Service Life Prediction of Sugarcane Bagasse Ash (SCBA) Blended Concrete

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Abstract: The use of agricultural waste materials as a partial replacement for cement in concrete production has gained considerable attention in recent years due to its environmental and economic benefits. Sugarcane Bagasse ash (SCBA) is a byproduct and has been studied as a pozzolanic material for use in concrete. This study aims to investigate the service life prediction of concrete blended with SCBA by conducting durability tests such as chloride ion penetration. The research results suggest that the incorporation of SCBA in concrete improves its durability and can extend its service life. Therefore, the use of SCBA as a sustainable alternative material in concrete production can contribute to a more environmentally friendly and economically viable construction industry. Control specimens with ordinary Portland cement (OPC) were made with other specimens, cement was replaced with 10%,15%,20%, and 25% of SCBA by weight of cement. Locally available Sugarcane waste was burnt to ash in a controlled manner, which was used in this study. The durability and compressive strength of that mortar mix using SCBA at different cement replacement percentages were investigated and compared with the control specimen. Also, the study considered the durability of SCBA blended concrete and howit affects the environment with high exposure levels.

Keywords: ***Sugarcane Bagasse ash, Concrete, Compressive strength, Durability.***

I. INTRODUCTION

Concrete strength and durability can be increased using pozzolanic compounds. Having a good quantum of availability of bagasse, SCBA being high in silica content canbe easily produced and used as an alternative cement replacement material in concrete products. Silica is abundant in by-product materials. Several earlier research studies have been reported on the excellent pozzolanic performance of sugarcane bagasse ash (SCBA) compared to ordinary Portland cement concrete. However, the service life prediction of SCBA blended concrete needs to be examined to ensure its durability enhancement in structures specifically exposed to aggressive environments. The durability of bagasse ash blended concrete and its influence on severe exposure environment were investigated in the study.

II. MATERIALS AND ITS PROPERTIES

Sugarcane bagasse ash was collected from Sakthi Sugars Ltd, Padamathur, Tamil Nadu, India. The collected ash was sieved through a 300 µm standard sieve and further to 300 m2/kg fineness as described in an earlier research study. The processed SCBA was blended with ordinary Portland cement (OPC) of 53-grade cement confirming the requirements of IS 12269- 2008 with five different proportions (5%, 10%, 15%, 20%, and 25%).

Table I. Physical properties of Sugarcane bagasse ash

S. No.	Property	Value
1.	Specific Gravity	2.2
2.	Mean particle size	0.1-0.2
3.	Min specific surface area	2500m^2/ kg
4.	Particle shape	Spherical

Table II. Chemical composition of Sugarcane bagasse ash

S No	Component	Percentage
1.	Silica (SiO_2)	63
2.	Alumina (Al_2O_3)	12.67
3.	Ferric Oxide (Fe_2O_3)	4.81
4.	Manganese Oxide (MnO)	0.004
5.	Calcium Oxide (CaO)	2.18
6.	Magnesium Oxide (MgO)	1.01

III. MIX PROPORTIONING FOR M35 GRADE CONCRETE (as per IS 10262-2019)

Water	Cement	Fine Aggregate	Coarse Aggregate
192	330	693.43	1232.78
0.45	1.0	2.10	3.73

IV. EXPERIMENTAL INVESTIGATION

A. THE COMPRESSIVE STRENGTH TEST

The compressive strength of the OPC concrete specimens was conducted. Concrete specimens of 150×150×150mm were made in accordance with the (BIS 2004) for compressive strength testing. The loading rate was set as 140 kg/cm2/min and concrete cylinders of 100 mm diameter and 200 mm height, The cast specimens for the rapid chloride permeability testing are also shown in Figures

B. SPLIT TENSILE STRENGTH

The cylinder measures 150 mm in diameter and 300 mm in height. Splitting tests, also known as break tensile strength of concrete, are well-known indirect tests for determining concrete performance. According to an elastic analysis, compression loading produces tensile strength that is almost uniform around the entire filled diameter. The estimate establishes the degree of tensile stress (IS 5816-1970)

Figure I. Specimen for Compressive and Split Tensile Tests

C.RAPID CHLORIDE PERMEABILITY TEST(RCPT)

The RCPT test apparatus consists of a cell in which the concrete disk specimen of a diameter of 100 mm and a height of 50 mm can be accommodated. One of the cells contains a chamber for filling 0.3N NaOH solution which acts as the anolyte and the other end of the cell has a chamber for filling 3% NaCI solution, which acts as a catholyte. The test specimen (concrete disk with epoxy-coated peripheral sides in order to prevent leakage through the sides) is kept in between these two cells tightly packed using rubber gaskets.

Figure II. Specimen for RCPT

A current of 60 V is applied across the cells to accelerate the movement of chloride ions under the potential gradient from one end of the specimen to the other end. The current readings were recorded at 30-minute intervals for 6hours.

