CHARACTERIZATION OF NON-INDUSTRIAL ASPHALT MATERIALS FROM NORTHERN ECUADOR USED IN THE MAINTENANCE OF ROAD INFRASTRUCTURE

[1]JORGE LUIS ARGOTY BURBANO, [2]JUAN CARLOS ARGOTI BURBANO,
[3]FERNEY QUIÑONES SINISTERRA
[1]jlargoty@udenar.edu.co
Universidad de Nariño
https://orcid.org/0000-0001-6661-1398
[2]juanarg@unicauca.edu.co
Universidad del Cauca
https://orcid.org/0000-0003-0288-3815
[3]ferneyquinones@unicauca.edu.co
Universidad del Cauca

Acceptance Date: April 02, 2022; Published Date : July 10, 2022

Summary
The main objective of this research was to characterize the non-industrial asphalt materials of northern Ecuador used in the maintenance of road infrastructure. This characterization of materials was carried out thanks to the collection of samples; To carry out the sampling of natural asphalt mixtures, the INV E-201 standards on sampling of materials for road construction and the INV E-701 standard on sampling of bituminous materials were followed due to the characteristics of these materials.
The natural asphalt sampled was from the Pungarayacu field located in the province of Napo, Ecuador. Among the main findings, it was determined that natural asphalt mixtures with original gradation plus the addition of emulsion do not meet the minimum values of conserved resistance, air and water resistance for cold mixtures with asphalt emulsion, so it is concluded that these mixtures are only recommended for the construction of tread layers or stabilized bases on secondary or tertiary roads. If you want to use it for roads with heavy traffic, you must improve these characteristics. Therefore, it is not justified to carry out an investigation aimed at establishing a method of design of mixtures with crude oils due to the great heterogeneity that occurs between them, which would imply too many variables to be standardized, such as the contents of solvents and their type, the water content, the characteristics of the asphalt residue and the presence of impurities such as sulfur and organic matter, among others.

Key words: *Characterization of Materials, Civil Works, Road Mesh, Asphalt Mixtures.*

1. INTRODUCTION

The road networks in every city of every country in different regions of the world are a sign of progress, economic, social, cultural and even political well-being. Terrestrial communication between the different territorial entities ensures vital factors such as trade, health care, education, security, among others that determine the level of development of each population. That is why the maintenance of road infrastructure is a very important issue for both public and private entities. In this research, we intend to characterize the materials used in the maintenance of the roads, specifically in the north of Ecuador.
Most of the secondary and tertiary roads are in an advanced state of deterioration, mainly caused by the old conservation policies and the use of traditional methodologies that are not very effective, such as the periodic maintenance of the tread course with firming material, which implies high investments with low internal rates of return and the consumption of a large percentage of the budget of the entities in charge of maintenance both at the national level In the end, unsatisfactory results

were obtained in the medium and short term, which are reflected in high transport times, high vehicle operating costs and inconvenience for users (See photographs 1 and 2).

Photograph 1. Pollution in the summer season of the roads with a tread layer made of asphalt material.

Photograph 2. Swamps in winter on the tracks with a tread layer in asphalt material.

As can be seen in the photographs recorded above, the deterioration is notorious in this type of roads and its understanding represents a maximum urgency for the competent entities. For this reason, it is expected to know which are the ideal mixtures and inputs for its repair, and this is only achieved through the different samples proposed as a methodological order for the development of this research, in order to conclude, the ideal types of materials for each type of soil studied.

2. GENERAL OBJECTIVE

To characterize the non-industrial asphalt materials of northern Ecuador used in the maintenance of road infrastructure.

3. METHODOLOGY

Next, the methodology that was followed for the development of this research work is presented.

3.1 Sampling

This activity was planned and carried out with the purpose of obtaining representative samples of the aggregates and each of the natural bituminous binders to be studied, using the corresponding regulations for each case, in such a way as to guarantee the obtaining of reliable results.

3.1.1 Heavy Crude Oil Sampling.

This was carried out following the standard for sampling bituminous materials (INV-E 701). Table 4.1 shows the location of the sampled heavy crude oils.

HEAVY CRUDE OIL SAMPLED	
Crude oil name	**Localization**
Cedrales	Putumayo-Colombia
Rubiales	Meta-Colombia
Pindo 6	Orellana-Ecuador
Snake 1,2 and 5	Orellana-Ecuador
Yulebra 2	Orellana-Ecuador
Aucas 2,6,26,27,30,40,45	Orellana-Ecuador
Auca East	Orellana-Ecuador
Repsol YPF	Sucumbios-Ecuador

Table 1. Heavy crudes sampled

3.1.2 Sampling of natural asphalt mixtures.

To carry out the sampling of natural asphalt mixtures, the INV E-201 standards on sampling of materials for road construction and the INV E-701 standard on sampling of bituminous materials were followed due to the characteristics of these materials.

The natural asphalt sampled was from the Pungarayacu field located in the province of Napo, Ecuador.

3.2 Aggregate selection

After analyzing different alternatives of aggregate sources, it was decided to work with a crushed material from the Puracé source, due to its availability and because it is the most representative of the existing materials in the region of the Pubenza Valley.

Aggregate sampling. For the development of this activity, the INV E-201 standard was followed, which deals with the sampling of materials for road construction. The aggregates were transported in such a way as to minimize segregation, a clean and stable stockpiling area was used to prevent contamination, and the necessary measures were taken to prevent the different aggregates from intermingling.

3.3 Binder evaluation

For the evaluation of heavy crude oils, it was assumed that a heavy crude oil is a natural liquid asphalt, that is, the mixture of an asphalt cement and several solvents of different degrees of volatilization, which is why its evaluation is based on the tests used to characterize industrial liquid asphalts in terms of their physical properties. chemical and rheological tests, knowing that these tests are adaptations due to the lack of regulations for this type of materials.

3.3.1 Heavy crude oils

3.3.1.1 Physical characterization

It consisted of carrying out tests on the original crude oil and the distillation residue in order to know the physical characteristics and thus control its quality and be able to predict some aspects of its behavior when it is part of an asphalt mixture.

The tests carried out on heavy crude oils can be seen in Tables 1 and 2.

ORIGINAL CRUDE OIL TESTS			DISTILLATION RESIDUE TESTS	
PRACTICE	**NORM**		**PRACTICE**	**NORM**
Specific Gravity	INV E-707		Viscosity	INV E-716 D88
Distillation	INV E-723		Softening Point	INV E-712

Viscosity	INV E-716, ASTM-D2170		Penetration	INV E-706, ASTM-D5
Water Content	INV E-704		Specific Gravity	INV E-707
Spark Point	INV E-709			
Point of Flame	INV E-709			

Table 1. Testing of the original crude oil. **Table 2.** Distillation residue tests.

