Utilization of Sewage Sludge Ash in Concrete

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Abstract : Sewage sludge ash (SSA) is obtained from incinerating sewage sludge. In this paper the study of performance of cubes and beams manufactured by using sewage sludge ash. At the same time, the performance of concrete made from sewage sludge ash was analyzed with varying percentage of sewage sludge ash (8%, 10%, and 14%) with constant percent of fly ash i.e. 20% to improve the pozzolanic activity. This study is to identify the possibilities of using sewage sludge ash in concrete as partial replacement for cement by subjecting wet concrete cubes and beams to determine consistency, workability, compressive strength and flexural strength of concrete. It was seen that when percentage of SSA was increased beyond 10%, water requirement as well as water absorption also increased. But at the same time compressive strength of the concrete decreased.

Key Words: Sewage sludge ash, pozzolanic, fly ash, incineration, sewage sludge, SSA, etc.

1 INTRODUCTION

Human activities on earth produce considerable quantities of sludge, which increases due to rise in population including industrial and agricultural waste from rural and urban societies. The common method used for sludge disposal is land filling, but the disposal of sludge has become a major issue which leads to adverse effect like ground water contamination which contains harmful heavy metals. This leads to the generation of bad odour and gases disposal of sludge is also creates problems like high cost for transportation and availability of land.

From previous research it has been investigated the use of sewage sludge ash (SSA) to produce bricks and aggregate for concrete. The proportion of sewage sludge ash used usually low normally less than 20%. There is significant potential for SSA to be used in concrete but the methods and quantities can be substituted depending on number of factors.

The Indian construction industry alone consumes approximately 400 million tons of concrete every year and relative amount of mortar too. Therefore the demand of concrete and the required raw materials is very high this causes hike in the cost of cement. The alternate material or the partial material for the cement is adopted by using sewage sludge ash. This provides economical, environment friendly and light weight construction product.

1.1 Problem statement

Sewage sludge is one of the largest contributors of waste material in India. Thus the disposal of sewage sludge has to be mitigated to avoid causing serious problems in the urban areas.

1.2 Aim of work

- To study the possibility of using sewage sludge ash as partial replacement of cement in concrete.
- To dispose sludge effectively.
- To utilise SSA for reducing the problems related to the environment and health concern

1.3 Objectives of work

- To determine the workability of sewage sludge ash in concrete.
- To determine the compressive strength of SSA concrete.
- To determine flexural strength of SSA concrete.
- To reduce problem of sewage sludge ash disposal
- To reduce the adverse effect on environment and

2 MATERIALS AND METHODS

2.1 Materials

1. Sewage sludge ash

With the help of incinerator the sludge is incinerate at 1400° C. SSA is formed from 30% by mass of inorganic matter present in sewage sludge. The particles diameter ranges from 1 to 100 µm, with a mean of 26 µm. Before use of SSA in concrete it can be sieved from 475 µm.The major elements present in SSA are Silica, Calcium, Ferrous, Aluminium, Phosphate and Oxides. SSA contains significate levels of phosphate usually between 10% and 20% by mass.

Table 2.1: Comparison of value ranges of some chemical compounds in SSA

Oxide	Range according to previous research	Mean according to previous research
Fe_2O_3	4.7 – 20.0	11.4
SiO_2	17.3 – 50.6	34.0
CaO	1.9 – 31.3	15.8
MgO	1.4 – 3.2	2.1
Al_2O_3	6.3 – 19.1	12.8
P2O5	1.7 – 18.2	10.8
TiO_2	0.3 – 1.0	0.7
Na_2O	0.3 – 1.3	0.7
K_2O	0.6 – 2.3	1.4

2. Fly Ash

Fly ash is good resource material for utilization in various areas such as manufacturing of cement, cement concrete, embankment construction, low lying area filling, etc. Fly ash is a very small particles which makes concrete highly dense and reduce permeability of concrete. Because of its pozzolanic property fly ash is used as a replacement of Portland cement in concrete. Use of fly ash also gives good concrete workability, durability and finishing.

