Effect of Sugarcane Bagasse Ash and Lime Stone Fines on the Mechanical Properties of Concrete

Naraindas Bheel
Department of Civil Technology
H.C.S.T
Hyderabad, Pakistan
naraindas04@gmail.com

Abdul Samad Memon
Department of Civil Technology
H.C.S.T
Hyderabad, Pakistan
samad.memon105@gmail.com

Imdad Ali Khaskheli
Department of Civil Technology
H.C.S.T
Hyderabad, Pakistan
imdadali961@gmail.com

Noor Muhammad Talpur
Department of Civil Technology
H.C.S.T
Hyderabad, Pakistan
mirnoor2018@gmail.com

Sher Muhammad Talpur
Department of Civil Technology
H.C.S.T
Hyderabad, Pakistan
shermohd168@gmail.com

Muhammad Awais Khanzada
Department of Civil Technology
H.C.S.T
Hyderabad, Pakistan
awais.khanzada145@gmail.com

Abstract—**Cement production releases huge amounts of carbon dioxide having a significant impact on the environment while also having huge energy consumption demands. In addition, the disposal and recovery of natural concrete components can lead to environmental degradation. The use of waste in concrete not only reduces cement production, but it also reduces energy consumption. The aim of this study is to evaluate the properties of fresh and hardened concrete by partially replacing cement with sugarcane bagasse ash (SCBA) and limestone fines (LSF). In this investigation work the cement was replaced with SCBA ash and LSF by 0% (0% SCBA+ 0% LSF), 5% (2.5% SCBA+ 2.5% LSF), 10% (5% SCBA+ 5% LSF), 15% (7.5% SCBA+ 7.5% LSF) and 20% (10% SCBA+ 10% LSF) by weight of cement. In this regard, a total of 60 samples of concrete specimens were made with mix proportion of 1:1.5:3 with 0.56 water-cement ratio. Cube specimens were tested for compressive strength and cylindrical specimens were used for determining splitting tensile strength at 7 and 28 days respectively. The optimum result displayed that the crushing strength and split tensile strength increased by 10.33% and 10.10% while using 5% SCBA+ 5% LSF as a substitute for cement in concrete after the 28th day. The slump value of concrete declined as the content of SCBA and LSF increased.**

Keywords-limestone fines; sugarcane bagasse ash; cement replacement; enhance strength and reduce environmental issues

I. INTRODUCTION

Concrete is a man-made construction material, which is most commonly used for the construction of various civil engineering structures [1-3]. Ordinary Portland cement (OPC) concrete is used in numerous structural applications and it is favorable for normal construction projects. However, due to some of its limitations, certain requirements have been difficult to satisfy especially in terms of strength and durability regarding complex structures. The need for the development of high-strength and high-performance concrete has extensively increased in order to meet the requirements for advanced and complex structures [4]. The development of High-Strength Concrete (HSC) requires a large amount of cement and the production of cement is considered as the most energy-intensive component for the production of concrete [5]. CO_2 emissions during the production of cement are an environmental concern. It is a well-known fact that approximately one ton of CO_2 is released into the environment through one-ton production of OPC cement. Moreover, cement manufacturing is responsible for 5% to 7% of CO_2 emissions from industrial sources [6]. Without compromising the performance of the concrete structures, the use of Portland cement needs to be reduced in order to reduce CO_2 emissions related to cement production while the sustainability of construction needs to be taken into consideration [7-9]. Partial substitutions of cement by a combination of cement replacing materials (CRMs) are advantageous not only from the economic point of view but also for their mechanical and microstructural characteristics [10]. The use of CRMs into concrete has gained popularity with emphasis on increasing the service life of concrete structures [11]. Many CRMs are commercially available and can be used in concrete. Some of the most common materials are sugarcane bagasse ash (SCBA) [12, 13], limestone fines (LSF), rice husk ash (RHA) [14-16], silica fume (SF), etc. [17, 18]. In this experimental investigation, the combined influence of SCBA and LSF used as cement replacement materials in cement concrete was determined.

