Compressive Strength of PPC Based Quaternary Blended Concrete

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Abstract. Production of sewage sludge is increasing day by day all over the world. By disposing of the sewage sludge the environmental issues take place in the society. Hence the research for replacement of cement using sewage sludge ash is essential to reduce the use of natural resources. Certainly as pond ash also coal ash as waste which composites of bottom ash and fly ash. They contain the major chemical components which cement contain. So the major aim in this research study is to the best use of Biochar and pond ash in concrete. Concrete M20 specimens are prepared according to IS10262-2019 and by replacing cement with 5% Biochar and sand with 2-30% of pond ash by varying percentages in steps of 2 and the compressive strength was determined finally observed that 20% replacement of pond ash and 5% Biochar is giving the optimum value of compressive strength.

Keywords: Biochar, Pond ash, Flyash, Sewage sludge, Compressive Strength.

1. Introduction

Over the last few years’ replacement of cement and sand is being experimented by researchers from all over the world by silica fume, fly ash, GGBS, rice husk ash on cement, and pond ash with sand in certain percentages. Septage ash is a by-product of the sewage sludge and wood pallets which absorbs the water in sewage sludge during incineration at 500oc-700oc to become ash and the pond ash in the bottom ash in the thermal power plants which are obtained after the fly ash is obtained from the bottom of plant by spraying water which is not finer than the fly ash so it is used in the replacement of fine aggregate. All these researches are done to maintain the sustainability of natural resources that can be maintained or kept in existence by replacing natural resources with renewable resources or manmade resources like fly ash, M sand, Risk husk, ash recycled aggregates, and with some waste materials. The alternative solution for sewage sludge disposal is incineration which makes sewage sludge to SSA (sewage sludge ash). In this process, main components are sewage sludge in presence of high temperature (500 to 700 degree Celsius) such as SiO2, CaO, Al2O3 (Wojciech Piasta 2016) [1], (Ciarán J. Lynn 2015) [2] are the components of OPC (Ordinary Portland cement). So, it can be used in place of cement content in concrete without any objection with the current population and urbanization, it is clear that the demand for cement
and fine aggregate will increase in the future. Sustainability of natural resources can be maintained or kept in existence by replacing natural resources with renewable resources or manmade resources like fly ash, M sand, Risk husk, ash recycled aggregates, and with some waste materials (Sankh 2018) [3]. It is clear that the demand for cement will increase in the future. (Ing 2016) [4]. The use of industrial by-products (waste material) as an alternate to cement and sand in concrete production (Barbora Krejcirikova 2018) [5]. When sewage sludge is used in agriculture within a certain timeframe (Nakic.D 2018) [6]. Sewage sludge contains SiO2, CaO, Al2O3, Fe3O4, and other components of cement it can be also used as a raw material for cement production.

2. Literature review

Researchers like (Prabhanjan 2020)[10] were studied by taking waste ballast by crushing to 10mm, 12.5mm, and 20mm sizes which are used for road pavements and added 5%EDTA solution and found that increased strength than the normal aggregate. (Laxmi 2020) [9] Made an attempt using rubber tyre chips (20mm) of 5%, 10%, 15%, and 20% as replacement of aggregate in concrete and found that about 5% to 8% can be used without loss of strength. (Ayyappa 2020) [7] Studied by using coconut shells by 2,4, and 6 percentages in place of coarse aggregate and eggshell power were used in place of cement by percentages of 5, 10 and 15 and observed optimum at 6% both eggshell powder and coconut shells and also observed that weight of the concrete was reduced. (Yadav 2020) [12] Used waste steel fibers by varying from 1 to 6% in steps of 1 and 1% polypropylene fibers constantly and observed that using waste steel fibers workability reduced and all the mechanical properties were increased. It also resulted in reduced cracks due to the presence of polypropylene fibers. (Guruprasad 2019) [8] Attempted an experiment using SIFRON fibers in concrete as slurry infiltrated hybrid fiber reinforced concrete and kept for curing in an Acid media for 60 days and compared with slurry infiltrated mono fiber reinforced concrete and found that in first case concrete is having better resistance to acid attack. The experimental work was done to observe the effects taking place during the replacement of the GGBS, Limestone powder, and pond ash on fresh and solidified properties of SCC. Replacement of pond ash by weight of fine aggregates in various percentages such as 20%, 40%, 60%, GGBS& limestone powder of same percentages such as 20%, 40%, and 60% by weight of cement. By observing the experimental results 40% replacement is optimum. As a part of using pond ash, we noticed settlement undergoes long time to settle. After that 60% replacement of any byproduct was not good for usage. Pond ash-poor to use as fine aggregate due to lack of initial setting time and strength obtained. By providing the confinement at different percentages use to increase strength at 28 days.

