Use of Paint Sludge with Cement and Lime for Construction Mortar Producing

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ABSTRACT

A significant amount of paint sludge exists in Turkey and day by day it is on the rise. The present research reveals investigation of construction materials production from recycled paint sludge as aggregate replacement. The use of PS waste in concrete will constitute positive outcome arising from the economic and environmental aspects due to the evaluation of waste. In this study paint sludge (PS) is obtained from white goods industry. Various PS content is used into both cement and lime separately then physical and mechanical properties are determined in hardened condition. In this study, PS with cement and also PS with lime were mixed separately then both were casted in their molds. Interestingly, in the research after casting, we have observed the specimens begun expanding. This expanding has been occurred in the first 25 min of the experiment. Volume expansions during moist curing in the first 25 min are very large. The expansion behavior of each specimen was measured. The binary PS with cement (PS - cement) and also PS with lime (PS - lime) do not have good compressive and flexural strength but tend to expansion at curing periods. Based on the obtained results, PS has promising characteristic potential for construction materials manufacturing applications.

1. Introduction

Waste paint sludge is an industrial hazardous material generated mainly by automotive, appliance, and other manufacturing industries involving metal dyeing. The current methods for the disposal of the waste by land filling, and incineration still either not completely effective or continue to pose environmental threats after treatment. To use the waste as a supplementary material in process industries, especially incorporating it in the raw materials mixture, could be a viable solution for the elimination of the waste paint sludge. To this end the convenience of admixing the waste sludge in the raw materials composition in the production of marketable products which has to meet certain standards and requires extensive research. Waste paint sludge comprises the off-sprayed metal dye with a volatile organic content, churned with water and detackificating additives. (Arce et al., 2009). The organic solvent content is the major source of the environmental hazard (Viguri et al., 2005; Ruffino et al., 2010).

In the 90s usage of paint sludge was investigated in automotive industries that cause to obtain various patents. The first attempt for using paint sludge is come out in the sealant industry (Johnson and Slater, 1990). Portion of polymeric components with paint sludge treatment (Gerace et al., 1999), decomposition of a dried paint sludge which aims to recover the organic and inorganic components of the paint sludge as gaseous, liquid and composite materials (Narula et al., 1996), mixture of paint sludge with Portland cement as reactive expansion additives in shrinkage compensating concrete (Soroushian and Okwuegbu, 1996), and also a process of some water-based paint sludge for producing building materials from paint booth operations (St. Louis, 1996) are the most important usage of paint sludge. Recently paint sludge was reported by researchers for removing from wastes and optimum usage in industry. Segala (2003) shows a method with use of waste paint industry for produce processed latex pigment (PLP) to replacing with a small amount as raw material of cement manufacturers. Gautam et al. (2010), for the complete destruction of the paint sludge used co-processing in a cement kiln in India. Ruffino et al. (2012), studied use of paint sludge with 10% amount on the base bitumen to obtain asphalt concrete mixtures and compared with traditional asphalt concrete mixtures.

On the other hand, using industrial wastes are alternative aggregate materials in concrete. Industrial wastes as aggregate can be divided into two types: 1) industrial by-products includes coal ash, various slags from metal industries, industrial sludge, waste from industries like pulp and paper mills, mine tailings, food and agriculture, and leather, 2) recycled wastes include different plastic and rubber wastes (De Brito J, and Saikia N, 2013). Usage of industrial wastes in order to evaluate its effect on concrete was studied by many researchers. Ramesh et al. (2013) studied the compressive strength of weld slags as a replacement of fine aggregates in concrete and then observed the compressive strength increase with replacement of sand by weld slags. Choi et al. (2009) investigated on recycled waste polyethylene terephthalate (PET) bottles to building lightweight aggregate concrete and reported that the increase of waste PET causes to decrease compressive strength in concrete. Experimental investigations of Kim and Lee (2011) were carried with bottom ash as fine and coarse aggregates in high-strength concrete to evaluation of physical and mechanical properties. Rao et al. (2009) displayed the bone char sludge can effectively be replaced with river sand to 3% with increasing of concrete compressive strength. Some other researches on industrial wastes were used as aggregate such as petroleum reservoir sludge (Kuo et al., 2007), paper sludge (Ahmadi and Al-Khaja, 2001) polyethylene terephthalate and polycarbonate (Hannawi et al., 2010), waste-expanded polystyrene foams (Kan and Demirboga, 2009), tire rubber waste and ash (Snelson et al., 2009).

