Experimental Study on Strength and Durability Of Concrete With Bagasse Ash And M-Sand

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Abstract - *Today researches all over the world are focusing on ways of utilizing either industrial or agricultural wastes as a source of raw materials for construction industry, which helps to create a sustainable and pollution free environment. This project reports the utilization of bagasse ash(fibrous waste product of sugar refining industries) as a cement replacement in concrete and usage of m-sand as replacement to river sand .These replacements are economic alternative which provides a solution to environmental concern and problems associated with waste management. In this study , bagasse ash has been characterized and partially replaced in the ratio of 0%,5%,10% ,15%and 20% by weight of cement in concrete and 100% replacement of river sand by m-sand .The impact of bagasse ash and m-sand content was investigated on strength and durability properties of hardened concrete, including compressive strength, split tensile strength , water sorptivity and gravemetric weight loss. Based on an analytical model the time from corrosion initiation to corrosion cracking of reinforced concrete which are subjected to chloride rich environment were predicted. The test results indicate that bagasse ash is an effective mineral admixture, with 10% as optimal replacement ratio of cement.*

Key Words: **Concrete, Bagasse ash, Manufactured sand, Strength, Durability property**

1. INTRODUCTION

Ordinary Portland cement is recognized as the major construction material throughout the world. Industrial wastes, such as fly ash, blast furnace slag and silica fume are being used as supplementary cement replacement materials. . India is one of the largest producers of sugarcane in the world, produces 300 million tons per year. Only a few studies have been reported on the use of bagasse ash as pozzolanic material in respect of cement paste. At present, there has been an attempt to utilize the bagasse ash, the residue from a sugar industry and the bagasse biomass fuel in electric generation industry. Studies were conducted on mortars and concrete containing 0-30%(with 5% increment)of bagasse ash as a replacement of Portland cement showed good development of high early strength and applicable resistance to chloride permeation and diffusion at 20% replacement[1]

Addition of bagasse ash in concrete caused a increase in strength of concrete upto a certain percentage and then decreases gradually, optimum value of replacement achieved was 10%.Replacement of cement by bagasse ash increases workability of fresh concrete, therefore use of superplasticizer is not substantial. Density of concrete decreases with increase in bagasse ash content [3]. At replacement ratio of 20% of cement by bagasse ash reduced the chloride diffusion by more than 50% without any adverse effects on other properties of hardened concrete [4]. Reinforced concrete containing sugarcane bagasse ash has the lowest corrosion rates which has a beneficial effect to protect the steel bar from corrosion because it will reduce the pore size in the cement paste [5].

River sand which is one of the constituents used in the production of conventional concrete, has become highly expensive and also scarce. It poses problems with respect to its availability, cost and environmental impact.Comparative study was carried out on the usage of quarry rock dust as hundred percent replacement as substitute for river sand and conventional concrete of three grades M20,M30,M40, using design approach IS, ACI, USBR, RN No.4 and BRITISH. The results indicate that the compressive , flexural strength and durability of concrete made with quarry rock dust are 10% more than the conventional concrete [6]. Application of manufactured sand is an attempt towards sustainable development in India, which will help to find viable solution to declining availability of natural sand to make eco-balance[7].

Prediction of time to corrosion cracking is a key element in evaluating the service life of corroding reinforced concrete structures. Corrosion crack is usually used to define the end of functional service life where rehabilitation of a corroding structural element is required. This paper compares various prevailing models with their deficiencies and presented a mathematical model in which a relationship between the steel mass loss and the internal radial pressure caused by corrosion was developed accounting the mathematical properties of concrete. The concrete around a corroding steel reinforcing bar is modeled as a thick-walled cylinder with a wall thickness equal to the thinnest concrete cover. The concrete ring is assumed to crack when the tensile stresses in the circumferential direction at every part of the ring have reached the tensile strength of concrete. According to it, the time from corrosion initiation to corrosion cracking, tcr is given as

$Tcr=[7117.5(D+2\delta_0)(1+\nu+\psi)/iE_{ef}][(2Cf_{ct}/D)+2E_{ef}/\{(1+\nu+\psi)(D+2\delta_0)\}]$ (1)

