Impact of Use Septic Tank Sludge for the application as Pozzolanic Material in high performance concrete

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Abstract

The disposal of septic tank sludge (SS) delivered from wastewater treatment plants is progressively getting to be a risk to the environment for includes Organic compounds which are scary to the public health and environment; over-volumes are every day created and deficiency of relevant landfill sites for wastes. This study aims to explore the impact of septic tank sludge as partial substitutions of ordinary Portland cement (PC) within the production of high-performance concrete (HPCs). The water/binder (W/B) ratio of all kinds of blends is fixed at 0.36 with total binder content of 492 kg/m³. The concrete mixtures, in portion, are replaced with 0%, 5%, 10%, 15% and 20% of SS, individually. The impact of SS used to be analyzed through physical and chemical tests. The workability test of HPC was once decided to utilize the slump flow, Meanwhile compressive strength and tensile strength splitting experiments were conducted to investigate the impact of septic tank sludge on the hardened properties of HPC. The results demonstrated that SS may be a responsive pozzolanic material (PM) ; consequently which could be used as PM in concrete mixes. The concrete blend contains 5% cement substitution with SS illustrated to improve hardened properties of concrete at the all-age of specimens evaluated by comparing to concrete control . Sensibly, the substitution of 20 % septic tank sludge is desirable for creating high-performance concrete.

Keywords: Septic tank sludge; High-performance concrete; Workability; Compressive strength; Splitting tensile strength.

1. INTRODUCTION

With the expanding sum of waste era from different forms, there has been a developing intrigued within the utilization of waste in producing developments materials to attain potential benefits. Attention was given to the advancement of feasible development material in needed to achieve the rising request. The sludge of sewage utilize as a by-product within the development industry has been discussed in investigates within the final decades [1, 2, 3, 4]. In spite of the fact that the sludge isn't the as it were waste created and due to the chemical characteristics and high efficiency, the sewage treatment strategy is generally regarded to be a fabulous environmental concern , particularly its last dumping [5].
Large quantities of sewage sludge (SS) may additionally impact the environment. In modern patterns, SS is organized via arrive filling, sea disposal, arrive utility, and farming utilization. Later survey has revealed that common disposal approaches offered up environmental aspects along with water, air, as well as atmospheric infection [6]. Sludge also has extent possible opposed to the numerous waste material-products produced in the SS processing approach and also its composition includes overwhelming metals [7]. Other than that, insoluble be counted used to be also discovered in a sludge of sewage along with organic matter, pathogenic organisms, solvents, and metals. Septic tank sludge (STS) a kind of fracking wastewater which is governed as a large portion emitted in the residential wastewater fluid production delays.

High-performance concrete can be extensively described as concrete made from suitable fabric combined agreeing to selected mix design and appropriately blended, transported, put, solidified, and cured so that the coming about concrete will provide fabulous execution. The utilize of pozzolans materials from industrial by-products and wastewater as substitutions for cement has obtained more consideration due to their improvement in engineering and durability characteristics and of blended cement-based materials as well as an environmental and financial perspective. Experiments were implemented to assess the feasibility that use sludge and sludge ash in the manufacturing of new construction materials, and also in the brick production, industrial aggregates, cement and ceramic tiles. Adopting sludge ash from sewage plants is a cementitious material for construction in normal situations [8, 9]. Oliveira et al. [10] appeared that the containing of pozzolanic materials (PM) as a partial substitute from cement is a positive implies for enhancing the hardened properties.

Until now, few distinctive investigations that find out about the impact binary blends of septic tank sludge on the fresh and hardened properties of HPC. Subsequently, the main goal of this study is to illustrate the suitability of the use of raw septic tank sludge as alternative cementing materials in concrete as well as to assess the influence of septic tank sludge as a new binder as Portland cement replacement in a variety of levels on hardened properties of sustainable HPC. A consultant set of parameters consisting of fundamental material characteristics, fresh and hard properties which including compressive and splitting tensile strengths measures are obtained in comparison to the control concrete requirements.

