eJSE International

Electronic Journal of Structural Engineering 13(1) 2013

Compressive Strength Evaluation of Stabilized and Solidified Metal Waste from Shipyard

H.S. J. KANG , M. G. SHAABAN, U.J.ALEGARAM , and S. SALLEH

Department of Civil Engineering, University of Malaya, Kuala Lumpur, Malaysia

Email: jk_jason@hotmail.com

ABSTRACT:

The abrasive blasting activities in shipyard produce very fine airborne dust in large volume, which is commonly known as abrasive blasting waste (ABW). ABW is a major concern in solid waste management. This ABW contains high concentration of hazardous pollutants such as antifouling paint and heavy metals. These pollutants cause adverse effect to the human health and environment especially the marine organisms. Currently, the available sanitary landfills are reaching the maximum capacity which could not withhold the increasing waste production. Further, there is a lack of information regarding solidification and stabilization (SS) treatment towards ABW in Malaysia. In this research, using Ordinary Portland cement (OPC) as binder and ABW as filler, attempt has been made to produce stabilized blocks. The variables include water to cement (W/C) of 0.4, 0.45 and 0.5 and cement to ABW (C/AB) ratio of 0.5, 0.75 and 1.0. In this paper, strength development of stabilized blocks is discussed. These blocks could be used as potential building material such as paving block, brick and filler material.

1 INTRODUCTION

Shipbuilding industries contribute much to the water and land pollution from the coating activities. These wastes include the volatile organic compound (VOC) emissions, antifouling paints, direct disposal from the ship (Valentukeviciene and Brannvall, 2008). Abrasive blasting waste (ABW) consists of copper slag that has been used as an abrasive in shot blasting to prepare ship's steel surfaces for painting. The widespread use of lead and other heavy metals in protective paints (Biprai *et al*, 2005) increases heavy metals in the used slag, which is classified as a hazardous waste.

Malaysian Environmental Quality Report by the Department of Environment (DOE) shows that there were 1.3 million and 1.7 million metric tons of scheduled wastes in 2008 and 2009, respectively. The main categories of waste producing by the country in year 2009 was found out to be dross/slag/clinker/ash, gypsum, electric waste, oil and hydrocarbon, clinical/pharmaceutical and heavy metal sludge (DOE, 2009).

Solidification/stabilization (S/S) is an increasingly attractive alternative to the remediation of improperly discarded hazardous materials, and is particularly effective when these toxic compounds are bound into a form immune to leaching (Alpaslan and Brannvall, 2008, Yin et al, 2006). S/S basically involves waste containment within a solid matrix using different binders such as cement, pozzolans, clay and polymer. It is a treatment process that produces a solid monolithic mass from a waste and leads to a product with improved structural integrity and physical characteristics (Bridha *et al*, 2010). It is a treatment process that has the potential to reduce leachability of hazardous constituents from the disposed waste (Malviya and Chaudhary, 2006).

In this research, the potential use stabilized ABW mortal as construction material, pillar filling and construction bricks will be explored.

2 MATERIALS AND METHODS

2.1 Materials

Ordinary Portland cement used for mortar preparation was conforming to the specifications of ASTM type I, ASTM C-150 (ASTM ,1998). ABW was collected from a shipyard in Johor, Malaysia. Table 1 shows a comparison of ABW and OPC physical data. Figure 1 shows the SEM photograph of ABW at 50x magnification.

Table 1: ABW and OPC physical data

Properties	ABW	OPC
Appearance	Shiny black, glassy, rough scratched surface	Grey, debris
Particle shape	Angular, sharp, colloidal	Fine, powdery
Particle size	0.144mm – 0.1825mm (similar to sand size)	10µm-60µm
Density (kg/m^3)	3.48	3.15
Water Absorption (%)	19.1	35
Cement consistency	-	0.35
Cement Initial Setting Time (min)	-	89

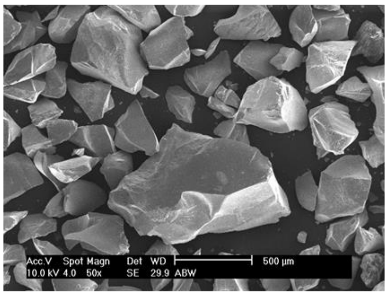

Figure 1: SEM photograph of ABW (magnification: 50x)

The ABW consists of sand, spent copper slag, and paint waste (Erdilla, 2011). Table 2 shows the concentration of metals in ABW.

Table 2: Concentrations of heavy metals in ABW

	Concentration of Metals (mg/L)					
	Al	Cu	Fe	Mn	Ni	Zn
ABW	0.932	11.64	3.657	0.048	0.097	0.991

2.2 Preparation of the specimens

Cement mortar cubes of 50 mm size were prepared with different proportions of ABW. The cement to ABW (C/AB) ratios used to produce mortars was 0.5, 0.75 and 1.0. Three different water to cement (W/C) ratios of 0.4, 0.45 and 0.5 were used. The materials were mixed in a rotating pan in accordance with ASTM C192-98 (ASTM, 1998). The mixes were compacted using vibrating table. The ABW mortar specimens were demoulded after 24hr, cured in curing cabinet and then tested at room temperature at different ages such as 1, 3, 7 14 and 28 days.

