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Research Article

Reuse of Drill Cuttings Contaminated with Diesel in the Formation of Asphalt Pavement

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Abstract

Current Cuban strategies to increase hydrocarbon production introduce new hazardous waste such as drilling cuttings contaminated with diesel. In order to manage them safely, the present work aims to evaluate their potential to be reused in the construction industry, hence, it is intended to use the drilling cuttings contaminated with diesel as a partial replacement for the conventional raw material for the Manufacture of asphalt pavement. To determine the composition of the dry and wet drill cuttings, physical, chemical and mechanical tests were carried out that showed a hydrocarbon content of 3.2% and 6.9% respectively, higher than the maximum limit established for final disposal, due to the presence of diesel in the composition. Regarding its granulometry, it is evident that more than 70% of its particles are fine, so it can be used as a modifier of the granulometry of the aggregate. Different mixing ratios were established to improve their properties in the application proposal, obtaining viable results. In this regard, resistances of 46%, 33% and 32% higher than the minimum limit were obtained to be used in pavement patching actions as a subbase. Elements that drill cuttings can replace conventional raw materials such as aggregates or aggregates in the restoration of sub-base of asphalt pavements, this management alternative being beneficial from an environmental point of view.

Keywords

Pollution, Drilling Cuts, Waste, Diesel, Construction, Pavement

1. Introduction

The inadequate management of hazardous waste has generated, on a global scale, a problem of soil, air and water pollution. Among the most severe impacts in hydrocarbon-producing countries, those caused by oil extraction and handling activities stand out. Nowadays, more and more nations are raising awareness about this problem and the effects it causes, not only on ecosystems but also on human health. One of the most worrying issues is the generation of large volumes of solid petroleum waste, especially drilling cuttings impregnated with diesel fuel-based mud.

Drilling muds are defined as circulating fluids that are used in rotary drilling to perform one or all of the various functions required in drilling operations. But the most important thing is that they maintain the stability and control of the well [1].

In Cuba, a water-based mixture was used as drilling fluids.

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However, the disadvantage was that the presence of active clays that react with water made the hole more unstable. That is why, due to the need to reduce geological obstacles in oil activity, the use of diesel oil-based fluids known by its acronym in English (oil based mud (OBM)) is introduced. With the incorporation of these in 2016, expenses were reduced with respect to the reduction of drilling time, making the process more effective and economical [2].

The insertion of diesel oil-based sludge causes one of the unfortunate side effects of hydrocarbon exploration; the generation and accumulation of cuts considered dangerous due to their high hydrocarbon content [3].

The management and disposal of these drilling cuttings trigger an environmental problem, which raises the question of what are the available and most economical technologies for their treatment and final disposal in the Cuban oil industry [4].

Currently, the world is replacing diesel with dearomatized oils, which are environmentally friendly, classified as low risk to health and biodegradable, but are very expensive. In addition, there are management alternatives such as the so-called reinjection of cuttings, which consists of mixing the cuttings, which are processed by grinding or other mechanical action, with seawater to form a stable viscous slurry. It is pumped into a well or through the annulus between casing strings in an active well and injected under pressure into the formations. Another option is the chemically enhanced solids removal process where the majority of fine solids are removed from non-aqueous fluids [5].

Other technologies identified and developed for the treatment of drill cuttings can be classified into two main groups: physical-chemical processes and biological processes. Depending on the type of contaminant, other options such as safety landfill or confinement may also be viable. Among the physical-chemical processes applied in the treatment of waste contaminated with hydrocarbons are incineration, solidification or chemical fixation, extraction of soil vapors, thermal desorption and extraction or washing with solvents [5].

All of the aforementioned techniques are very expensive, which is why Cuba has been more inclined to treat this waste through biological processes, which are more economical, such as bioremediation.

In this regard, there are experiences showing that bioremediation allows reducing the contaminating load of waste based on the degrading capacity of microorganisms. As a result, an effective process was obtained with final biodegradation rates of 71% for fats and oils and 68% for total hydrocarbons in a period of approximately 90 days, for final concentrations of 1% specified by the final waste disposal regulations [4]. However, the process is slow and ineffective when treating large volumes of accumulated waste. Furthermore, different studies and research have been carried out in the construction sector to use said waste as fuel in the manufacture of ceramic elements, showing a considerable energy contribution from said waste. However, the emissions of polluting gases during the combustion of the OBM cut exceed the limits established in the workplaces [6]. The potential of drill cuttings, contaminated with diesel, for reuse in the cement industry for use in the manufacture of Clinker as a mixture of ferritic soil and dry drill cutting has also been evaluated [2]. However, it does not solve the decrease in large stored volumes since very little quantity is used in said mixture.

