

Effect of the Addition of Sugar Cane Bagasse Ash on the Compaction Properties of a Granular Material Type Hydraulic Base

Laura Landa-Ruiz, Sabino Márquez-Montero, Griselda Santiago-Hurtado, Victor Moreno-Landeros, José Manuel Mendoza-Rangel, and Miguel Angel Baltazar-Zamora

Abstract — In the present investigation 8 soil samples were studied, with additions of 5 and 7% of addition of sugar Cane Bagasse Ash (SCBA), Portland Cement (PC) and combinations of these in different proportions. The characterization and classification of the study soil was carried out, determining the Natural Humidity, Granulometric Curve, Consistency Limits, soil classification according to the Unified Soil Classification System (USCS) and AASHTO compaction. The results show that the use of the SCBA is viable to significantly improve the physical properties of the granular soil type Hydraulic Base, The partial substitution of SCBA for PC according to the results can be considered that it would contribute to more durable and therefore economical roads. In addition to contributing to the reduction in cement consumption, which would imply a decrease in the release of CO₂ into the atmosphere due to the manufacture of Portland Cement.

Index Terms — SCBA; Hydraulic Base; Compaction Properties.

I. INTRODUCTION

The problem of climate change is closely linked to the type of development, since greenhouse gas emissions are one of the consequences of patterns of economic growth that affect the environment and society [1]. Portland Cement (PC), which is the most used construction material in the world and that its manufacture, in addition to requiring more than 4000 KJ per ton of cement, emits between 850 kg to 1000 kg of CO₂ per ton of Portland cement produced, having in the year 2012 a world production of Portland Cement of more than 3,800,000 tons worldwide, with its respective emission of at least 3,230,000 tons of CO₂ [2]. In addition to this environmental problem, the Civil Works are not complying with the durability necessary to reach the useful life for which they were designed, with the main cause of their deterioration being the corrosion of the

reinforcing steel used in reinforced concrete structures [3]-[9] a pathology that occurs mainly due to the exposure of sulfates [10], [11] or chlorides [12]-[15]. The corrosion of the steel in structures built on the basis of mechanically reinforced soils is of great importance in the structural integrity and durability of such works, as has been shown in some investigations [16], [17]. Industrial waste as Silica Fume, Fly ash, has been the subject of various studies in recent decades for its pozzolanic characteristics [18], [19], this wastes when used as partial substitutes for Portland Cement, concrete provides it with greater resistance against attacks from aggressive [20]. In the case of agro-industrial waste with greater potential due to its pozzolanic components [21], it is the SCBA, there are various works where it is used as a partial substitute for Portland Cement for the production of Ecological or Sustainable Concretes, where they have studied its effect on mechanical properties [22], as well as its durability [23]-[26]. In this research, the stabilization of a hydraulic-base type soil is evaluated with additions of sugar cane bagasse ash (SCBA) as a partial substitute for Portland cement, tests were carried out to determine the characterization and classification of the study soil was carried out, determining the Natural Humidity, Granulometric Curve, Consistency Limits, soil classification according to the USCS and AASHTO compaction. With the results obtained in the present investigation, it was verified that the use of CBCA as an addition in percentages of 5% and 7% improved the mechanical properties of the Hydraulic Base type material, which would contribute to the construction of roads with greater resistance, durability and sustainability, by making use of a waste that to date in Mexico, and even more so in the State of Veracruz, where a third of all the SCBA produced in the country is produced, the SCBA does not have a defined use, Considering just trash.

II. MATERIALS AND METHODS

A. Materials

The hydraulic base material was obtained from the material bank located 20 km from the City of Xalapa. The cementitious materials used as additions were Portland Cement type CPC 30R [27] and Sugar Cane Bagasse Ash from (SCBA), which was obtained from Sugar Factory Mahuixtlán S.A. de C.V., located 5 km from to Coatepec, Veracruz, Mexico.

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Laura Landa-Ruiz, Universidad Veracruzana, México.

(e-mail: lalanda@uv.mx)

Sabino Márquez-Montero, Universidad Veracruzana, México.

(e-mail: smarquez@uv.mx)

Griselda Santiago-Hurtado, Universidad Autónoma de Coahuila, México.

