PHYSICAL PROPERTIES OF LIGHTWEIGHT AGGREGATES USING SEWAGE SLUDGE

Rajen J. Patel[1], Prof. (Mrs) Reshma L. Patel[2], Dr. Jayeshkumar Pitroda[3]
[1]Final year M. Tech. Student, Environmental Engineering, B.V.M. Engineering college, Vallabh Vidyanagar, Gujarat, India
[2,3]Associate Professor, Civil Engineering Department, B.V.M. Engineering college, Vallabh Vidyanagar, Gujarat, India

Abstract: Sewage sludge management is one of the major environmental issues these days. Sewage sludge is generated from the sewage treatment plants, and this by-product is something that is not going to stop getting produced. As a result, it has become extremely important to manage this sewage sludge in a proper, well defined manner. One of the best alternatives for managing this sludge is to use it as a raw material in some other industry. This work studies the use of sewage sludge as a raw material for manufacturing lightweight aggregates.

Lightweight Aggregates were produced using various proportions of sewage sludge and clay. On the basis of this, four different types of aggregates were made with sewage sludge percentages 20%, 30%, 50% and 80%. Lightweigth aggregate with 20% sewage sludge proportion is found to be most economical and strong. Hence, the optimum ratio of sewage sludge from the study undertaken is found as 20% which is used for LWA-A. In the study, various tests like, crushing value test and water absorption test were carried out. LWA-A with 20% sewage sludge was found to be passing all these tests.

Keywords: Eco-Friendly, Lightweight aggregates, Sewage Sludge, environmental issues, crushing value, water absorption

I. INTRODUCTION

Sewage Sludge is a by-product collected at the end of Sewage and Water Treatment facility. Human activity is the main reason for the generation of Sewage Sludge. For this reason, there seems no chance of reduction in the quantity of sewage sludge generation in future.

Another reason for the increased rate of sewage sludge generation is the population expansion. There are various methods to deal with sewage sludge like, landfilling, incineration, using as a raw material, and so on.

Landfilling is the most commonly used method. Availability of land is the main problem with this method these days. Due to the problem of increasing population at our door step, it is not easy to get some spare land for sewage disposal. Disposal of sewage sludge by incineration on the other hand is uneconomical.

For these reasons sewage sludge management is an important issue in this recent time. Lots of research work is been carried out in this sector to find an appropriate alternative for disposal. That is where; the third method of sewage sludge management comes into picture, which is, use of sewage sludge as a raw material.

If we are able to use sewage sludge as a raw material, it will make us free from the trouble of managing that sewage sludge.

It is our prime duty as an environmental engineer to dispose off industrial as well as non-industrial wastes. For the treatment and management of industrial waste we use options like incineration, use as an alternate fuel, bio-methanation, landfilling, combustion and gasification, fermentation, composting etc. For different types of industrial waste there are various methods used for waste treatment and disposal of this waste.

For the better way of management of waste, we need to think on recycling and reuse of waste. By recycle and reuse of waste we can easily handle large quantities of the waste and also manage it in a better way and dispose off the waste.

II. MATERIALS AND METHODS

For the preparation of lightweight aggregates, sewage sludge and clay is used. Sewage Sludge is the main material in this study.

Table 1 and 2 shows the physical and chemical properties of sewage sludge collected. As seen from the characteristics, the sludge collected is dried with very small amount of moisture retained in it.

Physical properties of sewage sludge are very much important to carry out this study. Before manufacturing lightweight aggregates it is important that we find out the physical as well as chemical parameters of the sewage sludge collected.

It can be seen from the data in Table 1 that the sewage sludge collected is having very low moisture content. It shows that the sewage sludge collected is dried sewage sludge.

The low moisture content also shows that the dry mass of the sewage sludge collected is very high. From the Table 1 it can be seen that loss on ignition of the collected sewage sludge is 2.4%.

Table 1 Physical Properties of Sewage Sludge

Sr. No.	Parameter	Result
1	Specific Gravity	1.116
2	Density (g/mL)	1.114
3	Moisture Content (%)	0.94
4	Dry Mass (%)	99.05
5	Loss on Ignition (%)	2.4

Source : Environmental Engineering Laboratory, BVM College, Vallabh Vidhyanagar

Table 2 Chemical Properties of Sewage Sludge

Sr. No.	Parameter	Test Result
1	Zinc (Zn), ppm	389.94
2	Copper (Cu), ppm	448.86
3	Lead (Pb), ppm	100.02
4	Nickel (Ni), ppm	30.96
5	Phosphorous (P), ppm	33.63

Source : Geo Test House, Vadodara

Sewage Sludge used in this study is collected from a Sewage Treatment Plant in Vallabh Vidhyanagar area of Anand district of Gujarat. On the other hand clay used is the locally available black clay. Clay was collected from the outskirt of the Anand district.

