

Use of paper mill waste product for construction of internal roads and stockyard – a case study

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ABSTRACT

This paper presents a case study about using industrial waste products such as paper mill fly ash and paper mill bed ash for construction of internal roads and stockyard of paper mill. The industrial waste products used were Paper Mill Bed Ash and Paper Mill Fly Ash. A detailed mix design study was carried out to determine optimum combination of the waste products, soil from factory premises and admixtures such as lime and cement. The optimum combination was determined to achieve maximum strength by keeping the admixtures to minimum. Based on the mix proportion determined in the lab a field trial was carried out to understand construction related issues. The feedback from field trial was used to further refine the design mix. The construction of both internal roads and stockyard were carried out with design mix. The performance of the road was monitored over the last two years and found to be satisfactory. This paper presents the details of the laboratory study to arrive at the design mix, field trials and construction of the roads and stockyard.

1.0 Introduction

A paper and pulp production factory located in Rajahmundry wanted to construct internal roads and stockyard using paper mill waste material accumulated at the factory premises over the years. The waste products available were Paper Mill Bed Ash and Paper Mill Fly Ash. A detailed mix design study was carried out to determine optimum combination of the waste products, soil from factory premises and admixtures such as lime and cement. Based on the design mix determined in the material testing laboratory, internal roads and stockyard area were constructed and is in operation for the past two years. This paper presents procedures used for the mix design, field trial, construction of road and field performance.

2.0 Literature Study

As the industrial waste produced while converting bamboo pulp to paper has pozzolanic nature, many studies have been done to use the material for soil stabilization. Main reasons for using the paper mill waste products as cementitious material are (i) high alkalinity imparted to solution due to fast hydration [1] and (ii) lime has properties for stabilizing soils. Uses of residual paper sludge, generated by paper industry, after calcination was found to have many uses for construction industry [2]. Waste paper fly ash has been suggested to replace usual cementitious material in soil stabilization [3]. As the constituents from different paper mills are different, a mix design needs to be carried out to get optimum proportion. In this case study details of mix design carried out for construction of roads and stockyard using paper mill fly ash is explained.



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3.0 Soil Investigation

A soil investigation was carried out to determine soil properties at the site and also to collect soil samples for mix design. Soil samples for mix design were collected from trial pits from the proposed road and stockyard area. Samples were collected from various locations. Based on variability of soil across the site, three groups of samples were collected for mix design. Physical properties of soil as per lab tests carried out are given in Table 1 and chemical properties in Table 2. Results of tests are illustrated in Figure 1.

Table 1. Physical Properties of Soil

Description	Group 1 Soil	Group 2 Soil	Group 3 Soil
pH Value	8.8	8.3	8
MDD, gm/cc	1.674	1.615	1.672
OMC, %	18.7	18.8	16.9
CBR Value @ 2.5mm, %	21.7	26.6	23.5
CBR Value @ 5.0mm, %	28.9	28.0	30.1
Liquid and Plastic Limits	Non-Plastic	Non-Plastic	Non-Plastic
Free Swell Index, %	9.1	10	9.1
Loose Bulk Density, gm/cc	1.22	1.19	1.32
Compacted Bulk Density, gm/cc	1.38	1.33	1.45

Reference; [7], [5], [6] & [4]

