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Use of Sewage Sludge Ash & Fly Ash in Constructions

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Abstract: concrete in most widely used for construction of all the type of structures in the world. Cement, sand , coarse aggregate and water in preparation of concrete in common practice. Clay, limestone, shale and other natural resources are used in manufacture of cement. Cost of cement is increasing day by day and it is indispensible material for concrete. For manufacture of cement it requires natural resources, lot of man power and mechanical power and it is making environment pollution by releasing lot of carbon dioxide to the environment. To overcome these problems cementatious materials are used to improve properties of cement concrete.

Fly ash and sintered sewage sludge ash obtained from sewage treatment plant is used as an alternate cementatious materials in concrete to enhance the properties of cement concrete. By using these land filling and disposal problems of industrial wastes can b solved. Instead of sand quarry dust is used as a alternate building material in concrete.

I. Introduction

In present-day society, mortar and concrete are indispensable materials in building and civil engineering work: tunnels, dam, bridges, etc. There is growing concern with respect to topics related to the environment. The presence of sewage sludge ash and fly ash has been constantly on the increase. Their disposal is becoming a huge problem. Thus, from an environmental point of view, finding ways of their disposal has gained importance. They can be used as low cost construction material. The incorporation of these materials in concrete fabrication would result in a reduction of cement per unit volume of concrete, causing a reduction in CO_2 emissions.

The incineration of municipal solid waste is becoming increasingly important for waste management because of new European regulations which prohibits storing of untreated waste in landfills. Research concerning the use of residues from waste incinerators in concrete production is therefore a positive advance in sustainable development, by saving natural resources and decreasing waste volume stored in landfills. Today, modern reprocessing techniques lead to incinerator slag or ashes, which have the potential to be used as aggregates or mineral additions in cementitious building materials. Because of a highly sophisticated reprocessing technique residues with relatively stable composition, relatively well defined properties and with contents of harmful components, (such as heavy metals and hydrocarbons) below legal limits can be produced. Attempts are being made to custom design material properties according to their application by varying reprocessing methods.

To solve the water pollution problems in urban areas; many sewerage systems and sewage treatment plants have been constructed and operated all over the world. Through the sewerage systems and treatment plants, the sewage and wastewater discharged from households and industries are collected and purified. However, in the sewage treatment plants large quantities of sewage sludge are produced. To control the environmental impact caused by sewage sludge disposal, the interest of reusing sewage sludge is continuously rising. Many technologies have been developed to reuse sewage sludge beneficially and economically, among those technologies, utilization of the incinerated residues of sewage sludge, i.e., sewage sludge ash (SSA), has been investigated by many researchers previous work revealed that SSA exhibits pozzolanic activity, Therefore, SSA can potentially be used in concrete or mortar to partially replace Portland cement.

Although the SSA can be used as a mineral admixture, there are two major disadvantages when SSA is used in mortar. First, the pozzolanic activity of SSA is lower than that of some common pozzolanas such as fly ash. Tay and Show found that the strength activity index (SAI) of SSA with Portland cement was between 57.6% and 67.2%. On the other hand, the SAI value of F-class fly ash between 96% and 134%. Because the SAI valve of SSA is smaller than that of fly ash, the effectiveness of using SSA in mortar is lesser than that of fly ash. Second, the water demand of SSA mortar is higher than that of ordinary cement mortar. Pan et al., found that the addition of SSA affected the mortar workability. This phenomenon is primarily due to the porous and irregular morphology of SSA, Consequently, it is difficult to adequately maintain water to cement ratio and workability of SSA mortar simultaneously.

The incineration reduces the volume of MSW and provides energy, it is not a final solution since it generates bottom and fly ashes that must subsequently be disposed of. Bottom ash is collected at the base of the combustion chamber and consists of a slag-type material. However, it is the finer fraction, collected from the flue gas by the air pollution control devices, and referred to as fly ash, that poses the more serious environmental problems. Fly ash consists of fine particles that contain leachable heavy metals and is therefore classified as a toxic waste. In addition, highly toxic organic substances (dioxins, furans and PAHs) are also present, further adding to the problem. These aspects make fly ash management one of most important environmental issues related to the incineration of MSW. The use of landfills for fly ash disposal is currently the main option in many countries. However, more stringent measures for special waste landfills, in combination with an emerging recycling philosophy have encouraged the recycle and reuse of the waste. Fly ash is rich in some elements and compounds (such as metals and salts) and therefore has some potential to be used as raw material. Each potential application for fly ash results in three main advantages: First the use of a zero cost raw material, Secondly, the conservation of natural resources, and thirdly, the elimination of waste.

