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MODELING OF RIGID PAVEMENTS ON CLAYEY SUBGRADES OF LOW AND MEDIUM PLASTICITY IN RESIDENTIAL ROADS IN SINCELEJO CITY

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Abstract

Rigid concrete pavements are frequently used structures as a surface layer on the main roads of the world. This is due to its remarkable advantages that have made them a very attractive design alternative for streets and roads of different hierarchical level, both for low and high volumes of transit. This type of paving presents a somewhat high initial investment, if compared to asphalt pavements, but if they are designed and built in a adequate, maintenance during its service life is minimal or non-existent; that's why, in those roads where there are few resources for the maintenance of the themselves, turns out to be a viable alternative. Example of the above, are the streets of neighborhoods residential, where commercial vehicle traffic is low and it is sought that the pavement is kept in optimal conditions for long periods of time. The objective of this work is to present the modeling of various rigid pavement structures for roads in the city of Sincelejo, north of Colombia, in neighborhoods with residential streets, where the predominant traffic is light vehicles such as cars and trucks and where trucks rarely pass. Additionally, sites have been selected where subgrade soils of a fine nature of low or medium plasticity are found and which, in addition, have low values of bearing capacity. For purposes of the present investigation, the clayey soils found were characterized, in order to obtain its physical, mechanical and bearing capacity properties, from the analysis of 51 samples obtained. For the modeling of the pavement structures, the PCA method was used, taking the concrete pavement slab as a typical structure, a granular subbase and an improvement in selected material, to increase the capacity bearing of the pavement foundation. To carry out the modeling, 8 levels of concrete resistance were taken into account, for which the modulus of rupture was varied from 3.8 MPa to 4.5 MPa, in intervals of 0.1 MPa and work was done with reaction modules of the improved subgrade of 41, 46 and 49 MPa/m. In addition, we worked with the single wheel, single double wheel and tandem axles of two design trucks, a C2 and a C3, typical trucks that sometimes circulate on these roads and that correspond to the city's garbage collection trucks. The results obtained show the minimum values of slab thickness that these pavements must have to guarantee good performance during the design period. According to the results obtained, the truck that turned out to be more critical was the type C2 and the type of failure that predominated in the modeling was the Fatigue criterion. Additionally, the years of service that certain typical pavement structures that have been built in some parts of the city may have were estimated and it was possible to determine that their design periods are between 4 and 7 years, quite low values for the investment that a pavement represents and the useful life that it can have if it is well designed. Finally, some models were made to review the stresses in the aforementioned pavement structures, thus obtaining by means of EverFE software, the values of deformation and stresses on the paving slab.

Keywords: rigid pavement, pavement design, material properties, subgrade, finite elements

1. INTRODUCTION

A rigid pavement is made up, from a structural point of view, of a Portland cement concrete slab, which may or may not be reinforced and is usually supported on a layer called the sub-base or base of the rigid pavement, whose function is main to prevent the occurrence of bulge phenomenon [1]. Rigid pavements can be structured in various ways, depending on the particular needs of the project, such that the following types can be counted on: Plain pavements with dowels, Plain pavements without dowels, Conventionally reinforced pavements, and Continuously reinforced pavements [2].

An important aspect to note refers to the fact that rigid pavements, being made up of a Portland cement concrete slab, have a high rigidity [3], which allows the generation of load distribution over a relatively large surface, due to the greater modulus of elasticity that the concrete slabs have, with respect to the layer of material on which they rest. This situation can explain the fact that relatively low pressures are generated on the subgrade in this type of pavement.

From an environmental point of view, rigid pavements have certain advantages over other types of solutions, since they favor environmental sustainability due to their greater reflectance and lower heat absorption, which reduces the interaction between vehicles and the pavement, in addition to reducing carbon dioxide emissions [4]. On the other hand, due to its greater durability with respect to those of the asphalt type, traffic interruptions that are usually generated when maintenance work is required are prevented [5].

Rigid type pavements are usually quite attractive as a road infrastructure solution at the urban level, since lesser thicknesses of the structure are usually required than with other types of solution [6]. This aspect is of fundamental importance when intervening on a street within a city, since the greater the total thickness to be intervened, the more likely it is that during the construction process one of the existing public service networks may be affected, such as, aqueduct, sewerage, natural gas, among others.

In the case of the city of Sincelejo, most of the streets are paved in a rigid type structure. However, at present there is a worrying deterioration of the city's road network, this being one of the main reasons that have led to the realization of the present study, through which, it is intended to show, for the particular case of roads with low volume of heavy vehicles, what should be the minimum thickness of the concrete slab to be implemented in this type of roads and where there are also clayey subgrades. On the other hand, through the modeling carried out on pavements of typical thickness used in the city, it is intended to determine what the useful life of these structures would be, considering for this purpose that only garbage trucks enter the pavement, in a number of repetitions consistent with the frequency of weekly garbage collection.

