Solidification/Stabilization of Incinerated Hospital Waste

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Abstract— Solidification/stabilization (S/S) is a broadly used treatment for the management of polluted wastes, mostly those contaminated with substances categorised as hazardous in the United States. The treatment involves mixing a binding element into the contaminated waste. The treatment protects human health and the environment by halting contaminants within the treated material. Immobilization within the treated material avoids immigration of the pollutants to human, animal and plant receptors. S/S continues as a basis treatment technology for the treatment of radioactive waste, hazardous waste, and site remediation and brownfield improvement. In present study, the relative effectiveness of these S/S products is defined basically by two parameters strength and the leach resistance. MDD and OMC were estimated by conducting a series of improved proctor test in laboratory. Maximum dry density (MDD) increases at a point with increase in cement percentage and then it decreases continuously. Different type of binders used solidification/stabilization (S/S) as cement and lime. Also it is observed that the concentration of heavy metals decreased in leachate sample in 21 days leaching period in all type of S/S sample. As Incinerated hospital waste contains some toxic metals, it is necessary to check the migration of these toxic metals into sample due to XRF analysis.S/S is an actual treatment wide variation of organic and inorganic contaminants existing in polluted soil, sludge and sediment. The ability to competently treat a wide deviation of pollutants in the same media is a key reason why S/S is so frequently used in remediation.The effectiveness and wide-ranging use of S/S treatment for industrial hazardous waste and in remediation makes it important that ecological authorities appreciate the physical, chemical, and observing aspects of the technology as well as how to apply the technology in the field.

Key words: Hospital Waste, Solidification/Stabilization

I. Introduction

S/S treatment contains mixing a binding substance into the contaminated media or waste. While the terms solidification and stabilization sound similar, they define different effects that the binding substances create to immobilize hazardous elements. Solidification talks about to changes in the physical properties of a waste. The desired changes frequently contain an increase of the compressive strength, a decrease of permeability, and encapsulation of hazardous elements. Stabilization refers to chemical changes of the hazardous elements in a waste. The desired changes include exchanging the elements into a less solvable, mobile, or toxic form. S/S treatment contains a binding reagent into the polluted media or waste. Binding elements normally used contain cement, cement kiln dust (CKD), lime kiln dust (LKD), limestone, fly ash, slag, gypsum and phosphate mixtures, and a quantity of exclusive substances. Due to the great variation of waste elements and media, a mix design should be accompanied on each subject waste. Most mix designs are a mixture of the inorganic binding reagents enumerated above. Binding reagents that are organic have also been tried. These comprise asphalt, thermoplastics, and urea formaldehyde. Organic binding reagents are hardly used in commercial scale due to their high cost associated to inorganic binders.

Cement is a general material mostly used in concrete for construction. This material is also a multipurpose S/S binding reagent with the capability to both solidify and stabilize a wide range of wastes. Cement-based mix designs have been the wide-ranging S/S treatments and have been applied to a better variety of wastes than any other S/S binding reagent. Cement is frequently designated for the reagent's capability to (a) chemically bind free fluids, (b) decrease the permeability of the waste form, (c) condense waste particles surrounding them with an impervious coating, (d) chemically fix hazardous elements by reducing their solubility, and (e) facilitate the decrease of the toxicity of some contaminants. This is consummate by physical changes to the waste form and, often, chemical modifications to the hazardous elements themselves. Cement-based S/S has been used to treat wastes that have additionally inorganic and organic hazardous elements. Mix designs frequently include by-products or additives in addition to cement. Fly ash is often used to exploit on the pozzolanic effect of this material when mixed with hydrating cement. CKD and slag have minor cementations properties and are sometimes used for low-cost. Lime, LKD can be used to adjust pH or to drive off water using the extra heat of hydration produced by these S/S binders. Limestone can be used for pH regulation and bulking.

II. Experimental Material Used

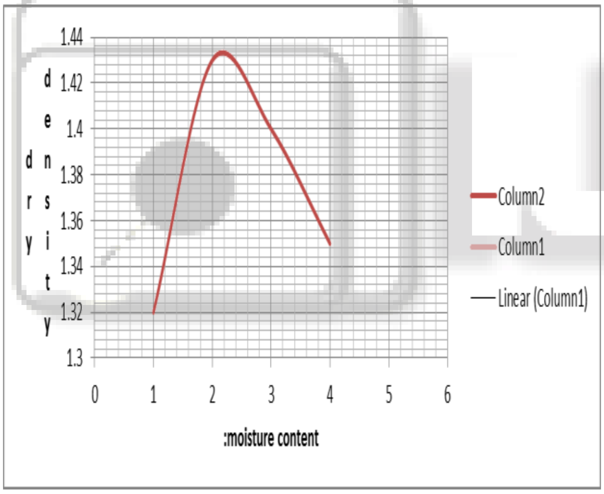
A. Incinerated Hospital Waste:

