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REUSING TREATED EFFLUENT IN CONCRETE TECHNOLOGY

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Abstract. In this paper, the feasibility of using treated effluent for concrete mixing was studied. Treated effluent from sewage treatment plants in Malaysia is currently being wasted through direct discharge into waterways. With proper water quality control, this treated effluent can also be considered as a potential water resource for specific applications. Two tests were carried out namely compressive strength test and setting time to determine the feasibility of using treated effluent for concrete mixing. The results were compared against the tests conducted on control specimens which used potable water. The results showed that treated effluent increases the compressive strength and setting time when compared with potable water.

Key words: treated effluent, mixing water, compressive strength, setting time, concrete technology.

1.0 INTRODUCTION

Sewage water originates mainly from domestic sources and comprises 99.9% water and 0.1% organic and inorganic solids in settleable, suspended, and soluble forms. Untreated sewage is a hazard to both public health and to the environment. Therefore, sewage water is treated in a sewage treatment plant before discharging into an inland waterway. Industrial and trade wastes in Malaysia are treated separately by on-site industrial waste treatment plants [1]. By the end of 1997, Indah Water Konsortium (IWK) was given the responsibility of maintaining a total of 4,539 sewage treatment plants with a population of 7,416,486 [2]. Table 1 shows the sewerage systems managed by IWK from 1994-1997. Currently, the treated effluent from sewage treatment plants is flowed directly into waterways. With proper water quality control, this treated effluent can also be considered as a potential water resource for specific applications.

The application of reusing treated effluent from sewage treatment plant in agricultural sector and industry has been carried out successfully in developed countries [3–5]. Therefore, the focus of this study is to consider the applicability of reusing the treated effluent in concrete technology since some non-potable water are found to be suitable as the concrete mixing water [6]. This paper presents the results of a laboratory study using treated effluent as mixing water for concrete.

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Table 1 Details of sewerage systems operated and maintained by IWK as at December, 1997 [2]

State	Network Pipelines (km)	Network Pump Stations	STPs	Septic Tanks	Population Served-Connected to STPs	Population Served-Septic Tanks+	Total Population Served
Perlis	2	–	15	11,002	2,725	55,010	57,735
Kedah	170	3	413	110,592	185,434	552,960	738,394
Pulau Pinang	1,372	29	394	4,886	1,427,422	24,430	1,451,852
Perak	803	42	660	184,810	844,855	924,050	1,768,905
Selangor	2,266	38	1,250	94,289	2,372,137	471,445	2,843,582
Kuala Lumpur	1,232	40	177	36,670	1,308,424	183,350	1,491,774
Labuan	23	4	14	3,120	24,446	15,600	40,046
N. Sembilan	466	6	435	29,993	492,083	149,965	642,048
Melaka	234	1	440	33,055	251,917	165,275	417,192
Johor	344	16	390	150,211	364,168	751,055	1,115,223
Pahang	100	–	176	59,760	106,925	298,800	405,725
Terengganu	40	1	175	18,409	35,950	92,045	127,995
Total	**7,052**	**180**	**4,539**	**736,797**	**7,416,486**	**3,683,985**	**11,100,471**

+Population using septic tanks is assumed to be five times the number of septic tanks.

2.0 MIXING WATER

Generally, any natural water that is drinkable and has no pronounced taste or odour is considered suitable for the use as mixing water in producing concrete [7]. The quality of the mixing water plays a significant role in the concrete. Impurities contained in the mixing water may interfere with the setting time of the cement, may affect drying shrinkage, durability, and may also lead to corrosion of the reinforcement. For this reason, the suitability of water for mixing and curing purposes should be considered important [8].

In the similar study conducted by Cebeci and Saatci [9], the results (setting time, mortar, and concrete strength test) showed that biologically treated average domestic sewage is indistinguishable from distilled water when used as mixing water. In 1992, Ghazaly and Ng [10] reported that rain water, river water, and treated domestic sewage are suitable for use with cement but not for the case of raw domestic sewage.

In the light of the present knowledge, it is not possible to issue a specification for water in producing concrete but only for the methods of testing such water [11]. BS 3148 [11] has outlined two methods by which questionable water may be tested in respect of its suitability for producing concrete. The initial setting time of the cement paste made with the questionable water must not differ by more than 30 minutes of the initial setting time of control paste. Also, the average compressive strength of the concrete cubes made with questionable water shall not less than 90% of the average strength of the control cubes. Cubes shall be tested 28 days after preparation except in the case of concrete cubes with high alumina cement which shall be tested 24 hours after preparation.

