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Characterization, Stabilization and Utilization of Sludge as a Construction material

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Abstract - *The industrial sludge may pose serious threat to human health and surrounding environment without safe treatment. The effluent treatment plant of the industries produces a huge quantity of sludge, which basically comprises of metal precipitates. Since these metals being hazardous in nature, their disposal is a big problem. Technologies being widely used to solve these problems of disposal of hazardous wastes are stabilization and solidification. In stabilization, some supporting media/binder or other modifier are added to the waste, so that the contaminated particles are fully or partially replaced with each other. The physical nature of waste is altered by employing additives. Finally the possibility of using this stabilized and solidified sludge as a construction material is being explored. This project investigates the feasibility of using the industrial sludge as construction materials.*

Key Words: Heavy metals, Solidification, Stabilization, Construction materials, sludge.

I. INTRODUCTION

Construction material with natural resources is very rare now a day. The causes of pollution and environmental problems are increasing rapidly. This project aims at converting the industrial sludge as a construction material. This shall help not only to control degradation of environment but conserve them for the use of future generation. This can be achieved by the process of recycling and making use of industrial wastes as a construction material. Paper sludge is an industrial waste produced in plenty by paper mills. Quarry dust is also an industrial waste produced from the Granite industry. This paper presents the physical and chemical characteristic of paper sludge and quarry dust and its use as a construction material. Objective of this experimental study is to find out the important parameters such a characterization, stabilization and utilization of sludge as a construction material.

II. MATERIAL PROPERTIES

A. Sludge

Sludge is a semi-solid slurry that can be produced from a range of industrial processes such as from water treatment, wastewater treatment or on-site sanitation systems. For example, it can be produced as a settled suspension obtained from conventional drinking water treatment, as sewage sludge from wastewater treatment processes or as fecal sludge from pit latrines and septic tanks. The term is also sometimes used as a generic term for solids separated from suspension in a liquid; this 'soupy' material usually contains significant quantities of 'interstitial' water (between the solid particles).

B. Lime sludge

Lime sludge is produced in a large amount as a byproduct of paper industry. It is a by-product obtained by deinking and pulping of paper and its disposal is in the form of land spreading. Lime sludge behaves like cement because of silica and magnesium properties. It is a major environmental problem for the paper industry.

There are many industries which produce large amount of sludge. But choosing one among them was a difficult task. Many industries hesitated to offer their sludge. This was another challenging task. Among all these we chose TNPL, Tamil Nadu Newsprint and Paper Limited industry at Karur who agreed to provide us the lime sludge.

Fig -1: Lime sludge

Chemical Reaction of Lime sludge:

Green liquor + Lime $\rightarrow$ Lime Mud + White liquor

$Na_2CO_3 + H_2O + CaO \rightarrow CaCO_3 + 2\ NaOH$

Sodium Carbonate + Water + Calcium Oxide → Calcium Carbonate + Sodium Hydroxide

$CaCO_3$ + Heat (800°C) → CaO + $CO_2 \downarrow$
Calcium carbonate → Lime Sludge

Lime sludge, an inert material mostly composed of calcium carbonate, is the result of various industries. Lime sludge is generated from paper, acetylene, sugar, fertilizer, sodium chromate, soda ash industries, and water softening plants. The study has revealed that sludge from paper industry can be utilized as composed of raw mix for the manufacture of cement.