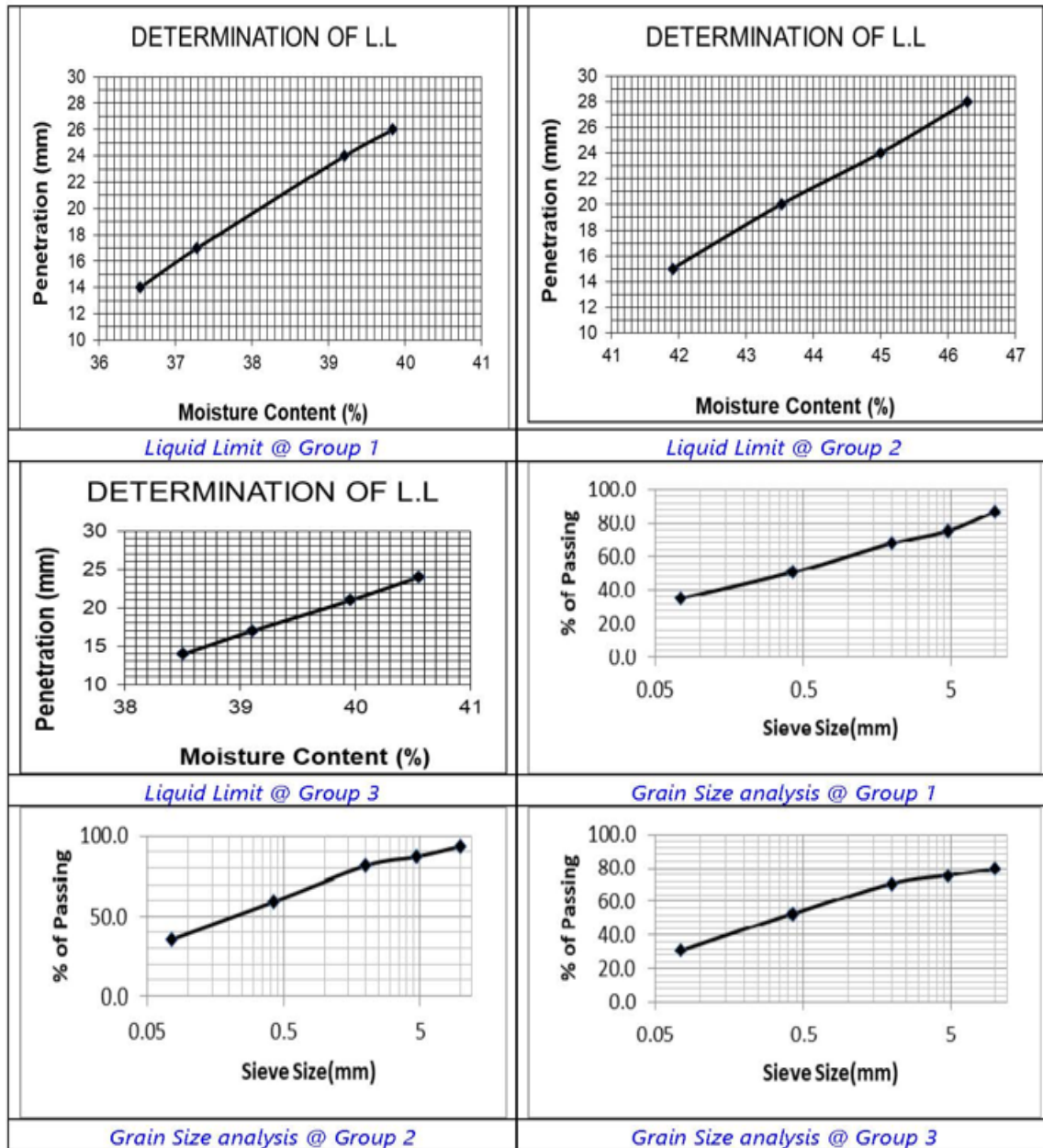


Figure 1 Physical properties result of soil collected from site

Table 2. Chemical Properties of Soil

Parameters	Group 1 soil	Group 2 soil	Group 3 soil
Sulphate as SO ₃ (% by mass)'	0.033	0.009	0.0110
Chloride (% by mass)''	0.014	0.014	0.008
Organic Matter (% by mass)'''	2.33	2.9	2.52

Reference; [8], [15] & [18]

4.0 Paper mill waste material

Two types of paper mill waste materials were available at site; Paper mill ash (bed ash) and Paper mill fly ash. These waste materials are produced during the process of converting

bamboo to pulp and eventually to paper. Many chemical compounds are used during the process of converting bamboo to paper. This process produces waste materials such as Paper mill ash and Paper mill fly ash. The waste materials were sampled from site and sent to laboratory for chemical analysis. Results of chemical tests done on Bed Ash are presented in Table 3 and that of Fly Ash in Table 4.

