Study on Utilization of Lime Mud from Paper Industry as A Construction Material

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ABSTRACT: *Environmental pollution is a serious issue that has arisen as a result of fast industrialization, urbanisation, and an increase in people's living standards. As a result, efforts should be undertaken to reduce pollution caused by trash disposal by converting undesired wastes into raw materials that may be used for a variety of purposes. Lime mud is a waste product from the pulp and paper industry that has shown to be a viable alternative binder in construction projects. To determine the strength qualities of blended concrete, experiments were conducted. The lime mud was used in place of the cement in nominal mixes. The nominal mix considered for the experimental work was of M-10 grade and produced by replacing cement partially with lime mud. The total of three mix proportions was prepared with varying percentage of Cement. Cubes were casted for the replacement of lime mud with cement in the proportions of 10, 30 and 50 percent. Compression tests were performed at 7 and 28 days to determine the strength qualities of the concrete grade. The test findings showed that ordinary concrete may be made by substituting lime mud for cement up to a specified percentage. Then by using the same grade we also made bricks using the same arrangement of materials and their compressive strength at 7 and 28 days was tested out.*

1.Introduction

In the construction field, traditional materials such as stone, sand, clay, gravels, bricks, cement, aggregates and tiles are employed as main components. All of these construction products, such as cement, sand, and coarse aggregate, are made from existing natural resources, and their continued exploitation will have an inherent risk of harming the environment. To meet the construction industry's demand, a large quantity of construction material is required due to the rise in infrastructure development. Other industries use these materials as well. As a result, natural resources are overburdened, resulting in their depletion. High consumption of these commodities will result in enormous amounts of garbage and hazardous gas emissions into the atmosphere, polluting the environment. Thus, the utilization of these wastes is the only solution for safe, sound and sustainable development.

1.1 Sources of Generation of Lime Mud/Sludge.

The huge waste arises from: -

- Sugar Mills
- Pulp and Paper Industry
- Fertilizer tanneries
- Soda Ash Industry
- Calcium carbide Industry

1.2 Properties of Lime Mud

Lime mud is a general term for carbonate sediment composed of particles up to 62μm. In the table below, the physical and chemical properties of six paper mill line wastes from Alabana pulp and paper mills are presented:

Table 1.1 Physical Properties

Property	Mean	Minimum	Maximum
pH	11.3	8.4	13.0
Bulk Density (Dry), g/cm^3	0.93	0.68	1.27
Total Alkalinity, % Calcium carbonate equivalency	102	91	109
Moisture, %	24	1	49
Particle size	----------%----------		
>2.0mm	5	1	13
>0.50mm	24	5	54
>0.25	39	8	90
>0.106mm	51	16	99
>0.106mm	49	1	84

Table 1.2 Chemical Properties

Property	Mean	Minimum	Maximum
	----------**mg/kg**----------		
Aluminum (A1)	1280	630	2230
Arsenic* (As)	1.7	---	---
Barium (Ba)	201	110	318
Cadmium (Cd)	0.3	0	0.6
Cobalt (Co)	6	5	9
Chromium (Cr)	67	50	95
Copper (Cu)	17	7	47
Iron (Fe)	1150	680	1920
Lead (PB	45	41	50

Magnesium (Mg)	7670	5680	10400
Manganese (Mn)	420	160	1070
Molybdenum (Mo)	5	4	5
Nickel (Ni)	35	4	158
Nitrate-N(No_3-N)	8	1	20
Nitrogen (total N)	1780	1000	3000
Phosphorus (water Soluble p)	2	0	24
Phosphorus (citrate insoluble P)	890	50	2520
Phosphorus (total P)	2040	1070	4970
Potassium (k)	470	130	920
Sodium (Na)	10800	3680	38000
Sulfur (S)	0.2	0.1	0.4
Zinc (Zn)	45	9	128

2. Objective of study

The main objectives of the study are listed below:

- To study generation rate of lime mud waste from various industries.
- To identify the impact of present disposal practice of lime mud waste on environment w.r.t. land and water.
- To study the physical and chemical properties of lime mud waste.
- To investigate the feasibility and use of lime mud waste as construction material.
- To maximize economic gains while protecting the environment at same time.
- To carry out the experimental work to use lime mud in the making of cement bricks.

