Partial Replacement of Cement with Sewage Sludge Ash in Concrete.

Prof. U. J. Jadhav[1], Himanshu Patil[2], Sarthak Nagmode[3], Sanyam Patil[4], Prathamesh Salunkhe[5], Navnath Pandharmise[6].

Abstract

The production of sewage sludge from waste water treatment plant is increasing all over the world. Disposal of sewage sludge is becoming a serious environmental problem. Another alarming issue is attributed to the high usage of concrete in the construction industry where concrete is one of its main material. This will lead to increased cement production and emission of carbon dioxide because the cement industry one of the major contributor of carbon dioxide emission. Hence, the research for replacement of cement by sewage sludge ash is essential to reduce both the emissions of carbon dioxide and the disposal problem of sewage sludge ash. An attempt has been made to investigate the use of sewage sludge ash as partial cement replacement in concrete. The sewage sludge is incinerated at the temperature of 600°C and a duration of 3 hours. The incinerated sewage sludge ash is sieved through size of 150 µm. Four different percentages of 5%, 10%, 15% and 20% of sewage sludge ash (SSA) is used to replace the cement in the concrete. Water absorption test and slump test has also been carried out to check the capacity of water absorption, durability and workability of the SSA concrete. The compressive strength of SSA concrete is also determined through rebound hammer and compression test.

Results show that SSA has the potential to replace cement as the major chemical component of SSA is similar to that of cement.5% of SSA concrete shows a lower absorption value than the control sample which shows that5% SSA would have a better durability. However, an increase in the percentage of SSA decreases the workability and compressive strength and yet, the5% SSA concrete possesses compressive strength higher than 25 N/mm2 which can be applied in structural applications. The findings suggested that the suitability of sewage sludge ash concrete in different cement replacement ratio is applicable for different usage. The application of sewage sludge ash in concrete will directly reduce the quantity of the cement used which also decreases the emissions of carbon dioxide and solving the disposal problem of sewage sludge.

1. Introduction

Concrete is the most used construction material in the industrialized countries. However, the concrete production needs natural resources (water and aggregates) and cement whose production is costly due to the energy required. In order to reduce the use of natural content, sludge from water treatment plant in Pune, which is used for concrete production as cement. This sludge has disposal problems in order to reduce that reuse of that resources are about to tested with different percentage of replacement. This may drastically reduce the sludge content and even the cost of concrete. Disposal of human sewage has become a necessity for societies, today. The construction of treatment plants has caused problems with huge contents of dry sludge. It has been found that each person produce 35 to 85 grams of solid sludge per day .Sludge is a product which is obtained during the treatment of wastewater. The characteristic of sludge differ upon the region and the method of treatment. Sludge are formed after undergoing various steps such as stabilization, composting, anaerobic digestion, and thickening, dewatering and drying. These sludge contains maximum amount of nitrogen content and so it is majorly used for agricultural purpose. This practice is considered unsatisfactory because of the presence of pathogens in the sludge in high numbers. There has been no thorough study, however, which has shown that there is an increase in the risk of acquiring illnesses associated with pathogens in the raw sludge when proper handling procedure and non-entry to the land following application is observed. Re-use of composted sludge as a soil conditioner in agriculture and horticulture returns carbon, nitrogen, phosphorus and elements essential for plant growth back to the soil. Less chemical fertilizers are required and the organic carbon helps to improve soil structure for soil aeration, water percolation and root growth. The nitrogen and phosphorus are also released gradually for plant uptake compared to the more soluble chemical fertilizers. The potential of leaching of the nutrients to ground or surface water by rainfall run-off is much reduced. Pathogens and heavy metals can however, limit the reuse of sludge. Pathogens should be reduced to levels that

do not pose health hazards to workers handling the sludge, potential health hazards from the spreading of helm in the eggs and from horticultural produce contaminated by pathogens. Stabilized sludge, which has been dewatered and dried on sand beds to attain low moisture content, can meet the same conditions. Heavy metals and toxic chemicals are difficult to remove from sludge. Preventing these chemicals from entering the wastewater or sludge should be the aim of wastewater management for sludge intended for reuse in agriculture or horticulture.