3.3.1.2 Chemical characterization

To know the chemical composition of the crude oil and the residual asphalt, the chemical characterization technique called infrared spectroscopy by fast Fourier transform was used, which was performed on the original crude oil and the crude oil after the distillation process following the INV E-723 standard, to then be able to correlate the effects of the change in composition with its mechanical properties and behavior in service.

3.3.1.3 Rheological characterization

To this end, rheological curves were elaborated from the viscosity and temperature values, found in the physical characterization of the crude oils, with which the handling temperatures of the natural asphalt binders were determined.

3.3.2 Natural asphalts

3.3.2.1 Physical characterization

At this stage, tests were carried out on the original natural asphalt and its components, both the mineral aggregate and the asphalt binder, in order to know and interpret their physical properties.
The tests carried out on the natural asphalt of the Pungarayacu field can be seen in Table 3.

TESTS CARRIED OUT ON NATURAL ASPHALT FROM THE PUNGARAYACU FIELD	
PRACTICE	**NORM**
Extraction	INV E-732
Binder recovery	INV E-759
Particle size analysis	INV E-213
Loose Unit Weight	INV E-217
Unit Weight Compact	INV E-217
Adhesion test Weber Riedel Method	INV E-774

Table 3. Tests carried out on the natural asphalt of the Pungarayacu field

3.3.2.2 Chemical characterization

The technique of infrared absorption spectroscopy by fast Fourier transform and the determination of the percentage of asphaltenes and maltenes were used to identify the chemical composition of the binder that constitutes the natural asphalt, with which its mechanical properties and possible behavior can be explained.

The percentage of asphaltenes and maltenes was determined by:

- Original natural asphalt (with sand)
- Asphalt obtained from the recovery test carried out on natural asphalt (without sand)

a.   Crude Snake 1

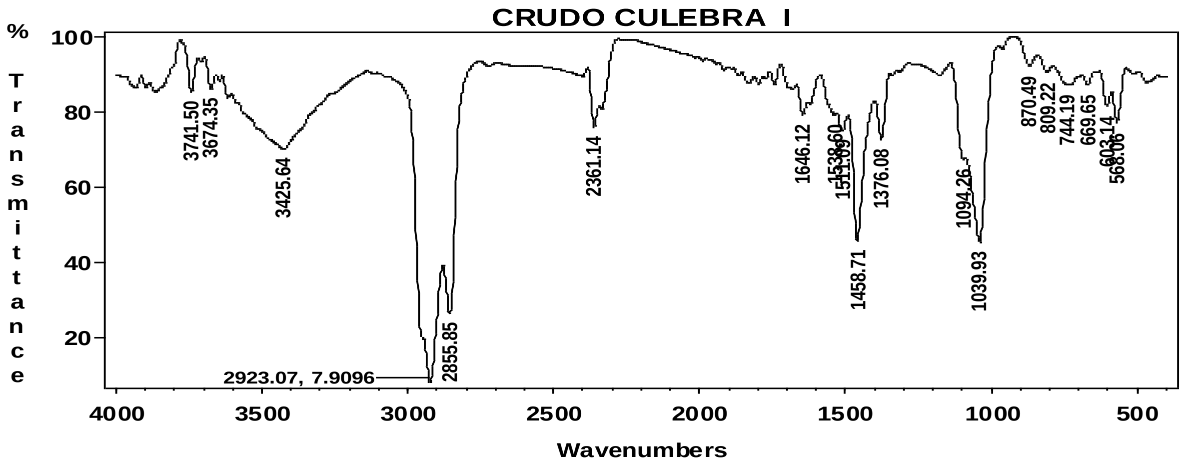

Figure 1 Spectrum of the original sample of Crude Oil Culebra 1

In the spectrum of Figure 1 two very important signals are observed, corresponding to N-H and O-H vibrations, the presence of these components can be corroborated by the intense signal at 1039 $^{cm-1}$, which is assigned to C-N vibration elongation overlapping with the elongation signals of the C-O bonds coupled to vibration voltages of the C-C bonds, Generally, these signals are as wide as the one observed in the spectrum

In the spectrum applied to the residue (see figure 2) it can be seen that after the distillation process there is a decrease in the intensity of the signals in the region between 3650 $^{cm-1}$ and 3200 $^{cm-1}$, as well as the signal at 1039 $^{cm-1}$ of oxygenated compounds (possibly water).