2. EXPERIMENTAL DESIGN, MATERIALS AND METHODS

2.1. Study area description

The study area of this research corresponds to the city of Sincelejo, capital of the Department of Sucre, which belongs to the Montes de María subregion (area between the departments of Bolívar and Sucre) and subregional center of the system urban of the Colombian Caribbean; It is located in the northeast of the country, at 9º 18" latitude North and 75º. 23" west longitude of the Greenwich meridian. The municipality presents a extension of the territory of 28,504 acres and a height above sea level of 213 meters. The study area is framed in an area of tropical dry forest and its characteristic landscape is the mountain. The climate is warm dry, with an average precipitation of 500 to 1200 millimeters; It has an average annual temperature of 27°C, with minimum temperatures of 19°C and maximums of 35°C [7] [8]. Regarding the road infrastructure of the municipality of Sincelejo, this has a length of 134.01 km of Tertiary Road Network, of of which 61.31% of the total is in good condition, 15.04% in fair condition and 11.68% in poor condition. This panorama is similar in some sectors of the urban area of the municipality, therefore, a significant investment is required to generate dynamics economy and local development [9]. Figure 1 shows the geographic location of the municipality of Sincelejo.

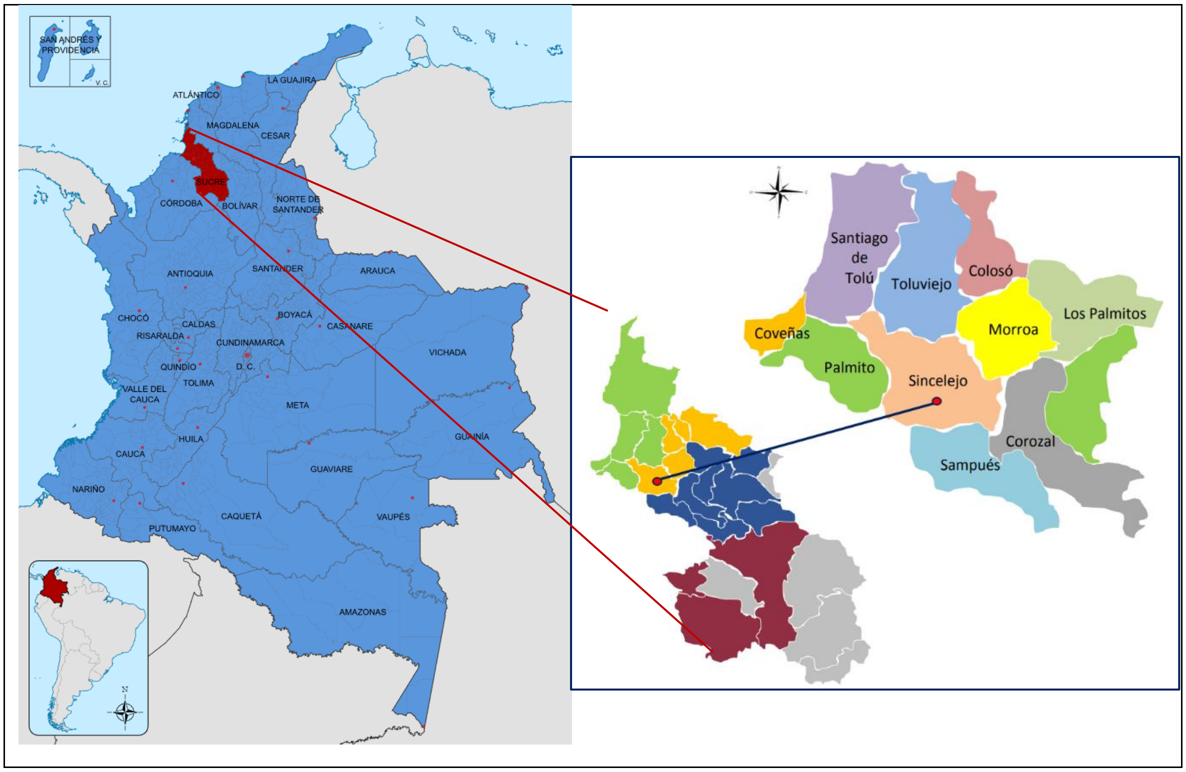


Figure 1. Location of the study area

Source: Cámara de Comercio de Sincelejo 2020

2.2. Material and Methods

The methodology followed for the development of this work was carried out in three phases: the first phase carried out was the characterization of the clayey subgrade soils found in the study area. The second phase consisted of modeling the rigid pavement structures through the PCA method, considering the following combination of variables: two design trucks (C2 and C3), three different thicknesses of material selected for subgrade improvement and eight modulus of rupture of the slab of pavement. Regarding the third stage, in this the useful life of the typical pavements that are frequently built on roads with low volumes of transit at the urban level in the city of Sincelejo.

2.2.1. Geotechnical characterization of the subgrade: To obtain the physical and mechanical properties of the characteristic soils of the subgrade of the study area, a geotechnical study, where a total of 51 representative soil samples were taken subgrade clay along several road sections located in different parts of the city, in neighborhoods classified as residential, where the entry of vehicles is restricted to light vehicles owned by area homeowners and where representative heavy vehicles correspond to garbage collection trucks. The geotechnical sampling was carried out manually up to a depth of 1.50 meters. These samples were obtained in order to obtain the characterization of the subgrade soils, as well as its bearing capacity properties, through standardized laboratory tests. The altered samples were processed in the laboratory to obtain information related to the granulometric distribution, through sieving [10] and the Atterberg limits (liquid limit and plastic limit) [11]. From these tests, it was possible to obtain the classification of soils through the Unified System Classification Soils (USCS) [12] and the AASHTO Soil Classification System [13]. Besides, undisturbed samples were also taken with standardized cylindrical molds, in order to perform the California Bearing Ratio (CBR) laboratory test [14]. To get the bearing capacity of soil through the CBR, the samples were previously subjected to a immersion curing process over a period of four days. Additionally, before immersing the samples for CBR, the natural humidity was determined and their respective wet and dry unit weights for each mold.