2. Literature Review

Daniel de Almeida Limaa, Charles Zulanasb (2016)(1) Investigated that Sludge has a severe negative impact on the environment, which will only become worse as the need for purified drinking water increases in the years to come. Using 5% sludge content in concrete aggregate will have a significant impact on sludge amounts in the environment, possibly eliminating sludge disposal into the environment for good.

Jamshidi, Mehrdadi N, Jamsidi M. (2011) (2) had conducted study on dry sewage sludge on concrete performances. The dry sewage sludge was replaced by fine aggregate in concrete mixes. The concrete blocks were prepared with 0%, 5%, 10%, 20% and 30% proportions of dry sewage sludge to the weight of fine aggregate.

Kartini K, Dahila Lema.et.al (2015)(3) had conducted study on domestic waste sludge powder(DWSP).The wet sludge was moisture, dried sludge was crushed into Los Angeles Abrasion test machine and sieved through 90μm.

M.Alqedra, M.Arafa, M.Mattar (2011) (4) Both sludge was taken as proportion 0%, 2.5% and 10%. The strength was checked at 28&90 days' age. The result shows that the strength of specimen containing sludge was higher at 90 days for the low organic sludge used as a sand replacement and that of compressive strength of high organic strength at 90-day age shows acceptable strength with2.5% and 5% sludge.

Maha Alqam et al (2011) (5) Investigated the use of water treatment sludge for cement replacement in the production of paving tiles for external use. They utilized sludge-cement replacement percentages of 10%, 20%, 30%, 40% and 50% and concluded that all tiles produced are non-vitreous, with a water absorption that is around 10%. The breaking strength results showed development with age, and that, with the exception of 50% sludge-cement replacement. All of the tiles produced comply with the minimum breaking strength of 2.8 MPa required by the standards.

Ghada Mourtada Rabie(2016)(6) Implemented a new way of discarding the large amount of sludge which produced from the wastewater treatment plants in Egypt, since the amount of sludge produced every year in Egypt are about "4 Million ton ", this amount of sludge is considered a big/dangerous problem which facing Egypt

dried in natural sunlight and then it was dried in furnace for 72 hours to remove

Shehde Mohamma Ghannam(2016)(7) The compressive strength of sludge concrete for treated water was compared with the strength of sludge concrete made by tap water. The results shows that; using sludge concrete mixes decrease the strength of cube about (9.3%) when treated water was used.

Roccaro p.1et al (2015) (8) Experimented that sludge from water treatment plants can be used as partial or total substitution of water in the production of concrete.

Shameela S F1 et al (2016) (9) Experimented that sludge from the marble extraction industry can be incorporated in concrete with partial replacement of cement up to 10%. It was also observed that the use of plasticizers improves the mechanical performance of concrete with marble sludge by offsetting the decline of its properties relative to conventional concrete.

Haider Mohammed Owaida, et.al (2013)(10)had carried out experimental work on use of alum sludge as partial cement replacement and compressive strength, splitting tensile strength and flexural strength of concrete block was checked. The Ordinary Portland Cement and admixture as added

3. Methodology

In this chapter, experiments and tests were carried out in order to examine the achievement of Sewage sludge ash as a filler in concrete. The procedure of preparing the sewage sludge, the materials used for the experiment and the type of testing such as Workability test, compressive test, and flexural are being discussed. The methodology and setup of the experiments for the concrete were conducted according to Indian standards.

3.1 Preparation of SSA:

In order to ensure the consistency of samples, the sewage sludge is acquired from the same treatment plant. The sewage sludge is collected after 7 consecutive non-raining days for best quality control purposes and to ensure the sewage sludge is in dry condition. When collecting the sludge, impurities such as grass, roots and trash is filtered and removed. Only the top layer of sewage sludge is being collected to prevent over deep excavation which may cause the bottom sand layer of the drying beds to be mixed together with the sewage sludge. Before the oven drying and incineration process of sewage sludge, the sewage sludge was kept in a container to prevent the sewage sludge from contact with other impurities. The sewage sludge is oven dried at the temperature of 100°C for a period of 24 hours to ensure that the samples are dry prior to incineration process.