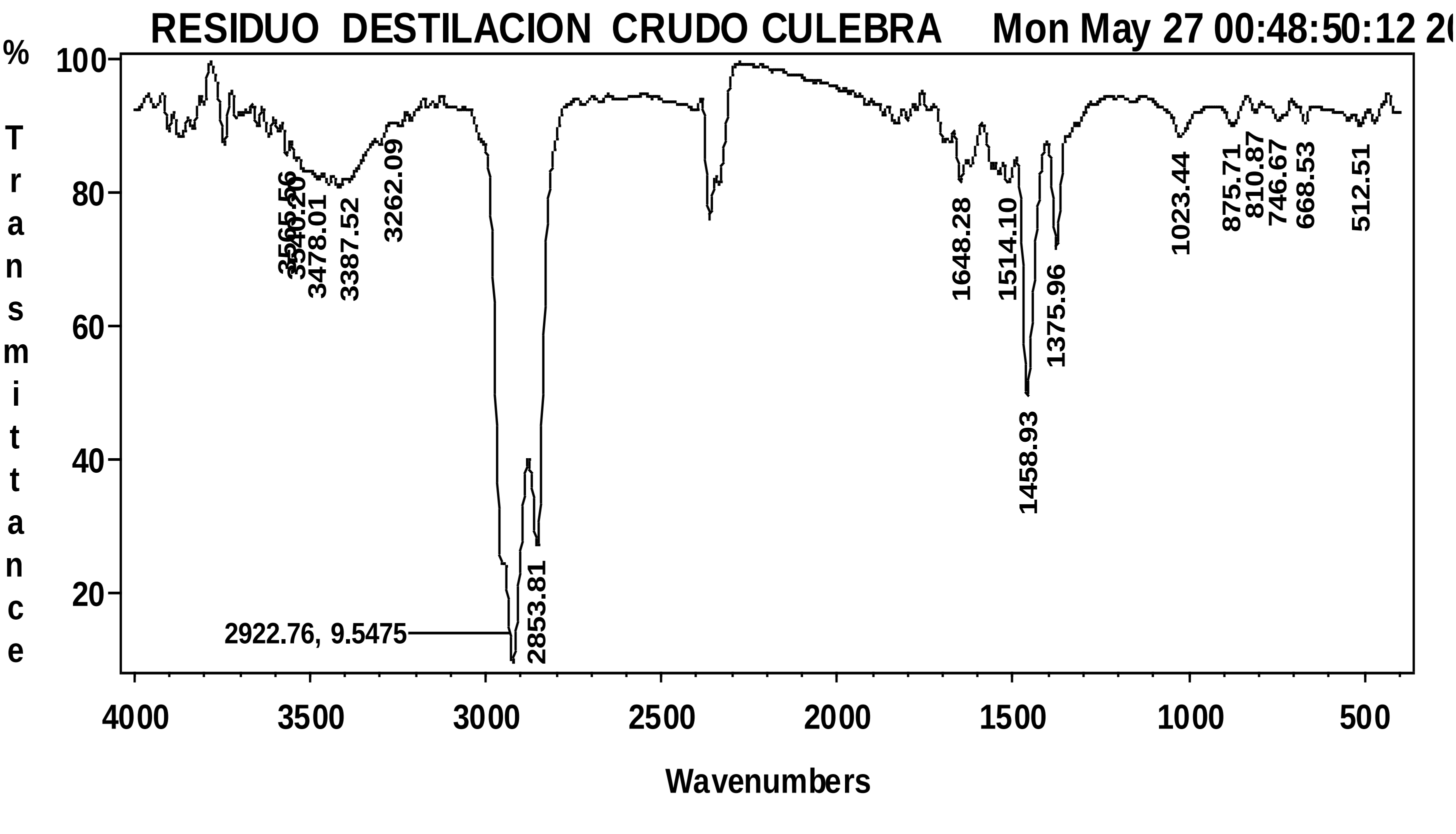

Figure 2 Spectrum of the residue after distillation of Culebra Crude

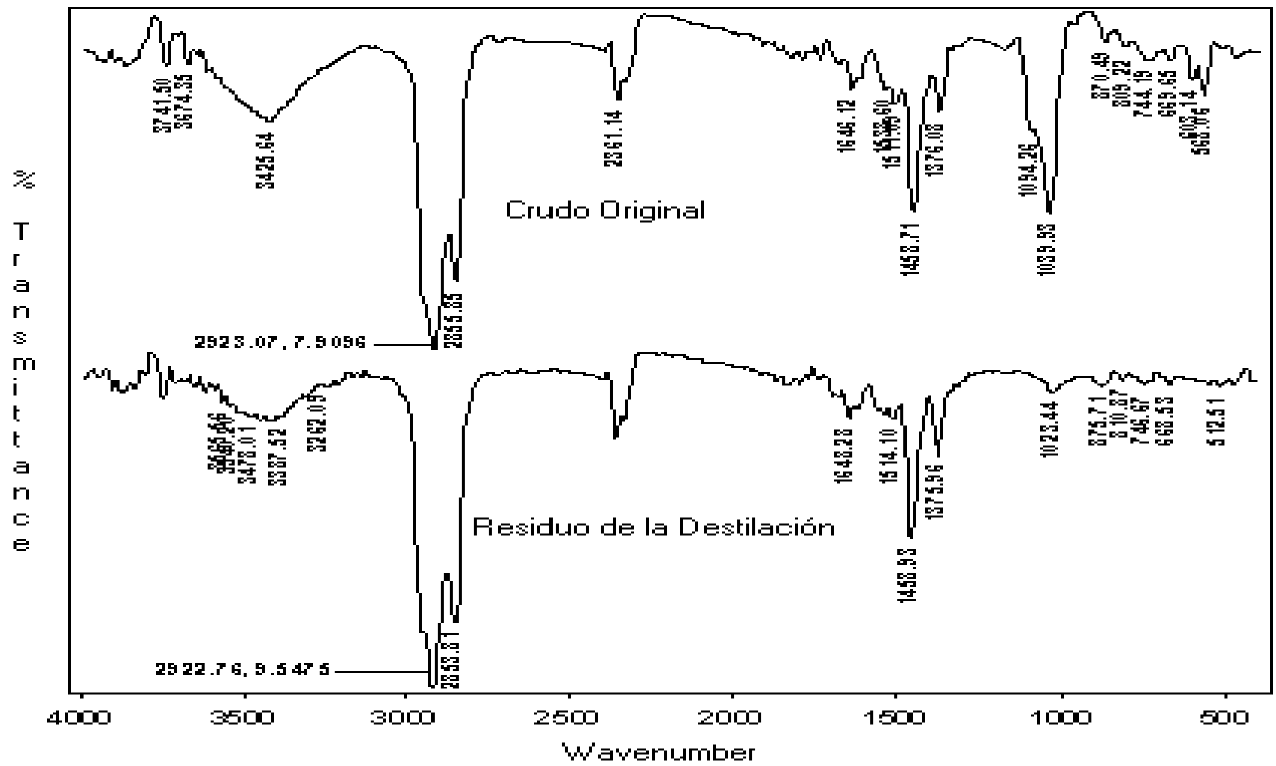

Figure 3. Comparison Between Original Crude and Culebra Distillation Residue 1

When comparing the two spectra in Figure 3, the most relevant changes are that after the distillation process, the decrease in the water present in the sample is observed. The bands located at 3425 $^{cm-1}$, and 1039 $^{cm-1}$, are indicative that the substances present in the distillate are basically saturated hydrocarbons, the spectrum presented is the closest to that of a hydrocarbon and it is important to note that despite the heating to which the sample was subjected, it does not affect the structure of the hydrocarbons present.