2.2.2. Modeling of the Pavement Structures: The analysis and modeling of the rigid pavement structures was carried out through the PCA methodology – The Portland Cement Association of the United States, which is used to determine the thicknesses of concrete slabs, which are appropriate to support the traffic of vehicles in streets, roads and highways, where the main objective is to find the minimum thickness of slab, which generates the lowest initial investment cost and annual maintenance [15]. Among the types of pavements that can be designed through this methodology are found: pavements in simple concrete, in simple concrete with dowels, in concrete with discontinuous reinforcement and concrete with continuous reinforcement. For this case it will work with simple concrete pavements, because the most economical solution is sought taking into account the type of projects that you want to carry out.

The 1984 PCA methodology for the design of rigid pavements is based almost entirely, in concepts of mechanics of materials rather than empirical. The method uses load spectral analysis to calculate the stresses and strains generated by various loads and shaft configurations. The method is based on answers of pavements mathematically calculated from the theories of Westergaard (1923), which were simplified by Bradbuty and later used by Pickett and Ray (1951) to build influence cards used in pavement design. The method is complemented with the analysis of finite element models of the behavior of slabs of concrete of variable thickness and established dimensions, to which loads were applied in the center, edges and corners, considering different support and support conditions, obtaining, that the edge loads, produce the worst tensions in the pavement and the corner loads produce the worst deflections in it. The results allowed the selection of design thicknesses based on cumulative damage considerations [16]. The main considerations of the model consist in controlling especially the fatigue (to prevent cracking due to loads) and erosion (to limit the deflection at the edges and corners of the slab). The fatigue stress criterion recognizes that the pavement may fail, presenting cracking derived from excessive load repetitions; on the other hand, the erosion criterion recognizes that the pavement can fail due to excessive pumping, erosion of the supporting ground and differences in elevations in the joints [17].

According to Lectures del Department of Civil Engineering of The University of Memphis [18] [19], both the fatigue analysis and the erosion analysis use the Miner's cumulative damage hypothesis, that is, the stresses or deflections produced by a class of vehicle or a type of load per given axles, are used to predict the number of repetitions necessary for the pavement to fail. Below are the Fatigue models and Erosion that uses the PCA [18] [19] [20] method.

PCA Fatigue model based on tensile stress due to edge loads: The fatigue analysis is based on on wheel loads applied near the edge of the slab and at the middle of the joints transverse. This is the worst load condition from the bending point of view, especially, if there is no platform, because the loads of the wheels have to be supported by the middle of the slab. Figure 2 shows the critical loading positions.

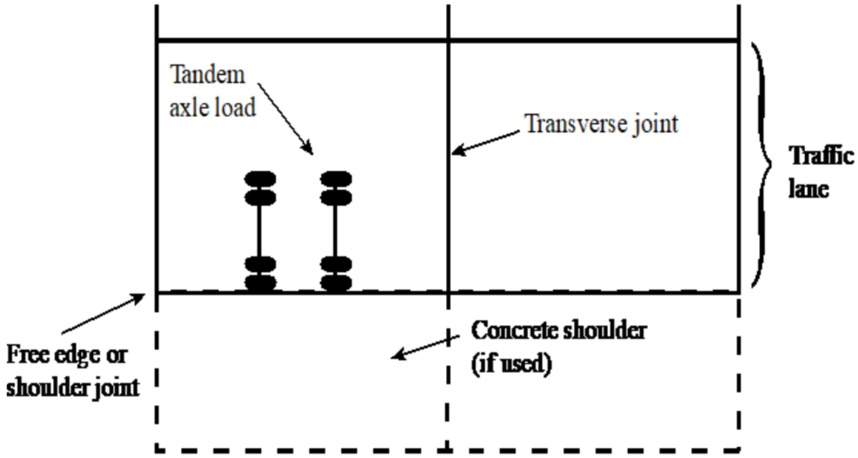


Figure 2. Axle-load position for critical flexural stresses (fatigue analysis)

The equations that govern the Fatigue in the PCA method are the following:

$$For\ \frac{\sigma}{S_c} \geq 0.55 \rightarrow logN_f = 11.737 - 12.077\left(\frac{\sigma}{S_c}\right) \quad (1)$$

$$For\ 0.45 < \frac{\sigma}{S_c} < 0.55 \rightarrow logN_f = \left[\frac{4.2577}{\frac{\sigma}{S_c} - 0.4325}\right]^{3.268} \quad (2)$$

$$For\ \frac{\sigma}{S_c} \leq 0.45 \rightarrow logN_f = \infty \quad (3)$$

Where,

σ is the flexural stress in the slab

S_c is the modulus of rupture of the concrete

PCA Erosion model based on deflections due to corner loads: Analysis of failure due to erosion, takes into account the phenomenon of pumping, the creation of voids under the pavement corners and joint failures. All of these are more related to the deflection of the slab than with the stresses in the slab. In this case, it is taken into account whether or not it provides support for the shoulders. Figure 3 shows the critical loading positions.

