PULMONOLOGY

Utilization of Sludge Waste in Concrete: An Experimental Investigation

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ABSTRACT

To evaluate the effect of dry sludge on concrete performance, its physical and mechanical properties were studied. In this research an attempt is taken to bring into play the sludge waste in various proportions so that the final product property of concrete mixture is same as the control mix. Waste sludge material was replace with fine and coarse aggregate in various percentages such as 50%, 45%, 40% ,35%,30%, 25%,20%,15%, 10%, 5%, 4% and 3%. Reference concrete mix is also made for comparative reasons.

KEYWORDS: concrete, Reference concrete mix, Waste water treatment plants.

INTRODUCTION

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. The production of sewage sludge from waste water treatment plants are increasing all over the world. This kind of sludge includes the solid material left from sewage treatment processes. Specific sludge production in wastewater treatment varies widely from 35 to 85 gm dry solids per population equivalent per day.

The dry sludge used in this studied was brought (free of cost) from Delawas, Jaipur, Rajasthan, India. The sewerage treatment plant is connected by mostly residential and commercial areas; hence, the sludge collected is categorized as domestic waste sludge. At the sewerage treatment plant, the sewage sludge was sun dried in the sludge bed. This waste is collected in plastic bags and bought to my research area, where it is spread on land for making it in the direct contact to sun and air.

LITRETURE RIVEW

Several experiments using alum sludge in brick making had been reported in many countries. Patricia et al.conducted ceramic brick manufacturing from drinking water treatment plants. They carried out experiments to get a sand replacement by 10% of sludge and this percentage is considered appropriate for ceramic brick. It indicated an interesting potential for reuse alum sludge as construction material. Elangovan and Subramanian produced a publication that deals with reuse of alum sludge in clay brick manufacturing. Alum sludge with commercial local clay were blended in various proportions and sintered at different temperature to produce clay-sludge brick. Their result indicated that alum sludge could be used as partial substitute in commercial clay bricks to maximum of 20% without compromising the strength of brick. Dunster and Wilsonconducted experiments on water treatment residues as a clay replacement and colorant in facing bricks. They also found that the results from laboratory trials demonstrated that water treatment residue could be used as a colorant and partial clay replacement in brick. Badr El-Din et al. presented some results from brick manufacturing by mixing water treatment sludge with rice husk ash. They were able to measure the optimum sludge addition to produce brick from sludge which was 75%. Their results based on the experimental program and the produced brick obeyed the required values of compressive strength, water absorption and efflorescence assigned by the standard specifications. Chiang et al. investigated experimentally light weight bricks manufactured from water treatment plant sludge and evaluated the environmental safety of sintered leaching produce concentration. Mohammed et al. indicated that sludge could be mix as partial substitute for clay in brick manufacturing and they also found the best of replacement proportion of sludge from clay is 50% to produce sludge- brick-mixture. Babatunde and Zhao produced a publication that deals with a comprehensive review of available literature on attempts at beneficial reuses of water treatment plants. The study investigated the percentage of incorporation when the sludge is substitute into the brick at different levels by many studies that studies that were reported. Quesada et al. carried out ceramic brick manufacturing from various industrial such as urban sewage sludge, bagasse, sludge from the brewing industry, olive mill wastewater and coffee grained residues. There wastes were blended with clay to produce bricks. Because of the compressive strength of ceramic materials is the most important engineering quality index for using as building materials. The results indicated that the waste addition decreased the compressive strength of the clay but still at range of standard specifications. Cusido produced paper that showed some leach ability and toxicity test (outgassing and off gassing) which demonstrated the environmental compatibility of these ceramic products to be used in building construction and for this case their results showed the sludge addition ranging from 5% to 25% in weight content of sludge included in structural ceramics seems to have no influence on the environmental characteristics of these products. Vicenza et al. produced a publication on evaluation of alum sludge as raw material for ceramic products. The percentage (10 – 30) % weight of alum sludge was added to clay and the results showed properties comparable to similar commercial products. The findings lead to potential for reusing alum sludge as raw material for ceramic products. Kung et al. tried to reduce the density of the brick by sintering mixes of dewatered treatment sludge with rice husk with 0, 5, 10, 20, 25% by weight. The samples produced from sintering up to 11000C low bulk density and obeyed to the standards specifications.

