International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 10 October 2024
Page No: 2446 - 2455
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0335

# Strength and Durability Studies on Concrete Utilizing Sewage Sludge Ash and Treated Sewage Water

*Lokesh B K*[1], *Ashwini L K*[2], *S Vijaya* [3]
[1]*PG Scholar, Dept. of Civil, Dr. Ambedkar Institute of Technology, Bengaluru, Karnataka, India.*
[2]*Assistant Professor, Dept. of Civil, Dr. Ambedkar Institute of Technology, Bengaluru, Karnataka, India.*
[3]*Professor, Dept. of Civil, Dr. Ambedkar Institute of Technology, Bengaluru, Karnataka, India.*
***Emails:*** *lokeshbk353@gmail.com*[1], *ashwinilk181@gmail.com*[2], *vijayas_cv@drait.edu.in*[3]

## Abstract

*The effects of incorporating sewage sludge ash and treated sewage water on the strength and durability of concrete, with the goal of evaluating their viability as sustainable alternatives in construction materials. The sewage sludge ash was used as a replacement material to cement after burning of sewage sludge with high temperature of 800°C. So obtained sewage sludge ash was analysed for chemical, physical and morphological properties. Burning sewage sludge at high temperatures imparts pozzolanic properties to the resulting ash, which, when used as a cement replacement, improves concrete's compressive and tensile strengths. Various SSA replacement levels (5%, 10%, 15%, 20%, and 25%) were tested, with 15% SSA showing the highest strength gains. SSA affects setting time and workability, but treated sewage water does not significantly impact concrete properties. Concrete with SSA showed superior strength compared to conventional mixes with both fresh and treated water. Durability tests revealed that while SSA concrete experienced minor efflorescence in saltwater, it resisted acid attacks better than conventional concrete, indicating its good durability.*

***Keywords:*** *Sewage Sludge, Sewage Sludge Ash, Sewage Treated Water, Temperature.*

## 1. Introduction

Sewage sludge, a byproduct of sewage treatment plants, contains organic and inorganic compounds in the form of suspended solids from human waste, food, and vegetables blended with water. The separation of these particles forms slurry known as sewage sludge, which is difficult to manage due to its 80-85% moisture content and complex composition (Chin-Wei Hsu, 2020). Methods like pyrolysis and anaerobic digestion reduce mass, odor, pathogens, and energy usage, and recover methane (Mahutjane, 2023). Supercritical water gasification can also produce hydrogen gas while addressing the sludge problem (Abebaw, 2020). Despite these treatments, sludge dumping continues, leading to soil and water contamination and the spread of harmful pathogens. Some countries have banned its disposal on land or in the sea for health reasons (Lynn, 2015). Incineration has been used to reduce sludge volume by 70-90%, but it may still cause air and soil pollution (Mahutjane, 2023) but have seen reduction in effect of foot and mouth diseases(Donatello, 2013). The production of sewage sludge worldwide is massive; for example, Karnataka produces 2647.5 MLD of sewage, far exceeding its treatment capacity. Globally, sludge production is significant, with Hong Kong about 1000tonnes every day in 2014(Zen Chen, 2017), 520 tons per year in Romania in 2018 (Rusănescu, 2022), 240 million tons of wet sludge in China in 2010, 1.03milliontons in England, 1.85million tons in Germany, and worldwide 45 million tons in 2017(Yan Xia, 2023). Traditional disposal methods, such as landfilling and incineration, are insufficient as population growth exacerbates sewage production. This highlights the need for alternative uses of sewage sludge, especially in the construction industry. Sewage sludge's high moisture content and organic matter can negatively impact cementitious materials, increasing porosity and reducing bonding strength when used directly (Ashwini L K, 2024). Research has shown its potential use in geo-polymer concrete, where it overcomes the drawbacks of high water demand and reduced strength by using NaOH and water glass (Thukkaram, 2024, Zhao 2023). It has also been used as a fine aggregate in concrete (Baeza-Brotons, 2014), as an additive in blocks (Arooj, 2021), and in mortar preparation (Haustein, 2022, Coutand, 2006), in production of brick (Lin 2001). Water, another crucial resource, is also under threat. While 70% of the Earth's surface is water, only 3% is drinkable, with large-scale groundwater extraction in countries like India, the US, and China. Contamination of groundwater through leachability affects water quality, causing health issues such as bone and dental problems. By 2030, the industry is projected to require 1500 billion m$^3$ of water, with concrete production alone consuming 500L per m$^3$ (Harshit Varshney, 2021). Construction activities, including washing Ready-Mix Concrete trucks, contribute to water and soil pollution. Wastewater reuse in the construction industry is underexplored example car wash water used in high strength concrete (Al-Jabri 2011), treated domestic waster used for curing and production of concrete (G. Asadollahfardi 2016). but shows promise, with research suggesting treated wastewater can maintain concrete strength. Recommendations state that water other than fresh water should not reduce strength by more than 10% compared to a nominal mix (IS 456).