b. Crude Pindo 6

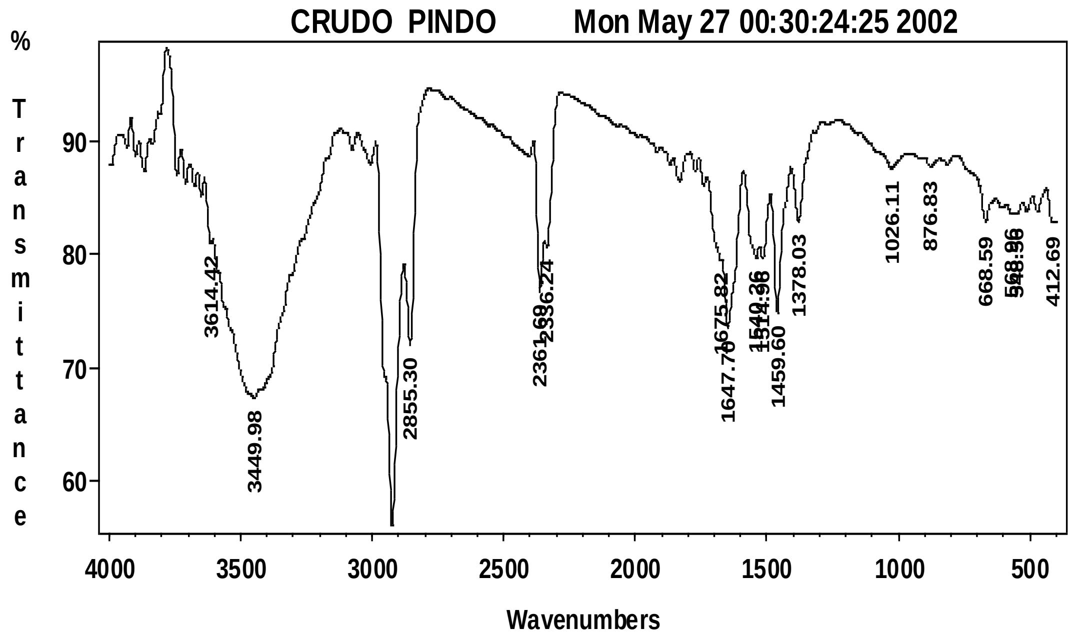

Figure 4. Spectrum of the original sample of Crude Pindo 6

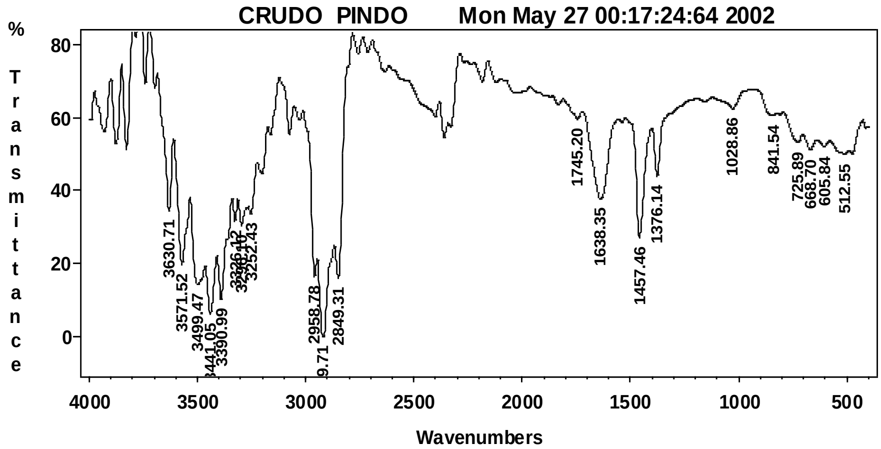

Figure 5. Spectrum of the residue after distillation of Pindo 6 crude oil.

In the spectra shown in figures 4 and 5, in addition to the typical signals corresponding to a mixture of hydrocarbons, a wide band is shown around 3450 $^{cm-1}$, this signal is characteristic of the O-H group it can be interpreted as the presence of water in the crude oil, on the other hand it is important to observe the signal around 1650 $^{cm-1}$, which can be attributed to the presence of carbonyl groups as well as deformation vibrations of the N-H bond

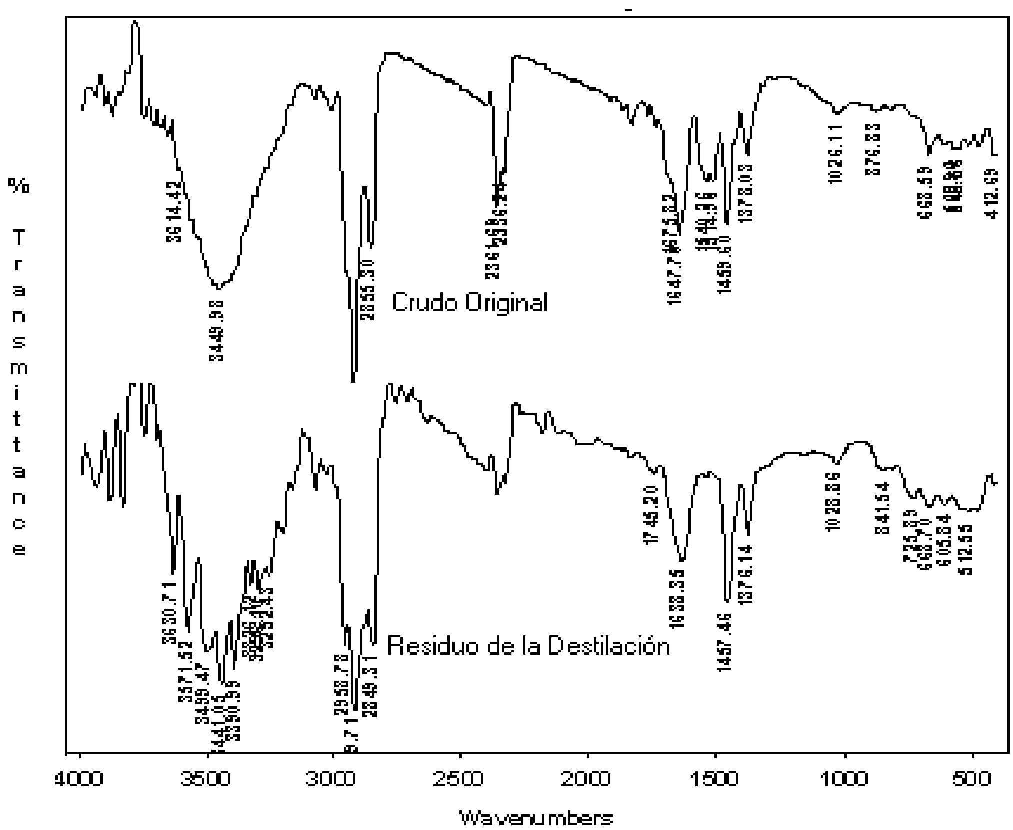

Figure 6. Comparison Between Original Crude and Pine 6 Distillation Residue

Comparing the two spectra in Figure 6 shows that after distillation there is a series of peaks in the region of 3450 $^{cm-1}$, which is indicative of the presence of N-H and O-H bonds of various types; a high water content is seen after the distillation process. The presence of aromatic polars is observed in the region of 1400 $^{cm-1}$ - 1600 $^{cm-1}$ and a small increase is observed in the bands of 500 $^{cm-1}$- 800 $^{cm-1}$ corresponding to the characteristic region of asphaltenes.

➢ In the spectrum of Pindo 6 crude oil, it is evident that it is the one with the highest water content, it also presents aromatic polars that are characterized by the presence of CO and is the crude oil with the lowest proportion of saturates of all those evaluated.