Therefore, the need to investigate and develop a proposal for the final disposal of said drilling cuts is justified to optimize it and use it as a replacement for conventional raw material in the manufacture of asphalt pavement.

2. Materials and Methods

In the evaluation of the use of cuts as raw material in new production processes, tests were carried out that focused on evaluating the optimal mixing ratio for the replacement of aggregates or aggregates and reduction of the volumes of conventional raw material in the formation of the asphalt pavement.

2.1. Residue Characterization

Samples of oil drilling cuttings were taken from a well located in Cuba. Said waste was located in pools prepared for temporary storage in the frame of the well esplanade. The samples were identified based on their physical characteristics and diesel content. In the latter case, it is defined as dry cutting at the outlet of the dryer (with a larger clay diameter and lower diesel content) and wet cutting coming from the centrifuge (with a smaller clay diameter and higher diesel content). Analyzes were performed such as: humidity (API 13B-2) [7], pH (NC 32, 2009) [8]; fats and oils (G and A) and total petroleum hydrocarbons (HCTP) (APHA 5520-D, 2017) [9].

In addition, steel shot was used to provide greater resistance to the mixture. This waste is generated from the shot blasting process in the preparation of metal surfaces for cleaning and painting fuel storage tanks.

Granulometric Analysis of the Drill Cutting as Soil

The granulometry of drill cuttings can vary depending on several factors, such as the composition of the soil or rock drilled and the amount of diesel present. The granulometry test was carried out according to the Cuban standard (NC 20:1999) [10]. It was determined by separating and classifying by size the particles that are passed through different grades of sieves. A dry cut sample (Gr_1) was taken and placed in a tray to be macerated for at least 24 hours. After this time, it was passed through a 2.00 mm sieve (No. 10) to eliminate the finest soil that could be present. attached. To do this, 20 kg of dry cut were weighed and subsequently placed in two metal trays in an oven at a temperature of 110 ^{0}C for 24 h, in order to eliminate the water contained. This process was carried out in duplicate. Once the soil was dry, it was passed through the different sieves (NC 20:1999) [10]. Depending on the percentage that passed through each sieve, the predominant material in said waste was analyzed according to the reference standard (NC 20:1999) [10].

2.2. Determination of Soil Compaction According to the Modified Proctor Test

The Proctor compaction test was carried out to determine the compaction characteristics of the soil formed by dry cutting and to establish its moisture content and dry unit weight. The dry cut used was sieved through a ¾" (19 mm) sieve, as specified in the reference standard (ASTM D 1557:12) [11]. Five dry cut specimens were formed (PS_1, PS_2, PS_3, PS_4, PS_5), each with a mass of 6,000 g where a % of water was added to each of the specimens (Table 1). They were subsequently added individually to the compactor equipment, until five layers were completed, 56 blows being made to each layer with an effort of 2.7 kN-m/m_3 as specified by the standard (ASTM D 1557:12) [11]. The sample was removed with the help of a test cylinder extractor and the cylinder of compacted soil was removed from the mold. The sample was divided to obtain a centric sample of the compacted soil. From the weights of the samples, the variables necessary to determine the compaction humidity and the maximum dry specific weight were determined. This determination was performed in duplicate.

Table 1. *Water content in each test cylinder.*

Test cylinder	Added water (%)
PS_1	3.0
PS_2	6.0
PS_3	9.0
PS_4	12.0
PS_5	15.0

Due to the characteristics of dry cutting, a normal specific weight of soils of 2.50 g/cm^3 is assumed, which will be used to determine the empty spaces in compaction.

The plasticity index of the soil was also determined, this being a measure of the humidity interval in which the soil exhibits plastic properties and is defined as the difference between the liquid limit and the plastic limit. It was determined using the multipoint method, according to (NC 58:2000) [12]. This was carried out in each of the test specimens to evaluate the potential in the design of flexible and semi-rigid pavements for roads and streets, with the characteristics of the traffic, as well as the humidity of the soil and temperature in the asphalt pavement, in the exploitation conditions of the national climate.

