International Research Journal of Environmental Sciences ISSN 2319–1414
Vol. **9(2),** 13-19, April **(2020)** *Int. Res. J. Environmental Sci.*

Low cost treatment and reuse of grinding sludge

Harshvardhan V. Bhoite* and Akshay Rajan Thorvat
Department of Environmental Engineering, Kolhapur Institute of Technology's College of Engineering (Autonomous), Kolhapur, India
1682harsh@gmail.com

Available online at: www.isca.in, www.isca.me
Received 11th May 2019, revised 31st December 2019, accepted 30th January 2020

Abstract

This paper presents the reuse of grinding sludge in concrete block and clay brick manufacturing. Grinding which is a product finishing operation generates considerable amount of sludge in automotive parts manufacturing. The disposal of the grinding sludge is a challenge for the industries. Currently, landfilling is one of the most adopted option for disposal of grinding sludge, which is the most expensive considering the environmental aspects. The grinding sludge comprises of oil based coolant (cutting oil) and metal chips. This study aims at treating the sludge economically for its oil removal and reusing dried sludge in concrete blocks and clay bricks. The paper includes major findings of the study and summarises the best detergent for washing of sludge. The dried sludge which is used for manufacturing of concrete blocks and clay bricks has been tested for compressive strength test, water absorption for clay bricks and slump test for concrete and are compared with conventionally manufactured concrete blocks and clay bricks.

Keywords: Grinding sludge, oil based coolant, detergent washing, concrete blocks, clay bricks.

Introduction

The industrial growth of a country is often seen as economic growth and development of the country. While the industrial waste management is still a major concern for many developed countries, there is much less awareness about it in developing countries. The waste generation and disposal are the two big reasons to worry for the world. The major disposal methods of waste such as landfilling and incineration have serious negative impacts on environment. Disposing techniques of waste cannot control the environmental degradation, but recycling and reusing of sludge does control degradation of environment. Grinding sludge is a solid waste formed at automobile parts manufacturing industries. This sludge contains fine metal chips and oil based coolant. According to solid waste management rules (2016), the sludge containing oil has to be handled by government authorised agencies for its disposal.

Grinding is an abrasive machining process that uses a grinding wheel as the cutting tool. It is a product finishing process to achieve smoother surfaces of mechanical parts, resulting in a sludge formation of very fine metal chips along with the coolant used for grinding operation. The sludge was collected from automotive parts manufacturing industry, M.I.D.C Shiroli, Kolhapur. This company manufactures various types of shafts and valve tappets for automobile industry, which involves grinding operation for finishing of products. The sludge produced in the industry is currently being transported to Ranjangaon for disposal which includes high transportation and handling costs and well known landfilling issues. This study aims to suggest techniques to treat this sludge at the same industry in an economical way and to reuse this sludge in concrete blocks and bricks manufacturing to avoid the environmental degradation and generate some revenue to the company.

Literature review: The paper uses the aqueous surfactants for washing the sludge to recover the steel from the sludge. They proposed a plant for washing of sludge and also determined 1:20 as a solid to liquid ratio for washing of sludge. Docusate sodium salt was selected as the best surfactant for washing of sludge. The proposed plant generated good revenue along with saving high landfill cost[1]. The scrubbing of grinding sludge using aqueous surfactant along with magnetic separation of recyclable metal was analysed. Scrubbing successfully removed 76% oil which was clean enough for alternative use[2]. The aqueous surfactant washing and super critical carbon dioxide extraction were used for cleaning of grinding swarf. The efficiency of the aqueous washing process greatly depends upon selection of surfactant, and study found SA8 has the good efficiency with 86% oil removal. While the efficiency of SCOO extraction greatly depends on temperature and pressure, which were 80ºC and 340atm respectively[3].

