Usage of Iron Ore Tailing and Mining Over-Burden for Construction Purposes

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Abstract
Mining is defined as all activities related to excavating rocks, stones, or minerals that can be sold at a profit. In a more general sense, it also includes the subsequent extraction of valuable metals. The adsorption test conducted on cadmium with tailings as adsorbent showed a very good removal efficiency of 98 %. The co efficient of isotherms Amax and k and the value of n<1 shows the high affinity and favourable conditions for adsorption. Sieve analysis and shear strength test shows the tailing is not completely sandy. The concrete blocks prepared with tailings failed to achieve the expected strength since it contained some amount of clay and silt which hinders the solidification process and hydration of concrete. The addition of fly ash (acted as pozzolanic material) increased the strength markedly since fly ash arrests alkali-aggregate reaction and acts as a pozzolanic material in binding the aggregates with cement. This combination can be used for high strength concrete. Hence Usage of tailings and fly ash to construct concrete blocks proves to be economical.
Keywords: iron ore tailing, sieve analysis, fly ash, Pozzolanic material, SEM image

1. INTRODUCTION

In Mining is defined as all activities related to excavating rocks, stones, or minerals that can be sold at a profit. In a more general sense it also includes the subsequent extraction of valuable metals. The extraction of valuable minerals and further refining is referred to as mineral processing which covers a wide range of metallurgical processes, ranging from simple gravimetrical separation to complex high-pressure acid leaching to smelting. The need for mineral extraction and production is an essential activity of modern society. For most of the countries, mining is a large source of economic upliftment. But at the same time, mining also causes severe detrimental effects on the environment. Mining in India meets the mineral demands of various industries. It employs about six million people and also generates revenues of 2.3% of India's gross domestic product (Source: IBM, 1995).

This study includes the assessment of tailings of iron ore from **Lakya Tailings dam at Kudremukh in Karnataka** and to study its utilizations for road construction purpose as a subgrade material. Utilizations of tailings will make the construction economical and also resolve certain environmental problems such as disposal of tailings, leaching of heavy metals from dam.

2. STUDY AREA:

Kudremukh is a mountain range located in the Aroli, Gangamoola regions in the Western ghats of Karnataka state in India. The Kudremukh National Park (latitudinal range 13°01'00'' to 13°29'17'' N, longitudinal range 75°00'55' to 75°25'00'' E) is the second largest declared

Wildlife Protected Area (600.32 km²) of a tropical wet evergreen type of forest in the Western Ghats. Kudremukh National Park is located in Dakshina Kannada and Chikmagalur districts of Karnataka states. The Tunga River and Bhadra River flow freely through the parklands. Kudremukh is supposed to be the largest reserve of a tropical wet evergreen forest in Karnataka still strongly adhering to its pure and natural beauty.

Kudremukh Iron Ore Company Limited (KIOCL) is a government run company which mined iron ore from the Kudremukh hills. KIOCL was conducting its operations on an area of 4,604.55 ha for a period of around 30 years. The mining lease was given to KIOCL in Kudremukh for an initial period of 25 years and was supposed to be closed by Dec 2001. However it had to face the ire of environmentalists as Kudremukh area is a biodiversity hotspot. The mining lease was temporarily extended. However, it was completely stopped in Dec 2005. Now, the plant runs on ores supplied by National Mineral Development Corporation (NMDC) Ltd.

The compositions of ore in this region are magnetite (Fe_3O_4), hematite (Fe_2O_3), goethite ($FeO(OH)$), limonite ($FeO(OH).n(H_2O)$) along with other few trace metals and elements. The region is rich in magnetite-quartzite deposits, and is estimated to have around 700 million tonnes of deposits. Every day, around 40,000 tonnes of ore was being mined by the KIOCL. According to company estimates there are 630 million tonnes of weathered ore (found on the top layers) and 450 million tonnes of primary ore (or the hard ore found below) in this area alone. So far 325 million tonnes of raw ore has been mined, out of which the concentrate accrued is 109 million tonnes thereby indicating that around 216 million tonnes is accumulated as waste.

The rainfall in Kudremukh, which is perhaps one of the highest for any open cast mining operation in the world, greatly accentuates the impacts of siltation as claimed by environmentalists. The topographic and rainfall characteristics in combination with the open cast mining of low grade iron ore and other land-surface disturbances caused by the KIOCL operations results in very high sediment discharge, with over 60% of the total siltation in the Bhadra system being contributed by the mining area which forms less than six per cent of the catchment.