2.3. Pavement Mix Design

In the formation of the pavement material, several mixing ratios were designed where dry and wet cuts, grit and ground aggregates (pavement construction waste (RCP)) were used. In preparing the mixtures with dry cutting, a total of seven test cylinder of 1 200 g were prepared. Of them, specimens S_1, S_2, S_3 and S_4 with different ratios of dry cutting, grit and ground aggregates. Specimen S_5 with dry cut: ground aggregates and specimens S_6 and S_7 with dry cut: grit, only.

On the other hand, with wet cutting, six specimens (H_1, H_2, H_3, H_4, H_5 and H_6) were prepared, all of them with different mixing ratios.

Each of the materials were weighed and mixed in different proportions to be transferred to the compactor hammer. In this, the first layer is incorporated with 600 g of mixture and then the other 600 g with compaction using 40 blows to each layer (NC 261:2005) [13]. At the end of this process they were extracted from the mold with the help of the extractor.

The prepared specimens were weighed and measured to calculate the density according to the gravimetric method (equation 1). The result must be greater than 2.33 g/cm^3 as specified in (NC 261: 2005) [13], for stability tests.

$$D_A = A/(\pi \cdot (d/2)^2 \cdot h) \quad (1)$$

Data:
A: Weight of the compacted specimen = g
d: diameter of the test cylinder mold = 10 cm
h: height of the test cylinder = cm
Determination of pavement stability

Pavement stability was performed as a preliminary test for future analysis of formulations with drill cuttings in asphalt pavement. In this test, no asphalt mixture was used since the purpose is to evaluate the behavior of diesel in the drilling cut, instead of the conventional asphalt mixture and to determine its influence on the stability of Marshall equipment, according to the characteristics of the material. In this case, the specimens obtained in the mix design were used.

The test evaluated the stability in the Marshall equipment by means of the maximum load resisted by the specimen and multiplied by the corresponding correction factor, which causes the decrease in diameter experienced by a specimen from the beginning of the load until the moment of its breakage (NC 261:2005) [13].

Marshall stability is given by equation 2:

$$E = Q \cdot Fc \cdot k \quad (2)$$

Data:
Q: Dynamometric ring reading
Fc: Correction factor for height
k: Ring constant = 172.4 kN/mm

2.4. Determination of Resistant Capacity for Pavement Design

In the analysis to evaluate whether the dry cut alone, or the mixture of said residual with other materials, has the characteristics of a soil to be used in layers of the asphalt layer for the construction of roads, the support ratio test was carried out. (from its acronym in English CBR). It measures the shear resistance (shear stress) of a soil under controlled humidity and density conditions as specified in the standard (ASTM D 1883:07) [14].

For this purpose, dry cutting only (C_{S1}) and a mixture of dry cutting, wet cutting, grit and ground aggregates (pavement construction waste) were used. For the latter, four specimens (SH_1, SH_2, SH_3, SH_4) with a mass of 6 000 g and different mixing ratios were used. Each mixture was added to the compaction equipment until five layers were completed, making 56 blows to each layer. At the end of this process, the specimen was weighed and measured according to (ASTM D 1883:07) [14]. In the event that both give the same CBR, either of the two is taken.

The applicability of the pavement design was evaluated according to the technical requirements for calcareous materials to be used in the base and sub-base of road pavements, as established in the reference Cuban standard (NC 161:2002) [15].

3. Results

This chapter presents the results achieved from the tests carried out on drilling cuttings contaminated with diesel. Likewise, the effectiveness of reusing the cuts as raw material in the formation of asphalt pavement and pilot scaling is assessed.

3.1. Waste Characteristics

Table 2. *Characteristics of drilling cuts.*

Sample	HCTP (%)	G and A (%)	Moisture (%)	pH (25 ℃)
dry cut	3.2	4.7	9.4	8.6
wet cut	6.1	14.7	15.4	8.9
MAL	1	1	-	6-8
CITMA	-	-	5	-

MAL: Maximum allowable limit (NC819: 2017)
CITMA: Science Technology and Environment
(-) Not specified

The results of the physical-chemical characterization are reported in Table 2. They showed values of fats and oils, total petroleum hydrocarbons and pH that exceed the regulated parameters for final disposal. For this reason, they cannot be disposed of without prior treatment, as defined by the oil waste treatment standard (NC 819:2017) [16].