The sewage sludge is incinerated in a closed-lid method to make sure that all the sewage sludge ash is fully trapped inside the cup. The sewage sludge is incinerated from room temperature to the maximum temperature of 600°C for a duration of 3 hours. Time taken to incinerate from room temperature to 600°C is approximately 15 minutes and cooling down duration from 600°C to 200°C is approximately 5 hours. The sewage sludge ash is removed from the incinerator at the lower temperature of about 200°C and stored in a container.

Sewage in Initial Condition

Sewage after Incineration and crushing.

3.2 Casting of Cubes

3.2.1. Properties of Cubes

Grade of Concrete - M25

Proportion - 1:1:2

No. of Cubes - 2

Water Cement Ratio - 0.45

3.2.2. Composition of Concrete

Sewage Percentage %	Sewage Sludge Ash (gm.)	Cement (gm.)
0 %	0 gm.	1870 gm.
5 %	98.5 gm.	1776.5 gm.
10 %	187 gm.	1683 gm.
15 %	280.5 gm.	1589.5 gm.
20 %	374 gm.	1496 gm.

Fine Aggregates	1.87 Kg.
Course Aggregate	3.74 Kg.

3.2.3. Preparation of Cubes

I. First of all put all the materials on metal pan in dry Condition according to Composition of concrete and mix thoroughly gradually add water in and mix simultaneously properly.
II. Clean the Cube from inside to remove any dirt and apply oil on inside surface of cube.
III. Fill the concert in cube in three layers compaction or tamping of concrete should be done with the help of tamping rod (with minimum 25 blows).
IV. After filling mould striking of any extra material from the surface of cube. And left the mould for drying at room temperature.
V. After 24hrs. Of drying Cubes immersed in clean water for purpose of curing.

3.3 Test Performed on Cubes

A) Workability Test :

Slump cone test determines the consistency and workability of all concrete mixtures. Slump cone test utilizing a metallic slump mould. The difference in level between the height of the mould and that of the highest point of the Subsided Concret is Measured.

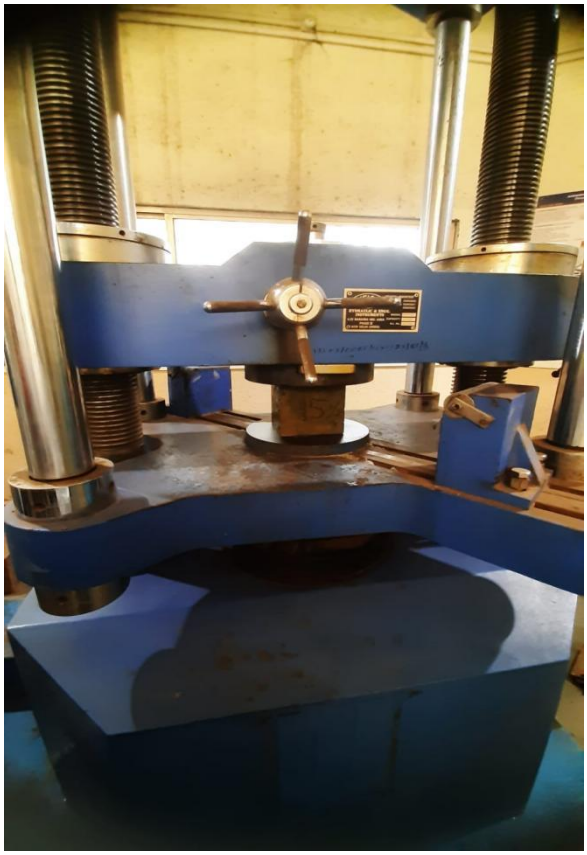
% of Replacement	Slump cone value (mm)
0%	75
10%	76
15%	76
20%	78

B) Compressive Strength Test :

Concrete cubes were casted (150mmX150mmX150mm) and cured for 28 days. Cubes were tested under compressive testing machine. The load was applied by increasing rate of 140kg/cm2/min. until the resistance of specimen to increasing load breaks down. Maximum load taken by specimen was recorded and failure was noted. From above compression strength reading for M25 grade concrete 15% sludge gives good reading. The compression strength at 28 days also good for the 15% sludge added.