Table 3. Chemical Properties of Bed Ash

Parameters	Test Method	Results
Sulphate as SO ₃ (% by mass)	IS 2720 (Part 27)-1977 (RA 2015)	0.072
Chloride (% by mass)	California Test 422 – April 2000	0.009

Table 4. Chemical Properties of Fly Ash

Parameters	Test Method	Results
Silicon dioxide (SiO ₂) plus aluminum oxide (Al ₂ O ₃) plus iron oxide (Fe ₂ O ₃), percent by mass, (Minimum)	IS 1727-1967 (RA 2018)	85.92
Silicon dioxide (SiO ₂), percent by mass, (Minimum)		57.46
Magnesium oxide (MgO), percent by mass, (Maximum)		1.00
Total sulphur as sulphur trioxide (SO ₃), percent by mass, (Maximum)		0.95
Available alkalis as equivalent sodium oxide (Na ₂ O), percent by mass, (Maximum)		1.10
Loss on ignition, percent by mass, (Maximum)		4.46
Total Chlorides, percent by mass, (Maximum)		0.007

5.0 Additives used

Lime and Cement were used as additives to improve strength of the mix. California Bearing Ration (CBR) tests results were used for deciding optimum mix proportion of soil, lime, bed ash, fly ash and cement. Results of chemical content test done on Lime are presented in Table 5.

Table 5. Chemical Properties of Lime

Parameters	Test Method	Results
Calcium Oxide (CaO) (% by mass)	IS 6932(Part 1)-1973 (RA 2019)	72.69

6.0 Mix design

To understand effect of the additive lime on soil, Eades & Grim tests were carried out. As per the test, effect of lime on in-situ soil is negligible. Results are presented in Table 6.

Table 6. Eedes & Grim Test

Sl. No.	Material	Mix Proportions	Group 1	Group 2	Group 3
1	Soil – lime mixture'	2 % of lime	9.48	8.21	8.40
2		3 % of lime	9.50	8.22	8.41
3		4 % of lime	9.51	8.24	8.42
4		5 % of lime	9.53	8.28	8.43
6		6 % of lime	9.54	8.30	8.44
7		12 % of lime	9.58	8.36	8.51

Reference; [7]

As per the test results on soil, the three groups of soil show more or less similar physical and chemical characteristics. Therefore, it was decided to use mix of soil from the three groups for carrying out tests required for determining optimum mix proportion with lime, bed ash, fly ash and cement. Each trial mix was blended with water and kept for a period of 30 minutes before compacting in CBR mould. Compacted specimen were moist cured for a period of 7 days and then immersed in water for 4 days before testing.

Two series of mixes, B-Mixes and C-Mixes were considered for the purpose of determining optimum proportions of available waste products bed ash and fly ash, lime, cement and in-situ soil. B-Mix series consists of varying combinations of in-situ soil, bed ash, fly ash, lime and cement. Mix proportions considered are presented in Table 7 and lab test results on the trial mixes are presented in Tables 8 & 9. C-Mix series consists of various combination of the constituents without in-situ soil. Trial mixes used for C-Mix are presented in Table 10 and test results on the trial mixes are presented in Table 11. Variation of physical properties of the trial mixes are illustrated in Figure 2. A summary of observations based on various tests on both series of tests are given below.