Table 2.2. Physical Requirements

Sr. No.	Characteristics	Requirements for Siliceous fly ash and Calcareous fly ash.
1	Fineness- Specific surface in m^2/kg by Blaine's permeability method (Minimum)	320
2	Particles retained on 45 micron IS sieve (wet sieving) in percent, Max. (Optional Test)	34
3	Lime reactivity – Average compressive strength in N/mm^2, Min.	4.5
4	Lime reactivity – Average compressive strength in N/mm^2, Min.	Not less than 80 percent of the strength of corresponding plain cement mortar cubes
5	Soundness by autoclave test - Expansion of specimen in percent, Max.	0.8

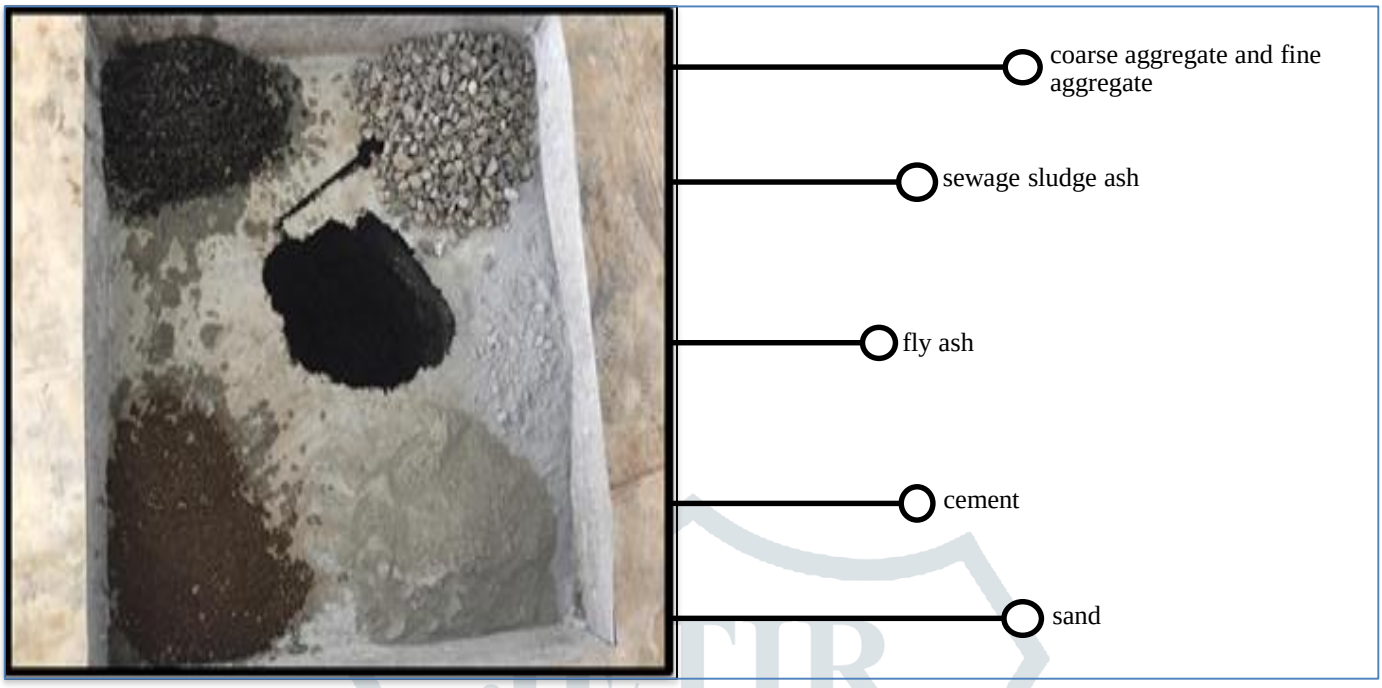


Figure 1. Materials

3. Cement

Cement is the powdery substance made by calcining lime and clay. The density of cement is 3.15g/cm$^{3.}$ Components of cement – SiO_2, Al_2O_3, Fe_2O_3, CaO, SO_3, Ca_3SiO_2, K_2O, etc.

4. Aggregates

Aggregates are used as base material in concrete**.** There are two types of aggregates are used, Fine aggregate (below 4.75 mm.) And coarse aggregate (above 4.75 mm and below 20 mm).

5. Sand

Sand plays vital role in production of concrete. Natural river sand is most preferable as it has more crushing strength than any other alternatives.