## 2. Voids and Aspirations

Many studies on sewage sludge usage in concrete show mixed results, with some reporting improved strength and pozzolanic activity, but increased water demand, while others show strength reductions. Research on treated wastewater also indicates performance depends on water properties. However, no study has combined sewage sludge ash (SSA) as a cement replacement with treated water. This research aims to evaluate compressive, split tensile and flexural strength using SSA and treated water, along with durability against acid ($H_2SO_4$) and saltwater attacks. It also examines SSA's morphology and composition using SEM and XRF analysis to understand its influence on concrete properties.

## 3. Assessment of Materials

### 3.1.Materials

Materials used in this study are as follows:

### 3.1.1. Cement

Cement used is ordinary Portland cement of grade 53 for conduction of tests and casting specimens. The chemical composition of cement analysed is illustrated in table 5. and others test conducted as per Indian standard codes are noted in table 2 such as specific gravity.

### 3.1.2. Fine Aggregate

Fine aggregate used is the available M-sand from the local suppliers which is used locally in construction activities the basic tests conducted on it are listed in table 2 as per the codes.

### 3.1.3. Coarse Aggregate

Used 20mm and down size coarse aggregate which is locally used for construction, the tests regarding the use of it is done and noted in table 2 as per code.

### 3.1.4. Sewage Sludge Ash

It is the byproduct of incineration of sewage sludge at 800$^{o}$C in the furnace. As studies suggested 750$^{o}$C-800$^{o}$C to yield good pozzolanic content (Sara Naamane, 2016). The sewage sludge was collected from the local sewage treatment plant. The collected sludge was semi solid type having 80-85% of moisture as in Figure 1.a), it was sun dried, and image after drying it can be seen in Figure1.b). The reduction in weight was around 350-400 grams per kilograms of sludge after burning. Thus obtained burnt product was in clinkers form shown Figure1.c), further the clinkers were grinded so that it passes through 90micron sieve which is used as a replacement to cement in the concrete specimen casted for compressive and tensile strength test. So obtained ash was used to conduct basic test which are noted in table 2.

### 3.1.5. Sewage Treated Water

Sewage treated water, also called effluent, undergoes a multi-stage process to remove harmful contaminants like bacteria and organic matter. This treated water isn't usually drinkable but can be safe for irrigation, industrial uses, etc. considering the demand for fresh water here a step is taken to use such treated water in concrete which is collected from same plant and having specific gravity of 1.01**.** The properties for use water other than fresh must have within the limit of code, hence various test were conducted which is illustrated in table 1 along with codal limits, it can be observed that the values are within the range.

**Figure 1** Sewage Sludge in Various Forms
**A.** Wet State (Semi Solid), **B.** Dry State **C.** Clinkers Form

**Table 1** Investigated Results of the Sewage Treated Water

| Parameters | Tested value | Codal limit |
|---|---|---|
| **Temperature** | 18-20 ºC | - |
| **pH** | 7.1 mg/l | >6 |
| **Turbidity** | 12 mg/l | - |
| **Sulfate ($SO_4$)** | 170 mg/l | 400mg/l |
| **Nitrate ($NO_3$)** | 12 mg/l | - |
| **Nitrite ($NO_2$)** | 3.2 mg/l | - |
| **Chloride** | 52 mg/l | - |
| **Total Solid (TS)** | 580 mg/l | 2000mg/l |
| **Total suspended solid (TSS)** | 350 mg/l | - |
| **Chemical Oxygen Demand (COD)** | 89 g/l | - |

### 3.2.Analytical Methods

#### 3.2.1. SEM and EDX Analyses

Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDX) analyses provide detailed insights into its microstructure and elemental composition. SEM captures high-resolution images of the material, revealing its porosity, cracks. This helps assess the quality of the material and its texture. EDX, integrated with SEM, identifies the elemental composition of specific areas, detecting elements like calcium, silicon, aluminum, and iron.

#### 3.2.2. XRF Analysis

X-ray fluorescence analysis is a non-destructive technique used to determine the elemental composition of materials, including admixtures in materials. In XRF analysis of an admixture, a sample is exposed to X-rays, causing elements within the sample to emit secondary (fluorescent) X-rays. The emitted X-rays are characteristic of specific elements, allowing the identification and quantification of major oxides (e.g., $SiO_2$, $Al_2O_3$, $Fe_2O_3$, CaO) and trace elements. This analysis helps assess the purity, composition of the materials.