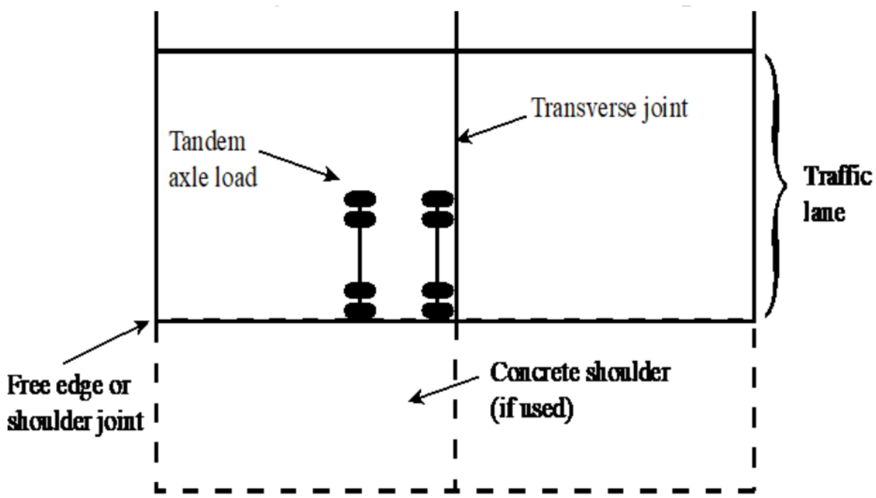


Figure 3. Axle-load for critical flexural (erosion analysis)

The equations that govern Erosion in the PCA method are the following:

$$logN_e = 14.524 - 6.777(CP - 9.0)^{0.103} \quad (4)$$

$$P = 268.7\,\frac{p^2}{hk^{0.73}} \quad (5)$$

Where,

P = rate of work

p = contact pressure (psi)

h = slab thickness (in)

k = modulus of subgrade reaction (psi/in)

C = 1.0 (granular subbase), 0.9 (stabilized subbase)

If there is an asphalt or gravel shoulder or no shoulder, there is no support for the outside edge of the traffic lane. In that case, the erosion damage is calculated as:

$$D_e = \sum \frac{0.06n_i}{N_i} \quad (6)$$

If there is a concrete shoulder, the deflection at the corners is not affected significantly by the location of the wheel loads. In that case, the damage erosion is calculated as:

$$D_e = \sum \frac{0.94n_i}{N_i} \quad (7)$$

Design Factors:

Only four design parameters are needed in the PCA[18] design procedure:

1. The modulus of rupture of the concrete

2. The modulus of subgrade reaction of the slab foundation

3. The design traffic volume

4. The axle load spectrum

For the present investigation, it was decided to work with pavement structures typical of roads with low volumes of traffic, which are mainly used by road users to mobilize in their automobile-type vehicles and where the presence of trucks is quite low. For this reason, a pavement structure of typical concrete representative of this type of roads, which consists of a concrete slab supported on a granular subbase, materials that had to comply with the specifications of the *Instituto Nacional de Vias* (INVIAS) of Colombia [21]; in addition, the Subbase layer is supported on an improvement in Granular Material, Selected Soil

(Table 220-1 of Article 220-13 of INVIAS) [22], which is used as an improvement for the clayey subgrade soils in the area, because the latter have a fairly low bearing capacity in the presence of water. The structure of selected typical pavement can be seen in Figure 4 and the information on the properties and characteristics of the materials that make up said structure can be see Table 1.

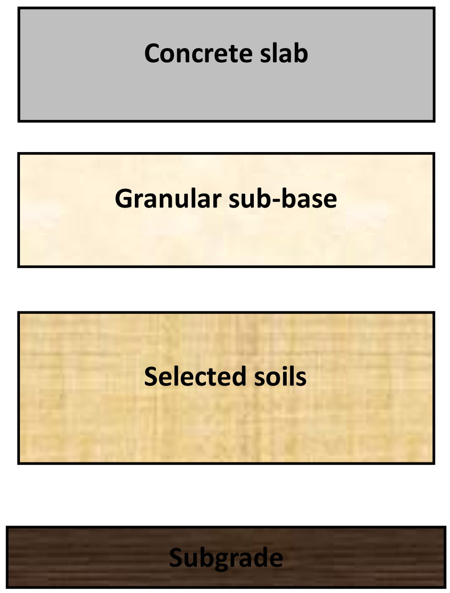


Figure 4. Typical pavement structure to be designed

Table 1. Properties of the materials used in the designs

Material	Variable	Value
Concrete Slab	Modulus of rupture (MR, MPa)	From 3.8 to 4.5
	Layer Thickness (mm)	To determinate
Granular Subbase	California Bearing Ratio (CBR, %)	30
	Layer Thickness (mm)	150
Selected Soils	California Bearing Ratio (CBR, %)	10
	Layer Thickness (mm)	200, 250, 300
Subgrade	California Bearing Ratio (CBR, %)	1.4
	Modulus of subgrade reaction combined Subgrade with Selected Soils (k, MPa/m)	41, 46, 49

The traffic loads were selected taking into account two commercial vehicles that frequent the roads under study, yielding three types of axes; a simple wheel axle single, a single double wheel axle and a tandem axle. The selected axes are detailed in Figure 5. It should be noted that the trucks referred to correspond to garbage collectors, who carry out their work three times a week, where to determine the expected repetitions during the 20-year design period, it is assumed that each time that carry out their work, leave and enter through the design lane, since the roads under study are generally narrow, for which reason the trucks must be centered on the road.