The cuts also have a high percentage of humidity associated with the diesel content in them and which is higher than the 5% established in the environmental license granted by the regulatory body (Resolution 136:2009) [17].

Granulometric Composition of the Dry Cut

The results of the granulometric analysis showed that the granulometry of the dry cut is within the interval 0.075 – 0.01 mm in sieving No. 200 since the largest amount passes (88%). This corresponds to a fine type aggregate composed of silt, clay and colloids (NC 20:1999) [10].

For the evaluation of the type of aggregate that makes up the drilling cut, the Cuban standard (NC 759:2010) on aggregates for asphalt mixtures was considered [18]. The dry cut is classified according to its granulometry as a filler for asphalt mixtures (mineral filler). In this case, a finely divided material is considered where more than 70% of the particles pass through the 200 sieve. Chemically inactive fillers such as calcium carbonate, fly ash and rock dust (as is the case with drill cutting) are mainly used as modifiers of the granulometry of the aggregate (NC 759:2010) [18]. In this way, it is possible to improve the workability, adhesion and durability of the aggregates, allowing the use of the cuts as a partial component in the replacement of the aggregates that are conventionally used for the production of asphalt pavements.

3.2. Compaction State of the Dry Cut as Soil

The average humidity of the plastic limits obtained was 27.5% as established by the standard (NC 58:2000) [12]. The liquid limit of the soil (54%) was obtained by the moisture content corresponding to the intersection of the straight line with the abscissa at the number of blows 25, as expressed in figure 1. By difference, a plasticity index of 26.5%, in accordance with what is specified in the Cuban standard (NC 58:2000) [12].

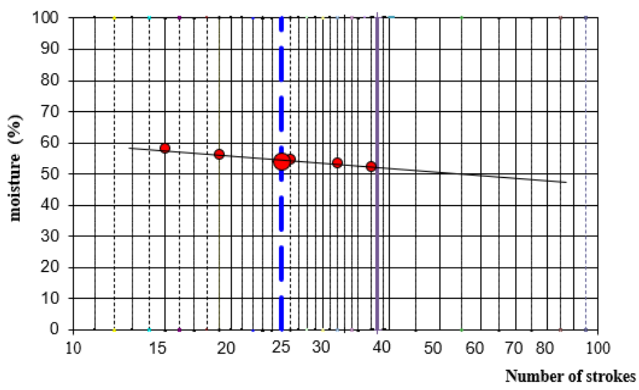

Figure 1. *Determination of the liquid limit.*

The plasticity index (PI) obtained does not meet the requirements for the calculation of flexible pavements. Being higher than 6%, maximum value allowed by the Cuban standard (NC 58:2000) [12], which may be associated with several factors such as: the composition of the soil or the drilled rock contaminated with diesel. The latter with a predominance of fine grain, which can result in greater plasticity and susceptibility to compaction. This situation corresponds to the fact that this material is not a conventional floor and the standard is governed by the characteristics and properties of the floors.

The variation in the percentage of humidity was represented graphically (Figure 2), with the aim of evaluating the dry cut with different water contents and not only its individual behavior. The analysis was performed for each property measured. The reference values marked in the graphs correspond to those required in the standard (ASTM D 1557:12) [11]. From the specific weight of the drilling cut in a dry and loose state (18.53 kN/m^3), the optimal humidity of 9.3% was obtained for the compaction of the material as soils, since with a moisture content greater than this it begins to decrease. the specific weight, which affects the compaction, integrity and quality of the material for use as pavement. This result must be taken into account in subsequent field tests because with an approximate humidity it is guaranteed that the dry cut compacts in a viable way, which influences the durability and quality of said soil. A saturation of 82% was also obtained, which means that the soil sample has been compacted with an amount of water that represents 82% of what it can retain and, still, be compacted to its maximum dry density. Such a situation is considered optimal as specified in the standard (ASTM D 1557:12) [11].

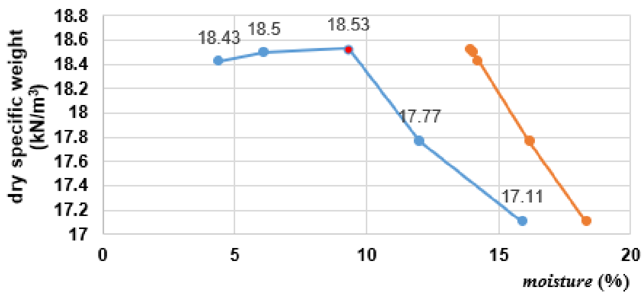

Figure 2. Compaction of the dry cut as soil.

