REPLACEMENT OF FINE AGGREGATE USING SLUDGE IN CONCRETE

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Abstract – *The purpose of this study is to find an alternate source for fine aggregate. In this project concrete was tested with w/c ratio of 0.45. Fine aggregate is partially replaced using sludge with different percentage such as 5, 10, 15, 20 and 25. Chemical composition was found using SEM and EDX. The mechanical properties such as compressive strength, split tensile strength and flexural strength were tested for 7, 14 and 28 days. This experimentation holds good strength till 20% of replacement with sludge in fine aggregate. The strengths decreased when the replacement of sludge is above 20%.*

Key Words:* *Cement, fine aggregate, Sludge, SEM, EDX, Compressive strength, Split tensile strength

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 Vellore Institute of Technology University, Vellore is used for concrete production as fine aggregate. 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. Sludge is a product which is obtained during the treatment of wastewater [1]. The characteristic of sludge differ upon the region and the method of treatment. Sludges are formed after undergoing various steps such as stabilization, composting, anaerobic digestion, thickening, dewatering and drying. These sludges 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 [2]. Re-use of composted sludge as a soil conditioner in agriculture and horticulture returns carbon, nitrogen, phosphorus and elements essential for plant growth bac k 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 helminth eggs and from horticultural produce contaminated by pathogens [3]. 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. Reuse may still be possible for purposes such as mine site rehabilitation, highway landscaping or for landfill cover. Sludge that has been conditioned for reuse is called 'bio solids' [4]. Conversion of sludge, which is heavily contaminated by heavy metals or toxic chemicals, to oil is technically feasible. A full-scale plant is operating in Perth, Western Australia. The conversion is by a pyrolysis process, heating dried sludge to a high temperature in the absence of oxygen or with a controlled amount of oxygen. Capital and running costs of oil from sludge process are high. Final or ultimate disposal of sludge, which cannot be reused, is by land filling or incineration [5]. Since sludge for land filling usually contains heavy metals or toxic chemicals, lining of the landfill with clay or plastic liner may be required to prevent contamination of groundwater. Incineration of sludge is by a multiple hearth furnace or fluidized bed furnace. Energy input is required to dry the sludge before combustion is self-sustaining. Combustion flue gases usually need treatment to meet air pollution control standards. Investment and operating costs are high. Due to these various reasons replacement of sludge in fine aggregate was considered.

2. MATERIALS USED

Primary and secondary sludge may be expected to contain settleable materials from raw wastewater and the products of microbial synthesis. Other materials are also removed from wastewaters and incorporated into primary and secondary sludge. The sludge image is shown **Fig 1**. The large surface area of particles incorporated into sludge provides sites for adsorption of constituents from the liquid phase. Non-degraded organic compounds in solution may partition into the organic fraction of the particles. Bio flocculation may incorporate colloidal particles that otherwise would not be removed by sedimentation into settle able particles. These and other mechanisms result in selective enrichment of wastewater constituents in sludge. Additionally, wastewater sludge is mostly water and, hence, wastewater constituents remaining in the liquid phase also are included in sludge. Because primary and secondary sludge have different properties, advantage is sometimes sought by treating them separately. As an illustration, secondary sludge thickens better using the dissolved air flotation process than by gravity thickening, and it is sometimes thickened separately from primary sludge. The two sludge almost invariably are combined prior to the end of the treatment, and, for purposes of discussing the ultimate utilization of treated sludge, they are not further distinguished. A wide variety of sludge treatment processes are used to reduce sludge volume and alter sludge properties prior to disposal or use of the treated product. Sludge treatment is considered herein to comprise engineered processes for altering sludge quality prior to disposal or reclamation. When sludge is applied to land, inactivation of remaining pathogenic organisms and viruses continues, biological stabilization of residual organic material progresses, and biologically-mediated and abiotic chemical transformations occur. Sludge is produced from the treatment of wastewater in septic tank and activated sludge systems. This is inherently so because a primary aim of wastewater treatment is removing solids from the wastewater. In addition, soluble organic substances are converted to bacterial cells, and the latter is removed from the wastewater. Sludge is also produced from the treatment of storm water, although it is likely to be less organic in nature compared to wastewater sludge. Sludge should, however, always be handled with care to avoid contact with pathogens. The results obtained from EDX is shown in **Fig 2** and **Table 1**. Sludge may be contaminated with heavy metals and other pollutants, especially when industrial wastes are disposed into the sewer. Pre-treatment of industrial wastes is therefore essential before discharge to the sewer. Treatment of sludge contaminated with high concentrations of heavy metals or toxic chemicals will be more difficult and the potential for re-use of the sludge will be limited. Faecal sludge contains essential nutrients such as nitrogen and phosphorus and is potentially beneficial as fertilisers for plants. The organic carbon in the sludge, once stabilised, is also desirable as a soil conditioner, because it provides improved soil structure for plant roots. Options for sludge treatment include stabilisation, thickening, dewatering, drying and incineration. The latter is costliest, because fuel is needed and air pollution control requires extensive treatment of the combustion gases. It can be used when the sludge is heavily contaminated with heavy metals or other undesirable pollutants. Prevention of contamination of the sludge by industrial wastes is preferable to incineration. A conversion process to produce oil from sludge has been developed, which can be suitable for heavily contaminated sludge. The costs of treatment of sludge are generally of the same order as the costs of removing the sludge from the wastewater.

