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MECHANICAL PROPERTIES AND DURABILITY STUDIES ON SLUDGE USE IN CONCRETE AS A REPLACEMENT OF CEMENT

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Abstract - Sludge is an unavoidable product of wastewater treatment that creates problems of disposal. Increasingly, strict environmental control regulations have resulted in limitations on sludge disposal options. Disposal by incineration has been found to be a good option. In this research, application of waste sludge was collected from sewage treatment plant (STP) Nashik was used as cement replacement in concrete mix. This study utilized replacement of 5%, 10 %, 15 % and 20% by weight of OPC with water binder (w/c) ratio of 0.50 and 0.45 for Grade 20 and Grade 30 respectively. The performance of sludge concrete in terms of its compressive strength, split tensile strength test, flexure strength test was investigated. All values of compressive strength for sludge concrete were lower compared to the OPC control, and the strength decreased as the percentage of replacement with sludge increased for Grade 20 and Grade 30, at replacement of 10 %. Meanwhile, water absorption and water permeability for the sludge concrete increased as the replacement increased. Overall, with further research in producing quality, the potential of using this waste as a cement replacement material is very promising.

Keywords: Coarse Aggregate, Compressive Strength, Fine Aggregate, Flexure strength, Waste Sludge

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 Nashik, can be used for concrete production as cement. This sludge already has disposal problem and it can be solved by reusing the same for construction work. This resource are about to test with different percentage of replacement. This may drastically reduce the sludge content and even the cost of concrete. Disposal of human sewage has become a necessity for societies, today. The construction of treatment plants has caused problems with huge contents of dry sludge. It has been found that each person produces 35 to 85 grams of solid sludge per day.

Sludge is a product which is obtained during the treatment of waste water. The characteristic of sludge differs upon the region and the method of treatment. Sludge is formed after undergoing various steps such as stabilization, composting, anaerobic digestion, thickening, dewatering and drying. This sludge 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

ISSN: 0474-9030
Vol-68-Issue-1
January-2020

handling procedure and non-entry to the land following application is observed. Re-use of composted sludge as a soil conditioner in agriculture and horticulture returns carbon, nitrogen, phosphorus and elements essential for plant growth back 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 helm in the eggs and from horticultural produce contaminated by pathogens. 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.

2. LITERATURE REVIEW

Daniel de Almeida Limaa, Charles Zulanasb [1] Investigated that Sludge has a severe negative impact on the environment, which will only become worse as the need for purified drinking water increases in the years to come. Using 5% sludge content in concrete aggregate will have a significant impact on sludge amounts in the environment, possibly eliminating sludge disposal into the environment for good. In [2] Jamshidi, Mehrdadi N, Jamsidi. M had conducted study on dry sewage sludge on concrete performances. The dry sewage sludge was replaced by fine aggregate in concrete mixes. The concrete blocks were prepared with 0%, 5%, 10%, 20% and 30% proportions of dry sewage sludge to the weight of fine aggregate. Kartini K, Dahila Lema.et.al had conducted study on domestic waste sludge powder(DWSP) [3]. The wet sludge was dried in natural sunlight and then it was dried in furnace for 72 hours to remove moisture, dried sludge was crushed into Los Angeles Abrasion test machine and sieved through 90μm. In [4] M.Alqedra, M.Arafa, M.Mattar Both sludge was taken as proportion 0%, 2.5% and 10%. The strength was checked at 28&90 days' age. The result shows that the strength of specimen containing sludge was higher at 90 days for the low organic sludge used as a sand replacement and that of compressive strength of high organic strength at 90-day age shows acceptable strength with2.5% and 5% sludge. Maha Alqam *et al.* [5] investigated the use of water treatment sludge for cement replacement in the production of paving tiles for external use. They utilized sludge-cement replacement percentages of 10%, 20%, 30%, 40% and 50% and concluded that all tiles produced are non-vitreous, with a water absorption that is around 10%. The breaking strength results showed development with age, and that, with the exception of 50% sludge-cement replacement. All of the tiles produced comply with the minimum breaking strength of 2.8 MPa required by the standards.

Ghada Mourtada Rabie [6] Implemented a new way of discarding the large amount of sludge which produced from the wastewater treatment plants in Egypt, since the amount of

ISSN: 0474-9030
Vol-68-Issue-1
January-2020

sludge produced every year in Egypt are about "4 Million ton ", this amount of sludge is considered a big/dangerous problem which facing Egypt Shehdeh Mohammad Ghannam [7] The compressive strength of sludge concrete for treated water was compared with the strength of sludge concrete made by tap water. The results shows that using sludge concrete mixes decrease the strength of cube about (9.3%) when treated water was used. Haider Mohammed Owaida, et.al [8] had carried out experimental work on use of alum sludge as partial cement replacement and compressive strength, splitting tensile strength and flexural strength of concrete block was checked.