3. RESEARCH METHODOLOGY

3.1 Material Used

1) Cement

Portland Pozzolana Ambuja Brand cement was procured from local sources for use of experimental work.

2) Fine Aggregate

Normal sand was collected from local source and used for the experimental work.

3) Coarse Aggregate

Coarse aggregate of 10 mm size crushed type was obtained from local source and used for the experimental work.

4) Water

Fresh water of the tap was used for mixing as well as for curing purpose as prescribed in IS 456:2000.

5) Lime Mud

Lime mud was obtained from the unit of Ruchira Papers Ltd situated at Trilokpur road, Kala Amb, (HP)

3.2 Mix of Concrete

Ordinary Concrete (Nominal Mix) as per IS: 456-1978 of Cement concrete mix (1:3:6) was considered for the experimental work. These mixes of concrete correspond to Grades M-10 which were adopted for casting of trial cubes.

3.3 Blending of Lime Mud

The lime mud was blended in concrete replacing cement in different percentages. Different mixes of concrete were prepared for various test trials to be conducted including one normal mix.

3.4 Concrete Mixing

Fine and coarse aggregates were collected and stored on a clean, levelled platform in the laboratory. For absorption, the coarse aggregates were totally immersed in water for time period of 24 hours. The surface of the aggregates was gently dried, spread, and then they were kept outside in open for 24 hours until it seemed to be dry wholly. In the case of fine aggregates, take into account the length of time it takes for the surface to dry from a wet state. The mix was prepared on a watertight platform for casting of trial cubes. All the materials i.e., cement, lime mud, fine and coarse aggregates were thoroughly mixed in dry as per required proportions. Then water was added accurately using water-cement ratio. Care was taken that no water may lost during mixing process.

3.5 Casting of Trial Cubes

The trial cubes were casted using three replacement levels with lime mud in place of cement and the percentage of cement varied i.e. 10%, 30% and 50% for the M10 grade of cement.

Clean and oiled cubical moulds of size 150x150x150 mm were used to prepare the specimen for the grade. Before casting, these were carefully fastened to the proper size. There was great care taken to ensure that no gaps existed where slurry could seep.

For adequate compaction, a vibrator was applied. All of these examples were made to the Indian Standard Specifications IS:516-1959. For the first 24 hours, the specimens were permitted to remain in the steel moulds at room temperature. Following that, these were carefully demoulded so that no edges were broken, and then placed in the curing tank at room temperature to cure.

3.6 Curing of Concrete Cubes

From the moment water was added to the dry ingredients, the trial test cubes were placed in a vibration-free environment and they were covered with wet gunny bags for a time period of 24 hours. Following this time, these specimens were numbered and taken from the moulds, then immersed in clean, fresh drinkable water in the curing tank. Every week, the water in the curing tank was replaced. From the date of casting, all specimens were maintained in water for 7 days and 28 days, as required for curing.

3.7 Testing of cubes for Compressive Strength

After a 7-day and 28-day curing time, the trial cubes were taken from the curing tank and allowed to dry on the surface. The cubes were then evaluated for compressive strength using the Indian Standard Code of Practice Methods of Test for Concrete Strength (IS: 516-1959). After then, the greatest load that could be applied to the specimen was recorded. The strength of three cubes was evaluated on the seventh day after casting, and the remaining three cubes were tested on the 28th day.

3.8 Cement bricks

The materials used in this study and their characteristics have been studied. The same material which was used above is being used here. The physical and chemical properties of the materials have been studied in the previous study.

3.9 Materials used

1) Cement

Portland Pozzolana Ambuja Brand cement was procured from local sources for use of experimental work.

2) Fine Aggregate

Normal sand was collected from local source and used for the experimental work.

3) Coarse Aggregate

Coarse aggregate of 10 mm size crushed type was obtained from local source and used for the experimental work.

4) Water

Fresh water of the tap was used for mixing as well as for curing purpose as prescribed in IS 456:2000.

