AIRO JOURNALS

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Peer Reviewed
Multidisciplinary
International

ISSN: 2320-3714
Volume: 4 Issue:3
December 2021
Impact Factor: 5.7
Subject Engineering

An Investigation on Mechanical Properties of Mortar made with Cement Sludge Mixture

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Abstract

The goal of this study is to provide a simple way for partially replacing cement with sludge ash. Sludge disposal has an environmental impact since it may contain diseases, heavy metals, and excess phosphorus and nitrogen. The sludge from the waste water treatment plant is burned. The retained sludge ash is partially replaced with cement in mortar at varied proportions (5, 10, and 13%), and the behaviour of the mortar is investigated. The curing strength of the casted specimens is tested for 7 days and 28 days according to Bureau of Indian Standards (BIS) specification codes. The sludge mortar's mechanical properties, such as compressive strength, tensile strength, and flexural strength, are determined. The difference in strength, flexure, and tension obtained from the foregoing method is compared to the nominal mortar.

Keywords: Sludge ash, casting, curing, compression test.

1. Introduction

Sludge from waste water treatment plants is one of the main reasons for the lack of land available for disposal. Water treatment plants are the most important for each company. It is unavoidable and necessary for the therapy process. It entails handling a huge volume of waste water from manual disposal and results in both dry and moist sludge. However, part of the sludge is placed in an artificial landfill, while others are dumped in the open, contaminating surface and ground water.

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Sludge (dry condition) is collected from Coimbatore's waste water treatment plant. The dry sludge contains random and non-uniform particles of varying sizes. Crushing equipment such as a drop weight hammer, jaw crusher, roll crusher, and ball mill are used in the process of breaking large sized particle sludge. The grounding of the particles into smaller sizes makes the burning process easier and faster. The dry sludge particles are manually sorted, and the larger particles are crushed with a drop weight hammer at a rate of 15 strikes per minute. The crushed particles are subsequently pulverised in a jaw and roll crusher before being put into a ball mill, which produces finer particles. The finer particles are then either burned in an open place or put into a mould and burned in saengalsoolai with the bricks. The particles become ashes, which are sieved via a 90 micron sieve plate, with the passing particles being partially replenished in the mortar's cement content.

2. Literature Review

The properties of paper sludge were examined by Prof. Jayeshkwnar Pitroda et al. (2013). When cement is used instead of paper sludge, the compressive strength is reduced. Compressive strength and split strength diminish as the percentage of paper sludge increases. The use of paper sludge in mortar can reduce disposal expenses for the paper industry while also producing a "greener" mortar for building. This study concludes that paper sludge can be a novel supplemental cementitious construction material, but engineers must make careful judgments. Sajad Ahmad et al. (2013) conducted research on mortars that used waste paper sludge ash as a partial replacement for cement. They found that replacing 5% of the cement with waste paper sludge ash resulted in a 10% improvement in compressive strength after 7 days and a 15% increase after 28 days. With increasing waste paper sludge ash content, splitting tensile strength drops and is greater than reference mortar at 5% replacement. Because it is a non-useful waste and is free, using waste paper sludge ash in mortar can be cost effective.

Abdullah Shahbaz et al. (2014) examined the structural performance of mortar by partially replacing cement with paper sludge (paper waste) and came to the following conclusion. The split tensile strength of M20 and M30 grade mortars is observed. When 10% of hypo sludge is replaced with cement, the strength of the mortar increases, and when 20% of hypo sludge is replaced with cement, the strength increases somewhat more or is equivalent, but when 30% is replaced, the strength begins to decrease. It has been discovered that when 10% of hypo sludge is replaced with cement, the flexural strength of M20 and M30 grade mortar increases, and when 20% of hypo sludge is replaced with cement, the strength increases slightly or is equivalent, but when 30% is replaced, the strength begins to decrease.

Yousuf (2014) conducted an experimental study on the long-term use of paper wastes (hypo sludge) in mortar mix design and found the following results: When cement replaces paper sludge, compressive strength increases initially as the amount is gradually increased from 0% to 15%. After 15% cement replacement, compressive strength and split strength decline as the proportion of paper sludge increases. The use of paper sludge in mortar can help the paper industry save money by lowering disposal costs and creating a "greener" mortar for building. A1,2013) (Sajad Ahmad et al.) This study

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concludes that paper sludge can be a novel supplemental cementitious construction material, but engineers must make careful judgments.

Paper waste in cement mortar was researched experimentally by Lodhi Ravindra Singh et al. in 2015. When compared to a control mix, mortar mixes containing 10% and 15% paper waste increased compressive strength by 3.0 percent and 1.4 percent, respectively, but adding 20% of paper waste decreased compressive strength by 1.9 percent. MehtabAlam et al. (2015) studied the usage of paper sludge in cement mortar in an experimental investigation. Experiments show that the slump lessens as the percentage of Paper sludge in the mix increases.