Where: $\psi=D'^2/2C(C+D')$, $D'=D+2\delta_0$ and E_{ef}(effective elastic modulus of concrete)=$[E_c/(1+\varphi_{cr})]$ in which E_c is elastic modulus of concrete and φ_{cr} is concrete creep coffecient,D is the diameter of rebar(mm), δ_0 is thickness of porous zone typically in a range of 10-20μm, ν is Poissons ratio of concrete(0.18),C is clear concrete cover(mm) and i is current density. Eqs.(2) and (3) may be used to calculate tensile strength and young's modulus of concrete where f_c' is characteristic strength of concrete in MPa

$f_{ct}=0.94\sqrt{f_c'}$ (2)
$E_c=4500\sqrt{f_c'}$ (3) [8]

Ability of faraday's law to predict the actual steel mass loss at different current density levels was confirmed in an earlier study that was carried out [9]. Alternative methods for inducing accelerated corrosion of steel in concrete have been reported [10].

2.EXPERIMENTAL PROGRAM

2.1Materials

Cement

OPC 53 Grade was used for the complete study. The Specific gravity test conducted on cement gave a value of about 3.15.

Fine and Coarse Aggregate

Manufactured sand with a fineness modulus of 2.64 was used as fine aggregate. Coarse aggregate comprised a maximum size of 20 mm. The fine and coarse aggregate specific gravities are 2.714 and 2.88 respectively.(Conforming to IS 383-1970 and IS 2720(Part I – Sec I):1980).

Bagasse Ash

Mill fired Bagasse ash was collected from Sakthi Sugars Factory, Appakudal, Tamil Nadu, India. The uncontrolled boiler fired ash was black in colour due to carbon content was sieved to remove any coarser and foreign particles.The particle size distribution measured was found to be between 40 and 90μm. The specific gravity was found to be 2.86 based on IS:1721-1967, used as a cement replacement material.

2.2Mix Proportion and Casting Of Concrete specimens

Grade of concrete used in this study is M20.Different proportions of concrete mixes (Bagasse Ash ranging from 5% to20% by weight of cement) including the control mix were prepared with a W/(C+BA) ratio of 0.55 for a design cube compressive strength of 20N/mm^2.These mixes were designated as B0 for control mix and B1,B1,B3 and B4 for bagasse ash concretes, containing 5,10,15 and 20% bagasse ash respectively. The mix proportions are summarized in Table 1.

Table -1: Quantity Of Materials

Mix Designation	Fine Aggregate (M-Sand)	Coarse Aggregate	Cement	Bagasse Ash	Water
B0	730	1212	360	0	197
B1	730	1212	342	18	197
B2	727	1207	324	36	197
B3	727	1206	306	54	197
B4	726	1205	288	72	197

The concrete was hand mixed in laboratory for 5min, including mixing in dry form. For each mixes 150mm^3 cubes were cast for compressive strength testing. Cubes measuring 100mm^3 were cast from each mix for determining sorptivity value of mix. Additionally, 100mm^3 cube specimens with rebar(act as and stainless steel bar embedded in it are cast from each mix for weight loss measurement. After casting, all specimens were left covered in the casting room for 24 hours. The specimens were then demolded and transferred to moist curing tank for a period of 28 days.

2.3Experimental Work

Compressive strength

Cubical specimens of size 150mm were cast and cube compressive strength was determined at 7 and 28 days moist curing as per IS 9013-1997.

Split Tensile strength

The tensile strength of the resultant mix is judged in terms of split tensile strength using cylindrical specimens of size 150 mm diameter x 300 mm height at 28 days of moist curing as per IS 5816-1999 was determined.

Sorptivity

Sorptivity is measure of the capillary forced exerted by the pore structure causing fluids to be drawn into the body of the material. Specimens were cast and they are immersed in water for 28 days curing. After curing specimens were oven dried for 3 days at 105°C .Initial dry mass was noted. Specimens was kept in contact with water level not more than 5 mm above the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non –absorbent coating. The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting upto 0.1 mg. surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds. Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t)

$I=St^{0.5}$ therefore $S=(I/t^{0.5})$

Where; S= sorptivity in mm,

t= elapsed time in mint.

