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ALUM SLUDGE - A PARTIAL REPLACEMENT TO CEMENT IN CONCRETE

Suchand B[1], Saritha Sasindran[2], Dr. Leena A V [3]

[1]PG Student, Department of Civil Engineering, Sree Narayana Guru College of Engineering & Technology, Payyanur, Kerala, India-670307
[2]Assistant Professor, Department of Civil Engineering, Sree Narayana Guru College of Engineering & Technology, Payyanur, Kerala, India-670307
[3]Associate Professor, Department of Civil Engineering, Sree Narayana Guru College of Engineering & Technology, Payyanur, Kerala, India-670307

Abstract - *A method to use sludge waste from water treatment plant and to reduce the environmental pollution by it has initiated the studies on possibility of integrating this waste in concrete production. The aim of this research work is to use alum sludge powder as a partial replacement of cement in concrete. In this research study an experimental investigation was conducted on varying percentages of (0%, 5%, 10%, 15%, and 20%) alum sludge powder as cement replacement for M20 grade of concrete to produce alum sludge concrete. Different tests were conducted to find the properties of materials used in concrete. Properties of concrete were obtained by strength test and durability test. The optimum percentage of replacement of alum sludge powder as cement in M20 grade of concrete was obtained as 15%. The results of the research work show that alum sludge powder is an effective alternative for partial replacement of cement in concrete, which also results in a good method of using this waste material in concrete.*

***Key Words*: Concrete, Alum sludge, Strength test, Durability.**

1. INTRODUCTION

Among all other materials, concrete is the most widely used in construction industry. From a small residential building to large infrastructure projects like dams, tunnels, multi storey buildings etc, concrete is being used. Being a multipurpose material, it is difficult to replace concrete with other construction materials. The main ingredients used for concrete production are cement, fine aggregates, coarse aggregates and water. Each and every material in concrete has its important role in overall performance of concrete. During the production of cement, our natural resources are being consumed and CO_2 is emitted in to the atmosphere. The heat of hydration also leads to increase in temperature of environment and this heat is also responsible for cracks in a structure after hardening of concrete. So there is a need to find some alternative material to reduce the production of cement and its use in concrete.

The sludge generated in water treatment plants consists of organic and inorganic compounds in solid, liquid, and gaseous states, and varies in terms of physical, chemical, and biologic characteristics. The remaining volumes that are wasted depend on the characteristics of the operational units involved and the quality of the raw water. Several chemicals have been used for water treatment, some of them include aluminum salts (Al_2 $(SO_4)_3.18H_2O$), ferric ion salts (such as $FeCl_3.6H_2O$), and ferrous iron salts (such as $FeCl_2$, $FeSO_4.7H_2O$). The addition of these chemical substances during water treatment may result in iron- or aluminum-rich sludge. These salts may be present in high concentrations that can be toxic to aquatic biota. To avoid this toxicity, the salts should be properly treated before disposal. Sludge from water treatment plants may also contain other heavy metals from raw water or from contaminants resulting from the addition of coagulants. All the chemicals mentioned above are harmful to the environment if it is not properly disposed. So using the sludge waste as a partial replacement for cement in concrete is a good idea for reusing the waste material.

In this research work alum sludge powder was used as a partial replacement for cement in concrete. Alum sludge (AS) is actually a by-product of water treatment plants that use aluminum salts as a primary coagulant, and is the most widely generated water treatment residual/sludge worldwide. It usually contains colloidal alum hydroxides which are often amorphous species. Aluminum sulfate (Al_2SO_4. $18H_2O$) is the most commonly used coagulant in drinking water treatment plants and as a result, tons of aluminum hydroxide containing sludge is unsafely disposed into the open environment daily. Alum sludge as waste materials are commonly sent to landfill.

Fig -1: (a)Alum sludge cakes (b)Ground alum sludge

2. OBJECTIVES AND SCOPE OF STUDY

- To utilize alum sludge powder in concrete
- To investigate the material properties and strength properties of concrete by using alum sludge powder as partial replacement to cement.
- To obtain the optimum percentage of replacement of cement with alum sludge powder in concrete. The percentage of replacement of alum sludge powder adopted were 0%, 5%, 10%, 15% and 20%.
- To compare the durability of alum sludge concrete and control mix.