METHODOLOGY

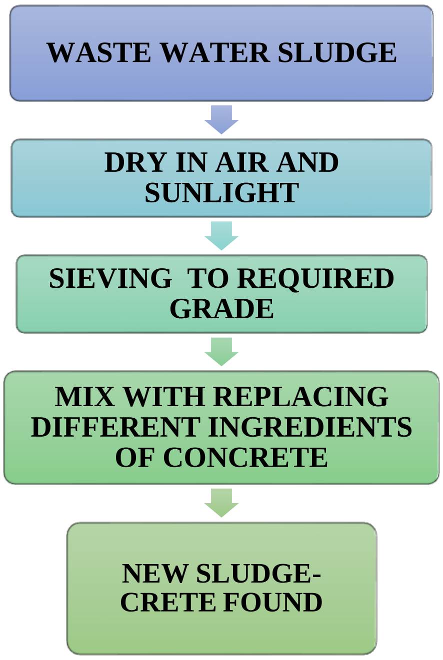


Figure no 1: Methodology of sludge concrete

The main purpose of the study is to utilize the sludge waste as a partial replacement of fine aggregate and also check the performance of sludge concrete with respect to the control mix in strength consideration. The methodology is clearly understood with the help of flow diagram showing in figure no 1.Experiments are done with reference to the IS 2386-1963, IS 516-1959 and IS 5819-1999 to check the performance with the control mix. In present study nominal mix taken is M20

EXPERIMENTAL INVESTIGATION

Several experimental investigation are carried out to check the performance of concrete by using sludge waste replacement with coarse and fine aggregate

PARTICLE SIZE ANALYSIS

Particle size analysis of Coarse Sewage waste 2000 gm total weight						
SNO	**SET OF SIEVE**	**SIEVE SIZE mm**	Weight Retained (in gm)	**% RETAINED gm**	**CUMULATIVE % RETAINED**	**CUMULATIVE WEIGHT PASSSING(% FINER)**
1	**80mm**	**80**	**0**	**0**	**0**	**100**
2	**40mm**	**40**	**0**	**0**	**0**	**100**
3	**20mm**	**20**	**346**	**17.3**	**17.3**	**82.7**
4	**10mm**	**10**	**1196**	**59.8**	**77.1**	**22.9**
5	**4.75mm**	**4.75**	**380**	**19**	**96.1**	**3.9**
6	**Pan**	**0**	**78**	**3.9**	**100**	**0**
	TOTAL		**2000**			

Table no 1: particle size of coarse sludge waste

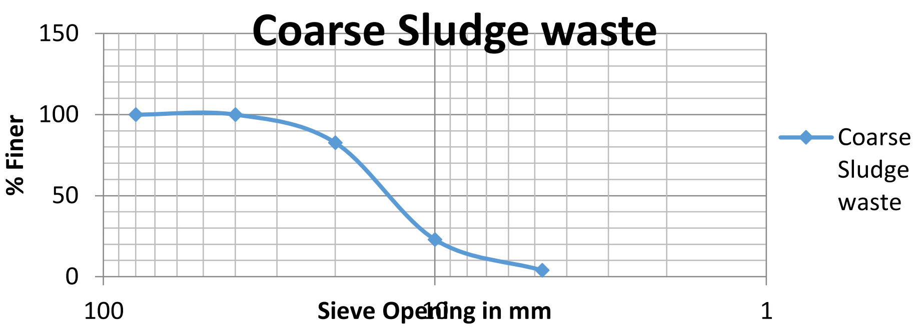


Figure 2: Curve of dry sludge coarse aggregate

Particle size analysis of Fine Sludge waste 500 gm total weight						
SNO	**SET OF SIEVE**	**SIEVE SIZE mm**	**Weight Retained (in gm)**	**% RETAINED gm**	**CUMULATIVE % RETAINED**	**CUMULATIVE WEIGHT PASSSING(% FINER)**
1	4.75mm	4.75	0	0	0	100
2	2.36mm	2.36	84	16.8	16.8	83.2
3	1.00mm	1.00	184	36.8	53.6	46.4
4	600 micron	0.6	42	8.4	62	38
5	300 micron	0.3	98	19.6	81.6	18.4
6	150 micron	0.15	44	8.8	90.4	9.6
7	90 micron	0.09	30	6	96.4	3.6
8	**Pan**		18	3.6	100	0
	TOTAL		**500**			