Nevertheless, the company has done many plantations of flora of different species such as Acacia, Casuarinas and several other local species of plants. A total of 117.8 Ha of area was covered with plantation out of the total 525 Ha of mined area. With high quality practices adopted by KIOCL to mine, the flora and fauna remained intact, causing no adverse affects on the nature.However, an earthen tailings dam was constructed to store the tailings coming from the beneficiation plant. The description about lakya dam is as follows:

1.length	1048m	6.Dam top level elevation	890m
2.Heigth	100m	7.Full reservoir level	885m
3.Catchment area	18.7sq.km	8.Gravity tunnel	980m

		length	
4.Reservoir area	6.05 sq.km	9.quantity of tailing till 2005	185 Mt
5.capacity	245 Mm^3	10.	

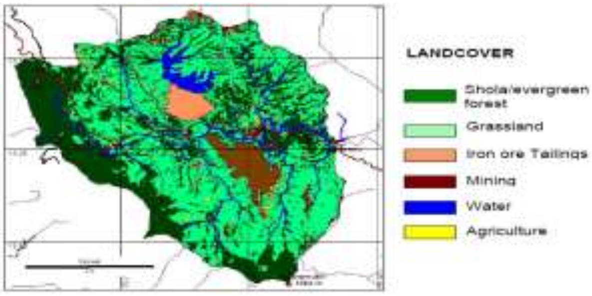

FIG 1: LAND COVER MAP OF THE STUDY AREA. SOURCE: IMPACT OF IRON ORE MINING IN KUDREMUKH ON BHADRA RIVER ECOSYSTEM (JAGDISH. K ET AL., 2006)

Table 1: Ore reserves in Kudremukh and outside kudremukh

Ore reserves	**Quantity (Mt)**	**Place**	**Quantity (Mt)**
Geological reserves	680	Nellibeedu	47
Mineable reserves	430	Gangrikal	370
Crude ore mined up to dec 2005	324 (39 % Fe)	Primary ore (Kudremukh)	302
Concentrate produced	110 (67.6 % Fe)	Soft weathered ore (Kudremukh)	47

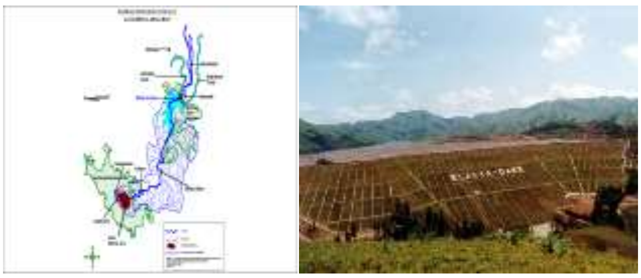

FIG 2: BHADRA RESERVOIR CATCHMENT AREA AND LAKYA DAM AT KUDREMUKH

3. TAILINGS MANAGEMENT IN KIOCL

The company has beneficiated the magnetite ore in spirals and by magnetic separation techniques. In these processes, the quantity of tailings generated was about 29,424 tonnes of solids per day as slurry (liquid to solid ratio is 1.5 to 1). The chemical constituents of the processed tailings include Fe, SiO2 and Al2O3. The mineralogical compositions are oxides of iron and silica (35 and 60–65%, respectively) with a specific gravity of 2.7.The company has constructed an earthen tailings dam (Lakya dam) whose capacity is 245 Mm^3 with the Reservoir area of 6.05sq.km as a step towards management of tailings.

4. MATERIALS AND METHODOLOGY

SAMPLING LOCATION

The tailing generated from beneficiation process was being disposed off into the Lakya dam.

Lakya Dam

A valley at Lakya stream which was in close proximity of the mining area was selected for tailing pond. Total catchment of this area is approximately 20 km^2. The stream originates at 840 m elevation and joins River Bhadra at 780 m elevation. The stream traverses through a total length of about 7 km at varying width of 10-20 m. The company completed the construction of Lakya tailings dam in 1976. This dam was constructed to dispose the tailings generated from beneficiation of the raw ore as one of the measures for pollution control. Every day, around 29,424 t of solids was being disposed into the pond in the form of slurry (liquid to solid ratio is 1.5 to 1). In a span of around fifteen years, 60 Mt of tailings was disposed into the pond by the year 1991. In 2005, the quantity reached up to 185 Mt during the closure of the plant.

