Use of Electric-Arc Furnace Dust (EAFD) As a Stabilizer for Mixer Drum Wash Water

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Abstract

Electric-Arc Furnace Dust (EAFD) is a waste by-product material generated during steelmaking process by the electric-arc furnace method at a rate of about 2% of the total steel product. It is classified as environmentally hazardous material and thus must be treated before being disposed of. Finding effective and safe method to dispose of the large quantities of EAFD produced from steel factory is a major environmental concern.

On the other hand, it is a normal practice to clean the ready-mix concrete mixer's drum after each day of operation using 400 to 1200 liters of waters. After cleaning, the mix between wash water and concrete residue in mixer drum is then need to be discharged properly according to local regulation because it is considered a hazardous substance as it contains caustic soda and potash, and it has high pH. Because of this, normally, the ready-mix concrete companies are not allowed to discharge the waste from mixer drum's wash water off-site and must contain it within the site.

Considering that the use of EAFD in concrete prolongs setting time of concrete, the current study has the objective to explore the potential of using EAFD as a stabilizer for mixer drum wash water. The stabilized wash water will then be used as part of mixing water for the next day concrete mixing. The desired stabilization time for this type of application is overnight stabilization.

For overnight stabilization of wash water amounts of EAFD in the range between 1 kg and 2 kg per 100 liter of wash water were found to be appropriate.

Fresh and hardened properties for concrete prepared using stabilized wash water were found to perform as good as the control mixes.

Keywords: EAFD, Stabilizer, Concrete, Wash Water

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1. Background

Electric-Arc Furnace Dust (EAFD) is a waste by-product material generated during steel making process by the electric-arc furnace method at a rate of about 2% of the total steel output (AISI 2001). Due to the present of heavy metals such as zinc, chromium and nickel in EAFD, it is classified as environmentally hazardous material by World Environmental Protection Agency (EPA) and thus must be treated first before being disposed. Thus, early on, many studies have been directed towards the solidification and/or stabilization of EAFD to reduce its disposal cost and to protect the environment (Hamilton and Sammes, 1999; Laforest and Duchesne, 2006; Pereira et al., 2001; Salihoglu and Pinarli, 2008; Salihoglu et al., 2007).

The utilization of EAFD in concrete industry has also been studied (Al-Zaid et al., 1997; de Fargas et al., 2006; Almutlaq, 2011). These studies have proven that EAFD might be used in concrete to enhance its performance. In general, early studies on utilization of EAFD in concrete mixtures were in the form of using EAFD as partial replacement of cement. Some promising benefits such as gain of compressive strength, better resistance against chloride penetration and improved long term durability were found. However, addition of EAFD prolongs the setting time of concrete – the larger the amount of EAFD the longer the setting time. Therefore, the maximum amount of EAFD that can be added to concrete will be governed by the acceptable setting time for a certain concrete mixture, and thus will be of small amount. Considering the fact that the addition of EAFD in concrete mixtures prolongs the setting time, the use of EAFD as a stabilizer and/or a set-controller is potential.

On the other hand, disposal of mixer drum wash water are problems commonly encountered by the ready mix concrete plants (Chini et al., 2000). The wash water is categorized as hazardous substance as it contains caustic soda and potash and thus has a high pH. Because of this, the concrete producers are normally required to restrict the wash water on-site and not allowed to discharge it off-site. Use of stabilizing agents to stabilize the concrete, or the cement contained in the wash water so that the wash water can be used in the next day concrete mixes provides a solution for such problems. Considering these facts, the potential of using EAFD as a stabilizer for mixer drum wash water was investigated. The amount of the stabilizer to be added depends on the amount of wash water present in the drum of the concrete truck, and on the time span desired for the reuse of the water. In this study, only the use of EAFD for over-night stabilizer for mixer drum wash water was investigated.

2. Experimental Program

The experimental work was carried out in two stages: (1) determining EAFD dosage suitable for an overnight stabilization of wash water; and (2) investigating the fresh properties and hardened properties of the concrete produced using stabilized wash water. The experimental work includes setting time, slump, slump retention, concrete temperature, heat of hydration, compressive strength, and rapid chloride permeability tests

For simulating the use of EAFD as a stabilizer for mixer drum wash water, a small scale concrete mixture was prepared, and the fresh concrete is discharged and mixer was cleaned using water. Part of the wash water was discharged from the mixer into a plastic bag to be used as a reference, and the remaining was discharged into a plastic container to determine the amount (weight) of wash water to be stabilized. The wash water was then put back into the mixer and the required amount of EAFD was added to it and the mixer was run for 2 minutes. This wash water was discharged into a plastic container and stored overnight to be used for mixing the concrete mixture in the next day. The stabilized wash water remained in a slurry form until the next day (see Figure 1).