### 3.3.Pozzolana Check

Pozzolanic check is required for the replacement materials and there are many methods for it, such as strength activity index (SAI), Frattini test, Chapelle test and some analytical methods are XRF, Thermo gravimetric test. Out of these strength activity index, Chapelle test were used in these study, for former one, the motor test was conducted with the required mix percent to know the pozzolanity of the sewage sludge ash for which motors with cement replaced with percentage of sewage sludge and control mix were prepared and cured for 7 and 28 days and test for compressive strength obtained with showing 78-80% that of control motor. The Chapelle test was used to determine the Pozzolana content in which the solution with SSA and calcium hydroxide was boiled under reflux for 16 hours and titration with HCl indicated having good pozzolana content having consumed calcium hydroxide is around 75-80% of SSA.

### 3.4.Density

The density of sewage sludge ash is around 455kg/m$^3$; this may be the reason for sewage sludge to have pores. The specific gravity of SSA is low of around 2.27 which is less than the cement. The effect also can be seen on specimen having less weight as the sample percent being increased. But the bonding of SSA after hydration along with cement though having less specific gravity reached high strength.

**Table 2** Physical Properties of Materials

| Physical Properties | | | | | |
|---|---|---|---|---|---|
| **Sl no** | **Properties** | **Materials** | | | |
| | | **Cement** | **Fine aggregate** | **Coarse aggregate** | **Sewage sludge ash** |
| **1** | **Specific Gravity** | 3.16 | 2.33 | 2.85 | 2.27 |
| **2** | **Fineness Module** | - | 2.8 | 6.5 | - |
| **3** | **Water Absorption** | - | 0.35% | 0.5% | 1% |
| **4** | **Impact value** | - | - | 27.08% | - |
| **5** | **Crushing value** | - | - | 25.72% | - |
| **6** | **Abrasion** | - | - | 9.14% | - |
| **7** | **Bulk density** | - | 16.64% | - | - |
| **8** | **LOI** | 2.16 | - | - | 2.36 |

## 4. Experimental Studies

### 4.1.Mixes and Methods

To prepare the specimens mix proportion was calculated with the reference of IS 10262:2019, with the use of required data from the material tests. The mixes were given some specification in order to differentiate between percentage additions and so on. They are as follows M0, M1, which represents nominal concrete using normal water, nominal concrete using sewage treated water and M2, M3, M4, M5 and M6 represents cement replaced with 5%, 10%, 15%, 20% and 25% sewage sludge ash and water was replaced by 100% sewage treated water respectively. Table 3 represents the mixes with their mix proportion. Required number of specimens was casted according this mixes.

**Table 3** Mixes with Their Proportions

| **MIXES** | **Cement (kg/m$^3$)** | **SSA (kg/m$^3$)** | **Fine Aggregate (kg/m$^3$)** | **Coarse Aggregate (kg/m$^3$)** | **Water (kg/m$^3$)** |
|---|---|---|---|---|---|
| **M0** | 492 | --- | 589 | 1127 | 197 |
| **M1** | 492 | --- | 590 | 1130 | 195 |
| **M2** | 468 | 24.6 | 588 | 1125 | 195 |
| **M3** | 443 | 49.2 | 544 | 1040 | 195 |
| **M4** | 418 | 73.8 | 534 | 1021 | 195 |
| **M5** | 394 | 98.4 | 524 | 1002 | 195 |
| **M6** | 370 | 123 | 514 | 983 | 195 |

### 4.2.Setting Time

Initial and final setting time was found for M0, M1, M2, M3, M4, M5 and M6 to know the effect of sewage sludge ash and sewage treated water in setting time. Also to know the effect of treated water the mixes with sewage sludge ash were tested with normal water too, they are specified as N1, N2, N3, N4 and N5 representing cement replaced with 5%, 10%, 15%, 20% and 25% sewage sludge ash and used normal water in the mixes the results are illustrated in Figure.2. It is observed that treated water not influence much on setting time, whereas replacement of cement with sewage sludge ash influence the setting time. Which can be observed with M1 having slight difference in its final setting compared to M0, while M2-M6 having increase in both initial and final setting time, reaching 70min for initial and 285 for final, but N1-N5 having similar values to M2-M6, having only slight difference in final setting for N5.

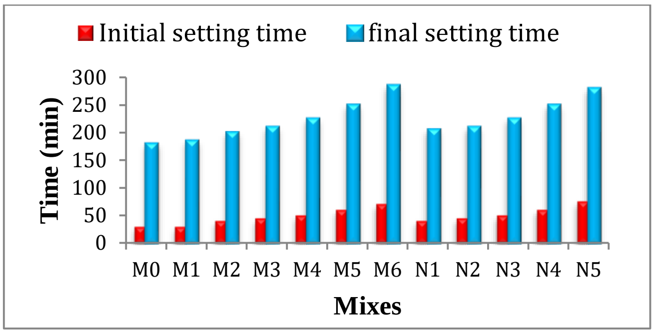

**Figure 2** **Initial and Final Setting Time of Mixes**

### 4.3. Consistency & Specific Gravity of Mixes

**Table 4** **Specific Gravity and Consistency of Various Mixes**

| Mixes | Specific gravity (g/cm$^3$) | Consistency (%) |
|---|---|---|
| M0 | 3.16 | 30 |
| M1 | 3.17 | 30 |
| M2 | 2.95 | 32 |
| M3 | 2.87 | 34 |
| M4 | 2.74 | 36 |
| M5 | 2.65 | 38 |
| M6 | 2.52 | 42 |