In this study, we investigated paint sludge as an aggregate material that was obtained from white goods industry. The purpose of the current study is to recycle abundant amount of paint sludge (PS) as waste which take place during the process, investigating the PS effects on concrete properties and determine the availability of production. The use of PS waste in concrete will constitute positive outcome arising from the economic and environmental aspects due to the evaluation of waste. In addition, our study is to investigate the effect of PS on concrete features. Therefore we analyzed compressive strength, flexural strength, capillary absorption, unit weight and expansion specimen for PS in presence with cement and lime.

2. Materials and methods

The main constituent materials used in the present study were a paint sludge (PS) provided by a white goods industry (Boyplast Ltd. Sti. in Eskisehir, Turkey). This plant in

process painting use different types of paints at any point of process. Most of the paints which are used in the plant are tecnocryl 2k acrylic paint inox 552 intended use in solvent based coating, zinc yellow intended use in primer paint, moonlight new metallic gray topcoat candy intended use in top coat paint. Chemical composition of paints and its compounds are shown in Table 1. The paint sludge employed in the investigation was dried and then used (Fig. 1a). In this study Portland cement CEM I 42.5R with the standard 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 TS EN 459-1 prepared Adacal Endustriyel Mineraller A.S. Chemical composition, physical and mechanical properties of cement and lime are given in Table 2 and Table 3, respectively.

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

a		c	
Chemical Composition	Conc. Range (%)	Chemical Composition	Conc. Range (%)
Toluene	20-40	2-Methoxy-1-Methylethyl Acetate	10-25
Xylene	5-10	Xylene (All Isomers)	10-25
Isobutylacetate	5-10	Toluene	2.5-10
Butylethanoate	5-10	Butanone	2.5-10
Cyclohexanon	15-30	Ethyl Benzene	1-2.5
Ethylacetate	< 5	1-Butanol (Butanol)	1-2.5
1-Methoxy-2-Propyl Acetate	< 5	Silicon Dioxide	1-2.5
		Solvent Naphta (Petroleum) Light Aromatics	0.5-1
b		TINUVIN 1130	0.5-1
Chemical Composition	Conc. Range (%)	1,2,4-Trimethyl Benzene	< 0.5
Toluene	25-50	Heavy naphtha processed with water	< 0.5
1-Butanol (Butanol)	2.5-10	Bis(1,2,2,6,6-Pentamethyl-4-Piperidyl) Sebacate	< 0.5
Zinc Oxide	2.5-10	Mesitylene	< 0.5
Methyl Isobutyl Ketone	2.5-10	Propyl Benzene	< 0.5
Xylene (Xylene) (All Isomers)	2.5-10		
Strontium Chromate	1-2.5		
Propan-2-Ol (Isopropyl Alcohol)	1-2.5		
Zinc Chromate	< 0.5		

Table 2. Chemical composition, physical and mechanical properties of cement used in mortars.

Chemical analysis (%)	Cement	Physical analysis	Cement
LOI	3.59	Specific gravity	3.15
SiO_2	18.90	Blaine fineness, cm^2/g	3212
Al_2O_3	5.15	Initial setting time, h	2.52
Fe_2O_3	3.36	Final setting time, h	4.36
CaO	63.59	Volume expansion, mm	2
MgO	1.57		
SO_3	2.65		
Na_2O	0.40		
K_2O	0.77		
Cl^-	0.0238	Mechanical properties	Cement
I.R	0.91	Compressive strength, MPa 7 days	38.7
Alkali Eq.	0.31	Compressive strength, MPa 28 days	46

Table 3. Chemical composition and physical properties of lime used in mortars.