➢ The spectrum of Culebra 1 crude oil has a good degree of purity in terms of hydrocarbons, it is the one with the highest proportion of saturates of the Ecuadorian crudes evaluated.

Chemical characterization of the Pungarayacu field. Once the spectra were applied to the original natural asphalt mixture and the asphalt recovered from it, the spectra shown in figures 7 and 8 were obtained by means of the infrared absorption spectroscopy technique, respectively:

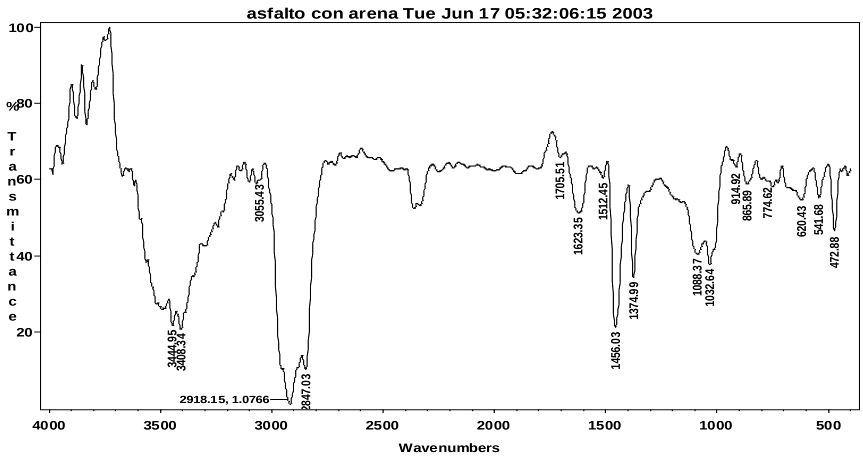

Figure 7. Spectrum of the original natural asphalt mix

Figure 7 shows the spectrum applied to the residual asphalt binder of the natural asphalt mixture of the Pungarayacu field, where a series of bands are seen indicating that it is a complex and impure mixture, probably containing water. The bands located around 3500 cm-1 indicate that the substances present in the asphalt binder are basically saturated hydrocarbons. Polar aromatics are present which manifest in signals around 1400 and 1700 cm-1

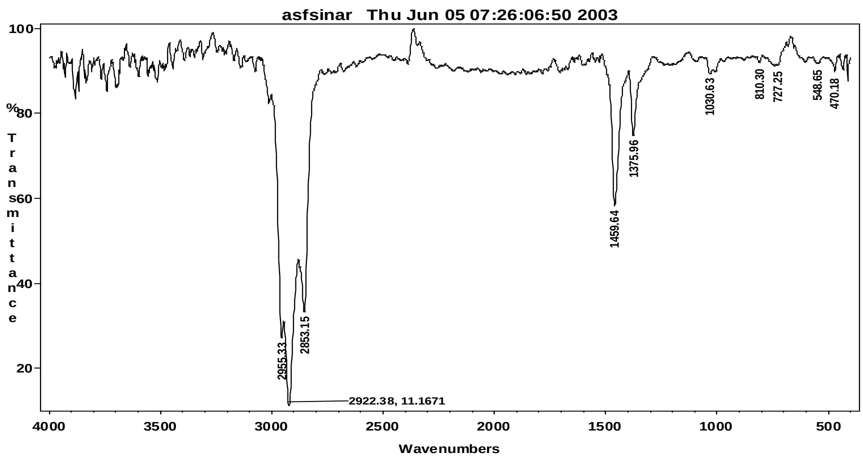

Figure 8. Spectrum of asphalt recovered from natural asphalt mix.

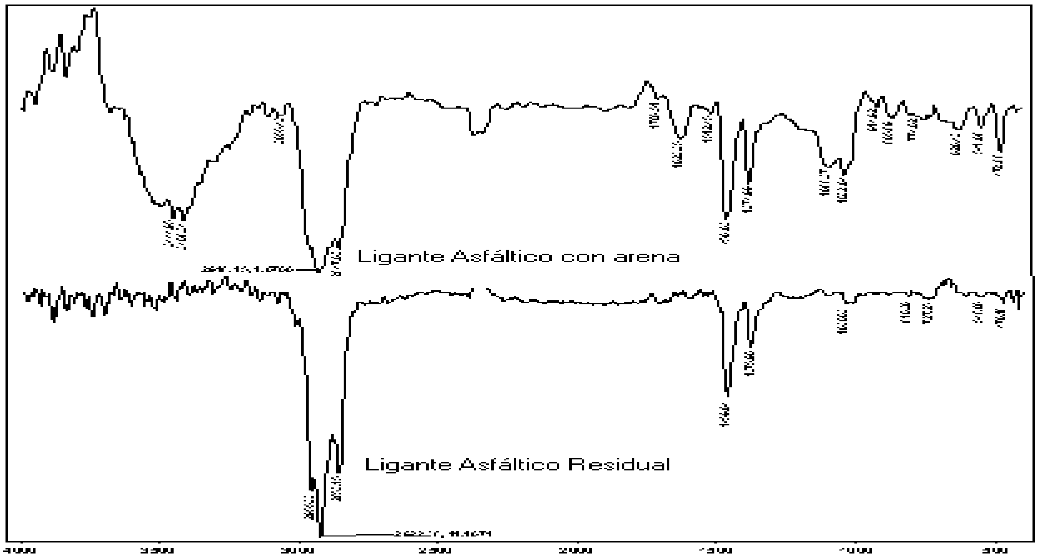

Figure 9 Comparison of spectra of natural asphalt mixture and its residual asphalt binder.

Figure 9 shows the spectrum of the residual asphalt binder, which was obtained by means of the recovery test, in which it can be seen that unlike the spectrum made to the residual asphalt binder plus sand, there are well-defined bands in 2922 $^{cm-1}$, 2955 cm-1.2853 $^{cm-1}$, 1459 $^{cm-1}$ and 1376 $^{cm-1}$ and low noise. According to the observed bands, the presence of saturated hydrocarbons can be corroborated. This spectrum is the closest to that of a typical saturated hydrocarbon.

3.3.2.3 Rheological characterization

It is carried out through the analysis of the rheological curve, which is determined from viscosity values at different temperatures of the asphalt binder that is part of the natural asphalt of the Pungarayacu field, which is separated from the asphalt mixture by the asphalt recovery test using the Rotavapor equipment (INV E-759).

4. RESULTS

4.1 Collection of information and sampling of heavy crude oil from the Republic of Ecuador.

Below is the location map of the heavy crude oils and natural asphalt evaluated, see figure 1.

