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Effect Of Viscosity, Application Rate And Incidence Of Dust On The Adhesion Of A League Irrigation Of Asphalt Layers Evaluated With The Nlt-382/08 Test

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Summary

The increase in traffic levels on the country's roads requires robust asphalt pavement structures with thicker folders (Portillo, 2020) that in most cases must be built in more than one layer: requiring joining through a league irrigation, which provides the effective adhesion between layers of pavement (LanammeUCR, 2019). Garter irrigation is critical to transfer the stresses induced by transit loads to the structure, precisely this concept has been the subject of extensive research over time, to try to establish the correct variations and mitigate the factors that influence its degree of adhesion (Dorado & Rosero, 2018). Various types of problems occur on asphalt pavements, due to the lack of adhesion between the asphalt tread layers (González, 2018). For this reason, the adhesion resistance of the interface was studied in the laboratory by means of the test of the Laboratorio de Caminos de Barcelona (LCB) of the Spanish standard NLT 382/08, which evaluates adhesion by means of a shear test between bonded layers. The aim of this study was to identify the adhesion behavior of bituminous layers in a rubber irrigation, using CRR-60 and CRR-65 fast-breaking cationic emulsions and stone aggregates from the municipality of Pasto.

This work considered the conditions of viscosity, application rate and dust as an external pollutant, as well as determined the maximum load and the resistance to shear stress generated by the asphalt emulsion at the interface between the bonded asphalt layers.

Finally, the study established that the application rates are similar. The best performing binder was the CRR-65 fast-breaking cationic emulsion, as well as a decrease in shear stress resistance with the presence of dust.

Key words: *Asphalt emulsion, Ligament irrigation, Dust, Adhesion, Shear stress.*

1. Introduction

Colombia's growth requires the modernization and increase of the capacity of its road infrastructure, the 2018-2022 Development Plan mentions that "the increase in productivity and the potential of the territories increase by connecting territories for competitiveness and sustainable logistics development" (National Planning Department, 2019). This modernization is focused on the road mode where projects for the construction, improvement and maintenance of the road network are developed (Private Council of Competitiveness, 2022) and like other countries, Colombia wide[1]ly builds asphalt pavements due to their characteristics, advantages

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and versatility (H.Jahanbakhsh et al., 2017), in the construction of roads and pavements the current concern to tend to less environmental pollution and energy savings predominates, therefore, asphalt emulsions are used (Archila & Aparicio, 2018).

The increase in population and economic development of population centers generates greater consumption of goods and services, causing an increase in the levels of heavy traffic, translated into greater thickness of pavement structures. The quality of the materials, as well as the thickness of the layers that make up a flexible pavement, plays an important role in the behavior during its service (Sandoval & Orobio, 2013). Layers with considerable thicknesses can present difficulties during the construction process, caused by compaction problems (Xu & Huang, 2012). For this reason, the construction of new asphalt pavements with considerable thicknesses is one of the challenges faced by the design and construction of pavements, which requires installation in one or more layers to achieve the required dimensions and degree of compaction. Something similar happens in the construction of asphalt reinforcement layers; The joining of one or more asphalt layers requires the use of a league irrigation. The bond generated at the interface of the asphalt layers is of high importance, since it directly influences the performance and durability of the asphalt pavement (Vargas, 2008). King and May (2003) conducted research on the simulation of pavement structure, in which they showed that the decrease in the adhesion state from total adhesion (no slippage) to a level of 90% (partial slippage), significantly increased the stress and strain values in the pavement and decreased the final service life by about 50% (King and May 2003).

Tack coat irrigation is a procedure that is carried out with the use of an asphalt emulsion and is used to ensure good adhesion between the existing surface and a new asphalt application (Asphalt Institute, 2008). To evaluate the adhesion between asphalt layers, various tests have been developed to verify the definitive dosage of binder, these tests are UNE-EN 12697-48 SBT or NLT-382 (Instituto Nacional de Vías, 2022). Other test methods for determining the bond strength between an asphalt layer and other new-construction layers or existing substrates on road or airfield pavements are the Torque Bonding Test (TBT), generally applicable to any layer thickness; the Shear Joint Test (SBT), generally applicable to layer thicknesses > 15 mm; the tensile adhesion test (TAT) (Salazar et al., 2014), generally applicable to layer thicknesses ≤ 15 mm. In addition, there are other non-standard test methods such as the Compressed Shear Joint Test (CSBT); the Alternative Shear Joint Test (ASBT); layered adhesion measurement (LAMI) (UNE-EN 12697-48, 2022).

In Colombia, the use of tests to evaluate the adhesion between asphalt layers has been very limited, this activity has been carried out empirically with a superficial knowledge of the physical and chemical characteristics involved (Dorado & Rosero, 2018). At present, there are incipient regulations on the established dosage of binder. This research was developed on a laboratory scale and seeks to identify the behavior of the adhesion of bituminous layers, using CRR-60 and CRR-65 Fast Breaking Cationic Emulsions in a league irrigation in which conditions of viscosity, application rate and the incidence of dust as an external agent in the adhesion between asphalt layers were modified. made with mixtures commonly used in the municipality of Pasto. To determine the shear strength of the interface, the test described in the Spanish standard NLT-382/08 was used, in which adhesion was evaluated with a shear test, which has been used in different studies related to adhesion (Dorado & Rosero, 2018).

1.2 Description of the problem

Asphalt concrete pavements are constructed in several layers, with different physical properties and particular characteristics, due to technical and economic considerations (Diakhaté et al. 2011). Likewise, they are considered as a multilayer system with specific thicknesses and characteristics, in which a perfect bond between the different layers is assumed. It is assumed

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that these behave in a monolithic way, to withstand the external factors of transit and climate; however, this does not happen in reality (Ontiveros, 2013). League irrigation is responsible for ensuring that the structure functions as a single system, this is a thin, uniform application of asphalt material, usually a water-diluted asphalt emulsion, which is typically applied to an existing pavement surface or a new layer of hot asphalt before a new layer of asphalt is laid (Mohammad et al, 2012). This irrigation will ensure durability and performance over the life of the pavement. Different researchers who studied this issue determined that low levels of rubber band translate into the appearance of cracks, premature fissures, transverse deformation and, in addition, they assured that excess rubber generates undulations. Commonly, the slippage of pavement layers is known to be the greatest deterioration that occurs due to the weak bond between pavement layers (Biglari, 2018) (Ziari and Khabiri, 2007). Generally, this type of impairment occurs in locations where there is significant acceleration/traffic statement. It is also common in curves and U-turns (West et al., 2005).