(a) (b) (c)

Figure 1: The plastic container condition: (a) before being used, (b) while being used and (c) after being used to store a stabilized wash water

2.1 Material properties

Portland cement Type I and EAFD from HADEED Factory in Al-Jubail, Kingdom of Saudi Arabia with the physical and chemical properties shown in Table 1 were used throughout the study. The grain size distribution of EAFD as compared to the cement used is shown in Figure 2. Crushed stone with a specific gravity of 2.62 was used as coarse aggregates. A combination of crushed sand and red sand with a combined specific gravity of 2.61 and fineness modulus of 2.22 was used as fine aggregates.

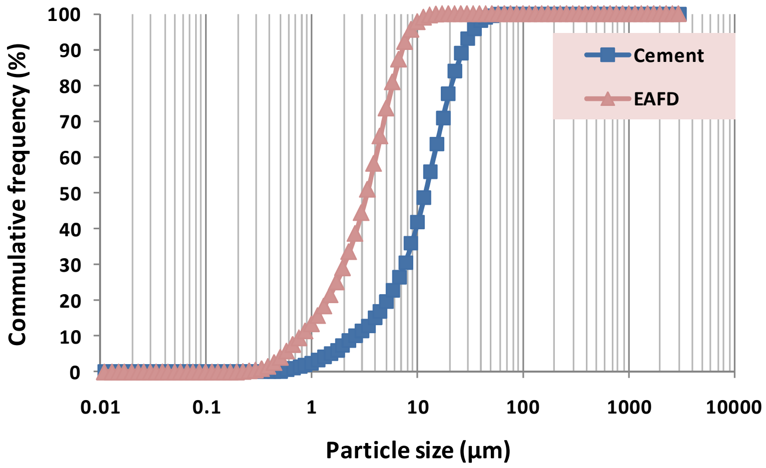

Figure 2: The grain size distributions of EAFD and cement

Table 1: Chemical and physical properties of cement and EAFD

	SiO_2	Al_2O_3	Fe_2O_3	CaO	ZnO	MnO	L.O.I (%)	Specific Gravity	Fineness (m^2/kg)	Median particle size (μm)
Cement	20.20	5.49	4.12	65.43	-	-	1.38	3.15	375	11.86
EAFD	1.91	0.26	48.52	7.04	27.73	3.04	5.68	3.97	398	3.30

2.2 Mix design and designation

The concrete mix design with water to binder ratio (w/b) of 0.52 was employed in this study and is shown in Table 2. The concrete mixing was carried out at laboratory temperature (20 ± 2 ºC). The different types of concrete mixes used in this study are designated as follows:

- CWB52L – Control mixture with w/b = 0.52. The letter L indicates that the concrete is mixed and cured under laboratory temperature.

- E1.0WB52WL – Concrete mixture with w/b = 0.52 and prepared using stabilized wash water using 1 kg EAFD /100 liter of wash water and casted under laboratory conditions.

- E2.0WB52WL – Concrete mixture with w/b = 0.52 and prepared using stabilized wash water using 2 kg EAFD /100 liter of wash water and casted under laboratory conditions.

Table 2: Concrete mix design (in kg/m³)

Cement	Coarse aggregate	Fine aggregate	Water
350	1050	785	182

3. Results and Discussions

Based on results and discussions presented in this chapter, the following conclusions can be drawn: experimental work was carried out in two stages: (1) determining EAFD dosage suitable for an overnight stabilization of wash water; and (2) investigating the fresh properties and short term hardened properties of the concrete produced using stabilized wash water.

3.1 Setting time

Figure 3 shows the setting time performance for the mixtures prepared using stabilized wash water and the control mixture tested at laboratory temperatures of 20 ºC. The setting times for the concrete prepared using a stabilized wash water were found to be almost similar to the control mixture

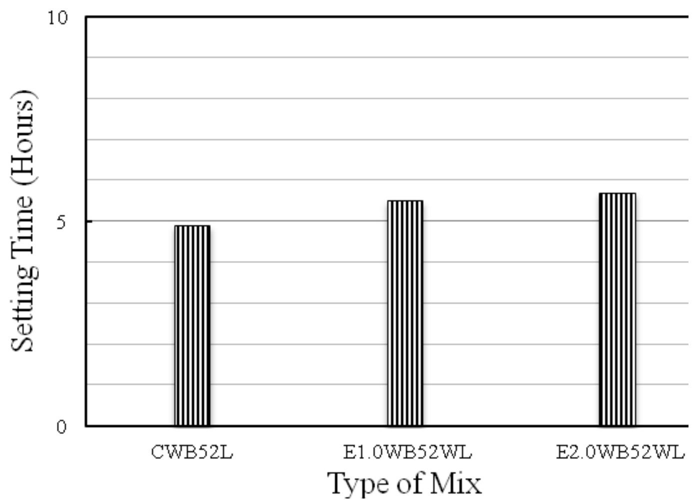

Figure 3: Setting time performance of control concrete and concretes prepared using stabilized wash water at temperature = 20 °C

3.2 Slump and slump retention

Concretes mixed with stabilized wash water were observed to have almost the same initial slumps as that of control one as shown in Figure 4. However, the slump retention of concrete mixed with stabilized wash water showed a better performance than the control one as shown in Figure 5.

