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Investigation and recycling of paint sludge with cement and lime for producing lightweight construction mortar

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ABSTRACT

Since paint sludge (PS) consists of many toxic substances, it has high pollution potential. Incorrect disposal of the significant amount of PS threats to public health and the environment, especially in developing countries. The present research reveals investigation of construction materials production from recycled PS as an aggregate replacement. In this study, PS has been obtained from white goods industry. Various PS content has been used in both cement and lime separately then physical and mechanical properties have been investigated in the hardened condition. Interestingly, all specimens have demonstrated unexpected expansion in compare with the pure matrix at curing periods. Although adding PS to cement (PS-cement) and to lime (PS- lime) result with the relative decrease in strength; based on the obtained results, the final structure has a promising characteristic potential for lightweight residential construction materials. Besides, it has thermal and sound insulation properties due to high expansion and high porous content with reducing sources of toxics entering to environment.

1. Introduction

Paint sludge is an industrial hazardous waste material. It is mainly generated by industries that are involving metal dyeing such as automotive, appliance, and other manufacturing industries. The current methods for the disposal of the waste by landfilling and incineration are not still completely effective in preventing the environment and the living creatures. It continues to pose a significant threat to health worldwide. The exact composition of the paint sludge can be varying according to the type of paints used and comprises the off-sprayed metal dye with a VOC, churned with water and detackificating additive [1].

Paint sludge is classified into toxicity class of 2 (toxic) in which the toxicity level 1 is considered as having a certain extent toxicity, whereas the toxicity level 3 is very toxic after the results of algae, bacteria contact and plant test [2]. Volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene xylene, and etc. are the primary concerns and can cause a major health problem if the proper safety precautions are not taken [3]. Moreover, many current research reports demonstrate a large variety of VOCs cause illnesses for people who are exposed to the higher amount of the compounds. On the other hand, the presence of toxic and heavy metals and a trace amount of organic solvent contents (e.g. dissolved organic carbon) are potentially the most hazardous substances in dried paint sludge [3–5]. Using this waste as Supplementary material in process industries, especially incorporating it with suitable raw material mixtures, can be a viable solution for the elimination of paint sludge. To this end, the convenience of admixing waste sludge into the raw materials composition for the production of marketable products have to meet certain standards and require extensive research.

In the 90s, some possible uses of paint sludge were investigated in the automotive industries. Several patents have emerged from those studies. The first attempt at using paint sludge was come out from the sealant industry [6]. Then, paint sludge has been used as a partial replacement of polymeric components for some other treatments [7,8] and followed by decomposition of a dried paint sludge with the aim of recovery of organic and inorganic components as the gaseous phase. Furthermore, liquid and

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composite materials [9] and the mixture of paint sludge with Portland cement as reactive expansion additives in shrinkage compensating concrete [10] are among of the patents. In addition to these, a process of some water-based paint sludge for producing building materials from paint booth operations [11] that can be pointed out. Recently, some researchers have reported the optimum removing possibilities of paint sludge waste in industry. Segala used a method that suggests using the waste paint for producing the processed latex pigment (PLP) to replace it with a small amount to be as raw material for cement manufacturers [12]. Gautam et al. have applied a co-processing method to the cement-kiln structure for the complete destruction of the paint sludge [13]. Ruffino et al. studied the use of 10% paint sludge with the base bitumen to obtain asphalt concrete mixtures and compared with traditional asphalt concrete [14].

On the other hand, using industrial wastes can be an alternative to common aggregate materials in concrete structures. Industrial wastes can be used as aggregate in two ways: i. Industrial by-products including coal ash, various slags from metal industries, and waste from other industries like pulp and paper mills, mine tailings, food, agriculture and leather; ii. Recycled wastes which include different plastic and rubber wastes [15]. Usage of industrial wastes in order to evaluate its effect on concrete was studied by many researchers. Ramesh et al. studied weld slags as a replacement of fine aggregates in concretes and then observed compressive strength increased by replacement of sand with the weld slags [16]. Choi et al. investigated the recycled waste polyethylene terephthalate (PET) bottles to build a lightweight aggregate concrete and reported that the increase of waste PET caused the decrease of the compressive strength of resulted concretes [17]. Kim and Lee experimentally investigated bottom ash as a fine and coarse aggregates in high-strength concrete for evaluation of its physical and mechanical properties [18]. Rao et al. displayed 3% of bone char sludge could be effectively replaced with river sand that resulting in increasing concrete compressive strength [19]. Some researchers have utilized other industrial wastes as aggregate component like petroleum reservoir sludge [20], paper sludge [21] polyethylene terephthalate, polycarbonate [22], waste-expanded polystyrene foams [23], and tire rubber waste and ash [24].