1. B-Mix

- Optimum moisture content as per Modified Proctor compaction test is 24%.
- CBR value of mix prepared at optimum moisture content increases with increase in cement content
- CBR value of the mix at 4% cement content is more than required for base material

2. C-Mix

- Minimum compressive strength of mixes is 5.8MPa
- Strength is maximum at about 20% water content. Beyond this water content, strength reduces
- CBR values are more than 100 for all the mixes considered

Table 7. Mix Proportions (B-Mix)

Mix Référence	Description of Materials	Mix Proportions
B-Mix - 1	Soil : Bed Ash : Lime : Fly Ash : Cement	60 : 20 : 6 : 12 : 2 @ 24% water
B-Mix - 2	Soil : Bed Ash : Lime : Fly Ash : Cement	58 : 20 : 6 : 12 : 4 @ 24% water
B-Mix - 3	Soil : Bed Ash : Lime : Fly Ash : Cement	56 : 20 : 6 : 12 : 6 @ 24% water

Table 8. Test Results on different mix proportions(B-Mix)

SL. No.	Test	B-Mix - 1	B-Mix - 2	B-Mix - 3
1	Water mix ratio	24 %	24 %	24 %
2	Bulk Density, gm/cc'	1.867	1.876	1.884
3	Swelling in 4 Days curing, %	2.4	2.4	2.4
4	CBR Value @ 2.5 mm''	37.2 %	75.2 %	82.3%
5	CBR Value @ 5.0 mm''	46.3 %	88.8%	104.7%

Reference; [6]

Table 9. CBR Test results (B-Mix)

Sl. No.	Test	B-Mix - 1	B-Mix - 2	B-Mix - 3
1	Water mix ratio	24 %	24 %	24 %
2	Bulk Density, gm/cc'	1.867	1.876	1.884
3	Swelling in 4 Days curing, %	2.4	2.4	2.4
4	CBR Value @ 2.5 mm''	37.2 %	75.2 %	82.3%
5	CBR Value @ 5.0 mm''	46.3 %	88.8%	104.7%

Reference; [6]

Table 10. Mix Proportions (C-Mix)

Mix Référence	Description of Materials	Mix Proportions
C-Mix - 1	Bed Ash : Fly Ash : Cement	77 : 18 : 5 @ 15% water
C-Mix - 2	Bed Ash : Fly Ash : Cement	65 : 30 : 5 @ 23 % water
C-Mix - 3	Bed Ash : Fly Ash : Cement	70 : 25 : 5 @ 20 % water

Table 11 Test results (C-Mix)

Sl. No.	Test	C-Mix - 1	C-Mix - 2	C-Mix - 3
1	Water mix ratio	15 %	23 %	20 %
2	Density, gm/cc'	1.557	1.577	1.552
3	Swelling in 4 Days curing, %	2.2	2.2	2.0
4	CBR Value @ 2.5 mm''	85.4%	112.4%	129.2%
5	CBR Value @ 5.0 mm''	115.1 %	134.3%	160.2%
6	Compressive strength at 7 days, N/mm ² '	5.8	6.1	7.4

Reference; [6] & [19]