2. MATERIALS AND METHODS

2.1. Materials

The ordinary Portland cement type I (OPC) was utilized for all of the concrete mixes, which meets ASTM C150-1992 [11]. Septic tank sludge (SS) used to be bought from the waste as it were residential sewage prepare as appeared in Fig. 1, and oven-dried for 24 hrs at 105 °C temperature. The dried sludge had been pulverized and screened to outcasted and extrinsic particulates from in the substance through that 10 mm sieve, and afterwards the specimen ground that used a Los Angeles (LA) machine until it reaches the desired fineness in this research paper. The processing time was characterized based on published work by way of Pan et al. [12]. The particle measurement distribution shows that the average diameter of the utilized SS is 25.7 µm. The schematic stream graph of the training of the raw SS test sometime recently it is blended with cement for the production of HPC appeared in Fig. 2. The chemical composition of SS was once analyzed by way of XRF method of calculating the consistent mass of the oven-drying sludge at 105 °C for 24 hours prior calcination at Thousand °C for 60 min. In Tables 1 and 2; respectively, the chemical and physical characteristics of OPC and SS are provided.

| Table 1. Chemical analysis of OPC and raw SS |

| Table 2. Physical characteristics of OPC and raw SS |
Table 2. Physical properties of OPC and raw SS

| Property                          | Cement  | Raw septic tank sludge |
|----------------------------------|---------|------------------------|
| Specific gravity                 | 3.12    | 2.62                   |
| Fineness m²/kg                   | 338     | 873                    |
| Moisture content (%)             | -       | 20°-25                 |
| Pozzolanic activity index (%)    | 100     | 57                     |
| 7 days                           | 100     | 76                     |
| 28 days                          | Grey    | Black grey             |
| Color                            |         |                        |

Fig. 1: Septic tank sludge distributed in dumping sites
As per the arrangement with ASTM, natural sand is being used as a fine aggregate (FA) with a maximum size distribution of 4.75 mm, as well as a fineness modulus (FM) of 2.86. Crushed gravel according to ASTM Standard with a maximum size of 10 mm was used as coarse aggregate (CA). In the presented work, the superplasticizer (SP) included is an acetic acid of an adjusted SP derived on polycarboxylates (Visocrete-2044).

2.2. Mix percentages and Experiment Preparing
The Mix percentages of HPC mixes are outlined in Table 3. Septic tank sludge was once used to in part substitute the Portland cement at 5%, 10%, 15%, and 20% through the weight of the binder. Concrete combinations had been prepared to have The same 489 kg / m³ binder quality material and the ratio of water to binder (w/b) remained at 0.36. When used, the SP was indeed an acetic acid of adapted polycarboxylates with dosages of 1.4 percent by manner of OPC mass.

2.3. Methods of Tests

2.3.1. Pozzolanic activity and reaction
As per Standard test method ASTM C311 (2006)[13], the strength activity index (SAI) can be used to identify the pozzolanic activity (PA) of a substance that is used as a pozzolan to PC. Three cubes were taken out of the curing tank at each testing age. The SAI of SS was evaluated in this research.

2.3.2. Workability
The workability of fresh control mix and concrete comprising septic tank sludge (SS) under ASTM C143 (2003) was examined by a slump test [14].

2.3.3. Bulk density
In this research study the theoretical bulk density is the bulk density of concrete cube samples. The density is computed by dividing the mass of each cube (150 mm/150 mm/150 mm) upon this volume of the cube following BS 1881 [15]. A certain cube specimens used to ascertain compressive strength have been used to measure the composition before crushing at 7, 28 and 56-day age.

2.3.4. Compressive Strength Test
For each combination, the concrete specimens strength had been decided by breaking three 150 mm measuring cubes at aged 7, 28, and 90 days. The experiment seems to be conducted in compliance with BS EN 12390-3[16], using a 5,000 KN compressive unit.