(e-mail: grey.shg@gmail.com)

Victor Moreno-Landeros, Universidad Autónoma de Coahuila, México.

(e-mail: vmmorlan@gmail.com)

José Manuel Mendoza-Rangel, Universidad Autónoma de Nuevo León, México.

(e-mail: jmmr.rangel@gmail.com)

Miguel Angel Baltazar-Zamora, Universidad Veracruzana, México.

(e-mail: mbaltazar@uv.mx)

1) Characterization of study materials

Geotechnical tests were carried out for the hydraulic base type of material (study soil) to determine the physical properties of the soil such as Natural Humidity, Granulometric, Consistency Limits as well as its classification according to the unified soil classification system (USCS) [28]-[30]. Chemical characterization of CBCA was also performed with the X-ray fluorescence analysis assay.

2) Design of soil mixtures

For the design of the mixtures, three percentages of Portland cement addition were established according to the classification of the material, as established by various technical prescriptions [31]. The percentages of addition materials were 5% and 7% with respect to the dry soil. Partial substitutions of Portland Cement for SCBA were also established in each previous percentage, of 0%, 25%, 50% and 75%, having a total of 8 mixtures, as shown in table I. In addition, all the tests were carried out to the Hydraulic Base type soil in its natural state (Without any addition of PC or SCBA), to have it as a reference.

TABLE I: DOSING OF ADDITIONS INTO THE SOIL

Mixture	% Addition	% PC	% SCBA	PC-SCBA
1	5%	100%	0%	100:0
2	7%	75%	25%	75:25
3	5%	50%	50%	50:50
4	7%	25%	75%	25:75
5	5%			
6	7%			
7	5%			
8	7%			

B. Method

1) Compaction test

The existing relationship of the maximum dry density and the optimal humidity of the soil-cement mixtures was determined in each of the percentages and at the partial substitutions of SCBA. By plotting the compaction curve, the compaction characteristics were obtained before setting the mixtures. For this compaction test, the conventional equipment for the modified AASTHO test was used, which consists of the mold with a volume of 2123 +/- 21 cm³, and the rammer weighing 4.54 kg with a diameter of 50.8 mm and a drop height of 45.7 cm.

A sample of approximately 5 kg of dry material was conditioned, adding the Portland Cement and the SCBA to be used, and mixing the two materials. Small amounts of water are added, mixing thoroughly and allowing 5 min time to allow moisture absorption. Once the material is homogeneous, the points of the compaction curve are determined by applying the specified compaction energy.

III. RESULTS AND DISCUSSION

A. Physical and Chemical Characterization of Materials

According to what is established by the USCS, the soil of this study is it is a Poorly Graded Gravel with symbol GP.

Table II shows the results of the characterization of the soil under study that show the capacity of the soil to be used

as a base layer material, complying with the characteristics of the N • CMT • 4 • 02 • 002/11 standard [32].

TABLE II: CHARACTERIZATION OF THE SOIL UNDER STUDY

Properties	Results
Natural Humidity (%)	6.4%
Pass the 3 "mesh (%)	100%
Pass mesh No. 4 (%)	44.3%
Pass the 200 mesh (%)	4.9%
Liquid limit (%)	20.3%
Plastic Limit (%)	NP
Plastic Index (%)	NP

Table III presents the chemical composition in oxides of the SCBA, it is observed that the sum of main oxides (SiO₂ + Al₂O₃ + Fe₂O₃) gives a total of 85.994%, ranking above 80% as established by the standard ASTM C-618 [33] for class N and F pozzolans and be used as supplementary materials. These results agree with those obtained in another research work where they used SCBA as a substitute material for Portland Cement [34].