In general, humidity can act on the loss of adhesion, which is the starting point of many failures in the pavement, since it directly attacks the compatibility between the asphalt and the aggregates, as well as the cohesion of the asphalt matrix. In this sense, it is possible that the diesel content present in the dry cut allows the compaction of the material with a lower degree of water, which has a positive influence to avoid the loss of adhesion or cohesion. As a result, the reduction of stiffness or resistance for road paving materials will be obtained [19].

3.3. Pavement Mix Evaluation

The results when using dry cutting to prepare the specimens with the designed mixtures showed favorable homogeneity and compaction from a visual point of view. However, the specimens containing the wet cuts showed signs of plasticity to the touch due to the high level of hydrocarbon in their composition. Such a situation compromised the partial integrity of the specimens as a result of the collapse. For this reason, it was decided to continue the tests only with the dry cut specimens.

The calculations of the densities of the dry cut specimens (S_1, S_2, S_3, S_4, S_6 and S_7) are presented in table 3, where viable values were obtained regarding the density (greater than 2.33 g/cm^3) proposed by the standard (NC 261:2005) [13]. This is because the mixture designs and each component that comprise them have essential properties such as: the resistance provided by the shot and the binder provided by the diesel, which allows compaction between the dry cut and the ground aggregates.

Table 3. Density of the test cylinder.

test cylinder	height (cm)	Density (g/cm^3)	Weight (g)
S1	5.9	2.506	1 161.4
S2	6.3	2.501	1 178.4
S3	5.7	2.666	1 151.5
S4	6.4	2.419	1 177.8
S5	7	2.019	1 110.1
S6	5.3	2.642	1 182.9
S7	5.6	2.773	1 176.6

However, specimen S_5 showed values lower than those established by the reference regulations (NC 261:2005) [13]. This may be associated with the absence of shot in the mixture design since it increases the weight per unit of volume with the contribution of metal and its oxides in its composition. If the density requirement is not met, specimen S_5 is disabled for the stability test.

3.4. Stability and Preliminary Deformation in Marshall Equipment

The preliminary Marshall stability test was carried out on the specimens without adding asphalt mixture, since the main objective is to analyze the behavior of diesel as a binder or stone adherent. In this regard, some observations were made on the results (Table 4), where it was evident that the correction factor varied between 1 and 1.39. Such a situation indicates that the load measured in the tests was correctly adjusted for the sample size used, as specified in the Cuban standard (NC 261:2005) [13]. The height of the specimens remains between 5.3 and 6.4 cm, which is also in the typical height interval for this test (NC 261:2005) [13].

Table 4. *Stability test results.*

test cylinder	Correction factor	Load (kN)	Stability (kN)
S_1	1.4	57	11.2
S_2	1	57	9.8
S_3	1.2	49	10.1
S_4	1	72	12.4
S_6	1.4	50	12
S_7	1.3	44	9.5

In the case of loading, maximum loads intervaling between 44 and 72 kN were recorded, which influenced the Marshall stability of all the specimens, obtaining values between 9.5 and 12.4 kN, which demonstrates that they are stable and capable of supporting loads without suffer plastic deformation since they are within the acceptable interval of 9 to 13 kN as established by the reference regulations (NC 261:2005) [13].

At lower loads they may show a lack of resistance to permanent deformation, while higher loads may indicate an overly rigid mixture that may crack or break under repeated loading.

The highest Marshall stability (12.4 kN) and the lowest density of the compacted mixture (2.41 g/cm^3), but higher than the acceptance value (> 2.33 g/cm^3) (NC 261:2005) [13], was recorded with specimen S_4, which is identified as the most viable.

In the formation of asphalt pavement, good stability is important because it indicates that the mixture has the ability to withstand traffic loads without deforming or breaking. If the asphalt mixture does not have good stability, it can suffer permanent deformations or crack prematurely, which can lead to a reduction in the useful life of the road and additional maintenance and repair costs [20]. On the other hand, a low density, but with a value higher than the acceptance value, can be beneficial because it reduces the weight of the asphalt mixture and, therefore, reduces the cost of transportation and the amount of asphalt necessary to build the road [21]. However, it is important to find a balance between the density and stability of the asphalt mixture to be formed, since a density that is too low can compromise the ability of the mixture to withstand traffic loads according to studies carried out [22].