Table 3: Concrete mix proportions of the HPC mixtures.

| Mix Description (%) | W/B   | Water Kg/m³ | Cement Kg/m³ | Septic tank sludge Kg/m³ | Fine aggregate Kg/m³ | Coarse aggregate Kg/m³ | SP \(^2\) Dosage (%) |
|---------------------|-------|--------------|--------------|--------------------------|----------------------|------------------------|---------------------|
| Control-OPC         | 0.36  | 147.2        | 489          | 0                        | 685                  | 1035                   | 1.4                 |
| SS-5                | 0.36  | 147.2        | 464.6        | 24.4                     | 685                  | 1035                   | 1.4                 |
| SS-10               | 0.36  | 147.2        | 440.1        | 48.9                     | 685                  | 1035                   | 1.4                 |
| SS-15               | 0.36  | 147.2        | 415.6        | 73.4                     | 685                  | 1035                   | 1.4                 |
| SS-20               | 0.36  | 147.2        | 391.2        | 97.8                     | 685                  | 1035                   | 1.4                 |

\(^{2}\) SP: Superplasticizer
2.3.5. Splitting tensile strength Test

The splitting tensile strength (STS) was computed in order to comply with the manner set out in ASTM 496/C 496M-2004[17]. Cylinders (10 cm x 20cm) were utilized to compute STS after 28 days.

3. RESULTS AND DISCUSSION

3.1. Activity of Pozzolanic

The observations of the chemical analysis are seen in Table 1, that the raw septic tank sludge (SS) waste is mainly composed of SiO$_2$ (32.42%), Al$_2$O$_3$ (22.26%) and smaller proportions of CaO (4.70%), Fe$_2$O$_3$ (4.90%), SO$_3$ (4.65%), P2O5 (5.11%), MgO (2.83%). The specimen summarised a loss on ignition (L.O.I) of 10.21%, indicating very suitable for concrete production. The pozzolanic activity of the raw SS was determined per ASTM C 311 (2006) [13]. The results of the strength activity index (SAI) of mortar cubes at 7 and 28 days are presented in Table 1. As shown in Table 1, SAIs of SS have low pozzolanic activity and it is 57% at 7 days, while 76% at 28 days, very close to the minimum value specified by ASTM C618 [18], for 28 days obtained similar results.

3.2. Workability

The concrete slump results are displayed in Figure 3. Despite the vast large range of cemented materials, excluding SS waste, with a small w/b percentage, the high-performance concrete mixtures did not tend inclinations to segregate or leak. The findings in Figure 3, tend to be prompting a declining trend in slump levels by the introduction of SS. The slump in SS-containing concrete declines from 105 to 70 mm as the SS replacement rate rises from 5 % to 20%. This findings indicated that the rise throughout the quantity of SS raises the need for concrete water which can be attributed to the quantity of replacement that consumed a portion of the blending water, decreasing the flowability which dramatically increasing the mortar consistency rate[19].

Consequently, because of the fact that the SS is finer than cement, it has resulted in an improved absorption of water; thus, the demand for water becomes increasing. The largest fall in water demand is for concrete with the 20 percent SS replacement level, while the decline is a 35.4 percent fall relative to the control concrete.

Fig. 3: Slump test of concretes with the addition of SS.

3.3. Bulk density

Mixed cement concrete's bulk densities consist of SS are smaller than the control concrete. The addition of SS diminished the bulk density with a comparison of control mix at 28 days as proven in Figure 4. Considering the fact that the specific gravity of SS is considerably lower than that of cement as stated in
Table 2, the 20 percent SS mixture has the lowest value which decreases the mass per unit volume. Figure 4, shows that concrete with the 20% SS combination famous a reduction in density of about 2.40% at aged 28 days, related to the mixture control.

![Figure 4: Bulk density at 28 days of concretes with the addition of SS.](image)

### 3.4. Compressive Strength

The impact of supplanting cement with SS on the compressive qualities of HPC at the curing ages 7, 28, and 90 days has appeared in Fig. 5. It should be considered from Fig. 5, an enormous enhancement was observed within the strength of the HPC with 5% cement substitution by septic tank sludge at 7 days onwards, compared with the control concrete. The enhancements within the compressive strength of the SS-5 concrete mixture larger than for the control blend. Meanwhile, during cement hydration, the pozzolanic reaction takes place simultaneously occurs for the a longer period thereby acquiring strength. This outcome might be ascribed to the fine grain size of the sludge and its association including an amorphous substance in the portion of silicate dioxide.