Chemical analysis (%)	Lime	Physical analysis	Lime
Active $Ca(OH)_2$	80.00-85.00	Color	White
Total CaO	64.00-66.00	Density	0.55-0.56 kg/dm^3
Moisture	0.50-1.00	Size	Over 90 µm max 90%
SiO_2	0.00-0.10	Water retention	65%-85%
MgO	0.20-0.40	$CaCO_3$	Min. 80%
SO_3	0.10-0.30		
R_2O_3	0.10-0.20		

The experiment was divided into two main phases. In the first experiment PS and cement were mixed with considering mixture standard. This mixture standard follows in Table 4 with the basic CEN standard. The latter experiments were prepared by mixing PS and lime certain rations. In the experiments PS added in certain proportions. The used molds standard size was 40x40x160 mm cubes. Molds were lubricated for not adhering of mortar and also providing convenience of disassembly stage. The prepared specimens were casted into molds. The assessment of all specimens was performed of the 28 days of age.

Table 4. Composition of standard mortar mixture.

Compound	Weight (g)
Cement	450
Water	225
Sand	1350

In the first step of experimental investigation was done on the mortar mixes in which sand was replaced by the PS at replacement levels of 2, 4, 6, 8 and 10% by weight and the cement content was fixed at 450 g to the building material mix. The exact mix compositions for mortar mixture are shown in the Table 5. In the second step, three series of mixtures

containing different percentages of PS were prepared with lime for this study. Experimental investigations were carried out by replacing PS with lime by weight. Three mixes were prepared using PS with 10, 20 and 30% replacement of lime.

Table 5. Composition of mortar mixture (by weight, g)

Series	Specimen	Cement	Water	Sand	PS	PS/Cement
1	PS (2%)	450	400	1323	27	0.06
2	PS (4%)	450	400	1296	54	0.12
3	PS (6%)	450	400	1269	81	0.18
4	PS (8%)	450	400	1242	108	0.24
5	PS (10%)	450	400	1323	135	0.30

3. Results and discussion

3.1. Expansion

In this study, PS with cement and also PS with lime were mixed separately then both were casted in their molds. After casting, we have observed the specimens begun expanding. This expanding has been occurred in the first 25 min of the experiment according to Fig. 1b. Volume expansions during moist curing in the first 25 min are very large. The expansion behavior of each specimen was measured. After measuring the expansion, relationship between expansion and PS content can be obtained according to the experimental results from Fig. 1c and 1d. As a result with increasing of PS, the degree of expansion has been increased. All experimental specimens' structure and various views are given in Table 6. It is important to note that the increase of expansion in PS-cement was nearly linear with the increase of PS content. The expansion rose rapidly at a PS content of 2 wt% increasing by 17.00%, 4 wt% increasing by 18:00%, 6 wt% increasing by 119.25%, 8 wt% increasing by 19.50%, and for 10 wt% increased by 119.75%. Moreover, the increase of expansion in PS- lime was also nearly linear; it is increased by 20.50% at 10 wt%, by 21.25% at 20 wt% and then by 22.25% at 30 wt% over the pure matrix. The most expansion rate for PS-lime was 30% and for PS-cement was 10%. The data exhibit an interesting trend in expansion for the cement and lime. The height expansion can rise further of obtained result because during cure time, mortar has been overflowed from mold and the result of this expansion is seen in Table 6. Moreover, when the PS-cement is compared with PS-lime which has PS content of 10 wt%, the results show an increase of 114% in the expansion of PS-cement over the PS- lime.