3.0 EXPERIMENTAL PROGRAMME

3.1 Materials Used

A Seladang's Ordinary Portland Cement (OPC) which complied to MS 522: Part 1 [12] was used in preparing the concrete specimens. The chemical analysis and physical properties of OPC is given in Table 2. Washed river sand (with 49% managed to pass through the 600 μm sieve and natural gravel of maximum size 20 mm were used in this study. Potable water from the public water supply system and treated effluent from a sewage treatment plant (waste stabilisation pond) in Taman Sri Pulai, Skudai were ued or mixing water. The quantity collected was about two hundred liters and were stored in a clean plastic container.

3.2 Mix Design and Specimen Preparation

Concrete cubes were designed according to the Department of Environment (DOE) Methods, United Kingdom [13]. Concrete cubes with mix design of Grade 30 (G30)

Table 2 Chemical analysis and physical properties of OPC

Chemical analysis	**Percentage**
Silicon dioxide (SiO_2)	20.20
Aluminium oxide (Al_2O_3)	5.70
Ferric oxide (Fe_2O_3)	3.00
Calcium oxide (CaO)	62.50
Magnesium oxide (MgO)	2.60
Sulphur trioxide (SO_3)	1.80
Sodium oxide (Na_2O)	0.16
Potassium oxide (K_2O)	0.87
Loss on ignition (LOI)	2.70
Physical properties	
Fineness – specific surface are (m^2/kg)	314
Soundness – LeChatelier method (mm)	1
Specific gravity	3.28

Source: Tenggara Cement Manufacturing Sdn. Bhd.

and Grade 35 (G35) that based on same workability were cast using treated effluent. Potable water was used in concrete cubes as the control specimens. Details of the mix proportions are given in Table 3.

The test cubes were cast in 150 mm cast-iron moulds. The concrete was mixed using pan mixer and fresh concrete was filled in the mould in three layers which was compacted using vibrating table. The cube moulds were stored in a place free of vibration and direct sunlight for 24 hours. At the end of this period, the mould was removed and the cubes were cured in potable water until the age of testing.

Table 3 Mix proportion of concrete cubes

Design Strength (N/mm^2)	**Mix Proportions (kg/m^3)**				**W/C Ratio**
	Water	**OPC**	**Aggregate**		
			Fine	**Coarse**	
G30	190	350	730	1160	0.54
G35	190	375	730	1140	0.51

3.3 Testing

A small portion of the treated effluent was retained for physical and chemical analysis. The characteristic of treated effluent and potable water were analysed according to the methods described in the Standard Methods [14]. Heavy metals were analysed using Atomic Adsorption Spectrophotometer while cations and anions were analysed by Spectrophotometer DR4000. The cubes were tested for their compressive strength after curing periods of 7, 28, and 90 days for both G30 and G35. The TONIPACK 3000 was used to determine the compressive strength of concrete cubes with a loading rate at 7.0 kN/s. The strength of the cube was taken as the average of three cube specimens.

For setting times, a cement paste was made with treated effluent and the ordinary Portland cement. The test was carried out in accordance with BS4550 Part 3: Section 3.5 and Section 3.6 [15–16]. The procedure also involved preliminary determination of the amount of mixing water required to produce a cement paste of standard consistence. Potable water was used as a control paste.

4.0 RESULTS AND DISCUSSIONS

The physical and chemical properties of the treated effluent and potable water are shown in Table 4. The treated effluent was slightly turbid (35 NTU) and faint yellowish-brown in colour. The total alkalinity, total hardness, sodium, and chloride concentration are relatively higher compared to potable water. However, the concentration of the constituents of treated effluent were well within the respective tolerable limits from various researcher, as shown in Table 4.