Taking into account the above, it is crucial for the good performance of the pavement structure to study the factors that influence adhesion so that the league irrigation develops an adequate adhesion strength and resistance to adhesion of the interface between the pavement layers (Dorado & Rosero, 2018). These factors, which have the greatest influence on adhesion and which are intended to be studied, are: viscosity, application rate and dust as an external pollutant.

Therefore, it is of vital importance to ensure the adhesion of the interface between the bituminous layers and also to know the effect of various factors on the adhesion capacity (Delbono, 2019). It is essential to mention that, in recent years, this topic has been researched at a global and national level, however, it is necessary to particularize the materials used in the regions and identify the incidence of several parameters that influence the performance of the adhesion of league irrigation (Andaluz, 2019).

Regarding the regulations of this type of irrigation, for Colombia, only in the general specifications for road construction of the year 2022, in article 421-22 League Irrigation, the adhesion tests between layers UNE-EN 12697-48 SBT or NLT-382 are mentioned, which allows the definitive dosage of the binder to be established. At present, previously existing standards are based mainly on experience, convenience, empirical judgment, general recommendations on the types of binders and the dosage to be applied. In addition to the above, control and quality tests are rarely carried out in the laboratory, nor of the construction process of the adhesion layers, which can have an impact on low durability and even premature failure of the pavement structure. (Mohammad et al., 2002).

There is evidence of an incipient development in the study of adhesion resistance that is capable of developing an asphalt emulsion in a league irrigation, when subjected to mechanical stresses (Elizondo et al., 2017). For this reason, it is necessary to determine the influence of factors such as viscosity, application rate and dust as an external pollutant on adhesion resistance in a league irrigation, using fast-breaking cationic asphalt emulsions, established in the country's regulations.

2. Objectives

To study the adhesion of asphalt layers at laboratory scale through the LCB assay, evaluating the viscosity, binder application rate and the incidence of dust as an external pollutant.

2.1 Specific objectives

- Obtain the optimal application rate with which the highest slip resistance is achieved, allowing the shear strength of the interface to be measured.
- To identify the incidence of viscosity in the adhesion of the link irrigation between asphalt layers of the materials used in the municipality of Pasto.

• Establish the incidence of fine material (dust) in the resistance to shear stress by simulating the presence of a contaminating external material as a typical condition present on site.

3. Methodology

3.1 Study area

This work will be developed in the municipality of San Juan de Pasto, the capital of the department of Nariño. It is located in the southwest of the country near the border with Ecuador, has an approximate territorial extension of 1,181 km2 and a population of 352,356 inhabitants (DANE, 2018). The laboratory tests were carried out in the Laboratory of Eng. Juan Carlos Trujillo, located in the same city; The study is carried out using the materials produced in the asphalt plant of the company PANAVIAS installed in the urban area of the municipality of Pasto, but it covers the entire departmental territory and uses bituminous binders marketed in the country.

3.2 Outline of the proposed work

In order to meet the proposed objectives, the methodological design is defined with two components: data and a deductive method with a quantitative approach, where it is proposed to develop an experimental design based on previously determined variables (Dorado & Rosero, 2018). In the data, the information is collected and characterized with the help of the LCB shear test, in which the shear strength of the interface generated between the layers joined by the league irrigation is determined. The data is recorded and subsequently organized, processed and statistically analyzed from the elaboration and testing of briquettes.

An outline of the work to be developed is proposed, where the stages and number of specimens that will be prepared in a total of 70 are presented, this scheme is presented in Figure 1.

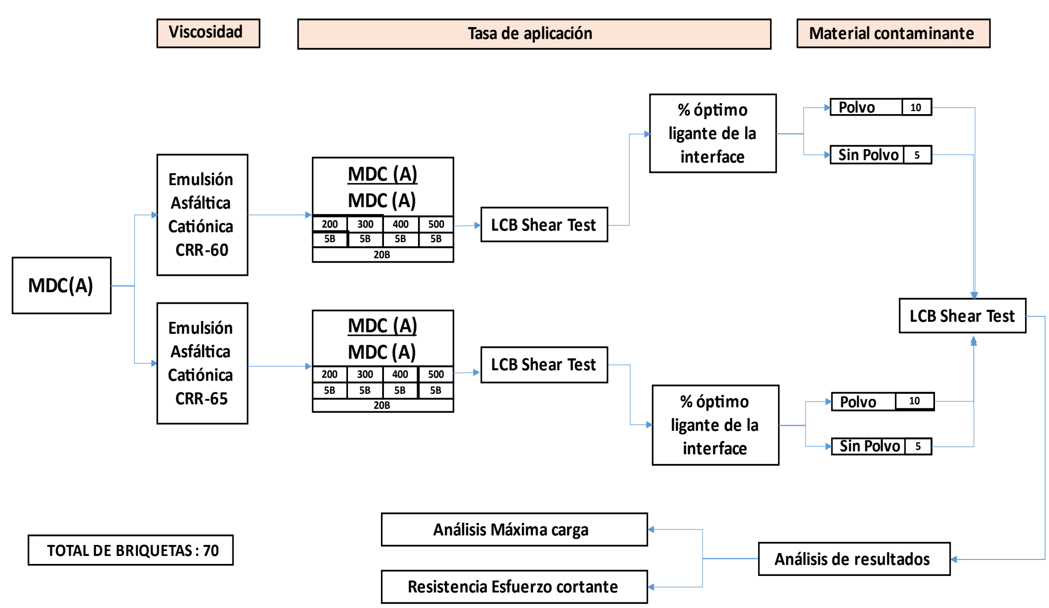

Figure 1. Proposed Research Scheme. In original Spanish language.

In the initial work plan, the study of two types of emulsions had been defined with the elaboration of 70 specimens, but finally 76 were elaborated in total, distributed as follows: for each emulsion four application rates were taken and with each rate 5 samples were elaborated, obtaining a total of 40 specimens. Then, in order to evaluate the incidence of dust in each type of mulsion, 3 dust conditions were taken and for each condition 6 briquettes were made, obtaining a total of 36 in total. Therefore, a total of 76 specimens were produced and failed for the two emulsions studied.