SCBA is a sugar mill by-product found after burning bagasse, which in turn was originated after the sugar extraction from sugarcane. It has been tested for volcanic ash properties and improvements have been found in mortar and concrete, such as in crushing strength, durability, and water resistance in certain proportions [19]. LSF were collected from Hyderabad and they can be used either as a cementitious material or as fine aggregates in concrete mix [20-22]. There are several studies

Corresponding author: Naraindas Bheel

conducted on the strength development of concrete containing SCBA and LSF. Authors in [23] determined the influence of SCBA on the hardened concrete. Concrete samples were prepared with 1:2:4 mix ratio and were tested for compressive and split tensile strength at 28 days. The test results advocated that the crushing and indirect tensile strength were enhanced by 7.90% and 14% at 10%. Authors in [24] studied the effects of LSF content on concrete's compressive strength and durability. They reported that increasing the amount of LSF in concrete enhances strength and decreases permeability. LSF concrete having 0.40w/b ratio performed better as compared to 0.50 and 0.60w/b ratio LSF concrete regarding strength development. The porosity and pore size of concrete were significantly decreased after 28 days. Authors in [25] observed that the crushing and bending strength and permeability related properties were improved by using LSF in concrete.

In the available literature there are a limited number of studies available on the individual and combined effects of SCBA and LSF as cement replacing material in concrete. Several types of mineral admixtures are used in concrete but their effects on concrete properties with binary and ternary blends are not investigated in satisfying depth. The main aim of this paper is to investigate the combined effect of SCBA and LSF with cement on fresh and hardened concrete. Since the compressive strength of concrete is an important parameter, and all other properties of concrete are judged on the basis of its compressive strength. In addition, statistical assessment on compressive strength of concrete using RSM has been performed in order to investigate the effectiveness of each material on the basis of its compressive strength.

II. RESEARCH METHODOLOGY

This research study aimed to determine the fresh, physical and hardening properties of concrete by using of 0% (0% SCBA+ 0% LSF), 5% (2.5% SCBA+ 2.5% LSF), 10% (5% SCBA+ 5% LSF), 15% (7.5% SCBA+ 7.5% LSF) and 20% (10% SCBA+ 10% LSF) cement replacement materials in concrete. A total of 60 concrete samples of 1:1.5:3 mix proportions were prepared (30 cylinders and 30 cubes) with 0.56 water/cement ratio and were cured for 7 and 28 days.

TABLE I. CONCRETE MIXES

ID	SCBA + LSF (%)	F.A & CA (%)	Cement (%)	Water-cement ratio (%)
01	0%+0%	100	100	0.56
02	2.5%+2.5%	100	95	0.56
03	5%+5%	100	90	0.56
04	7.5%+7.5%	100	85	0.56
05	10% +10%	100	80	0.56

Mix ratio 1:1.5:3

The variables cement (binder), coarse aggregates, fine aggregates, and water were considered. SCBA and LSF were used as CRMs and the concrete samples were tested on an UTM. In this study, concrete cubes (100mm×100mm×100mm) ware cast and tested for compressive strength. Similarly, cylinders (200mm×100mm) were tested for splitting tensile strength. Moreover, the concrete specimens were tested for water absorption and concrete density after 28 days. Three concrete samples were cast for each ratio, and the mean of the samples was considered as the ultimate result. The study was conducted in a laboratory of the Department of Civil Technology, H.C.S.T Hyderabad, Sindh, Pakistan [26, 27].

III. MATERIALS USED

A. Cement

In this investigational study, OPC was utilized with 33% normal consistency, and initial and final setting time of 46min and 160min respectively.

B. Fine and Coarse Aggregates

Hill sand was used as fine aggregates that passed through #4 sieves and crushed stones having 20mm in size were used as coarse aggregates. These aggregates were collected locally in the region of Hyderabad.