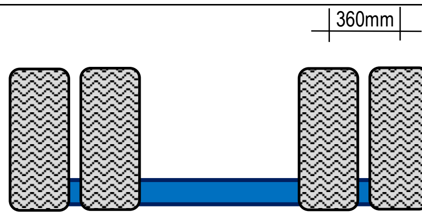
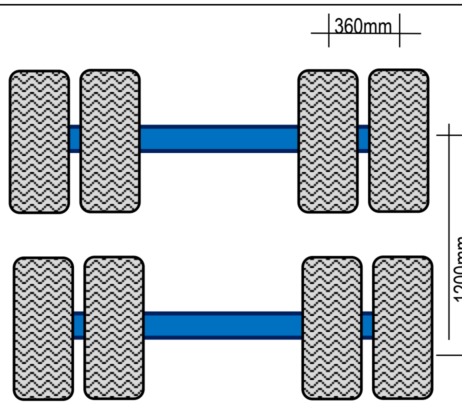
Axle Type	Configuration for analysis	Axle load (KN)	Truck Type
Steering axle		58.8	C2, C3
Single axle with dual wheel		80	C2
Tandem axle		160	C3

Figure 5. Configuration and characteristics of typical load axes

2.2.3. Verification of typical structures and modeling with finite elements: In the last stage of the investigation, the main pavement structures used on the roads under study were analyzed, which consist of a 15 cm thick pavement slab with a modulus of rupture (MR) of 3.8, 15 cm of a granular material granular subbase type, and improved subgrades that yield combined reaction module with the improvements and the subbase of 41, 46 or 49 MPa/m. With these typical structures and the loads of the most critical truck in the modeling (truck C2 shown in Figure 5), it is made the calculation to determine the useful life of the structures.

Additionally, the aforementioned structures were modeled through the method of the finite elements, in order to observe the efforts that are generated in the slab, due to the fact that the fatigue criterion was the one that prevailed in the design of all the modeled solutions. To carry out this, the EverFE software was used, which is a tool computational analysis of finite elements in 3D that allows to simulate the response of rigid concrete pavement systems to the loads imposed by traffic, as well as well as environmental effects. EverFE presents a highly interactive graphical user interface where you can model structures and visualize the results graphically or numerically, being able to visualize stresses and displacements in pavement slabs and granular layers, as well as internal forces and load moments in dowels. [23]. The modeling of the structure, was carried out considering a two-lane road of circulation, formed by two sections of slabs on each side. The modeled slabs were square, with plan dimensions of 3.00 m x 3.00 m and the axes with the loads were located on the edge and in the corner, to simulate the critical load conditions on the slab. Table 2 shows the characteristics of the materials used in the finite element modeling.

Table 2. Pavement material properties

Layer	Thickness (mm)	Density (Kg/m³)	Elastic Modulus (MPa)	Poisson's ratio (u)
Concrete Slab	150	2400	28000	0.20
Granular Subbase	150	2100	300	0.40
Selected Soils	200	1900	100	0.45

RESULTS

The main results of this work correspond to the design of rigid pavement structures for different load levels, associated with two design trucks, C2 and C3; as well as different levels of bearing capacity of the improved subgrade and various resistances of the concrete to flexion or rupture modulus of the paving slab. The results of the characterization of the typical subgrade soils showed that the soils classified as low compressibility clays (CL). To obtain the bearing capacity values of the foundation soils, the laboratory CBR test was used, carried out on 51 samples of clayey soil, with which a curve was constructed to obtain the design CBR value, through the percentile criteria. Figure 6 shows the CBR values obtained in the samples tested and 75% is selected as the design percentile, a value that is consistent with the level of importance of the roads under study. By entering this value, it was possible to obtain a CBR value of 1.40% as representative, for modeling purposes.