2.2 Methodology

The sewage sludge from treatment plant is collected and further dried on sludge drying bed for approximately 2 weeks. This dried sludge is then delivered to incinerator to incinerate sludge at temp of 1400^{o}C which converts this sewage sludge in ash. Then the sewage sludge ash is sieved finely in 475 µm.The fine SSA is partially replaced in cement as additive with varying percentage (i.e. 8%, 10%, & 14%) and keeping constant fly ash percent (i.e. 20%) to produce concrete.

Tests are carried out on fresh concrete for consistency and workability. The moulds of size (150mm X 150mm X 150mm) for cube and (150mm X150mm X 700mm) are used. The cubes are casted for determining the compressive strength of SSA concrete in CTM and the beams are casted for determining flexural strength in UTM.

2.2.1 Mix design

The concrete paste and testing specimen were mix designed in this study with help of IS 10262 (2009) for M40 concrete. The OPC was blended fine SSA which were used partially to replace 8%, 10% and 14% of OPC. And with this varying quantity of fine SSA the OPC is also replaced with fly ash for 20% for every variation for fine SSA replacement. The fly ash and fine SSA is replaced by weight of OPC. The testing specimen and wet concrete for workability and consistency test is prepared with same mix proportion. The mixing of concrete is prepared by using the following procedure.

First, the cement, aggregate (fine and coarse) , sand , fly ash and fine SSA is dry mixed the percentage of SSA used for replacement of OPC is as per the batch. Next, water was added and mixing was continued. Afterwards, the bottom of mixer was scraped manually with a steel trowel to avoid material sticking to the bottom. Finally the mixing was continued at a higher speed. Freshly mixed material is then casted in steel moulds and moulds are allowed to vibrate for 1 min to remove air bubbles.

Casted Specimen for flexural and compressive strength test were cast in size (150mm X 150mm X 700mm) and (150mm X 150mm X 150mm) respectively. After one day specimen were demoulded and placed in curing tank until testing for 7days and 28 days.

Table 2.3. Showing quantity of material used

Sr. no	% of SSA replacement	% of fly ash	Weight of cement (kg)	Weight of sand (kg)	Weight of aggregate (kg)	
					fine	coarse
1	0	0	16.167	17.56	16.8	21.75
2	8	20	14.45	17.26	16.5	21.13
3	10	20	13.76	17.491	16.4	20.77
4	14	20	13.24	18.415	16.2	20.65