The use of SSA in cement-based materials as cement or sand replacements is also reported in a few recent studies. In a general way, these studies show that SSA reduces the workability of fresh mortar and tends to increase the settling time of cement. Most studies also report a decrease of compressive strength of mortars and concrete when SSA is used as a cement or sand replacement: about 30% of decrease in the worst case found in the literature for 10% SSA. Only a few authors have shown strength similar to or greater than the reference with up to 5, 10 or even 15% of SSA in mortar. Since SSA is e waste material, attention must be paid to its environmental impact when it is reused in other applications. However, little information is available about the environmental impact of SSA in cement-based materials and no comparison has been made with reference concrete, so it is not possible to evaluate the pollutant potential of SSA.

A literature analysis shows that the effects of SSA and fly ash on mortars and concrete properties are more or less noticeable, depending on the characteristics of the specific SSA and fly ash used in each study. The inherent variability of this kind of residue remains one of the most important reasons for avoiding a systematic generalization of the results. So the aim of this work is to provide supplementary knowledge about the characteristics of SSA and fly ash and its effect on the properties of cement-based materials.

Advantages:

The following are the advantages of use of SSA and Fly ash in cement blocks.

- Conservation of resources of virgin materials.
- Emission reduction and less energy requirements due to the fluxing properties of SSA
- Production of 'green products' with recycled content
- Achieving brick sector sustainability objectives by minimizing the use of primary resources
- The need to buy primary materials such as sand is reduced
- Reduced energy cost due to the fluxing properties of bricks.
- The strength activity index (25% replacement of cement) reaches more than 90% after 28 days, showing a long-term positive effect, which might be related to the pozzolanic activity.
- These bricks can provide advantages being available in several load-bearing grades, savings in mortar plastering, and giving smart looking brickwork.
- High compressive strength eliminates breakages/wastages during transport and handling, the cracking of plaster is reduced due to lower thickness of joints and plaster and basic material of the bricks, which is more compatible with cement mortar.

II. Literature survey

In this paper "The potential for carbon dioxide reduction from the cement industry through the increased use of industrial pozzolanas" [1] Mark tyrer et al (September 2008) he discussed that each tonne of cement produced, releases a little under a tonne of carbon dioxide ,approximately half from calcination of limestone. This presentation consider the carbon reduction in the cement by use of pozzolanic materials such as fly ash, blast furnace slag, sewage sludge ash, paper mill sludge ash , container glass .He reviewed possible roots to co_2 reduction and estimates that energy required per tonne of Portland cement clinker

Finally he concluded the use of pozzolanic materials in cement to reduce its carbon emission. Use of these pozzolanic materials will increase the bonding property of cement .By using this supplementary cementitious will decrease in production costs and material costs.

In this paper "Mechanical performance of concrete with partial replacement of cement by sewage sludge ash" [2] Jamshidi et al (2010) he discussed the production of sewage sludge from waste water treatment plants is increasing all over the world. Disposal of sewage sludge is a serious environmental problem. He replaced amount sewage sludge ash such as 5% 10% and 20% by cement mass were used. His result shows that concrete with 20% of sewage sludge ash and w/c=0.45 has a 28 day compressive strength of almost 30MPa. This hydration period the sludge content influences the compressive strength in a proportional way.

He concluded that concrete mixtures with 5% and 10% sludge ash content show minor reductions in the mechanical performance. By increasing the sludge ash content to 20% sludge a decrease of compressive strength but concrete have some acceptable mechanical performance. Use of SSA in concrete will reduce slag disposal areas.