FIG 3: SAMPLING LOCATIONS AT LAKYA DAM AND SCHEMATIC REPRESENTATION OF TAILING HANDLING

5. SAMPLING

Samples were collected from six locations within the Lakya dam by Standard procedures as shown by the arrows in the figure above and analysed for various physical and chemical parameters as per the Standard methods. Microscopic examinations were also made with the help of SEM studies. Three sets of samples were collected in September during the monsoon period. And the next three sets of samples were collected in post monsoon period in December **(Plate 1).** The top 15cm of the soil/tailings was brushed off and removed and the soil was then excavated and collected in plastic carry bags. These soil samples were then carried to NITK; Surathkal; Karnataka for further examination and tested in the Civil department. A small volume of tailings at sufficient depth were collected and immediately packed in air-locked/self sealing covers and then tested for field moisture content in the Geotechnical laboratory.During September (first arrow), around 5kg of soil was collected from each location and during December (second arrow and third arrow), around 25kg of soil was collected from each location.

6. SAMPLE PREPARATION FOR TESTING

All the samples were initially dried to remove all the moisture content present in it. For testing the physical parameters, some amount of the samples were oven dried at 110°C in order to remove all organic content for a period of about 24 hrs. 500g of this oven dried soil sample was then subjected to sieve analysis to obtain the gradation. The rest of the samples were utilized for testing of other physical parameters as shown in the table below.

For testing the chemical parameters and to conduct SEM studies, the soil sample was air dried under room temperature (approx 27°C) for about 24 hrs. The as obtained soil sample was spread in thin layer and kept in the open to drive away all the moisture content in it. The dried soil was sieved to obtain soil of particle size <425µm. This sample was then immediately tested for pH, conductivity, salinity and organic content. Other chemical parameters mentioned below were also tested. All the tests were done according to Standard methods.

7. PRELIMINARY SOIL TESTING

TABLE 2. CONCRETE BLOCK RATIOS WITH TAILINGS AND FLY ASH

Cement + Tailings + Jelly	Cement + Fly ash + Tailings + Jelly
1: 3.11: 4.53	FA – 45 %, Cement – 55 %
1: 1.65: 2.92	FA – 30 %, Cement – 70 %
1: 1.057: 2.267	FA – 15 %, Cement – 85 %

The blocks were subjected to curing and were tested after 7 days and 28 days of curing. For every combination, three blocks were prepared to avoid errors and the test was conducted twice to check the repeatability. The following tests were conducted on the blocks after curing to check their strength.

TABLE 3.1: PHYSICAL PROPERTIES OF TAILINGS

Sample No. Parameters	Mixed sample	4	5
In situ moisture content (%)	42	2.816	3.35
Uniformity co efficient	4.15	6.1	4.94
Co efficient of curvature	0.86	0.98	1.14
Specific gravity	2.8	3.3	3.1
Optimum moisture content (%)	9.45	7.72	9.35
Co efficient of permeability (cm/s) $*10^{-3}$	0.564	0.672	0.483
Angle of internal friction	37°	35°	36°

Cohesion (kN/m²) **Particle size (µm)**	0.1167	0.144 58	0.1216 56
California bearing ratio (%) **Unsoaked soaked**	55.7 39.86	60.24 49.5	82 30.12

