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Recycling of Stone Cutting Waste in Floor Tiles Production

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ABSTRACT

This study aims to investigate the possible utilization of stone cutting sludge waste in terrazzo tiles production, which would reduce both the environmental impact and the production cost. Stone cutting wastes in the form of sludge is taken from Samara Factory and incorporated in the batch formulations of terrazzo tiles. The physio-chemical and mineralogical characteristics of the sludge were carried out in order to identify the major components. Result indicated that the sludge generated from stone cutting process could be used in producing of terrazzo tiles. Mixtures of aggregates with added amount of sludge were used successfully to produce the tiles. The results indicated that the transverse strength, water absorption and tiles measurements, for all the taken samples, are comply with Jordanian Standards. The transverse strength decreased as the ratio of the added sludge increased while water absorption increased as the sludge ratio increased.

Keywords: Sludge; Stone cutting waste; Floor tiles; Slurry waste; Recycle; clean

INTRODUCTION

The high consumption of raw materials by the construction sector, results in chronic shortage of building materials and the associated environmental damage. Concrete industry is particularly important as it is not only responsible for consuming natural resources and energy but also for its capacity of absorbing other industries waste and by-products (Almeida *et al*., 2007). In recent decades, the growing consumption and the consequent increase of industrial production has led to a fast decrease of the available natural resources such as raw materials and energy sources. On the other hand, a high volume of production rejects or sub-products is generated, and remain without recycling [Ferreira ,*et al*.,2004]. As a result of chronic shortage of building materials, the civil engineers have been challenged to convert such industrial wastes to useful building and construction materials [Turgut ,and Algin, 2007].

Stone cutting industry produces large amounts of solid wastes worldwide, which are expected to further increase as the world production of stone and marble industries has been increasing annually at alarming rate. At present, stone cutting factories generate high quantities of sludge, which increase the operation cost and decrease profits. The generated sludge from stone cutting factories is prohibited from being discharged to the public sanitary system [Ammary, 2007].

These factories currently hold the generated sludge in open or closed basins for two or three weeks based on the quantity of sludge and the volume of basins. During the holding, the sludge losses significant amount of water by evaporation especially during hot season. At the same time, the suspended particles settle and condense in the bottom of the basin, which increase its density. The contents of settling basins eventually have to be transported by trucks and disposed off in a sanitary landfill. In order to hold a high quantity of sludge, the factory should construct larger volume of basins, which increase the capital cost of the factory. The sludge produced through the cutting and working of stone is still considered an inert waste product. Once it has satisfied the required criteria for acceptance, it is given to authorized waste dump [Colombo, *et al*.2008].

As a result of environmental and economical parameters, recycling sludge in construction sectors is the focus of much ongoing researches. For utilizing waste stone and stone powder sludge generated from quarry and cutting process of stone, Korea Institute of Geology has developed the manufacturing technologies of artificial stone plate as a building material with firing method and hydrothermal synthesis [Park and Chung ,1996].

Balasubramanian, *et al.*, used textile effluent treatment plant sludge in many building materials such as hollow bricks, solid bricks, cement concrete flooring tiles and pavement blocks [Balasubramanian *et al.*,1995]. Weng et. al., investigated the possibility of producing bricks from dried sludge collected from an industrial wastewater treatment plant and they found that the sludge proportion and the firing temperature were the two key factors determining the brick quality [Weng ,*et al.*,2003]. Several researchers studied the possibility of using sludge generated from municipal wastewater treatment plant in producing clay bricks. They obtained good results concerning strength and water absorption, but the main problem is the present of biodegradable material in the sludge, which may cause voids, and weight loss in bricks [Valls *et al.*,2004, Abdul *et al.*,2004, Lin and Weng, 2001, Slim, Wakefield, 1991, Tay, 1986, Alleman and Berman, 1984,].

Stone cutting sludge has been used to improve the characteristics of agricultural soil and through adding limited portion of sludge to porous acidic soils would enrich them with potassium, magnesium, phosphorous and number of microelement, which are useful for vegetable production [Carrao and Castelli ,2008]. Ferreira *et al.*, have shown that the physico-chemical characteristics of granite sludge match well the requirements needed in brick and roof tile formulations. Thus, their incorporation results in negligible changes in the properties of the final products [Torres,*et al.*,2004]. Menezes *et al* have extensively reported the production of bricks and tiles using granite sludge [Torres,*et al.*,2004].