Many researchers and academics have conducted studies with various types of sludge waste from various industries. Some of the information was gathered from the articles listed below.

S. Arulkesavan investigated the use of textile water in mortar by examining its durability features. The effluent was examined at various stages, including raw effluent, anaerobic process outlet, and tertiary treatment outlet, with positive findings.

D. Vouk used sewage sludge ash to make cement mortars (SSA).The addition of supplementary cementitious material (SSA) to mortar mixes increases water consumption while lowering workability, compressive strength, and density. Because SSA varies significantly, its use in cementitious materials must be carefully monitored.

Doh ShuIng used sewage sludge ash as a partial replacement in mortar. After a series of tests, the findings of sludge, sludge ash, and cement were compared. When SSA replaces cement in mortar by 5%, the compressive strength of the mortar increases by 10% and the water absorption decreases by 10% when compared to normal samples.

When varied percentages of dry or wet sludge were employed in cement weights, GhadaMourtada Rabie discovered that the major strength loss was null. Wet sludge and dry sludge have approximate strengths of 13.76 percent and 7.73 percent, respectively, indicating that the former has a greater negative impact on compressive strength and strength development than the latter.

Sewage Sludge Ash was used to replace the cement and fine aggregate by ThevaneyanKrishta David. The compressive strength and density of mortar were determined. Ordinary Portland cement has certain Pozzolanic characteristics that are similar to Sewage Sludge Ash. The SSA will be pulverised and utilised as a cement substitute in a ball mill. The study found that when SSA is substituted with cement in 10% of the mortar, the compressive strength remains the same.

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3. Mechanical Properties

- **Compressive strength**

The compressive strength of mortar varies. However, the goal of this research is to raise the usual compressive strength values. IS516 was followed by the use of 150x150x150 mm cubes. A total of 45 cubes were cast for various percentages and stored for 7 days, 14 days, and 28 days of curing.

For the test, 150mm mortar cubes are cast. 7 days, 14 days, and 28 days are used to cure the cubes. Specimens are dried to a consistent mass in an oven at 100°C, then immersed in water once they have cooled to room temperature. The specimens are weighed during the tests.

- **Rapid Chloride Penetration Test**

The RCPT test is used to determine the electrical conductivity of mortar. The resistance of mortar to fluids that can cause corrosion determines its durability. The ability of mortar to enable fluids to travel through it is defined by RCPT. Slices of 100mm diameter x 50mm thickness were cut from 100 x 200mm cylinders for this test. Cylinders were cast and stored for 28 days to cure. The ASTM C-1202 test involved generating sodium hydroxide (0.3N) in the positive terminal and sodium chloride (3N) in the negative terminal of a diffusion cell.

4. Material Properties

- **Cement**

The following are the features of Ordinary Portland Cement (OPC) Grade 53, which is readily available locally.

Specific gravity, fineness test, initial setting time, standard consistency, and final setting time are all properties of cement. 3.15, 32 percent, 4 percent, 32 minutes, and 9 hours 20 minutes were found to have their comparable values.

- **Sludge ash**

The chemical characteristics of ETP sludge are shown below. The sludge, on the other hand, is burned as a replacement.

Sulphate and chloride concentrations in the sludge were found to be 1045 mg/l and 5012 mg/l, respectively. The sludge's specific gravity was found to be 2.45, with total hardness and water content of 750 mg/l and 22%, respectively, and a pH of 13. The percentages of some volatile solids were incorrect.

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Figure.1:Sludge Ash

- **Coarse aggregate**

The coarse aggregate in the mortar is 20 mm stone aggregate that can be found locally.

The coarse aggregate's fineness modulus was discovered to be 5.5.The specific gravity was 2.8 and the water absorption was 1.5 percent.

- **Fine aggregate**

Fine aggregate is made from locally available M-sand that passes through a sieve size of 4.75 mm. M-sand has the following characteristics.

Fineness modulus, specific gravity, and water absorption were the parameters of FA investigated in this project, and the corresponding values obtained from the tests were 2.34, 2.77, and 2.3 percent, respectively.

- **Water**

The mixing and curing of mortar are both done using ordinary portable water. The mortar is made with a W/C (Water-Cement Ratio) of 0.45. The pH level of the water is 6.7.