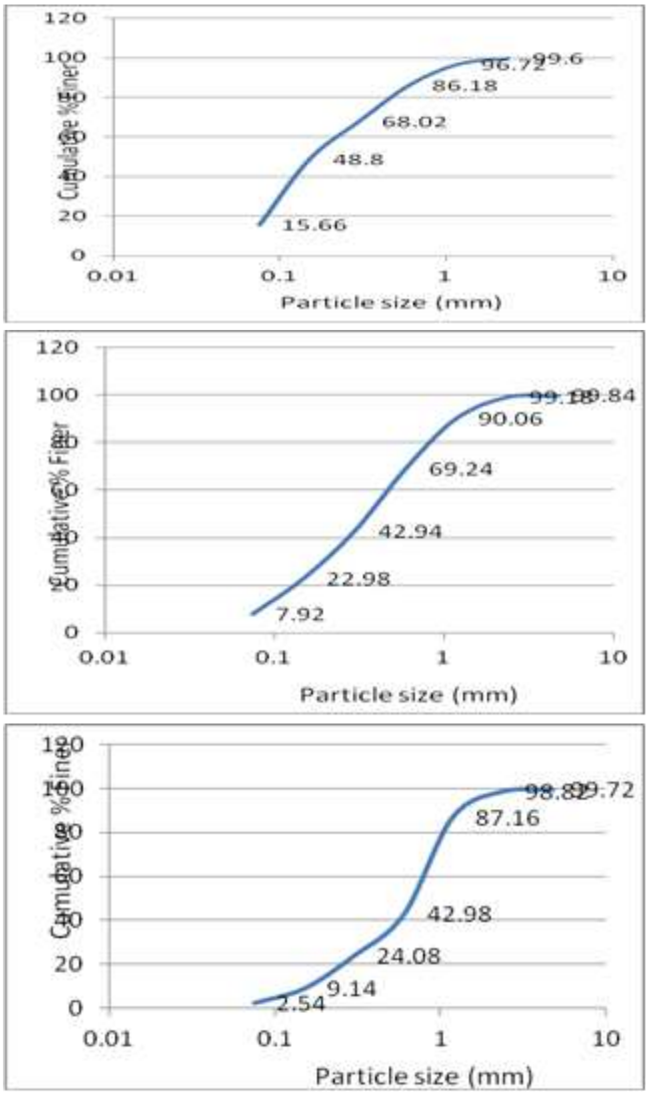

FIG 4 : PARTICLE-SIZE DISTRIBUTION OF MIXED,4 AND 5

8. CHEMICAL PARAMETERS

TABLE 4.1: CHEMICAL PROPERTIES OF TAILINGS

Sample No. Parameters (%)	**1**	**2**	**3**	**4**	**5**	**6**
pH	6.84	7.37	7.84	7.84	7.25	7.63
Conductivity (μS)	100	117	146	359.5	114.5	987.4
Salinity	0.007	0.006	0.008	0.02	0.007	0.06
Organic matter	4.9	4.09	4.632	6.3	5.41	9.53
Carbon	2.85	2.37	2.69	3.65	3.14	5.53
Silica	72.1	63.3	65.2	47.94	55.04	43.34
Iron oxide	13.3	17.3	25.2	32	25.25	27.89
Aluminium oxide	3.1	1.3	13.7	2.79	2.835	7.26
Chloride	0.0097	0.0083	0.0097	0.042	0.03	0
Sulphate	15.64	5.9	6.4	0	0.075	0
Calcium oxide	0.265	0.4	0.397	0.2155	0.378	1.064

Magnesium oxide	0.166	0.474	0.827	0.89	0.79	1.61
Sodium oxide	0.21	0.147	0.165	0.183	0.386	0.81
Potassium oxide	0.352	0.133	0.264	0.386	0.176	0.9158
Cation exchange capacity (meq %)	7.96	11.72	14.52	9.84	11.24	22.48

TABLE 4.2: HEAVY METAL CONCENTRATION IN THE TAILINGS

Elements (ppm) or (mg/kg)	**Sample No.**					
	1	**2**	**3**	**4**	**5**	**6**
Lead	0.928	0.912	1.078	0.316	0.028	0
Zinc	1.346	1.028	1.664	0.4	0.58	0.45
Nickel	0.12	0.264	0.37	0.1	0.107	0.03
Chromium	95.92	109.2	76.58	60.83	45	75.94
Cobalt	0.052	0.076	0.078	0.11	0.25	0.07
Cadmium	0.052	0.052	0.064	0.062	0.215	0.043
Manganese	8.2	10.3	10.94	07.4	10	11.7
Copper	0.432	0.828	1.26	0.94	0.2	0.6

9. CONCRETE BLOCK TESTING

STANDARD CONCRETE BLOCK

TABLE 4.3.PROPERTIES OF STANDARD CONCRETE BLOCKS AFTER CURING FOR 7 AND 28 DAYS

Blocks	**Curing (days)**	**Compressive strength (Mpa)**	**Rebound number**	**Time (µs)**	**Pulse velocity (m/s)**
1	7	35.11			
	28	46.66	44	30	5000
2	7	32.89			
	28	40	45	32	4687.5
3	7	33.33			
	28	44.44	42	31	4838.7
4	7	34.33			
	28	47	45	30	5000
5	7	33			
	28	45	45	30	5000
6	7	35.87			
	28	42.33	43	32	4687.5