Figure 1. Location of heavy crude oil and natural asphalt in the Republic of Ecuador

Crude Pindo 6

Crude oil name	Pindo 6.
Country	Ecuador
Place	Pindo Well 6.
Province	Orellana
Operating Company	PETROSUD - PETRORIVA
Remarks: API value supplied 16.1, sample size 5 gallons.	

Table 4. Pindo Crude Oil Sampling 6

Photograph 3. Pindo Crude Oil Sampling 6

Repsol YPF crude oil:

Crude oil name	Repsol YPF.
Country	Ecuador
Population	Nueva Loja
Province	Succumbed
Operating Company	REPSOL YPF.
Observations: A visit was made and samples were taken at the pumping station located in Nueva Loja.	

Table 5. Repsol YPF Crude Oil Sampling

Photograph 4. Repsol Crude Oil Sampling

Crude Snake 4

Crude oil name	Snake 4.
Country	Ecuador
Place	Pozo Culebra 4.
Province	Orellana
Operating Company	PETROECUADOR
Remarks: API value supplied 21.1, sample size 5 gallons.	

Table 6. Culebra Crude Oil Sampling 4

Crude Snake 1

Crude oil name	Snake 1.
Country	Ecuador
Place	Pozo Culebra 1.
Province	Orellana
Operating Company	PETROECUADOR
Remarks: API Value Supplied 18, Sample Size 5 Gallon	

Table 7. Culebra Crude Oil Sampling 1

4.1.1 Collection of information and sampling of the natural asphalt mix of the Pungarayacu Field

Below, the most relevant aspects in the stage of information collection and sampling of the natural asphalt mix of the Pungarayacu field are highlighted.

The Pungarayacu field is located in the province of Napo near the cities of Tena and Archidona, with vehicular access throughout its extension. Figure 2 shows a map showing the location of the field in the Republic of Ecuador.

indicating the location of the field in the Republic of Ecuador.

The Pungarayacu field has been exploited by the company Petroproducción, for which twenty-six (26) sampling wells have been drilled with average depths of 117 m and various studies have been carried out by the Central University and the School of Chemical Engineering, the Ministry of Public Works and other private and state entities of Ecuador, including the corporation for the research of asphalt for pavements CORASFALTOS of Colombia. All of them have aimed at the evaluation of the sands impregnated with crude oil from the point of view of asphalt mixture and residual asphalt binder. None of the studies have reached conclusions that allow a person interested in the subject to access the basic knowledge of how this natural resource should be optimized.

4.1.1.2 Geological characteristics of the Pungarayacu field.

The Pungarayacu field extends from the Macaw Range in the north, to the Pastaza Depression in the south, and from the metamorphic igneous complex of the Andes Mountains in the west, to the Napo uplift in the east. It is approximately 80 km long and 20 km wide.

Rocks dating from the Jurassic to the Quaternary outcrop in the field are represented by the following formations:

- **Misahualli.** It is made up of basalts and pyroclasts more than thirty meters thick.
- **Soot.** The total thickness of the formation reaches one hundred meters. It is considered to be the main reservoir of the field, made up of fine to medium-grained quartzose sandstones with cross-stratification of channel fluvial origin. There are laminar intercalations of clayey limonites and sandstones of fluvial origin from the floodplain and strata of limonites and fine-grained sandstones of marine origin, culminating in a layer of quartzose, glauconitic and calcareous sandstone.
- **Napo.** Of marine shelf origin, it consists of three members: the lower one made up of a sequence of sandstones and shalestones, the middle one by massive fossiliferous limestones and the upper one that presents a high degree of erosion, having preserved only fifteen meters of shale. The total thickness of this formation reaches 220 m.
- **Tena.** It is made up of brown and red clays, of continental marine transitional origin of the pre-coastal plain. It forms the main covering rock of the area, its thickness reaches 430 m.
- **Tiyuyacu.** It is mainly made up of silty clays and clayey sandstones with a basal conglomerate of quartz and flint pebbles, of fluvial origin at the foot of the mountain. Its average thickness reaches 250 m.
- **Quaternary.** It is made up of alluvial, colluvial and volcanic materials.

The field structure is defined as a bufante faulted monocline in a south- and south-easterly direction. It has endured intense weathering over time and washing of its reservoirs in the Quaternary, added to the strong silence and tectonic fracturing, has made the geological structure extremely complex and heterogeneous, finding blocks with heavy crude oil content and others completely sterile within the field.

4.1.1.3 Compilation of information on the natural asphalt mix of the Pungarayacu Field.

In the Ministry of Public Works of Ecuador, the following information was obtained after an interview with the construction engineers of the sections executed in the province of Orellana with the natural asphalt of the Pungarayacu field, which has been used in the maintenance and construction of various sites in the Provinces of Orellana and Napo:

Streets in the City of Francisco de Orellana- Province of Orellana, construction of a tread layer of approximately 10 cms, with a length of three (3) kilometers, (See photograph 5.)

Photograph 5. Street in the city of Francisco de Orellana (Province of Orellana)

Galeras Sector (On the Hollín – Loreto – El Coca road), tread layer with an average thickness of 10 cms with a length of two (2) kilometers, built in 1999 (See photograph 6)

Photograph 6. Road built with material from the PUNGARAYACU field belonging to the Ministry of Public Works (Napo Province - Ecuador)

Road maintenance of the Tena – Baeza section (See photograph 7).

Photograph 7. Road built with material from the natural asphalt mine of the PUNGARAYACU field

Regarding the use of natural asphalt from the Pungarayacu field in road construction and maintenance, it was observed:

- ✓ A technical evaluation of mix parameters such as gradations, mix design, enhancement, etc., was not performed. These guarantee a better performance of the structure built with this material.

- ✓ The construction process used was not adequate to obtain optimal results since inappropriate equipment was used (backhoe for mixing), the material was not spread under favorable climatic conditions, nor were the stone aggregates used in the improvement of the existing asphalt mixture selected.

- ✓ Despite the above deficiencies, results have been obtained in some cases that can be considered good, since there are structures built with this natural asphalt that have more than 10 years of useful life with light traffic and under climatic conditions of high rainfall and to date have not presented any serious problems.

- ✓ There is evidence of a lack of technical knowledge in the handling of these materials, so the results obtained are not the most satisfactory and therefore it is necessary to train and implement design and construction techniques.

4.2 Aggregate selection

The crushed material from the Puracé source was chosen because it has characteristics representative of the area of exploitation of the crude oil and the natural asphalt mixture studied in this research, because these areas present sources of materials similar to the one taken as the basis of the study.