C. Limestone Fines (LSF)

The LSF were collected from Hyderabad. After collecting, they were sieved through #300 sieves to obtain fine powder form and then they were utilized as cementitious material in concrete mixes.

D. Sugarcane Bagasse Ash (SCBA)

SCBA was collected from Matiari Sugar Mill. After collecting, it was dried under the atmosphere and the dried ash was sieved through #300 sieves to obtain the desired ash. This desired ash was utilized as cement replacement in concrete.

E. Water

Drinking water was used.

IV. RESULTS AND DISCUSSION

A. Slump Test

Slump test was studied based on slump losses using a standard slump cone in accordance with ASTM C 143-05. At 0% SCBA and 0% LSF, the maximum concrete slump is 65mm, and at 10% SCBA and 10% LSF, the minimum slump of fresh concrete is 29mm. The slump value reduced as the amount of SCBA and LSF increased as shown in Figure 1.

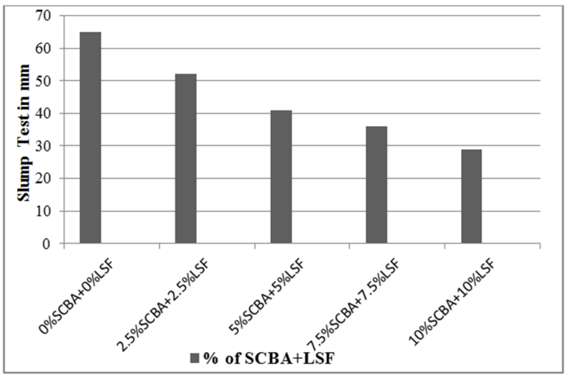

Fig. 1. Slump test results

B. Density of Concrete

The concrete samples were used to analyze the density of concrete with addition of several ratios of SCBA and LSF by weight of cement on the 28th day. The maximum value of 2380kg/m^3 was noted at 0% SCBA + 0% LSF and the minimum value of 2290kg/m^3 at 10% SCBA + 10% LSF after 28 days. The density of concrete reduced as the SCBA and LSF content increased as shown in Figure 2.

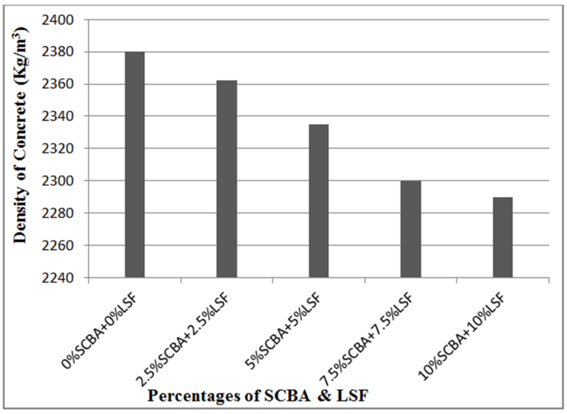

Fig. 2. Density of concrete

C. Water Absorption

The concrete samples were used to analyze the water absorption of concrete with addition of several ratios of SCBA and LSF by weight of cement at the 28th day. It was recorded maximum (4.30%) at 10% SCBA + 10% LSF and minimum 2.50% at 0% SCBA + 0% LSF after 28 days. The water absorption of concrete augmented with increasing content of SCBA and LSF as shown in Figure 3.

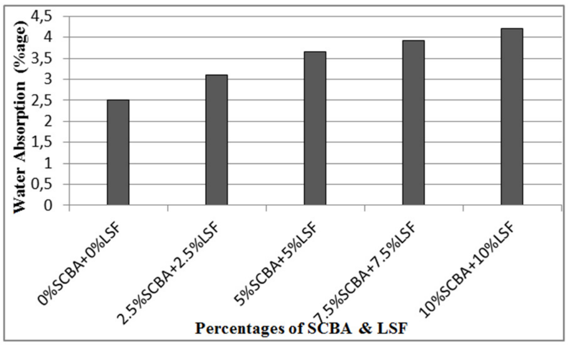

Fig. 3. Water absorption of concrete

D. Compressive Strength

The cubical samples were checked for analyzing compressive strength of concrete. The optimum crushing strength was increased to 8.96% and 10.33% at 5% SCBA + 5% LSF and it was decreased by 9.80% and 6.40% at 10% SCBA + 10% LSF after 7 days and 28 days respectively as shown in Figure 4.