The main objective of this study was to evaluate an alternative final destination for the growing production of sludge from stone cutting process. The proposed procedure includes recycling the sludge and using it to produce terrazzo tiles. Based on this, the stone cutting sludge can be transformed from an environmental problem to valuable material.

Terrazzo tiles are widely use with dimensions of 30*30*3 cm, 25*25*2.5 cm, and 20*20*2 cm. The tile consists of two layers: the upper layer and bottom one. Marble and quartz in addition to the cement, aggregate and colors are used in the production of the upper layer, while in the bottom layer, quartz , marble and colors are not used. The thickness of the upper layer is determined according to the Jordanian standards (>7mm), while the thickness of the bottom layer ranges from 2-3 cm depends on the tile's dimensions [MPWH,1985].

The strength of tiles vary from region to other depends on the nature of the available soil, size of aggregate, strength and shape of raw materials. Strength also varies from factory to another based on the technique adopted for moldings. The minimum required transverse strength for terrazzo tiles should not be less than 30 kg/cm^2 [MPWH, 1985].

MATERIALS AND METHODS

Sludge characteristics

In order to understand the influence of the incorporation of stone cutting sludge as a raw material for tiles production, samples of sludge were collected and analyzed to identify its general characterization. Analyzed characteristics included water content for slurry sludge, sieve analysis, density, total solid (TS), total volatile solid (TVS), silica oxide (SiO_2), calcium oxide (CaO), aluminum oxide (Al_2O_3), ferric oxide (Fe_2O_3), magnesium oxide (MgO), chloride (Cl), potassium oxide (K_2O), phosphorus oxide (P_2O_3), sodium ratio (SR), aluminum ratio (AR) and lime saturation factor (LSF) have been performed and examined. Typical drying method for 24 hours at 105 $^{\circ}C$ was used to determine water content, total solid and density of sludge. Four samples were burned at 550 $^{\circ}C$ in order to determine the total volatile solid. Other chemical components have been determined using X-ray diffraction method. Sample analyses were repeated in triplicate at different laboratories in order to achieve satisfy accuracy in the obtained results.

Fabrication of Floor tiles

Sieve analysis of sludge samples shows that all particles have sizes $\leq 160\,\mu m$, representing finer gradation of aggregates used to produce terrazzo tiles. The Jordanian Standard for civil works allows using fine aggregate with particle size 150 and 300 μm in the production of terrazzo tiles with percentage up to 10% and 30% respectively. Based on this limitation, sludge is used in the production of terrazzo tiles. Because the face (upper layer) of the tiles contains specified materials (quartz and marble) the sludge is used only in the preparation of the back layer (bottom part). Sludge was added to the standard mixture with different ratio (Table 1). Samples were labeled as T_1, T_2, T_3, T_4 which refers to the sludge ratio in the mixture (100%, 75%, 50%, 25%) respectively, while symbol T_R refers to the reference samples (free of sludge). Mixes were prepared according to the Jordanian Standards (item 803/6) where the face layer consists of cement and aggregate (1:3), fraction of marble or quartz and colors. The back layer consists of cement and gradating aggregates (1:3). Firstly all component were mixed appropriately in a dry phase to achieve homogenous component, then water was added and mixed with the components. After homogeneity is achieved, terrazzo tiles were fabricated in steel mould with internal dimensions of 300 mm in length, 300 mm in width, and 30 mm in depth. The mixed materials are put in the mould, and a compression force of 14 N/mm^2 with vibration was applied to achieve the optimum density and compression strength. Then the formed tiles were removed from the moulds and left for 48 hours in a humid condition. Samples were merged in a water tank for three days and stored again in the humid environment for 23 days. After the incurring period (28 days) is completed, samples were analyzed according to the Jordanian Standards. Visual inspection, tiles dimensions, thickness of face layer, transverse strength, and water absorption were considered.

RESULTS AND DISCUSSIONS

Characteristics of sludge

Physical and chemical characteristics

Table 2 shows the average physical and chemical composition of sludge samples generated from the stone cutting process. The result obtained shows that there is a great compositional difference in sludge derived from different cutting process. The variation in the mineralogical and chemical composition of the sludge depends on the type and origin of rocks. Water contents in the slurry samples ranges from 95.1-99.4%, making it a significant source of water and can be utilized for different production process. Dried sludge contains high quantity of calcium oxide (54 %) while undetectable limits of Cl and K_2O are found. In addition small amount of silica, ferric oxide, aluminum oxide and volatile solid were detected.