4. Results and analysis

As described, specimens made up of two asphalt layers were tested, where the first layer had a thickness of 6 cm of MDC-19 mixture and the second had a thickness of 5 cm of the same mixture, for a total thickness of 11 cm. Two types of emulsions, CRR-60 and CRR-65, were used as league irrigation, with 4 application rates of 200 g/m2, 300 g/m2, 400 g/m2 and 500 g/m2 of residual binder. The breaking force with which the shear stress resistance was obtained was calculated, and then the optimal irrigation application rate of the two emulsions was determined.

4.1 Breaking Shear Force

The breaking shear force is the maximum value recorded in the press at the time when the shear stress is generated on the surface of the joining of the layers that produces the separation of the same, using the B device established in the Spanish standard NLT 382/08. The breaking force (FCR) was calculated from the results obtained in the breaking of the specimens. Tables 1 and 2 show the results of the FCR obtained together with the standard deviation and coefficient of variation for CRR-60 and CRR-65 emulsion.

In Table 1, it can be seen that the shear force value for ligature irrigation with CRR-60 asphalt emulsion is lower for the lowest irrigation application rates and increases to values close to 400g/m2 of residual binder, and then decreases from that value. The standard deviation obtained is less than 0.5%, which indicates that the dispersion of data with respect to the mean and the coefficient of variation obtained is less than 10%, of which data sets of different populations can be compared, allowing to eliminate possible distortions of the means of two or more populations.

	CRR-60 DOSAGE			
Application rate (g/m2)	200	300	400	500
FCR (kN)	2.8	3.75	5.34	4.6
	3.2	3.34	5.28	4.96
	2.6	3.80	5.43	5.32
	3.2	3.30	5.71	4.7
	3.08	3.27	4.64	4.6
Stocking	2.97	3.48	5.28	4.83
OF	0.27	0.26	0.39	0.31
CV	9.10%	7.50%	7.40%	6.40%

Table 1. CRR-60 Emulsion Breaking Shear Force Results
Source: Authors' own creation

	CRR-65 DOSAGE

Application rate (g/m2)	200	300	400	500
FCR (kN)	3.55	4.4	6.56	5.87
	3.78	4.09	6.38	5.35
	3.56	4.5	6.7	5.12
	3.12	4.03	6.26	5.75
	3.25	4.35	6.49	6.32
Stocking	3.44	4.27	6.48	5.67
OF	0.26	0.20	0.17	0.47
CV	7.50%	4.70%	2.60%	8.30%

Table 2. CRR-65 Emulsion Breaking Shear Force Results
Source: Authors' own creation

It can be seen in Table 2 that the specimens bound with the CRR-65 emulsion have a higher value of shear force at break than the specimens where CRR-60 emulsion was used as a league irrigation and there is an increase as the application rate increases, obtaining the highest values with an application rate close to 450g/m2 and from that value it decreases. The standard deviation value obtained for each application rate dosage is less than 0.5 %, which indicates that the dispersion of data with respect to the mean and the coefficient of variation obtained is less than 10 %, from which data sets of different populations can be compared, allowing to eliminate possible distortions of the means of two or more populations.
Figure 2 shows a trend graph for the two emulsions used, showing the behavior of the shear force in relation to the increase in the application rate of the ligater irrigation.

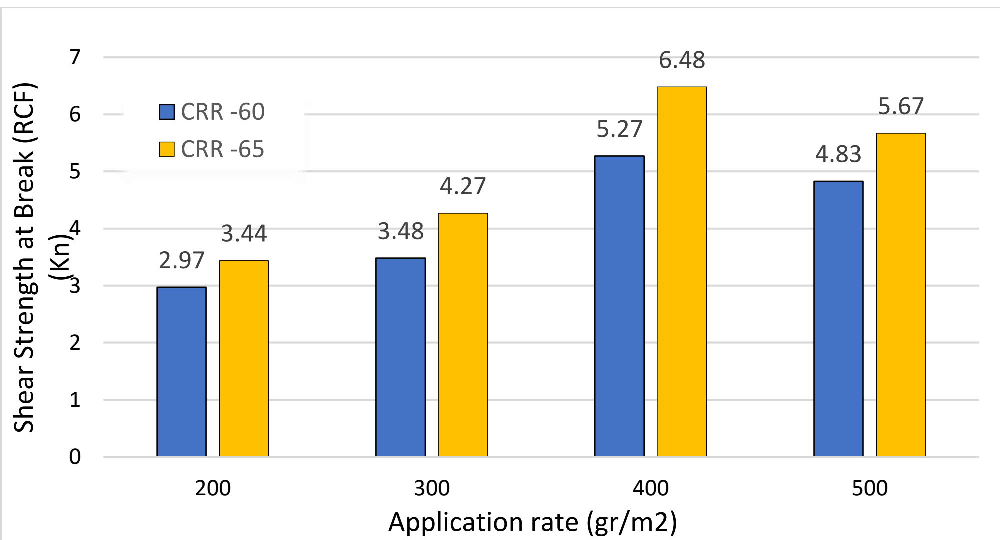

Figure 2. Comparison of the shear force obtained with CRR-60 and CRR-65 emulsions as a function of the application rate of the league irrigation
Source: Authors' own creation

4.2 Shear stress resistance

Using the formula mentioned and referred to in the Spanish standard NLT 382/08, with the average breaking force obtained and with the cross-sectional area, the resistance to the shear stress produced using the CRR-60 and CRR-65 emulsion was obtained.

The resistance to shear stress developed by the adhered interface of the two layers is defined as follows (Center for Studies and Experimentation of Public Works, 2008):

$$REC=(P/2) / S \quad (1)$$

Where

REC = Shear Strength, N/mm2 or MPa

P= Maximum Breaking Load, N

S= Cross-sectional area, mm2

Using the formula mentioned and referred to in the Spanish standard NLT 382/08, with the average breaking force obtained and with the cross-sectional area, the resistance to the shear stress produced using the CRR-60 and CRR-65 emulsion was obtained. The results of the Shear Stress Resistance (REC) obtained using the CRR-60 emulsion are presented in Table 3 and Figure 3.

Table 3 shows that the shear resistance value for ligature irrigation with CRR-60 asphalt emulsion is lower for the lowest irrigation application rates and increases to values close to 400g/m2 of residual binder, and decreases from that value. The standard deviation value obtained for each application rate dosage is less than 0.5 %, which indicates that the dispersion of data with respect to the mean and the coefficient of variation obtained is less than 10 %, from which data sets from different populations can be compared.