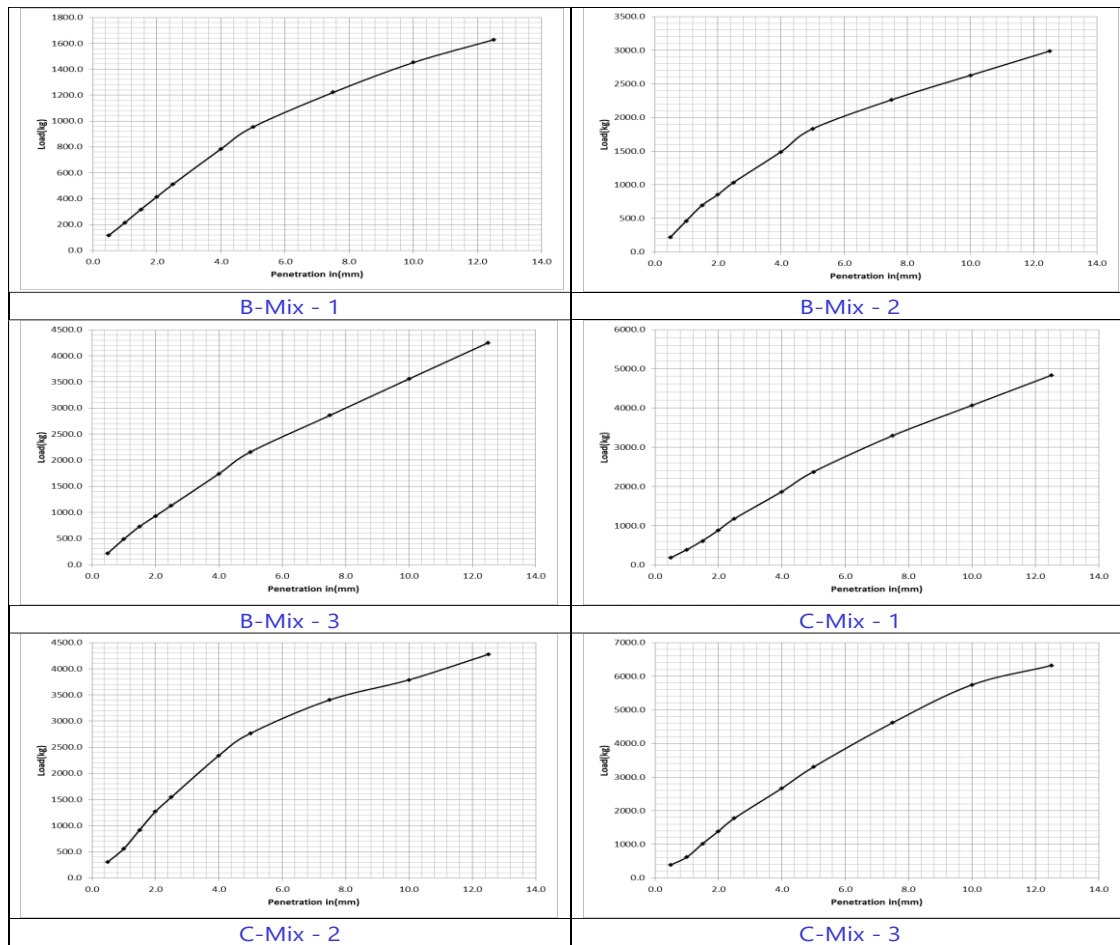


Figure 2 Physical properties result of B Mix & C Mix

Table 12. Design Mix Proportion for construction of Road and Stockyard

Location	Description of Materials	Mix Proportions	Minimum Layer thickness after compaction
Road	Soil : Bed Ash : Lime : Fly Ash : Cement	58 : 20 : 6 : 12 : 4 @ 24% water	Min. 300 mm
Stockyard	Bed Ash : Fly Ash : Cement	70 : 25 : 5 @ 20 % water	Min. 150 mm

Note: - The proportions are based on dry weight of constituents

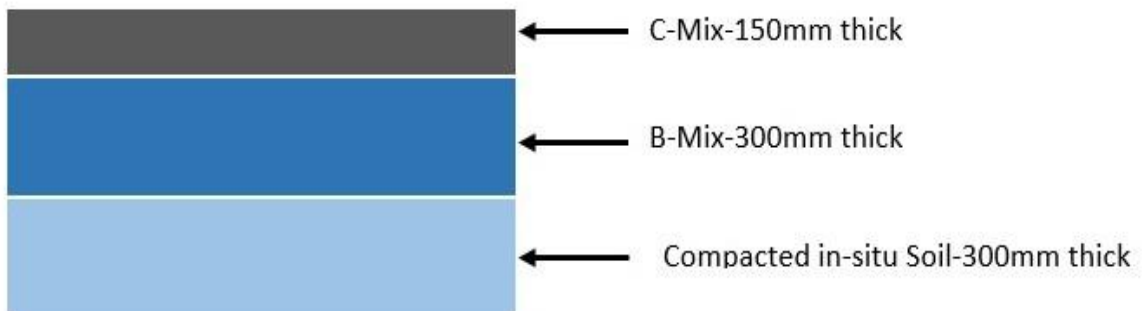


Figure 3 Cross section of B Mix & C Mix

7.0 Field Trial

Design mixes decided based on tests data are presented in Table 12. Composition of the different layers of the pavement considered is presented in Figure 3. In order to understand performance of the mix during installation a field trial was carried out. During field trial it was observed that the design mix lack sufficient workability for the field equipment considered and also evaporation during construction. Based on feedback, water content was adjusted to improve workability.

