SOIL STABILIZATION WITH WASTE OF PAPER INDUSTRY (WPI) FOR SUB-BASE OF FOREST ROADS

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Abstract: *The forest roads are one of the most important structures for forestry operations. The forest roads are deformed because of wood transportation by truck; tire pressure, drainage problems, frost, negative weather conditions and unsuitable construction techniques. In this reason maintenance cost of forest roads are increased.*
Forest roads should be constructed by using of suitable constructing techniques to prevent deformation on the forest roads and decrease road maintenance costs. Because the road superstructure is located on natural ground, it is affected physical structures of sub-grade. To obtain the suitable ground for forest road construction, road sub-grade is investigated geological aspects by using of technological possibilities. After determining of the appropriate road sub-grade, sub-base and base layers are constructed as a suitable size and structure. In this phase, various techniques and materials are used for improvement of the road ground.
In this study, effects of waste of paper industry have been investigated on various soils, which have different physical properties for stabilization. Waste of Paper Industry (WPI) was added various ratio as 3 different soils. Changing of physical properties of soils are determined by realizing atterberg limits, specific weight, triaxial compression test and compaction.

1. Introduction

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In the world, a large quantity of industrial wastes are stabilized with cement or used as an additive material in cement manufacturing sector. These materials are fly ash collected from power plant, municipal solid waste fly ash, various puzzolanas and the other industrial wastes (Eroğlu et al., 2003).
In recent years, researchers from many fields have attempted to solve the problems posed by industrial wastes. Finding way for the utilization of these wastes would be an advantageous way of getting free of them. Recent projects illustrated that successful waste utilization could result in considerable saving in construction costs (Çokca, 1999).

2. Literature Review on soil stabilization

According to result of the study examined two lime by-products of unstable (CBR<6) subgrade soils, dried lime kiln sludge and hydrated lime by-product reduced the maximum dry density and plasticity index. They also increased the optimum moisture contents, the compressive strengths, immediate bearing values (Heckel, 1997).

The study was undertaken to evaluate the effectiveness of cement kiln dust as a soil stabilizer, revealed that increases in the unconfined compressive strength of soil occurred with the addition of cement kiln dust. Increases in unconfined compressive strength were inversely proportional to the plasticity index of untreated soil. Significant plasticity index reductions occurred with cement kiln dust treatment, particularly for high plasticity index soils (Miller and Azad, 2000).

Lime piles, which essentially consist of holes in the ground filled with lime, have been used for two distinct purposes for the treatment of clay soils in situ. The first concerns the treatment of soft soils to improve their bearing capacity and in this case uses relatively large diameter quicklime piles at close spacing. The result is a significant reduction in the water content of soil, causing densification and concomitant increases in its strength and stiffness. The second application is in the stabilization of failing slopes, for which both quicklime and lime slurry piles have been used with the intention of causing ion migration and subsequent lime-clay reactions in the surrounding soil (Rogers and Glendinning, 1997).

Substantial improvements in resilient modulus of four soils including a gravel-sand mixture, a sandy silt, a silty sand and highly plastic lay, indicate that fly ash from the power plants have exceptionally high potential for soil stabilization. Moderate increases were observed in the unconfined compressive strength of the same four soils plus additional silty sand and sandy silt when treated with fly ashes from power plants (Turner, 1997).

3. Materials and Methods

Pulp-Paper Industry Solid Waste (PISW) used in this study was supplied from Cay Pulping Mill producing breached kraft pulp, Afyon, Turkey. Cay Pulping Mill produces 30.000 t/year bleached kraft pulp from raw material Wheat Straw (Triticum sativum L.) 65 % and Common Reed (Phragmites australis) 35 %).

Pulp-Paper Industry Solid Waste is lime mud, which are wasted from mud filter after rinsing of white material and washing of mud after processing of costification. Lime mud is reused other pulping mill but it is abandoned to nature because it has more silicate rate from using of reed and straw as a raw material. Chemical analysis of lime mud was made ACME laboratory in Canada, composite cement of composite cement was made in Trabzon Cement Factory Laboratory. Chemical composition of lime mud and composite cement are shown in Table 1.