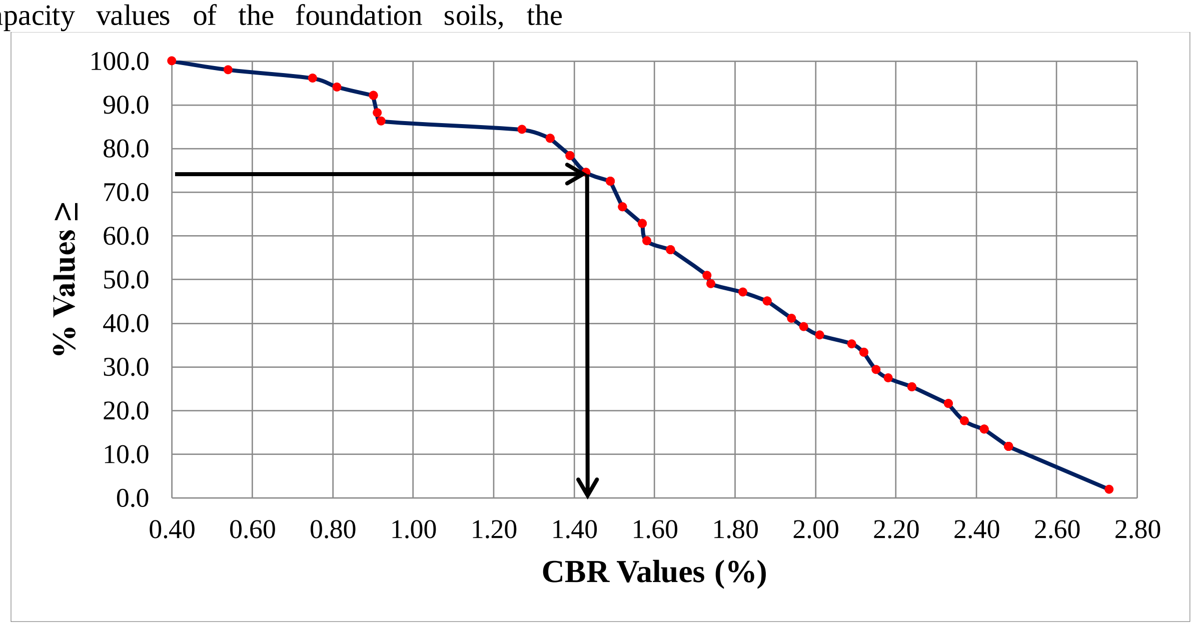


Figure 6. Percentile curve to determine CBR

The CBR value obtained for design purposes is a typical value of the subgrade soils in the study area. Taking into account the very low value obtained (CBR=1.4), it was deemed convenient to use the IVANOV Model [24], to calculate the thickness of granular material required to improve the subgrade; For this purpose, three different thicknesses of selected material were considered: 20, 25 and 30 cm of granular material, which must comply with INVIAS specifications as Selected Material (Article 220-13). Table 3 shows the results of the application of this methodology and the reaction modulus values for the subgrade and the selected fill, as well as the K-combined values for the subgrade, selected fill and granular subbase layers, which These will be the values used to calculate the thicknesses of the concrete slab of the pavement structures to be modeled.

Table 3. Pavement Modeling Results for Truck C2

Material	CBR-2	E2-deduted	h1	CBR-1	E1	n	E1-2	CBR1-2	K	K-combined
No.	Subgrade (%)	Kg/cm²	(mm)	(%)	Kg/cm²		Kg/cm²	(%)	Mpa/m	Mpa/m
1	1.4	140	200	10	1000	2.20	416.38	4.16	33	41
2	1.4	140	250	10	1000	2.20	487.43	4.87	37	46
3	1.4	140	300	10	1000	2.20	554.16	5.54	40	49

In the case of the design of pavement structures, 48 rigid pavement structures were modeled. These modeled and analyzed structures correspond to admissible road infrastructure solutions for the type of project that has been considered, that is, residential roads with low volumes of commercial vehicles, used as internal roads in gated community neighborhoods or urbanizations.

Table 4 presents the results of the modeling for the C2 truck, for eight modulus of rupture values (3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4 and 4.5), as well as three different fill solutions selected on the clayey subgrade with filler material thicknesses of 20, 25 and 30 cm, which together with the 15 cm of granular subbase give soil reaction values (k-combined) of 41, 46 and 49 MPa/m.

Table 4. Pavement Modeling Results for Truck C2

MR (MPa)	K-combined = 41 MPa/m			K-combined = 46 MPa/m			K-combined = 49 MPa/m		
	Slab Thickness (mm)	Fatigue (%)	Erosion (%)	Slab Thickness (mm)	Fatigue (%)	Erosion (%)	Slab Thickness (mm)	Fatigue (%)	Erosion (%)
3.8	**170**	26.58	0.81	**160**	79.93	1.30	**160**	64.82	1.28
3.9	**160**	73.55	1.35	**160**	50.46	1.30	**160**	41.14	1.28
4.0	**160**	47.06	1.35	**160**	32.60	1.30	**160**	26.72	1.28
4.1	**160**	30.78	1.35	**160**	21.52	1.30	**150**	82.91	2.20

4.2	**150**	97.89	2.31	**150**	66.58	2.24	**150**	54.04	2.20
4.3	**150**	64.20	2.31	**150**	44.06	2.24	**150**	35.93	2.20
4.4	**150**	42.91	2.31	**150**	29.71	2.24	**150**	24.34	2.20
4.5	**150**	21.21	2.31	**150**	20.39	2.24	**140**	87.04	3.90

Table 5 presents the results of the modeling for truck C3, for eight of the same values of modulus of rupture and soil reaction analyzed for truck C2.

Table 5. Pavement Modeling Results for Truck C3

MR (MPa)	**K-combined = 41 MPa/m**			**K-combined = 46 MPa/m**			**K-combined = 49 MPa/m**		
	Slab Thickness (mm)	**Fatigue (%)**	**Erosion (%)**	**Slab Thickness (mm)**	**Fatigue (%)**	**Erosion (%)**	**Slab Thickness (mm)**	**Fatigue (%)**	**Erosion (%)**
3.8	**150**	24.93	4.07	**140**	74.71	5.96	**140**	59.47	5.70
3.9	**140**	72.81	6.49	**140**	47.91	5.96	**140**	38.36	5.70
4.0	**140**	47.22	6.49	**140**	31.41	5.96	**140**	25.27	5.70
4.1	**140**	31.28	6.49	**140**	20.94	5.96	**130**	88.83	9.57
4.2	**140**	21.03	6.49	**130**	73.00	9.99	**130**	58.58	9.57
4.3	**130**	73.16	10.80	**130**	48.83	9.99	**130**	39.39	9.57
4.4	**130**	49.37	10.80	**130**	33.27	9.99	**130**	26.96	9.57
4.5	**130**	33.91	10.80	**130**	23.02	9.99	**130**	18.68	9.57

From the results of the previous tables, it can be said that in the case of trucks C2, the thicknesses range between 140 and 170 mm, while for C3 trucks, the values of the thicknesses of the paving slab are in the range 130 to 150 mm, with what which can be deduced that the C2 trucks generate a greater effort in the slabs, which is translates into greater consumption due to fatigue in the useful life of the pavement. Additionally, it can be observed that the criterion that dominates in the determination of the minimum thicknesses of paving slab, corresponds to consumption due to fatigue, with the value of Erosion quite low in all cases.