In this paper "Sustainable concrete for the construction industry" [3] Bala murughan et al (2013) His experimental investigation is mainly focused on the development of cost effective high strength concrete containing high volume fly ash. is a byproduct of coal fired electric power station. The current annual worldwide production of coal ash is estimated about 700 million tonne. Fly ash is a beneficial mineral admixture for concrete. It influences many properties of concrete in both fresh and hardened state concrete. Utilization of waste materials in cement and concrete industry reduces the environmental problems.

Due to increase in demand for cement, there is a need of alternate material. Since fly ash is pozzolanic in nature, it can act as partial replacement material for Portland cement. In this study, keeping the binder content as constant and replacing cement with fly ash up to 60% the mechanical behaviors such as compressive strength were studied. Concrete with higher percentage of fly ash (60%) attained compressive strength of 47.08 N/mm^2 and 50.50N/mm^2 at 28 and 90 days, respectively. Further the cost analysis was done for all the mixtures. C60 mixture concrete gives 22% savings of cost than conventional concrete

In this paper "Properties of cement mortar produced from mixed waste materials with pozzolanic characteristics" [4] Chi Lang yen et al,(2012) he discussed the waste materials, such as sewage sludge ash , coal combustion fly ash, and granulated blast furnace slag, were partial replacements for making cement mortar in this study. Experimental results revealed that with partial replacement of cement of up to 50% by combination of sewage sludge ash and fly ash. The compressive strength of the cement mortar at 28 and 56 days was 82.44% and 93.7% respectively. And also he discussed cement mortar with granulated blast furnace slag/sewage sludge ash replacement could generate more mono sulfa aluminates to fill capillary pores.

III. Methodology

The methodology adopted consists of both preliminary investigations and experimental investigations.

Preliminary investigations:

Cement: Cement is a basic binding material used in concrete and for all the construction works. In our project we used ordinary Portland cement. Ordinary Portland cement (OPC) is manufactured by using naturally occurring materials such as limestone chalk and marl argillaceous materials such as clay, shale and slate. In our project we used OPC 43 grade cement. The below table -1 shows the Oxide composition of OPC 43 grade cement.

Table 1: Oxide composition of Ordinary Portland Cement

Oxide	Percentage	Average
Lime, CaO	60-65	63
Silica, SiO_2	17-25	20
Alumina, Al_2O_3	3-8	6.3
Iron oxide, Fe_2O_3	0.5-6	3.6
Magnesia, MgO	0.5-4	2.4
Sulphur trioxide, SO_3	1-2	1.5
Alkalis i.e. soda and/or potash, $Na_2O + K_2O$	0.5-1.3	1.0

Fly ash: Fly ash is a solid material which is carried away from the burning in the flue gas during combustion. The properties of fly ash may vary considerably according to several factors such as the geographical origin of the source of fuel, conditions during combustion, and sampling position in the stack. Most fly ash particles are in the silt-sized range of 2-50 µm. The three major mineralogical matrices identified in fly ash are glass, mullite-quartz, and magnetic spinal. The major elemental constituents of fly ash are Si, Al, Fe, Ca, C, Mg, K, Na, S, Ti, P, and Mn. Nearly all naturally occurring elements can be found in fly ash in trace quantities. Certain trace elements, including As, Mo, Se, Cd, and Zn, are primarily associated with particle surfaces. The fineness of fly ash is an important factor because it affects the rate of pozzolanic activity and the workability of the concrete. Using fly ash with small and spherical shape in mortar or concrete will reduce water demand of the mixtures.

Figure: 1 Fly ash

Fly ash for the project was obtained from the Raichur Thermal power plant located in Raichur industrial area where coal is used as fuel sources for the boilers. The compositions of the fly ash are shown in the table-2.

Table 2: Chemical composition of fly ash

Composition	% by weight
SiO_2	40
Al_2O_3	18.8
Fe_2O_3	11.8
Ca_O	12.7
MgO	2.4
Na_2O	1.4
K_2O	2.8

Sewage Sludge Ash (SSA): Sewage sludge results from the accumulation of solids from the unit processes of chemical coagulation, flocculation and sedimentation during wastewater treatment. It is a complex and variable mixture of organic and inorganic substances in aqueous suspension and solution, and may contain viable pathogens and parasites as well as a variety of potentially toxic elements and compounds. Sewage sludge ash is the by-product produced during the combustion of dewatered sewage sludge in an incinerator. Sewage sludge ash is primarily a silty material with some sand-size particles. The specific size range and properties of the sludge ash depend to a great extent on the type of incineration system and the chemical additives introduced in the wastewater treatment process. The composition of SSA is shown in the table 3.