![Figure 5. Influence of SS waste on compressive strength of HPC at various ages.](image)

Compressive strength of the concrete sample with 5% SS used to be greater than those of the samples with 10%, 15%, and 20% AS in all ages. As can be viewed in Fig. 5, the improvement of the compressive strength
of HPC with 10% alternative of SS was barely higher than the control concrete after 28 days. It ensures that towards the longer intervals there really is a marginal gain in the strength of the HPC and can perhaps be ascribed to the superior evaluation of the SS included in this research. Whereas the compressive strength of HPC 20% substitution of SS gave compressive strength less than other substitution levels of SS and OPC concrete at all ages. The decrease in compressive strength for SS-20 compare to other substitution levels of SS and the control blend is clarified as a consequence of the a clinker dilution impact as in Fig.5. The SS concrete tends to be progressively strength with curing period and the decline of compressive strength contributes to the sludge ash intensity increase[20].

3.5. Splitting tensile strength
Test of tensile strength had been carried out at the sample age 28 days. The test outcomes for HPC across all combinations comprise that alum sludge in comparison to OPC is introduced in Fig. 6. This figure illustrates the tensile strength of concrete behaved in a similar way to the compressive strength. Therefore, the tensile strength of concrete is directly proportional to the compression strength [21]. In any case the proportion of these two strengths focuses on a popular level of concrete quality. In certain statements, as its compressive force increases, the tensile strength enhances consequently but at a declining rate.

The tensile strength average was within the allowable values, under design details. It can be seen clearly from Fig.6 the results revealed that the tensile strength of the concrete binary mixes of 5% SS has a more prominent tensile strength value than those of the samples with 10%, 15 and 20% SS and control concrete over especially within the afterward ages. As located from the parent the tensile electricity of combinations improved With a rise in SS level of up to 5 percent at several ages, the tensile strength diminishes beyond a substitute content. The enhancement of splitting tensile strength of the binary HPC mixture SS-5 used to be about 3.9% at 28 days greater than that of the control mix at aged 28 days. However, the increase in the splitting tensile strength was once smaller compared to that obtained in the compressive strength which is in understanding towards those supplied by Guneyisi et al. [22].

![Fig. 6: Effect of SS on STS of HPC at 28 days.](image)

CONCLUSION
The following conclusions can be drawn, based on the outcome of this experimental study identified above:
1) Raw septic tank sludge (SS) is a suitable material for use as a pozzolanic material for cement replacement in concrete since it satisfied the requirement for such material by the presence of a combined silica, alumina and iron oxides of more than 70% at 28 days.

2) The slump in SS-containing concrete decreases from 105 to 70 mm as from the SS substitution rate increases from 5 % to 20%. This findings revealed that its raise in SS quantity raises concrete water requirements.

3) The addition of SS decreased the bulk density with a comparison of the control mix at 28 days. Thus, the bulk densities of blended cement concrete contain SS is lower than that of the control concrete.

4) The compressive strength of SS concrete is lower than that of the control mix at early curing ages but improves significantly at later ages and this similar to concrete with other pozzolanic materials. The best replacement proportion of SS from cement was 5%. So although, in the early and later ages, the compressive strength of that growth rate was greater than that of the 10%, 15 % and 20% SS samples, and also it was higher than in the control concrete.

5) The strength of the splitting tensile followed the trend as the compressive force at all ages but really the development of the tensile strength is really rather.

REFERENCES

[1] I.-J. Chiou, K.-S. Wang, C.-H. Chen, Y.-T. Lin, Lightweight aggregate made from sewage sludge and incinerated ash, Waste Manage. 26 (2006) 1453–1461.

[2] Tay, J.H., K.Y. Show, S.Y. Hong, C.Y. Chien and D.J. Lee, 2002. Potential reuse of wastewater sludge for innovative applications in construction aggregates. Water Sci. Technol., 50(9): 189-196.