Incinerated hospital waste (Fig-2.1) was collected from the medical waste incinerated plant in Khalilabad, of District Sant kabir Nagar (Uttar Pradesh). The sample was directly collected from the waste incinerator ash outlet in baggage and take along to the soil mechanics laboratory of MMMUT Gorakhpur To evaluate the engineering properties of incinerated hospital waste, it was passes through sieves and filters ash used. The grain size distribution was determined by the mechanical sieve analysis (IS: 2720(Part 4)-1985) and hydrometer (IS: 2720(Part 4)-1985) tests. At the laboratory ash residuals were sieved using different sieve sizes; 75 µm, 125 µm, 212 µm, 425 µm, 1.00 mm 2.00 mm and 4.75 mm respectively in all runs. In spite of the variations in sieved ash weight distribution on each sieve, the average weights for different runs gave a curve averaged over the seven (7) runs. These variations were attributed to type and configuration of waste being incinerated for a particular run, which depends on the segregation efficiency in the hospital. A series of tests was conducted, including particle size distribution, mineralogical and chemical composition, and heavy metal leaching behaviour.

Fig. 2.1: Filtered incinerated hospital waste for Engineering Properties Testing

S.No.	Properties	Typical Value
1	Maximum Dry Density(g/cc)	1.43
2	OMC %	24.48
3	pH Value	9.0
4	Atterberg Limit	Non-Plastic
5	Sand Size Content %	50.00
6	Slit Size Content %	50.00
7	Permeability K (cm/sec)	6.7×10^{-6}
8	CBR Values	21.35

Table 2.1: Engineering Properties of Incinerated Hospital Waste



Graph 2.1 OMC Vs MDD

B. *Binding Material:*

Binder is a single reagent or mixture of reagents and additives used for Solidification/Stabilization of waste. Typical reagents that would be used for the stabilization process may contain lime, fly ash, betonies (clay), cement, saw dust, etc., in mixture of sodium silicate solution, if required to create supplementary binding properties of the wastes.

1) Cement:

Cement is a principle reagent which used frequently used for the stabilization of incinerated hospital waste. For cement based stabilization, waste materials are mixed with cement followed by the adding of water fur hydration, because the waste does not have sufficient water. Cement based stabilization is best suited for inorganic waste, especially those containing heavy metals.

2) Lime:

Lime can either be used alone or in combination with materials such as cement, pulverised fuel ash (PFA), ground granulated blast furnace slag (ggbs) and other pozzolanic materials to treat contaminated soil or waste. Lime is an alkali and can therefore also be used to raise the pH of a material if required.

Lime is available in the form of quicklime (calcium oxide), hydrated lime (calcium hydroxide) or milk of lime (calcium hydroxide suspension). Quicklime reacts with moisture to form calcium hydroxide with the release of heat. It is very effective as a drying agent and is commonly used to reduce the moisture content of materials, whether granular, cohesive or slurry and irrespective of initial moisture content. When insufficient moisture is available in the material, it is common practice to add additional water to achieve the target moisture content and ensure complete slaking of the quicklime.

III. Testing Procedure

Incinerated hospital waste ash lime and cement was mixed in various quantities and improvement in the engineering properties was studied. Weight starting from a lower percentage was considered in mixing till the stabilized ash continued to gain strength. The percentage of additive (lime+cement) was increased at regular interval. The addition of percentage ash discontinued when mix proportion resulted in decline in strength. Mixture of ash and additive material sample were prepared by dry blending of Incinerated hospital waste lime and cement in different percentage by weight for conducting various tests an improvement in the engineering properties has been studied.

In order to study the solidification/solidification of optimum incinerated hospital waste content, solidified samples were prepared with various percentages of cement and lime. Lime was fixed and increasing percentage of cement was added till the sample continued to gain the strength. When the mix quantity resulted in a declining in strength then investigation was discontinued.

IV. Result and Discussion

In this experimental programme, incinerated hospital waste (Ash) and mixed various percentage Cement with Lime stabilized engineering properties. sample were prepared using Incinerated hospital waste mixed with 3 percentage lime and cement with increasing percentage i.e. (3,6,9,12,15…) to determine optimum percentage of lime and Cement useful for solidification/ stabilization of sample.