Figure 2: Sewage sludge ash

Table 3: Chemical composition of SSA

Composition	% by weight
SiO2	44.89
Al2O3	11.62
Fe2O3	6.81
CaO	6.49
MgO	0.1
Na2O	0.04
K2O	2.93
P2O5	18.68
SO3	2.8

Quarry dust: It is a by-product obtained in the quarry. It is a waste material in the quarry industry but it can be used as one of constituent for concrete by replacing the sand. Quarry dust which was used in the brick manufacturing industry was used for our project.

Figure 3: Quarry dust.

Aggregates: aggregates are mainly considered as a filler material to increase the strength of the concrete. About 70-75% of concrete consists of both fine and coarse aggregate. Fine aggregate we collected from locally. Fine aggregate of 4.75mm down size are used in concrete. Similarly coarse aggregate of 20mm nominal size is used in concrete.

Water: water is essentially required in concrete for complete chemical hydration of cement in concrete. Water used in concrete should be free from suspended solids, alkali, organic impurities etc., and it should be equal to drinking water quality standards or else it directly affects on the strength of concrete. in our project we prepared a concrete with portable drinking water.

Experimental Investigations:

Preparation of Specimen: Totally 72 concrete cubes are prepared by replacing cement by fly ash and sewage sludge ash in increasing percentage at . Concrete is prepared and casted in standard concrete mould of size 150*150mm. freshly prepared concrete cubes are kept in room temperature for 24 hours for the complete hydration process. There after cubes are demoulded and submerged in water bath for curing. Prepared concrete cubes are cured at an age of 3days, 7days and 28days. The below table -7 shows the quantity of materials used for 3 cubes of concrete block.

Table 4: Quantity of materials used for 3 cubes of concrete block

% of replacement	Cement (kg)	Quarry dust (kg)	Aggregate (kg)	Fly ash (kg)	SSA (kg)
0	4.633	6.286	12.668	-----	-----
5	4.401	6.286	12.668	0.116	0.116
10	4.169	6.286	12.668	0.231	0.231
15	3.938	6.286	12.668	0.347	0.347
20	3.706	6.286	12.668	0.463	0.463
25	3.474	6.286	12.668	0.579	0.579

30	3.240	6.286	12.668	0.694	0.694
35	3.010	6.286	12.668	0.810	0.810

Figure: 4 Concrete moulds while casting.

Figure: 5 Mortar in the moulds after casting

Mix proportioning: Concrete is prepared for M-20 grade mix design. Mix proportioning by weight are used.
Testing Specimens: Concrete is prepared for M-20 grade and cured for 3days, 7days and 28 days. After the successful curing of concrete all prepared specimens are tested in compression testing machine by applying compressive load. Compressive load is applied on concrete cubes until the failure of prepared specimen. Compressive strength of the prepared concrete cube is calculated by using the formulae, compressive strength = Maximum compressive breaking load / area of concrete cube. Table-4 shows the compression test results of concrete at 7days and 28days.

Table 5: compressive strength test results for concrete cubes @ 3days

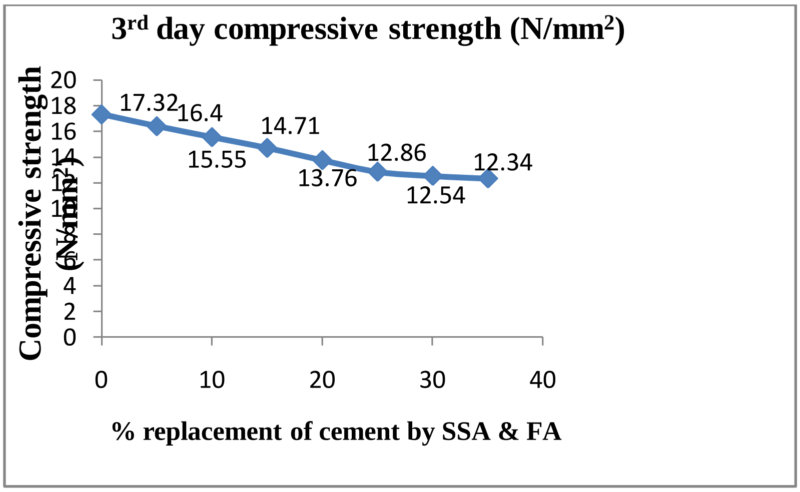
% of replacement	Avg. area (mm^2)	Avg. load applied (kN)	Compressive strength in N/mm^2
0	22500	389.9	17.329
5	22500	369.045	16.402
10	22500	349.875	15.550
15	22500	331.117	14.719
20	22500	309.62	13.761
25	22500	289.44	12.864
30	22500	282.195	12.542
35	22500	277.852	12.349