5) Lime Mud

Lime mud was obtained from the unit of Ruchira Papers Ltd situated at Trilokpur road, Kala Amb, (HP)

3.10 Manufacturing of brick specimen

A brick is a building material used to construct walls, pavements and other elements in masonary construction. The standard size of cement brick 190x90x90 mm was used for the purpose of this study.

3.11 Mixing and proportions

The mix for this experimental work was considered to be (1:3:6). This mix of cement concrete corresponds to grade M10 of the cement concrete which was adopted for this experiment purpose.

The cement was replaced by the lime mud in the mix and then we added cement in different percentages by replacing certain amount of lime from the mix.

Fine and coarse aggregates were collected and stored on a clean, levelled platform in the laboratory. For absorption, the coarse aggregates were totally immersed in water for time period of 24 hours. The surface of the aggregates was gently dried, spread, and then they were kept outside in open for 24 hours until it seemed to be dry wholly. In the case of fine aggregates, take into account the length of time it takes for the surface to dry from a wet state. The mix was prepared on a watertight platform for casting of the bricks. All the materials i.e., cement, lime mud, fine and coarse aggregates were thoroughly mixed in dry as per required proportions. Then water was added accurately using water-cement ratio. Care was taken that no water may lost during mixing process.

3.12 Casting of the bricks

The bricks were casted using three replacement levels with lime mud in place of cement and the percentage of cement varied i.e. 10%, 30% and 50% for the M10 grade of cement.

Clean rectangular moulds of size 190x90x90 mm were used to prepare the specimen for the grade. There was great care taken to ensure that no gaps existed where slurry could seep.

For the first 24 hours, the specimens were permitted to remain in the moulds at room temperature. Following that, these were carefully demoulded so that no edges were broken, and then placed in the curing tank at room temperature to cure.

3.13 Curing of the bricks

From the moment water was added to the dry ingredients, the bricks were placed in a vibration-free environment and they were covered with wet gunny bags for a time period of 24 hours. Following this time, these specimens were numbered and taken from the moulds, then immersed in clean, fresh drinkable water in the curing tank. Every week, the water in the curing tank was replaced. From the date of casting, all specimens were maintained in water for 7 days and 28 days, as required for curing.

3.14 Testing of the bricks

After a 7-day and 28-day curing time, the bricks were taken from the curing tank and allowed to dry on the surface. The bricks were then evaluated for compressive strength. After then, the greatest load that could be applied to the specimen was recorded. The strength of three bricks was evaluated on the seventh day after casting, and the remaining three bricks were tested on the 28th day.

4. RESULTS

4.1 Testing of stream water

Samples were collected form the upstream and downstream side of the stream. Various tests were conducted on the local stream water. Method of sampling and testing of water was carried out as per IS 3025:2009.

4.1.1 pH test on water

A pH test was performed on water samples and the results are represented in Table.

Table 4.1 pH value results

Name of Test	Location	Value
pH	U/S	7.25
	D/S	7.85

The results show that pH value increases from 7.25 to 7.85. Although the value has increased 0.60 unit only but the water quality has become alkaline.

4.1.2 TDS test on water

Total Dissolved Solids (TDS) were measured in water samples (TDS). The results are produced in Table below.

Table 4.2 Total dissolved solids results

Name of Test	Location	Value

TDS	U/S	545 mg/lit
	D/S	585 mg/lit

The result shows that TDS value increases from 545 mg/lit to 585 mg/lit. The value of TDS increased about 10% on D/S as compared to U/S water. Hence observed effect on water caused by lime mud.

4.1.3 Total Alkalinity test on water

A stream water alkalinity test was performed, and the findings are shown in Table.

Table 4.3 Total alkalinity on water results

Name of Test	Location	value
Total Alkalinity	U/S	30 mg/lit
	D/S	36 mg/lit

The result shows that the value of Total Alkalinity of D/S water was increased from 30 mg/lit to 36 mg/lit as compared to U/S water. This causes effect on stream water.

4.1.4 Hardness test on water

A hardness test on stream water was performed, and the findings are presented in Table.