	CRR-60 DOSAGE			
Application rate (g/m2)	200	300	400	500
REC (MPa)	0.173	0.231	0.329	0.284
	0.197	0.206	0.326	0.306
	0.16	0.234	0.335	0.328
	0.197	0.204	0.352	0.29
	0.19	0.202	0.286	0.284
REC Average (MPa)	0.183	0.215	0.325	0.298
OF	0.016	0.02	0.02	0.02
CV	8.80%	9.30%	6.20%	6.70%

Table 3. Results of the Shear Stress Resistance obtained with the CRR-60 emulsion
Source: Authors' own creation

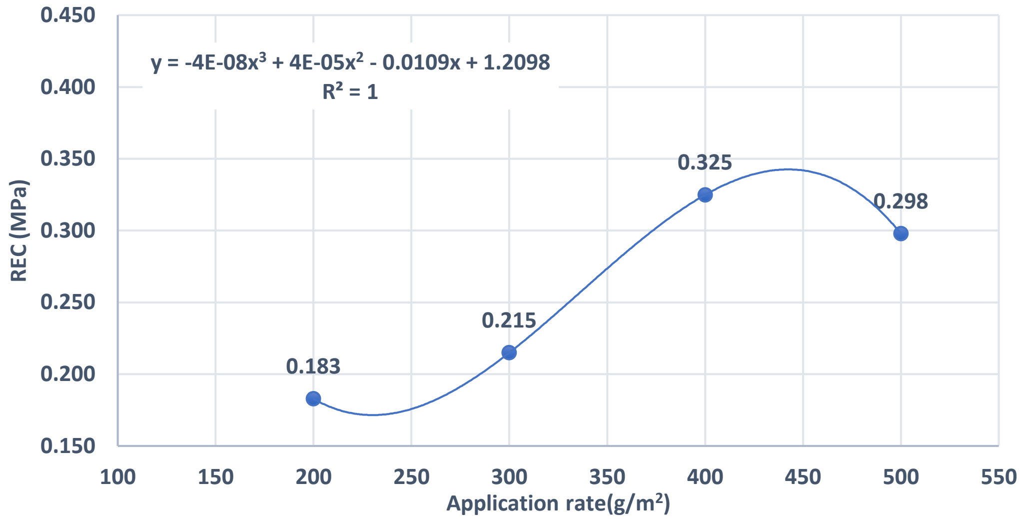

Figure 3. Shear stress resistance obtained with CRR-60 emulsion
Source: Authors' own creation

The results of the Shear Stress Resistance (REC) obtained using the CRR-65 emulsion are presented in Tables 4 and 4.
It is observed in Table 4 that the specimens bound with the CRR-65 emulsion have a higher value of resistance to shear stress than the specimens where CRR-60 emulsion was used as a league irrigation. There is an increase along with the application rate, obtaining the maximum values, with a rate close to 450g/m2 of residual binder and from that value, Descends.

	CRR-65 DOSAGE			
Application rate (g/m2)	200	300	400	500
REC (MPa)	0.219	0.271	0.405	0.362
	0.233	0.252	0.393	0.33
	0.22	0.278	0.413	0.316
	0.192	0.249	0.386	0.355
	0.2	0.268	0.4	0.39
REC Average (MPa)	0.212	0.263	0.399	0.350
OF	0.017	0.013	0.01	0.029
CV	8.00%	4.90%	2.50%	8.30%

Table 4. Results of the Shear Stress Resistance obtained with the CRR-65 emulsion
Source: Authors' own creation

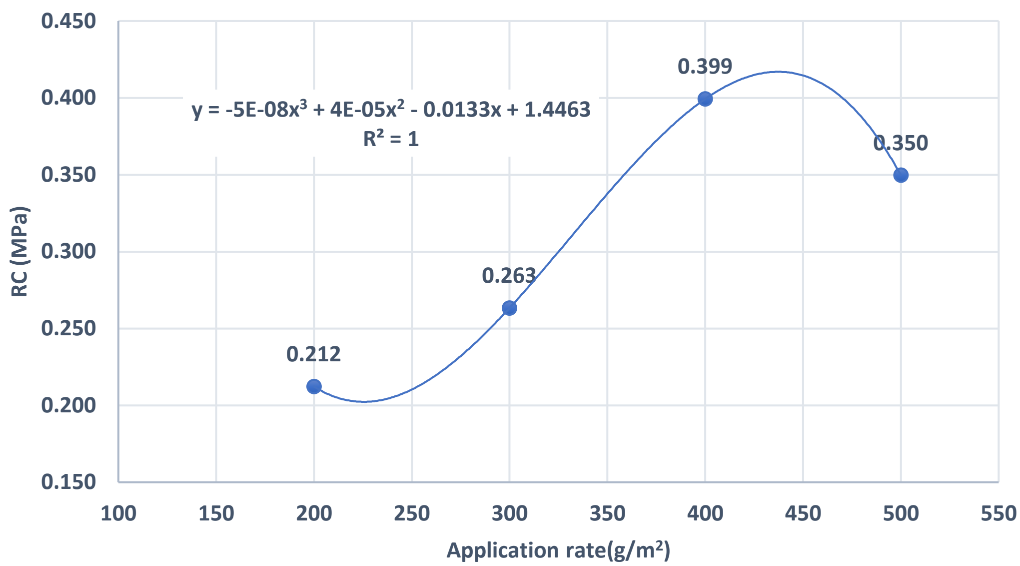

Figure 4. Shear stress resistance obtained with CRR-60 emulsion
Source: Authors' own creation

Figure 5 shows a trend graph for CRR-60 and CRR-65 emulsions, where the behavior of the shear stress resistance is observed in relation to the increase in the application rate, obtaining the maximum value close to 400 g/m2 of residual binder, in addition, the average values obtained for the CRR-65 emulsion are higher than those of the CRR-60 emulsion. with variations ranging in the order of 16% - 23%.