Sieve analysis of sludge's sample

In order to obtain accurate result, 32 sieves with diameter ranges from 0.5 µm to 300 µm were used to determine the sludge particles size distribution. Figure 1 shows the sieve analysis of the dried sludge and the differential particle size distribution. The average particle size, D50, is about 9.06 µm, while D10, D16, D84 and D90 are about 1.31µm, 1.8 µm, 30 µm and 37.69 µm, respectively. Sieve analysis also was done for the standard aggregate that used for terrazzo tiles production as shown in Figure 2. For aggregate samples, the average particle size, D50, is about 1.07mm, while D10, D16, D84 and D90 are about 0.145mm, 0.25 mm, 5.83 mm and 6.16 mm, respectively. Results of sieve analysis indicated that around 11.8 % of the aggregate volume has a particle size less than the maximum size of sludge particles (160µm).

Specifications of the terrazzo tiles samples:

Physical specifications

Many physical properties for the fabricated samples were tested such as, dimension measurements, visual inspection and thickness of the face layer. No deformation cracks or deflection was noticed for any of the samples. Table 3 shows the dimensions, total thickness, thickness of the face layer for each type of samples. All samples complied with Jordanian Standard in terms of total thickness (≥30mm), and thickness of the face layer (≥7mm). In spit of using the same mould, the thickness of the produced tiles varied as a result of the variation in the applied hydraulic load and the loading period.

Transverse strength

Table 4 shows the average of transverse strength values for all samples. The obtained results were compared with Jordanian Standards for terrazzo tiles, indicating that the average transverse strength for all tested samples is more than that required according to the mentioned standards (30 kg/cm^2). The transverse strength decrease as the ratio of the added sludge increases (Fig. 3). The strength values for all tested samples ranges from 28-71 kg/cm^2 and only one sample (type T_1) failed in achieving the required strength. All samples have the same amount of cement and the same thickness and components of the face layer, which explain the high strength value for all samples. The values of transverse strength for tiles types T_4 and (T_R) are comparable to each other, which indicate that the use of sludge in the mixture with 25%ratio, did not affect the strength. These results indicate that the sludge waste could be reused, with high percentage, in the bottom layer of terrazzo tiles. bottom layer represents about 75% of tile's volume, so using sludge in this layer with 25%, 50%, 75% and 100% ratios will conserves the used materials by 19%,38%,56%,and 75% respectively.

3.4.3 Water absorption of tiles:

All samples have absorption ratio much lesser than the required limit in Jordanian Standards (8%) as shown in Fig 4. Values for all samples ranged from 3.87%- 6.36 % which indicates that all values are less than the standard limit. Because of the fineness of sludge, it absorbs much water than the coarse aggregate, so the water absorption increased as the sludge ratio increased.

CONCLUSIONS AND RECOMMENDATIONS

Utilization of the sludge waste from stone cutting is essential in order to minimize the waste and the environmental considerations. Moreover, it is an effective utilization of the limited natural resources. The results presented and discussed earlier show that the sludge generated from the stone cutting processes can be regarded as an interesting raw material for the production of terrazzo tiles. The usage of sludge in these applications could serve as an alternative solution to disposal.

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REFERENCES

[1] G.L. Abdul, I. Azni, A.S. Abdul, H.K.W. Calvin, S.J. Mohd, and M.B. Aminuddin, *Journal of Material Cycles and Waste Management*, **6**(1): 141-47(2004).

[2] J.E. Alleman and N.A. Berman, *Journal of Environmental Engineering*, **110**(2): 301-311(1984).

[3] N. Almeida, F. Branco and J. R. Santos. *Building and Environment*, **42**(2): 810-819 (2007).

[4] B. Ammary, *International Journal of Environment and Waste Management*, **1**(2/3): 106-112(2007).

[5] J., Sabumon, C. John, U. Lazar and R. Ilangovan. *Journal of Materials Processing Technology*, **48**(1-4) pp. 379–384 (1995).

[6] G. Carrao and G.S. Castelli, http://www.aigt.ch/down load/rapporto _INTERREG-en.pdf 2008.

[7] Colombo, A. Tunesi, V. Barberini, L. Galimberti and A. Cavallo, 2008, http://www.aigt.ch/download/rapporto_INTERREG-en.pdf .

[8] J.M.F. Ferreira, P.M.C. Torres, M.S. Silva and J.A. Labrincha, *Journal of the European Ceramic Society,* **24**(10-11): 3177-3185(2004).