3 RESULTS AND DISCUSSION

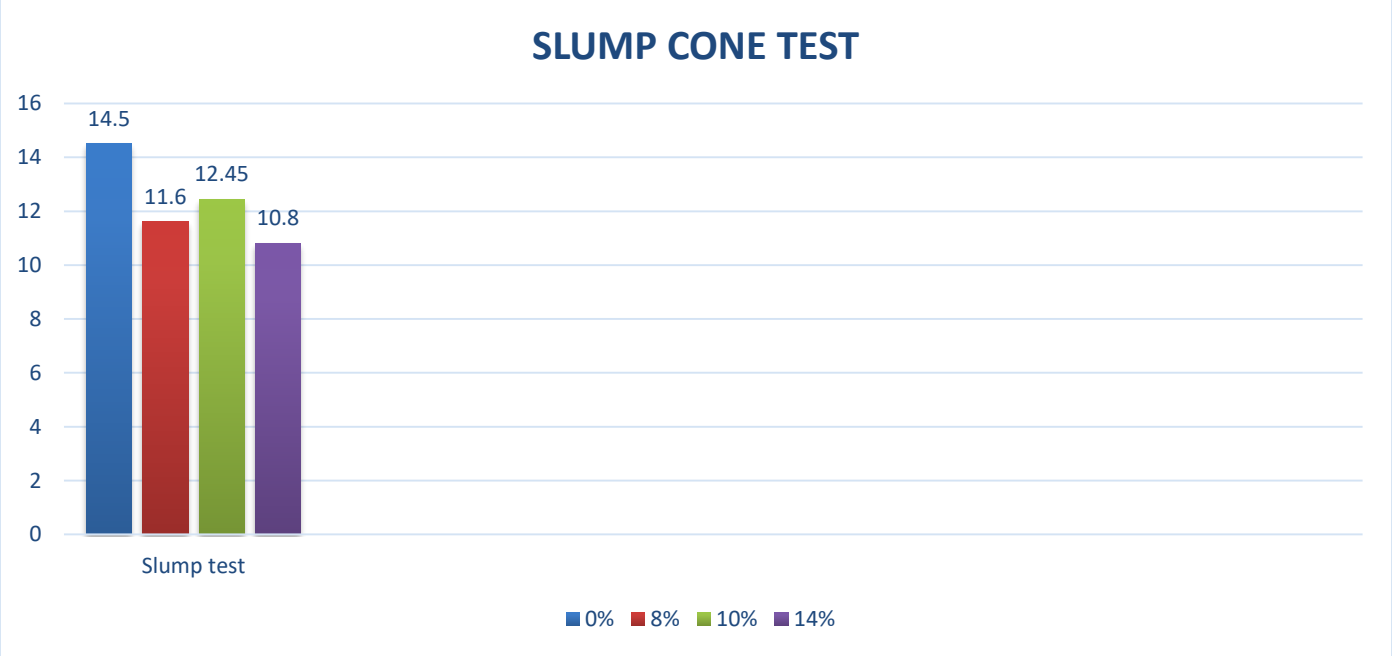
3.1 Consistency and workability

3.1.1 Slump cone test

This test is mainly used to understand the workability and consistency of wet concrete. The standard size of slump cone is 300 mm height, bottom diameter of 200mm and top diameter of 100mm is used to conduct this test. As per test we observed that 0%, 8%, 10% SSA concrete are true slump and 14% SSA concrete is shear slump.

Table 3.1 Results of slump cone test

	0%	8%	10%	14%
Slump (in cm)	14.5	11.6	12.45	10.8



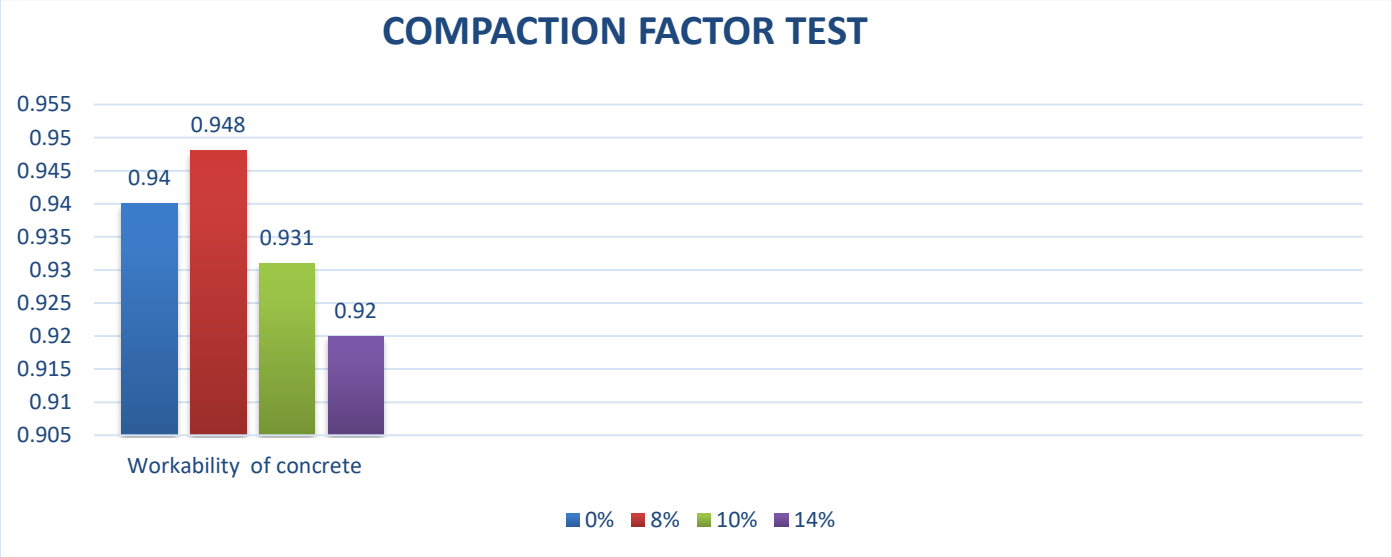
Graph 3.1 Results of slump cone test

3.1.2 Compaction factor test

Compaction factor is adopted to determine workability of concrete. Compacting factor apparatus consist of two conical hopper mounted above cylindrical mould and fixed to stand one above the other. The hoppers are provided with trap doors at bottom. The compaction factor is the ratio of weights of partially compacted to fully compacted concrete.