Table 1: Physical properties and chemical composition of Lime mud and composite cement

Physical Properties	Lime Mud (%)
Blain fineness (cm^2/gr)	4664
Water content (%)	28.00
Loss on ignition (%)	47.00
Specific Weight (gr/cm^3)	2.43
Fineness (90μ/200μ) (%)	39.8/80.6
Chemical composition	
SiO_2	9.19
Al_2O_3	0.10
Fe_2O_3	0.07
MgO	0.15
CaO	40.09
Na_2O	3.01
K_2O	0.19
SO_3	0,02
LOI	47.0
PH	10.5

To investigate effects of lime mud on different soil types, tree soils collected from Artvin (sandy clay; S1), Borçka (loamy clay; S2) and Trabzon (clay; S3) regions, were used. Some physical and chemical properties of these soils were shown in Table 2.

Table 2: Chemical composition and some physical properties and of Soils

	SOILS		
	S1	S2	S3
Sand (%)	60.76	50.76	33.76
Clay (%)	28.24	40.24	56.24
Silt (%)	11.00	9.00	10.00
Electric Conductivity mS/cm^{-1}	0.033	0.192	0.144
Organic matter (%)	0.39	0.81	1.13
Liquid limit (%)	34.5	53.6	33.9
Plastic limit (%)	21.8	28.4	19.2
Plasticity Index (%)	12.7	25.2	14.7
PH	4.81	6.30	7.03
$CaCO_3$ (%)	1.60	1.60	0.80
P (%)	0.16	0.02	0.02
Ca (%)	0.76	0.33	0.52
Mg (%)	0.04	0.04	0.04
K (%)	0.017	0.007	0.009
Na (%)	0.013	0.006	0.009
Cu (ppm)	0.404	0.175	0.019
Mn (%)	0.008	0.005	0.008
Zn (%)	0.0001	0.0001	0.0001
Fe (%)	0.0002	0.0014	0.0001

To investigate effects of lime mud on engineering properties of soils, lime mud was mixed to 3 different soils (S1, S2 and S3) as 0, 5, 10 and 15 %. After that Atterberg limits, specific weight, trixial soil strength and compaction test carried out on the mixtures.

4. Results and Discussion

The results of particle size analysis of soils were shown at Figure 1. According to result of these analyses, S2 has thinner grain than S1 and S3. On the other hand S1 has the roughest structure.