Sewage sludge is a byproduct of domestic sewage sludge treatment plant. Due to urbanization and population growth, the amount of SSA (sewage sludge ash) is also increased and also it will increase in the future. Before the installation of domestic sewage sludge treatment plants in urban areas, the public use to dispose of sewage sludge in open areas, lakes, and directly in damping areas. In this present study on replacement of cement with SSA (sewage sludge ash) and fine aggregate with pond ash in percentages such as SSA is kept at constant 5% as the cement is PPC already consists of 30-35% of fly ash so additional % of ash may result in a decrease in early strength and also 5% SSA gives the concrete higher early strength than any other % of SSA being replaced (Swamy 2019) [11] so keeping the SSA as constantly changing the fine aggregate % with pond ash such as 2%,4%,…30% was found.

3. Methods and Materials

3.1. Materials Used

3.1.1. Cement

The most commonly available Portland pozzolana cement(PPC) was used for the investigation. All the tests on cement are conducted as per IS 1489-1(1991). Cement was bought from the same source throughout the research work. While storing cement, all possible contact with moisture was avoided.

The specific gravity of cement = 3.16
The fineness of cement = 7.16
3.1.2. Fine Aggregates
Locally available river sand is used in the present study

The specific gravity of F.A = 2.71
Fineness Modulus = 246/100 = 2.46
The sand used is Fine Sand (Zone-II)

3.1.3. Coarse Aggregate
Crushed granite used as Coarse aggregate

The specific gravity of Coarse Aggregate = 2.65
Water absorption = 1%

3.1.4. Water
The important ingredient is water for concrete which participates in chemical reactions with cement. Portable water was used in the present work throughout.

3.1.5. Pond ash
In India, thermal power plants adopt wet techniques to remove the debris in large ponds. They have washed away with water in the form of slurry and forms Pond ash. If it is coarser and lees pozzolanic cannot be used. Hence researchers working worldwide are focussing to use it alternatively in the concrete industry is one of the effective methods to utilize. Thermal Power plant Ramagundam is producing plenty of pond ash which is made used in the present study.

3.1.6. Biochar
Septage or "septic tank matter" is mostly rewarded slime that is amassed and put away in a septic tank or comparative on location sewage facility. Septage debris is a side-effect from the pretreatment of family wastewater (sewage) in a septic tank. Following a couple of long stretches of collection, septage is normally siphoned out of a septic tank by a vacuum truck. Septic tanks receive black water from flush toilets, as well as greywater. To overcome this environmental impact by dumping of untreated sludge, sewage sludge ash is used as a replacement of cement in concrete in this project. The sewage treatment plant in Warangal producing Septage ash (Biochar) by the process of incineration of Septage. It is made use in the present work.

3.2. Methodology
Previous researchers used binders and fillers are replaced with flyash, GGBS, Rice husk ash, Biochar, pond ash, etc, separately but in the present work, the combination of binder and filler replaced with Biochar and pond ash together. Concrete cubes of 150mm of 6 numbers were cast per each Mix out of which 3 were tested for 7-day strength and remaining for 28 – day strength. In each Mix of Concrete cement is replaced with 5% Biochar constantly throughout the project and replacement of fine aggregate by varying percentages of the pond ash from 2% to 30% in steps of 2% each incrementally.

Figure 1. below shows the flow of the present work involved in various stages. The methodology follows initially material testing the basic properties of cement, fine aggregate, and coarse aggregate, and based on the results mix design for M20 concrete was made using IS10262-2019 and the quantities were estimated.
**Figure 1.** The flow of the present work involved in various stages.

The estimated quantities are represented in **Table 1.** given below calculated as per the IS10262-2019 mix design code.
Table 1. Quantities of Materials Used.