The recovery of cutting oil and alloy steel from grinding swarf using aqueous surfactant washing was investigated. Around 95% of oil removal was achieved after reasonable number of washings. The oil recovered had similar physical properties and could be recycled to in-line grinding operation. Amongst the various surfactants only Nonylphenyl polyethoxylate (NPE-10) and Tergitol 15-S-7 and 15-S-9 were found most effective[4]. The feasibility of grinding sludge in manufacturing of Portland cement has been studied. They used 1%, 2% and 3% grinding sludge by weight. The resulting cement turns out to be good in sulphate attack due to increase in CAF and grinding sludge can be a good alternative as a raw material for cement manufacturing[5]. The Soxhlet extraction apparatus was used to determine the oil content of oil contaminated soil. Methylene chloride was used as solvent because it is inexpensive and efficient in oil removal[6].

Materials and methods

Grinding sludge was collected from one of the industry situated at Shiroli MIDC, Kolhapur. The industry has two working units. Each unit generates approximately 2kg sludge daily, counting total sludge at the industry upto 100-120kg monthly. The sludge was preliminary analysed for few parameters such as physical texture, colour, pH, moisture content and metal content etc. Table-1 and 2 represent the preliminary analysis results of sludge. Table-3 shows the coolant name and its specification. The preliminary analysis revealed that all the parameters are well within CPCB guidelines.

After the preliminary analysis of sludge, the sludge was kept for sun drying to remove the water from it. The coolant consists of oil and water and hence it was dried to remove the water present in it. After 24 hours of drying, the oil content in the sludge was determined using Soxhlet extraction apparatus. The extraction was carried for 2 hours with Dichloro methane (DCM) as solvent. The extraction was carried out until clear liquid appears in upper thimble. The oil content of sundried sample is presented in Table-4.

Table-1: Preliminary Analysis of Sludge.

Property	Result
Physical Texture	Solid
Colour	Black
Moisture Content	95%
pH	8.60

Table-2: Metal Content Analysis of Sludge.

Parameter	Results (mg/lit)
Pb	BDL
Cr	00.460
Cd	00.082
Fe	83.140
Cu	00.842
Mn	16.880
Zn	01.236

Table-3: Coolant Specifications.

Description	Specification
Name	Blascout BC 20 SW
Form and Colour	Liquid, Brown
pH	8.5
Melting Point	NA
Boiling Point	> 300ºC
Flash Point	> 130ºC
Ignition Temperature	> 500ºC
Self-Igniting	Not self-igniting
Solubility in water	Emulsifiable

Table-4: Oil Content of Sun Dried Sample.

Sample Name	Oil Content (%)
Sun Dried	21.14

The sundried sample is further washed with hot water (60ºC) for further oil removal from it. The hot water washing was carried out with 50gm sun dried sludge and various quantities of water such as 50ml, 100ml, 150ml and 200ml. After washing with variable quantities of water each of the washed samples were again analysed to check the oil content in it using Soxhlet extraction apparatus. The Table-5 presents the oil content (%) of water washed sample by weight.

Table-5: Oil Content of Water Washed Sample.

Sludge Quantity (gm)	Water Quantity (ml)	Oil Content (%)
50	50	17.97
50	100	15.46
50	150	15.19
50	200	14.98

The analysis revealed that 100 ml quantity of water for 50gm of sludge is good for oil removal. Further increase in water quantity did not give the considerable decrease in oil content and also more wastage of water. The sludge after washing has considerable amount of oil in it and hence needed further treatment. The sludge further washed again with various locally and cheaply available detergents in various quantities of detergent to determine to most efficient and economical detergent for washing. This treatment was carried out with sample number 3 in Table-4. The five detergents were named as detergent-1 (clinic plus shampoo), detergent-2 (Nirma powder), detergent-3 (Surf excel powder), detergent-4 (commercial shampoo) and detergent-5 (vim bar). The analysis was carried out with 50gm of sludge and five detergents in the quantities of 5gm, 10gm, 15gm and 20gm along with 100ml water in each beaker. Each mixture consisting of 50gm sludge, detergent and 100ml water was mixed with Jar test apparatus for 5 minutes. After mixing the samples were kept for settling for 4 hours. Decant was removed and sludge was dried in oven at 105ºC. The oven dried sludge is then analysed for oil content by Soxhlet apparatus. The detergent washing reveals that detergent-1 with quantity of 10gm is efficient and economical. Further increase in detergent-1 quantity for washing did not remove considerable oil and leaded to unnecessary extra cost. Apart from these detergents, the sludge was also washed with NaCl and Diesel respectively. They did not perform well compared to detergent-1 in terms of both efficiency and economy. Hence Detergent-1 was adopted for further work. The detergent-1 washing was carried out on large scale for 25 kg of sludge and it gave the similar results. Table-6 represents the oil content of detergent washed samples with various quantities of detergents.