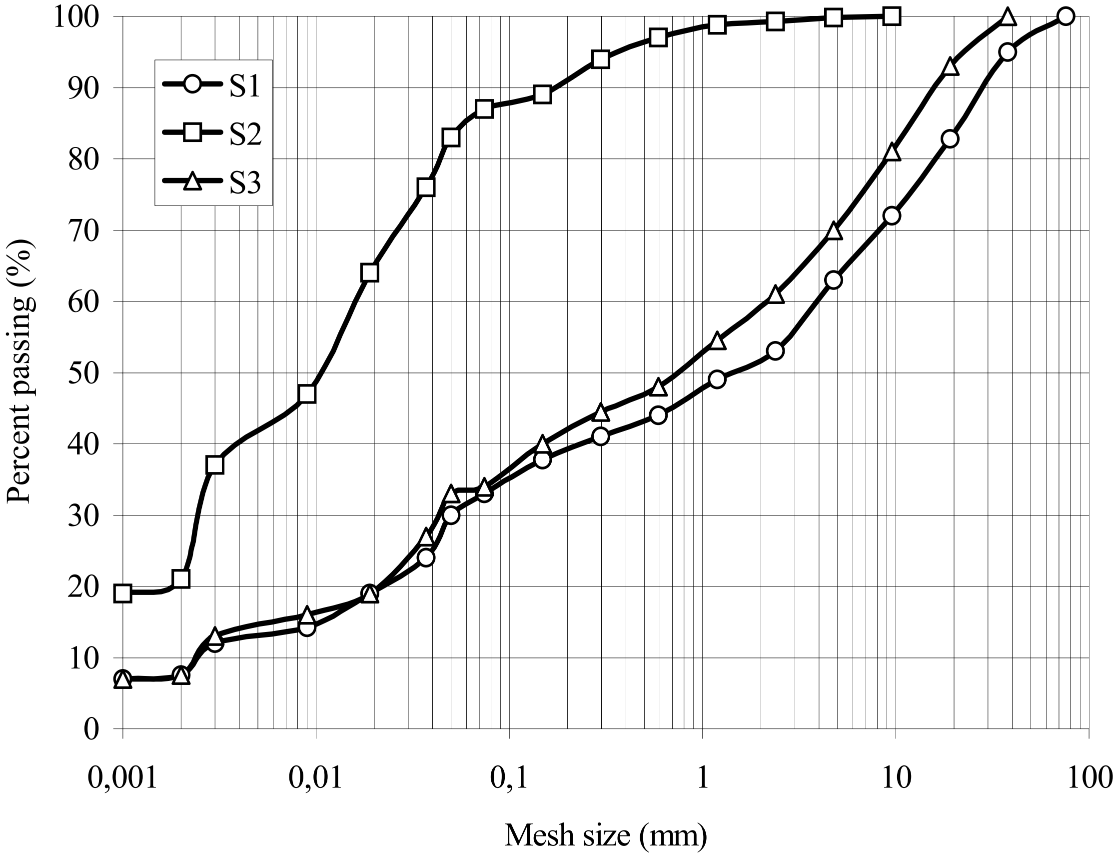

Figure 1: Particle size analysis of Soils for soil stabilization studies

4.1. Atterberg Limits

When effects of lime mud content on Atterberg limits of soils were investigated; liquid limit, plastic limit values of S1, S2 and S3 increase as the lime mud content increase. Plasticity index values of S1 and S3 increase as the lime mud content increase but plasticity index values of S2 decrease as lime mud content increase (Figure 2,3 ad 4).

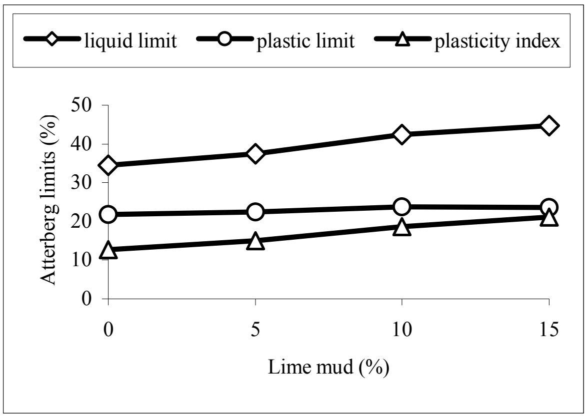

Figure 2: Variation of Atterberg limits depending on lime mud content for S1

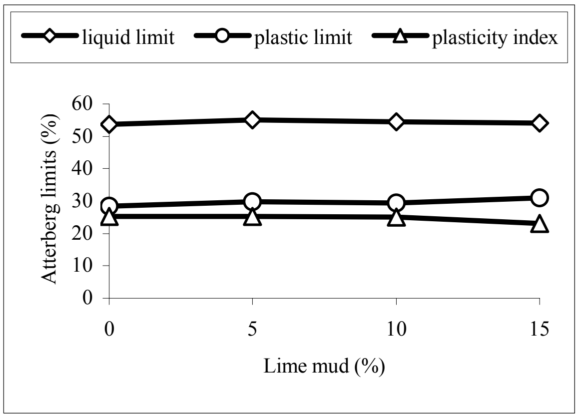

Figure 3: Variation of Atterberg limits depending on lime mud content for S2

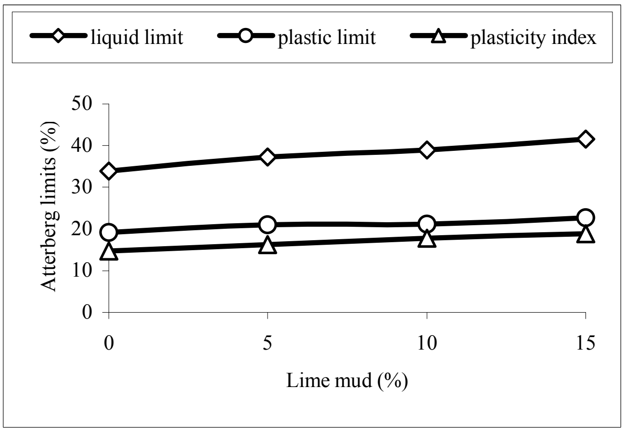

Figure 4: Variation of Atterberg limits depending on lime mud content for S3

4.2. Specific weight

When variation specific weight values of soils were examined; specific weight values of S1 and S2 decrease as the lime mud content increases. Specific weight values of S3 increases as the lime mud content increases (Figure 5).