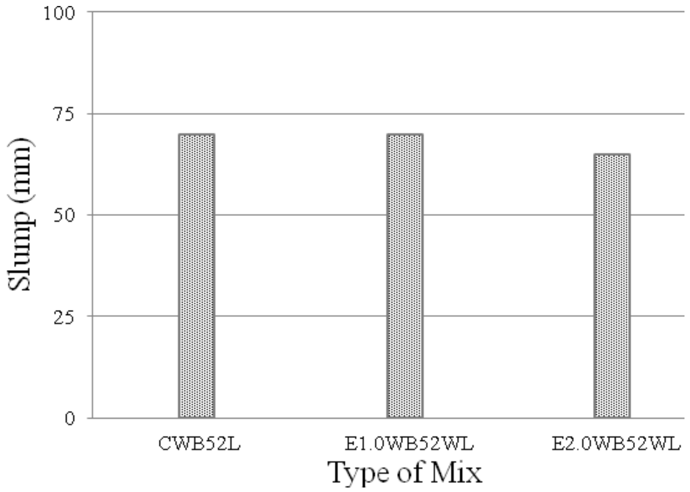

Figure 4: Slumps performance of control concrete and concretes prepared using stabilized wash water at temperature = 20 °C

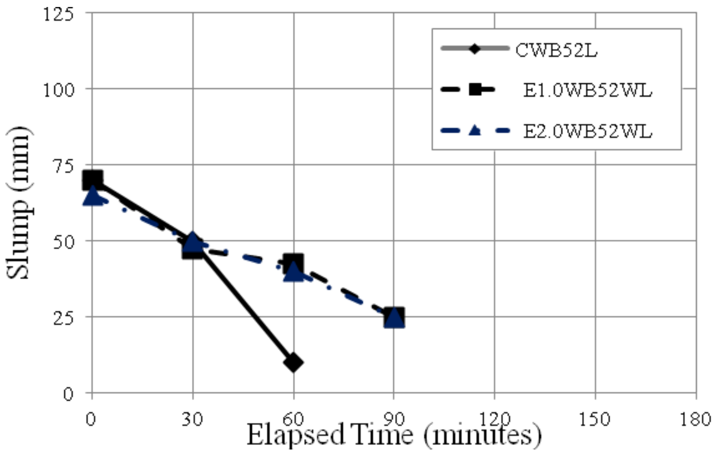

Figure 5: Slump retentions performance of control concrete and concretes prepared using stabilized wash water at temperature = 20 °C

3.3 Heat of hydration

The plots of heat generated during the hydration of concretes prepared using stabilized wash water are shown in Figure 6. Concrete prepared using stabilized wash water were observed to generate higher temperature than the control one.

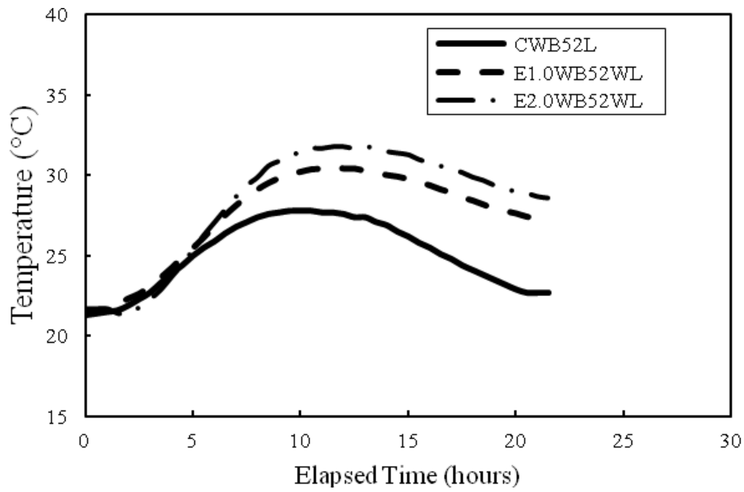

Figure 6: Heats of hydration performance of control concrete and concretes prepared using stabilized wash water at temperature = 20 °C

3.4 Drying shrinkage

Figure Concretes mixed with stabilized wash water gave less shrinkage strains as compared to the control mix as shown in Figure 7. The reduction in the shrinkage strain is increased with the amount of EAFD.