2.1 PREPARATION OF LIGHTWEIGHT AGGREGATES

For the preparation of lightweight aggregates, the very first step involved drying of sewage sludge and clay. Both the materials are dried at 105ºC. After drying of material, both of these starting materials are mixed in appropriate proportions by percentage weight. On the basis of the percentage of sewage sludge, four different types of aggregates are prepared namely, LWA-A, LWA-B, LWA-C and LWA-D. Once the mixture of sewage sludge and clay is ready, appropriate quantity of water as needed to get proper workability is added and round pellets of nearly 16 mm diameter are formed. Finally, these pellets are sintered at 1100ºC temperature for 30 minutes. The final product obtained after sintering is the lightweight aggregates.

2.2 TYPES OF LIGHTWEIGHT AGGREGATES PRODUCED

On the basis of percentage of sewage sludge in the mix, four different types of lightweight aggregates are produced.

LWA-A (SS:C- 20:80)
LWA-B (SS:C- 30:70)
LWA-C (SS:C- 50:50)
LWA-D (SS:C- 80:20)

Figure 1 shows the manufacturing process of lightweight aggregates.

As shown in the picture, first of all sewage sludge is collected from the sewage treatment plant. Than sewage sludge and clay are grinded into fine powder form. After that, sewage sludge and clay are mixed into various proportions. After mixing, appropriate quantity of water is added to get the desired workability.

At last, the mix is converted into round pellets and sintered at high temperature which gives us lightweight aggregates.

Collection of sewage sludge from STP

Weight of material

Various ratios of Sewage Sludge and Clay

Mixing of material

Production of raw LWA

Sintering of LWA at 1100^0 C

Figure 1 Manufacturing process of lightweight aggregates

III. PHYSICAL PROPERTIES OF LIGHTWEIGHT AGGREGATES

3.1 Water Absorption

Water absorption of the lightweight aggregates is determined as per the method described in IS 2386 (Part III) – 1963. The parameter was calculated using the equation (1).

Water Absorption (%) = [(B-C)/C]*100 ………. (1)

Where, B = Weight of surface dry aggregate in air

C = the weight in g of ovendried aggregate in air

3.2 Crushing Value Test

Crushing value of the produced lightweight aggregates is found as per IS 2386 (Part IV) – 1963 by using equation (2).

Aggregate Crushing Value = (B/A)*100 ………. (2)

Where, B = weight of fraction passing the appropriate sieve

A = weight of surface-dry sample

IV. RESULTS AND DISCUSSION:

Table 3 shows the crushing value and water absorption for the lightweight aggregates.

The physical properties of the lightweight aggregates were determined as per the standards. Table above shows various test results for four different types of lightweight aggregates produced.

It can be seen from the data in figure 2 that with the increase in the amount of sewage sludge, the crushing strength of the lightweight aggregates produced decreases. Hence, the lightweight aggregate with the minimum amount of sewage sludge (LWA-A) is having the maximum crushing strength.

On the other hand, lightweight aggregate with the maximum amount of sewage sludge (LWA-D) is said to have minimum crushing strength. LWA-A and LWA-B are said to have crushing value within the limit and can be used for purposes with less wear and tear.

Table 3 Crushing Value and Water Absorption of Lightweight Aggregates

Sr. No.	Lightweight Aggregates	Ratio (SS:C)	Crushing Value	Water Absorption
1	LWA-A	(20:80)	35	12.54
2	LWA-B	(30:70)	44.14	15.33