The reason of to be verify specific weight values of soils according to lime mud content is arisen from mineralogical structure of soils and clay, sand and silt content of soils. Clays have different characteristics and they give different reaction to verify treatment.

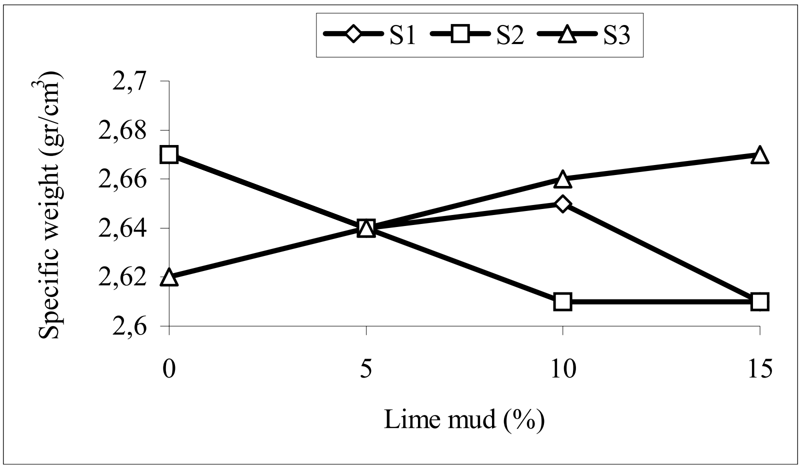

Figure 5: Relation between specific weight and lime mud content

4.3. Trixial soil strength

And of the trixial soil strength test; Mohr circles which shown strength situation of samples were drawn for tree samples and tree different cell pressure. Besides, breaking case curved was drawn as parallel the mohr circle. Angle between curved and horizontal axis is slip strength angle. Pink which curved intersect to slip strength axis is value of soil cohesion.

When variation of soil cohesion values depending on lime mud content was examined; cohesion values of S1 were decreased depending on lime mud content but cohesion values of S2 were increased. Cohesion values of S3 were increased until 10 % lime mud content, after that, its were decreased as lime mud content increase (Figure 6).

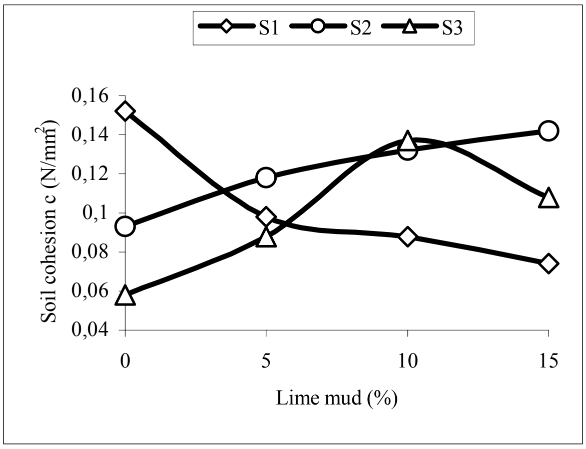

Figure 6: Variation of soil cohesion depending on lime mud content

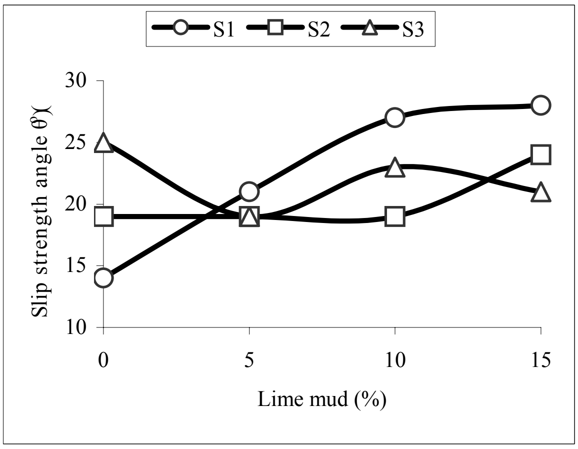

Figure 7: Variation of slip strength angle depending on lime mud content

Increasing lime mud content, the slip strength S1 was increased. Slip strength of S2 remain stable from 5 % to 10 % lime mud content and for 15 % lime mud content was increased. Slip strength S3 was decreased for 5 % lime content, was increased between the 5-10 % lime mud content, was increased after 10 % lime mud content (Figure 7).