[3] Tay, J.H., K.Y. Show, S.Y. Hong, C.Y. Potential Reuse of Wastewater Sludge for Innovative Aplications in Construction Industry, Bulletin of the College of Engineering. N.T.U. n. 86. 2002; p.103-112.

[4] Yiming, L., Z. Shaoqi, L. Fuzhen and L. Yixiao, 2012. Utilization of municipal sewage sludge as additives for the production of eco-cement. J. Hazard. Mater., 213/214: 457-465.

[5] E.P. Jordão, C.A. Pessoa, Sewage Treatment, 3th ed., ABES, Rio de Janeiro, 1995.

[6] Jamshidi, A., Jamshidi, M., Mehrdadi, N., Shasavandi, A. and Pacheco-Torgal, F. 2012. Mechanical Performance of Concrete with Partial Replacement of Sand by Sewage Sludge Ash from Incineration. Materials Science Forum, 730-732, 462-467.

[7] Fontes, C. M. A., Barbosa, M. C., Filho, R. D. T. and P, G. J. 2004. Potentiaility of Sewage Sludge Ash as Mineral Additive in Cement Mortar and High Performance Concrete, Use of Recycled Materials in Buildings and Structures, November 2004, Barcelona.

[8] Tay, J.H. & Show, K.Y., (1992). Utilization of municipal wastewater sludge as building and construction materials.” Resources, Conservation and Recycling, 6(3), 191-204.

[9] Tay, J.H. & Show, K.Y., (1993). Manufacture of cement from sewage sludge. Journal Materials Civil Engineering, AXE, 5(1),19-29

[10] Luiz Antonio Pereira de oliveira, Joao Paulo de castro gomes, Cristiana nadir gonilho Pereira. (2006). Study of sorptivity of self-compacting concrete with mineral additives. Journal of civil engineering and managment. 9, 215-220

[11] ASTM C 150-04. (2004). “Standard Specification for Portland Cement” Annual Book of ASTM Standard ,Vol. 04.02. Philadelphia: America society for Testing and Materials.

[12] S.C. Pan, D.H. Tseng, C. Lee, Influence of the fineness of sewage sludge ash on the mortar properties, Cem. Concr. Res. 33 (11) (2003) 1749–1754.

[13] ASTM C311. 2006. Standard test methods for sampling and testing of fly ash or natural pozzolan for use in Portland-cement concrete, ASTM C311-05, Annual book of ASTM standard 04.02, pp. 207-215.

[14] ASTM C143/C 143M. 2003. Standard test method for slump of hydraulic-cement concrete. Annual Book of ASTM Standard. West Conshohocken (PA), ASTM C143-03, Annual book of ASTM standard Vol. 04.02.
[15] British Standard BS 1881: Part 114. 1983. Methods for determination of density of hardened concrete. BSI, London.
[16] British Standard European Standard BS EN 12390-3. (2002). Testing hardened concrete. Compressive strength of test specimens. London: BSI.
[17] ASTM C 496/C 496M – 04. (2004). “Standard test method for splitting tensile strength of cylindrical concrete specimens.” West Conshohocken (PA): ASTM International.
[18] ASTM C618- 03. Standard specifications for coal fly ash and raw or calcined natural pozzolan for use in concrete. Annual Book of ASTM Standard. West Conshohocken (PA); 2003.
[19] Maria del Pilar Durante Ingunza, Gladis Camarini and Felipe Murilo Silva da Costa. Performance of mortars with the addition of septic tank sludge ash. Construction and Building Materials 160 (2018) 308–315.
[20] Doh Shu Ing, Siew Choo Chin, Tan Kim Guan1 and Adilen Suil. The use of sewage sludge ash (SSA) as partial replacement of cement in concrete. ARPN Journal of Engineering and Applied Sciences. VOL. 11, NO. 6, MARCH 2016.
[21] A.M. Neville, (2005). Properties of Concrete,” 4th ed, Essex, England: Pearson Education Ltd.,
[22] Guneyisi E, Gesoglu M, Mermerdas K. (2008). Improving strength, drying shrinkage, and pore structure of concrete using metakaolin. Materials and Structures;41:937–49.