3	LWA-C	(50:50)	54	20.27
4	LWA-D	(80:20)	59	23.35

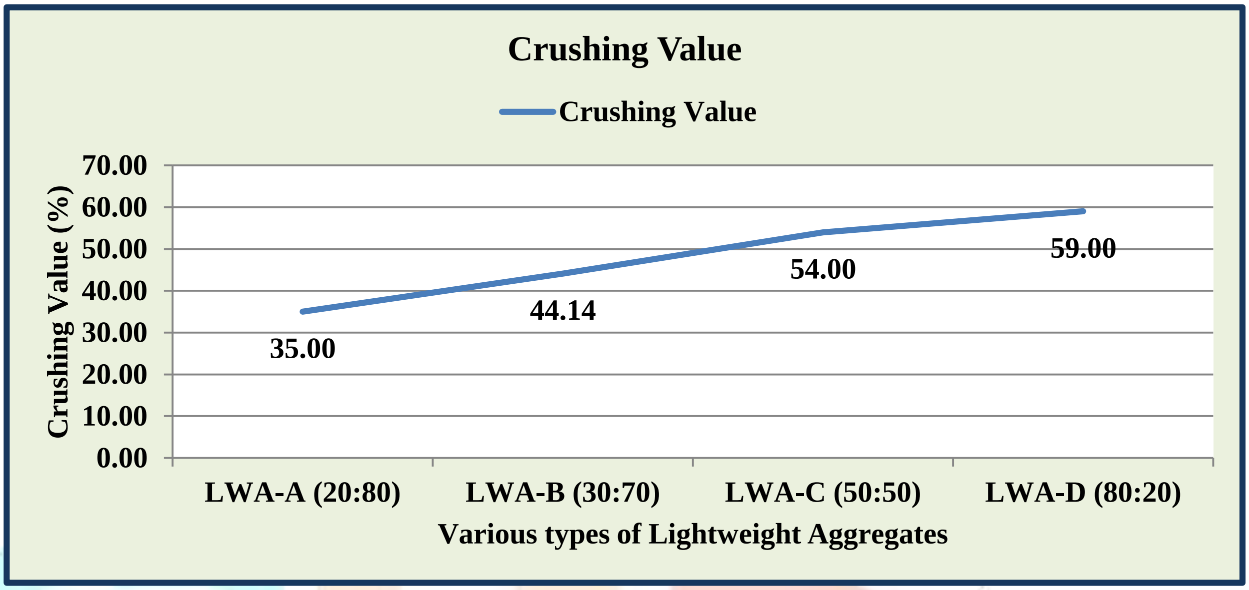

Figure 2 Various types of Lightweight Aggregates vs Crushing Value of Lightweight Aggregates

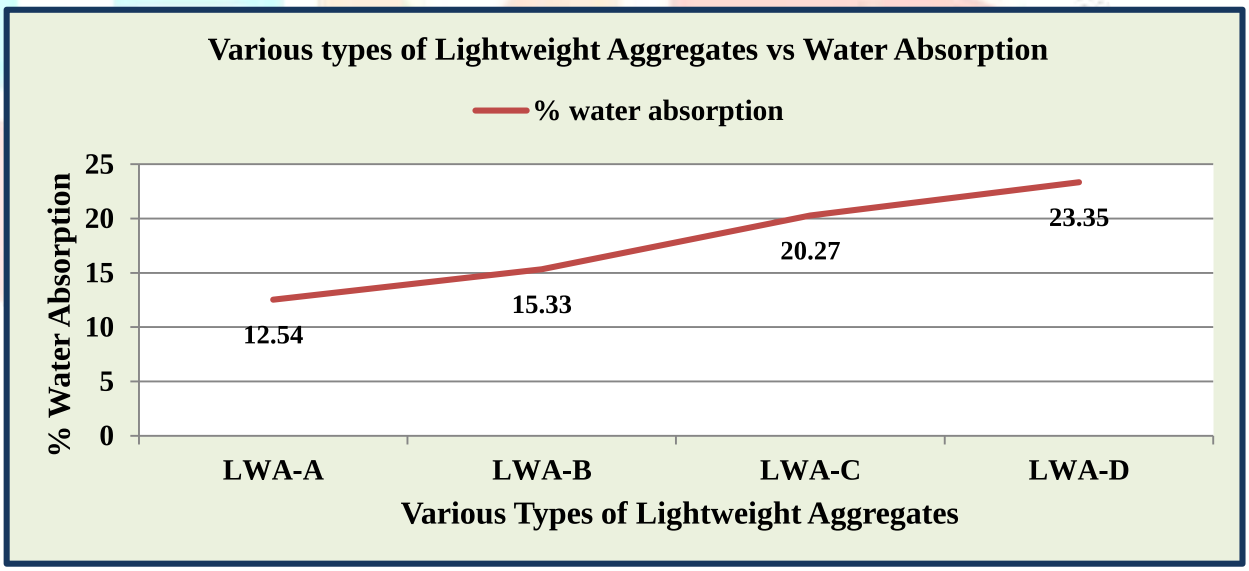

Figure 3 Various types of Lightweight Aggregates vs Water Absorption

Lightweight aggregate LWA-A is having the maximum crushing value i.e. 35 %. LWA-B is having the crushing value of 44.14 % which is 26.11% more than LWA-A. In the same way, LWA-C is having the crushing value of 54%, which is 54.28% more than LWA-A. In the end, LWA-D is having 68.57% more crushing value than LWA-A.

Figure 2 shows the decrease in crushing strength with increase in sewage sludge proportion.

