A Study of Paper Mill Lime Sludge for Stabilization of Village Road Sub-Base

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Abstract—This study has been carried out to study the possibility of use of paper mill waste for stabilization of village road sub-base. Some physical properties of soil collected from three different sites of Assam, India were determined in the laboratory. The properties investigated are particle size distribution, Atterberg limits (liquid limit, plastic limit and plasticity index), compaction properties (optimum moisture content and maximum dry density), California bearing ratio value and swelling properties (free swell index and differential free swell index). These are then mixed with paper mill lime sludge collected from Jagiroad Paper Mill, Jagiroad, Assam, India in different proportions and the physical properties of treated soils were determined. The Atterberg limit tests indicated that it was possible to decrease liquid limit and increase the plastic limit and plasticity index values of soil in addition of lime mud in the mixture. Depending on lime mud content, optimum moisture content increased and maximum dry density was decreased depending on soil type. Addition of lime mud affected positively to California bearing ratio depending on the type of soil. The village roads which get deformed and muddy during rainy season could be stabilized and maintained by using lime mud waste.

Keywords—Lime mud, village road, sub-base, treated soils, California bearing ratio.

I. INTRODUCTION

Village roads in India are generally earth roads constructed by using soil available in the vicinity of the roads. Paving of all the roads are also not possible due to heavy cost. Earth roads are generally dusty and form ruts quickly thereby destroying the roads crown [1]. The village roads in Assam, India is always in a deplorable condition due to lack of improvement of the road materials. Due to weather condition and unsuitable construction techniques the untreated village roads are easily deformed and become muddy in rainy season and dusty in dry weather. In a developing country like India, soil stabilization methods using local available materials have considerable scope in reducing the construction cost of roads. But the stabilization technique should be simple, lowest, labour-intensive and decentralized. Calcium chloride when used to treat the earth roads keep them slightly damp by absorbing moisture from the air [1].

The management of wastes, particularly industrial waste, in an economically and environmentally acceptable manner is one of the most critical issues facing modern industry, mainly due to the increased difficulties in properly locating disposal works and complying with even more stringent requirements imposed by legislation [2]. Best available techniques for reducing waste is to minimize the generation of solid waste and/or reuse these materials, wherever practicable. Although land filling is an alternative of waste disposal, concern has risen over the amount and quality of future landfill space. Landfills are becoming difficult because of more stringent regulations, diminishing land availability and public opposition. In recent years, researchers from many fields have attempted to solve the problems posed by industrial wastes.

The pulp and paper industry is one of the most pollution sources discharging a variety of gaseous, liquid and solid wastes into the environment. Waste handling is a concern in pulp and paper mills. Lime mud is a byproduct relatively free of any contaminants produced in pulp mills as part of the process that turns wood chips into pulp for paper [3]. Paper mill lime may also contain some hydrated lime (calcium hydroxide) but it also contains lots of water. Thus, many paper mills refer to this byproduct as "lime mud." It is very difficult to dry because of the tiny particle size of the suspended lime. Many paper mills have huge landfills full of this stuff. However, some mills have been successful in removing much of the water and making their byproduct lime available as an alternative soil liming material [4].

Nagaon Paper Mill (NPM) is one of the important paper mills under Hindustan Paper Corporation Limited, India, having ISO 14001:2004, Environmental Management System certification by Det Norske Veritas AS (DNV), The Netherlands. It produces 1,00,000 tonnes of paper annually. It is situated by the side of National Highway NH 37 at Jagiroad, Assam, India. Lime sludge is on of the main solid waste generated by the mill. The NPM generates about 448 tones (NEERI, 1990) of lime sludge per day as solid waste. The generated lime sludge has been disposed to a nearby low-lying area of the paper mill. The lime sludge contains huge amount of Calcium Carbonate [5].
Nagaon Paper Mill produces a considerable amount of lime sludge (main constituents: 78.60% CaCO₃, 13.70% SiO₂, 1.80% C₆O, 1.20% NaOH) from the causticizing plant [6]. Lime sludge is burnt in the Rotary Lime Kiln and re-used in the process and the dumped lime sludge is allowed to lift in a systematic manner to local SSI units and unemployed youth [7]. The solid waste disposal system of Nagaon paper mill, Jagiroad, Assam is one of the major problems in the Jagiroad area [8]. Land filling of lime sludge of Nagaon paper mill is still a great problem as it is lying by the side of NH 37. In recent years, researchers from many fields have attempted to solve the problems posed by industrial wastes. Recent projects illustrated that successful waste utilization could result in considerable saving in construction costs (Cokca, 1999) [9].

Village roads are generally low cost roads and are the life line of village transport. These roads are made of earth and they become dusty and form ruts quickly and thereby destroy the road crown. Maintaining and/or stabilization of the village roads which are the only means of road transport of the villagers could be a novel alternative way of lime mud disposal. The pulp mill cooks wood chips with sodium hydroxide to extract the wood fiber used to make paper from the lignin that binds the wood together. It has been reported that, during this process, sodium hydroxide is converted to sodium carbonate. The pulp mill than adds calcium oxide, also known as quicklime, to convert the sodium carbonate back to sodium hydroxide in order to use it again. In the process, calcium carbonate is formed and calcium carbonate is the major component of lime [3]. Lime is useful for stabilization of clayey soils.