Cement + tailings + jelly

TABLE 4.4: PROPERTIES OF BLOCKS WITH RATIO 1: 3.11: 4.53

Blocks	**Curing (days)**	**Compressive strength (Mpa)**	**Rebound number**	**Time (µs)**	**Pulse velocity (m/s)**
1	7	8.88			
	28	18	26	33	4545
2	7	8.88			
	28	17.77	25	33	4545
3	7	11.11			
	28	17.77	25	32	4687.5
4	7	8.58			
	28	15	21	32	4687.5
5	7	9			
	28	17.43	22	33	4545
6	7	8.01			
	28	15.53	19	32	4687.5

TABLE 4.5.PROPERTIES OF BLOCKS WITH RATIO 1: 1.65: 2.92

Blocks	Curing (days)	Compressive strength (Mpa)	Rebound number	Time (µs)	Pulse velocity (m/s)
1	7	12			
	28	18.22	27	34	4411
2	7	11.55			
	28	21.7	28	33	4545
3	7	11.11			
	28	20	28	34	4411
4	7	13.87			
	28	15	20	38	3947
5	7	11.26			
	28	21	22	33	4545
6	7	10.96			
	28	22.11	27	35	4385

Cement + fly ash + tailings + jelly

TABLE 4.6: PROPERTIES OF BLOCKS WITH FLY ASH 15 %

Blocks	Curing (days)	Compressive strength (Mpa)	Rebound number	Time (µs)	Pulse velocity (m/s)
1	7	2.67			
	28	4.44	14	45	3333
2	7	2.67			
	28	8.84	14	55	2727
3	7	2.22			
	28	2.22	12	51	2941
4	7	3			
	28	5	15	50	3000
5	7	2.5			
	28	8.33	17	56	2678
6	7	2.73			
	28	2.5	12	55	2727

TABLE 4.7: PROPERTIES OF BLOCKS WITH FLY ASH 30 %

Blocks	**Curing (days)**	**Compressive strength (Mpa)**	**Rebound number**	**Time (µs)**	**Pulse velocity (m/s)**
1	7	18.66			
	28	27.55	31	33	4545
2	7	22.22			
	28	28	31	31	4838.7
3	7	22.22			
	28	28.44	35	32	4687.5
4	7	15			
	28	28	36	32	4687.5
5	7	21			
	28	26	33	30	5000
6	7	22			
	28	26	34	35	4285

TABLE 4.8: PROPERTIES OF BLOCKS WITH FLY ASH 45 %

Blocks	**Curing (days)**	**Compressive strength (Mpa)**	**Rebound number**	**Time (µs)**	**Pulse velocity (m/s)**
1	7	45.33			
	28	48.44	45	30	5000
2	7	46.22			
	28	53.33	53	32	4687.5
3	7	44.44			
	28	50.88	54	32	4687.5
4	7	43			
	28	49.45	48	27	5555
5	7	46.53			
	28	50.9	55	29	5172
6	7	42.8			
	28	53.33	50	32	4687

TABLE 4.9: AVERAGE DATA OF ALL THE BLOCKS

Curing (days) Ratio	**7 days Compressive strength (MPa)**	**28 days** **Pulse velocity** **Compressive** **(m/s)** **strength (MPa)**
Cement + sand + jelly		
1 : 1.65 : 2.92	34	44.23 4868.9 (excellent)
Cement + tailings + jelly		
1 : 3.11 : 4.53	9.07	16.91 4616.25 (excellent)
1 : 1.65 : 2.92	11.79	19.68 4357 (good)
1 : 1.057 : 2.267	18.49	25.15 4799 (excellent)
Cement + fly ash + tailings + jelly		
15	Nil	5.22 2901 (poor)
30	20.18	27.33 4673 (excellent)
45	44.72	51.06 4964 (excellent)

10. ADSORPTION TEST

TABLE 4.10. REMOVAL EFFICIENCIES OF CADMIUM WITH DIFFERENT CONCENTRATIONS

Cadmium concentration (μg/ml) or (mg/L)		**C_i^o-C_i**	**% age removal of cadmium (C_i^o-C_i)/ (C_i^o)**
Before adsorption (C_i^o)	**After adsorption (C_i)**		
20	0.909	19.091	95.45
10	0.041	9.959	99.59
5	0.046	4.954	99.08
4	0.027	3.973	99.325
3	0.027	2.973	99.1
2	0.027	1.973	98.65
1.5	0.022	1.478	98.53
1	0.018	0.982	98.2
0.8	0.015	0.785	98.125
0.5	0.011	0.489	97.8