In this study, we investigated using paint sludge as an aggregate material that was obtained from the white goods industry. The purpose of the current study is to recycle PS waste, which is an abundant hazardous side product in several sectors, into the valuable concrete product. Also, the effects of the PS on the concrete features such as compressive strength, flexural strength, capillary absorption, unit weight, and expansion properties are investigated in the presence of cement and lime. The use of PS waste in concrete will generate economic and environmental positive outcomes.

2. Materials and methods

The primary constituent material used in the present study was a PS waste which was provided from a white goods industry of Boyplast Inc. in Eskisehir, Turkey. This plant for process painting uses various type of paints for different purposes. Most of the paints which are used in the plant are tecnocryl 2k acrylic paint inox 552 as solvent based coating, zinc yellow intended as primer paint, and moonlight new metallic gray topcoat candy as the top coat paint. Chemical composition of the paints which was received from the company and its compounds are shown in Table 1. The paint sludge in this investigation was provided in a dry form (Fig. 1a). In this study, also Portland cement CEM I 42.5R with the standard of TS EN 197-1 was used with CEN standard sand. Another raw material for the matrix was slaked lime CL 80-S with the standard of TS EN 459-1 prepared Adacal Endustriyel Mineraller A.S. The chemical composition, physical and mechanical properties of cement and lime are given in Table 2 [25] and Table 3 [26], respectively used as received unless stated otherwise.

Table 1
Chemical composition of paints of a) tecnocryl 2k acrylic paint inox 552, b) wash filler, zinc yellow, c) moonlight new metallic gray topcoat candy.

a

Chemical Composition	Conc. Range (%)
Toluene	20–40
Xylene	5–10
Isobutylacetate	5–10
Butylethanoate	5–10
Cyclohexanon	15–30
Ethylacetate	<5
1-Methoxy-2-Propyl Acetate	<5

b

Chemical Composition	Conc. Range (%)
Toluene	25–50
1-Butanol (Butanol)	2.5–10
Zinc Oxide	2.5–10
Methyl Isobutyl Ketone	2.5–10
Xylene (Xylene) (All Isomers)	2.5–10
Strontium Chromate	1–2.5
Propan-2-Ol (Isopropyl Alcohol)	1–2.5
Zinc Chromate	<0.5

c

Chemical Composition	Conc. Range (%)
2-Methoxy-1-Methylethyl Acetate	10–25
Xylene (All Isomers)	10–25
Toluene	2.5–10
Butanone	2.5–10
Ethyl Benzene	1–2.5
1-Butanol (Butanol)	1–2.5
Silicon Dioxide	1–2.5
Solvent Naphta (Petroleum) Light Aromatics	0.5–1
TINUVIN 1130	0.5–1
1,2,4-Trimethyl Benzene	<0.5
Heavy naphtha processed with water	<0.5
Bis(1,2,2,6,6-Pentamethyl-4-Piperidyl) Sebacate	<0.5
Mesitylene	<0.5
Propyl Benzene	<0.5

2.1. Preparation of PS-cement and PS- lime specimens

All experiments were divided into two main step. In the first phase, PS and cement were mixed following the mixture standard. This mixture standard is shown in Table 4 under the basic CEN standard. The last experiments were prepared by mixing PS and lime at certain ratios. In the experiments, PS was added in certain proportions. The standard size of used molds was $40 \times 40 \times 160$ mm cubes. Molds were lubricated in order to avoid adhering of mortar and also providing convenience for disassembly stage. The prepared specimens were cast into molds and assessment of all the specimens were performed at 28 days of aging.

In the first step of the experimental investigation, we have obtained the mortar mixtures in which sand was partially replaced by PS at a level of 0, 2, 4, 6, 8 and 10% by weight and the cement content was fixed at 450 g. The exact mixture compositions are shown in Table 5. In the second step, three series of combinations which are containing different percentages of PS were prepared