Table 2: particle size analysis of fine grained

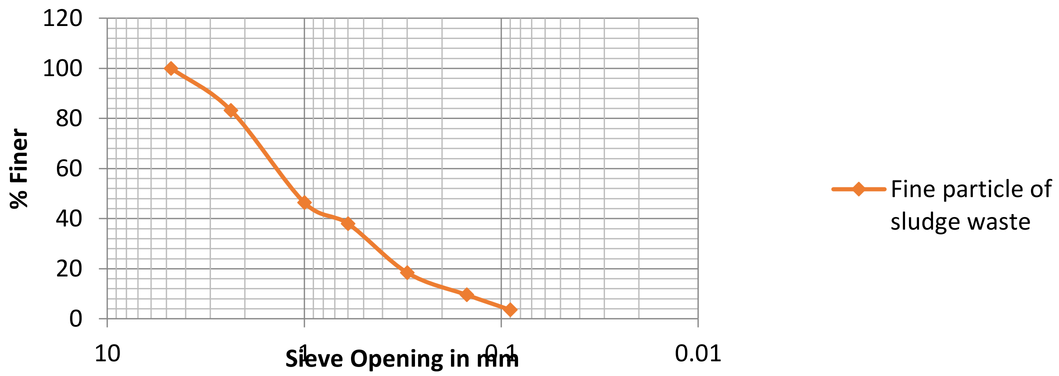


Figure 3:Sieve analysis curve of dry sludge fine aggregate

PHYSICAL AND CHEMICAL PROPERTY OF SEWAGE SLUDGE

S.No	Physical and chemical Properties of sewage sludge	
1	Specific gravity	2.56
2	pH	7.33
3	Colour	Blackish brown
4	conductivity	1.165

Table 3: physical property of sewage sludge

Figure 4: physical property of sewage sludge

Compositions	% sewge sludge
Silica	5.02
Iron	14
aluminium	2.15
phosphorus	3.1
calcium	1.03
sulphur	1.5
potessium	0.6
magnesium	0.16
zinc	0.66

Table 4: Chemical property of sewage sludge

MIX DESIGN AND EXPERIMENTAL WORK

For this study, 43 grade ordinary Portland cement were used. Graded angular aggregates of nominal size 20 mm and 10 mm; and river sand confirming to zone II were used. The coarse aggregates was of angular in nature and with nominal maximum size of 20mm. the fine aggregate used here is in the form of river sand, and it is originate from the Banas river, Tonk district. The physical properties of both coarse and fine aggregates are conformed to requirements specified in IS 383-1970(reaffirmed 2002).

Mix proportion was calculated on saturated surface dry (SSD) condition of aggregates. Workability of fresh concrete was selected as 125- 130 mm slump value for high workable concrete. Based on codal provisions of IS 456: 2000 and IS 10262: 2009, design mix proportions for M20 grade concrete for different ingredient compositions were calculated.

In nominal mix(Control Mix) M20 grade concrete, graded angular aggregate of nominal size 20 mm, zone II river sand, 43 grade OPC were used in conventional ratio 1.00 (cement) : 1.5 (sand) : 3.0 (CA). For required workability, w/c was maintained as 0.45. Density and cement content of the fresh concrete were found 23.45 kN/m^3 and 390.83 kg/m^3 respectively. Waste sludge material was replace with fine and coarse aggregate in various percentages such as 50%, 45%, 40% ,35%,30%, 25%,20%,15%, 10%, 5%, 4% and 3%.