The gradation used for asphalt mixtures with heavy crude oils was the emulsion-stabilized base (BEE-2) which corresponds to the general road construction specification INV-ARTICLE 340. Because this standard relates the cold mixing of a stone aggregate to an asphalt binder. The base stabilized with type two asphalt emulsion was chosen, since the maximum size of the aggregate is 1 1/2", which is the maximum dimension most representative in the asphalting materials

In natural asphalt mixtures, there is an original granulometry which was adjusted with the material of the Puracé source to the specification of an emulsion-stabilized base (BEE-2), INV-ARTICLE 340 standard.

The granulometry of the specification of emulsion-stabilized bases - type two is presented below (See Figure 3 and Table 8) and Table 9 shows the results of the tests carried out on the addition of the Puracé Source.

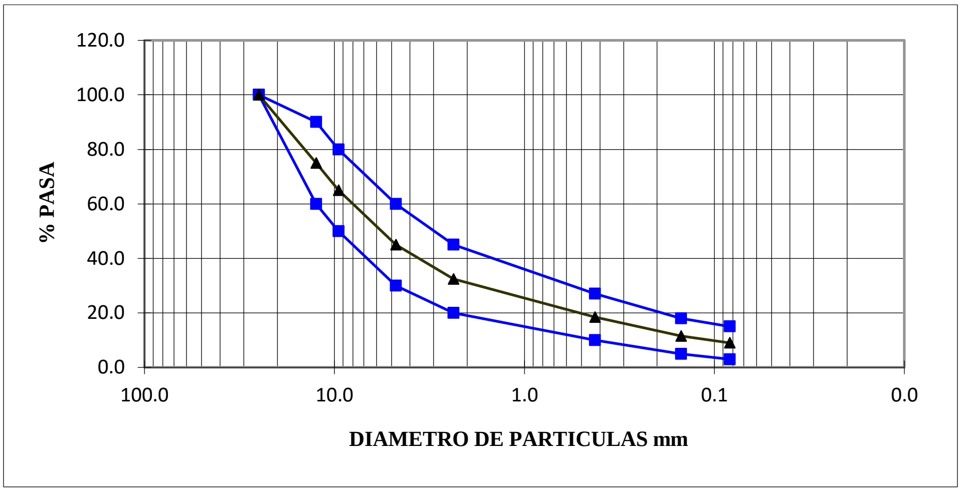

Figure 2. Base granulometry stabilized with emulsion type 2 (BEE-2)

OPENING		SPECIFICATION % THAT HAPPENS		GRADATION IDEAL	% RETAINED
IN	Mm				
1"	25.0	100.0	100.0	100.0	0
1/2"	12.5	60.0	90.0	75.0	25
3/8"	9.5	50.0	80.0	65.0	10
#4	4.75	30.0	60.0	45.0	20
#8	2.36	20.0	45.0	32.5	12.5
#40	0.426	10.0	27.0	18.5	14
#100	0.15	5.0	18.0	11.5	7
#200	0.083	3.0	15.0	9.0	2.5

Table 8. Base Granulometry Stabilized with Type 2 Emulsion (BEE-2)

PRACTICE	RESULTS		
Density in fine aggregate. INV-222	Average	Nominal	2.748 gr/cm3
		Apparent	2.579 gr/cm3
		Apparent SSS	2.641 gr/cm3
Density in Coarse Aggregate INV-223	Average	Nominal	2.715 gr/cm3
		Apparent	2.538 gr/cm3
		Apparent SSS	2.603 gr/cm3
Relative Specific Gravity of Fine Soils	Average	2.705 gr/cm3	
Wear on the machine of the INV-218 and INV-219 angels	Average	6.9 - 27.6 %	
	Specification	40% maximum	
INV-133 Sand Equivalent	Average	79 %	
	Specification	30% minimum	
Inv-230 Elongation Index	Average	5%	
	Specification	35% max	
INV-230 Flattening Index	Average	4%	
	Specification	35% max	

Table 9. Results of Assays of the Puracé Fountain.

According to the results presented in the previous table, it can be observed that the granular material studied complies with the values required in the specifications for the materials to be used as a granular base according to the INVIAS specifications.

5.3 Asphalt binder selection

Aspects that will guarantee an adequate behavior were taken as selection criteria, as they are part of the asphalt mix to be able to be used in the improvement of roads and also have the accessibility and availability of this material. The main selection parameters include:

- ✓ High consistency or viscosity
- ✓ API grade between 10-15.
- ✓ Good adhesion between aggregate and binder.
- ✓ Accessibility to the exploitation site.
- ✓ Availability of asphalt material

Taking into account the above parameters, the following crude oils were selected to be evaluated in this research:

- ✓ In the Republic of Ecuador, the following crude oil products were selected in relation to the parameters mentioned above:

a) Pindo 6.
b) Snake 1.

4.3 Ligand evaluation

The physical, chemical and rheological properties of heavy crude oils considered as natural asphalt binders were evaluated, the results of which are presented below.

Crude Snake 1.

PHYSICAL CHARACTERIZATION RESULTS OBTAINED WITH THE ORIGINAL CRUDE OIL		
PRACTICE	**RESULTS**	
Spark Point	Average	61 °C
Point of Flame	Average	87 °C
Relative density	Average	0.974 gr/cm3
Viscosity. Saybolt -Furol 60oC 70 °C 80 °C	 Average Average Average	 292.5 SSF 193 SSF 106.5 SSF
Distillation At 182 °C Temperature At 217 °C Temperature At 250 °C Temperature At 305 °C Temperature At 349 °C Temperature % Total Distillate % Residue	 Average Average Average Average Average Average Average	 0.9 % 2 % 3.9 % 6.9 % 8.6 % 22.3 % 77.7 %
Distillation % Total Distillate % Residue	Average Average	22.3 % 77.7 %
Water Content %	Average	30.6 %

Table 10. Physical characterization-results of tests obtained with the original Culebra 1 crude oil.

Culebra 1 crude oil has an API grade of 13.77 so it can be considered as a heavy crude (heavy crude oils API grade < 15), this crude contains 77.7% asphalt cement, 22.3% solvents of different volatility and 30.6% water, to avoid accidents in the handling of this crude oil should not exceed the temperature of 87ºC which corresponds to the temperature of the flame point, and caution must be exercised on site as the temperature of the spark point is 61ºC.
Based on its viscosity, flash point and total distillate characteristics at 360ºC, this crude oil can be classified as a natural liquid asphalt with properties similar to those of a medium-curing industrial liquid asphalt.

Raw Pindo 6.