On the other hand, in the case of the modeling carried out for the typical structures of pavement, which are built in the study area, these were modeled considering a truck C2 (Figure 5), corresponding to the garbage collection vehicle, which, according to the frequency of garbage collection established by the city cleaning company, it is expected to pass through the layout lane about 6 times a week. Table 6 shows the results obtained, where it is worth noting that the custom that still persists today on the part of some city developers, of projecting concrete slabs for rigid pavements 15 cm thick, is an erroneous practice, because with these thicknesses, and the minimum traffic of heavy vehicles expected, premature damage is generated in the structures of the slabs, which are reflected in less than seven years, when these structures must be designed to last for at least 20 years.

Table 6. Service life of typical pavements in the study area

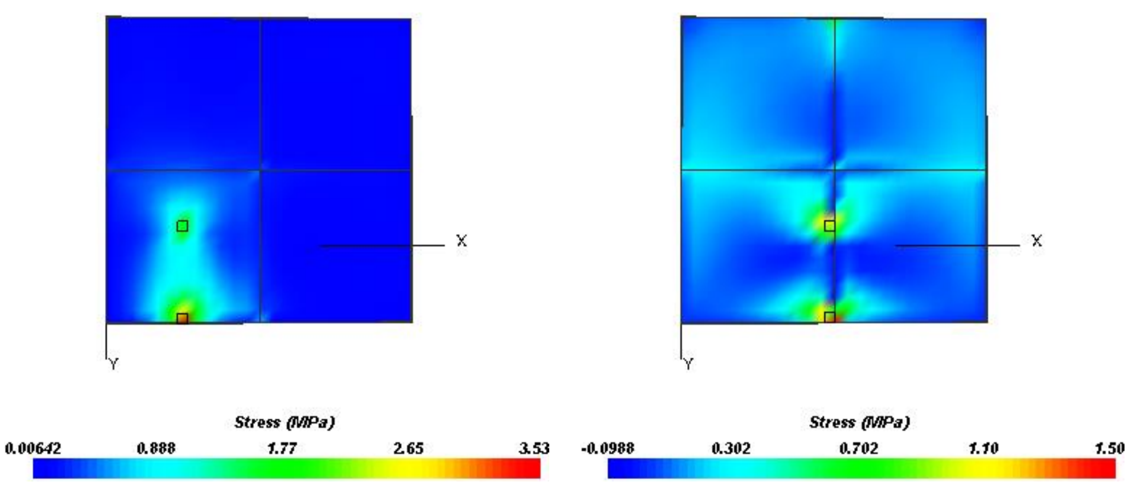
MR (MPa)	K-combined (MPa/m)	Slab Thickness (mm)	Fatigue (%)	Erosion (%)	Admissible repetitions	Pavement Service Life (years)
3.8	41	150	99.91	0.35	1138.00	**3.6**
3.8	46	150	99.96	0.52	1740.00	**5.6**
3.8	49	150	99.97	0.64	2190.00	**7.0**

As observed in Table 6, these pavements that are designed with a thickness of 15 cm of concrete slab have a fairly short service life, being less than 4 years for those with subgrade support of 41 MPa/m and approximately 7 years for pavements with a 15 cm concrete slab and a combined reaction modulus of 49 MPa. The results obtained are correct with many roads of these characteristics that have been built in the city, where in a period of between 5 to 10 years they already begin to present fissures and cracks in the pavement and that before their useful life they present quite severe damage.

Finally, the finite element modeling schemes of the most typical pavement structure within the study area are presented, which corresponds to a 15 cm concrete slab with MR = 3.8 MPa, a 15 cm thick granular subbase and fine subgrade improvement with a selected fill material 20 cm thick. For the modeling, the three axles shown in Figure 5 were used and the purpose of this analysis is to observe the stresses (Figure 7) that the axles of these trucks generate on the typical pavement slabs in Terms of Service.