2.3 Test of specimens

Consistency and setting time tests were carried out according to MS522: Part 2:1989 for cement (MS, 1989). Compressive strength was tested using a hydraulic type ELE250 testing machine in accordance with ASTM C109-92 from age 1 day to 28 days (ASTM, 1992). The loading rate was 0.5kN/s and the average strength of three cubes was taken as the final compressive strength.

3 RESULTS AND DISCUSSION

3.1 Results

The development of compressive strengths of the specimens is shown in Figures 2 to 4. The development of compressive strengths of pure cement mortar is shown by ABW "0". The highest strengths of control specimen and stabilized ABW mortar are 54 MPa and 47 MPa, respectively. However, the trend of ABW mortars tends to show higher strengths than the controlled mortars when the W/C ratio is increased.

w/c ratio at 0.4

Fig. 2 shows the result of control and stabilized ABW mortars from day 1 to day 28.

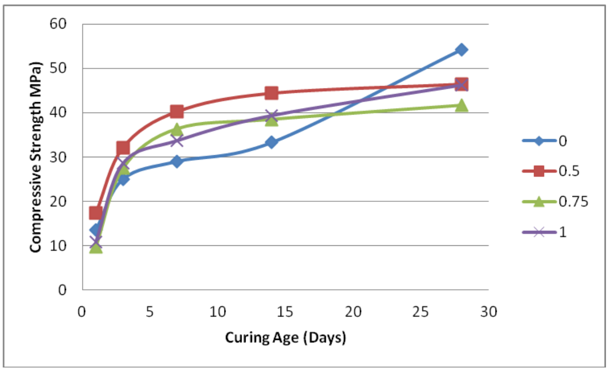

Figure 2: Compressive Strength Development for Specimens (W/C = 0.4)

The compressive strengths of all mortar specimens range from 10 to 20 MPa. There is an increase of 100 % strength between 1 day and 14 days with the results showing about 30 MPa to 40 MPa at the age of 14 day. However, the trend of strength development between 14 and 28 days is slow.The strength increase of cement mortar was higher compared to ABW mortar. As shown in Fig.2, the highest compressive strength at the age of 28-day of 54 MPa was found for the control sample at W/C ratio of 0.4. However, the compressive strength of the ABW mortars ranged from 40 to 45 MPa and this is generally lower than the control samples. In contrast, the early age strength of ABW mortars was generally found higher than the control mortars but later decreased at the age of 28 days.

w/c ratio at 0.45

Fig. 3 shows the result of control and stabilized ABW mortars from day 1 to day 28.

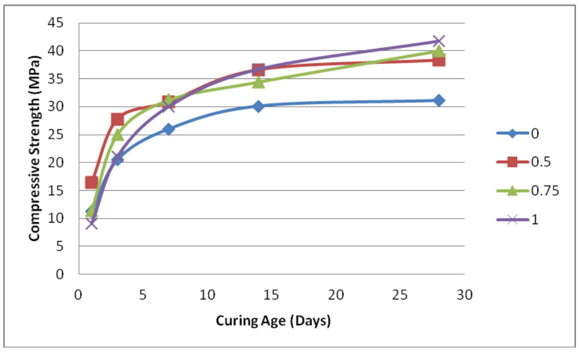

Figure 3: Compressive Strength Development for Specimens (W/C = 0.45)

The early strength developed ranged from 10 to 15 MPa. The strength increased 200 % from day 1 to day 14 to around 30 MPa. The cement mortar reached maximum strength at around 30 MPa but the stabilized ABW mortar increased to around 40 MPa. The 28-day strengths of all mortars were found around 40 MPa which is about 300 % strength development compared to day-1. As seen from Fig.3, the highest strength for ABW mortars at the age of 28-day was 42 MPa. There was an increasing trend for the mixtures with ABW mortars. The compressive strength values were found higher than the control specimens from day 1 to day 28.

w/c ratio at 0.5

Fig. 4 shows the result of control and stabilized ABW mortars from day 1 to day 28.

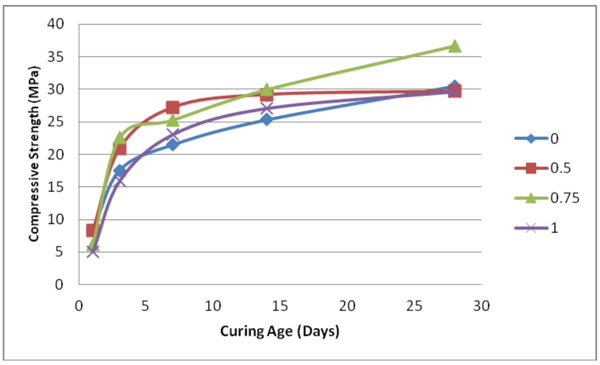

Figure 4: Compressive Strength Development for Specimens (W/C = 0.5)

The 1-day strength for all specimens was found in the range 5 to 10 MPa. However, the 28-day strength for all specimens, except for specimen with C/BA ratio was found about 30 MPa. The strength development from day 1 to day 14 at around 250 % increments. The average 28-day strength achieved was about 30 MPa. The highest strength was 37 MPa at C/AB ratio of 0.75. The readings of other mixtures with C/AB ratio of 0.5 and 1.0 were lower than the control except for C/AB at ratio at 0.75. Fig 4 shows that there was a rapid increment in strength at early age from day 1 to 14, but it slowed down from day 14 to 28.