The Ordinary Portland Cement and admixture as added. Shayan Pirouz, Seyed Mostafa Khezri [9] had conducted study on sludge from filtration plant. The dry sludge was taken as 0%, 10%, 20%, 30%, 40% and 50% mix proportions to the weight of cement with water to cement ratio=0.60. Roccaro p.et. al. [10] experimented that sludge from water treatment plants can be used as partial or total substitution of water in the production of concrete.

3. SYSTEM ARCHITECTURE

In this system OPC of 53 grade cement having specific gravity 3.15 is used. Natural sand used as fine aggregate in concrete mix design. The natural sand was passing through 4.75 mm sieve and retained on 60 micron sieve, having specific gravity 2.81 and water absorption 2.88%. The maximum size of course aggregate selected for this mix design is 10mm. The specific gravity of aggregate is 2.89 and water absorption rate is 1.63%. Waste sludge was produced from sludge obtained from Nashik wastewater treatment plant.

The wet digested sludge cake with its odor of tar was allowed to dry under the hot sun for a week to remove some of the moisture and later burnt under uncontrolled burning in a Ferro cement furnace for 72 hours. The dry sludge cakes of about 5 kg were ground using the Los Angeles (LA) Abrasion machine. Inside the LA drum, there were 45 ball bearings, each of diameter 25 mm. The drum was rotated at 5000 revolutions using an electric motor at a speed of 25.7 rpm. After grinding, in ensuring fineness, the crushed dry sludge was sieved through a 90 μm sieve in order to produce sludge powder. The fineness of 100 gram DWSP passing a 90 μm sieve is 25 %.

4. DESIGN MIX METHODOLOGY

The concrete mix design was proposed by using IS10262:2009. The grade of concrete used was M20 with water to cement ratio 0.50. When cement ratio get decreases then the percentage of the sludge get increases. In which water ratio is constant and F.A (kg/m^3), C.A (kg/m^3), Water (kg/m^3) are also constant. The chemical properties of sludge are shown in table 1 and mix proportion for M20 grade concrete are shown in table 2. Table 3 gives the mix proportion for M30 grade concrete.

ISSN: 0474-9030
Vol-68-Issue-1
January-2020

Table 1. Chemical properties of sludge

Property	Percentage
Carbon	40-52
Nitrogen	10-19
Oxygen	20-26
Manganese Oxide	5-8
Magnesium Oxide	5-10

Table 2. Mix proportion for M20 grade concrete

Sludge %	w\c ratio	Cement (kg/m3)	F.A (kg/m3)	C.A (kg/m3)	Water (kg/m3)	Sludge (kg/m3)
0	0.50	290	696	1029	145	-
5	0.50	275.5	696	1029	145	14.5
10	0.50	261	696	1029	145	29
15	0.50	246.5	696	1029	145	43.5
20	0.50	232	696	1029	145	58

Table 3. Mix proportion for M30 grade concrete

Sludge %	w\c ratio	Cement (kg/m3)	F.A (kg/m3)	C.A (kg/m3)	Water (kg/m3)	Sludge (kg/m3)
0	0.45	380	711	1283	145	-
5	0.45	361	711	1283	145	19
10	0.45	342	711	1283	145	38
15	0.45	323	711	1283	145	57
20	0.45	304	711	1283	145	76

5. EXPERIMENTAL INVESTIGATION AND RESULT

In all concrete mixtures we have used slump cone test using a metallic slump mould. The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured.

ISSN: 0474-9030
Vol-68-Issue-1
January-2020

Table 4. M30 Concrete grade Workability

Sr.no.	sludge	Compressive strength at 7 days(N/mm^2)	Compressive strength at 28 days(N/mm^2)
1.	0%	17.2	24.33
2.	5%	16.33	23.5
3.	10%	15.20	22.7
4.	**15%**	**14.11**	**21.1**
5.	20%	9.73	13.91

5.1 Compressive strength Test: IS 516:1959

Concrete cubes (150mm X 150mm X 150mm) were casted and cured for 28 days. Cubes were tested under compressive testing machine. The load was applied by increasing rate of 140kg/cm2/min until the resistance of specimen to increase load breaks down. Maximum load taken by specimen is recorded and failure is also noted. Three cubes are tested in each category.

Fig 1. Compressive strength test

Fig 2. Split tensile strength test

Two steel rollers are used in the assembly for applying loads. Load of 180kg/min is applied continuously until failure occurs.