Table -1: Physical characteristics of lime sludge

PROPERTY	CEMENT	SLUDGE
Specific gravity	3.15	2.28
Setting time		
Initial (min)	30	35
Final (min)	185	200
Fineness (%)	3.6	4.1
Soundness(mm)	0.5	1.0

Table -2: Chemical characteristics of lime sludge

PROPERTY	CEMENT (%)	SLUDGE (%)
CaO	54.5	72.6
SiO_2	28.3	21.3
Al_2O_3	13.6	6.7
Fe_2O_3	3.45	4.1
MgO	2.17	Nil
NaOH, KOH	0.55	1
SO_4	3	0.1- 0.3

C. Quarry dust

Quarry dust is a byproduct of the crushing process which is a concentrated material to use as aggregates for concreting purpose, especially as fine aggregates. In quarrying activities, the rock has been crushed into various sizes, during the process the dust generated is called quarry dust and it is disposed as waste. While disposing this waste, air gets polluted. Quarry dust can be used in construction works, which will reduce the cost of construction and the construction material would be saved and the natural resources can be used efficiently. Quarry dust has been used for different activities in the construction industry such as building materials, road development materials, aggregates, bricks and tiles.

The granite industry has a big problem in disposing the quarry dust. Every year, tones of quarry dust are produced which is left unused. We had an idea of using this quarry dust as a construction material. So we decided to use this quarry dust as replacement of sand and we collected it from a granite industry at Krishnagiri.

Table -3: Physical characteristics of Quarry dust

PROPERTIES	SAND	SAND+QUARRY DUST	QUARRY DUST
Specific gravity	2.72	2.68	2.70
Water absorption	1.52	2.13	3.32
Sieve analysis	Zone I	Zone II	Zone IV
Fineness Modulus	4.37	3.8	2.95
Type	Coarse	Coarse	Medium

Table -4: Chemical characteristics of Quarry dust

CONSTITUENTS	SAND (%)	QUARRY DUST (%)
SiO_2	80.72	62.22
Al_2O_3	10.50	18.13
Fe_2O_3	1.73	5.67
CaO	3.23	3.83
MgO	0.76	2.40
Na_2O	1.35	Nil
K_2O	1.25	3.13
TiO_2	Nil	1.25
Loss of ignition	0.39	0.45

Fig -2: Quarry dust

D. Cement

Ordinary Portland cement of 53 grade available in local market is used in the investigation. The cement used has been tested for various properties as per IS: 4031 and found to be confirming to various specification of IS:12269. The specific gravity of cement was 3.15 and fineness was 3200/cm^2/gm.

E. Coarse aggregate

Crushed granite metal of 20mm size from local source was used as coarse aggregate. The specific gravity of coarse aggregate was 2.72 and fineness modulus was 4.17.

F. Fine aggregate

River sand was used as fine aggregate. The specific gravity of fine aggregate was 2.72 and fineness modulus of 4.37 was found in the investigation.

G. Cornplast sp430

Cornplast sp430 available in local market is used in experimentation. Cornplast sp430 is a chloride free, super plasticizing admixture based on selected sulphonated naphthalene. It is supplied as a brown solution which instantly disperses in water.

III. STABILIZATION

Stabilization techniques are akin to locking the contaminants in the soil. It is a process that physically encapsulates the contaminants. The most common form of stabilization is a cement process. It simply involves the addition of cement or a cement based mixture, which thereby limits the solubility or mobility of waste constituents. These techniques are accomplished either in situ, by injecting a cement based agent into the contaminated material or ex situ, by excavating the materials, machine-mixing them with a cement-based agent.

IV. MIX DESIGN

A concrete grade 35 mixture was designed in laboratory according to IS method of mix design IS 10262 assuming a good quality control with severe exposure for designing a mix.
Designed compressive strength = 35 Mpa
Size of aggregate used = 20mm
Super plasticizer dosage = 2%
Specific gravity of Cement =3.15
Specific gravity of Coarse Aggregate = 2.65
Specific gravity of Fine Aggregate = 2.72
Specific gravity of Sludge = 2.28
Specific gravity of Quarry dust = 2.70
Water absorption of fine aggregate = 1%
Water absorption of coarse aggregate = 0.5%
Water absorption of Quarry dust = 0.9%