The consistency of the mixes was tested to determine their water demand. Mixes with sewage sludge ash as a replacement material significantly influenced consistency as the percentage increased, compared to those with treated water. Specific gravity seen to be decreased as the percent replacement of SSA increased. This may be attributed to low density of sludge ash which is around 455 kg/m$^3$. Table 4 illustrates values of consistency and specific gravity of the mixes.

### 4.4.Workability

Workability important factor while dealing with concrete, wherein having high workability leads segregation, bleeding and less leads in improper compaction and effects strength by having voids. Slump value of mixes obtained is illustrated in Figure 3. Nominal concrete with sewage treated water shows minor reduction in slump than that with normal water, indicating influence of sewage treated water on slump which is also mentioned by Harshit Varshney (2021), even though there was no difference in setting time some difference can be observed in slump value. Also slump value takes descending order as the ascending of sewage sludge ash percent in concrete.

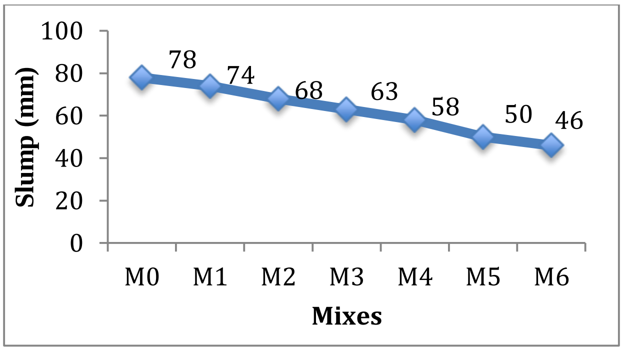

**Figure 3** **Slump Values of Different Mixes**

### 4.5.Analytical Methods

### 4.5.1. SEM & EDX Analysis

Figure 3. shows The sample appears to be composed of irregular, angular particles with varying sizes and shapes. The surface of the particles is rough and textured, suggesting the presence of surface features or irregularities. The overall morphology of the particles is indicative of a crystalline or polycrystalline material. The Energy Dispersive X-ray (EDX) spectrum of the same material, highlighting its elemental composition. Peaks for silicon (Si), oxygen (O), aluminum (Al), calcium (Ca), and smaller amounts of iron (Fe), potassium (K), and magnesium (Mg) suggest it may contain pozzolanic compounds, influencing both strength and durability of concrete when used as a replacement.

### 4.5.2. XRF Analysis

Chemical composition of sewage sludge and sewage sludge ash is observed in table 5. The high amounts of $SiO_2$, $Al_2O_3$, $Fe_2O_3$, and CaO contribute to strength gain. $SiO_2$ helps in the formation of calcium silicate hydrate (C-S-H), which is the primary strength-giving compound. $Al_2O_3$ enhances the pozzolanic properties, improving the long-term strength and durability. CaO also aids in the formation of C-S-H, further contributing to strength gain. The high content of $Fe_2O_3$ influences the color of the concrete and can improve its tensile strength. Other compounds are in lesser percent helped by having no significant effect on concrete. High amount of $SiO_2$ compared to sewage sludge which increased after incineration which suggests burning at high temperature leads to improved strength.