[9] D. Lin, and C. Weng, *Journal Env. Engg.*, **127**(10): 922-927 (2001).

[10] Ministry of Public Works and Housing , Specifications of the architectural and civil works, 1st edition, Amman, Jordan (1985).

[11] K. Park and H.S. Chung, http://www.gemeed.cl/medios/pdf/coreachil.pdf, (1996).

[12] J.A. Slim, R.W. Wakefield, Water SA WA SA DV, **17**(3): 197-202 (1991).

[13] Jh. Tay, *Resources and Conservation*, **13**(1): 53-58(1986).

[14] P. Torres, H.R. Fernandes, S. Agathopoulos, D.U. Tulyaganov, and J.M.F. Ferreira, *Journal of the European Ceramic Society*, **24**(10-11):3177-3185 (2004).

[15] P. Turgut, and H.M. Algin, *Building and Environment Journa*l, **42**(9): 3399-3403(2007).

[16] S. Valls, A. Yagüe, E. Vázquez and C. Mariscal, *Cement and Concrete Research,* **34**(12): 2203-2208(2004).

[17] C. Weng, D. Lin, and P. Chiang,,. *Advances in Environmental Research,* **7**(3): 679-685(2003).

Table 1. Sludge proportion for the terrazzo tiles samples

Sample Label	Volumetric sludge ratio in the mixture (%)	Terrazzo tiles dimensions (cm)	Number of samples
T_1	100	30*30*3	24
T_2	75	30*30*3	24
T_3	50	30*30*3	24
T_4	25	30*30*3	24
T_R	0	30*30*3	24

Table 2. Chemical and physical properties of the sludge

Parameter	Unit	Average	Note
Water content	% by wt	97.3	As slurry sludge
TS	Mg/l	26000	As slurry sludge
TVS	Mg/l	1.3	As slurry sludge
SiO_2	% wt	0.83	For dried material
CaO	% wt	54.72	For dried material
Al_2O_3	% wt	0.21	For dried material
Fe_2O_3	% wt	0.11	For dried material
MgO	% wt	0.91	For dried material
Cl	% wt	*BDL	For dried material
K_2O	% wt	*BDL	For dried material
SO3	% wt	0.11	For dried material
LSF	---	2064.34	For dried material
SR	---	2.53	For dried material
AR	---	1.88	For dried material

* Below detectable Limit

Table 3. Physical specifications of the terrazzo tiles samples

Sample label	Average dimensions (cm)	Average total thickness (mm)	Average thickness of the face layer (mm)
T_1	30*30	32.2	10
T_2	30*30	32.6	11
T_3	30*30	33	10
T_4	30*30	32.6	10
T_R	30*30	32	11

Table 4: Compression and water absorption for terrazzo tiles samples

Sample label	Volumetric sludge ratio in the mixture (%)	Transverse strength (Kg/cm2) At 28 days	Relative strength (%)	Water absorption %
T1	100	42	66	5.41
T2	75	46	72	5.31
T3	50	52	82	4.86
T4	25	63.1	99	4.77
TR	0	63.7	100	4.71