Table -5: Mix proportion by weight

DETAILS	MP1	MP2	MP3	MP4	MP5	MP6
Cement (kg)	2.5	2.2	2.5	2.2	2.5	2.2
Sludge (kg)	0.3	0.6	0.3	0.6	0.3	0.6
Sand (kg)	5.8	5.8	2.7	2.7	0	0
Quarry dust (kg)	0	0	2.7	2.7	5.06	5.06
Coarse aggregate (kg)	8.8	8.8	9.2	9.2	9.6	9.6
Water (ml)	946	946	946	946	946	946
Cornplast SP430 (ml)	48	48	48	48	48	48

IV. RESULT AND DISCUSSION

Compressive strength

Compressive strength of concrete is one of the most important and useful hardened properties of concrete. We have tested the compressive strength of concrete after 7 days and 28 days using compression testing machine.

Table -6: Compressive strength of concrete after 7 days

SL. NO	Specimen	Ultimate load (KN)	Compression strength (N/mm^2)
1.	CB	460	20.44
2.	Y1	475	21.11
3.	Y2	455	20.22
4.	Y3	450	20.00
5.	Y4	400	18.10
6.	Y5	360	16.00
7.	Y6	350	15.55

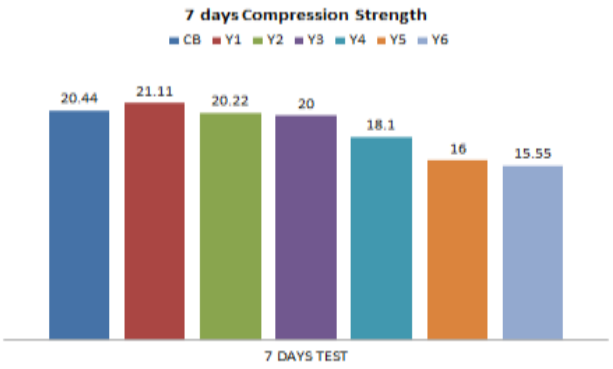

Chart -2: 7 days compression strength

Table -7: Compression strength of concrete after 28 days

SL.NO	Specimen	Ultimate load (KN)	Compression strength (N/mm^2)
1.	CB	770	34.22
2.	Y1	775	34.44
3.	Y2	770	34.22
4.	Y3	760	33.78
5.	Y4	700	31.11
6.	Y5	670	29.77
7.	Y6	650	28.88

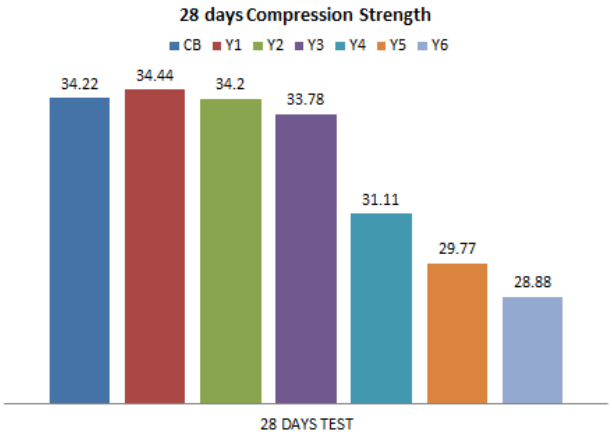

Chart -2: 28 days compression strength

Fig -3: Compression strength of cube

V. CONCLUSION

The replacement of cement with 10% and 20% lime sludge resulted in light weight concrete blocks than that of the conventional concrete blocks. The average weight is decreased by 5%. The judicious use of 10% and 20% paper sludge has shown significant gain in compressive strength. Partial replacement of sand with quarry dust showed no significant change in the compressive strength. But the full replacement of sand with quarry dust decreased the compressive strength when compared to the compressive strength of the conventional concrete blocks. The concrete block containing 10% and 20% of lime sludge and partial quarry dust is used for construction of masonry wall. Cost of construction is reduced by using the sludge and quarry dust. Lime sludge is a better innovative supplementary cementitious construction material which is used in concrete, so it can save the paper industries waste disposal cost and produces a 'greener' concrete for construction.

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