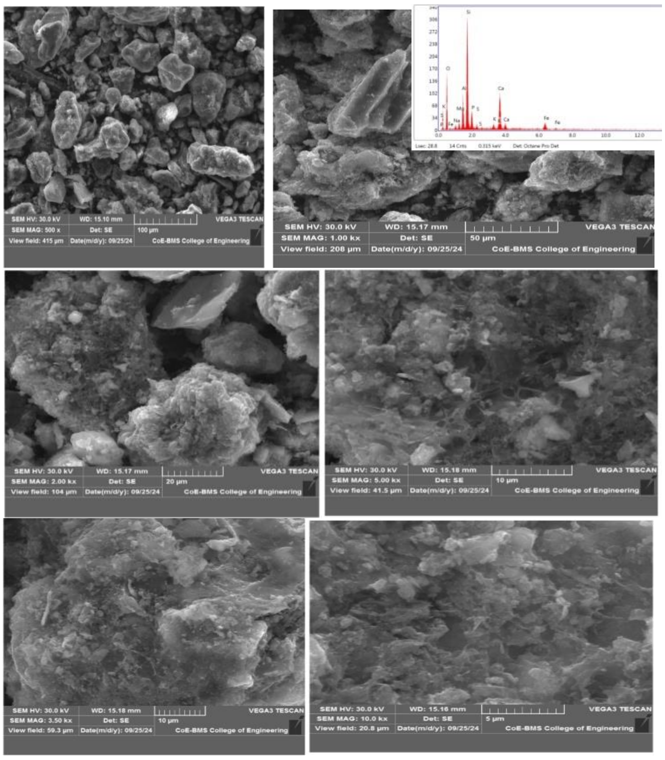

**Figure 4** **SEM-EDX Images of Sewage Sludge Ash**

**Table 5** **Chemical Composition**

| Chemical Composition | | | | |
|---|---|---|---|---|
| **S.No** | **Composition** | **SS** | **SSA** | **Cement** |
| 1 | **$SiO_2$** | 34.6 | 47.77 | 20.27 |
| 2 | **$Al_2O_3$** | 10.8 | 13.09 | 5.32 |
| 3 | **$Fe_2O_3$** | 5.53 | 4.54 | 3.56 |
| 4 | **CaO** | 13.3 | 12.95 | 60.41 |
| 5 | **MgO** | 3.1 | 2.78 | 2.46 |
| 6 | **$SO_3$** | 1.8 | 2.19 | - |
| 7 | **MnO** | 0.24 | - | - |
| 8 | **$P_2O_5$** | 15.8 | 12.55 | - |
| 9 | **$K_2O$** | 1.0 | 1.11 | - |
| 10 | **$Na_2O$** | 0.8 | - | - |

## 5. Behavior of Matured Concrete

### 5.1.Compressive Strength

Compressive strength, a key design characteristic of concrete, was assessed using 150mm³ cube specimens with various percentages of sewage sludge ash (SSA) and treated water. Concrete samples were tested after 7, 14, 28, and 56 days of curing. Results showed that concrete with SSA (15% replacement) achieved the highest strength across all curing periods, while 5%, 10%, 20% and 25% SSA replacements exhibited varying strength developments. Treated water had no significant effect on strength. The 15% SSA mix demonstrated superior strength due to its pozzolanic properties, enhancing binding through $Al_2O_3$ content.

### 5.2. Split Tensile Strength

Split tensile strength is a crucial indicator of concrete's tensile capacity, especially for structures subject to bending or lateral forces. The test applies a diametric compressive load to cylindrical specimens (15 cm diameter, 30 cm height) until failure. Results from Figure 5 show that M0 and M1 have similar final strengths, with M2 and M3 performing comparably. M4, containing 15% sewage sludge ash (SSA), exhibits the highest strength, likely due to the higher iron content in SSA compared to cement. However, M5 and M6, with higher ash percentages, demonstrate reduced tensile strength.

### 5.3.Flexural Strength

Flexural strength is a crucial property tested in concrete, measuring its ability to resist bending failure. This test is performed on an unreinforced concrete beam and is expressed as the Modulus of Rupture. It is determined using a two-point loading method following specific testing standards. Beam of dimension 100mmx100mmx500mm was cast for this test. Flexural strength in terms of modulus of rupture is represented in Figure 6. Results illustrate that use of sewage sludge may indicate the improved strength in tensile. M0 and M1, exhibit similar performance indicates sewage treated water not affecting the tensile strength. M2 and M3 perform comparably to M0 and M1. M4, with 20% ash replacement, achieves the highest strength at 5.18 MPa, it may be due to the presence of iron composition in SSA which is more than that in cement. M5 and M6, with their higher ash content, exhibit lower strength, suggesting a decrease in flexural strength.