3. MIX DESIGN

The standard procedure for the mix design of concrete has the design for M 40 is done by the concept of code IS 10262 (2009) "Concrete Mix Proportioning". Following are the steps for the mix design of M 40 concrete. water/cement ratio is 0.45. The ratio for mortar cube test was taken to be 1:3 as in 1 unit of cement and 3 units of fine aggregate.

Fig -1: Sludge sample (waste water treatment plant)

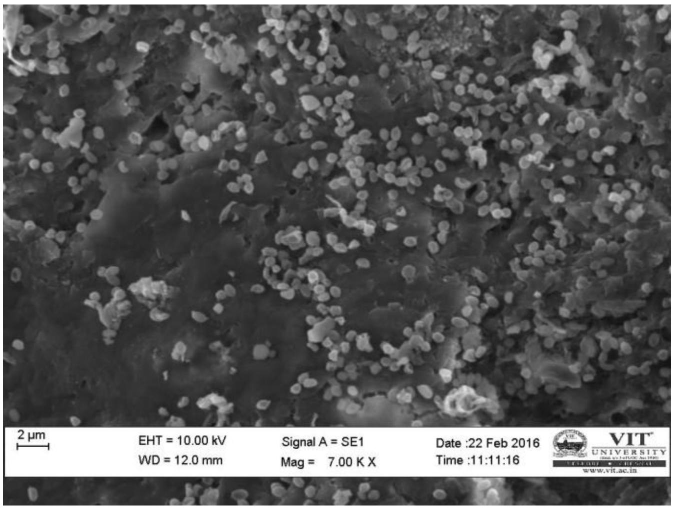

Fig -2: Sludge sample image

Table 1: Properties of Sludge

Property	Percentage
Carbon	40-52
Nitrogen	10-19
Oxygen	20-26
Manganese Oxide	5-8
Magnesium Oxide	5-10
Aluminium Oxide	1-3
Calcium Oxide	<1
Sulphur	0.5-1.0

3.1 MIXING

Cement, fine aggregate, course aggregate and sludge were mixed according to the mix proportion obtained from the above M40 design. The mixing procedure was done using hand mixing in the laboratory.

3.2 CURING

After proper hand mixing, the fresh concrete was placed accordingly in the steel molds. Initially compaction was done using iron rods and then compacted in vibrating table to avoid voids which leads to strength decrement. After proper compaction, the concrete specimens along with the molds were kept for drying over a period of 24 hours.

4. TESTS AND RESULTS

4.1 Compressive strength of concrete

As per IS 516 (1959), the compressive strength test was carried out on hardened concrete cube specimens. The compressive strength is determined for various mixes by testing the specimens in a digital compression machine of 2000 KN capacity operated at a loading rate of 2.5kN/s. Cube specimens of size 100x100x100 mm used to assess the compressive strength various concrete. Figure below indicates the cube specimen subjected to compression testing.