E. Split Tensile Strength

The cylindrical samples were checked for split tensile strength of concrete with several percentages of LSF and SCBA. The optimum indirect tensile strength was augmented by 8.20% and 10.10% at 5% SCBA + 5% LSF and was reduced by 9.84% and 4.04% at 10% SCBA + 10% LSF after 7 and 28 days respectively as displayed in Figure 5.

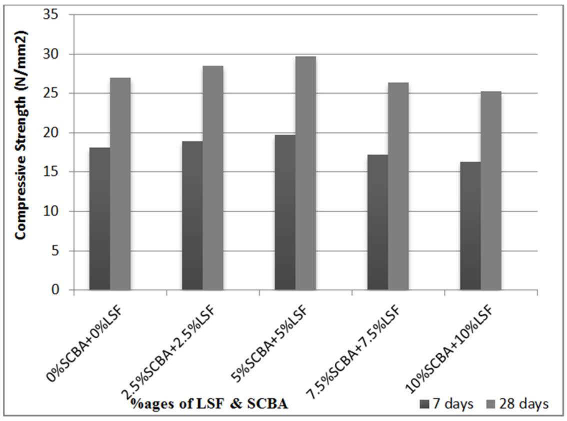

Fig. 4. Compressive strength of concrete

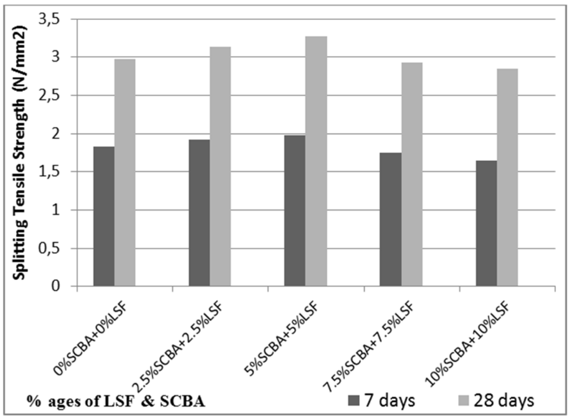

Fig. 5. Split tensile strength of concrete

V. CONCLUSIONS

The basic aim of this study was the utilization of SCBA and LSF as cement replacements in concrete and to determine their effect on the fresh and hardened concrete properties. From this research study, the following conclusions can be drawn:

- At 0% SCBA and 0% LSF, the concrete slump is maximum (65mm), and at 10% SCBA and 10% LSF, the slump of fresh concrete is minimum (29mm). Moreover, the slump value reduced as the amount of SCBA and LSF increased.
- The density of concrete was maximum (2380kg/m^3) at 0% SCBA + 0% LSF and minimum (2290kg/m^3) at 10% SCBA+10% LSF after 28 days. The density of concrete reduced as the SCBA and LSF content increased.
- Water absorption of concrete was maximum (4.30%) at 10% SCBA + 10% LSF and minimum (2.50%) at 0% SCBA+0% LSF after 28 days. The water absorption of concrete increased as the amount of SCBA and LSF increased.

- The optimum crushing strength increased by 8.96% and 10.33% at 5% SCBA + 5% LSF and decreased by 9.80% and 6.40% at 10% SCBA + 10% LSF after 7 and 28 days respectively.
- The optimum indirect tensile strength increased by 8.20% and 10.10% at 5% SCBA + 5% LSF and reduced by 9.84% and 4.04% at 10% SCBA + 10% LSF after 7 and 28 days respectively.

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