PHYSICAL CHARACTERIZATION RESULTS OBTAINED WITH THE ORIGINAL CRUDE OIL		
PRACTICE	**RESULTS**	
Spark Point	Average	83 °C
Point of Flame	Average	108 °C
Relative density	Average	0.978 gr/cm3

Viscosity. Saybolt -Furol 60oC 70 °C 80 °C 90 °C	 Average Average Average Average	 215.5 SSF 122.5 SSF 89 SSF 58.5 SSF
Distillation At 182 °C Temperature At 217 °C Temperature At 250 °C Temperature At 305 °C Temperature At 349 °C Temperature % Total Distillate % Residue	 Average Average Average Average Average Average Average	 2.2 % 0.8 % 2.4 % 6.8 % 9.3 % 21.5 % 78.5 %
Distillation % Total Distillate % Residue	 Average Average	 21.5 % 78.5 %
Water Content %	Average	22 %

Table 11. Physical characterization-results of tests obtained with the original Pindo 6 crude oil.

PHYSICAL CHARACTERIZATION RESULTS OBTAINED WITH THE DISTILLATION RESIDUE		
PRACTICE	**RESULTS**	
Viscosity. Absolute Capillary 25 oC- 300 mm Hg.	Average	20551 Poises
Viscosity. Absolute Capillary 35 oC- 300 mm Hg.	Average	3703 Poises
Viscosity. Absolute Capillary 45 oC- 300 mm Hg.	Average	944 Poises

Table 12. Physical characterization-results of tests obtained with the distillation residue of Pindo 6 crude oil.

For Pindo 6 crude oil, the API grade is 13.18, so it can be considered as a heavy crude (heavy crude oils API grade < 15), this crude contains 78.5% asphalt cement, 21.5% solvents of different volatility and 22% water, to avoid accidents in the handling of this crude oil, the temperature of 108ºC should not be exceeded, which corresponds to the temperature of the flame point, and caution must be exercised on site as the spark temperature is 83ºC.

Based on its viscosity, flash point and total distillate characteristics at 360ºC, this crude oil can be classified as a natural liquid asphalt with properties similar to those of a slow-curing industrial liquid asphalt.

5. CONCLUSIONS

In the preliminary selection of a heavy crude oil to be used in the improvement of secondary and tertiary roads, the following parameters must be taken into account as selection criteria that allow inferring an appropriate behavior: adhesion between the aggregate and the binder, accessibility to the exploitation site, availability of the asphalt material and API grade.

Culebra 1 crude oil has an API grade of 14 so it can be considered as a heavy crude, this crude contains 77.7% asphalt cement, 22.3% solvents of different volatility and 30.6% water, the temperature of the spark point is 61ºC and can be classified as a natural liquid asphalt with properties similar to those of a medium-curing industrial liquid asphalt.

Pindo 6 crude oil has an API grade of 13 so it can be considered as a heavy crude, this crude contains 78.5% asphalt cement, 21.5% solvents of different volatility and 22% water, the temperature of the flame point is 108ºC and the spark temperature is 83ºC; It can be classified as a natural liquid asphalt with properties similar to those of a slow-curing industrial liquid asphalt

Fast Fourier transform infrared spectroscopy can be used to detect changes during the different processes to which an asphalt mixture made with natural bituminous products is subjected, by determining the different concentrations of the characteristic functional groups and thus predicting more accurately their behavior in service. This assay can be used as a complement to other traditional assays

It is important to determine in a heavy crude oil what is the optimal temperature that provides the appropriate viscosity to obtain a correct binder-aggregate mixing, compaction and curing of the asphalt mixture, because if this viscosity is very high it will not be possible to obtain an optimal coating and if it is very low it is possible that runoff of the crude oil may occur during the transport of the mixture producing loss of binder. For this, the rheological curve must be performed and analyzed, which is the relationship between the change in consistency generally measured by viscosity with respect to the change in temperature, thanks to the thermoplastic characteristics of the asphalt cement contained in the crude oil.

There are no standardized tests for heavy crude oils as an asphalt binder, so they are evaluated based on the hypothesis that they are considered as a natural liquid asphalt and their characterization is based on the tests used for industrial liquid asphalts

The adhesion results obtained, between the asphalt binders and the aggregate evaluated in this research, are classified between good and optimal, which guarantees good results in asphalt mixtures from the point of view of affinity.

For Pindo 6 and Culebra 1 crude oils, it was not necessary to subject each of the samples to a curing process before compacting, since in the mixing stage a volatilization of more than 25% of the solvents and water present in the crude oil was achieved, in such a way that if a curing process is insisted on, the asphalt binder loses a large percentage of its binding properties.

The natural asphalt mix with original gradation plus emulsion improved its properties when the asphalt content is around 6.0% and its compaction is carried out with a humidity of 3.5% for a pre-wrapped humidity of 5%

The mineral aggregate particles that make up the natural asphalt mixture of the Pungarayacu field are classified as a poorly graded, silicic, rounded and smooth sand, which means that the mixture containing high percentages of crude oil and is subjected to the action of heavy traffic and high temperatures presents problems of plastic deformation of the mixture.

The natural asphalt mixture of the Pungarayacu field has a higher asphaltene content than that of a refinery asphalt cement, which ranges between 20% and 25%, this is due to the high oxidation conditions to which the binder is subjected in the quarry

The natural asphalt mix of the Pungarayacu field has low rigidity at medium service temperatures, which decreases its resistance to fatigue induced by heavy traffic, this condition can be modified by improving the mineral skeleton with the addition of aggregate, in addition the low consistency of the binder helps to make the mixture manageable during the placement and compaction process, allowing these processes to be carried out at room temperature.

The behavior at high service temperatures of the natural asphalt mix from the Pungarayacu field is in the viscosity range of most asphalt cements produced in refineries, which indicates that the residual asphalt (oxidized heavy crude oil) has a consistency that helps to counteract a potential problem of plastic deformation of the mixture. but the characteristics of its mineral skeleton made up of smooth and rounded particles favor this phenomenon, especially when it has high percentages of binder.

The residual asphalt content of the natural asphalt mix from the Pungarayacu field has an average value of 6.3%. It should be noted that this value is in the range of the natural asphalt mixtures studied in other studies (5% and 7%).

Natural asphalt mixtures with original gradation plus the addition of emulsion do not meet the minimum values of preserved strength, air and water resistance for cold mixes with asphalt emulsion, so it is concluded that these mixtures are recommended only for the construction of tread courses or stabilized bases on secondary or tertiary roads. If you want to use it for roads with heavy traffic, you must improve these characteristics.

The alternatives of improving the natural asphalt mixture by adding aggregate plus emulsion is the best option, because the values obtained of resistance are higher than the other alternatives, and also the optimal asphalt content is reduced compared to the original gradation plus emulsion option

In the improvement alternative by adjusting the granulometry and adding the heavy crude Pindo 6, it is observed that the mechanical properties do not improve substantially, but the preserved strength and the optimal asphalt content is the lowest of the proposed alternatives.

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