Table 2: Compressive strength of concrete in which sludge partially replaced in fine aggregate

No of days	Compressive Strength (MPa)
7	24.6
14	29.0
28	33.1

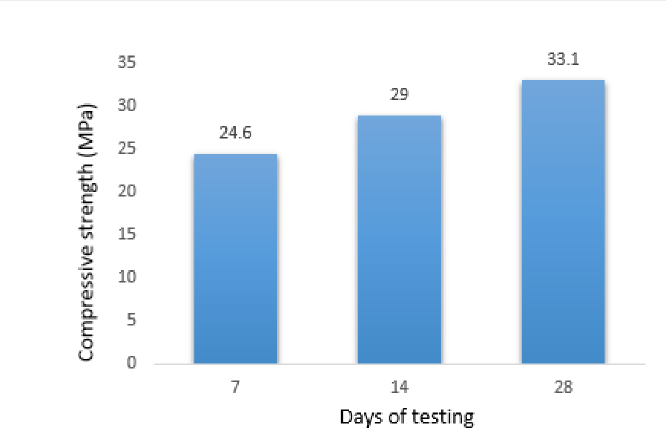

Chart 1: Compressive strength of concrete in which sludge partially replaced in fine aggregate.

4.2 Split tensile strength of concrete

In this project, cylinders of size 150 mm in diameter and 300 mm height were tested. The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the lord at which the concrete members may crack.

Table 3: Split tensile strength concrete in which sludge partially replaced in fine aggregate

No of days	Tensile strength(MPa)
7	1.35
14	2.56
28	3.29

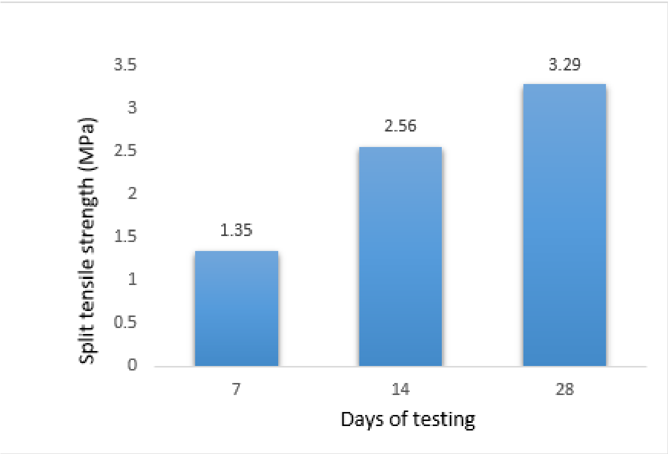

Chart 2: Split tensile strength of concrete in which sludge partially replaced in fine aggregate.

4.3 Flexural strength of concrete

The flexural strength value was obtained using a concrete prism of size 100x100x500 mm for various concrete mixes with and without addition of sludge's. The specimens after the accelerated curing is tested in a load controlled machine at a loading rate of 2kN/s and subjected to third point loading arrangement

Table 7: Flexural strength concrete in which sludge partially replaced in fine aggregate

No of Days	Flexural strength (MPa)
7	4.6
14	4.85
28	5.2

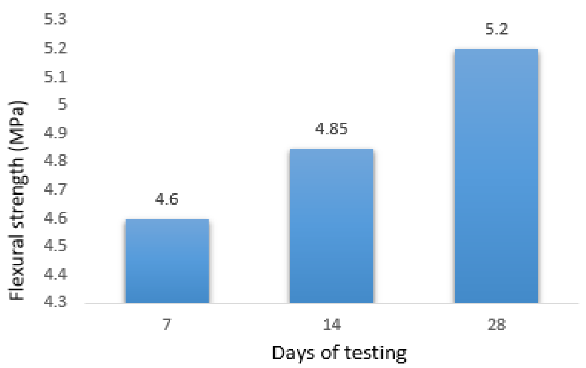

Chart 3: Flexural strength of concrete in which sludge partially replaced in fine aggregate.

Fig -3: Flexural strength testing setup.

5. CONCLUSION

Sludge can be used as an effective replacement of fine aggregate and it can be replaced with 20% in concrete. The compressive strength is increased with the addition of sludge. Flexural strength is increased when compared with the control mix. The maximum compressive strength and flexural strength value obtained were 41.2 MPa and 7.5 MPa respectively for OPC 43 grade cement. The maximum compressive strength and flexural strength value obtained were 44.5 MPa and 8.5 MPa respectively for OPC 53 grade cement. Among all the mixes tested4th mix which contained 20% of sludge showed better results in which the split tensile test values is also higher for that mix. Thus replacement of sludge for fine aggregate is suitable up to 20% replacement.

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