Chemical analyses of lime mud have shown that it is relatively free of any contaminants [3]. Some of the mechanical properties of soil can be changed by addition of paper mill lime sludge in different proportions and forests roads could be stabilized and maintained by using lime mud waste. [9]. Effects of two types of lime on unstable (CBR<6) sub-grade soil were investigated by Hieckel (1997) and it was found that dried lime kiln sludge and hydrated lime by-product reduced the maximum dry density and plasticity index. Limes also increased optimum moisture contents, compressive strengths and immediate bearing values of sub-grade soils. The effectiveness of cement kiln dust as a soil stabilizer was investigated and it was found that the addition of cement kiln dust increased the unconfined compressive strength of soil [9]. Significant progress has been made in the use of paper mill sludge as a material for land fill cover by replacing the clays or geo-composites.

PMS behaves similar to a highly organic soil and has good chemical, hydrodynamic and geotechnical properties which make it an efficient impermeable hydrodynamic barrier for the land field cover [9].

Also if a by-product can be shown to have a beneficial reuse, it is not regulated as industrial waste and lime sludge is a by-product of pulp mill that is useful as liming agent. An effort has therefore been made here to study the possibility of the use of NPM lime sludge as stabilizing agent of village road sub-base.

II. COLLECTION OF MATERIALS

Collection of soil samples

Three disturbed soil samples were collected from different sites of Assam.

Collection of paper mill sludge

Lime mud sludge which is a typical paper mill waste was procured from the dumping site of Nagaon paper mill, Nagaon, Assam, India.

III. METHODOLOGY USED

Determination of particle size

The particle size analysis of soil samples and lime sludge was performed to determine the gravel, sands, silts and clay contents. The percentages of various sizes of particles in all the soil samples and lime sludge were obtained by wet sieve analysis and the percentages of different fractions are presented in Table 1.

Determination of Consistency limit

The consistency is largely related with the amount of water content of soil and mostly used for fine grained soils. Liquid limit (LL) was determined by using cone penetrometer and plastic limit (PL) was obtained by thread rolling method. Shrinkage limit was not determined here. The tests results are shown in Table 2. The soils are then classified as per IS (IS: 1498-1970). Soils are found to be silts and clay of low compressibility (CL; S₁ and S₂) and silts and clay of high compressibility (CH; S₃).

Determination of Compaction Property and CBR value

Compaction properties are determined by standard Proctor test as per IS:2720 (PartVII).The test was performed in a cylindrical mould of 1000 ml capacity using a rammer of weight 2.6 kg with 310 mm height of free fall. Soaked CBR values of soil sample were determined as per procedure laid down in IS: 2720 (Part XVI) - 1979. The values are presented in Table 2.
Determination of properties of soil lime sludge mixture

In order to investigate the effects of lime sludge on the properties of soils mentioned above, the collected soils (S₁, S₂ and S₃) were treated with the percentage of 0, 5, 10 and 15% lime mud based on the dry weight and then standard samples were prepared for physical testing. Due to the high water content of lime mud, initially it was dried to environment temperature and subsequently screened before being mixed with the soil samples. All the tests as stated above (except particle size analysis) were performed on the mixture of soil and lime mud.

IV. RESULTS AND DISCUSSIONS

Particle size analysis

Results of particle size analysis of soils and lime mud were shown in fig.1. From the test results it can be said that all the soil samples are fine grained (clays) and the lime mud is clayey sands (>12% fines). As the lime sludge contains an appreciable amount of sands (84.90%) it will provide proper drainage in the road sub base.

Atterberg limits

Variations of Atterberg limits are presented in figures 2-4. Figures 2-4 depicts the effects of addition of lime sludge on the Atterberg limits of the soil under study. Addition of lime sludge lowers the liquid limit, raised the plastic limit and reduces the plasticity index of all the soil under study. This will render the clayey soil friable, easy to be pulverized and will reduce the shrinkage [1]. These are favorable conditions for earth roads.
Compaction Properties

Effects of lime sludge on soil compaction properties are reflected in figures 5-6. From figures 6 and 7 it is clear that optimum moisture content increases and maximum dry density decreases with increase in lime mud in all types of soil. The increase may be due to consumption of more water by lime and the decrease in maximum dry density may be due to increase in OMC.

California Bearing Ratio (CBR) Value

Effect of lime waste on CBR value of soil is shown in figure 7.

From figure 7 it is evident that CBR value increases with addition of lime mud in all types of soil. At 15% addition of lime sludge, the increase in CBR is 19.76% for soil S₁. For soil S₂ and S₃ the increase is 23.90% and 9.33% respectively.

V. CONCLUSIONS

From the above study the following conclusions can be made:

- Lime sludge of Nagaon Paper Mill contains about 84.90% of sands.
- Addition of lime sludge lowers the liquid limit, raised the plastic limit and reduces the plasticity index of clayey soils.
- Optimum moisture content increases and maximum dry density decreases with increase in addition lime mud with clayey soils.
- CBR value of clayey soils increases with addition of paper mill lime mud in all types of sludge. The percentage of increase depends on the type of soil.
- Lime sludge of NPM may be used for stabilization of village road sub-base.
REFERENCES