Results and discussion

Casting and Testing of Concrete Blocks: The concrete blocks were designed for M_{20} grade concrete. The well washed sludge with detergent-1 on large scale was used in the process. The grinding sludge was used for replacement to cement as 0%, 10%, 15% and 20% by weight. The M_{20} design worked out cement quantity as 5.016kg for 3 concrete cubes. The sludge replaced this quantity with 0, 10, 15 and 20%. The sizes of the blocks were 15x15x15cm. The sludge mixed concrete was tested for workability and compressive strength and compared with conventionally manufactured blocks. The blocks were manufactured in 3 cycles; cycle 1 includes blocks A1 to A10, cycle 2 includes blocks B^1 to B^{10} and cycle 3 includes blocks C^1 to C^{10}. The slump test values are presented in Table-7a, 7b and 7c. Table-8 shows the average compressive strength values. Each value shown in Table-8 is average value of 3 cubes. The expected compressive strength as per Indian standards at the end of 3, 7 and 28 days are 8 N/mm², 13 N/mm² and 20 N/mm ² respectively.

Table-6: Results of Oil Content (%) after washing using different detergents.

Detergent Name	Detergent Quantity (gm)	Oil Content (%)	Sr No	Detergent Name	Detergent Quantity (gm)	Oil Content (%)
Detergent-1	5	5.39	11	Detergent-3	15	6.89
Detergent-1	10	3.47	12	Detergent-3	20	6.05
Detergent-1	15	3.32	13	Detergent-4	5	6.41
Detergent-1	20	3.28	14	Detergent-4	10	5.89
Detergent-2	5	9.29	15	Detergent-4	15	4.74
Detergent-2	10	8.46	16	Detergent-4	20	4.49
Detergent-2	15	8.19	17	Detergent-5	5	10.21
Detergent-2	20	8.10	18	Detergent-5	10	8.46
Detergent-3	5	8.84	19	Detergent-5	15	7.89
Detergent-3	10	7.22	20	Detergent-5	20	7.22

Table-7a: Slump test for cycle 1.

Cycle 1	Slump Values (mm)
0%	78
10%	74
15%	72
20%	69

Table-7b: Slump test for cycle 2.

Cycle 1	Slump Values (mm)
0%	81
10%	77
15%	75
20%	70

Table-7c: Slump test for cycle 3.

Cycle 1	Slump Values (mm)
0%	80
10%	78
15%	77
20%	73

Table-8: Compressive strength test.

Block Name	3 Days (N/mm^2)	7 Days (N/mm^2)	28 Days (N/mm^2)
A (0%)	9.93	14.12	19.36
A (10%)	10.48	14.19	20.03
A (15%)	10.51	14.21	20.11
A (20%)	9.59	13.89	19.20
B (0%)	10.31	14.42	20.09
B (10%)	10.33	14.47	20.16
B (15%)	10.38	14.51	20.31
B (20%)	10.09	14.39	19.74
C (0%)	10.59	13.98	20.46
C (10%)	10.63	14.01	20.69
C (15%)	10.66	14.12	20.82
C (20%)	9.47	13.24	20.15