V. SERVICE LIFE

The deterioration process in concrete structures because of corrosion can be classified into four periods concerning time-initiation period, and the propagation period. acceleration period and deterioration period. In the study, the time period between construction and the time for the first repair is considered as the service life of the structure. The time required by the chloride to enter in the concrete and accumulate an inadequate quantity on the embedded steel from the outer environment to initiate the corrosion is defined as the initiation period for the corrosion. It is a function of the quality of concrete, clear cover to main reinforcement, exposure conditions, and chloride threshold concentration. The propagation period defines the time period essential for enough corrosion to occur to come to an unacceptable level of damage to the building or structural component. Service life of concrete structures can be effectively predicted based on material characteristics and exposure conditions

A. SERVICE LIFE PREDICTION

Service life prediction in aggressive environments involves assessing the durability and endurance of materials, components, or structures when exposed to severe conditions such as extreme temperatures, corrosive chemicals, high humidity, and cover depth. Service life prediction helps in designing, maintaining, and replacing resources effectively. This guide provides a step-by-step approach to predicting service life in aggressive environments.

B. SELECTED DIFFUSION COEFFICIENT MODEL

In the present study, observations from rapid chloride permeability tests were used to determine the diffusion coefficient of SCBA blended concrete. Several researchers proposed various relations between the total charge passed in the RCPT test and the chloride diffusion coefficient of concrete. Different chloride diffusion coefficient models which are the function of total charge passed are summarized by comparing all the models an appropriate model (Yang & Cho, 2003) was selected in the study based on the suitability for calculating the diffusion Coefficient of the SCBA blended concretes with the help of observations from Rapid chloridepermeability test.

Yang et al., 2003

$Q = 903.72 \times Dcl - 582.36$

Q- Total Charge Passed ; Dcl- Diffusion Coefficient

C. LIFE 365 SOFTWARE

In the present study, severe exposure conditions were considered. The average annual temperature profile of the specified location was considered. Moreover, the surface chloride level was considered as 0.8 % weight of concrete as per Life-365 manual because of severe conditions, particularly for marine splash zone concrete, the cover was adopted as 50 mm, w/c ratio was considered 0.45 as per mix proportion and chloride threshold value was 0.05% weight of concrete for the black steel as per manual. To evaluate the influence of pozzolanic performance in service life, all these parameters were considered as constant for control concrete. Life-365 software was used for predicting the service life. The model is based on Fick's second law and assumes diffusion of chloride is the dominant mechanism. It considers diffusion coefficients depending on both time as well as temperature. To complete the analysis, the following input parameters such as,

1. Mix proportion characteristics
2. Diffusion rate at 28 days (D_{ref})
3. Diffusion Decay index (m)
4. Maximum surface chloride level (C_S)
5. Temperature profile throughout the year
6. Chloride threshold to initiate corrosion of steel (C_t)
7. Clear cover to reinforcement

D. SERVICE LIFE OF SUGARCANE BAGASSE ASH BLENDED CONCRETE

Service life prediction involves estimating the duration for which a material will remain functional and effective. Replacement strategies play a crucial role in determining the overall service life and reliability of the system. Here, we will explore different levels of replacement strategies and their impact on service life prediction.

E. INFLUENCE OF SERVICE LIFE ON DIFFERENT EXPOSURE CONDITION

The service life of a material or structure refers to the duration of time during which itcan effectively perform its intended function under specific conditions.Exposure conditions playa significant role in determining the service life of materials and structures. Different exposure conditions can lead to various forms of degradation and deterioration, ultimately influencing the longevity and performance of the material or structure. Here are some common exposure conditions and their influences on service life,

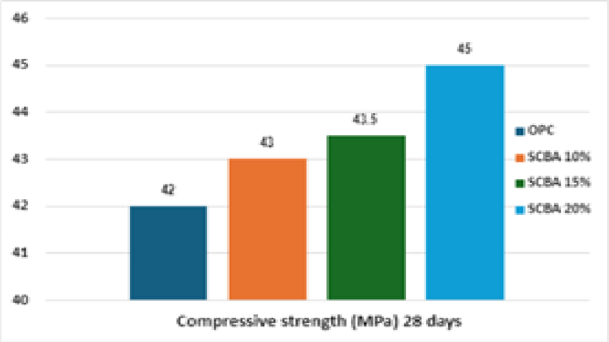
1. Marine Splash Zone
2. Zone 800m away from the Ocean
3. Zone 1.5km away from the Ocean

In this study, Optimum replacement is taken as 20%. The major comparison made betweenControl concrete and SCBA 20% for service life on different exposure conditions

VI. RESULT AND DISCUSSION

TABLE III. Result for Compressive strength and split tensile strength at 28 days

Specimen	Compressive strength (MPa)		Split tensile strength (MPa)	
	7 Days	28 Days	7 Days	28 Days
OPC	26	42	1.95	3.25
SCBA 10%	28	43	1.98	3.39
SCBA 15%	29.5	43.5	1.99	3.55
SCBA 20%	29	45	2.01	3.42