According to images of Table 6, it is obvious that pores exist on the structure surfaces. However, in PS- lime with increase of PS contents small holes also appeared in the specimens. Small holes can be seen clearly in PS- lime with 30 wt% (Table 6). These small holes can affect mechanical properties and probably it is one of the most important reasons to observe the lower strength. Moreover, the surface morphology of specimens can be observed by naked eyes. It has been seen that some specimens not have good appearance. There are spots marked on the surface of specimens (Table 6). The reason of existence spot at top view of specimens is available coarse grains in paint sludge (Fig. 1a)

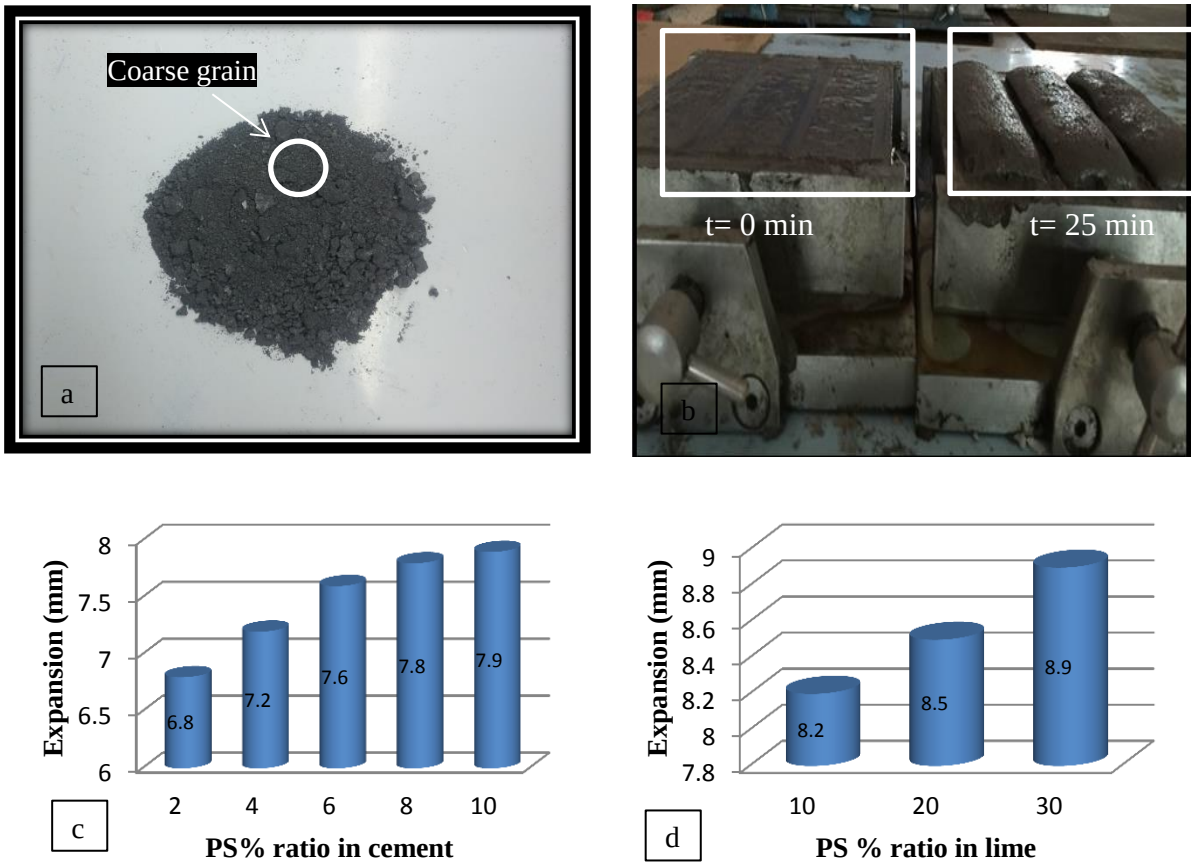


Fig. 1. a) Paint sludge after dry, b) the state of specimens in 0 min and after 25 min casting of PS-cement and relationships among expansion and PS contents, c) in cement, d) in lime.