Table 3.2 Results of compaction factor test

	0%	8%	10%	14%
Compaction factor	0.94	0.948	0.931	0.92



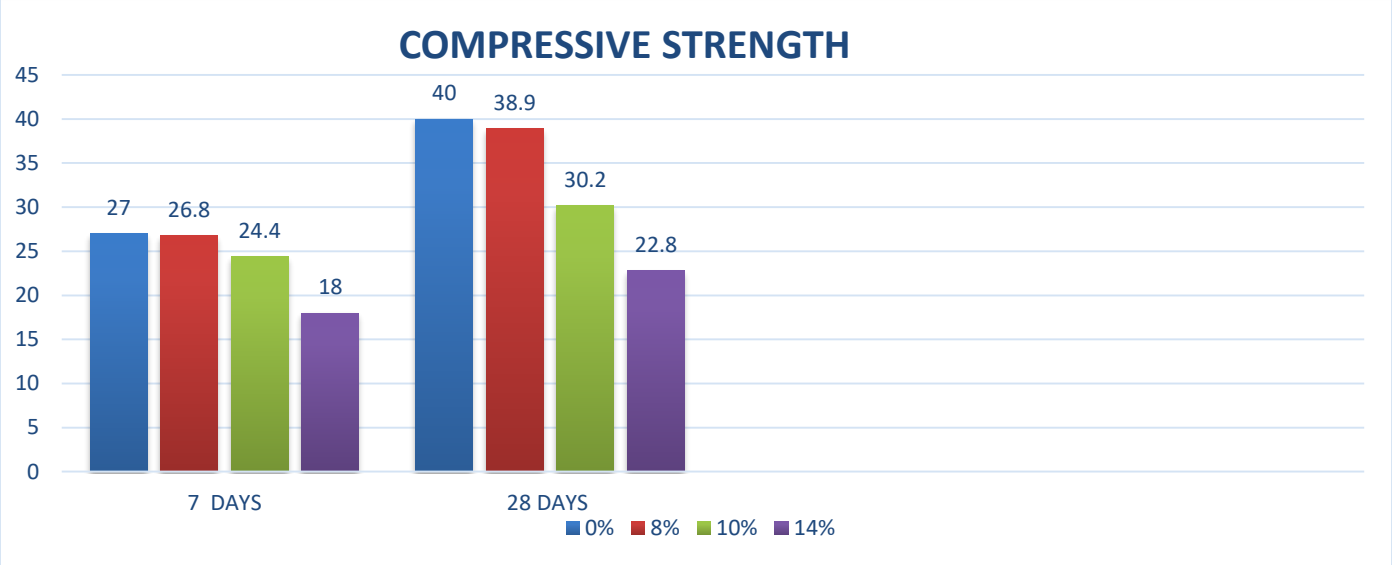
Graph 3.2 Results of compaction factor test

3.2 Compressive strength

Compressive strength test were performed on both conventional and SSA concrete cubes. This test was carried out to determine load bearing capacity of cubes. This test is conducted on cubes after curing for 7 days and 28 Days. These cured cubes are stacked for two hours to normalize the temperature and to make the cube relatively dry or free from moisture. The cubes was then crushed and the corresponding failure load recorded. The compressive strength is then achieved when the crushing force is divided by sectional area of cubes.