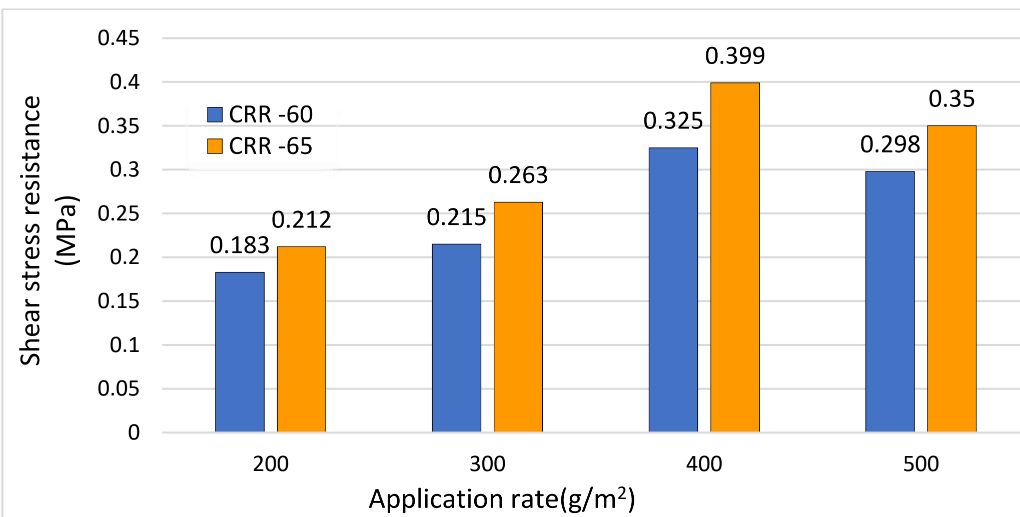

Figure 5. Comparison of shear stress strengths obtained with CRR-60 and CRR-65 emulsions as a function of the application rate of league irrigation
Source: Authors' own creation

4.3 Determining the Optimal Application Rate of League Irrigation

After calculating the Shear Stress Resistance (REC) generated at the interface by the ligament irrigation with the CRR-60 and CRR-65 emulsion, the results were plotted for each type of emulsion and it was obtained that the line that is best approximated is of polynomial tendency of degree three, according to the data obtained. presented in Figure 6.

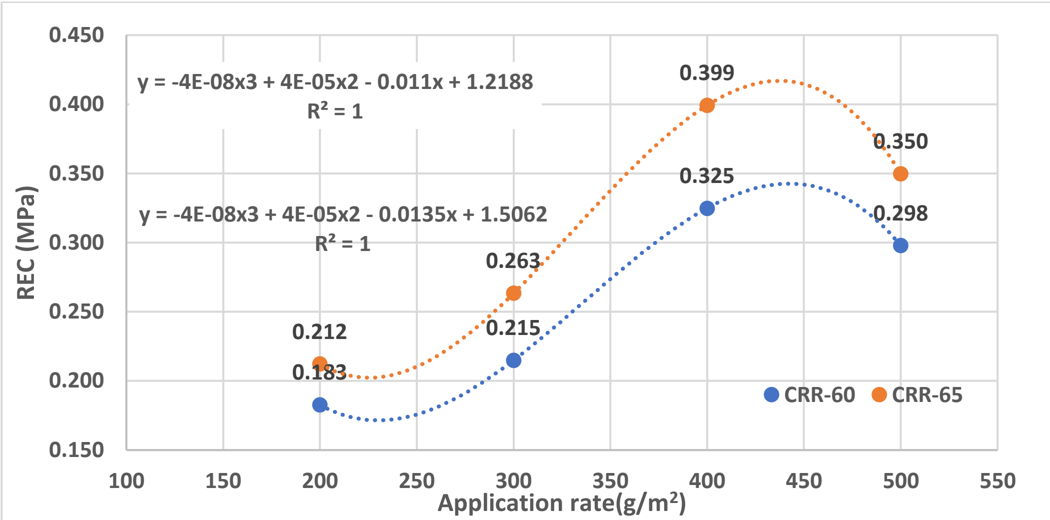

Figure 6. Comparison of shear stress strengths obtained with CRR-60 and CRR-65 emulsions as a function of the application rate of league irrigation
Source: Authors' own creation

According to the graphs obtained, it is observed that the shear strength for the CRR-65 emulsion is higher than for the CRR-60, for all the application rates evaluated. In the lowest application rates, the difference is smaller and a greater difference is reached between the range of 400 g/m2 to 500 g/m2 of residual binder, finding that the optimal rate of application of league irrigation is in this range for the two types of emulsions. Table 5 shows the optimal application rates obtained using third-degree polynomial regression trend lines.

Type of Emulsion	Optimal application rate (g/m2)	Shear stress resistance MPa
CRR-60	445	0.345
CRR-65	440	0.418

Table 5. Optimal Application Rate of League Irrigation
Source: Authors' own creation

The test used in this work is European and is part of the technical specifications aimed at controlling the quality of adhesion risks. In Colombia, this control has been included in the 2022 specifications of the National Institute of Roads - INVIAS, Chapter 4. Asphalt pavements, Article 421-22 Ligament irrigation, in which the use of the NLT 382/08 test is mentioned in numeral 421.4.2 Determination of the binder dosage, however, only the dosages per square meter (200 g/m2 -300 g/m2) are established in the Colombian regulations; On the other hand, the Spanish specification NLT 382/08 was complemented in 2014 by ORDER FOM/2523/2014 + FOM/510/2018, where article 531 of the PG-3 specifies adhesion risks and prescribes a minimum requirement of 0.6 MPa under the tread course and 0.4 MPa in the lower layers. The NLT-382 test standard establishes a travel speed of 2.5 mm/min, compared to the 50 mm/min used in countries such as Germany and Switzerland, where it prescribes a minimum strength of 0.85 MPa for the junction between a tread course and its support, and 0.68 MPa for the junction of intermediate layers (Ortiz et al., 2020).
Having these minimum reference strengths and with the results obtained of resistance for the two emulsions evaluated in this work, where a REC of 0.345 MPa was obtained for CRR-60

and 0.418 MPa for the CRR-65 emulsion, it is observed that the minimum referenced requirements of 0.6 MPa under the tread course are not met.

4.4 Evaluation of the impact of dust on the adhesion of league irrigation

Once the optimal application rate for each type of binder was determined, 18 cores bound with CRR-60 emulsion and the same number for cores bound with CRR-65 were failed. As mentioned in the methodology, three conditions were determined, which are zero absence (0) g of dust and two conditions of presence: 0.5 g of dust (61.73 g/m2) and 1.0 g of dust (123.46 g/m2). The breaking shear force was calculated to obtain the resistance to the shear stress for the conditions of absence and presence of dust. Tables 6 and Table 7 show the results of the Breaking Shear Force for the CRR-60 and CRR-65 emulsion.