ISSN: 0474-9030
Vol-68-Issue-1
January-2020

Table 5. Spilt tensile test for M20 grade concrete

Sl. No	Sludge %	Spilt tensile strength at 28 days (N/mm^2)
1	0	2.93
2	5	2.80
3	10	2.72
4	15	2.55
5	20	2.30

The split tensile strength at 28 day (N/mm^2) when the sludge is added in increasing order the test reading of the tensile reading get deceasing for the M20 grade concrete.

Table 6. Spilt tensile test for M30 grade concrete

Sl. No	Sludge %	Spilt tensile strength at 28 days (N/mm^2)
1.	0	4.02
2.	5	3.91
3.	10	3.79
4.	15	3.26
5.	20	3.01

The split tensile strength at 28 day (N/mm^2) when the sludge is added in increasing order the test reading of the tensile reading get deceasing for the M30 grade concrete.

5.2 Flexure Strength Test: IS 516:1959

The beams were casted for this test having dimension (150mmX150mmX1000mm). The specimen was placed in machine for uniform loading. The load was applied to uppermost part of mound along with two loading points. For

Table 7. Flexural strength test for M20 grade concrete

Sr. No	Sludge %	Spilt tensile strength at 28 days (N/mm^2)
1	0	4.52
2	5	4.06
3	10	3.89
4	15	3.05
5	20	2.89

ISSN: 0474-9030
Vol-68-Issue-1
January-2020

Table 7 shows the Flexural strength test at 28 day (N/mm^2) for M20 grade concrete. We can observe that when the sludge is added in increasing order the test reading of the tensile reading get deceasing gradually for the M20 grade concrete.

Table 8. Flexural strength test for M30 grade concrete

Sr.no	sludge	Spilt tensile strength at 28 days(N/mm^2)
1.	0	5.16
2.	5	5.01
3.	10	4.89
4.	15	3.65
5.	20	3.02

Table 8 shows the Flexural strength test at 28 day (N/mm^2) for M30 grade concrete. In this when the sludge is added in increasing order then test reading of the tensile reading get deceasing gradually for the M30 grade concrete.

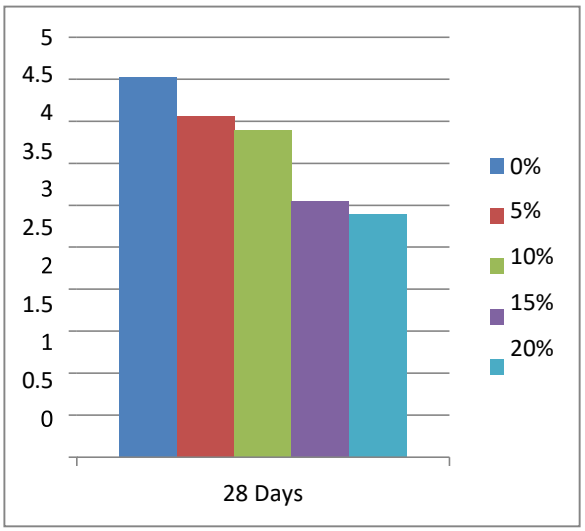

Fig. 3 Flexural strength test for M20 grade concrete

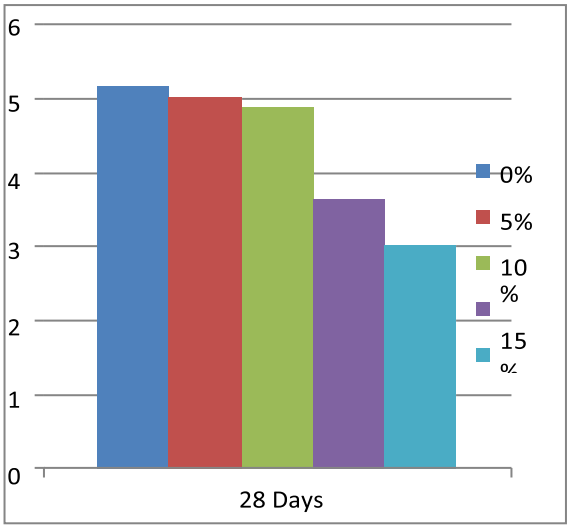

Fig. 4 Flexural strength test for M30 grade concrete

In fig. 3 is very clearly seen that flexural strength test M20 grade concrete get decreasing when the sludge percentage get increases. In fig.4 we come to know that the flexural strength test for M30 grade concrete get decreasing when the sludge percentage get increases.

6. CONCLUSION

As we are increasing the percentage of sludge in compressive strength for M20 grade by the weight of cement we find that compressive strength decreases after 15%. For M30 grade compressive strength decreases after 10 % replacement of sludge. In the split tensile test strength is decreasing after 10% replacement of sludge in M20 grade concrete and for M30 it

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Vol-68-Issue-1
January-2020

is decreasing after 15% replacement. From the above results we conclude that M20 grade concrete gives better result than M30 grade concrete.

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