Sr.no	Sludge	Compressive strength at 7 days(N/mm 2)	Compressive strength at 28 days(N/mm- 2)
1.	0%	16.7	25.05
2.	5%	23.2	30.7
3.	10%	13.4	23.2
4.	15%	12.3	20.0
5.	20%	10.03	16.73

Compression Test Under UTM



C) Water Absorption Test :

The specimens were prepared and initial weights of all cubes taken. After completion of 7,14 and 28 days of curing period concrete cubes are immersed in water for 24 hours. The amount water absorbed by the concrete cubes are calculated by its initial weight. The amount of water absorption in air dried cubes and self cured cubes is calculated and compared.

Sr. No	Sludge %	Dry Weight (kg)	Wet-weight (kg)	%Water Absorption
1	0	7.76	7.854	1.21
2	5	7.85	7.949	1.26
3	10	7.88	8.048	2.13
4	15	7.94	8.054	1.43
5	20	7.96	8.07	1.38

4. Result

I. Due to incineration of Sewage sludge it reduces to 50% of its volume, that's why it will be the better way to dispose the sewage sludge Economically.

II. Use of SSA lowers the production of cement which will eventually leads to lesser emission of Green house gases.

III. As per the workability test conducted on the concrete cube we can observe that Workability of Concrete gets reduced a little as we increases the percentage of SSA.

IV. Water Absorption is minimum in 5% Sample and highest in 10% Sample From which we can conclude 5% sample is more Water Resistance and more Durable.

V. Compressive Strength of 5% SSA Sample Cube have More Strength among all the Cubes and further increase in SSA will result in loss of strength.

5.

6. Conclusion

In summary, the Replacement of SSA with Cement in Concrete Shows the Enhancement in Properties of Concrete Such as water absorption, Compressive Strength, etc. at Particular percentage of Sewage in our Case it is 5% as per the various Tests Carried out. But further use of SSA can leads to adverse effect on Concrete. Ultimate Benefit through this study is that because of use of SSA in Concrete it will eliminates the problem of Disposal of Sewage also the production of cement leads to various Green house gases Emission this problem also can be reduced by this method.

References:

1. Lin, K., and Lin, C. 2007. Hydration Characteristics of Waste Sludge Ash Utilized as Raw Cement Material. Journal of Cement and Concrete Research, 35(2005), 1999-2007.
2. Monzo, J., Paya, J., Borrachero, M. V. and Corcoles, A. 1996. Use of Sewage Sludge Ash (SSA)-Cement Admixtures in Mortars. Journal of Cement and Concrete Research, 26(9), 1389–1398.
3. Pan, S., Tseng, D., Lee, C. and Lee, C. 2003. Influence of the Fineness of Sewage Sludge Ash on the Mortar Properties. Journal of Cement and Concrete Research, 33, 1749–1754.
4. Paya, J., Borrachero, M. V and Girbe, I. 2003. Reuse of Sewage Sludge Ashes (SSA) in Cement Mixtures : The Effect of SSA on the Workability of Cement Mortars. Journal of Waste Management, 23, 373-381.
5. Siti Noorain Roslan, S. S. G. 2013. Study on the Characteristics and Utilization of Sewage Sludge at Indah Water Konsortium (IWK). International Journal of Environment, Earth Science and Engineering. 7(8), 536- 540.
6. Tay, J.-H., and Show, K.-Y. 1994. Municipal Wastewater Sludge as Cementitious and Blended Cement Materials. Journal of Cement and Concrete Composites, 16(1), 39- 48.
7. Tenza-abril, A. J., Saval, J. M., and Cuenca, A. 2011. Using Sewage-Sludge Ash as Filler in Bituminous Mixes. Valls, S. and Va, E. 2001. Accelerated Carbonation of Sewage Sludge-Cement-Sand Mortars and its Environmental Impact, Journal of Cement and Concrete Research, 31, 1271-1276.
8. Yagüe, A., Valls, S., Vázquez, E. and Albareda, F. 2005. Durability of Concrete with Addition of Dry Sludge from Waste Water Treatment Plants. Journal of Cement And Concrete Research, 35(6), 1064-1073.
9. Yip, W. and Tay, J. 1990. Aggregate Made from Incinerated Sludge Residue. Journal of Materials in Civil Engineering, 2(2), 84-93.