These stability test results are preliminary, but they generally suggest that the drilling cuttings have the potential to be used as a partial component in reducing the volume of asphalt mixture in the manufacture of asphalt pavement since it meets the requirements of the Cuban standard (NC 261:2005) [13].

3.5. CBR Behavior of Dry Cutting

The CBR test for dry cutting obtained a high percentage of soil compaction (87–99%), which suggests that the soil has been adequately compacted. A humidity of 10.6% was also reached, which must be taken into account for subsequent field tests because with a higher humidity content the specific weight begins to decrease, which affects the compaction, integrity and quality of the material for its use as pavement.

Table 5. *Behavior of the CBR in dry cutting.*

Mold Number	E	G	H
Number of strokes	10	25	55
% CBR 2.54 mm	23	25	46
% CBR 5.08 mm	21	24	38
% compaction	87	88	99
Dry specific weight (kg/m^3)	1 593	1 617	1 823

Also the dry specific weight of the dry cut indicated that the soil is dense and can provide some resistance to deformation as specified by the standard (ASTM D 1883-07) [14]. The CBR values for the two piston diameters (2.54 mm and 5.08 mm) are relatively low. This is analyzed to determine the possible use as layers of the asphalt layer according to the standard (NC 334:2004) [23], indicating that the soil has a limited load capacity and cannot be used as a base on roads.

However, a CBR rate of 46% was obtained after 55 strokes, higher than the minimum interval of (20 to 30)% established in the reference standard (NC: 334:2004) [23]. In this way, the dry cut can be used as the main raw material for the formation of sub-base in asphalt pavements.

According to the CBR value of 46%, it is possible to use it as a sub-base on highways, airports, low-traffic and low-cost roads as specified by the Cuban standard (NC 161:2002) [15] for highways, bases and sub-bases. -soft limestone bases.

Taking into account the previous results, CBR samples with different mixture ratios that influence properties such as resistance to deformation were analyzed. Such is the case of shot and thus being able to evaluate improvements in the properties for the application.

3.5.1. Behavior of CBR in Different Mixture Ratios

The results of the CBR tests demonstrate that specimens SH1 and SH3 have the highest CBR values with percentages of 33% and 32% for the 2.54 mm test.

Table 6. Behavior of CBR in mixture designs.

test cylinder	SH1	SH2	SH3	SH4
Mold Number	P	L	L	P
% CBR 2.54 mm	33	8	32	13
% CBR 5.08 mm	32	8	28	13
Dry density (kg/m^3)	2 258	2 178	2 195	2 197

The determinations indicated that said specimens can be recommended for use in sub-base layers in a vial to be repaired or new; or in cases of deep potholes where the impact reaches the level of the subgrade, as specified in the flexible road pavement standard (NC 334:2004) [23].

On the other hand, specimens SH2 and SH4 have CBR values less than 20%, as established (NC: 334:2004) [23], which is not suitable for use in vials.

The average humidity is similar in all the specimens, with values between 3.2 and 5.5%, which must be taken into account for the formation of the mixtures in subsequent field tests.

Although the resistance values with SH_1 and SH_3 were slightly lower (33 and 32%, respectively) than those obtained with dry cutting, they are also effective for use as a subbase on highways, airports, roads with low traffic intensity and low cost as specified by the Cuban standard (NC 161:2002) for roads [15].

3.5.2. Statistical Analysis of the CBR Specimens with the Best Results

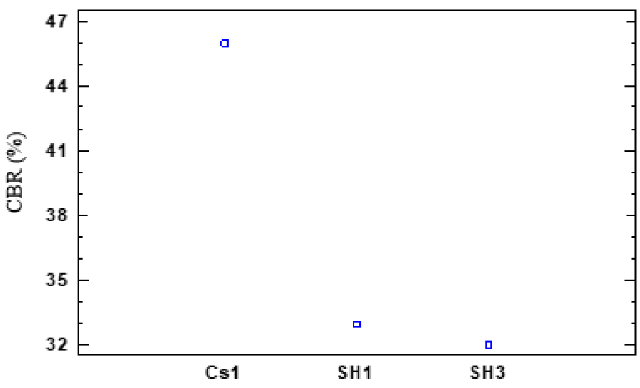

Figure 3. Statistical analysis: dispersion by level code.