3.2. Unit weight

Unit weights reduce in PS-cement and PS-lime with increase of PS amount for the specimens. The unit weight for all specimens is shown in Fig 2. For the PS-cement, the decreases were in unit weight 1.56, 1.50, 1.42, 1.34 and 1.33 gram for specimens with PS contents of 2, 4, 6, 8 and 10 wt%, respectively. Another experiment for lime, the data indicate decrease of unit weight with 1.20, 1.13 and 0.96 for the specimens with PS contents of 10, 20 and 30 wt%, respectively. These changes are seen for PS-cement specimens more apparently than PS-lime specimens. The most probably reason of this difference is that the sand is heavier than lime. In other words, PS is very lightweight material because it is used in cement instead of some sand. Meanwhile, when the PS-cement is compared with PS-lime with PS contents of 10 wt%, the data indicate an increase of 110% in the unit weight of the PS-cement over the PS-lime.

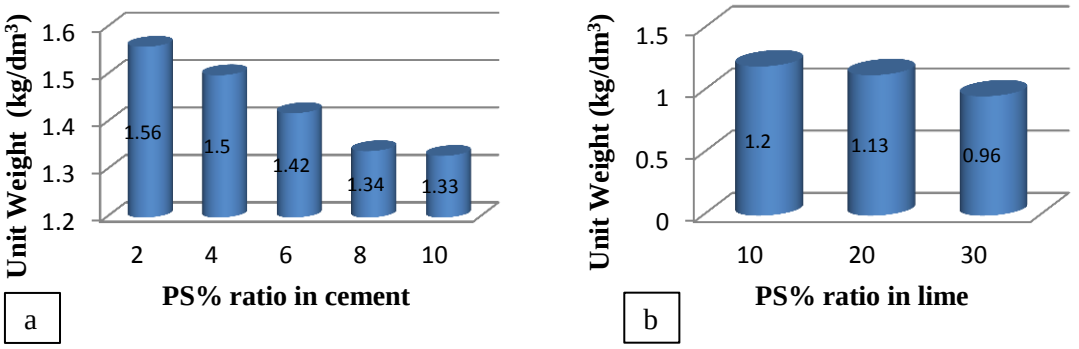


Fig. 2. Relationships among unit weight and wt% PS ratios, a) in cement, b) in lime.

Table 6. Structure and various views of specimens.

Specimens	Side view of specimens (length)	Top view of specimens	Side view of specimens (width)
PS (2%)-cement	Exp= 6.8 cm, 40 mm, 160 mm	Coarse grain	Exp, 40 mm
PS (4%)-cement	Exp= 7.2 cm		
PS (6%)-cement	Exp= 7.6 cm		
PS (8%)-cement	Exp= 7.8 cm		
PS (10%)-cement	Exp= 7.9 cm		
PS (10%)- lime	Exp= 8.2 cm		
PS (20%)- lime	Exp= 8.5 cm		
PS (30%)- lime	Exp= 8.9 cm	Small hole	

3.3. Flexural Test

The three point bent tests were conducted to determine the flexural resistance of the specimens. The results were depicted in Fig. 3 to analyses the influence of material on the flexure property. From this figure, it is understood that strength reduction is occurred in both experiments. By analyzing the effect of adding PS to cement, the data indicate reduction in the bending strength with 1.172 MPa, 1.054 MPa, 0.937 MPa, 0.982 MPa and 0.469 MPa for specimens with PS contents of 2, 4, 6, 8 and 10 wt%, respectively. High bending strength concrete is made by lowering the paint sludge-cement (PS/C) ratio to 0.06. Similar to the PS-cement in PS-lime, an increase in the PS content reduced the strength of the specimens. For the specimens by increasing of PS content, the bending strength is decreased with 0.937 MPa, 0.703 MPa and 0.000 MPa. When PS content reached 30% in lime, the strength is decreased to approximately 0.000 MPa, which is not having any strength indeed. On the other hand, when the PS-cement is compared with PS-lime which has PS content of 10 wt%, the results reveal an increase of 125% in the bending strength of the PS-cement over the PS-lime.