Figure 3 shows change in water absorption with change in percentage of sewage sludge. From table 3 it can be seen that water absorption of the lightweight aggregates is dependent on the amount of sewage sludge used. There is a direct relation between water absorption and percentage of sewage sludge. For the lightweight aggregates with minimum amount of sewage sludge (LWA-A), water absorption is minimum.

Also, it is evident from figure 3 that lightweight aggregate with maximum amount of sewage sludge (LWA-D) shows maximum water absorption.

Water absorption in LWA-A is 12.54%. Water absorption in LWA-B is 22.24% more than LWA-A, having the value of 15.33%. Also, water absorption in LWA-C is 20.27% which is 61.64% more than the value in LWA-A. In the end, LWA-D is having the highest amount of water absorption, which is 86.20% more than that in LWA-A and have the value equal to 23.35%.

Also, water absorption and crushing value for the lightweight aggregate is interdependent. For the lightweight aggregate with minimum water absorption crushing strength seems to be maximum. This might be due to the fact that with the increase in water absorption there is increase in porosity which ultimately leads to decrease in crushing strength.

Water absorption for LWA-A, which is considered to be the optimum type of lightweight aggregate is found to be 12.54%, almost same as that of Lytag which is 12.3. **[13]**

Water Absorption for LWA-A and LWA-B is said to be within the limit and hence out of both of these two, lightweight aggregate with the minimum water absorption i.e. LWA-A is considered to be of optimum type.

V. CONCLUSION

Lightweight aggregates prepared using sewage sludge is cheap when compared with other commercial lightweight aggregates available. When compared with expanded clay shell lightweight aggregates, it was found out that lightweight aggregates prepared by this method are almost 26.5 % less expensive.

In case of strength of lightweight aggregates, lightweight aggregates LWA-A and LWA-B are in the limiting range of crushing values of 35% and 44.14% respectively. Hence, both of these lightweight aggregates can be used in the less wearing course or where there is less wear and tear. On the other hand, one can also try to produce lightweight aggregates with 10% sewage sludge proportion. There are chances of this type of lightweight aggregates to get better crushing value than those made in this study.

Over and above, the lightweight aggregate prepared with 20% sewage sludge and 80% clay (LWA-A) is said to be good in strength compared to the other three and can be used in construction.

At the same time, water absorption for LWA-A is minimum and hence lightweight LWA-A can be said to be the best suited lightweight aggregate.

VI. ACKNOWLEDGEMENT

The Authors thankfully acknowledge Prof. (Dr.) Indrajit Patel, Principal, B.V.M. Engineering College, Vallabh Vidyanagar, Gujarat, Prof. R. L. Patel, Associate Professor, P.G. Coordinator, B.V.M Engineering College, Vallabh Vidyanagar, Gujarat, Dr. Jayeshkumar Pitroda, Associate Professor, P.G. Coordinator Construction Engineering and Management, Civil Engineering Department, B.V.M Engineering College, Gujarat, India for their motivations and infrastructural support to carry out this research.