Table 3.3 Results of compressive strength test

	0%	8%	10%	14%
7 days (N/mm^2)	27	26.8	24.4	18
28 days (N/mm^2)	40	38.9	30.2	22.8



Graph 3.3 Results of compressive strength

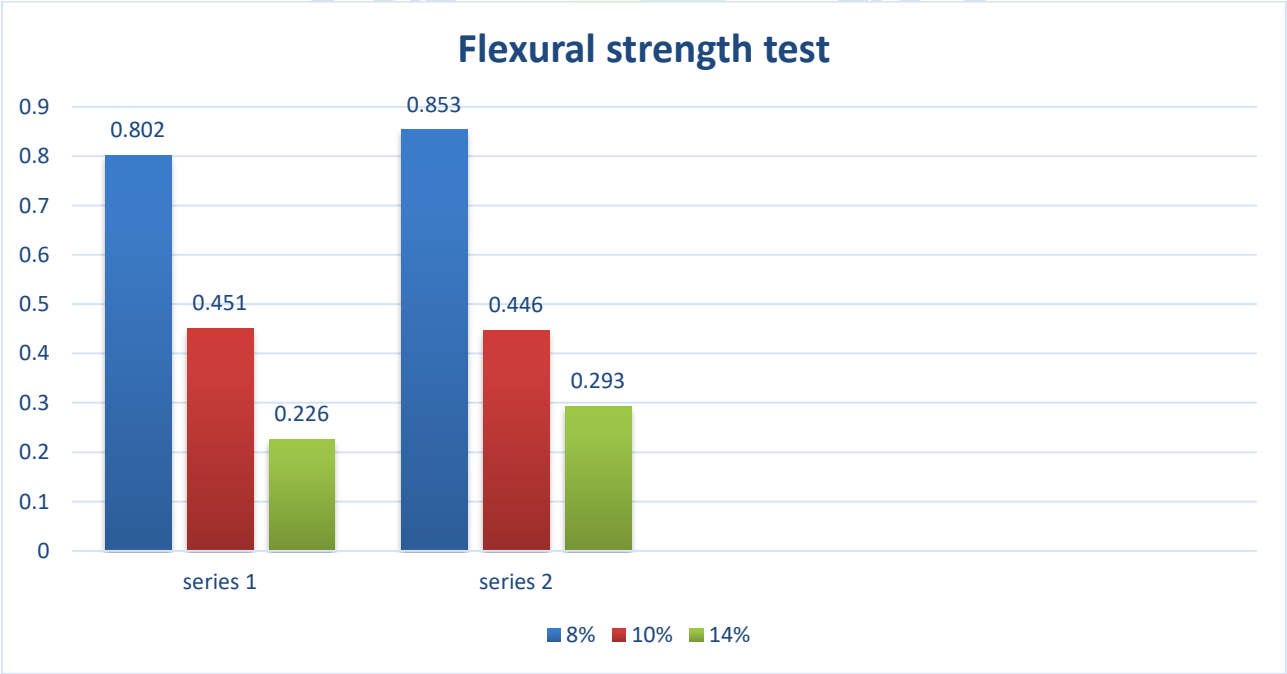
3.3 Flexural Strength

Flexural test evaluates the tensile strength of concrete indirectly. It shows the ability of unreinforced concrete beam to withstand failure in bending.

Flexural strength test were also performed on both conventional and SSA concrete beams by subjecting 4- point loading, the area of uniform stress exits between the inner span loading points. The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa.

Table 3.4 Results of flexural strength

Strength (N/mm2)	8%	10%	14%
Series 1	0.802	0.451	0.226
Series 2	0.853	0.446	0.293



Graph 3.4 Results of flexural strength

4 CONCLUSION

Sewage sludge produced in the treatment plant can be effectively disposed by utilizing sewage sludge ash in concreting work. Different engineering properties of sewage sludge ash such as specific gravity, physical and chemical content were studied. The water requirement as well as water absorption is observed to be increased, when percentage of sewage sludge ash was increased in mix. But at the same time the compressive strength of SSA concrete decreased. And we also observed that the properties of the SSA concrete have shown the tendency to be used as concrete by-product (i.e. bricks, pavement blocks, divider, mortar) and temporary structures but only for 8% to 10% of SSA. The decrease in strength indicate that it cannot be used for high rise buildings.

5 FUTURE SCOPE

5.1 Mix proportion

In this study fly ash was used in constant percentage with respect to percentage of sewage sludge ash. The strength of concrete might be improved if fly ash is increased.

5.2 Binding

Different other kind of additives such as lime, charcoal husk, steel fibers, etc. can be used.

5.3 Type of SSA used

In this study, we used domestic sewage sludge ash which has high organic matters due to which decrease in strength was observed. So, if industrial sewage sludge ash is used it might improve the properties of SSA concrete as it contain more or high organic matter and have chemical composition.

6 ACKNOWLEDGEMENT

This work was supported by Civil Department of Trinity Academy Of Engineering, Pune for providing the laboratory facilities for carrying out various tests. Pune municipal corporations sewage treatment plant for providing us with information about sewage sludge production and its contents. The leaf society for allowing us to use incinerator to produce sewage sludge ash.

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