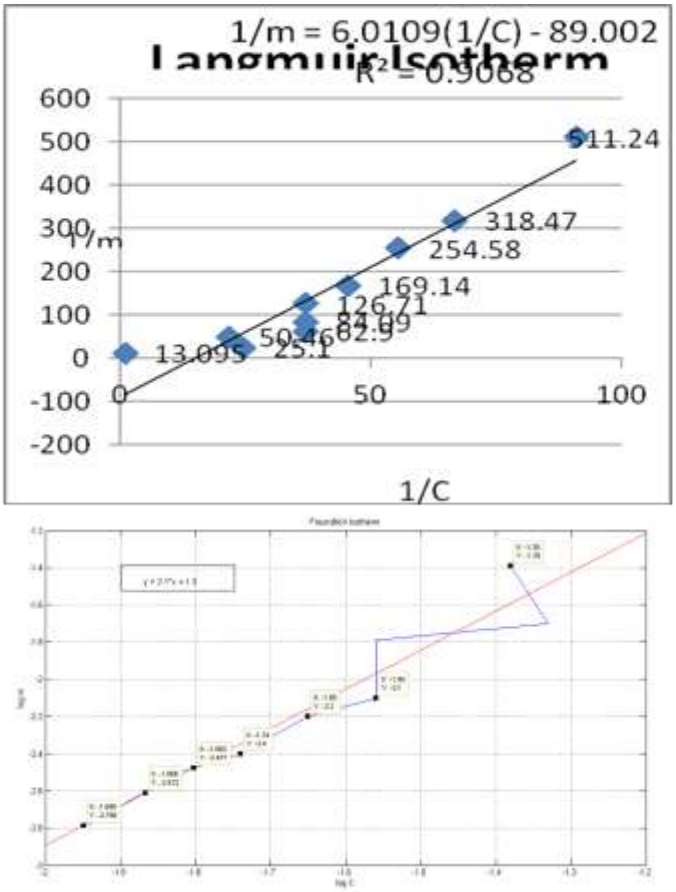

FIG 5: GRAPH OF 1/M VS. 1/C OF LANGMUIR ISOTHERM AND LOG (M) VS. LOG(C) OF FREUNDLICH ISOTHERM

FIG 6: TAILING AND ITS SEM IMAGE

11. CONCLUSIONS

From the studies conducted on tailings regarding its properties and utilization, the following conclusions can be drawn:

Characteristics of tailings:

1. Sieve analysis and shear strength test (Fig 4.1-4.3 & Table 4.1) shows that the tailings are not completely sandy. They contain some amount of silt and clay. This results in decrease in 28-day compressive strength of the concrete when compared to natural sand.

Concrete blocks with tailings and fly ash:

2. During cement hydration process, aggregate constituent may affect the hydration and solidification process. Predicting these reactions in the aggregates is difficult and cumbersome process. Heavy metals present in the aggregates (Table 4.3) such as Zn, Cu, Pb and Cd retard hydration, while iron compounds accelerate the cement hydration. It is possible that in this case, the presence of iron in higher concentrations might have the positive effect on strength attainment.
3. Since the fine tailing aggregate conform to grading zone IV, it should not be used in reinforced concrete unless tests have been made to ascertain the sustainability of proposed mix proportions.
4. The concrete blocks prepared with tailings failed to achieve the expected strength since it contained some amount of clay and silt which hinders the solidification process and hydration of concrete. However, appreciable strength of 28 MPa was achieved. Hence it can be used for building construction, partition walls, pavement of low load bearing roads etc. Sieving and washing of tailings prior to its utilization will remove the unwanted constituents and silt that will subsequently increase the strength of concrete.
5. Addition of fly ash acted as pozzolanic material increased the strength markedly since fly ash arrests alkali-aggregate reaction and it acts as a pozzolanic material in binding the aggregates with cement. This combination can be used for high strength concrete such as in dams etc with pre-treatment to arrest the heavy metal leaching.
6. Using tailings and fly ash to construct concrete blocks proves to be economical since natural sand is estimated to cost Rs.3000/truck load and also provides high strength than the natural conventional method.

Adsorption:

8. The adsorption study (Table 4.12) conducted on cadmium with tailings as adsorbent showed a very good removal efficiency of 98 %. The co efficient of isotherms A_{max} and k and the value of n<1 shows the high affinity and favourable conditions for adsorption.

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