Table 4 Characteristics of treated effluent and potable water

Parameter	**Unit**	**Concentration**		**Tolerable Limits**	**References**
		TE	**PW**		
pH	–	7.48	7.41	6.0–8.0	McCoy [17]
Total solid	mg/l	89.5	–	2000	White [7]
Total suspended solid	mg/l	17	-	2000	Mindness and Young [18]
Total alkalinity	mg/l as $CaCO_3$	62	20	1000	Neville [8]
Sulfate, SO_4^{2-}	mg/l	10.49	11.06	1000	BS3148 [11]
Chloride, Cl^-	mgl	11.98	7.58	500	BS3148 [11]
Lead, Pb	mg/l	N.D.	N.D.		Mindness
Copper, Cu	mg/l	0.0817	0.0743	500	and Young
Manganese, Mn	mg/l	0.124	0.045		[18]
Zinc, Zn	mg/l	0.0460	0.0378		
Calcium, Ca	mg/l	46.00	0.17	2000	
Magnesium, Mg	mg/l	6.9	2.2	(include	
Sodium, Na	mg/l	29.033	1.317	sulfate	BS3148 [11]
Ferum, Fe	mg/l	0.490	0.153	and	
Nitrate, NO_3^{2-}	mg/l	2.1	2.9	chloride)	

Note: TE : Treated Effluent; PW : Potable Water

Table 5 summarizes the result of compressive strength for the cubes mixed with different mixing water. The cubes were tested on the 7th, 28th, and 90th day. The compressive strength of cube mixed with treated effluent at 7-day was 26.22 N/mm^2 compared to 24.46 N/mm^2 of potable water. Similarly at 28-day, treated effluent was 37.17 N/mm^2 and 90-day was 41.24 N/mm^2 compared to 33.20 N/mm^2 and 38.27 N/mm^2 of potable water, respectively.

Table 5 Compressive strength with different mixing water

Grade (N/mm^2)	Age (Day)	Compressive Strength (N/mm^2)		
		Mixing water		Percentage of increasing (%)
		Potable water (fc)	Treated effluent (ft)	
30	7	24.46	26.22	7.20
	28	33.20	37.17	11.96
	90	38.27	41.24	7.76
35	7	27.54	28.52	3.56
	28	38.41	41.88	9.03
	90	43.56	45.16	3.67

Meanwhile, the same observation was found for concrete cube G35. At curing age of 7-day, treated effluent (28.52 N/mm^2) was found to be slightly higher than control specimen (27.54 N/mm^2). The strength pattern for curing age of 28-day and 90-day were also similar as before, i.e. the strengths of treated effluent were higher than the strengths of potable water.

Overall, a higher strength was obtained from specimens mixed with treated effluent than from control specimens. The increase is between 7.2 – 12.0% for G30 and 3.6 – 9.0% for G35 respectively. Higher compressive strength of concrete made with a reclaimed wastewater as compored to concrete mixed with potable water was also reported by Tay and Ng [19].

Figure 1 and Figure 2 show the development of compressive strengths for concrete cubes G30 and G35 at different ages respectively. All the graphs have similar pattern shapes, that is, an increase in compressive strength was observed with an increase of age. The results of overall compressive strength tests are found to be consistent with the achieved design strength and the requirement stated in the BS 3148: 1980 [11]. The treated effluent seems to increase the compressive strength of the concrete cubes compared to the control for both grades. The percentages of increase in strength for treated effluent concrete cubes compared to the control concrete cube are shown in Figure 3. The pattern of strength increase was almost similar in both mixes. After 28 days of curing, the strength increase in concrete cube cast with treated effluent was about 1.2 times than the control cubes for G30. The