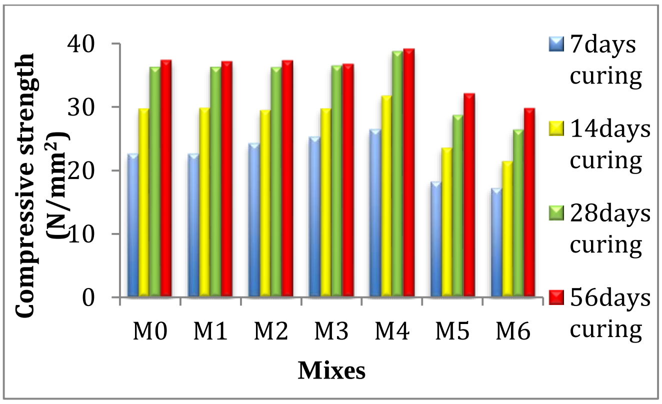

**Figure 5** Compressive Strength Results of 7, 14, 28 and 56 days Curing Period

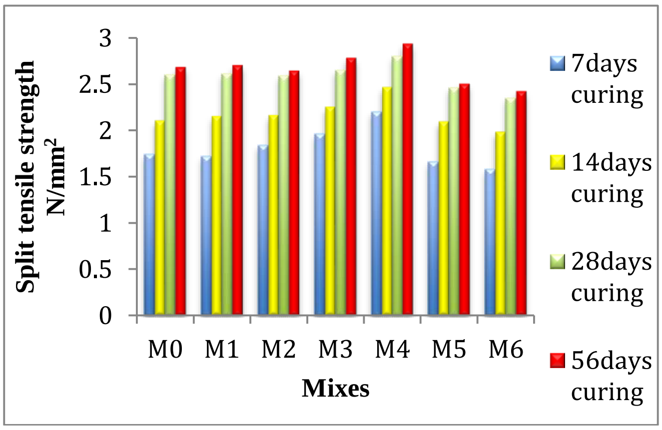

**Figure 6** Split Tensile Strength Results of 7, 14, 28 and 56 days Curing Period

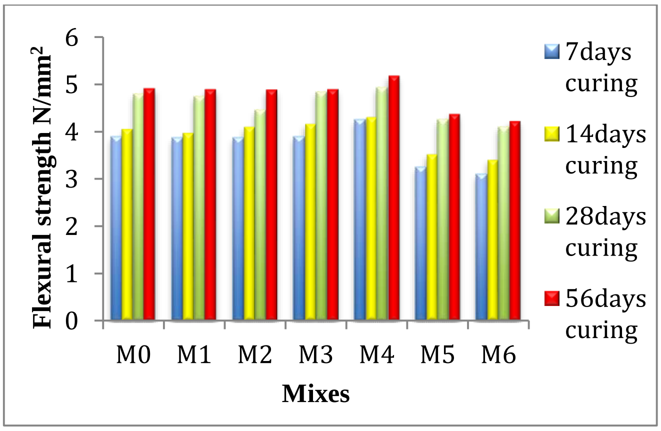

**Figure 7** Flexural Strength Results of 7, 14, 28 and 56 Days Curing Period

## 5.4. Durability

The durability of concrete refers to its ability to withstand various environmental conditions and maintain its strength and integrity over time. It is influenced by factors like water permeability, freeze-thaw resistance, chemical exposure, and the quality of materials used in the mix. A durable concrete resists deterioration caused by physical, chemical, or biological processes, ensuring long-term performance in structures. Proper curing, mix design, and protective measures can enhance concrete durability. High durability is essential for minimizing maintenance costs and extending the lifespan of infrastructure, especially in harsh environments such as coastal areas or areas with heavy chemical exposure.

### 5.4.1. Water Absorption

The immersion test is a common method to assess the water resistance of concrete. In this test, concrete specimens are submerged to determine the quantity of water that penetrates them. Lower water absorption indicates enhanced durability, as it reflects the concrete's improved capacity to resist moisture intrusion. Table 6 mentions the percentage absorption of the mixes at different immersion period. Specimens of nominal mix with normal and treated water as the absorption more than the specimens with SSA percent's this may be attributed to its permeability whereas the SSA occupies the voids in other specimen leading to less absorption. Specimens with 15% SSA as less absorption than 10% which is less than 5%, but 20% shows similar absorption to that of 15%, while at later days the absorption is less and 25% showing lesser than all, this illustrates that the absorption at initial was for the hydration, as compressive strength reached the target strength at later stage of curing only, hence as reduced pores and leads to less permeability.

**Table 6** Percentage Absorption of Various Mixes

| Mixes | Immersion period | | | |
|---|---|---|---|---|
| | 7 days | 14 days | 28 days | 56 days |
| **M0** | 1.9% | 2.41% | 2.84% | 2.89% |
| **M1** | 2.0% | 2.38% | 2.8% | 2.84% |
| **M2** | 1.89% | 2.2% | 2.62% | 2.71% |
| **M3** | 1.8% | 2.12% | 2.5% | 2.58% |
| **M4** | 1.5% | 1.61% | 1.9% | 1.94% |
| **M5** | 1.5% | 1.62% | 1.88% | 1.89% |
| **M6** | 1.48% | 1.6% | 1.7% | 1.78% |

### 5.4.2. Salt Attack

Resistance to salts is required mainly in the coastal areas and marine areas. Salts in water may influence on concrete forming efflorescence, expansion and deterioration. Hence to study this behavior the cube specimens were immersed in 5% salt solution and tested their compressive strength, results are interpreted in Figure 8. M0 to M3 show slight reductions in strength over time, indicating moderate resistance and M4 maintaining highest strength throughout, demonstrate excellent durability against salt exposure even to there was some efflorescence formation on surface of specimen. While the effect was found on M5 and M6, as it failed to achieve the target strength which was achieved in normal curing.