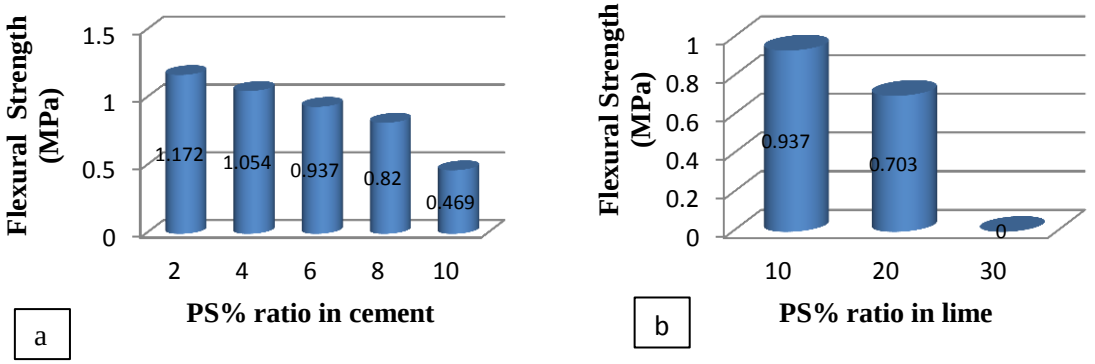


Fig. 3. Relationships among tensile strength and wt% PS, a) in cement, b) in lime.

3.4. Compressive Test

Compressive test has performed to measure the specimen's compressive strength. Fig. 4 shows the result of compressive tests for PS-cement (Fig. 4a) and PS-lime (Fig. 4b) specimens. As can be seen, the compressive strength of specimens with increase of PS is on the decline. It is understood that when the PS content is high, strength reduction rate is also high. The compressive strength are 5.973 MPa, 5.625 MPa, 5.625 MPa, 5.313 MPa and 4.687 MPa for specimens of PS-cement with PS contents of 2, 4, 6, 8 and 10 wt%, respectively. The decrease in the compressive strength of the PS-cement was not linear with the increase in PS content. Surprisingly, the 6 wt% specimen exhibited equal compressive strength in maximum stress, compared with that of 4 wt% specimen. High compressive strength PS-cement is made by lowering the paint sludge-cement (PS/C) ratio to 0.06. In PS-lime experiment, the compressive strength is reduced with PS content, results display 4.675 MPa at 10 wt%, 3.75 MPa at 20 wt% and 2.18 MPa at 30 wt%. This decrease was nearly linear. Furthermore, when the PS-cement is compared with PS-lime with PS contents of 10 wt%, the data show approximately equal compressive strength for both PS-cement and PS-lime.

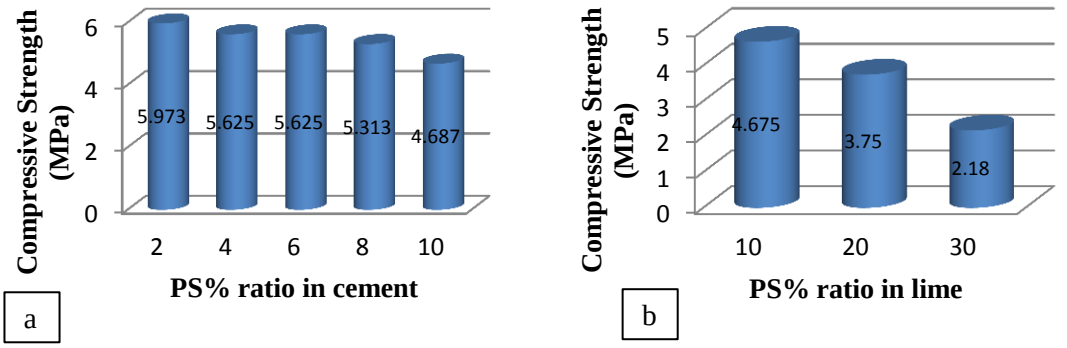


Fig. 4. Relationships among compressive strength and wt% PS, a) in cement, b) in lime.