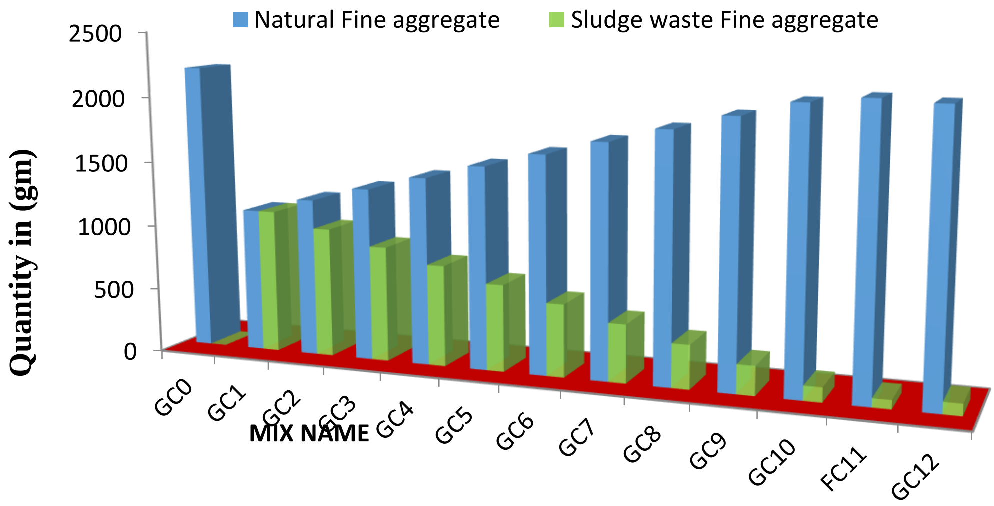
S no	Symbol	Notification
1	GC0	Control Mix M 20
2	GC1	Control Mix M 20+ 50% replaced with sludge waste CA and FA
3	GC2	Control Mix M 20+ 45% replaced with sludge waste CA and FA
4	GC3	Control Mix M 20+ 40% replaced with sludge waste CA and FA
5	GC4	Control Mix M 20+ 35% replaced with sludge waste CA and FA
6	GC5	Control Mix M 20+ 30% replaced with sludge waste CA and FA
7	GC6	Control Mix M 20+ 25% replaced with sludge waste CA and FA
8	GC7	Control Mix M 20+ 20% replaced with sludge waste CA and FA
9	GC8	Control Mix M 20+ 15% replaced with sludge waste CA and FA
10	GC9	Control Mix M 20+ 10% replaced with sludge waste CA and FA

11	GC10	Control Mix M 20+ 05% replaced with sludge waste CA and FA
12	GC11	Control Mix M 20+ 04% replaced with sludge waste CA and FA
13	GC12	Control Mix M 20+ 03% replaced with sludge waste CA and FA

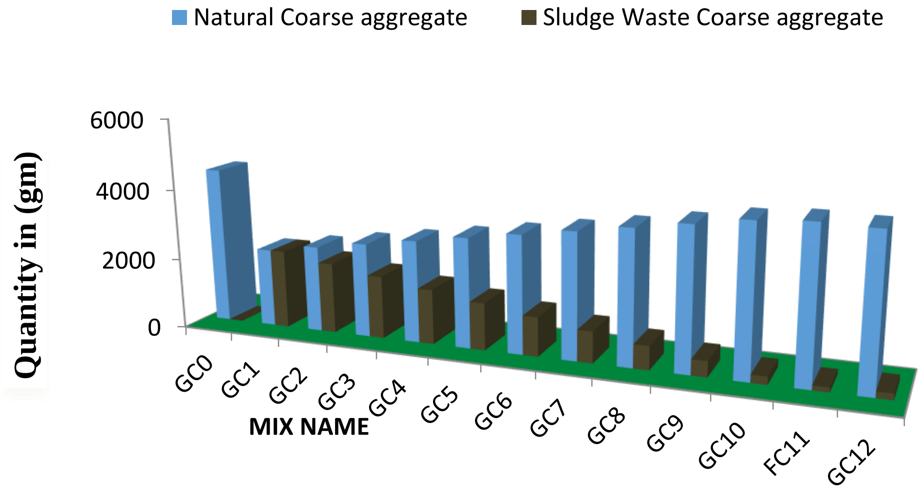
Table 5:: Notification symbols used in sludge waste concrete