3.2 Discussions

Effect of water to cement (w/c) ratio on compressive strength

The strength development under different W/C ratios showed variable results as expected. The highest compressive strength recorded at W/C ratio of 0.4 was 54 MPa. It is well known in cement chemistry that the reaction between water and both of C_3S and C_2S volume and water content influence the formation of $Ca(OH)_2$ and C-S-H gel which is responsible in the development of specimen strength (LaGrega et al, 2001). Higher water content aided in workability but decreased the strength development. The hydration process in cement mortar was higher than stabilized ABW mortar after 14 day of curing period in W/C ratio of 0.4. This indicates that the hydration processes in the block slowed down after day 14. Generally, the increasing water in the mix decreased the compressive strength development.

Effect of cement to abrasive blasting waste (c/ab) ratio on compressive strength

The strength development of the mixtures with ABW mortars was slightly lower than the control specimens. The decline in the compressive strength might be attributed to the retardation of cement hydration due to the presence of heavy metals in the ABW. The highest compressive strength was obtained for mix with C/AB is 0.75.

4 FUTURE INVESTIGATIONS

The present investigation focuses on the development of compressive strength only. The development of strength for different C/AB ratio shows higher early strength development and it is higher than the control specimens. This needs further investigation as AWB tends to enhance high early strength. In addition, strength development for longer curing period at different C/AB and W/C ratios is to be investigated. The leaching test will be carried out to probe the presence of heavy metals content in the stabilized blocks. The contribution of C_3S and C_2S in the strength development will have to be carried out using XRD and SEM analyses.

5 CONCLUSIONS

The use of ABW waste from shipyard in the development of pavement blocks is being investigated through this research. From the tests conducted, the following conclusions could be drawn.

The highest strength of about 43 MPa was achieved for ABW mortars with W/C and C/AB ratios of 0.4 and 0.45 and 0.5 and 1.0, respectively. The ABW mortars generally give higher early strength compared to control specimens. However, later day strength of ABW mortars is lower than the control specimens. The strength development of ABW mortars of up to 40 MPa is seen as potential structural grade material. However, further investigations on heavy metals and long term strengths are to be investigated. The hydration processes that contribute to the strength development might be affected due to the presence of heavy metals in ABW. The experiment will be extended for longer curing age and other C/AB ratios. All the strengths recorded were higher than requirement minimum strength of EPA and US at 28-day strength of 35 MPa (Malviya and Chaudhary, 2006). The stabilized blocks are qualified to be used as the construction material. The stabilized blocks can be used for the construction purposes due to the high strength development.

6 REFERENCES

Alpaslan, B., Mehmet Ali Yukselen (2002) *Remediation of lead contaminated soils by stabilization/solidification*. Water, Air, and Soil Pollution 133: pp 253–263.

American Society for Testing and Materials. (1992) Standard test method for compressive strength of hydraulic cement mortars (using 50mm cube specimens), ASTM C109-92.

American Society for Testing and Materials. (1998) Standard practice for making and curing concrete test specimens in the laboratory, ASTM C192-98.

American Society for Testing and Materials. (1998) Standard specification for Portland cement), ASTM C-150.

Biprai Gorai, R.K. Jana, Premchand. (2005) Characteristics and utilisation of copper slag – a review. Resources, Conservation and Recycling 43: pp 353-360.

Chun-Yang Yin, Hilmi Bin Mahmud, Md Ghazaly Shaaban. (2006) *Stabilization/solidification of lead-contaminated soil using cement and rice husk ash.* Journal of Hazardous Materials B137 : pp 1758–1764.

D. Brindha, T. Baskaran, s. Nagan. (2010) Assessment of Corrosion and Durability Characteristics of Copper Slag Admixed Concrete. International Journal of Civil and Structural Engineering, Volume 1: pp. 2.

Department of Environment (DOE). (2009) Malaysia Environmental Quality Report, 2009.

Erdilla b. Zaidin. (2011) Studies on Compressive Strength and Leachability of Stabilized and Solidified Metal Waste from Shipyard Repair. Thesis of University Malaya.

Michael D. LaGrega, Philip L. Buckingham and Jeffrey C. Evans. (2001) Hazardous Waste Management, 2nd Edition.

MS 522: Part 2. (1989) Specification for Portland Cement (ordinary and rapid-hardening): Part 2: physical tests (First revision).

Rachana Malviya, Rubina Chaudhary. (2006) *Factors affecting hazardous waste solidification/stabilization: A review.* Journal of Hazardous Materials B137 : pp 267–276.

Valentukevičienė M., Brannvall. (2008) E. *Marine pollution: an overview*. Geologija. Vilnius. 2008. No. 1(61): pp. 17–23.