A. *Stabilization Of Incinerated Hospital Waste With Lime And Cement:*

Different percentage of cement and lime mixed with Incinerated hospital waste and it's OMC and other properties are given in table 4.1

Sr. No.	IHW	Lime	Cement	OMC	MDD (g/cc)	CBR
1	100%	0%	0%	24.51	1.44	21.32
2	100%	3%	3%	25.49	1.42	14.59
3	100%	3%	6%	21.65	1.48	28.63
4	100%	3%	12%	26.51	1.36	22.48

5	100%	3%	15%	27.14	1.38	16.83

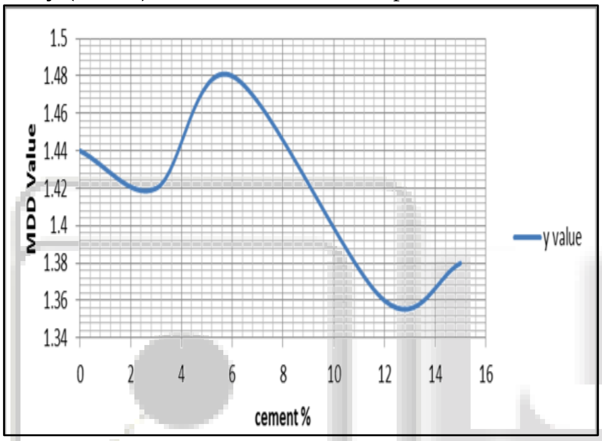
Table 4.1: Stabilization of Incinerated hospital waste with Lime and cement

It is evident Table 4.1 shown that different percentage cement and lime with incinerated hospital waste. When 6% cement and 3% of lime was mixed with Incinerated hospital waste, It is found that maximum dry density (MDD) and also CBR (California Bearing Ratio) value increases.

The graphical representation of various value of OMC vs. MDD is shown below. The optimum value which have high OMC, MDD and CBR on 3 percentage of lime and 6 percentage of cement with Incinerated hospital waste shown in graph below;

B. Maximum Dry Density Values At Different % Cement And Lime:

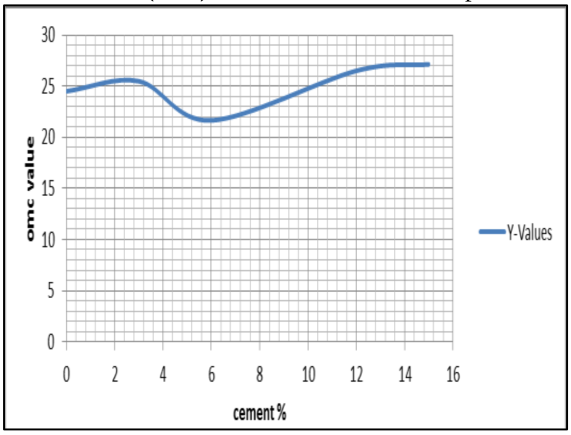
Incinerated hospital waste was mixed with 3% of lime and cement with increasing percentage i.e. (3,6,9,12,15…) and experimental data is given in the variation of Maximum Dry Density (MMD)values is shown in Graph.



Graph 4.1 MDD Vs Cement

C. OMC Values At Different % Cement And Lime:

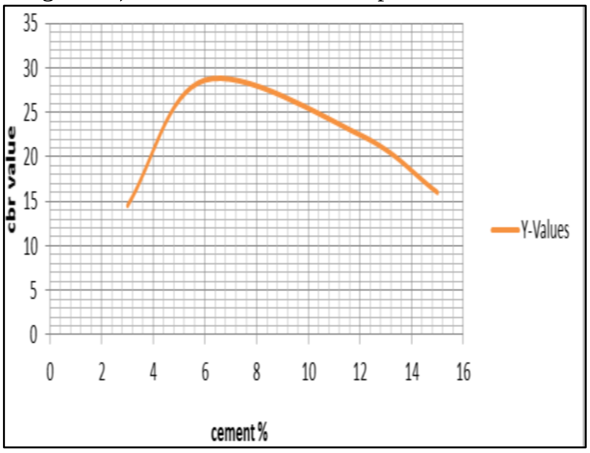
Incinerated hospital waste was mixed with 3% of lime and cement with increasing percentage i.e. (3,6,9,12,15…) and experimental data is given in the variation of Optimum moisture content (omc) values is shown in Graph.



Graph 4.2 OMC Vs Cement %

D. California Bearing Ratio Values At Different % Cement And Lime:

Incinerated hospital waste was mixed with 3% of lime and cement with increasing percentage i.e. (3,6,9,12,15…) and experimental data is given in the variation of CBR (California Bearing Ratio) values is shown in Graph.