| Mix | Cement (kg/m³) | Biochar (kg/m³) | Fine Aggregate (kg/m³) | Pond ash (kg/m³) | Coarse Aggregate (kg/m³) | Water (kg/m³) |
|-----|----------------|-----------------|------------------------|-----------------|--------------------------|--------------|
| M0  | 450.0          | 0.0             | 640.75                 | 0.00            | 1204.053                 | 202.74       |
| M2  | 427.5          | 22.5            | 627.93                 | 12.81           | 1204.053                 | 202.74       |
| M4  | 427.5          | 22.5            | 615.12                 | 25.63           | 1204.053                 | 202.74       |
| M6  | 427.5          | 22.5            | 602.30                 | 38.44           | 1204.053                 | 202.74       |
| M8  | 427.5          | 22.5            | 589.50                 | 51.26           | 1204.053                 | 202.74       |
| M10 | 427.5          | 22.5            | 576.67                 | 64.07           | 1204.053                 | 202.74       |
| M12 | 427.5          | 22.5            | 563.86                 | 76.89           | 1204.053                 | 202.74       |
| M14 | 427.5          | 22.5            | 551.04                 | 89.70           | 1204.053                 | 202.74       |
| M16 | 427.5          | 22.5            | 538.23                 | 102.52          | 1204.053                 | 202.74       |
| M18 | 427.5          | 22.5            | 525.41                 | 115.33          | 1204.053                 | 202.74       |
| M20 | 427.5          | 22.5            | 512.60                 | 128.15          | 1204.053                 | 202.74       |
| M22 | 427.5          | 22.5            | 499.78                 | 140.03          | 1204.053                 | 202.74       |
| M24 | 427.5          | 22.5            | 486.97                 | 153.78          | 1204.053                 | 202.74       |
| M26 | 427.5          | 22.5            | 474.15                 | 166.59          | 1204.053                 | 202.74       |
| M28 | 427.5          | 22.5            | 461.34                 | 179.41          | 1204.053                 | 202.74       |
| M30 | 427.5          | 22.5            | 448.52                 | 192.22          | 1204.053                 | 202.74       |

The estimated quantities are mixed thoroughly as shown in Figures 2 and 3 in dry condition and then by the addition of water the ingredients were mixed to get a good consistency.

![Figure 2. Mixing of concrete ingredients by hand.](image1)

![Figure 3. Mixing of concrete ingredients by Concrete mixer.](image2)
After mixing required consistency the concrete was placed in the prepared molds of size 150x150x150 mm cubes shown in Figure 4, and are placed in a curing tank for 28-days, then they were tested in standard compression testing machine shown in Figure 5 to get compressive strength.

4. Results and Discussions

Based on the results obtained from the experimental data the compressive strength of M20 concrete with 5% of Biochar being replaced with Cement and alternate proportion replacing fine aggregate with pond ash at 2%, 4%, …30%. Plots were drawn and conclusions were made. Figure 6 shows the variation of compressive strength with varying percentages of pond ash after 7-days.

![Figure 4. The casting of cubes.](image1)

![Figure 5. Testing of cubes.](image2)

![Figure 6. Compressive Strength at 7-Day.](image3)
The variation of 7-Day compressive strength shows decreasing throughout as the percentage of pond ash increases. This indicates low early strength. After 28-day the compressive strength was observed to be increasing by increasing the percentage of pond ash indicating the pozzolanic nature of pond ash.

![Compressive Strength at 28-Day](image)

**Figure 7.** Compressive Strength at 28-Day.

The variation of compressive strength shown in Figure 7 after 28 – day increasing initially and found maximum at 20% replacement of pond ash and compressive strength is reducing by the addition of pond ash further.

5. Conclusion
The following conclusions were made based on the results using Biochar and Pond ash together in concrete, it is giving low early strength and later showing better results. The optimum percentage of pond ash in place of fine aggregate was found to be 20%. As giving later strength this combination may be useful for durable structures. It may be observed that the cost of concrete was reduced, as the cement content is reducing about 5% makes the concrete eco-friendly. Use of pond ash in place of fine aggregate we conclude that sustainability of non-renewable resources can be maintained. Further research can be done by applying the same concrete to structural members. Durability Properties can be checked for the same concrete. It can be used for different mixes using the same combinations.

References
[1] Piasta W and Lukawska M 2016 The effect of sewage sludge ash on properties of cement composites *Procedia engineering* **161** 1018-24.
[2] Lynn CJ, Dhir RK and Ghataora GS 2018 Environmental impacts of sewage sludge ash in construction: leaching assessment *Resources, Conservation and Recycling* **136** 306-14.
[3] Sankh AC, Biradar PM, Naghathan SJ and Ishwargol MB 2014 Recent trends in replacement of natural sand with different alternatives In *Proc. of the Int. Conf. on Advances in Engineering and Technology* 59-66.
[4] Ing DS, Chin SC, Guan TK and Suil A 2016 The use of sewage sludge ash (SSA) as partial replacement of cement in concrete *ARPN Journal of Engineering and Applied Sciences* **11** 3771-5.
[5] Krejcirikova B, Kolarik J and Wargocki P 2018 The effects of cement-based and cement-ash-based mortar slabs on indoor air quality *Building and Environment* **135** 213-23.
[6] Nakic D, Vouk D, Serdar M and Cheeseman CR 2018 Use of MID-MIX® treated sewage sludge in cement mortars and concrete *European Journal of Environmental and Civil Engineering* **16** 1-6.
[7] Ayyappa RA, Sandeep Reddy B, Swamy Yadav G, Sudarshan DS 2020 Partial Replacement of Cement and Coarse Aggregate by Egg Shell Powder and Coconut Shells International Journal of Innovative Technology and Exploring Engineering 4 1242-1246.