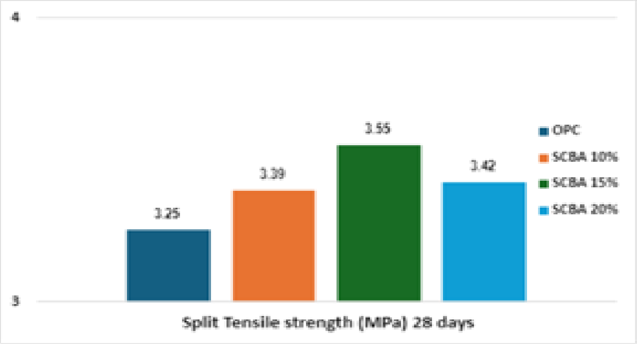
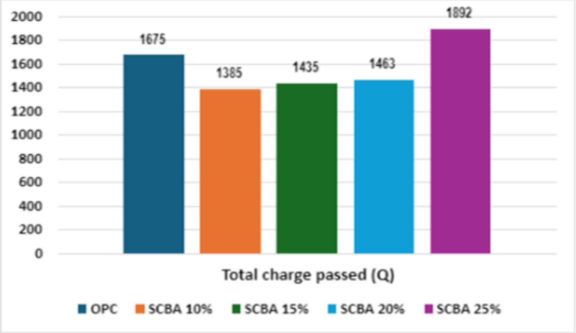


Table IV. RESULT OF RCPT

Specimen	harge Passed Q (Coulombs)	Chloride Ion Permeability
OPC	1675	LOW
SCBA 10%	1385	LOW
SCBA 15%	1435	LOW
SCBA 20%	1463	LOW
SCBA 25%	1892	LOW



A. DIFFUSION CO-EFFICIENT

The diffusion coefficient of concrete can vary depending on several factors including the composition of the concrete, its porosity, moisture content, temperature and the cover depth. Different substances will have different diffusion coefficients in concrete due to variations in their molecular size, charge, and contact with the material.

Table V. Calculation of Diffusion Coefficient

Specimen	Diffusion Coefficient × $10^{-12} m^2/s$
OPC	2.4978
SCBA 10%	2.1769
SCBA 15%	2.2323
SCBA 20%	2.2632
SCBA 25%	2.7379

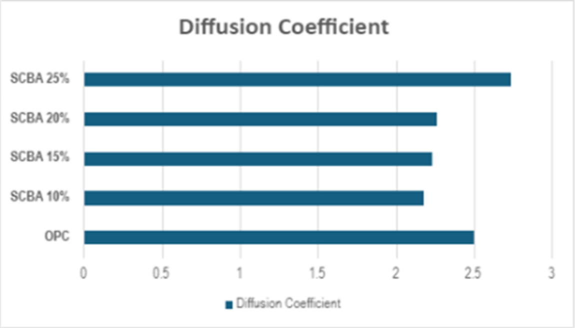


Table VI. Influence of Replacement of Exposure Condition

Concrete Mixes	Diffusion Coefficient $\times 10^{-12} m^2/s$	m	Ct % weight of concrete	itiationPeriod (years)	pagationPeriod (years)	Service life(years)
MARINE SPLASH ZONE						
OPC	2.4978	0.2	0.050	6.17	6.0	12.17
SCBA 20%	2.2632	0.36	0.050	8.13	6.0	14.13
Zone 800m away from the Ocean						
OPC	2.4978	0.2	0.050	7.6	6.0	13.6
SCBA 20%	2.2632	0.36	0.050	8.8	6.0	14.8
Zone 1.5km away from the Ocean						
OPC	2.4978	0.2	0.050	9.2	6.0	15.2
SCBA 20%	2.2632	0.36	0.050	12	6.0	18

VII. CONCLUSION

When the replacement level rises the diffusion coefficient decreases indicating reduced concrete permeability due to higher Sugarcane bagasse ash content. This highlights how incorporating more Sugarcane bagasse ash in concrete can effectively decrease its permeability, enhancing its durability and potential for sustainable construction. The proportion of Sugarcane bagasse ash (SCBA) in concrete rises and the service life of the material improves. Utilizing SCBA as an admixture presents a possibility to enhance the durability of structures facing aggressive environmental conditions. Through its incorporation, the concrete resistance to damaging factors can be supported, contributing to prolonged service life and reduced maintenance needs. When structures are positioned farther from aggressive environmental conditions, the initiation of corrosion is postponed. This phenomenon can be attributed to reduced exposure to corrosive elements leading to an extended period before corrosive processes commence. The alteration in temperature profile has the smallest impact on the initiation time of corrosion, indicating insignificant changes in the corrosion initiation period. The replacement of Sugarcane bagasse ash (SCBA) impacts the concrete durability, with varying degrees of improvement observed. This underscores the complexity of the relationship between SCBA content and service life, suggesting the need for careful selection of SCBA replacement percentages to achieve desired outcomes.

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