- **Course Aggregate:**

Coarse aggregate is defined as aggregate with a size more than 4.75mm and is one of the most essential ingredients in mortar. It gives the mortar strength and accounts for 70 to 75 percent of the total volume of the mortar. Crushed stone is a coarse aggregate that is black in colour, angular, and called locally as "gitti" or "black metal." A locally accessible coarse aggregate from a quarry was employed in this investigation. The table below shows the specific gravity of coarse aggregate.

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5. Mix Proportion

The M20 grade mix design complies with the mortar mix IS 10262: 2009 requirements.

Table.1 Mix Proportion - M20

S. No	Materials	Quantity (kg/m^3)
1	Cement	438
2	Fine aggregate	657.02
3	Coarse aggregate	1179.17
4	Water	197
5	Water-Cement ratio	0.45

Hence, the mix ratio of mortar obtained is 1: 1.5: 2.69.

- **Epoxy**

Because of its strong compressive and tensile strengths, as well as outstanding adhesive characteristics, epoxy resin has found a place in mortar construction. In recent years, the majority of applications have been in mending damaged or deteriorating building by bonding mortar to mortar. As a result, research and applications have focused on its adhesive characteristics.

6. Experimental Investigation

- **Compressive strength testing**

After 7, 28, days of curing, the compressive strength of standard size 150 mm x 150 mm x 150 mm cubes is evaluated. Three experimental cube mixes were used to determine the mortar's strength. The coarse aggregate and fine aggregate are mixed first, and then cement and sludge ash are added in quantities of 5%, 10%, and 13%, respectively. Water is added to the mixture and thoroughly stirred. The mortar is then poured in three layers into the cubes, tampered with a 12 mm tamping rod, and compacted thoroughly. The cubes are removed from the mould and cured. After the curing period, the cubes are removed and tested for compressive strength. The load is increased until the failure point is achieved.

Compressive strength of the specimen is calculated by,

$$f_{ck} = P/A$$

Where, f_{ck} = Compressive strength (N/mm2) P = Ultimate load (N) A = Loaded Area (mm2)

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Figure.2: Compressive strength of mortar

- **Split tensile strength testing**

The split tensile strength of standard size 150 mm x 300 mm cylinders is investigated. The maximum compressive strength obtained from the aforementioned value is used to cast three trial mixes. After that, the casted cylinders are demolded and cured for 28 days. After the dampness on the specimen has been wiped away, the specimen will be tested. The cylinder is attached between the lower and higher plates of the compressive testing equipment. The load is applied to the specimen until it breaks. The specimen's split tensile strength is noted by,

T = 0.637 x k x (P/S)

Where,

T = Tensile splitting strength (N/mm2)

K = 1.3-30 x (0.18-t/1000)2

P = failure load (N)

S = area of failure (mm)

S = l x t

l = length of failure (mm)

t = thickness of failure plane (mm)

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- **Flexural strength testing**

The flexural strength test is performed on a standard size prism of 500 mm × 100 mm x 100 mm. The specimen is cast after testing three trial mixes with the highest compressive strength value. The curing process takes 28 days. The prism is inserted into the universal testing machine, and the load is applied until the specimen fails.

The flexural strength of the specimen is calculated by using,

$$f_b = pl / bd^2$$

Where,

p = maximum load (Kg)

l = supported length (cm)

b = width of the specimen (cm)

d = failure point depth (cm)

Figure.3:Flexural strength of mortar

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- **Tests on Coarse Aggregate**

According to IS-2386:1963, Sieve Analysis, the following experiments were carried out to determine the parameters of coarse aggregate.

- **Fresh Mortar Tests:**
- **Workability Test:**

There is no single test that can accurately assess workability. There are, however, a variety of approaches for determining specific physical parameters that attempt to correlate workability to some extent. None of these methods are completely satisfactory, but they do provide useful guidance on various aspects of workability within limited parameters. Because the workability of mortar is so crucial in the control of hardened mortar, measuring and managing it is critical. The methods for determining workability are listed below. Test for slump

Figure.4:Slump Cone Test

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1. Compaction Factor

2. Vee bee Consistometer

- **Hardened Mortar Tests**

✓ **Moulds Prepared**

Figure.5 Cube, Cylinder & Beam Casted Element

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7. Results and Discussions

Table.2 Average compressive strength

Mix	% of sludge	Average compressive strength (MPa)	
		7 days	28 days
M1	0	21.3	29.4
M2	5	20.9	28.2
M3	10	18.5	27.6
M4	13	16.4	23.4

Table.3 Average Tensile strength

Mix	% of sludge	Average Tensile strength for 28 days (MPa)	
		7 days	28 days
M1	0	12.1	14
M2	5	11.8	13.2
M3	10	9.7	10.2
M4	13	7.6	9.5