[8] Guruprasad M, Priyanka A, Prabhanan N and Swamy G 2019 Behaviour of Slurry Infiltrated Hybrid Fiberreinforced Concrete Subjected to Acidic Attack International Journal of Recent Technology and Engineering 4 6598-6602.

[9] Laxmi E, Yadav GS, Patil K, Jalade S and Priyamka A 2020 Effects of Scrap Rubber TYRE Aggregates as Partial Replacement of Natural Aggregates in High Strength Concrete. International Journal of Innovative Technology and Exploring Engineering 4 2039-2043.

[10] Prabhanjan N, Yadav GS, Sahithi G, Sravanthi B and Tipraj B 2020 Assesment to Increase the Mechanical Properties of used Ballast by EDTA Solution as a Construction Material International Journal of Recent Technology and Engineering 5 157-160.

[11] Swamy G, Krishna EV, Kumar SY, Prasad GH and Pavan R 2019 Potential Use of Biochar as Construction Material International Journal of Recent Technology and Engineering 1 1570-1572.

[12] Yadav GS, Prabhanjan N, Sahithi G and Sangeetha G 2020 Strength Investigation of Fly Ash Based Concrete Waste Steel Fibre and Polypropylene Fibre as Reinforcing Materials In Int. Conf. on Emerging Trends in Engineering (ICETE) 155-161.

[13] Nakic D, Vouk D, Serdar M and Cheeseman CR 2018 Use of MID-MIX® treated sewage sludge in cement mortars and concrete European Journal of Environmental and Civil Engineering 16 1-6.

[14] Arumugam K, Ilango van R and Manohar DJ 2015 A study on characterization and use of pond ash as fine aggregate in concrete International Journal of Civil & Structural Engineering 2 466-74.

[15] Sumeet, Munnr S 2015 Study on Strength and Durability of Concrete with Partial Replacement of Fine Aggregate by Pond Ash IJSRD - International Journal for Scientific Research & Development 2 296-299.

[16] Bagwan KM and Kulkarni DS 2014 A Study of Characteristic and Use of Pond Ash for Construction. International Journal of Emerging Technology and Advanced Engineering 4 835-840.

[17] Haldive SA and Kambekar AR 2013 Experimental study on combined effect of fly ash and pond ash on strength and durability of concrete International Journal of Science and Engineering Research 4 81-6.

[18] Patel J, Patel K and Patel G 2013 Utilization of pond fly ash as a partial replacement in fine aggregate with using fine fly ash and alccofine in HSC IJRET: International Journal of Research in Engineering and Technology 2 2319-1163.

[19] Arumugam K, Ilango van R and Manohar DJ 2011 A study on characterization and use of pond ash as fine aggregate in concrete International Journal of Civil & Structural Engineering 2 466-74.

[20] Ganesh B, Bai HS and Nagendra R 2011 Effective utilization of pond ash for sustainable construction--need of the hour International Journal of Earth Sciences and Engineering 4 151-4.

[21] Stolaroff JK, Lowry GV and Keith DW 2005 Using CaO-and MgO-rich industrial waste streams for carbon sequestration Energy Conversion and Management 46 687-99.

[22] Torres A, Bartlett L and Pilgrim C 2017 Effect of foundry waste on the mechanical properties of Portland Cement Concrete Construction and building materials 135 674-81.

[23] Toutanji H, Delatte N, Aggoun S, Duval R and Danson A 2004 Effect of supplementary cementitious materials on the compressive strength and durability of short-term cured concrete Cement and Concrete Research 34 311-9.

[24] Van der Lugt P, Van den Dobbelsteek AA and Janssen JJ 2006 An environmental, economic and practical assessment of bamboo as a building material for supporting structures Construction and building materials 20 648-56.
[25] Vaughn SF, Kenar JA, Tisserat B, Jackson MA, Joshee N, Vaidya BN and Peterson SC 2017 Chemical and physical properties of Paulownia elongata biochar modified with oxidants for horticultural applications Industrial Crops and Products 97 260-7.

[26] Vegas I, Frias M, Urreta J and San José JT 2006 Obtaining a pozzolanic addition from the controlled calcination of paper mill sludge. Performance in cement matrices Materiales de Construcción 56 49-60.