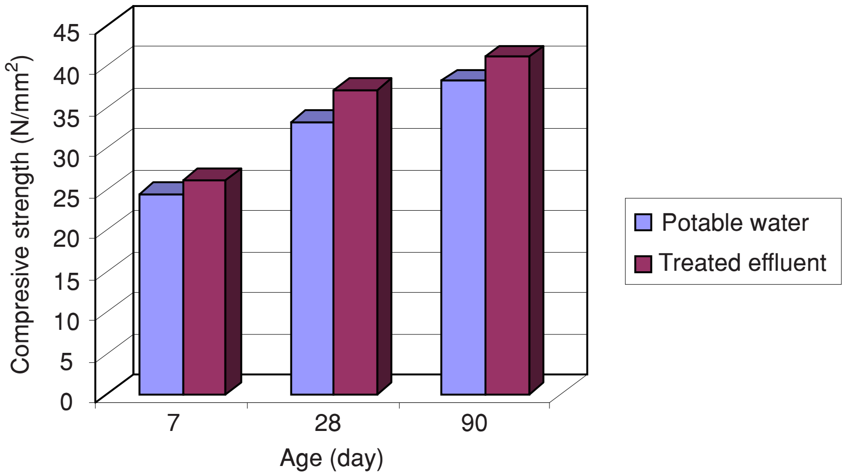

Figure 1 Compressive strength of concrete G30

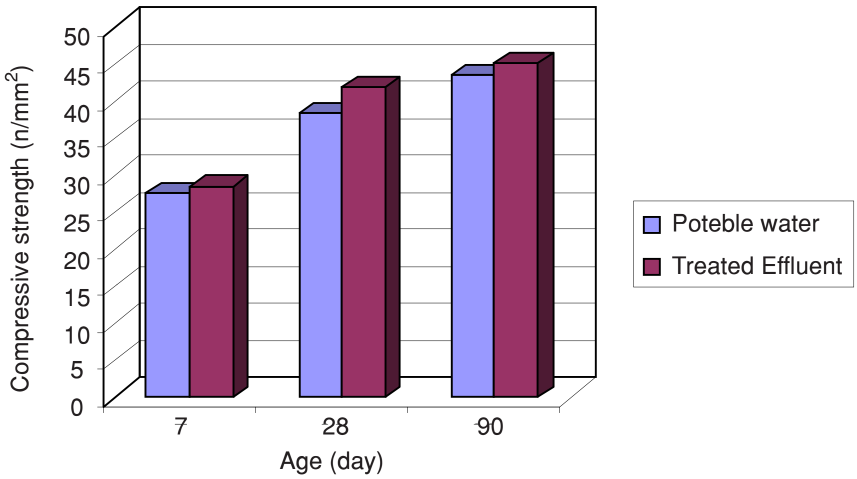

Figure 2 Compressive strength of concrete G35

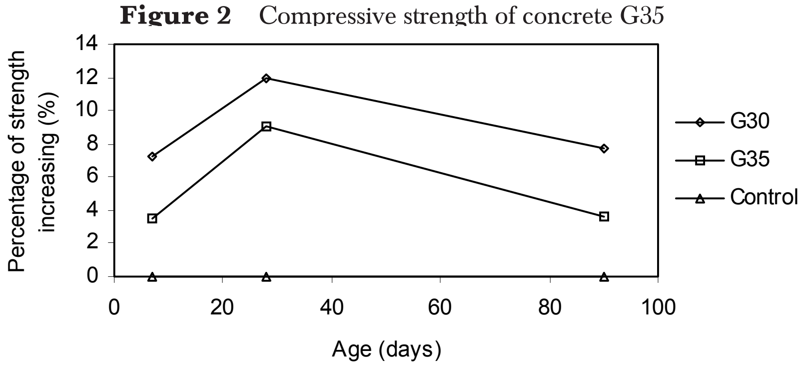

Figure 3 The percentage of strength increasing of concrete cube

data for G35 also indicated a trend similar to that of G30, except that the strength increase in cube G30 was slightly higher than the cube of G35.

The increased in that was observed in this study may due to the higher concentration of sodium and calcium salt of chloride in treated effluent, compared to potable water. Mindess and Young [18] reports that sodium chloride and calcium chloride may increase early strength but reduce ultimate strength. Calcium chloride increases the rate of heat liberation during the first few hours after mixing and acts as catalyst in the reaction of hydration of C_3S and C_2S [8].

The results of setting time test are shown in Table 6. Initial and final setting times are slightly higher for treated effluent paste compared to the control paste. This probably due to the impurities in treated effluent such as zinc and copper salts which varies in setting time process. Other salts that react actively as retarders include sodium iodate, sodium phosphate, sodium arsenate, and sodium borate [7].

The requirement of BS3148: 1980 for ordinary Portland cement stated that the initial setting time should not be less than 75 minutes. The setting time for cement paste mixed with treated effluent is well within the requirement of the standards.

Table 6 Setting time

Type of water	Water content (%)	Setting time (min)	
		Initial	Final
Potable water	32	145	165
Treated effluent	32	155	170

5.0 CONCLUSIONS

From the results of this study, the properties of treated effluent used in this study were found to be within the tolerable limits from the various researchers. Higher compressive strength was achieved for concrete cube with treated effluent compared to the concrete cube with potable water. The initial and final setting times of cement paste mixed with treated effluent increase compared with potable water. The result obtained from this study indicates that treated effluent could be used as mixing water in concrete in accordance with BS3184.

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