Graph 4.3 CBR Vs Cement %

E. Leachate Properties Of Sample:

As Incinerated hospital waste contains some toxic metals, it is necessary to check the migration of these toxic metals into sample due to leaching. Leaching tests were conducted and Leachate sample were collected at various intervals ranging from the 7 days, 14 days and 21 days of curing. The concentration of heavy metals present in leachate sample is given in table ,,,,, The permissible limits of effluent discharge on land

F. Initial Sample (Ash):

S.No.	constituentes	Leachate after 7 days curing (mg/l)	Leachate after 14 days curing (mg/l)	Leachate after 21 days curing (mg/l)	Permissible Limit of effluent as per Indian Standards (mg/l)
1	Lead (Pb)	0.41	0.274	0.27	0.1
2	Copper (Cu)	0.03	0.076	0.02	1.0
3	Cadmium(Cd)	0.172	0.58	0.166	0.1
4	Chromium (Cr)	0.012	0.016	0.009	0.05

Table 4.2: Concentration of heavy metals present in leachate sample

It is evident from table 4.2 that the concentration of heavy metals such as Lead (Pb) and Chromium (Cr) after 7 days curing of samples are around 3.41mg/l and 0.012mg/l which is more than permissible limit, these values may be reduced after 21 days of curing. It is also found that conc. Of copper (Cu) are within the permissible limit. Thus it is clear that Incinerated hospital waste (IHW) cannot be utilized in soil improvement unless the conc. Of toxic metals gets reduced to thepermissible limit by solidification/stabilization.

G. Final Sample (Ash+3% Lime + 6% Cement):

S.No.	constituentes	Leachate after 7 days curing (mg/l)	Leachate after 14 days curing (mg/l)	Leachate after 21 days curing (mg/l)	Permissible Limit of effluent as per Indian Standards (mg/l)
1	Lead (Pb)	0.103	0.004	0.022	0.1
2	Copper (Cu)	0.032	0.00	0.00	1.0
3	Cadmium(Cd)	0.048	0.256	0.154	0.1
4	Chromium (Cr)	0.08	0.004	0.124	0.05

Table 4.3: Concentration of heavy metals present in leachate sample

It is evident from table 4.3 that the concentration of heavy metals such as Lead (Pb) and Chromium (Cr) after 7 days curing of samples are around 0.103mg/l and 0.08mg/l which is with permissible limit, these values reduced also after 21 days of curing. It is also found that conc. Of copper (Cu) and Cadmium (Cd) are also within the permissible limit. The above mentioned table only cement is the most effective solidification/ encapsulation agents as compared to other solidification agents.

H. X-Ray Fluorescence (XRF) Properties Of Sample:

X-Ray Fluorescence is defined as "The emission of characteristic "secondary" (or fluorescent) X-rays from a material that has been excited by bombarding with high-energy X-rays or gamma rays. The phenomenon is widely used for elemental analysis."

As Incinerated hospital waste contains some toxic metals, it is necessary to check the migration of these toxic metals into sample due to XRF analysis given below in table,

S.No.	Elements	Initial Sample (Ash)	Final Sample (Ash+3% lime + 6% cement)
1	Si	13.67	12.15
2	Sx	9.05	13.64
3	Cl	16.60	13.76
4	Mg	5.58	3.80
5	Al	3.70	3.30
6	Zn	2.14	1.48
7	Fe	1.26	1.16
8	Cu	0.285	0.246
9	Pb	0.244	0.159
10	Cr	0.0136	0.0120

From the data obtained, we can conclude that although the samples looked very similar, they have slightly different counts in each element. Their composition is pretty consistent meaning that the mass fractions of each element were similar to each sample if not the same. Each sample contained about the same of each element. From the table, we can see that the most abundant elements in the samples from the mass fraction data is Sx.

The optimum percentage of lime and cement is evaluated based on an increase in the CBR values. It is found that the 3% of lime with 6% of cement to use for the stabilized of Incinerated Hospital Waste.

The possibility of secondary raw material consumption as s/s agents was proved for solved type of hazardous waste. Cement and Lime were chosen for laboratory research as secondary raw material. Lowering the quality of Lime in s/s formula caused increasing of s/s effectively. Cement was proven as more effective s/s binder.

Lower content of contaminants in aqua leach of solidificates was achieved by the formula with use of ground s/s agents. As the more effective formula (that consisted 3% of lime with 6% of cement) with using ground s/s agents.