VII. REFERENCES

PAPERS

1. Abdul G. Liew Azni Idris Abdul A. Samad Calvin H.K.Wong Mohd S. Jaafar Aminuddin M. Baki (2004), “Reusability of sewage sludge in clay bricks”, J Mater Cycles Waste Manag, Volume 6, 41–47
2. Alaa.A.Shakir, Sivakumar Naganathan, Kamal Nasharuddin Bin Mustapha (2013), “Development of Bricks From Waste Material: A Review Paper”, Australian Journal of Basic and Applied Sciences, Volume 7, Issue 8, 812-818
3. Andrey Bagreev and Teresa J. Bandosz (2004), “Efficient Hydrogen Sulfide Adsorbents Obtained by Pyrolysis of Sewage Sludge Derived Fertilizer Modified with Spent Mineral Oil”, Environmental Science & Technology, American Chemical Society, Volume 38, Issue 1, 345-351
4. Angelo Sarabèr, Robert Overhof, Terry Green, Jan Pels (2012), “Artificial lightweight aggregates as utilization for future ashes – A case study”, Waste Management, Volume 32, 144–152
5. B. Gonzalez-Corrochano, J. Alonso-Azcarate, M. Rodas, J.E Barrenechea, EJ. Luque (2016), “Microstructure and mineralogy of lightweight aggregates manufactured from mining and industrial wastes”
6. B. Gonza´lez-Corrochano, J. Alonso-Azca´rate, M. Rodas (2009), “Production of lightweight aggregates from mining and industrial wastes”, Journal of Environmental Management, Volume 90, 2801–2812
7. Bui Le Anh Tuan; Mewael Gebregiorgis Tesfamariam; Yuan-Yuan Chen; Chao-Lung Hwang; Kae-Long Lin; and Mung-Pei Young (2014), “Production of Lightweight Aggregate from Sewage Sludge and Reservoir Sediment for High-Flowing Concrete”, J. Construction Engineering and Management, Volume 140, 1-7
8. C.R. Cheeseman, A. Makinde, S. Bethanis (2005), “Properties of lightweight aggregate produced by rapid sintering of incinerator bottom ash”, Resources Conservation and Recycling, Elsevier, Volume 43, 147–162
9. Chao-Wei Tang, How-Ji Chen, Shun-Yuan Wang, Jack Spaulding (2011), “Production of synthetic lightweight aggregate using reservoir sediments for concrete and masonry”, Cement & Concrete Composites, Volume: 33, 292-300
10. D. Fytili, A. Zabaniotou (2008), “Utilization of sewage sludge in EU application of old and new methods—A review”, Renewable and Sustainable Energy Reviews, Volume 12, 116–140
11. E. Fakhfakh, W. Hajjaji, M. Medhioub, F. Rocha, A. López-Galindo, M. Setti, F. Kooli, F. Zargouni, F. Jamoussi (2007), “Effects of sand addition on production of lightweight aggregates from Tunisian smectite-rich clayey rocks”,Proceedings of ECOpole, Volume 35, 228–237
12. Guangyin Zhen, Xueqin Lu, Youcai Zhao, Jing Niu, Xiaoli Chai, Lianghu Su,Yu-You Li, Yuan Liu, Jingru Du, Toshimasa Hojo, Yong Hu (2013), “Characterization of controlled low-strength material obtained from dewatered sludge and refuse

incineration bottom ash: Mechanical and microstructural perspectives", Journal of Environmental Management, Volume 129, 183-189

13. P. J. Wainwright, D. J. F. Cresswell, H. A. van der Sloot (2002), "The production of synthetic aggregate from a quarry waste using an innovative style rotary kiln", Waste Management & Research, Volume 20, 279–289

14. Rajen J. Patel, Prof. (Mrs) Reshma L. Patel, Dr. Jayeshkumar Pitrida (2018), "Utilization of Sewage Sludge in the Manufacturing of Lightweight Aggregates", International Journal of Constructive Research in Civil Engineering (IJCRCE), Volume 4, Issue 2, 7-14

AUTHORS' BIOGRAPHY

Rajen J. Patel received his Bachelor of Engineering degree in Civil Engineering from the Maharaja Sayajirao University, Vadodara, Gujarat in 2013. At present, he is a final year student of Master's Degree in Environmental Engineering from Birla Vishvakarma Mahavidyalaya, Gujarat Technological University.

Prof. Reshma L. Patel received her Bachelor of Engineering degree in Civil Engineering from the Birla Vishvakarma Mahavidyalaya, Sardar Patel University in 1991. In 1993 she received her Master's Degree in Civil (Environmental) Engineering from Birla Vishvakarma Mahavidyalaya, Sardar Patel University. She joined Birla Vishvakarma Mahavidyalaya Engineering College as a faculty in 1994, where she is Associate Professor of Civil Engineering Department with a total experience of 22 Years in the field of Research, Designing and education. She is guiding M.E. (Environmental Engineering) Thesis work in the field of Civil/ Environmental Engineering. She has published many papers in National/ International Conferences and International Journals.

Dr. Jayeshkumar Pitroda, received his Bachelor of Engineering Degree in Civil Engineering from Birla Vishwakarma Mahavidyalaya Engineering College, Sardar Patel University in 2000. In 2009 he received his master's degree in Construction Engineering and Management form Birla Vishwakarma Mahavidyalaya Sardar Patel University. In 2015 he received his Doctor of Philosophy (Ph.D.) Degree in Civil Engineering from Sardar Patel University. He has joined Birla Vishwakarma Mahavidyalaya Engineering College as a faculty in 2009, where he is lecturer of Civil Engineering Department and at present working as Associate Professor from February 2018 having total experience of 18 years in the field of Research, Designing and Education. At present holding charge of PG Coordinator Construction Engineering and Management. He is guiding M.E. / M.Tech (Construction Engineering and Management/ Construction Project Management/ Environmental Engineering) thesis work in the field of Civil / Construction Engineering. He has published many papers in National / International Conferences and International Journals. He has published nine Research Books in the field of Civil Engineering, Rural Road Construction, National Highways Construction, Utilization of Industrial Waste, Fly Ash Bricks, Construction Engineering and Management, Eco-friendly Construction.