4.4. Compaction

Results of compaction experiments, dry density and water content values were obtained for soils and 0, 5, 10 and 15 % lime mud mixtures. When variations of soils dry density values are examined; dry density values of S1, S2 and S3 were decreased depending on lime mud content (Figure 8).

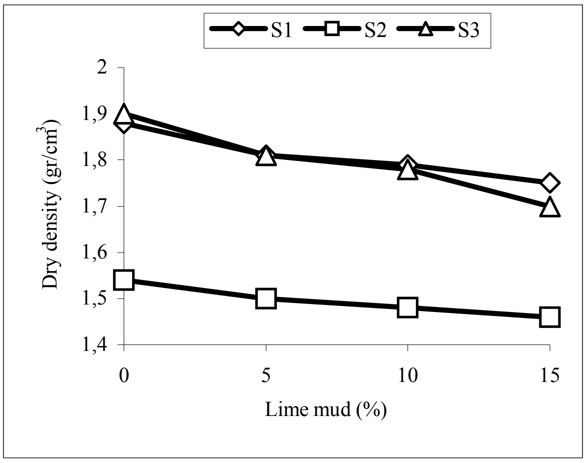

Figure 8: Relation between dry density and lime mud content

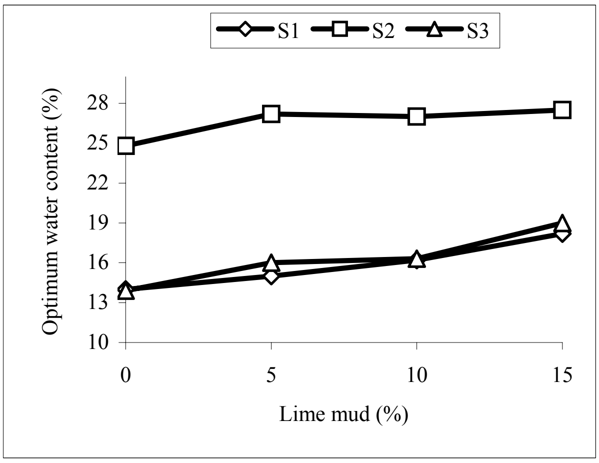

Figure 9: Relation between optimum water content and lime mud content

According to result of compaction test; optimum water content of soils were increased depending on lime mud content (Figure 9).

As shown in figures, increasing the lime mud content in mixture optimum water content was increased. This situation indicates that maximum dry density of mixtures is obtained from more water content