Casting and Testing of Clay Bricks: The brick manufacturers are using waste materials such as bagasse, rice husk in manufacturing of bricks to ensure equal inside heating of bricks. The grinding sludge after sun drying has good percentage of oil in it and hence it served the same purpose of heating the brick. The manufacturers are using 5% to 10% of waste material while mixing the clay. The grinding sludge was used in the quantity of 5% and 10% by weight. The non-modular size of bricks was 240*165*110 mm. The bricks were tested for water absorption and compressive strength. For the testing of compressive strength, frogs were filled with 1:3 mortar to ensure equal distribution of the load. The performance of sludge mixed bricks was compared with rice husk mixed bricks by water absorption and compressive strength test. All the values indicated in table no. 9 and 9.1 are average values of 3 bricks. The bricks were manufactured in two sets; Set-1 contains 5% sludge while Set-2 contains 10% sludge. The compressive strength of bricks manufactured using rice husk was in the range of 3.80 to 4.10 N/mm² and 10 to 12% water absorption after 24 hours immersion in water. The water absorption for sludge based bricks was in the range of 9 to 12%. Indian standard recommends minimum strength of 3.5N/mm² and maximum water absorption of 20% by weight after immersing 24 hours in water.

Table-9a: Compressive strength test for Set- 1.

Brick ID	5% Sludge – Strength (N/mm²)
A^1	4.17
A^2	4.38
A^3	4.09
A^4	3.98
A^5	4.40
A^6	4.11
A^7	3.91
A^8	4.56
A^9	3.94
A^{10}	4.76

Table-9b: Compressive strength test for Set- 2.

Brick ID	10% Sludge – Strength (N/mm²)
B^1	4.89
B^2	4.55
B^3	3.99
B^4	5.18
B^5	4.76
B^6	5.24
B^7	5.67
B^8	5.09
B^9	4.27
B^{10}	4.96

Cost Analysis: i. Transportation and collection of sludge: Rs. 100, ii. Treatment Cost with detergent-1: Total Quantity of sludge required for concrete blocks and clay bricks = 40.51 kg sludge. iii. Detergent required for washing 40.51 kg sludge = 8.1kg, iv. Cost of 8kg detergent: Rs. 2186.58, v. Concrete Cost: Cost of 1 cum concrete = Rs. 2307.9, Manufacturing Cost of 1 concrete block = Rs. 7.789, vi. Manufacturing Cost per clay bricks: Rs. 3, vii. Total Cost: Rs. 3300, viii. The water used for the treatment is not considered in total cost.

Figure-1(a): Sun Drying of Sample.

Figure-1b: Sludge digestion with HNO_3 acid.

Figure-1c: Soxhlet extraction setup.

Figure-1d: Sludge mixed with cement and aggregates.

Figure-1e: Compressive strength test for clay brick.

Figure-1f: Compressive strength test for concrete block.

Conclusion

The grinding sludge proved to be very good replacement material for cement and rice husk in concrete and clay bricks respectively. Detergent-1 was found to be very economical and efficient for washing. The sludge saved about 15% cement in concrete and can be a used along with rice husk and bagasse for bricks. The sludge based products when tested found to be well within Indian standard limits. The total cost of the project was also well justified when compared to current disposal cost and land cost involved in landfilling and most importantly, reuse of grinding sludge avoids the environmental depletion that is currently being done.

References

1. Ruffino, B., & Zanetti, M. C. (2008). Recycling of steel from grinding scraps: Reclamation plant design and cost analysis. *Resources, conservation and recycling*, 52(11), 1315-1321.

2. CWC. Recovery of a Recyclable Metal Alloy from High Speed Grinding Swarf. Seattle, WA: CWC, Pacific Northwest Economic Region (PNWER); 2000

3. Fu, H., Matthews, M. A., & Warner, L. S. (1998). Recycling steel from grinding swarf. Waste Management, 18(5), 321-329.

4. Chang, J. I., Lin, J. J., Huang, J. S., & Chang, Y. M. (2006). Recycling oil and steel from grinding swarf. Resources, conservation and recycling, 49(2), 191-201.

5. Punmathari, T., Rachakornk, M., Imyim, A., & Wecharatan, M. (2010). Co-processing of grinding sludge as alternative raw material in portland cement clinker production. *JApSc*, 10(15), 1525-1535.

6. McGill, W. B., & Rowell, M. J. (1980). Determination of oil content of oil contaminated soil. *Science of the Total Environment*, 14(3), 245-253.