3. METHODOLOGY

The analysis of test results and methodology adopted are as follows

- Selection of materials
- Testing of materials
- Concrete mix design
- Preparation of test specimen
- Testing of properties of hardened concrete such as compressive strength test, split tensile strength test and flexural strength test
- Durability test
- Conclusion

4. MATERIALS AND TESTS

Materials used in concrete specimen preparation were cement, fine aggregate(M sand), coarse aggregate and water. For experimental work cement was replaced with various percentage of alum sludge powder. Reinforcement bars used in the beam specimen in each mix was Fe 415. To analyze material properties various tests were conducted on cement, fine aggregate (M sand), coarse aggregate and alum sludge powder. Properties of all these above materials were tested and analyzed. The results are shown in the table 1 ,table 2, table 3, table 4 and table 5. Water used for mixing and curing was clean and free from Oils, Acids, Alkalis, Salts, Sugar and Organic materials. Potable water was used.

Table -1: Properties of cement

Properties	Values obtained
Fineness	1%
Specific Gravity	2.93
Consistency	30%
Initial Setting Time	75 Minutes
Final Setting Time	255 Minutes

Table -2: Properties of fine aggregate

Properties	Values obtained
Fineness Modulus	3.9
Specific Gravity	2.5
Grading Zone	II

Table -3: Properties of coarse aggregate

Properties	Values obtained
Fineness Modulus	5.9
Specific Gravity	2.8
Grading Zone	II

Table -4: Physical properties of alum sludge powder

Properties	Values obtained
Fineness	2%
Specific Gravity	2.8
pH	4.35
Moisture	<30%
Ash	66.67%

Table -5: Chemical properties of alum sludge powder

Chemicals	Percentage
SiO_2	42.38
Al_2O_3	35.03
Fe_2O_3	4.94
CaO	0.13
MgO	0.29
SO_3	0.14
Na_2O	0.10
K_2O	1.87
P_2O_5	0.26
LOI	11.5

5. DESIGN MIX

The mix design of concrete is done based on properties of cement, fine aggregate, coarse aggregate and water. The mix proportion for concrete is obtained as 1: 1.86: 3.31 and water cement ratio was 0.55

6. EXPERIMENTAL INVESTIGATION

Experimental investigations have been conducted on concrete specimens in which cement was partially replaced with alum sludge powder at various percentages. The tests were conducted to determine the properties of hardened concrete.

6.1 Compressive Strength Test

Compressive strength is defined as the load which causes the failure of standard specimen divided by area of cross section in uni-axial compression under given rate of loading. Compressive strength test was conducted on cubes for different percentage of replacement (0%, 5%, 10%, 15%, and 20%) and average of 6 results obtained from 6 identical cubes for each percentage of replacement was reported.

6.2 Split Tensile Strength Test

Concrete is brittle in nature because of its low tensile strength**.** It is not capable to take direct tension. So concrete is strong in resisting compressive force and weak in resisting tensile force. Tensile strength of concrete is determined indirectly by conducting splitting tensile strength test.

6.3 Flexural Strength Test

Flexural strength of concrete is the ability to resist deformation under loading. Flexural strength of the specimen was expressed as the modulus of rupture. It is the maximum tensile stress acting on the bottom of the testing beam. Flexural strength reported is the average of 3 results obtained from 3 identical beams.

6.4 Durability Test

Durability of concrete is referred as the capability of concrete to resist the chemical attack, weathering action, or any other action which destroy its condition. The main chemicals and reactions which effect the durability of concrete is chloride attack, sulphate attack, and alkali aggregate reaction. Durability of concrete replaced with alum sludge powder is tested based on acid attack test (sulphate attack).

7. RESULTS AND DISCUSSION

7.1 Compressive Strength Test

The average compressive strength obtained for each percentage of replacement by testing six concrete cube specimens on 28th day of curing is shown in table 6. Chart 1 shows the rectangular graph of variation of compressive strength with increase in percentage of replacement.

Table -6: Average compressive strength results

Percentage of Replacement	Average Compressive Strength (MPa)
0%	25.6
5%	24.4
10%	23.1
15%	21.7
20%	15.1

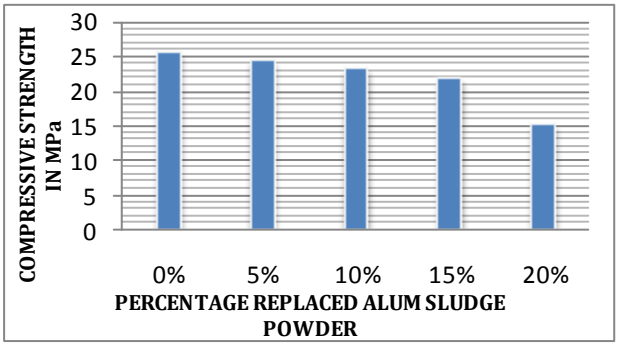

Chart -1: Rectangular graph of variation in compressive strength with increase in percentage of replacement

Fig -2: (a) Compressive strength test and (b) Cracked cube after compressive strength test

7.2 Split Tensile Strength Test

Three cylindrical specimens were casted for each percentage of replacement and cured for 28 days for conducting split tensile strength test. The cylindrical specimen was subjected to a compressive force on the loading area and a uniform tensile stress along the length of cylindrical specimen. The average split tensile strength obtained for each percentage of replacement on 28th day of curing are shown in Table 7. The rectangular graph of variation of split tensile strength with increase in percentage of replacement is shown in chart 2.