The ANOVA analysis (figure 4) of repeated means to compare the percentages of CBR between the three types of soil with the specimens with the best results (dry cut and the selected mixtures). Between repeated measurements within each soil type, data variability was demonstrated within each soil level (Cs_1, SH_1 and SH_3) with significant differences between the three soil types at a 95% confidence level (figure 3). Greater variability is observed within the Cs_1 soil level than in the other two levels. It also showed that the CBR percentages are similar between the other two specimens at each level and that the type of soil had a significant effect on the CBR percentage.

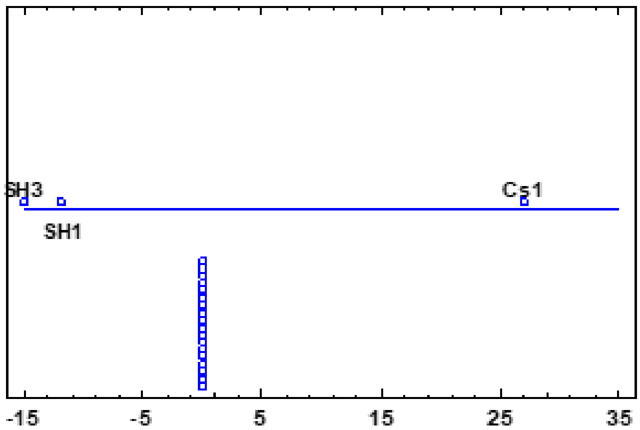

Figure 4. Statistical analysis: Anova for CBR.

Taking into account the above, another complementary study is necessary at the laboratory level using the different variants in filling layers in potholes, but penetrated by asphalt emulsion as a way of stabilizing the material given its non-compliance with the plasticity parameters. This ensures that it meets the requirements of Cuban standards and the best practices of the construction industry.

In any case, it is considered that dry cuts (Cs_1) have greater potential for use in the construction of roads and pavements.

3.6. Social and Environmental Impact

Within a concept of sustainable development and positive environmental and social impact, the evaluated proposal guarantees that the oil industry is framed in the objective of conservation and rational use of natural resources, protection of the ecosystem and human health. In addition, it contributes to reducing the stored volumes of hazardous waste of this type with the development of new methods in recovery and recycling processes for the efficient use of resources and the use of waste materials as a green resource. In addition to that, the risks to which workers and people from the communities near the entities containing the cuts are exposed are reduced. In addition, training and awareness of all people involved will be promoted, which ensures compliance with the environmental regulations established by CITMA.

4. Conclusions

1. The drilling cuttings contaminated with diesel have a hydrocarbon content of 3.2% and 6.9% in dry and wet cuttings respectively, which fails to comply with the

stipulation of 1% for final disposal. They also present a granulometry where 70% of the particles are fine, so it can be used as a modifier of the granulometry of the aggregate.

2. A favorable humidity of 9.3% was obtained for the compaction of the material as soil with dry shear and Marshall stability of 12.4 kN in specimen S_4, showing the potential to be used as a partial component in reducing the volume of asphalt mixture in the manufacture of pavement asphalt.
3. It was determined that both the dry cut (Cs_1) and its mixture with wet cut, shot and aggregate (SH_1 and SH_3) can be used as a sub-base on highways, airports, roads with low traffic intensity and low cost, showing a CBR rate of 46%, 33% and 32%, respectively.
4. Using diesel-contaminated drill cuttings as construction materials represents an innovative strategy to implement a circular economy and carry out waste management with a zero waste approach.

Abbreviations

OBM: oil based mud
G and A: fats and oils (G and A)
NC: Cuban standard
ASTM: American Society for Testing and Materials
HCTP: Total Petroleum Hydrocarbons
A: Weight of the Compacted Specimen
d: Diameter of the Test Cylinder Mold
h: Height of the Test Cylinder
Q: Dynamometric Ring Reading
Fc: Correction Factor for Height
k: Ring Constant
MAL: maximum allowable limit (NC819: 2017)
CITMA: Science Technology and Environment
RCP: Pavement Construction Waste
CBR: Support Ratio Test
PI: Plasticity Index

Conflicts of Interest

The authors declare no conflicts of interest.

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