V. CONCLUSIONS

S/S treatment continues to enjoy significant use in the United States to treat industrial waste and contaminated media at remediation sites. EPA considers S/S to be an established treatment technology and has used the technology at 25% of the nation's Superfund program sites where the bases of contamination have been addressed. S/S technology can be used to treat a wide range of hazardous elements within the same media or waste. This flexibility is a key reason for the high incidence of use of the technology in remediation. S/S treatment shields human health and the environment by safely immobilizing contaminants within the treated material. S/S treatment is a useful technology for port facilities and nearby Brownfields sites S/S treated soils have improved construction characteristics allowing the soil to be reused at the redevelopment site. An appreciation of the versatility of the treatment technology can be gained by review of example projects. S/S is expected to continue to be an essential tool in waste management, remediation, and port improvement.

Based on this study, the following Conclusions are drawn-

1) Incinerated hospital waste (IHW) and of lime is quite effective in the stabilization of Soil.
2) Maximum CBR value of 28.63was obtained where IHW was treated with 6% Cement and 3% of lime.

Thus, Incinerated hospital waste and lime may be used for stabilization of soil subjected to leachate studies confirm the encapsulation of toxic element metals present in the mixture.

VI. SCOPE OF FUTURE WORK AND RECOMMENDATIONS

Most of the Incinerated hospital waste (IHW) in India is dumped on open land in an uncontrolled manner due to inadequate storage tanks. Such disposal process may lead to the problems that will impair human and animal health and result in economic, environmental and biological losses. So the further study on Incinerated hospital waste (IHW) may be taken up to explore suitable utility for a sustainable eco-friendly world.

1) It is recommended to study the effect of lime with cement as stabilizing material so that more and good strength in soil can be attained.
2) Encapsulation properties of different heavy metals can be studied using different binding/stabilizing agents.

In addition to this above important studies, the research work may be extended on gas formation and Leachate properties analysis and Stabilization/ Encapsulation for the Incinerated hospital waste (IHW) in future to ensure user friendly application in the field of Geotechnical Engineering.

REFERENCES

[1] Robert Delisio, presented at the Cement Association of Canada, Remediation Technology Workshop: Solidification and Stabilization Treatment, Toronto, ON, Canada, May 2001 (unpublished).
[2] Department of the Army, U.S. Army Corps of Engineers, Guide Specification for Military Construction—Solidification/Stabilization of Contaminated Material, CEGS-02445, December 1995.
[3] R.L. Einhaus, P. Erickson, Fate Of Polychlorinated Biphenyls (PCBs) In Soil Following Stabilization With Quicklime, U.S.EPA, EPA/600/2-91/052, September 1991.
[4] K. Loest, C.M. Wilk. “Brownfield Reuse of Dredged New York Harbor Sediment by Cement-based Solidification/Stabilization” Proceedings of the 91st Annual Meeting & Exhibition, Air and Waste Management Association 1998.
[5] U.S.EPA. Stabilization/Solidification of CERCLA and RCRA Wastes—Physical Tests, Chemical Testing Procedures, Technology Screening, and Field Activities, EPA/625/6-89/022, May 1989.
[6] U.S.EPA. Engineering Bulletin—Solidification/Stabilization of Organics and Inorganics, EPA/540/S-92/015. May 1993.
[7] U.S.EPA. Technology Resource Document--Solidification/Stabilization and its Application to Waste Materials, EPA/530/R-93/012. June 1993.
[8] U.S.EPA. Innovative Treatment Technologies: Annual Status Report, 10th Edition, EPA-542-R-01-004, February 2001.
[9] L. Weitzman, J.R. Conner. “Descriptions of Solidification/Stabilization Technologies”, Immobilization Technology Seminar—Speaker Slide Copies and Supporting Information, U.S. EPA, CERI-89-222, October 1989.
[10] Khan, A. H. (2013), “Utilization of incinerated hospital waste in soil improvement”, International Journal of Biological Science & Technological Research paper Vol.1, No.10 ,pp: 1-4
[11] Paswan, A. K. (2014), “Stabiilization/Solidification of Incinerated Hospital Waste.” M.Tech Thesis, M.M.M.University of technology, Gorakhpur.
[12] Singh, K. L. (2013) and Jawaid, S. M. A. , “ Geotechnical Properties of Soil Stabilized with Bagasse Ash”,International Journal of Biological Science & Technological Research paper Vol. 1, No 9, pp1-4
[13] Singh, K. L. and Paswan, A. K.(2014),” Stabilization of soft soil using Sugar Cane Bagasse Ash for rural road”, Conf on Recant of Advance Civil Engineering in M M M University of Technology, Gorakhpur.
[14] International Journal of Current Engineering and Technology ISSN2277-4106