	CRR-60 DOSAGE		
Powder (g)	0	0.5	1.0
Briquette Series	J	K	L
FCR (kN)	5.71	4.35	2.31
	5.90	4.25	2.52
	5.46	5.06	2.2
	5.95	4.75	2.41
	5.10	5.12	2.85
	5.84	4.39	2.68
Stocking	5.65	4.64	2.49
OF	0.33	0.38	0.24
CV	5.80%	8.20%	9.70%

Table 6. Results of Breaking Shear Force with and without Powder Emulsion CRR-60
Source: Authors' own creation

	CRR-65 DOSAGE		
Powder (g)	0	0.5	1.0
Briquette Series	M	Q	R
FCR (kN)	6.34	5.88	4.13
	7.12	6.15	4.78
	5.83	6.25	4.56
	7.02	5.97	4.85
	6.84	5.74	5.11
	6.45	5.41	4.89
Stocking	6.59	5.89	4.71
OF	0.49	0.3	0.34
CV	7.40%	5.10%	7.20%

Table 7. Results of Breaking Shear Force with and without Powder Emulsion CRR-65
Source: Authors' own creation

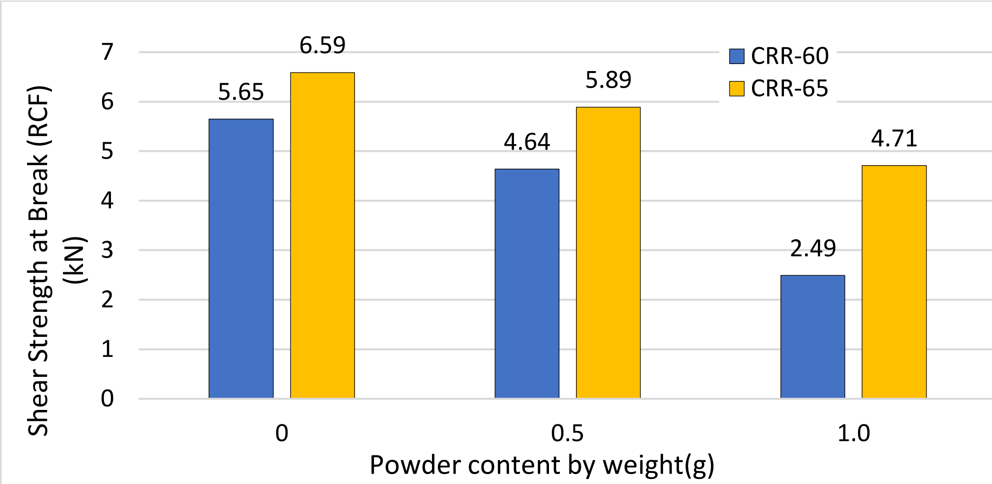

Figure 7. Comparison of shear stress strengths obtained with CRR-60 and CRR-65 emulsions as a function of the application rate of league irrigation
Source: Authors' own creation

In Figure 7, it can be seen that as the powder content on the surface of the briquette increases, the shear force decreases for both the CRR-60 emulsion and the CRR-65, presenting for the CRR 60, a decrease of 17.8% between the dustless condition and the one with 0.5 g of powder and a fairly strong decrease of 56% between the 0.5 g to 1.0 g condition. For the CRR-65 emulsion, there is a less strong decrease, since between the condition of 0.5 g to 1.0 g, there is a decrease of 20%. It is observed that the presence of dust has a greater influence on the CRR-60 emulsion than on the CRR-65 emulsion.
The resistance to the shear stress produced using the CRR-60 and CRR-65 emulsion was then determined, in the presence and absence of dust. The results for the CRR-60 emulsion with absence and presence of dust are presented in Table 8 and Figure 8.

	CRR-60 DOSAGE		
Powder (g)	0	0.5	1.0
REC (MPa)	0.352	0.268	0.142
	0.364	0.262	0.155
	0.337	0.312	0.136
	0.367	0.293	0.149
	0.315	0.316	0.176
	0.36	0.541	0.165
Stocking	0.35	0.32	0.15
OF	0.02	0.1	0.01
CV	5.70%	31.20%	6.50%
REC (MPa)	0.349	0.286	0.153

Table 8. Results of Breaking Shear Force with and without Powder Emulsion CRR-65
Source: Authors' own creation

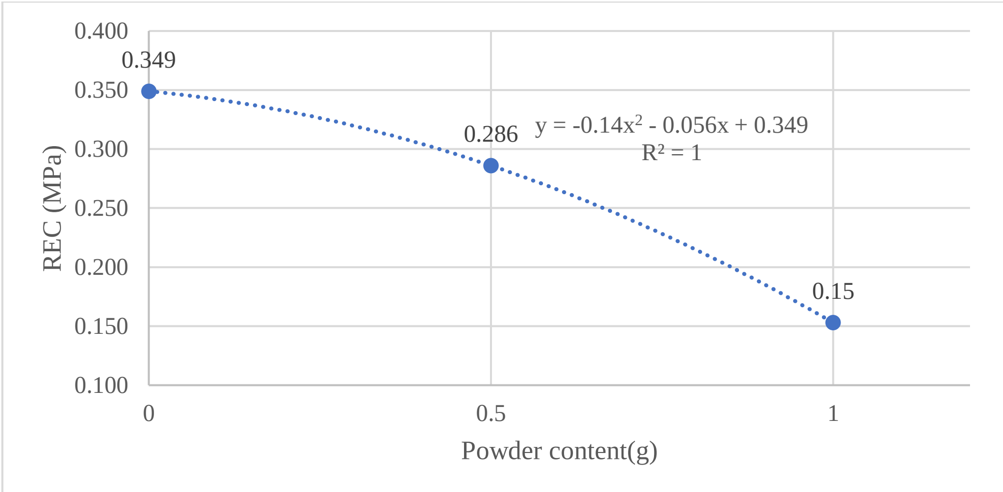

Figure 8. Incidence of Dust on Shear Stress Resistance Bond with CRR-60 Emulsion
Source: Authors' own creation

The results of the Shear Stress Resistance (REC) obtained using the CRR-65 emulsion with the absence and presence of dust are presented in Table 9 and Figure 9.