Mix Name	Cement (gm)	Fine aggregate (gm)	Fine Aggregate Sewage Waste (gm)	Course Aggregate (gm)	Coarse Aggregate Sewage Waste (gm)	Water Cement Ratio	Super Plasticiser Wt(Kg)	Slump
GC0	1473	2209	0	4420	0	0.55	0	100
GC1	1473	1105	1105	2210	2210	0.55	0.044	95
GC2	1473	1214	995	2431	1989	0.55	0.044	95
GC3	1473	1325	884	2652	1768	0.55	0.044	95
GC4	1473	1435	774	2873	1547	0.55	0.044	90
GC5	1473	1546	663	3094	1326	0.55	0.044	85
GC6	1473	1656	553	3315	1105	0.55	0.044	85
GC7	1473	1767	442	3536	884	0.55	0.044	85
GC8	1473	1877	332	3757	663	0.55	0.044	90
GC9	1473	1988	221	3978	442	0.55	0.044	95
GC10	1473	2098	111	4199	221	0.55	0.044	100
FC11	1473	2120	89	4243	177	0.55	0.044	102
GC12	1473	2142	67	4287	133	0.55	0.044	110

Table 6: : Ingredient used in sludge waste concrete



	GC0	GC1	GC2	GC3	GC4	GC5	GC6	GC7	GC8	GC9	GC10	FC11	GC12
Natural Fine aggregate	2209	1105	1214	1325	1435	1546	1656	1767	1877	1988	2098	2142	2120
Sludge waste Fine aggregate	0	1105	995	884	774	663	553	442	332	221	111	67	89



	GC0	GC1	GC2	GC3	GC4	GC5	GC6	GC7	GC8	GC9	GC10	FC11	GC12
Natural Coarse aggregate	4420	2210	2431	2652	2873	3094	3315	3536	3757	3978	4199	4287	4243
Sludge Waste Coarse aggregate	0	2210	1989	1768	1547	1326	1105	884	663	442	221	133	177

Figure 5: Variation of CA and FA

RESULTS AND DISCUSSION

COMPRESSIVE STRENGTH OF CONCRETE CUBE

S NO	Mix name	Symbol	3 days strength (MPa)	7 days strength (MPa)	28 days strength (MPa)
1	Control Mix M 20(GC0)	GC0	18.67	22	26.89
2	Control Mix M 20+ 50% replaced with sludge waste	GC1	8.31	10.32	15.88
3	Control Mix M 20+ 45% replaced with sludge waste	GC2	9.17	10.37	16.45
4	Control Mix M 20+ 40 replaced with sludge waste	GC3	10.81	10.72	17.99
5	Control Mix M 20+ 35% replaced with sludge waste	GC4	11.28	11.28	19.21
6	Control Mix M 20+ 30% replaced with sludge waste	GC5	12.43	13.4	20.8
7	Control Mix M 20+ 25% replaced with sludge waste	GC6	13.67	14.21	22.18
8	Control Mix M 20+ 20% replaced with sludge waste	GC7	14.87	14.72	22.84
9	Control Mix M 20+ 15% replaced with sludge waste	GC8	15.2	15.38	24.01
10	Control Mix M 20+ 10% replaced with sludge waste	GC9	15.85	16.61	24.13
11	Control Mix M 20+ 05% replaced with sludge waste	GC10	16.2	14.18	25.83
12	Control Mix M 20+ 04% replaced with sludge waste	GC11	16.45	20.26	25.89
13	Control Mix M 20+ 03% replaced with sludge waste	GC12	17.13	21.3	26.29