I= absorption per unit area (mm)=Δw/Ad

Δw= change in weight = W2-W1 W1 = Oven dry weight of cylinder in grams W2 = Weight of cylinder after30 minutes capillary suction of water in grams

A= surface area of the specimen through which water penetrated.

d= density of water

Gravimetric Weight Loss Measurement

100mm x 100 mm x 100 mm concrete cubes were cast using various proportions of bagasse ash at 5%,10%.15%and 20% replacement levels. Mild steel rebar of 12 mm diameter and 95 mm long was embedded at 20 mm from outer face of the concrete. Initially the mild steel rebar samples were cleaned in pickling solution .The initial weight of the rebar sample was taken before casting for gravimetric weight loss measurement. The specimen were casted, demoulded after 24 hours were completely immersed in 3.5% NaCl solution .The specimen were maintained in the same condition for 5 days and then subjected to drying for another 5 days. One alternate wetting and drying cycle consists of 5 days immersion in 3.5% NaCl solution and 5 days drying in open air at room temperature. In order to induce the accelerated corrosion 3.5% NaCl solution was used. after completion of this cycle for 60 days , the rebar was demoulded from the specimen and they were treated with pickling solution to find the final weight of rebar after corrosion. The degree of induced corrosion was expressed in terms of the percentage weight loss (ρ) is calculated as

$$\rho = (Wi-Wf)/Wi*100$$

Where, Wi-initial weight of rebar before cxorrosion (gm)
Wf-final weight of rebar after corrosion(gm)

3.RESULTS AND DISCUSSION

3.1 Compressive strength

The compression strength of bagasse ash blended concrete specimens for 7 and 28 days are shown in Table2. Comparision of compressive strength data shows that the strength increases upto 10% replacement of bagasse ash and then at 15 and 20% of bagasse ash the strength value gradually decreases. The reason foe early compressive strength development of bagasse ash concrete and increase in compressive strength upto 10% cement replacement of bagasse ash may be due to silica content, fineness, degree of reactivity of bagasse ash and pozzolanic reaction between calcium hydroxide and reactive silica in bagasse ash.

Table -2: Compressive Strength Of Bagasse Ash Blended Concrete

Mix Designation	Average Compressive strength (MPa)	
	7 days	28 days
B0	15.33	20.71
B1	15.53	22.09
B2	17.73	25.36
B3	15.26	20.34
B4	14.82	19.03

3.2 Split Tensile strength

The splitting tensile strength values of bagasse ash blended m-sand concretes after 28 days of curing are shown in Table 3. It can be clearly seen that upto 10% of replacement , the splitting tensile strength value increases and then at 15 and 20% of bagasse ash , the value decreases. Obviously from tensile strength point of view also, 10% of bagasse ash is the optimal limit.

Table -3: Split Tensile Strength Of Bagasse Ash Blended Concrete

Mix Designation	Average Split Tensile strength (MPa)
B0	2.73
B1	2.854
B2	2.187
B3	2.655
B4	2.396

3.3 Water Sorptivity

The sorptivity values calculated for bagasse ash blended m-sand concrete specimens after 28 days are presented in Table4. It can be seen that at 28 days curing, sorptivity progressively decreases with increase in bagasse ash content.

3.4 Gravimetric Weight Loss Measurement

The percentage mass loss of rebar embedded in concrete of varying proportion of bagasse ash which has undergone accelerated corrosion test of alternate wetting and drying cycle was reported in Table 4, which infers that the increase in percentage of bagasse ash decreases the percentage metal loss ,thereby increases the corrosion resistance of steel embeded in concrete.

3.5 Prediction Of Time From Corrosion Initiation To Corrosion Cracking

An analytical model has been used to predict the time from corrosion initiation to corrosion cracking based the 28 days compressive strength, diameter of bar embedded in concrete, clear concrete cover thickness, percentage mass loss obtained from gravimetric weight loss, thereby obtaining the tensile strength and effective elastic modulus of concrete based on 28 days compressive strength obtained from standard equations. The results are presented in Table 4 which indicate that the increase in percentage of bagasse ash increases the propagation time from of corrosion initiation to corrosion cracking .

Table-4 Sorptivity, Percentage mass loss of rebar and Tcr of Bagasse Ash Blended Concrete

Mix Designation	Sorptivity (10^{-4} mm/min$^{0.5}$)	Percentage Mass Loss	Tcr (Years)
B0	6.14	2.50	10
B1	2.97	0.96	26
B2	2.19	0.83	30
B3	1.70	0.64	39
B4	1.58	0.42	59

4. CONCLUSIONS

From the present investigation , the following conclusion can be drawn. Up to 10% of ordinary Portland cement can be optimally replaced with bagasse ash in m-sand concrete without any adverse effect on the desirable properties of concrete. The specific advantage of such replacements are reduction in water permeability of concrete, increases the corrosion resistance of rebar embedded in concrete. These observations have a direct bearing on the durability of reinforced concrete structures

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