	CRR-65 DOSAGE		
Powder (g)	0	0.5	1.0
REC (MPa)	0.391	0.363	0.255
	0.439	0.379	0.295
	0.36	0.385	0.281
	0.433	0.368	0.299
	0.422	0.354	0.315
	0.398	0.334	0.302
Stocking	0.41	0.36	0.29
OF	0.03	0.02	0.02
CV	7.40%	5.50%	6.90%
REC (MPa)	0.406	0.363	0.29

Table 8. Results of the Shear Stress Resistance obtained with the CRR-65 emulsion
Source: Authors' own creation

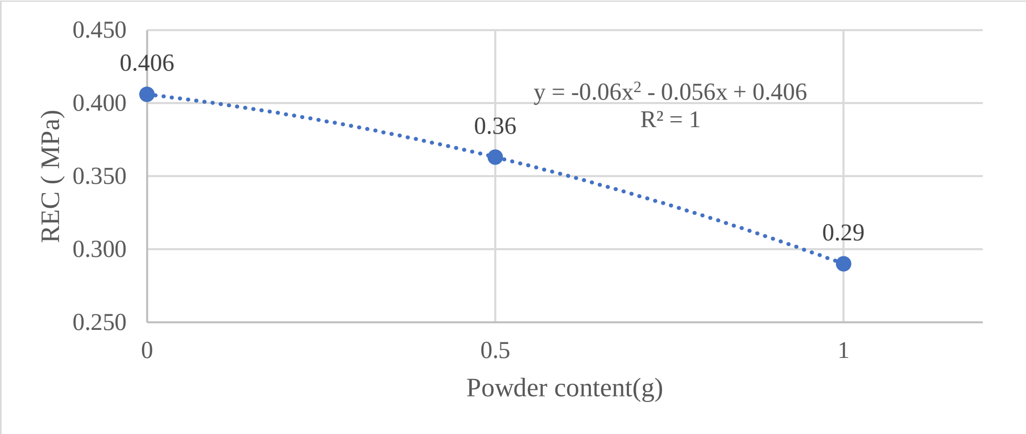

Figure 9. Incidence of dust on Shear stress resistance of CRR-65 emulsion bond
Source: Authors' own creation

Figure 10 shows a comparison of the dust incidence of the two emulsions studied.

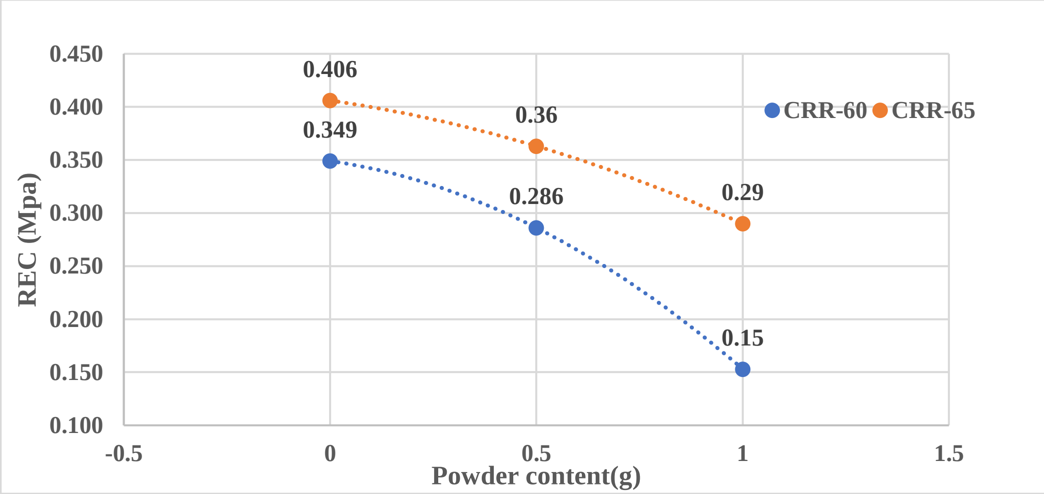

Figure 10. Comparison of the incidence of dust on the REC of CRR-60 and CRR-65 emulsions
Source: Authors' own creation

Figure 18 shows that as the powder content on the surface of the briquette increases, the shear stress resistance decreases for both CRR-60 and CRR-65 emulsion, with an 18% decrease between the dustless condition and the 0.5 g powder condition and a 47.5% decrease between the 0.5 g to 1.0 g condition. For the CRR-65 emulsion, there is a lower decrease, since between the powderless condition and the one with 0.5 g of powder and a decrease of 11.3% and between the 0.5 g to 1.0 g condition, there is a decrease of 19%. It is observed that the presence of dust has a greater influence on the CRR-60 emulsion than on the CRR-65 emulsion. It is important to highlight that in the laboratory it was observed that high percentages of dust on the surface of the briquette generate difficulty for the application of the ligater irrigation, so increasing the dust content would not correspond to a real condition in the field, nor does it allow adequate contact between the league irrigation and the surface of the briquette, reaching values of resistance to shear stress close to zero.

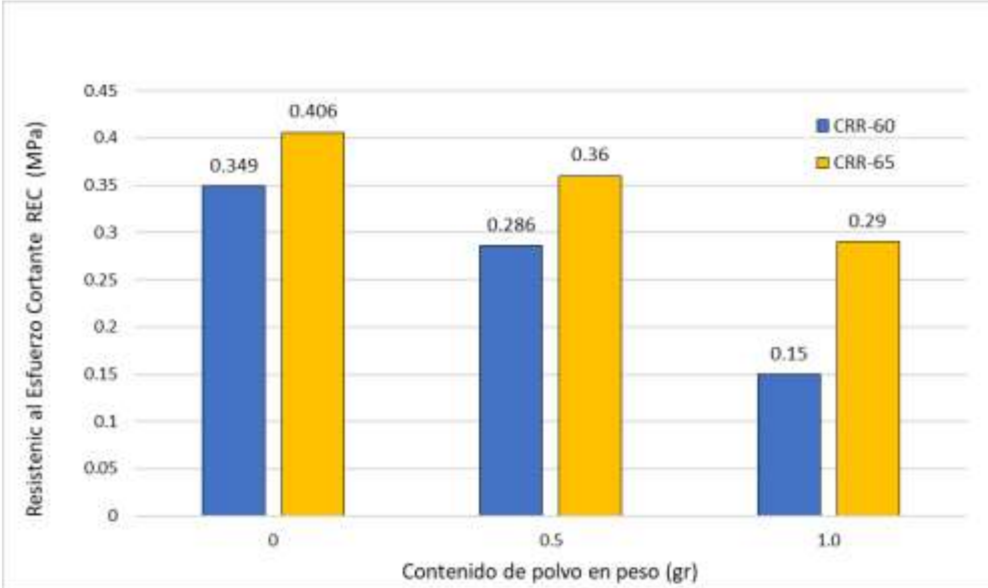

Figure 11. Comparison of the incidence of dust on the REC of CRR-60 and CRR-65 emulsions
Source: Authors' own creation. In original Spanish language.