Table 7: Characteristic strength of waste sludge concrete in MPa

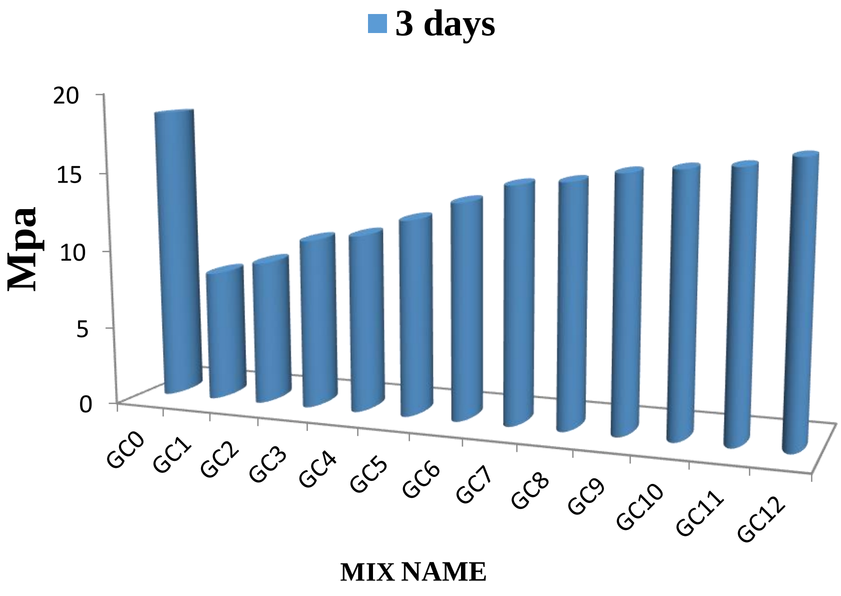


Figure 6A: 3 Days compressive strength of sludge waste concrete

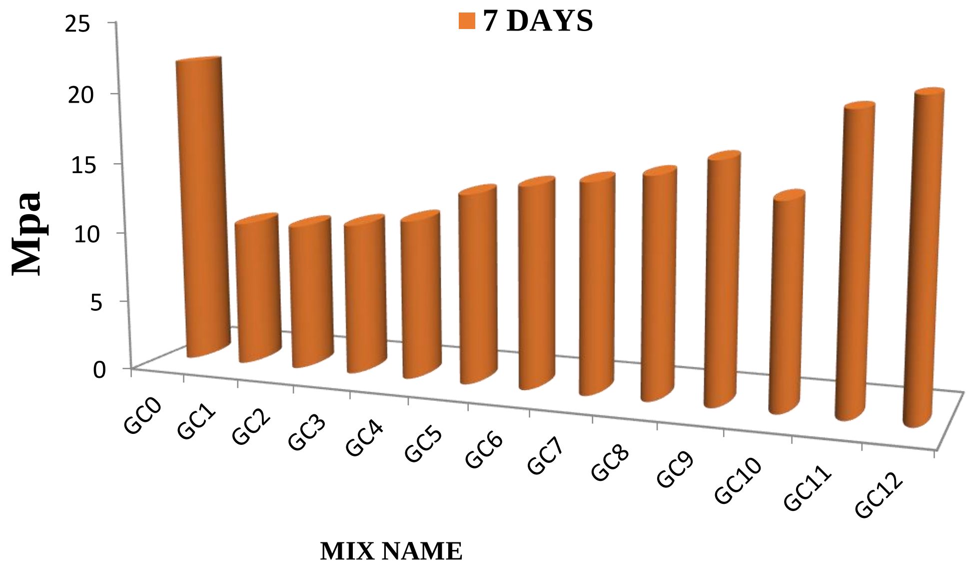
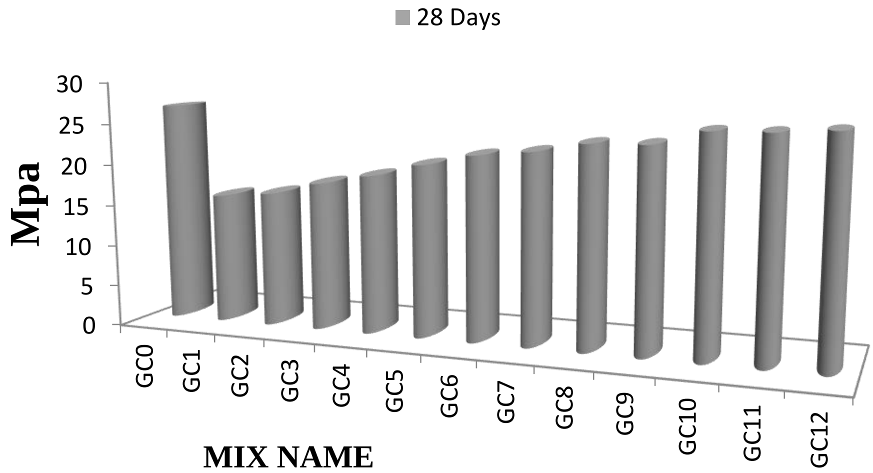
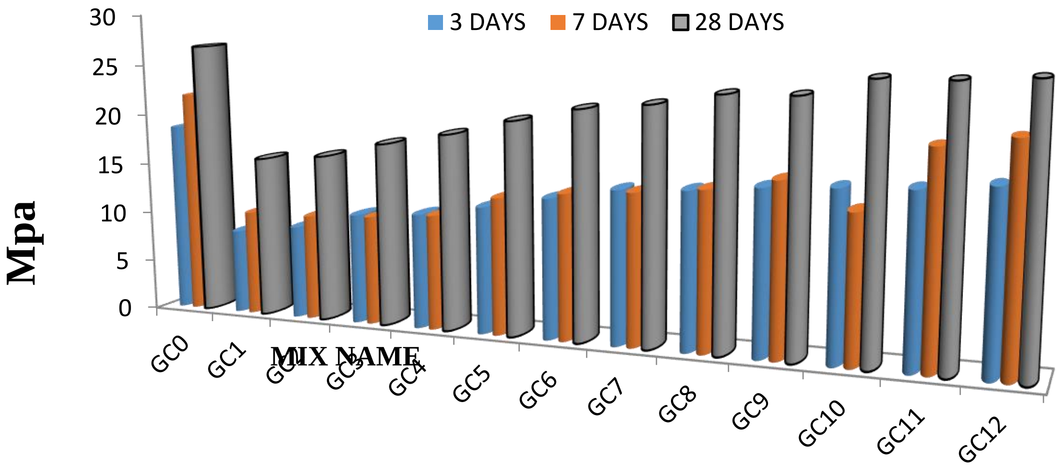