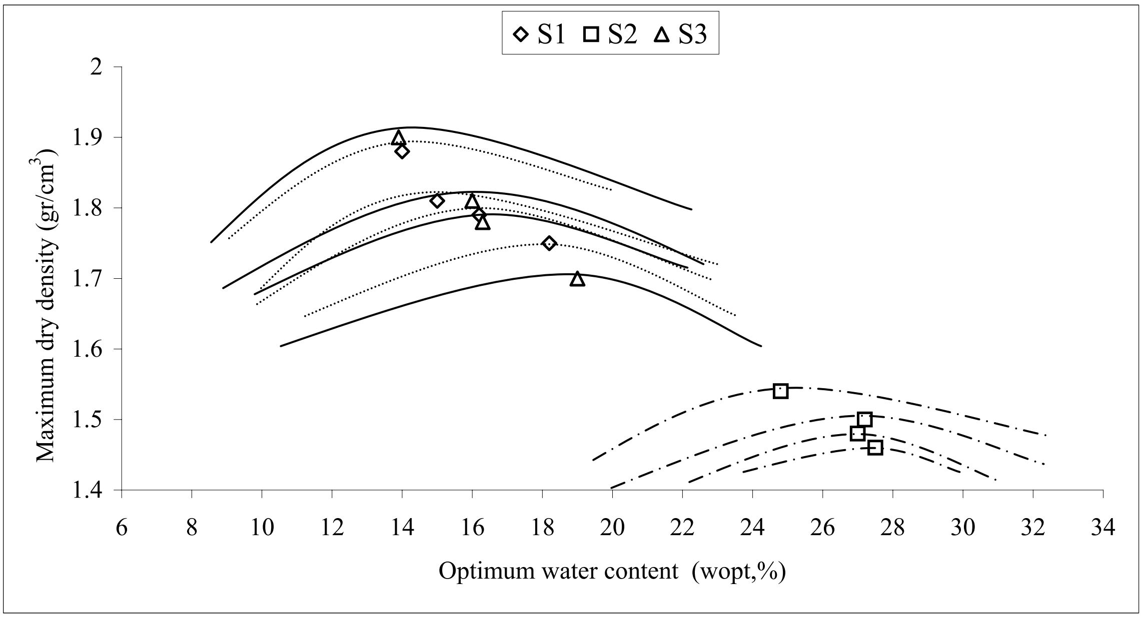

Figure 10: Relation between maximum dry density and optimum water content

Increasing lime mud content in mixtures optimum water content was increased. Dry density of mixtures was decreased. Namely, increasing the lime mud content in the mixture, samples have maximum dry density by way of more water content and values of sample dry density was decreased depending on lime mud content (Figure 10).

5. Conclusions

- Increasing the lime mud content liquid limit and plastic limit values were increased for S1, S2 and S3. Plasticity index values of S1 and S3 increasing depending on lime mud content but plasticity index values of S2 were decreased.
- Specific gravity values of S1, S2 and S3 were decreased as increasing lime mud content.
- Depending on lime mud content, cohesion value of S1 was decreased; cohesion value of S2 was increased. For S3 cohesion value was increased until 10 % lime content, after it was decreased.
- Slip strength angles of S1 were decreased depending on lime mud content. For S2 slip strength angle remained stable between 5 - 10 % lime mud content, on 15 % lime mud content it was increased. Slip strength angle of S3 was decreased until 5 % lime mud content, it was increased between 5- 10 % lime mud content after that it was decreased also.
- Increasing the lime mud content, slip strength coefficients were increased for tree soils. Namely, addition of lime mud was affected positively to slip strength of soils.
- Increasing the lime mud content dry density values of tree soils were decreased, optimum water content of soils were increased. To obtain maximum dry density more water content was required on mixtures. Decreasing of dry density values depending on lime mud content means that addition of lime mud was effected negatively compressing ability of soils.
- Forest roads are deformed depending on environmental effects and exceed loading. To prevention this situation, forest roads superstructures should be built immediately. Verify techniques and materials are used on superstructure construction. Lime mud used this study is alternative materials for stabilization of forest road superstructures.

6. References

Çokça, E. (1999) Effect of Fly Ash on Swell Pressure of an Expansive Soil, The Electronic Journal of Geotechnical Engineering, Vol.4.

Eroğlu, H.; Ucuncu, O.; Acar, H. H. (2003) Compressive Strength of Cement Stabiled Sludge-Ash of Pulp-Paper Industry Solid Waste (PISW), Fifth International Conference on The Fate and Effect of Pulp and Paper Mill Effluents, CD proceeding, 1-4 June 2003, Seattle, Washington.

Hieckel, G. (1997) Alternative Materials for the Modification and Stabilization of Unstable Soils, Laboratory Testing Report. Illinois Department of Transportation, Bureau of Materials and Physical Research Springfield, Illinois, May, USA.

Miller, G. A. and Azad, S. (2000) Influence Of Soil Type On Stabilization With Cement Kiln Dust, Construction and Building Materials 14, 89-97.

Rogers, C. D. F.; Glendinning, S. (1997) Improvement of Clay Soils In-Situ Using Lime Piles in the UK, Engineering Geology, 47, 243-257.

Turner, J. P. (1997) Evaluation of Western Coal Fly Ashes for Stabilized of Low-Volume Roads, Testing Soil Mixed with Waste or Recycled Materials, ASTM STP 1275, Mark A. Wasemiller, Keith B. Hoddinott, Ads., American Society for Testing and Materials.