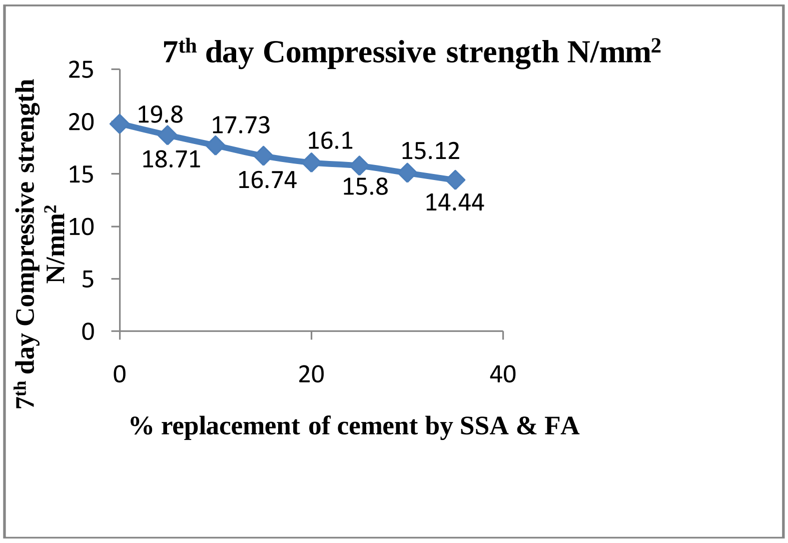
Table 6: compressive strength test results for concrete cubes @ 7 days

% of replacement	Avg. area (mm^2)	Avg. load applied (kN)	Compressive strength in N/mm^2
0	22500	445.52	19.801
5	22500	421.087	18.715
10	22500	399.015	17.734
15	22500	376.762	16.745
20	22500	362.362	16.105
25	22500	355.612	15.805
30	22500	340.222	15.121
35	22500	325.012	14.445

Table 7: compressive strength test results for concrete cubes @ 28 days

% of replacement	Avg. area (mm^2)	Avg. load applied (kN)	Compressive strength in N/mm^2
0	22500	575.775	25.59
5	22500	558.472	24.821
10	22500	544.72	24.210
15	22500	534.600	23.76
20	22500	520.965	23.154
25	22500	509.872	22.461
30	22500	453.847	20.170
35	22500	425.362	18.905