Figure 6B: 7 Days compressive strength of sludge waste concrete



	GC0	GC1	GC2	GC3	GC4	GC5	GC6	GC7	GC8	GC9	GC10	GC11	GC12
28 Days	26.89	15.88	16.45	17.99	19.21	20.8	22.18	22.84	24.01	24.13	25.83	25.89	26.29

Figure 6C: 28 Days compressive strength of sludge waste concrete



	GC0	GC1	GC2	GC3	GC4	GC5	GC6	GC7	GC8	GC9	GC10	GC11	GC12
3 DAYS	18.67	8.31	9.17	10.81	11.28	12.43	13.67	14.87	15.2	15.85	16.2	16.45	17.13
7 DAYS	22	10.32	10.37	10.72	11.28	13.4	14.21	14.72	15.38	16.61	14.18	20.26	21.3
28 DAYS	26.89	15.88	16.45	17.99	19.21	20.8	22.18	22.84	24.01	24.13	25.83	25.89	26.29

Figure 6D: Comparative Compressive Strength of sludge waste concrete

From the above observations shown in table and figure it was observed that domestic sewage sludge can be used in mass concrete up to a level of 30 percentage replacement of both coarse and fine aggregate and for this it was observed that the compressive strength of concrete was 20.8 MPa, which is in safer limit according to IS 456.

After taking further observation it was find that on replacement level of 15 percentages the compressive strength improves to 24.1 MPa. On the basis of primary observation it was suggested that sludge waste can be replaced with natural coarser and finer aggregate up to a level of 15%.

Hence it was found that use of this sludge as raw material in cement concrete is an effective means for its management and leads to saving of sand and economy. Hence it is a safe and environmentally consistent method of disposal of sewage sludge.