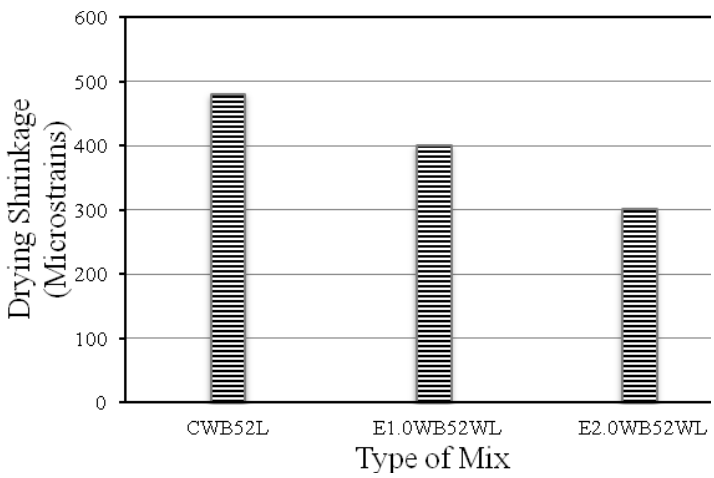

Figure 7: Drying shrinkages performance after one year of control concrete and concretes prepared using stabilized wash water at temperature = 20 °C

3.5 Compressive strength

Concretes prepared using stabilized wash water showed almost the same performance compared to that of control one as shown in Figure 8.

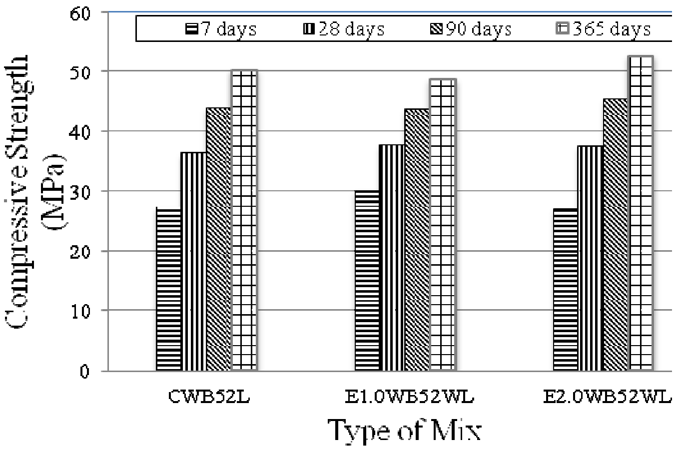

Figure 8: Compressive strengths performance of control concrete and concretes prepared using stabilized wash water at temperature = 20 °C

3.6 Rapid chloride permeability

The rapid chloride permeability test results are shown in Figure 9. Concretes mixed using stabilized wash water showed almost similar chloride penetrability.

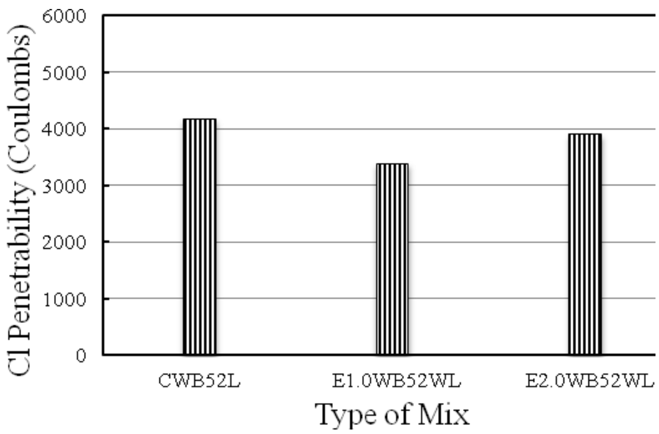

Figure 9: Rapid chloride permeability performance of control concrete and concretes prepared using stabilized wash water at temperature = 20 °C

4. Conclusion

Based on results and discussions presented in previous section, the following conclusions can be drawn:

1. In general, EAFD has proven to be an effective stabilizing agent for mixer drum wash water.

2. The setting time, slump, drying shrinkage, compressive strength and chloride penetrability of concrete prepared using the overnight-stabilized mixer drum wash water showed similar if not better performance compared to those of the respective control mixes.

3. Although the initial slump was slightly reduced, slump retention capability of concrete prepared using stabilized wash water was improved.

4. The temperatures due to the evolution of heat of hydration for concrete prepared using stabilized wash water were slightly higher than that for the control mixture.

Acknowledgements

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