been recorded per year. This wastewater can be utilized to replace clean water usage in concrete industry. Previously, [2] has find out that no significance difference of concrete compressive strength using treated wastewater. Meanwhile, [3] investigated the primary and secondary treated wastewater provided a positive compressive strength result in replacing potable water as concrete’s main ingredient. 10.68% increment of compressive strength have been recorded with the 20% of wastewater replacement in the concrete mix. Salim et al. (2018) [4] investigated the ability sewage sludge ash (SSA) to replace the potable water and fine aggregate in concrete. They found that, the 10% of SSA replacement for both materials have provide the optimum density and compressive strength as compared with the control sample. A lot of study on the effect of rainwater, river water, lake water and sea water on concrete have been conducted. However, the study on of the effect of wastewater to the compressive strength of concrete still insufficient especially in Perlis areas and need to be conducted. Optimum percentage of wastewater replacement in concrete shall be investigated through this
experimental study. The main objective of this research study is to find out whether wastewater could be serves as a substitute of potable water as a material in the process of concrete making.

2. Methodology
In this experimental study, 60 cubes have been designed and constructed. The standard concrete mix design has been used to replicate the existence structures in Malaysia. The cubes were design and constructed using wastewater with the portion of 10%, 20%, 30% and 100% for each group. All of these samples have been compared with control sample. Each cube with differ percentage of wastewater content have experienced curing process for 7, 14 and 28 days.

All of the samples have been tested with compressive strength, density test and X-Ray Fluorescence test. The main purposed of conducting these tests are to investigate the behaviour of concrete cube casting using wastewater at different wastewater content [5]. Meanwhile, several tests on the wastewater have been tested such as pH, Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) test. These tests were conducted to determine the quality level of wastewater before been added in concrete mix.

3. Experimental results

3.1 Compressive Strength
Figure 1 shows the comparison of compressive strength for 5 different samples. The highest compressive strength is obtained from 30% wastewater sample recorded at 28 days of curing period. The control sample ranked at third place as compared among all the sample used in this study. The utilization of 100% of wastewater content in concrete sample indicates the lowest compressive strength as compared with other samples. Meaning that, fully wastewater content is not recommended to be used in concrete mix. The chemical content in wastewater for 100% wastewater sample has affected the concrete strength during mixing process [6].

![Graph of Average Compressive Strength](image)

**Figure 1.** Comparison of compressive strength for all samples

3.2 Density test
Table 1 indicates the differences of density in concrete cubes with average initial and final density after respective days of curing session. 20% of wastewater content recorded the highest percentage different obtained at 7 days curing period. The chemical substances in wastewater may cause this
difference as compared with other samples used in this study. Most of the initial density of the concrete sample greater than final density due to the absorption process during curing period for the strength development [7].

### Table 1. Comparison of percentage different of density for all samples

| Sample Control Sample | Curing period | Percentage different between initial and final density (%) |
|-----------------------|---------------|----------------------------------------------------------|
|                       | 7             | 1.5                                                      |
|                       | 14            | 1.13                                                     |
|                       | 28            | 0.76                                                     |
| 10% WWC               | 7             | 0.93 0.80                                                |
|                       | 14            | 0.71                                                     |
|                       | 28            |                                                          |
| 20% WWC               | 7             | 2.24 1.33                                                |
|                       | 14            | 1.89                                                     |
|                       | 28            |                                                          |
| 30% WWC               | 7             | 1.66                                                     |
|                       | 14            | 1.29                                                     |
|                       | 28            | 1.37                                                     |
| 100% WWC              | 7             | 1.38 1.16                                                |
|                       | 14            | 1.10                                                     |
|                       | 28            |                                                          |

### 3.3. X-Ray Fluorescence Test

X-Ray Fluorescence Test indicates the composite materials content in concrete cubes for controlled samples, 10%, 20%, 30% and 100% of wastewater sample. Figure 2 shows the comparison of composite material contents obtained at 7, 14 and 28 days curing period, respectively. Calcium indicates the highest content of chemical in all concrete samples. Based on plotted graph, the 100% of wastewater content indicates the reduction of calcium content in concrete sample. Meaning that, the chemical substances in wastewater effected the calcium carbonate (limestone) in cement. This reduction has reflected the reduction of concrete strength obtained from 100% wastewater sample. The usage of 100% of wastewater content is not recommended unless the additional admixture of other suitable materials is proposed to maintain the strength of concrete [8]. It also observed that as the curing period increase the CA content will be decreased for control sample due to the chemical reflection in cement.
(a)

(b)
3.4. pH test

Based on the result from Table 2, the pH of tap water obtained is 6.961 and the pH of wastewater is 7.673. The pH of tap water shows that it is neutral trait and not too far with being acidic while pH of wastewater is slightly alkali. Wastewater has an alkali trait due to nitrification process of changing ammonia to nitrate. Hence, it was used for treatment of wastewater. A researcher stated that acidic substances are not suitable for concrete due to concrete deterioration where the presence of pores will increase with greater value of acidic [9].

| pH               | pH               |
|------------------|------------------|
| Potable water    | 6.961            |
| Wastewater       | 7.673            |

3.5. COD and BOD test

The BOD of potable water is 0.76mg/L, while average BOD for wastewater is 0.39mg/L. It shows that the number of dissolved oxygen in wastewater is lower than potable water with difference of 0.37mg/L. By referring to National Water Quality Standards for Malaysia, it shows that the BOD values for both water samples are below than 1mg/L, which is within the required range. Meaning that wastewater can be used to replace potable water as an alternative for casting of concrete. Table 3 shows the different in percentage of COD and BOD test for both water samples. The difference in BOD was high compared
to COD Test which is almost 50%. This is due to biodegradation process in potable water is higher than treated wastewater.

\[\textbf{Table 3. COD and BOD for both water samples}\]

|          | Potable water | Wastewater |
|----------|---------------|------------|
| COD      | 14.33         | 14.67      |
| BOD      | 0.76          | 0.39       |

\[\textbf{4. Conclusion}\]

The compressive strength of concrete samples using 30% of wastewater content indicates the 18% increment compared with the control sample. However, 100% of wastewater content recorded the lowest compressive strength among other samples. The 30% of wastewater content indicates the alkalinity behaviour obtained from pH test conducted in this experimental study. Meanwhile, the COD results indicates that the wastewater is still in approval range which is less than 25mg/L by referring to the National Water Quality Standards. However, the long-term effect of wastewater replacement in concrete shall be studied to investigate the concrete strength effect. It is suggested to provide enough data before wastewater utilize in construction industry.

\[\textbf{References}\]

[1] Ramkar A P, Ansari 2016 Effect of treated wastewater on strength of concrete Journal of Mechanical and Civil Engineering 13(6) 41-45.

[2] Ghair A M, Al-mashaqbeh O A, Sarireh M K, Al-kouz, N, Farfoura M, & Megdal S B 2016 9(4), 1519–1525.

[3] Khatavkar N K, Professor A. 2017 ijcesr.2/9-13

[4] Salim N S A, Kadir A A, Maliki A I F A, Shahidan S 2018

[5] Ooi S L, Mohd R S, Mohammad I, Ali M I 2001 J. Tek. 34(F) 1-10

[6] Banerjee D, 2017 J Eng. Tech 4(4)

[7] Olugbenga A, 2011 IISTE

[8] Wang Z, Yang J, Deng X, Lan X 2015 J Sustain.

[9] Barbhuiya, S., & Kumala, D. 2017 Behaviour of a sustainable concrete in acidic environment Sustainability 9(9) 1556.