CONCLUSION

1. The workability of concrete shows a decreasing trend with the addition of waste dry sludge.
2. From XRF analysis it was observed that raw sewage sludge contains mainly quartz (silicon dioxide, SiO2), phosphorus-pentoxide (P2O5) and iron oxide (Fe2O3).
3. The optimum percentage of sludge coarse and fine aggregate was 15 percentages.
4. On the basis of experiments it was observed that the replacement level of 15 percentages of sludge coarse and fine aggregate ,the compressive strength improves to 24.1 MPa on 28 days, which was in safer limit according to IS456[1].
5. After 15% replacement the compressive strength shows a decreasing value
6. Flexure strength and tensile strength was also show a increasing value up to 15% and after that these values are also tends to decreases.

REFERENCES

[1] IS 456-2000- "Plain and reinforced concrete code of practice (fourth revision)"
[2] IS 383-1970- "specification for coarse and fine aggregates from natural sources for concrete (second revision)"
[3] IS8112-2013-"ordinary portland cement,43 grade specification (second revision)"
[4] IS 3025(1-56 parts) –"Methods of sampling and test (physical and chemical) for water and wastewater"
[5] IS 3025(1-56 parts) –"Methods of sampling and test (physical and chemical) for water and wastewater"
[6] AS 1379 "Specification and supply of concrete Standards Australia"
[7] ASTM C-94 "Standard Specification for Ready mix Concrete-1996"
[8] ACI 318M-08, "Building Code Requirements for Structural Concrete and Commentary"
[9] ASTM 1602M-06 "Standard Test Method for Mixing Water Used in the Production of Hydraulic Cement Concrete"
[10] Elangoven C. & Subramanian K., Reuse of alum sludge in clay brick manufacturing. Water Science & Technology: water supply, 11 (3), 33- 341.
[11] Andrew D. B., & Evaggelia, P. S. (2007). Water treatment residues as clay replacement and colorant in facing bricks. Characterisation of Mineral Wastes, Resources and Processing technologies – Integrated waste management for the production of construction material - WR0115.
[12] Badir E. H., Hanan A. F., & Ahmed M. H. (2012). Brick Manufacture from Water Treatment Sludge and Rice Husk Ash. Australian Journal of Basic and Applied Science, 6(3): 453-461.
[13] Chiang K.Y., Chou P. H., & Chien K. L. (2000). Novel Lightweight building bricks manufactured from water treatment plant sludge and agricultural waste. A case study in Feng-Chia University, Tai-Chung, Taiwan.
[14] Mohammed O. R., Hanan A. F., & Ahmed M. H. (2008). Reuse of water treatment plant sludge in brick manufacturing . Journal of Applied Science Research, 4(10),1123-1229.
[15] Babatunde, A.O., & Zhao, Y.Q. (2007). Constructive approaches toward water treatment works sludge management: An international review of beneficial reuses. Critical Reviews in Environmental Science and Technology, 37(2), 129–164.
[16] Eliche-Quesada, Martínez-García D., C., Martínez-Cartas M.L., Cotes-Palomino M.T., Pérez-Villarejo L., Cruz-Pérez N., & Corpas-Iglesias F.A. (2011). The use of different forms of waste in the manufacture of ceramic bricks. J. Appl. Clay Sci., 52, 270-276.
[17] Joan A. C., & Lazaro V. C. (2012). Environmental effects of using clay brick produce with sludge: leaching and toxicity studies. Waste management, 32, 1202-1208.
[18] Vicenzi J., Moura B. A., & Perez B. (2005). Evaluation of alum sludge as raw material for ceramic products. Industrial ceramics, 25, 7-16. doi:10.5402/2012/487037
[19] Chiang, K. Y., Chou, P. H., Hua, C. R., Chien, K. L. & Cheeseman, C. (2009). Lightweight bricks manufactured from water treatment sludge and rice husks. J. Hazard. Mater, 171, 76-82.
[20] Nagar Bharat , Bhargava v.p. "Effect of glass powder on various properties of concrete",International Journal of Science,Engineering and Technology, ISSN (Online): 2348-4098