8.0 Performance

The proposed mix had good strength in the laboratory and at field after construction. Though post-construction plate load tests were planned, tests could not be carried out. Truck movement after the curing period over the newly laid road with the proposed mix showed good strength. Main concern for the mix was durability. But, observation over the past two years shows that the road and stockyard are durable in spite of heavy truck movements.



Figure 4. Photographs from the site taken two years after construction

9.0 Concluding Remarks

Many attempts have been done in the past to use industrial waste from paper mill to stabilize soil [3]. As the chemical composition of waste products from different mills is not same, mix design need to be carried out for the use of the waste product from each mill to stabilize soil. In this study, paper mill waste stabilized soil was used as pavement for stockyard and internal roads. Field investigation carried out at site, laboratory tests to get physical and chemical properties of in-situ soil and paper mill waste products and tests on trial mixes carried out in

the lab are presented in this paper. Field trails carried out, construction details and performance of the pavement after a period of two years are explained. Performance for the past two years proved that the waste product from the paper mill can be successfully used for pavement construction

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References

1. Mozaffari, E.; Kinuthia, J.M.; Bai, J.; Wild, S. "An investigation into the strength development of Wastepaper Sludge Ash blended with Ground Granulated Blastfurnace Slag". *Cem. Concr. Res.* 2009, 39, 942–949
2. Raúl Fernández , Belén Nebreda , Raquel Vigil de la Villa , Rosario García , Moisés Frías . Mineralogical and chemical evolution of hydrated phases in the pozzolanic reaction of calcined paper sludge. *Cement & Concrete Composites* 32 (2010) 775–782.
3. Hani Baluchi, Diego Aponte and Marilda Barra. "Soil Stabilization Using Waste Paper Fly Ash: Precautions for Its Correct Use". *Appl. Sci.* 2020.
4. IS 2720: Part 4 & 5: 1985 (RA 2015) -Grain size analysis & Determination of liquid and plastic limit
5. IS 2720: Part 8: 1983 (RA 2015)- Determination of water content-dry density relation using heavy compaction
6. IS 2720: Part 16: 1987 (RA 2016)- Laboratory Determination of California bearing ratio.
7. IS 2720: Part 26 :1987 (RA 2016-)- Determination of ph Value
8. IS 2720: Part 27 :1977 (RA 2015)- Determination of Total soluble sulphates
9. IS 1727 & IS 4031: (RA 2015)- Methods of test for Pozzolanic materials &- Methods of physical tests for hydraulic cement
10. IS 6932: Part 01 :1973 (RA 2019)- Methods of Tests for Building limes
11. ASTM D -6276-standard Terminology Relating to Materials for Roads and Pavements
12. ASTM D559 / D559M - Standard Test Methods for Wetting and Drying Compacted Soil-Cement Mixtures.
13. ASTM D560 / D560M - Test Methods for Freezing and Thawing Compacted Soil-Cement Mixtures.
14. ASTM D1632 - Preparation of Soil-Cement Specimens in the Laboratory.
15. BS 1377 - Methods of Test for Soils for Civil Engineering Purposes.
16. BS EN 14227 - Hydraulically Bound Mixtures – Specifications.
17. EN 13242 - Aggregates for Unbound and Hydraulically Bound Materials for Use in Civil Engineering Work and Road Construction.
18. IS 2720: Part 27 :1977 (RA 2015)- Determination of organic matter
19. IS 516 : 1959 – Method of test for strength of concrete