### 5.4.3. Acid attack

Chemical resistance is crucial for concrete durability, particularly in modern industries where exposure to acids, alkalis, and industrial salts causes significant deterioration. To assess this, cube specimens were immersed in a 5% $H_2SO_4$ solution, and their compressive strength and weight evaluated. The results, shown in Figures 8 and Table 7, indicate that strength decreased as the immersion period increased. Mixes M0 to M3 showed moderate resistance, with M4 demonstrating the highest strength and durability. Mixes M5 and M6, with lower initial strengths, remained relatively stable. Weight loss followed a similar trend, with M0, M1, M5, and M6 experiencing greater deterioration.

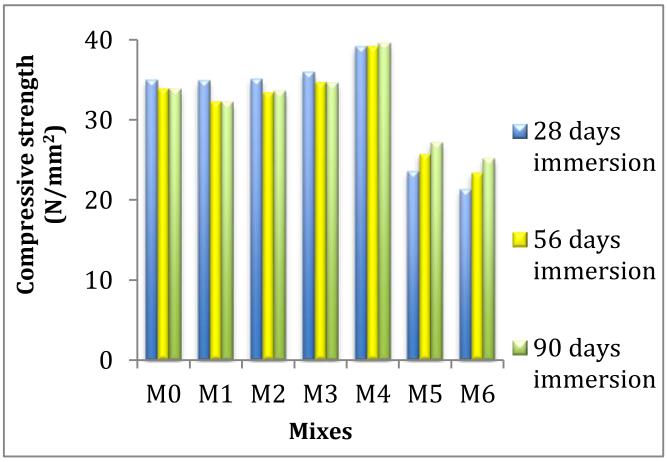

**Figure 8** **Compressive Strength Results of 28, 56 and 90 days' Immersion Period in Salt Solution**

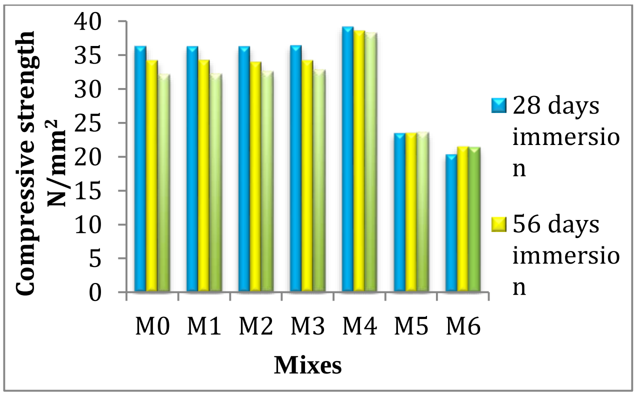

**Figure 9** **Compressive Strength Results of 28, 56 and 90 day's Immersion Period in Acid Solution**

**Table 7** **Percentage Weight Loss of Various Mixes**

| Mixes | Immersion period | | |
|---|---|---|---|
| | **28 days** | **56 days** | **90days** |
| **M0** | 2.43% | 2.84% | 3% |
| **M1** | 2.41% | 2.8% | 3.1% |
| **M2** | 1.45% | 1.6% | 1.78% |
| **M3** | 1.48% | 1.69% | 1.9% |
| **M4** | 1.58% | 1.89% | 1.94% |
| **M5** | 2.12% | 2.16% | 2.2% |
| **M6** | 2.28% | 2.32% | 2.35% |

## Conclusion

This paper focused on investigating influence of using sewage sludge ash as re-placement to cement after incineration of sewage sludge at 800$^{o}$C and use of sewage treated water instead of fresh water. The study revealed that use of sewage sludge ash in concrete shows in concrete improved strength than the control mix. The improved strength can be rewarded to its properties like, fines which were achieved by grinding the burnt sewage sludge, pozzolonic content, and surface texture. The high amount ferric content in ash may be the key factor for its improvement in its tensile strength which was measured in terms modulus of rupture and split tensile having its value higher than the nominal. The grinding to finer particles helps the ash to fill the voids in concrete along with the addition of binding property. Though the weight of specimens were lighter than the nominal mix the strength was higher the nominal, also the permeability is decreased as the curing days pass and also with the increase of SSA percent. Use of sewage treated water for nominal mix and also with SSA used as replacement as no negative impact in its strength and also other properties, indicating that use of treated water having its properties within the code as no negative impact. Increase in percent replacement of Sewage Sludge Ash in concrete affected the workability.

The increase in strength was more for replacement percent of 15% which was higher than nominal, 10% replacement though less than 15% replacement strength as its strength nearer to the nominal mix, whereas 20% managed to reach the target strength during period of 56 days curing while it was possible to achieve the strength more the grade designed during the curing period of 28 days.