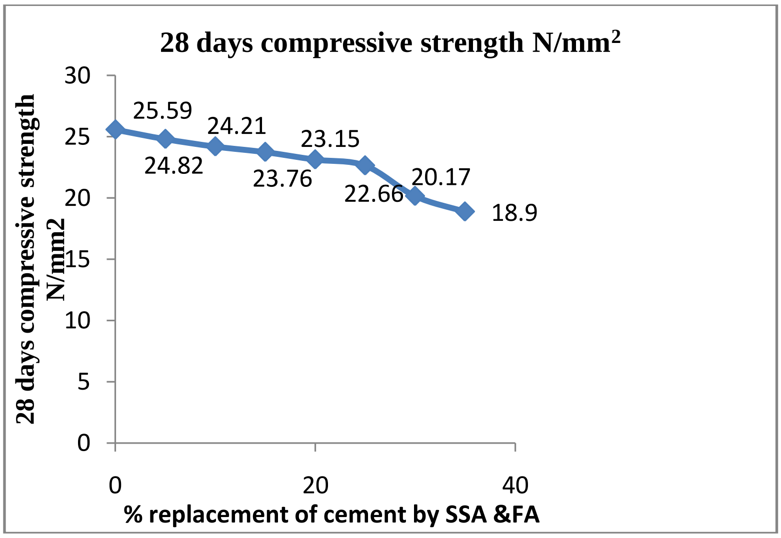


Figure 6: compressive strength of concrete at 3, 7 and 28 days

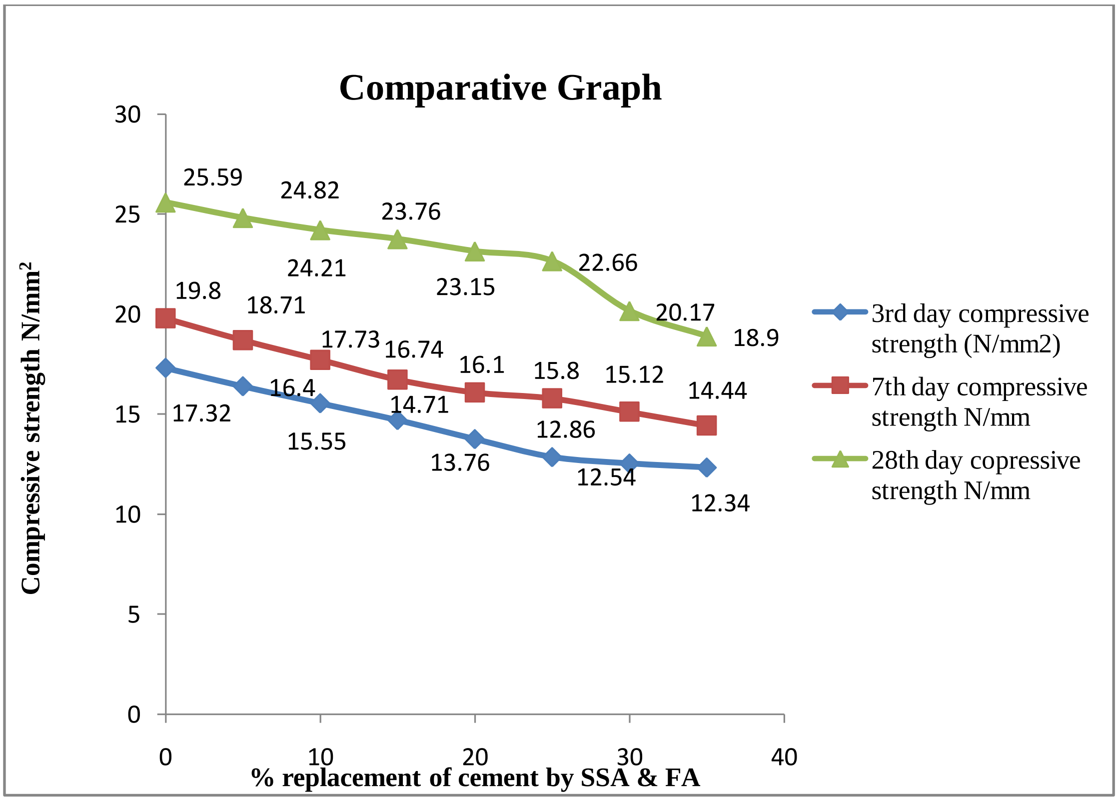


Figure 7: comparative graph showing variation of compressive strength with percentage of replacement for 3rd, 7th and 28th day of curing for concrete compressive strength of concrete at 3, 7 and 28 days

IV. Conclusions

The following conclusions can be drawn from the results discussed above.

- 5-30% replacement showed good compressive strength when compared to 35% replacement, and hence were considered for the preparation of concrete blocks.
  of cement as determined by the mortar results.
- Compression testing results showed optimum replacement at 30%.
- The best possible extent up to which cement can be replaced by a combination of sewage sludge ash and fly ash was found to be 30%. The compression strength at 30% replacement for M-20 design was found to be lesser than 20N/mm^2. Hence, the concrete so formed can be used only for non-structural purposes.
- From this replacement we can conclude that carbon content in cement can be reduced to some extent

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