5. Conclusions and recommendations

5.1 Conclusions

For the development of this work, the test described in the Spanish standard NLT-382/08 and in article 531 of the PG-3 was used, which was partially included in the specifications of the National Institute of Roads year 2022, two emulsions referenced in the INVIAS-2022 regulations were studied through a shear stress test that allows to obtain characterization parameters of the adhesion developed at the union of the two asphalt layers of the elaborated specimen. From the results obtained from the work carried out, the following conclusions are obtained:

• The NLT-382/08 shear test has advantages in its performance. such as the ease in its implementation and low investment of resources, but it also presents some aspects that must be controlled and improved, such as the application of irrigation, which is established to be carried out with a brush, being difficult to control the dose applied and its correct distribution, especially with the presence of dust and although it is done controlling the weight, Since the specimen area is small, a slight loss of mass can affect the residual calculation.

• In order to ensure correct adhesion between asphalt layers, the top layer must be made once the emulsion has broken. This breakage time depends on the type of emulsion, in this case, because it is a fast-breaking emulsion, it was generated immediately, so the 24-hour breakage time that the specimens must be taken to the oven, must be reviewed. It is observed that roughness and texture is a variable that directly influences the resistance to cutting.

• The NLT-382/08 shear test developed showed that, for the two emulsions used as league irrigation, the CRR-65 emulsion is the one that provides the best adhesion.

• For the materials and test conditions, it was determined that the higher the viscosity, the higher the Shear Strength (REC) values; Thus, in the specimens where the CRR-65 asphalt emulsion was used as league irrigation, a REC of 0.41 MPa was obtained, representing 16% more than for the CRR-60 emulsion, where a REC of 0.35 MPa was obtained, concluding that viscosity has an effect on adhesion in league irrigation.

• In relation to the application rate, it was determined that the range where the optimal percentages for league irrigation are found, both of the CRR-65 asphalt emulsion and the CRR-

60 asphalt emulsion, is between 400 g/m2 and 500 g/m2 of residual binder, obtaining that the rates of optimal application or dosage of residual binder of irrigation were very similar. with values of 445 g/m2 for CRR-60 and 440 g/m2 for CRR-65. In the present study, it was observed that an increase in the application rate increases the effect that the type of asphalt binder has on the resistance to shear stress and, therefore, on the adhesion at the interface. This value found is within the results obtained by other researches carried out, where the irrigation endowments that provide the best results in shear resistance are those between 250 and 500 g/m2 of residual binder.

• In relation to the incidence of dust in the application of league irrigation for the conditions considered in this study, the increase in the amount of dust decreases the effect that the type of asphalt binder has on the resistance to shear stress, with the loss of REC being greater for the CRR-60 emulsion than for the CRR-65 emulsion, where for CRR-60, 43% is lost when there is a dust rate of 1.0 g per briquette (123.46 g/m2) with respect to the condition of no dust presence. For the CRR-65 emulsion, a decrease of 28% was observed when there is a dust rate of 1.0 g per briquette (123.46 g/m2) compared to the non-powder condition.

• It was observed that the specimens bound with the CRR-65 emulsion present a higher value of shear force of rupture than the specimens where CRR-60 emulsion was used as a league irrigation, concluding that the emulsion with the highest residual asphalt content, CRR-65, generated greater adhesion at the junction of the two asphalt layers.

• In the regulations in Colombia, the minimum values of Shear Stress Resistance that the league irrigation must comply with, both for the asphalt tread layer and for the lower layers, must be included. It currently exists in the specifications of the year 2022 of the National Institute of Roads - INVIAS, Chapter 4. Asphalt pavements, Article 421-22, in relation to league irrigation, the dosages per square meter, but not the minimum values that must comply with REC.

• Based on the results obtained in the two emulsions evaluated, where a REC of 0.345 MPa was obtained for CRR-60 and 0.418 MPa for the CRR-65 emulsion, it is concluded that the minimum requirements referenced in Spain, of 0.6 MPa under the running course, are not met.

• In the laboratory, it was observed that high percentages of dust on the surface of the briquette generate difficulty for the application of the ligater irrigation, so that increasing higher dust contents would not correspond to a real condition in the field, nor does it allow adequate contact between the ligater irrigation and the briquette surface, reaching values close to zero resistance to shear stress.

• During the development of the laboratory, it was possible to observe, which directly influences the results, the way in which the specimen is placed in terms of the recommended separation between supports. A distance of less than 5 mm from the interface of the support of the mold body translates into an increase in resistance, which gives a result that is not valid.

5.2 Recommendations

Based on the results obtained, the following recommendations can be made for future research:

• The elaboration of briquettes of the first layer can be carried out in trays and then extracted by means of drill bits, in order to approach the closest development of what is referred to in the Spanish standard NLT-382/08.

• Study other variables such as the surface texture of the layers to be adhered, since this parameter is fundamental in the application rate of the league irrigation and in the adhesion generated at the interface, also use diluted emulsions as worked in the field and apply the second layer of the test specimen before the emulsion breaks.

• Carry out the NLT-382/08 test, using other conditioning temperatures at low and high ambient temperatures, to determine the behavior of the same materials for regions different from the one in the study, but which exist in the department of Nariño.

• Improvements should be made to the methodology of the LCB shear test, of variables such as the time that elapses between the compaction of the first layer and the preparation of the

second layer, since, due to an increase in the mechanical properties of the first layer, this is another variable that could influence the results of the joining of the layers of a pavement or overlays.
• Simultaneously study asphalt layers with compacted laboratory specimens, the first layer in a tray and cores extracted from the field, since it is necessary to know the efficiency of league irrigation under real construction conditions.

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