The durability studies examined resulted as having no much loss in strength when exposed to salt solution even though there was slight efflorescence on surface of specimen for concrete with sewage sludge ash and treated water, but observed more decrease for nominal mix with normal and treated water. Exposure to an acid attack caused a decrease in strength for 10% SSA replacement, while other percentages did not show as significant a reduction. The nominal mix exhibited a notable decrease in strength. Further studies required to examine the effect of SSA in reinforced concrete and way to find strength gain for higher percent replacement.

## Acknowledgements

I would like to express my sincere gratitude to the Karnataka State Council for Science and Technology (KSCST) for their financial support in the 47th series of projects. This research was made possible through their generous grant of ₹7000, which provided essential resources and funding for the successful completion of the work. Their support has been instrumental in advancing this study, and I am deeply appreciative of their commitment to fostering scientific research and innovation.

## References

[1]. Hsu, Chin-Wei, and Chun-Tao Chen. "Strength development of cement pastes with alkali-activated dehydrated sewage sludge." Construction and Building Materials 255 (2020): 119243.

[2]. Mahutjane, T. Charles, Léonel N. Tchadjié, & Thandiwe N. Sithole. "The feasibility of utilizing sewage sludge as a source of aluminosilicate to synthesise geopolymer cement." Journal of Materials Research and Technology 25 (2023): 3314-3323.

[3]. Abebaw, Dereje. Effect of sewage sludge as partial replacement of fine aggregate in concrete at elevated temperature: compressive and tensile strength characterstics. Diss. 2020.

[4]. Lynn, Ciarán J., et al. "Sewage sludge ash characteristics and potential for use in concrete." Construction and Building Materials 98 (2015): 767-779.

[5]. Donatello, Shane, and Christopher R. Cheeseman. "Recycling and recovery routes for incinerated sewage sludge ash (ISSA): A review." Waste Management 33.11 (2013): 2328 2340.

[6]. Chen, Zhen, and Chi Sun Poon. "Comparative studies on the effects of sewage sludge ash and fly ash on cement hydration and properties of cement mortars." Construction and Build ing Materials 154 (2017): 791-803.

[7]. Rusănescu, Carmen Otilia, et al. "Recovery of Sewage Sludge in the Cement Industry." Energies 15.7 (2022): 2664.

[8]. Xia, Yan, et al. "Value-added recycling of sludge and sludge ash into low-carbon con struction materials: current status and perspectives." Low-carbon Materials and Green Con struction 1.1 (2023): 23

[9]. Ashwini L K, “Sewage Sludge potential use and various testing on concrete” Journal of Civil Engineering, Vol.14 issue 1pp29-35 2024.

[10]. Thukkaram, Sathya, and Arun A. Kumar. "Data-driven approach for sustainable geopolymer mortar production with treated sewage sludge." Australian Journal of Civil Engineering (2024): 1-17.

[11]. Zhao, Qiuhong, et al. "Development of alkali activated cementitious material from sewage sludge ash: Two-part and one-part geopolymer." Journal of Cleaner Production 384 (2023): 135547.

[12]. Baeza-Brotons, Francisco, et al. "Portland cement systems with addition of sewage sludge ash. Application in concretes for the manufacture of blocks." Journal of Cleaner Production 82 (2014): 112-124.
[13]. Arooj, Muhammad Farhan, et al. "A sustainable approach to reuse of treated domestic wastewater in construction incorporating admixtures." Journal of Building Engineering 33 (2021): 101616.
[14]. Haustein, Elżbieta, et al. "Influence of cement replacement with sewage sludge ash (SSA) on the heat of hydration of cement mortar." Materials 15.4 (2022): 1547.
[15]. Lin, Deng-Fong, and Chih-Huang Weng. "Use of sewage sludge ash as brick material." Journal of environmental engineering 127.10 (2001): 922-927.
[16]. Varshney, Harshit, Rizwan Ahmad Khan, and Iqbal Khaleel Khan. "Sustainable use of different wastewater in concrete construction: A review." Journal of Building Engineering 41 (2021): 102411.
[17]. Al-Jabri, K. S., et al. "Effect of using wastewater on the properties of high strength concrete." Procedia Engineering 14 (2011): 370-376.
[18]. Asadollahfardi, G., et al. "Use of treated domestic wastewater before chlorination to produce and cure concrete." Construction and Building Materials 105 (2016): 253-261.
[19]. Sara Naamane, Zakia Rais, and Mustapha Taleb. "The effectiveness of the incineration of sewage sludge on the evolution of physicochemical and mechanical properties of Portland cement." Construction and Building Materials 112 (2016): 783-789.
[20]. Coutand, M., M. Cyr, and P. Clastres. "Use of sewage sludge ash as mineral admixture in mortars." Proceedings of the Institution of Civil Engineers-Construction Materials 159.4 (2006): 153-162.