Table 4.4 Hardness test on water results

Name of Test	Location	Value
Calcium Hardness	U/S	46 mg/lit
	D/S	61 mg/lit
Magnesium Hardness	U/S	120 mg/lit
	D/S	126 mg/lit
Total Hardness	U/S	166 mg/lit
	D/S	187 mg/lit

The results show that Calcium Hardness increases about 40% and at the same time Magnesium Hardness increases only 5% on D/S water as compared to U/S water.

Table 4.5 Water quality as per IS 10500:2012

Test on Water	**Desired values**	**Permissible value**
pH	6.5 to 8.5	None

TDS	500 mg/lit	2000 mg/lit
Alkalinity	200 mg/lit	600 mg/lit
Total Hardness	300 mg/lit	600 mg/lit

4.2 Testing of Soil

The pH test was performed on soil samples gathered from a nearby land and under a lime mud mound. The results are produced in Table below.

Table 4.6 pH test on soil results

Name of Test	Location	Value
pH	Under Heap	8.3
	Nearby Heap	6.6

The result shows that the pH of soil under the heap of lime mud has increased about 25% as compared to the soil pH of the nearby land. The increased pH value in the soil can cause unwanted weed growth.

4.3 Strength test on concrete cubes of M-10 grade

The strength test results are given below in tables and reproduced graphically.

Table 4.7 Compressive strength results of trial cubes of grade M-10 at 7 days

Sample no.	Percentage of cement	Compressive strength
1	10	0.4
2	30	1.6
3	50	4.0

Table 4.8 Compressive strength results of trial cubes of grade M-10 at 28 days

Sample no.	Percentage of cement	Compressive strength
1	10	1.8
2	30	10.8
3	50	5.5

It has been observed from the results that the 10 N/mm^2 required compressive strength is only seen in the cube with 70% lime mud and 30% cement.

4.4 Water Absorption Test

The sample was soaked for 24 hours in water and before soaking the dry weight was noted. After 24 hours the sample was taken out of the water and the wet weight was measured.

Dry weight =7475g

Wet weight=7600g

Difference in weight=125g

So, from here we can see that the amount of water absorbed by the cube is equivalent to 125g.

4.5 Compressive strength Test on Bricks

Compressive strength or compression is the capacity of a material or structure to withstand loads tending to reduce size. Compressive strength resists these forces or loads. The bricks were tested for the compression test by firstly curing the bricks for a day. The bricks were covered with a damp jute bag for a day. After drying, the bricks were placed in the compression testing machine by their length and the compressive strength was measured.

4.6 Strength test on bricks

The strength tests are given below in the tables.

Table 4.9 Compressive strength results of the bricks of grade M-10 at 7 days

Sample no.	Percentage of cement	Compressive strength
1	10	0.6
2	30	1.4
3	50	4.2

Table 4.10 Compressive strength results of the bricks of grade M-10 at 28 days

Sample no.	Percentage of cement	Compressive strength
1	10	1.4
2	30	10.2
3	50	5.2

From the above observations we can see that the required strength of 10 N/mm^2 is achieved only in the brick no.2 with 70% lime mud and 30% cement.

5. CONCLUSIONS

The research work is concluded in this way that:

1. The lime mud from the paper industry can be used as an additive in the development of bricks.
2. The use of the lime mud is environment friendly as the quantity of cement will be less so the heat of hydration will be less which harmful for the environment.
3. The test conducted on the soil shows its pH value increases on soil under lime mud heap as compared to surrounding soil.
4. The tests conducted on stream water shows that values of pH, TDS, Alkalinity and hardness has increased when we add certain quantities of lime mud.
5. The strength properties of concrete get enhanced after the replacement of lime mud with small amount of cement.
6. The required compressive strength of 10 N/mm^2 was achieved when we replace 30% lime mud with cement in trial cubes.
7. The required strength of 10 N/mm^2 was achieved when we replace 30% lime mud with cement in the bricks sample too.
8. The difference between dry weight and wet weight of the sample was 125g.
9. No incompatibility problems occurred during the experimental work.

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