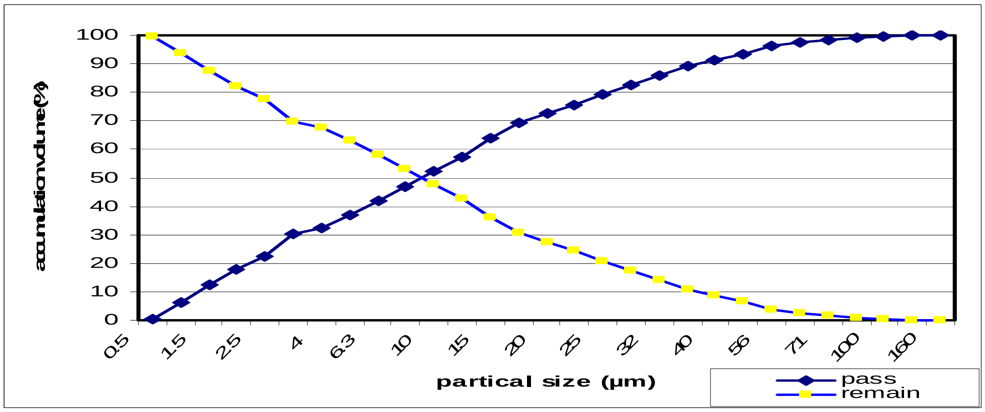

Fig. 1 Particle size distribution of the sludge

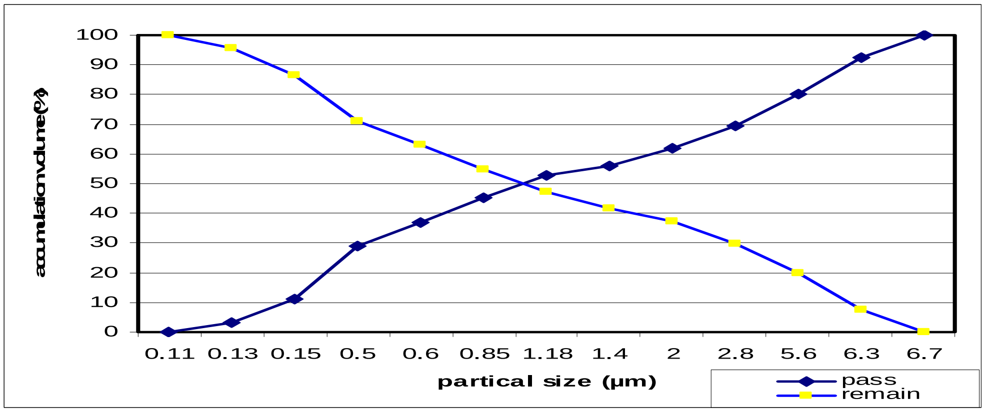

Fig. 2 Particle size distribution of the aggregate

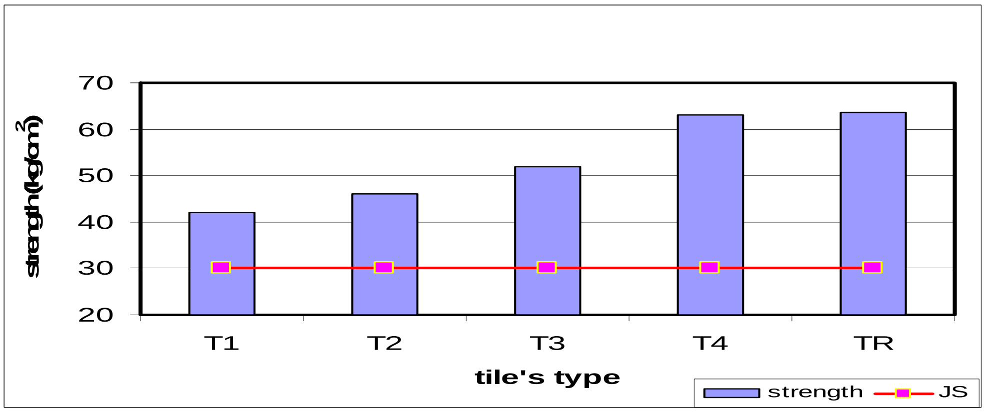

Fig. 3 Transverse strength values of the tile samples, JS: Jordanian standard

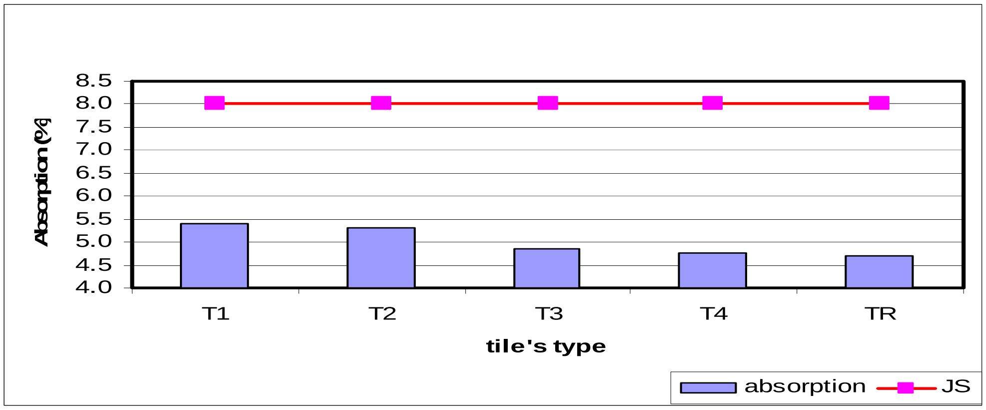

Figure 4. Water absorption of the tile samples, JS: Jordanian standard.