a) Steering axle - Edge loads

b) Steering axle - Corner loads



c) Single axle with dual wheel - Edge loads

d) Single axle with dual wheel - Corner loads

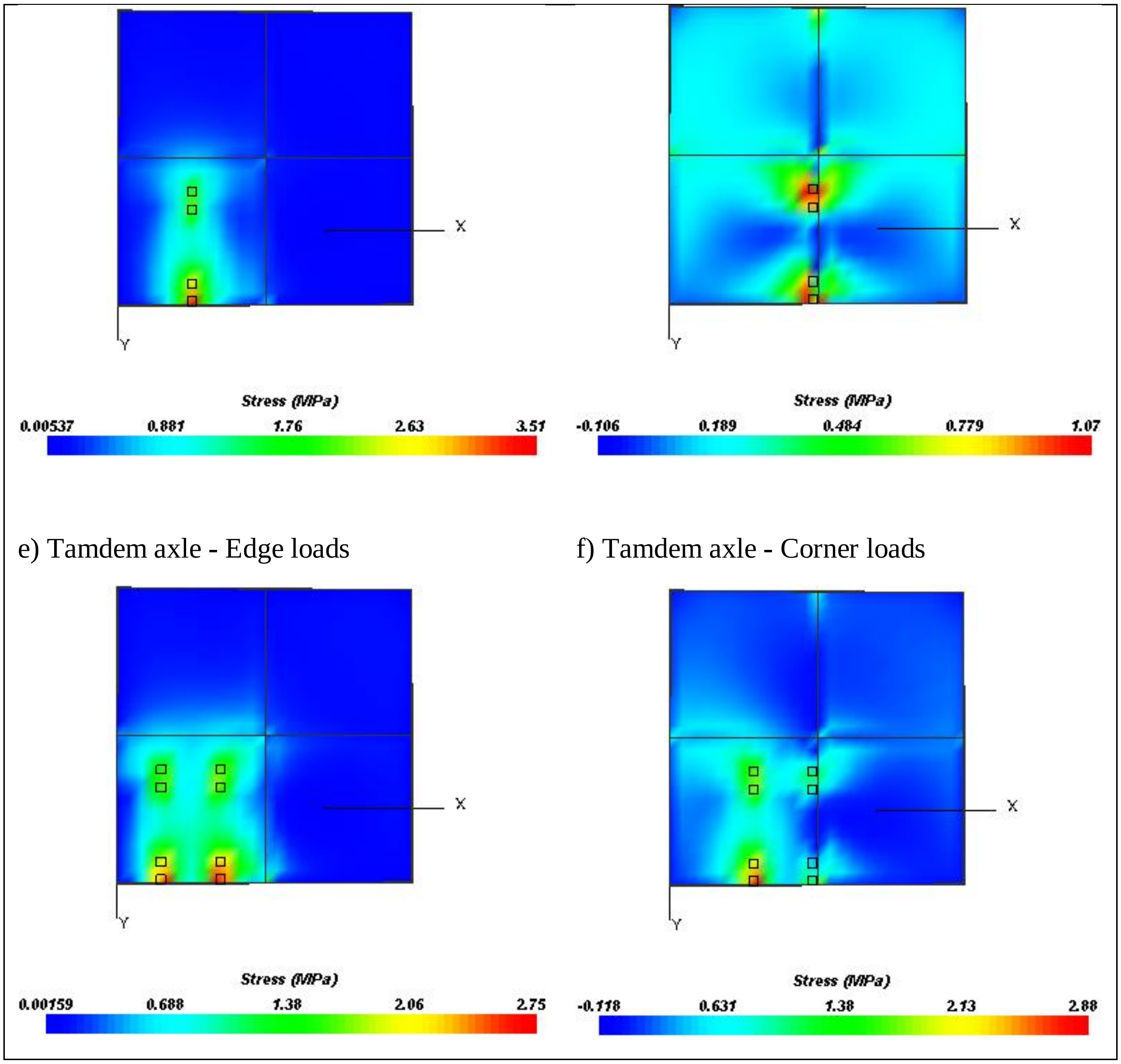


Figure 7. Distribution of maximum principal stresses in the paving slabs.

Figure 7 shows the states of stress that a paving slab presents, considering the effect generated by the loads of a single directional axle, a single axle with a double wheel and a tandem axle, which have been located in two positions very particular, which are associated with the phenomena of fatigue and erosion, respectively. As shown, the single axle with a single wheel and the single axle with a double wheel generate significantly higher edge stresses than the corner stresses, which is indicative that fatigue damage is the prevailing failure criterion for this type of shaft. On the other hand, in the case of the tandem axle, the corner stresses are slightly higher than the edge stresses, which allows us to establish that, in this case, the tandem axles tend to be more critical to erosion than to pavement fatigue.

4. CONCLUSIONS

The rigid-type pavement project on roads for residential use located in the city of Sincelejo, such as neighborhood streets, with low volumes of heavy traffic, the same as for the case of pavements in closed residential complexes, where If there are subgrade soils of the clayey type of low and medium plasticity, it is recommended to carry out an improvement of the subgrade, consisting of a selected granular type material at least 25 cm thick. Subsequently, a layer of granular sub-base at least 15 cm thick must be placed. It should be noted that both materials must satisfy the quality requirements established in the technical specifications of the *Instituto Nacional de Vías* de Colombia.

On the other hand, according to the results obtained in the modeling carried out with the PCA method, it was possible to verify that the critical design truck for the type of road under study corresponds to a class C2 garbage collector truck (two-axle truck).

Under the considerations established above, regarding the characteristics of the foundation proposed for the structure, the minimum pavement thickness to be projected in these cases must correspond to a 160 mm concrete slab, with a modulus of rupture of 3.8 MPa.

It is important to note that the implementation of slabs with a thickness of 150 mm or less is not recommended for the case under study, since the pavement is condemned to seriously compromise its durability, due to the early appearance of damage associated with fatigue in the structure, which will appear between 3 and 7 years after being built.

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