Table -7: Average split tensile strength results

Percentage of Replacement	Split Tensile Strength (MPa)
0%	3.1
5%	2.8
10%	2.65
15%	2.57
20%	2.3

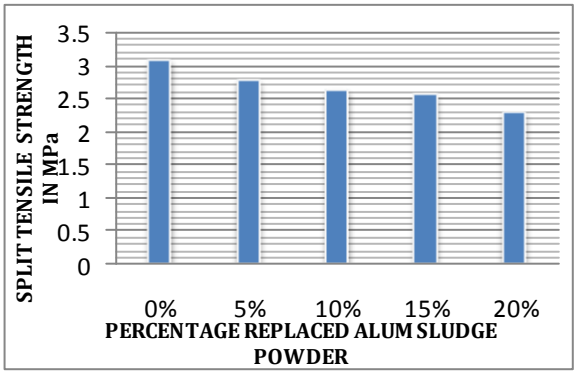

Chart -2: Rectangular graph of variation in split tensile strength with increase in percentage of replacement

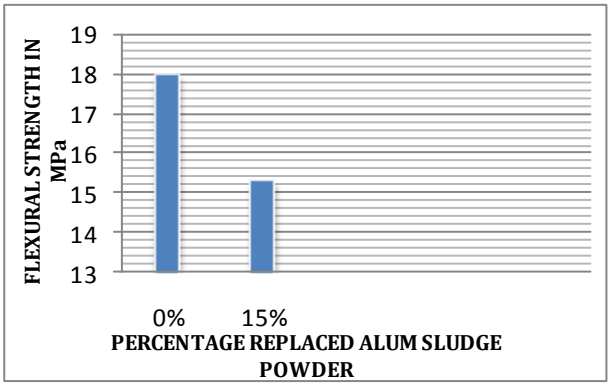

Chart -3: Rectangular graph of variation in flexural strength with increase in percentage of replacement

Fig -3: (a) Split tensile strength test and (b) Cracked cylinder after split tensile strength test

Fig -4: (a) Flexural strength test and (b) Cracked beam during flexural strength test

7.3 Flexural Strength Test

Flexural strength reported is the average of three results obtained from three identical beams. The beam placed for flexural strength test in Universal Testing Machine (UTM). The average flexural strength obtained for each percentage of replacement specimens on 56 th day of curing are as shown in table 8. The rectangular graph of variation of flexural strength with increase in percentage of replacement is shown in chart 3.

Table -8: Average flexural strength results

Percentage of Replacement	Flexural Strength (MPa)
0%	17.97
15%	15.3

7.4 Durability Test

The percentage weight loss obtained for acid attack test for various percentage of replacement of cement with alum sludge powder are given in table 9 Cubes of standard size are prepared for each percentage of replacement and cured for 7 days .It was kept in atmosphere for 2 days and weighed. Then cubes are kept in 5% sulphuric acid for 60 day. Again kept in atmosphere for 2 days and weighed to find percentage weight loss. Fig. 5 shows the cubes placed for acid attack test.

Table -9: Durability test results

Percentage of replacement	Percentage weight loss
0%	4.46 %
15%	5.7 %

Fig -5: Durability test

* For flexural strength test and durability test, only 0% replacement and optimum percentage(15%) replacement specimens were used, and also the variation in flexural strength value is because of the delay in testing due to lockdown (covid-19).

8. CONCLUSIONS

Based on the results and observations of experimental work conducted, the following conclusions were drawn:

- Replacing cement in concrete using alum sludge powder is an effective way of utilizing this chemical and thereby reducing the pollution.
- Test result shows that physical and chemical properties of alum sludge is enough for naming it a binding material.
- The compressive strength showed only a small variation by the replacement of cement by alum sludge powder and the maximum percentage of replacement was found to be 15%.
- The split tensile strength also showed only a small variation by the replacement of cement by alum sludge powder and the maximum percentage of replacement was found to be 15%
- Optimum percentage of replacement was found to be 15%.
- The flexural strength value of alum sludge concrete for 15% replacement is comparable with control mix concrete.
- The difference in percentage weight loss of control mix and alum sludge concrete is less than 2%. So replacing cement by alum sludge powder gave a durable concrete.

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