TABLE III: CHEMICAL CHARACTERIZATION OF SCBA

Component	Concentration
SiO ₂	77.739
Al ₂ O ₃	3.150
Fe ₂ O ₃	5.105
TiO ₂	0.789
CaO	3.995
MgO	0.563
SO ₃	0.406
K ₂ O	6.672
Na ₂ O	0.569
P ₂ O ₅	1.673

B. Results Maximum Dry Volumetric Weight

In Figure 1 it can be observed that the maximum dry volumetric weight decreased its value when adding 5% and 7% of portland cement, as well as partially substituting cement for SCBA. The combination of 100% PC- 0% SCBA and 25% PC- 75% SCBA in the stabilizer percentage of 5% have similar values, which means that to use stabilizer at 5% of dry soil study the decrease in PC is possible. The 75% PC-25% SCBA mixture had the lowest Maximum Dry Volumetric Weight of all the combinations; It can also be observed that at 7% stabilizer the MDVW gives similar values in all the combinations, except the 100% PC-0% SCBA combination. The previous results agree with that reported by the literature [35].

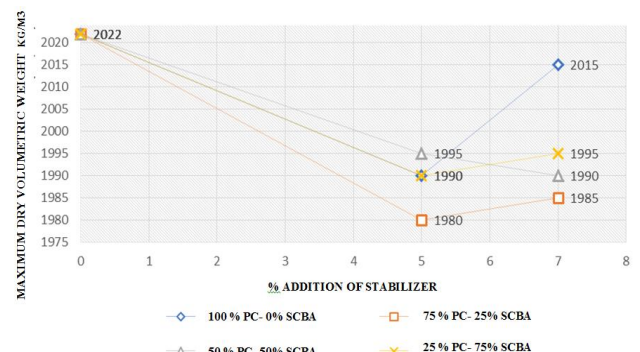


Fig. 1. MDVW behavior vs PC-SCBA combinations (% of Stabilizer).

C. Results Optimal Humidity

In Fig. 2 it is observed that the optimal compaction humidities increase when PC and SCBA are added, this due to the need to absorb a greater quantity of water due to the pozzolanic characteristics of both materials added to the soil. It is evident that the optimal humidities in the cases of 5 and 7% stabilizer are very similar, where the combination of 100% PC- 0% SCBA is the highest in both cases of 0% stabilizer, varying less than 2% between the major and minor.

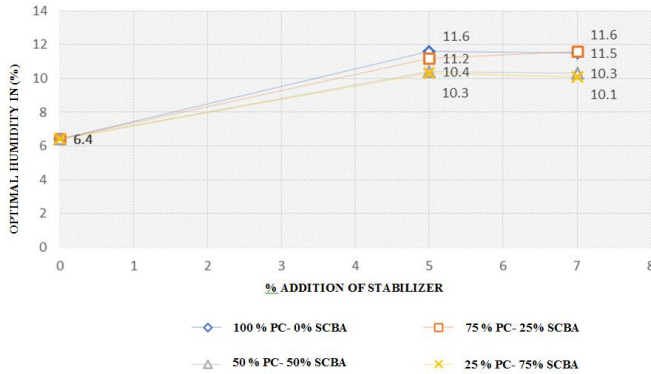


Fig. 2. Optimal Humidity Behavior vs PC-SCBA combinations (% of Stabilizer).

IV. CONCLUSIONS

In the Standard ASTM C-618, the physical-chemical composition of pozzolans established, specifies that class N and F pozzolans must add in their main oxides which are: Silicon oxide, Aluminum Oxide, and Iron Oxide ($\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$) a percentage higher than 70% of its chemical composition. In the analysis, the sum of these main oxides is 85.058%, which is why the SCBA complies as pozzolan.

The maximum dry volumetric weight increased in all the mixtures when substitutions of PC for SCBA were added, the combination of 100% PC-0% SCBA being the most favorable in both cases with regard to compaction characteristics, since densities are obtained above those obtained in natural soil.

Optimum compaction humidity increases when PC is substituted for Sugar Cane Bagasse Ash, this phenomenon is attributed to the absorption of water by SCBA and PC during the compaction process. The maximum absorption is in substitutions of 100% PC.

The positive influence on the physical properties is verified by partially substituting SCBA for PC for stabilization or improvements in the properties of the Hydraulic Base and can be used as coatings on feeder roads, where there is no paving road infrastructure.

The partial substitution of SCBA for PC according to the results can be considered that it would contribute to more durable and therefore economical roads. In addition to contributing to the reduction in cement consumption, which would imply a decrease in the release of CO_2 into the atmosphere due to the manufacture of Portland Cement.

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