3.5 Capillary Absorption Test

Constant water content of the specimens was measured by placing the specimens in water for one hour. The result of capillary absorption test is given in Fig. 5. The results displayed that absorption water was increased by increasing of PS content in two experiments. At PS-cement, the water absorption are 6.8 g, 7.2 g, 7.6 g, 7.8 g and 7.9 g, for the specimens with PS contents of 2, 4, 6, 8 and 10 wt%, respectively. In the same order, water absorption of PS-lime specimens was increased as the same as PS-cement specimens. The decrease in water absorption of the specimens was nearly linear with the increase of it in PS content. The water absorption is increased rapidly to 24 g at PS content of 10 wt%, for 20 wt% increased to 25 g and for 30 wt% increased to 27 g. The reason of absorption water increase is the availability of PS content in the specimen in which it reveals that PS absorbs water.

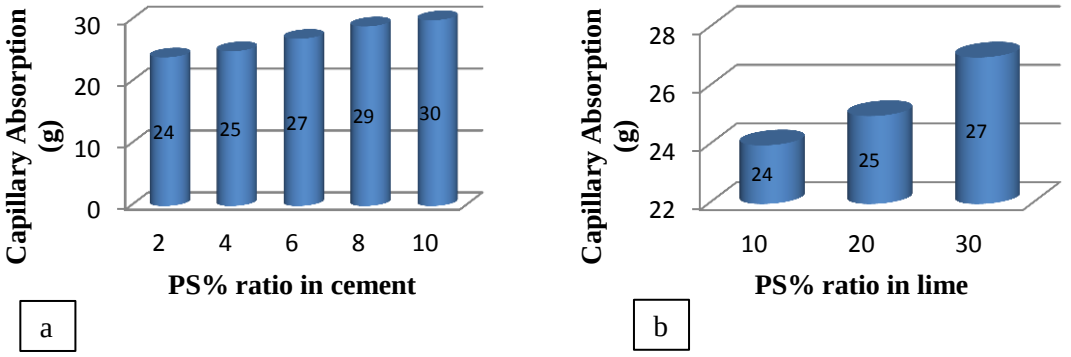


Fig. 5. Relationships among capillary absorption and wt% PS, a) in cement, b) in lime

4. Conclusion

This study investigated the use of waste paint as a partial replacement for sand and lime admixtures separately in cement and lime, respectively. Based on the obtained results in PS-cement specimens, changes were occurred according to the CEN standards mortar. In two experiments, various important changes in physical properties were caused due to existence of

spots and degradation of view in specimens. Moreover, when strength of specimens was dropped more mechanical properties changes was obtained. Expansion of PS, quickly removing any unpleasant odor of PS and lightweight in specimens can be promising features of PS for construction materials manufacturing applications. Summary of results expressed in following;

- Adding PS cause to reduce the unit weight of the specimens in the both experiment groups. With expansion of specimens by PS cause to unit volume to grow and as a result unit weight to drop.
- Adding PS has negative effect on the mechanical properties. Flexural and compressive strength were decreased with the increase of PS in specimens.
- Adding PS caused to expand and as a result porous structure of the specimens has been shown. Therefore, increasing of porous and small holes in specimens had adversely effect on the mechanical and physical properties like unit weight dropping.
- Adding PS had increase of capillary water absorption in the specimens.

The resulting material can provide economical value in certain applications while also decrease land disposal of hazardous paint waste sludge providing a better environment.

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