Table.4 Average flexural strength

Mix	% of sludge	Average Flexural strength for 28 days (MPa)	
		7 days	28 days
M1	0	3.1	3.5
M2	5	2.95	3.12
M3	10	2.7	2.88
M4	13	2.63	2.79

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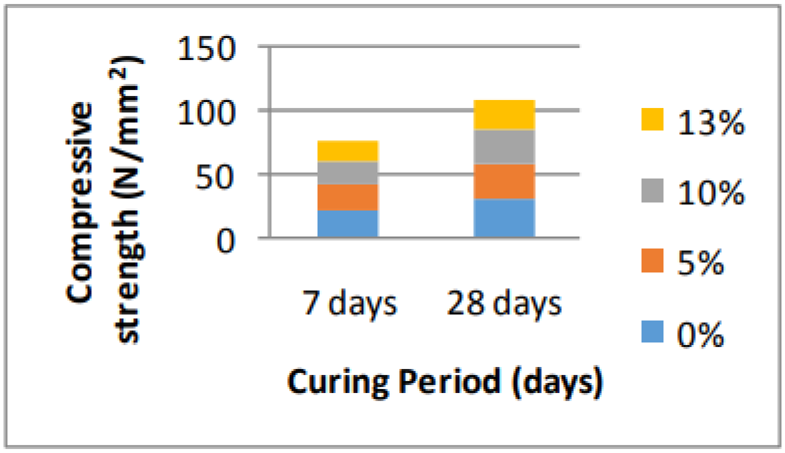

Figure.5 Comparison chart for compressive strength of mortar cubes

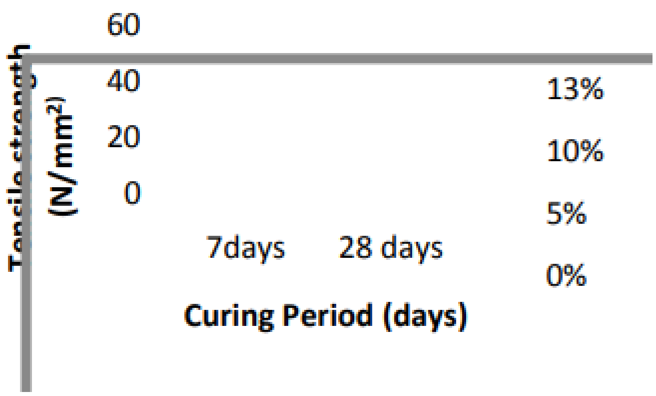

Figure.6 Comparison chart for tensile strength of mortar cylinders

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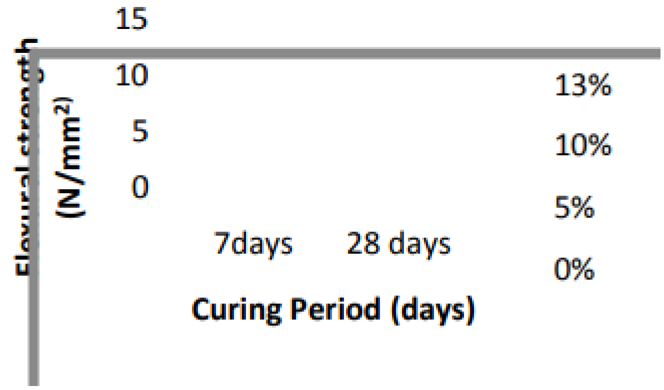

Figure.7 Comparison chart for flexural strength of mortar prism

8. Conclusion

This investigation compares the performance of traditional mortar versus sludge ash-replaced mortar. The strengths (compressive, tensile, and flexural) are investigated, and the graphical depiction shows the highest strength. For 5 percent, 10 percent, and 13 percent replacement, the percentage variance between the compressive strength of conventional mortar and sludge ash mortar for 7 days is 1.88 percent, 13.15 percent, 23.01 percent, and for 28 days it is 4.09 percent, 6.12 percent, 20.41 percent. For 7 days, the percentage variance between the tensile strength of conventional mortar and sludge ash mortar is 2.48 percent, 19.9%, 37.2 percent, and for 28 days, the percentage variation is 5.8 percent, 27.16 percent, 37.15 percent for 5 percent, 10%, and 13 percent replacement, respectively. For 5 percent, 10 percent, and 13 percent replacement, the percentage variance between the flexural strength of conventional mortar and sludge ash mortar for 7 days is 4.84 percent, 12.91 percent, 15.17 percent, and for 28 days is 10.86 percent, 17.72 percent, 20.29 percent. The percentage variation between the strength of conventional mortar and sludge ash mortar is less for a 5% replacement, and the variation increases as the percentage replacement with sludge ash increases, as shown in the above study findings.

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